UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 1990/91

Mac/April 1991

MSG362 - Statistik Gunaan I

Masa: [3 jam]

Jawab mana-mana LIMA soalan. Semua soalan mesti dijawab dalam Bahasa Malaysia. Satu set lampiran dikepilkan.

1. (a) Apakah tujuh alat utama kawalan kualiti itu? Apakah fungsi-fungsinya?
Huraikan, secara ringkas, bagaimana 3 daripada alat itu digunakan di dalam bidang kawalan kualiti.

(50/100)

(b) Sebuah kilang mempunyai 5 buah mesin untuk menghasilkan sejenis barangan. Pada suatu pemeriksaan, sampel yang tak bersandar daripada setiap mesin diambil dan yang berikut adalah datanya:

Sampel	Ukuran					
Mesin I	6.35	6.45	7.05	6.95		
Mesin II	7.75	7.85	6.90	6.75	6.95	6.80
Mesin III	6.15	6.30	6.10	6.25		
Mesin IV	6.80	6.70	6.55	6.70		
Mesin V	6.20	6.35	6.05	6.10	6.15	

Berdasarkan maklumat sampel-sampel ini, bolehkah kita menyatakan min kelima-lima mesin itu adalah sama? Gunakan $\alpha = 0.05$.

(50/100)

2. (a) Huraikan setiap yang berikut:

(i) Lengkung cirian pengoperasian
(ii) AQL, paras kualiti yang boleh diterima
(iii) LQL, paras kualiti penghad
(iv) AOQ, kualiti keluar secara purata
(v) AOQL, had kualiti keluar secara purata

(30/100)

(b) Tentukan satu rancangan pensampelan tunggal supaya:

(i) risiko pengguna 0.10 untuk menerima barangan yang peratus kecacatannya ialah 3.0%; dan

(ii) risiko pengeluar 0.05 untuk menolak barangan yang peratus kecacatannya 0.7%.

Pilih rancangan pensampelan penerimaan yang saiznya paling kecil.

(30/100)

(c) Sampel sebanyak 200 cerap diambil daripada suatu populasi dan didapati ukuran-ukurannya:

Kelas	Frekuensi
6.315-6.345	2
6.345-6.375	10
6.375-6.405	28
6.405-6.435	35
6.435-6.465	56
6.465-6.495	36
6.495-6.525	23
6.525-6.555	9
6.555-6.585	1

Gunakan ujian Kolmogorov-Smikhov untuk menguji hipotesis bahawa populasinya ialah normal dengan min $\mu = 6.45$ dan $\sigma = 0.27$. Gunakan $\alpha = 0.05$.

(40/100)

3.(a) Carta kawalan $\bar{X}$ telah dibina dan digunakan untuk subsampel yang saiznya 5. Yang berikut ialah maklumatnya:

Carta $\bar{X}$

Garis tengah = 5.25
$UCL_{\bar{X}} = 7.027$
$LCL_{\bar{X}} = 3.473$

(i) Jika satu permintaan yang spesifikasinya ialah 5.25 ± 0.55, apakah keupayaan proses penghasilan itu?

(ii) Jika min proses dipindah ke 5.30, apakah kebarangkalian suatu butir yang dipilih secara rawak akan memenuhi spesifikasi di atas? Andaikan varians bagi proses penghasilan tidak berubah.

(30/100)

(b) Carta kawalan $\bar{X}$-R telah digunakan untuk suatu proses penghasilan dan didapati proses itu sudah stabil. Kini pihak pengurus ingin menggunakan carta kawalan median julat untuk menjaga proses penghasilan tersebut. Daripada 25 subsampel setiap saiz 3, datanya seperti berikut:

Subsampel	X_1	X_2	X_3	Subsampel	X_1	X_2	X_3
1	1.30	1.24	1.37	14	1.14	1.04	1.03
2	1.24	1.12	1.24	15	1.16	1.21	1.30
3	1.10	1.15	1.27	16	1.32	1.06	1.23
4	1.08	1.05	1.20	17	1.22	1.12	1.13
5	1.02	1.26	1.16	18	1.05	1.08	1.07
6	1.18	1.26	1.04	19	1.23	1.22	1.29
7	1.24	1.16	1.06	20	1.11	1.21	1.20
8	1.42	1.24	1.18	21	1.23	1.23	1.29
9	1.02	1.22	1.06	22	1.04	1.24	1.32
10	1.33	1.21	1.20	23	1.17	1.06	1.23
11	1.36	1.38	1.31	24	1.22	1.24	1.34
12	1.14	1.14	1.14	25	1.28	1.27	1.15
13	1.24	1.31	1.07				

(i) Binakan carta kawalan median julat.

(ii) Jika spesifikasi daripada pengguna ialah 1.10 ± 0.05, apakah indeks keupayaan proses ini?

(30/100)

(c) Suatu proses penghasilan telah diketahui stabil dan dijalan lincin. Kini pihak pengurus ingin menggunakan carta-D (carta demerit per unit) untuk menjaga proses penghasilannya. Daripada 26 subsampel setiap saiz 200 maklumat yang berikut diperolehi:

Jenis kecacatan	Genting	Major	Minor
Bilangan kecacatan	10	47	475

(i) Dapatkan carta-D jika pemberat bagi 3 jenis kecacatan ini di dalam kadaran 25 : 5 : 1.

(ii) Pada suatu sampel yang saiznya 200 didapati

Jenis kecacatan	Genting	Major	Minor
Bilangan kecacatan	2	12	45

Dapatkan demerit per unit untuk sampel ini. Merujuk kepada carta-D, adakah prosesnya di dalam kawalan?

(40/100)

4. (a) Sebuah kilang mengeluarkan semi-conductor dengan bilangan yang besar. Pada 25 subsampel awal, setiap bersaiz 300, datanya adalah seperti yang berikut:

Subsampel	Bilangan butir yang cacat	Subsampel	Bilangan butir yang cacat
1	10	14	12
2	12	15	10
3	23	16	8
4	14	17	6
5	10	18	7
6	8	19	9
7	5	20	8
8	14	21	7
9	8	22	21
10	7	23	12
11	4	24	10
12	0	25	8
13	6		

(i) Dapatkan carta-p percubaan.

(ii) Periksakan semula. Jika terdapat titik di luar had kawalan percubaan, anggapkan sebabnya terumpukkan dan tidak diambil kira.

(30/100)

(b) Pihak pengurusan ingin menggunakan carta $\bar{X}$-S untuk proses penghasilannya. Data awal 25 subkumpulan setiap bersaiz 6 telah diambil, dan yang berikut ialah ringkasannya:

Subkumpulan	$\bar{X}$	S	Subkumpulan	$\bar{X}$	S
1	6.38	0.07	14	6.36	0.10
2	6.38	0.08	15	6.45	0.08
3	6.40	0.10	16	6.41	0.06
4	6.42	0.06	17	6.34	0.10
5	6.40	0.30	18	6.51	0.12
6	6.36	0.12	19	6.38	0.06
7	6.65	0.14	20	6.46	0.08
8	6.40	0.12	21	6.40	0.12
9	6.40	0.14	22	6.42	0.06
10	6.38	0.08	23	6.38	0.07
11	6.35	0.10	24	6.38	0.08
12	6.43	0.34	25	6.40	0.06
13	6.42	0.12			

Binakan carta kawalan $\bar{X}$-S dengan mengikut langkah:

(i) Dapatkan carta percubaan.

(ii) Periksa semula had-had kawalan dengan anggapan data di luar had-had kawalan percubaan itu disebabkan sebab-sebab terumpukkan dan tidak digunakan di dalam pengiraan had-had kawalan akhirnya.

(30/100)

(c) Suatu populasi bertaburan normal dengan minnya μ dan varians $\sigma^2 = 4$. Di dalam ujian berjujukan nisbah (ujian nisbah kebolehjadian maksimum) tentang

$H_0 = \mu = 4$.

$H_A = \mu = 6$. $\alpha = 0.05$, $\beta = 0.10$

(i) Tunjukkan rantau penerimaan, rantau penolakan, dan rantau berterusan pensampelan di dalam satah mY. m ialah bilangan cerapan yang digunakan, X_1, X_2, ..., X_m, ... cerapan dan $Y = \sum_{i=1}^{m} X_i$.

(ii) Pada suatu sampel, cerapannya ialah

5.6, 5.8, 4.8, 6.2, 6.5, 4.4
6.2, 7.2, 6.2, 7.2, 5.8, 6.4

Apakah keputusan? Tolak H_0? Terima H_0? Atau kena terus mengambil cerapan?

(40/100)

5. (a) Untuk saiz lot N = 3000, AQL = 10%, gunakan MIL-STD-105D paras inspeksi II, tentukan rancangan pensampelan penerimaan tunggal untuk inspeksi normal, ketat dan longgar. Terangkan nombor-nombor yang anda berikan.

(30/100)

(b) Jika saiz lot N = 30,000, AQL = 15%, gunakan MIL-STD-105D pada paras inspeksi II untuk menentukan rancangan pensampelan penerimaan berganda dua untuk inspeksi normal, ketat dan longgar. Terangkan nombor-nombor yang anda berikan itu.

(30/100)

(c) Yang berikut ialah rancangan pensampelan penerimaan berganda tiga yang dipersetujui di antara pengeluar dan pengguna:

Saiz lot N = 2000

$n_1 = 50$, $c_1 = 2$, $r_1 = 4$

$n_2 = 50$, $c_2 = 4$, $r_2 = 6$

$n_3 = 50$, $c_2 = 6$, $r_3 = 7$

Katakan X_1, X_2, X_3 masing-masing ialah bilangan butir yang cacat di dalam sampel yang pertama, sampel kedua dan sampel ketiga.

(i) Dapatkan lengkung-lengkung cirian pengoperasian selepas sampel pertama, dan sampel kedua.

(ii) Dapatkan persamaan untuk lengkung cirian pengoperasian pada sampel yang ketiga.

(40/100)

6. (a) Huraikan perhubungan-perhubungan di antara spesifikasi-spesifikasi pengguna dan kebolehan bagi suatu proses penghasilan.

(30/100)

(b) X ialah pembolehubah rawak masahayat suatu alat untuk sebuah kapal angkasa lepas, dan kadar bahayanya ialah h(x),

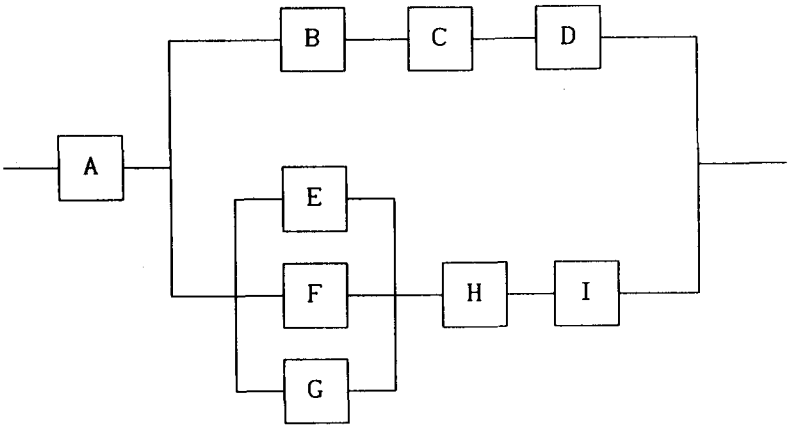
$$h(x) = \alpha\lambda x^{\alpha-1}, \qquad \alpha > 0,\ \lambda > 0,\ x > 0$$

(i) Tentukan fungsi ketumpatan kebarangkalian bagi pembolehubah X ini.

(ii) Apabila $\alpha = 1$, cari $R(\mu)$, μ ialah min bagi X.

(40/100)

(c) Di dalam sistem campuran yang berikut:



Setiap komponen tak bersandar dan mempunyai masahayat yang taburannya mengikut fungsi ketumpatan kebarangkalian suatu pembolehubah rawak X:

$$f(x) = \frac{1}{100\sqrt{2\pi}} \exp\left\{-\frac{1}{2}\left[\frac{x - 500}{100}\right]^2\right\} \quad -\infty < x < \infty \ .$$

Cari kebolehpercayaan sistem campuran ini pada masa t = 750.

(30/100)

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Table 6-4 ***np'*** **Values for Corresponding *c* Values and Typical Producer's and Consumer's Risks**

c	$P_a = 0.95$ ($\alpha = 0.05$)	$P_a = 0.10$ ($\beta = 0.10$)	*Ratio of* $p'_{0.10}/p'_{0.95}$
0	0.051	2.303	44.890
1	0.355	3.890	10.946
2	0.818	5.322	6.509
3	1.366	6.681	4.890
4	1.970	7.994	4.057
5	2.613	9.275	3.549
6	3.286	10.532	3.206
7	3.981	11.771	2.957
8	4.695	12.995	2.768
9	5.426	14.206	2.618
10	6.169	15.407	2.497
11	6.924	16.598	2.397
12	7.690	17.782	2.312
13	8.464	18.958	2.240
14	9.246	20.128	2.177
15	10.035	21.292	2.122

Source: Extracted by permission from J. M. Cameron, "Tables for Constructing and for Computing the Operating Characteristics of Single-Sampling Plans," *Industrial Quality Control*, 9, No. 1 (July 1952), p. 39.

Table 6-5 Sample-Size Code Letters (Table I of MIL-STD 105D)

Lot or batch size	Special inspection levels				General inspection levels		
	S-1	S-2	S-3	S-4	I	II	III
2 to 8	A	A	A	A	A	A	B
9 to 15	A	A	A	A	A	B	C
16 to 25	A	A	B	B	B	C	D
26 to 50	A	B	B	C	C	D	E
51 to 90	B	B	C	C	C	E	F
91 to 150	B	B	C	D	D	F	G
151 to 280	B	C	D	E	E	G	H
281 to 500	B	C	D	E	F	H	J
501 to 1200	C	C	E	F	G	J	K
1201 to 3200	C	D	E	G	H	K	L
3201 to 10000	C	D	F	G	J	L	M
10001 to 35000	C	D	F	H	K	M	N
35001 to 150000	D	E	G	J	L	N	P
150001 to 500000	D	E	G	J	M	P	Q
500001 and over	D	E	H	K	N	Q	R

Note.

Small sample inspection levels of MIL-STD-105C	*Convert to these special inspection levels*
L-1 and L-2	S-1
L-3 and L-4	S-2
L-5 and L-6	S-3
L-7 and L-8	S-4

Table 6-2 Single Sampling Plans for Normal Inspection (Table II-A of MIL-STD 105D)[a]

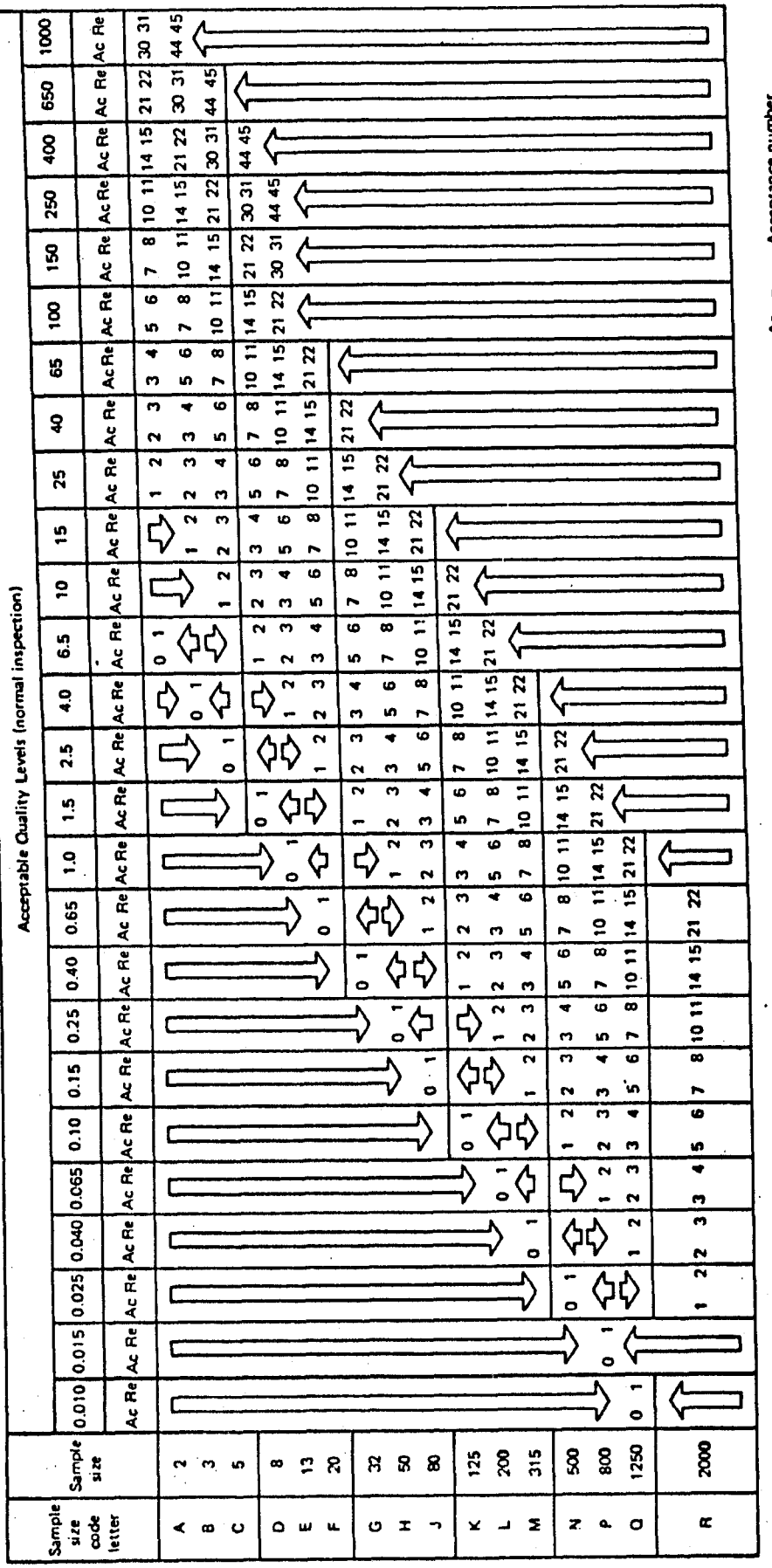
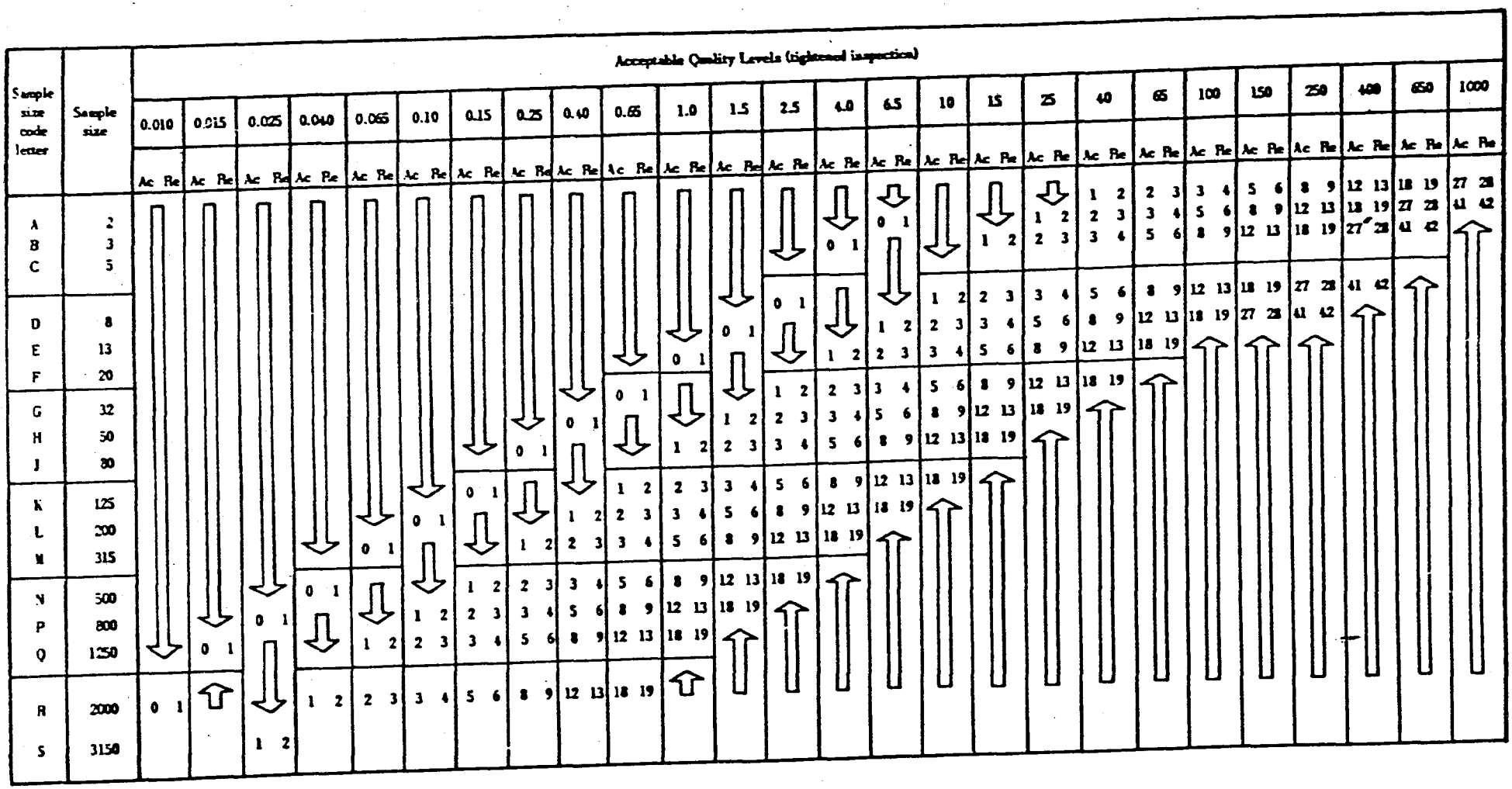


Table 6-7 Single Sampling Plans for Tightened Inspection (Table II-B of MIL-STD 105D)[a]



Sample size code letter	Sample size	Acceptable Quality Levels (tightened inspection)																																					
		0.010		0.015		0.025		0.040		0.065		0.10		0.15		0.25		0.40		0.65		1.0		1.5		2.5		4.0		6.5		10		15		25		40		65		100		150		250		400		650		1000	
		Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re
A	2																											⇩								1	2	2	3	3	4	5	6	8	9	12	13	18	19	27	28
B	3																											0	1							2	3	3	4	5	6	8	9	12	13	18	19	27	28	41	42
C	5																																			3	4	5	6	8	9	12	13	18	19	27	28	41	42		
D	8																																	⇩		1	2	2	3	3	4	5	6	8	9	12	13	18	19	27	28	41	42		
E	13																																	1	2	2	3	3	4	5	6	8	9	12	13	18	19	27	28	41	42		
F	20																																	1	2	2	3	3	4	5	6	8	9	12	13	18	19	27	28	41	42		
G	32																																	1	2	2	3	3	4	5	6	8	9	12	13	18	19	27	28	41	42		
H	50																																	1	2	2	3	3	4	5	6	8	9	12	13	18	19	27	28	41	42		
J	80																																	1	2	2	3	3	4	5	6	8	9	12	13	18	19	27	28	41	42		
K	125																																	1	2	2	3	3	4	5	6	8	9	12	13	18	19	27	28	41	42		
L	200																																	1	2	2	3	3	4	5	6	8	9	12	13	18	19	27	28	41	42		
M	315																																	1	2	2	3	3	4	5	6	8	9	12	13	18	19	27	28	41	42		
N	500																																	1	2	2	3	3	4	5	6	8	9	12	13	18	19	27	28	41	42		
P	800																																	1	2	2	3	3	4	5	6	8	9	12	13	18	19	27	28	41	42		
Q	1250																																	1	2	2	3	3	4	5	6	8	9	12	13	18	19	27	28	41	42		
R	2000																																	1	2	2	3	3	4	5	6	8	9	12	13	18	19	27	28	41	42		
S	3150																																	1	2	2	3	3	4	5	6	8	9	12	13	18	19	27	28	41	42		

⇩ = Use first sampling plan below arrow. If sample size equals or exceeds lot or batch size, do 100 percent inspection.
⇧ = Use first sampling plan above arrow.
Ac = Acceptance number.
Re = Rejection number.

Table 6-8 Single Sampling Plans for Reduced Inspection (Table II-C of MIL-STD 105D)[a]

Sample size code letter	Sample size	Acceptable Quality Levels (reduced inspection)†																																			
		0.010		0.015		0.025		0.040		0.065		0.10		0.15		0.25		0.40		0.65		1.0		1.5		2.5		4.0		6.5		10		15		25		40		65		100		150		250		400		650		1000	
		Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re
A	2	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 1		⇩		0 2		1 3		2 4		3 5		5 6		7 8		10 11		14 15		21 22		30 31	
B	2	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 1		⇧		⇩		0 2		1 3		2 4		3 5		5 6		7 8		10 11		14 15		21 22		30 31	
C	2	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇧		⇩		0 2		1 3		1 4		2 5		3 6		5 8		7 10		10 13		14 17		21 24		⇧	
D	3	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 1		⇩		⇩		0 2		1 3		1 4		2 5		3 6		5 8		7 10		10 13		14 17		21 24		⇧	
E	5	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 1		⇧		⇩		⇩		0 2		1 3		1 4		2 5		3 6		5 8		7 10		10 13		14 17		21 24		⇧	
F	8	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		1 3		1 4		2 5		3 6		5 8		7 10		10 13		14 17		21 24		⇧	
G	13	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 1		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		1 3		1 4		2 5		3 6		5 8		7 10		10 13		⇧		⇧	
H	20	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇧		⇧		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		1 3		1 4		2 5		3 6		5 8		7 10		10 13		⇧	
J	32	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		1 3		1 4		2 5		3 6		5 8		7 10		10 13	
K	50	⇩		⇩		⇩		⇩		⇩		0 1		⇧		⇩		0 2		1 3		1 4		2 5		3 6		5 8		7 10		10 13		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧	
L	80	⇩		⇩		⇩		⇩		0 1		⇧		⇧		0 2		1 3		1 4		2 5		3 6		5 8		7 10		10 13		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧	
M	125	⇩		⇩		⇩		0 1		⇧		⇧		0 2		1 3		1 4		2 5		3 6		5 8		7 10		10 13		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧	
N	200	⇩		⇩		0 1		⇧		⇩		0 2		1 3		1 4		2 5		3 6		5 8		7 10		10 13		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧	
P	315	⇩		0 1		⇧		⇧		0 2		1 3		1 4		2 5		3 6		5 8		7 10		10 13		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧	
Q	500	0 1		⇧		0 2		1 3		1 4		2 5		3 6		5 8		7 10		10 13		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧	
R	800	⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧		⇧	

⇩ = Use first sampling plan below arrow. If sample size equals or exceeds lot or batch size, do 100 percent inspection.

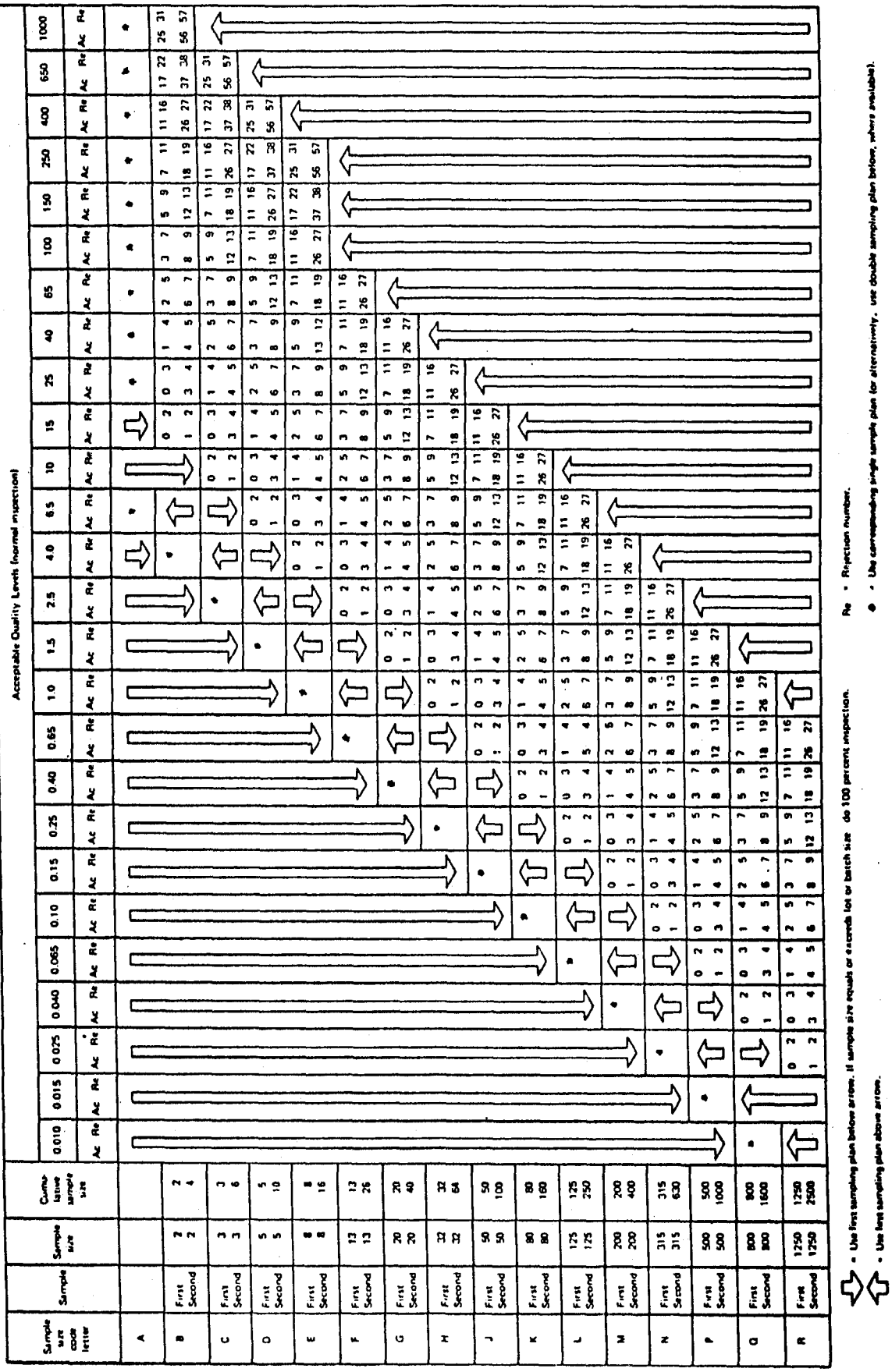
⇧ = Use first sampling plan above arrow.

Ac = Acceptance number.

Re = Rejection number.

† = If the acceptance number has been exceeded, but the rejection number has not been reached, accept the lot, but reinstate normal inspection (see 10.1.4).

Table 6-9 Double Sampling Plans for Normal Inspection (Table III-A of MIL-STD 105D)[a]



↓ = Use first sampling plan below arrow. If sample size equals or exceeds lot or batch size do 100 percent inspection.

↑ = Use first sampling plan above arrow.

Ac = Acceptance number.

Re = Rejection number.

* = Use corresponding single sample plan (or alternatively, use double sampling plan below, where available).

Table 6-10 Double Sampling Plans for Tightened Inspection (Table III-B of MIL-STD 105D)[a]

Sample size code letter	Sample	Sample size	Cumulative sample size	Acceptable Quality Levels (tightened inspection)																																					
				0.010		0.015		0.025		0.040		0.065		0.10		0.15		0.25		0.40		0.65		1.0		1.5		2.5		4.0		6.5		10		15		25		40		65		100		150		250		400		650		1000	
				Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re
A				⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩	
B	First	2	2	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24	
	Second	2	4																																	1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53	
C	First	3	3	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24	
	Second	3	6																															1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53	
D	First	5	5	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24	
	Second	5	10																													1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53	
E	First	8	8	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24			
	Second	8	16																											1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53			
F	First	13	13	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24			
	Second	13	26																									1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53			
G	First	20	20	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24			
	Second	20	40																							1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53			
H	First	32	32	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24					
	Second	32	64																					1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53					
J	First	50	50	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24							
	Second	50	100																			1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53							
K	First	80	80	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24									
	Second	80	160																	1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53									
L	First	125	125	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24									
	Second	125	250																	1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53									
M	First	200	200	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24									
	Second	200	400																	1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53									
N	First	315	315	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24									
	Second	315	630																	1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53									
P	First	500	500	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24									
	Second	500	1000																	1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53									
Q	First	800	800	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24									
	Second	800	1600																	1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53									
R	First	1250	1250	⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		⇩		0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24									
	Second	1250	2500																	1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53									
S	First	2000	2000					0 2														0 2		0 3		1 4		2 5		3 7		6 10		9 14		15 20		23 24									
	Second	2000	4000					1 2														1 2		3 4		4 5		6 7		11 12		15 16		23 24		34 35		52 53									

⇩ = Use first sampling plan below arrow. If sample size equals or exceeds lot or batch size, do 100 percent inspection.

⇧ = Use first sampling plan above arrow.

Ac = Acceptance number.

Re = Rejection number.

* = Use corresponding single sampling plan (or alternatively, use double sampling plan below, where available).

Table 6-11 Double Sampling Plans for Reduced Inspection (Table III-C of MIL-STD 105D)[a]

Acceptable Quality Levels (reduced inspection) †

Sample size code letter	Sample	Sample size	Cumulative sample size	0.010 Ac Re	0.015 Ac Re	0.025 Ac Re	0.040 Ac Re	0.065 Ac Re	0.10 Ac Re	0.15 Ac Re	0.25 Ac Re	0.40 Ac Re	0.65 Ac Re	1.0 Ac Re	1.5 Ac Re	2.5 Ac Re	4.0 Ac Re	6.5 Ac Re	10 Ac Re	15 Ac Re	25 Ac Re	40 Ac Re	65 Ac Re	100 Ac Re	150 Ac Re	250 Ac Re	400 Ac Re	650 Ac Re	1000 Ac Re
A B C				↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓ *	↓ * ↑	* ↑↓	↓ *	↓ * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * ↑
D	First Second	2 2	2 4	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	*	↑	↓	0 2 0 2	0 3 0 4	0 4 1 5	0 4 3 6	1 5 4 7	2 7 6 9	3 8 8 12	5 10 12 16	7 12 18 22	11 17 26 30	↑	↑
E	First Second	3 3	3 6	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	*	↑	↓	0 2 0 2	0 3 0 4	0 4 1 5	0 4 3 6	1 5 4 7	2 7 6 9	3 8 8 12	5 10 12 16	7 12 18 22	11 17 26 30	↑	↑	↑
F	First Second	5 5	5 10	↓	↓	↓	↓	↓	↓	↓	↓	↓	*	↑	↓	0 2 0 2	0 3 0 4	0 4 1 5	0 4 3 6	1 5 4 7	2 7 6 9	3 8 8 12	5 10 12 16	↑	↑	↑	↑	↑	↑
G	First Second	8 8	8	↓	↓	↓	↓	↓	↓	↓	↓	*	↑	↓	0 2 0 2	0 3 0 4	0 4 1 5	0 4 3 6	1 5 4 7	2 7 6 9	3 8 8 12	5 10 12 16	↑	↑	↑	↑	↑	↑	↑
H	First Second	13 13	13 26	↓	↓	↓	↓	↓	↓	↓	*	↑	↓	0 2 0 2	0 3 0 4	0 4 1 5	0 4 3 6	1 5 4 7	2 7 6 9	3 8 8 12	5 10 12 16	↑	↑	↑	↑	↑	↑	↑	↑
J	First Second	20 20	20 40	↓	↓	↓	↓	↓	↓	*	↑	↓	0 2 0 2	0 3 0 4	0 4 1 5	0 4 3 6	1 5 4 7	2 7 6 9	3 8 8 12	5 10 12 16	↑	↑	↑	↑	↑	↑	↑	↑	↑
K	First Second	32 32	32 64	↓	↓	↓	↓	↓	*	↑	↓	0 2 0 2	0 3 0 4	0 4 1 5	0 4 3 6	1 5 4 7	2 7 6 9	3 8 8 12	5 10 12 16	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
L	First Second	50 50	50 100	↓	↓	↓	↓	*	↑	↓	0 2 0 2	0 3 0 4	0 4 1 5	0 4 3 6	1 5 4 7	2 7 6 9	3 8 8 12	5 10 12 16	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
M	First Second	80 80	80 160	↓	↓	↓	*	↑	↓	0 2 0 2	0 3 0 4	0 4 1 5	0 4 3 6	1 5 4 7	2 7 6 9	3 8 8 12	5 10 12 16	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
N	First Second	125 125	125 250	↓	↓	*	↑	↓	0 2 0 2	0 3 0 4	0 4 1 5	0 4 3 6	1 5 4 7	2 7 6 9	3 8 8 12	5 10 12 16	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
P	First Second	200 200	200 400	↓	*	↑	↓	0 2 0 2	0 3 0 4	0 4 1 5	0 4 3 6	1 5 4 7	2 7 6 9	3 8 8 12	5 10 12 16	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
Q	First Second	315 315	315 630	*	↑	↓	0 2 0 2	0 3 0 4	0 4 1 5	0 4 3 6	1 5 4 7	2 7 6 9	3 8 8 12	5 10 12 16	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
R	First Second	500 500	500 1000	↑	↑	0 2 0 2	0 3 0 4	0 4 1 5	0 4 3 6	1 5 4 7	2 7 6 9	3 8 8 12	5 10 12 16	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑

↓ = Use first sampling plan below arrow. If sample size equals or exceeds lot or batch size, do 100 percent inspection.

↑ = Use first sampling plan above arrow.

Ac = Acceptance number.

Re = Rejection number.

* = Use corresponding single sampling plan (or alternatively, use double sampling plan below, when available).

† = If, after the second sample, the acceptance number has been exceeded, but the rejection number has not been reached, accept the lot, but reinstate normal inspection (see 10.14).

TABLE B Factors for Computing Central Lines and 3σ Control Limits for $\bar{X}$, s, and R, Charts

Observations in Sample, n	Chart for Averages: Factors for Control Limits			Chart for Standard Deviations: Factors for Central Line		Chart for Standard Deviations: Factors for Control Limits				Chart for Ranges: Factors for Central Line		Chart for Ranges: Factors for Control Limits				
	A	A_2	A_3	c_4	$1/c_4$	B_3	B_4	B_5	B_6	d_2	$1/d_2$	d_1	D_1	D_2	D_3	D_4
2	2.121	1.880	2.659	0.7979	1.2533	0	3.267	0	2.606	1.128	0.8865	0.853	0	3.686	0	3.267
3	1.732	1.023	1.954	0.8862	1.1284	0	2.568	0	2.276	1.693	0.5907	0.888	0	4.358	0	2.574
4	1.500	0.729	1.628	0.9213	1.0854	0	2.266	0	2.088	2.059	0.4857	0.880	0	4.698	0	2.282
5	1.342	0.577	1.427	0.9400	1.0638	0	2.089	0	1.964	2.326	0.4299	0.864	0	4.918	0	2.114
6	1.225	0.483	1.287	0.9515	1.0510	0.030	1.970	0.029	1.874	2.534	0.3946	0.848	0	5.078	0	2.004
7	1.134	0.419	1.182	0.9594	1.0423	0.118	1.882	0.113	1.806	2.704	0.3698	0.833	0.204	5.204	0.076	1.924
8	1.061	0.373	1.099	0.9650	1.0363	0.185	1.815	0.179	1.751	2.847	0.3512	0.820	0.388	5.306	0.136	1.864
9	1.000	0.337	1.032	0.9693	1.0317	0.239	1.761	0.232	1.707	2.970	0.3367	0.808	0.547	5.393	0.184	1.816
10	0.949	0.308	0.975	0.9727	1.0281	0.284	1.716	0.276	1.669	3.078	0.3249	0.797	0.687	5.469	0.223	1.777
11	0.905	0.285	0.927	0.9754	1.0252	0.321	1.679	0.313	1.637	3.173	0.3152	0.787	0.811	5.535	0.256	1.744
12	0.866	0.266	0.886	0.9776	1.0229	0.354	1.646	0.346	1.610	3.258	0.3069	0.778	0.922	5.594	0.283	1.717
13	0.832	0.249	0.850	0.9794	1.0210	0.382	1.618	0.374	1.585	3.336	0.2998	0.770	1.025	5.647	0.307	1.693
14	0.802	0.235	0.817	0.9810	1.0194	0.406	1.594	0.399	1.563	3.407	0.2935	0.763	1.118	5.696	0.328	1.672
15	0.775	0.223	0.789	0.9823	1.0180	0.428	1.572	0.421	1.544	3.472	0.2880	0.756	1.203	5.741	0.347	1.653
16	0.750	0.212	0.763	0.9835	1.0168	0.448	1.552	0.440	1.526	3.532	0.2831	0.750	1.282	5.782	0.363	1.637
17	0.728	0.203	0.739	0.9845	1.0157	0.466	1.534	0.458	1.511	3.588	0.2787	0.744	1.356	5.820	0.378	1.622
18	0.707	0.194	0.718	0.9854	1.0148	0.482	1.518	0.475	1.496	3.640	0.2747	0.739	1.424	5.856	0.391	1.608
19	0.688	0.187	0.698	0.9862	1.0140	0.497	1.503	0.490	1.483	3.689	0.2711	0.734	1.487	5.891	0.403	1.597
20	0.671	0.180	0.680	0.9869	1.0133	0.510	1.490	0.504	1.470	3.735	0.2677	0.729	1.549	5.921	0.415	1.585
21	0.655	0.173	0.663	0.9876	1.0126	0.523	1.477	0.516	1.459	3.778	0.2647	0.724	1.605	5.951	0.425	1.575
22	0.640	0.167	0.647	0.9882	1.0119	0.534	1.466	0.528	1.448	3.819	0.2618	0.720	1.659	5.979	0.434	1.566
23	0.626	0.162	0.633	0.9887	1.0114	0.545	1.455	0.539	1.438	3.858	0.2592	0.716	1.710	6.006	0.443	1.557
24	0.612	0.157	0.619	0.9892	1.0109	0.555	1.445	0.549	1.429	3.895	0.2567	0.712	1.759	6.031	0.451	1.548
25	0.600	0.135	0.606	0.9896	1.0105	0.565	1.435	0.559	1.420	3.931	0.2544	0.708	1.806	6.056	0.459	1.541

TABLE 3-6 Factors for Computing 3σ Control Limits for Median and Range Charts from the Median Range

Subgroup Size	A_5	D_5	D_6	d_3
2	2.224	0	3.865	0.954
3	1.265	0	2.745	1.588
4	0.829	0	2.375	1.978
5	0.712	0	2.179	2.257
6	0.562	0	2.055	2.472
7	0.520	0.078	1.967	2.645
8	0.441	0.139	1.901	2.791
9	0.419	0.187	1.850	2.916
10	0.369	0.227	1.809	3.024

Source: Extracted by permission from P. C. Clifford, "Control Charts Without Calculations," *Industrial Quality Control*, 15, No. 6 (May 1959), 44.

7 Kolmogorov-Smirnov Test

Table 7. Solutions c of Equation (1) in Sec. 15.3
n = Size of sample

n	$\alpha = 20\%$	$\alpha = 10\%$	$\alpha = 5\%$	$\alpha = 2\%$	$\alpha = 1\%$
	0.	0.	0.	0.	0.
1	900	950	975	990	995
2	684	776	842	900	929
3	565	636	708	785	829
4	493	565	624	689	734
5	447	509	563	627	669
6	410	468	519	577	617
7	381	436	483	538	576
8	359	410	454	507	542
9	339	387	430	480	513
10	323	369	409	457	486
11	308	352	391	437	468
12	296	338	375	419	449
13	285	325	361	404	432
14	275	314	349	390	418
15	266	304	338	377	404
16	258	295	327	366	392
17	250	286	318	355	381
18	244	279	309	346	371
19	237	271	301	337	361
20	232	265	294	329	352
21	226	259	287	321	344
22	221	253	281	314	337
23	216	247	275	307	330
24	212	242	269	301	323
25	208	238	264	295	317
26	204	233	259	290	311
27	200	229	254	284	305
28	197	225	250	279	300
29	193	221	246	275	295
30	190	218	242	270	290
35	177	202	224	251	269
40	165	189	210	235	252
45	156	179	198	222	238
50	148	170	188	211	226
55	142	162	180	201	216
60	136	155	172	193	207
65	131	149	166	185	199
70	126	144	160	179	192
75	122	139	154	173	185
80	118	135	150	167	179
85	114	131	145	162	174
90	111	127	141	158	169
95	108	124	137	154	165
100	106	121	134	150	161
Approximation for large n	$1.07/\sqrt{n}$	$1.22/\sqrt{n}$	$1.36/\sqrt{n}$	$1.52/\sqrt{n}$	$1.63/\sqrt{n}$