Federal Aviation Administration
Aviation Rulemaking Advisory Committee

Transport Airplane and Engine Issue Area
Powerplant Installation Harmonization Working Group

Task 9 – Harmonize 14 CFR 25.903(e)

Task Assignment

exemption is necessary or appropriate in the public interest and consistent with the protection of investors and the purposes fairly intended by the policies and provisions of the Act. OLDE Management states that the requested relief satisfies this standard.

4. OLDE Management asserts that the Transaction arose out of business considerations unrelated to the Trust and OLDE Management. OLDE Management states that there is insufficient time to obtain shareholder approval of the New Agreements prior to the Closing Date.

5. OLDE Management represents that under the New Agreements, during the Interim Period, the scope and quality of services provided to the Funds will be at least equivalent to the scope and quality of the services it previously provided under the Existing Agreements. OLDE Management states that if any material change in its personnel occurs during the Interim Period, OLDE Management will apprise and consult with the Board to ensure that the Board, including a majority of the Independent Trustees, are satisfied that the scope and quality of the advisory services provided to the Funds will not be diminished. OLDE Management also states that the compensation payable to it under the New Agreements will be no greater than the compensation that would have been paid to OLDE Management under the Existing Agreements.

Applicant's Conditions

OLDE Management agrees as conditions to the issuance of the exemptive order requested by the application that:

1. The New Agreements will have the same terms and conditions as the Existing Agreements except for the dates of execution and termination.

2. Fees earned by OLDE Management in respect of the New Agreements during the Interim Period will be maintained in an interest-bearing escrow account, and amounts in the account (including interest earned on such fees) will be paid to (i) OLDE Management in accordance with the New Agreements, after the requisite shareholder approvals are obtained, or (ii) the respective Fund, in absence of such shareholder approval.

3. The Trust will convene a meeting of shareholders of each Fund to vote on approval of the respective New Agreements during the Interim Period (but in no event later than April 15, 2000).

4. OLDE Management or an affiliate, not the Funds, will bear the costs of preparing and filing the application and the costs relating to the solicitation of shareholder approval of the Funds necessitated by the Transaction.

5. OLDE Management will take all appropriate steps so that the scope and quality of advisory and other services provided to the Funds during the Interim Period will be at least equivalent, in the judgment of the Trust's Board, including a majority of the Independent Trustees, to the scope and quality of services previously provided under the Existing Agreements. If personnel providing material services during the Interim Period change materially, OLDE Management will apprise and consult with the Board to assure that the trustees, including a majority of the Independent Trustees, of the Trust are satisfied that the services provided will not be diminished in scope or quality.

For the SEC, by the Division of Investment Management, under delegated authority.

Margaret H. McFarland,

Deputy Secretary.

[FR Doc. 99-30709 Filed 11-24-99; 8:45 am]

BILLING CODE 8010-01-M

SECURITIES AND EXCHANGE COMMISSION

SUNSHINE ACT MEETING

AGENCY MEETING: Notice is hereby given, pursuant to the provisions of the Government in the Sunshine Act, Pub. L. 94-409, that the Securities and Exchange Commission will hold the following meeting during the week of November 29, 1999.

A closed meeting will be held on Wednesday, December 1, 1999, at 11:00 a.m.

Commissioners, Counsel to the Commissioners, the Secretary to the Commission, and recording secretaries will attend the closed meeting. Certain staff members who have an interest in the matters may also be present.

The General Counsel of the Commission, or his designee, has certified that, in his opinion, one or more of the exemptions set forth in 5 U.S.C. 552b(c) (4), (8), (9)(A) and (10) and 17 CFR 200.402(a) (4), (8), (9)(A) and (10), permit consideration for the scheduled matters at the closed meeting.

Commissioner Unger, as duty officer, voted to consider the items listed for the closed meeting in a closed session.

The subject matter of the closed meeting scheduled for Wednesday, December 1, 1999, will be:

Institution and settlement of injunctive actions

Institution and settlement of administrative proceedings of an enforcement nature

At times, changes in Commission priorities require alterations in the scheduling of meeting items. For further information and to ascertain what, if any, matters have been added, deleted or postponed, please contact:

The Office of the Secretary at (202) 942-7070.

Dated: November 23, 1999.

Jonathan G. Katz,

Secretary.

[FR Doc. 99-30918 Filed 11-23-99; 2:54 pm]

BILLING CODE 8010-01-M

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

Aviation Rulemaking Advisory Committee; Transport Airplane and Engine Issues—New and Revised Tasks

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of new and revised task assignments for the Aviation Rulemaking Advisory Committee (ARAC).

SUMMARY: Notice is given of new tasks assigned to and accepted by the Aviation Rulemaking Advisory Committee (ARAC) and of revisions to a number of existing tasks. This notice informs the public of the activities of ARAC.

FOR FURTHER INFORMATION CONTACT: Dorenda Baker, Transport Airplane Directorate, Aircraft Certification Service (ANM-110), 1601 Lind Avenue, SW., Renton, WA 98055; phone (425) 227-2109; fax (425) 227-1320.

SUPPLEMENTARY INFORMATION:

Background

The FAA has established an Aviation Rulemaking Advisory Committee to provide advice and recommendations to the FAA Administrator, through the Associate Administrator for Regulation and Certification, on the full range of the FAA's rulemaking activities with respect to aviation-related issues. This includes obtaining advice and recommendations on the FAA's commitment to harmonize its Federal Aviation Regulations (FAR) and practices with its trading partners in Europe and Canada.

One area ARAC deals with is transport airplane and engine issues. These issues involve the airworthiness standards for transport category airplanes and engines in 14 CFR parts 25, 33, and 35 and parallel provisions in 14 CFR parts 121 and 135. The corresponding Canadian standards are contained in Parts V, VI, and VII of the Canadian Aviation Regulations. The corresponding European standards are contained in Joint Aviation Requirements (JAR) 25, JAR–E, JAR–P, JAR–OPS–Part 1, and JAR–26.

As proposed by the U.S. and European aviation industry, and as agreed between the Federal Aviation Administration (FAA) and the European Joint Aviation Authorities (JAA), an accelerated process to reach harmonization has been adopted. This process is based on two procedures:

(1) Accepting the more stringent of the regulations in Title 14 of the Code of Federal Regulations (FAR), Part 25, and the Joint Airworthiness Requirements (JAR); and

(2) Assigning approximately 41 already-tasked significant regulatory differences (SRD), and certain additional part 25 regulatory differences, to one of three categories:

- Category 1—Envelope
- Category 2—Completed or near complete
- Category 3—Harmonize

The Revised Tasks

ARAC will review the rules identified in the "FAR/JAR 25 Differences List," dated June 30, 1999, and identify changes to the regulations necessary to harmonize part 25 and JAR 25. ARAC will submit a technical report on each rule. Each report will include the cost information that has been requested by the FAA. The tasks currently underway in ARAC to harmonize the listed rules are superseded by this tasking.

New Tasks

The FAA has submitted a number of new tasks for the Aviation Rulemaking Advisory Committee (ARAC), Transport Airplane and Engine Issues. As agreed by ARAC, these tasks will be accomplished by existing harmonization working groups. The tasks are regulatory differences identified in the above-referenced differences list as Rule type = P–SRD.

New Working Group

In addition to the above new tasks, a newly established Cabin Safety Harmonization Working Group will review several FAR/JAR paragraphs as follows:

ARAC will review the following rules and identify changes to the regulations necessary to harmonize part 25 and JAR:

(1) Section 25.787;
(2) Section 25.791(a) to (d);
(3) Section 25.810;
(4) Section 25.811;
(5) Section 25.819; and
(6) Section 25.813(c).

ARAC will submit a technical report on each rule. Each report will include the cost information that has been requested by the FAA.

The Cabin Safety Harmonization Working Group would be expected to complete its work for the first five items (identified as Category 1 or 2) before completing item 6 (identified as Category 3).

Schedule

Within 120 days of tasking/retasking:

- For Category 1 tasks, ARAC submits the Working Groups' technical reports to the FAA to initiate drafting of proposed rulemaking documents.
- For Category 2 tasks, ARAC submits technical reports, including already developed draft rules and/or advisory materials, to the FAA to complete legal review, economic analysis, coordination, and issuance.

June 2000: For Category 3 tasks, ARAC submits technical reports including draft rules and/or advisory materials to the FAA to complete legal review, economic analysis, coordination, and issuance.

ARAC Acceptance of Tasks

ARAC has accepted the new tasks and has chosen to assign all but one of them to existing harmonization working groups. A new Cabin Safety Harmonization Working Group will be formed to complete the remaining tasks. The working groups serve as staff to ARAC to assist ARAC in the analysis of the assigned tasks. Working group recommendations must be reviewed and approved by ARAC. If ARAC accepts a working group's recommendations, it forwards them to the FAA and ARAC recommendations.

Working Group Activity

All working groups are expected to comply with the procedures adopted by ARAC. As part of the procedures, the working groups are expected to accomplish the following:

1. Document their decisions and discuss areas of disagreement, including options, in a report. A report can be used both for the enveloping and for the harmonization processes.

2. If requested by the FAA, provide support for disposition of the comments received in response to the NPRM or review the FAA's prepared disposition of comments. If support is requested, the Working Group will review comments/disposition and prepare a report documenting their recommendations, agreement, or disagreement. This report will be submitted by ARAC back to the FAA.

3. Provide a status report at each meeting of ARAC held to consider Transport Airplane and Engine Issues.

Partcipation in the Working Groups

Membership on existing working groups will remain the same, with the formation of subtask groups, if appropriate. The Cabin Safety Harmonization Working Group will be composed of technical experts having an interest in the assigned task. A working group member need not be a representative of a member of the full committee.

An individual who has expertise in the subject matter and wishes to become a member of the Cabin Safety Harmonization Working Group should write to the person listed under the caption **FOR FURTHER INFORMATION CONTACT** expressing that desire, describing his or her interest in the tasks, and stating the expertise he or she would bring to the working group. All requests to participate must be received no later than December 30, 1999. The requests will be reviewed by the assistant chair, the assistant executive director, and the working group chair, and the individuals will be advised whether or not the request can be accommodated.

Individuals chosen for membership on the Cabin Safety Harmonization Working Group will be expected to represent their aviation community segment and participate actively in the working group (e.g., attend all meetings, provide written comments when requested to do so, etc.). They also will be expected to devote the resources necessary to ensure the ability of the working group to meet any assigned deadline(s). Members are expected to keep their management chain advised of working group activities and decisions to ensure that the agreed technical solutions do not conflict with their sponsoring organization's position when the subject being negotiated is presented to ARAC for a vote.

Once the working group has begun deliberations, members will not be added or substituted without the approval of the assistant chair, the assistant executive director, and the working group chair.

The Secretary of Transportation has determined that the formation and use of ARAC are necessary and in the public interest in connection with the performance of duties imposed on the FAA by law.

Recommendation Letter

Gerald R. Mack
Director
Certification &
Government Requirements

Boeing Commercial Airplane Group
P.O. Box 3707, MS 67-UM
Seattle, WA 98124-2207

August 8, 1995
B-T000-ARAC-95-006

Mr. Anthony J. Broderick
Associate Administrator for Regulations and Certification, (AVR-1)
Department of Transportation
Federal Aviation Administration
800 Independence Avenue, S.W.
Washington DC 20591
Tele: (202) 267-3131
Fax: (202) 267-5364

BOEING

Dear Mr. Broderick:

On behalf of the Aviation Rulemaking Advisory Committee, I am pleased to submit the enclosed recommendations for publication on the following subjects:

AC 20.128A Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxilary Power Unit Rotor Failure

AC 29.2A Advisory Material for Compliance with Rotor Burst Rule

The enclosed packages are in the form of final draft ACs. The packages were developed by the Powerplant Installation Harmonization Working Group chaired by Bruce Honsberger of Boeing and Wim Overmars of Fokker. The membership of the group is a good balance of interested parties in the U.S. and Europe. This group can be made available if needed for docket review.

The members of ARAC appreciate the opportunity to participate in the FAA rulemaking process and fully endorse these recommendations.

Sincerely,

G.R. Mack

Gerald R. Mack
Assistant Chairman
Transport Airplane & Engine Issues Group
Aviation Rulemaking Advisory Committee
Tele: (206) 234-9570, Fax: 237-0192, Mailstop: 67-UM

Enclosure

cc:	M. Borfitz	(617) 238-7199
	B. Honsberger	67-UW
	S. Miller	(206) 227-1100
	W. Overmars	31-206052895

Recommendation

Gerald R. Mack
Director
Certification &
Government Requirements

Boeing Commercial Airplane Group
P.O. Box 3707, MS 67-UM
Seattle, WA 98124-2207

August 8, 1995
B-T000-ARAC-95-006

Mr. Anthony J. Broderick
Associate Administrator for Regulations and Certification, (AVR-1)
Department of Transportation
Federal Aviation Administration
800 Independence Avenue, S.W.
Washington DC 20591
Tele: (202) 267-3131
Fax: (202) 267-5364

BOEING

Dear Mr. Broderick:

On behalf of the Aviation Rulemaking Advisory Committee, I am pleased to submit the enclosed recommendations for publication on the following subjects:

AC 20.128A Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxilary Power Unit Rotor Failure

AC 29.2A Advisory Material for Compliance with Rotor Burst Rule

The enclosed packages are in the form of final draft ACs. The packages were developed by the Powerplant Installation Harmonization Working Group chaired by Bruce Honsberger of Boeing and Wim Overmars of Fokker. The membership of the group is a good balance of interested parties in the U.S. and Europe. This group can be made available if needed for docket review.

The members of ARAC appreciate the opportunity to participate in the FAA rulemaking process and fully endorse these recommendations.

Sincerely,

G.R. Mack

Gerald R. Mack
Assistant Chairman
Transport Airplane & Engine Issues Group
Aviation Rulemaking Advisory Committee
Tele: (206) 234-9570, Fax: 237-0192, Mailstop: 67-UM

Enclosure

cc:	M. Borfitz	(617) 238-7199
	B. Honsberger	67-UW
	S. Miller	(206) 227-1100
	W. Overmars	31-206052895

Draft Advisory Circular

U.S. Department
of Transportation
Federal Aviation
Administration

Subject: DESIGN CONSIDERATIONS FOR MINIMIZING HAZARDS CAUSED BY UNCONTAINED TURBINE ENGINE AND AUXILIARY POWER UNIT ROTOR FAILURE

Date: July 18, 1995
AC No. 20-128A
Initiated by: ANM-110

THIS DOCUMENT IS A WORKING DRAFT AND IS NOT FOR PUBLIC RELEASE

1. PURPOSE. This advisory circular (AC) sets forth a method of compliance with the requirements of §§ 23.901(f), 23.903(b)(1), 25.901(d) and 25.903(d)(1) of the Federal Aviation Regulations (FAR) pertaining to design precautions taken to minimize the hazards to an airplane in the event of uncontained engine or auxiliary power unit (APU) rotor failures. The guidance provided within this AC was harmonized as of the issuance date with that of the European Joint Aviation Authorities (JAA) and is intended to provide a method of compliance that has been found acceptable. As with all AC material, it is not mandatory and does not constitute a regulation.

2. CANCELLATION. Advisory Circular 20-128, "Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor and Fan Blade Failures," dated March 3, 1988, is cancelled.

3. APPLICABILITY. This advisory circular applies to Part 23 and Part 25 airplanes for which a new, amended, or supplemental, type certificate is requested.

4. RELATED DOCUMENTS. Sections 23.903, and 25.903 of the FAR, as amended through Amendment 25-tbd and 23-tbd **(FAA to insert appropriate Amendment levels prior to publication)** respectively, and other sections relating to uncontained engine failures.

a. Related Federal Aviation Regulations. Sections which prescribe requirements for the design, substantiation and certification relating to uncontained engine debris include:

§ 23.863, 25.863	Flammable Fluid Fire Protection
§ 25.365 (e)(1)	Pressurized Compartment Loads

§ 25.571 (a), (e)(2)(3)(4)	Damage Tolerance and Fatigue evaluation of structure.
§ 25.963 (e)	Equipment, systems and installations
§ 25.1189	Shutoff means.

b. Advisory Circulars (AC's) and Users Manual.

AC 25-8	Auxiliary Fuel System Installations
AC 23-10	Auxiliary Fuel System Installations
AC 20-135	Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria (or the equivalent International Standard Order 2685)
AC 25-571	Damage Tolerance and Fatigue Evaluation of Structure
Users Manual	Users Manual for AC20-128A, "Uncontained Engine Failure Risk Analysis Methodology", dated tbd.

Advisory Circulars and the Users Manual can be obtained from the U.S. Department of Transportation, M-443.2, Subsequent Distribution Unit, Washington, D.C. 20590.

c. Technical Standard Orders (TSO's).

TSO C77a (or JAR APU)	Gas Turbine Auxiliary Power Units

Technical Standard Orders can be obtained from the Federal Aviation Administration (FAA), Aircraft Certification Service, Aircraft Engineering Division, Technical Analysis Branch (AIR-120), 800 Independence Ave. S.W., Washington, DC, 205921.

d. Society of Automotive Engineers (SAE) Documents.

AIR1537	Report on Aircraft Engine Containment, dated October, 1977.
AIR4003	Uncontained turbine Rotor Events Data Period 1976 through 1983.
AIR4770 Draft	Uncontained turbine Rotor Events Data Period 1984 through 1989.

These documents can be obtained from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Pennsylvania, 15096.

5. BACKGROUND. Although turbine engine and APU manufacturers are making efforts to reduce the probability of uncontained rotor failures, service experience shows that uncontained compressor and turbine rotor failures continue to occur. Turbine engine failures have resulted in high velocity fragment penetration of adjacent structures, fuel tanks, fuselage, system components and other engines of the airplane. While APU uncontained rotor failures do occur and to date the impact damage to the airplane has been minimal, some rotor failures do produce fragments that should be considered.. Since it is unlikely that uncontained rotor failures can be completely eliminated, Parts 23 and 25 require that airplane design precautions be taken to minimize the hazard from such events.

---

a. Uncontained gas turbine engine rotor failure statistics are presented in the Society of Automotive Engineers (SAE) reports covering time periods and number of uncontained events listed in the table shown below. The following statistics summarize the service experience for fixed wing airplanes and do not include data for rotorcraft and APU's:

			No. of Events	
Report No.	Period	Total	Category 3	Category 4
AIR1537	1962-75	275	44	5
AIR4003	1976-83	237	27	3
AIR4770 (Draft)	1984-89	164	22	7
TOTAL		676	93	15

The total of 676 uncontained events includes 93 events in the Category 3 and 15 events in Category 4 damage to the airplane. Category 3 damage is defined as significant airplane damage with the airplane continuing flight and making a safe landing. Category 4 damage is defined as severe airplane damage involving a crash landing, critical injuries, fatalities or hull loss.

During this 28 year period there were 1,089.6 million engine operating hours on commercial transports. The events were caused by a wide variety of influences classed as Environmental (bird ingestion, corrosion/erosion, foreign object damage (FOD)), Manufacturing and Material Defects, Mechanical, and Human Factors (maintenance and overhaul, inspection error and operational procedures).

b. Uncontained APU rotor failure statistics covering 1962 through 1993 indicate that there have been several uncontained failures in at least 250 million hours of operation on transport category airplanes. No category 3 or 4 events were reported and all failures occurred during ground operation. These events were caused by a wide variety of influences such as corrosion, ingestion of deicing fluid, manufacturing and material defects, mechanical, and human factors (maintenance and overhaul, inspection error and operational procedures).

c. The statistics in the SAE studies indicate the existence of many different causes of failures not readily apparent or predictable by failure analysis methods. Because of the variety of causes of uncontained rotor failures, it is difficult to anticipate all possible causes of failure and to provide protection to all areas. However, design considerations outlined in this AC provide guidelines for achieving the desired objective of minimizing the hazard to an airplane from uncontained rotor failures. These guidelines, therefore, assume a rotor failure will occur and that analysis of the effects of this failure is necessary. These guidelines are based on service experience and tests but are not necessarily the only means available to the designer.

6. DEFINITIONS.

a. Rotor. Rotor means the rotating components of the engine and APU that analysis, test, and/or experience has shown can be released during uncontained failure. The engine or APU manufacturer should define those components that constitute the rotor for each engine and APU type design. Typically rotors have included, as a minimum, disks, hubs, drums, seals, impellers, blades and spacers.

b. Blade. The airfoil sections (excluding platform and root) of the fan, compressor and turbine.

c. Uncontained Failure. For the purpose of airplane evaluations in accordance with this AC, uncontained failure of a turbine engine is any failure which results in the escape of rotor fragments from the engine or APU that could result in a hazard. Rotor failures which are of concern are those where released fragments have sufficient energy to create a hazard to the airplane.

d. Critical Component. A critical component is any component whose failure would contribute to or cause a failure condition which would prevent the continued safe flight and landing of the airplane. These components should be considered on an individual basis and in relation to other components which could be damaged by the same fragment or by other fragments from the same uncontained event .

e. Continued Safe Flight and Landing. Continued safe flight and landing means that the airplane is capable of continued controlled flight and landing, possibly using emergency procedures and without exceptional pilot skill or strength, with conditions of considerably increased flight crew workload and degraded flight characteristics of the airplane,

f. Fragment Spread Angle. The fragment spread angle is the angle measured, fore and aft from the center of the plane of rotation of an individual rotor stage, initiating at the engine or APU shaft centerline (see Figure 1).

g. Impact Area. The impact area is that area of the airplane likely to be impacted by uncontained fragments generated during a rotor failure (see Paragraph 9).

h. Engine and APU Failure Model. A model describing the size, mass, spread angle, energy level and number of engine or APU rotor fragments to be considered when analyzing the airplane design is presented in Paragraph 9.

7. DESIGN CONSIDERATIONS. Practical design precautions should be used to minimize the damage that can be caused by uncontained engine and APU rotor fragments. The most effective methods for minimizing the hazards from uncontained rotor fragments include location of critical components outside the fragment impact areas or separation, isolation, redundancy, and shielding of critical airplane components and/or systems . The following design considerations are recommended:

a. Consider the location of the engine and APU rotors relative to critical components, systems or areas of the airplane such as:

(1) Any other engine(s) or an APU that provides an essential function ;

(2) Pressurized sections of the fuselage and other primary structure of the fuselage, wings and empennage;

(3) Pilot compartment area;

(4) Fuel system components, piping and tanks;

(5) Control systems, such as primary and secondary flight controls, electrical power cables, wiring, hydraulic systems, engine control systems, flammable fluid shut-off valves, and the associated actuation wiring or cables;

(6) Any fire extinguisher system of a cargo compartment, an APU, or another engine including electrical wiring and fire extinguishing agent plumbing to these systems;

(7) Engine air inlet attachments and effects of engine case deformations caused by fan blade debris resulting in attachment failures;

(8) Instrumentation essential for continued safe flight and landing;

(9) Thrust reverser systems where inadvertent deployment could be catastrophic; and

(10) Oxygen systems for high altitude airplanes, where these are critical due to descent time.

b. Location of Critical Systems and Components. Critical airplane flight and engine control cables, wiring, flammable fluid carrying components and lines (including vent lines), hydraulic fluid lines and components, and pneumatic ducts should be located to minimize hazards caused by uncontained rotors and fan blade debris. The following design practices should be considered:

(1) Locate, if possible, critical components or systems outside the likely debris impact areas.

(2) Duplicate and separate critical components or systems, or provide suitable protection if located in debris impact areas.

(3) Protection of critical systems and components can be provided by using airframe structure or supplemental shielding.

These methods have been effective in mitigating the hazards from both single and multiple small fragments within the ± 15 degree impact area. Separation of multiplicated critical systems and components by at least a distance equal to the 1/2 blade fragment dimension has been accepted for showing minimization from a single high energy small fragment when at least one of the related multiplicated critical components is shielded by significant structure such as aluminum lower wing skins, pylons, pressure cabin skins or equivalent structures.

Multiplicated critical systems and components positioned behind less significant structures should be separated by at least a distance equal to the 1/2 blade fragment dimension, and at least one of the multiplicated critical systems should be:

i) located such that equivalent protection is provided by other inherent structures such as pneumatic ducting, interiors, bulkheads, stringers, or

ii) protected by an additional shield such that the airframe structure and shield material provide equivalent shielding.

(4) Locate fluid shutoffs and actuation means so that flammable fluid can be isolated in the event of damage to the system..

(5) Minimize the flammable fluid spillage which could contact an ignition source.

(6) For airframe structural elements, provide redundant designs or crack stoppers to limit the subsequent tearing which could be caused by uncontained rotor fragments.

(7) Locate fuel tanks and other flammable fluid systems and route lines (including vent lines) behind airplane structure to reduce the hazards from spilled fuel or from tank penetrations. Fuel tank explosion-suppression materials, protective shields or deflectors on the fluid lines, have been used to minimize the damage and hazards.

c. External Shields and Deflectors. When shields, deflection devices or airplane structure are proposed to be used to protect critical systems or components, the adequacy of the protection, including mounting points to the airframe structure, should be shown by testing or validated analyses supported by test data, using the fragment energies supplied by the engine or APU manufacturer or those defined in paragraph 9. For protection against engine small fragments, as defined in paragraph 9, no quantitative validation as defined in paragraph 10 is required if equivalency to the penetration resistant structures listed (e.g. pressure cabin skins, etc.) is shown.

8. ACCEPTED DESIGN PRECAUTIONS. Design practices currently in use by the aviation industry that have been shown to reduce the overall risk, by effectively eliminating certain specific risks and reducing the remaining specific risks to a minimum level, are described within this paragraph of the AC. Airplane designs submitted for evaluation by the regulatory authorities will be evaluated against these proven design practices.

a. **Uncontrolled Fire.**

(1) Fire Extinguishing Systems. The engine/APU fire extinguishing systems currently in use rely on a fire zone with a fixed compartment air volume and a known air exchange rate to extinguish a fire. The effectiveness of this type of system along with firewall integrity may therefore be compromised for the torn/ruptured compartment of the failed engine/ APU. Protection of the airplane following this type of failure relies on the function of the fire warning system and subsequent fire switch activation to isolate the engine/APU from airframe flammable fluid (fuel and hydraulic fluid) and external ignition sources (pneumatic and electrical). Fire extinguishing protection of such a compromised system may not be effective due to the extent of damage. Continued function of any other engine, APU or cargo compartment fire warning and extinguisher system, including electrical wiring and fire extinguishing agent plumbing, should be considered as described in Paragraph 7.

(2) Flammable Fluid Shutoff Valve. As discussed above, shutoff of flammable fluid supply to the engine may be the only effective means to extinguish a fire following an uncontained failure, therefore the engine isolation/flammable fluid shutoff function should be assured following an uncontained rotor failure. Flammable fluid shutoff valves should be located outside the uncontained rotor impact area. Shutoff actuation controls that need to be routed through the impact area should be redundant and appropriately separated in relation to the one-third disc maximum dimension.

(3) Fire Protection of Critical Functions. Flammable fluid shutoff and other critical controls should be located so that a fire (caused by an uncontained rotor event) will not prevent actuation of the shutoff function or loss of critical aircraft functions. If shutoff or other critical controls are located where a fire is possible following an uncontained rotor failure (e.g. in compartments adjacent to fuel tanks) then these items should meet the applicable fire protection standards such as AC 20-135, "Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria" or the equivalent ISO 2685.

(4) Fuel Tanks. If fuel tanks are located in impact areas, then the following precautions should be implemented:

(i) Protection from the effects of fuel leakage should be provided for any fuel tanks located above an engine or APU and within the one-third disc and intermediate fragment impact areas. Dry bays or shielding are acceptable means. The dry bay should be sized based on analysis of possible fragment trajectories through the fuel tank wall and the subsequent fuel leakage from the damaged fuel tank so that fuel will not migrate to an engine, APU or other ignition source during either in flight or ground operation. A minimum drip clearance distance of 10 inches from potential ignition sources of the engine nacelle, for static conditions, has been acceptable (see Figure 5).

(ii) Fuel tank penetration leak paths should be determined and evaluated for hazards during flight and ground phases of operation. If fuel spills into the airstream away from the airplane no additional protection is needed. Additional protection should be considered if fuel could spill, drain or migrate into areas housing ignition sources, such as engine or APU inlets or wheel wells. Damage to adjacent systems, wiring etc., should be evaluated regarding the potential that an uncontained fragment will create both an ignition source and fuel source. Wheel brakes may be considered as an ignition source during takeoff and initial climb. Protection of the wheel wells may be provided by airflow discharging from gaps or openings, preventing entry of fuel, a ventilation rate precluding a combustible mixture or other provisions indicated in §§ 23.863 and 25.863.

(iii) Areas of the airplane where flammable fluid migration is possible that are not drained and vented and have ignition sources or potential ignition sources should be provided with a means of fire detection and suppression and be explosion vented or equivalently protected.

b. Loss of Thrust.

(1) Fuel Reserves. The fuel reserves should be isolatable such that damage from a disc fragment will not result in loss of fuel required to complete the flight or a safe diversion. The effects of fuel loss, and the resultant shift of center of gravity or lateral imbalance, on airplane controllability should also be considered.

(2) Engine Controls. Engine control cables and/or wiring for the remaining powerplants that pass through the impact area should be separated by a distance equal to the maximum dimension of a one-third disc fragment or the maximum extent possible.

(3) Other Engine Damage. Protection of any other engines from some fragments should be provided by locating critical components such as engine accessories essential for proper engine operation (e.g. high pressure fuel lines, engine controls and wiring, etc.), in areas where inherent shielding is provided by the fuselage, engine or nacelle (including thrust reverser) structure (see Paragraph 7).

c. Loss of Airplane Control.

(1) Flight Controls. Elements of the flight control system should be adequately separated or protected so that the release of a single one-third disc fragment will not cause loss of control of the airplane. .Where primary flight controls have duplicated (or multiplicated) elements, these elements should be located to prevent all elements being lost as a result of the single one-third disc fragment. Credit for maintaining control of the airplane by the use of trim controls or other means may be obtained, providing evidence shows that these means will enable the pilot to retain control.

(2) Emergency Power. Loss of electrical power to critical functions following an uncontained rotor event should be minimized. The determination of electrical system criticality is dependent upon airplane operations. For example, airplanes approved for Extended Twin

Engine Operations (ETOPS) operations that rely on alternate power sources such as hydraulic motor generators or APUs may be configured with the electrical wiring separated to the maximum extent possible within the one-third disc impact zone.

(3) Hydraulic Supply. Any essential hydraulic system supply that is routed within an impact area should have means to isolate the hydraulic supply required to maintain control of the airplane.

(4) Thrust reverser systems. The effect of an uncontained rotor failure on inadvertent in-flight deployment of each thrust reverser and possible loss of airplane control shall be considered. The impact area for components located on the failed engine may be different from the impact area defined in Paragraph 6. If uncontained failure could cause thrust reverser deployment, the engine manufacturer should be consulted to establish the failure model to be considered. One acceptable method of minimization is to locate reverser restraints such that not all restraints can be made ineffective by the fragments of a single rotor.

d. Passenger and Crew Incapacitation.

(1) Pilot Compartment. The pilot compartment of transport category airplanes should not be located within the ±15 degree spread angle of any engine rotor stage or APU rotor stage that has not been qualified as contained, unless adequate shielding, deflectors or equivalent protection is provided for the rotor stage in accordance with paragraph 7 (c). For other airplanes (such as new Part 23 commuter category airplanes) the pilot compartment area should not be located within the ±5 degree spread angle of any engine rotor stage or APU rotor stage unless adequate shielding, deflectors, or equivalent protection is provided for the rotor stage in accordance with Paragraph 7c of this AC, except for the following:

(i) For derivative Part 23 category airplanes where the engine location has been previously established, the engine location in relation to the pilot compartment need not be changed.

(ii) For noncommuter Part 23 category airplanes satisfactory service experience relative to rotor integrity and containment in similar engine installations may be considered in assessing the acceptability of installing engines in line with the pilot compartment.

(iii) For noncommuter new Part 23 category, airplanes where due to size and/or design considerations the ±5 degree spread angle cannot be adhered to, the pilot compartment/engine location should be analyzed and accepted in accordance with Paragraphs 9 and 10.

(2) Pressure Vessel. For airplanes that are certificated for operation above 41000 ft. the engines should be located such that the pressure cabin cannot be affected by an uncontained one-third or intermediate disc fragment. Alternatively, it may be shown that rapid decompression due to the maximum hole size caused by these fragments and the associated cabin pressure decay rate

will allow an emergency descent without incapacitation of the flightcrew or passengers. A pilot reaction time of 17 seconds for initiation of the emergency decent has been accepted. Where the pressure cabin could be affected by a one-third disc or intermediate fragments, design precautions should be taken to preclude incapacitation of crew and passengers. Examples of design precautions that have been previously accepted are:

(i) Provisions for a second pressure or bleed down bulkhead outside the impact area of a one-third or intermediate disc fragment.

(ii) The affected compartment in between the primary and secondary bulkhead was made inaccessible, by the use of operating limitations, above the minimum altitude where incapacitation could occur due to the above hole size.

(iii) Air supply ducts running through this compartment were provided with nonreturn valves to prevent pressure cabin leakage through damaged ducts.

> NOTE: If a bleed down bulkhead is used it should be shown that the rate of pressure decay and minimum achieved cabin pressure would not incapacitate the crew, and the rate of pressure decay would not preclude a safe emergency descent.

e. Structural Integrity. Installation of tear straps and shear ties within the uncontained fan blade and engine rotor debris zone to prevent catastrophic structural damage has been utilized to address this threat.

9. ENGINE AND APU FAILURE MODEL. The safety analysis recommended in Paragraph 10 should be made using the following engine and APU failure model, unless for the particular engine/APU type concerned, relevant service experience, design data, test results or other evidence justify the use of a different model.

a. Single One-Third Disc fragment. It should be assumed that the one-third disc fragment has the maximum dimension corresponding to one-third of the disc with one-third blade height and a fragment spread angle of ± 3 degrees. Where energy considerations are relevant, the mass should be assumed to be one-third the bladed disc mass and its' energy, the translational energy (i.e., neglecting rotational energy) of the sector traveling at the speed of its' c.g. location as defined in Figure 2.

b. Intermediate Fragment. It should be assumed that the intermediate fragment has a maximum dimension corresponding to one-third of the bladed disc radius and a fragment spread angle of ± 5 degrees. Where energy considerations are relevant, the mass should be assumed to be 1/30 th of the bladed disc mass and its energy the translational energy (neglecting rotational energy) of the piece traveling at rim speed (see Figure 3).

c. Alternative Engine Failure Model. For the purpose of the analysis, as an alternative to the engine failure model of Paragraphs 9(a) and (b), the use of a single one-third piece of disc having a fragment spread angle ± 5° would be acceptable, provided that the objectives of Paragraph 10(a) are satisfied.

d. Small Fragments. It should be assumed that small fragments (shrapnel) range in size up to a maximum dimension corresponding to the tip half of the blade airfoil (with exception of fan blades) and a fragment spread angle of ± 15 degrees. Service history has shown that aluminum lower wing skins, pylons, and pressure cabin skin and equivalent structures typically resist penetration from all but one of the most energetic of these fragments. The effects of multiple small fragments should also be considered. Penetration of less significant structures such as fairings, empennage, control surfaces and unpressurized skin has typically occurred at the rate of 2 1/2 percent of the number of blades of the failed rotor stage. Refer to paragraph 7(b) and 7(c) for methods of minimization of the hazards. Where the applicant wishes to show compliance by considering the energy required for penetration of structure (or shielding) the engine manufacturer should be consulted for guidance as to the size and energy of small fragments within the impact area.

For APUs, where energy considerations are relevant, it should be assumed that the mass will correspond to the above fragment dimensions and that it has a translational energy level of one percent of the total rotational energy of the original rotor stage.

e. Fan Blade Fragment. It should be assumed that the fan blade fragment has a maximum dimension corresponding to the blade tip with one-third the blade airfoil height and a fragment spread angle of ± 15°. Where energy considerations are relevant the mass should be assumed to be corresponding to the one-third of the airfoil including any part span shroud and the energy the translational energy (neglecting rotational energy) of the fragment traveling at the speed of its c.g. location as defined in Figure 4. As an alternative, the engine manufacturer may be consulted for guidance as to the size and energy of the fragment.

f. Critical Engine Speed. Where energy considerations are relevant the uncontained rotor event should be assumed to occur at the engine or APU shaft red line speed.

g. APU Failure Model. For all APU's, the installer also needs to address any hazard to the airplane associated with APU debris (up to and including a complete rotor where applicable) exiting the tailpipe. Subparagraph (1) or (2) below or applicable service history provided by the APU manufacturer may be used to define the size, mass, and energy of debris exiting that tailpipe. The APU rotor failure model applicable for a particular APU installation is dependent upon the provisions of the Technical Standard Order (TSO) that were utilized for receiving approval:

(1) For APU's where rotor integrity has been demonstrated in accordance with TSO C77a/JAR APU, i.e. without specific containment testing, Paragraphs 9(a), (b), and (d), or Paragraphs 9(c) and 9(d) apply.

(2) For APU rotor stages qualified as contained in accordance with the TSO, historical data shows that in-service uncontained failures have occurred. These failure modes have included bi-

hub, overspeed, and fragments missing the containment ring which are not addressed by the TSO containment test. In order to address these hazards, the installer should use the APU small fragment definition of Paragraph 9d or substantiated in-service data supplied by the APU manufacturer.

10. SAFETY ANALYSIS.

a. Analysis. An analysis should be made using the engine/APU model defined in Paragraph 9 to determine the critical areas of the airplane likely to be damaged by rotor debris and to evaluate the consequences of an uncontained failure. This analysis should be conducted in relation to all normal phases of flight, or portions thereof.

(1) A delay of at least 15 seconds should be assumed for the emergency engine shut down drill. The extent of the delay is dependent upon circumstances resulting from the uncontained failure including increased flight crew workload stemming from multiplicity of warnings which require analysis by the flight crew.

(2) Some degradation of the flight characteristics of the airplane or operation of a system may be permissible, if the ability to complete continued safe flight and landing is provided. Account should be taken of the behavior of the airplane under asymmetrical engine thrust or power conditions together with any possible damage to the flight control system, and of the predicted airplane recovery maneuver.

(3) When considering how or whether to mitigate any potential hazard identified by the model, credit may be given to flight phase, service experience, or other data, as noted in Paragraph 7.

b. Drawings. Drawings should be provided to define the uncontained rotor impact threat relative to the areas of design consideration defined in Paragraphs 7a(1) through (10) showing the trajectory paths of engine and APU debris relative to critical areas. The analysis should include at least the following:

(1) damage to primary structure including the pressure cabin, engine/APU mountings and airframe surfaces. Note: Any structural damage resulting from uncontained rotor debris should be considered catastrophic unless the residual strength and flutter criteria of AC 25.571, paragraph 8(c), and ACJ 25.571 (a) subparagraph 2.7.2 can be met without failure of any part of the structure essential for completion of the flight. In addition, the pressurized compartment loads of § 25.365 (e)(1) (g) must be met.

(2) damage to any other engines (the consequences of subsequent uncontained debris from the other engine(s), need not be considered).

(3) damage to services and equipment essential for safe flight and landing (including indicating and monitoring systems), particularly control systems for flight, engine power, engine fuel supply and shut-off means and fire indication and extinguishing systems.

(4) pilot incapacitance, (see also paragraph 8 (d)(1)).

(5) penetration of the fuel system, where this could result in the release of fuel into personnel compartments or an engine compartment or other regions of the airplane where this could lead to a fire or explosion.

(6) damage to the fuel system, especially tanks, resulting in the release of a large quantity of fuel.

(7) Penetration and distortion of firewalls and cowling permitting a spread of fire.

(8) Damage to or inadvertent movement of aerodynamic surfaces (e.g.. flaps, slats, stabilizers, ailerons, spoilers, thrust reversers, elevators, rudders, strakes, winglets, etc.) and the resultant effect on safe flight and landing.

c. Safety Analysis Objectives. It is considered that the objective of minimizing hazards will have been met if:

(1) The practical design considerations and precautions of Paragraphs 7 and 8 have been taken;

(2) The safety analysis has been completed using the engine/APU model defined in paragraph 9;

(3) For Part 25 transport and Part 23 commuter category airplanes, the following hazard ratio guidelines have been achieved:

(i) Single One-Third Disc Fragment. There is not more than a 1 in 20 chance of catastrophe resulting from the release of a single one-third disc fragment as defined in Paragraph 9a.

(ii) Intermediate Fragment. There is not more than a 1 in 40 chance of catastrophe resulting from the release of a piece of debris as defined in Paragraph 9.

(iii) Multiple Disc Fragments. (Only applicable to any duplicated or multiplicated system where all of the system channels contributing to its function have some part which is within a distance equal to the diameter of the largest bladed rotor, measured from the engine centerline). There is not more than 1 in 10 chance of catastrophe resulting from the release in three random directions of three one-third fragments of a disc each having a uniform probability of ejection over the 360° (assuming an angular spread of ±3° relative to the plane of the disc) causing coincidental damage to systems which are duplicated or multiplicated.

NOTE: Where dissimilar systems can be used to carry out the same function (e.g. elevator control and pitch trim), they should be regarded as duplicated (or

Multiplicated) systems for the purpose of this subparagraph provided control can be maintained .

NOTE: The numerical assessments described above may be used to judge the relative values of minimization. The degree of minimization that is feasible may vary depending upon airplane size and configuration and this variation may prevent the specific hazard ratio from being achieved. These levels are design goals and should not be treated as absolute targets. It is possible that any one of these levels may not be practical to achieve.

(4) For new non-commuter Part 23 airplanes the chance of catastrophe is not more than twice that of 10 (c)(3)(i), (ii) and (iii) for each of these fragment types.

(5) A numerical risk assessment is not requested for the single fan blade fragment, small fragments, and APU and engine rotor stages which are qualified as contained.

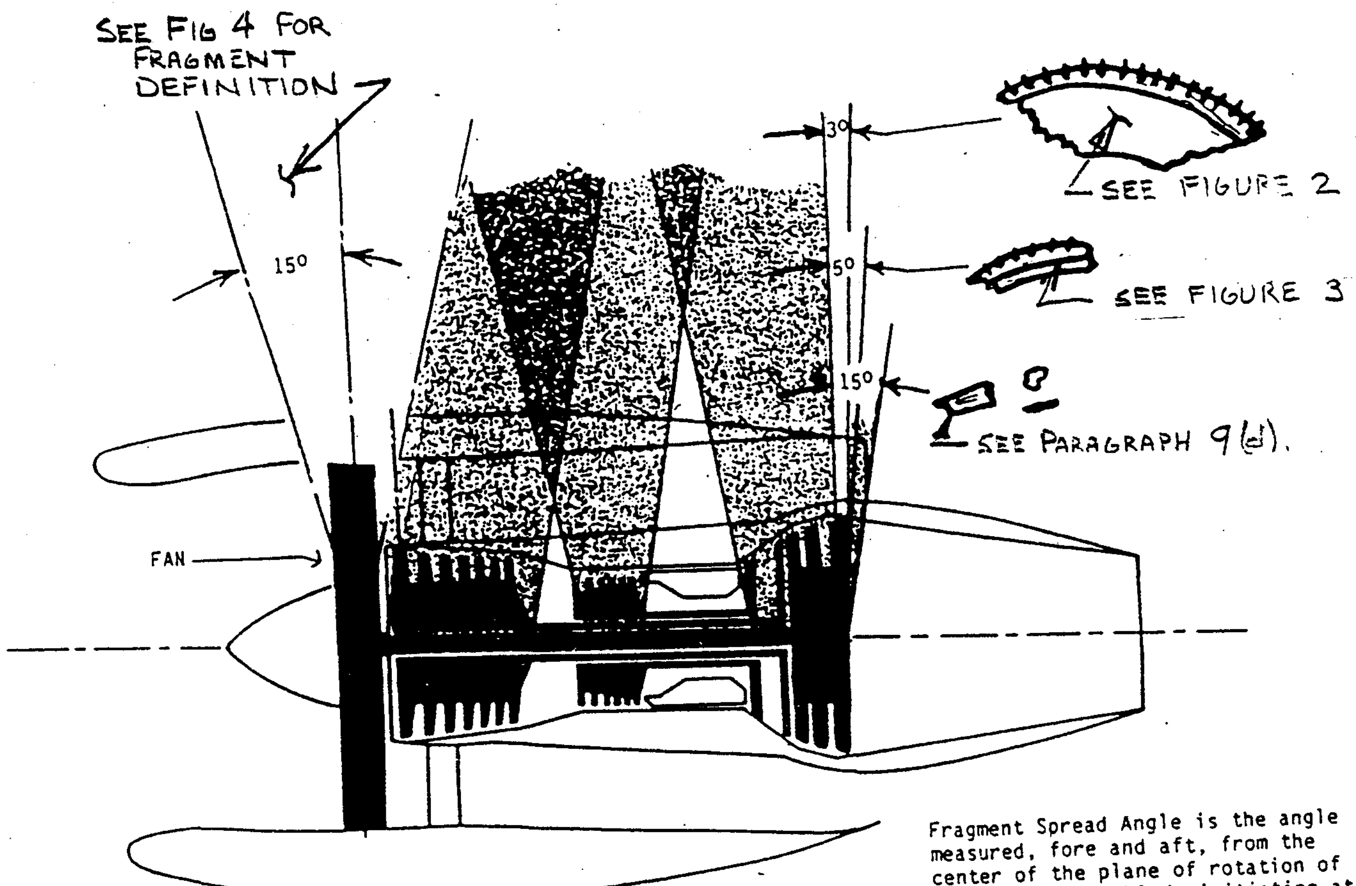
d. APU Analysis For APU's that are located where no hazardous consequences would result from an uncontained failure, a limited qualitative assessment showing the relative location of critical systems/components and APU impact areas is all that is needed. If critical systems/components are located within the impact area, more extensive analysis is needed. For APU's which have demonstrated rotor integrity only, the failure model outlined in Paragraph 9g(1) should be considered as a basis for this safety assessment. For APU rotor stages qualified as contained per the TSO, the airplane safety analysis may be limited to an assessment of the effects of the failure model outlined in Paragraph 9g(2).

e. Specific Risk The airplane risk levels specified in Paragraph 10c, resulting from the release of rotor fragments, are the mean values obtained by averaging those for all rotor on all engines of the airplane, assuming a typical flight. Individual rotors or engines need not meet these risk levels nor need these risk levels be met for each phase of flight if either--

(1) No rotor stage shows a higher level of risk averaged throughout the flight greater than twice those stated in Paragraph 10c.

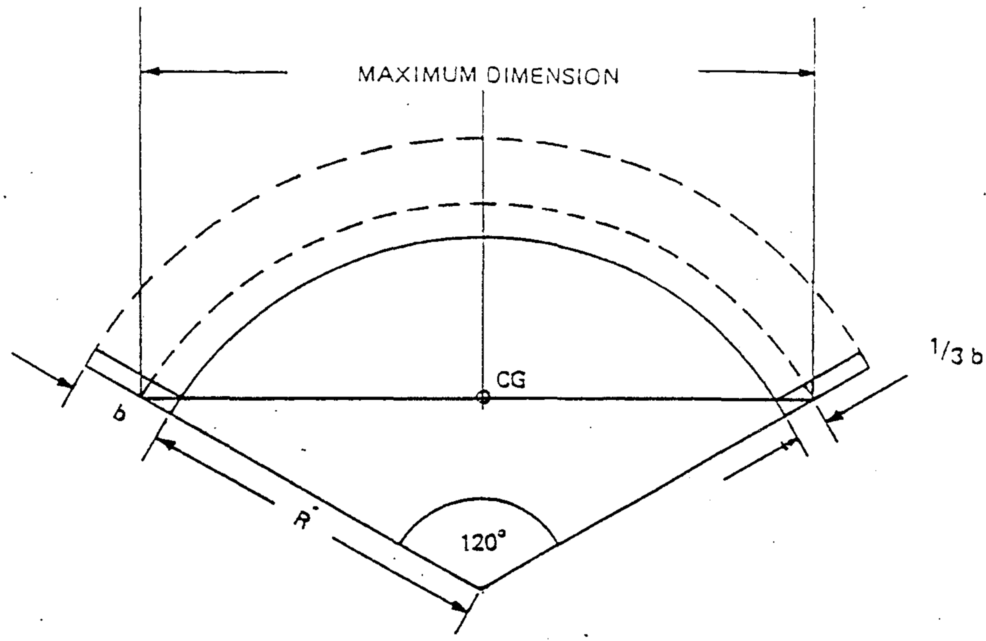
NOTE: The purpose of this Paragraph is to ensure that a fault which results in repeated failures of any particular rotor stage design, would have only a limited effect on airplane safety.

(2) Where failures would be catastrophic in particular portions of flight, allowance is made for this on the basis of conservative assumptions as to the proportion of failures likely to occur in these phases. A greater level of risk could be accepted if the exposure exists only during a particular phase of flight e.g., during takeoff. The proportional risk of engine failure during the particular phases of flight is given in SAE Papers referenced in paragraph 4 (d). See also data contained in the CAA paper "Engine Non-Containments - The CAA View", which includes Figure 6. This paper is published in NASA Report CP-2017, "An Assessment of Technology for Turbo-jet Engine Rotor Failures", dated August 1977.



Fragment Spread Angle is the angle measured, fore and aft, from the center of the plane of rotation of the disc or fan blade initiating at the engine or APU shaft centerline.

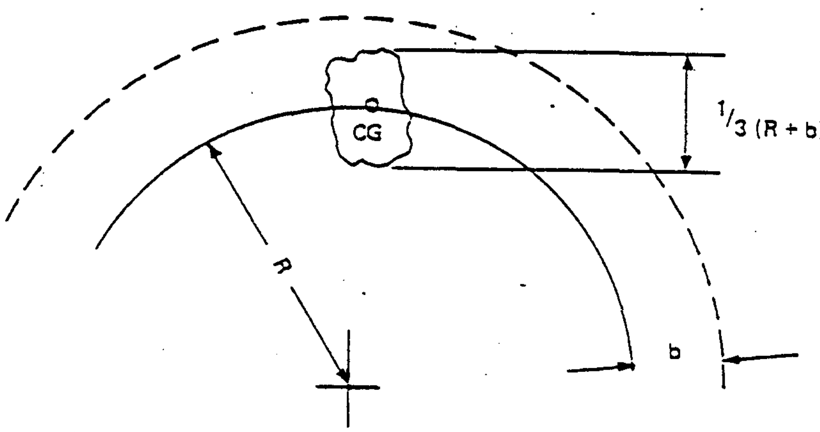
FIGURE 1
ESTIMATED PATH OF FRAGMENTS



Where R = disc radius
b = blade length

The CG is taken to lie on the maximum dimension as shown.

FIGURE 2 - SINGLE ONE-THIRD ROTOR FRAGMENT



Where R = disc radius
b = blade length

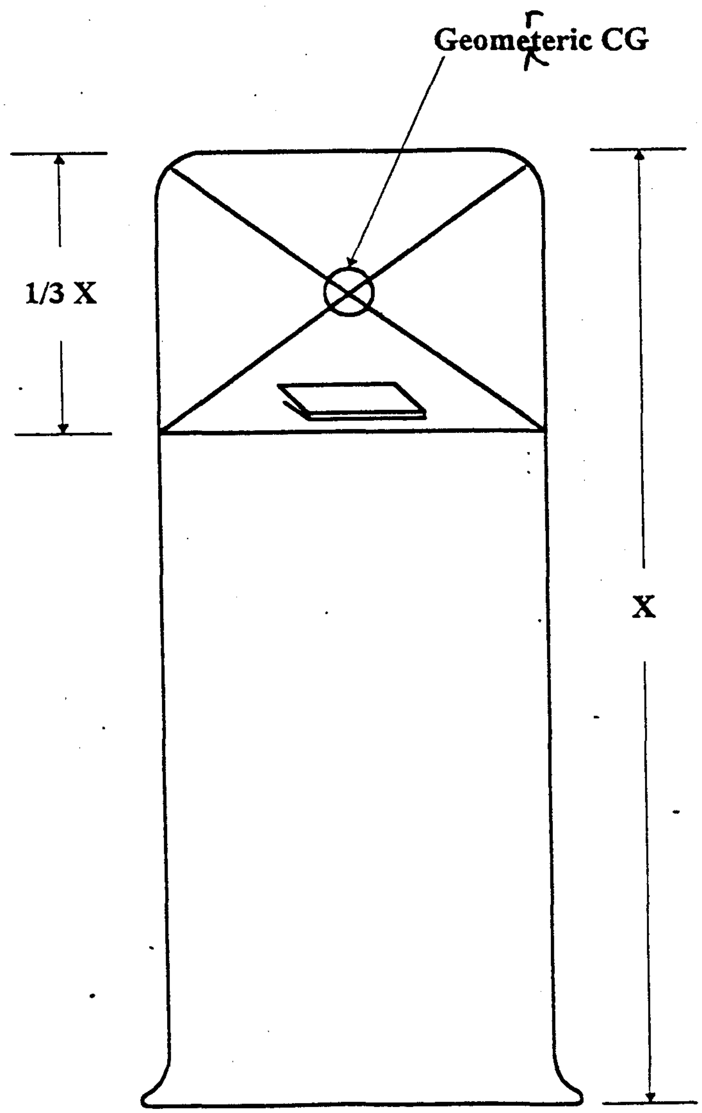
Maximum dimension = ⅓ (R + b)

Mass assumed to be $^1/_{30}$th of bladed disc

CG is taken to lie on the disc rim

FIGURE 3 - INTERMEDIATE FRAGMENT

FIGURE 4
FAN BLADE FRAGMENT DEFINITION



Where X = Airfoil Length (less blade root & platform)

CG is taken to lie at the centerline of the 1/3 fragment

Fragment velocity taken at geometric CG

Fragment mass assumed to be 1/3 of the airfoil mass

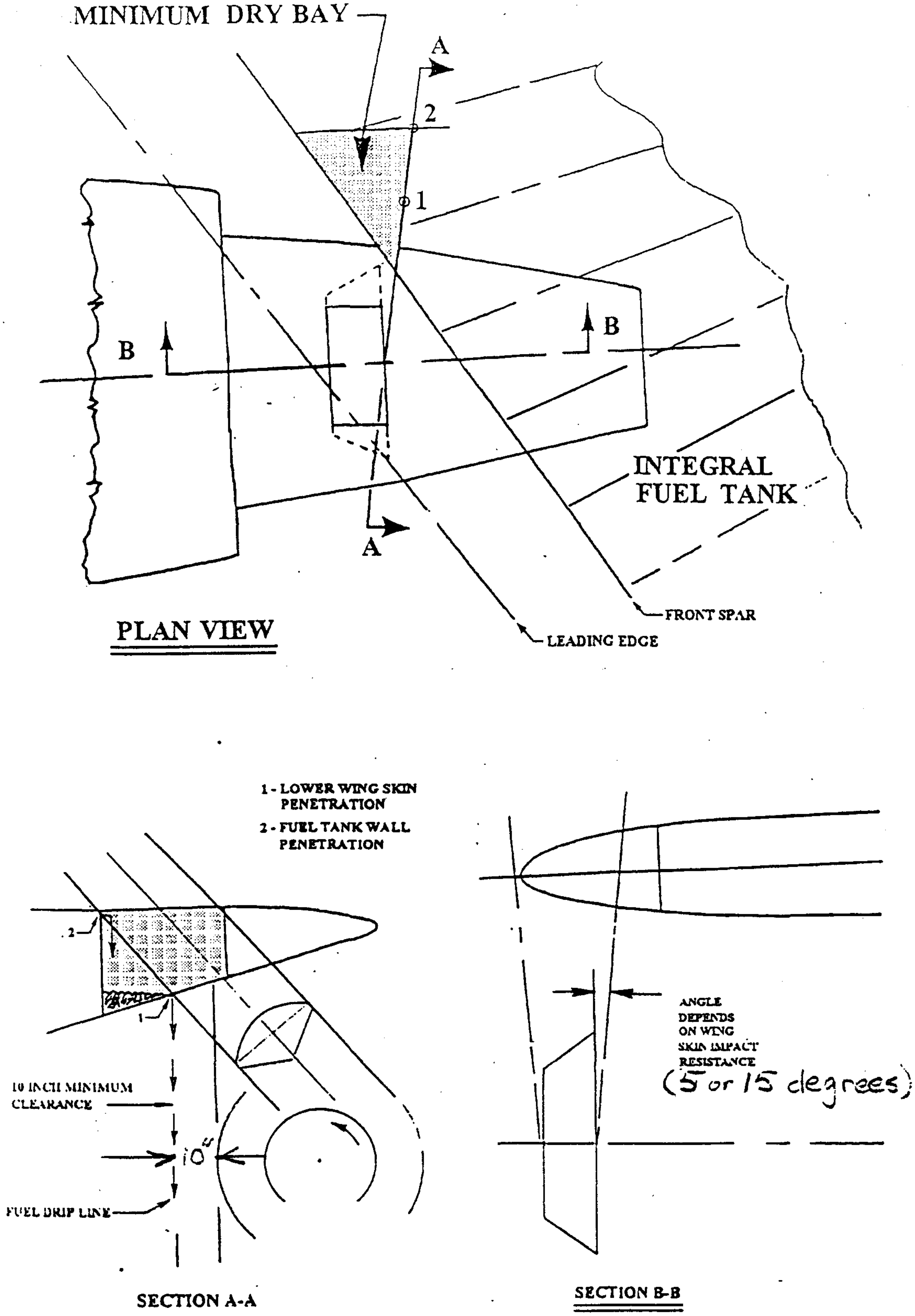


FIGURE 5- DRY BAY SIZING DETERMINATION EXAMPLE

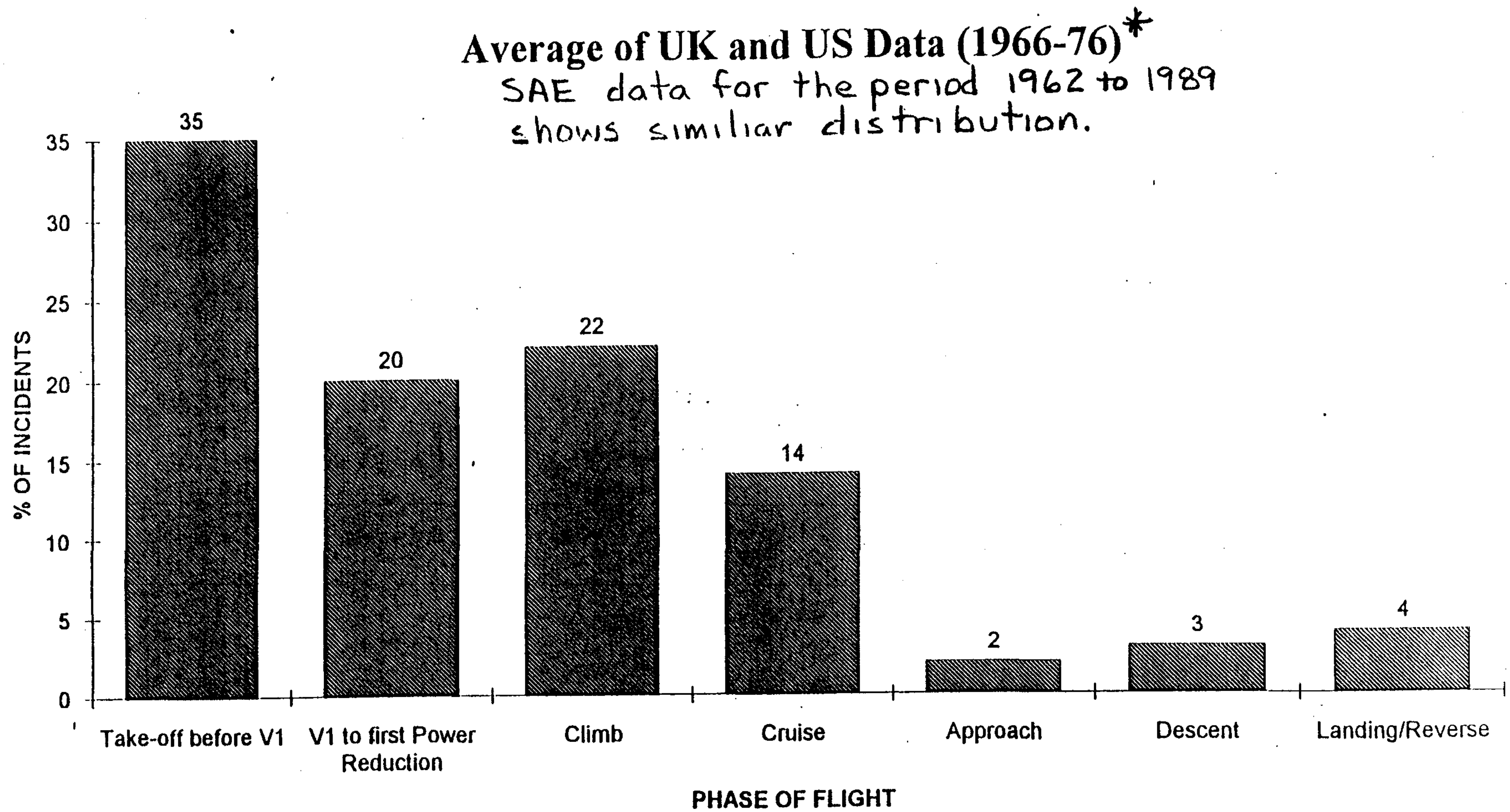


FIGURE 6 - ALL NON-CONTAINMENTS BY PHASE OF FLIGHT

Draft no. 8

April 18, 1995

Advisory Material for Compliance

with Rotor Burst Rule

(Appendix to AC 29-2A)

<u>DRAFT</u>

NOT FOR PUBLICATION

1. **PURPOSE**. This advisory material sets forth a method of compliance with the requirements of 29.901, 29.903(b)(1), and 29.903(d)(1) of the Federal Aviation Regulations (FAR) pertaining to design precautions taken to minimize the hazards to rotorcraft in the event of uncontained engine rotor (compressor and turbine) failure. It is for guidance and to provide a method of compliance that has been found acceptable. As with all AC material, it is not mandatory and does not constitute a regulation.

2. **RELATED FAR/JAR SECTIONS**. Sections 29.901(c) and 29.903(d)(1) of the FAR/JAR.

3. **BACKGROUND**. Although turbine engine manufacturers are making efforts to reduce the probability of uncontained rotor failures, service experience shows that such failures continue to occur. Failures have resulted in high velocity fragment penetration of fuel tanks, adjacent structures, fuselage, system components and other engines of the rotorcraft. Since it is unlikely that uncontained rotor failures can be completely eliminated, rotorcraft design precautions should be taken to minimize the hazard from such

events. These design precautions should recognize rotorcraft design features that may differ significantly from that of an airplane, particularly regarding an engine location and its proximity to another engine, systems and components.

A. Uncontained gas turbine engine rotor failure statistics for rotorcraft are presented in the Society of Automotive Engineers (SAE) Reports no. AIR 4003 (period 1976-83) and AIR 4770 (period 1984-89).

B. The statistics in the SAE studies indicate the existence of some failure modes not readily apparent or predictable by failure analysis methods. Because of the variety of uncontained rotor failures, it is difficult to analyze all possible failure modes and to provide protection to all areas. However, design considerations outlined in this AC provide guidelines for achieving the desired objective of minimizing the hazard to rotorcraft from uncontained rotor failures. These guidelines, therefore, assume a rotor failure will occur and that analysis of the effects or evaluation of this failure is necessary. These guidelines are based on service experience and tests but are not necessarily the only means available to the designer.

4. <u>DEFINITIONS</u>

A. **Minimize** Means to reduce to a minimum, decrease to the least possible amount, that can be shown to be both technically feasible and economically justifiable to the certification authority.

B. **Separation**. Positioning of redundant critical structure, systems, or system components within the impact area such that the distance between the components minimizes the potential impact hazard. Redundant critical components should be separated within the spread angles of a rotor by a distance at least equal to either a 1/2 unbladed disk (hub, impeller) sector, or a 1/3 bladed disk (hub, impeller) sector with 1/3 blade height, with each rotating about its c.g., whichever is greater (see Figure 6).

C. **Isolation**. A means to limit system damage so as to maintain partial or full system function after the system has been damaged by fragments. Limiting the loss of hydraulic fluid by the use of check valves to retain the capability to operate flight controls is an example of "isolation." System damage is confined allowing the retention of critical system functions.

D. Rotor. Rotor means the rotating components of the engine and APU that analysis, test, and/or experience has shown can be released during uncontained failure with sufficient energy to hazard the rotorcraft.

The engine or APU manufacturer should define those components that constitute the rotor for each engine and APU type design. Typical rotors have included, as a minimum, disks, hubs, drums, seals, impellers, and spacers.

E. **Uncontained Engine or APU Failure (or Rotorburst)**. For the purposes of rotorcraft evaluations in accordance with this AC, uncontained failure of a turbine engine is any failure which results in the escape of rotor fragments from the engine or APU that could create a hazard to the rotorcraft. Rotor failures which are of concern are those where released fragments have sufficient energy to create a hazard to the rotorcraft. Uncontained failures of APU's which are "ground operable only" are not considered hazardous to the rotorcraft.

F. Critical Component (System). A critical component is any component or system whose failure or malfunction would contribute to or cause a failure condition that would prevent the continued safe flight and landing of the rotorcraft. These components (systems) should be considered on an individual basis and in relation to other components (systems) that could be degraded or rendered inoperative by the same fragment or by other fragments during any uncontained failure event.

G. **Fragment Spread Angle**. The fragment spread angle is the angle measured, fore and aft, from the center of the plane of rotation of the disk (hub, impeller) or other rotor component initiating at the engine or APU shaft centerline or axis of rotation (see figure 1). The width of the fragment should be considered in defining the path of the fragment envelope's maximum dimension.

H. **Ignition Source**. Any component that could precipitate a fire or explosion. This includes existing ignition sources and potential ignition sources due to damage or fault from an uncontained rotor failure. Potential ignition sources include hot fragments, damage or faults that produce sparking, arcing, or overheating above the auto-ignition temperature of the fuel. Existing ignition sources include items such as unprotected engine or APU surfaces with temperature greater than the auto-ignition temperature of the fuel or any other flammable fluid.

5. SAFETY ASSESSMENT

A. **Procedure** - Assess the potential hazard to the rotorcraft using the following procedure:

(1) **Minimizing Rotor Burst Hazard**. The rotorburst hazard should be reduced to the lowest level that can be shown to be both technically feasible and economically justifiable. The extent of minimization that is possible will vary from new or amended certification projects and from design to design. Thus the effort to minimize must be determined uniquely for each certification project. Design precautions and techniques such as location, separation, isolation, redundancy, shielding, containment and/or other appropriate considerations should be employed, documented, agreed to by the certifying authority, and placed in the type data file. A discussion of these methods and techniques follows.

(2) **Geometric Layout and Safety Analysis**. The applicant should prepare a preliminary geometric layout and safety analysis for a minimum rotorburst

hazard configuration determination early in the design process and present the results to the certification authority no later than when the initial design is complete. Early contact and coordination with the certifying authority will minimize the need for design modification later in the certification process. The hazard analysis should follow the guidelines indicated in paragraph 397c(2) of AC 29-2A and 5.F. of this document. Geometric layouts and analysis should be used to evaluate and identify engine rotorburst hazards to critical systems, powerplants, and structural components from uncontained rotor fragments, and to determine any actions which may be necessary to further minimize the hazard. Calculated geometric risk quantities may be used in accordance with paragraph D following, to define the rotorcraft configuration with the minimum physical rotorburst hazard.

B. Engine and APU Failure Model. The safety analysis should be made using the following engine and APU failure model, unless for the particular engine/APU type concerned, relevant service experience, design data, test results or other evidence justify the use of a different model. In particular, a suitable failure model may be provided by the engine/APU manufacturer. This may show that one or more of the considerations below do not need to be addressed.

(1) <u>**Single One-Third Disc Fragment**</u>. It should be assumed that the one-third disc fragment has the maximum dimension corresponding to one-third of the disc with one-third blade height and a fragment spread angle of $\pm 3°$. Where energy considerations are relevant, the mass should be assumed to be one-third the bladed disc mass and its energy-the translational energy (i.e. neglecting rotational energy) of the sector (see Figure 2).

(2) <u>**Intermediate Fragments**</u>. It should be assumed that the intermediate fragment has a maximum dimension corresponding to one-third of the disc radius with one-third blade height and a fragment spread angle of $\pm 5°$. Where energy considerations are relevant, the mass should be assumed to be 1/30th of the bladed disc mass and its energy the translational energy (neglecting rotational energy) of the piece traveling at rim speed (see Figure 3).

(3) <u>**Alternative Engine Failure Model**</u>. For the purpose of the analysis, as an alternative to the

engine failure model of section (1) and (2) above, the use of a single one-third piece of disc having a fragment spread angle of $\pm5°$ would be acceptable, provided that the objectives of the analysis are satisfied.

(4) Small Fragments. It should be assumed that small fragments have a maximum dimension corresponding to the tip half of the blade airfoil and a fragment spread angle of $\pm15°$. Where energy considerations are relevant the mass should be assumed to be corresponding to the above fragment dimensions and the energy is the translational energy (neglecting rotational energy) of the fragment travelling at the speed of its c.g. location. The effects of multiple small fragments should be considered during this assessment.

(5) Critical Engine Speed. Where energy considerations are relevant the uncontained rotor event should be assumed to occur at the engine shaft speed for the maximum rating appropriate to the flight phase (exclusive of OEI ratings), unless the most probable mode of failure would be expected to result in the engine rotor reaching a red line speed or a design burst speed. For APU's,

use the maximum rating appropriate to the flight phase or the speed resulting from a failure of any one of the normal engine control systems.

(6) **APU Failure Model:** Service experience has shown that some APU rotor failures produced fragments having significant energy have been expelled through the APU tailpipe. For the analysis, the applicable APU service history and test results should be considered in addition to the failure model as discussed in paragraph 5 (b) above for certification of APU installations near critical items. In addition, the APU installer needs to address the rotorcraft hazard associated with APU debris exiting the tailpipe. Applicable service history or test results provided by the APU manufacturer may be used to define the tailpipe debris size, mass, and energy. The uncontained APU rotor failure model is dependent upon the design/analysis, test and service experience.

(a) For APU's where rotor containment has been demonstrated in accordance with TSO C77a/JAR APU, i.e. without specific containment testing. Paragraphs 5.(B)(1), 5.(B)(2) and 5.(B)(4) or Paragraph 5.(B)(3) and 5.(B)(4) apply. If shielding of critical airframe components is proposed, the energy level that should be considered is that of the tri-hub failure released at the critical speed as defined in Paragraph 5.(B)(5). The shield and airframe mounting point(s) should be shown to be effective at containing both primary and secondary debris at angles specified by the failure model.

(b) For APU rotor stages qualified as contained in accordance with the TSO, an objective review of the APU location should be made to ensure the hazard is minimized in the event of an uncontained APU rotor failure. Historical data shows that in-service uncontained failures have occurred on APU rotor stages qualified as contained per the TSO. These failure modes have included bi-hub and overspeed failure resulting in some fragments missing the containment ring. In order to address these hazards, the installer should use the small fragment failure model, or substantiated in-service data supplied by the APU manufacture . Analytical substantiation for the shielding system if proposed is acceptable for showing compliance.

C. <u>Engine/APU Rotorburst Data</u>. The engine or APU manufacturer should provide the required engine data to accomplish the evaluation and analysis necessary to minimize the rotorburst hazard such as:

1. engine failure model (range of fragment sizes, spread angles and energy)
2. engine rotorburst probability assessment
3 list of components constituting the rotors

D. **Fragment Impact Risks**. FAA research and development studies have shown that, for rotorcraft conventional configurations (one main rotor and one tail rotor), the main and tail rotorblades have minimal risks from a rotorburst, and thus, they require no special protection. However, unique main and tail rotor blade configurations should be carefully reviewed. Certain zones of the tail rotor drive shaft and other critical parts which may be necessary for continued safe flight and landing may not have natural, minimal risk from uncontained rotor fragments.

E. **Engine Service History/Design**. For the purpose of a gross assessment of the vulnerability of the rotorcraft to an uncontained rotor burst, it must be taken that an uncontained engine rotor failure (burst) will occur. However, in determining the overall risk to the rotorcraft, engine service history and engine design features should be included in showing compliance with 29.903 to minimize the hazard from uncontained rotor failures. This is extremely important since the engine design and/or the service history may provide valuable information in assessing the potential for a rotor burst occurring and this should be considered in the overall safety analysis.

Information contained in the recent SAE studies (see paragraph 3.A.) should be considered in this evaluation.

F. **Certification Data File**. A report, including all geometric layouts, that details all the aspects of minimizing the engine rotorburst hazards to the rotorcraft should be prepared by the applicant and submitted to the certification authority. Items which should be included in this report are the identification of all hazardous failures that could result from engine rotor failure strikes and their consequences (i.e., an FMEA or equivalent analysis) and the design precautions and features taken to minimize the identified hazards that could result from rotor failure fragment strikes. Thus an analysis that lists all the critical components; quantifies and ranks their associated rotorburst hazard; and clearly show the minimization of that quantified, ranked hazard to the "maximum practicable extent" should be generated and agreed upon during certification. Critical components should all be identified and their rotorburst hazard quantified, ranked, and minimized where necessary. Design features in which the design precautions of this guidance material are not accomplished should be identified along with the alternate means used to minimize the hazard. To adequately address minimizing the hazards, all rotorcraft design disciplines should be involved in the applicant's compliance efforts and report preparation.

6. **DESIGN CONSIDERATIONS**. Practical design precautions should be used to minimize the damage that can be caused by uncontained engine and APU rotor debris. The following design considerations are recommended:

A. **Consider the location of the engine and APU rotors relative** to critical components, or areas of the rotorcraft such as:

(1) **Opposite Engine** - Protection of the opposite engine from damage from 1/3 disc rotor fragments may not be feasible. Protection of the opposite engine from other fragments may be provided by locating critical components, such as engine

accessories essential for proper engine operation (e.g. high pressure fuel lines, engine controls and wiring, etc.), in areas where inherent shielding is provided by the fuselage, engine, or other structure.

(2) **Engine Controls** - Controls for the remaining engine(s) that pass through the uncontained engine failure zone should be separated/protected to the maximum extent practicable.

(3) Primary structure of the fuselage

(4) Flight crew - The flight crew is considered a critical component.

(5) Fuel system components, piping and tanks including fuel tank access panels (**NOTE:** Spilled fuel into the engine or APU compartments, on engine cases or on other critical components or areas could create a fire hazard.)

(6) Critical control systems, such as primary and secondary flight controls, electrical power cables, systems and wiring, hydraulic systems, engines

control systems, flammable fluid shut-off valves, and the associated actuation wiring or cables

(7) Engine and APU fire extinguisher systems including electrical wiring and fire extinguishing agent plumbing to engine and APU compartments

(8) Instrumentation necessary for continued safe flight and landing

(9) Transmission and rotor drive shafts

B. <u>**Location of Critical Systems and Components**</u>.

The following design practices have been used to minimize hazards to critical components:

(1) Locate, if possible, critical components or systems outside the likely debris impact areas.

(2) Duplicate and separate critical components or systems if located in debris impact areas or provide suitable protection.

(3) Protection of critical systems and components can be provided by using airframe structure where shown to be suitable.

(4) Locate fluid shutoffs so that flammable fluids can be isolated in the event of damage to the system. Design and locate the shut-off actuation means in protected areas or outside debris impact areas.

(5) Minimize the flammable fluid spillage which could contact an ignition source.

(6) For airframe structural elements, provide redundant designs or crack stoppers to limit the subsequent tearing which could be caused by uncontained rotor fragments.

(7) Consider the likely damage caused by multiple fragments.

(8) Fuel tanks should not be located in impact areas. However, if necessitated by the basic configuration requirements of the rotorcraft type to locate fuel tanks in impact areas, then the engine rotorburst hazard should be minimized by use of design features such as minimization of hazardous fuel spillage (that could contact an ignition source by drainage or migration); by

drainage of leaked fuel quickly and safely into the airstream; by proper ventilation of potential spillage areas; by use of shielding; by use of explosion suppression devices (i.e., explosion resistant foam or inert gases); and by minimization of potential fuel ignition sources or by other methods to reduce the hazard.

(9) The rotor integrity or containment capability demonstrated during APU evaluation to TSO-C77a, or JAR-APU should be considered for installation certification.

(10) The flight data recorder, cockpit voice recorder and emergency locator transmitter, if required, should be located outside the impact zone when practical.

(11) Items such as human factors, pilot reaction time, and correct critical system status indication in the pilot compartment after an uncontained engine failure has occurred should be considered in design to permit continued safe flight and landing.

C. <u>Rotorcraft Modifications</u>. Modifications made to rotorcraft certified to this rule should be assessed with the considerations of this AC. These modifications include but are not limited to re-engining installations (including conversion from reciprocating to turbine powered), APU installations, fuselage stretch, and auxiliary fuel tank installations. Auxiliary fuel tank(s) should be located as much as practical so as to minimize the risk that this tank(s) will be hit by rotor failure fragments. The need to remain within the approved C.G. limits of the aircraft will of necessity limit the degree to which the risk may be minimized.

7. **PROTECTIVE MEASURES**. The following list is provided for consideration as some measures which may be used to minimize effects of a rotor burst:

A. Powerplant Containment

(1) **Engine Rotor Fragment Containment**. **It should be clearly understood that containment of rotor fragments is not a requirement**. However, it is one of many options which may be used to minimize the hazards of an engine rotor burst. Containment structures (either around the engine, or APU, or on the rotorcraft) that have been demonstrated to provide containment should be accepted as minimizing the hazard defined by the rotor

failure model for that particular rotor component. Contained rotor in-service failures may be used to augment any design or test data. Containment material stretch and geometric deformation should be considered in conjunction with fragment energies and trajectories in defining the hazards to adjacent critical components such as structures, system components, fluid lines, and control systems. Data obtained during containment system testing along with analytical data and service experience should be used for this evaluation.

(2) **APU Containment**

Rotor integrity or containment capability demonstrated during APU TSO evaluation should be considered for installation certification. If rotor containment option was shown by analysis or rig test, an objective review of the APU location should be made to ensure the hazard is minimized in the event of an uncontained APU rotor failure.

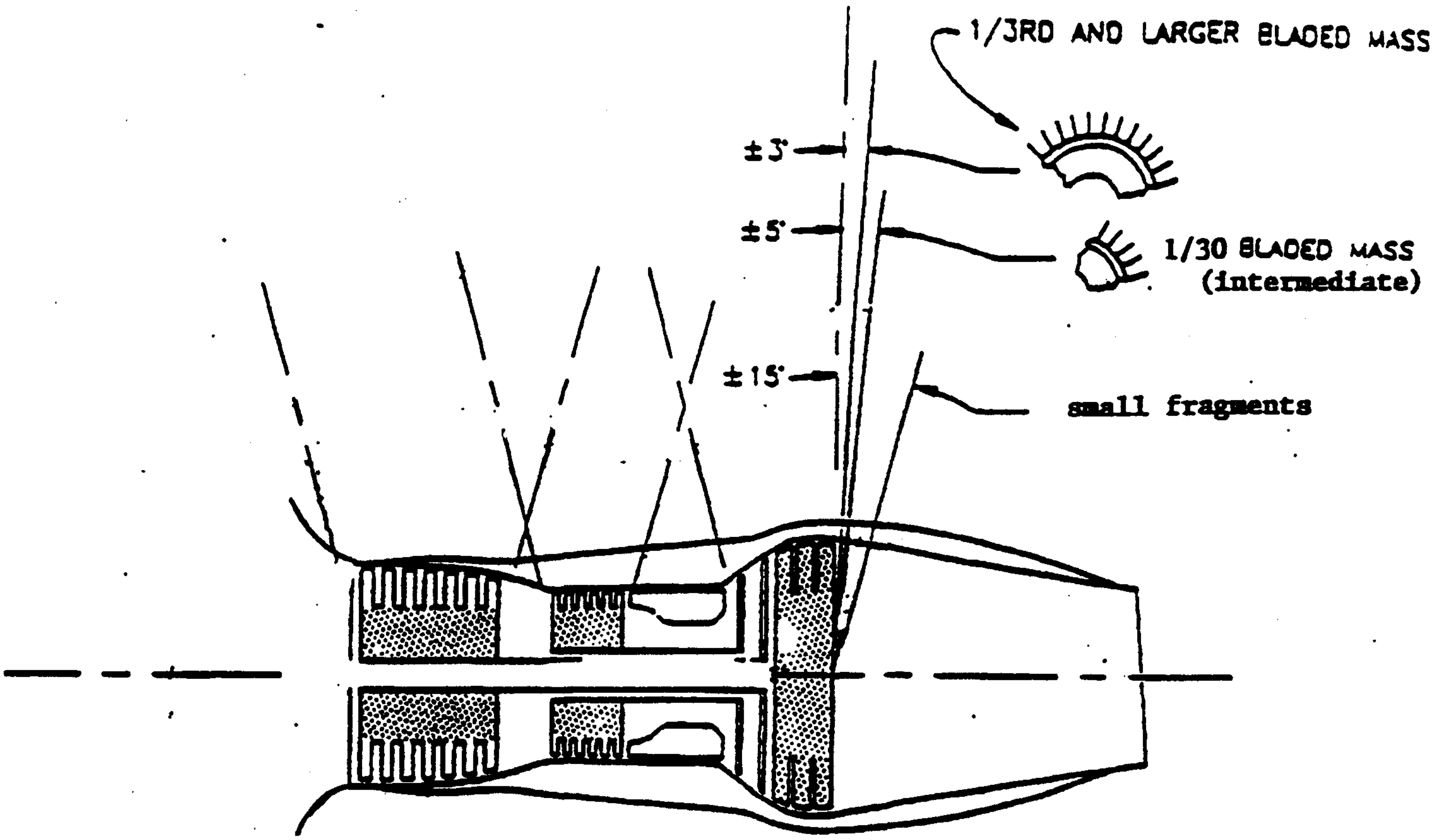
B. **Shields and Deflectors**. When shields, deflection devices, or intervening rotorcraft structure are used to protect critical systems or components, the adequacy of the protection should be shown by testing or analysis supported by test data, using the impact area, fragment mass, and fragment energies based on the definitions stated herein. Analytical methods used to compute protective armor or shielding thicknesses and energy absorption requirements should reflect established methods, acceptable to the certifying authority, that are supported by adequate test evidence. Protective armor, shielding, or deflectors that stop, slow down, or redirect uncontained fragments redistribute absorbed energy into the airframe. The resulting loads are significant for large fragments and should be considered as basic load cases for structural analysis purposes (reference paragraph 29.301). These structural loads should be defined and approved as ultimate loads acting alone. The protective devices and their supporting airframe structures should be able to absorb or deflect the fragment energies defined herein and still continue safe flight and landing. If hazardous, the deflected fragment trajectories and residual energies should also be considered.

C. **Isolation or Redundancy**.

(1) **Other Engines** - Although other engines may be considered critical, engine isolation from rotorburst on multi-engine rotorcraft is not mandatory. Other methods of minimizing the risk to the engine(s) may be acceptable.

(2) **Other Critical Components -** Isolation or redundancy of other critical components, the failure of which would not allow continued safe flight and landing should be evaluated relative to the risk of occurrence and where the risk is deemed unacceptable isolation or shielding or other means of reducing the risk should be incorporated.

D. **Composite Materials**. If containment devices, shields or deflectors are chosen by the applicant to be wholly or partially made from composites; they should comply with the structural requirements of AC 20-107A, "Composite Aircraft Structure", and AC 29-2A, Paragraph 788, "Substantiation of Composite Rotorcraft Structure", (which includes glass transition temperature considerations). Glass transition temperature considerations are critical for proper certification of composite or composite hybrid structures used in temperature zones that reach or exceed 200° to 250°F (93° to 121°C) for significant time periods. Hot fragment containment is typically accommodated in such protective devices by use of metal-composite hybrid designs that use the metal component's properties to absorb the fragment heat load after the entire hybrid structure has absorbed the fragment's impact load. These devices should comply with paragraphs 29.609 and 29.1529 to ensure continued airworthiness.



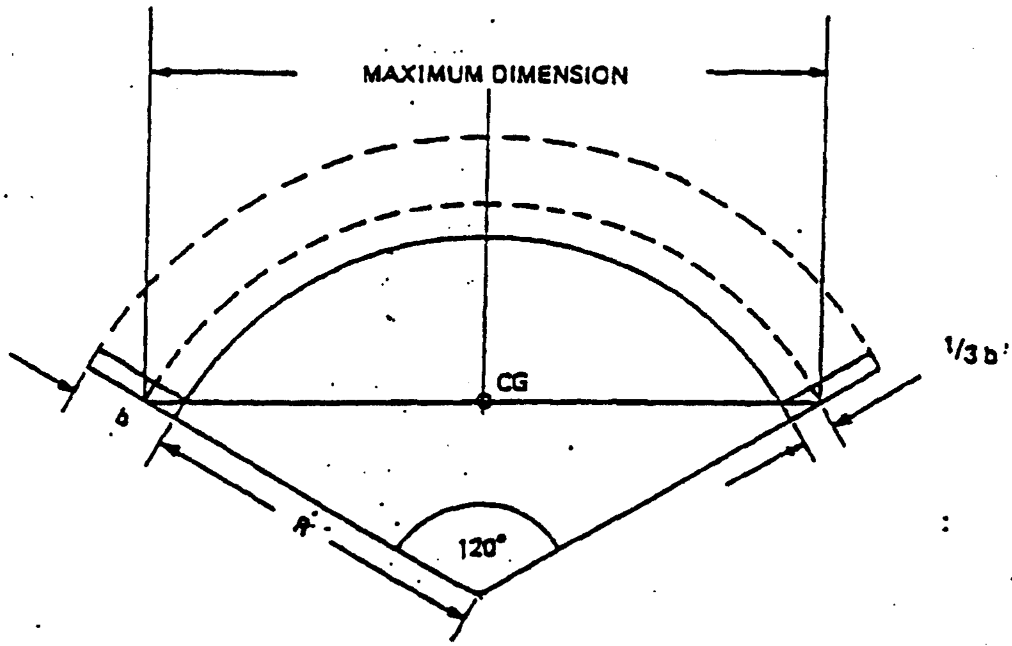
FRAGMENT SPREAD ANGLE IS THE ANGLE MEASURED, FORE AND AFT, FROM THE CENTER OF THE PLANE OF ROTATION INITIATING AT THE ENGINE OR APU SHAFT CENTERLINE.

NOTE: 1) THE POSSIBILITY OF TURBINE MOVEMENT SHOULD BE CONSIDERED.

2) ALL ROTORS ARE CONSIDERED TO BE FULLY BLADED FOR CALCULATING MASS.

3) FAILURE OF EACH ROTOR STAGE SHOULD BE CONSIDERED.

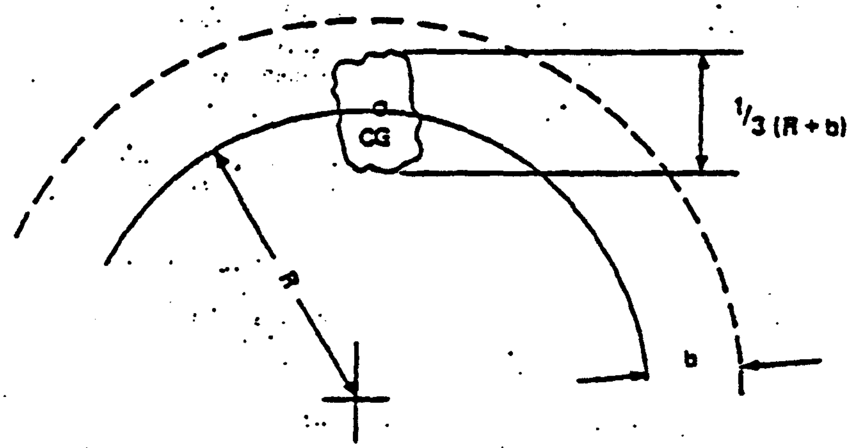
Figure 1 - Estimated Path of Fragments



Where R = disc radius
b = blade length

The CG is taken to lie on the maximum dimension as shown.

FIGURE 2— SINGLE ONE-THIRD DISC FRAGMENT



Where R = disc radius
b = blade length

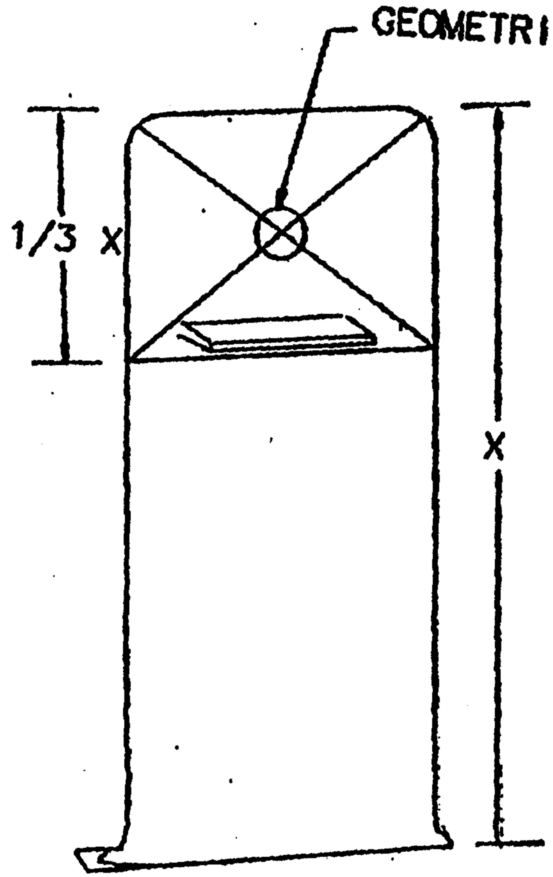
Maximum dimension = ⅓ (R + b)

Mass assumed to be 1/30th of bladed disc

CG is taken to lie on the disc rim

FIGURE 3— INTERMEDIATE & SMALL PIECE OF DEBRIS

Fig 4 BLADE FRAGMENT DEFINITION



WHERE X = AIRFOIL LENGTH
(LESS BLADE ROOT & PLATFORM)

CG IS TAKEN TO LIE AT THE
CENTERLINE OF THE 1/3 FRAGMENT

FRAGMENT VELOCITY TAKEN AT
GEOMETRIC CG

FRAGMENT MASS ASSUMED TO BE
1/3 OF THE AIRFOIL MASS

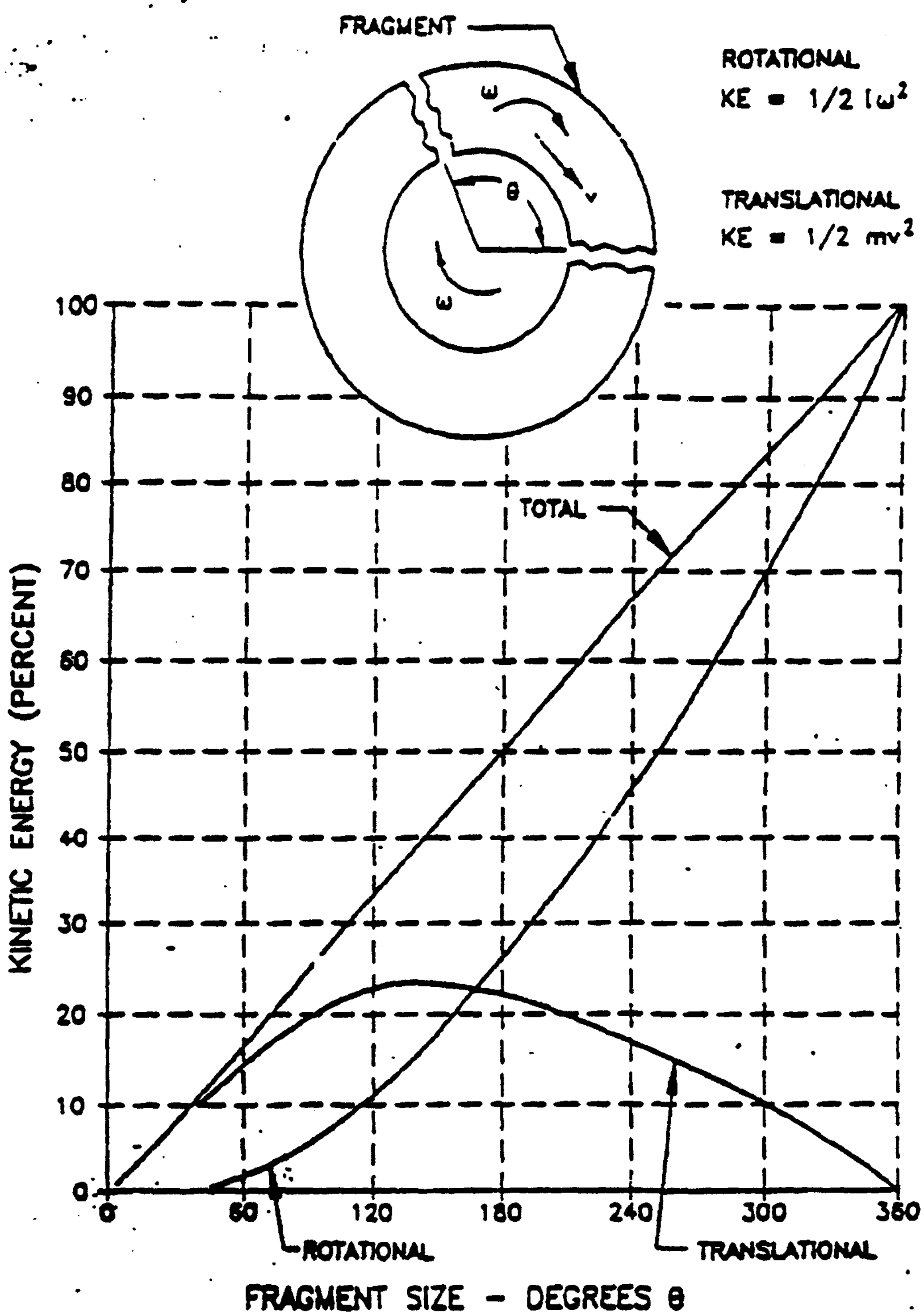


Figure 5 - Distribution of Translational and Rotational Kinetic Energy of Rotor-Component Fragments as a Function of Fragment Size θ

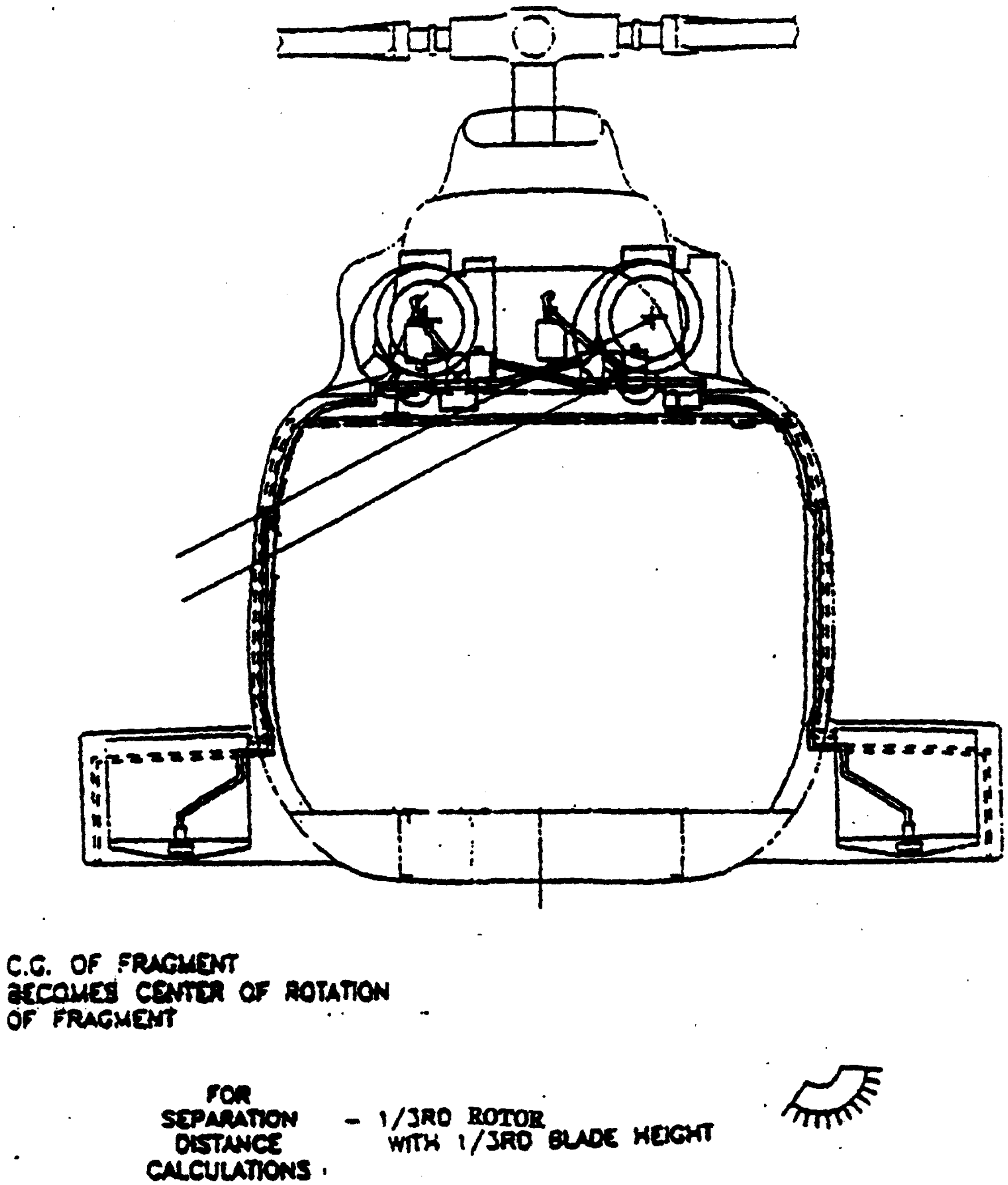


Figure 6 - Cross Section Through Rotorcraft at Plane of Rotation of the Engine Disk Fragment