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THE STATISTICAL ENTROPY METHOD OF DETERMINING WEIBULL PARAMETERS FOR AIRCRAFT FIELD FAILURES

INTRODUCTION

It is an accepted fact of life that in order to cope with situations and circumstances arising in our efforts to control threats against the successful survival of any systems used in daily operations, we must use techniques which are effective in correcting faults, and which accurately indicate impending troubles early enough to take corrective actions. In particular, this is true in the handling and analysis of aircraft field failures. Without the proper approach the information contained in failure data banks will remain hidden and, consequently dangerous situations will go unnoticed. It is specifically for this reason that the STATISTICAL ENTROPY APPROACH to studying field failures is so important, especially where critical questions of customer safety are involved. We shall illustrate the technique with an example of air frame failures.

OUTLINE OF THE STATISTICAL ENTROPY APPROACH

Below we list a dozen items making up the entire **Statistical Entropy Approach**:

1. Systematic Data Collection on Air Frame Failures in Cycle of Compression - Decompression.

2. Dividing the Fleet's Stress Cycle Data into Intervals between Failures Consecutive to one Another in Terms of Cycles.

3. Counting the Number of Failures in Each Interval

4. Determining the Number of Planes in the Fleet Which are Active in Each Interval. This Must Include Both Fully Active Planes and Partially Active Planes.

5. Computing the Hazard in Each Interval by the Quotient $\left[\frac{\text{No. of Failures}}{\text{No. Active}} \right]$

6. Accumulating Hazards to Form Statistical Entropy (Which is Failures per Plane).

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7. Doing Regression Analysis on log-log Paper, with Cycles as Abscissa and Failures per Plane (Statistical Entropy) as Ordinate.

8. Finding the Slope of the Regression Line. (This will be the Weibull Slope.)

9. Finding the Characteristic Life by Locating the Number of Cycles on the Regression Line at Unit Entropy, Where There is **1 Failure per Plane**.

10. Finding the Median Life at an Entropy Level Equal to the Natural Logarithm of 2, i.e., Where Entropy = .69315 .

11. Finding the B_{10} Life at an Entropy Equal to ln(1/.9) = .10536 .

12. Checking the Goodness of Fit (Correlation Coefficient) in Order to Make Sure the Regression Line is a Good Predictor.

ILLUSTRATIVE EXAMPLE: AIR FRAME DATA

PLANE #1	PLANE #2	PLANE #3	PLANE #4	PLANE #5
11015 Cycles (Rivet Failure)	17510 Cycles (Nothing) (Failed Yet)	15059 Cycles (4 Inch) (Fuselage) (Crack)	16700 Cycles (Nothing) (Failed Yet)	21951 Cycles (8 Inch) (Fuselage) (Crack)
18975 Cycles (5 Inch) (Fuselage) (Crack)		18340 Cycles (Nothing) (Further) (Failed)		24158 Cycles (5 Rivets) (Replaced)
22400 Cycles (Nothing) (Further) (Failed)				26105 Cycles (Nothing) (Further) (Failed)

FAILURES AND ACTIVITY BY INTERVALS

INTERVAL END POINT	FAILURES IN INTERVAL	NUMBER OF ACTIVE PLANE IN INTERVAL
11015 Cycles	1	4.6818 = 4 + 7510/11015
15059 Cycles	1	4
18975 Cycles	1	$3.2569 = 2 + \frac{16700 - 15059}{18975 - 15059} + \frac{18340 - 15059}{18975 - 15059}$
21951 Cycles	1	2
24158 Cycles	1	$1.2034 = 1 + \frac{22400 - 21951}{24158 - 21951}$

HAZARD AND STATISTICAL ENTROPY ANALYSIS

INTERVAL END POINT	HAZARD	(STATISTICAL ENTROPY) FUSELAGE FAILURES/PLANE
11015 Cycles	1/4.6818 = .2136	.2136
15059 Cycles	1/4 = .25	.4636
18975 Cycles	1/3.2569 = .3070	.7706
21951 Cycles	1/2 = .5000	1.2706
24158 Cycles	1/1.2034 = .8310	2.1016

FROM COMPUTER PROGRAM PRINTOUT

Weibull Slope = 2.7794

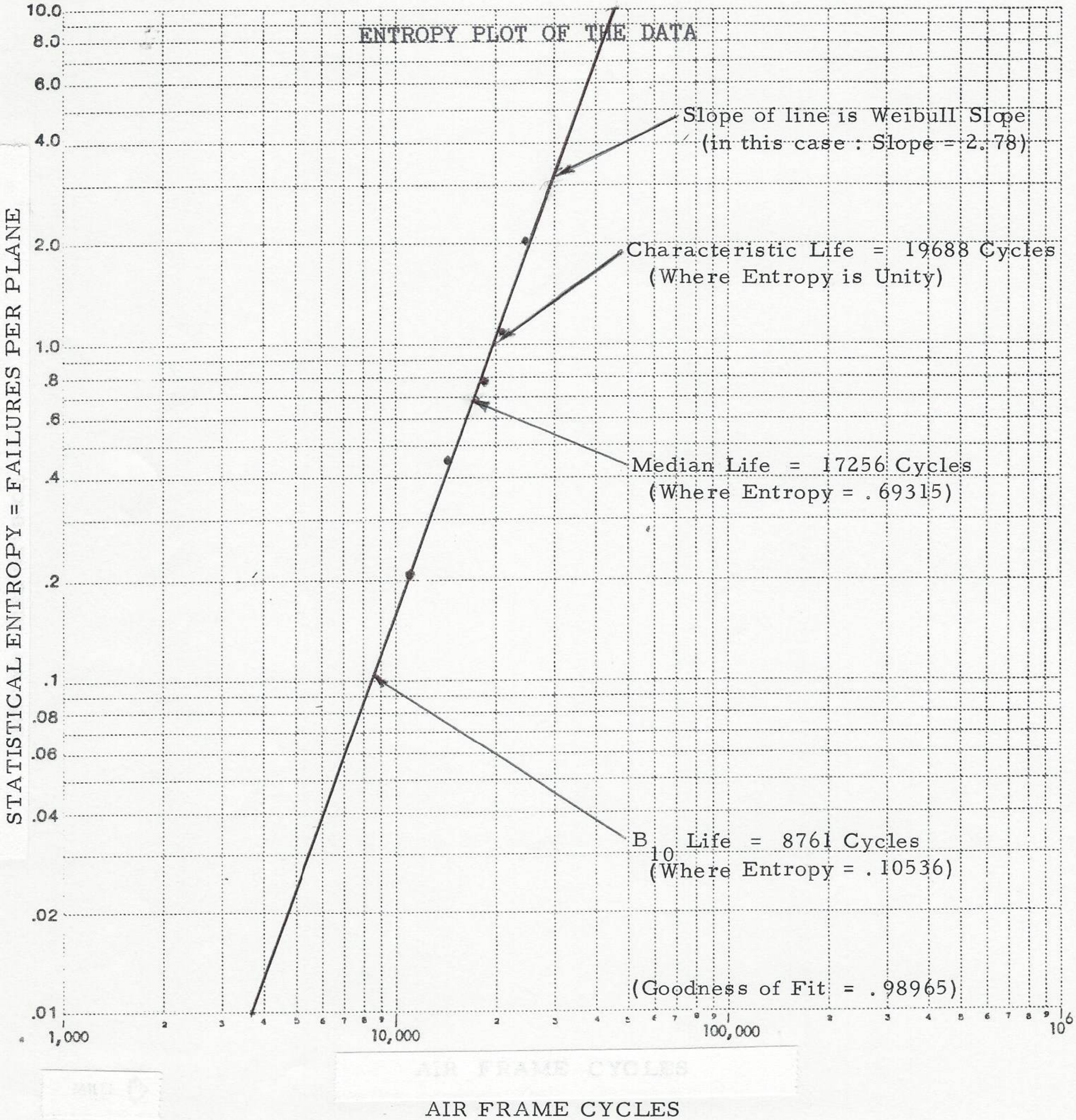
Char. Life = 19688 Cycles

Median Life = 17256 Cycles

B_{10} Life = 8761 Cycles

B_1 Life = 3762 Cycles

Goodness of Fit= .98965


ENTROPY PLOT OF THE DATA
Slope of line is Weibull Slope
(in this case : Slope = 2.78)
Characteristic Life = 19688 Cycles
(Where Entropy is Unity)
Median Life = 17256 Cycles
(Where Entropy = .69315)
B_{10} Life = 8761 Cycles
(Where Entropy = .10536)
(Goodness of Fit = .98965)
STATISTICAL ENTROPY = FAILURES PER PLANE
10.0
8.0
6.0
4.0
2.0
1.0
.8
.6
.4
.2
.1
.08
.06
.04
.02
.01
1,000
10,000
100,000
10^6
AIR FRAME CYCLES

CONCLUSION

The example shows clearly how the regression line on Entropy paper indicates the probabilities associated with early failures (like B_{10} life) and intermediate failures (like Median life), and late (Long life failures), like B_{90} life or B_{99} life, whose Entropies are 2.3 and 4.6. respectively. Without such a warning line it is easily possible to be unaware of the need for early service and maintenance at sufficiently frequent intervals in order to catch the weaklings in a fleet before they are able to produce disastrous consequences.