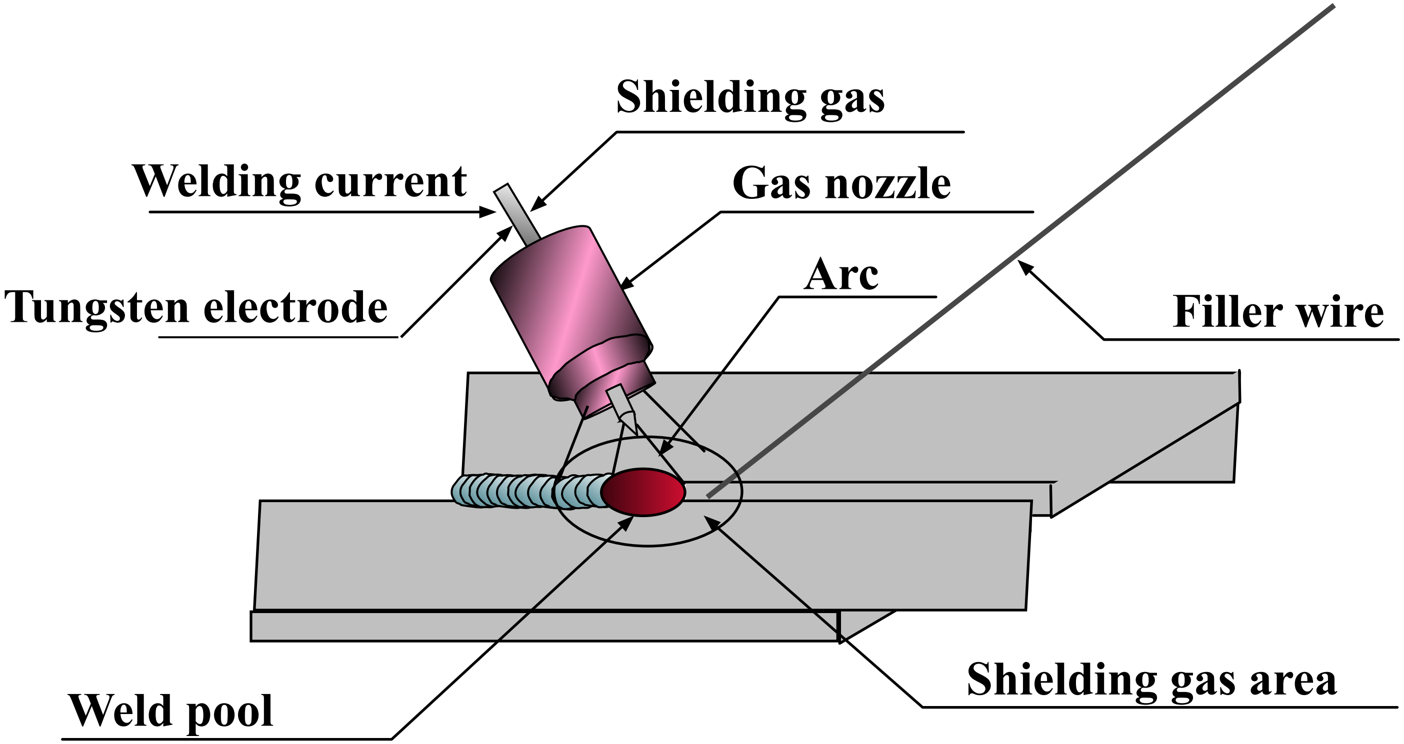
Steel DC TIG welding training material

Version 1.0

DC TIG welding

Process principle:



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DC TIG welding

T = Tungsten **I** = Inert **G** = Gas (General name)

W = Wolfram **I** = Inert **G** = Gas (Germany)

G = Gas **T** = Tungsten **A** = Arc **W** = Welding (USA)

DC = Direct current is needed to weld steel and steel alloys.

CC = In TIG welding is needed a power source which has constant current characteristics.

TIG benefits and features

- Good visibility to the weld pool, no smoke or welding slag.
- "Easy" to learn.
- High quality, clean weld result, no spatters.
- Welding of thin materials, min current 3 A.
- Welding without filler material is possible.
- Energy and amount of filler material is not related together.
- Good profile of weld seam in all positions.
- Narrow and concentrated arc form with controlled penetration.
- Versatile use of process, welding can also be mechanized.
- Special functions & equipment: Minilog
  Pulsed TIG welding
  Foot pedal
  Special TIG torches

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TIG process limitations

- Lower productivity than in MIG / MAG welding.
- Sensitive for base or filler material impurity, rust, oil, moisture, paint.
- Welding technique more demanding than in MMA or MIG / MAG.
- Welding outdoors needs special arrangements for shielding gas.
- TIG torch components vary according of needs:
  Tungsten electrode diameter
  Gas nozzle or gas lens
  Collet body and collet
- Tungsten electrode needs maintenance:
  Correct shape of grinding in electrode head
  Correct type (alloy) and diameter
- Manual filler material feeding

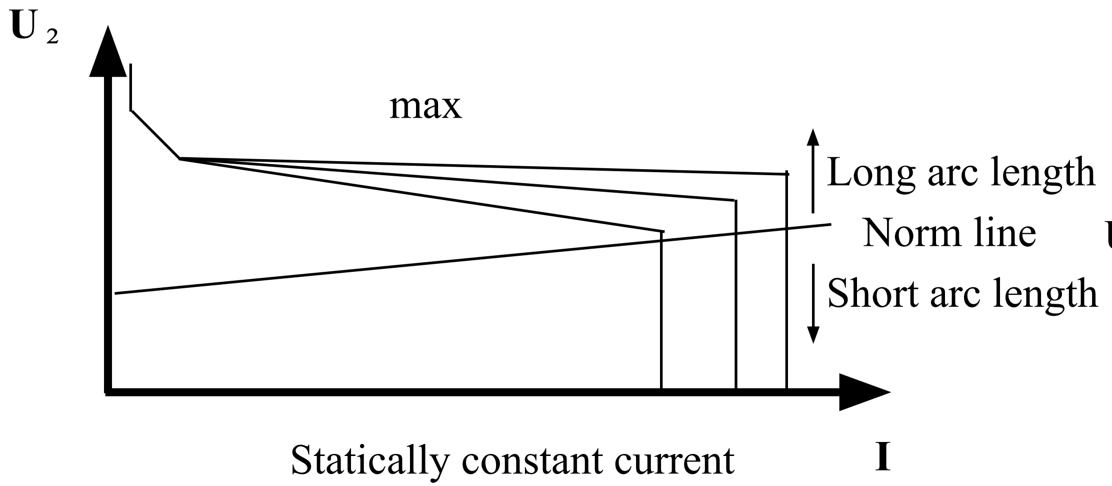
TIG applications

TIG is suitable in steel welding cases where quality and visual appearance of weld seam are the most important matters.

- With TIG can be welded all weldable steels and steel alloys.
- General applications for seams which need good visual look.
  Metal furniture, machine building, bicycles etc.
- Chemical industry needs smooth weld profiles.
  Pipes, tanks, etc.
- Aviation and air force industry use TIG welding for it´s reliability.
- Thin sheet industry
  Automotive and car industry, bus industry, etc.
- Repair welding of all kind of steel products.
  Machinery, maintenance, etc.
- X-ray quality root passes.

Constant current (CC):

Norm line: IEC 974-1
EN 60 974-1



$U_2 = 10\ V + 0{,}04 \times I_2$

Constant current means that welding current setting and used arc length determine the arc voltage level. Despite arc length variation welding current is constant by the means of CC characteristic.

100 A < = > U = 10 V + 0,04 x 100 A = 14,0 V (Argon gas)

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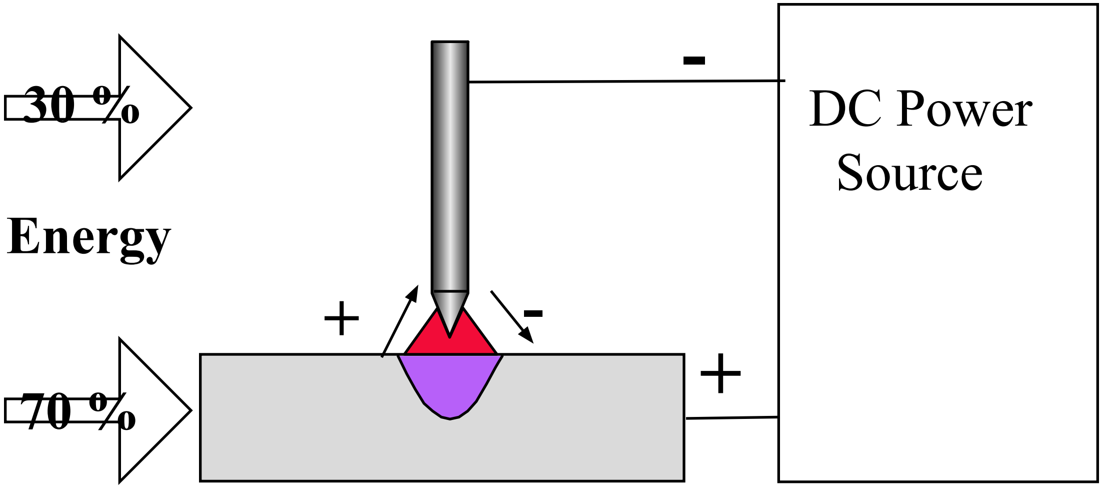
DC TIG polarity

On steel TIG welding is used DC current, electrode connected to -pole (Straight polarity, DCEN).
This optimize heat deviation between electrode and base material.

Benefits:

- Small electrode diameter can be used.
- Penetration is deep and narrow.
- Arc is stable and concentrated.
- Low temperature to the TIG torch.



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High frequency ignition (HF)

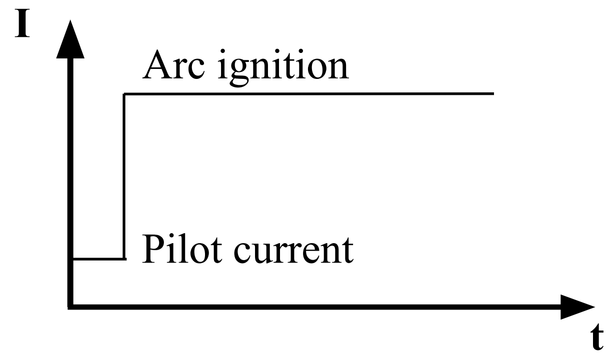
- In steel welding DC TIG arc is recommended to ignite with high Voltage spark (10 kV) ignition.
- High Voltage spark is ionizing shielding gas electrically conductive, which utilize TIG arc ignition without mechanical contact between electrode head and base material.

Benefits:

- Good quality ignition without risk of base material or electrode head contamination.
- All adjustable TIG welding parameters are located to the HF unit.
- High X-ray quality weld result with controlled start and ending of welding.
- Exact ignition point

Contact ignition

DC TIG arc can also be ignited by contacting with tungsten electrode to the base material and lifting it off (Lift arc).



- During contact power source give low pilot current to eliminate electrode sticking
- Ignition happens so fast that sharpened electrode head is not damaged.
- After ignition welding current goes automatically to the set current value.

Benefits:

- For environments where high frequency ignition can produce EMC disturbances (nuclear, computers, robots, etc).
- Smaller and lighter welding unit which is more portable to use
- Cheap and "easy to use" equipment.

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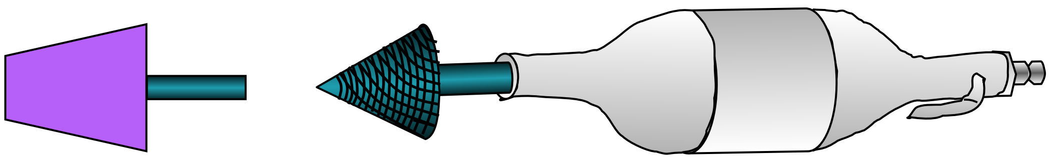
Welding preparations

- Steel is having normally on it´s surface slag coming from the material hot rolling manufacturing process, also rust or primary paint.
- Plates or pipes can also be cutted with plasma or by oxygen acetylene flame cutting.
- Before TIG welding all impurities must be removed.
- Grooves and also 20 mm from welding joint surface on both sides must be cleaned with grinding disk or machine file to guarantee good weld quality.



Steel plates and pipes must be dry and clean from the welding area before welding.

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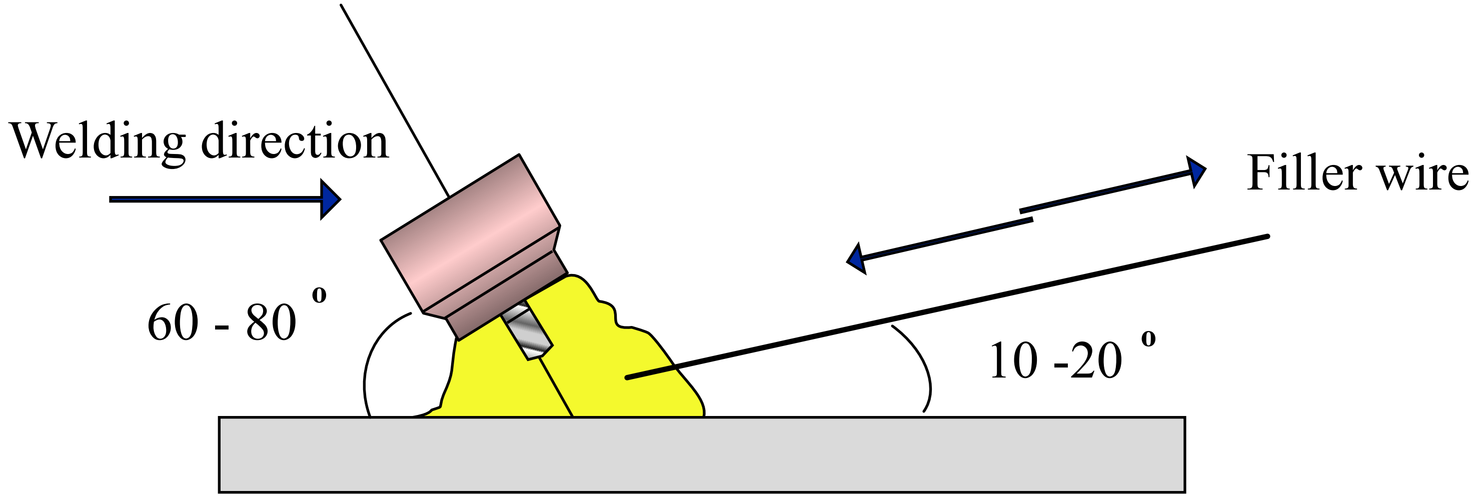
Torch angle



- In welding without filler wire TIG torch angle is 75º - 80º
- Welding wire feeding technique can be continuous or “drop by drop” feeding technique
- Wire feeding can also be mechanized

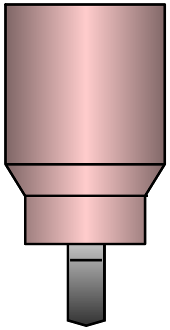
Filler wires

- In TIG - welding is minimum number of alloy loses, because filler wire is not running through the arc like in MIG / MAG.
- Filler wire is normally having a small overalloy compared to base material alloy and thin layer of copper for protection.

BASE MATERIAL mm	FILLER WIRE Ø mm
1,0 - 1,5	1,0 - 1,6
2,0 - 4,0	2,4 - 3,2
4,0 - 8,0	2,4 - 4,0
8,0 ⇨	3,2 ⇨

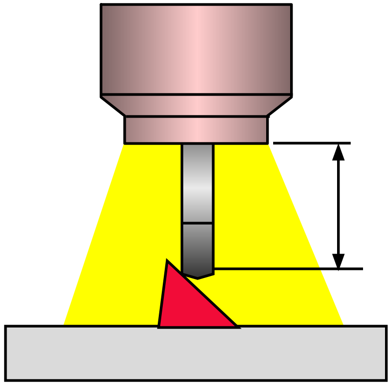
- Don´t use in normal welding filler wire, which is a cut from the plate.
- Use in steel TIG welding filler wires which are designed for TIG.
- Don't use oxygen / acetylene welding wires (porosity).

Gas lens / nozzle



Gas nozzle:

For general applications in steel welding is mainly recommended to use gas nozzle.
When welding current is increasing also the need of shielding is increasing.



Gas lens:

- Better gas shielding, no turbulence on gas flow
- Better visibility to the weld pool
- Electrode max stick out 20 mm in good conditions
- Better to reach joints in tight weld joints
- Longer lifetime of TIG torch components

In market is various lengths / sizes of gas lenses, profiles and materials for different joint types and applications.

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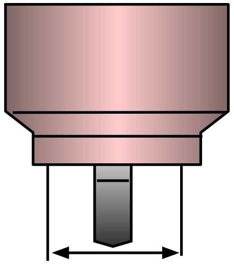
Gas nozzle / lens inside diameter



Gas nozzle / lens n:o is coming from 1/16” (1,5875mm)
Ex. diameter on n:o 5 is 5 x 1,5875 mm = 7,9 mm

n:o 5

Gas nozzle / lens inside diameter must be in minimum as big as weld pool.

Gas nozzle / lens inside diameter must be in minimum 4 times electrode diameter.

NOTICE !

Large nozzle / lens diameter guarantees minimum risk for porosity.

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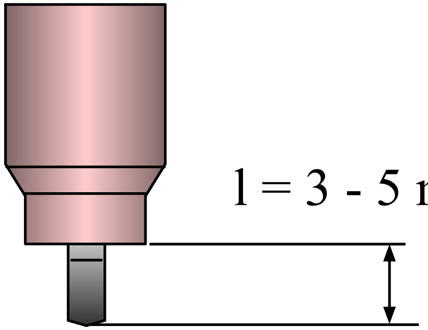
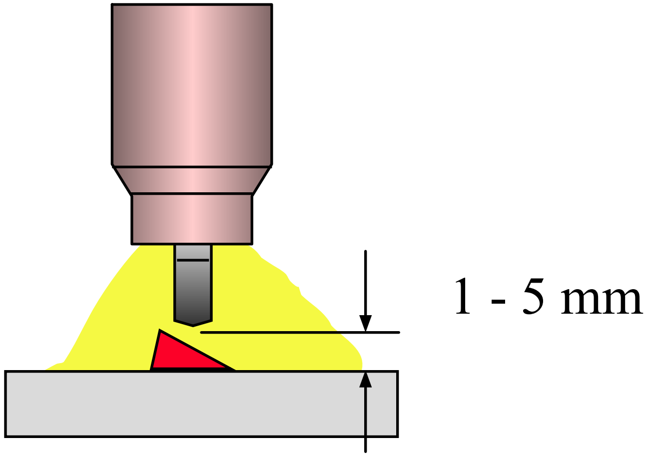
Electrode stick out and arc length in DC TIG welding





- General recommendation on DC TIG welding for electrode stick out with normal gas nozzle.

l = 2 - 3 x Electrode diameter

- Longer arc length makes wider weld seam and increase heat.

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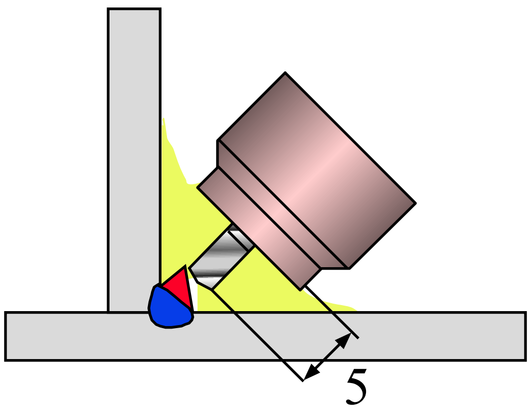
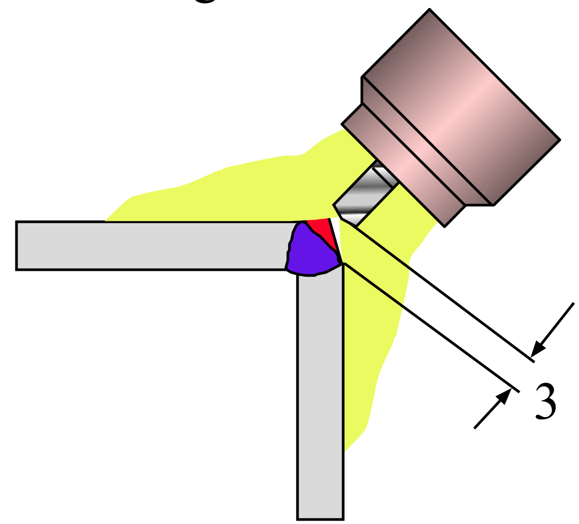
Electrode stick out and arc length

Max stick out with nozzle



Max arc length with nozzle



Arc length depends on used current and joint type as follows:

- Fillet joints collect gas, electrode max stick out distance 5,0 mm.
- Corner joints separate gas, electrode max stick out distance 3,0 mm.

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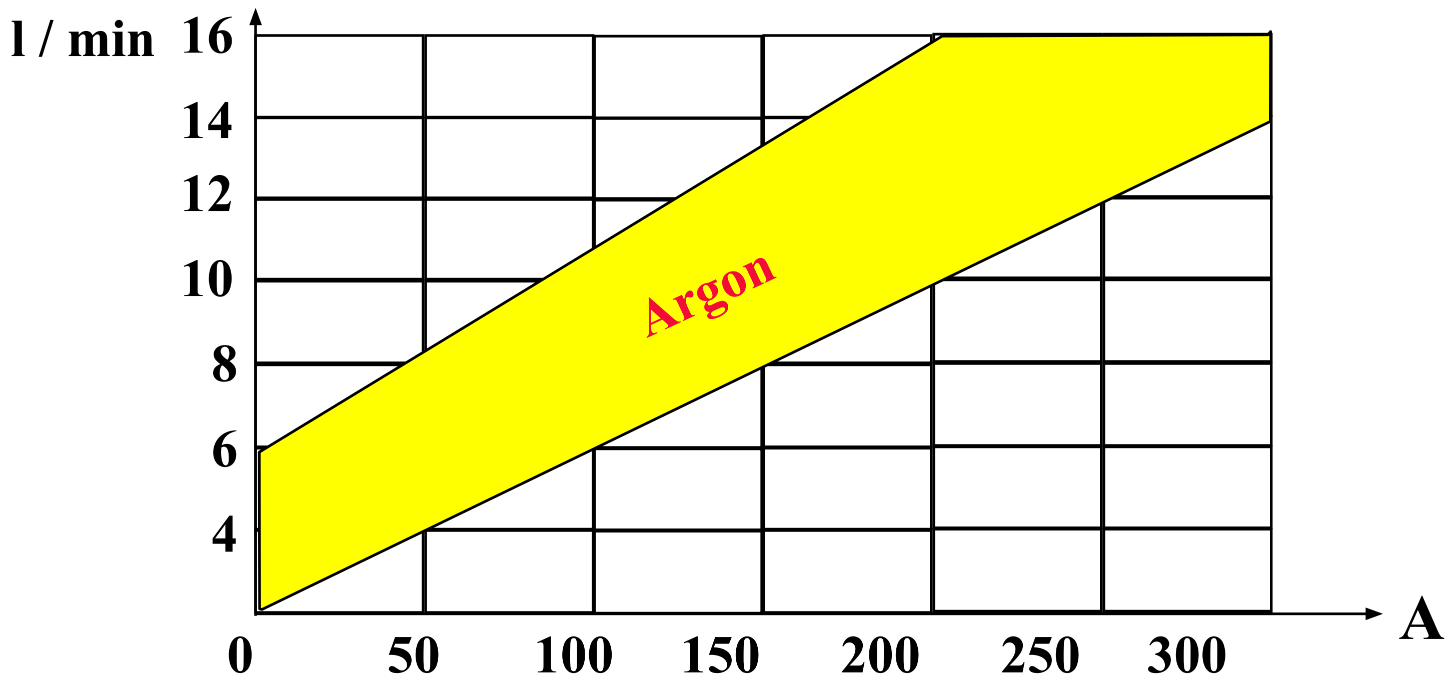
Steel DC TIG gas flow



Flow of shielding gas is depending lot of welding conditions:

- Inside / outside welding (wind effect)
- TIG torch accessories nozzle or lens (diameters)
- Base material cleaning etc.

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Electrode diameter selection

Electrode diameter	Gas nozzle no:	Gas flow	Current range
1,6 mm	4 - 5	5 - 8 l / min	20 - 140 A
2,4 mm	5 - 6	6 - 10 l / min	100 - 250 A
3,2 mm	6 - 8	8 - 12 l / min	150 - 320 A
4,0 mm	6 - 10	8 - 14 l / min	200 - 500 A

NOTICE !

Different alloys of TIG tungsten electrodes are having different optimum operation ranges in Amperes.

Tungsten electrodes

CODE	ALLOY	COLOUR CODE	USE
WP	100% W	Green	(AC)
WC 20	98% W + 2% Ce	Gray	AC / DC
WT 10	99% W + 1% Th	Yellow	DC (AC)
WT 20	98% W + 2% Th	Red	DC
WT 30	97% W + 3% Th	Lilac	DC
WT 40	96% W + 4% Th	Orange	DC
WZ 8	99% W + 1% Zr	White	(AC)
WL 10	99,0% W + 1% La	Black	AC / DC
WL 15	98,5% W + 1,5% La	Gold	AC / DC

Normally for steel TIG welding recommended electrode types are WC 20, WT 20 and WL 15.

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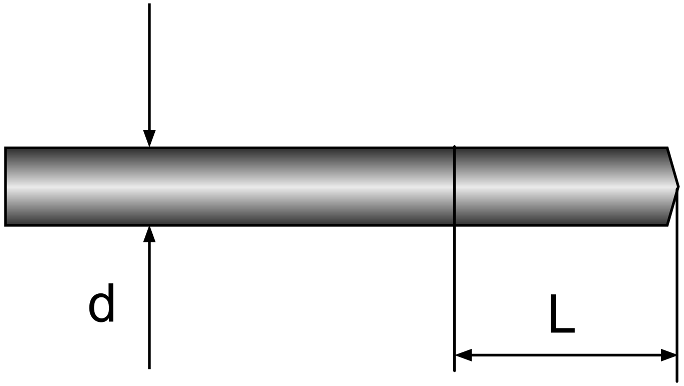
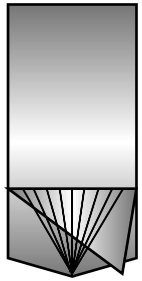
Electrode sharpening



L = 1...5 x d

d = 2,4 mm
L = 5 x 2,4 mm = 12,0 mm

- Correct electrode diameter depends on used welding current
- Used sharpening length depends on used welding current
- Grind sharpening angle so that grinding scratches are longitudinal.



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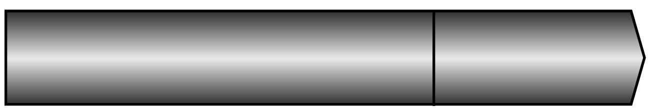
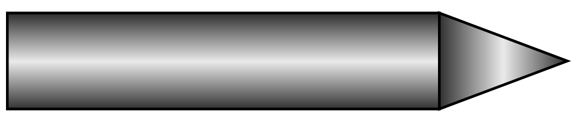
Electrode diameter / welding current

TIG electrode diameter / max welding current (DC):

0,8 mm	**45 A**
1,2 mm	**70 A**
1,6 mm	**145 A**
2,4 mm	**240 A**
3,2 mm	**380 A**



Low current, 1 : 5 - 1 : 3
Minimum - 70 A



Medium current, 1 : 4 - 1 : 2
70 A - 200 A

High current and automatic welding, 1 : 1 - 1 : 2
Over 200 A

Steel TIG shielding gases

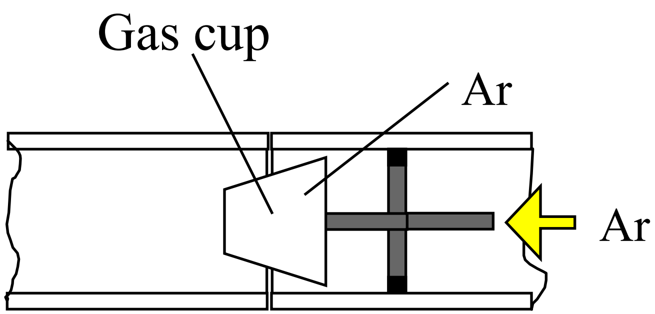
GAS	USE
Argon + 0,03% NO	General use
Argon 99,99%	General use
Argon 99,998%	High quality products

Steel TIG root gases:

GAS	USE
Argon + 0,03% NO	Power plants etc
Argon 99,99%	Power plants etc.
Nitrogen + 12% Hydrogen	General use
Argon + 5% Hydrogen	Low quality products

Root protection

- For general applications most of the steel pipes are TIG welded without shielding in pipe root side.
- Root side paste can be used to decrease oxidisation in root side.
- In power plants, high pressure vessels etc where small diameter pipes root passes have high requirements of quality protection must be used to minimise risk of welding defects.



- Porous sintered gas cup is mainly used in welding of small diameter steel pipes.
- It gives good shielding even when pipe is “open” from the other end.
- Flow of root gas is 4,0 - 8,0 l / min.
- All root protection gases can be used.

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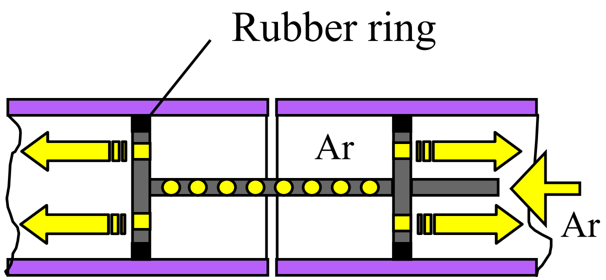
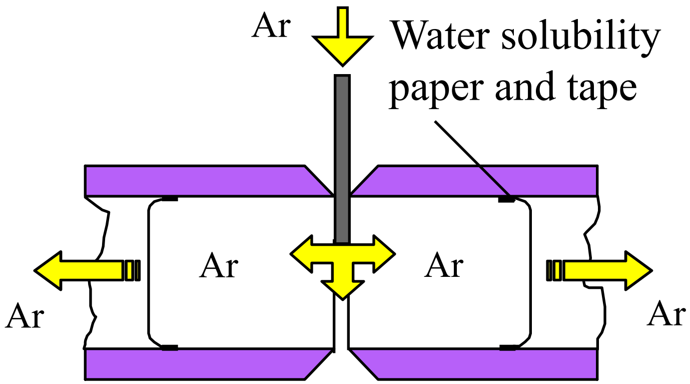
Root gas on pipe welding

- Best root protection is shielding gas.
- Flush shielding space with shielding gas before welding.
- Number of flushing gas inside pipe is 10 x shielded space size.



- On less demanding joints can be used root protection paste.



- Root gas flow is normally 4 - 8 l / min.
- Shielding gas is leaded with small pipe through the opening inside to pipe shielding space.

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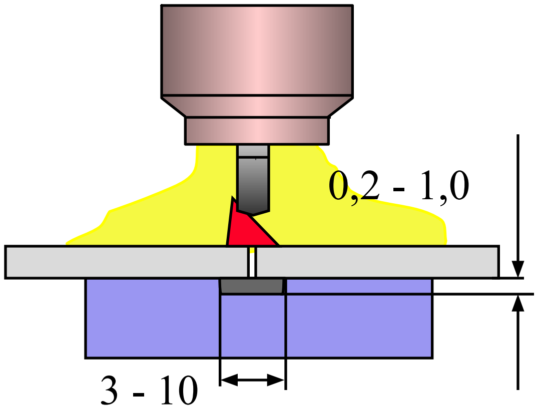
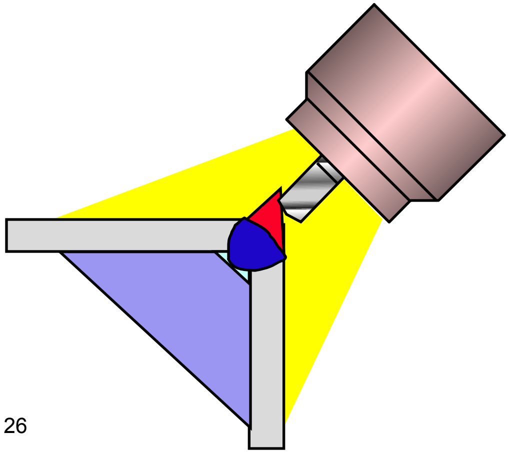
Removable root backing bar





On steel welding backing bar is normally manufactured from copper.

- Avoid situation where TIG arc burns directly against backing bar.
- With thick base materials backing bar can have separate water cooling.
- Backing bar groove size and form varies according to base material thickness and joint type.

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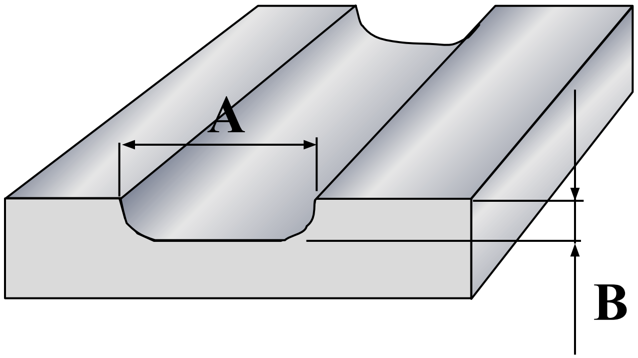
Copper backing bars

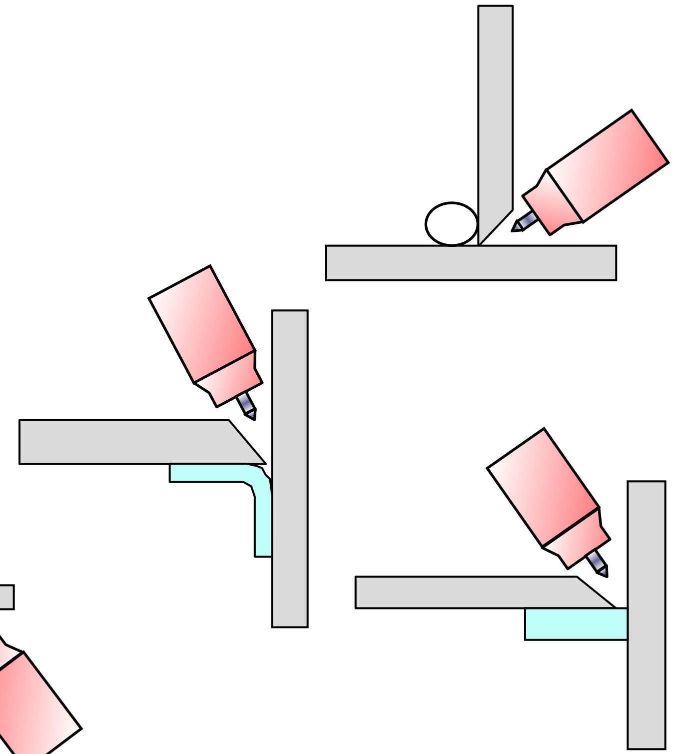
- Backing bar groove depth should be according to plate thickness.
- Too shallow groove is cooling the seam too early and cause faults into the seam root side.
- Too deep groove produces large root pass and large welding pool.
- This causes: high heat input, low welding speed, wrong shape of weld seam.

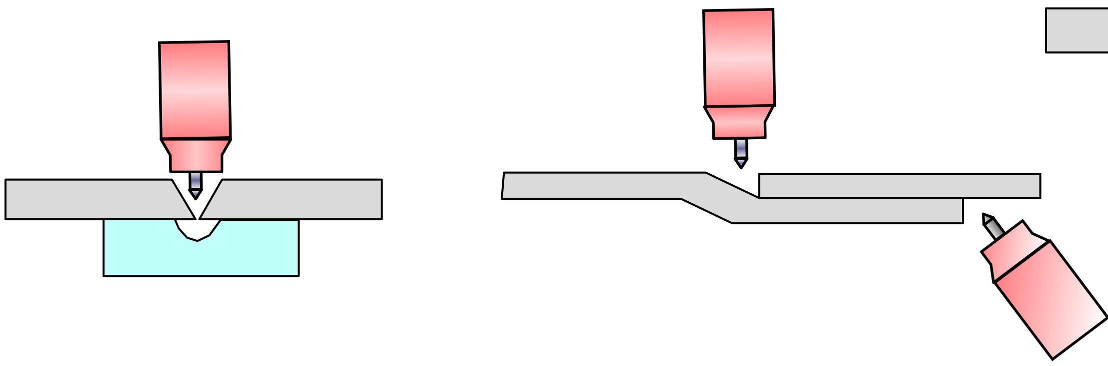
Thickness (mm)	A	B
≤ 1.5	10	0.2 - 0.5
≤ 6.0	10 - 15	1.0 - 2.5
> 6.0	10 - 15	2.5 - 3.5



Benefits and task of backing bars

- Protect root side against oxidisation
- Support and forms a root profile
- Cools weld metal
- Allows larger air gap
- Higher welding current can be used
- Increase travelling speed ⇨ Productivity
- Can be a part of the welding seam





Pre gas / Post flow functions

During Pre gas function shielding gas is flowing to the welding area regulated time before ignition.

Benefits:

- Stable gas flow on ignition moment
- "Flushing" of long TIG torch gas hose free of air
- Groove area cleaning of air

During gas post flow time hot tungsten electrode and the end of weld seam are cooled inside shielding gas protection after arc has cut off.

Benefits:

- Good electrode re ignition
- No oxidization on tungsten electrode
- Longer electrode sharpened head lifetime
- Smaller risk for welding defects

Up / Down slope functions

During Up slope time welding current is raising from ignition level to the regulated welding current.

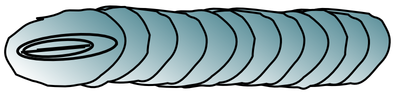
Benefits:

- Stabile ignition with high current
- Electrode head protection
- Decreases risk of base material overheating and burn through

During Down slope time welding current decreases from regulated current level to the ending current level.

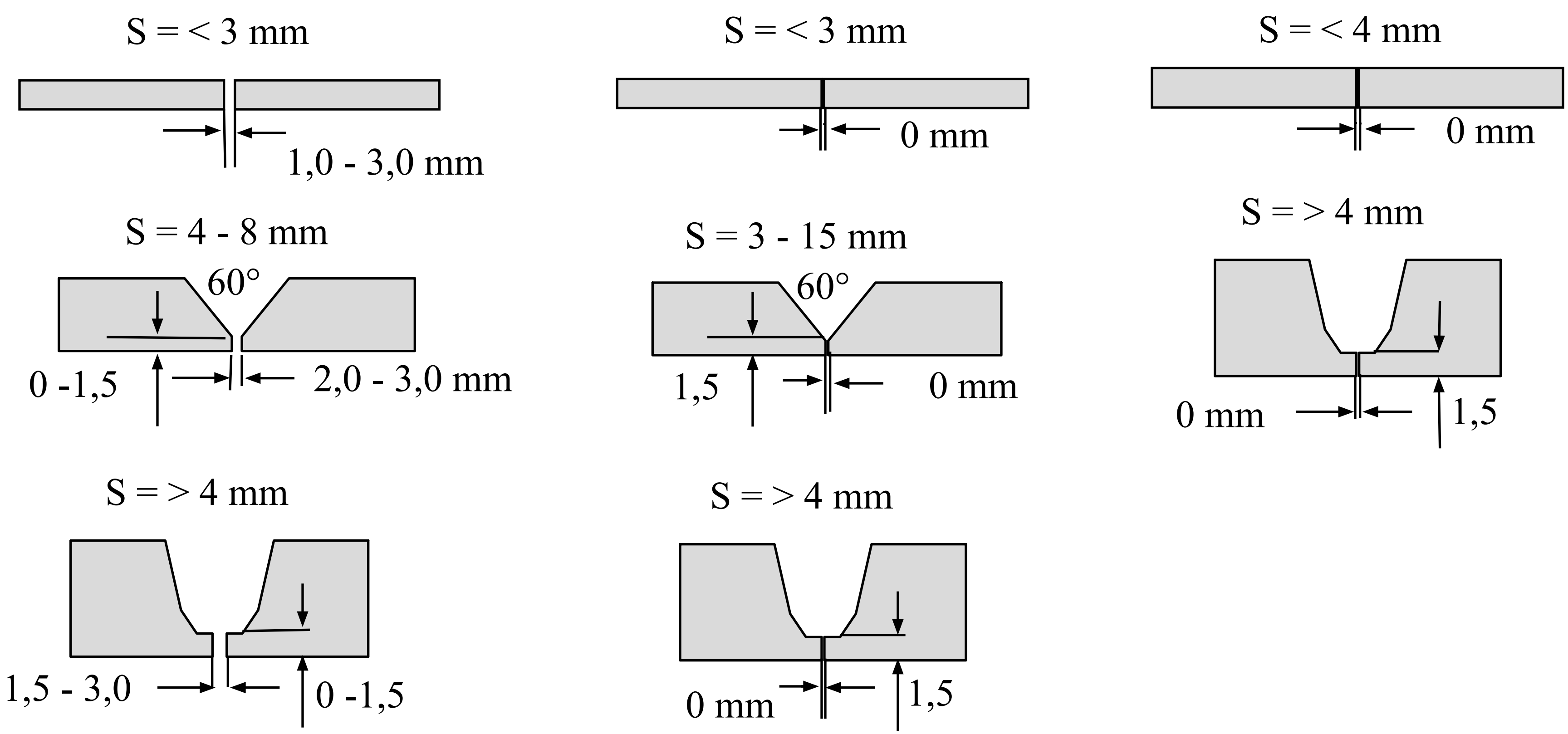
Benefits:

- Controlled ending without ending crater
- Eliminates material overheating (plate edges)
- Possibility for heat input regulation in openings



Steel joint forms

Manual TIG welding with filler | Manual TIG no filler | Mechanized TIG welding



Heat input

Heat what arc is bringing to base material is called **Heat input (Q) (EN 1011)**

To heat input is influencing: **Welding current (I)**

Arc voltage (U)

Travel speed (v)

Arc energy (E)

Heat input can be calculated in Joules (**J**) or kilo Joules (**kJ**) for cm or mm.

$$E = \frac{I\,(A) \times U\,(V) \times 60}{v\,(mm/min) \times 1000} \quad <=>$$

$$E = \frac{70\,A \times 12{,}5V \times 60}{30 \times 1000} = \underline{1{,}75\ kJ/mm}$$

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Thermal efficiency

Calculate total heat input (**Q**) by using **thermal efficiency correction factor (n)** of used welding process.

Correction factor compensates thermal losses of different welding processes

MIG / MAG / FCW	**0,8**
Pulsed MIG	**0,8**
MMA	**0,8**
TIG	**0,6**
Plasma welding	**0,6**
SAW	**1,0**

Heat input Q = E x n < = > 1,75 x 0,6 = 1,05 kJ / mm

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Average current

In case that machine is not having automatic function to calculate average current on Pulsed TIG welding, it can be calculated with formula.

$$I_{ave} = \frac{I_{back} + (I_{pulse} - I_{back}) \times t_{pulse}}{t_{cycle}} \quad <=>$$

$$I_{ave} = \frac{40\ A + (125\ A - 40\ A) \times 0{,}35\ s}{1{,}0\ s} \quad <=> \quad \underline{70\ A}$$

For calculation exact read outs are needed for all pulse parameters.

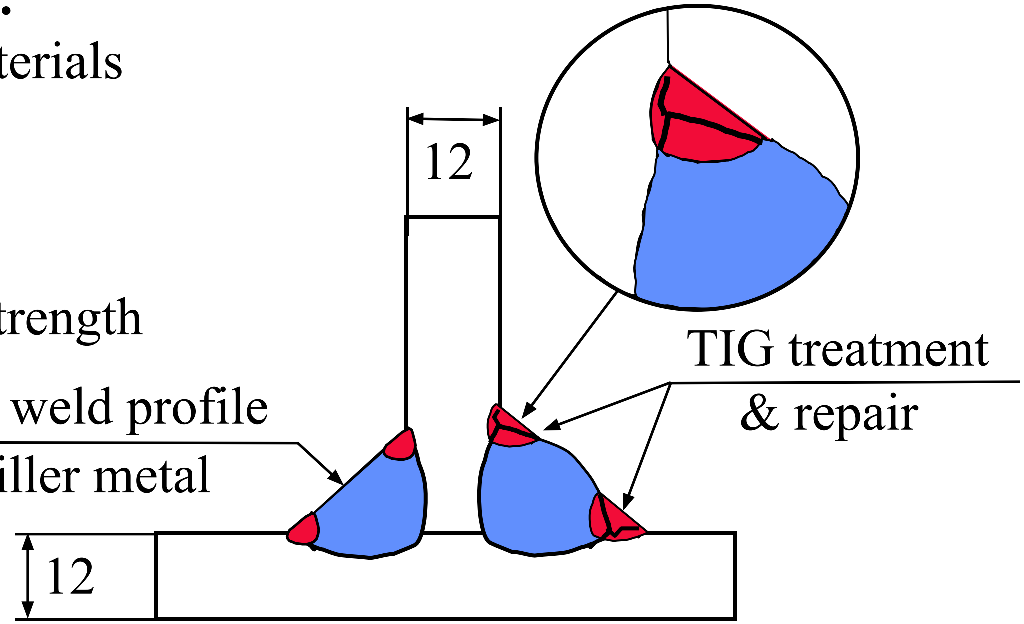
TIG treatment

TIG treatment is used in cases where MIG / MAG seam needs:

- improve dynamically loaded welded constructions strength
- Used mainly with high strength steels (Hardox, Weldox, Raex)
- visual reasons, wrong weld profile (convex)
- repair of weld joint failures (undercut)
- to avoid grinding

TIG treatment is mainly used:

- heavy machinery and thick materials
- mining machinery
- diggers & earth movers
- lifting brackets
- to improve weld joint impact strength



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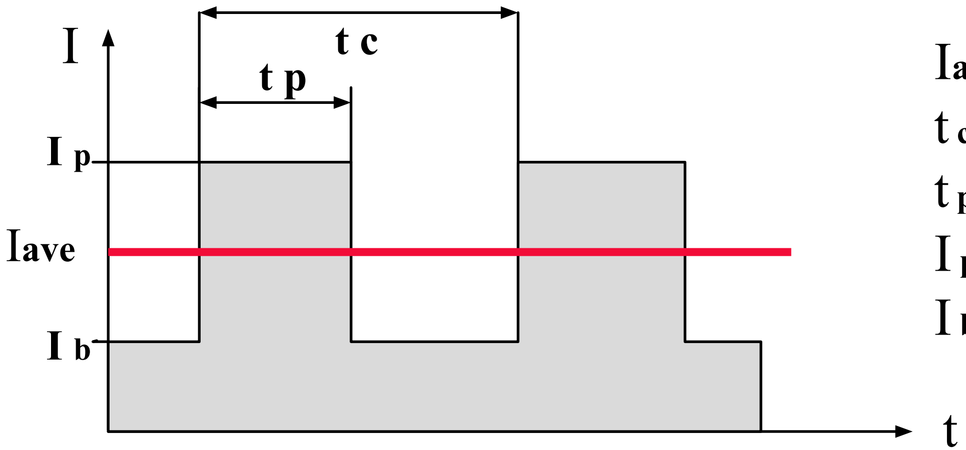
Steel Pulsed TIG welding

In Pulsed TIG welding current changes according set frequency between higher pulse current and lower background current.



I_{ave} = Average current
t_c = Cycle time / f = Frequency
t_p = Pulse time
I_p = Pulse current
I_b = Background current

Modern TIG machine calculates automatically average current from pulse parameters.

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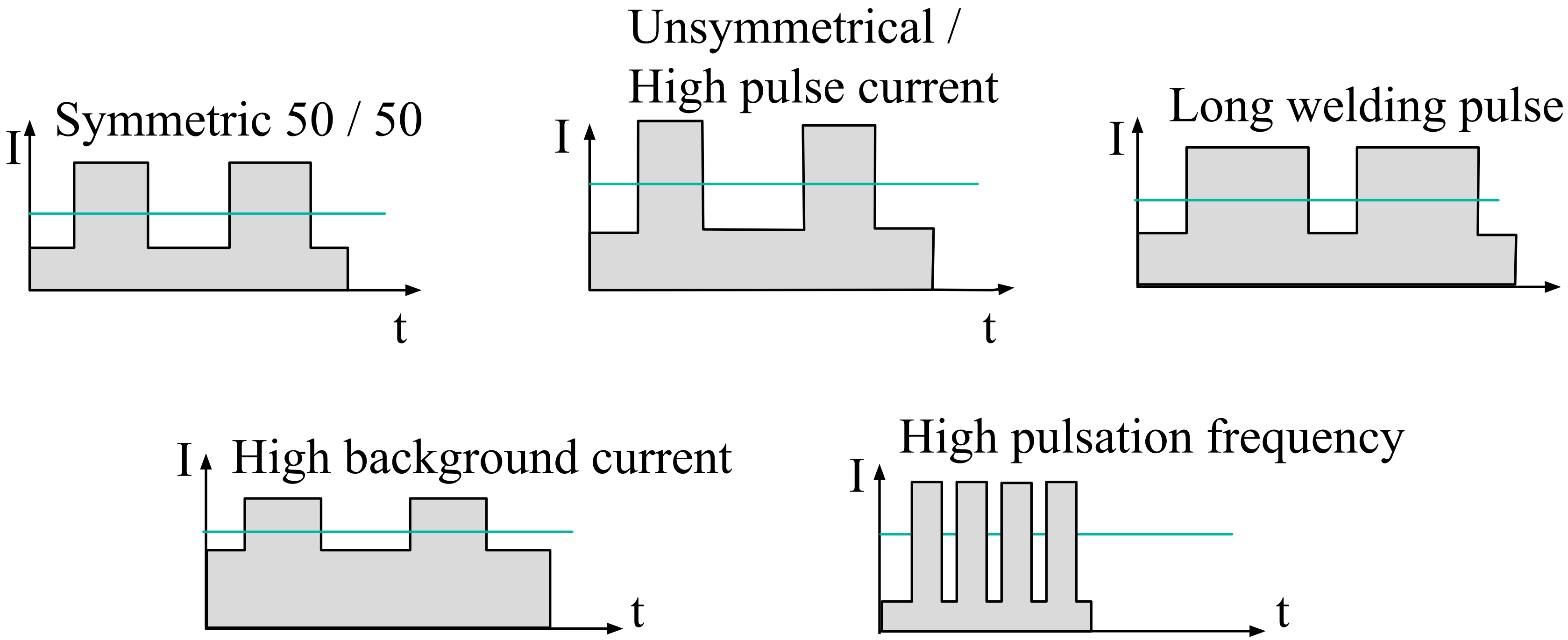
Pulse parameters regulation variants



Various pulse profiles can give same average current but different welding speed and heat input.

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Rapid pulse (RP)

Pulsed TIG welding is divided to two main section:

- Frequency from 50 to 500 Hz (0,02 s - 0,002 s cycle time)
- High pulse current ensures deep penetration
- Low background current makes weld pool smaller
- Synergic Rapid Pulse TIG makes control easier
- Wire feeding can be continuos or “ drop by drop “ technique
- Low heat input
- Arc looks like continuous TIG welding
- Sound level is higher (due high pulse frequency)
- For thin plates (max 3,0 mm)
- Especially good for materials with low thermal conductivity (Fe, Ss)
- Better welding speed than with continuous TIG

Long pulse (LP)

Pulsed TIG welding is divided to two main section:

- From 5 to 0,1 Hz (0,2 s - 10 s cycle time)
- Two visually clear periods, pulse and background
- Better weld pool control than on continuous TIG welding
- Out of position welding
- Wider seam, filler wire feed during pulse current time, ”drop by drop” filler wire feeding technique.
- Filler wire feeding can also be continuos (wire in weld pool)
- Lower heat input than in continuous TIG welding
- Easier to do visually good looking weld seam
- Better welding speed than with continuos TIG welding
- Smaller deformation than with continuos TIG welding

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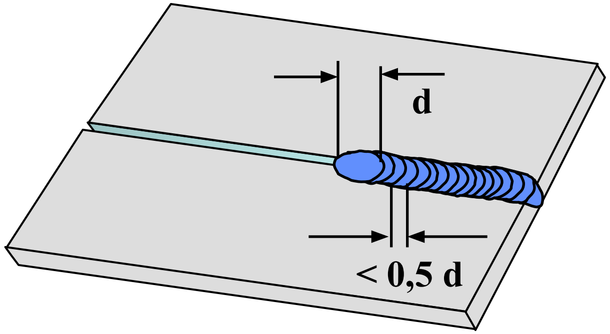
Pulsed TIG welding technique

- Welding speed must be adjusted so that overlapping of weld pools is at least 50%.
- In pipe welding overlapping can be 90%.
- This guarantees good weld result even if the torch movement is little unstable in hand welding.



- In Pulsed TIG welding filler wire can stay continuously in the weld pool without feeding movement.

- If filler wire is feed to the weld pool with “drop by drop” technique pulse time (t_p) and frequency (f) must be regulated according to this, longer pulse time and lower frequency.

Parameter setting on Pulsed TIG

- In welding of steel use unsymmetrical pulse profile, pulse time t_p = 30 - 40%.
- This gives long cooling time to avoid base material overheating.
- Use LP with slow pulse frequency, f = 0,5 - 1,0 Hz and continuous filler wire feeding or “drop by drop” technique.
- Rapid pulsation RP (f = > 50 Hz) can also used with continuos filler wire feeding.
- Regulate Pulse current according to base material thickness so that penetration is correct.
- Regulate background current low, so that cooling is effective.
- In outside corner joint welding is possible with or without filler wire.

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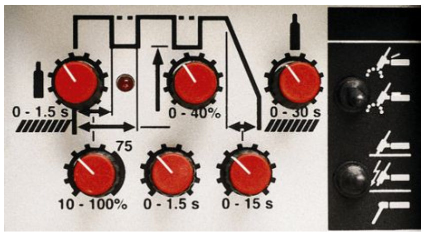
Kemppi`s Pulsed TIG equipment

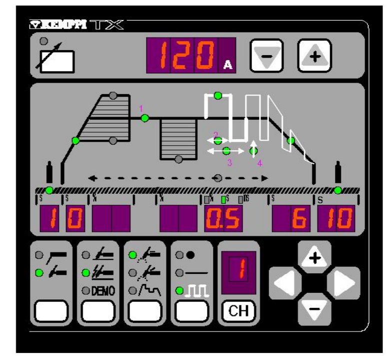
Modern TIG machine allows exact regulations and also possibility to memorise pulse parameters.



Mastertig
2200 / 2850 / 2850 W

Mastertig AC / DC
Pulse panel

Mastertig MLS™
MTM and MTX
operation panels



Protig 400
TX-panel

With Multisystem PS / PSS + TU equipment use C 100 P remote pulse unit.

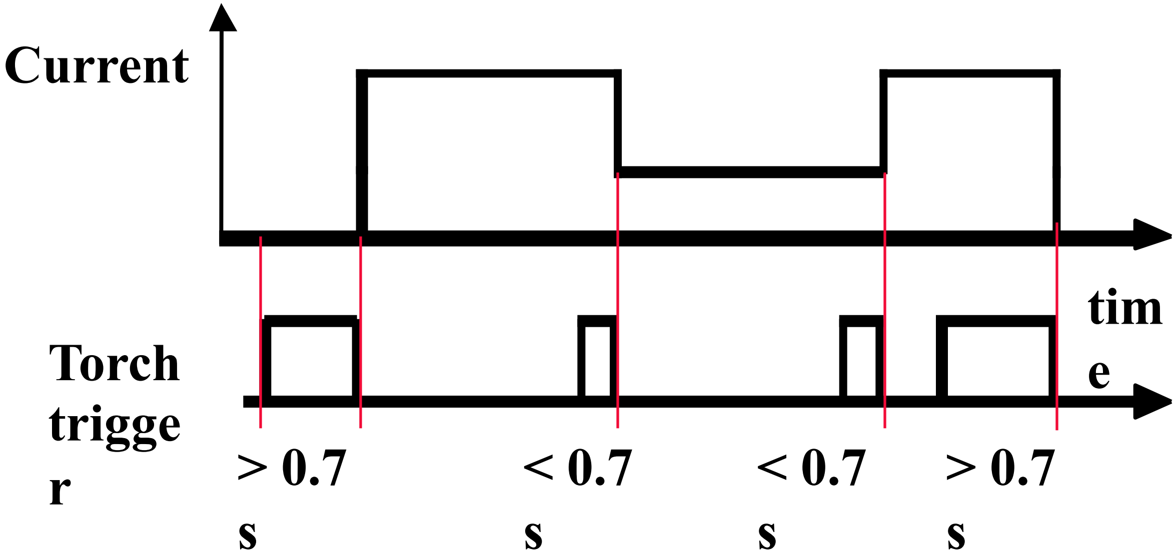
Pulsed DC TIG welding applications

Pulsed DC TIG welding is a flexible welding process for all positions and plate thickness

- Out of position welding
- Pipe welding
- Visually important welds
- Welding without filler wire
- Welding of different plate thickness (thick + thin)
- Special steel welding applications (Steel + Ss)
- To avoid material overheating (oxidization)
- To minimize deformation and control heat input
- Best results on outside corner joints and pipes

TIG Minilog function

With Minilog function welder can select between two pre-set current levels from the TIG torch trigger.



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TIG Minilog benefits

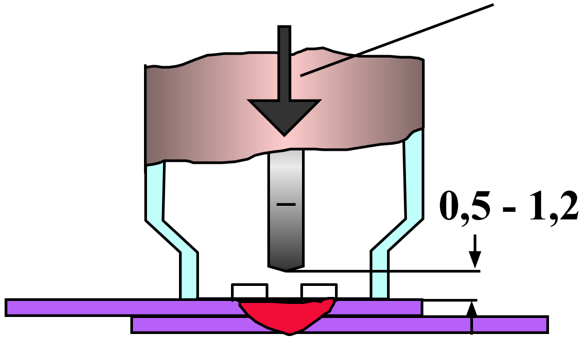
- To avoid welding faults at starts
- Better weld pool control in positional welding
- Better weld pool control if air gap is varying
- Welder can change position or take more filler wire without breaking the arc
- For soft or hot - start
- Two value current “memory”
- Decreases need of remote control use

TIG Minilog applications

- Pre heat of base material before welding
- Starting from thin material or from air cap
- Out of position welding
- Pipe welding
- When air gap is varying
- Welding of two different material thickness
- Welding of long seams
- Better control of penetration and heat input
- When two different current levels are needed
- Filler wire position change

TIG Spot welding of steel

Press TIG torch against welded plates

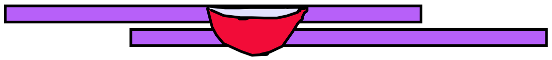


- TIG Spot welding is done from one side only by using special gas nozzle
- Plates must be pressed against each other
- Max thickness in practice is 1,5 + 1,5 mm
- With thicker plates use hole on top plate, after spot filling with wire

- Spot penetration is regulated with short spot welding time and high welding current.
- Welded plates must be without oil, paint, rust etc.
- If welded pieces are having separation between plates TIG spot quality vary and spots are too deep.

OK result

Too deep spot



Weld data: Steel

Plate Thickness	Joint type	Flat pos. (A)	Vertical pos. (A)	Overhead pos. (A)	Filler wire	Electrode diameter	Travel speed
1,0 mm	Butt joint	30 - 50	30 - 45	30 - 40	1,6	1,0	250 - 300
	Overlapped	65	65	55	1,6	1,0	250 - 300
	Corner joint	50	40	40	1,6	1,0	250 - 300
	Fillet joint	50	50	50	1,6	1,0	250 - 300
2,0 mm	Butt joint	80 - 110	75 - 100	70 - 100	1,6 - 2,4	1,6 - 2,4	175 - 225
	Overlapped	110	100	100	1,6	1,6 - 2,4	175 - 225
	Corner joint	80	75	70	1,6	1,6 - 2,4	175 - 225
	Fillet joint	105	95	95	1,6	1,6 - 2,4	175 - 225
3,0 mm	Butt joint	100 - 180	100 - 185	110 - 180	2,4 - 3,2	2,4	125 - 175
	Overlapped	130	120	115	2,4 - 3,2	2,4	125 - 175
	Corner joint	110	100	100	2,4 - 3,2	2,4	125 - 175
	Fillet joint	125	115	110	2,4 - 3,2	2,4	125 - 175
4,0 mm	Butt joint	120 - 200	110 - 185	110 - 180	3,2	2,4 - 3,2	100 - 150
	Overlapped	185	170	165	3,2	2,4 - 3,2	100 - 150
	Fillet joint	180	165	160	3,2	2,4 - 3,2	100 - 150
5,0 mm	Corner joint	160	140	140	2,4 - 3,2	3,2	100 - 150

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