

AQL – What is an Acceptable Quality level?

By John Spashett (Technical Manager)



In the distant past goods were produced by hand or using simple machinery that guaranteed a slow but steady introduction of products into the marketplace. These products were generally finished by individual workmen and closely inspected prior to sale, guaranteeing that each product attained the level of quality that was required by their customer.



With the advent of mass production many products ceased to be hand finished and were instead machined and passed into the marketplace faster than any team of inspectors could possibly check them. This created a dilemma; how do you ensure that your customers receive the quality of product that they expect without inspecting each and every finished item? For some-time no answer was apparent and industry continued to churn out millions of products without any agreed and systematic way of checking their quality.

The problem was finally solved in the years between the Great War and the Second World War by statisticians working for the US Army. These statisticians were given the task of ensuring that any ammunition purchased by the army functioned as was intended. They rightly felt that the army would not accept their conducting a 100% inspection on the ammunition as this would involve detonating all of the rounds. Therefore, they devised a series of statistical tables that enabled a small proportion of randomly chosen samples from each delivery to be tested. The results from this small proportion could then be used to accurately predict the behaviour of all of the untested ammunition. This momentous piece of work that was to change the way business was done across the world was given the title Military Standard 105-D. Military Standard 105-D was so successful in predicting the performance of ammunition that the military started using it to control the testing of their other bulk purchases. Suppliers to the military

became used to the statistical tables and, in turn, began to using them to check their non-military products. When other countries realised that the system was successful they also adopted it. In the 1970's the UK took the tables and re-published them as British Standard BS6001 and the International Community re-published them as International Standard ISO2859.

Today almost every statistically controlled mass production process uses these tables to sample and test its output.



So where does AQL come into all this?

Whichever characteristic a Quality Control Inspection is measuring can be assigned an Acceptable Quality Level (AQL). The AQL corresponds to the maximum percentage of a production run that the manufacturer is prepared to accept as rejects when tested.

Examples:

European Standards state that medical examination gloves shall have an AQL of 1.5 for pinholes. This means that it is acceptable for up to 1.5% of all gloves that are made to contain a hole.

US and International standards for medical examination gloves only require an AQL of 2.5. This means that it is acceptable for 2.5% of all gloves that are made to contain a hole.

As you can see, a lower AQL number means that there is less risk of encountering a defect. However, it means that higher levels of inspection are required, leading to increased prices. It is one of the responsibilities of European standards makers to decide what percentage of defects is permissible in any market. For pinholes in medical gloves the Standards Committee

felt that the internationally accepted AQL of 2.5 did not provide sufficient protection for European Healthcare Workers and so set a stricter level of 1.5.

Of course, an AQL defines the worst a manufacturer can allow his process to become before action is taken. Good manufacturers regularly produce product that is significantly better than the AQL level suggests.

So how many do you actually test?

The BS6001 standard is a sixty-eight page document detailing multiple methods of inspection each justified according to statistical principles and based upon the binomial distribution. However, at its simplest the test quantity and pass / fail criteria are determined as follows.

Firstly a manufacturer must know the size of his production lot and the level of inspection required. For medical gloves this level is always General Inspection Level I. He cross references these on table 1 to get a Code Letter (the letter where the two requirements intersect).

Table 1: Code Letters. The highlighted values are regularly used when inspecting for pinholes in disposable gloves.

Lot size	Special inspection level				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
1201 to 3 200	C	D	E	G	H	K	L
3201 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

The sampling plan and AQL are then cross-referenced on a Master Inspection Table, this instructs how many products are to be inspected and how many are allowed to fail inspection. An example is shown in table 2.

Table 2:

Master Inspection Table. Highlighted values are those typically used for disposable gloves (code letter L, AQL 1.5).

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	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	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	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑

This table tells the manufacturer to take two-hundred samples from his production run and test them for the property concerned (in this case pinholes). If seven or less gloves contain a pinhole then the batch is passed. If eight or more contain a pinhole the batch is rejected.

Seven out of two-hundred?

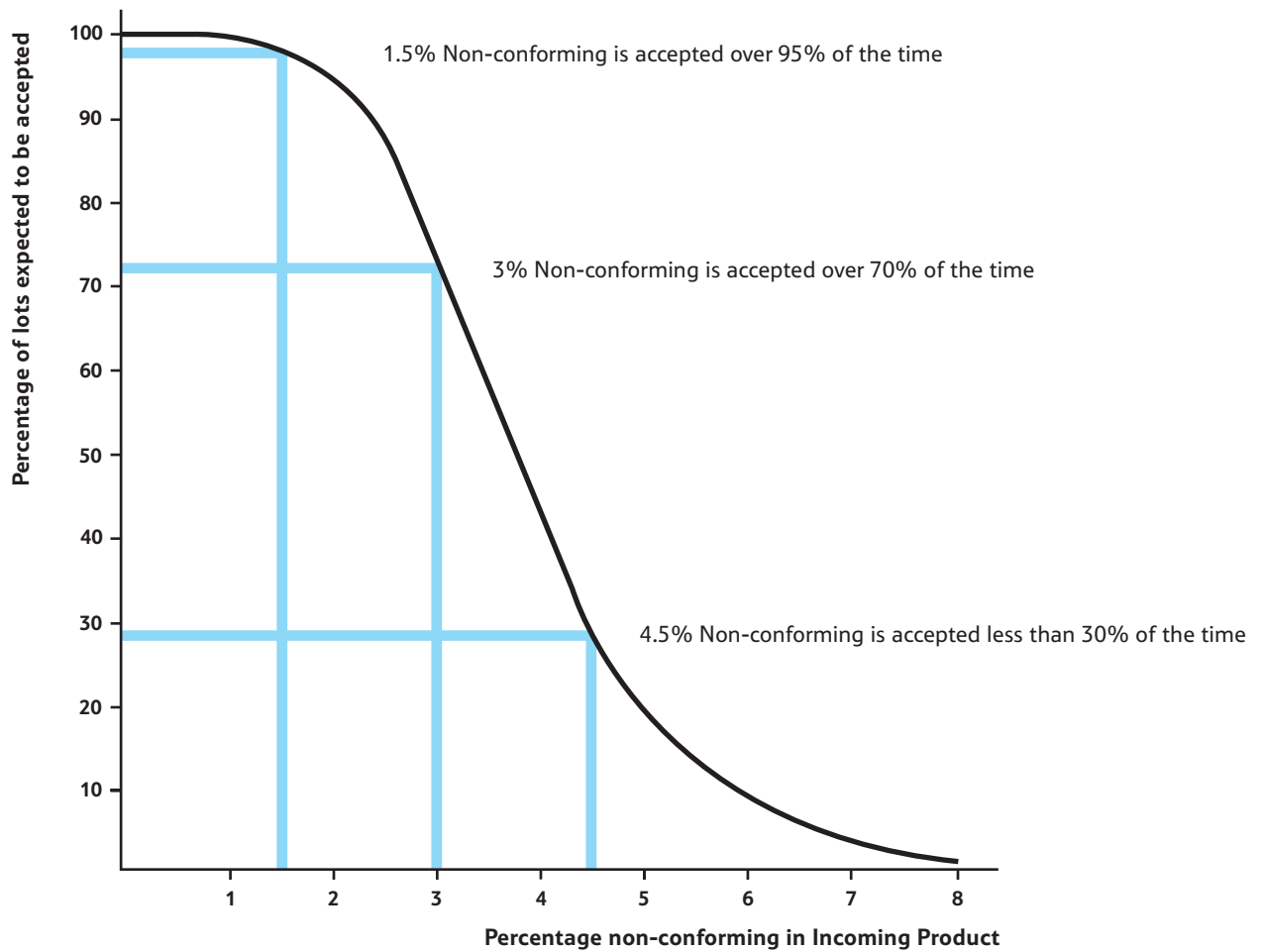
In the above example two-hundred gloves were tested and up to seven were allowed to fail; this is 3.5% of the gloves tested. At first glance this doesn't seem to match with the idea that the gloves are AQL 1.5. The answer lies in the fact that the AQL applies to the whole production lot of 35001 to 150000 gloves.

When you test a small sample (two-hundred gloves) and use the results to predict the behaviour of a large sample (the whole production) you can't be certain that the small sample you picked truly represents the large sample you picked it from. If the small sample is significantly worse than the whole production then you may end up rejecting good

product and therefore causing a shortage or price increase. To counteract this risk the tables select pass and fail numbers that make it highly probable that any product meeting the AQL is passed. The downside of this is that one-off occurrences of product failing to meet the AQL may pass through inspection undetected. A product that regularly fails to meet the AQL will be detected over time as multiple batches are tested.

The chance of gloves containing different levels of pinholes passing through the inspection detailed above is shown in table three.

Table 3:



Sample size: $n = 200$
Acceptance number: $A_c = 7$
Rejection number: $R_e = 8$

So for one inspection a product with 3% pinholes has a 70% chance of passing through the system without notice.

However, if the second delivery has 3% pinholes the chance of them both being passed drops to 49% (70% of 70%). As BM Polyco Ltd. repeats the waterleak testing already conducted by the factory this is the initial level of testing experienced by their gloves.

On a third delivery of the product with 3% pinholes the chance of all three passing through is only 34% (70% of 70% of 70%).

Therefore, by conducting Quality Control Tests on each batch, and examining the trend, a manufacturer can quickly identify any product that fails to meet its AQL and move to correct his process. The use of AQLs to ensure product quality is a time-tried system that ensures a stable quality of product over the medium to long term.