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Six Sigma Modified Quick Switching Variables Sampling System of type SSMQSVSS (n_T, n_N; k) Indexed by Six Sigma Quality Levels

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ABSTRACT
This paper is devoted to the designing of six sigma modified quick switching variables sampling system [SSMQSVSS- r ($n_{T\sigma}$, $n_{N\sigma}$; k_σ), r=2 and 3]. This plan gives operating and designing procedures. That procedure verified with practical applications and also used to construct tables.

Keywords
Modified Quick Switching Variables Sampling System, Operating Characteristic Curve, Six Sigma AQL and Six Sigma LQL.

1. INTRODUCTION
Acceptance Sampling is the practice of testing a sample of product from a large batch, then dispositioning (accept or reject) the entire batch (or lot) based on the results of the inspection. A variables sampling plan is an acceptance sampling technique. Plans for variables are intended for quality characteristics that are measured in a continuous scale. One of the plan of acceptance sampling is Quick switching system, it was originally proposed by Dodge (1967). The proposed plan was investigated by Romboski (1969) and he has made a brief study of the modified quick switching systems, namely QSS-r (n_σ; c_N, c_T), r = 2 and 3. Romboski (1969) has studied the QSS-1 by taking a single sampling plan as reference plan. Based on this study, he has made some modification to the switching rules of QSS. The modified systems are designated as QSS-2 and QSS-3. Soundararajan and Arumainayagam (1989) have studied the properties of these modified systems. Soundararajan and Arumainayagam (1990) have provided tables for the selection of QSS for various given conditions. Since the single sampling QSS-r(n, kn; c_0), r = 2 and 3 system has more than two parameters, a variety of plans can be found satisfying the given (AQL, LQL) condition. The modified system result in a composite OC curve, which is more discriminating one than the original QSS-1. These are more efficient than QSS-1. Palanivel (1999) has studied, modified Quick switching system designing procedures applied in variables sampling plan for given a combination of (AQL, LQL). Senthilkumar and Esha Raffie (2012) have studied six sigma quick switching variables sampling system (n_σ; k_T, k_N) constructed by six sigma quality levels. In later Senthilkumar and Esha Raffie (2015) have studied six sigma quick switching variable sampling system ($n_{T\sigma}$, $n_{N\sigma}$; k_σ) for given sigma quality levels of (SSAQL, SSLQL).

In this paper, tables and procedures for selection of SSQSVSS-r($n_{T\sigma}$, $n_{N\sigma}$; k_σ), r=2 and 3 indexed by SSAQL and SSLQL are given. This study was made by following conditions for application and basic assumptions:

- The production is steady, so that results on current and preceding lots are broadly indicative of a continuous process.
- Lots are submitted substantially in the order of production.
- Inspection is by variables, with the quality being defined as the fraction of non- conforming.
- The sample units are selected from a large lot and production is continuous.
- The production process depends on automation and human involvement in the process is negligible.
- The industry may adopt system method with decision makers have an experience in adopting the six sigma quality initiatives.

2. BASIC ASSUMPTIONS
- The quality characteristic is represented by a random variable X measurable on a continuous scale.
- Distribution of X is normal with mean and standard deviation.
- An upper limit U, has been specified and a product is qualified as defective when X>U. [when the lower limit L is Specified, the product is a defective one if X<L].
- The Purpose of inspection is to control the fraction defective, p in the lot inspected.

The following operating procedure should adopt above conditions for application and basic assumptions, for known σ are given below:

Step 1: Draw a sample of size n_σ from the lot, inspect and record the measurement of the quality characteristic for each unit of the sample. Compute the sample mean $\overline{X}_N = \frac{\sum x_i}{n_N}$.

Step2: If $\overline{X}_N + k_\sigma\,\sigma \le U$ or $\overline{X}_N - k_\sigma\,\sigma \ge L$ accept the lot and repeat Step 1 otherwise, reject the lot and follow Step 3.

Step 3: Draw a sample of size n_σ from the next lot inspect and record the measurement of the quality characteristic for each unit of the sample. Compute the sample mean $\overline{X}_T = \frac{\sum x_i}{n_T}$.

Step 4: If $\overline{X}_T + k_\sigma \sigma \leq U$ or $\overline{X}_T - k_\sigma \sigma \geq L$ accept the lot. When r consecutive lots are accepted, switch to step 1 otherwise, reject the lot and repeat Step 3.

where $n_{T\sigma}$ and $n_{N\sigma}$ are the sample size of normal and tightened sampling plan respectively and k_σ is the acceptance constant.

3. OPERATING CHARACTERISTIC FUNCTION

Romboski (1969) derived the OC function of the QSS-r(n, c_N, c_T), r=2 and 3. Based on this, the OC function of SSQSVSS-2($n_{T\sigma}$, $n_{N\sigma}$; k_σ), and SSQSVSS-3($n_{T\sigma}$, $n_{N\sigma}$; k_σ), are respectively given by

The OC function of SSQSVSS-2($n_{T\sigma}$, $n_{N\sigma}$; k_σ), is

$$P_a(p) = \frac{P_N \quad P_T^2 + P_T(1-P_N)(1+P_T)}{P_T^2 + (1-P_N)(1+P_T)} \qquad (1)$$

The OC function of SSQSVSS-3($n_{T\sigma}$, $n_{N\sigma}$; k_σ), is

$$P_a(p) = \frac{P_N \quad P_T^3 + P_T(1-P_N)(P_T^2+P_T+1)}{P_T^3 + (1-P_N)(P_T^2+P_T+1)} \qquad (2)$$

where P_T and P_N are the proportion of lots expected to be accepted using tightened (n_T, k) and normal (n_N, k) variable single sampling plans respectively. Under the assumption of normal approximation to the non-central t distribution (Abramowitz and Stegun, 1964), the values of P_N and P_T are given by

$$P_N = F(w_N) = pr[\frac{U - \overline{X}_N}{\sigma} \geq k]$$

$$P_T = F(w_T) = pr[\frac{U - \overline{X}_T}{\sigma} \geq k]$$

Where $W_T = \sqrt{n_{T\sigma}}(U\text{-}k_\sigma - \mu)/\sigma = (V-k)\sqrt{n_{T\sigma}}$

$W_N = \sqrt{n_{N\sigma}}(U\text{-}k_\sigma - \mu)/\sigma = (V-k)\sqrt{n_{N\sigma}}$

and $\nu = (U - \mu)/\sigma$

4. DESIGNING SSQSVSS-r($n_{T\sigma}$, $n_{N\sigma}$; k_σ), r=2 AND 3 SATISFYING $P_a(p_1) \geq 1-\alpha$ AND $P_a(p_2) \leq \beta$

In view of the properties of SSAQL and SSLQL are same as QSS-1, p_1 and p_2 are used as the reference quality levels defined as

$$P_a(p_1) \geq 1\text{-}\alpha$$

$$P_a(p_2) \leq \beta$$

Table 1 and 2 give the values of $n_{T\sigma}$, $n_{N\sigma}$, and k_σ the given values of p_1, p_2, α and β.

Selection of SSQSVSS-r($n_{T\sigma}$, $n_{N\sigma}$; k_σ), r=2 and 3 with known σ for given SSAQL and SSLQL

For SSQSVSS-2($n_{T\sigma}$, $n_{N\sigma}$; k_σ), to determine the values of $n_{T\sigma}$, $n_{N\sigma}$ and k_σ the given values of p_1, p_2, α and β should satisfy the following equations.

$$P_a(p_1) = \frac{P_{N_1} \quad P_{T_1}^2 + P_{T_1}(1-P_{N_1})(1+P_{T_1})}{P_{T_1}^2 + (1-P_{N_1})(1+P_{T_1})} \geq 1-\alpha \qquad (3)$$

$$P_a(p_2) = \frac{P_{N_2} \quad P_{T_2}^2 + P_{T_2}(1-P_{N_2})(1+P_{T_2})}{P_{T_2}^2 + (1-P_{N_2})(1+P_{T_2})} \leq \beta \qquad (4)$$

For SSQSVSS-3($n_{T\sigma}$, $n_{N\sigma}$; k_σ), to determine the values of $n_{T\sigma}$, $n_{N\sigma}$ and k_σ the given values of p_1, p_2, α and β should satisfy the following equations.

$$P_a(p_1) = \frac{P_{N_1} \quad P_{T_1}^3 + P_{T_1}(1-P_{N_1})(P_{T_1}^2 + P_{T_1} + 1)}{P_{T_1}^3 + (1-P_{N_1})(P_{T_1}^2 + P_{T_1} + 1)} \geq 1-\alpha \qquad (5)$$

$$P_a(p_2) = \frac{P_{N_2} \quad P_{T_2}^3 + P_{T_2}(1-P_{N_2})(P_{T_2}^2 + P_{T_2} + 1)}{P_{T_2}^3 + (1-P_{N_2})(P_{T_2}^2 + P_{T_2} + 1)} \leq \beta \qquad (6)$$

where

$$P_{T_1} = \Pr\left[\frac{\overline{X}_T - \overline{X}_{p_1}}{\sigma/\sqrt{n_{T_\sigma}}} \geq (z_{p_1} - k)\sqrt{n_{T_\sigma}}\right] \quad P_{N_1} = \Pr\left[\frac{\overline{X} - \overline{X}_{p_1}}{\sigma/\sqrt{n_{N_\sigma}}} \geq (z_{p_1} - k)\sqrt{n_{N_\sigma}}\right]$$

$$P_{T_2} = \Pr\left[\frac{\overline{X} - \overline{X}_{p_2}}{\sigma/\sqrt{n_{T_\sigma}}} \geq (z_{p_2} - k)\sqrt{n_{T_\sigma}}\right], \text{and} \quad P_{N_2} = \Pr\left[\frac{\overline{X} - \overline{X}_{p_2}}{\sigma/\sqrt{n_{N_\sigma}}} \geq (z_{p_2} - k)\sqrt{n_{N_\sigma}}\right]$$

5. DESIGNING SSQSVSS-r($n_{T\sigma}$, $n_{N\sigma}$; k_σ), r=2 AND 3 WITH KNOWN σ FOR GIVEN SSAQL AND SSLQL

Example

Table 1 can be used to determine SSQSVSS-2($n_{T\sigma}$, $n_{N\sigma}$; k_σ), for specified values of SSAQL and SSLQL. For example, if it is desired to have a SSQSVSS-2($n_{T\sigma}$, $n_{N\sigma}$; k_σ), for given SSAQL = 0.000002 and SSLQL = 0.000008, m=2, α= $3.4\text{x}10^{-6}$, β ≥ 2α. Table 1 gives n_N = 4837and k = 4.401. The sample size $n_{T\sigma}$ = m $n_{N\sigma}$ = (2) (4837) = 9673. Thus, for the given requirement, the SSQSVSS-2($n_{T\sigma}$, $n_{N\sigma}$; k_σ) is specified by the parameters n_T = 9673, n_N = 4837 and k = 4.401 as desired system parameters, which is associated with 4.6 sigma level.

Practical Application

For the test, lot-by-lot acceptance inspection of cell phone battery it is proposed to apply the system with n_T= 9673, n_N=4837, and k=4.401. The characteristic to be inspected is the cell phone battery with the upper limit (U) height of 58 mm with a known standard deviation (σ) of 0.008 mm.

Now, a random sample of size n_N=4837 is taken and the heights of each cell phone battery is recorded. Compute the sample mean ($\overline{X}_N$). If $\overline{X}_N$+k σ ≤ U ⇒ $\overline{X}_N$+ (4.401) (0.008) ≤ 58, accept the lot. Otherwise, switch to tightened inspection. Draw a sample of 9673 from the next lot and record the results. Compute the sample mean ($\overline{X}_T$) and a known standard deviation (σ) of 0.008. If $\overline{X}_T$+k σ ≤ U ⇒ $\overline{X}_T$+(4.401) (0. 008) ≤ 58, accept the lot. When 2 consecutive lots are accepted, then switch to normal inspection. Otherwise, continue with tightened inspection process.

Example

Table 2 can be used to determine SSQSVSS-2($n_{T\sigma}$, $n_{N\sigma}$; k_σ), for specified values of SSAQL and SSLQL. For example, if it is desired to have a SSQSVSS-3($n_{T\sigma}$, $n_{N\sigma}$; k_σ), for given SSAQL = 0. 000005 and SSLQL = 0.000006, m=2, α= $3.4\text{x}10^{-6}$, β ≥ 2α. Table 2 gives $n_N = 9426$, k = 3.562. The sample size $n_{T\sigma} = m\, n_{N\sigma}$ = (2) (9426) = 18853. Thus, for the given requirement, the SSQSVSS-3($n_{T\sigma}$, $n_{N\sigma}$; k_σ) is specified by the parameters n_T = 18853, n_N = 9426, k = 3.562 as desired system parameters, which is associated with 4.9 sigma level.

Practical Application

For the test, lot-by-lot acceptance inspection of small cracker it is proposed to apply the system with n_T= 18853, n_N=9426, and k=3.562. The characteristic to be inspected is the small cracker with the upper limit (U) length of 5.5 mm with a known standard deviation (σ) of 0.007 mm.

Now, take a random sample of size n_N=9426 and record the barrel length of each small cracker. Compute the sample mean ($\overline{X}_N$). If $\overline{X}_N + k\ \sigma \leq U \Rightarrow \overline{X}_N$ + (3.562) (0.007)≤ 5.5, accept the lot. Otherwise, switch to tightened inspection.

Draw a sample of 18853 from the next lot and record the results. Compute the sample mean ($\overline{X}_T$) and a known standard deviation (σ) of 0.00 If $\overline{X}_T + k\ \sigma \leq U \Rightarrow \overline{X}_T$ + (3.562) (0.007) ≤ 5.5, accept the lot. When 3 consecutive lots are accepted, then switch to normal inspection. Otherwise, continue with tightened inspection process.

Selection of SSQSVSS-r(n_{Ts}, n_{Ns}; k_s), where r=2 and 3, with unknown σ for given SSAQL and SSLQL

The steps involved in this procedure are as follows

Step 1: Draw a sample of size n_{Ns} from the lot, inspect and record the measurement of the quality characteristic for each unit of the sample. Compute the sample mean $\overline{X}_N$ and sample standard deviation S.

Step 2: If $\overline{X}_N + k_S S_N \leq U$ or $\overline{X}_N - k_S S_N \geq L$ accept the lot and repeat Step 1, otherwise go to step 3.

Step 3: Draw a sample of size n_s from the next lot inspect and record the measurement of the quality characteristic for each unit of the sample. Compute the sample mean $\overline{X}_T$ and sample standard deviation S.

Step 4: If $\overline{X}_T + k_S S_T \leq U$ or $\overline{X}_T - k_S S_T \geq L$ accept the lot. When r consecutive lots are accepted, switch to step 1, otherwise repeat Step 3.

where $\overline{X}_T, \overline{X}_N, S_N$ and S_T are the averages and the standard deviation of quality characteristic respectively from the normal and tightened sample. Under the assumptions for a Six Sigma Quick Switching System stated, the probability of acceptance $P_a(p)$ of a lot is SSQSVSS-2 and SSQSVSS-3 are given by (2) and (3) and P_T and P_N respectively are

$$P_T = \int_{-\infty}^{w_T} \frac{1}{\sqrt{2\pi}} e^{-z^2/2}\, dz \quad \text{and} \quad P_N = \int_{-\infty}^{w_N} \frac{1}{\sqrt{2\pi}} e^{-z^2/2}\, dz$$

With

$$w_N = \frac{U - k\, S_N - \mu}{S_N} \quad \frac{1}{\sqrt{\left(\frac{1}{n_{Ns}} + \frac{k^2}{2n_{Ns}}\right)}}$$

and

$$w_T = \frac{U - k\, S_T - \mu}{S_T} \quad \frac{1}{\sqrt{\left(\frac{1}{n_{Ts}} + \frac{k^2}{2n_{Ts}}\right)}}$$

For SSQSVSS-2(n_{Ts}, n_{Ns}; k_s), to determine the values of n_{TS}, n_{NS} and k_S the given values of p_1, p_2, α and β should satisfy the equations (3) and (4). For SSQSVSS-3(n_{Ts}, n_{Ns}; k_s), to determine the values of n_{TS}, n_{NS} and k_S the given values of p_1, p_2, α and β should satisfy the equations (5) and (6). The P_{T1}, P_{T2}, P_{N1}, and P_{N2} would change, these are given,

Where

$$P_{T_1} = \Pr\left[\frac{\overline{X} - \overline{X}_{p_1}}{S_T\sqrt{\frac{1}{n_{T_s}} + \frac{k^2}{2n_{T_s}}}} \geq \frac{(k - z_{p_1})}{\sqrt{\frac{1}{n_{T_s}} + \frac{k^2}{2n_{T_s}}}}\right], \quad P_{N_1} = \Pr\left[\frac{\overline{X} - \overline{X}_{p_1}}{S_N\sqrt{\frac{1}{n_{NS}} + \frac{k^2}{2n_{Ns}}}} \geq \frac{(k - z_{p_1})}{\sqrt{\frac{1}{n_{NS}} + \frac{k^2}{2n_{Ns}}}}\right],$$

$$P_{T_2} = \Pr\left[\frac{\overline{X} - \overline{X}_{p_2}}{S_T\sqrt{\frac{1}{n_{T_s}} + \frac{k^2}{2n_{T_s}}}} \geq \frac{(k - z_{p_2})}{\sqrt{\frac{1}{n_{T_s}} + \frac{k^2}{2n_{T_s}}}}\right], \quad P_{N_2} = \Pr\left[\frac{\overline{X} - \overline{X}_{p_2}}{S_N\sqrt{\frac{1}{n_{NS}} + \frac{k^2}{2n_{Ns}}}} \geq \frac{(k - z_{p_2})}{\sqrt{\frac{1}{n_{NS}} + \frac{k^2}{2n_{Ns}}}}\right]$$

where, $S_N = \sqrt{\frac{\sum (x_i - \overline{x})^2}{n_N - 1}}$ and $S_T = \sqrt{\frac{\sum (x_i - \overline{x})^2}{n_T - 1}}$

6. DESIGNING SSQSVSS-r(n_{Ts}, n_{Ns}; k_s), WHERE r=2 AND 3, WITH UNKNOWN σ FOR GIVEN SSAQL AND SSLQL

Example

Table 1 can be used to determine SSQSVSS-2(n_{TS}, n_{NS}; k_S) for specified values of SSAQL and SSLQL. For example, if it is desired to have a SSQSVSS-2(n_{TS}, n_{NS}; k_S) for given SSAQL = 0.00001 and SSLQL = 0.00008, m=2, α= 3.4×10^{-6}, β ≥ 2α. Table 1 gives n_N = 7828, and k = 3.92 The sample size $n_{Ts} = m\, n_{Ns}$ = (2) (7828) = 15656. Thus, for the given requirement, the SSQSVSS-2(n_{Ts}, n_{Ns}; k_s) is specified by the parameters n_{Ts} = 15656, n_{Ns} = 7828, k = 3.927 which is associated with 4.8 sigma level.

Practical Application

For the test, lot-by-lot acceptance inspection of Pen Drive it is proposed to apply the system with n_T= 15656, n_N=7828, and k=3.92 The characteristic to be inspected is the Pen Drive with the upper limit (U) height of 3 mm.

Now, take a random sample of size n_N=7828, record the height of each Pen Drive. Compute the sample mean ($\overline{X}_N$) and unknown standard deviation (S). If $\overline{X}_N + k\ S_N \leq U \Rightarrow \overline{X}_N$ + (3.927) $S_N \leq 3$, accept the lot. Otherwise, switch to tightened inspection.

Draw a sample of 15656 from the next lot and record the results. Compute the sample mean ($\overline{X}_T$) and unknown standard deviation (S). If $\overline{X}_T + k\ S_T \leq U \Rightarrow \overline{X}_T$ + (3.927) $S_T \leq 3$, accept the lot. When 2 consecutive lots are accepted, then switch to normal inspection. Otherwise, continue with tightened inspection process.

Example

Table 2 can be used to determine SSQSVSS-3(n_{TS}, n_{NS}; k_S) for specified values of SSAQL and SSLQL. For example, if it is desired to have a SSQSVSS-3(n_{TS}, n_{NS}; k_S) for given SSAQL = 0. 000002 and SSLQL = 0.00004, m=2, α= 3.4×10^{-6}, β ≥ 2α. Table 2 gives n_N = 9709, and k = 4.198. The sample size $n_{Ts} = m\, n_{Ns}$ = (2) (9709) = 1941 Thus, for the given requirement, the SSQSVSS-3(n_{Ts}, n_{Ns}; k_s) is specified by the parameters n_{Ts} = 19417, n_{Ns} = 9709, k = 4.198 which is associated with 4.8 sigma level.

Practical Application

For the test, lot-by-lot acceptance inspection of Remote Transmitter it is proposed to apply the system with n_T= 19417, n_N=9709, and k=4.198. The characteristic to be inspected is the Remote Transmitter with the upper limit (U) weight of 0.8 ounces.

Now, take a random sample of size n_N=9709, record the weight of each Remote Transmitter. Compute the sample mean ($\overline{X}$) and unknown standard deviation (S). If $\overline{X}_N + k\, S_N \le U \Rightarrow \overline{X}_N + (4.198)\, S_N \le 0.8$, accept the lot. Otherwise, switch to tightened inspection. Draw a sample of 19417 from the next lot and record the results. Compute the sample mean ($\overline{X}$) and unknown standard deviation (S). If $\overline{X}_T + k\, S_T \le U \Rightarrow \overline{X} + (4.198)\, S_T \le 0.8$, accept the lot. When 3 consecutive lots are accepted, then switch to normal inspection. Otherwise, continue with tightened inspection process.

7. CONSTRUCTION OF TABLE 1 AND 2

The OC function of SSMQSVSS-r($n_{T\sigma}$, $n_{N\sigma}$; k_σ), r=2 and 3, is given by equation (1) and (2). Using iterative procedure equations, (3), (4), (5) and (6) are solved forgiven values of p_1, p_2, m, α and β to get the values of $n_{N\sigma}$ and k_σ for specified pair of points, say (p_1, α) and (p_2, β) on the OC curve. Here, the values of m can be taken m > 1and find the desired parameters. In Table 1 and Table 2 provide, if m=2, the values of $n_{T\sigma}$, $n_{N\sigma}$ and k_σ are constructed. The sample size $n_{T\sigma}$ equals $mn_{N\sigma}$ and n_{Ts} equals mn_{Ns}, and hence only $n_{N\sigma}$ and n_{Ns} are tabulated.

The values of $n_{T\sigma}$, $n_{N\sigma}$, k_σ, n_{Ts}, n_{Ns} and k_s are obtained by using computer search routine through C++ programme. Table 1 and Table 2 provided the values of $n_{T\sigma}$, $n_{N\sigma}$, k_σ, n_{TS}, n_{NS} and k_s which satisfy the equations (3), (4), (5) and (6). The sigma (σ) value is calculated using the process sigma calculator for given n_T, n_N and k for known σ and unknown σ methods.

8. CONCLUSION

Conventionally, SSMQSVSS has wide potential applications in industries to ensure a higher standard of quality attainment and increased customer satisfaction. Here, an attempt made to apply the concept of Modified Quick Switching Variable Sampling System to propose a designated as Six Sigma Modified Quick Switching Variable Sampling System in which disposal of a lot on the basis of normal and tightened plan. The SSMQSVSS has reduces manpower, checking time and cost. The present development would be a valuable addition to the literature and a useful device to the quality practitioners. The concept of this article may be used for assistance to quality control engineers and plan designers in further plans development, which were useful and tailor made for industrial shop-floor situations.

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APPENDIX

Table 1: SSQSVSS-2(n_T, n_N; k, σ – level) with known and unknown σ indexed by SSAQL and SSLQL (α=3.4 x 10^{-6} and β≥2α). ($n_{T\sigma}=mn_{N\sigma}$, where m = 2)

SSAQL	SSLQL	$n_{T\sigma}$	$n_{N\sigma}$	k_σ	σ - level	n_{TS}	n_{NS}	k_S	σ - level
0.000001	0.000002	27280	13640	4.667	4.9	324371	162186	4.667	5.5
	0.000003	18018	9009	4.624	4.8	210643	105321	4.624	5.4
	0.000004	15490	7745	4.594	4.7	178947	89473	4.594	5.4
	0.000005	13166	6583	4.565	4.7	150351	75175	4.565	5.3
	0.000006	10894	5447	4.544	4.6	123363	61682	4.544	5.3
	0.000007	8730	4365	4.528	4.6	98225	49112	4.528	5.2
	0.000008	6596	3298	4.513	4.5	73767	36883	4.513	5.2
	0.000009	4510	2255	4.499	4.4	50153	25077	4.499	5.1
	0.00001	2448	1224	4.487	4.2	27091	13545	4.487	4.9
	0.00002	2362	1181	4.405	4.2	25278	12639	4.405	4.9
	0.00003	2082	1041	4.356	4.1	21835	10917	4.356	4.9
	0.00004	1830	915	4.319	4.1	18898	9449	4.319	4.8
	0.00005	1778	889	4.301	4.1	18223	9112	4.301	4.8
	0.00006	1546	773	4.279	4.0	15700	7850	4.279	4.8
	0.00007	1332	666	4.259	4.0	13413	6706	4.259	4.7
	0.00008	1116	558	4.242	3.9	11157	5578	4.242	4.7
	0.00009	884	442	4.225	3.8	8774	4387	4.225	4.6
0.000002	0.000003	22031	11015	4.512	4.8	246284	123142	4.512	5.5
	0.000004	19237	9618	4.482	4.8	212454	106227	4.482	5.4
	0.000005	16683	8341	4.453	4.8	182084	91042	4.453	5.4
	0.000006	14190	7095	4.432	4.7	153554	76777	4.432	5.4
	0.000007	11814	5907	4.416	4.7	127007	63503	4.416	5.3
	0.000008	9673	4837	4.401	4.6	103354	51677	4.401	5.3
	0.000009	7385	3693	4.387	4.5	78454	39227	4.387	5.2
	0.00001	5113	2556	4.375	4.4	54044	27022	4.375	5.1
	0.00002	2598	1299	4.293	4.2	26540	13270	4.293	4.9

Table 1 (continued…)

SSAQL	SSLQL	$n_{T\sigma}$	$n_{N\sigma}$	k_{σ}	σ - level	n_{TS}	n_{NS}	k_S	σ - level
0.000002	0.00003	2290	1145	4.244	4.2	22915	11458	4.244	4.9
	0.00004	2013	1007	4.207	4.1	19827	9913	4.207	4.8
	0.00005	1956	978	4.189	4.1	19116	9558	4.189	4.8
	0.00006	1701	850	4.167	4.1	16465	8233	4.167	4.8
	0.00007	1465	733	4.147	4.0	14064	7032	4.147	4.7
	0.00008	1228	614	4.130	4.0	11697	5849	4.130	4.7
	0.00009	972	486	4.113	3.9	9197	4599	4.113	4.6
0.000003	0.000004	21160	10580	4.400	4.8	225994	112997	4.400	5.5
	0.000005	18351	9175	4.370	4.8	193573	96787	4.370	5.4
	0.000006	15609	7805	4.341	4.8	162679	81340	4.341	5.4
	0.000007	12995	6498	4.320	4.7	134258	67129	4.320	5.3
	0.000008	10641	5320	4.304	4.7	109197	54599	4.304	5.3
	0.000009	8124	4062	4.289	4.6	82846	41423	4.289	5.2
	0.00001	5624	2812	4.275	4.5	57016	28508	4.275	5.1
	0.00002	2858	1429	4.263	4.2	28828	14414	4.263	4.9
	0.00003	2519	1260	4.181	4.2	24538	12269	4.181	4.9
	0.00004	2214	1107	4.132	4.2	21117	10559	4.132	4.9
	0.00005	2151	1076	4.095	4.2	20190	10095	4.095	4.8
	0.00006	1871	935	4.077	4.1	17418	8709	4.077	4.8
	0.00007	1612	806	4.055	4.1	14862	7431	4.055	4.8
	0.00008	1350	675	4.035	4.0	12343	6172	4.035	4.7
	0.00009	1070	535	4.018	3.9	9704	4852	4.018	4.6
0.000004	0.000005	20186	10093	3.643	4.9	154134	77067	3.643	5.4
	0.000006	17170	8585	4.288	4.8	175021	87510	4.288	5.4
	0.000007	14295	7147	4.258	4.7	143883	71941	4.258	5.3
	0.000008	11705	5852	4.229	4.7	116372	58186	4.229	5.3
	0.000009	8936	4468	4.208	4.6	88055	44028	4.208	5.2
	0.00001	6186	3093	4.192	4.5	60544	30272	4.192	5.1

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Table 1 (continued…)

SSAQL	SSLQL	$n_{T\sigma}$	$n_{N\sigma}$	k_{σ}	σ - level	n_{TS}	n_{NS}	k_S	σ - level
0.000004	0.00002	3144	1572	4.177	4.3	30569	15285	4.177	5.0
	0.00003	2771	1386	4.163	4.2	26784	13392	4.163	4.9
	0.00004	2436	1218	4.151	4.2	23421	11710	4.151	4.9
	0.00005	2367	1183	4.069	4.2	21957	10979	4.069	4.9
	0.00006	2058	1029	4.020	4.2	18685	9342	4.020	4.8
	0.00007	1773	886	3.983	4.1	15836	7918	3.983	4.8
	0.00008	1485	743	3.965	4.1	13162	6581	3.965	4.7
	0.00009	1177	588	3.943	4.0	10323	5162	3.943	4.7
0.000005	0.000006	18887	9443	3.571	4.9	139310	69655	3.571	5.4
	0.000007	15724	7862	3.548	4.8	114696	57348	3.548	5.3
	0.000008	12875	6438	3.531	4.8	93140	46570	3.531	5.3
	0.000009	9830	4915	4.176	4.6	95542	47771	4.176	5.3
	0.00001	6805	3403	4.146	4.5	65293	32646	4.146	5.2
	0.00002	3458	1729	4.117	4.3	32766	16383	4.117	5.0
	0.00003	3048	1524	4.096	4.3	28619	14309	4.096	4.9
	0.00004	2679	1340	4.080	4.2	24980	12490	4.080	4.9
	0.00005	2603	1302	4.065	4.2	24111	12055	4.065	4.9
0.00001	0.00002	3804	1902	4.034	4.4	34756	17378	4.034	5.0
	0.00003	3353	1677	4.005	4.3	30245	15122	4.005	5.0
	0.00004	2947	1474	3.984	4.3	26337	13168	3.984	4.9
	0.00005	2863	1432	3.968	4.3	25406	12703	3.968	4.9
	0.00006	2490	1245	3.953	4.2	21943	10972	3.953	4.9
	0.00007	2145	1073	3.939	4.2	18787	9394	3.939	4.8
	0.00008	1797	899	3.927	4.1	15656	7828	3.927	4.8
	0.00009	1424	712	3.845	4.0	11948	5974	3.845	4.7

Table 2: SSQSVSS-3(n_T, n_N; k, σ – level) with known and unknown σ indexed by SSAQL and SSLQL ($\alpha=3.4 \times 10^{-6}$ and $\beta \geq 2\alpha$). ($n_{T\sigma}=mn_{N\sigma}$, where m = 2)

SSAQL	SSLQL	$n_{T\sigma}$	$n_{N\sigma}$	k_σ	σ - level	n_{TS}	n_{NS}	k_S	σ - level
0.000001	0.000002	27104	13552	4.658	4.9	321141	160571	4.658	5.5
	0.000003	17842	8921	4.615	4.8	207843	103922	4.615	5.4
	0.000004	15314	7657	4.585	4.7	176281	88141	4.585	5.4
	0.000005	12990	6495	4.556	4.7	147808	73904	4.556	5.3
	0.000006	10718	5359	4.535	4.6	120932	60466	4.535	5.3
	0.000007	8554	4277	4.519	4.6	95896	47948	4.519	5.2
	0.000008	6420	3210	4.504	4.5	71538	35769	4.504	5.2
	0.000009	4334	2167	4.490	4.4	48021	24010	4.490	5.1
	0.00001	2272	1136	4.478	4.2	25052	12526	4.478	4.9
	0.00002	2186	1093	4.396	4.2	23308	11654	4.396	4.9
	0.00003	1906	953	4.347	4.1	19914	9957	4.347	4.8
	0.00004	1654	827	4.310	4.1	17016	8508	4.310	4.8
	0.00005	1602	801	4.292	4.1	16357	8179	4.292	4.8
	0.00006	1370	685	4.270	4.0	13860	6930	4.270	4.7
	0.00007	1156	578	4.250	3.9	11596	5798	4.250	4.7
	0.00008	940	470	4.233	3.9	9362	4681	4.233	4.6
	0.00009	708	354	4.216	3.8	7000	3500	4.216	4.5
0.000002	0.000003	22013	11006	4.503	4.8	245190	122595	4.503	5.5
	0.000004	19227	9613	4.473	4.8	211569	105785	4.473	5.4
	0.000005	16653	8326	4.444	4.8	181090	90545	4.444	5.4
	0.000006	14166	7083	4.423	4.7	152730	76365	4.423	5.4
	0.000007	11780	5890	4.407	4.7	126174	63087	4.407	5.3
	0.000008	9639	4820	4.392	4.6	102610	51305	4.392	5.3
	0.000009	5099	2549	4.378	4.4	53963	26981	4.378	5.1
	0.00001	5083	2541	4.366	4.4	53527	26763	4.366	5.1
	0.00002	2574	1287	4.284	4.2	26196	13098	4.284	4.9
	0.00003	2256	1128	4.235	4.2	22489	11244	4.235	4.9
	0.00004	1979	990	4.198	4.1	19417	9709	4.198	4.8
	0.00005	1687	843	4.180	4.1	16421	8211	4.180	4.8
	0.00006	1683	841	4.158	4.1	16228	8114	4.158	4.8
	0.00007	1455	728	4.138	4.0	13914	6957	4.138	4.7
	0.00008	1198	599	4.121	4.0	11367	5683	4.121	4.7
	0.00009	948	474	4.104	3.9	8935	4468	4.104	4.6

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Table 2 (continued…)

SSAQL	SSLQL	$n_{T\sigma}$	$n_{N\sigma}$	k_{σ}	σ - level	n_{TS}	n_{NS}	k_S	σ - level
0.000003	0.000004	18337	9168	4.391	4.8	195112	97556	4.391	5.4
	0.000005	18333	9166	4.361	4.8	192663	96331	4.361	5.4
	0.000006	15599	7800	4.332	4.8	161966	80983	4.332	5.4
	0.000007	12965	6483	4.311	4.7	133445	66722	4.311	5.3
	0.000008	10617	5308	4.295	4.7	108540	54270	4.295	5.3
	0.000009	8090	4045	4.280	4.6	82187	41094	4.280	5.2
	0.00001	5590	2795	4.266	4.5	56456	28228	4.266	5.1
	0.00002	2505	1253	4.254	4.2	25173	12587	4.254	4.9
	0.00003	2501	1251	4.172	4.2	24269	12134	4.172	4.9
	0.00004	2204	1102	4.123	4.2	20940	10470	4.123	4.9
	0.00005	2121	1061	4.086	4.2	19830	9915	4.086	4.8
	0.00006	1847	923	4.068	4.1	17127	8563	4.068	4.8
	0.00007	1578	789	4.046	4.1	14491	7246	4.046	4.8
	0.00008	1316	658	4.026	4.0	11985	5992	4.026	4.7
	0.00009	806	403	4.009	3.8	7286	3643	4.009	4.6
0.000004	0.000005	20156	10078	3.634	4.9	153245	76623	3.634	5.4
	0.000006	17146	8573	4.279	4.8	174115	87058	4.279	5.4
	0.000007	14261	7130	4.249	4.7	142994	71497	4.249	5.3
	0.000008	11671	5835	4.220	4.7	115590	57795	4.220	5.3
	0.000009	6172	3086	4.199	4.5	60588	30294	4.199	5.1
	0.00001	6168	3084	4.183	4.5	60135	30068	4.183	5.1
	0.00002	3134	1567	4.168	4.3	30355	15177	4.168	5.0
	0.00003	2741	1371	4.154	4.2	26391	13196	4.154	4.9
	0.00004	2412	1206	4.142	4.2	23100	11550	4.142	4.9
	0.00005	2333	1166	4.060	4.2	21557	10778	4.060	4.9
	0.00006	2024	1012	4.011	4.2	18303	9151	4.011	4.8
	0.00007	1471	736	3.974	4.0	13090	6545	3.974	4.7
	0.00008	1467	734	3.956	4.0	12950	6475	3.956	4.7
	0.00009	1147	573	3.934	4.0	10019	5010	3.934	4.7
0.000005	0.000006	18853	9426	3.562	4.9	138454	69227	3.562	5.4

Table 2 (continued…)

SSAQL	SSLQL	$n_{T\sigma}$	$n_{N\sigma}$	k_σ	σ - level	n_{TS}	n_{NS}	k_S	σ - level
0.000005	0.000006	18853	9426	3.562	4.9	138454	69227	3.562	5.4
	0.000007	12861	6431	3.539	4.8	93402	46701	3.539	5.3
	0.000008	12857	6429	3.522	4.8	92601	46301	3.522	5.3
	0.000009	9820	4910	4.167	4.6	95076	47538	4.167	5.3
	0.00001	6775	3388	4.137	4.5	64753	32376	4.137	5.2
	0.00002	3434	1717	4.108	4.3	32411	16206	4.108	5.0
	0.00003	3014	1507	4.087	4.3	28189	14094	4.087	4.9
	0.00004	2645	1323	4.071	4.2	24566	12283	4.071	4.9
	0.00005	2249	1125	4.056	4.2	20753	10376	4.056	4.9
	0.00006	2245	1123	4.042	4.2	20589	10294	4.042	4.9
	0.00007	1940	970	4.030	4.1	17695	8848	4.030	4.8
	0.00008	1604	802	3.948	4.1	14104	7052	3.948	4.8
	0.00009	1270	635	3.899	4.0	10926	5463	3.899	4.7
0.00001	0.00002	3339	1670	4.025	4.3	30387	15193	4.025	5.0
	0.00003	3335	1668	3.996	4.3	29962	14981	3.996	5.0
	0.00004	2937	1469	3.975	4.3	26142	13071	3.975	4.9
	0.00005	2833	1417	3.959	4.3	25039	12520	3.959	4.9
	0.00006	2466	1233	3.944	4.2	21644	10822	3.944	4.9
	0.00007	2111	1056	3.930	4.2	18415	9207	3.930	4.8
	0.00008	1763	882	3.918	4.1	15298	7649	3.918	4.8
	0.00009	1078	539	3.836	4.0	9009	4504	3.836	4.6
0.00005	0.00006	2709	1354	3.832	4.3	22597	11299	3.832	4.9
	0.00007	2336	1168	3.818	4.2	19360	9680	3.818	4.9
	0.00008	1943	972	3.806	4.2	16016	8008	3.806	4.8
	0.00009	1532	766	3.724	4.1	12155	6078	3.724	4.7
	0.0001	776	388	3.675	3.8	6017	3009	3.675	4.5
	0.0002	772	386	3.638	3.8	5882	2941	3.638	4.5

