Digital Computer Laboratory
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SUBJECT: A METHOD FOR ACCEPTANCE TESTING OF FERRITE CORE PRODUCTION LOTS

To: Group 63 Staff

From: P. K. Baltzer

Date: December 4, 1952

Abstract: A method for screening the Production Lots of ferrite cores to be tested for MTC is required because of testing limitations and large variations found between Production Lots. It is proposed that a sample of 100 cores be taken from each lot and tested at the factory. The mean of the sample must be between the Screening Limits specified for the lot to be accepted, from the manufacturer, for complete testing. The Per Cent Yield of the total number of cores to be tested individually has been calculated as a function of Screening Limits (see Figure 1).

Problem Defined

The urgent need for memory cores for MTC has placed considerable pressure on those involved in testing and selecting them. Two independent production lots of ferrite cores have been tested. The material and core size were different in each case. It was found that both production lots of 1,000 had the same relative distribution about their respective mean value of "Disturbed One" output voltage. Therefore, as long as the method of manufacture is not grossly changed, the information gained from the testing of these two batches of 1,000 cores can be utilized for statistical calculations concerning future production.

In the very near future, the cores needed for MTC will be in the process of being tested here. Regardless of what testing mechanism is used, the yield percentagewise of the cores tested is an important factor. Therefore, a preliminary selection of production lots is necessary at the factory.

Method Proposed

It is proposed that each Production Lot be accepted or rejected at the factory on the basis of testing a random sample of fixed size. The "Disturbed One" output voltage of the sample cores should be measured in the same way that all the cores will be tested before being placed in the memory. The arithmetic mean of the sample must lie within specified "Screening Limits" for a production lot to be accepted.

The accepted Production Lot must still be completely tested at MIT. Each core that will be used must satisfy the specifications given; that is, the "Disturbed One" output of an individual core must lie within specified "Tolerance Limits."

"Screening Limits" therefore must apply only to sample means, for the purpose of screening Production Lots. Whereas "Tolerance Limits" apply only to individual cores and are not necessarily equal to the "Screening Limits."

Tolerance Limits will remain constant, however, the Screening Limits may have to be varied to suit the manufacturer's ability to maintain uniformity between production lots. The size of the Screening Limits will determine the total number of cores necessary to test individually to obtain a given number of useful cores. Per Cent Yield will be defined as:

$$\%\ \text{Yield} = \frac{\text{Number of Useful Cores}}{\text{Number Tested Individually}} \times 100$$

Hence, it is necessary to know the relationship between Per Cent Yield and Screening Limits. This relationship was found by calculations based on the two production lots already tested, and is shown in Figure 1. This curve will enable us to know what Percentage Yield is sacrificed for any expansion that might be necessary in the Screening Limits.

Sampling

The sample taken from each Production Lot of about 2,000 cores must be large enough to truly represent the lot, and yet not be unwieldy. The mean of a random sample of 30 cores has a standard error from the mean of the production unit of 0.003 volts. However, the manufacturer has found that a sample of 100 cores is necessary to obtain a representative sample. This large size is necessary because of difficulty in obtaining a truly random sample of a smaller size. Therefore, since the present testing methods permit a larger sample, it is proposed that a sample of 100 cores be used. The standard error of the mean of a 100 core sample would be 0.002 volts.

Calculations

All calculations have been based on the assumption that the distribution within a lot is normal and that the sample is random. The expression for the normal distribution is given by the following function:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}}\, e^{-\frac{x^2}{2\sigma^2}}$$

where x is measured from the mean of the distribution, and σ is the standard deviation.

The probability (P_1) that a lot with a given mean will contain desired cores will simply be the area under distribution curve enclosed by the Tolerance Limits (T.L.) (see Figure 2a).

Hence:

$$P_1 = \int_{M-T.L.}^{M+T.L.} f(x - M - \sigma_L)\, dx$$

where σ_L is Lot Deviation and defined as the variation of Lot Mean from the Desired Mean (M).

Therefore P_1 can be found as a function of σ_L (see Figure 2b). σ_L is plotted in σ (Standard Deviation) units since the distribution involved in the calculations was the total distribution within a lot. The Standard Deviation found, for the two lots of 1,000 cores tested, was (0.15)M or 0.016 volts for a mean of 0.11 volts. This curve indicates the fractional yield of desired cores that can be expected from any lot, when the Lot Mean is known.

Since the true mean of any lot is not known until the lot is completely tested, we must sample and base our screening process on the mean of the sample. It is known that the distribution of the Sample Mean of random samples of a given size will be normal about the lot mean, with a Standard Error (S.E.) of S.E. = $\sigma/\sqrt{N}$ where N is the number in sample.

The probability (P_2), that a lot will pass the screening process, is the area under the distribution curve of Sample Means between the Screening Limits (see Figure 3a).

Hence:

$$P_2 = \int_{M-S.L.}^{M+S.L.} f(x - M - \sigma_L)\, dx$$

Therefore P_2 can be found as a function of σ_L for any given value of Screening Limits (see Figure 3b). σ_L is plotted in S.E. units since the distribution involved is that of Sample Means.

Now we have the probability (P_1) that a lot will contain desired cores and the probability (P_2) that a lot will pass screening process. The final objective is to obtain the Percentage Yield from total cores tested individually as a function of the Screening Limits, for a given size sample. This is given by:

$$\%\ \text{Yield} = \frac{\int_{-\infty}^{\infty} P_1 P_2\, d(\sigma_L)}{\int_{-\infty}^{\infty} P_2\, d(\sigma_L)} \times 100$$

Unfortunately, it is no longer possible to keep the calculations general concerning Sample Size (see Figure 1). P_1 was found using σ units and P_2 using S.E. units; and to find Per Cent Yield, they must be combined.

Thus a factor of $\sqrt{N}$ is involved. It was assumed in the calculation of P_2 that each Lot Mean was equally probable. Therefore since the manufacturer will attempt production control, the curve of Per Cent Yield vs. Screening Limits is more likely to be pessimistic than optemistic.

Signed P. K. Baltzer
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Approved DRB
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PKB/jk

Drawings attached:

A-53282
A-53272
A-53273

cc: W. Papian
W. Ogden

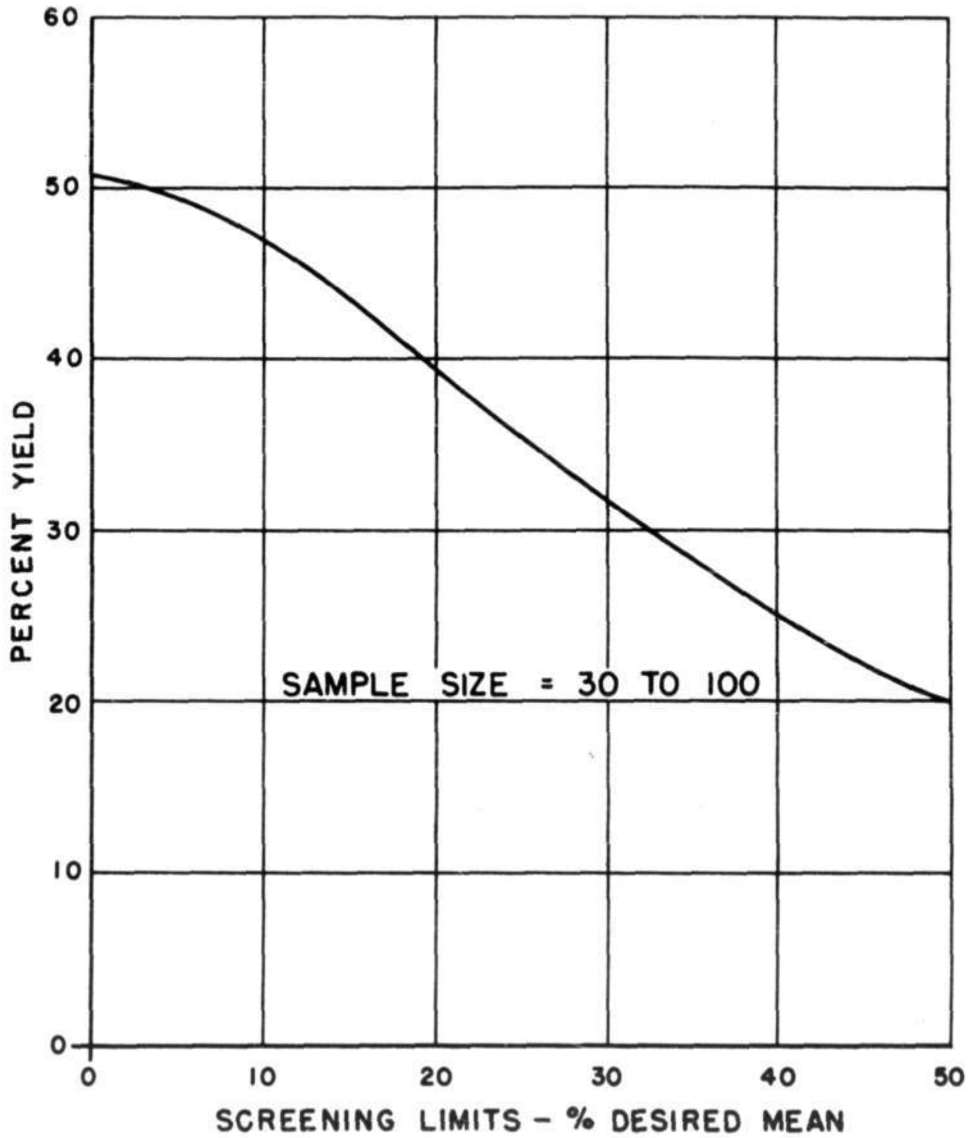

FIG. 1
PERCENT YIELD
VS.
SCREENING LIMITS

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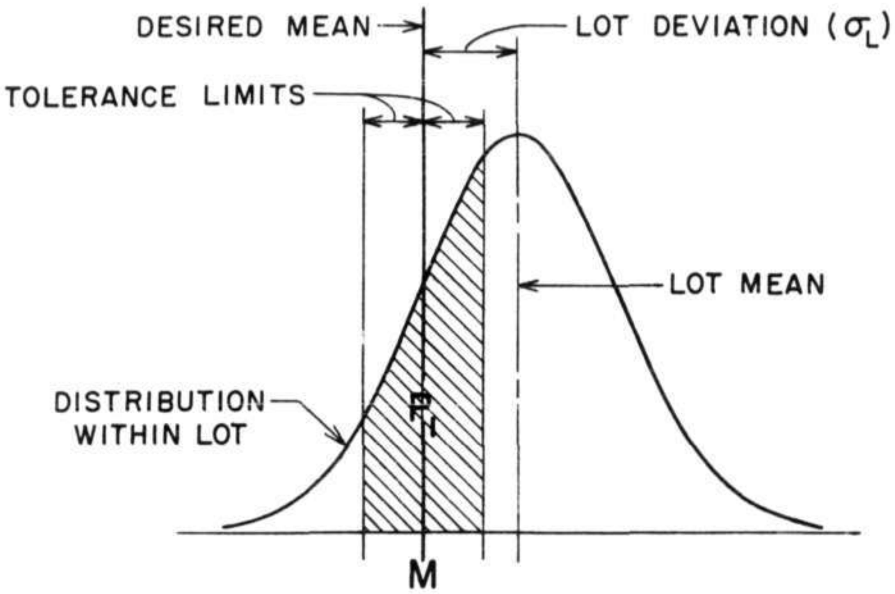

FIG. 2a

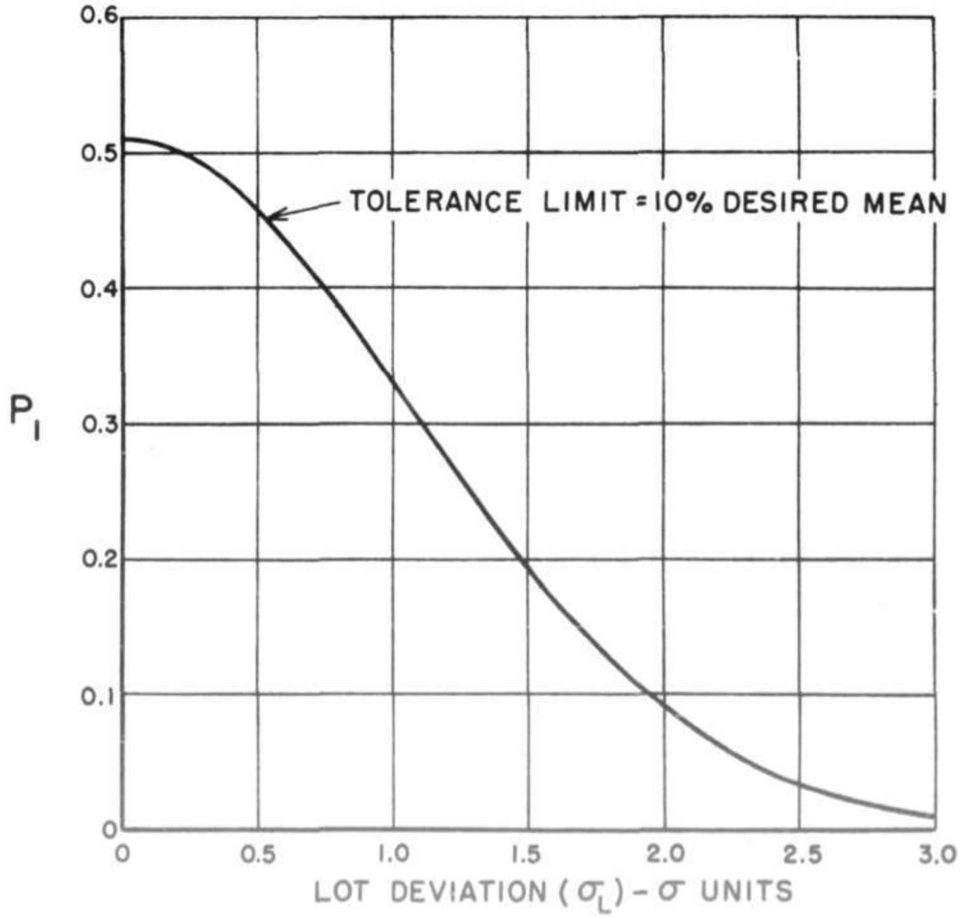

FIG. 2b

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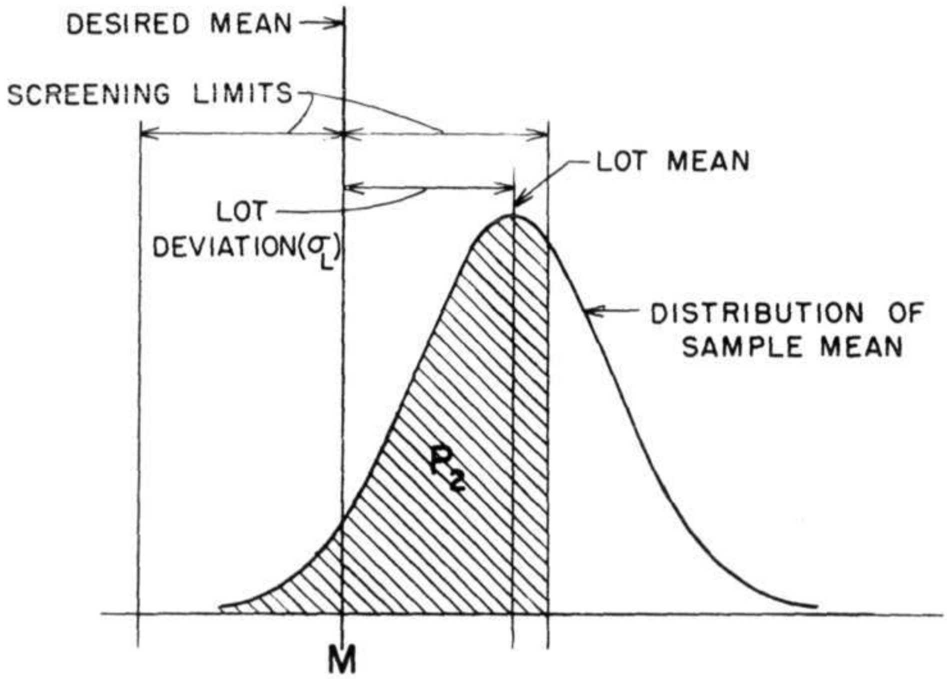

FIG. 3a

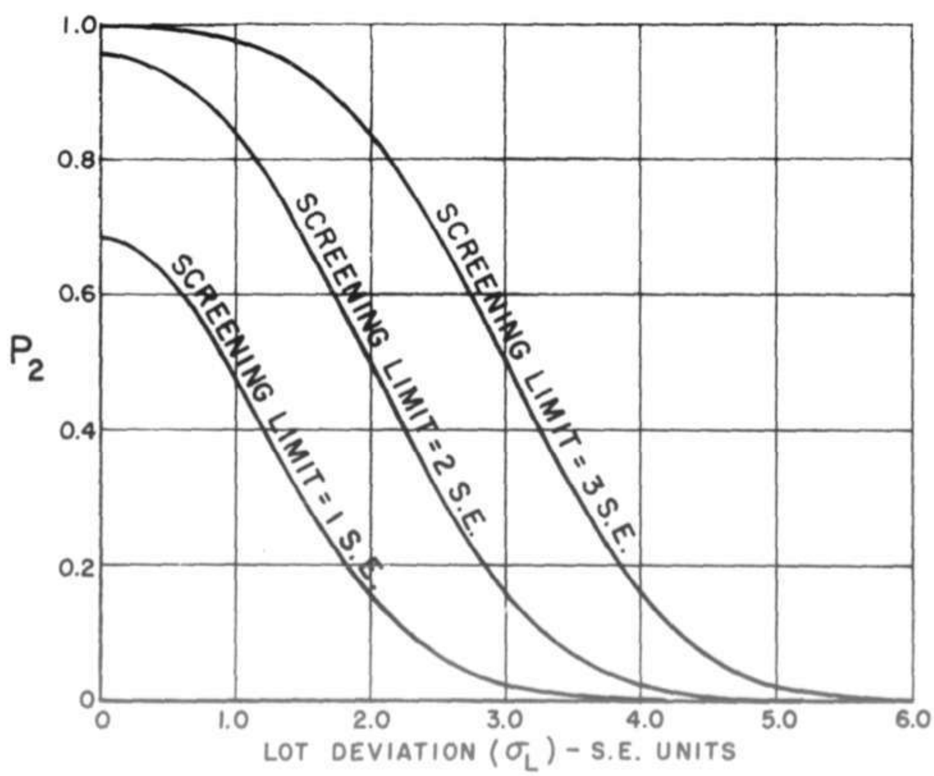

FIG. 3b

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