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Acceptance Sampling Using Statgraphics Centurion

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Acceptance Sampling

 Given a lot or batch containing N items, a decision to accept or reject the lot is made based on statistical sampling.



 In Statgraphics, the acceptance sampling procedures are contained under SPC on the main menu.



Outline

- OC/AOQL/LTPD plans
- ANSI Z1.4/Z1.9 standards (formerly MIL-STD-105E and MIL-STD-414)
- MIL-STD-1916
- Sequential sampling



Types of Acceptance Sampling

 Attribute sampling – Select items from the lot and inspect them. Based on their attributes, classify each item as acceptable or unacceptable. The acceptability of the lot is based on the proportion of unacceptable items.

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 Variable sampling – Select items from the lot and measure them. Calculate the mean and standard deviation of the measurements. The acceptability of the lot is based on how close the mean is to the specification limits.



Sampling Methods

 Single sampling – Inspect or measure n randomly sampled items. Accept or reject the lot based on that one sample.

 Double/multiple sampling – Inspect or measure n randomly sampled items. Accept or reject the lot based on the first sample if the results are very good or very bad. Otherwise take an additional sample. Accept or reject the lot based on the combined samples (or take a third sample).



Sampling Methods

- 3. Continuous sampling Inspect or measure items continuously sampled from the lot. The sample results affect the frequency of sampling.
- 4. Sequential sampling Inspect or measure randomly selected items one at a time. After each item, accept the lot, reject it, or select another item.



Example #1: Single Sampling Plan for Attributes

- 1. Take a sample of size *n* from a lot containing *N* items and inspect each item.
- 2. Let X = number of nonconforming items.
- 3. If $X \le c$, accept the lot. (*c* is called the *acceptance number*.)
- 4. If X > c, reject the lot.

Rejected lots are either returned for rework or "rectified" using 100% inspection.



Data Input Dialog Box

	Acceptance	Sampling - Attributes	×
	Action	Quality Levels	
A Stanson	 Create OC plan 	Acceptable quality level (AQL):	
00	C Create AOQL plan	1 %	
	C Create LTPD plan	Lot tolerance percent defective (LTPD):	
1000	C Analyze existing plan	3 %	
	Lot size: 5000		
100 S	Desired Features	Current Plan	10 ¹
	Producer's risk (alpha):	Sample size (n):	
	5.0 %		20.000
	Consumer's risk (beta):	Acceptance number (c):	
	10.0 %		
	ОК	Cancel Help	6
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	statgr	aphics.com Centurion	

3 Types of Plans

Type of plan	Input #1	Input #2
OC plan	Producer's risk (alpha) at the AQL	Consumer's risk (beta) at the LTPD

AQL = Acceptable Quality Level or Acceptance Quality Limit (the poorest level of quality that the consumer finds acceptable on average.)

LTPD = Lot Tolerance Percent Defective (the poorest level of quality that the consumer is willing to tolerate in any given lot.)



Operating Characteristic (OC) Curve





Average Outgoing Quality (AOQ)





Average Total Inspection (ATI)





3 Types of Plans

Type of plan	Input #1	Input #2
OC plan	Producer's risk (alpha) at the AQL	Consumer's risk (beta) at the LTPD
AOQL plan	Percent defective at which inspection is minimized (process average)	Average outgoing quality limit

AOQL – Average Outgoing Quality Limit (maximum average percent of nonconforming items over all incoming quality levels.)



3 Types of Plans

Type of plan	Input #1	Input #2
OC plan	Producer's risk (alpha) at the AQL	Consumer's risk (beta) at the LTPD
AOQL plan	Percent defective at which inspection is minimized (process average)	Average outgoing quality limit
LTPD plan	Percent defective at which inspection is minimized (process average)	Consumer's risk (beta) at the LTPD

LTPD = Lot Tolerance Percent Defective (the poorest level of quality that the consumer is willing to tolerate in any given lot.)



Example #2: Single Sampling Plan for Variables

- 1. Take a sample of size *n* from the lot of *N* items.
- 2. Measure each item and calculate the sample mean \overline{x} and the sample standard deviation s.
- 3. Calculate Z scores for each specification limit:

$$Z_L = \frac{\bar{X} - LSL}{S}$$
 and $Z_U = \frac{USL - \bar{X}}{S}$

- 4. If both $Z \ge k$, accept the lot. (k = critical value)
- 5. If either Z < k, reject the lot.

Rejected lots are either returned for rework or "rectified".



Data Input Dialog Box

Action Quality Levels
Create OC plan Acceptable quality level (AQL):
C Create AOQL plan
C Create LTPD plan Lot tolerance percent defective (LTPD):
C Analyze existing plan
Lot size: O Assume known value
5000
Use sample estimate
Desired Features Current Plan
Producer's risk (alpha): Sample size (n): 5.0 %
Consumer's risk (beta): Critical distance (k):
OK Cancel Help



Operating Characteristic (OC) Curve





Example #3: ANSI Z1.4 for Attributes

- Based on original MIL-STD-105E developed by U.S.
 Department of Defense.
- Intended primarily for continuing series of lots or batches.
- Gives sample sizes for normal, tightened, and reduced sampling, and rules for switching between them.
- May be used for percent nonconforming items (binomial) or conformities per unit (Poisson).



Data Input Dialog Box

Acceptance Sampling Options (MIL-STD-105E)

Attribute Percent nonconforming Nonconformities per unit	
Lot size:	
3,201-10,000 ▼ Inspection level:	
AQL:	1. 18 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1.0% Type of inspection:	
Normal Sampling plan:	
Single 🔹	Ip



Single Sampling

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Double Sampling

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		MIL-S	TD-105E (ANSI Z1.4/I	SO 2859)	
		NSI Z1.4/ISO 2859	<u>9)</u>		
	e: Percent nonco 3,201-10,000	nforming			
	on level: II (defai	ult)			
AQL: 1.0					
Type of	inspection: Nom	nal			
Sampling	g plan: Double (o	ode L)			_
Stage	Sample size	Cumulative size	Acceptance number	Rejection number]
1	125	125	2	5]
2	125	250	6	7]

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The derived sampling plan has two stages. In the first stage, take a sample of 125 units. If the number of nonconforming units is no more than 2, accept the lot. If the number of nonconforming units is 5 or more, reject the lot. Otherwise, take a second sample of 125 units. If the total number of nonconforming units in both samples is no more than 6, accept the lot. If the total number of nonconforming units is 7 or more, reject the lot.



Multiple Sampling

MIL-STD-105E (ANSI Z1.4/ISO 2859)

MIL-STD-105E (ANSI Z1.4/ISO 2859)

Attribute: Percent nonconforming Lot size: 3,201-10,000 Inspection level: II (default) AQL: 1.0% Type of inspection: Normal

Sampling plan: Multiple (code L)

Stage	Sample size	Cumulative size	Acceptance number	Rejection number
1	50	50	acceptance not permitted	4
2	50	100	1	5
3	50	150	2	6
4	50	200	3	7
5	50	250	5	8
6	50	300	7	9
7	50	350	9	10

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The derived sampling plan has seven stages. At each stage, take a sample of 50 units. If the number of nonconforming units in all samples is no more than the acceptance number for that stage, accept the lot. If the number of nonconforming units in all samples is equal to or greater than the rejection number for that stage, reject the lot. Otherwise, move to the next stage and take another sample.



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Example #4: ANSI Z1.9 for Variables

- Based on original MIL-STD-414 developed by U.S.
 Department of Defense.
- Intended primarily for continuing series of lots or batches.
- Gives sample sizes for normal, tightened, and reduced sampling, and rules for switching between them.
- Assumes that measurements are characterized by a normal distribution.



Data Input Dialog Box

	Acceptance Sampling Options (MIL-STD-414	14) ×
•	Variability © Unknown © Known	
	Lot size: 3,201-10,000	
A	Inspection level:	
•	AQL: 1.0% Type of inspection:	
	Normal	100 00 00 00 00 000 000 000 000 000 000
	OK Cancel Help	



Second Data Input Dialog Box

Variables Acceptance Sampling	
Action	
(Select.) (Lower specification limit.) (Upper specification limit.)	
Sort column names	
OK Cancel Delete Transform Help	
statgraphics.com	

Analysis Summary

🔢 MIL-STE	0-414 (ANSI Z1.9/ISO 3951)	
MIL-STD-414 (ANSI Z1.9/ISO 3951)		
Variability: Unknown		
Lot size: 3,201-10,000		
Inspection level: II (default)		
AQL: 1.0%		
Type of inspection: Normal		
Sampling plan: (code L)		
Sample size	n=75	
Maximum allowable percent nonconforming	M=2.270%	
waxindin allowable percent noncontonning	111-2.2/070	
The StatAdvisor		
	e of 75 units. From measurements made on each unit, the	mean and standard
	te the estimated percent of nonconforming units in the lot	
than 2.27%, the lot should be rejected.	e are estimated percent of noncomonning dates in the lot	. In that estimate is greater
man 2.2770, the for should be rejected.		



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Random Numbers

- Suppose specification for my product is 200±10.
- Let's generate n=75 random numbers with mean $\mu = 204$ and standard deviation $\sigma = 2$.

Generate Data	×
Expression: Variables: X I I I I I I I I I I I I	Operators: ABS(?) ACOS(?) ACOSG(?) ACOSR(?) ASIN(?) ASING(?) ASINB(?) ATAN(?) ATANG(?) ATANB(?)
OK Cancel Display	Help
statgraphics.com	

Data Input

Va	riables Acceptance Sampling	
×	Action C Determine sample size Analyze mean and sigma Mean: Sigma:	
	Analyze data sample Analyze data sample X (Select:) [
Sort column names	190 210 Delete Transform	
	statgraphics®	

Analysis Summary

	Ν	IL-STD-414 (AN	ISI Z1.9/ISO 3951)	
MIL-STD-414 (ANSI	Z1.9/ISO 3	951)		
Variability: Unknown				
Lot size: 3,201-10,000				
Inspection level: II (default))			
AQL: 1.0%				
Type of inspection: Normal	I			
-)				
Sampling plan: (code L)				
Sample size			n=75	
Maximum allowable percer	nt nonconform	ing 1	M=2.270%	
Sample results Data variable: X				
Data variable: A		Quality index	Est. lot percent nonconforming	
Sample mean	203.76	Quality maex	Est. tot percent nonconjorming	
Sample std. deviation	3.04158			
LSL	190.0	4.52	0.000%	
USL	210.0	2.05	1.900%	
Total	210.0	2.05	1.900%	
Since the estimated lot perce	ent defective i	s not larger than 2.2		
sales are commerced for point				
The StatAdvisor				
		d that there are 1.89	976% nonconforming units in the lot. S	Since the estimate is not greater
than 2.27%, the lot should t	be accepted.			
l .				



MIL-STD-1916

- 3 matched sampling plans for product acceptance:
 - Lot sampling by attributes (c = 0 plans)
 - Lot sampling by variables (based on Z scores and a new F criterion)
 - Continuous sampling by attributes



Example 5:MIL-STD-1916 for Attributes

Acceptance Sampling Options (MIL-STD-1916)	
Lot size: 3,073-5,440	
Verification level:	
Type of inspection: Normal	1 ⁴ 0 0
OK Cancel Help	
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Analysis Summary

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MIL-STD-1916 (Attributes)

MIL-STD-1916 (Attributes)

Lot size: 3,073-5,440 Verification Level: IV Type of inspection: Normal

Sampling plan: Single (code D)

l	Sample size	Acceptance number	Rejection number
l	160	0	1

Alternative Continuous Sampling Plan

	Units
Screening phase clearance number	815
Sampling phase sampling fraction	1/34

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The derived sampling plan has a single stage. Take a sample of 160 units. If the number of nonconforming units is no more than 0, accept the lot. If the number of nonconforming units is 1 or more, reject the lot.

A continuous sampling plan is also available. It consists of a screening phase in which 100% inspection is applied to the first \$15 units. If all units in the screening phase are acceptable, a sampling phase is initiated in which 1 of every 34 units are inspected. If any units inspected during the sampling phase are not acceptable or other conditions occur, the screening phase must be repeated.



Example 6:MIL-STD-1916 for Variables

	Acceptance Sampling Options (MIL-STD-1916)	
	Lot size:	
	Verification level:	
6	Type of inspection: Normal	1 ⁴ a 4
	OK Cancel Help	
		and a second and a second a
	statgraphics.com	

Analysis Summary

III MIL-STD-19	16 (Variables)		
MIL-STD-1916 (Variables) Lot size: 3,073-5,440 Verification Level: IV Type of inspection: Normal			
Sampling plan: (code D)			
Sampling plan: (code D) Sample size	n=41	7	
	n=41 k=2.630	-	

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The derived sampling plan requires taking a sample of 41 units. From measurements made on each unit, the mean and standard deviation are calculated. The program then computes quality indices which indicate how well the process behaves with respect to the specification limits. If the calculated quality indices meet the criteria of the plan and all measurements are within the specification limits, the lot is accepted.



Calculations

$$Z = \min\left(Z_L = \frac{\bar{X} - LSL}{s} , Z_U = \frac{USL - \bar{X}}{s}\right)$$
$$F = \frac{s}{USL - LSL}$$

Sample Results

Real and a second		ables Acceptance Sampling	
		Action O Determine sample size Analyze mean and sigma Mean: Sigma: Analyze data sample Select:)	
	Sort column names	(Lower specification limit:) (Upper specification limit:) 190.0 Delete Transform Help	555593 • •
		statgraphics.com	

Analysis Summary

X

		MIL-STD-1916 ((Variables	.)	
MIL-STD-1916 (Vari Lot size: 3,073-5,440 Verification Level: IV Type of inspection: Norma					
Sampling plan: (code D)					
Sample size			n=41		
Minimum allowable k-crite			k=2.6		
Maximum allowable F-crit	erion (double-s	sided only)	F=0.1	77	
Data variable: X	202.670	Quality index (k)	F Value		
Sample mean	203.678				
Sample std. deviation	2.49815				
LSL	190.0	5.475			
USL	210.0	2.531			
Sample F Value			0.125		
deviation are calculated. T	requires takin; he program th	g a sample of 41 units. F en computes quality ind	from measur	ements made on each ur ndicate how well the pro	nit, the mean and standard ocess behaves with respect to the s are within the specification



Sequential Sampling

- Useful for sampling very large lots.
- Postulate 2 hypotheses:
 - Null hyp: p = AQL
 - Alt. hyp: p = LTPD
- Set producer's risk (α) and consumer's risk (β).
- Inspect items 1 at a time. After each item, plot the results on a cumulative sum chart and accept the lot, reject the lot, or continue sampling.



Example 7: Sequential Attribute Sampling

 Let's generate some data from a binomial distribution with p = 0.01.

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RUNIFORM(5000,0,1) <= 0.01	& I [] Delete 7 8 9 + = <> 4 5 6 - < > 1 2 3 * <= >=	Operators: ABS(?) ACOS(?) ACOSG(?) ACOSR(?) ASIN(?) ASING(?) ASINR(?)	
ОК	Cancel Display	ATAN(?) ATANG(?) ATANR(?) Help	a Station and

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Data Input Dialog Box

 Select Describe – Categorical Data – Sequential Sampling.

5	Sequential Sampling	
192	X (Data variable:)	
	(Select:)	
P		P
	Sort column names	
	OK Cancel Delete Transform Help	
	statgraphics.com	_

Sampling Options

Sequential Sampling Op	tions
Test parameter O Normal mean (sigma known) Sigma: 1.0	OK Cancel
 Normal mean (sigma unknown) Normal sigma (mean known) Mean: 0.0 Normal sigma (mean unknown) Binomial proportion Poisson rate Negative binomial mean K: 3 	Help
Null hypothesis H0: 0.01 Alpha risk: 0.05	
Alternative hypothesis H1: 0.03 Beta risk: 0.10 Two-sided test	





Cumulative Sum Plot





ASN (Average Sample Number) Function





Compare to Fixed Size Sample

O Normal Mean Cancel O Absolute Error O Normal Sigma	×
Help Image: Binomial Droportion Image: Binomial Proportion Poisson Rate Hypothesized Mean: 0.0 Hypothesized Sigma: 1.0 Hypothesized Sigma: 1.0 Hypothesized Rate: 1.0 Hypothesized Rate: 1.0 Hypothesized Rate: 1.0 Hypothesized Rate: 1.0 Help Image: Poisson Rate Image: Poisson Rate	



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Summary

To assure quality levels for consumer/producer:

- OC plans
- Sequential sampling

To assure average outgoing quality level:

AOQL plans

To assure quality is no worse than target:

LTPD plans

To maintain quality at a target:

- MIL-STD-105E or ANSI/ASQ Z1.4 for attributes
- MIL-STD-414 or ANSI/ASQ Z1.9 for variables
- MIL-STD-1916 for attributes or variables

Source: Montgomery (2012)



References

Standards

- DOD Military Standard MIL-STD-105E <u>Sampling Procedures and Tables for</u> <u>Inspection by Attributes</u> (1989)
- ANSI/ASQ Z1.4 <u>Sampling Procedures and Tables for Inspection by</u> <u>Attributes</u> (2008)
- DOD Military Standard MIL-STD-414 <u>Sampling Procedures and Tables for</u> <u>Inspection by Variables for Percent Defective</u> (1957)
- ANSI/ASQ Z1.9 <u>Sampling Procedures and Tables for Inspection by</u> <u>Variables for Percent Nonconforming</u> (2008)
- DOD Test Method Standard MIL-STD-1916 (1996)

Textbooks

- Edward Schilling and Dean Neubauer, <u>Acceptance Sampling in Quality</u> <u>Control</u>, second edition (2009).
- Douglas Montgomery, <u>Introduction to Statistical Quality Control</u>, seventh edition (2012).
- Kenneth Stephens, <u>The Handbook of Applied Acceptance Sampling: Plans</u>, <u>Procedures and Principles (2001)</u>.



More Information

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Go to www.youtube.com

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