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DEEP DRAW DESIGN HANDBOOK

Design rules, draw scheduling and defect avoidance for deep drawn sheet metal parts -
written for the engineer who signs the drawing and the buyer who releases the tool.

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How to use it

Read chapter 3 before you finalise the drawing. Read chapter 4 if the part is deeper than half its diameter.

What it is not

Not a substitute for a tool design, and not a price list. It contains no customer data.

Units

Dimensions in millimetres. Sheet thickness **t**. Draw ratio written beta.

Where the numbers come from

Two sources only. Ranges marked as planning values come from our own tool room: the radii, ratios and clearances we lay out a first schedule with. Everything else - ISO 2768, the material designations, the standard terminology - is published reference material and is quoted as such. No number in this handbook is a customer measurement.

How a planning value becomes a commitment

It does not, until the first article. A DFM review turns the ranges here into a specific blank size, a specific schedule and a specific set of tolerances for one part. Until that review exists, treat every range as a starting point for a conversation rather than a capability statement.

CHAPTER 01

WHEN DEEP DRAWING IS THE RIGHT PROCESS

Deep drawing turns a flat blank into a seamless shell in one press stroke or a short series of them. It is the cheapest way to make a thin walled, closed bottom part at volume - and the most expensive way to make it when the geometry fights the process.

It wins when

- The part has a closed bottom and a wall that is thin relative to its diameter.
- Annual volume is high enough to amortise a die - from a few thousand pieces upward, depending on size.
- A weld seam is not acceptable: pressure tightness, magnetic symmetry or appearance rules out welded tube.
- Concentricity between the bottom and the wall matters more than the absolute diameter.
- The material work hardens: stainless, deep drawing steel, aluminium, copper, brass.

It loses when

- Batch size is in the tens. A machined or spun part is cheaper at that volume.
- The wall is thick relative to the diameter - a forged or machined blank wins.
- The part is a deep rectangular box with sharp internal corners.
- The bottom must be flat to a few hundredths without a coining operation.
- The material is brittle, or already at its forming limit.



FIG 1.1 The same wall thickness, four different depths. Depth is what the drawing schedule buys, and what the tooling budget pays for. Illustration is representative.

The economics in one line

Deep drawing moves cost from the machine to the die. Raising annual volume therefore lowers unit price faster than any other metal forming process - and lowering volume raises it just as fast. If volume is uncertain, say so at the RFQ stage: it changes the die specification more than it changes the process.

CHAPTER 02

MATERIAL DRIVES THE SCHEDULE

The grade decides how much you can draw in one pass, whether an anneal has to be inserted, and how much the wall will thin. Drawability below is a planning guide for a first conversation, not a specification.

DRAWABILITY PLANNING GUIDE

FAMILY	TYPICAL DESIGNATION	DRAWABILITY	ANNEAL BETWEEN DRAWS	WHY YOU WOULD CHOOSE IT
Deep drawing steel	DC01 / DC03 / DC04 EN 10130	DC04 excellent DC01 fair	DC04 usually not needed at moderate depth	Lowest cost and best formability. Not for magnetic circuits.
Cold rolled low carbon	SPCC / SPCD / SPCE JIS G3141	SPCE good	As required	Widely stocked in Asian supply chains, easy to dual source.
Electrical pure iron	DT4 / DT4E GB/T 6983	Fair - low ductility	Usually yes	Soft magnetic parts: solenoid housings, armatures, pole pieces.
Austenitic stainless	304 / 1.4301 316L / 1.4404	Fair - work hardens fast	Often between draws	Corrosion resistance, cleanability, non magnetic after forming.
Ferritic stainless	430 / 1.4016	Fair	Sometimes	Magnetic, cheaper than 304, less corrosion resistance.
Aluminium, soft	1050 / 1100 (O)	Good	No	Light, non magnetic, thermally conductive, easy to draw.
Aluminium alloy	3003 - 5052	3003 fair to good 5052 limited	Sometimes	3003 for general parts. 5052 only for shallow draws.
Copper and brass	C11000 (ETP) C26000 (cartridge)	Good	No	Conductivity, appearance, deep draws with generous radii.
Nickel alloys	Inconel 600 Monel 400	Difficult	Usually, with intermediate anneal	High temperature or corrosive service. Low volume, high cost.

Thickness matters as much as grade

A 0.4 mm wall draws further than a 3 mm wall of the same grade, because the blank holder can control a thin sheet with less force. If the part has a thick wall and a small diameter, expect to machine it instead - or to accept a much larger radius.

Ask the mill, not the press

Minimum order quantity and lead time follow the mill, not the press. Exotic grades and non standard thicknesses can add weeks to a first article even when the die is already finished.

CHAPTER 02 - CONTINUED

WORK HARDENING, AND WHEN TO ANNEAL

A drawn wall gets harder with every pass. The blank arrives annealed; the first draw raises the yield strength in the wall, and the second draw starts from that harder state. This is why a second draw needs a larger radius and a smaller reduction than the first - and why stainless and electrical pure iron frequently need an anneal inserted between draws.

WHEN AN ANNEAL HAS TO BE PLANNED

SITUATION	ACTION
Stainless 304 or 316, more than two draws	Plan an intermediate anneal after draw 1 or 2.
Electrical pure iron (DT4 / DT4E), any multi draw part	Anneal before the final draw, then confirm the magnetic properties after forming.
Aluminium 1050 / 1100	Usually none.
Aluminium 5052, deep parts	Anneal between draws.
Brass C26000, deep parts	Stress relief if the part cracks at the base.
Draw 2 cracks where draw 1 did not	The wall is already at its limit. Anneal, or add a draw and reduce the reduction per pass.

Annealing is a cost, not a detail

An intermediate anneal adds a process step with its own cost, lead time and distortion. It also changes the surface. Introducing it after the quotation is the single most common reason a quoted price moves upward.

Temper is a specification

Stainless, 1 mm is not a specification. State the grade, the temper on arrival, the surface condition, and whether the finished part has to be magnetic. A magnetic requirement can rule out 304 entirely.

A practical test before you release the drawing

Compute the reduction you are asking for in one pass: blank diameter divided by cup diameter. If it exceeds the first draw ratio for your material, the part needs more than one draw and the tool needs more stations. If nobody did that arithmetic before the RFQ, the first quote will be wrong.

NINE RULES THE DRAWING HAS TO RESPECT

Rules 1 to 4 are geometry the tool has to follow. Rules 5 to 9 are limits and features. Every value below is a planning range: the tool room confirms it against the material, the volume and the surface requirement.

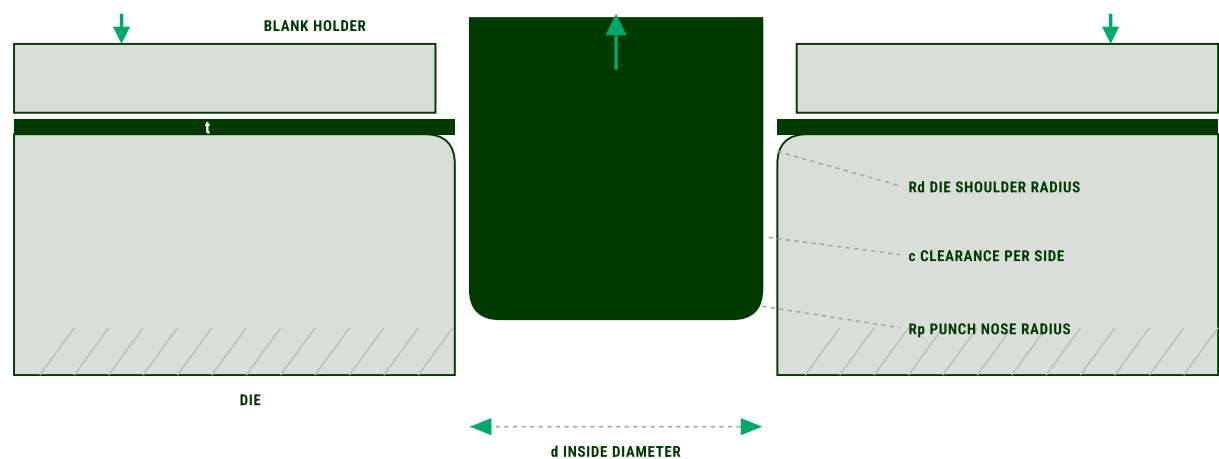


FIG 3.1 First draw section. The material is pulled over the die shoulder radius and around the punch nose radius; the blank holder keeps the flange from wrinkling while the clearance sets the wall.

1 - Radii decide everything

Punch nose radius normally 2t to 4t on the first draw and 0.8t to 1.5t on later draws; die shoulder radius 4t to 8t on the first draw and 2t to 4t after that. Too small tears, too large wrinkles.

3 - Do not ask for a thin wall silently

A finished wall thinner than the blank means an ironing operation: a separate die, a separate cost, and less elongation left in the material. Say so on the drawing rather than in a note at the bottom.

2 - Clearance per side 1.1t to 1.3t

Tighter clearance thins the wall deliberately (ironing); looser clearance costs roundness. If the drawing does not state a wall tolerance, we assume the wall equals the blank thickness.

4 - Be realistic about bottom flatness

As drawn, the bottom of a cup is slightly domed and the corner radius is never sharp. Flatness in the hundredths needs coining or machining after the draw.

WHAT TO WRITE DOWN FOR EACH RULE

RULE	ON THE DRAWING	IF YOU CANNOT STATE IT
1 - Radii	Bottom radius as a minimum, not a maximum. State the inside radius of the punch face.	We will choose the largest radius the part allows and flag it in the DFM note.
2 - Clearance and wall	Wall thickness with a tolerance, and whether it may differ from the blank.	We assume the wall equals the blank and quote accordingly.
3 - Ironing	The finished wall, plus a note that the part is ironed.	The part is quoted as a straight draw, and the price will move if ironing is added later.
4 - Bottom flatness	Flatness with a datum and the area it applies to.	We quote as drawn, which means a slightly domed bottom.

CHAPTER 03 - CONTINUED

RULES 5 TO 9

5 - Stay inside the draw ratio

Draw ratio is blank diameter divided by cup diameter. Exceed the first draw limit and the part becomes a two or three station job - a tooling decision, not a press decision.

6 - Specify the temper you need

Grade plus temper plus surface condition. A magnetic requirement can rule out austenitic stainless, and a hardness requirement can rule out drawing at all.

7 - Holes and slots go in after the draw

Keep pierced features at least 2t from the wall, and 3t where the feature has to hold position. Where a hole has to be true, pierce it after drawing rather than before.

8 - Give us a trim allowance

A drawn rim is never level. The blank is calculated with roughly 5 to 10 percent extra height and the rim is trimmed afterwards. If the finish height is critical, say which face the trim is measured from.

9 - State the datum and the measuring height

A drawn wall is not a cylinder of constant diameter: it tapers slightly and springs back when it leaves the die. Without a stated height and datum, two inspectors measure two different diameters and both are right.

DRAW RATIOS - PLANNING VALUES

MATERIAL	FIRST DRAW	SUBSEQUENT DRAWS	PRACTICAL NOTE
Deep drawing steel DC01 - DC04	1.7 - 2.0	1.2 - 1.4	DC04 at the top of the range, DC01 at the bottom.
Austenitic stainless 304 / 316L	1.6 - 1.8	1.2 - 1.4	Plan an anneal above two draws.
Ferritic stainless 430	1.6 - 1.8	1.2 - 1.3	Lower elongation in the transverse direction.
Electrical pure iron DT4 / DT4E	1.5 - 1.7	1.1 - 1.3	Annealing is normal, not exceptional.
Aluminium 1050 / 1100 (O)	1.7 - 2.0	1.3 - 1.5	Soft temper only. Scratches easily in the die.
Brass C26000	1.6 - 1.8	1.2 - 1.4	Excellent for small housings and cups.

Ranges are planning values used to lay out a first drawing schedule. The real limit is measured on the first article: the blank is adjusted and, if necessary, the schedule is extended by one station.

CHAPTER 04

BLANK DEVELOPMENT AND DRAW SCHEDULE

Two numbers decide the tooling: the blank diameter and the number of draws. Both come from the same arithmetic, and both are checked on the first article.

Blank for a plain cylindrical cup

$$D = \sqrt{d^2 + 4 d h}$$

D blank diameter, **d** mean cup diameter (inside diameter plus one wall), **h** cup height.

The formula ignores the corner radius and the trim allowance. In practice we add 5 to 10 percent to the height before calculating, then trim the rim after drawing.

Worked example

Inside diameter 40.0 mm, wall 1.0 mm, height 78 mm. Mean diameter **d** = 41.0 mm.

$$D = \sqrt{(41.0^2 + 4 \times 41.0 \times 78)} = 118.7 \text{ mm}$$

First draw ratio for DC04 is about 1.85, so the first draw can reach $118.7 / 1.85 = 55.9$ mm. A second draw at 1.36 reaches 41.0 mm. Two draws, then a sizing pass to hold the diameter and the roundness.

ONE PART, FOUR OPERATIONS

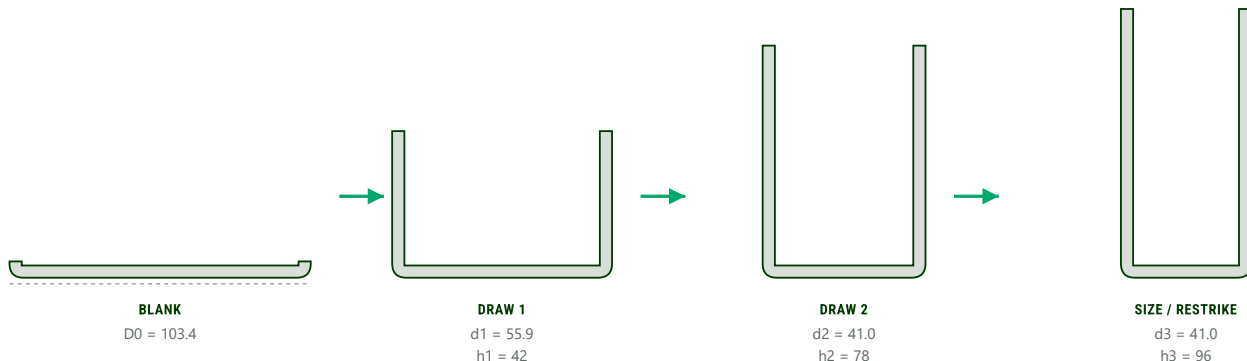


FIG 4.1 The same part in four operations. Diameter falls, height rises, and the wall keeps its thickness - until an ironing pass is added deliberately.

Why the schedule is not optional

A part that needs two draws cannot be made in a single station die without a transfer. That changes the tool cost, the press, the cycle time and the scrap. The arithmetic above is what turns a drawing into a quotation.

CHAPTER 04 - CONTINUED

THE SCHEDULE ON ONE PAGE

This is the same part as the worked example, written the way it reaches the tool room.

OPERATION SCHEDULE - 41 MM INSIDE DIAMETER, 78 MM DEEP, DC04, WALL 1.0 MM

OP	OPERATION	DIAMETER	HEIGHT	RATIO	NOTE
00	Blank	118.7	-	-	Deburred, lightly oiled, thickness tolerance confirmed.
10	Draw 1, blank holder	55.9	42	1.85	Die shoulder radius at the top of the range.
20	Draw 2, redraw	41.0	78	1.36	Punch radius reduced. No anneal needed for DC04.
30	Size and restrike	41.0	80	-	Holds diameter and roundness after springback.
40	Trim rim to length	41.0	78	-	Trim fixture referenced to the inside bottom.
50	Ironing - only if the wall must thin	41.0	78	15% wall	Adds a die, a lubricant step and a stress relief question.

Ironing is a decision, not a default

Wall reduction per ironing pass is normally kept at or below about 40 percent, and most parts run well under that. Every pass reduces the remaining elongation and adds a die. If the wall does not have to be thinner than the blank, do not ask for it.

Sizing is what buys the diameter

Springback after draw 2 is real and it is not constant around the circumference. A sizing or restrike operation is normally what turns an as-drawn diameter into a specified one - and it is where roundness and concentricity are won or lost.

What a schedule lets you check before you commit

Number of stations, number of dies, whether an anneal sits in the middle of the route, whether a transfer is needed, and where the scrap is created. Every one of those is a cost line. A drawing without a schedule is a price without a basis.

CHAPTER 05

TOOLING: WHAT IS WORTH PAYING FOR

The die is where the money goes, and where the part is won. Three things inside the tool decide the delivered part: the radii, the blank holder pressure, and the surface the material slides against.

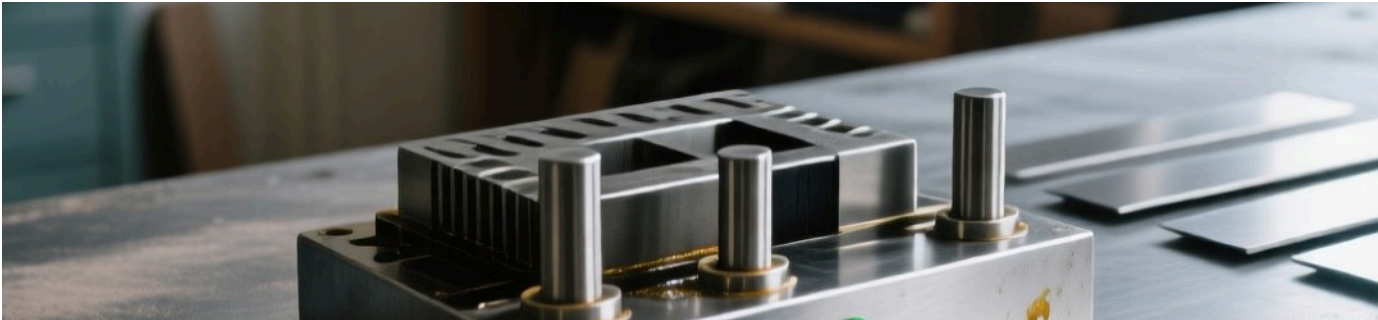


FIG 5.1 A draw die set on the bench: die plate, guide pillars and punch, with the first tryout blanks beside it. Illustration is representative.

TYPICAL DIE SPECIFICATION

ELEMENT	TYPICAL MATERIAL	WHAT IT BUYS
Punch and die inserts	Cold work tool steel: D2, DC53, SKD11	The standard choice for steel and stainless. Good life, repairable, predictable cost.
Inserts, high volume	Tungsten carbide	For runs in the millions and for small parts where wear shows quickly. Higher die cost, much longer life.
Blank holder and pressure pad	Hardened tool steel	Sets the pressure that prevents wrinkling. Pressure is tuned at tryout, not computed on paper alone.
Ironing rings	Carbide or polished hardened steel	Surface finish transfers directly to the drawn wall. A scored ring marks every part that follows.
Lubricant	Chlorine free drawing compound	Stainless needs high film strength; whatever is used still has to be cleanable before welding or passivation.

Die life, as planning numbers

Tool steel inserts commonly give a few hundred thousand to around a million strokes depending on material and lubrication; carbide runs several million. These are ranges for budgeting maintenance, not promises for a specific part.

Tryout is part of the price

A draw die is not finished when it is machined. It is finished when the blank size, the blank holder pressure and the radii together produce a part with no wrinkles and no tears. That loop is what the tooling price buys.

CHAPTER 06

DEFECTS: CAUSE AND REMEDY

Almost every draw failure appears in one of a handful of places on the part. Naming the location is most of the diagnosis.

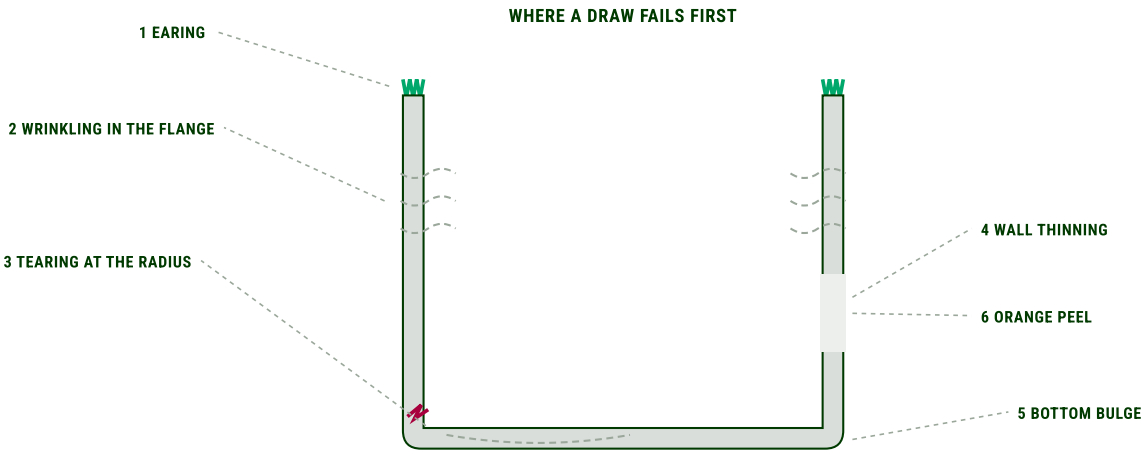


FIG 6.1 Where a draw fails first. The rim, the wall and the radius each fail for different reasons, and each has a different remedy.

DEFECT - CAUSE - REMEDY

DEFECT	MOST LIKELY CAUSE	REMEDY
Wrinkling in the flange or wall	Blank holder pressure too low, clearance too large, or the wall is thin for the diameter.	Raise the blank holder pressure, tighten the clearance, or add a draw and reduce the reduction per pass.
Tearing at the punch radius	Punch or die radius too small, reduction too large, or the material is at its forming limit.	Increase the radii, split the reduction over more draws, or anneal before the critical draw.
Earing - an uneven rim	Anisotropy in the rolled sheet: the material draws differently along and across the rolling direction.	Accept and trim, rotate the blank, or change to a grade with less directionality.
Wall thinning above the radius	Clearance too tight, or too much material pulled past the radius in one pass.	Open the clearance to 1.1t to 1.3t, or redistribute the reduction.

Continued on the next page.

CHAPTER 06 - CONTINUED

THE REMAINING FAILURE MODES

DEFECT	MOST LIKELY CAUSE	REMEDY
Orange peel surface	Coarse grain in the sheet, or a draw that pushed the material past its limit.	Change to a finer grain or drawing quality grade. The surface cannot be polished out of a drawn wall.
Bottom bulge or doming	Residual stress released when the part leaves the die, or a punch face that is not flat.	Add a restrike or a coining operation if flatness is functional.
Springback on the diameter	The wall relaxes elastically after the punch withdraws. It is never zero.	Size the part, overdraw slightly, or accept a wider diameter tolerance.
Longitudinal scratches or galling	Material picking up on the die, poor lubrication, or a scored die surface.	Polish or re-coat the die, change the lubricant, and stop the press to repair before running on.
Cracks only after trimming or flattening	The material was already at its limit; the secondary operation only revealed it.	Return to the draw schedule. Trimming cannot fix a wall with no ductility left.
Rim height varies around the part	Earing combined with a trim fixture that references the outside rather than the bottom.	Reference the trim to the inside bottom, and expect a taller trim allowance on anisotropic grades.
Magnetic properties out of specification	Too much cold work in the wall, or an anneal that was skipped to save a process step.	Anneal before the final draw and verify on the finished part, not on the blank.

Reading a failure photo before you send it

Three things are visible in almost any photograph and they narrow the cause immediately. A crack with a bright torn edge means the material ran out of ductility; a crack with a dull, jagged edge usually means a tooling mark or a burr started it. A wrinkle that runs around the circumference is a pressure problem; a wrinkle that runs up the wall is a clearance problem. A rim that is higher in two opposite places is earing, and no amount of tool tuning will remove it.

What to send us when a part fails

- Photograph of the failure with a scale in frame.
- Location on the part: rim, wall, radius, bottom.
- Batch number, press and die station.
- Whether the failure is on every part or on some.
- The material certificate for that coil.

Why the list is this short

Because those five answers separate a tooling problem from a material problem from a drawing problem. Without them the first reply is usually a question, and a week is lost. With them the diagnosis is often the same day.

CHAPTER 07

WHAT IS ACHIEVABLE AS DRAWN

These are typical as-drawn results for a cylindrical housing. Anything tighter is bought with a second operation - and the second operation has to be in the price from the first quotation.

TYPICAL AS-DRAWN CAPABILITY

FEATURE	TYPICAL AS DRAWN	TIGHTER BY
Inside diameter	IT9 - IT11	Sizing or ironing pass
Roundness	0.03 - 0.10 mm	Sizing pass
Concentricity, ID to OD	0.05 - 0.15 mm	Same pass, single datum
Wall thickness variation	about +/- 5% of nominal	Ironing
Overall height	+/- 0.2 - 0.5 mm	Trim fixture
Bottom flatness	0.10 - 0.30 mm	Coining or machining



FIG 7.1 The drawn wall carries the marks of the die and the ring it passed through. Surface and tolerance are the same conversation.

If the drawing is silent

Where a tolerance is not stated we work to ISO 2768-m as a default, plus the as-drawn values above. If a feature is functional, state it - a general note will not protect the assembly.

Say where you measure

A drawn wall tapers and springs. State the height at which the diameter is measured and the datum it is taken from. That one sentence removes most disputes about a first article.

HOW EACH CALL-OUT IS ACTUALLY CHECKED

CALL-OUT	METHOD	PRACTICAL NOTE
Inside diameter	Bore gauge or CMM, at the stated height	The reading moves with the height. State it once and both sides measure the same way.
Roundness	CMM circle fit in one plane	Springback is not uniform, so sample more than one height on the first article.
Concentricity	CMM, inside diameter to outside diameter, one datum axis	Needs a defined datum. Without one the result depends on how the part is clamped.
Wall thickness	Ultrasonic or sectioned sample	A sectioned sample is the honest check: it shows the thinning pattern, not just one number.

CHAPTER 08

THE DRAWING WE NEED TO QUOTE PROPERLY

A DFM review is only as good as the package behind it. This is the list that lets us answer with a schedule and a price instead of a list of questions.

On the drawing

- Finished inside and outside diameters, with the measuring height.
- Wall thickness, as drawn and after any ironing.
- Height, and whether it is measured over the dome or to the trimmed rim.
- Corner and radii requirements, including the bottom radius.
- Concentricity and roundness call-outs with their datums.
- Flatness of the bottom, if it is functional.
- Holes, slots and cut-outs with position tolerances.
- Surface finish and any post-treatment: passivation, plating, annealing.

Around the drawing

- Material grade, temper and surface condition.
- Annual volume and the expected batch size per order.
- Any magnetic, pressure tightness or cleanliness requirement.
- Which dimensions are functional and which are reference.
- Whether a first article and PPAP are required, and at what level.
- Destination and packaging, because they change the unit price.

What happens next

We return a DFM note: the draw schedule we would use, the radii we would change, the points where the drawing asks for something the process cannot hold, and what each of those costs if the requirement stays. That note is the basis of the quotation.

One thing worth doing before you send

Mark the three dimensions that actually matter to the assembly. Everything else can be released to general tolerance - and general tolerance is where the cost comes out of the part.

WHAT MOST OFTEN DELAYS A FIRST QUOTE

MISSING ITEM	WHAT IT CHANGES
No annual volume, or a range only	Die specification, and therefore the tooling line and the unit price.
Wall thickness without a tolerance	Whether the part needs ironing, and whether a second die is in the price.
Concentricity call-out with no datum	The inspection plan, and sometimes the process route.
A magnetic or pressure requirement discovered later	The material, which resets the whole quotation.

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DEEP DRAWN AND STAMPED METAL PARTS, FROM TOOLING TO PPAP

Zhejiang Balford Mechatronics makes deep drawn housings, cups and shells for sensor, solenoid valve and automotive programmes, with in-house tooling, drawing, ironing and inspection.

Process

Deep drawing, redrawing, ironing, progressive die stamping, secondary machining and surface treatment.

Materials

Deep drawing steel, stainless 304 and 316L, ferritic stainless, electrical pure iron, aluminium, copper and brass.

Quality

First article, PPAP, material certificates, and IMDS data where the programme requires it.

Send a drawing

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This whitepaper

WP-01 Deep Draw Design Handbook, edition 2026. Superseded editions are withdrawn. Illustrations are representative of the process and are not drawings of any customer part.