PRODUCTION · QC · INSPECTION · REFERENCE DOCUMENT · PUBLIC

Quality control and inspection

Reference for AQL sampling, defect classification, inspection-point design, process capability, and the golden-sample workflow that catches defects before they ship.

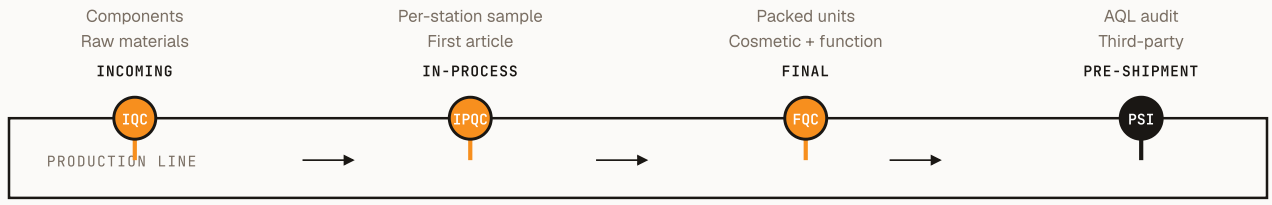
REVISION	ISSUED	OWNER	COMPANION
1.0	May 2026	Ideambox engineering	PDF reference

ABSTRACT

Quality control is the operational expression of the specification. A spec sheet without a matching QC plan creates ambiguity: each side judges quality against an unstated standard. The QC plan converts the spec into measurable inspection criteria, sampling sizes, disposition rules, and the records that survive an audit or a recall.

Section 1 covers the four production-line inspection points. Section 2 covers AQL sampling math (ISO 2859-1 / ANSI Z1.4). Section 3 covers defect classification. Section 4 covers process capability (Cp, Cpk). Section 5 catalogues process-specific defects. Section 6 provides the QC plan template structure.

QC INSPECTION POINTS — FROM INCOMING MATERIALS TO PRE-SHIPMENT



FOUR PRODUCTION-LINE INSPECTION POINTS. IQC CATCHES INCOMING MATERIAL DEFECTS; PSI CATCHES WHAT MADE IT THROUGH EVERYTHING ELSE.

CONTENTS

1. Inspection points

Four checkpoints, each with a defined scope, sample basis, and disposition authority.

POINT	WHEN	SAMPLE BASIS	DECISION	RECORDS
IQC (incoming)	Materials arrive	Per shipment, per AQL	Accept / reject / quarantine	C of C, lot, inspection report
IPQC (in-process)	During assembly	First article + per AQL	Continue / rework / stop	First-article report, control charts
FQC (final)	Finished units	Per AQL on packed boxes	Pass / hold / scrap	Per-lot disposition log
PSI (pre-shipment)	Before goods ship	3rd-party per AQL	Pass / hold / fail batch	PSI report + photographs

1.1 Golden sample workflow

- **Physical sample signed and dated by both buyer and supplier**
  the acceptable production unit.
- **Production QC measures against the golden sample, not against the prototype, render, or buyer's expectations.**
- **Both parties keep an identical signed sample**
  yours in the office, theirs on the production floor.
- **Photograph and document**
  High-res images, dimensional report, tag attached to the physical sample.
- **Disputes resolve by reference to the golden sample**
  Not by argument; by inspection of the signed reference.

2. AQL sampling

ISO 2859-1 (international) and ANSI/ASQ Z1.4 (US-equivalent) define the sampling math. Same tables; different cover. Level II / Normal inspection is the default.

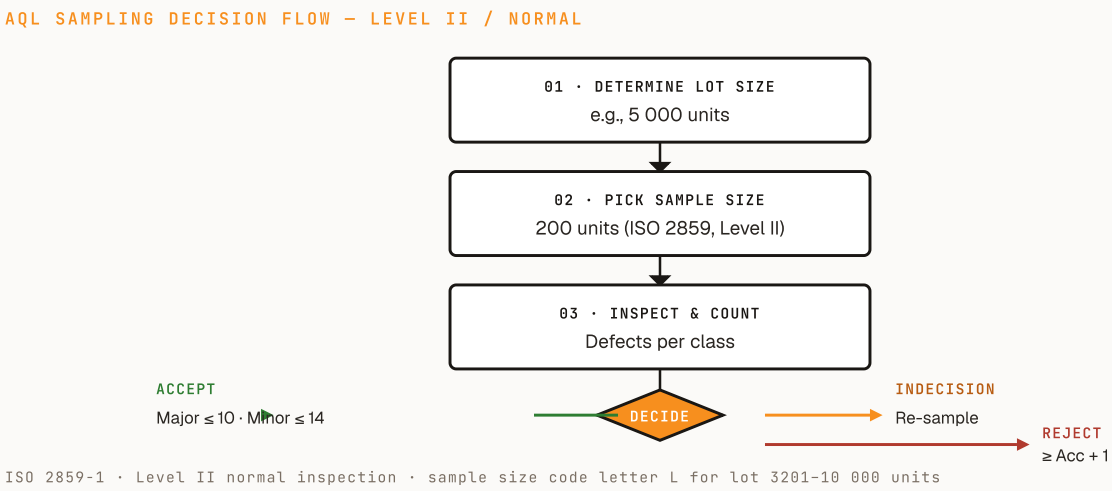


FIG 2.1 AQL SAMPLING FLOW. SAMPLE SIZE IS SET BY LOT SIZE (NOT DEFECT RATE). ACCEPT / REJECT THRESHOLDS ARE SET BY AQL LEVEL.

2.1 Standard AQL levels by defect class

- **Critical defects
  0.0 % AQL.** Any critical defect rejects the batch.
- **Major defects
  2.5 % AQL.** Significantly reduces usability.
- **Minor defects
  4.0 % AQL.** Cosmetic, does not affect function.

Tighter AQLs (1.0 % major, 2.5 % minor) for medical, automotive, mil-spec. Looser AQLs (4.0 % major, 6.5 % minor) for promotional or one-shot goods.

2.2 Sample size table (Level II, Normal inspection)

LOT SIZE	CODE	SAMPLE	ACC/REJ @ 2.5 %	ACC/REJ @ 4.0 %	ACC/REJ @ 1.0 %
91–150	F	20	1 / 2	2 / 3	0 / 1
151–280	G	32	2 / 3	3 / 4	1 / 2
281–500	H	50	3 / 4	5 / 6	1 / 2
501–1200	J	80	5 / 6	7 / 8	2 / 3
1201–3200	K	125	7 / 8	10 / 11	3 / 4
3201–10000	L	200	10 / 11	14 / 15	5 / 6
10001–35000	M	315	14 / 15	21 / 22	7 / 8
35001–150000	N	500	21 / 22	30 / 31	10 / 11

2.3 Switching rules

Quality drifts over time; the inspection level adapts.

DIRECTION	TRIGGER	NEW LEVEL
Normal → Tightened	2 of 5 lots rejected	Tightened (tighter sample)
Tightened → Suspend	5 lots rejected	Stop production
Tightened → Normal	5 consecutive lots pass	Normal
Normal → Reduced	10 consecutive lots pass + low defect rate	Reduced sample
Reduced → Normal	1 lot fails	Normal

3. Defect classification

DEFECT CLASSIFICATION — CRITICAL / MAJOR / MINOR

DEFECT CLASS

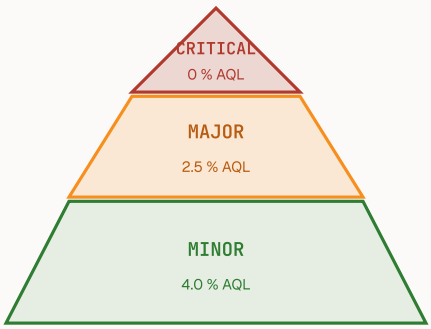
Document explicitly in the QC plan.

DECISION RULE

Per ISO 2859 sampling level II (normal).

DEFECT CATALOGUE

Photograph each type; attach to QC plan.



CRITICAL · 0 %

Safety hazard
Fails primary function
Non-compliant labels

MAJOR · 2.5 %

Reduced performance
Visible cosmetic flaws
Wrong configuration

MINOR · 4.0 %

Subtle cosmetic
Manual misprint
Off-by-mm packaging

FIG 3.1 DEFECT CLASSIFICATION TRIANGLE. CRITICAL → 0 %, MAJOR → 2.5 %, MINOR → 4.0 %. DOCUMENT EACH CLASS EXPLICITLY IN THE QC PLAN WITH A PHOTO.

3.1 Critical defects (0.0 % AQL)

- **Safety hazards**
  Sharp edges (per IEC 62368-1 test fingers), exposed conductors, battery shorts, choking risk on toys (<31 mm part per ASTM F963).
- **Failure to perform primary function**
  Does not power on, sensor doesn't read, transmitter doesn't transmit, app cannot connect.
- **Regulatory non-compliance**
  Missing required marks (CE, FCC ID, country of origin), wrong importer details, RoHS-restricted substances above threshold.
- **Counterfeit or substituted components**
  Any deviation from the approved BoM, even when functional.

3.2 Major defects (2.5 % AQL)

- **Reduced performance**
  Battery life ≤80 % of spec, sensor accuracy outside tolerance, charging slower than spec, RF range below qualified.
- **Visible cosmetic flaws**
  Scratches >0.5 mm at arm's length (~50 cm), gap >0.3 mm at mating, mis-aligned parts, distorted logos.
- **Wrong configuration**
  Wrong firmware version, wrong colour, missing accessory, wrong packaging insert.
- **Packaging damage**
  Crushed boxes (>10 % surface dented), missing inserts, deformed inner trays.

3.3 Minor defects (4.0 % AQL)

- **Subtle cosmetic**
  Marks <0.5 mm not visible from 50 cm, minor finish irregularity, gloss inconsistency.
- **Documentation**
  Manual misprint not affecting safety, label slightly misaligned (<1 mm), language tag in wrong position.
- **Packaging**
  Barcode placement off by a few mm, slight crease in retail box.

3.4 Per-product defect catalogue (template)

Each defect needs an entry. Photo each defect type at the actual scale and lighting. The catalogue is the contractual reference for accept/reject decisions.

```
Defect: Scratch on cosmetic A-surface Class: Major Limit: Visible from 50 cm under 500 lux office lighting Photo: CAT-MAJ-001.jpg (with ruler at 1:1 scale) Notes: Below 0.5 mm: minor. Above 1 mm: critical.
```

4. Process capability (Cp, Cpk)

Process capability indices quantify how well a process holds tolerance. Required for medical/automotive; useful for any tooled production.

4.1 Cp — process potential

``` Cp = (USL − LSL) / (6σ)

USL = Upper Specification Limit LSL = Lower Specification Limit σ = Process standard deviation ```

- **Cp ≥ 1.0**
  Process barely fits within tolerance. Marginal.
- **Cp ≥ 1.33**
  Industry-typical target for production.
- **Cp ≥ 1.67**
  Six Sigma target. Critical features.
- **Cp ≥ 2.0**
  Ultra-stable process. Rare in consumer hardware.

## 4.2 Cpk — process performance (centered)

`` `Cpk = min[(USL - μ) / (3σ), (μ - LSL) / (3σ)] μ = Process mean` ``

Cpk accounts for process centering. **A process can have high Cp but low Cpk if it's not centered.** Cpk ≤ Cp always.

## 4.3 Worked example

Critical dimension: 25.00 ± 0.20 mm. Production sampled 50 units.

- **Sample mean μ = 24.92 mm**
- **Sample std dev σ = 0.04 mm**
- **USL = 25.20 mm, LSL = 24.80 mm**
- **Cp = (25.20 − 24.80) / (6 × 0.04) = 0.40 / 0.24 = 1.67 (excellent spread)**
- **Cpk = min[(25.20 − 24.92) / 0.12, (24.92 − 24.80) / 0.12] = min[2.33, 1.00] = 1.00 (off-centre)**
- **Action: Adjust tooling to centre the mean at 25.00 mm. Cpk will rise to ~1.67.**

> READING CAPABILITY DATA QUICKLY
>
> - **High Cp, low Cpk** → Process is precise but off-centre. Adjust nominal, not variability. - **Low Cp, low Cpk** → Process is unstable. Investigate sources of variation. - **Cpk ≥ 1.33 across all critical dims** → Process is ready for ramp-up. - **Cpk < 1.0** → Process out of tolerance; investigate before scaling production.
```

5. Process-specific defects

Each manufacturing process has characteristic failure modes. Include the relevant set in the QC plan.

5.1 Injection molding defects

DEFECT	CAUSE	SEVERITY	VISUAL SIGNAL
Sink mark	Uneven cooling, thick walls	Major	Surface depression over thick section
Flash	Worn mold, high pressure, low clamp	Major	Thin film at parting line
Short shot	Low pressure, cold material	Critical	Incomplete fill, visible holes
Weld line	Flow fronts meeting	Minor / structural	Faint line on surface
Burn mark	Air entrapment	Major	Dark spot, often near vent
Warp	Uneven wall thickness	Critical	Part doesn't sit flat
Splay	Moisture in material	Minor	Silvery streaks
Drag mark	Poor draft, scuff during ejection	Major	Linear scratch in ejection direction
Jetting	Gate flow turbulence	Minor / cosmetic	Snake-like pattern from gate

5.2 PCBA defects

DEFECT	CAUSE	SEVERITY	DETECTION
Tombstoning	Reflow profile, pad imbalance	Critical	AOI / visual
Solder bridge	Stencil aperture, paste volume	Major	AOI / electrical test
Cold joint	Reflow profile (insufficient peak)	Major	Visual / X-ray
Missing component	Pick-and-place feeder issue	Critical	AOI / electrical test
Wrong polarity	Operator error, programming	Critical	AOI / function test
Lifted pad	Rework damage	Major	Visual after rework
Insufficient solder	Stencil aperture too small	Major	Visual / X-ray
Component shift	Reflow drift, no fiducial	Minor / major	AOI
BGA voids	Reflow profile / flux	Major	X-ray (mandatory for BGA)

5.3 Sheet metal defects

- **Burrs**
  Sharp edges from cutting; functional + safety risk. Deburr per ISO 13715 (broken edge).
- **Spring-back**
  Bent angle deviates from intent. Material- and tool-dependent; compensate in tool design.
- **Scratches**
  Tooling marks or post-process handling.
- **Mis-aligned holes**
  Punch wear or stamp misalignment. Punch lifetime: typically 100k–500k strokes.

5.4 Final assembly defects

- **Mis-aligned screws**
  Stripped threads (over-torque), backed-out screws (under-torque). Spec torque per fastener.
- **Mis-mating connectors**
  Forced or partial seating. Specify keying or asymmetric profiles to design out.
- **Wrong accessory bundled**
  Mixed SKU at packaging station. Bar-code scan per unit at packaging eliminates.
- **Surface contamination**
  Fingerprints, dust, oil from line. Gloves and dust extraction at cosmetic stations.

6. QC plan template

The deliverable. One document, version-locked with the spec sheet.

6.1 Document structure

`Document header`	Product, model, revision, applicable spec revision, author, effective date
`Sampling plan`	AQL levels per class, inspection level (II), switching rules, PSI thresholds
`Inspection points`	IQC/IPQC/FQC/PSI scope, frequency, accept criteria per stage
`Defect catalogue`	Per-defect class, description, photo, allowed limit, reference
`Disposition rules`	Accept / rework / hold / scrap by defect type
`Test equipment`	Calibrated tools with calibration dates and traceability
`Records`	Lot ID, date, inspector, defects, disposition; trend analysis
`Capability data`	Cp/Cpk per critical dimension, control charts

6.2 Standard inspection equipment

TOOL	USE	CALIBRATION INTERVAL
Caliper (digital, 0.01 mm)	General dim	6 months
Micrometer (0.001 mm)	Critical dim	6 months
Comparator microscope	Optical comparison	12 months
Hi-pot tester	Electrical safety	12 months
Multimeter (DMM)	Continuity, V, I	12 months
Drop tester	Drop test per IEC 60068-2-32	12 months
Salt-spray chamber	Corrosion test ASTM B117	12 months
Environmental chamber	T/RH cycling per IEC 60068	12 months
Force gauge	Latch/snap force	6 months
Light meter	Cosmetic inspection lighting	12 months

6.3 Standard inspection lighting

- **Office lighting**
  300–500 lux. Acceptable for routine cosmetic inspection at arm's length.
- **Inspection station**
  750–1 000 lux, daylight 5500 K. Catches subtle cosmetic defects.
- **Critical surface inspection**
  2 000+ lux with directional + diffuse mix. Catches micro-scratches.

> `FINAL NOTE.` a QC plan that is not updated when the spec sheet changes is worse than no QC plan. Both should share the same revision number. The plan, the spec sheet, and the golden sample are the three documents that decide every dispute during production.