# A Study on the Attributes Sampling Plans in MIL-STD-1916

M. H. C. Li, A. Al-Refaie and C. W. Tsao

***Abstract*—The Department of Defense-USA adopted MIL-STD-1916 (Military Standard-1916) sampling plans instead of the traditional MIL-STD-105E (Military Standard-105E) sampling plans in 1996. MIL-STD-1916 emphasizes on an effective prevention-based strategy quality system. Its attributes sampling plans are based on "zero accept one reject" as criteria of judgment. In this paper, the lot sizes are regrouped from 11 groups into 18 new groups such that 100% inspection and sampling plan could be clearly separated. The results of this research provide guidance for both supplier and customer who use MIL-STD-1916.**

***Index Terms*—Attribute Sampling Plan, MIL-STD-1916, MIL-STD-105E**

## I. Introduction

Since 1996, the Department of Defense-USA has adopted MIL-STD-1916 (Military Standard-1916) sampling plans [1-2] instead of the traditional MIL-STD-105E (Military Standard-105E) sampling plans [3]. MIL-STD-1916 is based on "zero accept one reject" as criteria of judgment. It emphasizes on the non-existence of nonconforming product. Also, the tables of MIL-STD-1916 are less than those of MIL-STD-105E. It makes the sampling plan much simple and user friendly. Also, ISO 16949 [4] adopts zero acceptance criteria for attribute sampling plan. However, there were seldom research papers investigating MIL-STD-1916 since it was published. Gillies [5] combined MIL-STD-1916 and ISO19114 into a methodological framework for the development of quality assurance procedures.

The purposes of this research are twofold. First, the lot sizes are regrouped such that 100% inspection is totally separated from sampling plan. Second, the probability of acceptance, $P_a$, is investigated while there is only one defective item in the lot. The results show that the lot size and verification level (VI) can be divided into 5 blocks.

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## II. The Probability of Acceptance for Finite Population

Suppose there are $D$ defective items in a lot size, $N$. Then, the fraction nonconforming, $p$, is ($D/N$). Randomly select $n$ samples from this lot without replacement, the probability of $x$ nonconforming items, $P(x)$ is a hypergeometric distribution [6] as shown in (1).

$$P(x) = \frac{C_x^D C_{n-x}^{N-D}}{C_n^N}, \quad 0 \le x \le \min(D,n) \qquad (1)$$

Given the criteria of acceptance ($n$, $c$), if the number of nonconforming items, $x$, is less or equal to $c$, then the lot is accepted. Otherwise, it is rejected. The probability of acceptance, $P_a$, is shown in (2).

$$P_a = \sum_{x=0}^{c} \frac{C_x^D C_{n-x}^{N-D}}{C_n^N} \qquad (2)$$

If $c$ is zero, the probability of acceptance, $P_a$, can be expressed as shown in (3) by replacing $c$ with zero in (2).

$$P_a = \frac{C_0^D C_n^{N-D}}{C_n^N} = \frac{C_n^{N-D}}{C_n^N} = \frac{(N-D)!(N-n)!}{(N-D-n)!N!} \qquad (3)$$

## III. Investigation of Verification Level

### A. *Separation of 100% Inspection with Sampling Plan*

In MIL-STD-1916, the verification levels (VL) are specified in the contract or product specifications. The VL and code letters for entry into the sampling tables is shown in Table 1. The lot sizes are divided into 11 groups and there are 7 verification levels (I-VII). In section 5.2.2.1 of MIL-STD-1916, the attributes sampling plans for lots or batches are described in Table 2 for normal, tightened, and reduced inspection. There are 9 verification levels in Table 2. The 2 extra verification levels are tightened inspection, $T$, and reduced inspection, $R$.

In order to match the sample size $n$ for each lot size $N$ with each verification level (VL) directly, Table 1 and Table 2 are integrated together. Since there is neither tightened inspection nor reduced inspection in Table 1, only from verification level I to VII are combined together as shown in Table 3. From Table 3, it is shown that some sample size (Bold Case), $n$, are larger than lot size, $N$. It is not reasonable. Thus, for those sample size larger than lot size, the sample size should be adjusted to be equal to its lot size. Group 1 is regrouped into five new groups and illustrated as follow:

1. If the lot size $N$ is within [2,5], then 100% inspection are needed for all VL.
2. If the lot size $N$ is within [6,12], then 100% inspection are needed for VL=II-VII and sampling plan is needed for VL=I.
3. If the lot size $N$ is within [13, 32], then 100% inspection are needed for VL=III-VII and sampling plan are needed for VL=I-II.
4. If the lot size $N$ is within [33, 80], then 100% inspection are needed for VL=VI-VII and sampling plan are needed for VL=I-III.
5. If the lot size $N$ is within [81, 170], then 100% inspection are needed for VL=V-VII and sampling plan are needed for VL=I-VI.

Thus, the original groups should be divided into more groups such that 100% inspection can be clearly separated from sampling plan for each VL. After careful examination, the lot sizes are divided into 18 new groups as shown in the third column of Table 4. The corresponding new 18 lot sizes are in the fourth column of Table 4. Now all the sample size are less than or equal to lot size. For the 18 new groups with 7 VL, there are 126 (=18×7) cases or cells. Among the 126 cells, 35 cells (Bold case) are 100% inspection and 91 cells are sampling plans. Thus, 100% inspection and sampling plan are totally separated.

### B. The relationship between probability of acceptance and percent defective

For 100% inspection, the lot will be rejected, if there is one or more defective items in the lot. For sampling plan, there are ($N$+1) conditions for the finite population $N$. That is, $D$=0, 1, 2, ⋯, $N$-1, $N$. Similarly, the percent defective $p$ also have ($N$+1) conditions. i. e. $p$=0, 1/$N$, 2/$N$, ⋯, ($N$-1)/$N$, 1. If $D$ is zero, then $p$ is zero too, the probability of acceptance is one. If $0 < D < (N\text{-}n)$, the probability of acceptance $P_a$ is shown in (3). If $D$ is larger than ($N$-$n$), then there will exist at least one defective item in the sample. Thus, the probability of acceptance is zero and the lot will be definitely rejected.

From Table 4, the smallest lot size of sampling plan is $N \in [6, 12]$ and its corresponding cell is (VL=I, $n$= 5). The value of $P_a$ in this cell is computed according to (1). For example, if $N$ is 6 and $D$ is 1, then $p$ is 1/6. The probability of acceptance, $P_a$, is 1/6. If $N$ is 7 and $D$ is 1, then $p$ is 1/7. The probability of acceptance, $P_a$, is 6/21. If $N$ is 7 and $D$ is 2, then $p$ is 2/7 and $P_a$ is 1/21. For each combination of $N$ and $D$, the value of $p$ and $P_a$ could be exactly computed. Similarly, for the other combination of lot size $N$ and VL, the sample size can be found in Table 4. The values of $p$ and $P_a$ can be exactly computed for each value of $D$.

### C. The value of $P_a$ while D is one in the lot

Since MIL-STD-1916 is zero based acceptances, the lot will be rejected, if there is a defective item in the sample. However, no defective item in the sample could not guarantee that there is no defective item in the population. If there is only one defective item in the population, the lot still has the possibility of acceptance. If $D$=1, the percent defective $p$ is 1/$N$ and the probability of acceptance $P_a$ is shown in (4).

$$P_a = \frac{(N-D)!(N-n)!}{(N-D-n)!N!} = \frac{(N-1)!(N-n)!}{(N-1-n)!N!} \qquad (4)$$

The range of $P_a$ in each cell is shown in Table 5 and illustrated as follows.

1. There are 35 cells (Bold case) in which $P_a$ =0 because of 100% inspection in these cells.
2. For the other 91 cells, sampling plans are executed. The minimum value of $P_a$ is computed by sampling from the minimum value of $N$ in this cell. The maximum value of $P_a$ is computed by sampling from the maximum value of $N$ in this cell. For example, in the cell of $N \in [6, 12]$ and VL=I, $n$ is 5.
   1) If $N$ is 6, then using (4), $P_a$ is 0.167. It is the smallest value in this cell.
   2) If $N$ is 12, then $P_a$ is 0.583, which is the largest value in this cell.

   Thus, the value of $P_a$ in this cell is within [0.167, 0.583]. By this way, the range of $P_a$ in each cell is computed.
3. In the18th group, the lot size N is equal to or larger than 30721. There is only one value of $P_a$. It means that the probability of acceptance will be equal to or larger than the value of $P_a$.
4. With the same lot size $N$, the larger the VL is, the smaller the value of $P_a$ is. It is because the larger the VL is, the larger the sample size is. Eventually, the smaller the $P_a$ is.
5. With the same VL, the larger the lot size is, the larger the $P_a$ is. It is because the larger the VL is, even if the larger the sample size is, still the smaller the value of $p$(=1/$N$) is. The effect of increase in sample size $n$ could not offset the effect of decrease in percent defective $p$.
6. Finally, according to the value of $P_a$ in Table 5, the 126 cells can be divided into 5 blocks as shown in Table 6. Block {1} is 100% inspection and the others are sampling plan. There are 35 cells in Block {1} and $P_a$ is zero in this Block. There are 53 cells in Block {2} and $P_a$ is within [0, 0.95] in this Block. There are 53 cells in Block {2} and $P_a$ is within [0, 0.95] in this Block. There are 22 cells in Block {3} and $P_a$ is within [0.95, 0.99] in this Block. There are 13 cells in Block {4} and $P_a$ is within [0.99, 0.999] in this Block. There are 3 cells in Block {5} and $P_a$ is larger than 0.999 in this Block.

## IV. Conclusion

MIL-STD-1916 replaced MIL-STD-105E for several years. However, there are still some difficulties in the implementation. In MIL-STD-1916, it mentions that assign different VL for different quality requirement. It suggest to adopt VL=I-III for minor quality requirement, III-VI for major quality requirement, and VII for critical quality requirement. However, the criteria of VL are not easy to determine. In this paper, the lot sizes are divided into 18 new groups instead of original 11 groups. In this way, 100% inspection is totally separated from sampling plan. MIL-STD-1916 adopt “zero accept and one reject” in the sample. However, if there is one defective in the population, the lot still has possibility to be accepted. The values of $P_a$ are computed for each cell and the cells are divided into 5 Blocks. Thus, the supplier and customer will realize the probability acceptance if there is one defect in this lot.

Future research will investigate the acceptable quality level and reject quality level of attribute sampling plan for MIL-STD-1916.

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Table 2: Attributes sampling plans

| Code letter | Verification levels | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | T | VII | VI | V | IV | III | II | I | R |
| | Sample size (*n*) | | | | | | | | |
| A | 3072 | 1280 | 512 | 192 | 80 | 32 | 12 | 5 | 3 |
| B | 4096 | 1536 | 640 | 256 | 96 | 40 | 16 | 6 | 3 |
| C | 5120 | 2048 | 768 | 320 | 128 | 48 | 20 | 8 | 3 |
| D | 6144 | 2560 | 1024 | 384 | 160 | 64 | 24 | 10 | 4 |
| E | 8192 | 3072 | 1280 | 512 | 192 | 80 | 32 | 12 | 5 |

Note 1. When the lot size is less than or equal to the sample size, 100 percent attributes inspection is required.
2. One verification level (VL) to the left/right of the specified normal VL is the respective tightened/reduced plan. Tightened inspection of VL-VII is T, reduced inspection of VL-I is R.

Table 1: Code letters for entry into the sampling tables

| Original group | Lot or production interval size | Verification levels | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | VII | VI | V | IV | III | II | I |
| 1 | 2-170 | A | A | A | A | A | A | A |
| 2 | 171-288 | A | A | A | A | A | A | B |
| 3 | 289-544 | A | A | A | A | A | B | C |
| 4 | 545-960 | A | A | A | A | B | C | D |
| 5 | 961-1632 | A | A | A | B | C | D | E |
| 6 | 1633-3072 | A | A | B | C | D | E | E |
| 7 | 3073-5440 | A | B | C | D | E | E | E |
| 8 | 5441-9216 | B | C | D | E | E | E | E |
| 9 | 9217-17408 | C | D | E | E | E | E | E |
| 10 | 17409-30720 | D | E | E | E | E | E | E |
| 11 | ≧30721 | E | E | E | E | E | E | E |

Table 3: Convert Code letters into Sample size for each Lot size and VL

| Original group | Lot or production interval size (N) | Verification levels | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | VII | VI | V | IV | III | II | I |
| | | Sample size (n) | | | | | | |
| 1 | 2-170 | **1280** | **512** | **192** | **80** | **32** | **12** | **5** |
| 2 | 171-288 | **1280** | **512** | **192** | 80 | 32 | 12 | 6 |
| 3 | 289-544 | **1280** | **512** | 192 | 80 | 32 | 16 | 8 |
| 4 | 545-960 | **1280** | 512 | 192 | 80 | 40 | 20 | 10 |
| 5 | 961-1632 | **1280** | 512 | 192 | 96 | 48 | 24 | 12 |
| 6 | 1633-3072 | 1280 | 512 | 256 | 128 | 64 | 32 | 12 |
| 7 | 3073-5440 | 1280 | 640 | 320 | 160 | 80 | 32 | 12 |
| 8 | 5441-9216 | 1536 | 768 | 384 | 192 | 80 | 32 | 12 |
| 9 | 9217-17408 | 2048 | 1024 | 512 | 192 | 80 | 32 | 12 |
| 10 | 17409-30720 | 2560 | 1280 | 512 | 192 | 80 | 32 | 12 |
| 11 | ≧30721 | 3072 | 1280 | 512 | 192 | 80 | 32 | 12 |

Note: For those sample size (n) larger than lot size (N) are shown in **Bold case**

Table 4: Sample size for each New lot size and VL

| Original group | Lot size (N) in Table 1 | New group | New lot size (N) | Verification level | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | VII | VI | V | VI | III | II | I |
| | | | | Sample size (n) | | | | | | |
| 1 | 2-170 | (1) | 2-5 | **2-5** | **2-5** | **2-5** | **2-5** | **2-5** | **2-5** | **2-5** |
| | | (2) | 6-12 | **6-12** | **6-12** | **6-12** | **6-12** | **6-12** | **6-12** | 5 |
| | | (3) | 13-32 | **13-32** | **13-32** | **13-32** | **13-32** | **13-32** | 12 | 5 |
| | | (4) | 33-80 | **33-80** | **33-80** | **33-80** | **33-80** | 32 | 12 | 5 |
| | | (5) | 81-170 | **81-170** | **81-170** | **81-170** | 80 | 32 | 12 | 5 |
| 2 | 171-288 | (6) | 171-192 | **171-192** | **171-192** | **171-192** | 80 | 32 | 12 | 6 |
| | | (7) | 193-288 | **193-288** | **193-288** | 192 | 80 | 32 | 12 | 6 |
| 3 | 289-544 | (8) | 289-512 | **289-512** | **289-512** | 192 | 80 | 32 | 16 | 8 |
| | | (9) | 513-544 | **513-544** | 512 | 192 | 80 | 32 | 16 | 8 |
| 4 | 545-960 | (10) | 545-960 | **545-960** | 512 | 192 | 80 | 40 | 20 | 10 |
| 5 | 961-1632 | (11) | 961-1280 | **961-1280** | 512 | 192 | 96 | 48 | 24 | 12 |
| | | (12) | 1281-1632 | 1280 | 512 | 192 | 96 | 48 | 24 | 12 |
| 6 | 1633-3072 | (13) | 1633-3072 | 1280 | 512 | 256 | 128 | 64 | 32 | 12 |
| 7 | 3073-5440 | (14) | 3073-5440 | 1280 | 640 | 320 | 160 | 80 | 32 | 12 |
| 8 | 5441-9216 | (15) | 5441-9216 | 1536 | 768 | 384 | 192 | 80 | 32 | 12 |
| 9 | 9217-17408 | (16) | 9217-17408 | 2048 | 1024 | 512 | 192 | 80 | 32 | 12 |
| 10 | 17409-30720 | (17) | 17409-30720 | 2560 | 1280 | 512 | 192 | 80 | 32 | 12 |
| 11 | ≧30721 | (18) | ≧30721 | 3072 | 1280 | 512 | 192 | 80 | 32 | 12 |

Note: For those sample sizes which are equal to lot sizes, 100% inspection are required which are shown in **Bold case**

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Table 5: The value of $P_a$ for $D$=1 in the lot $N$

| new group | New lot size | parameter | Verification level | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | VII | VI | V | IV | III | II | I |
| (1) | 2-5 | $n$ | **2-5** | **2-5** | **2-5** | **2-5** | **2-5** | **2-5** | **2-5** |
| | | $P_a$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (2) | 6-12 | $n$ | **6-12** | **6-12** | **6-12** | **6-12** | **6-12** | **6-12** | 5 |
| | | $P_a$ | 0 | 0 | 0 | 0 | 0 | 0 | 0.167-0.583 |
| (3) | 13-32 | $n$ | **13-32** | **13-32** | **13-32** | **13-32** | **13-32** | 12 | 5 |
| | | $P_a$ | 0 | 0 | 0 | 0 | 0 | $7.69\times10^{-2}$-0.625 | 0.615-0.843 |
| (4) | 33-80 | $n$ | **33-80** | **33-80** | **33-80** | **33-80** | 32 | 12 | 5 |
| | | $P_a$ | 0 | 0 | 0 | 0 | $3.03\times10^{-2}$-0.600 | 0.636-0.850 | 0.848-0.938 |
| (5) | 81-170 | $n$ | **81-170** | **81-170** | **81-170** | 80 | 32 | 12 | 5 |
| | | $P_a$ | 0 | 0 | 0 | $1.23\times10^{-2}$-0.529 | 0.605-0.812 | 0.852-0.929 | 0.938-0.971 |
| (6) | 171-192 | $n$ | **171-192** | **171-192** | **171-192** | 80 | 32 | 12 | 6 |
| | | $P_a$ | 0 | 0 | 0 | 0.532-0.583 | 0.813-0.833 | 0.930-0.938 | 0.965-0.969 |
| (7) | 193-288 | $n$ | **193-288** | **193-288** | 192 | 80 | 32 | 12 | 6 |
| | | $P_a$ | 0 | 0 | $5.18\times10^{-3}$-0.333 | 0.585-0.722 | 0.834-0.889 | 0.938-0.958 | 0.969-0.979 |
| (8) | 289-512 | $n$ | **289-512** | **289-512** | 192 | 80 | 32 | 16 | 8 |
| | | $P_a$ | 0 | 0 | 0.336-0.625 | 0.723-0.844 | 0.889-0.938 | 0.945-0.969 | 0.972-0.984 |
| (9) | 513-544 | $n$ | **513-544** | 512 | 192 | 80 | 32 | 16 | 8 |
| | | $P_a$ | 0 | $1.95\times10^{-3}$-$5.88\times10^{-2}$ | 0.626-0.647 | 0.844-0.853 | 0.938-0.941 | 0.969-0.971 | 0.984-0.985 |
| (10) | 545-960 | $n$ | **545-960** | 512 | 192 | 80 | 40 | 20 | 10 |
| | | $P_a$ | 0 | $6.06\times10^{-2}$-0.467 | 0.648-0.800 | 0.853-0.917 | 0.927-0.958 | 0.963-0.979 | 0.982-0.990 |
| (11) | 961-1280 | $n$ | **961-1280** | 512 | 192 | 96 | 48 | 24 | 12 |
| | | $P_a$ | 0 | 0.467-0.600 | 0.800-0.850 | 0.900-0.925 | 0.950-0.963 | 0.975-0.981 | 0.988-0.991 |
| (12) | 1281-1632 | $n$ | 1280 | 512 | 192 | 96 | 48 | 24 | 12 |
| | | $P_a$ | $7.81\times10^{-4}$-0.216 | 0.600-0.686 | 0.850-0.882 | 0.925-0.941 | 0.963-0.971 | 0.981-0.985 | 0.991-0.993 |
| (13) | 1633-3072 | $n$ | 1280 | 512 | 256 | 128 | 64 | 32 | 12 |
| | | $P_a$ | 0.216-0.583 | 0.686-0.833 | 0.843-0.917 | 0.922-0.958 | 0.961-0.979 | 0.980-0.990 | 0.993-0.996 |
| (14) | 3073-5440 | $n$ | 1280 | 640 | 320 | 160 | 80 | 32 | 12 |
| | | $P_a$ | 0.583-0.765 | 0.792-0.882 | 0.896-0.941 | 0.948-0.971 | 0.974-0.985 | 0.990-0.994 | 0.996-0.9978 |
| (15) | 5441-9216 | $n$ | 1536 | 768 | 384 | 192 | 80 | 32 | 12 |
| | | $P_a$ | 0.718-0.833 | 0.859-0.917 | 0.929-0.958 | 0.965-0.979 | 0.985-0.991 | 0.994-0.997 | 0.9978-0.9987 |
| (16) | 9217-17408 | $n$ | 2048 | 1024 | 512 | 192 | 80 | 32 | 12 |
| | | $P_a$ | 0.778-0.882 | 0.889-0.941 | 0.944-0.971 | 0.979-0.989 | 0.991-0.995 | 0.997-0.998 | 0.9987-0.9993 |
| (17) | 17409-30720 | $n$ | 2560 | 1280 | 512 | 192 | 80 | 32 | 12 |
| | | $P_a$ | 0.853-0.917 | 0.926-0.958 | 0.971-0.983 | 0.989-0.994 | 0.995-0.997 | 0.998-0.9990 | 0.9993-0.9996 |
| (18) | ≧30721 | $n$ | 3072 | 1280 | 512 | 192 | 80 | 32 | 12 |
| | | $P_a$ | 0.900 | 0.958 | 0.983 | 0.994 | 0.997 | 0.9990 | 0.9996 |

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Table 6: The probability blocks of acceptance when D is one in the lot

| Group | Lot size in Table 2 | New group | New lot size (N) | Verification level | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | VII | VI | V | IV | III | II | I |
| 1 | 2-170 | (1) | 2-5 | | | | | | | |
| | | (2) | 6-12 | | | | | | | |
| | | (3) | 13-32 | | {1} | | | | | |
| | | (4) | 33-80 | | | | | | | |
| | | (5) | 81-170 | | | | | | | |
| 2 | 171-288 | (6) | 171-192 | | | | | | | |
| | | (7) | 193-288 | | | | | | | |
| 3 | 289-544 | (8) | 289-512 | | | | {2} | | | |
| | | (9) | 513-544 | | | | | | | |
| 4 | 545-960 | (10) | 545-960 | | | | | | | |
| 5 | 961-1632 | (11) | 961-1280 | | | | | | | |
| | | (12) | 1281-1632 | | | | | | {3} | |
| 6 | 1633-3072 | (13) | 1633-3072 | | | | | | | |
| 7 | 3073-5440 | (14) | 3073-5440 | | | | | | | |
| 8 | 5441-9216 | (15) | 5441-9216 | | | | | | | |
| 9 | 9217-17408 | (16) | 9217-17408 | | | | | | {4} | |
| 10 | 17409-30720 | (17) | 17409-30720 | | | | | | | |
| 11 | ≧30721 | (18) | 30721 | | | | | | | {5} |

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