

# Welding Terminology

## TIG – MIG/MAG

BIL

2022

# Program

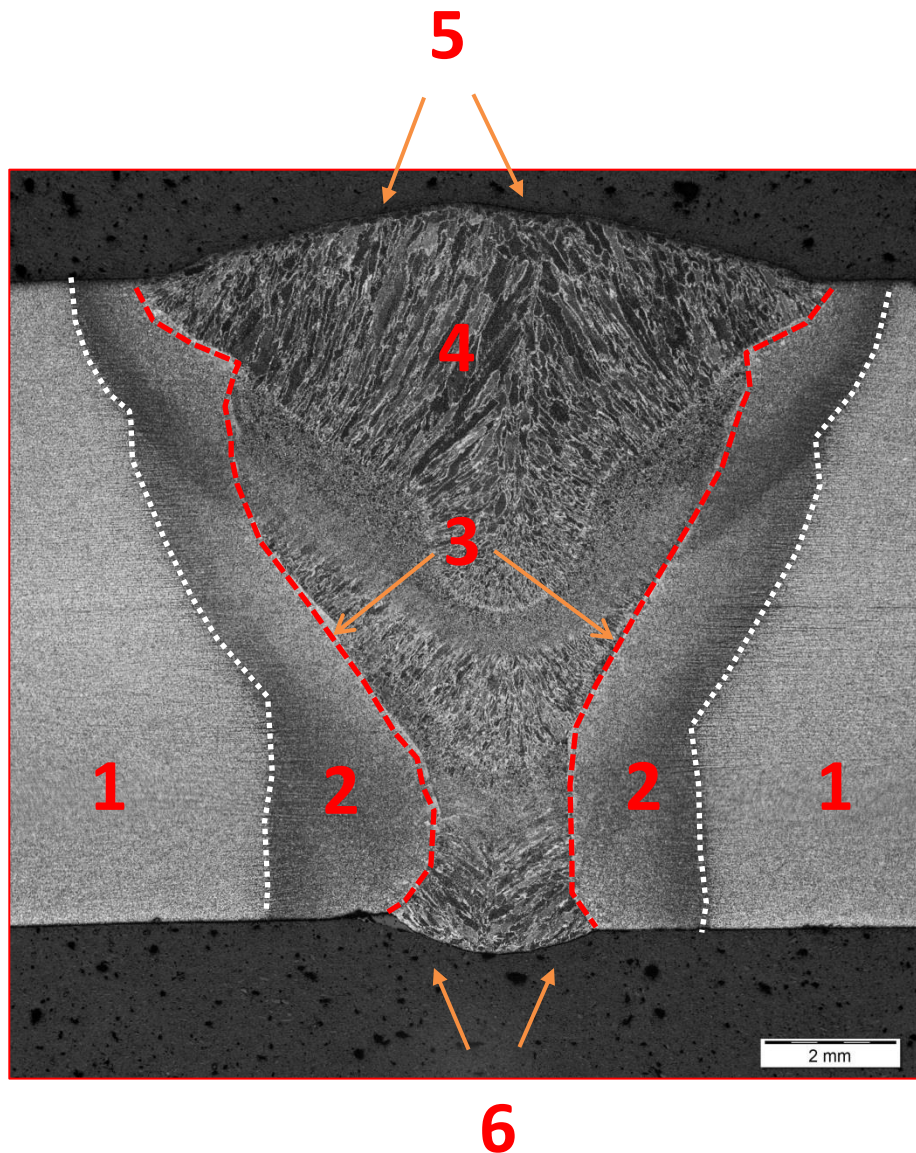
Timing	Program
13h00 - 15h00	Welding terminology TIG welding MIG-MAG welding
15h00 - 15h10	Break
15h10 - 17h00	Destructive testing

# 1 Welding Terminology

## 2 TIG welding

## 3 MIG/MAG welding

# Welding Terminology



- 1 Base material (BM)
- 2 Heat affected zone(HAZ)
- 3 Fusion line
- 4 Weld metal (WM)
- 5 Cap of the weld
- 6 Root of the weld

# Welding Terminology: type of welds

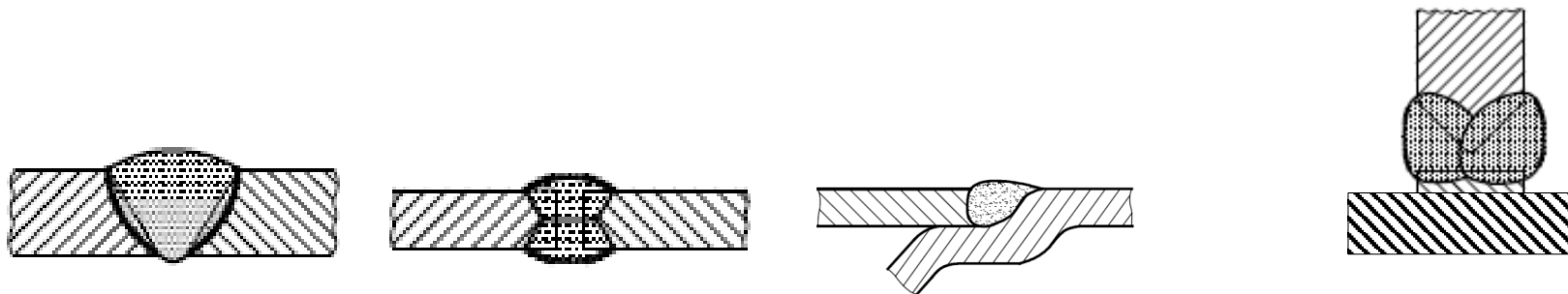
- ▶ **FW** = **Fillet Weld**

Triangular weld in a square preparation for making a T-joint, corner joint or lap joint



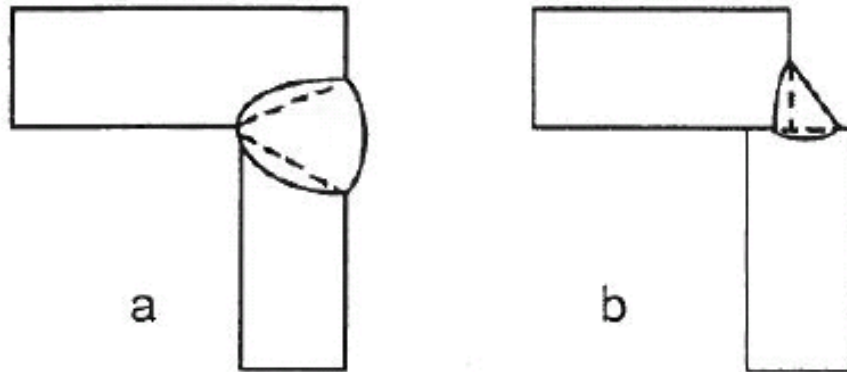
- ▶ **BW** = **Butt Weld**

Weld other than a fillet weld, made in a groove or in a square preparation



# Welding Terminology: type of joints

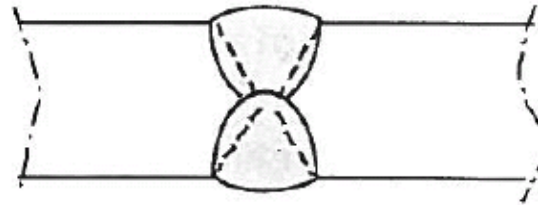
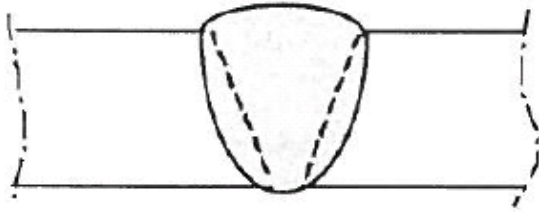
- ▶ **Joint**: junction of workpieces or the edges of workpieces that are to be joined
- ▶ **Corner joint**
  - ▶ Parts  $\pm$  perpendicular
  - ▶ Weld on both plate edges
  - ▶ Single sided or double sided
  - ▶ With or without full penetration



# Welding Terminology: type of joints

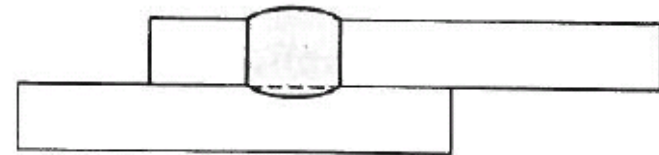
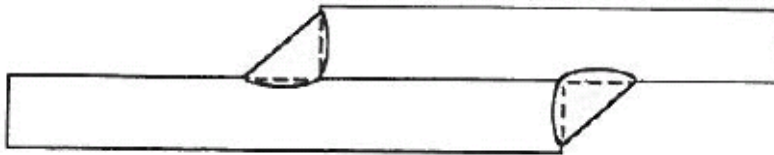
## ► Butt joint

- Plates / tubes  $\pm$  in the same plane



## ► Overlap joint

- Advantage : no preparation
- Disadvantage: additional moment in the connection

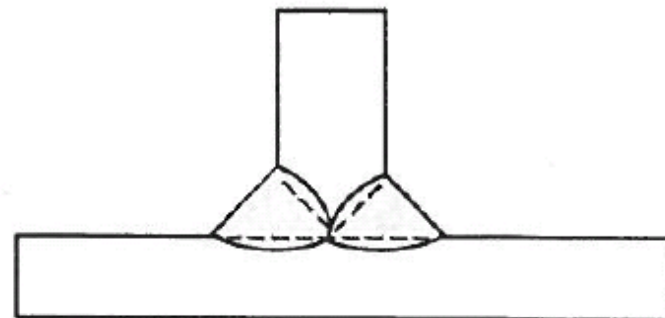
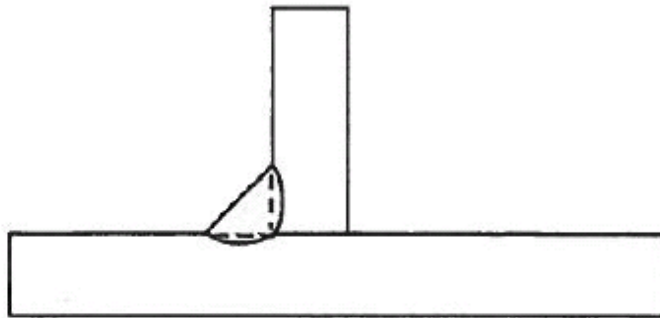


Plug welds

# Welding Terminology: type of joints

## ► T-joint

- Parts  $\pm$  perpendicular in T-shape
- Without weld preparation  $\rightarrow$  fillet weld
- With weld preparation  $\rightarrow$  combination BW+FW

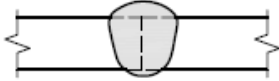



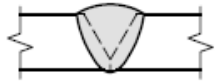

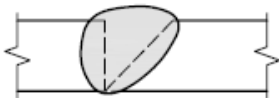

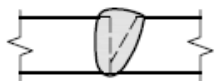


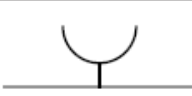


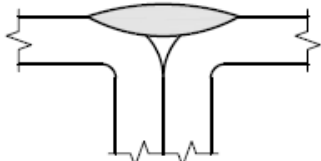
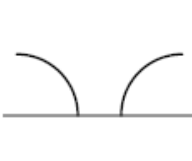
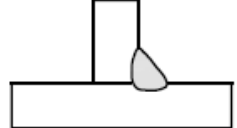
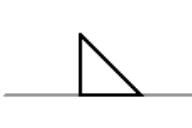




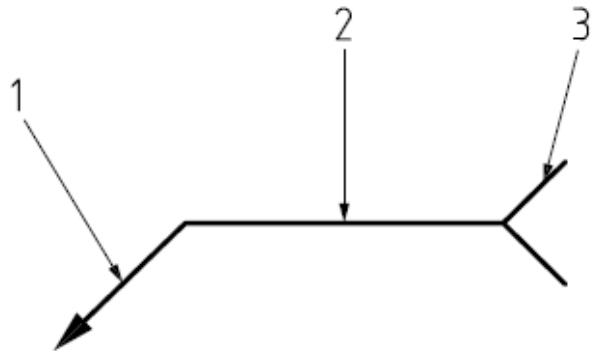
# Elementary welding symbols ISO 2553

The symbol used to indicate a weld represents more or less the shape of the weld preparation.

This symbol says nothing about the welding process to be used!

No.	Designation	Illustration (dashed lines show joint preparation prior to welding)	Symbol <sup>a</sup>
1	Square butt <sup>b</sup>		
2	Single-V butt <sup>b</sup>		
3	Single-V butt with broad root face <sup>b</sup>		
4	Single-bevel butt <sup>b</sup>		
5	Single-bevel butt with broad root face <sup>b</sup>		
6	Single-U butt <sup>b</sup>		
7	Single-J butt <sup>b</sup>		
8	Flare V		
10	Fillet		

# Welding Terminology: basic welding symbol ISO 2553



**Basic welding symbol:**  
**Used to indicate the location  
of a weld**

## **1) Arrow line:**

- Shall point to and shall be in contact with a solid line of the joint on the drawing
- Shall be drawn at an angle and joined to a reference line and completed with a closed filled arrowhead

## **2) Reference line:**

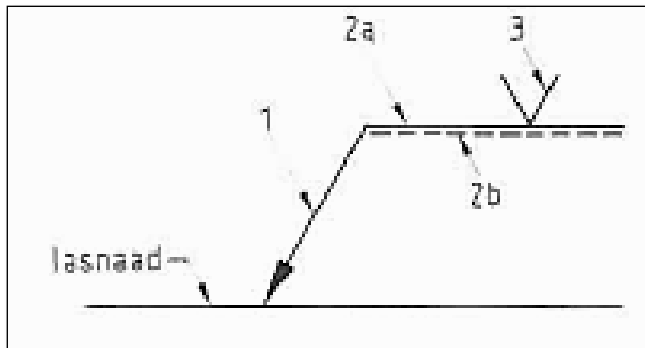
- parallel to the bottom edge
- Location for elementary symbol

## **3) Tail:**

- Optional, only if there is extra information

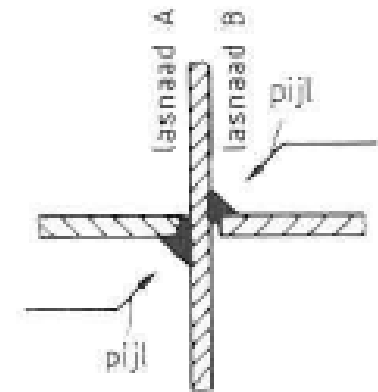
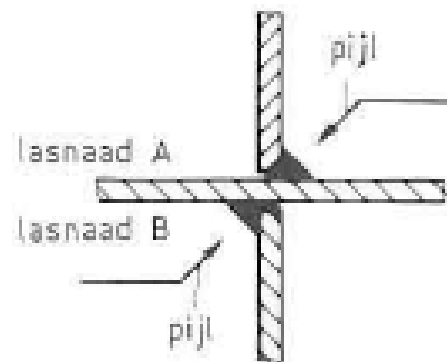
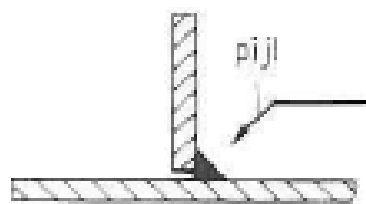
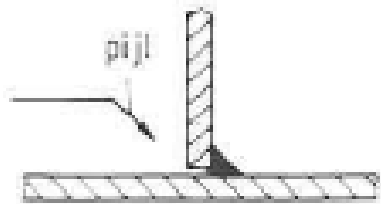
# Welding Terminology: basic welding symbol ISO 2553

## ► Arrow and Reference line system A:



### > Elementary symbol:

- on continuous line = weld arrow side
- on dashed line = weld on the other side of the arrow

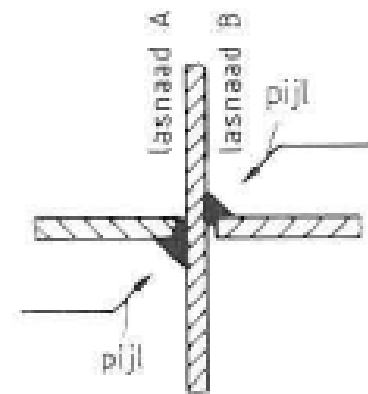
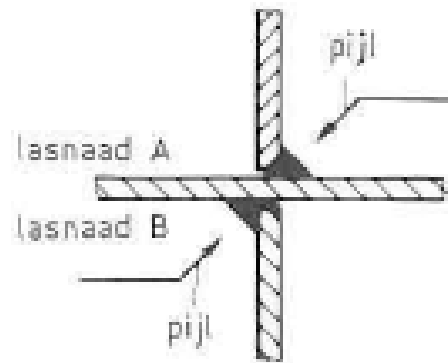
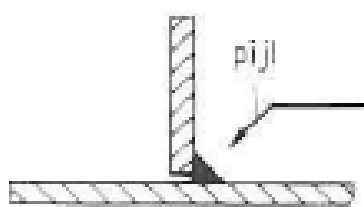
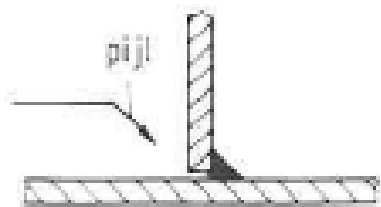
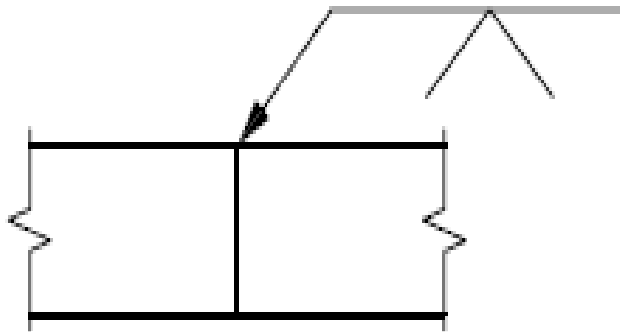


# Welding Terminology: basic welding symbol ISO 2553

## ► Arrow and Reference line system B:

### > Elementary symbol:

- above reference line = weld on the other side of the arrow
- below reference line = weld arrow side

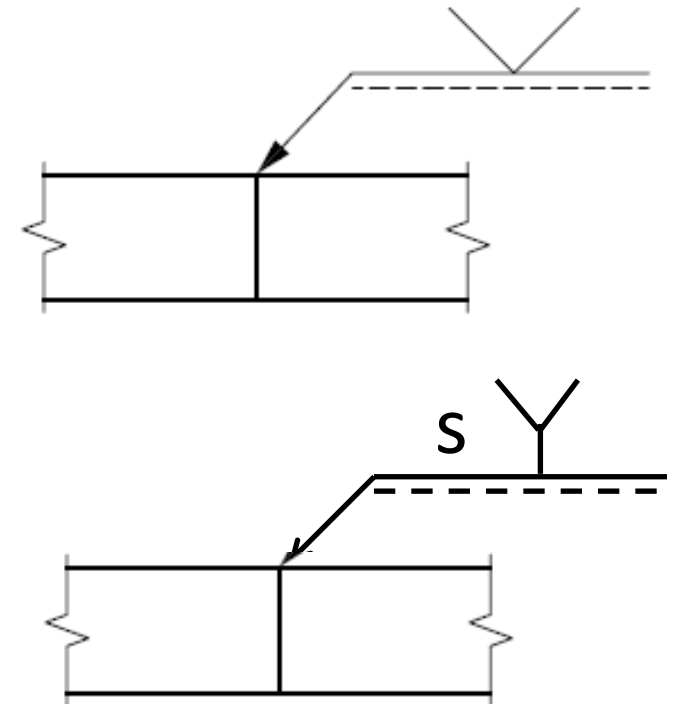
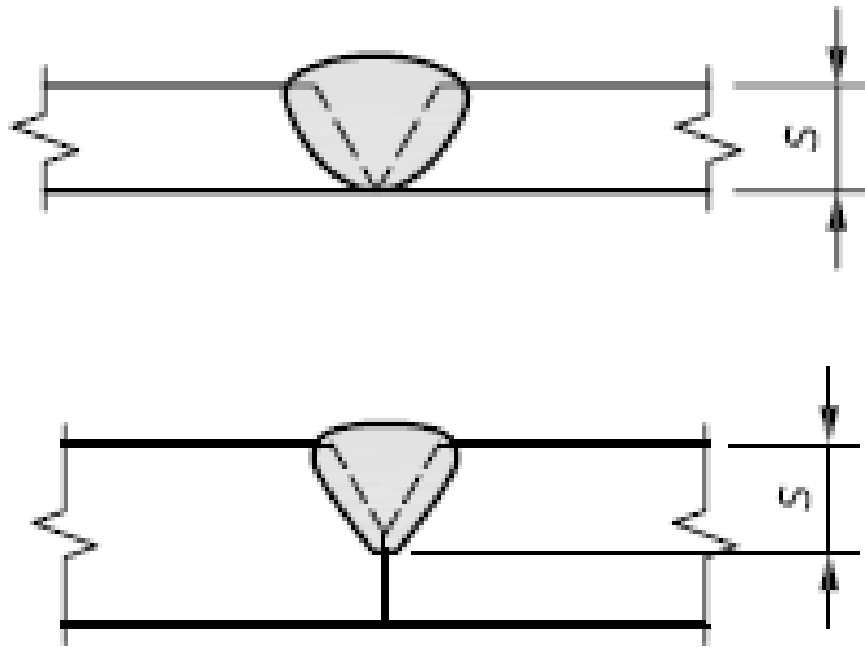


# Welding Terminology: dimension of welds ISO 2553

## ► Butt weld:

- penetration depth « s »: thickness of the weld metal excluding any reinforcement

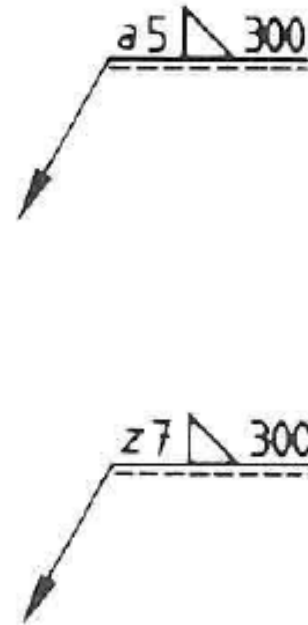
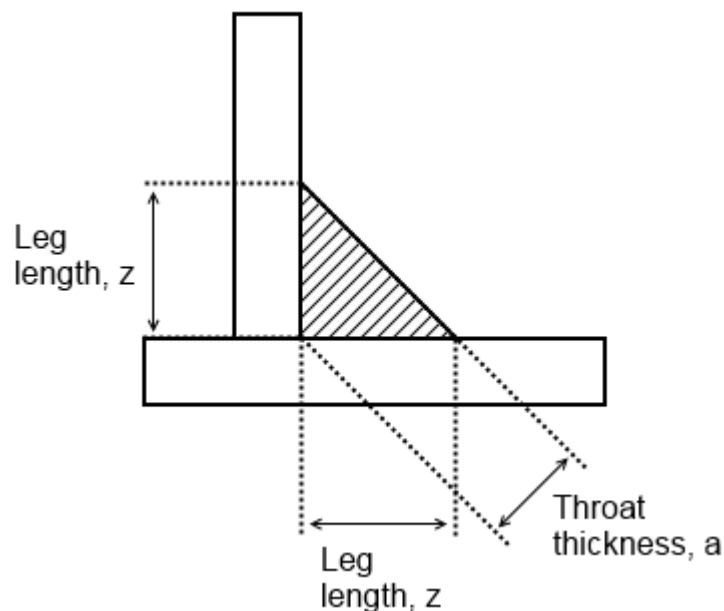
No cross-sectional dimension > full penetration!



# Welding Terminology: dimension of welds ISO 2553

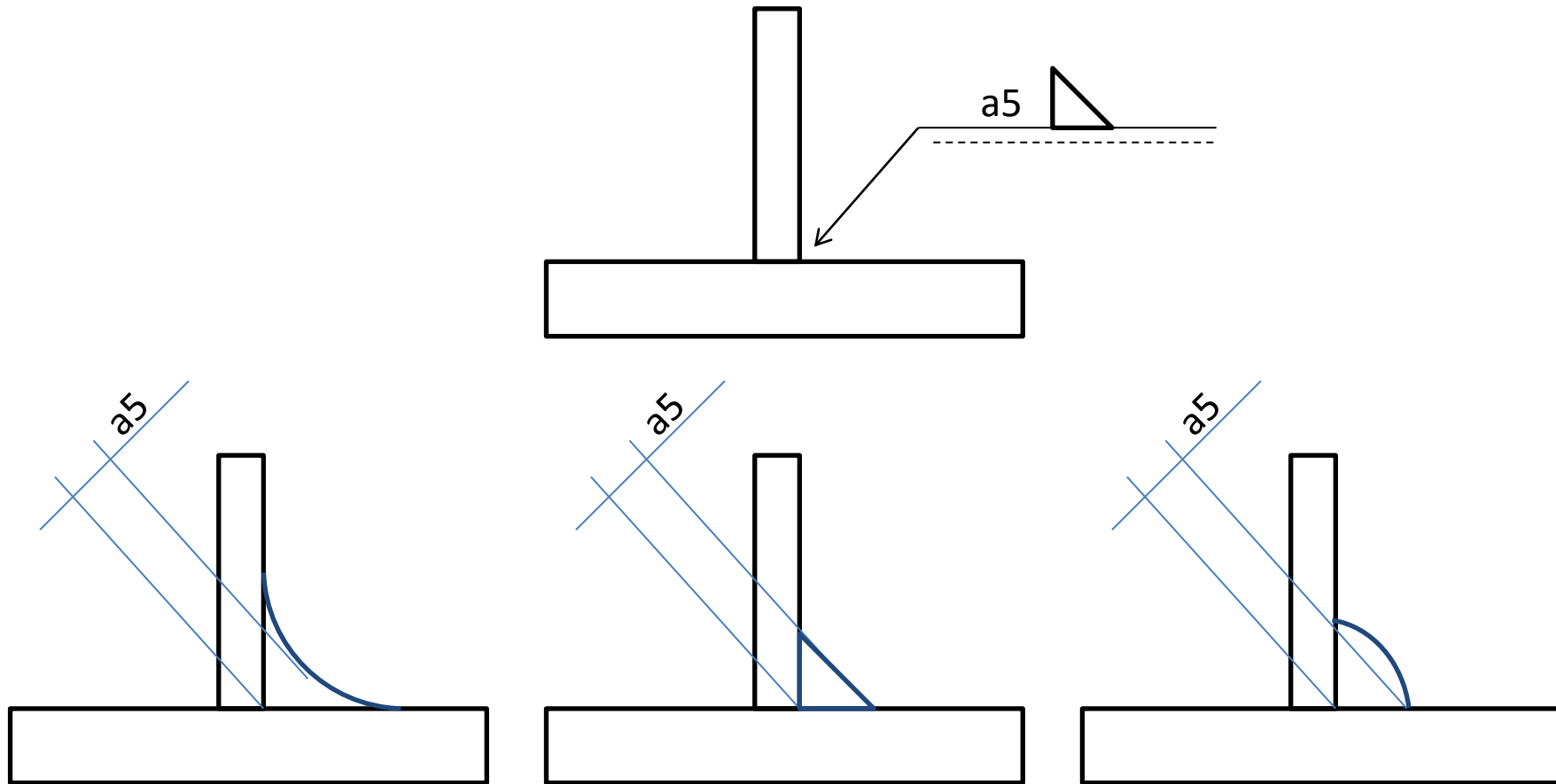
## ► Fillet weld:

- throat thickness « a »: height of the largest isosceles triangle that can be inscribed in the section of a fillet weld
- leg length « Z »: distance of the intersection of the fusion faces and the toe of a fillet weld



# Welding Terminology: dimension of welds ISO 2553

- **Cross-sectional dimensions:**
  - **Fillet weld:**




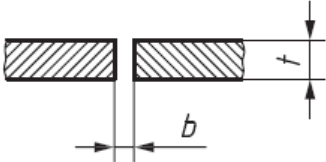


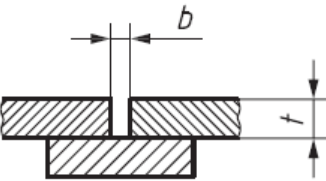

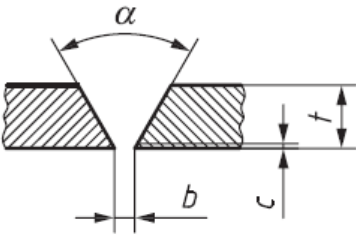


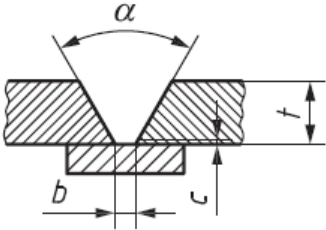
# Welding Terminology: Weld preparation

- Which weld preparation to choose?
- ISO 9692-series gives recommendations:
  - Part 1: Electrode, MAG, TIG, autogenous welding of steel
  - Part 2: Submerged arc welding of steel
  - Part 3: MIG en TIG welding of Alu
  - Part 4: Clad steels



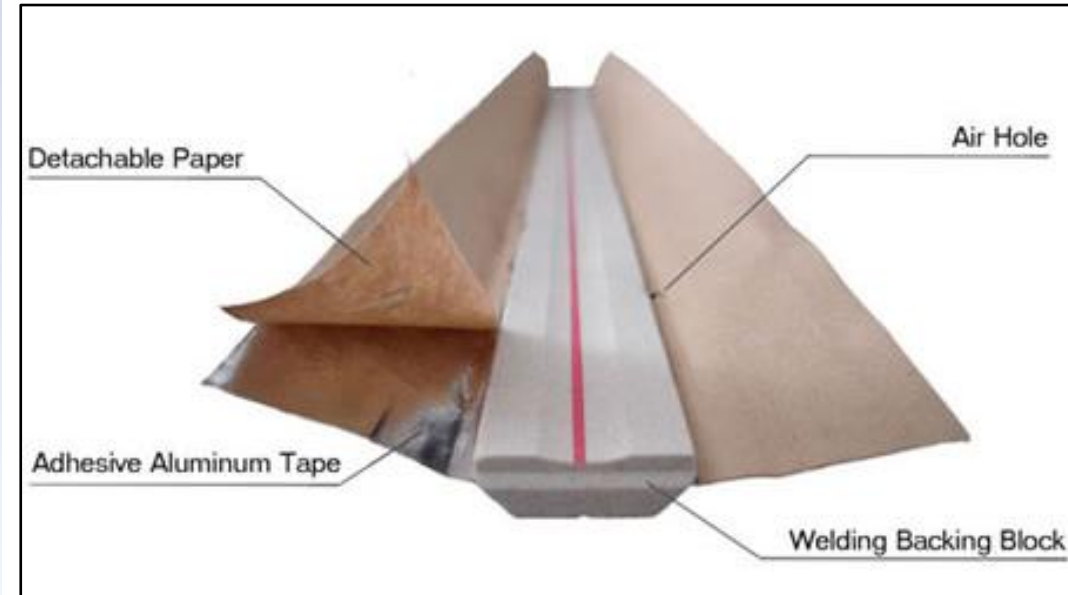
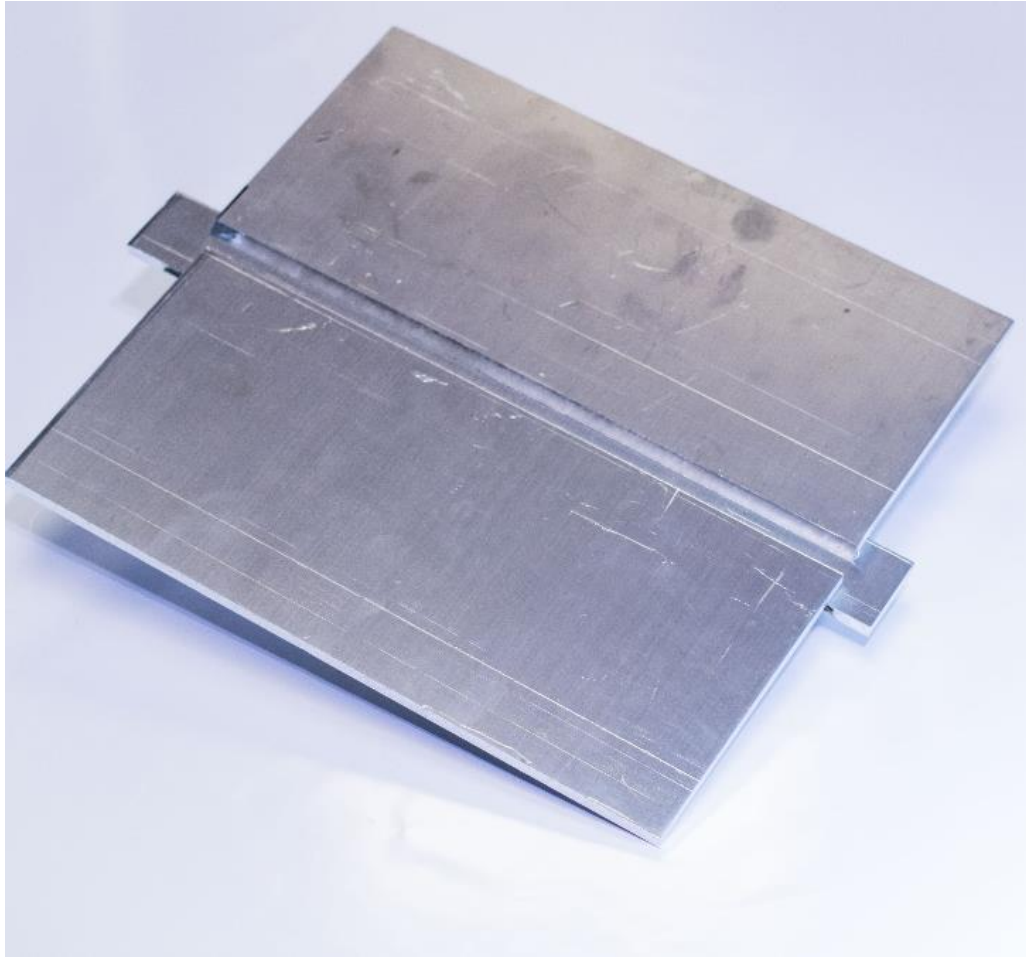
# Welding Terminology: Weld preparation

ISO 9692-3: MIG en TIG welding of Alu

Weld				Joint preparation					
Workpiece thickness $t$	Designation	Symbol <sup>b</sup>	Illustration	Cross-section	Angle $\alpha, \beta$	Gap $b$	Thick- ness of root face $c$	Other dimensions	Recommend- ed welding process <sup>c</sup>
$t \leq 4$	Square butt weld				—	$b \leq 1$	—	—	141
$2 \leq t \leq 4$	Square butt weld with temporary (MR) or permanent (M) backing				—	$b \leq 1,5$	—	—	131
$3 \leq t \leq 5$	Single-V butt weld	V			$60^\circ \leq \alpha \leq 90^\circ$	$b \leq 2$	$c \leq 2$	—	131
	Single-V butt weld with removable/ temporary (MR) or permanent (M) backing				$60^\circ \leq \alpha \leq 90^\circ$	$b \leq 4$	$c \leq 2$	—	131

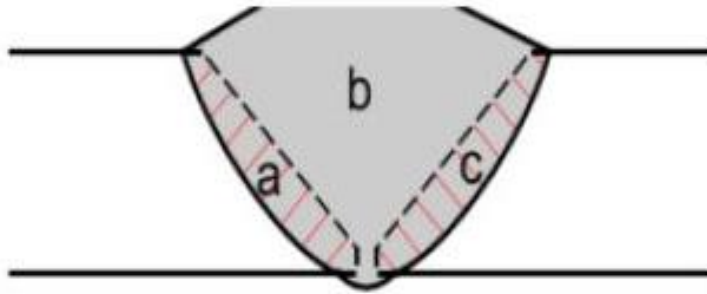
# Welding Terminology: Weld preparation

## Backing:



# Welding Terminology: Dilution

- Dilution: used to evaluate the chemical composition of the weld metal

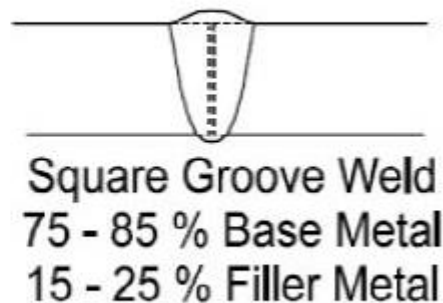
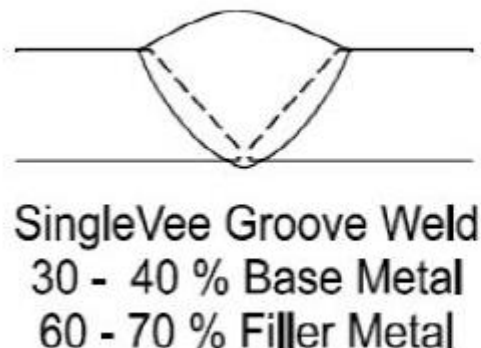
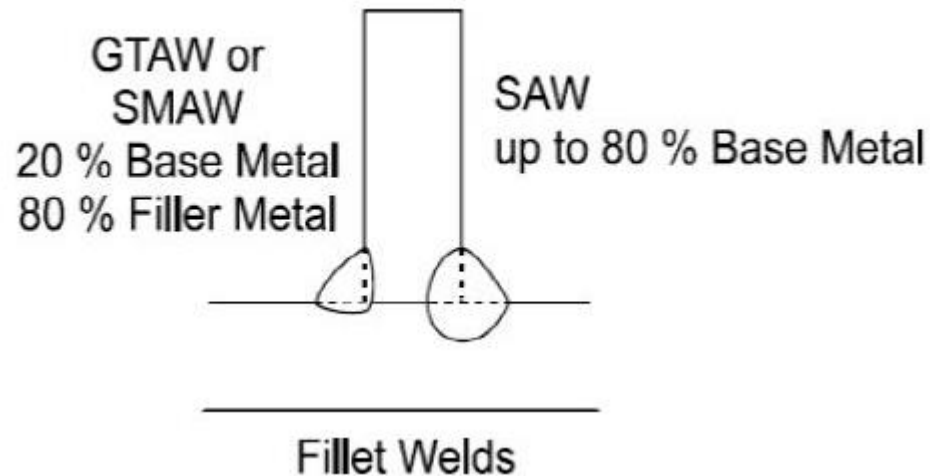


% Base Metal Dilution =

$$\frac{a + c}{a + b + c} \times 100\%$$

# Welding Terminology: Dilution

- Influencing factors: joint type, welding process, location



- MIG/MAG: root 10-40%; filler 5-20%

# 1 Welding Terminology

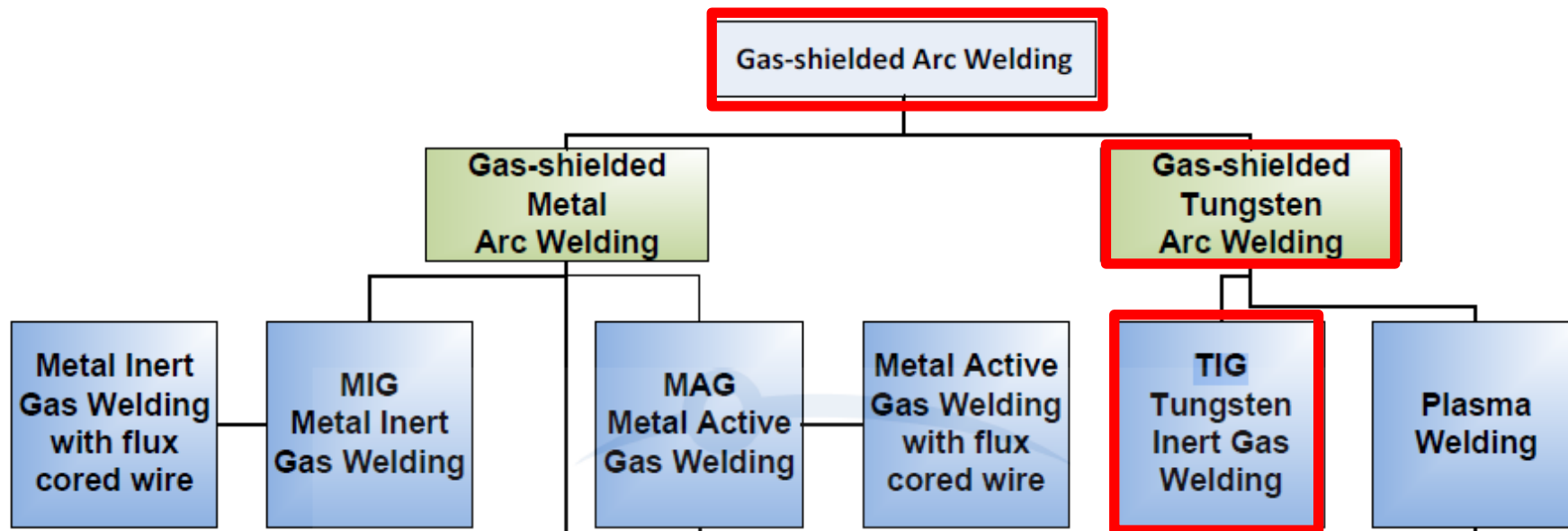
## 2 TIG welding

## 3 MIG/MAG welding

# Arc Welding with gas

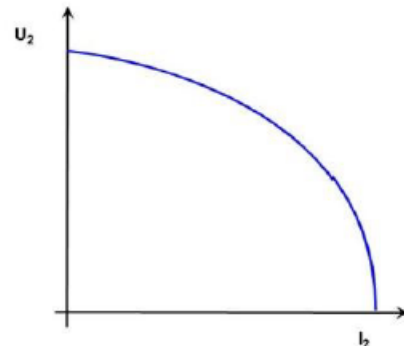
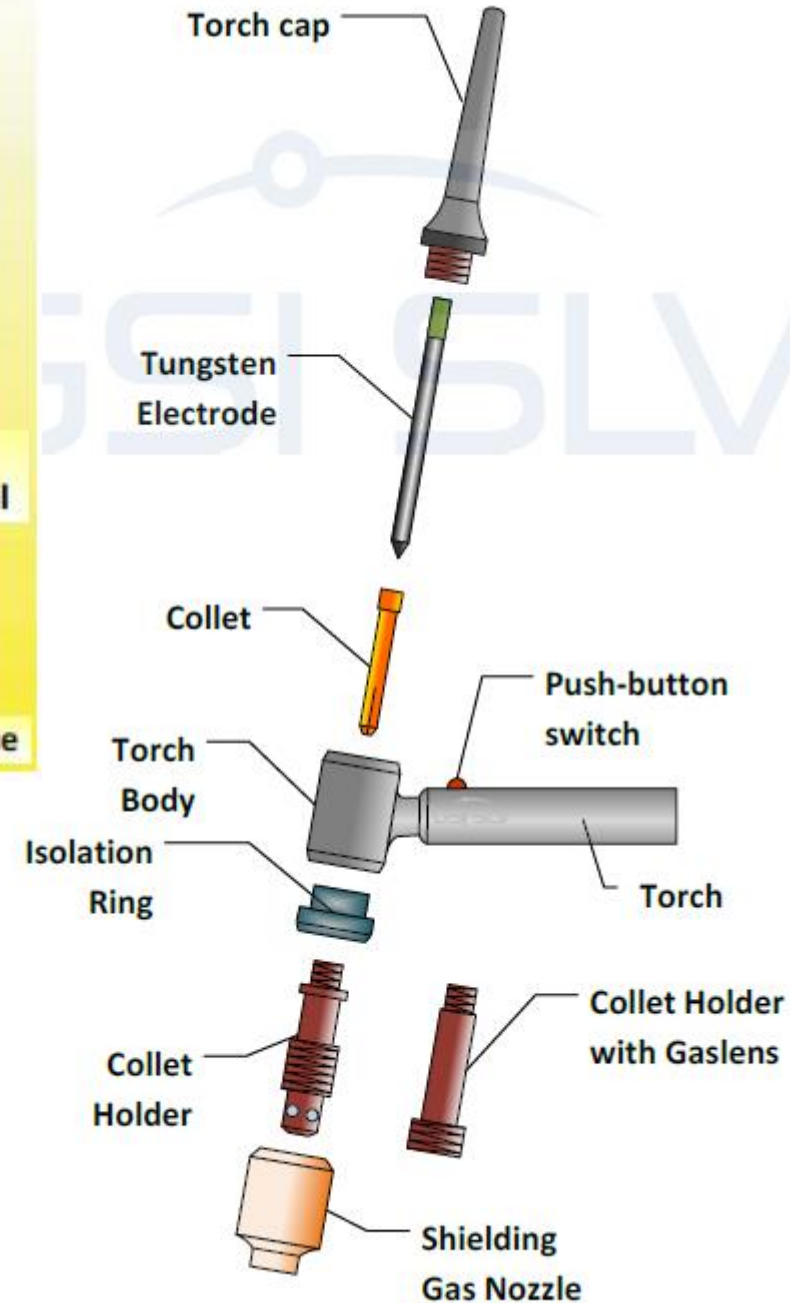
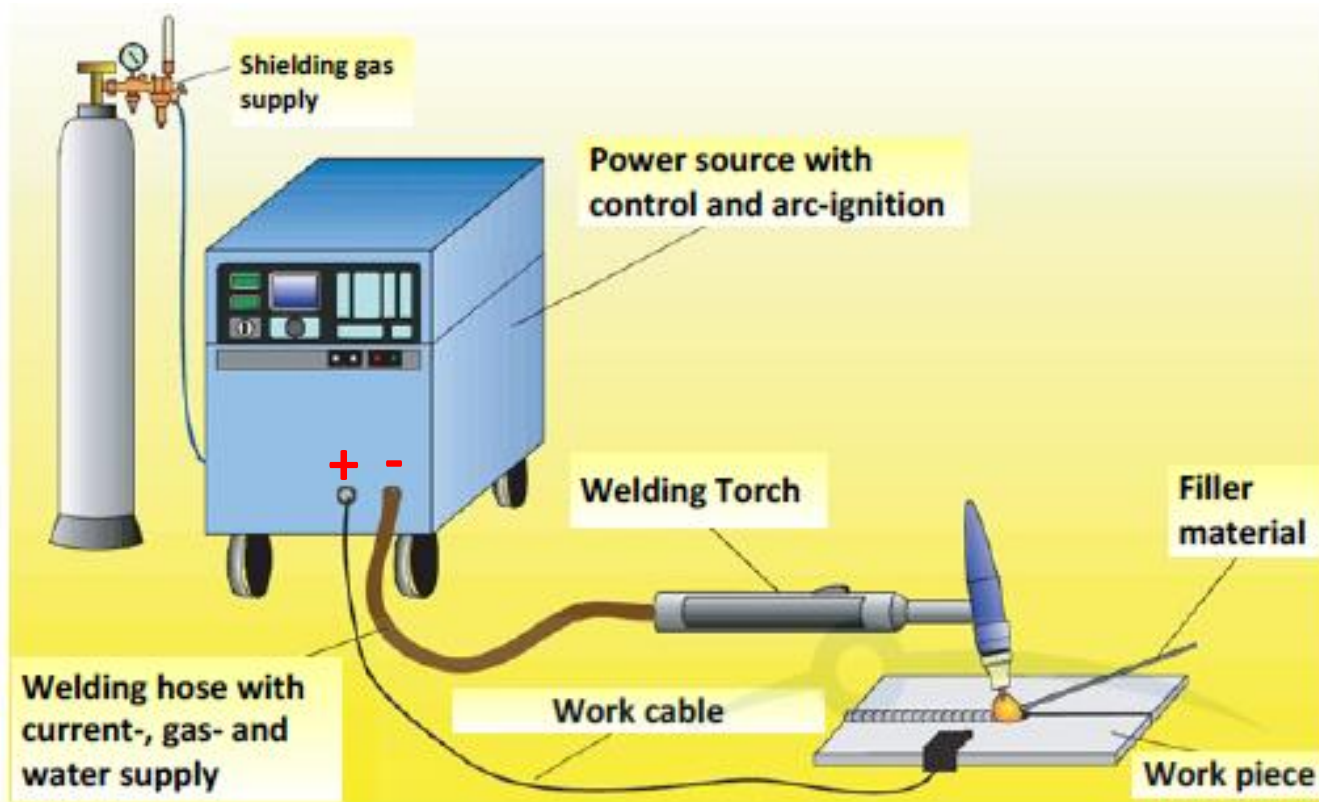
- ▶ Why do we need gas?
  - ▶ Protection of weld pool against environmental influences (shielding gas)
    - ▶ Air composition: 78% N<sub>2</sub> + 21% O<sub>2</sub> + 1% remaining gas
  - ▶ Protection electrode (TIG)
  - ▶ Melt pool reactions (MAG)
    - ▶ Adding active components: oxidizing or reducing
  - ▶ Ionization of the arc (arc energy)
    - ▶ Welding arc = electrically conductive gas column
  - ▶ Weld seam formation
    - ▶ Influence of the surface tension
    - ▶ Influencing the weld pool shape

# TIG welding





# TIG welding: overview equipment

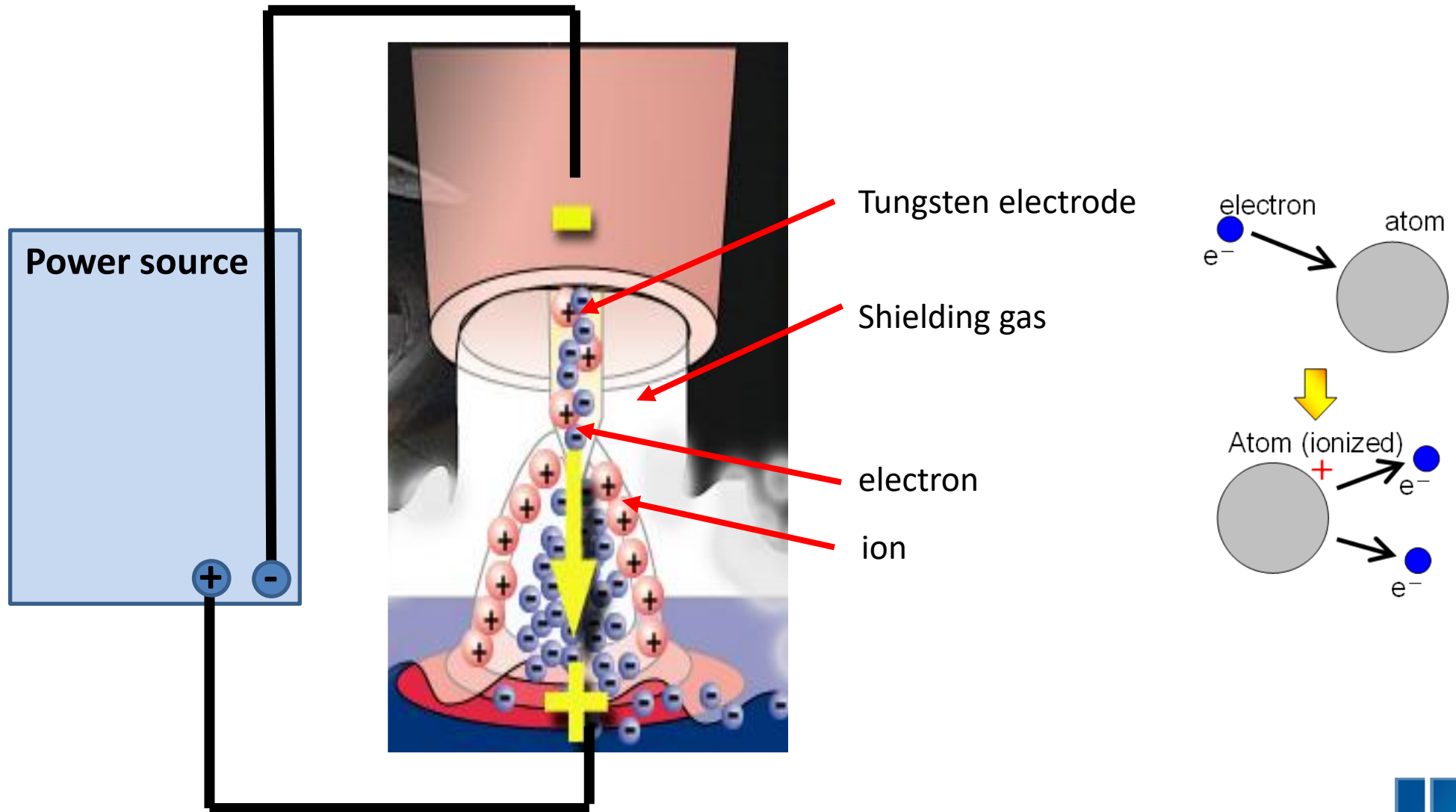




# TIG welding:

- ▶ Application:
  - ▶ Welding of
    - ▶ C-steel
    - ▶ Stainless steel
    - ▶ Aluminium
    - ▶ Thickness 0,5mm up to 5mm
    - ▶ The root in higher thicknesses
  
- ▶ + :
  - ▶ High quality
  - ▶ Fewer welding defects
  
- ▶ - :
  - ▶ Slow
  - ▶ Low deposition rate

# TIG welding: The arc



# TIG welding: The arc

- ▶ **Ignition**

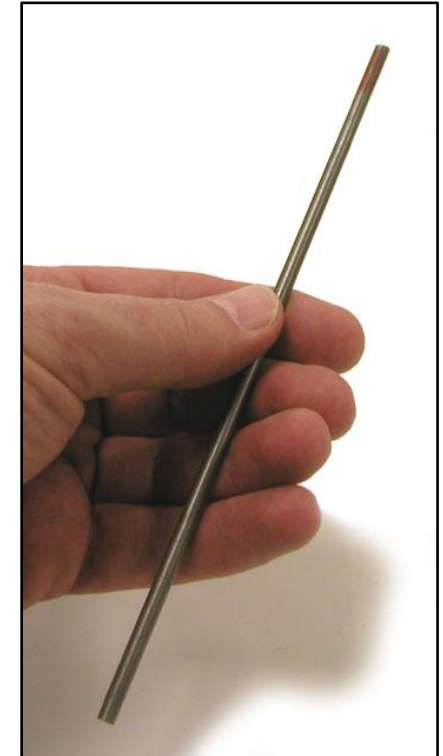
- ▶ Lift-arc, scratch arc
- ▶ High frequency (Mhz) and high voltage (kV)



# TIG welding: The electrode

## ► Requirements

- ▶ High melting temperature
- ▶ Emission of electrons should be easy
- ▶ Ignition of arc should be easy
  
- ▶ Tungsten: melting point: 3422 °C (3695K)
- ▶ Addition of oxides to improve electron emission and ignition
  - (Thorium Th) radioactive, so limited use
  - Zirconium Zr
  - Lanthanum La
  - Cerium Ce



# TIG welding: The electrode

## ► Types

### Tungsten Electrode Types

#### (Green)

Unalloyed, pure tungsten. Good arc stability with AC with either balanced wave or continuous high-frequency stabilization. Preferred for AC welding of aluminum and magnesium. When heated, the pure tungsten electrode forms a balled end.

#### EWTh-1 (Yellow),

#### EWTh-2 (Red)

Designed for DC applications. Thoria content is dispersed evenly throughout entire length. Maintains a sharpened point well, which is desirable for welding steels. Good arc

#### EWCe-2 (Orange)

Alloyed with about 2 percent ceria, the most abundant of the rare elements. These are all-purpose electrodes that operate with AC or DC of either polarity. Provide long life and high current-carrying capacity. Unlike thoria, ceria is not a radioactive material.

#### EWLa-1 (Black)

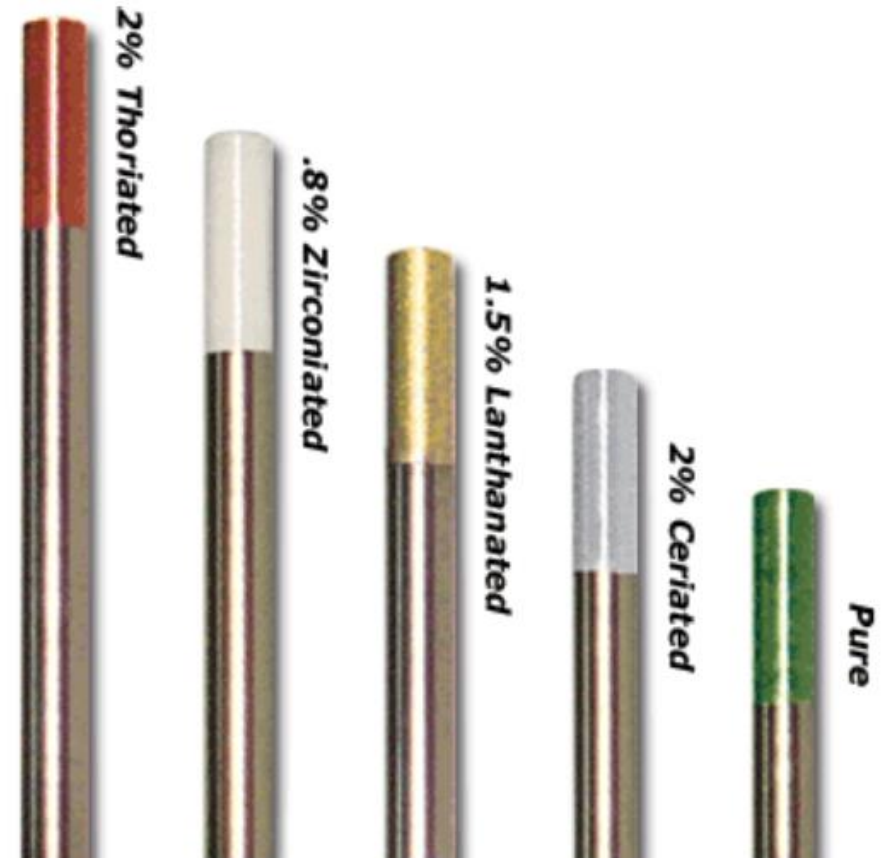
Has 1 percent lanthanum oxide, often referred to as lanthana, another of the rare-earth elements. The operating characteristics and advantages are similar to the EWCe-2 electrode.

#### EWZr-1 (Brown)

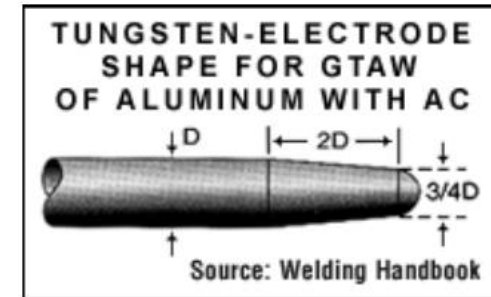
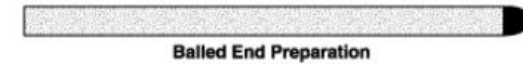
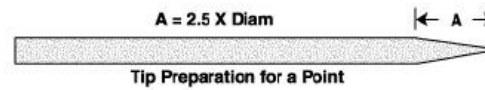
Designed for AC welding when the highest-quality work is necessary. Contains less than 1 percent zirconium oxide, which produces a stable arc. Current-carrying capacity equal to or greater than equal-sized thorium electrode. Not recommended for DC welding.

#### EWG (Gray)

Contains unspecified additions of rare-earth oxides or combinations of oxides, which must be identified by the manufacturer. Electrode capabilities also should be identified by the manufacturer.

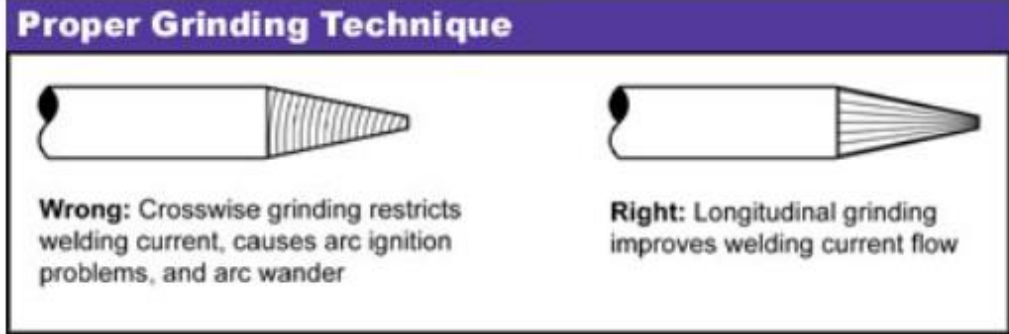


# TIG welding: The electrode



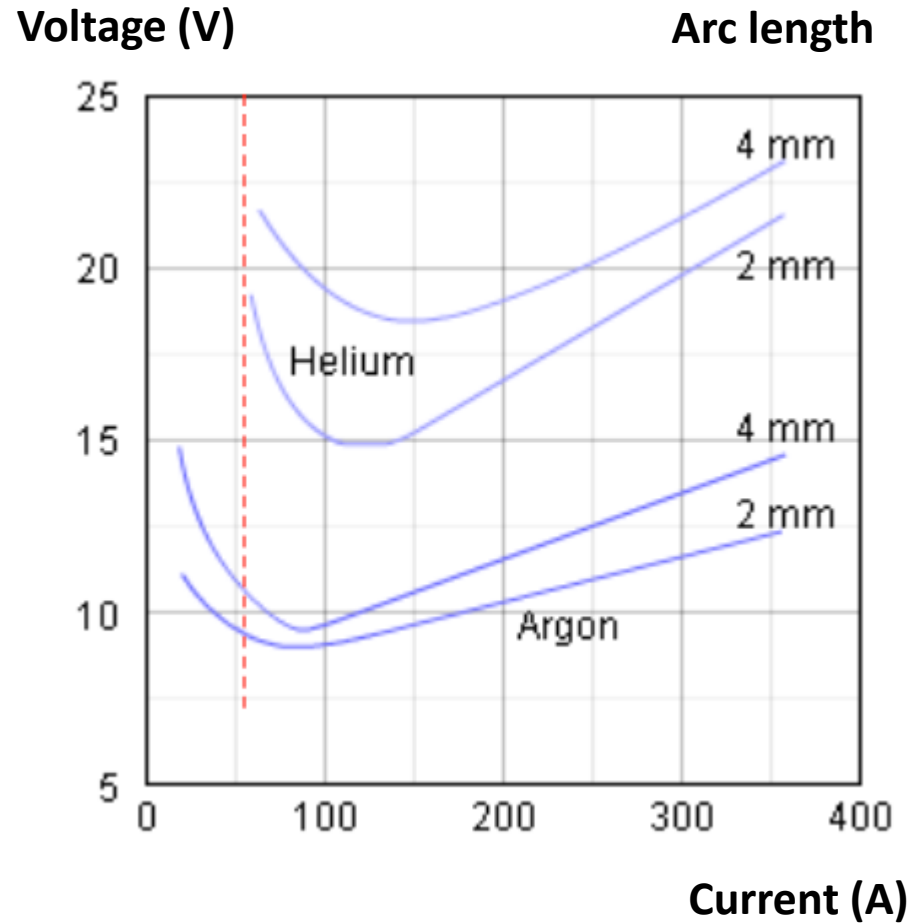


# TIG welding: The electrode



# TIG welding: The gas

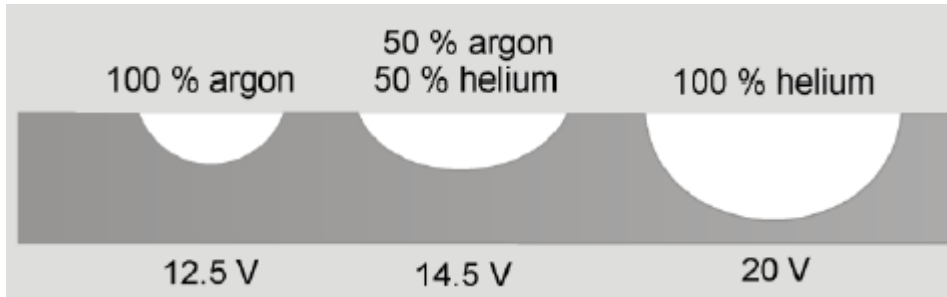
## ► Ar or He



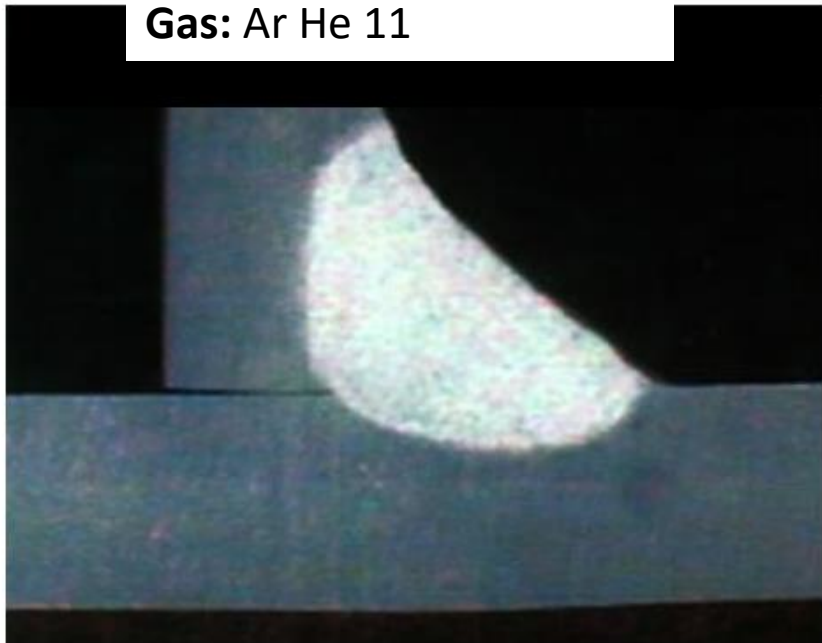


# TIG welding: The gas

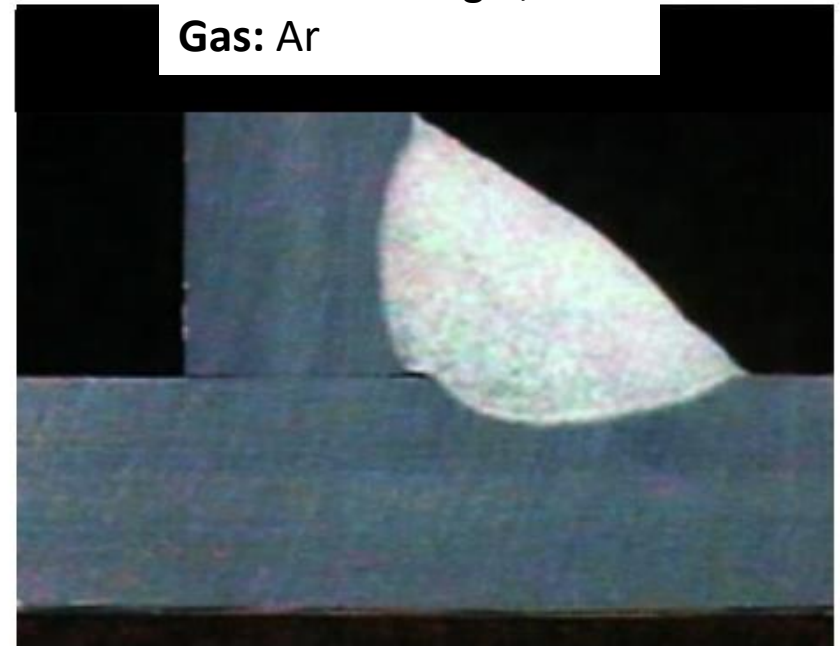
## ► Penetration



**Material:** Al Mg 4,5 Mn  
**Gas:** Ar He 11



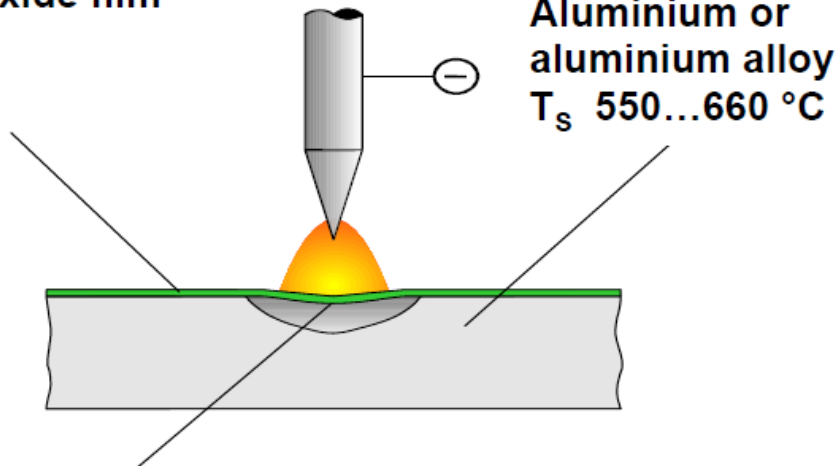
**Material:** Al Mg 4,5 Mn  
**Gas:** Ar



# TIG welding: Welding alu

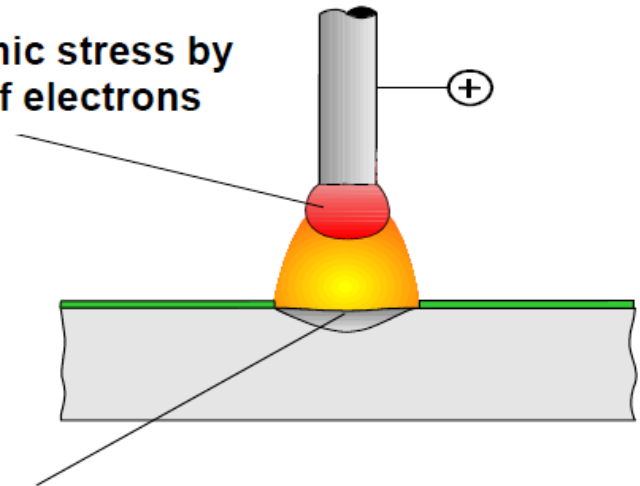
## ► Problem of welding Aluminium

Aluminium oxide film  
 $\text{Al}_2\text{O}_3$   
 $T_s = 2050^\circ\text{C}$



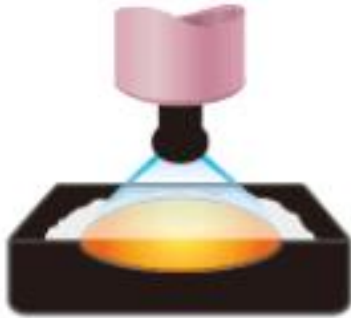
No or insufficient destruction  
of the oxide film at simultaneous  
melting of aluminium

High thermic stress by  
collision of electrons

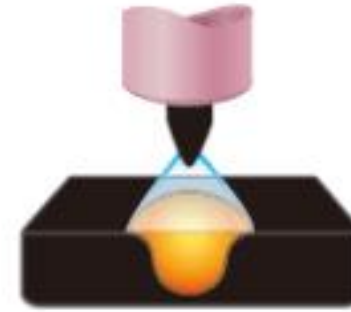


Destruction of the oxide film  
by collision of ions

# TIG welding: Welding alu



Wider bead, good penetration ideal for buildup work



Narrower bead, good penetration ideal for buildup work



Wider bead and cleaning action



Narrower bead, with no visible cleaning

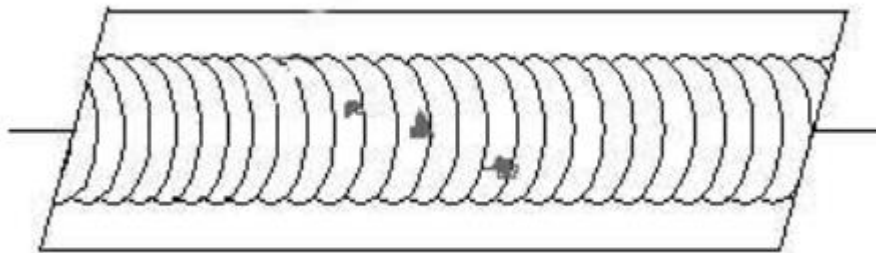
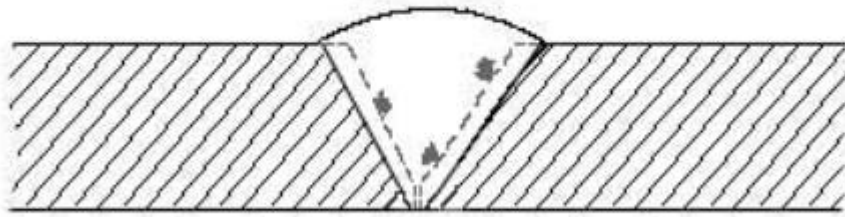


# TIG welding: Welding alu

Workpiece thickness mm	Shape of groove weld	Tungsten electrode diameter mm	Welding current *) A	Filler rod diameter mm	Argon consumption L/min.	Amount of Layers
1	II	1.6	50 ... 60	2	4 ... 5	1
2	II	2.4	60 ... 90	2	5 ... 6	1
3	II	2.4	90 ... 150	3	5 ... 6	1
4	II	3.2	150 ... 180	3	6 ... 8	1
6	V	3.2	180 ... 240	4	8 ... 10	2
8	V	4.0	200 ... 280	4	8 ... 10	2
10	V	4.8	260 ... 350	5	10 ... 12	2 ... 3
12	V	6.4	320 ... 400	5	12 ... 14	3
*) Values for butt welds; in the case of fillet welds these should be increased by 10 to 20%.						

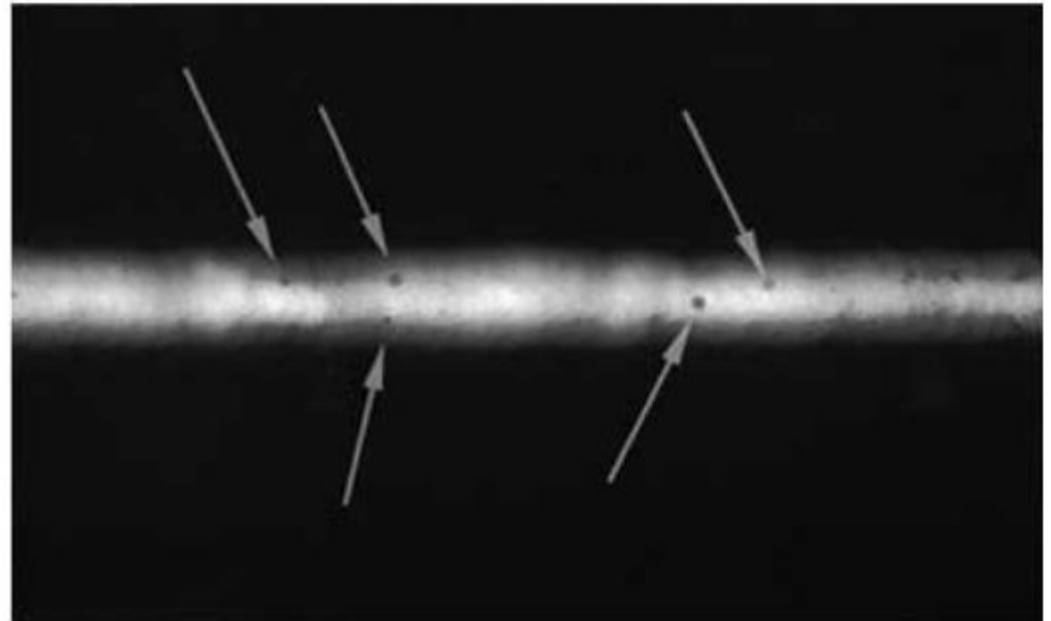
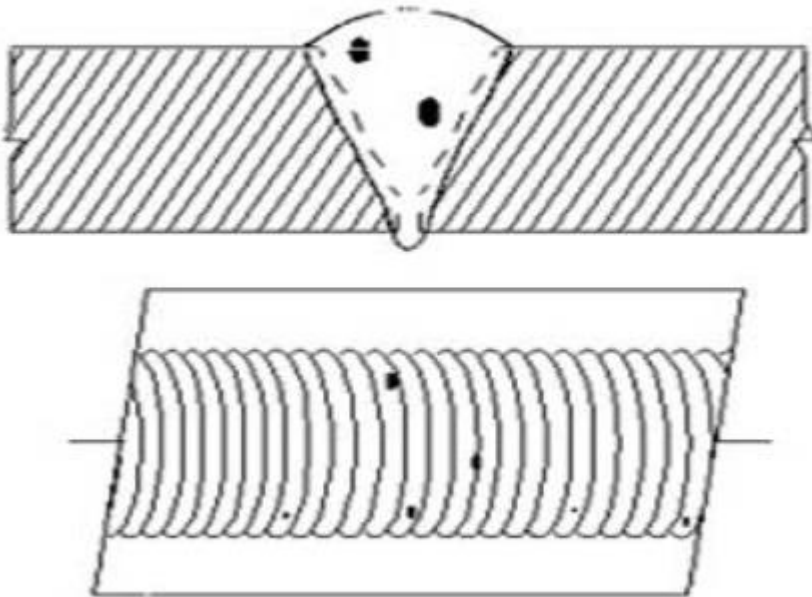
# TIG welding: Imperfections

- ▶ Tungsten inclusions



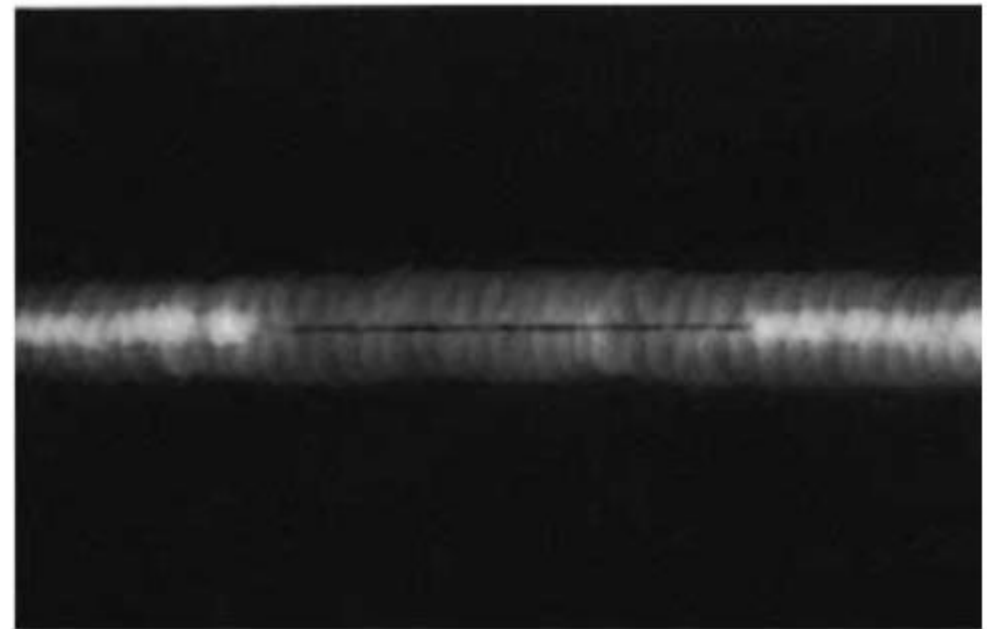
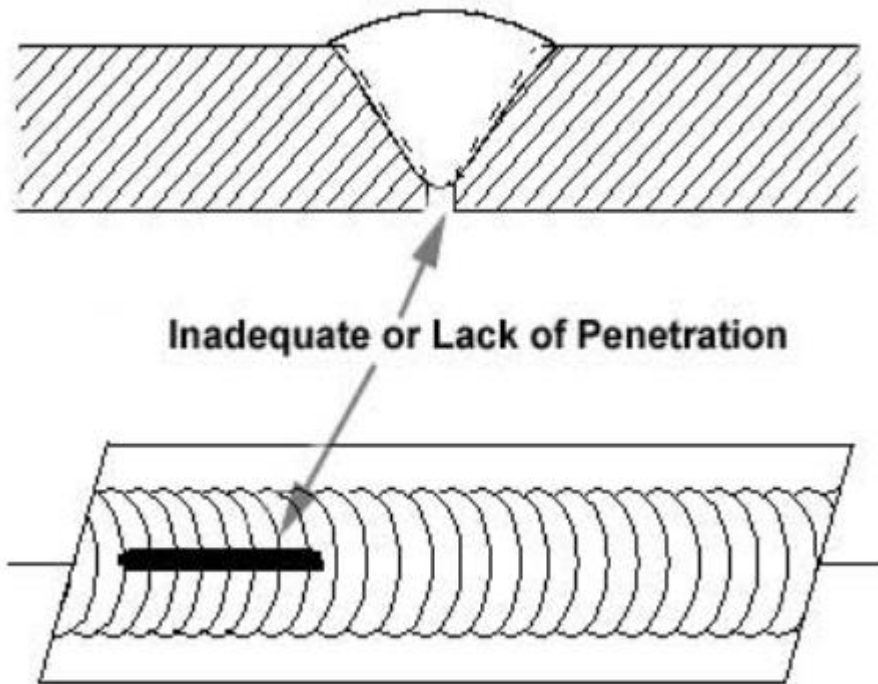
# TIG welding: Imperfections

- Porosity



# TIG welding: Imperfections

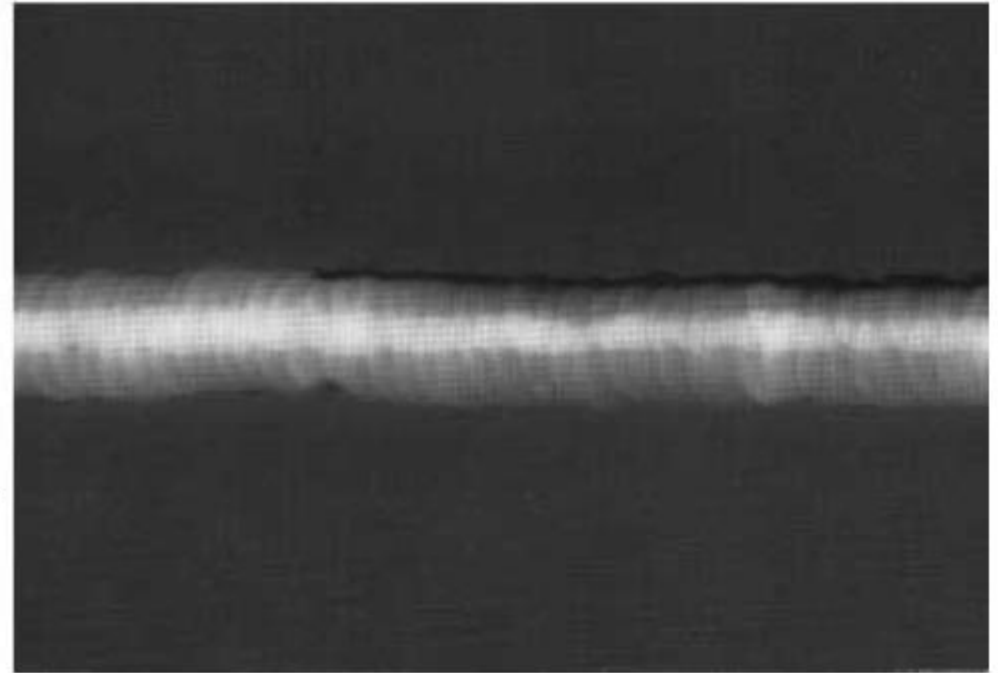
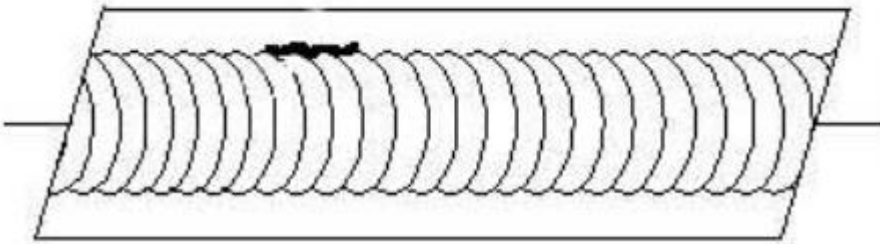
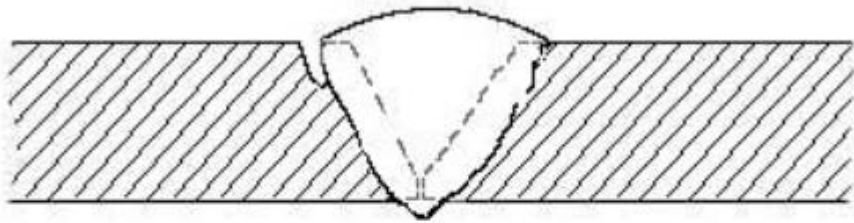
- ▶ Lack of penetration





# TIG welding: Imperfections

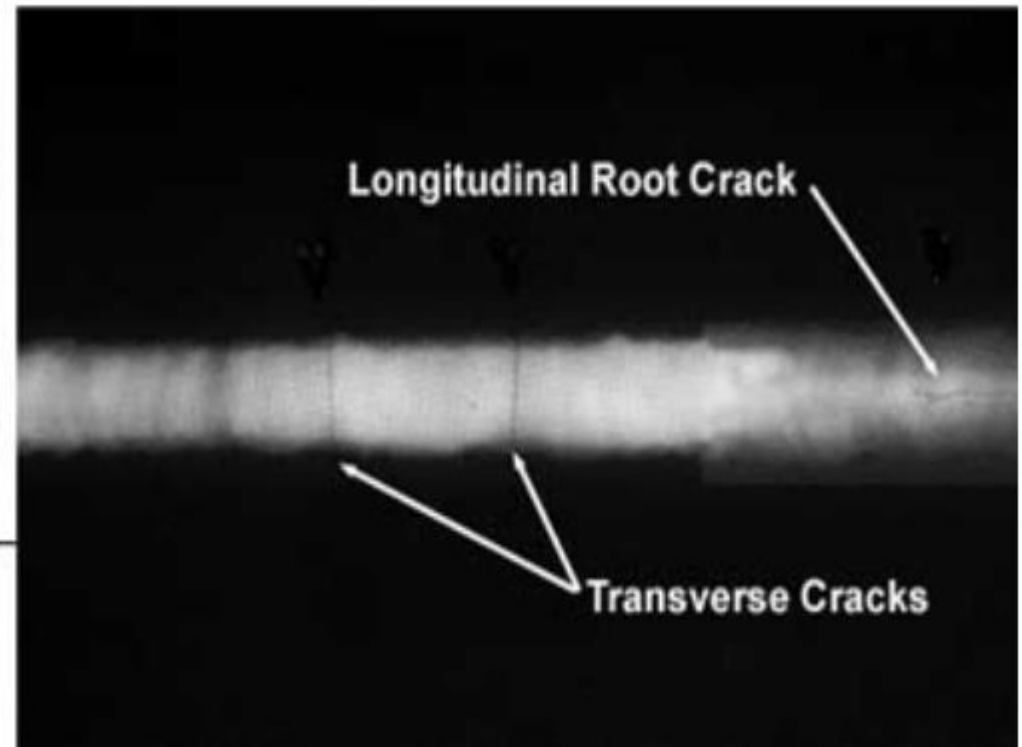
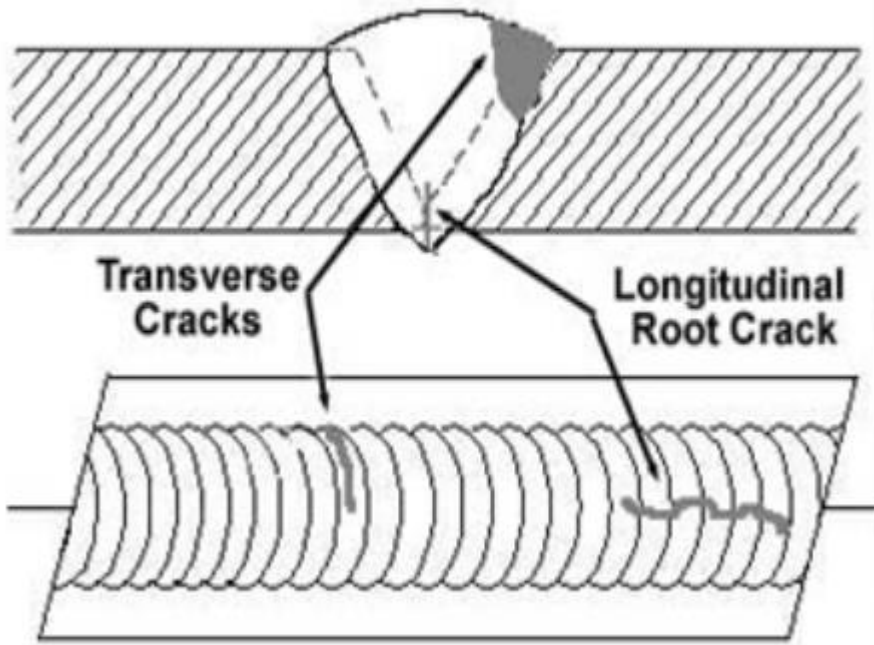
- Undercut





# TIG welding: Imperfections

- Cracks

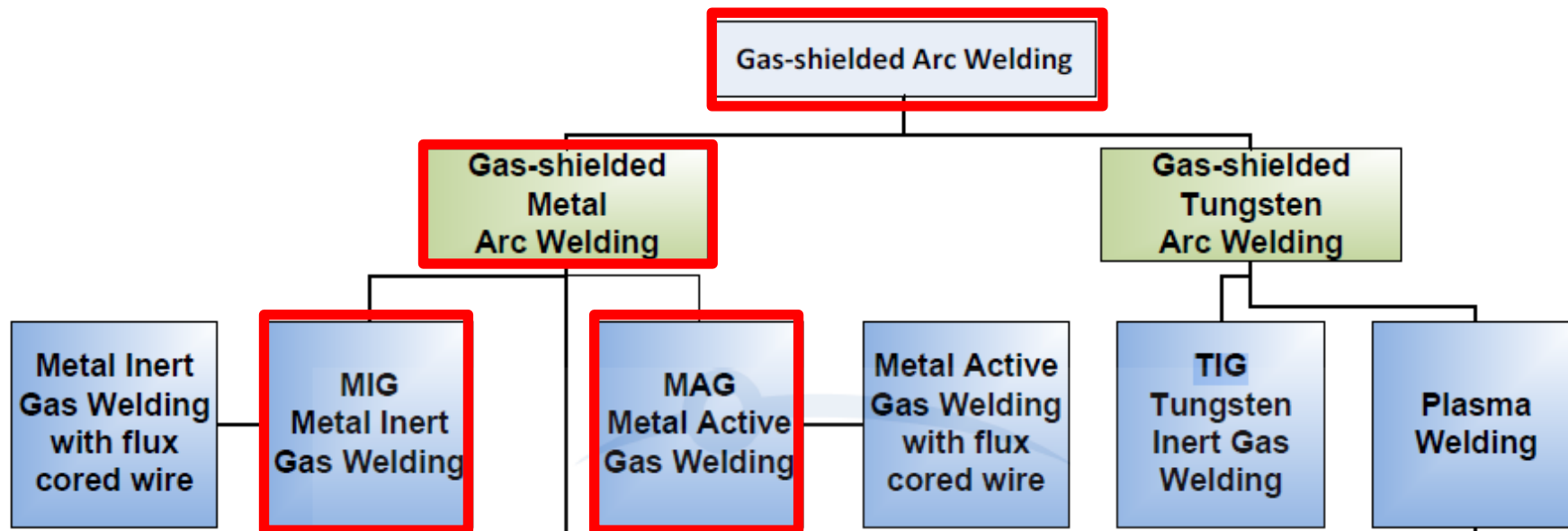


# 1 Welding Terminology

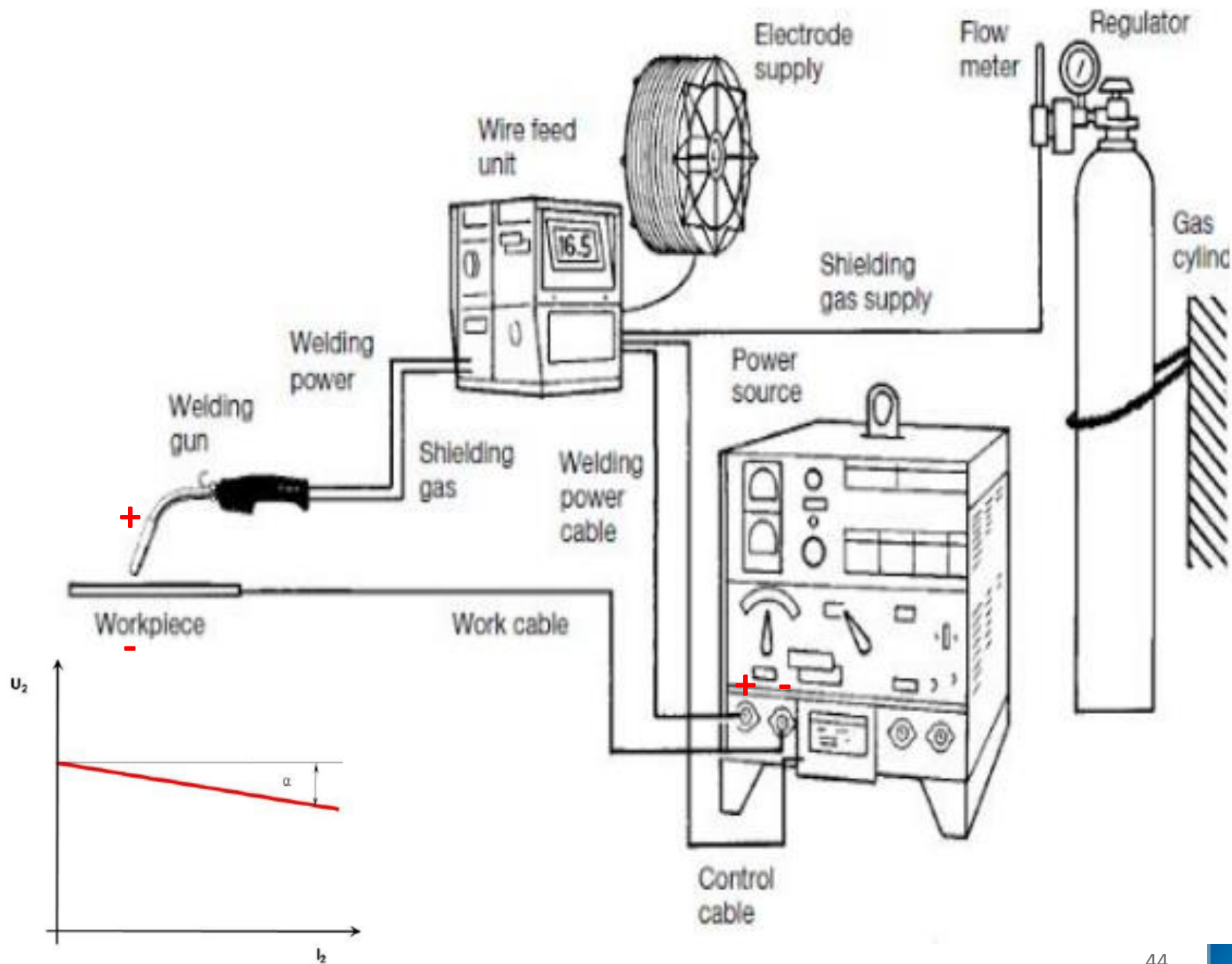
## 2 TIG welding

## 3 MIG/MAG welding

# MIG – MAG welding



# MIG – MAG welding: overview equipment



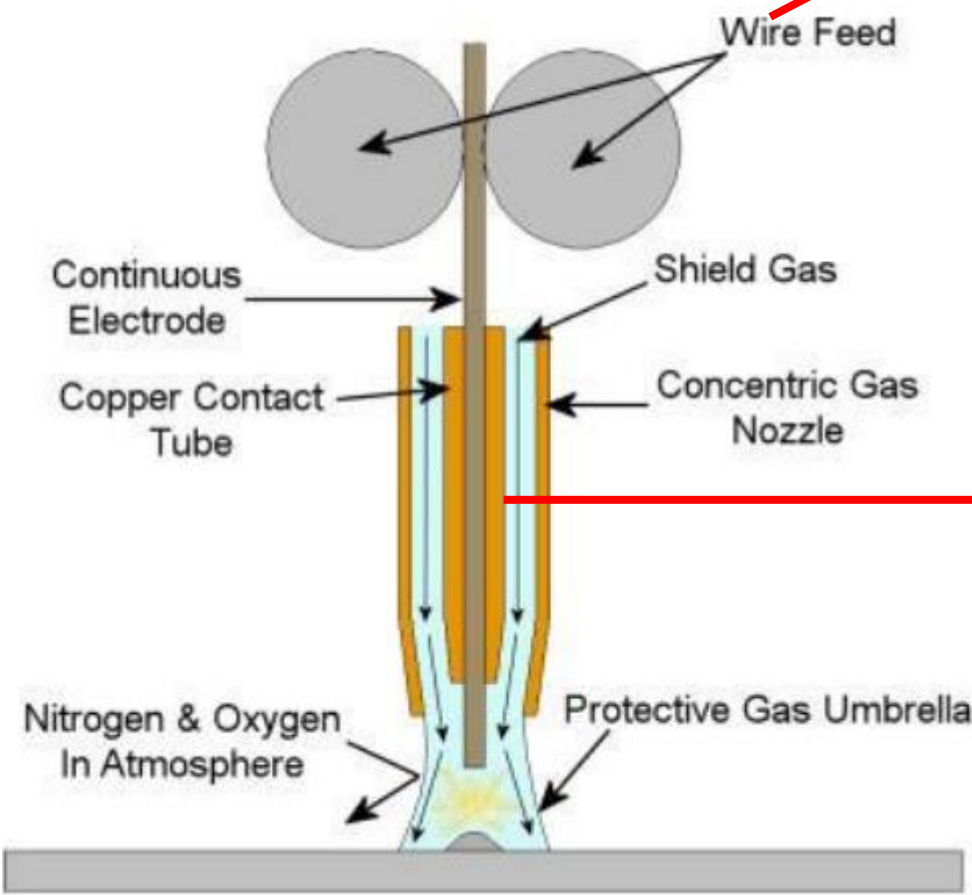
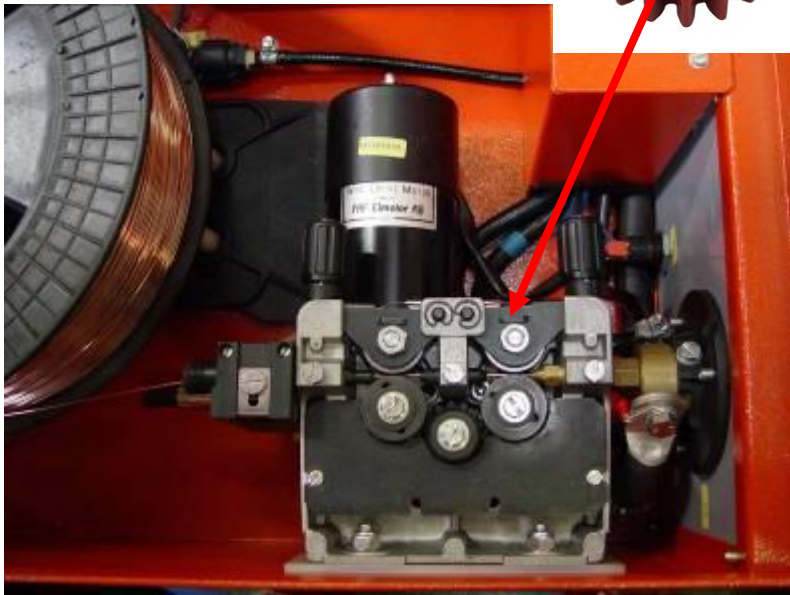
# MIG – MAG welding:

- ▶ Application:
  - ▶ Welding of
    - ▶ C-steel
    - ▶ Stainless steel
    - ▶ Aluminium
    - ▶ Thickness  $\geq 1\text{mm}$
- ▶ + (compared to TIG) :
  - ▶ Higher deposition rate (1 to 6 kg/h)
  - ▶ Easier to automate
- ▶ - (compared to TIG):
  - ▶ Higher risk of weld defects
  - ▶ More complex equipment
  - ▶ More critical welding parameters



# MIG – MAG welding

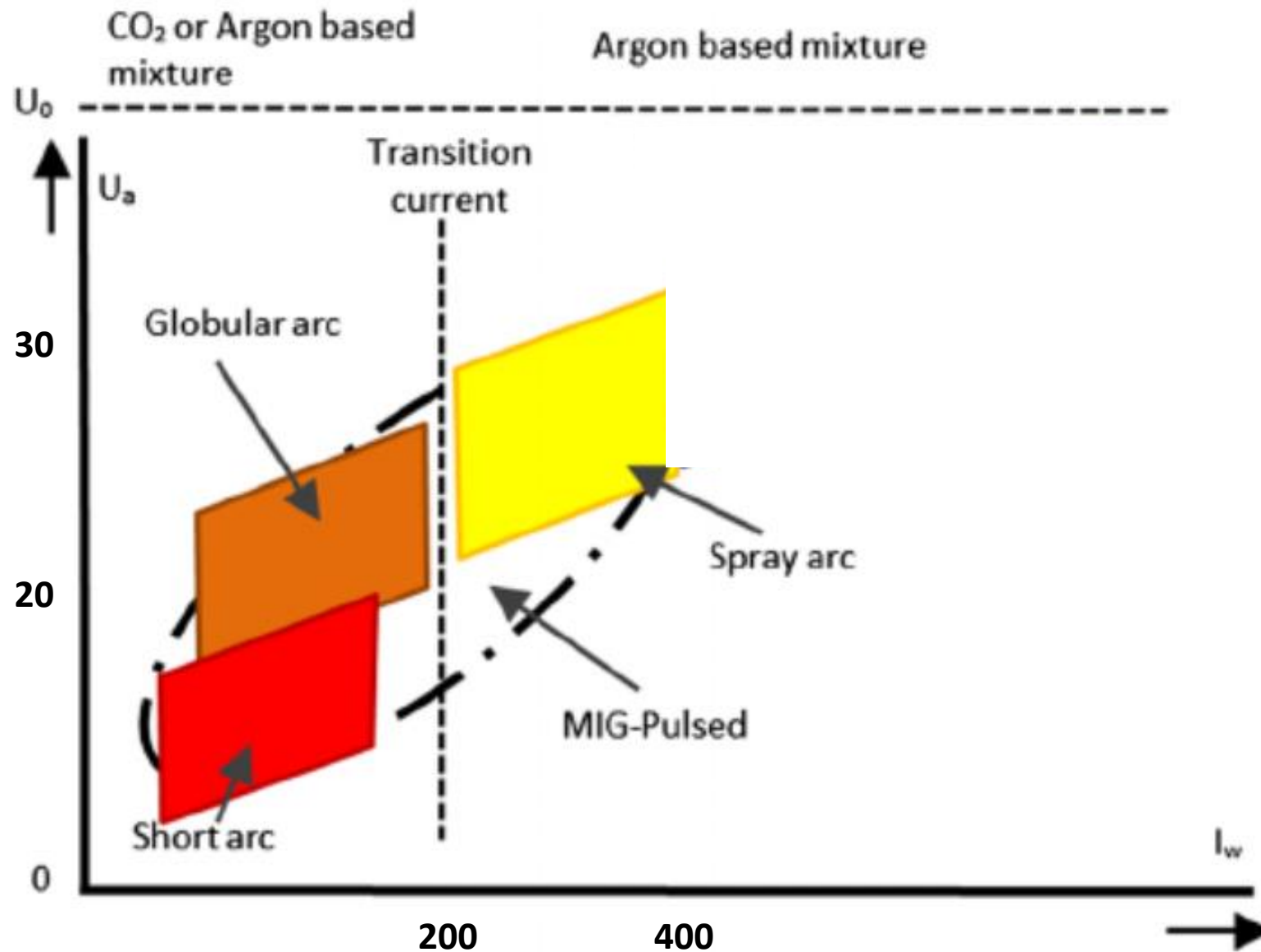
Wire feeder



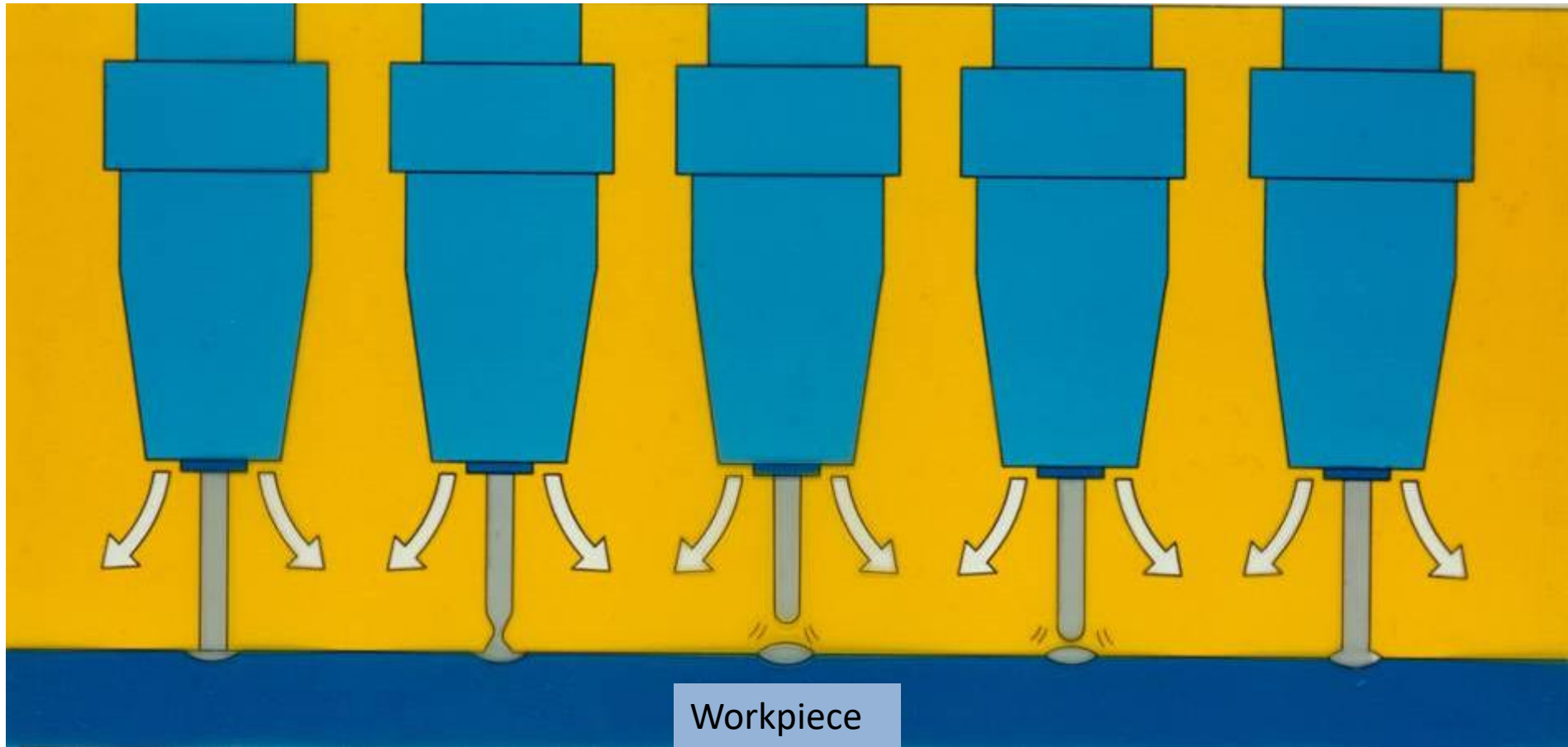
Contact tips



# MIG – MAG welding: Arc transfer modes

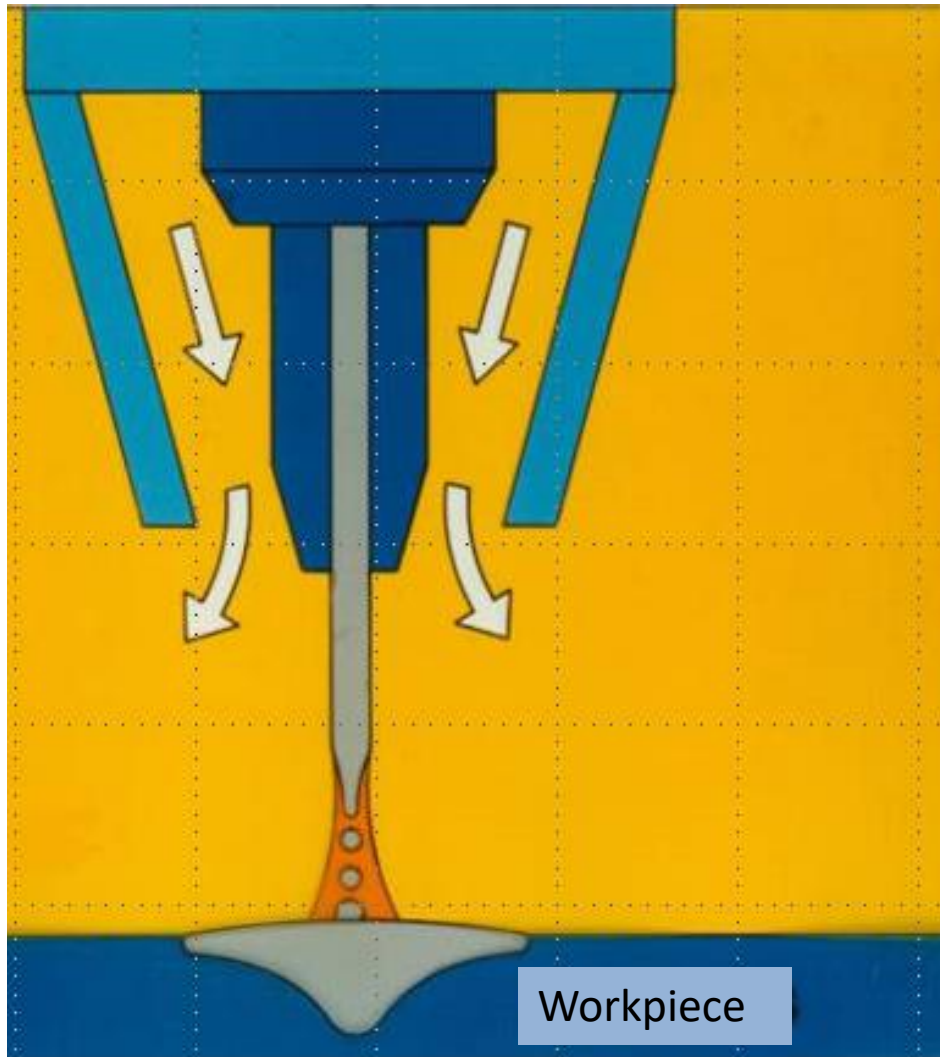


# MIG – MAG welding: Arc transfer mode: short circuit





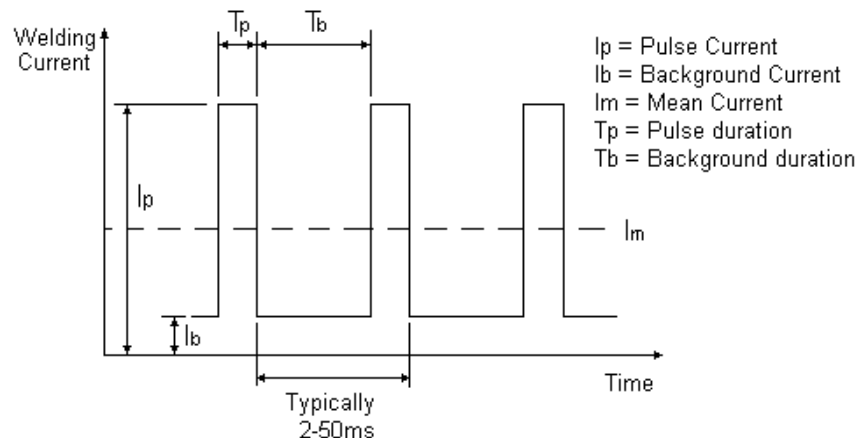
# MIG – MAG welding: Arc transfer mode: spray



# MIG – MAG welding: Arc transfer mode:

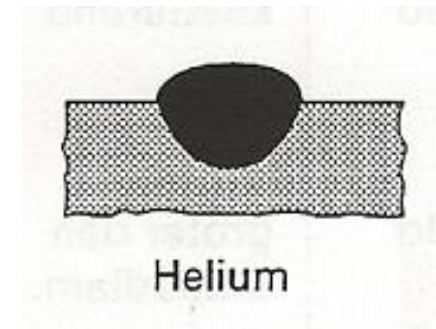
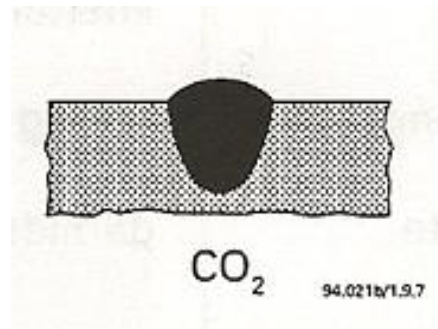
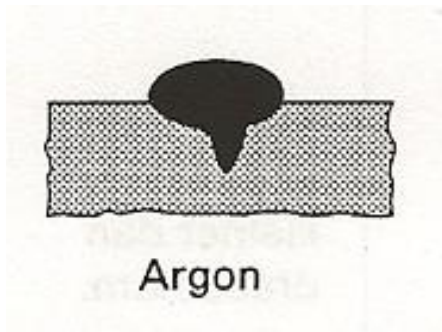
	Advantage	Disadvantage
<b>Short-circuit transfer</b>	<ul style="list-style-type: none"><li>- Welding in position</li><li>- HI <math>\searrow</math></li><li>- Thin material (root)</li></ul>	<ul style="list-style-type: none"><li>- Limited deposition rate</li><li>- Rough weld appearance</li><li>- Spatter</li></ul>
<b>Spray transfer</b>	<ul style="list-style-type: none"><li>- High deposition rate</li><li>- less spatter</li><li>- Smooth weld appearance</li></ul>	<ul style="list-style-type: none"><li>- Not in position</li><li>- Hard to control</li><li>- No thin plate</li></ul>

**Pulse welding > combines advantages of spray and short-arc**



# MIG – MAG welding: gas

- ▶ MIG: Ar, He or mixtures
  - ▶ Ar/He 30-75%,... (Alu)
- ▶ MAG: mixtures (with an active component)
  - ▶ Ar/CO<sub>2</sub> mixtures → eg. Ar/CO<sub>2</sub> 5-20%,... (carbon steel)
  - ▶ Ar/O<sub>2</sub> mixtures → eg. Ar/O<sub>2</sub> 1-5%,...
  - ▶ Ar/ 2-3%CO<sub>2</sub>/1%H<sub>2</sub> (stainless steel)



# MIG – MAG welding: wire

- ▶ Solid wire:
  - ▶ Diameter 0,8 to 2,4 mm
  - ▶ Composition depends of the material to be welded
    - ▶ unalloyed steel: addition of Mn and Si
  - ▶ Thin copper layer on outside of the wire
  - ▶ in metal or plastic coils (about 15 kg)
  - ▶ in barrels of 250-1000kg
  - ▶ Classification according to standards
- ▶ Cored wire: (more expensive)
  - ▶ Diameter 1 to 2,4 mm
  - ▶ Metal cored > no slag is formed
  - ▶ Flux cored > slag is formed on the weld
    - ▶ Alloy elements and arc stabilizers



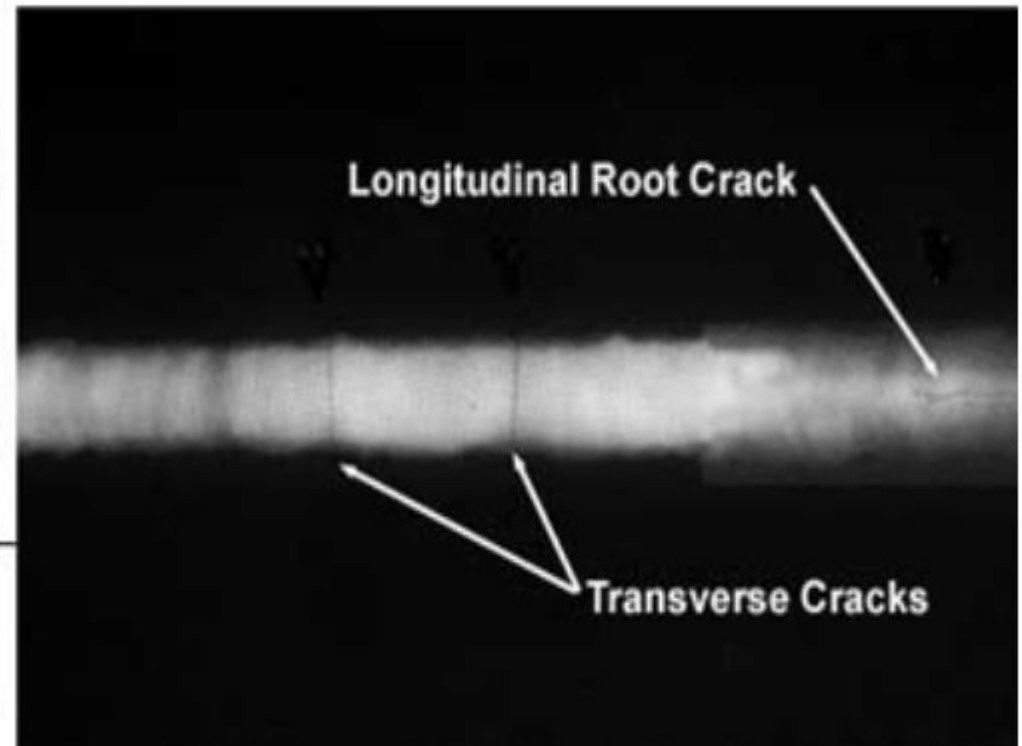
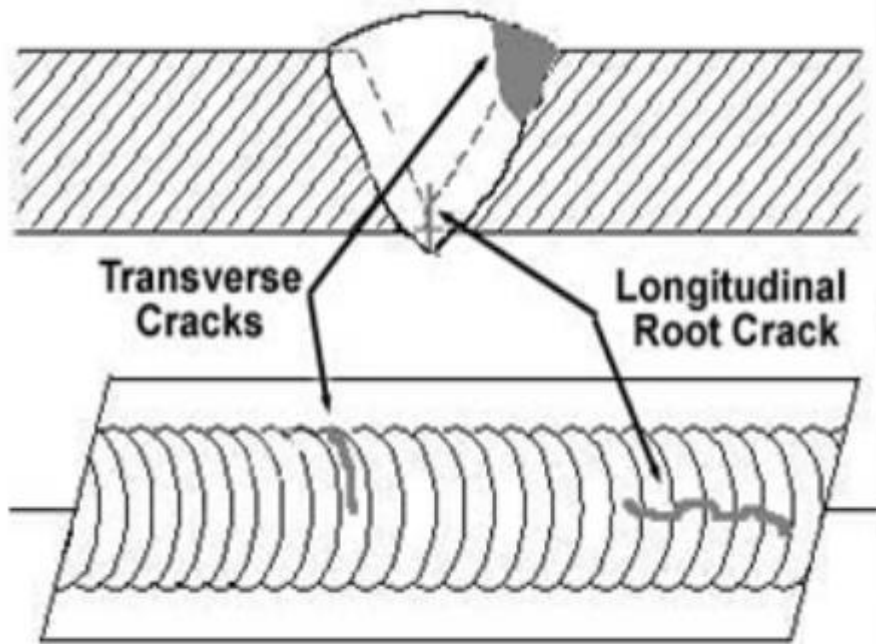
# MIG – welding: welding Alu

- ▶ MIG welding:
  - ▶ Ar/He mixture (no CO<sub>2</sub>)
  - ▶ He increase penetration and/or welding speed
  - ▶ Pure gas with low H
  - ▶ High Q wire with low H in oxide layer
  - ▶ Pulsed welding (No short-circuit transfer)
  - ▶ DC + (good cleaning)



# MIG – MAG welding: Imperfections

- Cracks





# MIG – MAG welding: Imperfections

- ▶ Crater crack



# MIG – MAG welding: Imperfections

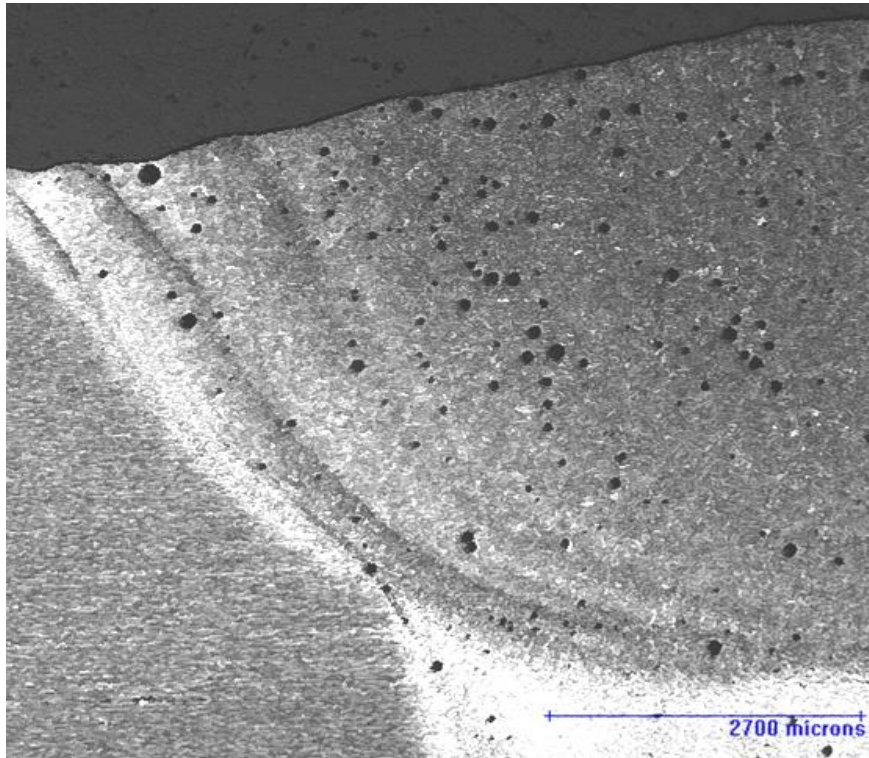
- ▶ Surface porosity



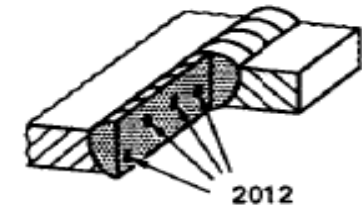


# MIG – MAG welding: Imperfections

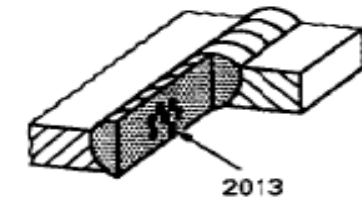
## ► Porosity internal



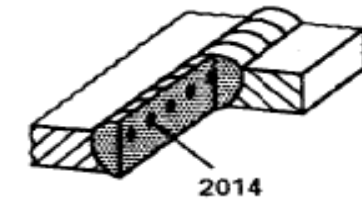
Uniformly distributed



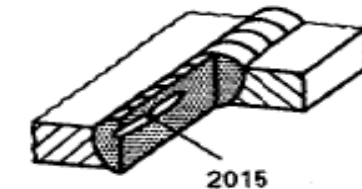
clustered



Linear porosity

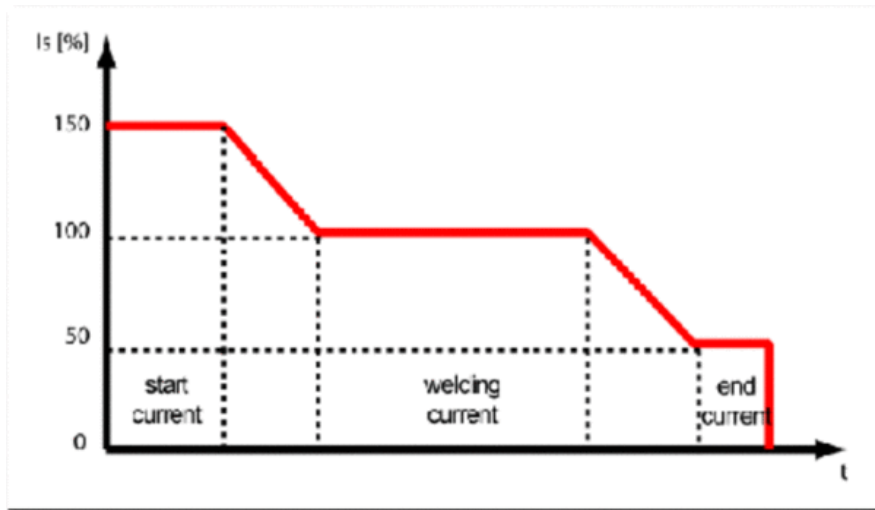
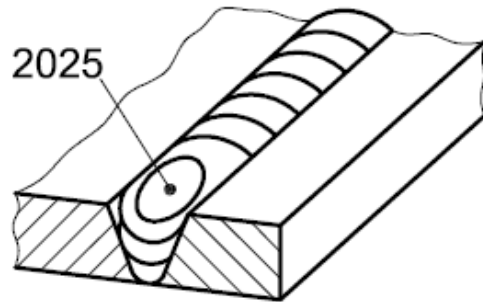


Elongated cavity



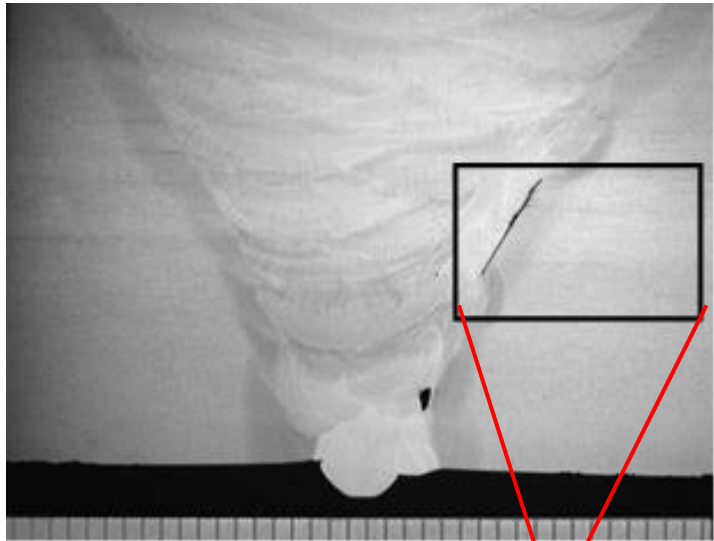
# MIG – MAG welding: Imperfections

- ▶ End crater pipe

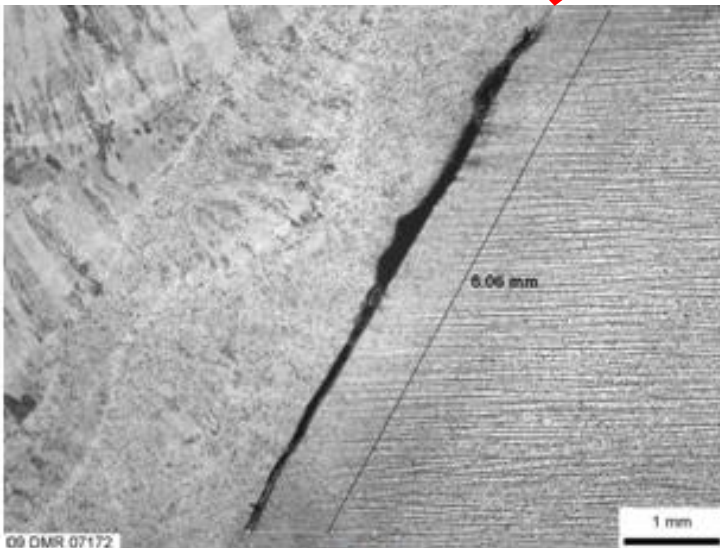
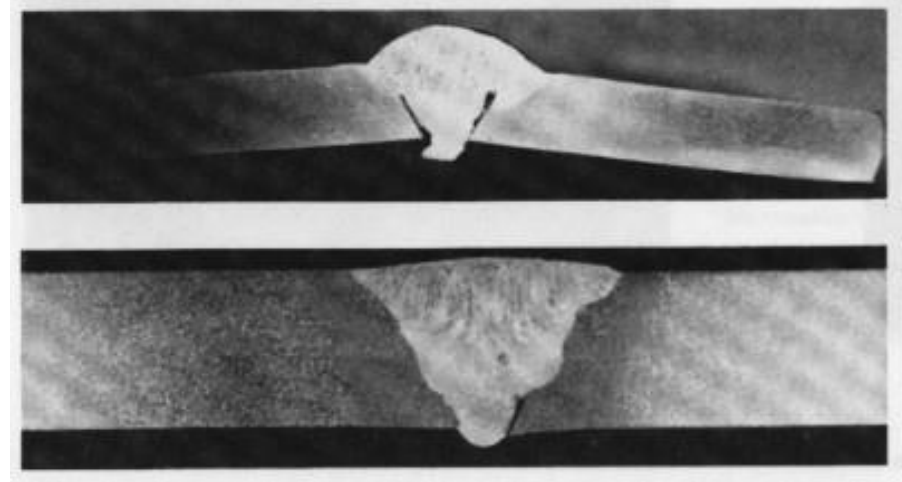


# MIG – MAG welding: Imperfections

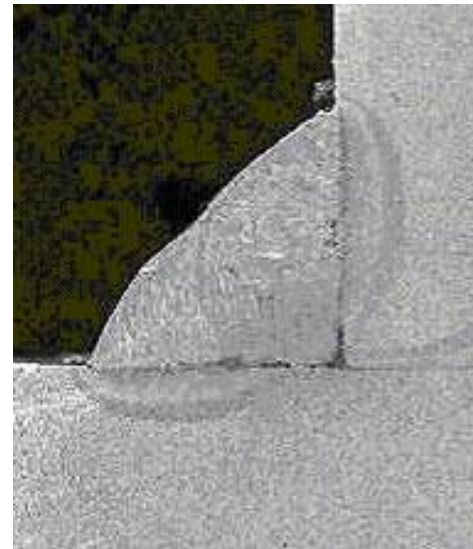
- Lack of fusion



(a)



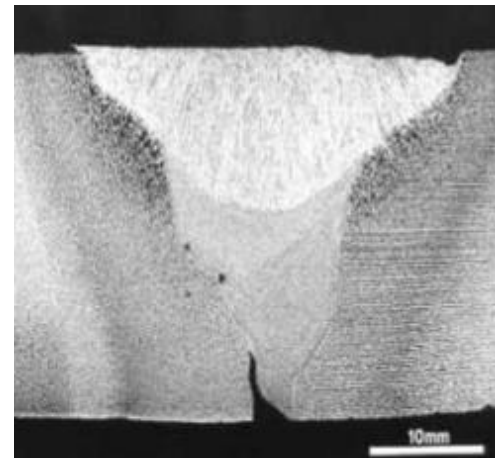
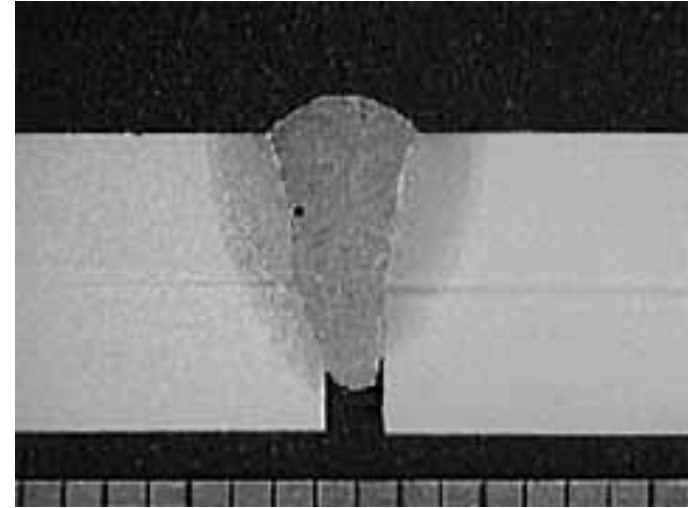
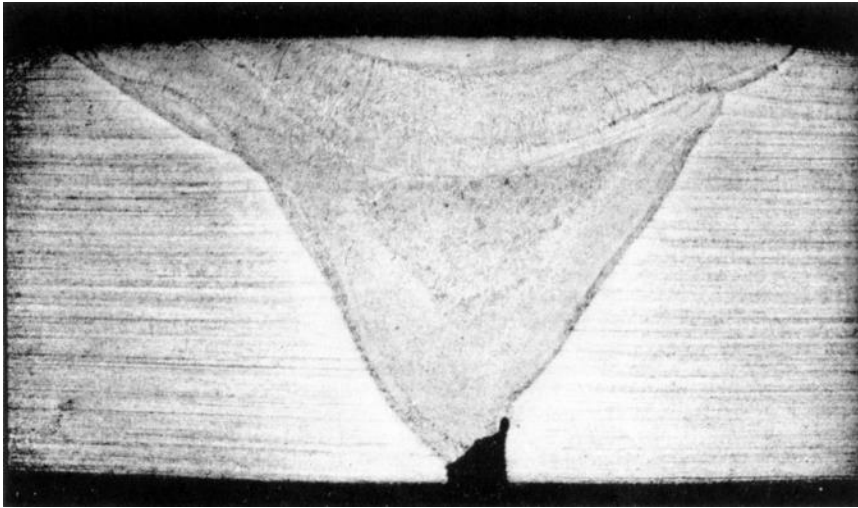
(b)





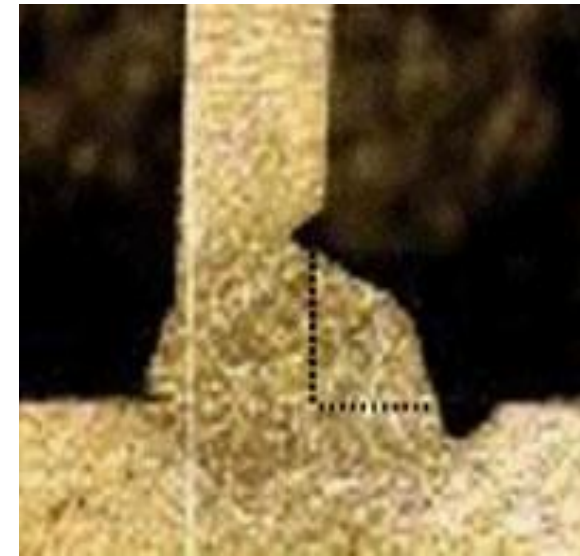
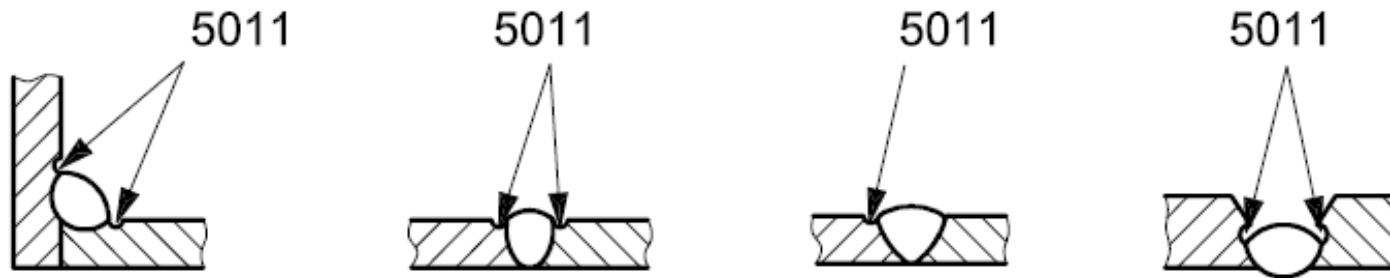
# MIG – MAG welding: Imperfections

- ▶ Lack of penetration



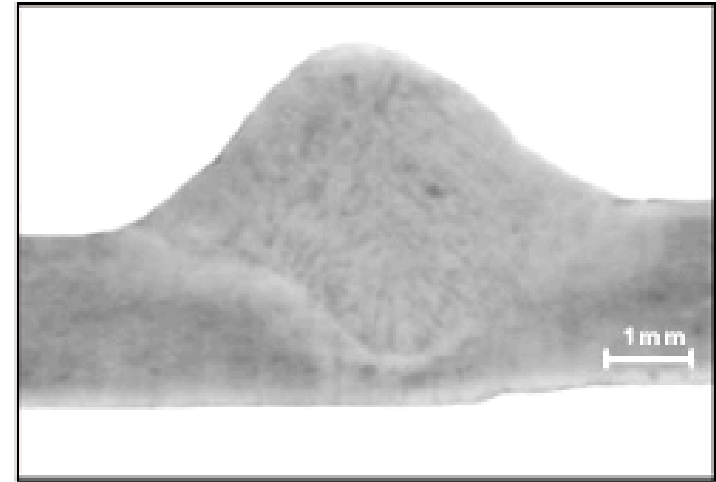
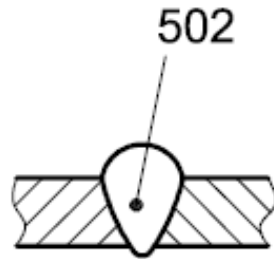
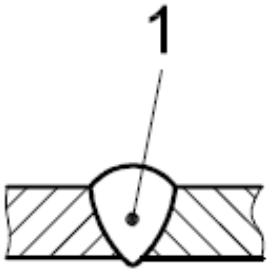
# MIG – MAG welding: Imperfections

- ▶ undercut



# MIG – MAG welding: Imperfections

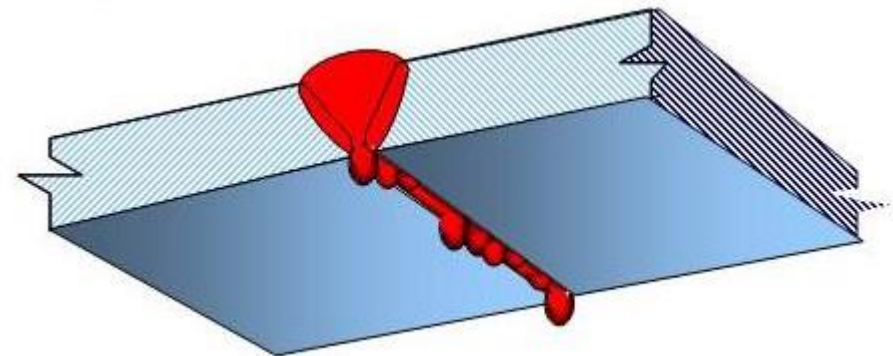
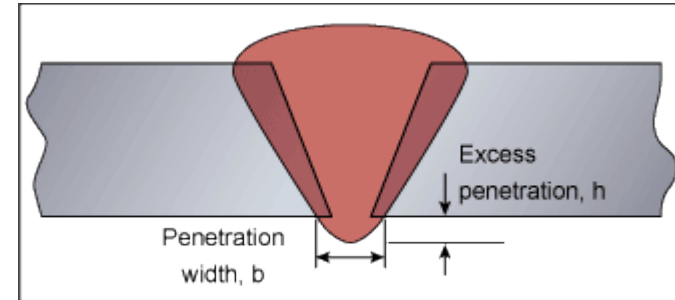
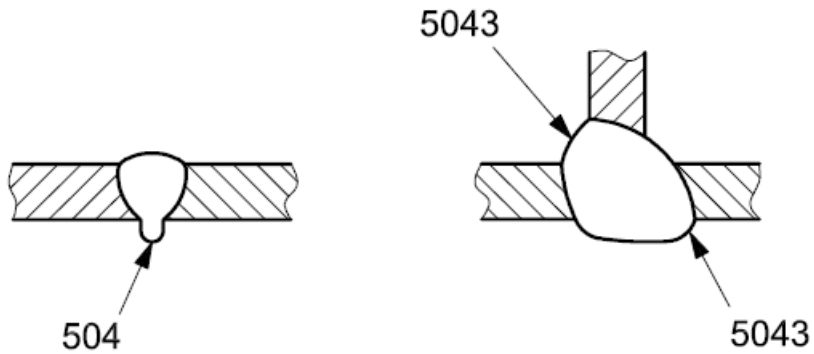
- ▶ Excess weld metal





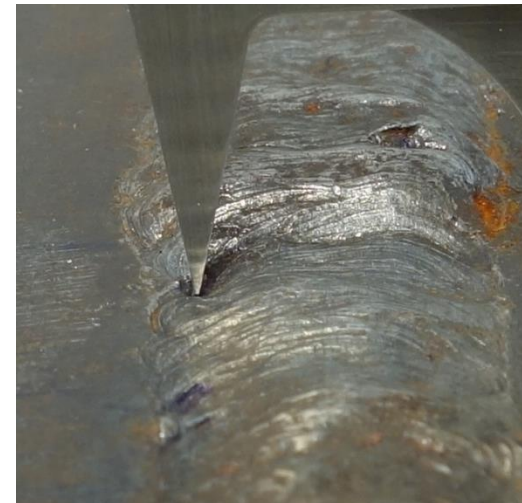
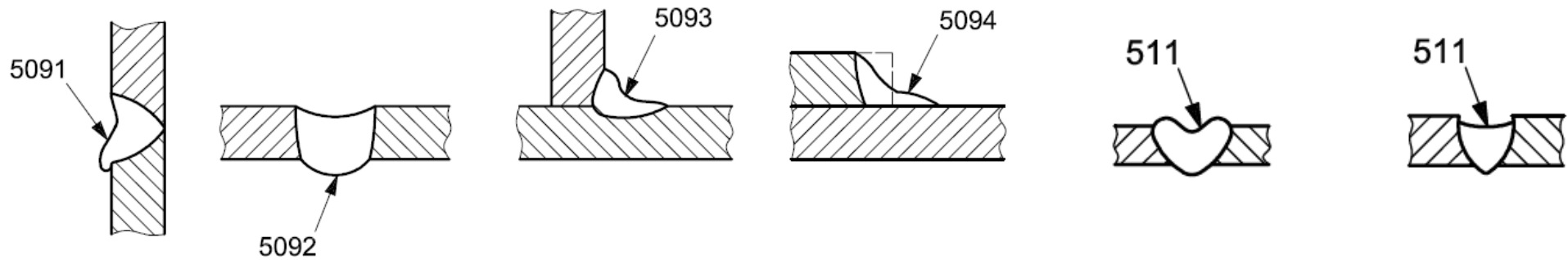
# MIG – MAG welding: Imperfections

- Excessive penetration



# MIG – MAG welding: Imperfections

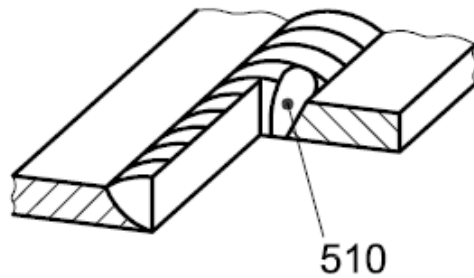
- Sagging / incompletely filled groove





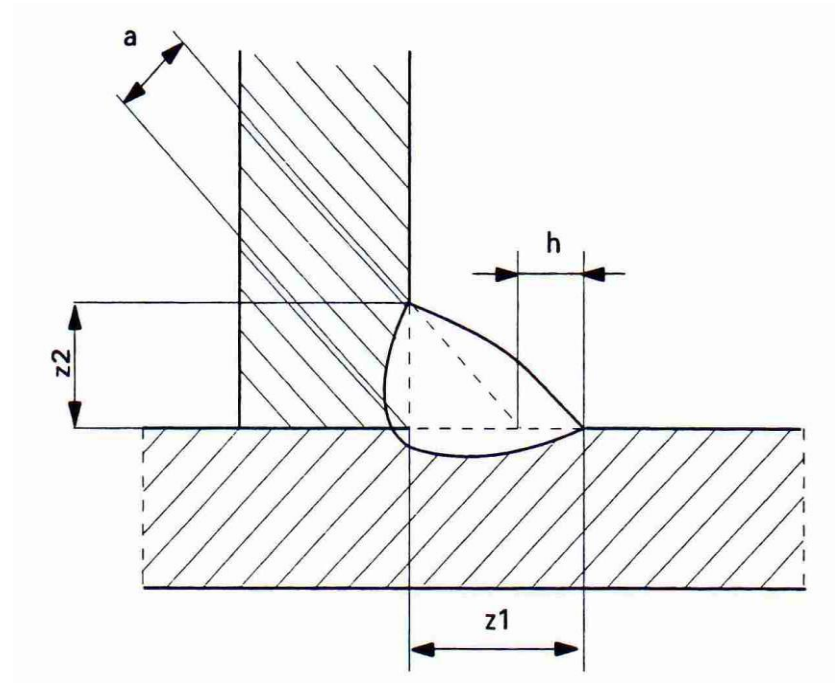
# MIG – MAG welding: Imperfections

- ▶ Burn through



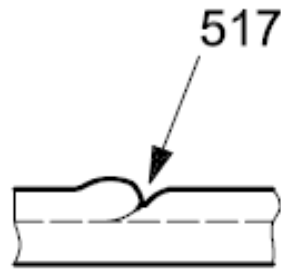
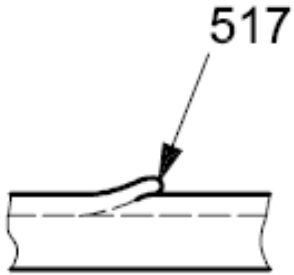
# MIG – MAG welding: Imperfections

- ▶ Excessive asymmetry of fillet weld



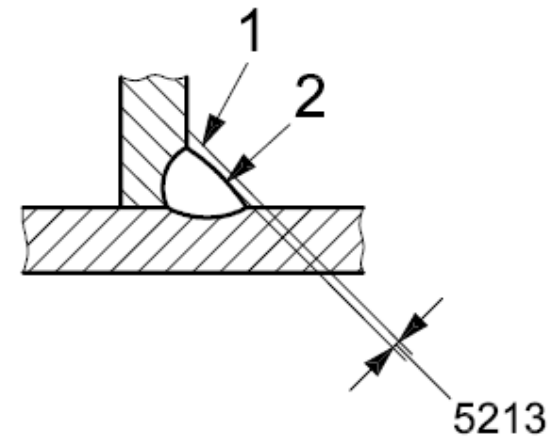
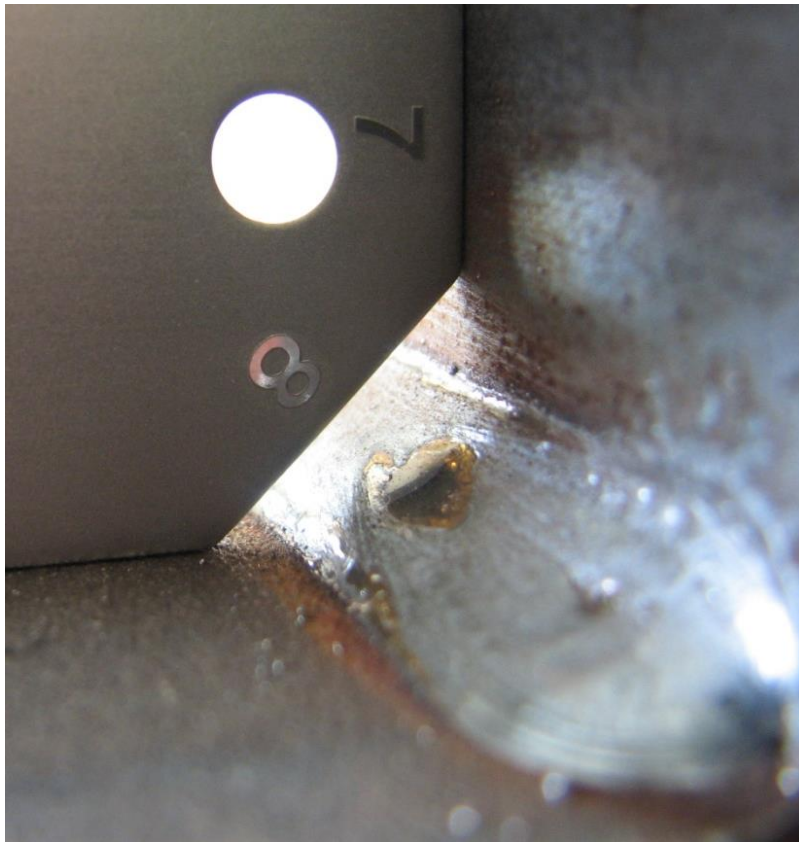
# MIG – MAG welding: Imperfections

- ▶ Bad restart



# MIG – MAG welding: Imperfections

- Insufficient throat thickness



- 1 design throat thickness  
gorge théorique  
Sollnahtdicke
- 2 actual throat thickness  
gorge réelle  
tatsächliche Nahtdicke



# MIG – MAG welding: Imperfections

- ▶ Spatter / (wire)



# CONTACT



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