Statistical Bulletin
Reliability & Variation Research

DETROIT RESEARCH INSTITUTE
21900 GREENFIELD ROAD • OAK PARK, MICHIGAN 48237 • (313) 968-1818

LEONARD G. JOHNSON
EDITOR

WANG H. YEE
DIRECTOR

VOLUME 8 BULLETIN 3 JULY , 1978

MODIFYING NON-DEBITED RENEWAL THEORY TO ACCOUNT FOR REPAIR EFFECTIVENESS AND DESIGN IMPROVEMENTS

INTRODUCTION

A machine which is subject to repeated breakdowns and repairs and (or) replacements of some particular component must be evaluated by using what is known as non-debited renewal theory. Conventional non-debited renewal theory assumes that each renewal simply restores the defective part (component) to the same status it had when the machine was new. The theory is called non-debited because the part is not charged with the age of the machine, but goes back to age zero.

However, what conventional theory does not account for is the real situations in which the repair process is not 100% effective, or in which the replacement part is better or worse than the original part (or the part employed in the preceding repair job).

The purpose of this bulletin is to provide an analytical procedure for handling such problems, in which repair effectiveness and design improvements must be considered.

Vol. 8 Bulletin 3 July, 1978

TAKING INTO ACCOUNT THE REPAIR EFFECTIVENESS FACTOR

Let λ = Repair Effectiveness Factor

Let θ_1 = Characteristic Life of the part when correctly installed

Then $\lambda\theta_1$ = Actual Characteristic Life of the part with REPAIR EFFECTIVENESS FACTOR λ.

Assuming NON-DEBITED RENEWAL with the part having a WEIBULL SLOPE b, we can state that for a service time $X \leq \theta_1$ hours:

$$\boxed{\text{FAILURES PER MACHINE} = \left(\frac{X}{\lambda_X \theta_1}\right)^b} \qquad (X \leq \theta_1)$$

where $$\lambda_X = 1 + \left(\frac{\lambda^{1/b} - 1}{\theta_1}\right) X$$

However, for service times $X > \theta_1$ hours:

$$\boxed{\text{FAILURES PER MACHINE} = \frac{X}{\lambda \theta_1}} \qquad (X > \theta_1)$$

NOTE: "Failures" refers to failures of the particular part only.

TAKING DESIGN IMPROVEMENT INTO ACCOUNT

Let a part be improved between the original installation and the first replacement, such that the part exhibits a new characteristic life $\theta_2 = K\,\theta_1$, where $K > 1$, and θ_1 = Original Characteristic Life of the part.

($K < 1$ would indicate that the new part is inferior to the original part.)

Assuming NON-DEBITED RENEWAL with the part having a Weibull slope b (unchanged for the improved part) , we can state that for a service time $X \leq \theta_1$ hours:

$$\boxed{\text{FAILURES PER MACHINE} = \left(\frac{X}{K_x\,\theta_1}\right)^b} \qquad (X \leq \theta_1)$$

where

$$K_x = 1 + \left(\frac{K^{1/b} - 1}{\theta_1}\right) X$$

For $X > \theta_1$ hours:

$$\boxed{\text{FAILURES PER MACHINE} = \frac{X}{K\,\theta_1} = \frac{X}{\theta_2}}$$

NOTE: "Failures" refers to failures of the particular part only.

TAKING INTO ACCOUNT BOTH REPAIR EFFECTIVENESS AND DESIGN IMPROVEMENT AT REPLACEMENT

Let λ = Repair Effectiveness Factor

Let K = Design Improvement Factor

Assuming NON-DEBITED RENEWAL , with a part of Weibull slope b (unchanged for the improved part) , we can state that for service times $X \leq \theta_1$ (where θ_1 is the Characteristic Life of the original part in the new machine) :

$$\boxed{\text{FAILURES PER MACHINE} = \left(\frac{X}{\lambda_x \; K_x \; \theta_1}\right)^b} \qquad (X \leq \theta_1)$$

where

$$\lambda_x = 1 + \left(\frac{\lambda^{1/b} - 1}{\theta_1}\right) X$$

$$K_x = 1 + \left(\frac{K^{1/b} - 1}{\theta_1}\right) X$$

For service times $X > \theta_1$: $\boxed{\text{FAILURES PER MACHINE} = \frac{X}{\lambda K \theta_1}}$

NOTE: "Failures" refers to failures of the particular part only.