SAMPLING FOR
INTERMITTENT SHORTS IN
ELECTRON TUBES

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The primary purpose of sampling is to provide data from which a decision can be made to accept or reject the lot from which the sample was drawn. However, if the lot contains both permanent and intermittent defects, this decision may be biased in addition to the known sampling risks by these data to the extent that they are themselves no longer certainties but rather, probabilities. This is due to the nature of intermittent defects which are defined in part as having a probability of occurrence designated by "q", wherein $0 < q < 1.0$. For example, a sample may exhibit no defects when tested, indicating no permanent defects, even though the units in the lot and those tested have a probability of displaying intermittent defects which is larger than can be tolerated in terms of use requirements.

To minimize the risk of accepting units which have a value of q which is larger than desirable we may

- (1) eliminate these units by sufficient 100 percent testing, or
- (2) sample the lot on the basis of very strict acceptance criteria, or
- (3) use a combination of (1) and (2).

If we attempt to eliminate tubes which have a specified value of q for intermittent shorts, we also must establish a value for the tester efficiency, E, where $0 \leq E \leq 1.0$. In this case the probability that the tester will not detect an intermittent short in a tube which has an intermittent short probability of q is given by the probability of accepting the tube:

$$P_a = p + q (1 - E) = 1 - qE, \quad (1)$$

where, p = probability that the short will not occur ($= 1 - q$),
 $1 - E$ = probability that the tester will not detect a short if it occurs.

After a series of n repeated tests, the probability that the tester has not detected a short is

$$P_a = (1 - qE)^n \quad (2)$$

The probability of a tester of efficiency $E = 0.75$ accepting tubes with intermittent shorts for a number of consecutive tests is shown in Figure 1. Although the curves in this figure are similar to OC curves of sampling plans, in this case we are concerned with the probability of acceptance as a function of the frequency of occurrence of a defect rather than the fraction defective in the lot. It should be noted from this figure that as the frequency of occurrence of an intermittent short (q) becomes smaller, a greater number of tests are required to obtain the same probability of detecting the defect.

For example, if we wish to reject tubes with a $q \geq 0.5$ in 90 percent of the cases, each tube must be tested a minimum of five times. However, if we wish to reject tubes with a $q \geq 0.25$ in 90 percent of the cases, each tube must be tested a minimum of ten times.

It should be emphasized that this method of testing requires the rejection of tubes which exhibit an intermittent short on any one trial. Further, this method cannot economically eliminate tubes which have a relatively low probability of exhibiting intermittent defects. Figure 2 illustrates this problem. For example, if we wish to reject tubes with a $q \geq 3$ percent in 90 percent of the cases, each tube would have to be tested a minimum of 75 times if the tester were 100 percent efficient or 100 times if the efficiency were 75 percent.

If a lot of tubes is sampled for shorts after a number of successive screening tests, the probability of accepting the lot by sampling to a specified AQL is determined by the fraction defective remaining in the lot. In this case the fraction defective is the sum of the fraction of the lot with permanent and intermittent shorts and is expressed as:

$$F_d = C + \int_0^1 f(q) dq, \text{ where } (3)$$

$C = \text{fraction chronically defective (permanent shorts),}$
 $\int_0^1 f(q) dq = \text{fraction intermittently defective (area of distribution of tubes with intermittent shorts).}$

However, since tubes with intermittent shorts fail only q of the time on any one test, the relative frequency of failure due to intermittent shorts is $\int_0^1 qf(q) dq$. Therefore, the probability of a short occurring if a tube is randomly selected from the lot and tested is:

$$P_s = C + \int_0^1 qf(q) dq \quad (4)$$

(Note: tester efficiency assumed equal to 1.0 in this case)

Since equation (4) expresses the failure probability expected in use rather than the fraction of tubes which might fail, as expressed by equation (3), it would appear more reasonable to establish acceptance criteria in terms of this failure probability rather than the fraction of the lot which might fail. Although the fraction intermittently defective may be relatively high, the probability of tubes exhibiting intermittent shorts may be at an acceptably low level, particularly if the tubes have been tested a required number of times.

Acceptance criteria for the failure probability, P_s , may be established by assigning two values to P_s :

- (1) A value which is acceptable and has a probability of acceptance by sampling of approximately 95 percent. Since this is similar to the AQL for fraction defective, we will call this the "APL", i.e., acceptable probability level.
- (2) A value which is unsatisfactory and has a probability of acceptance by sampling of only 10 percent. Since this is similar to the LTPD for fraction defective, we will call this the "LTP", i.e., the lot tolerance probability.

The following acceptance criteria are proposed for the failure probability, P_s , for short testings:

APL = 0.4 percent, and

LTP = 3.0 percent

The OC curves for the following single sampling plans in MIL-STD-105A satisfy these acceptance criteria:

<u>Sample Size</u>	<u>Acceptance Number</u>
225	3
150	1
110	0

To provide a reasonable chance of lot acceptance to these criteria, it is necessary that the short failure probability, P_s , be less than LTP and preferably be equal to or less than the APL. The number of prior screening tests necessary to minimize the failure probability to the desired level may be determined if an estimate is made of the fraction of tubes intermittently defective in the lot. The allowable frequency of occurrence of intermittent defects may then be determined (for the proposed acceptance criteria).

Figure 3 shows the frequency of intermittent defects, q , as a function of the fraction of intermittently defective tubes for a specified failure probability. For example, if an estimate is made from available data that the fraction of the lot containing intermittent defects is one percent, the value of q for an APL of 0.4 percent is 0.4. This assumes that all chronic defectives will be eliminated by screening prior to sampling. From Figure 2 the number of times each tube must be tested to eliminate tubes with a q of 0.4 or greater in 90 percent of the cases is shown to be 7 times if the tester efficiency is 0.75. If the fraction intermittently defective is estimated to be relatively large, this will necessitate a greater number of repeat tests before sampling. If in the previous example the fraction intermittently defective were actually 7.5 percent rather than one percent, the failure probability would be at least

3 percent, resulting in only a 10 percent probability of acceptance by sampling to the specified acceptance criteria. In this case, instead of seven repeat tests, each tube should have been tested about 60 times to meet the specified APL. (Tester efficiency of 0.75).

The economics of this situation relative to the number of times each tube must be tested to provide reasonable assurance of acceptance by sampling is such that the fraction intermittently defective must be held to approximately one percent. This can only be accomplished through quality of design and manufacturing conformance to that design. Inspection may reduce the probability of nonconformance but it cannot improve the quality of finished tubes.