SLV DUISBURG

Tungsten Inert Gas Welding TIG

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Mechanical & Materials Engineering for Particle Accelerators and Detectors
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GSI - Gesellschaft für Schweißtechnik International mbH

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- Company headquarters of GSI
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- **Training of supervisors**
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- **Training of welders**
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- **Training of testers**
  Tester and tester-supervisors part 1 – 3 acc. to DIN EN ISO 9712 for processes RT, RT2.FI, UT, MT, PT, VT
- **International Welding Inspector**
  (IWI-P acc. to IIW 1178)
- **Training of personnel for corrosion protection** Inspector for surface treatment (FROSIO)
- **Special Training**
  Track welding, thermal spraying, plastics welding, bonding, robot welding, stud welding and others
- **European material tester**
- **Material tester** Participants receive a Chamber of Industry and Commerce leaving certificate
- **Conferences and Colloquia**

Services: Quality Assurance

Certified SLV Company
Zertifizierter GSI SLV Schweißfachbetrieb

- Testing, monitoring and certification body for products and manufacturers
- corrosion protection technology
- Building supervision
- Consulting
- Expert reports
- Supplier evaluation
- Certification of QM-systems
- Certification of procedure and welder qualification tests
- Non destructive testing (NDT), selection of NDT methods

Services: Research and Development

- Processing of publicly funded projects with involvement of industry partners for ensuring the technological and material advance
- Technological as well as material research and development within a customer's order
- Procedural examinations for industry partners in line with the manufacturing engineering
- Support for companies in the introduction and optimization of production processes for welding and cutting
- Development and manufacturing of special purpose machinery
- Testing and evaluation of equipment for welding and cutting
- Expertise and equipment for practically all processes and techniques of joining and thermal cutting

Tungsten Inert Gas Welding (TIG)

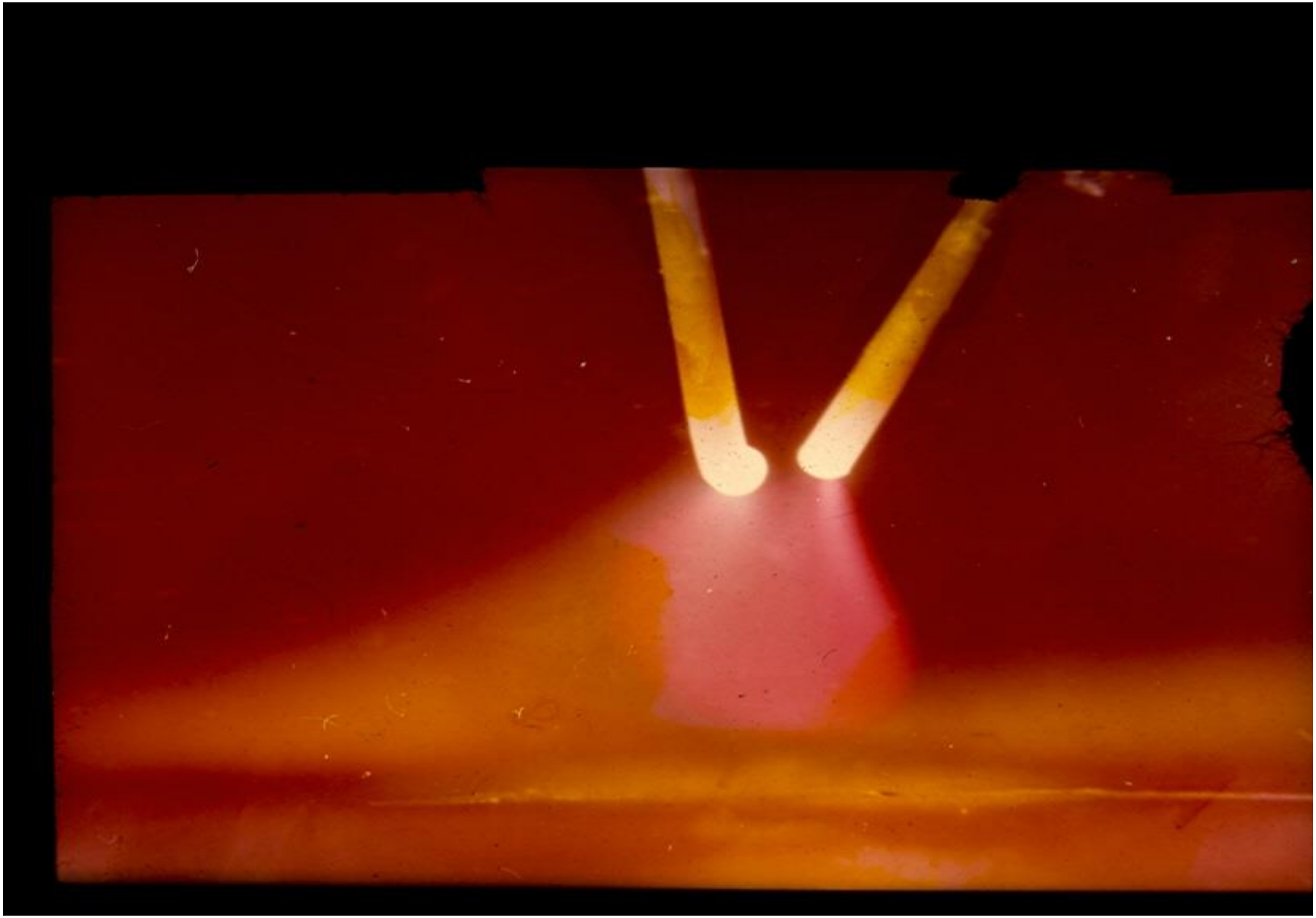
Outline

Introduction

Tungsten Inert Gas welding was developed in the USA in the 1940s and introduced to industrial production in Europe in the 1950s under the name of **Argon Arc Welding**. In German-language today's name is:

Wolfram-**I**nert **G**as Welding (WIG) (TIG)

TIG Welding

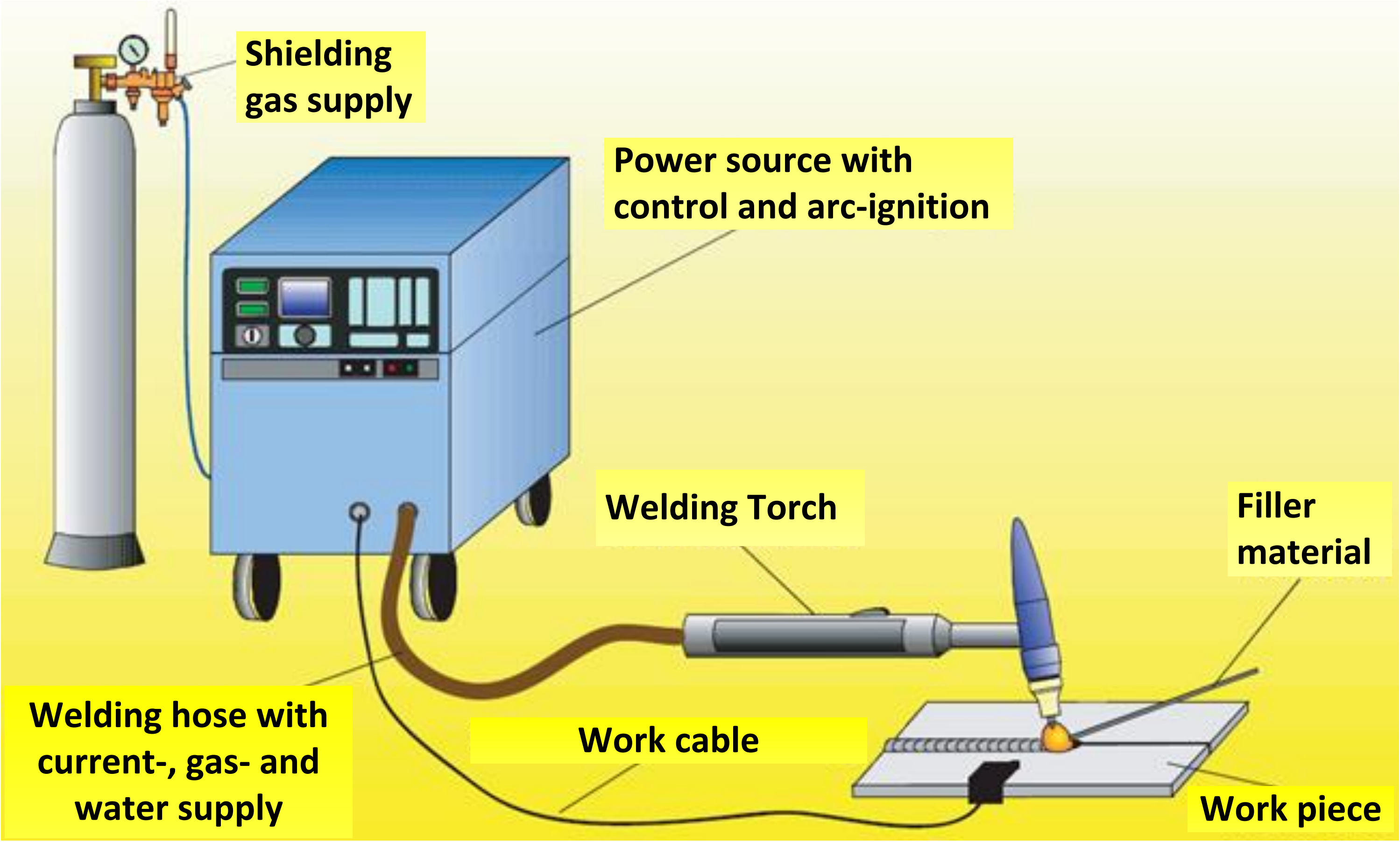


Materials and applications

- All melt-weldable steels and non-ferrous metals can be welded in all positions
- Economical use with component thicknesses of approx. 0.5 to 5
- For thicker components, often only the root pass is welded using the TIG process
- Applications:
  - **Aerospace industry**
  - **Precision Engineering**
  - **Chemical industry**
  - **Apparatus and container construction**
  - **Medical industry**

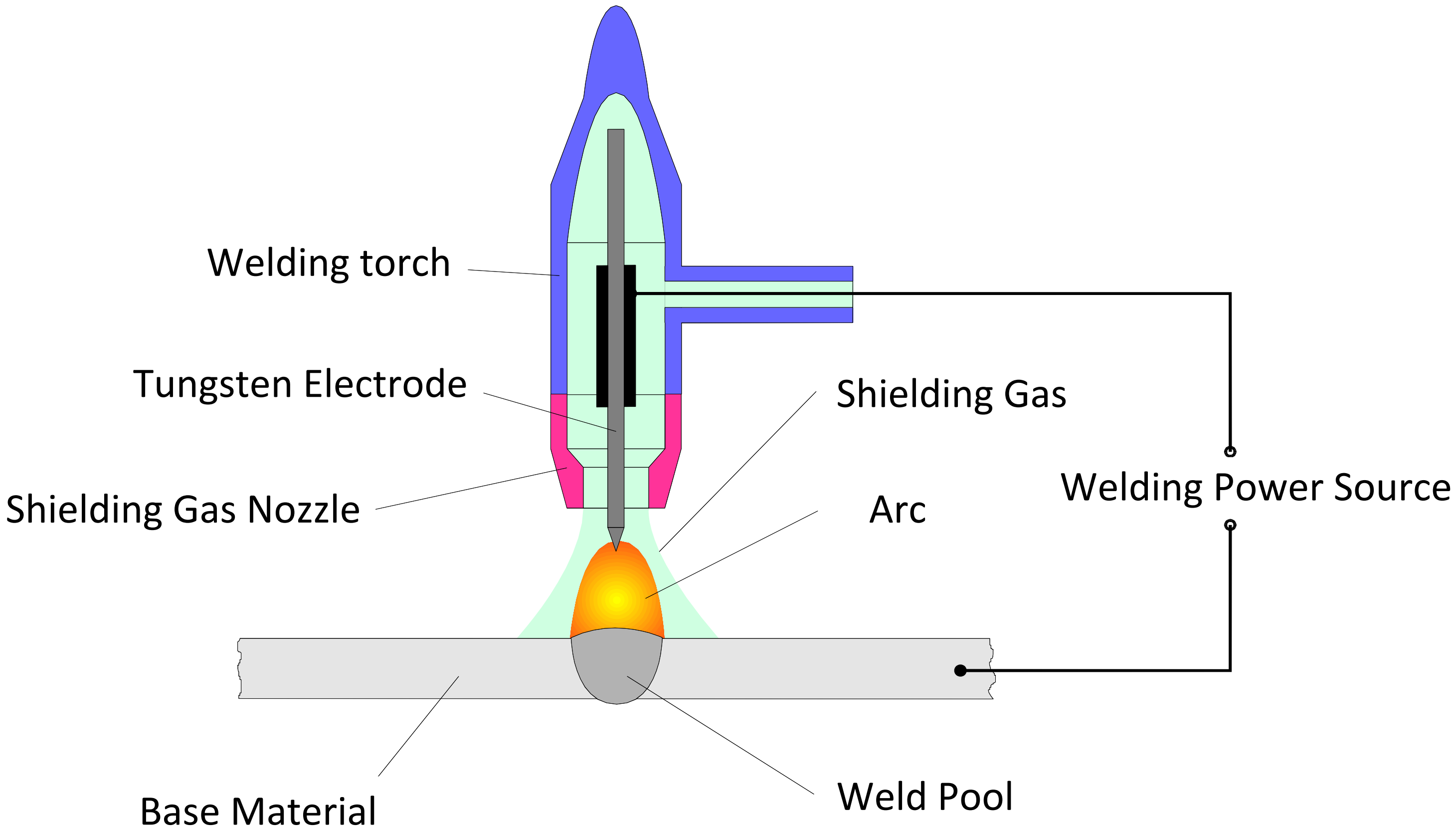
TIG Welding of Pressure Vessel

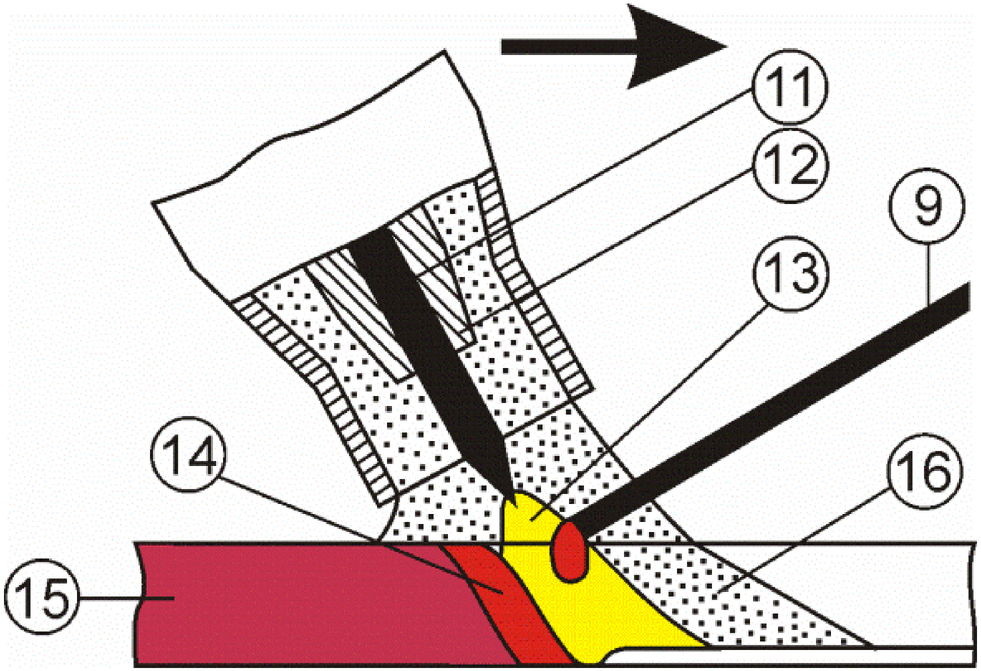
A TIG welding system basically consists of the following components:



Process principle

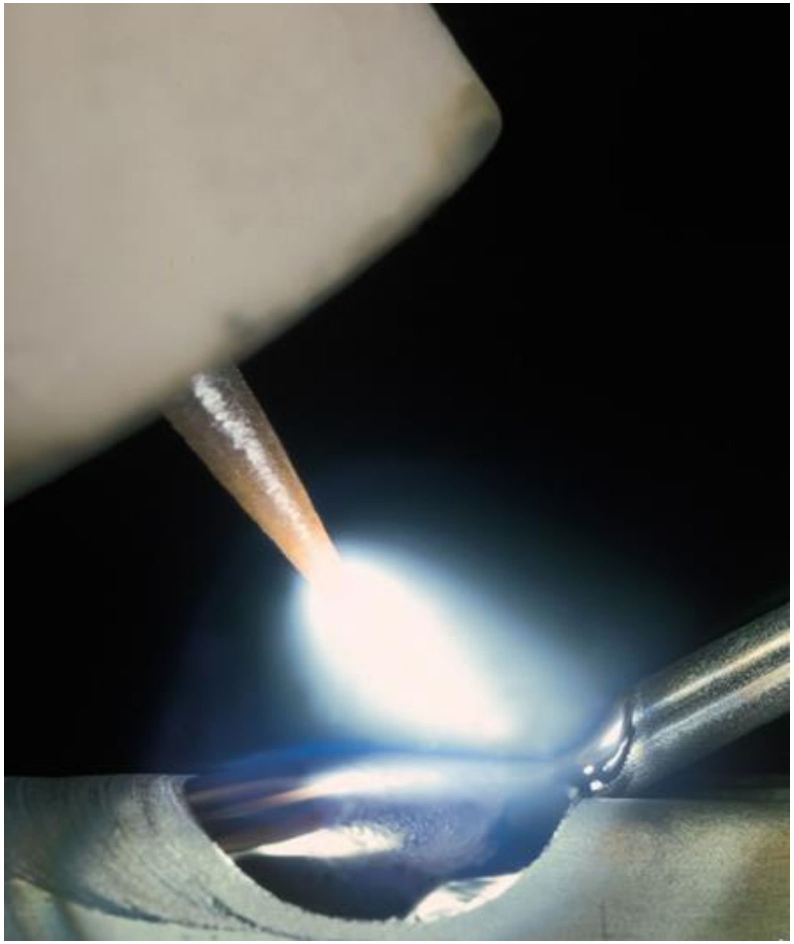
The heat source is the arc burning between a non-consumable tungsten electrode and the base material in an **inert** gas atmosphere.





11. Tungsten electrode
12. Collet body, and collet
13. Arc
14. Liquid weld metal (pool)
15. Solid weld metal (bead)
16. Inert shielding gas

TIG Arc

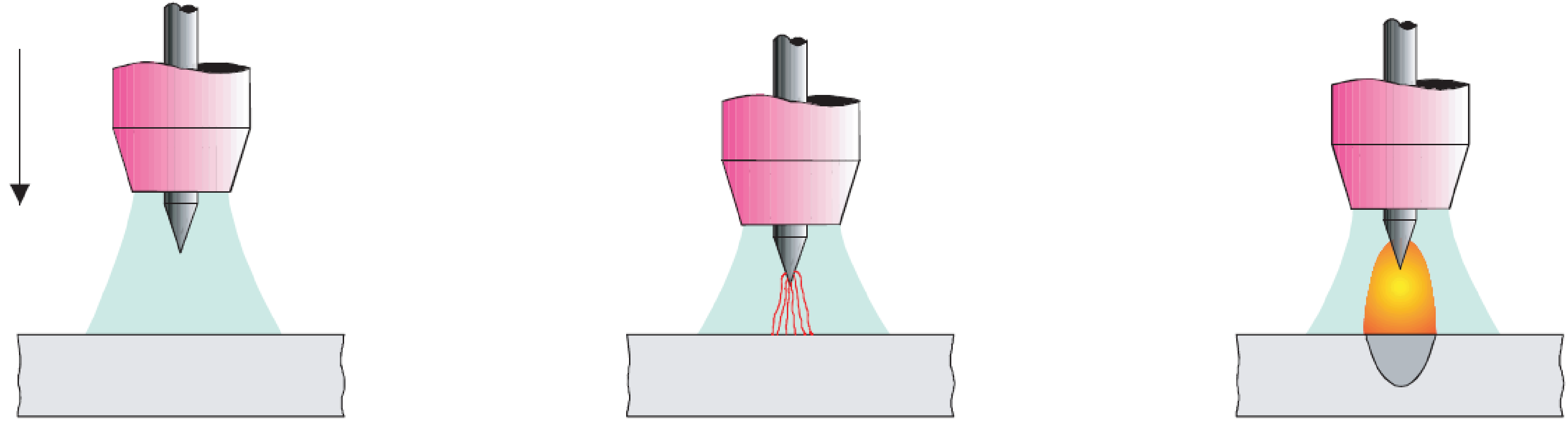


source: Linde

Non-contact ignition by HF ignitors

- No Torch movement is required for ignition.
- Thanks to non-contact ignition, avoidance of **tungsten particles** in the seam area.
- The ionization of the arc space used to be done by high frequency, but today it is mainly done by high-frequency high-voltage pulses. However, the term HF ignition is also generally used for high-voltage pulse ignition.
- The HF ignition and the high-voltage pulse ignition lead to particular dangers for people and for sensitive electronic devices due to their voltage amplitude, the energy content of the pulses and the short-term high-frequency electromagnetic radiation. The electronic devices in the vicinity (a few meters) of the welding power cables and the torch must be interference-proof (suitable for an industrial environment) so that malfunctions or defects do not occur.
- The accessible areas of the TIG torch, the torch cable and plugs must be well insulated to prevent unwanted high-voltage flashovers (sparks). Perfect dry insulating gloves should be a given when operating the torch manually.

Non-contact ignition by HF ignitors

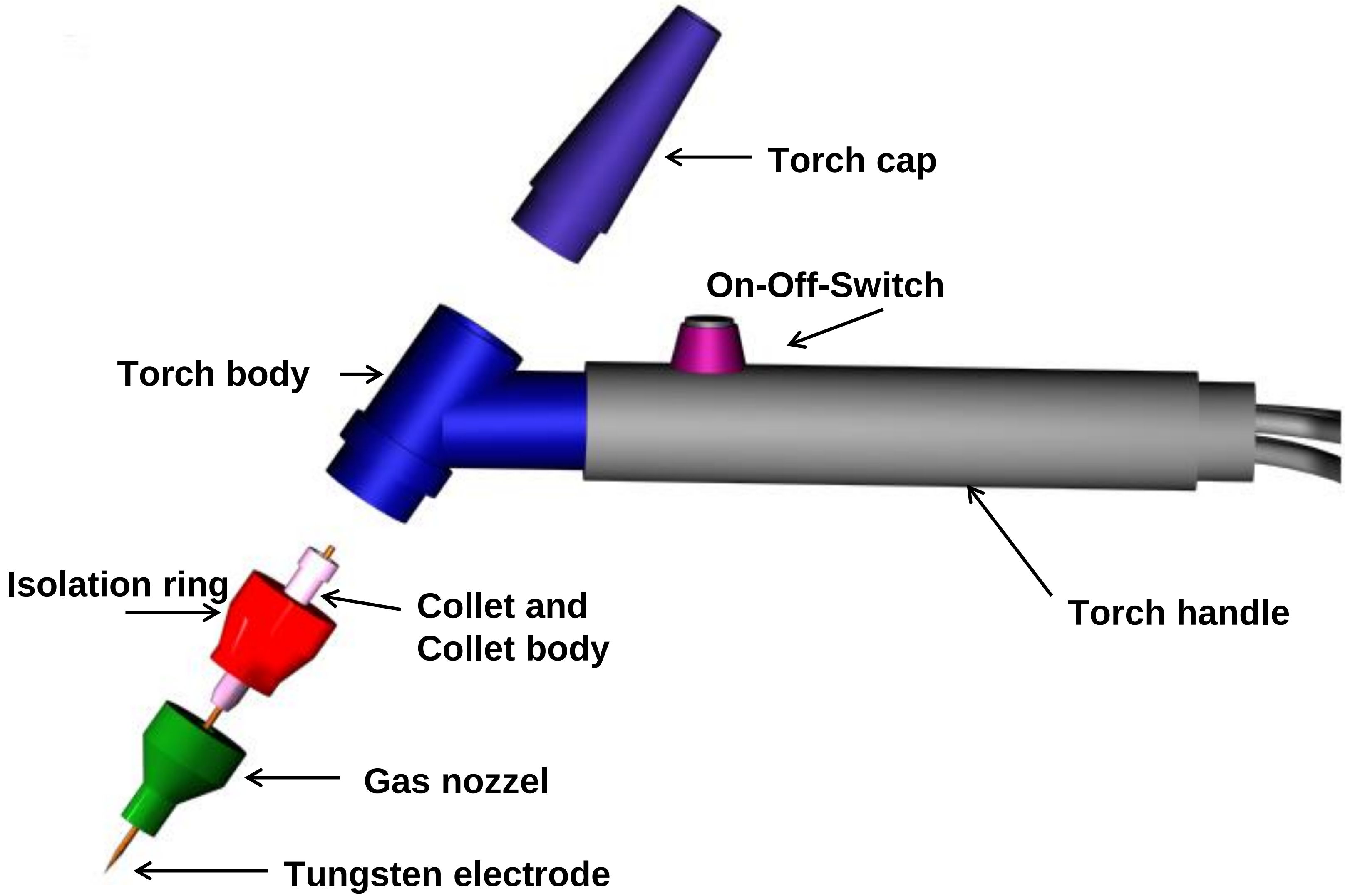


Approach to the Workpiece

Preionization by high-frequency high-volage pulses

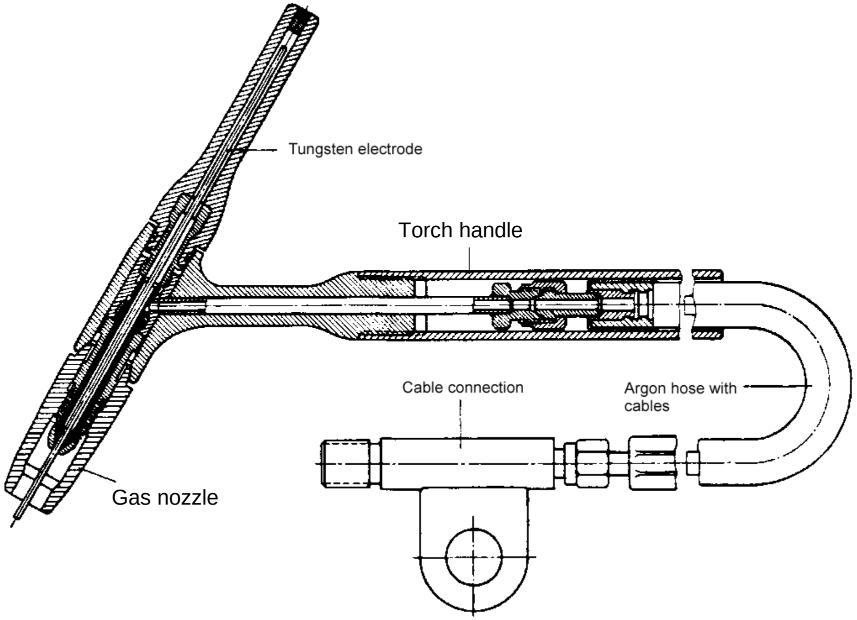
Non-contact ignition of the Arc

Construction of a TIG torch

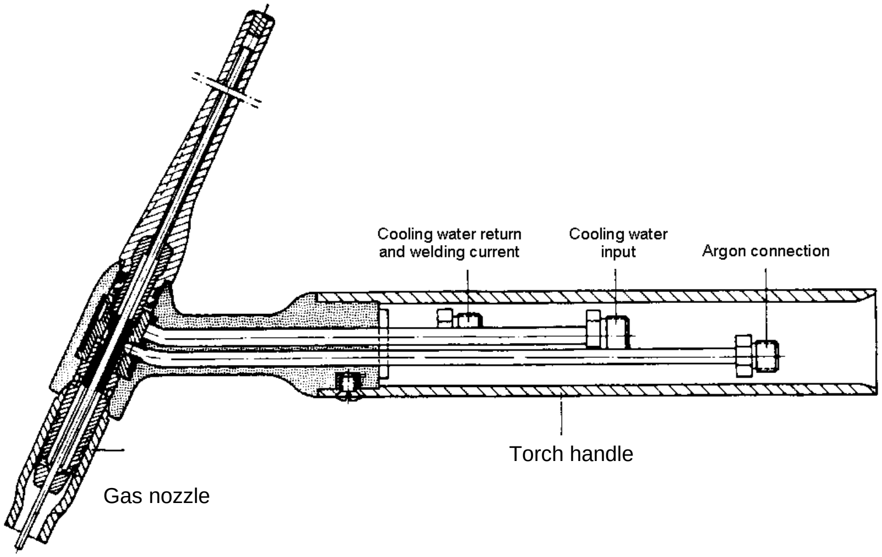


Section through Air-Cooled And Water- Cooled torch

TIG welding torches with cable assembly must be selected according to the current carrying capacity and the application. They are subject to a high thermal load and are either air cooled (gas cooled) or water cooled.



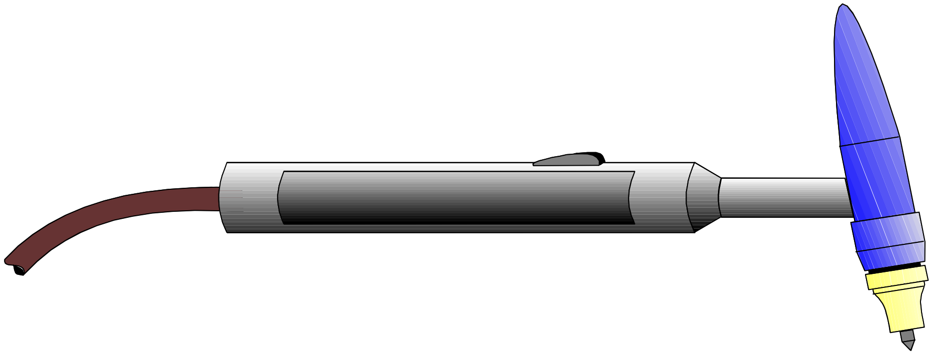
AIR / GAS COOLED



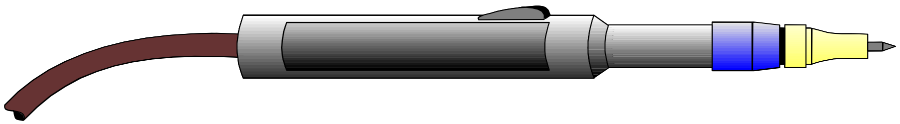
WATER COOLED

Types of manual TIG torches

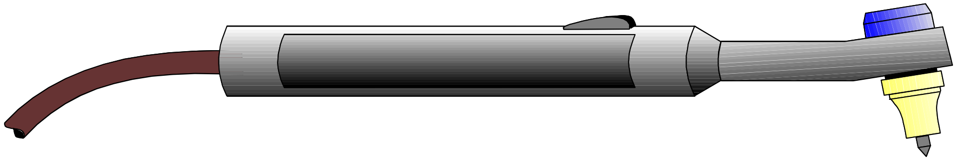
Depending on the welding task, different torch shapes and sizes are used.



normal form



straight form



short form head for
hard to reach places

Types of manual TIG torches

Types of Automated TIG torches

Tungsten electrodesoden

Due to the high melting point of tungsten (3422 ° C), the tungsten electrode consumes only a small amount under a shielding gas when the current load is matched to the diameter.

To protect the tungsten electrode against overheating, contamination and oxidation, the arc may only be ignited and operated under inert gas.

Tungsten electrodes are standardized in DIN EN ISO 6848. The service life, the current carrying capacity and the ignition behavior of the electrodes (electron work function) can be increased by additions of rare earth oxides such as thorium, lanthanum, cerium and zirconium as heavy metal or mixed oxides thereof.

Influence of the chemical composition of the tungsten electrodes

Pure tungsten:

– particularly suitable for welding non-ferrous metals with alternating current
– good arc stability

Tungsten with thorium oxide:

Increase in electron emission with increasing thorium oxide content, thereby

– better ignition properties
– higher service life and higher current carrying capacity than WP electrodes
– slightly radioactive

Tungsten with zirconium oxide:

– less risk of melt contamination by tungsten
– worse ignition properties than WTh electrodes

Influence of chemical composition

Tungsten with lanthanum oxide:

- longer service life than WTh electrodes
- worse ignition properties than WTh electrodes
- preferably for plasma processes

Tungsten with cerium oxide:

- similar ignition and welding properties as WT electrodes
- more environmentally friendly than WTh electrodes

Tungsten electrodes with admixtures of oxides different rare earths:

- similar ignition and welding properties as WT electrodes, no radiation exposure

Classification of the tungsten electrodes according to DIN EN ISO 6848

Short symbol	Requirement of the Chemical Composition				Identification colour,
	Oxide Additive		Pollution content in %	Tungsten content in %	RGB colour value and colour sample[a]
	Main Oxides	Contents in %			
WP	non	N.A.[b]	0.5 max.	99.5 min.	Green #008000
WCe 20	CeO_2	1.8 to 2.2	0.5 max.	Rest	Grey #808080
WLa 10	La_2O_3	0.8 to 1.2	0.5 max.	Rest	Black #000000
WLa 15	La_2O_3	1.3 to 1.7	0.5 max.	Rest	Gold #FFD700
WLa 20	La_2O_3	1.8 to 2.2	0.5 max.	Rest	Blue #0000FF
WTh 10	ThO_2	0.8 to 1.2	0.5 max.	Rest	Yellow #FFFF00
WTh 20	ThO_2	1.7 to 2.2	0.5 max.	Rest	Red #FF0000
WTh 30	ThO_2	2.8 to 3.2	0.5 max.	Rest	Violet #EE82EE
WZr 3	ZrO_2	0.15 to 0.50	0.5 max.	Rest	Brown #A52A2A
WZr 8	ZrO_2	0.7 to 0.9	0.5 max.	Rest	White #FFFFFF

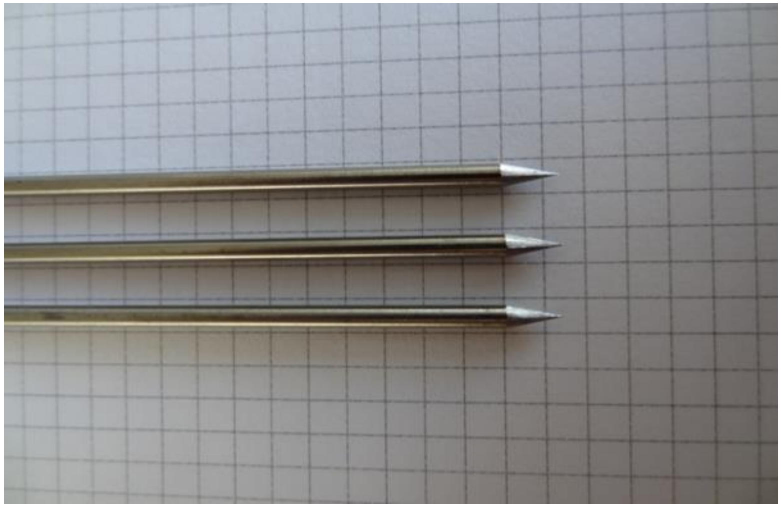
a RGB colour value and colour samples can be found on the following website: http://msdn.microsoft.com/library/default.asp?url=/workshop/author/dhtml/reference/colors/colors.asp

b * N.A. = not applicable

Selection of suitable electrode type

The selection of the appropriate electrode type and diameter is i.a. depends on the following factors:

- Type and thickness of the base material
- amperage
- Current type and polarity
- shielding gas
- Cooling of the welding torch
- free electrode length
- welding position

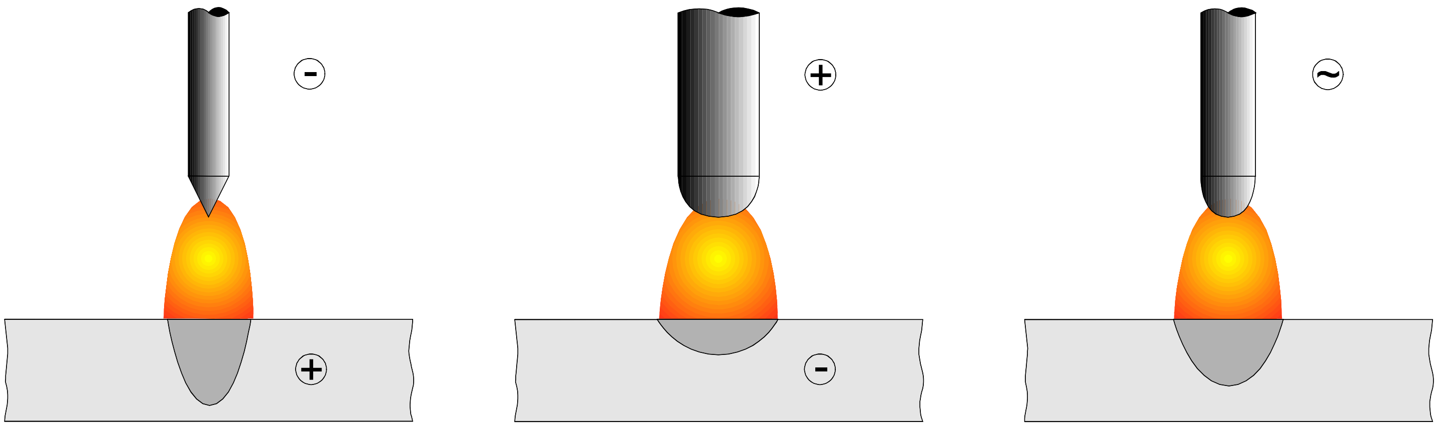


Current ranges depending on the electrode diameter, polarity and current type

Electrode diameter [mm]	Direct current [A]				Alternating current [A]	
	Electrode negative (-)		Electrode positive (+)			
	Pure tungsten	Tungsten with oxide addition	Pure tungsten	Tungsten with oxide addition	Pure tungsten	Tungsten with oxide addition
0.5	2 - 20	2 - 20			2 - 15	2 - 15
1.0	10 - 75	10 - 75			15 - 55	15 - 70
1.6	40 - 130	60 - 150	10 - 20	10 - 20	45 - 90	60 - 125
2.0	75 - 180	100 - 200	10 - 20	10 - 20	65 - 125	85 - 160
2.5	130 - 230	170 - 250	17 - 30	17 - 30	80 - 140	120 - 210
3.2	160 - 310	225 - 330	20 - 35	20 - 35	150 - 190	150 - 250
4.0	275 - 450	350 - 480	35 - 50	35 - 50	180 - 260	240 - 350
5	400 - 625	500 - 675	50 - 70	50 - 70	240 - 350	420 - 575
6.3	550 - 875	650 - 950	65 - 100	65 - 100	300 - 450	420 - 575
8						650 - 830
10						

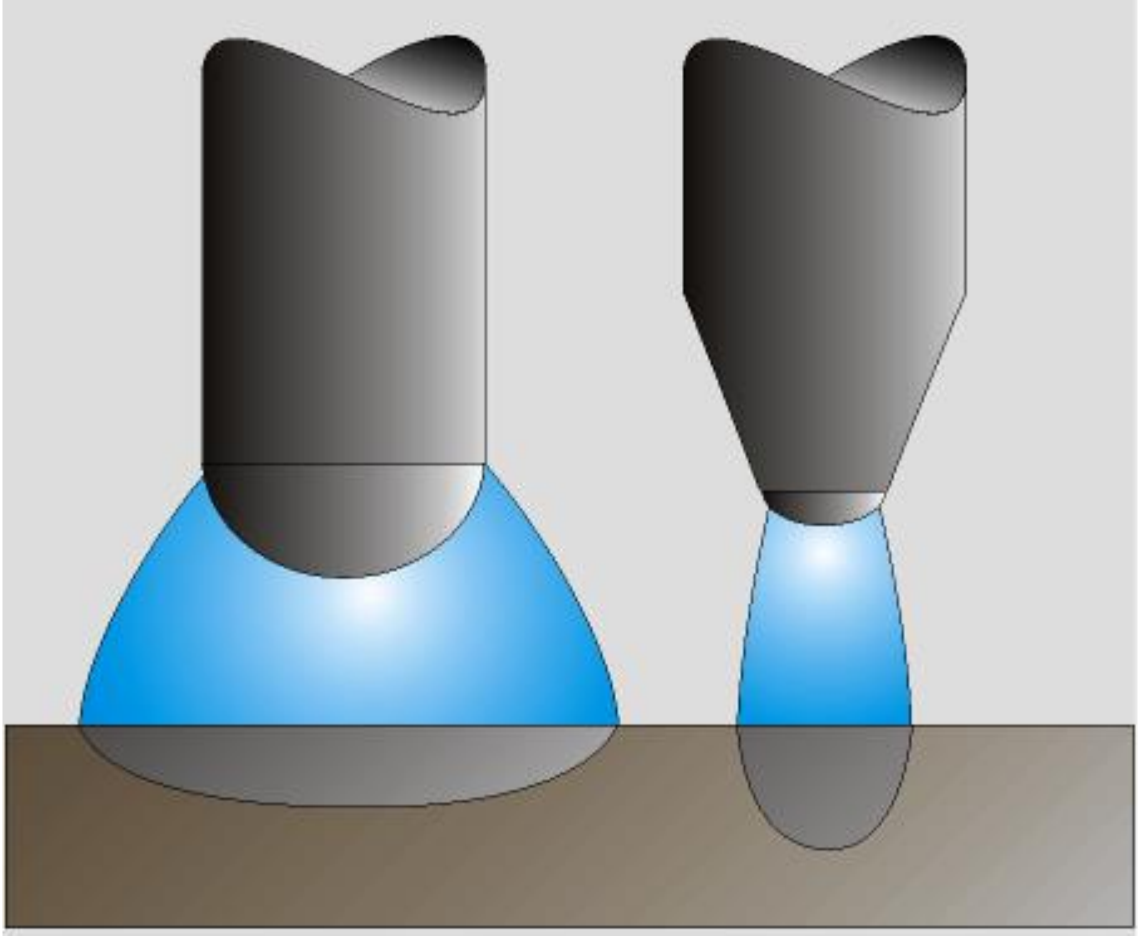
Influence of polarity and current type in TIG welding

- The type of current and polarity in TIG welding depend on the material to be welded. The most common variants are welding with direct current and a negatively polarized electrode for steels, and welding with alternating current for aluminum.
- The type of current and the polarity used have an impact on the arc, the electrode shape and the weld seam result, among other things.



Effect of different types of current and polarity on the arc, electrode shape and penetration depth

End forms of tungsten electrodes



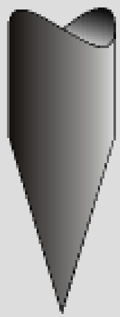
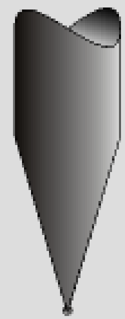
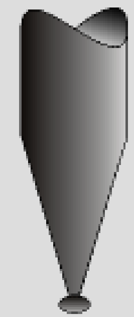
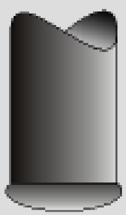
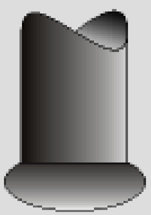
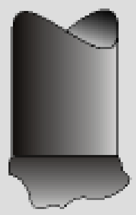
Dependence of the penetration during TIG welding –
of the electrode shape with the same welding current

Influence of the flow profile on the formation of the tungsten electrode tip

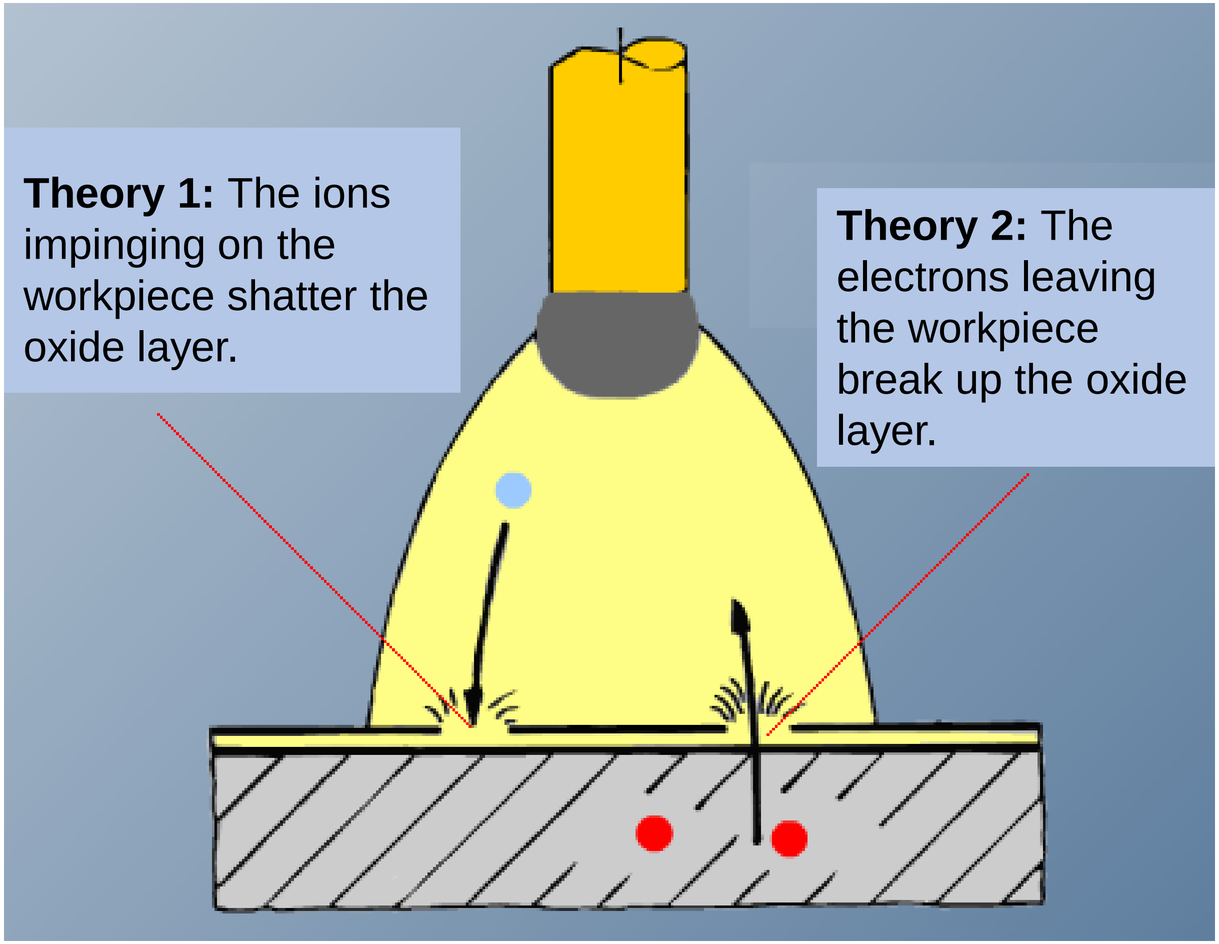
with out gas distributor

with gas distributor

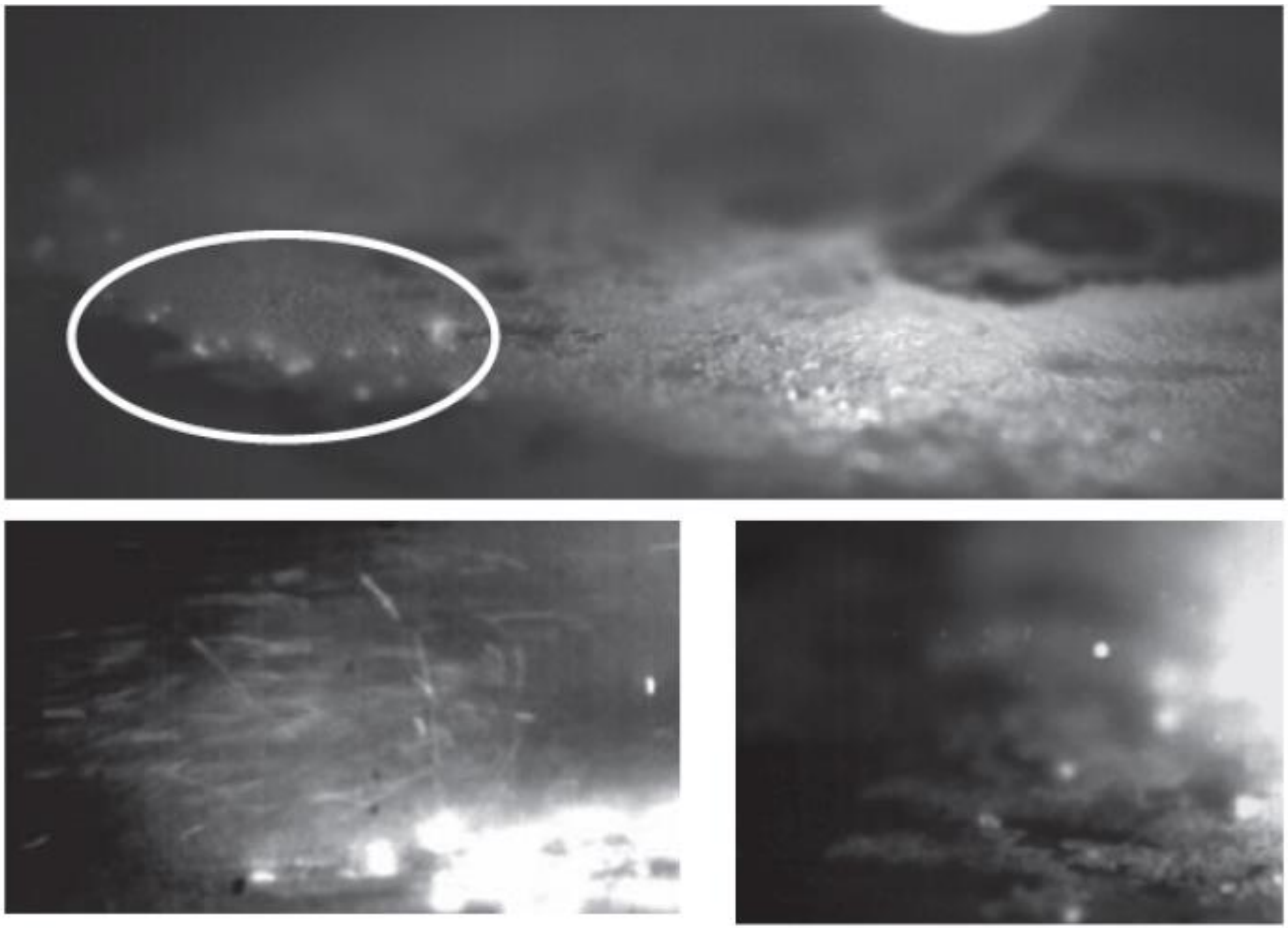
Formation of the electrode shape at different current intensity

Process variants	Tungsten with oxide additives	Current Too Low	Current correct	Current Too High
Direct current	Thoriated			
Alternating current	Pure			
	Thoriated			

alternating current (AC) arc effect on aluminum

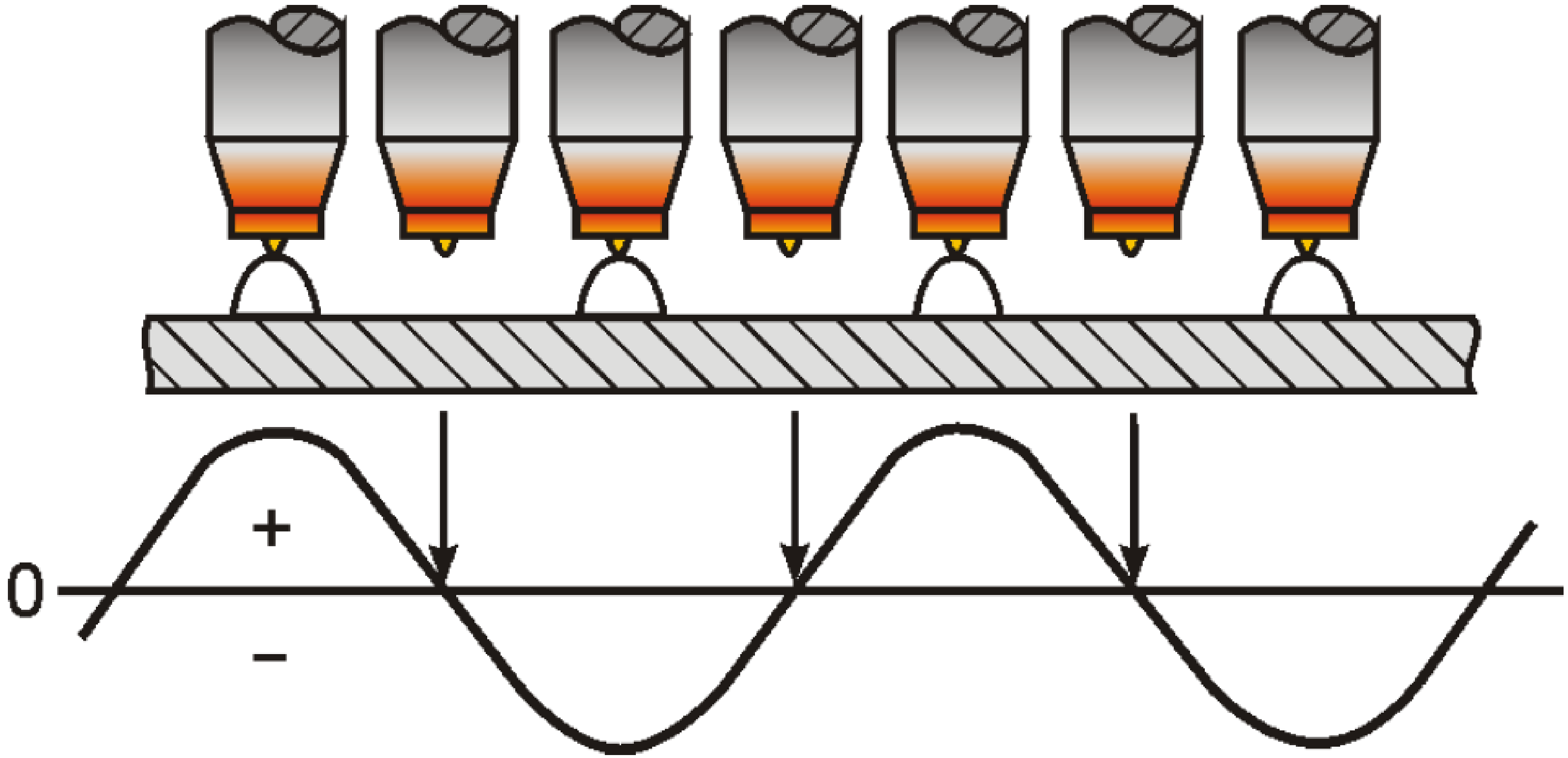


AC arc removing the oxide layer

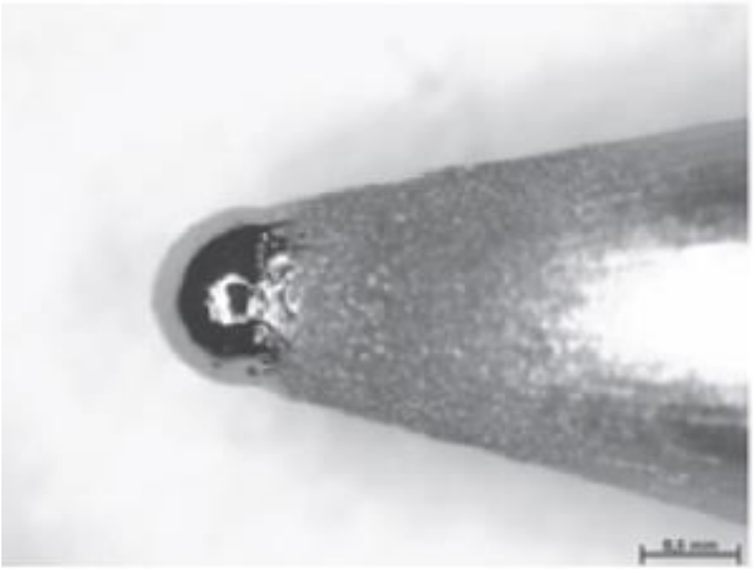


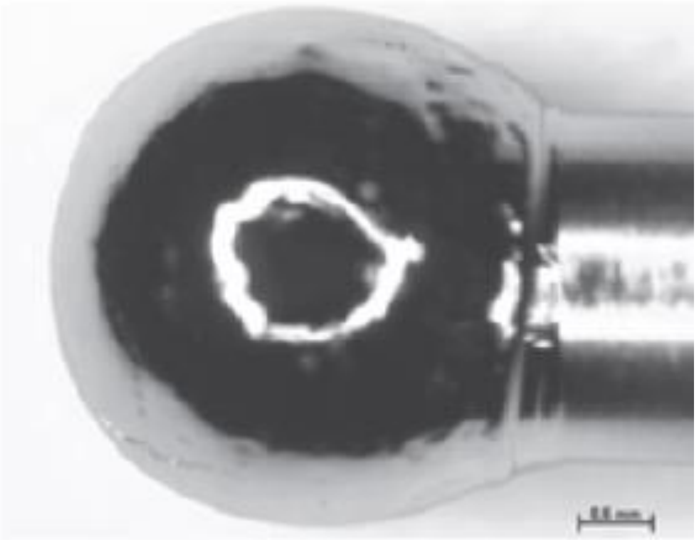
Quelle: Rose et al.

TIG arc with alternating current



Balling of the Electrode from the Positive wave of AC Current





Quelle: Rose et al.

Shielding gases

The shielding gases used are mainly inert gases, in particular argon, but also helium or mixtures of both gases (I1, I2 or I3). In some cases, mixtures of argon and a small proportion (< 10 %) of hydrogen are used for **austenitic solidifying** Cr-Ni steels (R1).

I1 Ar			
I2 He	I3 Ar/He	R1 Ar/H_2	R2 Ar/H_2
N1 N_2	N2 Ar/N_2	N4 $Ar/H_2/N_2$	N5 H_2/N_2

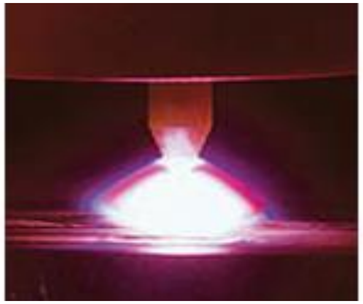
Shielding gas adjustment

The adjustment of the amount of shield gas depends on many factors, e. g.

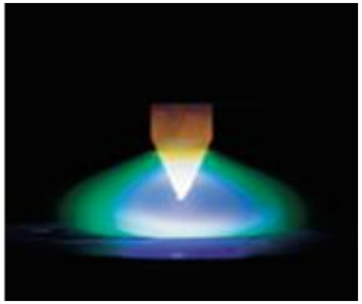
- material
- welding current
- Size and design of the gas nozzle
- groove form
- welding position
- material thickness
- type of shielding gas
- nozzle distance
- welding speed

Influence of the shielding gases on the penetration profile

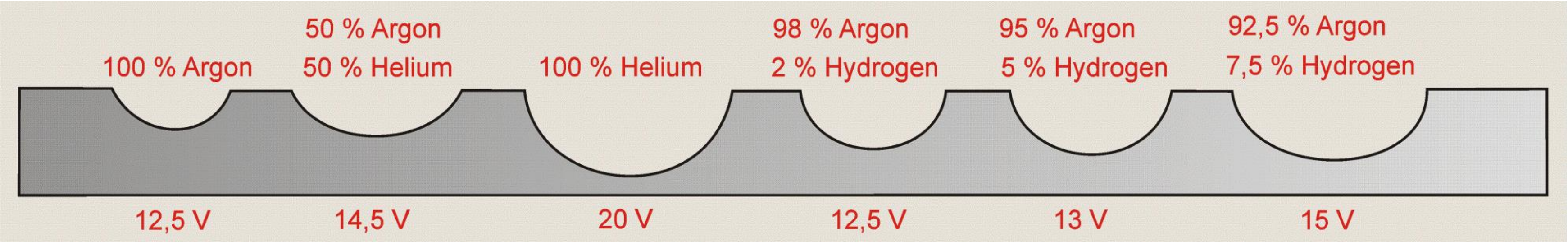
TIG Argon Arc



WIG Varigon H5 Arc

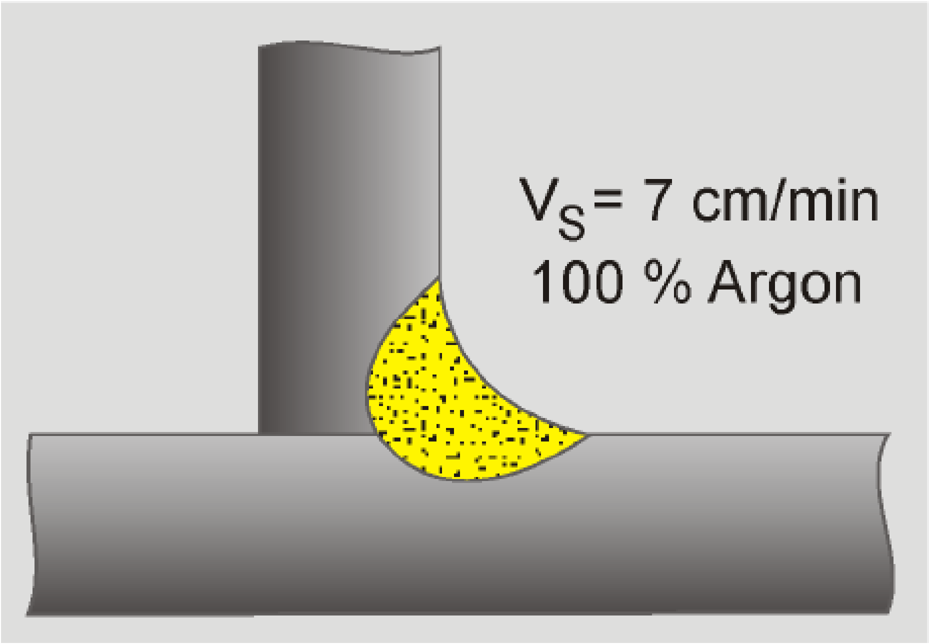


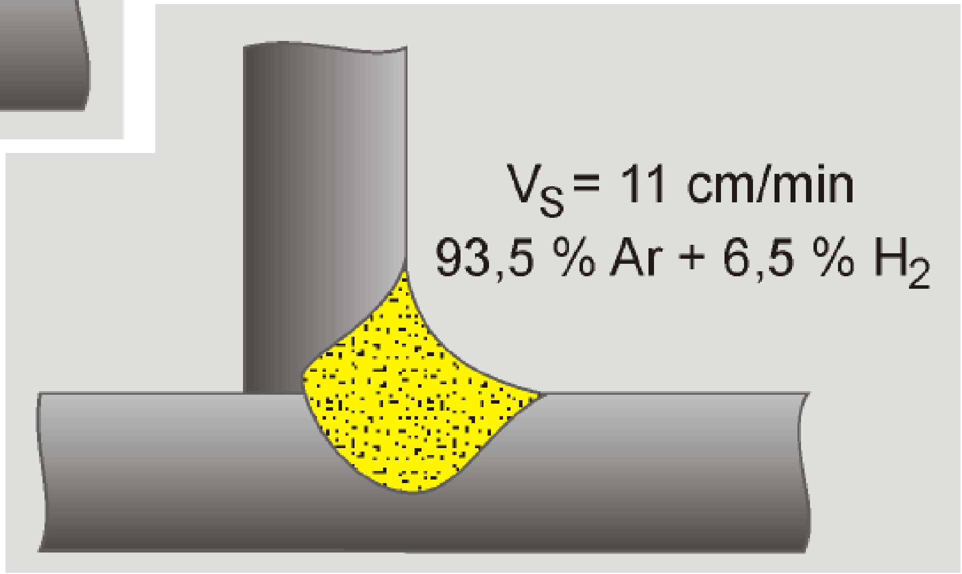
WIG Helium Arc



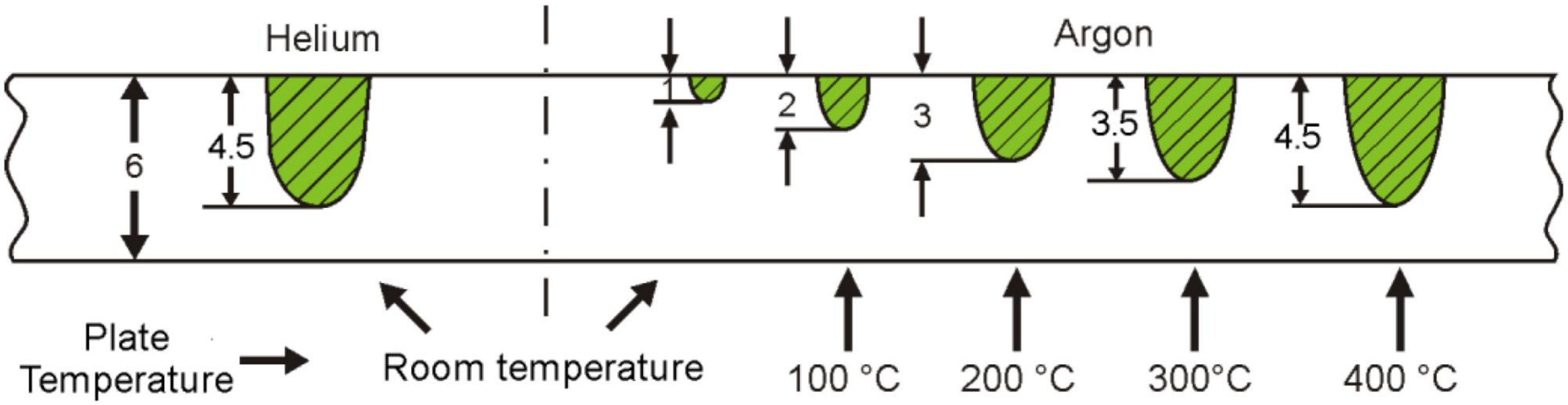
Penetration profiles for TIG welding with Different shielding gases on a 5 mm thick plate, Current 130 A, arc length 4 mm, Welding speed 15 cm / min

Penetration profiles TIG welding under various shielding gases, base material 1.4301





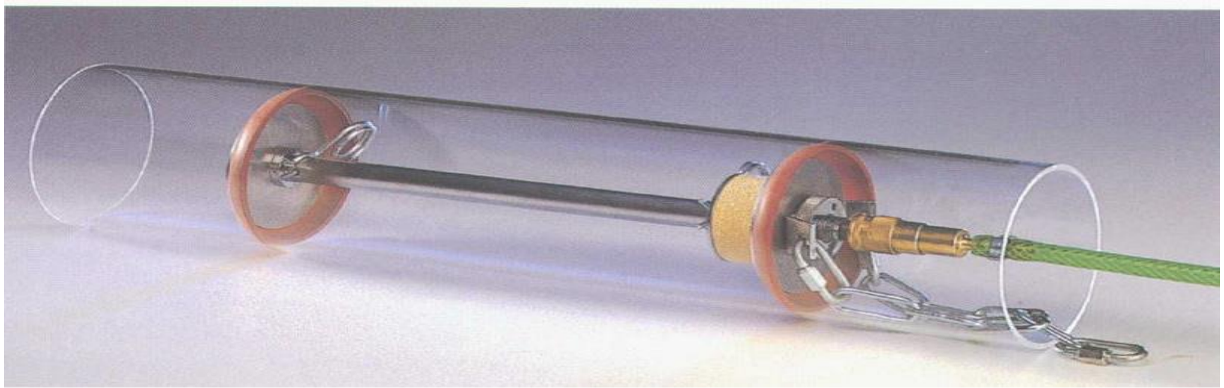
Influencing the depth of penetration



Purging (root protection, backing gas)

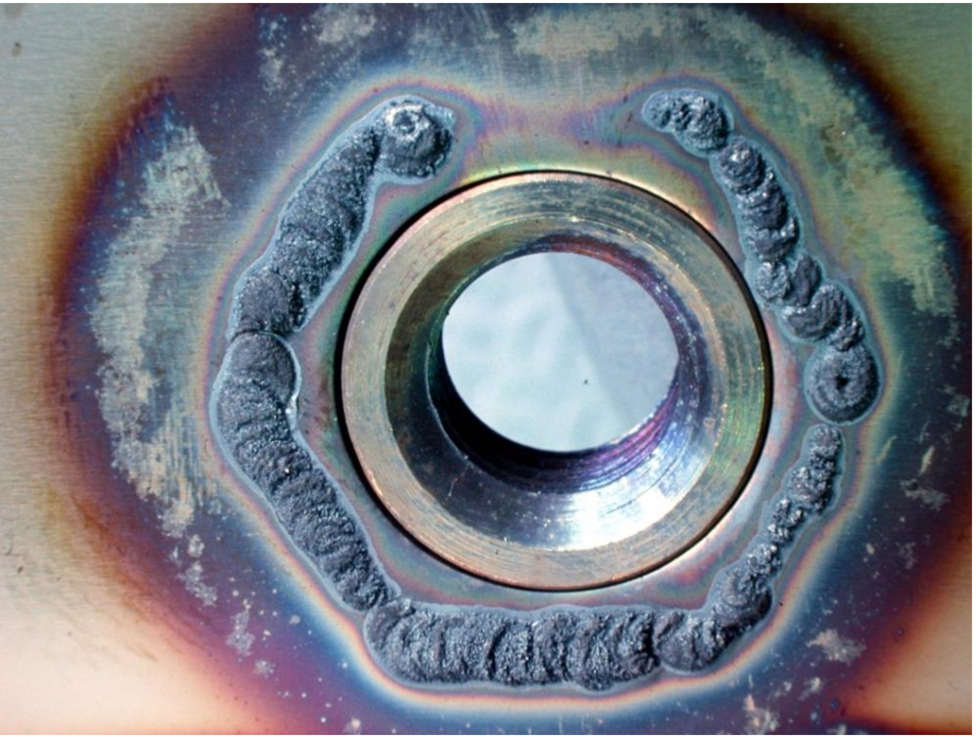
- for high-alloy steels
- Target: Gas protection at the weld root
- Preventing oxidation (tarnish colors)
- with nitrogen, argon, helium → oxygen supply to avoid danger of suffocation
- Purg gases containing Flammable hydrogen → flare (burn) off at

  10 % hydrogen content

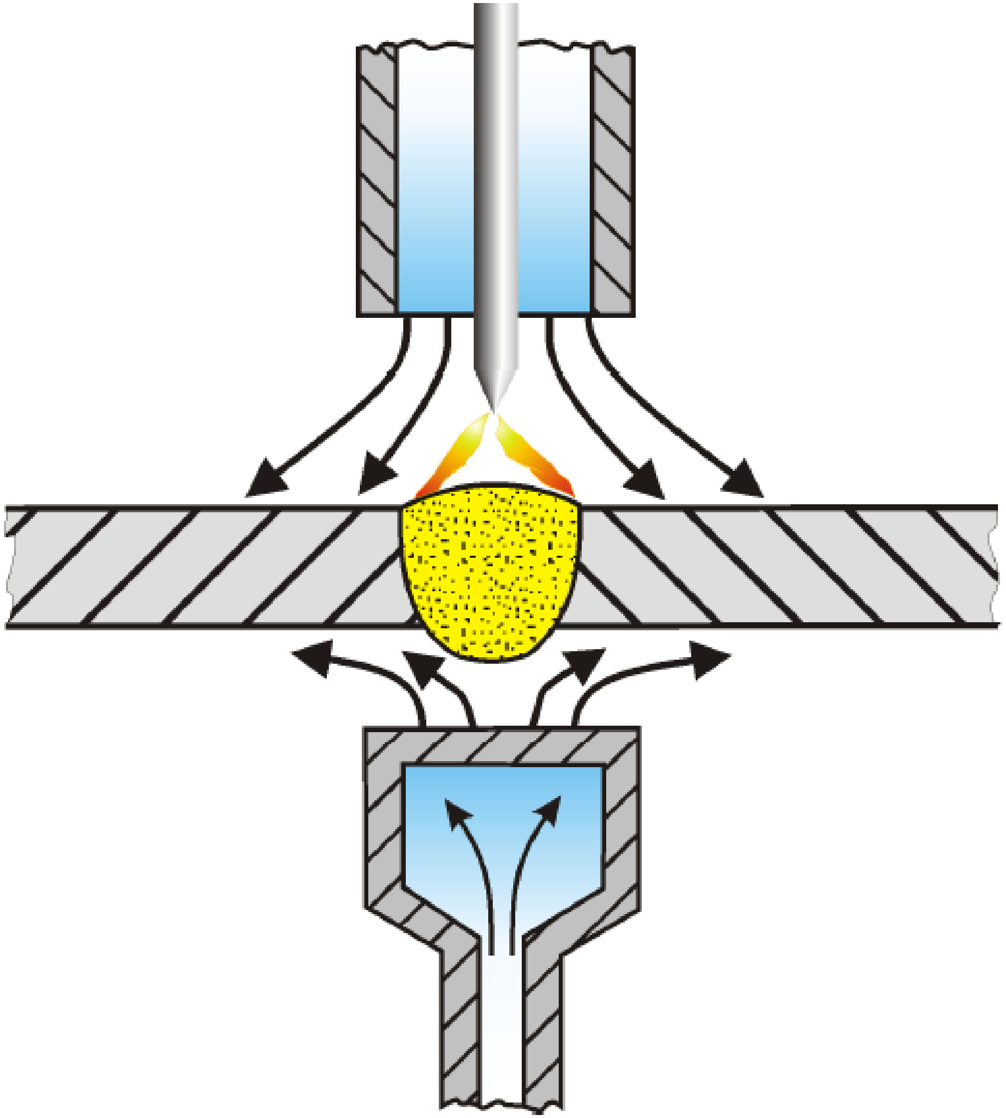


Tarnish (coloration) **and already corrosion**

„Burnt "weld root

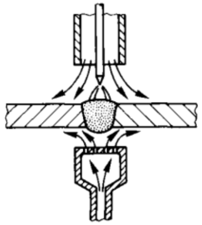


Purging devices (DVS leaflet 0937)

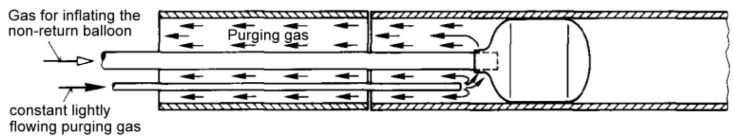


Different ways to purg

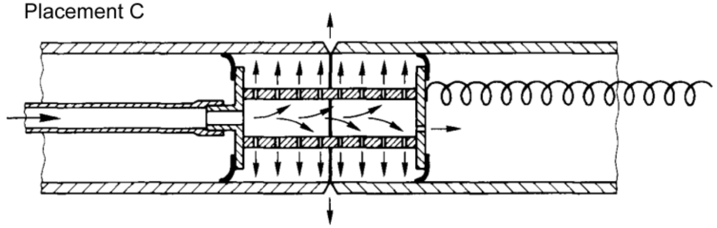
Placement A



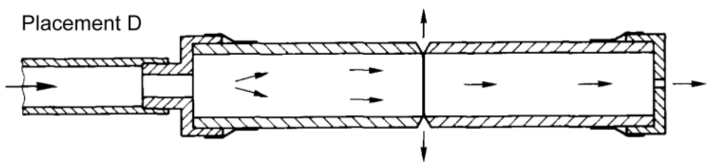
Placement B



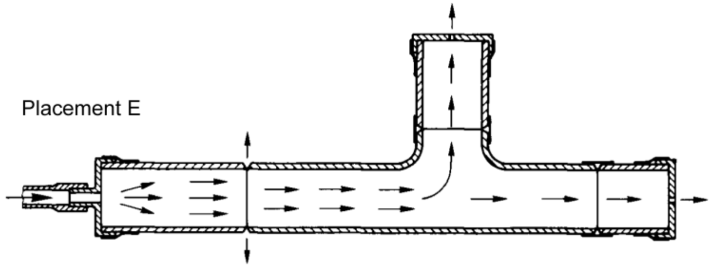
Placement C



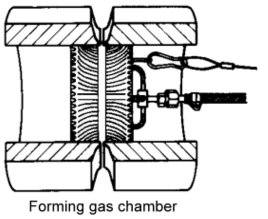
Placement D



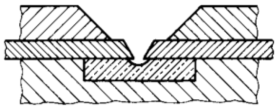
Placement E



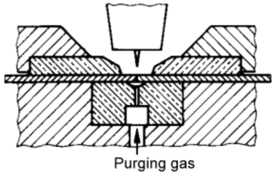
Placement F



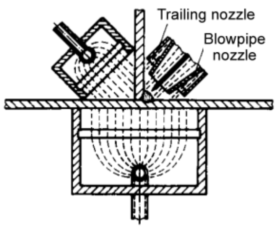
Placement G



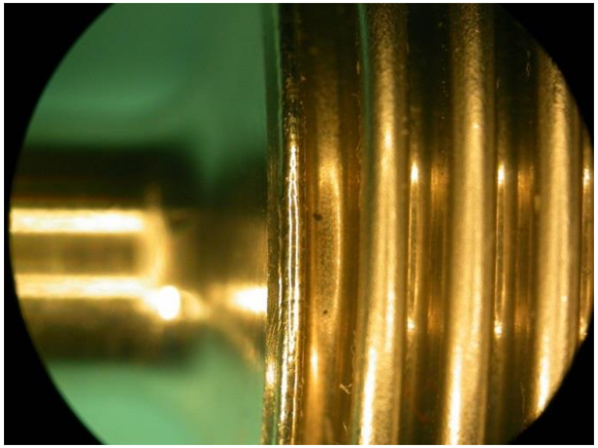
Placement H



Placement I



TIG welding of thin components

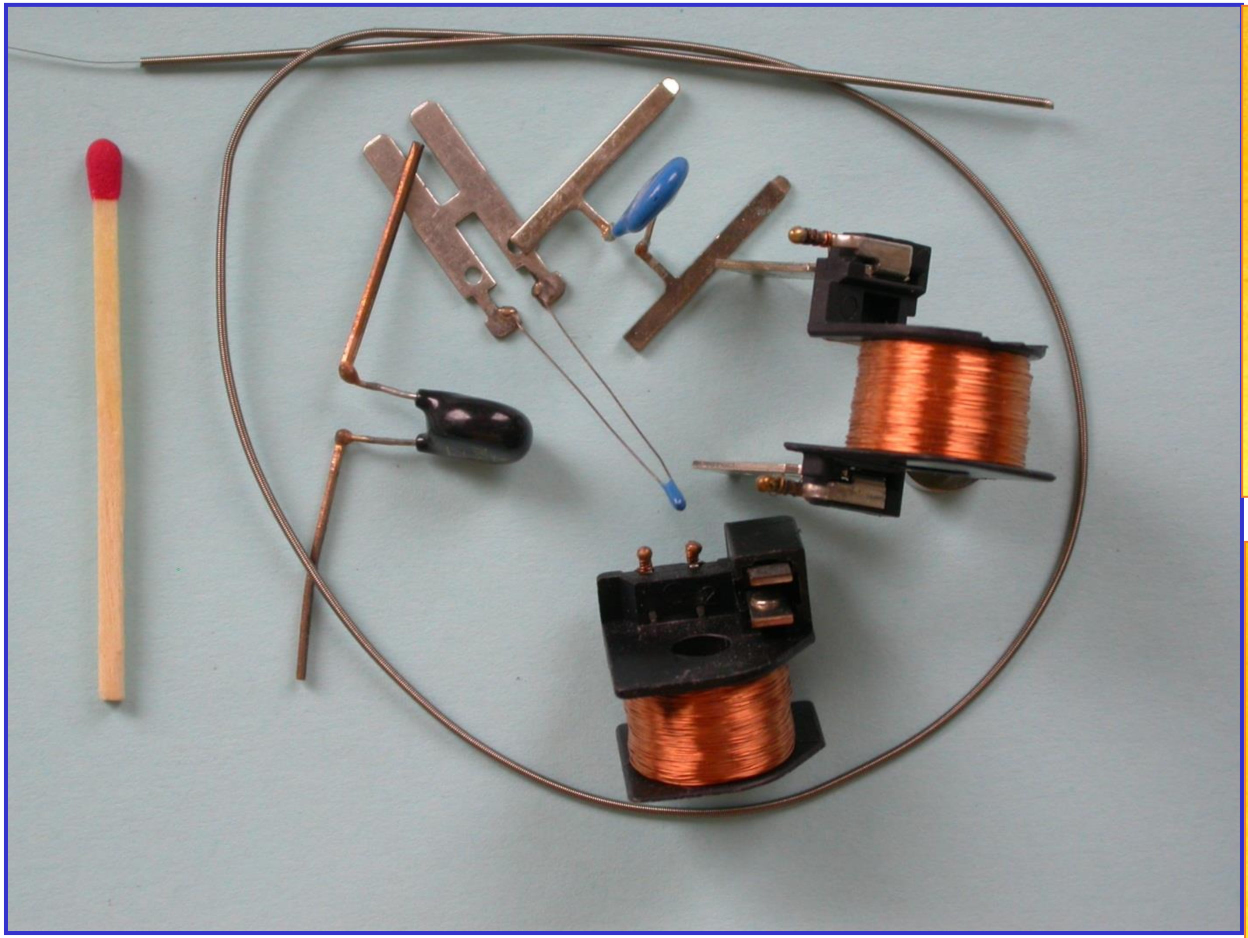


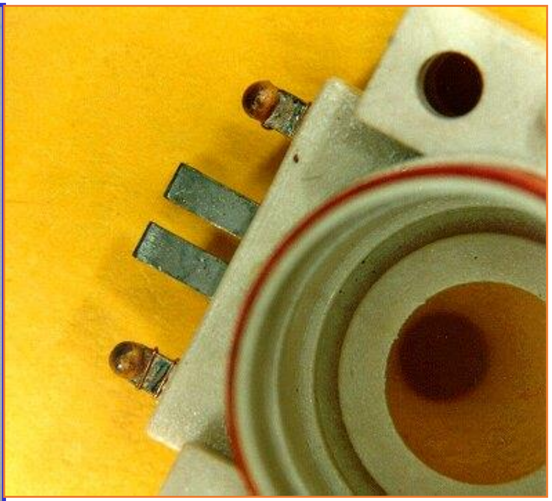
TIG welding of membranes and metal hoses

Materials: - austenitic CrNi steels
- Alloy 600 (Ni-Base-alloy.)
- Duratherm (Co-Base-alloy.)

Material thickness: 50 µm - 200 µm

TIG spot welding



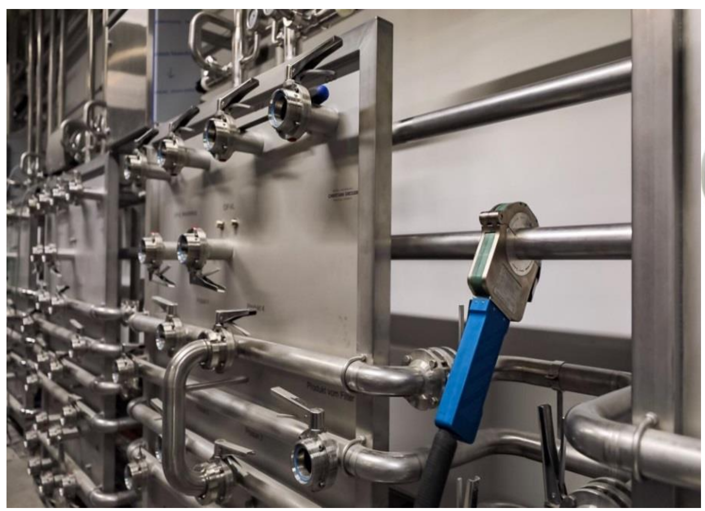


TIG welding of copper wire, capacitors and thermocouples

Orbital pipe joint welding

- Schematic representation of mechanized butt welding of pipes with a pipe welding gun
- Pipe diameter less than 10 to greater than 1000 mm
- Wall thicknesses from tenths of a mm up to 50 mm
- thin-walled pipes and root welds without additives
- all others with cold or hot wire feed
- More complex technology for Al and Cu materials

Pipe wrench with cold wire addition

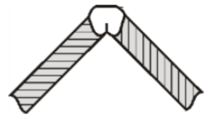
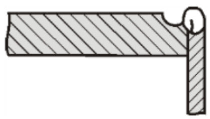


Quelle: Orbitalum

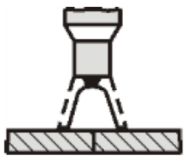
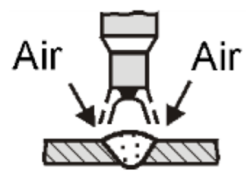
Defects due to mistakes in weld preparation and in gas protection

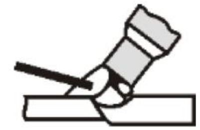
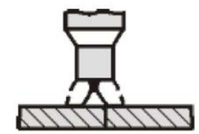
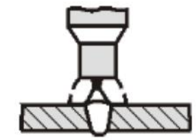
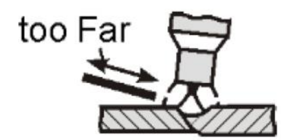
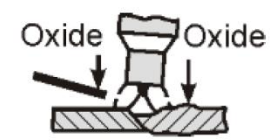
Defects	Reasons	Remedy
Dull surface, weld edges rough, too little flow	Incorrect preparation of the weld area and welding rod (not metallic clean)	Brushing, grinding, pickling, blasting
Pores	Workpiece dirty, oil, grease, paint, moisture	Cleaning, gloves clean?
Surface oxidised, dull, incorrect melting flow	Air in argon, leaking hoses and gas nozzle sucks air in, swirled air, draft, torch distance too large, argon flow too high	Control of argon flow, torch inclination, draft, fan wind, nozzle size, argon l/min
Whitish smoke, electrode tip oxidised	Lack of argon	
Bottom has annealing colours, grey oxidisation, rough, burned surface	Too little back purge	
Dark sediments, pores, unstable arc	Water leaks into torch, condensed water in torch	Control torch, water solenoid valve does not close during welding pauses, prepare electrodes again
Arc flickering, condensate of metallic vapour, lower penetration	Dirty electrode tip	

Typical defects in TIG welding of aluminum materials

Oxide Inclusions	Causes
	Insufficient welding current - excessive gap, lower web edge not broken
	Weld areas not cleaned, hot rod end is taken out of the shielding gas area after dipping and is dipped back into the weld pool after it has reacted with the oxygen in the air
 Without joint preparation or filler metal	Cleaning effect of the arc does not penetrate significantly below the pool
 Welded on both sides in succession	I-shaped weld on excessively thick workpieces
	Workpiece distortion
 Welded on both sides simultaneously	I-shaped weld on excessively thick plates
Pores 	Hydrogen input, humidity in oxide layers, grease and paint residuals in the welding zone, on the rod-surface, leaking water cooling, condensed water in torch head (if cooling water circulation is not interrupted during pauses) Arc instability during welding, especially at the start of welding and the welding over tack-welds Cooling rate is too high: pores in the weld interface between the weld and the base material are caused by the insufficient degassing of the base material.

General errors due to wrong torch and rod guide

Fault	**Possible effects**
 Arc is too long	 Notch  Oxide pores  Low penetration

 Torch angle too big	 Gas absorption
 Torch tilted	 Bead, single-sided notches
 Torch offset	 Single-sided root fusion defect
 Wire end moves out of shielded zone after welding	

Thank you for listening!

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