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AIA Project Group for Helicopter One-Engine-Inoperative Ratings

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GENERAL ELECTRIC

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Abbreviations and Nomenclature

AEO	All Engines Operating
AIA	Aerospace Industries Association of America
CAA	Civil Aviation Authority (United Kingdom)
CDP	Critical Decision Point
FAA	Federal Aviation Administration (United States)
FADEC	Full Authority Digital Electronic Control
FAR	Federal Aviation Regulations (United States)
H	Vehicle Height
OEI	One Engine Inoperative
SAE	Society of Automotive Engineers
TOSS	Take-Off Safety Speed
V	Flight Velocity
Vy	Climb Velocity

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Abstract

An ad hoc committee of representatives of the helicopter and turbine engine industry has been established by the Aerospace Industries Association of America (AIA). This committee has prepared a proposal for helicopter contingency ratings to be submitted to the FAA and CAA for their consideration and possible future rule-making.

These proposed ratings are better matched to multi-engine helicopter requirements for Category A operation, offering significantly improved economics with the same or better level of safety.

Proposals for changes to several of the Federal Aviation Regulations have been prepared along with substantiating information.

Proposed changes include rating definitions, block tests, overspeed and overtemperature tests, and helicopter rotor tests. Substantiating information includes material on power assurance, reliability and safety, engine power and helicopter productivity.

1. Introduction

The Aerospace Industries Association of America, following work done by the Society of Automotive Engineers (SAE) in their S12 committee, has undertaken a program to produce a proposal for rule-making to the Federal Aviation Administration of the United States and the Civil Aviation Authority of the United Kingdom.

The purpose of this work is to provide a turboshaft engine rating structure which is better matched to multi-engine turbine helicopter requirements and which will permit more economical operation for Category A use.

The AIA Project Group has been preparing a proposal and substantiating information for changes in the engine section of the regulations, FAR33. In addition, supporting work is being carried out by the AIA to prepare the proposed changes that must be incorporated in the helicopter section of the rules to take advantage of the engine rating changes.

When complete, these two sets of changes will be approved by the appropriate standing committees of the AIA and then will be submitted to the regulatory agencies as an alternative to the current regulations rather than as a replacement of them. As a result, if the changes are adopted, an engine and helicopter system may be certificated either to the current ratings or to the new, proposed ratings.

It is expected that this proposal will be submitted to the FAA and CAA late this year.

2. Helicopter Requirements

Current regulations permit multi-engine helicopter operation of two types at the option of the operator. These two types are identified as Category A and B (also called Group A and B).

Category B operation requires that the helicopter be landed if power is lost from one engine, while Category A is defined so that once past the takeoff Critical Decision Point (CDP) the mission can be completed in the event of an engine failure. The power from the operating engine(s) must be sufficient, therefore, to complete the mission. As a result, Category B permits a greater payload providing that a suitable flight path can be established to permit landing in the event of an engine failure.

A typical Category A takeoff profile is shown in Figure 1 for both a runway and a helipad type of operation. For these types of operation, a Critical Decision Point can be defined; this is the lowest or earliest point from which the takeoff and climbout can be completed if an engine failure occurs. The CDP is a combination of height and forward speed, being lower in elevation as speed increases. Therefore, the CDP would be lower for a runway takeoff than for a helipad takeoff where forward speed is zero. However, to simplify Figure 1, the CDP is shown as a single point for both types of operation.

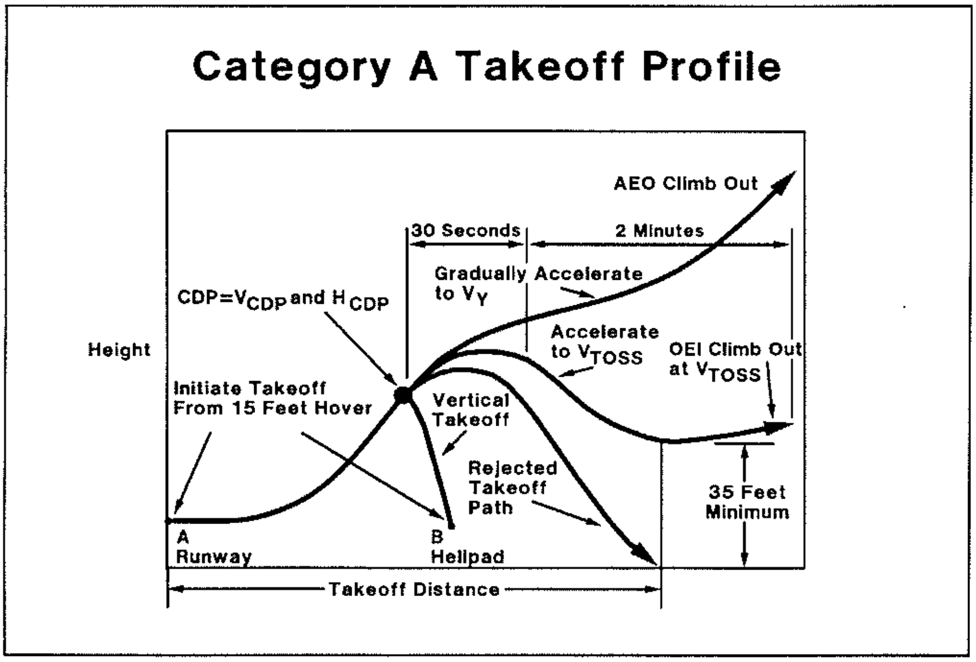

Figure 1.

Current helicopter powerplants provide a two and one-half minute takeoff contingency rating that is typically between five and ten percent above takeoff power while helicopters need, and the regulations specify, requirements that would imply much higher power values as shown in Table 1. With current ratings, a significant quantity of payload must be sacrificed for Category A operation; in many cases Category B operation is the only practical solution. On the other hand, the power levels required to permit full payload under Category A operation would lead to substantially larger and heavier powerplant installations which would compromise the helicopter operation in two ways:

(1) Extra weight must be carried all the time for rare occasions of engine failure

(2) Higher fuel consumption would result from further throttling back at cruise power

Helicopter Ratings
Category A Takeoff Requirements

	Condition	Duration	% Relative Power*		
			Desirable		Practical
			Pad	Strip	
FAA	• Climb at 100 Feet/Minute, Takeoff Safety Speed (TOSS) 35 Feet Above Takeoff Site	Up to 2 Minutes	128	128	115
FAA, CAA	• Enroute Climb of 150 Feet/Minute at 1,000 Feet Above Takeoff Site	Indefinite	108	108	100-105
FAA, CAA	• Rejected Takeoff	5 to 30 Seconds	149	128	125
CAA	• Climb Gradient of 3 Percent From 50 to 500 Feet Above Takeoff Site	3.5 to 4.5 Minutes	134	134	100-105
CAA	• Climb Gradient of 1.5 Percent From 500 to 1,000 Feet Above Takeoff Site	7 to 10 Minutes	134	134	100-105

*Baseline Power (100%) is Normal Takeoff

Table 1.

For these reasons, a compromise set of relative power values is shown on Table 1 under the heading "Practical." These power values are selected to have little effect on engine size yet permit substantially more payload to be lifted than current systems are capable of under Category A rules. The considerations shown in Figure 1 and Table 1 lead to a new set of helicopter engine ratings which are better matched to helicopter requirements yet reasonable in their impact on engine size; these are shown in Table 2.

Helicopter Ratings
Desired Power

Rating	Relative Power, Percent
• Takeoff Contingency	
30 Second	125
2 Minute	115
• Takeoff	100
• Enroute Contingency (Continuous)	105
• Maximum Continuous	80

Table 2.

Note that the current two and one-half minute takeoff contingency rating is replaced by two ratings: (1) a thirty second rating which is needed for the initial thirty seconds after the CDP is reached (See Figure 1) and a two minute rating immediately after to complete the takeoff. A continuous en route contingency rating is also defined for cruise use to be compatible in payload capability with the takeoff contingency ratings. This rating must be available for longer than the current FAA requirement of thirty minutes to permit completion of fairly long missions such as returning to land from remote oil rigs.

The takeoff contingency ratings - the thirty second and two minute power conditions - are considered limited-use ratings. They would be automatically selected in the event of engine failure and would not be available under normal operation through pilot action. When either one of the two takeoff contingency powers is used on any mission, the engine must be inspected and repaired as necessary. The inspections and repair procedures must be defined by the engine manufacturer for each engine model certificated. Under some conditions of operation it might be necessary to use the contingency ratings more than once before inspection and repair.

For example, if power from an engine is lost approaching an oil rig the thirty second power could be used on the operating engine(s) to land and then would be used a second time in the subsequent takeoff to return to base. Inspection and repair would then be required before any further operation. The short duration of use and requirement for inspection and repair will help to make possible increased power levels for these ratings that are better suited to helicopter requirements.

The en route contingency power is not a limited use rating and its use does not require any special inspection or maintenance action. It must only be used, however, for OEI operation.

One final note concerning Table 2: the relative power values given will not be specified in the AIA proposal to the regulatory agencies. Actual power values will be selected by the engine manufacturer at the time of engine certification to satisfy specific applications of the engine. They are shown here as guidelines and are based upon the requirements of typical helicopters.

3. <u>Engine Considerations</u>

In order to respond to the rating and power requirements specified earlier several areas in the engine regulations must be addressed:

(1) Rating Definitions

(2) Block Tests

(3) Overspeed Test

(4) Overtemperature Test

In addition it will be necessary in the design of each engine model certificated to these new ratings to consider several special or new requirements:

(1) Automatic setting of the limited-use ratings.

(2) Recording of any use of the limited-use ratings.

(3) Definition of a power assurance method.

(4) Transient characteristics of the engine up to the 30 second OEI power.

Definitions of the ratings are as shown in Table 2 and the Block Tests for this proposed new rating structure are defined in two parts: (1) a block test similar to the current test for all ratings except the two limited-use takeoff contingency ratings (the thirty second and the two minute ratings), and (2) a thirty minute block test on the same engine hardware to demonstrate the thirty second and two minute power ratings.

Following the initial block tests for the non-limited-use ratings the engine must meet the inspection requirements of FAR 33.93 that currently apply to the Block Test engine. This says in part that "each engine component must conform to type design and must be eligible for incorporation into an engine for continued operation." An engine disassembly and inspection may be made between the two tests to demonstrate this. Following the second set of tests for the limited-use ratings an inspection must be made of the engine hardware and there must be no evidence of incipient failure or critical distortions which could cause hazards to an aircraft. At the option of the engine manufacturer the intermediate disassembly and inspection of the engine can be omitted. In this case the engine must meet the current inspection standards at the conclusion of all the tests.

Helicopter Ratings
Block Test
Hours:Minutes

Rating	FAA (FAR 33-8)	CAA (BCAR C4-6)	Combined FAA/CAA Requirements
• 2 1/2 Minute Contingency	2:05	2:05	2:05
• Takeoff	11:40	16:40	16:40
• Enroute Contingency (1)	12:30	25:00	25:00
• Maximum Continuous	50:00	20:00	32:30
• Incremental Powers	50:00	62:30	50:00
• Idle	23:45	23:45	23:45
Total	150:00	150:00	150:00

(1) Thirty Minute Rating FAA; Continuous CAA and Combined

Table 3.

Tables 3 and 4 show the current Block Test schedules and the proposed Block Tests for the new limited-use ratings. The thirty second and two minute ratings are tested for five and ten minutes, respectively, on the proposed Block Tests as compared with the current two hours and five minutes for the two and one-half minute contingency rating. However, the current two and one-half minute rating can be used for that length of time without inspection and repair while the proposed ratings require such special action after any mission on which they are used.

In the new proposal the time at takeoff power has been established at 18 hours and 45 minutes; this is the sum of the times of takeoff and two and one-half minute contingency power for a typical combined FAA/CAA cycle under today's rules (See Table 3). The Incremental power and Idle runs are unchanged from the current combined cycle and the remainder of the 150 hours is divided into 37 hours and 30 minutes for Maximum Continuous and 20 hours for Enroute Contingency. This effectively moves five hours from Enroute Contingency into Maximum Continuous. This is done on the basis that it provides a better balance of the high power times and because Takeoff and Enroute Contingency are very close power ratings and their combined times of 38 hours and 45 minutes contribute to substantiation of both ratings.

Proposed Block Test Schedule
Combined FAA/CAA Requirements

• 150-Hour Block Test	Hours:Minutes		
Takeoff	18:45		
Enroute Contingency	20:00		
Maximum Continuous	37:30		
Incremental	50:00		
Idle	23:45		
Subtotal		150:00	
• Tear Down and Inspection (Optional)			
• Subsequent Test - 5 Cycles - (On Same Engine)			
Takeoff	1 Minute		
30 Second Power	30 Seconds	Limited Use	
2 Minute Power	2 Minutes		
Idle	1 Minute		
30 Second Power	30 Seconds		
Idle	1 Minute		
Total	6 Minutes (X 5 Cycles) = 30 Minutes		
Total Test Time			150:30
• Tear Down and Inspection			

Table 4.

The second part of the Block Tests has been structured in a manner so as to simulate an actual requirement for the limited-use contingency ratings. If we assume power loss from one engine in a multi-engine system which is one minute into its takeoff (one minute at Takeoff power) we can visualize using the maximum rating for thirty seconds followed by two minutes at the two minute contingency power to reach the cruise condition. At the final destination it might be necessary to employ thirty second power a second time to complete a helipad landing. Idle power is employed for one minute as a buffer between the two minute power and the second setting of thirty second power; it is used a second time for the last minute of the cycle. Note that the cycle defined is six minutes long and must be done five times to complete the Block Test.

The engine overspeed and overtemperature tests will each be done in two parts analogous to the Block Tests. Each test may be done on a separate test vehicle as is now the case for overspeed and over-temperature tests.

An overspeed and an overtemperature test will be done to the current FAA requirements (five minutes at fifteen percent overspeed; five minutes at 75°F overtemperature) based upon the highest power condition among the non-limited-use ratings demonstrated in the first part of the Block Tests. This rating normally will be the enroute contingency or the takeoff power rating.

A second overspeed and overtemperature test will be run based upon the conditions of the 30 second rating as run in the second part of the Block Test. These two tests will be for two and one-half minutes each; the overtemperature test will be 35°F above that on the Block Test and the overspeed will be as defined in the current FAA rule. The two and one-half minute test provides a time factor of five relative to the thirty second rating as compared with a factor of two for the tests done under the current rating system and use of a 35°F temperature increase provides an overall life-safety-factor of ten compared with a value of nine for the current system. The life-safety-factor is the ratio of the life substantiated during the overtemperature test to that consumed in service operation at the maximum conditions of the contingency rating for the time specified for that rating.

The Block Tests, overspeed and overtemperature tests combined with the requirement to inspect and repair as necessary when the limited-use ratings are used provides a level of safety equivalent to or better than that for the current two and one-half minute contingency rating.

In addition to the required changes in the regulations for the rating definitions, Block Tests, overspeed and overtemperature tests, there are additional design and development considerations associated with this new rating system. Significant among these are the control requirements to make the limited use ratings available automatically when needed and to provide a permanent record when they are used. New developments in the area of electronic control systems make this requirement practical.

Engine designs will have to provide satisfactory operation over a wider speed range to make the higher contingency power available with minimum acceleration time, without excessive vibration and with no surge or stall indications.

Greater emphasis will be placed upon the contingency ratings in establishing the engine design. While engine service life will be based primarily upon the takeoff and maximum continuous ratings -- since contingency ratings are rarely used in service and have essentially no impact on the engine fleet life -- the ratings will be defined to cater to the contingency case so that reliability and safety are assured in cases where contingency power is required. The certification Block Tests, overspeed and overtemperature tests, defined to assure a level of safety at least equivalent to that experienced to date, will be a stronger determining factor in setting engine rating levels of power for normal service use.

4. Supporting Material

There are three important areas that require supporting information in order to substantiate this proposal for consideration by the regulatory agencies:

Safety

Power Assurance

Economics or Productivity

On the subject of safety, the certification tests, power assurance procedure and the requirement to inspect and repair when takeoff contingency powers are used, provide a total system that assures engine reliability and safety.

Helicopter safety after an engine failure will be equivalent to operational safety under the current regulations because the basis for aircraft safety will be maintained. Safety following an engine failure is dependent upon assurance that OEI power is available, and that the operating engine(s) will maintain structural integrity at OEI power. Both items have been addressed for the proposed new rating structure.

Currently, power assurance checks are done on a regular basis according to a procedure agreed to by the engine manufacturer, airframe manufacturer, and the regulatory agency. For the limited use ratings, it is proposed that this procedure continue. On this basis, the first item of helicopter safety -- assurance of available power when required -- is equivalent to operation under current regulations.

Structural integrity of the operating engine(s) at the limited-use power will be equivalent to that required by the current rules due to improved definition of engine capability, shorter usage time and improved control of usage in the field. Additionally the requirement that the engine must be inspected and repaired as necessary after any mission on which the limited-use ratings are used enhances the safety and reliability of the proposed rating system.

Improved definition of engine capability will be achieved by implementation of representative Block Tests and expanded use of the engine safe life concept. Block tests have been refined to reflect anticipated engine usage profiles.

Improved engine control in the field will be achieved by incorporation of new engine control technology and by rules which implement controlled use of single engine power. Modern technology engine controls will allow automatic limitation of engine parameters. Implementation of this technology will improve the precision of power setting and duration for critical engine conditions.

Power Assurance techniques will be developed using statistics generated from:

(1) Engines used in development testing

(2) Certification tests

(3) Periodic production line tests and sample testing under cold inlet conditions where high power can be achieved without high speed and temperature.

(4) Periodic overhaul engine tests

These data will be used to establish acceptable boundaries of performance so that assurance testing can be done at reasonable levels of speed and temperature and confidence can be established that the engine and control systems will produce the required contingency power when needed. New control system designs such as Full Authority Digital Electronic Controls (FADEC) will help greatly with the precision needed to set and achieve power required under contingency conditions.

Studies have been done on typical helicopters to demonstrate the improvement in economics that can be achieved with the new rating system. Two parameters have been used to represent this productivity increase: since a large segment of helicopter operation is done to Category B requirements, the first measure used is the ratio of Category A payload under the new ratings to the payload under Category B rules, while the second is the ratio of payload with the new ratings to payload with the old ratings, both for Category A operation. The first measure is always less than one since Category B operation permits a maximum amount of payload; the ratio represents the percentage of full load that the new ratings permit. The second measure represents the improvement in payload for Category A that results from the new ratings, relative to that available for Category A with the current rating structure.

These studies have been done for typical helicopters with a 400 nautical mile range in three weight classes: 7,500, 17,500 and 37,500 pounds takeoff gross weight with takeoff from an elevated helipad. Results are shown in Figures 2 through 5, where Figures 2 through 4 show the Category A/Category B measure for each vehicle at several altitudes and Figure 5 shows the improvement in the Category A ratio for all three vehicles at sea level. Altitudes represent both field elevation (takeoff) and the cruise condition. Productivity results are plotted in these figures as a function of the ratio of thirty second power to takeoff power. At a ratio of 1.25, the typical thirty second power ratio for this rating proposal, Figures 2, 3 and 4 show that a substantial portion of the Category B payload can be carried over a wide range of field elevations, the impact of increases in thirty second power being most dramatic for the lighter vehicles. In addition, the improvement shown in Figure 5 for Category A operation with the thirty second/two minute rating combination is dramatic. Again, the small helicopter benefits most, showing a productivity increase of 124 percent at 125 percent power while the medium and heavy vehicles give 60 and 48 percent improvement respectively. The curves on this figure intersect zero at a power ratio of 105.5 percent since this value was assumed for the current two and one-half minute contingency rating.

Results of this study would be fairly sensitive to variations in the assumptions made, but these levels shown are representative of improvements that can be made to current, real helicopters. Also for the Category A productivity ratio (Figure 5) any change in conditions that makes helicopter performance more difficult - such as hot day, higher field elevation or takeoff from a ground helipad - would show increased benefit for the additional power of the proposed rating structure.

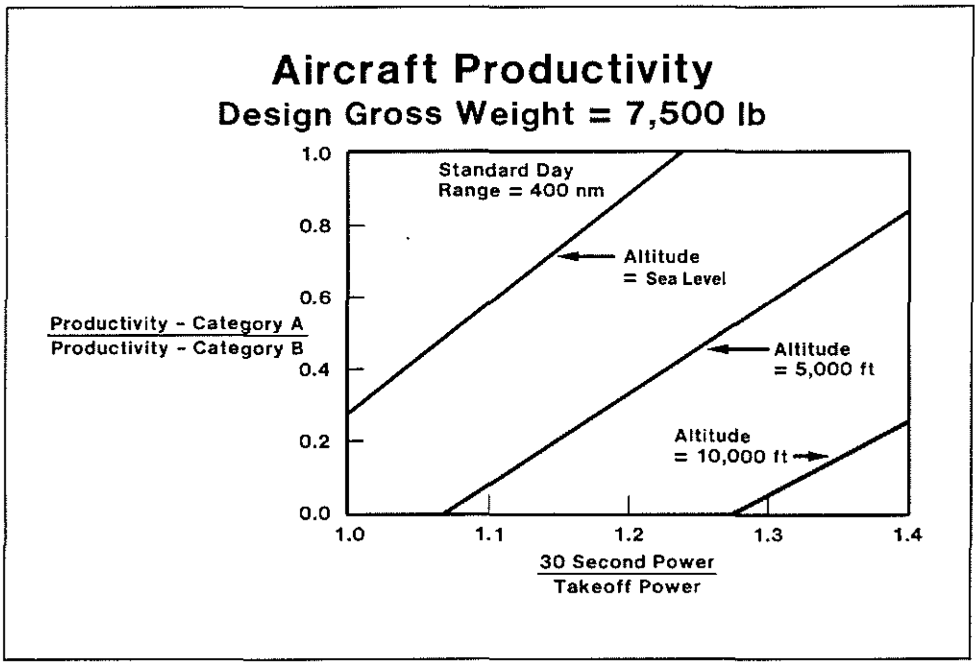

Figure 2.

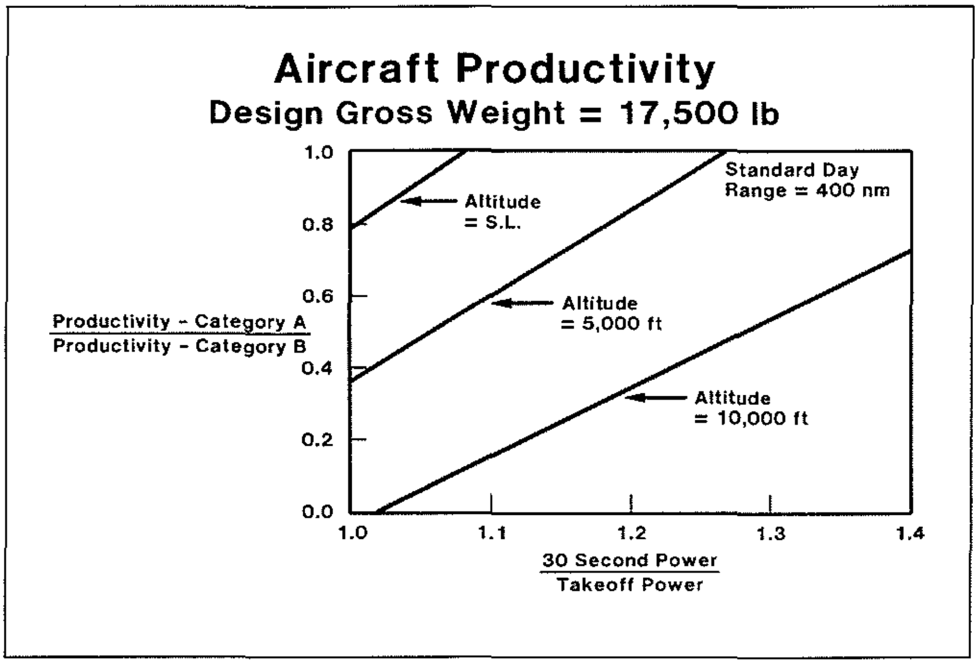

Figure 3.

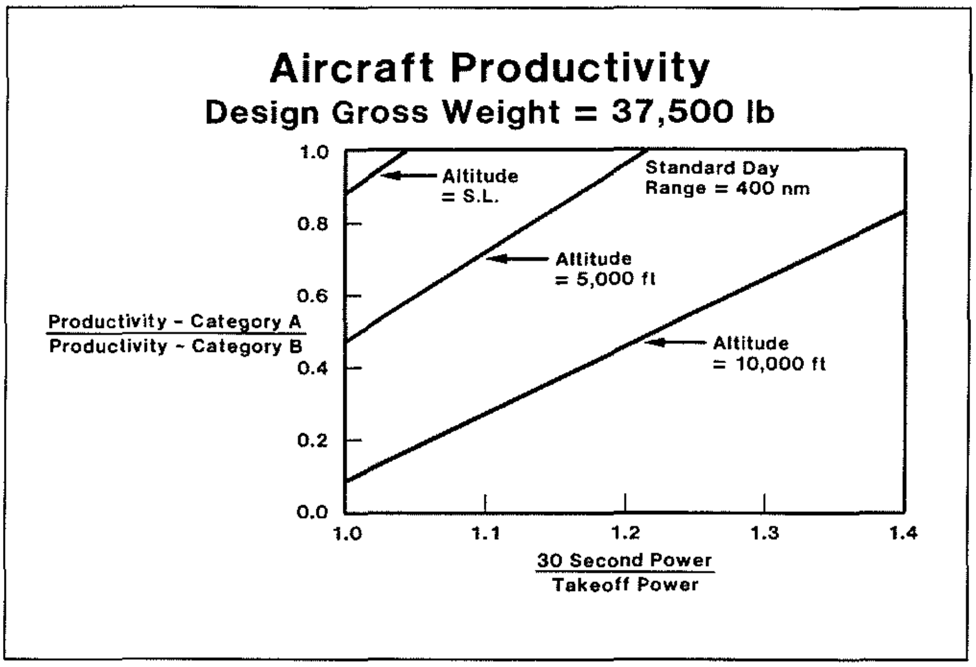

Figure 4.

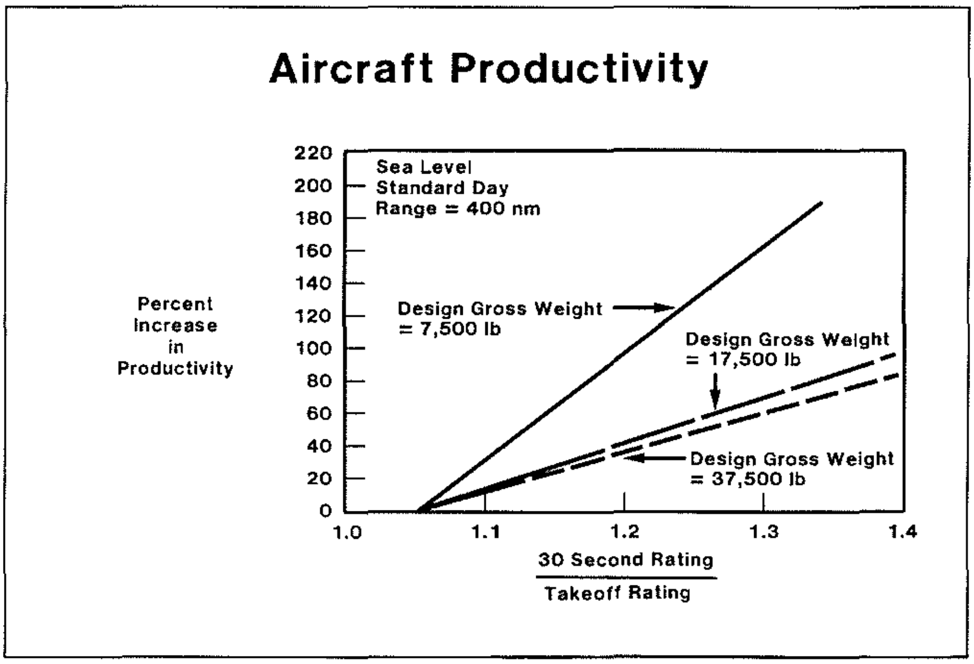

Figure 5.

5. Regulatory Proposal

In summary, the following items will be submitted to the FAA and CAA as a proposal for their consideration:

Engine Changes to:
- Rating Definitions
- Block Tests
- Overspeed Tests
- Overtemperature Tests
- Miscellaneous Related Material

Helicopter Changes to:
- Rating Definitions
- Rotor Certification
- Miscellaneous Related Material

Additional Substantiating Data will be Prepared for:
- Safety
- Power Assurance
- Productivity

6. Conclusion

The work of the AIA Project Group for Helicopter One-Engine-Inoperative Ratings has been summarized. This work has led to the definition of a set of helicopter engine ratings for multi-engine helicopters that matches the vehicle requirements better than the current ratings. Using these ratings, Category A helicopter operations could be conducted more economically over a larger envelope of operating conditions.

The new rating structure, associated rules changes and supporting material will be prepared, approved by AIA and submitted to the FAA and CAA for consideration as a potential rule change.

7. References

Federal Aviation Regulations (United States)
Civil Aviation Regulations (United Kingdom)