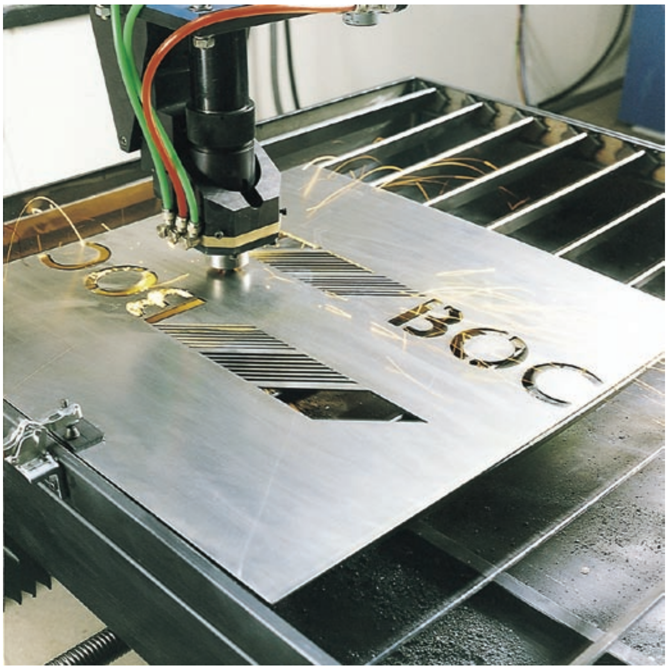
Laser Gases



Laser Cutting

A focused laser beam is used to melt or chemically degrade the material being cut. The process uses an assist gas jet to remove the molten material and, in the case of oxygen, to react chemically with the material to produce additional thermal energy.

The choice of assist gas depends on the material being cut.

Gases for Laser Cutting

	Oxygen	Nitrogen*	Argon
Mild Steel	●	●	
Stainless Steel		●	
Aluminium		●	
Titanium			●

*Nitrogen or compressed air is normally used for cutting non-metallic materials

The main gases used for cutting are oxygen and nitrogen, while special applications may require argon.

- When cutting mild steel, using oxygen can enable cutting at higher speeds and greater thickness at lower pressure and flow rate than nitrogen.
- Nitrogen and other inert gases prevent surface oxidation, producing a higher quality finish and requiring minimal preparation for other fabrication processes (such as welding) and surface treatment.

Assist Gas Selection Guide for Cutting Mild Steel

With ever higher laser power levels becoming available, nitrogen is now frequently used for mild steel, which is the traditional application for oxygen. Cutting mild steel with nitrogen is the same as cutting stainless steel (i.e. no oxidised edge), but requires higher pressures and flow rates with increasing thickness.

Assist gas selection for cutting mild steel sheet depends on the laser power and material thickness.

The following assist gas guide can be used for laser cutting of mild steel:

Thin Section (<2 mm)

- Nitrogen cuts faster than oxygen
- Nitrogen flow rates are much higher than oxygen
- At high powers (>4 kW), it is possible to 'plasma cut' with nitrogen:
  - High power intensities form a plasma-filled keyhole, 'trapping' the laser beam
  - 'Plasma' cutting requires lower pressures and flow rates

Medium Section (2–5 mm)

- Cutting speeds similar for nitrogen and oxygen
- Nitrogen flow rates are much higher than oxygen
- Nitrogen gives a clean, unoxidised cuting edge

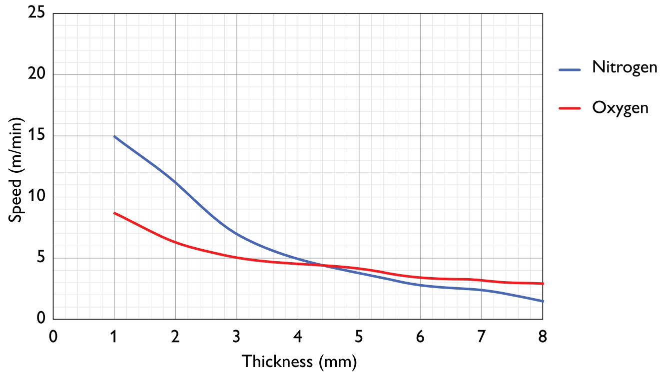
Thick Section (5–8 mm)

- Nitrogen cuts slower than oxygen
- Nitrogen flow rates are much higher than oxygen (up to 10x)

Ultra Thick Section (8–25 mm and beyond)

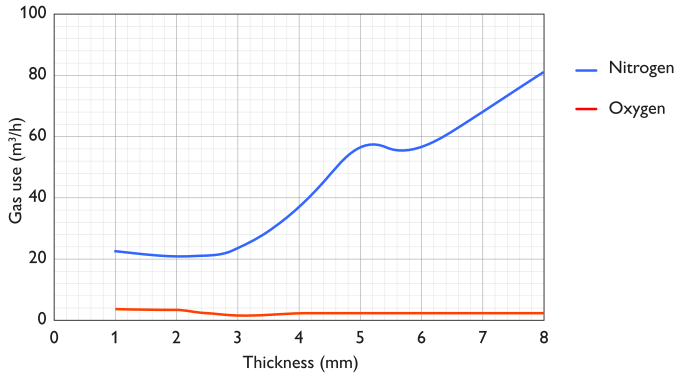
- Extra energy from oxygen is critical
- Nitrogen cutting requires high powers and pressures
- High powers (>5 kW) required

Speed versus thickness



Effect of cutting assist gas on mild steel using 5.2kW laser power

Gas consumption versus thickness



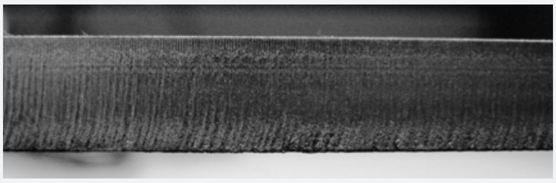
Effect of cutting assist gas on mild steel using 5.2kW laser power

Higher laser powers also call for higher nitrogen assist gas pressures for cutting. There is evidence, for example, that cutting performance at a laser power of 6 kW continues to improve at nitrogen pressures above 30 bar. See page 35 for the various supply options available for nitrogen assist gas.

Laser Cutting (cont)

Correct conditions

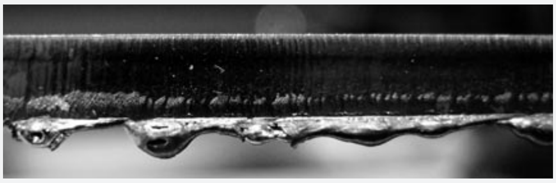
Good cut



This shows a good cut in 8 mm mild steel.

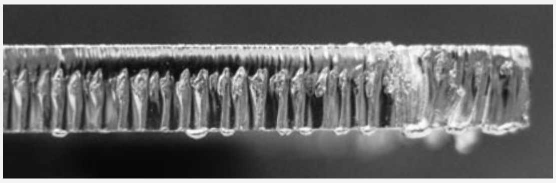
- Smooth, square cut edge with a light scale of oxide

Common faults



Effect ***Dross*** (oxygen and nitrogen cutting)

Problem	Action
Insufficient melt clearance	Reduce speed
Processing too fast – evidence of curved drag lines	
Low pressure – evidence of curved drag lines	Increase gas pressure
Low power	Increase power
Poor focus	Check lens
Nozzle too narrow	Increase nozzle diameter



Effect ***Side burning*** (oxygen cutting)

Problem	Action
Oxygen pressure too high	Reduce gas pressure
Processing too slowly	Increase speed
Damaged nozzle	Check/replace nozzle

Effect ***Cutting unequal in x-y plane***

Problem	Action
Polarisation problems	Check and replace
Damaged phase retarder	
Beam off centre	Align to nozzle

If you are not getting a good cut from your laser, you may be experiencing any of the following:

Troubleshooting checklist

	Check and correct	Time required (mins)
A	Nozzle contamination	1–2
B	Laser power and pulsing conditions	1–5
C	Cutting speed	1–2
D	Cutting gas	1–2
E	Nozzle stand-off	1–2
F	Nozzle type, condition and alignment	1–10
G	Material specification and condition	1–5
H	Lens type, condition and alignment	10–20
I	Beam steering mirror condition and alignment	5–60 per mirror
J	Laser mode quality and polarization	20–40

A Nozzle contamination

- Dirt or spatter on the nozzle may deflect the gas jet to one side
  - Wipe the nozzle or replace if damaged

B Laser power and pulsing conditions

1. Compare laser power and pulse settings to those used successfully on similar jobs
2. If power level is lower than usual:
   - The laser may need time to warm up (up to 30 mins)
   - The helium supply is running low
   - The laser needs tuning
   - The laser needs servicing
   - E.g. internal mirrors need to be cleaned
   - Requires trained personnel

C Cutting speed

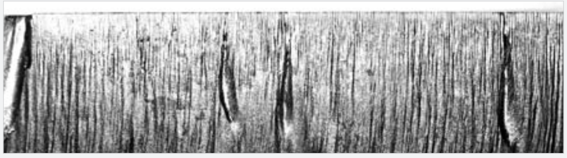
- Compare cutting speed to those used successfully on similar jobs
  - Try increasing and decreasing the speed by 10% and 20%

D Cutting gas

1. Check the type of gas being used against similar successful jobs
2. Check supply pressure and flow
   - Nozzle blockages will affect pressure and flow
   - It is best to have both a flow meter and a pressure gauge
   - Excessive oxygen pressure results in burning of corners and loss of fine details
3. Insufficient gas purity or gas supply contamination
   - Contact your gas supplier
   - Oxygen cutting: cutting speed reduced
   - Nitrogen cutting: surface quality reduced

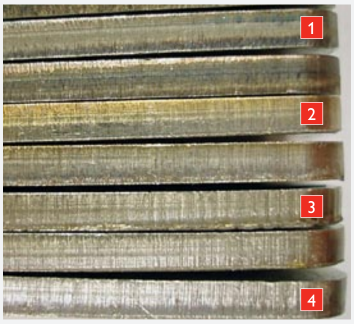
Laser Cutting (cont)

Material related fault



Example of how material quality can affect cut quality – oxygen cutting of low grade mild steel.

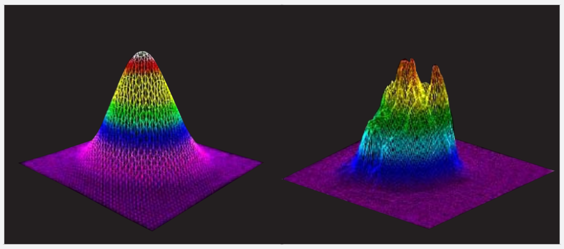
Nitrogen purity related faults



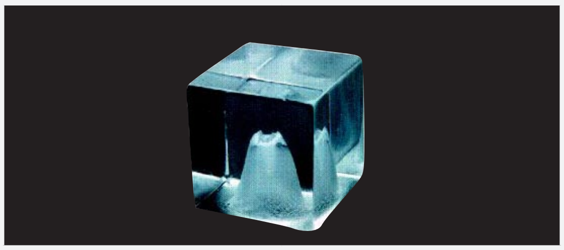
1	Nitrogen, 1% oxygen
2	0.1% oxygen – cut edge oxidised
3	100 ppm oxygen
4	25 ppm oxygen

- Oxidation of the cut is evident at 100 ppm purity
- The edge becomes rough at 0.1% purity (1,000 ppm)

Laser mode quality and polarisation



Good mode (TEM_{00}) *Bad mode*



Perspex 'mode burn'. Laser evaporation gives good 3D approximation of beam profile, but it requires practice for reproducibility, and produces noxious fumes.

E Nozzle material stand-off

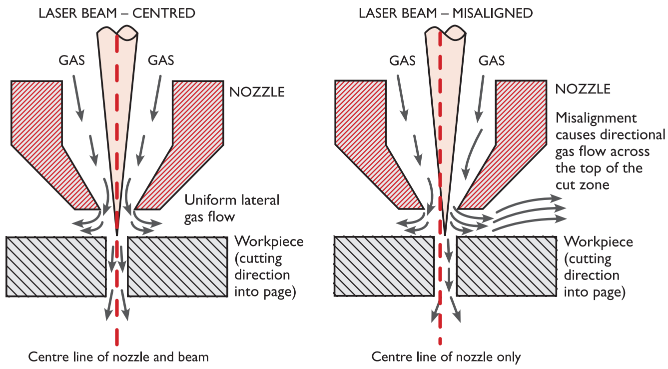
- Compare to earlier successful results:
  - Normally the stand-off is 0.25–2 mm
  - Changing non-identical nozzles may change stand-off
  - Alter nozzle-lens distance to re-optimise process

F Nozzle type, condition and alignment

1. Is the nozzle of the right type (exit diameter) for the job?
2. Is the nozzle worn or scratched?
3. Is the laser in the centre of the nozzle (i.e. centre of the gas jet)?

If not:

- The machine will not cut equally well in all directions:
- Sparks may exit top of the cut zone when cutting in certain directions
- Reduction of sparks leaving the bottom of the cut when cutting in certain directions



G Material specification and condition

1. What is the material?
2. Is the condition of the material affecting the cutting?
   - Surface coating (rust, paint, mill scale etc.)
   - Deep scratches

H Lens type, condition and alignment

1. Is the right focal length lens being used? Is it fitted correctly?
2. Is the lens scratched or dirty? Both can give cutting problems. Even if it is clean, it may have become over-heated
3. Is the laser beam correctly aligned onto the lens?
   - Beam steering mirrors may need re-alignment

I Beam steering mirror condition and alignment

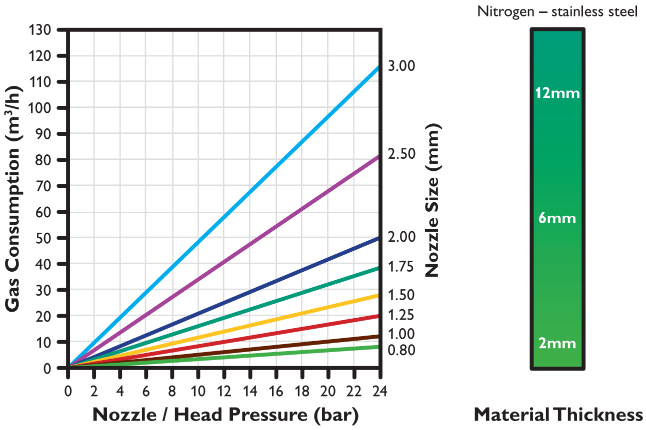
1. Are the mirrors clean?
   - Take power readings after each one. Power losses should be below 5% per mirror
2. Alignment should be square and central
   - Realignment of mirrors requires training

Laser Cutting (cont)

J Laser mode quality and polarisation

1. The distribution of energy across the laser beam cross section is called its mode
   - Poor mode quality results in poor cutting quality
   - Laser mode identification and tuning require training
2. CO_2 laser beam polarisation requires careful control for successful metal cutting
   - If circular profiles are oval on the bottom, but circular on top, the polarising mirror(s) may need cleaning or replacing

Gas consumption v. nozzle size



Acknowledgements:
Dr John Powell – LIA Guide to Laser Cutting (Pub: Laser Institute of America)

Laser Welding

Laser welding is a fast growing application area for industrial lasers. Owing to the high energy density of the laser beam, laser welding is a low heat input process compared to conventional arc welding and results in deep penetration and low distortion welds.

The laser beam is focused on the materials to be welded and the process is generally autogenous, requiring no additional filler material. A shielding gas is normally needed to protect the welding pool from oxidation and the choice of this shielding gas can have a significant effect on both the weld quality and the process productivity.

Helium is the preferred shielding gas for CO_2 laser welding. Because it has a high ionisation potential, it reduces plasma formation, which in turn allows greater penetration resulting in superior welds with most metallic materials. For specialised applications, shielding gas mixtures may give enhanced performance.

Gases for Laser Welding

	Helium	Argon
CO_2 Laser	●	●*
Nd:YAG/Fibre/Disk Laser		●

* Suitable for low power, thin sheet welding applications