Chapter 6
Repetitive Group Sampling Plan for Truncated Life Test

In this chapter, a repetitive group acceptance sampling plan is proposed for a truncated life test when the lifetime of an item follows different distributions. The minimum sample size required 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.

The reputation of companies depends upon the high reliability of their products. Recently, different companies compete with each other on the basis of quality and reliability. Consumer prefers those items. Inspection of the final product is very important to set the reliability or lifetime of the product. Even if advanced machinery is available to produce high quality product, without proper inspection it is almost not possible to set the standard of the quality. For example, during the coin manufacturing, after strict inspection, coins are sent to banks. In the lot, if few coins are not according to the standard, the complete lot of coins is discarded. Inspection of the item is done on the basis of few items selected from the lot of the product. So, producers and consumers risks are always there. The researchers are trying to propose various types of acceptance sampling plans to minimize these risks. Repetitive group sampling plan is not very common in life tests. This chapter deals with repetitive group sampling plan for life time distributions which is very effective in reducing the sample size. Sherman [68] was the first to propose the repetitive group sampling plan and Muhammad Aslam et. al., [46] proposed the repetitive group sampling for time truncated life tests for Burr type XII distribution to calculate the minimum number of groups for predetermined testers.

Conditions for its application
Repetitive group sampling plan comes under special purpose plans. It is intermediate in sample size efficiency between the single sampling plan and sequential probability ratio test plan. It has certain conditions for its application.
1. The size of the lot is taken to be sufficiently large.
2. Under normal conditions, the lots are expected to be of eventually the same quality.
3. The product comes from a source in which the consumer has confidence.

Operating Procedure for Repetitive Group Sampling Plan for Truncated Life Test

The operating procedure for a repetitive group sampling plan for truncated life tests, given by Muhammad Aslam [46] is as follows:

1. Select the number of groups $g$ and allocate predefined $r$ items to each groups so that the sample size for a lot will be $n= rg$.
2. Accept the lot if the number of failures, $d$ is smaller than or equal to $c_1$ in every group, before time $t_0$. Truncate the test and reject the lot of the product as soon as the number of failures, $d$, from a group exceeds $c_2$, (where $c_2 \geq c_1$), before time $t_0$.
3. If the number of failures, $d$, with $c_1 < d \leq c_2$, for every group, then go to step 1 and repeat the experiment.

The following is the operating procedure for two – stage group acceptance sampling plan for life test in the form of a flow chart.
The repetitive group sampling for truncated life test is characterized by three parameters $c_1$, $c_2$ and $g$. The probability of acceptance for the repetitive group sampling plan is given by
Here \( p_a \) and \( p_r \) are binomial model. We have used binomial model to determine the sample size.

In case of binomial distribution (6.1) becomes

\[
L(p) = \frac{p_a}{p_a + p_r} \quad ; \quad 0 < p < 1
\]  

(6.1)

\[
L(p) = \frac{\sum_{i=0}^{c_1} \binom{n}{i} p^i (1 - p)^{n-i}}{1 - \sum_{i=0}^{c_2} \binom{n}{i} p^i (1 - p)^{n-i} + \sum_{i=0}^{c_1} \binom{n}{i} p^i (1 - p)^{n-i}}
\]

(6.2)

Here in (6.1) \( p_a \) and \( p_r \) are

\[
p_a = \sum_{i=0}^{c_1} \binom{n}{i} p^i (1 - p)^{n-i}
\]

and

\[
p_r = 1 - \sum_{i=0}^{c_2} \binom{n}{i} p^i (1 - p)^{n-i}
\]

where \( p \) is the failure probability. These failure probabilities are the cumulative distribution function of the life time distributions. The following are the life time distributions used in this chapter to determine the sample size with the help of repetitive group sampling plan.

**Lomax distribution**

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

\[
F(t / \sigma) = 1 - (1 + t / \sigma)^{-\lambda}
\]

(6.3)

where \( \sigma \) is a scale parameter and \( \lambda \) is the shape parameter and it is fixed as 2.
**Burr XII distribution**

The cumulative distribution function (cdf) of the Burr XII distribution is given by

\[
F(t / \sigma) = 1 - \left(1 + \left(\frac{t}{\sigma}\right)^{\gamma}\right)^{-\lambda}
\]  

(6.4)

where $\sigma$ is a scale parameter and $\lambda$ and $\gamma$ are the shape parameters and it is fixed as 2.

**Exponential distribution**

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

\[
F(t / \sigma) = 1 - e^{-t/\sigma}
\]  

(6.5)

where $\sigma$ is a scale parameter.

**Generalized Exponential Distribution**

The cumulative distribution function (cdf) of the generalized exponential distribution is given by

\[
F(t, \sigma) = \left(1 - e^{-t/\sigma}\right)^{\lambda}
\]  

(6.6)

where $\sigma$ is a scale parameter and $\lambda$ is the shape parameter and it is fixed as 2.

**Marshall – Olkin extended Lomax distribution**

The cumulative distribution function (cdf) of the Marshall – Olkin extended Lomax distribution is given by

\[
F(t, \sigma) = \frac{(1 + t/\sigma)^{\theta} - 1}{(1 + t/\sigma)^{\theta} - \gamma}, \gamma = 1 - \gamma
\]  

(6.7)
where $\sigma$ is a scale parameter and $\gamma, \theta$ are the shape parameters and they are fixed as 2.

**Marshall–Olkin extended exponential distribution**

The cumulative distribution function (cdf) of the Marshall–Olkin extended exponential distribution is given by

$$
F(t, \sigma) = \frac{1 - e^{-t/\sigma}}{1 - \tilde{\gamma}e^{-t/\sigma}}, \text{ where } \tilde{\gamma} = 1 - \gamma
$$

(6.8)

where $\sigma$ is a scale parameter and $\gamma$ is the shape parameter and it is fixed as 2.

**Weibull Distribution**

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

$$
F(t / \sigma) = 1 - e^{-\left(\frac{t}{\sigma}\right)^\lambda}
$$

(6.9)

where $\sigma$ is a scale parameter and $\lambda$ is the shape parameter and it is fixed as 2.

**Exponentiated Weibull Distribution**

The cumulative distribution function (cdf) of the exponentiated Weibull distribution is given by

$$
F(t, \sigma) = \left[1 - e^{-\left(\frac{t}{\sigma}\right)^m}\right]^\lambda
$$

(6.10)

where $\sigma$ is a scale parameter and $\lambda, m$ are the shape parameters and they are fixed as 2.

**Log–Logistic distribution**

The cumulative distribution function (cdf) of the Log–Logistic distribution is given by
where $\sigma$ is a scale parameter and $\lambda$ is the shape parameter.

**Exponentiated Log – Logistic Distribution**

The cumulative distribution function (cdf) of the exponentiated Log – Logistic distribution is given by

$$F(t, \sigma) = \left( \frac{t}{\sigma} \right)^{\lambda} \right]^{\lambda} \right)$$

(6.11)

where $\sigma$ is a scale parameter and $\lambda$ is the shape parameter.

**Rayleigh distribution**

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

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

(6.13)

where $\sigma$ is a scale parameter.

**Inverse Rayleigh Distribution**

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

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

(6.14)
where $\sigma$ is a scale parameter.

By fixing the time $t_0$ as 0.628, 0.912, 1.257, 1.571, 2.356, 3.141, 3.927 and 4.712, the consumer’s risk $\beta$ as 0.25, 0.10, 0.05, and 0.01 and the mean ratios $\sigma/\sigma_0 = 2, 4, 6, 8, 10$ and 12, one can find sample size $n$ by fixing the shape parameters as 2, substituting the failure probability at worst case in the equation (6.2) and using the following inequality.

$$L(p_0) \leq \beta$$  \hspace{1cm} (6.15)

where $p_0$ is the failure probability at $\sigma = \sigma_0$.

The sample size generated using repetitive group sampling plan for the above cited lifetime distributions are presented in the Table 6.1, Table 6.2, Table 6.3, Table 6.4, Table 6.5, Table 6.6, Table 6.7, Table 6.8, Table 6.9, Table 6.10, Table 6.11 and Table 6.12 respectively.

The probability of acceptance are obtained by fixing the time termination ratio $t/\sigma_0$ as 0.628, 0.912, 1.257, 1.571, 2.356, 3.141, 3.927 and 4.712 and the mean ratios, $\sigma/\sigma_0 = 2, 4, 6, 8, 10$ and 12 and using the above cited lifetime distributions in the equation (6.2) and are presented in the Table 6.13, Table 6.14, Table 6.15, Table 6.16, Table 6.17, Table 6.18, Table 6.19, Table 6.20, Table 6.21, Table 6.22, Table 6.23 and Table 6.24 respectively.
Table 6.1: Minimum sample size $n$ for RGS plan when the lifetime of the items follows the Lomax distribution

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Table 6.2: Minimum sample size $n$ for RGS plan when the lifetime of the items follows the Burr XII distribution

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Table 6.3: Minimum sample size $n$ for RGS plan when the lifetime of the items follows the exponential distribution

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Table 6.4: Minimum sample size $n$ for RGS plan when the lifetime of the items follows the generalized exponential distribution

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**Table 6.6:** Minimum sample size \( n \) for RGS plan when the lifetime of the items follows the Marshall – Olkin extended exponential distribution

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Table 6.7: Minimum sample size $n$ for RGS plan when the lifetime of the items follows the Weibull distribution

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Table 6.8: Minimum sample size $n$ for RGS plan when the lifetime of an item follows the exponentiated Weibull distribution

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Table 6.12: Minimum sample size $n$ for RGS plan when the lifetime of the items follows the inverse Rayleigh distribution

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Table 6.13: Probability of acceptance for RGS plans with $c_1 = 0$ and $c_2 = 2$ when the lifetime of the items follows the Lomax distribution

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Table 6.14: Probability of acceptance for RGS plans with $c_1 = 0$ and $c_2 = 2$ when the lifetime of the items follows the Burr XII distribution

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Table 6.15: Probability of acceptance for RGS plans with $c_1 = 0$ and $c_2 = 2$ when the lifetime of the items follows the exponential distribution

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Table 6.16: Probability of acceptance for RGS plans with $c_1 = 0$ and $c_2 = 2$ when the lifetime of the items follows the generalized exponential distribution

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Table 6.17: Probability of acceptance for RGS plans with \( c_1 = 0 \) and \( c_2 = 2 \) when the lifetime of the items follows the Marshall – Olkin extended Lomax distribution

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Table 6.18: Probability of acceptance for RGS plans with $c_1 = 0$ and $c_2 = 2$ when the lifetime of the items follows the Marshall – Olkin extended exponential distribution

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Table 6.19: Probability of acceptance for RGS plans with $c_1 = 0$ and $c_2 = 2$ when the lifetime of the items follows the Weibull distribution

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Table 6.20: Probability of acceptance for RGS plans with \( c_1 = 0 \) and \( c_2 = 2 \) when the lifetime of the items follows the exponentiated Weibull distribution

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Table 6.24: Probability of acceptance for RGS plans with \( c_1 = 0 \) and \( c_2 = 2 \) when the lifetime of the items follows the inverse Rayleigh distribution

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Example 6.1

Assume that an experimenter wants to establish that the lifetime of the AC adapter produced in the factory ensures that the true unknown mean life is at least 1000 hours. It is desired to stop the experiment at 628 hours. It is assumed that \( c_1 = 0 \), \( c_2 = 2 \) and \( \beta = 0.25 \). Based on consumer’s risk values and the time termination ratio, the minimum sample size is determined using the repetitive group acceptance sampling plan for truncated life test. Following are the results obtained when the lifetime of the test items follows the Lomax distribution, Burr XII distribution, exponential distribution, generalized exponential distribution, Marshall – Olkin extended Lomax distribution, Marshall – Olkin extended exponential distribution, Weibull distribution, exponentiated Weibull distribution, log – logistic distribution, exponentiated log – logistic distribution, Rayleigh distribution and the inverse Rayleigh distribution, respectively.

Lomax distribution

Let the distribution followed be the Lomax distribution. When the acceptance number is predefined as \( c_1 = 0 \), \( c_2 = 2 \), the required \( n \) from Table 6.1 is 3. If, during 628 hours, no failures out of 3 are observed, then the experimenter can assert, with a confidence level of 0.75 that the average life is at least 1000 hours and if more than 2 failures occur, the lot is rejected and otherwise the experiment is repeated. For this distribution the probability of acceptance for \( c_1 = 0 \), \( c_2 = 2 \), \( \beta = 0.25 \) and \( \sigma/\sigma_0 = 2 \) will be 0.722752.

Burr XII distribution

Let the distribution followed be the Burr XII distribution. When the acceptance number is predefined as \( c_1 = 0 \), \( c_2 = 2 \), the required \( n \) from Table 6.2 is 4. If, during 628 hours, no failures out of 4 are observed, then the experimenter can assert, with a confidence level of 0.75 that the average life is at least 1000 hours and if more than 2 failures occur, the lot is rejected and otherwise the experiment is repeated. For this distribution the probability of acceptance for \( c_1 = 0 \), \( c_2 = 2 \), \( \beta = 0.25 \) and \( \sigma/\sigma_0 = 2 \) will be 0.964072.
**Exponential distribution**

Let the distribution followed be the exponential distribution. When the acceptance number is predefined as \( c_1 = 0, c_2 = 2 \), the required \( n \) from Table 6.3 is 4. If, during 628 hours, no failures out of 4 are observed, then the experimenter can assert, with a confidence level of 0.75 that the average life is at least 1000 hours and if more than 2 failures occurs, the lot is rejected and otherwise the experiment is repeated. For this distribution the probability of acceptance for \( c_1 = 0, c_2 = 2, \beta = 0.25 \) and \( \sigma/\sigma_0 = 2 \) will be 0.820135.

**Generalized exponential distribution**

Let the distribution followed be the generalized exponential distribution. When the acceptance number is predefined as \( c_1 = 0, c_2 = 2 \), the required \( n \) from Table 6.4 is 10. If, during 628 hours, no failures out of 10 are observed, then the experimenter can assert, with a confidence level of 0.75 that the average life is at least 1000 hours and if more than 2 failures occurs, the lot is rejected and otherwise the experiment is repeated. For this distribution the probability of acceptance for \( c_1 = 0, c_2 = 2, \beta = 0.25 \) and \( \sigma/\sigma_0 = 2 \) will be 0.937814.

**Marshall – Olkin extended Lomax distribution**

Let the distribution followed be the Marshall – Olkin extended Lomax distribution. When the acceptance number is predefined as \( c_1 = 0, c_2 = 2 \), the required \( n \) from Table 6.5 is 5. If, during 628 hours, no failures out of 5 are observed, then the experimenter can assert, with a confidence level of 0.75 that the average life is at least 1000 hours and if more than 2 failures occurs, the lot is rejected and otherwise the experiment is repeated. For this distribution the probability of acceptance for \( c_1 = 0, c_2 = 2, \beta = 0.25 \) and \( \sigma/\sigma_0 = 2 \) will be 0.635756.

**Marshall – Olkin extended exponential distribution**

Let the distribution followed be the Marshall – Olkin extended exponential distribution. When the acceptance number is predefined as \( c_1 = 0, c_2 = 2 \), the required \( n \) from Table 6.6 is 7. If, during 628 hours, no failures out of 7 are observed, then the
The experimenter can assert, with a confidence level of 0.75 that the average life is at least 1000 hours and if more than 2 failures occurs, the lot is rejected and otherwise the experiment is repeated. For this distribution the probability of acceptance for $c_1 = 0$, $c_2 = 2$, $\beta = 0.25$ and $\sigma/\sigma_0 = 2$ will be 0.790582.

**Weibull distribution**

Let the distribution followed be the Weibull distribution. When the acceptance number is predefined as $c_1 = 0$, $c_2 = 2$, the required $n$ from Table 6.7 is 6. If, during 628 hours, no failures out of 6 are observed, then the experimenter can assert, with a confidence level of 0.75 that the average life is at least 1000 hours and if more than 2 failures occurs, the lot is rejected and otherwise the experiment is repeated. For this distribution the probability of acceptance for $c_1 = 0$, $c_2 = 2$, $\beta = 0.25$ and $\sigma/\sigma_0 = 2$ will be 0.976511.

**Exponentiated Weibull distribution**

Let the distribution followed be the exponentiated Weibull distribution. When the acceptance number is predefined as $c_1 = 0$, $c_2 = 2$, the required $n$ from Table 6.8 is 20. If, during 628 hours, no failures out of 20 are observed, then the experimenter can assert, with a confidence level of 0.75 that the average life is at least 1000 hours and if more than 2 failures occurs, the lot is rejected and otherwise the experiment is repeated. For this distribution the probability of acceptance for $c_1 = 0$, $c_2 = 2$, $\beta = 0.25$ and $\sigma/\sigma_0 = 2$ will be 0.999167.

**Log – logistic distribution**

Let the distribution followed be the log – logistic distribution. When the acceptance number is predefined as $c_1 = 0$, $c_2 = 2$, the required $n$ from Table 6.9 is 7. If, during 628 hours, no failures out of 7 are observed, then the experimenter can assert, with a confidence level of 0.75 that the average life is at least 1000 hours and if more than 2 failures occurs, the lot is rejected and otherwise the experiment is repeated. For this distribution the probability of acceptance for $c_1 = 0$, $c_2 = 2$, $\beta = 0.25$ and $\sigma/\sigma_0 = 2$ will be 0.964268.
**Exponentiated log – logistic distribution**

Let the distribution followed be the exponentiated log – logistic distribution. When the acceptance number is predefined as $c_1 = 0$, $c_2 = 2$, the required $n$ from Table 6.10 is 26. If, during 628 hours, no failures out of 26 are observed, then the experimenter can assert, with a confidence level of 0.75 that the average life is at least 1000 hours and if more than 2 failures occurs, the lot is rejected and otherwise the experiment is repeated. For this distribution the probability of acceptance for $c_1 = 0$, $c_2 = 2$, $\beta = 0.25$ and $\sigma/\sigma_0 = 2$ will be 0.998543.

**Rayleigh distribution**

Let the distribution followed be the Rayleigh distribution. When the acceptance number is predefined as $c_1 = 0$, $c_2 = 2$, the required $n$ from Table 6.11 is 12. If, during 628 hours, no failures out of 12 are observed, then the experimenter can assert, with a confidence level of 0.75 that the average life is at least 1000 hours and if more than 2 failures occurs, the lot is rejected and otherwise the experiment is repeated. For this distribution the probability of acceptance for $c_1 = 0$, $c_2 = 2$, $\beta = 0.25$ and $\sigma/\sigma_0 = 2$ will be 0.969091.

**Inverse Rayleigh distribution**

Let the distribution followed be the inverse Rayleigh distribution. When the acceptance number is predefined as $c_1 = 0$, $c_2 = 2$, the required $n$ from Table 6.12 is 27. If, during 628 hours, no failures out of 27 are observed, then the experimenter can assert, with a confidence level of 0.75 that the average life is at least 1000 hours and if more than 2 failures occurs, the lot is rejected and otherwise the experiment is repeated. For this distribution the probability of acceptance for $c_1 = 0$, $c_2 = 2$, $\beta = 0.25$ and $\sigma/\sigma_0 = 2$ will be 1.
Table 6.25: Minimum sample size and the probability of acceptance for different lifetime distributions when $c_1 = 0$, $c_2 = 2$ and $\beta = 0.25$

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<td>Rayleigh</td>
<td>12</td>
<td>0.969091</td>
</tr>
<tr>
<td>Inverse Rayleigh</td>
<td>27</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

From all the above distributions one can see that that Burr XII distribution is comparatively better than the other life time distribution in case of sample sizes and the probability of acceptance ($n = 4$ and $L(p) = 0.964072$) when repetitive group sampling plan is used (from Tables 6.1 to 6.12).

It is observed that the sample size decreases as the time termination ratio increases. Moreover the operating characteristic values increases when the quality improves. This sampling plan can be suggested for the industrial purposes to save time and cost of the life test experiments.