ICAS-84-4.3.1

CURRENT AIRWORTHINESS REQUIREMENTS - A NEED TO REEXAMINE

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Abstract

The concept behind all the airworthiness requirements, as related to performance of an aeroplane, is to ensure a given level of design incident probability by defining a performance margin over the assumed datum performance. The quantum of performance margin depends on engine reliability and statistical variations in parameters like drag, thrust, engine speed, runway friction coefficient and so on. With the advent of more reliable turbojet and turbofan engines, wide bodied aeroplanes, better instrumentation etc. performance margins, presently defined on the basis of aeroplanes of the forties and early fifties, call for a review. In addition, all technological innovations/improvements in civil aviation can be translated into economic gains only through the regulatory framework. A review of performance margins is, needless to say, of key importance especially in view of the difficult economic times ahead.

In this paper the necessity and desirability of revising the current airworthiness requirements in respect of turbojet and turbofan aeroplanes have been established on the basis of characteristics of such aeroplanes flying all over the world today. The treatment of the problem is largely based on the classical methods as used by ICAO in 1953. In order to establish the point, the following two areas of performance have been presented in the paper:

(i) Accelerate stop distance

(ii) Time limit on two engined aeroplanes engaged in extended over water operations.

The first aspect determines the payload carrying capability of an aeroplane from a given airfield for a given sector distance. The second determines the operational capability of an aeroplane. It may be mentioned that the paper does not aim at formulating airworthiness requirements but discusses the need for a review of existing airworthiness requirements and, with the help of the examples, gives suggestions in this regard.

1. Introduction

Airworthiness requirements particularly those related to performance of an aeroplane were formulated on a rational basis, in the early fifties. The rational basis was to define a design incident probability and to ensure that the performance of an aeroplane did not fall below a specified performance more often than the design incident probability. This led to the concept of datum performance and performance margin. It was also ensured that the newly derived requirements provided safety levels at least equal to those achieved by earlier aeroplanes. The evolution of airworthiness requirements has been slow since then and no major change has been seen in the last three decades.

Historically, the first foundations of airworthiness were laid by designers, constructors and pilots of the early aeroplanes and a lot depended on the ingenuity and courage to make the machine fly. Although some design requirements were formulated in 1912 for the issue of an airworthiness certificate to a tractor biplane, the first step towards consolidation of airworthiness requirements was taken in the period 1914-18 with limited flight testing and allied work. It was the structural integrity of aeroplanes which occupied airworthiness engineers in the beginning. Upto 1939, the requirements were simple in nature, for example the absolute maximum figure for takeoff distance was 656 yards and for landing 273 yards. The pilot was expected to form his own judgement on adverse effects of temperature, altitude etc. The aim in design was to restrict the stalling speed so as to minimize risks. The period between 1939-50 saw radical changes in design methods and airworthiness requirements. The original three cases of CP forward, CP back and nose dive were replaced by a rationalized system of stressing based on a flight envelope. The concept of a safety factor of 2 was replaced by a proof factor of 1.125 and an ultimate factor of 1.5. In the area of performance the noteworthy developments were regulation of field performance based on operational considerations, ensuring adequacy of performance of a multi-engined aeroplane to cope with loss of power from one engine, definition of handling and control qualities and so on. It was also realized that the heavy dependence of performance requirements on the stalling speed was not conducive to the growth and development of aeroplanes with high wing loading and high speed. In the post World War II period, first PICAO and later on ICAO made major contributions in rationalizing and unifying various airworthiness requirements. These efforts culminated in the derivation of performance requirements on a rational basis.

The experience on turbine engines was extremely limited for arriving at optimum requirements in respect of aeroplanes powered by such engines. In spite of the limited experience, airworthiness engineers succeeded in performing a commendable task by using their judgement and foresight. Even after 30 years, these requirements have generally not been found lacking from safety considerations. However, in the last 30 years the following developments are noteworthy from the point of view of performance of aircraft.

(i) Manifold increase in air traffic

(ii) Increased use of turbojet and turbofan aeroplanes

(iii) Increased speed and range

(iv) Increased size and weight of aeroplanes (viz. wide bodies)

(v) Increase in the use of high lift devices

(vi) Increase in the application of complex systems to aircraft

(vii) Use of sweep back

(viii) Design of increasingly reliable engines

Normally, airworthiness requirements maintain a time lag with relation to development of technology and operating experience. This time lag on one hand leads to under utilization of technological developments but on the other hand it reduces the risks further by increasing the built in conservatism as safety aims are not revised. It may also be appreciated that safety aims cannot be enhanced for the sake of enhancement alone as this may lead to an incongruity with the present living pattern of mankind and its associated systems. In the last 20 years, the maximum cruising speed has come to a stable level. The present indications are that aerodynamic design in the next 10 years is likely to be an extension of the existing practices and barring developments in the field of aircraft systems, major changes in other technical areas do not seem likely at least from the considerations of airworthiness.

In the above context, it is felt that now is the time to have a close look at the existing airworthiness requirements for possible improvement and/or further rationalization so that a better combination of safety and economics can be identified. This paper discusses the performance requirements (as applicable to jet aeroplanes) related to specific areas listed below in the light of new evidence from operating experience. The idea is to indicate that the existing airworthiness requirements need to be re-examined and reviewed. The areas are:

(a) Accelerate Stop Distance

(b) Extended Overwater Operations by Twin-jets

2. Accelerate Stop Distance (ASD)

The present requirements are based on the concept of a decision speed (V_1) achieved during the ground roll with all engines operating. The pilot has to decide whether to abort or continue the takeoff if an engine fails at the decision speed. It is not necessary that only engine failure would lead to ASD as the takeoff may have to be aborted due to other reasons such as tyre burst, structural failure etc. The airworthiness requirements have however been defined based on engine failure. While accounting for all the other factors, the probability of engine failure is multiplied by the ratio of total number of aborted takeoffs to the number of aborted takeoffs due to engine failure. In the framework of this rational basis, the incident probability during any phase of flight should not exceed the design incident probability of $2x10^{-6}$ to $7x10^{-6}$. During the takeoff phase either ASD/takeoff distance or the takeoff net flight path requirements are critical. Hence the case design incident probability in each portion will be equal to half of the design incident probability i.e. $1x10^{-6}$ to $3.5x10^{-6}$. The delay time after the decision speed to deploy brakes and throttle back the operating engines has been taken as 2 seconds in the present requirements, this time delay not having been specified before the early seventies. However, a delay time of 3 seconds has also been recommended(1),(2) and the difference of one second would lead to an extra distance of 220 to 380 ft. Further, the requirements do not explicitly define the datum performance and performance margin in respect of ASD. ICAO did determine margins for various values of incident probability(3) but the applicability of these margins in the light of new evidence needs to be reassessed.

An analysis of accidents related to aborted takeoffs was made based on data from 1946 to 1978. The data was collected from the world accident summary published by CAA(4). The following facts emerge from the analysis:

(i) 3.5% of the total accidents reported related to aborted takeoff. However, during 1970-78 this value varied from 4 to 10%, the period 1975-78 showing a value from 7 to 10%.

(ii) Broadly speaking the break up of causes of aborted takeoff is shown below:

Cause	%	Cause	%
Engine failure	35	Premature retraction of landing gear	3.1
Tyre related	16	Obstruction on runway	1.3
Structural failure	11	Excessive crosswind	1.3
Direction/Pitch Control	11	ASI not working	1.3
Bird ingestion	4	Others	16

The above figures indicate only the order of magnitude of various contributions and do not project an exact analysis of causal factors. 65% of the aborted takeoffs were due to reasons other than engine failure. Hence, the probability of engine failure will have to be multiplied by a factor of 2.80 for assessing the incident probability of accelerate stop distance. In the earlier analysis of ICAO, this factor was taken as 2.25.

(iii) About 75% of the tyre related accidents were observed between 1970-78 and the period 1975-78 constituted about 66% of the 75% cases. This period coincides with the period of operation of the wide bodied aeroplanes.

(iv) In 25% of the cases of aborted takeoffs, aeroplanes overran the runways. In at least 30% of the cases related to overruns, the decision to abort the takeoff was taken at/below the decision speed. The statistics of overruns during 1979-82 also show a similar trend in regard to number of overruns as percentage of aborted takeoffs.

(v) In atleast 4% of the cases of overruns the decision to abort the takeoff was taken after the decision speed and in another 2% cases, wet runways were apparently responsible for overruns. The abort speed is not specified in other accidents.

The statistics of overrun accidents indicate that a case incident probability of 1.0×10^{-5} is being achieved. The estimated margin on the ASD of a two engined aeroplane would be 4 to 6%. The incident probability thus exceeds the design value. Evidently the shortcomings could lie in the stipulated ASD and/or in operating practices. As ASD is normally established on the basis of a few tests only, the variability due to runway friction braking efficiency, speeds etc. cannot be built in exactly. Under operating practices, while there could be many reasons the more important ones are inadequate knowledge of runway friction, use of retreaded tyres, inadequate attention to the tyre inflation pressure, delay in decision making and so on.

In the subsequent analysis, margins on ASD have been worked out for the two, three and four engined aeroplanes. In the absence of data related to tyre pressure, retreading etc. it is not possible to include these in the analysis. The analysis is limited to the use of dry runways.

Methodology

The accelerate stop distance (S) has been divided into three stages:

Stage 1: distance from rest to the point where V_1 is achieved with all engines operating (S_1)

Stage 2: distance from the point of V_1 to the point of application of brakes and shutting down operating engines (S_2)

Stage 3: distance from brake application point to a full stop (S_3)

The distance covered in each stage would depend on the average acceleration/deceleration in that stage. The acceleration in each stage is given by

Stage 1: $\alpha_1 = (T/W - D_1/W - \mu r)g$

Stage 2: $\alpha_2 = (n-1)T/nW - D_2/W - \mu r\ g$

Stage 3: $\alpha_3 = -(D_3/W + \mu_B)g$

In the above expressions α_1, α_2 and α_3 represent acceleration and D_1/W, D_2/W and D_3/W represent drag to weight ratios in Stage 1, 2 and 3 respectively. μ_r and μ_B indicate runway rolling friction and braking friction respectively. T/W is the thrust to weight ratio and n is the number of installed engines.

D/W for various aeroplanes has been estimated by using the information available in the published documents of various aeroplanes. The takeoff weight of an aeroplane corresponding to a value of climb gradient in the second segment is determined at ISA, SL condition with the assumption that the thrust variation with speed can be neglected. T/W and D/W were determined corresponding to this weight. Now in the second segment we have:

$$\gamma = (n-1)T/nW - D/W$$

and for small angle of climb

$$C_L = 2W/dV_2^2S; \quad C_D = 2D/dV_2^2S$$

where

γ - gradient of climb
d - air density at S.L.
V_2 - climb speed
S - wing area

Thus, by knowing C_L and C_D, the task of estimating C_{D_0} becomes simpler as we know

$$C_D = C_{D_0} + C_L^2/\pi A\varepsilon \text{ ; A being the aspect ratio}$$

This C_{D_0} will represent the drag coefficient during ground roll provided we add to it the landing gear drag coefficient which has been taken as 0.015(5). ε is taken as 0.7(5). μ_r has been found to vary between 0.015 and 0.035. Further, during the deceleration phase, μ_B is taken as 0.35 with a variation of 12% from the standard value(6). D/W in each stage has been worked out at the average speed of each stage. The values of important parameters derived are given in Table-1. The difference in values of various parameters can now be compared with those obtained in Ref.3. It is observed that during the ground roll D/W does not vary appreciably with different settings of high lift devices.

PARAMETER	2 ENGINED AEROPLANE	3 ENGINED AEROPLANE	4 ENGINED AEROPLANE
D_1/W	0.015 to 0.025	0.03	0.03
D_2/W	0.035 to 0.050	0.07	0.07
T/W	0.23 to 0.35	0.23 to 0.35	0.23 to 0.35
(n-1)T/nW	0.115 to 0.170	0.153 to 0.230	0.17 to 0.26
μ_r	0.015 to 0.035	0.015 to 0.035	0.015 to 0.035
$\alpha_1(ft/s^2)$	5.5 to 10.3	5.3 to 9.8	5.3 to 9.8
$\alpha_2(ft/s^2)$	1.0 to 3.9	1.5 to 4.7	2.1 to 5.6
μ_B	0.35	0.35	0.35
D_3/W	0.025 to 0.035	0.054	0.064
$-\alpha_3(ft/s^2)$	12.1 to 12.4	13.0	13.2

TABLE 1 VALUES OF IMPORTANT PARAMETERS

The ASD(S) is given by

$$S = S_1 + S_2 + S_3$$

hence we can write the standard deviation of ASD as

$$\sigma^2(S) = \Sigma(\delta S_1/\delta X_i + \delta S_2/\delta X_i + \delta S_3/\delta X_i)^2\sigma^2(X_i)^*$$

The effects of signs of $\delta S_1/\delta X_i$, $\delta S_2/\delta X_i$ and $\delta S_3/\delta X_i$ have been taken into consideration. The standard deviation of distance in various stages may be worked out by using Ref.3. The time delay between V_1 and application of brakes has been taken as 3 sec with a standard deviation of 1 sec. While determining the standard deviation of ASD, a number of aeroplanes in the two, three and four engined categories have been considered. The standard deviations $\sigma(S_1)$, $\sigma(S_2)$ and $\sigma(S_3)$ for Stages 1, 2 and 3 respectively are shown in Table 2 alongwith $\sigma(S)$:

PARAMETER (%)	2 ENGINE	3 ENGINE	4 ENGINE
$\sigma(S_1)/S_1$	10.5 to 3.1	6.9 to 2.9	6.5 to 2.7
$\sigma(S_2)/S_2$	51.1 to 33.8	21.0 to 4.6	12.3 to 4.1
$\sigma(S_3)/S_3$	11.0	10.0	10.0
$\sigma(S)/S$	10.0 to 6.0	6.0 to 3.0	5.0 to 3.0

TABLE 2

*Xi represents the independent variables influencing S_1, S_2 and S_3.

It may be seen that the variability is the maximum in Stage-2. This may be attributed to low acceleration in this stage. However, the effect of acceleration on S_2 in this stage is very small as compared to the contribution of V_1, hence the average S_2 has been taken as $3V_1$. Based on the above, margins required as percentage of ASD have been plotted against incident probability in Figure-1.

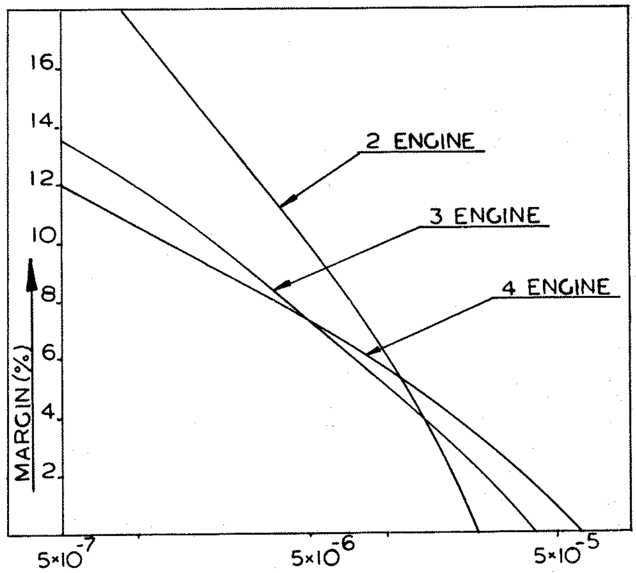

FIG. I

CASE INCIDENT PROBABILITY Vs MARGIN

Briefly, the procedure adopted in arriving at the above figure is as follows. The average time to reach V_1 for two, three and four engined aeroplanes would be 30 sec, 34 sec and 38 sec. respectively based on the acceleration in Stage-1. The probability of an engine failure during takeoff is taken as 2.86×10^{-7} per sec. as against 1.00×10^{-6} per sec. in Ref.3. This is explained by the fact that the modern turbofans and turbojets have much better reliability (inflight shutdown rate of 1.0×10^{-4} per engine hour) than the reliability of earlier engines (inflight shutdown rate of 3.5×10^{-4} per engine hour). The probability of engine failure is multiplied by a factor of 2.8 to consider failures, other than the engine failure, which may lead to an aborted takeoff. It is seen that the desirable margins on ASD for the design case incident probability of 1.0×10^{-6} to 3.5×10^{-6} would be 12 to 17% for two engined, 8 to 12% for three engined and 8 to 10% for four engined aeroplanes. Thus, there is a case for reviewing ASD requirements and its presentation in flight manuals. Further, the datum performance for ASD can also be defined as the average ASD plus the margin as calculated above.

In the first two stages the direct contribution of runway rolling friction to the variability in ground distance is upto 20% but in stage 3 the variability in the braking friction practically determines the total variability in distance. It may be worthwhile to explore the feasibility of using runway friction as an operation parameter like temperature.

3. Extended Overwater Operations

The airworthiness and operational requirements relating to the performance of an aeroplane during the enroute phase are designed to ensure that the aeroplane can clear all obstacles by a sufficient margin in the event of one engine becoming inoperative. In addition the aeroplane is required to be capable of a positive climb gradient at 1500ft above the landing place (destination/alternate). In regard to extended overwater operations three factors have to be carefully looked into (1) time limit to reach an alternate if one engine fails enroute (2) the desired performance margin with one engine inoperative and (3) the reliability of the aircraft systems in such an emergency.

Under FAA requirements, no two engine aeroplane may operate over a route that contains a point farther than 60 min flying time with an engine inoperative, from an adequate airport[7]. Annex 6 of ICAO stipulates a limit of 90 min in respect of turbine engine aeroplanes only[8]. However, this 90 minutes are at the normal cruising speed, whether normal speed with both engines or single engine operating is not clear. Obviously, ICAO requirements are more lenient than that of FAA. Air Navigation Orders, while not specifying any time limit, require safe landing capability at a given place (with the exception of performance group X aeroplanes)[9].

Historically, the 60/90 min rule is based on the reliability of old piston and turbine engines. During the last decade, the reliability of jet engines has improved substantially. The benefits of this enhanced reliability have not been translated, so far, in optimizing the requirements. Further no consideration was earlier given to the reliability of various systems while fixing the above limits. In the following analysis, the validity of 60/90 min rule is examined from (i) engine consideration and (ii) electrical generation system consideration. Also, the suitability of the existing performance margin is reviewed in the present context.

Engine Consideration

The desired level of safety with one engine inoperative is ensured by specifying a minimum performance margin ($\gamma m\%$) above a specified datum performance. The former is 1.1 and latter is zero, in terms of climb gradient during the enroute phase. Performance margin depends on the selected design incident probability (ICAO stipulated, during the early 1950's, a value ranging from 2.0×10^{-6} to 7.0×10^{-6} per flight), engine failure rate per engine hour (p), standard deviation of climb gradient σ_γ, and duration of flight (t).

The climb gradient distribution is taken as normal and the standard deviation was determined using Ref.3 which was then modified by taking the effects of side slip and turbulence[10]. Assuming each engine to be independent of the other, the probability of an engine failure per flight (π_1) is 2pt and that of both engines failing (π_2) is p^2t^2. The resultant incident probability is given by

$$Q = 2p_0pt + p^2t^2$$

where p_0 is the probability of the performance falling below the datum in the event of failure of one engine

In Table 3 some representative values of Q have been shown for a range of γm and π_1 at $\sigma_\gamma = 0.35\%$.

$\gamma_m(\%)$	Q_1	Q_2	Q_3	Q_4	Q_5
1.5	0.07	0.13	0.21	0.31	0.44
1.4	0.08	0.15	0.23	0.34	0.47
1.3	0.12	0.20	0.31	0.43	0.58
1.2	0.24	0.38	0.51	0.69	0.89
1.1	0.53	0.78	1.04	1.33	1.64
1.0	1.22	1.75	2.49	2.86	3.44
0.9	2.83	4.00	5.19	6.40	7.62
$\pi_1 \times 10^{-4}$	5.0	7.0	9.0	11.0	13.0

TABLE 3 INCIDENT PROBABILITY ($Q \times 10^{-6}$); $\sigma_\gamma = 0.35\%$

The following useful expressions can be derived with a little under estimation of Q at lower values of π_1 and a slight over estimation at higher values of π_1

$$\begin{aligned} \pi_1 &= 176.0\ Q^{0.94};\ \gamma_m = 1.0 \\ &= 157.0\ Q^{0.88};\ \gamma_m = 1.1 \\ &= 70.4\ Q^{0.78};\ \gamma_m = 1.2 \\ &= 19.0\ Q^{0.67};\ \gamma_m = 1.3 \end{aligned}$$

Using an inflight shutdown rate for the modern jet engines as 1×10^{-4} per engine hour, Fig.2 has been drawn between duration of flight and γ_m for different combinations of Q and for $\sigma_\gamma = 0.35\%$. Regarding σ_γ very little published data is available. However, a σ_γ of 0.35% is considered high for jet engines and a value of 0.30% seems more realistic.

As the probability of second engine failing is also being taken into account, it would be proper to consider the probability of a fatal accident (1×10^{-6} per flight) as the yardstick. The permissible duration of flight then would be 4.5 hr at $\gamma_m = 1.1$ and $\sigma_\gamma = 0.35$ with $p = 1 \times 10^{-4}$, thus implying a rule of 135 min as against 60/90 min. At $Q = 2 \times 10^{-6}$ the duration of flight would be 8 hr, implying a rule of 240 min. The effect of σ_γ would be to enhance the duration. At $\sigma_\gamma = 0.30\%$, $Q = 2 \times 10^{-6}$ the duration of flight would be over 10 hr[11].

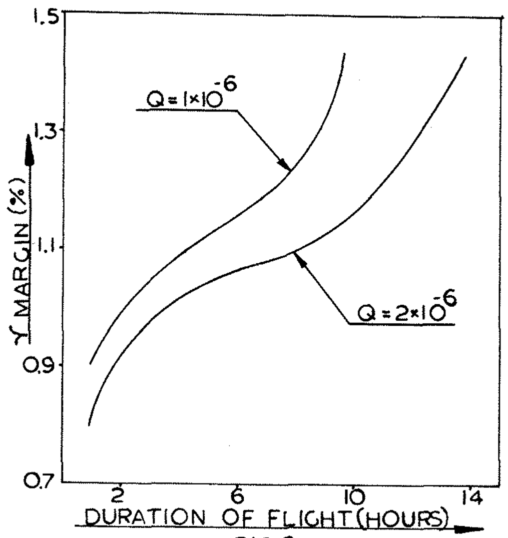

FIG.2.
FLIGHT DURATION Vs. MARGIN.

Obviously, any reduction in the flight time could be used for reducing the performance margin thus effecting carriage of higher payload on some sectors. A revision of 60/90 min, rule would no doubt enhance the operational capability of modern twin jets.

Electrical Generation System

The availability of systems after and engine failure may be an important matter. A detailed reliability analysis of systems would be required to ascertain the time limit from systems consideration. A simple reliability assessment of the electrical generator system on a two engined aeroplane has been made. On a typical two engined aeroplane being currently used for medium haul operations, there are 3 generators of identical capacity with one each coupled to the two engines and one to the auxiliary power unit (APU) and 3 batteries. Each generator is designed to run for a long time at its nominal capacity and can meet all the power requirements of the aircraft. APU is normally deployed on the ground before takeoff, hence its availability is ensured during the flight within its reliability range. In order to take advantage of the APU coupled generator, APU needs to be on the minimum equipment list. Each battery in the aircraft is capable of starting the APU in air and supplying power to essential instruments and items.

The whole system is broken into two subsystems Ⓐ and Ⓑ shown below. These two subsystems are then synthesized in Ⓒ. The symbols P_1, P_2 etc. indicate the probability of failure of the corresponding element. The model used is slightly conservative in the sense that APU is being assumed to start in flight through batteries, whereas in actual operation it would be started by DC-bus bar after the failure of an engine. Secondly, the capability of batteries has not been taken into account.

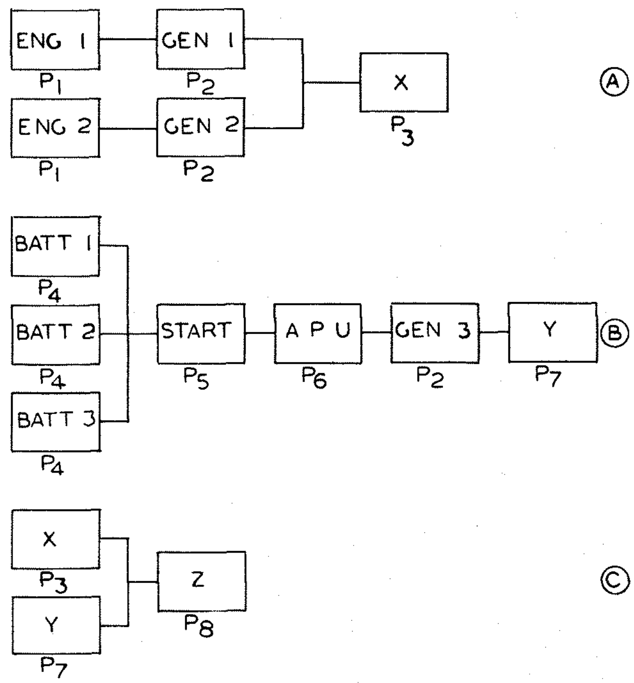

FIG-3

The probability of failure P_3 of Ⓐ, P_7 of Ⓑ and P_8 of Ⓒ in Figure 3 above can be written as:

$$P_3 = (P_1 + P_2 - P_1P_2)^2$$

$$P_7 = 1-(1-P_4^3)(1-P_5)(1-P_6)(1-P_2)$$

$$P_8 = P_3P_7$$

Now we take $P_1 = 1\text{x}10^{-4}$ per engine hour; $P_2 = 1\text{x}10^{-3}$ per generator hour (in the absence of actual data) and $P_4 = 3.6\text{x}10^{-4}$ per battery hour[12]. The probability of the APU not getting started by batteries in flight has been taken as $1\text{x}10^{-3}$ per flight. The probability of failure of the APU can be safely taken as $3.5\text{x}10^{-4}$ per APU hour. However, as the APU and APU coupled generator are normally not kept on throughout the flight, it is assumed that the APU and the generator would operate only for half the duration of the flight. Thus, P_6 has been taken as $1.75\text{x}10^{-4}$ and P_2 as $0.5\text{x}10^{-3}$ in Ⓑ. Considering a flight of one hour duration we get $P_3 = 4.8\text{x}10^{-6}$ and $P_7 = 1.7\text{x}10^{-3}$ resulting into $P_8 = 0.8\text{x}10^{-8}$. Thus, the electrical generation system is as reliable as the two engines because the probability of both engine failing would also be $1\text{x}10^{-8}$ in one hour flight. Hence one could see that the electrical generation system is prima facie, not an additional limiting factor for determining the time limit for extended overwater operations. The above deduction is further supported by the fact that the capability of batteries to power essential systems in an emergency has not been taken into account and the APU is being assumed to get started by batteries only.

According to the present practice an extremely improbable event leading to a catastrophe is defined to have a probability of occurrence of less than or equal to 10^{-9}. The failure of both engines on a two engined aeroplane should fall in this category of risk. However, the probability of failure of both engines on a twinjet is $1x10^{-8}$ which is higher than the laid down limit. The target of 10^{-9} suggests that at least a triplicate system should be deployed to achieve this target. However, the engine reliability will remain a limiting factor. Hence, any action to achieve a system reliability of the order of 10^{-9} in a two engined aeroplane should be carefully weighed.

4. Discussion/Conclusions

The two examples discussed above indicate that there is a need to reexamine the present airworthiness requirements at least in respect of the specific cases. It is also noted that this reexamination need not be aimed at improving only the operational capability and economics but some safety related issues need also be reviewed. Areas, such as accelerate stop distance, where enhanced safety requirements may be called for, will have to be assessed from the economic angle also.

The case of ASD has been dealt with in slight isolation i.e., without considering the requirements for takeoff distance, climb gradients etc. in order to meet the basic objective of the paper. Obviously in all the related areas the requirements would need to be updated on the rational basis, and in regard to climb gradients of twin jets during the takeoff phase, it may be stated that a fresh analysis is called for as the earlier efforts in this direction were mainly concentrated on four engine aeroplanes. It is seen that the variability in ASD is rather high. If braking efficiency and tyre rolling characteristics could be assessed accurately during operations, there is a possibility that this variability may come down.

The use of twin jets on long routes is a relatively new phenomenon, against the earlier emphasis on four and three engines. In fact many airlines are currently using their twin jets for extended overwater operations[13]. Hence, the requirements for twin jets in this regard assume a new dimension. In view of increasing fuel prices and stringent financial outlook it may not be healthy to have unattended conservatism in the requirements. This conservatism in respect of twin jets is evident as far as the overwater operations are concerned. From the systems consideration we could be more hopeful for the future as the newer systems are likely to be more reliable than the earlier ones.

The performance margin of 1.1% may not be revised in isolation as it is going to affect the landing phase requirements. However, it is to be appreciated that an economic benefit could accrue if a reduction from the present margin of 1.1% could be achieved.

Within the jet engine population, also, engine failure rates vary considerably with the type of engine. For the purpose of requirements of operational nature like the 60/90 min rule, each type of aeroplane may be assessed on its own merit rather than assessing all types against a common rule. Further the global average of engine failure rates may be disturbed by local conditions and short term deviations. Hence, each authority may take into account the experience and level maturity in operating an aeroplane fleet while arriving at limits such as the 60/90 min rule.

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Note: The paper conveys the author's views only and does not reflect the views of his department.