Sampling

Roger Kissling

New Zealand

Agenda

- Basic Definitions
- Motivating Example
- Statistical Approach to Sampling
- Demonstration of Tool
- Comments on ISO Standards
- Measurement Error

Principles:

- Create awareness
- Focus on Concepts

Some Definitions

Sampling

Sampling

The procedure used to draw one or more items from a population (or lot) and intended to serve as a basis for a decision about the population (or lot)

Not to be confused with *physical sampling* e.g.

- IDF50/ISO707 ***Milk and milk products -- Guidance on sampling*** and
- ISO7002 ***Agricultural food products—Layout for a standard method of sampling from a lot***

Sampling Plan

Sampling Plan

- A plan according to which one or more samples is taken [from a lot] in order to obtain information and possibly reach a decision
  - Examples include surveys, opinion polls

Acceptance Sampling Plan

- A sampling plan intended for determining the acceptance or rejection of a lot

The Aim of Acceptance Inspection (Sampling)

"The aim of sampling inspection is to see that the customer receives the quality required,

while remembering that financial resources are not unlimited,

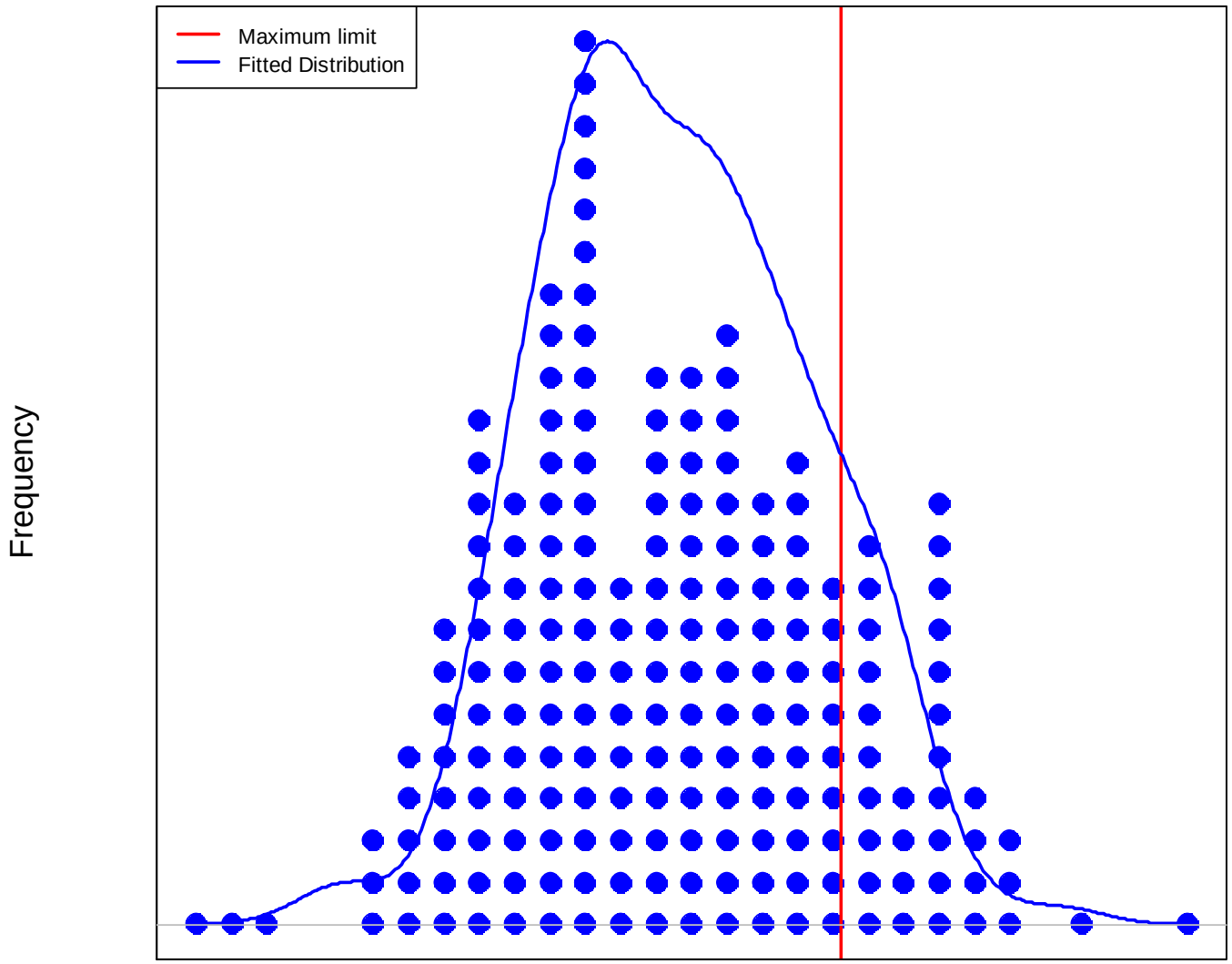
and the cost of the product must reflect the cost of inspection as well as the cost of production"

ISO2859 -10 (2004)

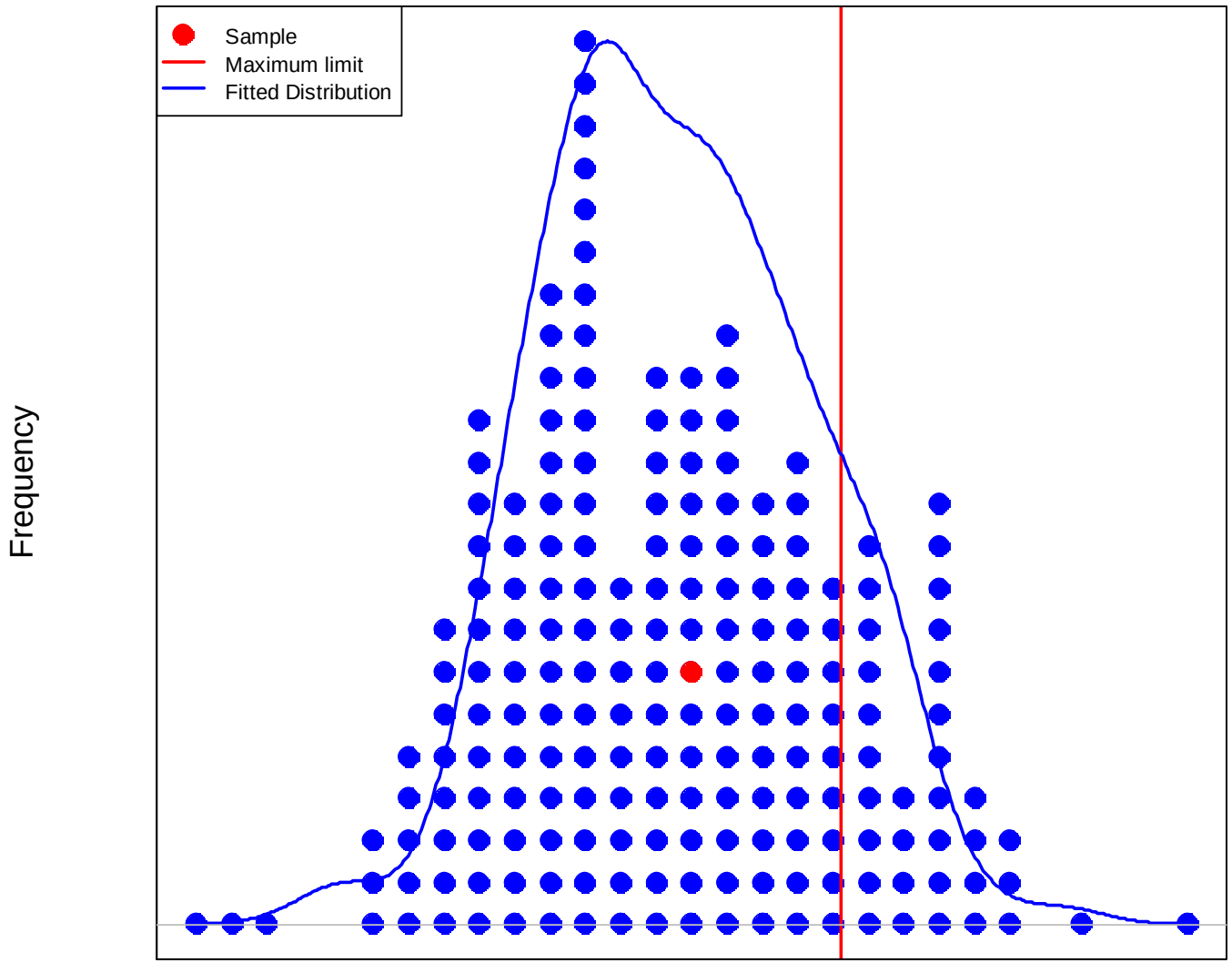
Motivating Example

Compliance of Results

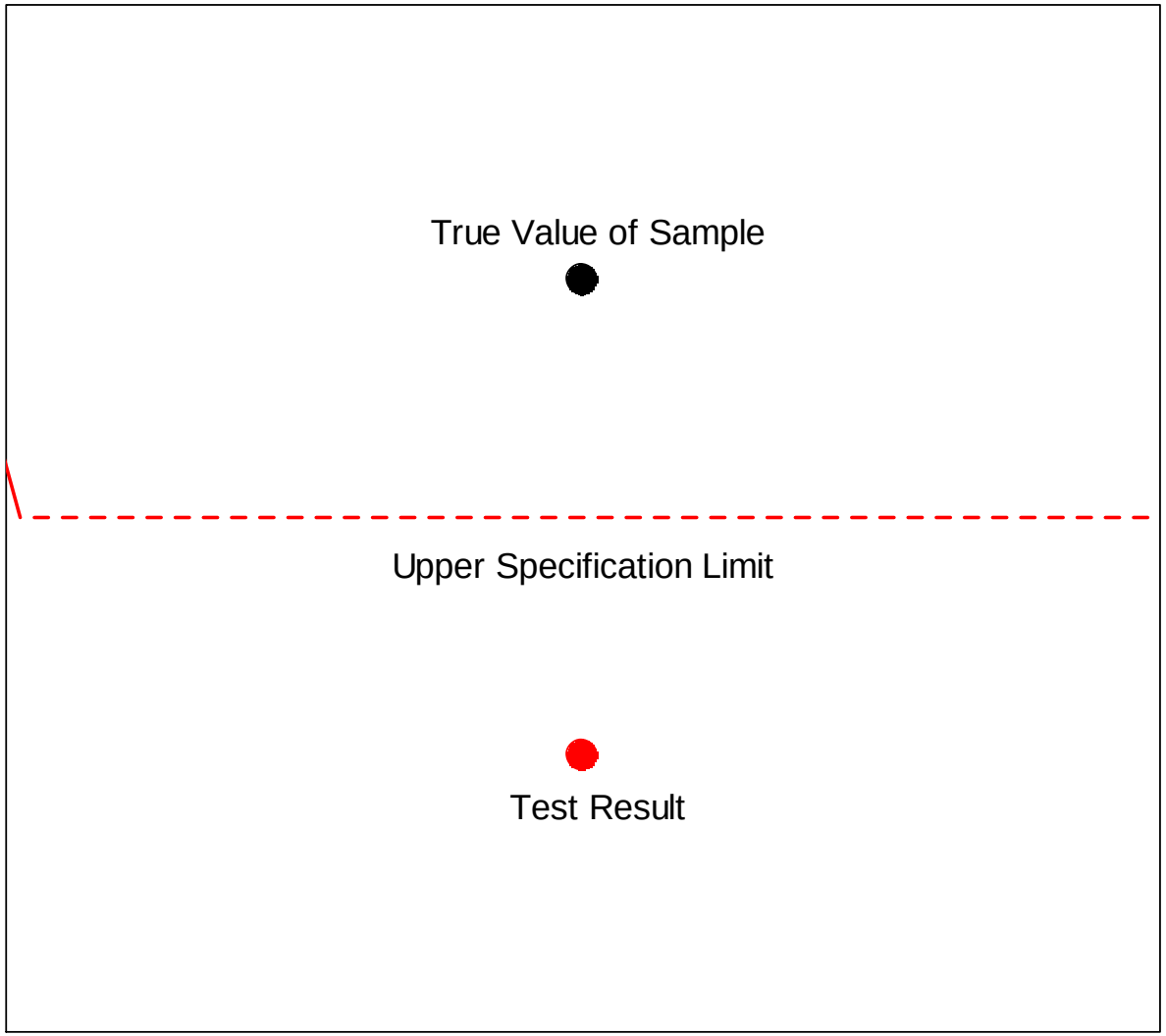
Batch containing 20% out of specification

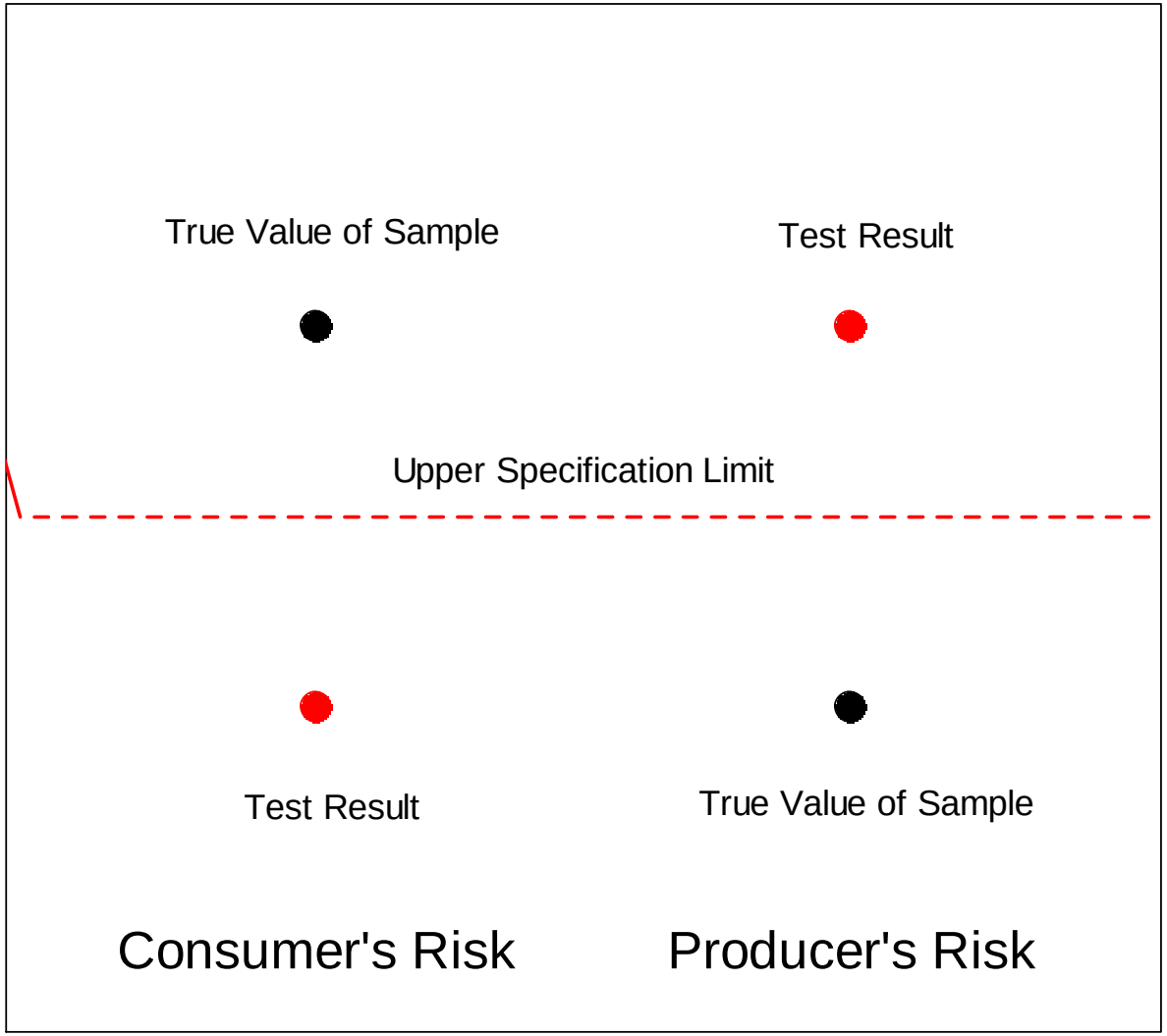


Batch containing 20% out of specification

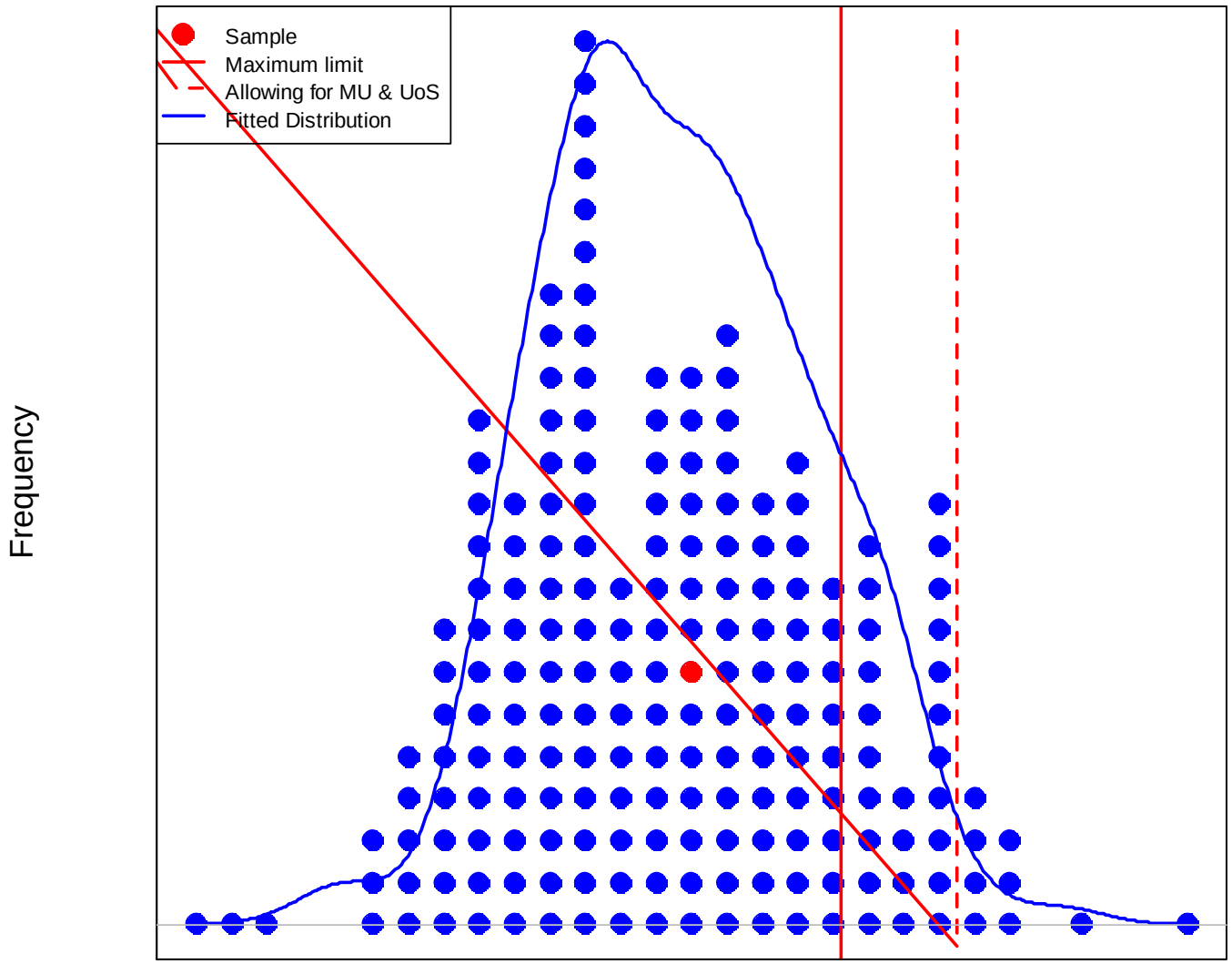


Possible Effect of Measurement Error




True Value of Sample
Test Result
Upper Specification Limit
Test Result
True Value of Sample
Consumer's Risk
Producer's Risk

Batch containing 20% non-conforming



Representative samples

The word representative has no meaning, statisticians do not use this word

…why not use sampling procedures that are dictated by statistical theory, with the advantages of less cost, and with meaningful, calculable tolerances?

- W.E. Deming

Statistical Approach

Sampling - how to proceed?

ISO2859:

There are three possible ways of selecting items for inspection:

a. 100% inspection, in which every item produced is inspected

b. Sampling based on the theory of probability

c. Ad hoc sampling based on some sampling rule, for example the inspection of a fixed percentage, or occasional random checks

Comments (ISO2859)

a. 100% sampling can be a formidable task, it is expensive and not always successful. It is not possible if the inspection method necessitates destructive testing
b. Sampling based on probability has the disadvantage that some items will not be inspected. But the risks involved can be precisely calculated and a plan chosen to allow no more risk than required.
c. Ad hoc sampling is not to be recommended since it leads to uncalculated risks, and often to unjustifiably high risks; further there is no logical basis for either the acceptance or rejection of the product.

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Sampling based on probability

We cannot provide a 100% guarantee that all product in a lot complies when using sampling - we do not test all the product.

There are two types of risk that can occur:

- Consumer's risk, accepting product of unacceptable quality
- Producer's risk, rejecting product of acceptable quality

Dodge reasoned that if the samples are taken at random from the lot, it was possible to design a sampling plan to control these risks to desired levels:

- we can only provide assurance, on average over the longer term, across many lots (i.e. in terms of probability)

Risks

Risks can be expressed in terms of:

- a level non-conforming
- the associated chance of acceptance at that level

Example:

Producer’s risk

- 95% chance of acceptance at 1% non-conforming

Consumer’s risk

- 10% chance of acceptance at 5% non-conforming

Confidence

- The term “confidence” is often used in conjunction with sampling plans
- While it is a statistical term in reality it has nothing to do with acceptance sampling
- It is easier to express risks in terms of probabilities of acceptance or rejection
- Confidence can be associated with Consumer’s Risk
  - 95% confidence [that the lot is of satisfactory quality] means there is only 5% chance of acceptance
  - However confidence does not work well with Producer’s Risk

Things to consider when setting risks

- Stringency required
  - How the risks of incorrect decisions are to be controlled
- Use of food
  - e.g. whether the food is intended for direct consumption or used as an ingredient, the content in the final food and the nature of any further processing steps
- Relativity
  - e.g. not having plans more stringent for composition than those used for food safety
- Fairness
  - e.g. not imposing unnecessary costs on producers to reduce inspection costs by consumers
- Practicality
  - e.g. whether the sampling plan can be implemented at reasonable cost

Inspection by Attributes

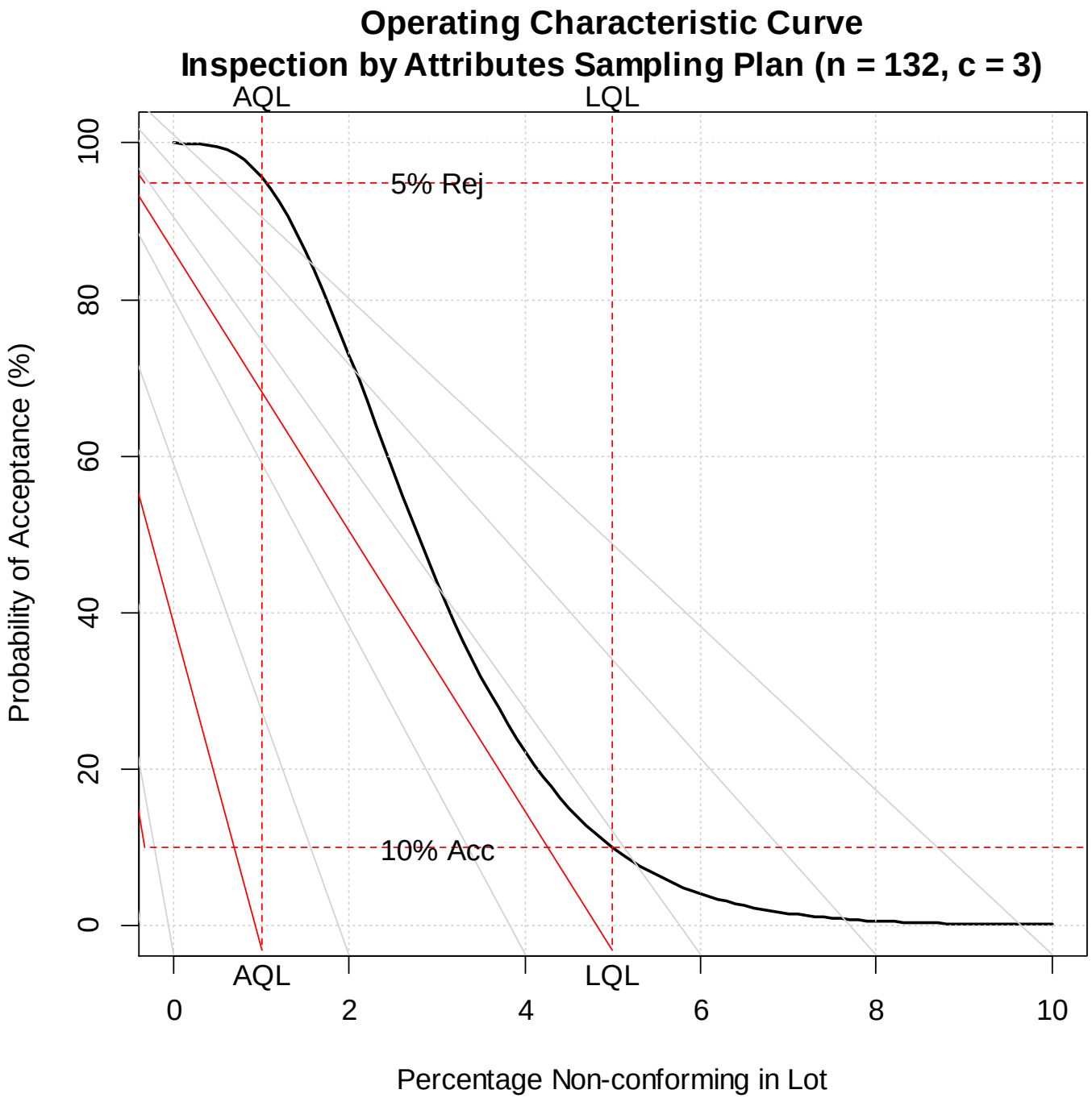
- A sample of “n” items is taken at random from the lot
- Items are classified as conforming or non-conforming
- A lot is accepted if no more than a certain number of items “c” in the sample are non-conforming
  - The number “c” is called the acceptance number of the sampling plan
  - Its value can be non-zero
  - The values of n and c are worked out from the specified levels of allowable risk

Inspection by Variables

- A sample of “n” items is taken at random from the lot
- The items are measured
- The lot is accepted against a maximum limit if

$$\bar{x} + k \times sd \leq Maximum$$

  - The acceptance criterion is based on the average value $\bar{x}$ and the standard deviation of the results from the testing
  - The values of n and k are worked out from the specified levels of allowable risk


Operating Characteristic Curve
Inspection by Attributes Sampling Plan (n = 132, c = 3)
AQL
LQL
5% Rej
10% Acc
Probability of Acceptance (%)
100
80
60
40
20
0
AQL
LQL
0
2
4
6
8
10
Percentage Non-conforming in Lot

Demonstration of Tools

ISO Standards

As used in GL50

ISO Standard 2859

- Inspection by Attributes

INTERNATIONAL STANDARD

ISO 2859-1

Second edition
1999-11-15

Sampling procedures for inspection by attributes —

Part 1:
Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection

Règles d'échantillonnage pour les contrôles par attributs —

Partie 1: Procédures d'échantillonnage pour les contrôles lot par lot, indexés d'après le niveau de qualité acceptable (NQA)

Sampling Schemes versus Sampling Plans

"An individual sampling plan has much the effect of a lone sniper, while the sampling plan scheme can provide a fusillade in the battle for quality improvement." Schilling (1989)

Sampling scheme

A set of sampling plans

Switching rule

instruction within an *acceptance sampling* scheme for changing from one *acceptance sampling* plan to another of greater or lesser severity based on demonstrated quality history

- Typically between normal, tightened and reduced inspection

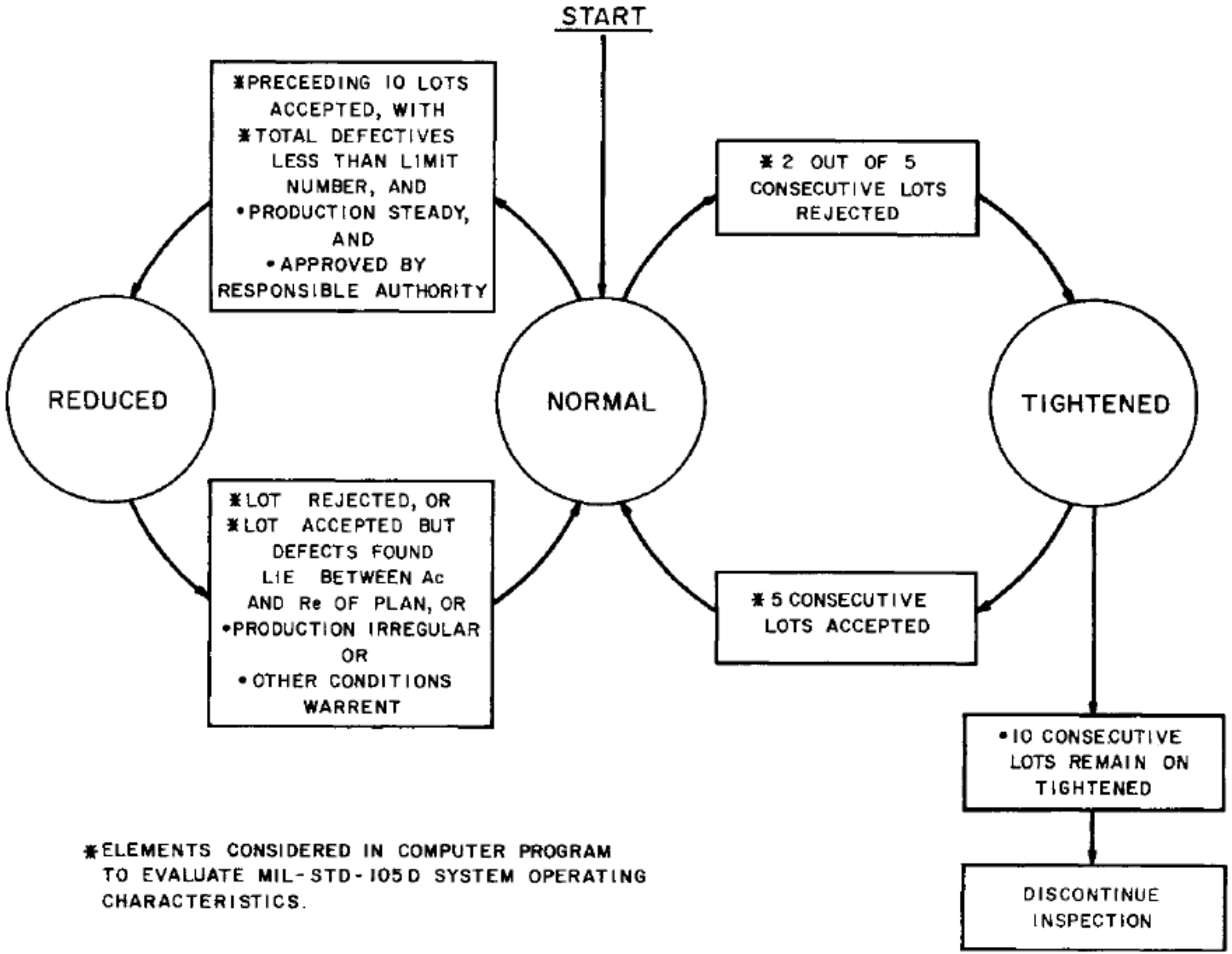


FIGURE 1. Switching Rules for MIL-STD-105D

Table 1 - Sample size code letters (see 10.1 and 10.2)

Lot 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 150	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 1 200	C	C	E	F	G	J	K
1 201 to 3 200	C	D	E	G	H	K	L
3 201 to 10 000	C	D	F	G	J	L	M
10 001 to 35 000	C	D	F	H	K	M	N
35 001 to 150 000	D	E	G	J	L	N	P
150 001 to 500 000	D	E	G	J	M	P	Q
500 001 and over	D	E	H	K	N	Q	R

Table 2-A — Single sampling plans for normal inspection (Master table)

Sample size code letter	Sample size	Acceptance quality limit, AQL, in percent nonconforming items and nonconformities per 100 items (normal inspection)																									
		0,010	0,015	0,025	0,040	0,065	0,10	0,15	0,25	0,40	0,65	1,0	1,5	2,5	4,0	6,5	10	15	25	40	65	100	150	250	400	650	1 000
		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	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	44 45
C	5	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	0 1	⇧	⇩	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45	⇧
D	8	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	0 1	⇧	⇩	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45	⇧	
E	13	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	0 1	⇧	⇩	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45	⇧		
F	20	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	0 1	⇧	⇩	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	⇧	⇧	⇧	⇧	⇧	⇧
G	32	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	0 1	⇧	⇩	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	⇧	⇧	⇧	⇧	⇧	⇧	⇧
H	50	⇩	⇩	⇩	⇩	⇩	⇩	⇩	0 1	⇧	⇩	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧
J	80	⇩	⇩	⇩	⇩	⇩	⇩	0 1	⇧	⇩	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧
K	125	⇩	⇩	⇩	⇩	⇩	0 1	⇧	⇩	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧
L	200	⇩	⇩	⇩	⇩	0 1	⇧	⇩	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧
M	315	⇩	⇩	⇩	0 1	⇧	⇩	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧
N	500	⇩	⇩	0 1	⇧	⇩	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧
P	800	⇩	0 1	⇧	⇩	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧
Q	1 250	0 1	⇧	⇩	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧
R	2 000	⇧	⇧	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧

⇩ = 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 6-A — Consumer's risk quality for normal inspection

(in percent nonconforming for single sampling plans, for inspection for percent nonconforming)

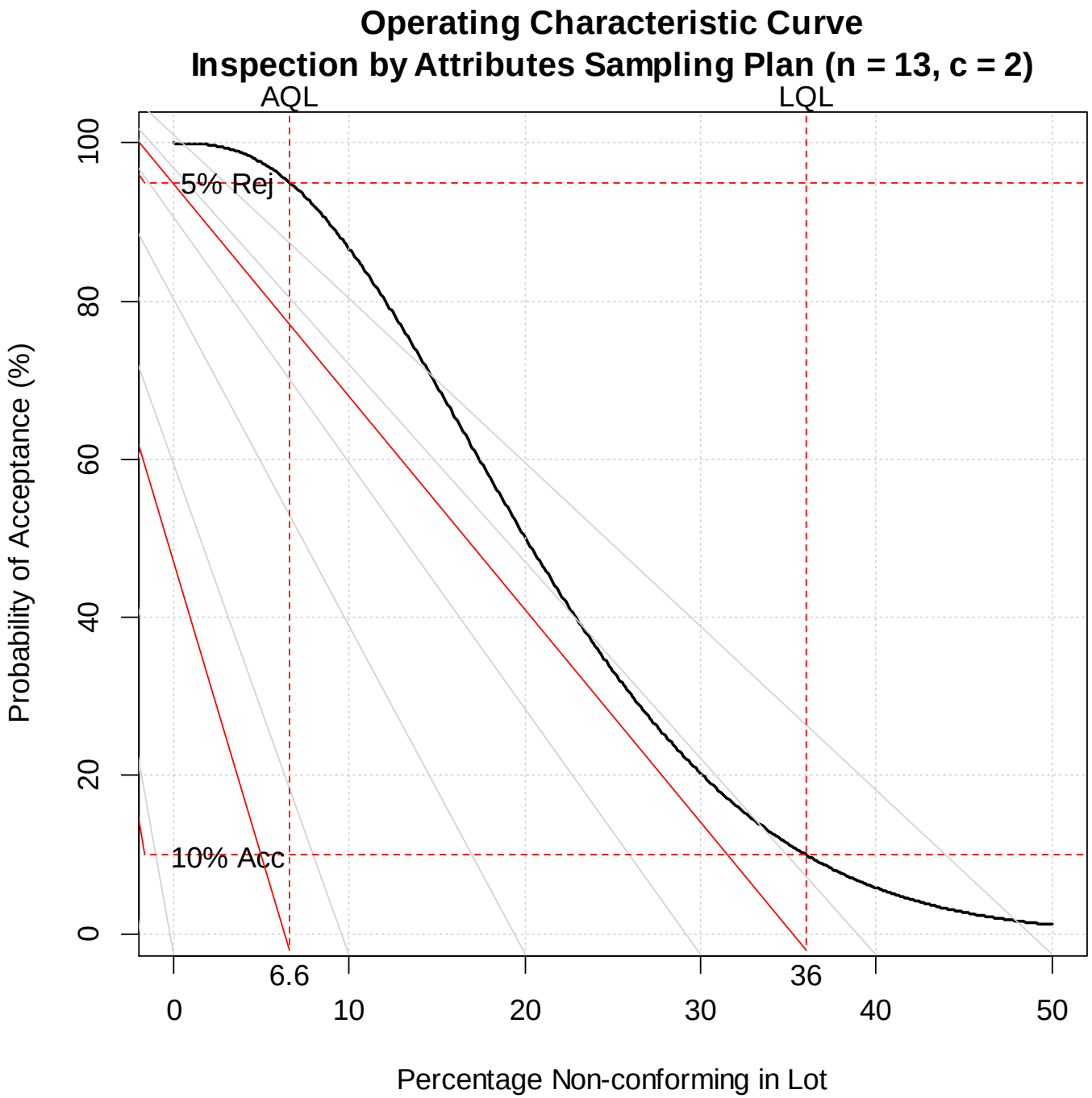
Sample size code letter	Sample size	Acceptance quality limit, AQL, percent nonconforming items															
		0,010	0,015	0,025	0,040	0,065	0,10	0,15	0,25	0,40	0,65	1,0	1,5	2,5	4,0	6,5	10
A	2															68,4	69,0*
B	3														53,6	54,1*	57,6*
C	5													36,9	37,3*	39,8*	58,4
D	8												25,0	25,2*	27,0*	40,6	53,8
E	13											16,2	16,4*	17,5*	26,8	36,0	44,4
F	20										10,9	11,0*	11,8*	18,1	24,5	30,4	41,5
G	32									6,94	7,01*	7,50*	11,6	15,8	19,7	27,1	34,0
H	50								4,50	4,54*	4,87*	7,56	10,3	12,9	17,8	22,4	29,1
J	80							2,84	2,86*	3,07*	4,78	6,52	8,16	11,3	14,3	18,6	24,2
K	125						1,83	1,84*	1,97*	3,08	4,20	5,27	7,29	9,24	12,1	15,7	21,9
L	200					1,14	1,16*	1,24*	1,93	2,64	3,31	4,59	5,82	7,60	9,91	13,8	
M	315				0,728	0,735*	0,788*	1,23	1,68	2,11	2,92	3,71	4,85	6,33	8,84		
N	500			0,459	0,464*	0,497*	0,776	1,06	1,33	1,85	2,34	3,06	4,00	5,60			
P	800		0,287	0,290*	0,311*	0,485	0,664	0,833	1,16	1,47	1,92	2,51	3,51				
Q	1 250	0,184	0,186*	0,199*	0,311	0,425	0,534	0,741	0,940	1,23	1,61	2,25					
R	2 000	0,116*	0,124*	0,194	0,266	0,334	0,463	0,588	0,769	1,00	1,41						

NOTES

1 At the consumer's risk quality, 10% of lots will be expected to be accepted.

2 All the values are based on the binomial distribution.

3 Superscript * denotes that the value is for the optional fractional acceptance number sampling plan (see Table 11-A).


Operating Characteristic Curve
Inspection by Attributes Sampling Plan (n = 13, c = 2)
AQL
LQL
5% Rej
10% Acc
6.6
36
Probability of Acceptance (%)
Percentage Non-conforming in Lot
0
20
40
60
80
100
0
10
20
30
40
50

ISO (GL50) Sampling Plans/Schemes

- Intended for lots consisting of discrete items
- Contain sampling schemes (sets of sampling plans)
- No allowance for measurement error
- Control Producer's Risk (AQL) or Consumer's Risk (LQL) but not both
- Lot size versus sampling size relationship is arbitrary

Use of Sampling Schemes

Sampling schemes are impractical to use in trade.

Proposed plan:

- Evaluate sampling schemes
  - determine AQL and LQL
- Develop equivalent sampling plans
  - Including reinspection plans to maintain fairness

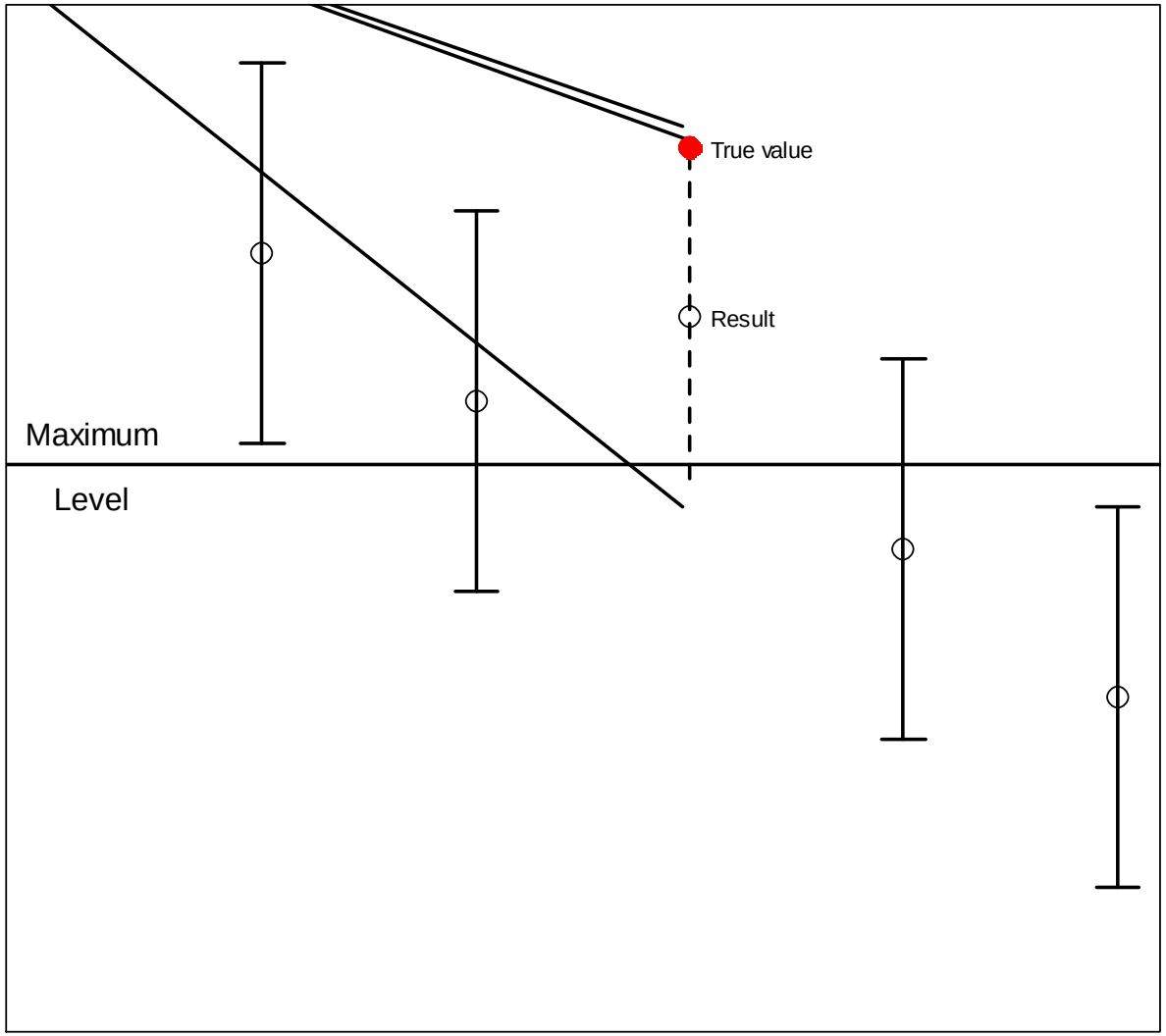
Measurement Error

Role of Measurement Uncertainty

MU has defined roles in:

- the reporting of results, as outlined in ISO17025, and in accordance with standard scientific practice
- conformity assessment, i.e. the assessment whether the true values of the samples tested complies with the limit, as described in ISO10576

However MU does not appear useful in sampling inspection, at least in its current form.


True value
Result
Maximum
Level

Model for MU

Often MU is represented by the reproducibility standard deviation, estimated from collaborative studies:

$$u = s_R$$

- However u represents a randomly chosen laboratory from the 'population' of laboratories
  - This does not account for biases at individual laboratories, or the difference between repeatability and reproducibility
- ISO5725 describes the appropriate model:

$$Result = True\ Value + Bias + Error$$

$$y = m + B + e$$

Uses of MU

- Coverage factor k=2 does <u>not</u> provide 95% confidence of 95% coverage when values of u is estimated from trials
  - 95% of a [normal] distribution lies in the range $\mu \pm 1.96\sigma$, where μ and σ are the true mean and standard deviation.
  - Procedure provides approximately 50% confidence

- The methods described in Annex O of ISO3951 allow only for the <u>repeatability</u> component of measurement error
  - It is not correct to use measurement uncertainty in this context
  - Appropriate adjustments can be made to the ISO procedure to allow for this

Concluding Comments

- Sampling plans should be derived from specifications of allowable risk
  - All sampling plans should be evaluated prior to use
- ISO plans, and plans demonstrated by the tool, are the simplest examples
  - Other sampling plans and strategies can provide more economical levels of testing
- Measurement error needs to be taken into account
- Plans to develop sampling plan toolset using R shiny apps
  - to include other options and measurement error