Part 2 - Sampling Standards and Plans

Alright, are you ready for the **second part** of this chapter which is the **actual sampling standards and plans** themselves**.**

This includes a review of basic sampling plans such as **single, double, multiple, sequential, and continuous sampling plans.**

Then we will review the more complex **sampling schemes** in **ANSI/ASQ Z1.4 and Z1.9 standards**.

Let's start with the simple concepts of **single sampling plan** and **double/multiple sampling plans**.

Single Sampling Plans

A single sampling plan is the easiest and most common sampling plan where an entire lot is accepted or rejected based on the inspection results of a single sample group of size n, taken from the entire lot (population - N).

Single sampling plans are defined by **three parameters**:

N = Total Lot Size, n = sample size, c = the acceptance number (derived from AQL)

The **total lot size** is designed as N, and the **Sample Size (n)** is the number of samples to be inspected.

I'll jump ahead to the **ANSI/ASQ Z1.4** standard to give you an example of what this looks like in practice.

Most normal inspections use **General Inspection Level II**, and let's say that your **Total Lot Size (N)** is 5,000, then your sample size is determined by the **Sample Size Code Letter, L.**

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	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	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	D	E	H	K	N	Q	R

The **Acceptance Number (c)** is the maximum number of non-conformances allowed within the sample. **The acceptance number is derived from a combination of the AQL you select for the attribute being inspected for, and the sample size.**

Again, let's use the **ANSI/ASQ Z1.4** standard to demonstrate how to find your acceptance number using your **AQL** and **Sample Size Code Letter**.

For this example, let's say your **AQL is 1.0**. So, you start by finding your AQL across the top, and your sample size code letter (L in this case) along the side, and you find their intersection in the matrix.

It's also important to know that this table also specifies the number of samples you should be using during inspection. So you can see that for a sample size code letter of L, you should be inspecting **200 samples (n)**, and the **acceptance number (c) is 5**, and the **rejection number is 6**.

Sample Size Code Letter	Sample Size	AQL (Acceptance Quality Limit) for Normal Inspection												
		0.25	0.4	0.65	1	1.5	2.5	4	6.5	10	15	25	40	65
		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
B	3							0 1			1 2	2 3	3 4	5 6
C	5						0 1			1 2	2 3	3 4	5 6	7 8
D	8					0 1			1 2	2 3	3 4	5 6	7 8	10 11
E	13				0 1			1 2	2 3	3 4	5 6	7 8	10 11	14 15
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			1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22			
K	125		1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22				
L	200				5 6	7 8	10 11	14 15	21 22					
M	315	2 3	3 4	5 6	7 8	10 11	14 15	21 22						
N	500	3 4	5 6	7 8	10 11	14 15	21 22							
P	800	5 6	7 8	10 11	14 15	21 22								
Q	1250	7 8	10 11	14 15	21 22									
R	2000	10 11	14 15	21 22										

The last **key parameter** of any sampling plan is the **number of non-conformances**, d. This is the actual number of non-conformances observed in a sample.

At the conclusion of your inspection of the 200 samples, you would accept the lot if the number of non-conformances found (d) is 5 or less, and you'd reject the lot with 6 or more non-conformances.

The single sampling plan is the simplest to administer and execute, however it results in the largest **Average Sampling Number** of all the various plans.

If you're goal is to minimize sampling, you can use the double or sequential sampling plans, which are often able to disposition lots with fewer samples than the single sampling plan.

Double Sampling Plans

While a single sampling plan is executed with only a single sample of units, in double sampling, you can take up to two different samples.

Double sampling plans are effective because oftentimes an incoming lot of product **can be so good or so bad** that we can **make a reasonable conclusion about its quality** by taking a sample size much smaller than what is required in a single sampling plan.

Double sampling plans take advantage of this by first taking a smaller sample, then depending on the results, the lot can either be accepted, rejected, or the sampling may continue.

Double sampling plans are defined by n_1, c_1, r_1, and n_2, c_2, r_2. The 1 & 2 subscripts (n_1 v n_2) simply denote the 1st and 2nd sample.

n = sample size, c = acceptance number, r = rejection number

A lot can be accepted within the 1st sample if the actual number of non-conformances is less than the acceptance number (c). Similarly, a lot can be rejected if the actual number of non-conformances is greater than the reject number.

If the number of non-conformances observed is greater than that the **1st acceptance number** (c_1) but less than the **1st rejection number** (r_1) then the sampling continues with the second sample, n_2.

Double Sampling Example

Let's say you want to turn that previous example into double sampling, using the same AQL and starting with the same lot size.

If the overall lot size (N) does change, then the sample size code letter also won't change, **L**.

Code Letter	Sample	Sample Size	Total Sample	AQL (Acceptance Quality Limit) - Double Sampling Plans for Normal Inspection																							
				0.25		0.40		0.65		1.0		1.5		2.5		4		6.5		10		15		25		40		65		100	
				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				↓		↓		↓		↓		↓		↓		↓		■		↑		↓		•		•		•		•	
B	First	2	2																			0	2	0	3	1	4	2	5	3	7
	Second	2	4																			1	2	3	4	4	5	6	7	8	9
C	First	3	3																	0	2	0	3	1	4	2	5	3	7	5	9
	Second	3	6																	1	2	3	4	4	5	6	7	8	9	12	13
D	First	5	5															0	2	0	3	1	4	2	5	3	7	5	9	7	11
	Second	5	10															1	2	3	4	4	5	6	7	8	9	12	13	18	19
E	First	8	8													0	2	0	3	1	4	2	5	3	7	5	9	7	11	11	16
	Second	8	16													1	2	3	4	4	5	6	7	8	9	12	13	18	19	26	27
F	First	13	13					■						0	2	0	3	1	4	2	5	3	7	5	9	7	11	11	16		
	Second	13	26											1	2	3	4	4	5	6	7	8	9	12	13	18	19	26	27		
G	First	20	20			■						0	2	0	3	1	4	2	5	3	7	5	9	7	11	11	16				
	Second	20	40									1	2	3	4	4	5	6	7	8	9	12	13	18	19	26	27				
H	First	32	32	■						0	2	0	3	1	4	2	5	3	7	5	9	7	11	11	16						
	Second	32	64							1	2	3	4	4	5	6	7	8	9	12	13	18	19	26	27						
J	First	50	50					0	2	0	3	1	4	2	5	3	7	5	9	7	11	11	16								
	Second	50	100					1	2	3	4	4	5	6	7	8	9	12	13	18	19	26	27								
K	First	80	80			0	2	0	3	1	4	2	5	3	7	5	9	7	11	11	16										
	Second	80	160			1	2	3	4	4	5	6	7	8	9	12	13	18	19	26	27										
L	First	125	125	0	2	0	3	1	4	2	5	3	7	5	9	7	11	11	16												
	Second	125	250	1	2	3	4	4	5	6	7	8	9	12	13	18	19	26	27												
M	First	200	200	0	3	1	4	2	5	3	7	5	9	7	11	11	16														
	Second	200	400	3	4	4	5	6	7	8	9	12	13	18	19	26	27														
N	First	315	315	1	4	2	5	3	7	5	9	7	11	11	16																
	Second	315	630	4	5	6	7	8	9	12	13	18	19	26	27																
P	First	500	500	2	5	3	7	5	9	7	11	11	16																		
	Second	500	1000	6	7	8	9	12	13	18	19	26	27																		
Q	First	800	800	3	7	5	9	7	11	11	16																				
	Second	800	1600	8	9	12	13	18	19	26	27																				
R	First	1250	1250	5	9	7	11	11	16																						
	Second	1250	2500	12	13	18	19	26	27																						

Executing this sampling plan means taking the initial sample (n_1) of 125 units and inspecting for non-conformances.

Let's review quickly how to respond to the various outcomes of this first sample:

- If 2 or fewer non-conformances (c_1**, acceptance number**) are found in this initial 125 units, then the entire lot is accepted.
- If 5 or more non-conformances **(r_1, rejection number)** are found in this initial 125 units, then the entire lot is rejected.

If, let's say **three non-conformances** is found in this initial 125 units, then we move on to the second sample of another 125 samples (n_2).

Then the results of both samples are combined to make a final decision, so let's review those possible outcomes:

- If, a combined total of 7 non-conformances are found between both samples (250 total), then the lot is rejected.
- If, a combined total of 6 (or fewer) non-conformances are found between both sample groups, then the lot is accepted.

Remember, the final decision at the end of the second sample is **cumulative**. You must combine the non-conformances found in the first and second sample and compare that against **r_2**.

Multiple Sampling Plans

A multiple sampling plan is simply an extension of the double sampling plan, where sampling can go on for up **7 to different samples**.

Similar to the double sampling plan, each sample taken has its own accept(c) and reject (r) requirements.

Let's look at the **multiple sampling plan** for **sample size code letter L, with an AQL of 1.0**.

	Sample Size	Acceptance Number (c)	Rejection Number (r)
Sample 1	$n_1 = 50$	$c_1 = NA$	$r_1 = 4$
Sample 2	$n_2 = 50$	$c_2 = 1$	$r_2 = 5$
Sample 3	$n_3 = 50$	$c_3 = 2$	$r_3 = 6$
Sample 4	$n_4 = 50$	$c_4 = 3$	$r_4 = 7$
Sample 5	$n_5 = 50$	$c_5 = 5$	$r_5 = 8$
Sample 6	$n_6 = 50$	$c_6 = 7$	$r_6 = 9$
Sample 7	$n_7 = 50$	$c_7 = 9$	$r_7 = 10$

Similarly, to the double sampling plan, over time, these plans have shown to have a lower **average sampling number (ASN),** when compared to a double or single sampling plan.

The downside is that it these plans can be difficult to administer and create **waste (muda)** in the form of excess motion when picking samples.

Sequential Sampling Plans

The sequential sampling plan is a further extension of the multiple sampling plan where sampling can go on indefinitely until the entire lot is inspected.

ANSI/ASQ Z1.4 - The Attribute Sampling Plan

The ANSI/ASQ **Z1.4 standard** is acceptance sampling for **attribute data** and originated as **Military Standard 105**.

This standard applies to processes that are continuous in nature, and do not apply to processes that operator infrequently or irregularly.

The Z1.4 standard allows the user to choose between **single, double, or multiple sampling plans**, and then assists the user in setting up their **sampling scheme**.

Since we've already discussed the nuances of the single, double, multiple and sequential plans, let's focus now on the **sampling schemes** and **switching rules** within the **ANSI/ASQ standard**.

A **sampling scheme** is a set of sampling plans that are used along with **switching rules** that govern with sampling plan should be used. These various sampling plans include **normal sampling, heightened sampling** and **reduced sampling**.

These switching rules are integral to the standard.

Many people simply use various sampling plans with no switching rules. This is not the intention of the standard.

The intention of the standard is to be used as a system that uses the switching rules. **If you're not using the switching rules, you're not inspecting per ANSI Z1.4.**

These sampling schemes are meant to reward vendors who have demonstrated a stable, **high quality process** with **reduced sampling**, and **encourage continuous improvement** for poorly performing vendors with **heightened sampling**.

Let's jump into the standard itself and discuss how to use it specifically.

The ANSI standard has **3 general inspection levels (I, II and III)**, and **4 special inspections**, which you can see below.

The **special inspection levels** should only be used when small sample sizes are necessary due to high inspection costs. These small sample sizes naturally **result in large sampling risks** for both the producer and consumer. Using these special plans must come with an assessment, and acceptance of those risks.

We're going to focus mainly on the **general inspection levels within the standard**.

Normal sampling starts with **General Inspection Level II**, this should be the default starting point for any sampling plan or scheme.

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	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	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	D	E	H	K	N	Q	R

As you can see in the table above, **moving between inspection level I, II and III changes the sample size code letter**, which **changes the number of samples associated with a sampling plan**.

For example, if your lot size is 100,000 units, here are the sample size code letters and sample sizes:

- Level I translates to a sample size code letter **L**, which has a sample size of 200
- Level II translates to a sample size code letter **N**, which has a sample size of 500
- Level III translates to a sample size code letter **P**, which has a sample size of 800

Lot or Batch Size			General Inspection Levels		
			I	II	III
35001	to	150000	L	N	P
150001	to	500000	M	P	Q
	>	500001	N	Q	R

Sample Size Code Letter	Sample Size
K	125
L	200
M	315
N	500
P	800
Q	1250
R	2000

While these different inspection levels might all have the same AQL, inspecting more samples always reduces the **consumers risk of accepting a bad lot**. So **General Inspection Level I** may be used when more risk can be tolerated, and **General Inspection Level III** may be used when less risk can be tolerated.