

Design of Acceptance Sampling Plan as an Opportunity for Consumers' Risk Reduction

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Abstract— In every transaction, either in buying or selling, inspecting whether products comply with the describe standards is very essential. Since, hundred percent inspections are not recommended or it may not be practical, sampling a lot and deciding to accept or reject is a well-practiced approach. However, the accuracy of this method is highly dependent on the design of acceptance sampling plan. In acceptance sampling applications, there are two unavoidable risks. One is the risk of rejecting a good lot, called the producer's risk (α), and the other is the risk of accepting a bad lot called the consumer's risk (β). Both the producer and the consumer focus on particular points on the operating characteristics (OC) curve to reflect their interests. The aim of this study is to reduce the consumer's risk (β) through the design of acceptance sampling plan. Addis Ababa Bottle and Glass Share Company (AABGSCo), the oldest glass bottle producer Ethiopian manufacturing industry, is selected and studied to demonstrate the impact of acceptance sampling plan on the consumers' risk for two products, liquor and hair oil bottles. As a result, the consumers' risk for existing sampling plan is found to be 72.6% for both liquor and hair oil bottles, and after the implementation of a new acceptance sampling plan it was reduced to 4% and 0.6% respectively, which implies significant reductions.

Index Terms— Acceptance sampling, Consumer's risk, Ethiopia, OC-Curve,

1 INTRODUCTION

Acceptance sampling is a common practice to ensure the quality of products that producers would like to sell and/or consumers would like to buy. However, acceptance sampling involves determining the sample size and the acceptance criteria on which a lot is accepted or rejected. Acceptance sampling procedures are most useful in the case of destructive tests or when inspection is quite costly [1]. It is a middle ground between the extremes of hundred percent inspections and no inspection. It often provides a methodology to move between these extremes as sufficient information is obtained on the control of the manufacturing process that produces the product. It also provides for an accumulation of quality history regarding the process that produces the lot, and it may provide feedback that is useful in process control at the vendor's plant. In addition, it may place economic or psychological pressure on the vendor to improve the production process [10].

In Ethiopia, it is also common to check the quality of products before selling by producers and while purchasing by customers. Some of them have their own laboratory facility to inspect incoming or outgoing products, while some others use public, private and/or research laboratories. The main problem in Ethiopia manufacturing industries are too much consumers' risk. In fact, producers may sell even those products considered as bad lot. On the contrary, it is true in the case of customers. In the sampling process, whether the producer or the consumer takes samples and then it will be tested and the conformances of the products are approved (the customers would decide to accept the lot). Just after the decision, the customers' often will find nonconformance of many products within the lot. The buyers' try to do their best to minimize the acceptance of lots with defects, but they fail to practically achieve their objective. The hypothesis of this research is that the customers' accept a lot with too much defect while a sample is inspected and approved because of the sampling design. To examine and proof the current sampling practice in Ethio-

pian manufacturing industry, Addis Ababa Bottle and Glass Share Company was selected and studied as a case. Therefore, the aim of this study is to study the sampling methods adopted in one of the Ethiopian manufacturing industries and then to propose a new sampling method that possibly minimizes the risk of accepting bad lot by the customers. The remaining part of the study includes methodology, literature review, case study, performance measurement, design of new acceptance sampling plan and finally conclusion.

2 LITERATURE REVIEW

Acceptance sampling is a codified standard for procurement and contractual performance specifications in industry [6]. Originally, acceptance sampling method is the work of Dodge and Romig at Bell Labs in the 1930s. The methodology gained wide recognition during World War II, when applied by the U.S. military to test bullets. Later extensions were incorporated in a series of Military Standards. Military Standard 105D was issued by the U.S. government in 1963, adopted in 1971 by the American National Standards Institute as ANSI Standard Z1.4, and also adopted (with minor changes) in 1974 by the International Organization for Standardization as ISO Std. 2859. The last revision, MIL-STD-105E, was issued in 1989. These similar standards are continuously being updated and revised, but the underlying concepts remained the same. The basic mathematics and methods of acceptance sampling were covered in many standard works on statistical quality control such as Grant and Leavenworth (1988) [5], Juran and Gryna (1993) [7] and Montgomery (2005) [8]. Software to support acceptance by attributes, such as: the Reliability Test Planner (RTP) was also developed by Pryor in 2007 for the U.S. Army [6].

Currently, quality theory stresses prevention rather than detection of defects. Accordingly, Total Quality Management (TQM) tools have been emphasized while acceptance sam-

pling has been de-emphasized. Yet there is still a recognized role for acceptance sampling. Montgomery (2005) [8] suggested that acceptance sampling can improve upstream production quality, indirectly, when applied against a vendor consistently and over a long period of time. DeVore (2008)[4] also pointed out that, it can be used by firms to monitor the quality of raw materials, components and finished products. Smith et al., (2003) [11] advocated the application of acceptance sampling in the context of water quality assessment. Their objective was to determine whether stream segments should be listed as conforming or not conforming to water quality standards based on sample data. Creasey et al., (2006) [3], recognized that acceptance sampling provides a well-established, consistent, and statistically valid approach to understand sampling error and prescribe acceptable risk tolerances that apply equally well to any stochastic sampling experiment. Recently, there are also many researches in the area of acceptance sampling such as: (Belmiro and Pedro 2010 [2]; Wichai, 2013 [12]; Muhammad et al., 2011 [9]; Amin and Salem, 2012 [1]).

Though acceptance sampling theory is well explored worldwide, there is limited practice as well as researches in designing acceptance sampling plan in Ethiopia. This study, therefore, will help to explore the challenges and the risks of the consumers due to inappropriate sampling. Moreover, it will give guidelines on how to design acceptance sampling plan for day-to-day application in Ethiopian industries.

3 METHODOLOGY

To achieve the objective of this study, primarily a case company was selected. The selection is made because of three reasons: first availability of sampling procedure, second, availability of historical data and third the readiness of the company to provide the necessary information to conduct the research. Based on these factors, Addis Ababa Bottle and Glass Share Company (AABGSCo) was selected as a case study. The authors observed the case company for one month (three days in a week) to collect the necessary data and understand the cause and effect in the sampling process, especially to the customers. The authors also closely worked with Quality Assurance Department of the company to obtain its daily inspection reports. Before the analysis, the data were compared and cross checked for its reliability. Then the performance of AABGSCo sampling plan was measured by using an Operating Characteristics (OC) curve. As seen in Figure 1, OC is created by plotting the Percent defective (P) versus the matching Probabilities of acceptance (P_a). In acceptance sampling plan, the vendor (supplier) would usually focus on a specific product quality level, called AQL (Acceptable Quality Level). The AQL also represents the maximum percent nonconforming in a lot that can be considered satisfactory as a process average. While, the buyer (consumer) would focus on a point at the other end of the OC curve, called LTPD (Lot Tolerance Percent Defective). The LTPD is the poorest quality level that the consumer is willing to accept. The producer and the customer must reach an agreement with the values of AQL, LTPD, α , and β . They may be determined by customers, special studies, or past experience.

From literatures, the most common values to use for α and β are 0.05 and 0.10 respectively.

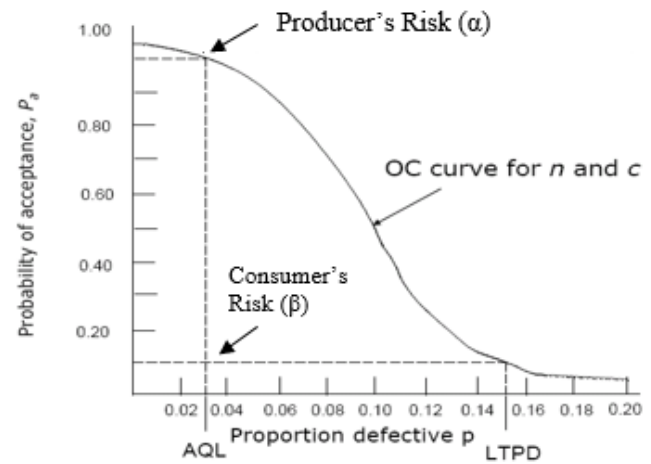


Fig 1 Operating Characteristics (OC) curves

4 CASE STUDY

AABGSCo, the case study is located in Addis Ababa, the capital city of Ethiopia. The company is the older manufacturer and the main supplier of glass. The company produces different ranges of bottles, glass containers and tumblers such as bottles for soft drinks, beer, alcohol and liquor, hair oil, wine, mineral water, glass containers like jam jars and squash bottles for horticultural products, and tumblers of different sizes and designs for households and commercial purposes. The bottle types vary depending on their weight, size and shape. This study only deals with liquor bottles and hair oil bottles. The products general production information is described in Table 1 and Table 2.

The company controls the quality of the manufactured lots using partial inspection method. Before passing into the stock of finished goods, every piece of product undergoes different quality checkups including visual test (i.e. ovality test, color test, cracks test; etc.) and physical measurements (i.e. verticality of containers, uniformity of stress relieving, internal pressure resistance, thermal shock resistance, weight and capacity limits; etc.). For both visual and physical inspection, the operator takes eight samples (two bottles from each mold) to the laboratory every hour. For example, in case of liquor bottles and hair oil bottles, the factory produces approximately 883 bottles and 2,640 bottles per hour respectively, in each case the operator takes eight samples for inspection. Past data demonstrated that, the Quality Assurance Department took approximately 192 samples per month, but on average there are 9.433 defects per day (see Table 3). The company, practically does not reject when it finds defective products; rather it tries to improve the process and hence the probability of sending defective products to customers is very high. Though, the company never missed to inspect the eight samples every hour from each mold, there are high level of complains from the major customers of the company. Some of the customers even

withdraw their partnership and started importing bottles from other countries.

TABLE 1
LIQUOR BOTTLES GENERAL PRODUCTION INFORMATION

Liquor bottles						
Furnace Melting Point	Machine Efficiency	Gob	Average Weight	Production	Scrap	Net Production
22 tons/day	80%	Single Gob	610g	1,104 bottle/hr	20%	883 bottles/hr

TABLE 2
HAIR OIL BOTTLES GENERAL PRODUCTION INFORMATION

Liquor bottles						
Furnace Melting Point	Machine Efficiency	Gob	Average Weight	Production	Scrap	Net Production
22 tons/day	92%	Double gob	294g	2,870 bottle/hr	8%	2,640 bottles/hr

TABLE 3
DEFECTIVES BOTTLES PER DAY

Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Defective	6	3	11	6	9	4	4	6	5	6	8	2	4	4	10
Days	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Defective	21	4	9	7	9	6	7	19	11	18	10	37	20	0	17

5 PERFORMANCE OF ACCEPTANCE SAMPLING PLAN IN AABGSCO

Based on the Operating Characteristics (OC) curve, probability distribution of the existing sampling method is computed and presented graphically. Hyper-geometric distribution, Binomial distribution and Poisson distribution are probability distributions that can be commonly used to find the probability of acceptance. Since Poisson distribution is the most popular, in this study it is used to compute acceptance sampling plan in AABGSCO. The shape of an OC-curve is determined primarily by sample size (n) and acceptance number (c), although there is a small effect of lot size (N). Probability of acceptance can be computed by the following Poisson's Distribution equation.

$$P(x) = \frac{e^{-np}(np)^c}{c!}$$

Where n= sample size
c=acceptance number
p=percentage of defectives

ABGSCO uses single sampling plan. As discussed above, for all product types that produced in an hour the company uses fixed number of sample size (i.e n=8). There is no defined acceptance number (c) for each product. For the purpose of our calculation purpose we assumed c=0. The inspector checked a sample of 8 liquor and hair oil bottles in an hour and if numbers of bottles defectives are less than c (i.e. c = 0), then the inspector accepts the lot, but if it is more than (c = 0, 1, 2, 3 ...), the lot is rejected. To illustrate the existing sample plan using OC-curve, we selected liquor and hair oil bottles produced in an hour (Fig.2) which consists of a lot size (N), 883 products for liquor bottles and 2,640 products for hair oil bottles. Assume the percentage of defectives (P) in a lot as 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9% and 10%. Then, calculate probability of acceptance (Pa) for each percentage of defectives (P) using the Poisson's distribution equation mentioned above.

The result shows that, for both products, if LTPD is equal to 4%, the corresponding consumer's risk (β) will be 72.6%. From the literatures, the common value of consumer's risk (β) is not more than 10%. Therefore, consumer's risk in AABGSCO is too large with the existing sampling plan. This problem is apparent because of the following reasons: (1)there is no agreement between the company and customers on AQL, LTPD, the sampling plan to be used and their mutual obligations, (2) the number of sample bottles does not represent number of production and (3) there is no defined acceptance number (c) for each product. If these problems are not going to be solved by designing appropriate acceptance sampling plan and implementing it, then the survival of the business will be in doubt due to high level of customers' dissatisfaction.

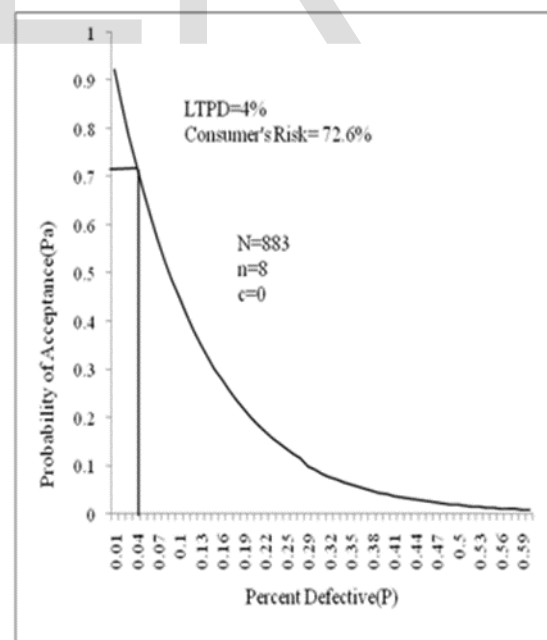


Fig 2 OC curve for existing sampling plan for liquor bottle and hair oil bottles

6 DESIGN OF ACCEPTANCE SAMPLING PLAN FOR AABGSCo

According to Montgomery (2005), the selection of acceptance sampling plan depends on both the objective and the history of an organization. If the objective of an organization is related to assuring quality levels for consumer/producer and maintaining quality at a target, the company can use MIL STD 105E tables and illustrate the sampling plan using OC-Curve. Accordingly, the main objective of ABGSCO is providing the beverage sector, the cosmetic industries, Agro industrial complexes and pharmaceuticals with high quality and suitable glass containers. Military standard 105E is one of the sampling schemes most widely used in industry. The sampling plans contained in the military standard are arranged very conveniently and are very easy to select and apply. The standards' ease of use and its widespread acceptance among manufacturers in turn account for its use in contrast between private buyers and sellers.

The procedure for MIL STD 105E acceptance sampling are:

1. There must be an agreement between the company and customers on AQL, LIPD, α , and β
2. Decide on the inspection level
3. Decide on sample size code letter from Table 4 (See Appendix A)
4. Decide on type of sampling to be used (Single, Double, Multiple)
5. Select proper table to find the plan to be used (Refer Table 5, Table 6, Table 7 from Appendix A)
6. Begin with normal inspection; follow the switching rules and the rule for stopping the inspection (if needed) (See figure 3 from Appendix A)

Before implementing the procedure, we have to make some assumptions. As discussed above, the company uses single sampling plan. General inspection level II is used in the proposed sampling plan, because, in ABGSCO there is no specified inspection level. Unless otherwise specified, inspection level II is used. Depending upon the situation the company will shift from level II to I or from II to III. Master table for Normal inspection is used for the proposed plan, because sampling starts from normal inspection. For further explanation see Appendix A.

Based on the new approach, the OC curve is constructed and compared with the traditional way of doing the acceptance sampling plan. The lot size (N) is the same-883 products (liquor bottles) and 2,640 products (hair oil bottles). LTPD is assumed to be 4%. For a lot size of this amount, sample size would be 80 and 125 bottles for liquor and hair oil bottles respectively. Table 4(see appendix A) indicates that the appropriate sample code letter is J for liquor bottles and K for hair oil bottles. Using this result, from Military Standard 105E master table (see table5 on Appendix A), the sample size and the acceptance number are identified for different AQL. Acceptance number (c) is considered to be zero. Now, with the new acceptance sampling, draw an OC-curve by assuming the percentage of defectives (P) in a lot as 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9% and 10%. Finally, calculation of probability of acceptance (Pa) for above percentage of defectives (P) in a simi-

lar fashion (See Fig 3 for liquor bottles and Fig 4 for hair oil bottles) has been done. The result clearly showed that the proposed sampling plan reduced the Consumer's risk (β) down to 4% (liquor bottles) and 0.6% (hair oil bottles) for a constant LTPD of 4%. Hence, when the consumers' risk is compared a significant amount of reduction has been observed that from 72.6% to 4% (liquor bottles) and 72.6% to 0.6% (hair oil bottles).

This means implementing the proposed sampling plan helps ABGSCO to identify the suitable sample size (n) and acceptance number (c) for each product lot size (N). It also provides an accumulation of quality history regarding the production process and feedback that may be useful in process control. It may place economic or psychological pressure on the company to improve the production process. Generally, by improving the existing sampling plan the company can increase the quality of its products and create relations with its customers.

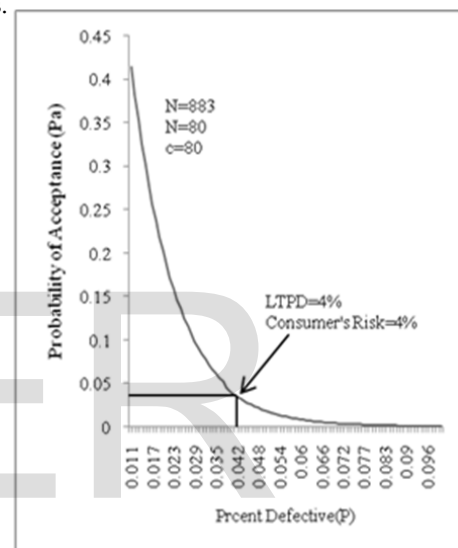


Fig 3 OC-curve for proposed sampling plan for liquor bottle

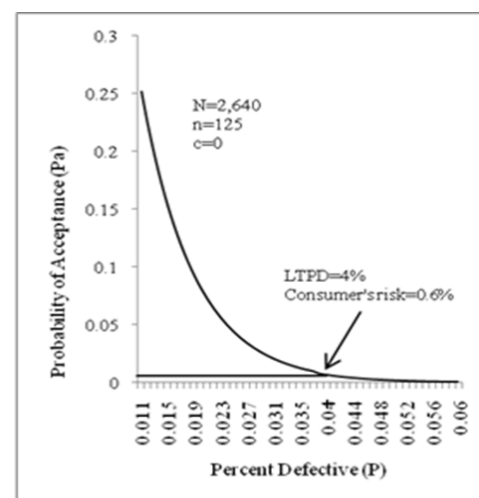


Fig 4 OC-curve for proposed sampling plan for hair oil bottles

7 CONCLUSION

In Ethiopia, though customers/producers often test sample products to check the conformity of a lot with the standards of the customers, customers' often have very high probability of accepting a bad lot. The research, initially, assumed that consumer's risk was very high because of the acceptance sampling plan. Based on this, the aim of the study was to design acceptance sampling plan that can reduce customers' risk by taking AABGSCo as a case study. The existing sampling plan performance of the company showed that the customers' risk may run up to 72.6% for 4% of LTPD. On the other hand, by using Military Standard 105E a new acceptance sampling plan was designed and the performance was measured in a similar way. The result showed a reduction of customers risk down to 4% and 0.6% for same value of LTPD. This proves that if the producers and consumers work together to design and decide acceptance sampling plan, then consumers' risk will be significantly reduced. Moreover, since zero defect is becoming the order of the day, manufacturers should strive to achieve this objective to win the global competition. However, this research revealed the fact that there is sampling problem in AABGSCo and hence more research should be undertaken by taking representative samples from the manufacturing industries. In addition, future research could also be conducted in the importing processes and the operating mechanisms of laboratories in the country where the decision they make will have negative consequences in the national development effort.

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APPENDIX A: GLOSSARY USED IN MILITARY STANDARD 105E/ANSI/ASQC Z1.4/

8.1 Inspection Levels

Three general and four special inspection levels are provided. The general inspection levels (I to III) are commonly used for non-destructive inspection. Normal Inspection (level II) is used at the start of the inspection activity. Tightened Inspection (level III) is instituted when the vendor's recent quality history has deteriorated. Acceptance requirements for lots under tightened inspection (Level I) are more stringent than under normal inspection. Reduced inspection is instituted when the vendor's recent quality history has been exceptionally good. The sample size generally used under reduced inspection is less than that under Normal inspection. Special Levels S-1, S-2, S-3 and S-4 may be used where relatively small sample sizes are necessary or large sampling risks can be taken. Examples of this are inspections involving destructive or costly (time consuming) type inspection, or where large lots are involved, small sample sizes are desired and large risks can be tolerated such as repetitive processes (screw machine, stamping, bolting operations, etc.) performed by a quality supplier. Larger sample sizes are for inspection levels increasing from S-1 to S-4.

In early negotiations between a buyer and a seller it is expected an agreement will be reached as to which level of inspection is appropriate. If there is no specified inspection level, unless otherwise specified, inspection level II will be used. Depending up on the situation the company will shift from level II to I or from II to III.

8.2 Master Tables

In Mil Standard 105E/ANSI/ASQC Z1.4/, there are master tables for normal (Table 5), tightened (Table 6) and reduced (Table 7) inspection for single sampling plans. Mil Standard 105E/ANSI/ASQC Z1.4/ contains similar master tables for double and multiple sampling plans. These tables used to identify the accepted and rejected defective numbers.

8.3 Switching Rules

Generally, sampling starts with normal inspection (general inspection level II—Table 5). When 2 out of 5 consecutive lots are not accepted, a switch is made to tightened inspection (Table 6). Tightened inspection requires a larger sample size and uses a smaller acceptance number. This brings the OC curve closer to the ideal shape. Normal inspection may resume when 5 consecutive lots are accepted under tightened inspection. Should 10 consecutive lots remain on tightened inspection (i.e. no 5 consecutive lots are accepted in the first 10 lots inspected under tightened inspection), sampling under MIL STD 105E

should be discontinued.

A switch is often made from normal to reduced inspection (Table 7) when 10 consecutive lots are accepted under normal inspection, production is steady, and the switch is approved by the responsible authority (See Fig 5).

TABLE 4
SAMPLE SIZE CODE LETTERS (MIL STD 105E/ ANSI/ASQC Z1.4/)

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 151	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 to over	D	E	H	K	N	Q	R

TABLE 5
SINGLE SAMPLING PLANS FOR NORMAL INSPECTION (MASTER TABLE)

↓=use the first sampling plan below the arrow. If sample size equals or exceeds lot size carry out 100% inspection
 ↑= use the first sampling plan above the arrow
 Ac=Acceptance number
 Re= Rejection number

[illegible]

↓=use the first sampling plan below the arrow. If sample size equals or exceeds lot size carry out 100% inspection
 ↑= use the first sampling plan above the arrow
 Ac=Acceptance number
 Re= Rejection number

TABLE 7
SINGLE SAMPLING PLANS FOR REDUCED INSPECTION (MASTER TABLE)

Sample size code letter	sample size	Acceptance Quality Limits (Reduced Inspection)																																			
		0.01	0.015	0.025	0.04	0.065	0.1	0.15	0.25	0.4	0.65	1	1.5	2.5	4	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		
A	2															0	1			1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	30	31
B	3															0	1			1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	30	31
C	5															0	1			1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	30	31
D	8															0	1			1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	30	31
E	13															0	1			1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	30	31
F	20															0	1			1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	30	31
G	32															0	1			1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	30	31
H	50															0	1			1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	30	31
I	80															0	1			1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	30	31
J	125															0	1			1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	30	31
K	200															0	1			1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	30	31
L	315															0	1			1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	30	31
M	500															0	1			1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	30	31
N	800															0	1			1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	30	31
P																																					
Q																																					
R																																					

↓=use the first sampling plan below the arrow. If sample size equals or exceeds lot size carry out 100% inspection
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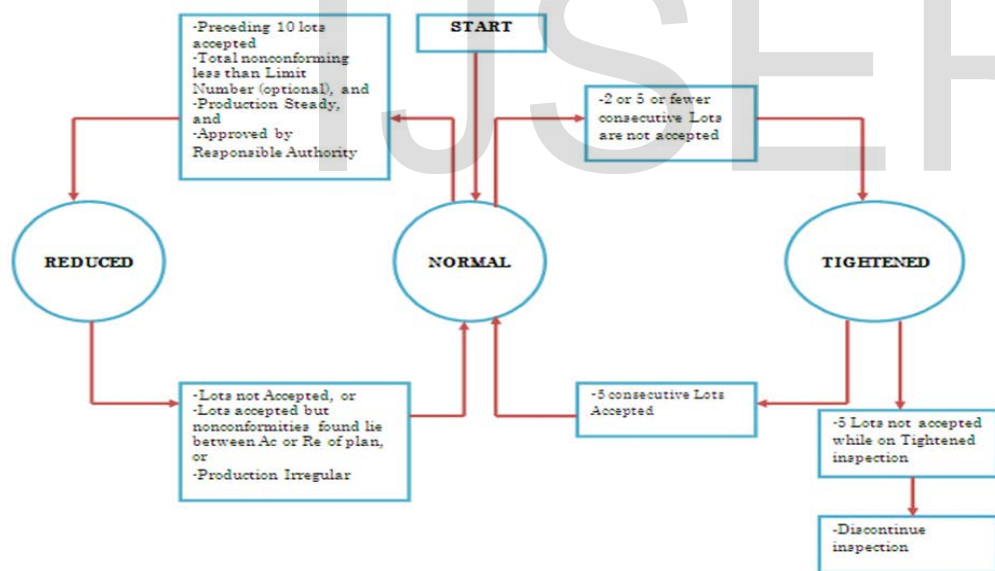


Fig 5, Switching Rules