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A Two Stage Group Acceptance Sampling Plans Based On Truncated Life Tests For Inverse And Generalized Rayleigh Distributions

Dr. Priyah Anburajan
Research Scholar,
Department of Mathematics,
Avinashilingam University,
Coimbatore, Tamil Nadu,
India

Dr. A. R. Sudamani Ramaswamy
Associate Professor,
Department of Mathematics,
Avinashilingam University,
Coimbatore, Tamil Nadu,
India

ABSTRACT

In this paper, a two stage group acceptance sampling plan is developed for a truncated life test when the lifetime of an item follows Inverse Rayleigh distribution and Generalized Rayleigh distribution. The minimum number of groups required for a given group size and the acceptance number is determined when the consumer's risk and the test termination time are specified. The operating characteristic values according to various quality levels are obtained. The results are explained with examples.

Keywords

Inverse Rayleigh distribution, Generalized Rayleigh distribution, Group acceptance sampling, consumer's risk, Operating characteristics, Producer's risk, truncated life test.

1. INTRODUCTION

Acceptance sampling is a methodology commonly used in quality control and improvement. The aim is to make an inference about the quality of a batch/lot of product from a sample. Depending on what is found in the sample, the whole lot is then either accepted or rejected, and rejected lots can then be scrapped or reworked. Understanding and improving quality is a key factor leading to business success, growth and an enhanced competitive position. There is a substantial return on investment from improved quality and from successfully employing quality as an integral part of overall business strategy. Quality improvement is the reduction of variability in processes and products. There are three major areas of statistical and engineering technology useful in quality improvement. They are i) statistical process control ii) design of experiments and iii) acceptance sampling. Acceptance sampling defined as the inspection and classification of a sample of units selected at random from a larger batch or lot. The ultimate decision about disposition of the lot usually occurs at two points; incoming raw materials or components or final production. Thus a specific plan that states the sample size or sizes to be used and the associated acceptance and non-acceptance criteria is an acceptance sampling plan.

In most acceptance sampling plans for a truncated life test, determining the sample size from a lot under consideration is the major issue. In the usual sampling plan, it is implicitly assumed that only a single item is put in a tester. However testers accommodating a multiple number of items at a time are used in practise because testing those items simultaneously. Items in a tester can be regarded as a group and the number of items in a group is called as group size. The acceptance sampling plan based on these groups of items is called group acceptance sampling plan.

The quality of the product is tested on the basis of few items taken from an infinite lot. The statistical test can be stated as: Let μ be the true average life and μ_0 be the specified average life of a product. Based on the failure data, we want to test the hypothesis H_0: $\mu \geq \mu_0$ against H_1: $\mu < \mu_0$. A lot is considered as good if $\mu \geq \mu_0$ and bad if $\mu < \mu_0$. This hypothesis is tested using the acceptance sampling scheme as: In a life test experiment, a sample of size n selected from a lot of products is put on the test. The experiment is terminated at a pre – assigned time t_0. when we set acceptance number as c, H_0 is rejected if more than c failures are recorded before time t_0 and H_0 is accepted if there are c or fewer failures before t_0. Probability of rejection of good lot is called the producer's risk and probability of accepting a bad lot is known as consumer's risk. If the confidence level is p*, then the consumers risk will be β = 1-p*. A well acceptance sampling plan minimizes both the risks.

Many authors have discussed acceptance sampling based on truncated life tests. Abbur Razzaque Mughal, Muhammad Hanif, Azhar Ali Imran, Muhammad Rafi and Munir Ahmad (2011) have studied economic reliability two – stage group sampling plan for truncated life test having Weibull distribution. Aslam M. (2007) have studied Double acceptance sampling based on truncated life tests in Rayleigh distribution. Aslam M., and Jun C.H. (2009) have studied a group acceptance sampling plans for truncated life tests based on the inverse Rayleigh and log-logistic distributions. Epstein B. (1954) has studied truncated life tests in the exponential case. Rosaiah K. and Kantam R.R.L. (2005) have studied acceptance sampling based on the inverse Rayleigh distribution. Rosaiah K., Kantam R.R.L. and Pratapa Reddy J. (2007) have studied economic reliability test plan with Inverse Rayleigh Variate. Srinivasa Rao G. (2009) has studied a group acceptance sampling plans for truncated life tests for Marshall-Olkin extended Lomax distribution. Stephens, K. S. (2001) have given The Handbook of Applied Acceptance Sampling and Tsai, T.R. and Wu, S.J. (2006) have studied acceptance sampling based on truncated life tests for generalized Rayleigh distribution.

Here we apply two – stage GASP on the truncated life tests when a lifetime of the product assumed to follow Inverse Rayleigh and Generalized Rayleigh distributions. In this type of tests, determining the sample size is equivalent to determining the number of groups.

2. CUMULATIVE DISTRIBUTIVE FUNCTION

2.1 Inverse Rayleigh Distribution

The cumulative distribution function (cdf) of the Inverse Rayleigh distribution is given by

$$F(t) = e^{-\frac{\sigma^2}{t^2}} \qquad (1)$$

where σ is a scale parameter.

2.2 Generalized Rayleigh Distribution:

The Rayleigh distribution, which has many applications in life testing of electro-vacuum devices and in communication engineering was first derived by Rayleigh (1880) in the field of acoustics. The cumulative distribution function (cdf) of the Rayleigh distribution is

$$F(t,b) = 1 - \exp(-t^2 / 2b^{2)}), t > 0 \qquad (2)$$

where b>0 is the scale parameter.

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Voda (1976) derived a generalized version of the Rayleigh distribution called the generalized Rayleigh distribution (GRD), whose cdf is given by:

$$F_k(t,\lambda) = 1 - \sum_{j=0}^{k} \frac{(t^2/\lambda)^j e^{-\frac{t^2}{\lambda}}}{j!}$$

where k is a positive integer called the shape parameter and λ>0 is the scale parameter. The i^{th} moment of the random variable *T* having GRD is:

$$E[T^i] = \frac{(k+i/2+1)^{\frac{1}{2}}}{(k+1)^{\frac{1}{2}}} \lambda^{\frac{i}{2}}, i = 1,2,....$$

So the mean of GRD is given by:

$$\mu = E[T] = m\lambda^{1/2}$$ where m = Γ(k+3/2)/ Γ(k+1)

If some other parameters are involved, then they are assumed to be known, for an example, if shape parameter of a distribution is unknown it is very difficult to design the acceptance sampling plan. In quality control analysis, the scale parameter is often called the quality parameter or characteristics parameter. Therefore it is assumed that the distribution function depends on time only through the ratio of t/ σ.

The failure probability of an item by time t_0 is given by

$$p = F\,(t_{0\,:}\,\sigma) \qquad (3)$$

The quality of an item is usually represented by its true mean lifetime although some other options such as median lifetime or B_{10} life are sometimes used. Let us assume that the true mean μ can be represented by the scale parameter. In addition, it is convenient to specify the test time as a multiple of the specified life so thataμ_0 and the quality of an item as a ratio of the true mean to the specified life (μ/μ_0).

Then we can rewrite (3) as a function of 'a' (termination time) and the ratio μ/μ_0.

$$p = F(a\,\mu_0 : \mu/\mu_0) \qquad (4)$$

Here when the underlying distribution is the Inverse Rayleigh distribution

$$p = \exp\left(-\frac{1}{a^2 \pi} \left(\frac{\mu}{\mu_0} \right)^2 \right) \tag{5}$$

When the underlying distribution is the Generalized Rayleigh distribution

$$p = 1 - \sum_{j=0}^{k} \frac{\left(\dfrac{am}{\mu/\mu_0} \right)^{2j} e^{-\left(\frac{am}{\mu/\mu_0} \right)^2}}{j!} \tag{6}$$

3. DESIGN OF THE PROPOSED PLAN

The following two – stage group sampling plan having testers with the group size r,

1. (First stage) Draw the first random sample size n_1 from a lot, allocate r items to each of g_1 groups (or testers) so that $n_1 = rg_1$ and put them on test for the duration of t_0. Accept the lot if the number of failures from each group is c_1 or less. Truncate the test and reject the lot as soon as the number of failures in any group is larger than c_2 before t_0. Otherwise, go to the second stage.
2. (Second stage) Draw the second random sample of size n_2 from a lot, allocate r items to each of g_2 groups so that $n_2 = rg_2$ and put them on test for t_0. Accept the lot if the number of failures in each group is c_1 or less. Truncate the test and reject the lot if the number of failures in any group is larger than c_1 before t_0.

The two – stage economic reliability group sampling plan constitute the design parameters of g_1, g_2, c_1 and c_2 when the group size r and both risks are specified.

The probability of lot acceptance at the first stage can be evaluated as,

$$P_a^{\,1} = \left[\sum_{i=0}^{c_1} \binom{r}{i} p^i (1-p)^{r-i} \right]^{g_1} \tag{7}$$

The probability of lot rejection at the first stage is given by,

$$P_r^{\,1} = 1 - \left[\sum_{i=0}^{c_2} \binom{r}{i} p^i (1-p)^{r-i} \right]^{g_1} \tag{8}$$

where the probability of lot acceptance at the second stage is

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$$P_a^{\ 2} = \left[1-(P_a^{\ 1}+P_r^{\ 1})\right]\left[\sum_{i=0}^{c_1}\binom{r}{i}p^i(1-p)^{r-i}\right]^{g_2} \qquad (9)$$

Therefore, the probability of lot acceptance for the proposed two – stage economic reliability group sampling plan is given by

$$L(p) = P_a^{\ 1} + P_a^{\ 2} \qquad (10)$$

Now here we used two – point approach for finding the design parameters of the proposed group sampling plan. Consider p1, p2 be the probability of failure corresponding to the consumer's and producer's risk respectively. Then, as minimum termination time for two stages and probability of lot acceptance satisfying the following two inequalities simultaneously.

$$L(p_1) = P_a^{\ 1} + P_a^{\ 2} \le \beta$$

$$L(p_2) = P_a^{\ 1} + P_a^{\ 2} \ge 1-\alpha \qquad (11)$$

The plan parameters can be obtained from the solution of the following inequalities

$$L(p_1) = P_a^{\ 1} + P_a^{\ 2} \le \beta$$

$$L(p_2) = P_a^{\ 1} + P_a^{\ 2} \ge 1-\alpha$$

$$1 \le g_2 \le g_1$$

$$0 \le c_1 \le c_2 \qquad (12)$$

The minimum number of groups required can be determined by considering the consumer's risk when the true median life equals the specified median life ($\mu = \mu_0$) (worst case) by means of the following inequality:

$$L(p_0) \le \beta \qquad (13)$$

where p_0 is the failure probability at $\mu = \mu_{0.}$ Here minimum group size (g) is obtained using (5) and (6) in (12) at worst case.

4. Operating Characteristic functions:

The probability of acceptance can be regarded as a function of the deviation of the specified value μ_0 of the median from its true value μ. This function is called Operating Characteristic (OC) function of the sampling plan. Once the minimum sample size is obtained, one may be interested to find the probability of acceptance of a lot when the quality (or reliability) of the product is sufficiently good. As mentioned earlier, the product is considered to be good if $\mu \ge \mu_0$. Te probabilities of acceptance are displayed in Table 3 and 4 for various values of the median ratios μ/μ_0, producer's risks β and time multiplier a.

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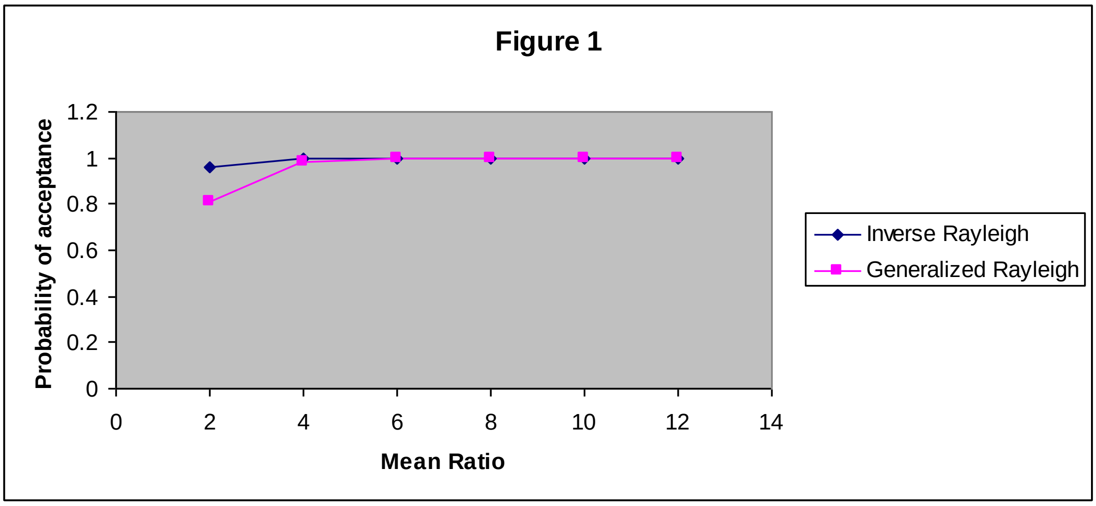
5. Notation:

g_1	-	Number of groups in first stage
g_2	-	Number of groups in second stage
r_1	-	Number of items in a group in first stage
r_2	-	Number of items in a group in second stage
n_1	-	First sample size
n_2	-	Second sample size
c_1	-	Acceptance number of sample first
c_2	-	Acceptance number of sample second
t_0	-	termination time
a	-	test termination time multiplier
b	-	scale parameter
β	-	consumer's risk
p	-	failure probability
$L(p)$	-	Probability of acceptance
μ	-	Mean life
μ_0	-	Specified life

6. Description of tables and examples:

Based on various test values of consumer's risk and the test termination time multiplier, the number of groups of GASP is found using the inequalities (11). Suppose that we want to develop an economic reliability two – stage group sampling plan to test if the median is greater than 1,000 hours based on a testing time of 700 hours and using testers equipped with 6 items each. It is assumed that $c_1 = 0$ and $c_2 = 2$ and $\beta = 0.1$. This gives the termination multiplier $a = 0.7$. If the life time follows Inverse Rayleigh distribution, from Table 1 the design parameters can be written as (g_1, g_2, c_1, c_2) = (1, 1, 0, 2). We will implement the above sampling plan as, draw the first sample of size $n_1 = 6$ items and put to 6 testers, if no failure occur during 700 hours we accept the lot. The test is terminated and the lot is rejected if more than 2 failures occurs, otherwise if 1 or 2 failures occurs, then we move on to the second stage, where the second sample of size $n_2 = 6$ is chosen and allocated to 6 testers. If suppose the life time follows Generalized Rayleigh distribution, from Table 2 the design parameters can be written as (g_1, g_2, c_1, c_2) = (2, 1, 0, 2) We will implement the above sampling plan as, draw the first sample of size $n_1 = 12$ items and put to 6 testers, if no failure occur during 700 hours we accept the lot. The test is terminated and the lot is rejected if more than 2 failures occurs, otherwise if 1 or 2 failures occurs, then we move on to the second stage, where the second sample of size $n_2 = 6$ is chosen and allocated to 6 testers. For this proposed sampling plan if r = 3 and the life time follows Inverse Rayleigh distribution with β = 0.25, the probability of acceptance is 1 when the true mean is 10,000 hrs from Table 3 and if the life time follows Generalized Rayleigh distribution the probability of acceptance is 0.999479 when the true mean is 10,000 hrs from Table 4. Thus comparing the probability of acceptance, the Inverse Rayleigh distribution is better than the Generalized Rayleigh distribution as the later is lesser when compared and is shown in Figure 1.

Figure 1: Operating Characteristic curve for the two – stage group sampling plan when the lifetime of an item follows different lifetime distributions with $c_1 = 0$ and $c_2 = 2$ and $a = 0.7$



7. Conclusion

In this paper, a group acceptance sampling plan from a truncated life test is proposed for Marshall – Olkin extended Inverse Rayleigh distribution and Generalized Rayleigh distribution. The number of groups are determined for r = 1,2,….,6 when the consumer's risk (β) and the other plan parameters are specified. It is observed that the lot acceptance probability increases as the mean ratio increases and the number of groups tends to increase as the test duration decreases. Moreover, the operating characteristic function increases disproportionately when the quality improves. Clearly, this would be beneficial in terms of test time and test cost.

Table 1: Minimum number of groups (g_1 and g_2) for the two – stage group sampling plan with $c_1 = 0$ and $c_2 = 2$ when the lifetime of the items follows the inverse Rayleigh distribution

β	r	a											
		0.7		0.8		1.0		1.2		1.5		2.0	
0.25	2	3	1	2	1	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1	1	1	1
	5	1	1	1	1	1	1	1	1	1	1	1	1

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	6	1	1	1	1	1	1	1	1	1	1	1	1
0.10	2	3	2	2	2	2	1	1	1	1	1	1	1
	3	2	1	2	1	1	1	1	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1	1	1	1
	5	1	1	1	1	1	1	1	1	1	1	1	1
	6	1	1	1	1	1	1	1	1	1	1	1	1
0.05	2	3	3	2	2	2	2	2	1	1	1	1	1
	3	2	2	2	1	1	1	1	1	1	1	1	1
	4	2	1	1	1	1	1	1	1	1	1	1	1
	5	1	1	1	1	1	1	1	1	1	1	1	1
	6	1	1	1	1	1	1	1	1	1	1	1	1
0.01	2	4	4	3	3	3	2	2	2	2	2	2	1
	3	3	2	2	2	2	1	2	1	1	1	1	1
	4	2	2	2	1	1	1	1	1	1	1	1	1
	5	2	1	2	1	1	1	1	1	1	1	1	1
	6	2	1	1	1	1	1	1	1	1	1	1	1

Table 2: Minimum number of groups (g_1 and g_2) for the two – stage group sampling plan with c_1 = 0 and c_2 = 2 when the lifetime of the items follows the generalized Rayleigh distribution

β	r	a											
		0.7		0.8		1.0		1.2		1.5		2.0	
0.25	2	4	3	2	2	2	1	1	1	1	1	1	1
	3	2	2	2	1	1	1	1	1	1	1	1	1
	4	2	1	1	1	1	1	1	1	1	1	1	1
	5	1	1	1	1	1	1	1	1	1	1	1	1
	6	1	1	1	1	1	1	1	1	1	1	1	1
0.10	2	4	4	3	3	2	2	2	2	1	1	1	1

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	3	3	3	2	2	2	1	1	1	1	1	1	1
	4	2	2	2	2	2	1	1	1	1	1	1	1
	5	2	2	2	1	1	1	1	1	1	1	1	1
	6	2	1	1	1	1	1	1	1	1	1	1	1
0.05	2	5	5	4	4	3	3	2	2	2	1	1	1
	3	4	3	3	3	2	2	2	1	1	1	1	1
	4	3	2	2	2	2	1	1	1	1	1	1	1
	5	2	2	2	1	1	1	1	1	1	1	1	1
	6	2	2	2	1	1	1	1	1	1	1	1	1
0.01	2	7	7	6	5	4	4	3	3	2	2	2	1
	3	5	5	4	4	3	2	2	2	2	1	1	1
	4	4	3	3	3	2	2	2	1	1	1	1	1
	5	3	3	2	2	2	1	1	1	1	1	1	1
	6	3	2	2	2	2	1	1	1	1	1	1	1

Table 3: Operating characteristic values of the group sampling plan for r = 3 using Inverse Rayleigh distribution

β	a	g_1	g_2	μ/μ_0					
				2	4	6	8	10	12
0.25	0.7	1	1	0.956750	1.000000	1.000000	1.000000	1.000000	1.000000
	0.8	1	1	0.870901	0.999999	1.000000	1.000000	1.000000	1.000000
	1.0	1	1	0.598855	0.999663	1.000000	1.000000	1.000000	1.000000
	1.2	1	1	0.349040	0.992766	0.999999	1.000000	1.000000	1.000000
	1.5	1	1	0.139982	0.920306	0.999663	1.000000	1.000000	1.000000
	2.0	1	1	0.032280	0.598855	0.973729	0.999663	0.999999	1.000000
0.10	0.7	2	1	0.922393	1.000000	1.000000	1.000000	1.000000	1.000000

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	0.8	2	1	0.787307	0.999998	1.000000	1.000000	1.000000	1.000000
	1.0	1	1	0.598855	0.999663	1.000000	1.000000	1.000000	1.000000
	1.2	1	1	0.349040	0.992766	0.999999	1.000000	1.000000	1.000000
	1.5	1	1	0.139982	0.920306	0.999663	1.000000	1.000000	1.000000
	2.0	1	1	0.032280	0.598855	0.973729	0.999663	0.999999	1.000000
0.05	0.7	2	2	0.861519	1.000000	1.000000	1.000000	1.000000	1.000000
	0.8	2	1	0.787307	0.999998	1.000000	1.000000	1.000000	1.000000
	1.0	1	1	0.598855	0.999663	1.000000	1.000000	1.000000	1.000000
	1.2	1	1	0.349040	0.992766	0.999999	1.000000	1.000000	1.000000
	1.5	1	1	0.139982	0.920306	0.999663	1.000000	1.000000	1.000000
	2.0	1	1	0.032280	0.598855	0.973729	0.999663	0.999999	1.000000
0.01	0.7	3	2	0.812890	1.000000	1.000000	1.000000	1.000000	1.000000
	0.8	2	2	0.653839	0.999996	1.000000	1.000000	1.000000	1.000000
	1.0	2	1	0.444211	0.999333	1.000000	1.000000	1.000000	1.000000
	1.2	2	1	0.207138	0.986144	0.999998	1.000000	1.000000	1.000000
	1.5	1	1	0.139982	0.920306	0.999663	1.000000	1.000000	1.000000
	2.0	1	1	0.032280	0.598855	0.973729	0.999663	0.999999	1.000000

Table 4: Operating characteristic values of the group sampling plan for r = 3 using Generalized Rayleigh distribution

β	a	g_1	g_2	μ/μ_0					
				2	4	6	8	10	12
0.25	0.7	2	2	0.806790	0.981917	0.996138	0.998744	0.999479	0.999747
	0.8	2	1	0.831435	0.984494	0.996698	0.998927	0.999555	0.999784

	1.0	1	1	0.798702	0.981155	0.995977	0.998692	0.999457	0.999736
	1.2	1	1	0.666616	0.963231	0.991883	0.997329	0.998886	0.999457
	1.5	1	1	0.448713	0.919633	0.981155	0.993662	0.997329	0.998692
	2.0	1	1	0.165313	0.798702	0.946497	0.981155	0.991883	0.995977
0.10	0.7	3	3	0.663406	0.962080	0.991583	0.997224	0.998841	0.999435
	0.8	2	2	0.718070	0.970437	0.993537	0.997880	0.999117	0.999570
	1.0	2	1	0.685629	0.964877	0.992208	0.997431	0.998927	0.999477
	1.2	1	1	0.666616	0.963231	0.991883	0.997329	0.998886	0.999457
	1.5	1	1	0.448713	0.919633	0.981155	0.993662	0.997329	0.998692
	2.0	1	1	0.165313	0.798702	0.946497	0.981155	0.991883	0.995977
0.05	0.7	4	3	0.601981	0.951156	0.988952	0.996332	0.998463	0.999250
	0.8	3	3	0.539699	0.939276	0.986048	0.995341	0.998043	0.999043
	1.0	2	2	0.517469	0.934753	0.984928	0.994958	0.997880	0.998963
	1.2	2	1	0.520309	0.933438	0.984494	0.994795	0.997809	0.998927
	1.5	1	1	0.448713	0.919633	0.981155	0.993662	0.997329	0.998692
	2.0	1	1	0.165313	0.798702	0.946497	0.981155	0.991883	0.995977
0.01	0.7	5	5	0.415666	0.908219	0.978045	0.992560	0.996853	0.998456
	0.8	4	4	0.392265	0.901274	0.976193	0.991909	0.996573	0.998317
	1.0	3	2	0.420891	0.908650	0.978100	0.992572	0.996857	0.998457
	1.2	2	2	0.327616	0.880109	0.970437	0.989870	0.995693	0.997880
	1.5	2	1	0.293898	0.861702	0.964877	0.987826	0.994795	0.997431
	2.0	1	1	0.165313	0.798702	0.946497	0.981155	0.991883	0.995977

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