Original Research Article

Construction and selection of skip-lot sampling plan (SKSP-2) with special type double sampling plan through acceptable and limiting quality level

S Jayalakshmi

Assistant Professor, Department of Statistics, Bharathiar University Coimbatore, Tamil Nadu, Pin code - 641046, INDIA.
Email: jayalakshmi@buc.edu.in

Abstract

In this paper a Skip Lot Sampling Plan with Special Type Double Sampling Plan as reference plan has been studied. Under Acceptance Sampling Producer's risk and Consumer's risk has become increasingly common in maintaining quality Products especially in industries. Producer's risk and Consumer's risk has been Minimized by minimizing the tangent angle passing though (AQL, 1- α) and (LQL, β). Designing methodologies are provided to illustrate the solution procedures.

Key Words: Skip-Lot Sampling Plan, Special type Double Sampling Plan, Minimum Angle Method, Acceptable Quality Level, Limiting Quality Level.

***Address for Correspondence:**
Dr. S. Jayalakshmi, Assistant Professor, Department of Statistics, Bharathiar University Coimbatore, Tamil Nadu, Pin code - 641046, INDIA.
Email: jayalakshmi@buc.edu.in

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INTRODUCTION

Acceptance sampling is an important tool of statistical quality control. This tool is used to enhance the quality of the product through the inspection from the raw stage to the final stage. Without the proper inspection or testing the product may cause the bad reputation of the company in the global market. Good products sent to the market after the inspection increase the demand and alternately increase the profit of the company. Therefore, sampling plans have received the attention of the industrial engineers. The primary objective of sampling inspection is to reduce the cost of inspection while at the same time assuring the customer to satisfy an adequate level of quality on items being inspected. Inspection of raw materials, semi finished products, or a finished product is an important part of quality assurance. When inspection is done for the purpose of acceptance or rejection of a product, and it is based on adherence to a standard the type of inspection procedure employed, such a procedure is usually called acceptance sampling. Sampling is widely used in government sector and industry for controlling the quality of shipment of components, supplies and final products. In this paper a skip lot sampling plan of type SkSP-2 with Special Type Double Sampling plan as reference plan has been proposed. Producer risk and Consumer Risk has been minimized through minimizing the tangent angle passing through (AQL, 1-α) and (LQL, β). It is discussed how the declination angle of the tangent at the inflection point of the OC curve. Tables are presented for the selection of plans based on Acceptable Quality Level (AQL) and Limiting Quality Level (LQL). Dodge (1955) has introduced the concept of skip-lot sampling, by applying the principles of a continuous sampling plan of type CSP-1 to a series of lots or batches of material. This plan is designated as the SkSP-1 plan and specifically applicable for bulk materials or products produced in successive lots. Perry (1970) has developed a

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system of sampling inspection plan known as SkSP-2. This Plan involves inspection of only a fraction 'f ' of the submitted lots when quality of the submitted product is good as demonstrated by the quality of the product. Peach and Littaur (1946) have considered two points on the OC curve as (p_1,1- α), and (p_2, β) and propose another method which minimizes the angle between them. Normal Bush *et al*. (1953) have suggested two points on the OC curve namely (AQL, 1-α), and (IQL, 0.50), and the cosine angle of chord length to describe the direction of OC curve. Suresh (1993) has given for the selection of Skip-lot Sampling Plan of type SkSP-2 with reference plans SSP(c=0), SSP(c≠0) and DSP(0,1) using consumer and producer quality levels. Kalaichelvi (2012) has studied the selection of skip-lot sampling plans for given p_1, p_2, α, and β involving producer and consumer risks with various reference plans. Suresh and Kavithamani (2013) have proposed the minimum angle approach between two points on the OC curve using the attribute sampling plan of SkSP-V with MRGS plan as reference plan. Recently, a new type of skip-lot sampling plan called SkSP-R was developed by Balamurali.et.al (2014) based on the principle of continuous sampling procedure and resampling scheme for the quality inspection of continuous flow of bulk products. The design parameters are determined so as to minimize the average sample number while the specified producer risk and the consumer risks are satisfied. Special Type Double Sampling (STDS) plan in which acceptance is not allowed in the first stage of sampling. When sampling plants are set up for Product characteristics that involve costly or destructive testing by attributes, it is usual practice to use a single sampling plan with acceptance number such as Ac=0 and Ac=1. [Hahn (1974) and Dodge (1955a)]. But the OC curves of single sampling plans with Ac=0 and Ac=1 lead to conflicting interest between the producer and the consumer. Such conflict can be overcome if one is able to design a suitable plan having an OC curve lying between the OC curves of Ac=0 and Ac=1 plans. Govindaraju (1984) has proposed the Special Type of Double Sampling Plan procedure. Special Type Double Sampling (STDS) plan in which the acceptance is not allowed in the first stage of sampling. When sampling plans are set for product characteristic that involves costly or destructive testing by attributes. It is usual, practice to use a single sampling plan with acceptance number c = 0 and c = 1. But the OC curve of single sampling plan with c = 0 and c = 1, leads to conflicting interest between the producer and consumer.

Special type double sampling plan is valid under general conditions for application of attributes sampling inspection. However, this plan will specially be useful to product characteristics involving costly or destructive tests.

OPERATING PROCEDURE

A SkSP-2 plan is one that uses a given lot inspection plan by the method of attributes (single, multiple sampling, chain sampling, etc.) called the 'reference plan' together with a procedure that calls for normally inspecting every lot, but for inspecting only a fraction of the lots when the quality is good. The plan includes specific rules based on the record of lot acceptance and rejection, for switching back and forth between 'normal inspections' (inspecting every lot) and 'skipping inspection' (inspecting only a fraction of the lots). The operating procedure is given below.

- Start with normal inspection, using the reference plan
- When 'i' consecutive lots are accepted on normal inspection switch to skipping inspection of inspecting a fraction 'f' of the lots.
- When a lot is rejected on skipping inspection, switch to normal inspection.
- Screen each rejected lot and correct or replace all defective units found.

Associated with the SkSP-2 are, a given reference plan, and the parameters i and f. in general, $0 < f < 1$ and i is a positive integer. When f = 1, the plan degenerates into the original reference plan.

Operating characteristics function of SkSP-2: The OC function associated with an SkSP-2 by two approaches namely (1) power series approach and (ii) Markov chain approach. The OC function for a SkSP-2 plan is obtained by $Pa(p) = (f P + (1 – f) P^i)/ (f + (1-f) P^i)$ where P is the OC function of the reference plan, i is the clearing interval and f is the sampling traction.

Operating procedure:

1. From a lot select a random sample of n_1 units and observe the number of defectives d_1. if $d_1 \geq 1$, reject the lot. If $d_1=0$, select a second random sample of n_2 units and observe the number of defectives d_2.
2. If $d_2 \geq 1$, accept the lot; otherwise (that is, if $d_2 \geq 2$), reject the lot.

The OC function of STDS plan

The operating characteristic function for STDS plan by

$P_a(p) = e^{-np} (1+\Phi np)$

Where $\Phi = n_2/n$ and $n=n_1+n_2$

Although this plan is valid under general conditions for application of attributes sampling inspection. This will be especially useful to product characteristics involving costly or destructive testing.

Selection Procedure for SkSP-2 with STDS Plans: Table :1 can be used for obtaining plan parameters with the minimum tangent angle (ntanθ) between the lines formed by the points (AQL, 1-α) (AQL, β) and (AQL, 1-α), (LQL, β). One can find the sampling plan from the tables with minimum tangent angle (ntanθ) by the following procedures:

- compute the operating ratio p_2/p_1
- With the computed values of p_2/p_1 enter the value from the table headed by p_2/p_1 this is equal to or just greater than the computed ratio.
- The sample size is then obtained as $n = np_1/p_1$, since θ is known, the parameter n_1 and n_2 can be computed.
- Thus the minimum angle can be found as {(θ = tan θ / n)}

Selection of plan for given, 'i', f, p_1 and p_2: To select a plan for given 'i', f, p_1 and p_2, first calculate the operating ratio p_2/p_1. Select and then the table corresponding to the given 'i' and locate the value or in the row headed with OR which is very close to the desired ratio. The parameter np_1, c and ntanθ are can obtained from the selected table corresponding to given 'i' and 'f' along with producers and consumers risk. The sample size thus obtained as $n=np_1/p_1$ and the minimum angle θ = tan {(ntanθ)/n}.

For example for given i=2, f =2/3, p_1=0.01, p_2=0.3 one can compute p_2/p_1 = 0.30/0.01=30. The OR value exactly equal to 30 with 'i' = 2 and f =2/2 one find the following values for skip-lot plans from the constructed table 6.2.1

n tanθ = 4.7324 φ = 0.70 α = 3.37% β = 4.7%
n tanθ = 6.0675 φ = 0.85 α = 2.88 % β =1.52%
n tanθ = 7.5199 φ = 0.90 α = 3.16% β = 0.43%
n tanθ = 9.0055 φ = 0.95 α = 3.31 % β = 0.12%

The skip-lot plans corresponding to minimum angle from the above set of values are

(2, 2/3, 30, 0.70) with θ = 17.51 α = 3.37% β = 4.71%
(2, 2/3, 30, 0.85) with θ = 16.87 α = 2.88% β = 1.52 %
(2, 2/3, 30, 0.90) with θ = 16.74 α = 3.16% β = 0.43%
(2, 2/3, 30, 0.95) with θ = 16.71 α = 3.31% β = 0.12%

Thus for given i = 2, f = 2/3 the minimum angle plan is (2, 2/3, 30, 0.95)

Construction of tables: The probability of acceptance for SkSP-2 with reference plan is

$Pa(p) = (f P + (1 – f) P^i)/ (f + (1-f) P^i)$

When p is STPS reference plan and its OC function as:

$STDS = Pa(p) = e^{-np} (1+ φnp)$

Where $φ = n_2/n$ and $n = n_2+n_1$

When np_1 and p_2/p_1 are known np_2 can be calculated from $np_2 = np_1 (p_2/p_1)$. The following search procedure is used to obtained the parametric value fixing α = 0.05 and β = 0.10.

1. set φ = 0
2. compute α and β using equation 1 and 2 for given 'i',f, np_1 and OR
3. If Pa (p_1) ≤ 1 - α go to step (6)

If Pa (p_2) ≥ β, go to step (6)

1. Find n tan θ using np_1, α and β and computed np_2 = OR x np_1
2. Record minimum of n tanθ
3. Increase φ by 0.5 go to step (2)
4. If the current value of φ > 1, step the process otherwise repeat steps 2 to 7
5. Select the φ values for which, n tanθ is minimum. This φ values for the corresponding α + β values are optimum φ value and it is given in the table 1 enclosed for various 'i' (4, 6, 8, 10) values are applicable in the tables.

Computer program is used to search for optimum parametric values. Table 1 gives such optimum values of f,p_1 and p_2 and corresponding to the ntanϴ when i= 1,2,3,4,5.

CONCLUSION

Acceptance Sampling is the technique, which deals with procedures in which a decision either to accept or reject lot of process based on examination of samples. Skip Lot Sampling Plan with Special Type Double Sampling Plan as reference plan involving minimum angle criteria is proposed. The procedure and necessary tables for the Selection of Skip - Lot Sampling Plan (SkSP-2) with Special Type Double Sampling Plan through Acceptable and Limiting Quality Levels. This paper is mainly used on the acceptance sampling plans when compared with 100% inspection which has the following advantages: The plan is more economical, owing to fewer inspections. Causes less handling damage during inspection. Upgrading the inspection job from monotonous piece-by-piece decisions to lot-by-lot decisions. It is applicable to destructive testing. Rejection of entire lots rather than the return of defectives provide stronger motivation for improvement.

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Table 6.2.1: Minimum Angle SkSP – 2 with STDS plans for given OR and np_1 for ‘i’ = 2

	F	2/3				½				1/3				1/5			
OR	np_1	ntanθ	ϕ	α%	β%	ntanθ	ϕ	α %	β%	ntanθ	ϕ	α%	β%	ntanθ	ϕ	α%	β%
	0.05	3.4523	0.00	3.36	3.95	3.4255	0.00	2.56	4.02	3.4007	0.00	1.74	4.17	3.3865	0.00	1.06	4.45
	0.06	4.1152	0.15	3.43	3.26	4.0818	0.15	2.61	3.31	4.0498	0.15	1.77	3.41	4.0287	0.15	1.08	3.61
	0.07	4.7576	0.30	3.31	2.53	4.7197	0.30	2.52	2.56	4.6827	0.30	1.71	2.62	5.3543	0.30	16.33	0.00
	0.08	5.3878	0.40	3.26	1.71	5.3450	0.40	2.48	1.73	5.3023	0.40	1.68	1.76	5.2694	0.40	1.02	1.81
65	0.09	6.0270	0.45	3.38	1.05	5.9771	0.45	2.58	1.06	5.9268	0.45	1.75	1.07	5.8867	0.45	1.06	1.09
	0.10	6.6723	0.50	3.44	0.64	6.6161	0.50	2.62	0.64	6.5592	0.50	1.78	0.65	6.5132	0.50	1.08	0.66
	0.15	9.9393	0.70	3.37	0.05	9.8577	0.70	2.57	0.05	9.7747	0.70	1.74	0.05	9.7073	0.70	1.06	0.05
	0.20	13.1806	0.85	2.88	0.00	13.0876	0.85	2.19	0.00	12.9932	0.85	1.48	0.00	12.9167	0.85	0.90	0.00
	0.25	16.5220	0.90	3.16	0.00	16.3946	0.90	2.41	0.00	16.2651	0.90	1.63	0.00	16.1601	0.90	0.99	0.00
	0.30	19.8566	0.95	3.31	0.00	19.6965	0.95	2.52	0.00	19.5337	0.95	1.71	0.00	19.4016	0.95	1.04	0.00
	0.05	3.2224	0.00	3.36	5.10	3.1987	0.00	2.56	5.21	3.1783	0.00	1.74	5.45	3.1709	0.00	1.06	5.91
	0.06	3.8362	0.15	3.43	4.29	3.8061	0.15	2.61	4.38	3.7788	0.15	1.77	4.55	3.7644	0.15	1.08	4.88
	0.07	4.4289	0.30	3.31	3.44	4.3945	0.30	2.52	3.50	4.3620	0.30	1.71	3.61	4.3414	0.30	1.04	3.83
	0.08	5.0047	0.40	3.26	2.43	4.9654	0.40	2.48	2.46	4.9268	0.40	1.68	2.52	4.8988	0.40	1.02	2.63
60	0.09	5.5859	0.45	3.38	1.56	5.5398	0.45	2.58	1.57	5.4937	0.45	1.75	1.60	5.4577	0.45	1.06	1.64
	0.10	6.1739	0.50	3.44	1.00	6.1219	0.50	2.62	1.00	6.0694	0.50	1.78	1.01	6.0274	0.50	1.08	1.03
	0.15	9.1670	0.70	3.37	0.09	9.0917	0.70	2.57	0.09	9.0151	0.70	1.74	0.09	8.9529	0.70	1.06	0.09
	0.20	12.1514	0.85	2.88	0.01	12.0656	0.85	2.19	0.01	11.9786	0.85	1.48	0.01	11.9081	0.85	0.90	0.01
	0.25	15.2313	0.90	3.16	0.00	15.1138	0.90	2.41	0.00	14.9945	0.90	1.63	0.00	14.8976	0.90	0.99	0.00
	0.30	18.3053	0.95	3.31	0.00	18.1577	0.95	2.52	0.00	18.0077	0.95	1.71	0.00	17.8858	0.95	1.04	0.00
	0.05	2.9981	0.00	3.36	6.58	2.9780	0.00	2.56	6.77	2.9634	0.00	1.74	7.15	2.9655	0.00	1.06	7.90
	0.06	3.5638	0.15	3.43	5.66	3.5377	0.15	2.61	5.80	3.5163	0.15	1.77	6.09	3.5114	0.15	1.08	6.65
	0.07	4.1083	0.30	3.31	4.69	4.0779	0.30	2.52	4.79	4.0511	0.30	1.71	4.99	4.0393	0.30	1.04	5.38
	0.08	4.6303	0.40	3.26	3.44	4.5948	0.40	2.48	3.50	4.5614	0.40	1.68	3.61	4.5403	0.40	1.02	3.83
55	0.09	5.1532	0.45	3.38	2.31	5.1111	0.45	2.58	2.34	5.0696	0.45	1.75	2.39	5.0390	0.45	1.06	2.49
	0.10	5.6832	0.50	3.44	1.54	5.6355	0.50	2.62	1.56	5.5877	0.50	1.78	1.58	5.5503	0.50	1.08	1.62
	0.15	8.3977	0.70	3.37	0.18	8.3287	0.70	2.57	0.18	8.2585	0.70	1.74	0.18	8.2015	0.70	1.06	0.18
	0.20	11.1228	0.85	2.88	0.02	11.0443	0.85	2.19	0.02	10.9647	0.85	1.48	0.02	10.9001	0.85	0.90	0.02
	0.25	13.9406	0.90	3.16	0.00	13.8331	0.90	2.41	0.00	13.7239	0.90	1.63	0.00	13.6353	0.90	0.99	0.00
	0.30	16.7540	0.95	3.31	0.00	16.6189	0.95	2.52	0.00	16.4816	0.95	1.71	0.00	16.3701	0.95	1.04	0.00

Table 6.2.1: Continued

	f	2/3				½				1/3				1/5			
OR	np_1	ntanθ	ϕ	α%	β%	ntanθ	ϕ	α%	β%	ntanθ	ϕ	α%	β%	ntanθ	ϕ	α%	β%
50	0.05	2.7801	0.00	3.36	8.52	2.7647	0.00	2.56	8.82	2.7579	0.00	1.74	9.43	2.7738	0.00	1.06	10.62
	0.06	3.2992	0.15	3.43	7.46	3.2781	0.15	2.61	7.70	3.2648	0.15	1.77	8.18	3.2737	0.15	1.08	9.11
	0.07	3.7974	0.30	3.31	6.37	3.7720	0.30	2.52	6.55	3.7532	0.30	1.71	6.90	3.7546	0.30	1.04	7.61
	0.08	4.2667	0.40	3.26	4.87	4.2360	0.40	2.48	4.98	4.2093	0.40	1.68	5.19	4.1988	0.40	1.02	5.62
	0.09	4.7314	0.45	3.38	3.42	4.6938	0.45	2.58	3.47	4.6580	0.45	1.75	3.58	5.1769	0.45	18.60	0.00
	0.10	5.2031	0.50	3.44	2.39	5.1599	0.50	2.62	2.41	5.1173	0.50	1.78	2.47	5.0860	0.50	1.08	2.58
	0.15	7.6336	0.70	3.37	0.35	7.5707	0.70	2.57	0.35	7.5069	0.70	1.74	0.35	7.4551	0.70	1.06	0.35
	0.20	10.0956	0.85	2.88	0.04	10.0243	0.85	2.19	0.04	9.9520	0.85	1.48	0.04	9.8934	0.85	0.90	0.04
	0.25	12.6502	0.90	3.16	0.00	12.5527	0.90	2.41	0.00	12.4536	0.90	1.63	0.00	12.3731	0.90	0.99	0.00
	0.30	15.2028	0.95	3.31	0.00	15.0802	0.95	2.52	0.00	14.9556	0.95	1.71	0.00	14.8544	0.95	1.04	0.00
45	0.06	3.0440	0.15	3.43	9.84	3.0295	0.15	2.61	10.24	3.0276	0.15	1.77	11.03	2.6005	0.00	1.06	14.35
	0.07	3.4983	0.30	3.31	8.65	3.4797	0.30	2.52	8.97	3.4723	0.30	1.71	9.59	3.0570	0.15	1.08	12.56
	0.08	3.9168	0.40	3.26	6.87	3.8922	0.40	2.48	7.08	3.8754	0.40	1.68	7.49	3.4941	0.30	1.04	10.81
	0.09	4.3236	0.45	3.38	5.03	4.2914	0.45	2.58	5.15	4.2636	0.45	1.75	5.38	4.2360	0.40	1.06	0.00
	0.10	4.7369	0.50	3.44	3.67	4.6988	0.50	2.62	3.74	4.6630	0.50	1.78	3.86	4.6486	0.45	1.07	0.00
	0.15	6.8779	0.70	3.37	0.67	6.8212	0.70	2.57	0.67	6.7637	0.70	1.74	0.68	4.6410	0.50	1.08	4.11
	0.20	9.0714	0.85	2.88	0.11	9.0073	0.85	2.19	0.11	8.9423	0.85	1.48	0.11	6.7174	0.70	1.06	0.69
	0.25	11.3605	0.90	3.16	0.01	11.2729	0.90	2.41	0.01	11.1839	0.90	1.63	0.01	8.8896	0.85	0.90	0.11
	0.30	13.6517	0.95	3.31	0.00	13.5416	0.95	2.52	0.00	13.4297	0.95	1.71	0.00	11.1117	0.90	0.99	0.01
40	0.08	3.5838	0.40	3.26	9.68	3.5679	0.40	2.48	10.07	3.5664	0.40	1.68	10.83	3.6005	0.40	1.02	12.32
	0.09	3.9338	0.45	3.38	7.40	3.9090	0.45	2.58	7.63	3.8934	0.45	1.75	8.10	3.9037	0.45	1.06	9.02
	0.10	4.2893	0.50	3.44	5.64	4.2578	0.50	2.62	5.78	4.2318	0.50	1.78	6.06	4.2256	0.50	1.08	6.62
	0.15	6.1363	0.70	3.37	1.30	6.0858	0.70	2.57	1.31	6.0349	0.70	1.74	1.32	5.9947	0.70	1.06	1.35
	0.20	8.0534	0.85	2.88	0.26	7.9965	0.85	2.19	0.26	7.9387	0.85	1.48	0.26	7.8920	0.85	0.90	0.26
	0.25	10.0728	0.90	3.16	0.05	9.9951	0.90	2.41	0.05	9.9161	0.90	1.63	0.05	9.8521	0.90	0.99	0.05
	0.30	12.1011	0.95	3.31	0.01	12.0035	0.95	2.52	0.01	11.9043	0.95	1.71	0.01	11.8237	0.95	1.04	0.01

Table 1: Continued

	f	2/3				½				1/3				1/5			
OR	np_1	ntanθ	ϕ	α%	β%	ntanθ	ϕ	α%	β%	ntanθ	ϕ	α%	β%	ntanθ	ϕ	α%	β
35	0.10	3.8662	0.50	3.44	8.62	3.8442	0.50	2.62	8.93	3.8345	0.50	1.78	9.55	3.8570	0.50	1.08	10.77
	0.15	5.4169	0.70	3.37	2.48	5.3730	0.70	2.57	2.51	5.3298	0.70	1.74	2.57	5.2985	0.70	1.06	2.69
	0.20	7.0481	0.85	2.88	0.64	6.9982	0.85	2.19	0.64	6.9477	0.85	1.48	0.64	6.9071	0.85	0.90	0.65
	0.25	8.7901	0.90	3.16	0.14	8.7222	0.90	2.41	0.14	8.6532	0.90	1.63	0.14	8.5973	0.90	0.99	0.14
	0.30	10.5521	0.95	3.31	0.03	10.4670	0.95	2.52	0.03	10.3805	0.95	1.71	0.03	10.3102	0.95	1.04	0.03
30	0.15	4.7324	0.70	3.37	4.71	4.6967	0.70	2.57	4.81	4.6652	0.70	1.74	5.01	4.6511	0.70	1.06	5.41
	0.20	6.0675	0.85	2.88	1.52	6.0247	0.85	2.19	1.53	5.9819	0.85	1.48	1.56	5.9489	0.85	0.90	1.60
	0.25	7.5199	0.90	3.16	0.43	7.4617	0.90	2.41	0.43	7.4027	0.90	1.63	0.43	7.3549	0.90	0.99	0.44
	0.30	9.0085	0.95	3.31	0.12	8.9358	0.95	2.52	0.12	8.8619	0.95	1.71	0.12	8.8019	0.95	1.04	0.12
25	0.15	4.1014	0.70	3.37	8.86	4.0795	0.70	2.57	9.19	4.0713	0.70	1.74	9.84	4.6511	0.70	1.06	5.41
	0.20	5.1327	0.85	2.88	3.60	5.0984	0.85	2.19	3.66	5.0666	0.85	1.48	3.78	5.9489	0.85	0.90	1.60
	0.25	6.2792	0.90	3.16	1.29	6.2306	0.90	2.41	1.30	6.1818	0.90	1.63	1.31	7.3549	0.90	0.99	0.44
	0.30	7.4811	0.95	3.31	0.45	7.4205	0.95	2.52	0.45	7.3591	0.95	1.71	0.45	8.8019	0.95	1.04	0.12
20	0.20	4.2813	0.85	2.88	8.36	4.2623	0.85	2.19	8.65	4.2564	0.85	1.48	9.24	4.2835	0.85	0.90	10.39
	0.25	5.1037	0.90	3.16	3.77	5.0664	0.90	2.41	3.84	5.0318	0.90	1.63	3.97	5.0117	0.90	0.99	4.23
	0.30	5.9988	0.95	3.31	1.67	5.9504	0.95	2.52	1.69	5.9021	0.95	1.71	1.71	5.8647	0.95	1.04	1.77

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