BIRD STRIKE COMMITTEE EUROPE

LONDON, 24-28 May 1976

Ref: BSCE/11 WP/3

BIRD STRIKES TO ENGINES

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SUMMARY

Data on bird strikes to engines from four countries for 1973 and 1974 has been analysed to show some of the factors affecting strikes and damage.

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1. Introduction

1.1 An earlier version of this Paper was presented under Agenda Item 7 to the Eleventh Meeting of the ICAO Airworthiness Committee in Montreal on 1st March 1976. This version is slightly modified to take account of later numerical information, the text remaining unaltered.

1.2 For some years the Bird Strike Committee Europe has been collecting statistical information from its members. An aspect of major concern has been engine strikes, and this Paper shows some trends from analyses made in this area.

1.3 It should be appreciated that the information in this Paper is only as good as the reporting standard of the Countries from which the information was obtained. Furthermore the sample sizes are in some cases still quite small.

1.4 In view of the above, definite conclusions cannot be drawn; however, although as with many Airworthiness subjects, the figures do not always agree in a tidy manner, possible trends even at this early stage should not be ignored.

2. Source of Information

2.1 Data from France, Germany, Netherlands and U.K. for the years 1973 and 1974 have been used in compiling this Paper, as shown in Table 1. This was in order to provide a wide variety of aircraft and engine types used by countries with a fairly high annual flying rate.

2.2 In order to take account of 2, 3 and 4 engined aircraft the data has been changed from the more usual movements (two per flight), to engine flights (i.e. engine flights = $\frac{\text{movements}}{2}$ x number of engines per aircraft).

2.3 The weight of bird has been ignored, since in Europe only 1% of cases where the bird is identified, involves a bird weight greater than 1.81 Kg (4 lbs).

2.4 The term "damage" ranges from bent or torn blades sufficient to require replacement, to uncontained engine failure. Cases where blade damage is dressed out, or carried over to the next overhaul, have not been included in the category "damaged". Thus there is considerable variation in the degree to which usable thrust has been lost.

3. Discussion

3.1 It is suggested that bird strikes reported as having struck engines are based on the following factors:-

1) a strike is dependent on
- (a) engine location
- (b) engine frontal area
- (c) circumstances, i.e. route, time of day, etc.

2) reported rate is dependent on
- (a) operators reporting standard
- (b) how easy to detect

3) damage is dependent on
- (a) a strike
- (b) engine strength

3.2 Much of the data used in this Paper is from many operators, from several countries and using many different routes. Thus it is believed that 1) (c), and 2) (a) and (b) can probably be ignored, allowing this Paper to examine the other factors.

4. Results

4.1 Factor 1 (a) - Engine location

4.1.1 This is shown in Table 2, the reported strike rate per million engine flights. The Conway in 707, JT8D in 737, JT9D in 747, JT3D in DC8 and CF6 in DC10 show above average strike rates. These are all wing mounted podded installations, (except for the DC10 which is 2 + 1). The difficulty of drawing conclusions is demonstrated by the considerable differences between the various types of Boeing 707 and the DC8, where similar rates could be expected.

4.1.2 When all the engine types are combined into Table 3, irrespective of aircraft type a clearer pattern emerges. It can be seen that the wing mounted engines have an average strike rate around 4 times that for aft mounted engines.

4.2 Factor 1(b) - Engine frontal area

From Table 3 and Fig. 1 it can be seen that in general where there is a reasonable sample size the trend of increasing strike rate with increasing area is apparent. It is very probable that the larger the engine, particularly with the high by-pass ratio fan engines, the less likely it is that a non-damaging strike will be noticed, in fact the bird can exit through the by-pass leaving no noticeable trace.

4.3 Factor 3(b) - Engine strength

4.3.1 It can be seen from Table 4 that the percentage of reported strikes which cause damage is subject to considerable variation. This gives a measure of each aircraft/engine combination's resistance to bird strike damage.

4.3.2 Subject to the cautionary note of para 1.2 about small samples it can be seen that the mean is 30%, and that the RR Avon in both Comet and Caravelle, Conway in Boeing 707, P & W JT9D in 747 and GECF6 in the DC10 are significantly above the mean figure. The Avon and Conway are both relatively old engine designs which were produced before the current Airworthiness Requirements on medium ($1\frac{1}{2}$ lb) bird testing were introduced. However the JT9D and the CF6 are very recent designs which it might have been expected would have a better resistance to bird strike damage.

4.3.3 The P & W JT8D appears best able to withstand the effect of bird strikes.

4.4 Damage Rates - a combination of all factors.

4.4.1 From Table 2 it can be seen that the worst damage rates reported are the CF6 and the JT9D, whilst the best rates are the Spey in Trident and RB211 in Tristar. The aft mounted JT8D in the Boeing 727 and the Douglas DC9 have an identically low rate, whilst the same engine wing mounted in the Boeing 737 shows the higher rate due to its more vulnerable installation.

4.4.2 Table 5 shows the damage rate per million engine flights for each engine type. The rate of 79×10^{-6} (i.e. 7.9×10^{-5}) for the JT9D and CF6, falls well within the Reasonably Probable rate in British Civil Airworthiness Requirements, i.e. between 1 per 1000 and 1 per 100,000 flights, whilst other engines are mainly well within the Remote area.

5. Conclusions. Although in some instances there is as yet inadequate evidence, the data from 1973 and 1974 does show some trends that at this early stage should not be ignored.

5.1 Wing mounted engines are more likely to suffer bird strikes than aft mounted engines, perhaps by a factor of about 4.

5.2 The strike rate is, in general, dependent upon engine intake area, although it may not be linear. It is possible that the probability of undetected strikes increases with intake area.

5.3 Some engine designs appear much more prone to damage than others, and relatively low resistance to bird strike damage is not confined to the older designs. Two of the most recent designs, approved to later, but not the latest Airworthiness criteria appear to have the highest vulnerability, namely the General Electric CF6 and the Pratt and Whitney JT9D, and these rates are well within the Reasonably Probable area of BCAR. The limited data available for the Rolls-Royce RB211 does not as yet show this trend.

5.4 The Pratt and Whitney JT8D appears best able to withstand bird strikes, it would be interesting to have the Manufacturer's comments as to the reason for this.

5.5 The results of this Paper support the necessity of continued collection of bird strike data in order to monitor trends in respect of damage to engines and hence decide whether any specific or general action is needed to avoid undue hazard to aircraft from this cause.

Table 1 - Source of Information

Aircraft Type	Engine Type	Germany*	France	Netherlands	UK
HS Comet 4	RR Avon				+
BAC 1-11	RR Spey	+			+
Boeing 707	P & W JT3D		+ †		+
" 707	RR Conway				+
" 707	P & W JT4D		+		+
" 727	P & W JT8D	+	+		+
" 737	P & W JT8D	+			+
" 747	P & W JT9D	+	+	+	+
Caravelle	RR Avon		+		
"	P & W JT8D		+		
Douglas DC8	P & W JT8D		+	+	
" DC9	P & W JT8D			+	
" DC10	GE CF6	+	+	+	+
BAC VC10	RR Conway				+
HS Trident	RR Spey				+
L1011 Tristar	RB 211				+

*Note 1.1 Data for 1973 only.

† 1.2 Data for 1974 only.

Table 2 - Aircraft Type, Strike Rate and Damage Rate

Aircraft Type	Engine Type	Engine Location	Engine Flights	Number of Engine Strikes	Strike Rate per million engine flights	Number of engine Changes/ Repairs	Damage rate per million engine flights
Boeing 747	P & W JT9D	W	228,100	37	162	18	79
Douglas DC10	GE CF6	-	50,600	7	138 *	4	79 *
Boeing 707	RR Conway	W	91,800	12	131 *	6	65 *
HS Comet 4	RR Avon	-	93,900	4	43 *	4	43 *
Douglas DC8	P & W JT3D	W	263,100	57	216	11	42
Boeing 737	P & W JT8D	W	219,400	27	123	5	23
Caravelle	RR Avon	A	267,400	9	34	5	19
Boeing 707	P & W JT3D	W	181,040	15	83	3	17
Boeing 707	P & W JT4A	W	97,860	1	10 *	1	10 *
BAC 1-11	RR Spey	A	445,900	11	25	4	9
Boeing 727	P & W JT8D	A	422,050	16	38	3	7
Douglas DC9	P & W JT8D	A	147,700	10	68	1	7
BAC VC10	RR Conway	A	198,400	7	35 *	1	5
Caravelle	P & W JT8D	A	36,600	0	-	0	- *
HS Trident	RR Spey	A	531,900	3	6	1	2
L1011 Tristar	RB 211	-	7,700	2	- *	0	0 *
TOTAL/MEAN			3,283,450	218	66	67	20

Notes: 2.1 Engine locations A = Aft, W = Wing mounted

*2.2 Small sample size, the results should be treated with caution.

Table 3 - Engine Strike Rates.

ENGINE			ALL STRIKES					
			AFT MOUNTED			WING MOUNTED		
	Area Sq. Metres	Area Sq Inches	No.	Engine Flights	Rate†	No.	Engine Flights	Rate†
RR Spey	0.54	845	14	977,800	14	-	-	-
RR Avon	0.52	805	9	267,400	34	-	-	-
P & W JT4A	0.81	1260	-	-	-	1	97,860	10*
P & W JT8D	0.81	1260	26	606,300	43	27	219,400	123
RR Conway — A / W	0.71 / 1.03	1105 / 1590	7	198,400	35	12	91,800	131
P & W JT3D	1.31	2030	-	-	-	72	444,140	162
GE CF.6	3.78	5860	2	16,900	118*	5	33,700	148*
P & W JT9D	4.29	6650	-	-	-	37	228,100	162
TOTAL/MEAN			58	2,066,800	28	154	1,115,000	138

Notes: 3.1* Small sample size, the results should be treated with caution.

3.2 The HS Comet with 4 RR Avons buried in the wing has been excluded.

3.3 The RB 211 due to its low hours has been excluded.

3.4 The DC10 GE CF6 strikes have been separated into the 2 wing engines, and one aft mounted engine.

3.5† The rate is per million engine flights.

3.6 Area is cross sectional area at front of compressor.

Table 4 - Aircraft Type - Percentage of Damaging Strikes

Aircraft Type	Engine Type	Engine Location	No. of engine strikes	No. of engine changes/ repairs	% of strikes which cause damage/repair
HS Comet 4	RR Avon	-	4 *	4	100*
Boeing 707	P & W JT4A	W	1 *	1	100*
Douglas DC10	GE CF6	-	7 *	4	57*
Caravelle	RR Avon	A	9 *	5	55*
Boeing 707	RR Conway	W	12	6	50
Boeing 747	P & W JT9D	W	37	18	49
BAC 1-11	RR Spey	A	11	4	36
HS Trident	RR Spey	A	3*	1	33*
Boeing 707	P & W JT3D	W	15	3	20
Douglas DC8	P & W JT3D	W	57	11	19
Boeing 727	P & W JT8D	A	16	3	19
Boeing 737	P & W JT8D	W	27	5	18
BAC VC10	RR Conway	A	7*	1	14*
Douglas DC9	P & W JT8D	A	10	1	10
Caravelle	P & W JT8D	A	0*	0	-*
L1011 Tristar	RB 211	-	2 *	0	0*
TOTAL/MEAN			218	67	31%

Notes: 4.1 Engine locations A = Aft, W = Wing mounted

*4.2 Small sample size, the results should be treated with caution.

Table 5 - Engine Damage Rates

ENGINE	Area		DAMAGING STRIKES					
			AFT MOUNTED			WING MOUNTED		
	Sq. Metres	Sq. Inches	No.	Engine Flights	Rate †	No.	Engine Flights	Rate †
RR Spey	0.54	845	5	977,800	5	-	-	-
RR Avon	0.52	805	5	267,400	19	-	-	-
P & W JT4A	0.81	1260	-	-	-	1	97,860	10*
P & W JT8D	0.81	1260	4	606,300	7	5	219,400	23
RR Conway — A RR Conway — W	0.71 1.03	1105 1590	1	198,400	5	6	91,800	65*
P & W JT3D	1.31	2030	-	-	-	14	444,140	32
GE CF.6	3.78	5860	1	16,900	59*	3	33,700	89*
P & W JT9D	4.29	6650	-	-	-	18	228,100	79
TOTAL/MEAN			16	2,066,800	8	47	1,115,000	42

Notes:
5.1* Small sample size, the results should be treated with caution.

5.2 The HS Comet with 4 RR Avons buried in the wing has been excluded.

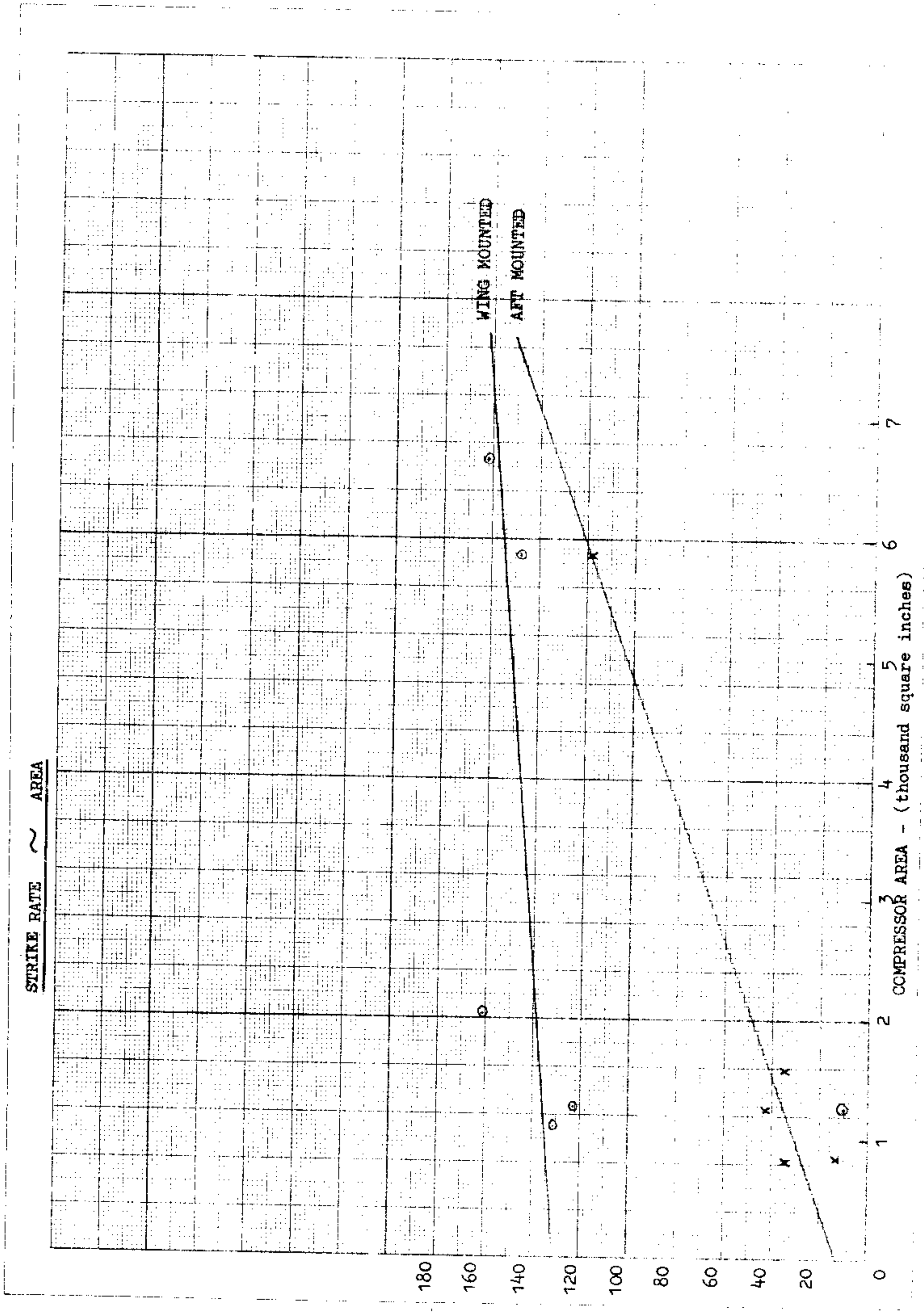
5.3 The RB 211 due to its low hours has been excluded.

5.4 The DC10 GE CF6 strikes have been separated into the 2 wing engines, and one aft mounted engine.

5.5† The rate is per million engine flights.

5.6 Area is cross sectional area at front of compressor.

Figure 1



STRIKE RATE ~ AREA
WING MOUNTED
AFT MOUNTED
COMPRESSOR AREA - (thousand square inches)
0
1
2
3
4
5
6
7
RATE - PER MILLION ENGINE FLIGHTS
0
20
40
60
80
100
120
140
160
180