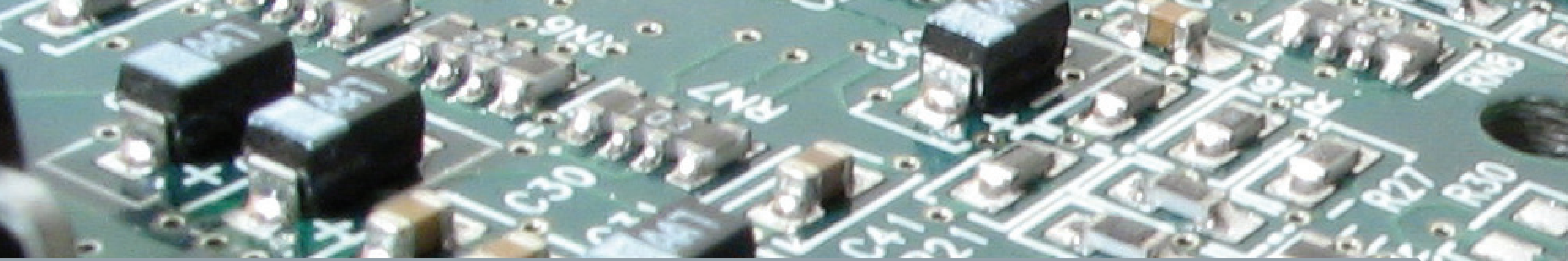


CONVERTING A RIAC 217PLUS RELIABILITY PREDICTION CALENDAR HOUR-BASED FAILURE RATE TO AN OPERATING HOUR-BASED FAILURE RATE

David Nicholls, RIAC (Quanterion Solutions Incorporated)

The Reliability Information Analysis Center (RIAC) 217Plus System Reliability Assessment methodology calculates component failure rate contributions based on operating periods, non-operating periods and cycling events. The details of these component models have been explained in previous issues of the RIAC Journal [References 1 through 7], so they are not repeated here, but the basic component model form for calculating a 217Plus inherent failure rate (i.e., ignoring induced failures) is given as:

$$\lambda_P = \left(\lambda_{OB}\pi_{DCO}\pi_{TO}\pi_V + \lambda_{EB}\pi_{DCN}\pi_{TE}\pi_{RH} + \lambda_{TCB}\pi_{CR}\pi_{DT}\right) + \lambda_{SJ}\pi_{SJDT}$$

where,

$\lambda_{OB}\pi_{DCO}\pi_{TO}\pi_V$ = the component failure rate during the system operating period

$\lambda_{EB}\pi_{DCN}\pi_{TE}\pi_{RH}$ = the component failure rate during the system non-operating (or dormant) period

$\lambda_{TCB}\pi_{CR}\pi_{DT}$ = the component failure rate based on cycling transitions between the operating and non-operating periods

The solder joint failure rate (λ_{SJ} and its associated pi-factor) are impacted by the temperature cycling that results from the cycling between operating and non-operating conditions.

Since the 217Plus models calculate non-operating and cycling failure rates in addition to operating failure rates, the units of a 217Plus reliability prediction are in failures per million calendar hours, not the traditional MIL-HDBK-217 failures per million operating hours (which do not explicitly account for the contributions of non-operating and cycling failures to the overall component failure rate).

The DCO, DCN and CR Pi-factors in the above equation represent multipliers based on the operating duty cycle, the non-operating duty cycle and the cycling rate, respectively. They reflect the percentage of calendar time that the component is in the operating or non-operating (dormant) calendar period, and how many times the component is cycled during that period.

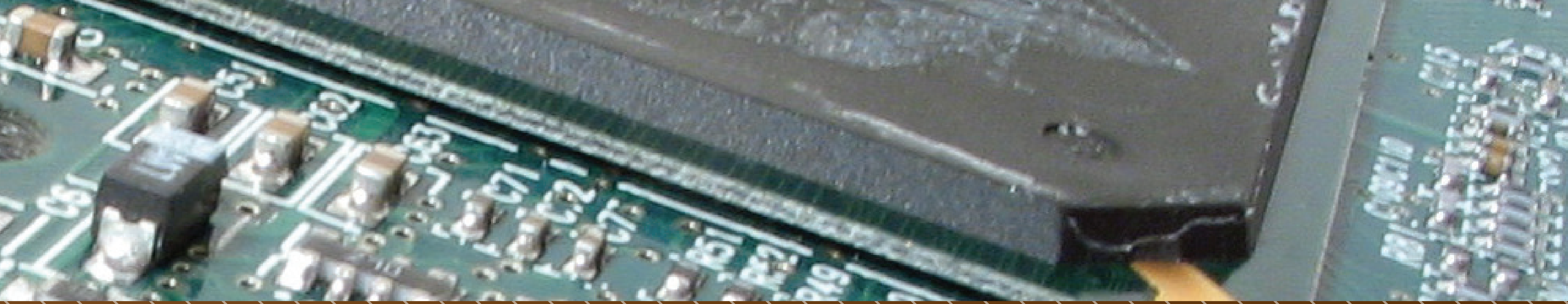
In general, while the RIAC does not recommend converting a 217Plus prediction based on calendar hours to a prediction based on operating hours as a means to make comparisons to a MIL-HDBK-217 prediction (or any other operating hour-based prediction) because these latter methods do not account for non-operating or cycling, there is a preferred way to do it in 217Plus.

Approach A

If an equivalent operating failure rate is desired in units of failures per million operating hours, the 217Plus prediction should first be performed using the actual operating duty cycle to which the units will be selected (e.g., 30%), resulting in a failure rate expressed in failures per million calendar hours. This result should then be divided by the decimal form of the duty cycle (e.g. 0.30) to yield a failure rate expressed in terms of failures per million operating hours. Calculation of the operating failure rate in this manner essentially makes the simplifying assumption that all failures, regardless of whether they are a result of operation, non-operation, or cycling, can be combined for the purposes of calculating an operating failure rate. The observation that the equivalent 217Plus predicted operating failure rate is higher than the original 217Plus calendar failure rate is simply an artifact of this assumption. In other words, the operating failure rate is artificially increased. Consequentially, the 217Plus failure rate for the non-operating and cycling related causes is artificially low (i.e., zero). An example that illustrates this concept will be presented shortly.

Approach B

It should be noted that the incorrect way to predict a 217Plus failure rate in units of failures per million operating hours is to artificially set the duty cycle within 217Plus to 100% (i.e., 1.00). By "artificially", I mean that the actual duty cycle is not 100%. If the true duty cycle is not 100%, then this method does not account for the failures that occur during the non-operating periods, or as a result of cycling. In other words, the failures that occur during non-operating and cycling periods exist, but they are ignored by not combining them with the failures in the operating period. If the true duty cycle is 100%, then there are no non-operating or cycling-related failures to contend with anyway (i.e., the non-operating and cycling related causes are, in reality, zero), so this approach would be considered valid.



It is easiest to illustrate the concepts above by virtue of a simple example which includes a graphical interpretation of the results.

Suppose that the results of a specific 217Plus reliability prediction, based on a 30% operational duty cycle, indicate a failure rate of 15 failures per million calendar hours. For the sake of this example, let's say that 10 of the failures are attributed to the operating portion of the 217Plus model, 4 failures are attributed to the non-operating portion of the 217Plus model, and 1 failure is attributed to the cycling portion of the 217Plus model. The 217Plus failure rate for this example is mathematically represented as:

$$\lambda_p = \frac{15 \text{ failures}}{1000000 \text{ calendar hours}} = 0.000015 \text{ failures per calendar hour}$$

To convert this failure rate to an equivalent failure rate in terms of operating hours using the 30% Duty Cycle and Approach A (Approach B is not relevant), the expression becomes:

$$\lambda_p = \frac{15 \text{ failures}}{1000000 \text{ calendar hours} * 0.30 \text{ duty cycle}}$$

$$= \frac{15 \text{ failures}}{300000 \text{ operating hours}}$$

$$= 0.000050 \text{ failures per operating hour}$$

The failure rate based on operating hours is higher because the original 15 failures (including those from the non-operating and cycling periods) have been condensed into the 300,000 hour operating period, artificially inflating the 217Plus operating failure rate and artificially treating the 217Plus non-operating and cycling failure rates as zero.

Figure 1 provides a generic graphical representation of how to interpret the conversion of a 217Plus prediction based on calendar hours to one based on equivalent operating hours.

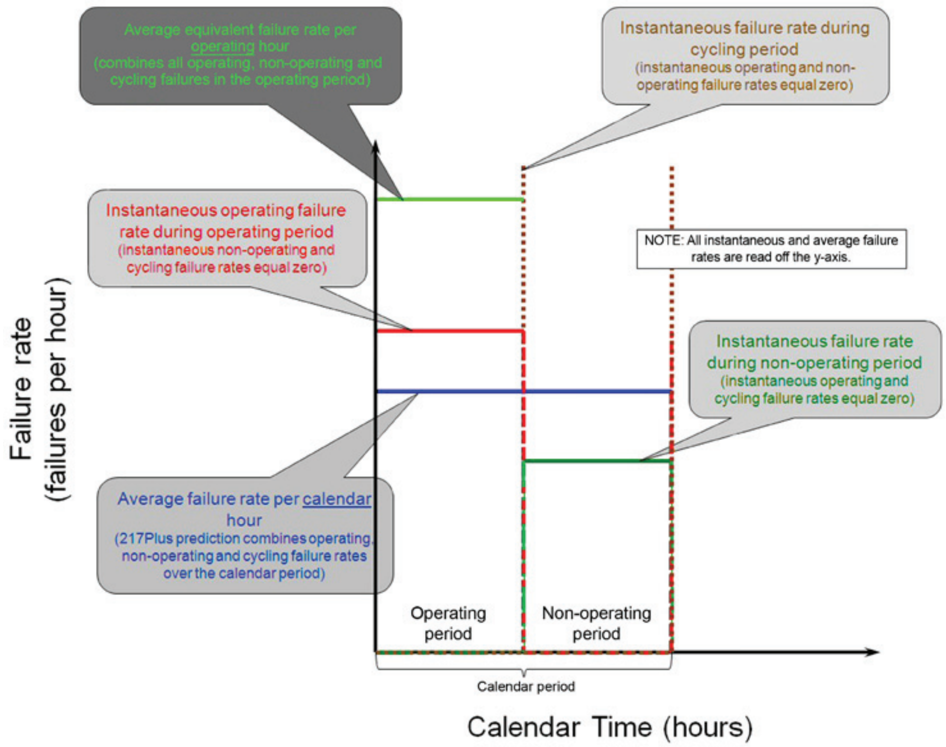


Figure 1: Conversion of 217Plus Failure Rate per Calendar Hour to Equivalent 217Plus Failure Rate per Operating Hour

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The red line in Figure 1 represents the operating portion of the 217Plus calendar period which, on this graph, represents a 50% duty cycle. Where the red line intersects the y-axis defines the 217Plus instantaneous operating failure rate, i.e., it is based on only those failures that occur during the operating period within the overall calendar period (the instantaneous non-operating and cycling failure rates are zero during the operating period).

The dark green line in Figure 1 represents the non-operating portion of the 217Plus calendar period which, on this graph, represents pretty much the balance of the calendar period not consumed by the operating period. The virtual intersection of the green line with the y-axis defines the 217Plus instantaneous non-operating failure rate, i.e., it is based on only those failures that occur during the non-operating period within the overall calendar period (the instantaneous operating and cycling failure rates are zero during the non-operating period).

The vertical brown dashed line in Figure 1 represents the cycling portion of the 217Plus calendar period, which represents the transition between the operating and non-operating portions of the calendar period. The virtual intersection of the brown dashed line with the y-axis defines the 217Plus instantaneous cycling failure rate, i.e., it is based on only those failures that occur during the cycling period within the overall calendar period (the instantaneous operating and non-operating failure rates are zero during the cycling period).

The solid blue line represents the average 217Plus predicted failure rate in calendar hours over the entire calendar period (whose value is defined by its intersection with the y-axis), combining the operating, non-operating and cycling failure rates.

The solid bright green line represents the equivalent 217Plus predicted failure rate in operating hours over the operating period (whose value is defined by its intersection with the y-axis), combining all operating, non-operating and cycling failure rates into the operating period and treating the non-operating and cycling failure rates as zero.

Another implied concept in the conversion of a 217Plus reliability prediction from failures per million calendar hours to failures per million operating hours is that, even though the failure rate in operating hours is significantly larger, it will take a significantly longer calendar time period for the item whose reliability prediction is being calculated to accumulate 1 million hours of operation (unless the actual 217Plus duty cycle is 100%, in which case the operating time period is equal to the calendar time period). For example, at a 30% duty cycle, the number of calendar hours required to accumulate one million operating hours is given by:

$$\text{Calendar hours} = \frac{1000000 \text{ operating hours}}{0.30 \text{ operating hours per calendar hour}}$$

$$= 3.3 \text{ million calendar hours}$$

This concept is illustrated in Figure 2.

The upper half of Figure 2 represents the original 217Plus prediction of 15 failures per million calendar hours, where the operating failures are experienced over 300K hours of operation and the non-operating and cycling failures are experienced over 700K hours of non-operation and cycling.

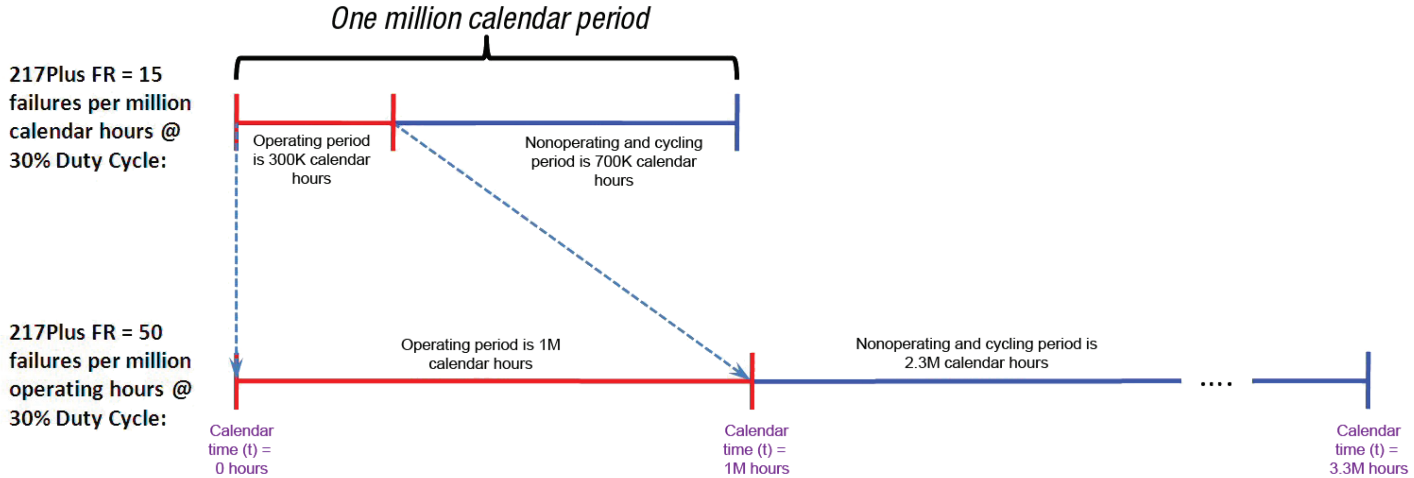

Figure 2: Conversion of One Million Operating Hours to Equivalent Calendar Hours at a 30% Duty Cycle

The conversion of the 217Plus prediction to 50 failures per million operating hours is shown in the bottom half of Figure 2. In this graphic, all operating, non-operating and cycling failures are assigned to the 1M hour operating period (i.e., there are no non-operating or cycling failures, per se, during the non-operating and cycling 2.3M hour period). The appropriate interpretation of this timeline is that, in reality, it will take a total of 3.3M calendar hours to accumulate the required 1M operating hours (and the 50 failures associated with those hours) to generate the equivalent 217Plus operating hour failure rate.

The equivalency of the 217Plus failure rate of 15 failures per million calendar hours and 50 failures per million operating hours is confirmed in the equations below, using our example duty cycle of 30%:

$$\frac{15 \text{ failures}}{1\text{M calendar hours}} = \frac{50 \text{ failures}}{1\text{M operating hours}}$$

1 operating hour = 0.30 calendar hours

$$\frac{15 \text{ failures}}{1\text{M calendar hours}} = \frac{50 \text{ failures}}{1\text{M operating hours}} * \frac{0.30 \text{ operating hours}}{1 \text{ calendar hour}}$$

$$\frac{15 \text{ failures}}{1\text{M calendar hours}} = \frac{15 \text{ failures}}{1\text{M calendar hours}}$$

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