PLASMA CUTTING

The 4th state of matter puts a 30,000°C supersonic jet on your bench — every principle, parameter, process comparison, consumable, quality rule, history and safety fact on one sheet

30,000 °C	plasma arc core temperature
~80 mm	plate thickness plasma will cut
3–8×	faster than oxy on thin steel
1.5–4 mm	kerf (cut width per pass)
Any metal	steel · stainless · Al · Cu · brass · Ti

THE BASICS

WHAT IS PLASMA CUTTING?

A **thermal cutting process** that severs **electrically conductive metals** using a high-velocity jet of **ionised gas (plasma)** heated by an electric arc to extreme temperature. The jet **melts** the metal along the cut line while the gas blast **blows the molten material** out of the kerf (the slot left behind).

Plasma = the 4th state of matter. When a gas is heated hard enough, electrons are stripped from the atoms to leave a mixture of **free electrons + positive ions** — electrically conductive and able to carry an arc.

Cuts **mild & carbon steel, stainless, aluminium, copper, brass, cast iron, titanium** — any material that conducts electricity, far more versatile than oxy-fuel.

Why gas matters: the plasma gas choice sets cut speed, edge colour and consumable life — air is cheapest and general-purpose, oxygen is fastest on mild steel with cleaner edges, nitrogen gives bright oxide-free edges on stainless/aluminium, and argon–hydrogen (65/35) is hottest for thick stainless (12 mm+). F5 (95% N■ / 5% H■) is a cheaper mechanised alternative.

THE PHYSICS

HOW A CUT HAPPENS — STEP BY STEP

- **1. Gas flows** — compressed air/O■/N■/Ar spins in through the swirl ring
- **2. Pilot arc** — a high-frequency spark ionises gas between electrode & nozzle (non-transferred)
- **3. Transfer** — as the torch nears the workpiece the arc jumps to the metal (transferred arc; workpiece = anode → heat goes into the cut)
- **4. Plasma** — the arc superheats the constricted gas into a supersonic jet (3–6× the speed of sound)
- **5. Melt** — the jet's heat melts metal instantly along the cut line
- **6. Blow out** — high-velocity gas expels molten metal through the bottom → kerf
- **7. Travel** — torch moves (hand or CNC) and the cut follows; shield gas protects the edge

Why constriction matters: squeezing the gas through the small nozzle orifice raises both **current density** and **jet velocity** — the same arc energy concentrated into a narrower, faster stream gives the intense melting power. The result is a plasma core of **15,000–30,000 °C**, several times hotter than the Sun's 5,500 °C surface, exiting at up to **3–6× the speed of sound** (supersonic).
It works because the **circuit completes through the workpiece** — you must connect the **work lead (ground clamp)** or there is no transferred arc.

THE TOOL

ANATOMY OF A PLASMA TORCH

- **Electrode (cathode)** — copper body with a **hafnium** (occasionally zirconium) tip that survives the arc; tip erodes with every start
- **Swirl ring** — angled gas ports spin the gas to centre & stabilise the arc
- **Nozzle** — copper with a precision orifice that **constricts** the arc into a tight jet
- **Shield cup** — directs secondary shielding gas over the edge, protects the nozzle from spatter
- **Pilot arc** — the small internal arc that ionises the gas for starting
- **Work lead / ground clamp** — completes the return circuit through the workpiece
- **CNC height control** — holds standoff steady on warped plate (mechanised)

Power supply: inverter rectifier, ~20–400 A DC; **gas supply** must be clean, dry & oil-free — moisture is the #1 killer of consumables.

DIAL IT IN

CUTTING PARAMETERS — TYPICAL VALUES (AIR PLASMA, MILD STEEL)

Amperage, speed, standoff and gas pressure all interact — change one and the others may need adjusting. Always use the manufacturer's cut chart for your exact torch, consumables and gas; values here are indicative.

Plate thickness	Current (A)	Speed (mm/min)	Standoff (mm)	Gas / nozzle note
3 mm	30	1200–1500	1.5–3 (drag)	Fine nozzle; fast, clean cut
6 mm	45	800–1000	2–3	Standard nozzle
10 mm	60	500–700	3–4	Standard nozzle
16 mm	80	350–450	3–5	Large nozzle
25 mm	100	200–300	4–6	Large nozzle; strong current, slower feed
50 mm	200 (mech.)	100–150	4–6 + THC	Heavy-duty; pierce high first
Severance (max)	unit rating	slow	—	Absolute max — rough, not a quality cut

How each knob affects the cut — current (A): more = faster + wider kerf + thicker plate, too much = dross and double-arc. **Speed:** more = less HAZ/dross, too fast = jet lag (drag lines), bevel, no penetration. **Standoff / arc voltage (THC):** too high = wide kerf + rounded top edge + arc wander; too low = nozzle shorts (double arc destroys it). **Gas pressure:** more momentum to clear dross, too high = rough edge/blow-out, too low = weak start. **Pierce delay:** always pierce with the torch high and pause to let the jet blow through, THEN drop to cut height — protects the nozzle from molten-metal splash-back.

PICK THE RIGHT PROCESS

PLASMA vs OXY-FUEL vs LASER vs WATERJET vs CNC MILL

Plasma is the all-round champion for any conductive metal — but it's not the only one. Oxy-fuel, laser/waterjet win precision; CNC milling adds 3-D geometry.

Process	Principle	Materials	Max thickness	Edge quality	Kerf	HAZ	Speed on 10 mm steel	Equipment cost
Oxy-fuel	Gas flame + O■ jet burns steel	Mild/carbon steel only	300+ mm	Rough; heavy dross; large HAZ	2–5 mm	Very large	Slow ~0.3 m/min	Low
Plasma	Ionised-gas arc melts + blows metal	All conductive metals	~150 mm	Good; HyDefinition ≈ laser	1.5–4 mm	Medium (small if fast)	Fast ~0.6–1 m/min	Medium
Laser	Focused light beam melts/vapourises	Most metals (thin) + non-metals	~25–30 mm (steel)	Excellent, square, smooth	0.1–0.5 mm	Medium–low	Very fast on thin	High
Waterjet	Abrasive water erodes material	Almost anything (metal, stone, glass, composite)	200+ mm	Excellent; no heat at all	0.8–1.5 mm	None (cold)	Slow	Very high
CNC mill	Rotating cutter physically removes chips	Metals, plastics, wood	any (by machine)	Excellent; true 3-D	cutter Ø (≥ ~1 mm)	Low–medium	Slow	Very high

When to reach for each — plasma: general fabrication, any conductive metal, mid thicknesses, low running cost. **Oxy-fuel:** very thick structural steel (300 mm+) and demolition. **Laser:** precision thin-sheet work, fine features, tight kerf. **Waterjet:** heat-sensitive and exotic materials, thick non-metals. **CNC mill:** 3-D milled geometry, finished holes and pockets — the only one that removes material in three dimensions.

WHY CHOOSE IT

ADVANTAGES OF PLASMA

- Cuts **any conductive metal** — the big advantage over oxy-fuel
- **Fast on thin & medium steel** — 3–8× (up to 10×) faster than oxy up to ~50 mm
- **Low setup** — no preheat, instant hot jet; portable hand units from ~15 A, run on 230 V mains
- **CNC-capable** — easily automated for repeatable, nested parts
- **No preheat required** — saves time and gas
- Cuts **painted, rusty or stacked plate** without preparation
- **Cheaper than laser** on heavy/mid plate — cheap consumables, low running cost with shop air
- Narrow kerf & small HAZ vs oxy-fuel

WATCH OUT

LIMITATIONS

- **HAZ + heat distortion** on thin sheet — heat input warps and hardens edges
- **Dross** on the bottom edge — resolidified metal to grind off
- **Consumables wear** — electrode & nozzle are sacrificed parts that must be replaced
- **Edge squareness varies** — standard bevel 1–4° (less on high-definition)
- **Fumes, glare & UV** — needs extraction and eye protection
- **Kerf 1.5–4 mm** — wider than laser/waterjet, more material waste
- Only **conductive** metals — no wood, plastic, glass
- **Loud** (95–115 dB) — hearing protection required

SACRIFICIAL PARTS

CONSUMABLES & THEIR LIFE

Plasma is a **consumable-hungry** process — the electrode erodes with every arc start and wears out with hours/amperage.

- **Electrode (hafnium tip)** — 300–1,000+ starts; deep pit in tip = replace, never rotate a worn one
- **Nozzle** — wears together with the electrode; oval/enlarged orifice = poor cuts, one-sided bevel
- **Swirl ring** — long life; blocked gas ports make the arc wander
- **Shield cup** — long life; clean spatter, replace cracked ceramic

Extending life: use **clean, dry gas** (drain the separator daily — water contamination ruins consumables faster than anything), respect the cut chart, minimise pilot time, replace worn parts as a set.
Maintenance cadence — daily: drain water from the compressor/separator, check hoses, cables and the ground clamp. **Weekly:** inspect consumables and replace worn parts as a set, clean the torch head. **Monthly:** verify air pressure and quality at the torch, check O-rings and insulation, test the pilot-arc start. A clean, dry system is the cheapest way to buy consistent cut quality.

AUTOMATION

CNC PLASMA TABLES

- **Gantry table** — X/Y motion moves the torch over stationary plate
- **THC (torch height control)** — senses **arc voltage** (voltage ∝ standoff) to keep torch height constant over warped plate
- **CAM nesting** — nests parts tightly in sheet stock for minimal scrap
- **Cut charts** — machine reads current/speed/height tables per material & thickness
- **Bevel / tilt heads** — rotate the torch (0–45°+) for weld-prep V-bevels in one pass
- **Table options** — **water table** (catches dross, cuts fumes/noise/distortion) or **downdraft** (fume extraction through the bed)
- Delivers repeatable, nested parts straight from CAD
- **Piercing/thinning:** for thin sheet, THC runs an automatic pierce-and-drop cycle; multi-tool heads cut, mark and drill in one setup

TIMELINE

HISTORY — HOW PLASMA DEVELOPED

Born from **plasma spraying** research (1950s plasma-spray torches), cutting quickly followed.

- **1940s** — arc-cutting experiments; oxy-fuel dominates industry
- **1955** — plasma arc cutting invented at Union Carbide (Linde), Ar–H■ for stainless & aluminium
- **1960s** — dual-flow & **water-injection** torches for thick plate; underwater cutting
- **1970s** — compressed-air plasma → small affordable hand units for workshops
- **1980s** — **CNC tables + automatic THC** bring repeatable production cutting
- **1990s–2000s** — **high-definition (HyDefinition) plasma**: tighter kerf, squarer edges
- **Today** — precision plasma ≈ laser quality on plate; inverter supplies, robotic cells, fine-feature cutting

THE EDGE

CUT QUALITY / EDGE FINISH

Read the **cut face** — it tells you instantly if the parameters are right.

- **Top edge** — rounding means standoff too high; square means height is right
- **Dross** — bottom edge = too slow / too low amps; top edge = too fast
- **Squareness / bevel** — angle off 90°; standard plasma 1–4°, HyDefinition 1–2° or less
- **Tolerances** — plasma edge quality is a secondary process (not a precision bore)
- **Drag lines** — straight vertical = ideal speed; deep curves = too slow

Conventional vs HyDefinition: high-definition plasma uses a smaller orifice, tighter arc and finer gas control → narrower kerf (~1.5–2 mm), squarer edges and near-laser finish on plate — at a fraction of laser cost. Standard plasma trades edge quality for speed and low consumable cost.
Warping/management: reduce distortion by cutting fast (less heat input), using a water table, cutting parts in a balanced sequence and clamping thin sheet. Tolerances on a good CNC plasma table typically land within ±0.5–1 mm — more than adequate for fabrication fit-up, not a precision machining operation.

STAY SAFE

SAFETY — PLASMA CUTTING IS DANGEROUS

Arc rays, high current, toxic fume, noise, UV, and energy even before you touch an arc.

Hazard	Risk	Control
Electric shock	Open-circuit 200–400 V	Insulated gloves, dry boots/floor, proper earthing; never touch the nozzle while the pilot arc is live
Arc flash (UV/IR)	Arc eye, skin sunburn	Auto-darkening helmet, shade 8–13 filter; full cover clothing; screens for bystanders
High current	Severe burns, fire from hot work	Correct current for thickness; keep leads tidy; fire watch for hot work
Fumes	Metal-oxide, O■, NO■, zinc/chromium fume highly toxic	Local exhaust ventilation / water table at the cut; respirator in confined spaces; never cut coated metal indoors without extraction
Noise	95–115 dB — permanent hearing damage	Ear defenders/plugs at all times
Hot sparks & spatter	Ignite flammables up to ~10 m away	Clear/wet/cover combustibles; fire extinguisher + fire watch
Compressed gas	Cylinder/regulator failure	Secure cylinders upright, correct regulators, never oil O■ fittings, check hoses
EMI	Disrupts electronics / pacemakers	Earthing and bonding rules; keep leads tidy and close together

IN THE WILD

APPLICATIONS — WHERE PLASMA SHINES

Where plasma is used — **fabrication & sheet-metal shops** · **automotive repair** (body panels, exhausts, chassis) · **structural steel & construction** · **shipbuilding & marine repair** · agricultural & earth-moving equipment · HVAC ductwork · **sign-making & metal art** (CNC letters, sculptures) · demolition & scrap-yard cutting · rail & heavy-plant maintenance · custom motorcycle & automotive parts. Wherever conductive metal must be cut fast and cheaply, plasma is usually the first choice.

FIX IT

TROUBLESHOOTING — COMMON PROBLEMS AND FIXES

Symptom	Likely cause	Fix
Excess dross, bottom edge	Too slow / low amps / wrong height	Raise speed or amps; re-check torch height
Dross on top edge	Too fast	Slow the travel speed
Bevel both sides	Standoff high / worn nozzle / gas pressure high	Lower torch; new nozzle; reduce pressure
Cut leans to one side	Worn/half-blocked orifice; torch tilted	Replace nozzle; keep torch perpendicular
Nozzle damage (double arc)	Standoff low / long pierce at cut height / moist gas	Pierce high then drop; dry the air
Short consumable life	Moist/oily air, many starts, amps high	Drain dryer/filter; minimise pilot time
Arc won't start	Bad ground, worn electrode, faulty pilot	Clean/retighten ground; replace electrode
Arc blows out / wanders	Pressure high, worn swirl ring, arc long	Reduce pressure; replace swirl ring; lower standoff
Cut won't penetrate	Amps low / speed fast / beyond rating	Check cut chart; reduce speed; bigger unit

FOOTER · GLOSSARY — 12 KEY TERMS

Plasma — ionised gas of free electrons + ions that conducts electricity
Electrode — cathode with hafnium tip that ignites the arc
Pilot arc — small non-transferred arc that ionises the gas to start
Kerf — width of material removed by the cut
HAZ — heat-affected zone — metal beside the cut altered by heat
HyDefinition — high-definition plasma — near-laser edge quality on plate
Arc — the electric discharge; transferred arc passes through the workpiece
Nozzle — copper orifice that constricts the arc into a tight jet
Work lead — ground clamp completing the circuit through the workpiece
Dross — resolidified metal on the underside (or top) of the cut
THC — torch height control — holds standoff via arc voltage
Standoff — gap between nozzle tip and workpiece