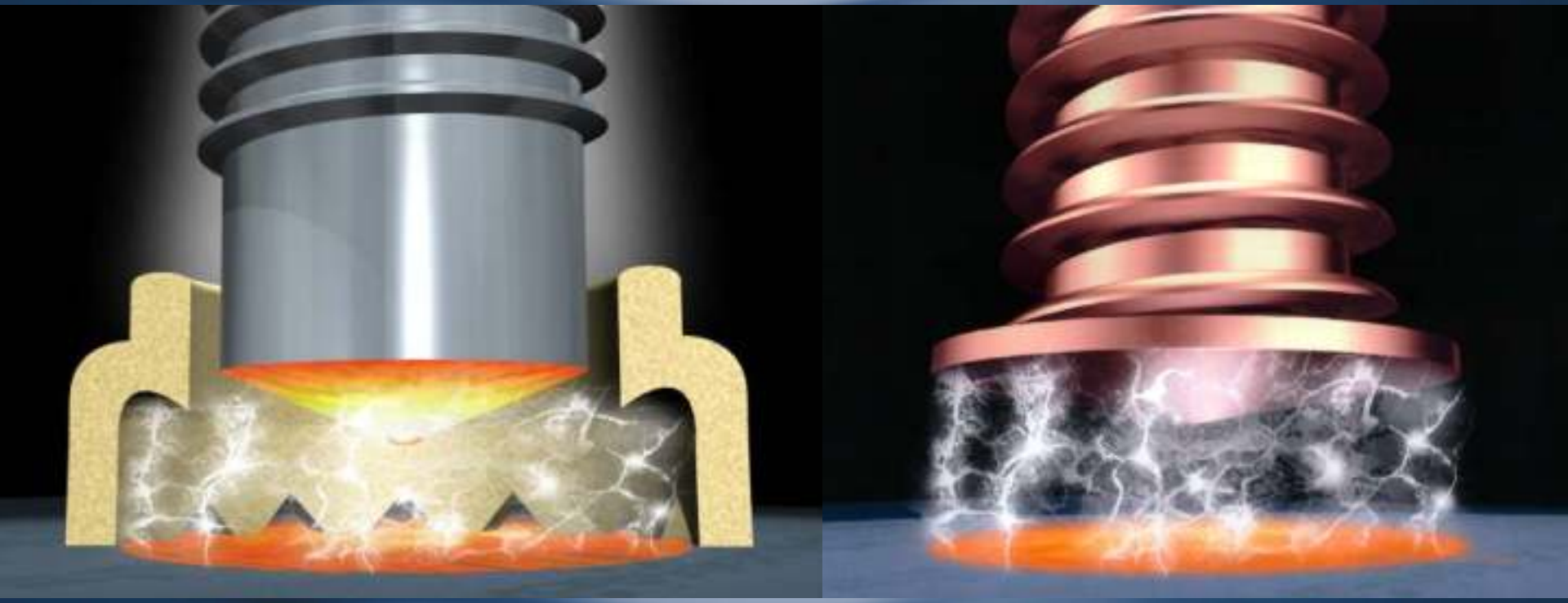


Drawn-Arc Studwelding

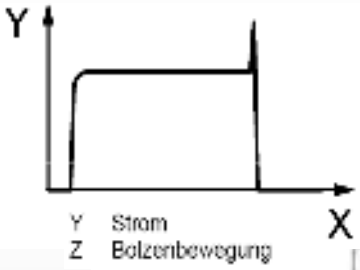
ARC - Process Training

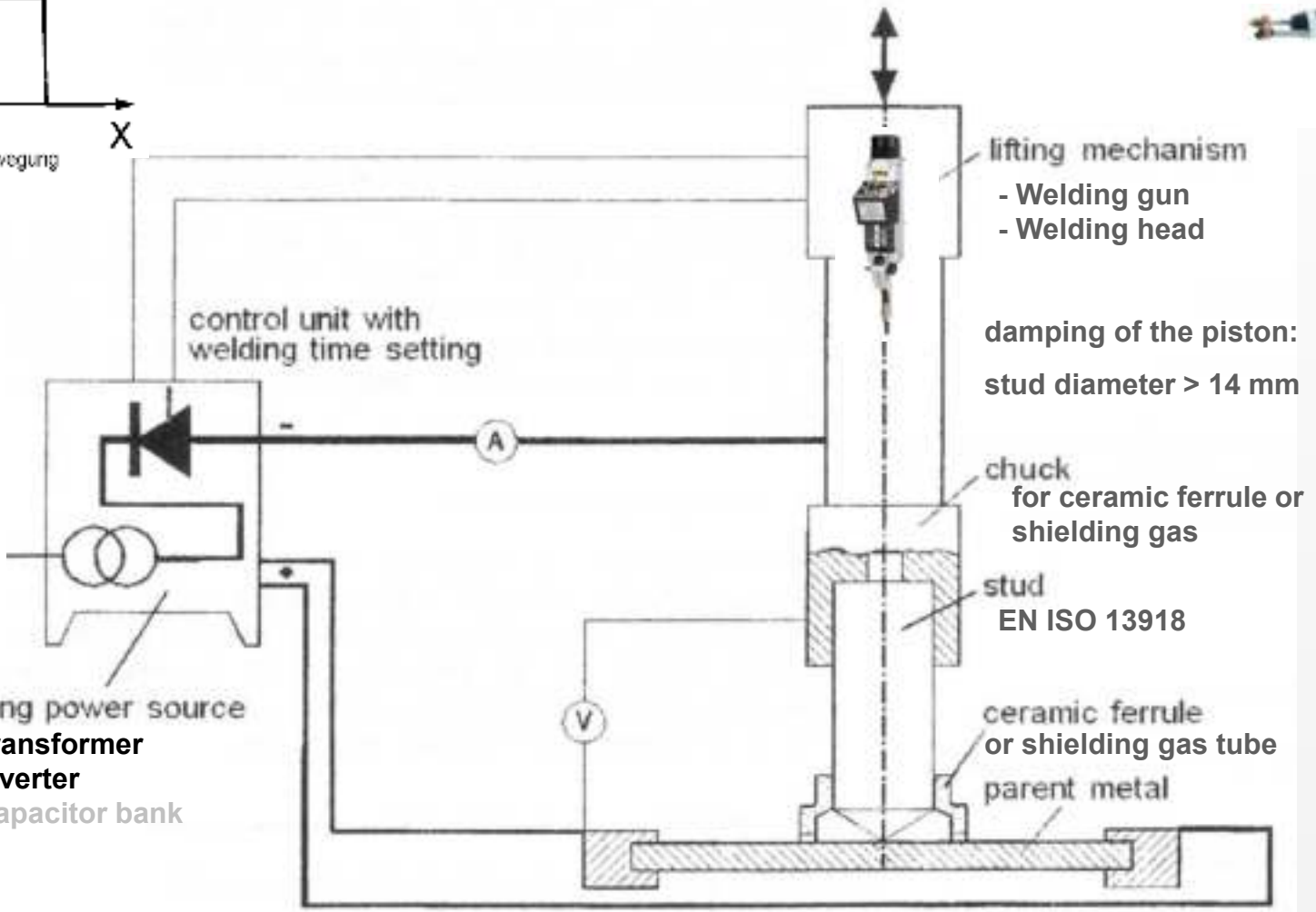
Process:
Drawn Arc Stud welding (DS)

Short-Cycle Welding time < 100 ms	Standard Arc Shielding Gas D ≤ 16 mm	Standard Arc Ceramic Ferrule D ≤ 25 mm
Studs Type PS / US / IS (PT / UT / IT)	Studs Type RD / PD / ID / UD	Studs Type RD / PD / ID / UD
Thin sheet metals	Studs without Aluminum ball	Concrete anchors Shear conectors Type SD
Automotive industry	Industrial application	Overhead position (PE) Horizontal Position (PC)
Christmas tree studs		Jobside applications
		Steel construction
		Refractory Anchoring systems & Pins

ARC - Process

Cirquit diagram





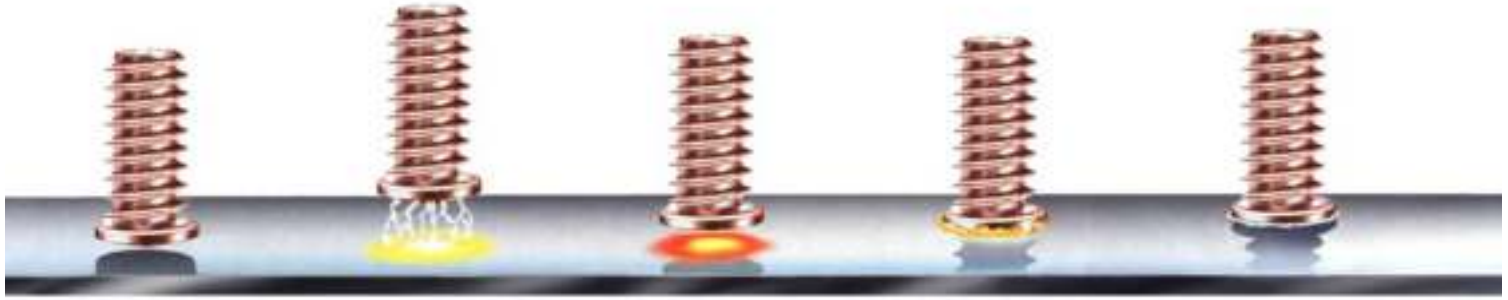
ARC Stud Welding (DS)

Drawn Arc processes

Ceramic Ferrule (CF)
EN ISO 4063 - 783

Shielding Gas (SG)
EN ISO 4063 - 783

Short-Cycle (NP)
EN ISO 4063 - 784



ARC Stud Welding

Drawn Arc processes (ISO 14555)

Drawn arc Processes	ISO 4063	Welding time t [ms]	Stud diameter d [mm]	Current intensity I [A]	Weld pool protection	Minimum sheet
stud welding with ceramic ferrule or shielding gas	783	> 100	3 to 25	300 to 3,000	CF	1/4 d but not less than 1 mm[1)]
		> 100	3 to 16	300 to 3,000	SG	1/8 d but not less than 1mm
Short-Cycle stud welding	784	< 100	3 to 12	up to 1,500	NP, SG, (CF)	1/8 d but not less than 0.6mm
Capacitor discharge drawn arc stud welding	785	< 10	3 to 10	up to 3,000 (peak)	NP (SG)	1/10 d but not less than 0.5mm

1) The minimum sheet thickness avoids burn through. Other application requirements can call for bigger thickness.

ARC - Process

Weld Pool Protection (CF)

Ceramic ferrule (CF) (for studs with Al-ball)

- It forms a combustion chamber around the weld location
- Shielding the welder from both arc and spatter
- Concentrates the arc in a small region
- Reduces heat loss and cooling rate
- The atmosphere is only slightly held off
- When the stud is plunged into the weld pool, it forces molten metal out sideways to form an annular weld collar around the stud
- Welding in any position can thus be carried out
- used only for one weld and is removed once the molten metal has solidified

ARC - Process

Weld Pool Protection (SG)

Shielding gas (SG) – ISO 14175 (studs without Al-ball)

- The atmosphere is displaced from the arc region
- Greatly reduces the formation of pores
- Influences the arc and affects the fusion of the stud and work piece
- Influences as well the shaping of the weld collar and the penetration shape
- Welding position: Downhand welding position (PA)
- **Steels** (mild steel, stainless steel):

  widely used: 82% Ar / 18% CO_2 — ISO 14175 – M21 – ArC – 18
  HBS preferred: 92%Ar / 8% CO_2 — ISO 14175 – M20 – ArC – 8

- **Aluminium** and its alloys:

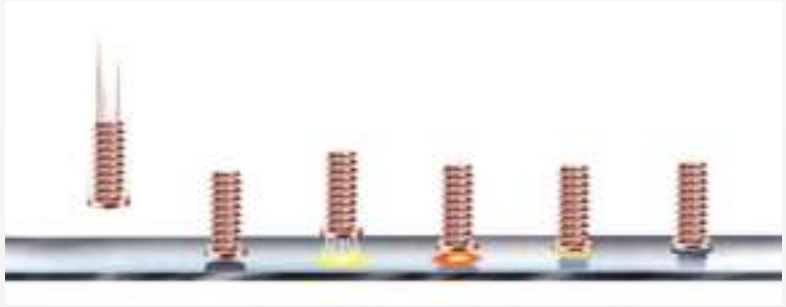
  Ar-He mixtures: 85% Ar / 15% He — ISO 14175 – I3 – ArHe – 15
  Argon (99.9) — ISO 14175 – I1

ARC / SC - Process

Weld Pool Protection (NP)

No protection (NP)

- Only for small stud diameter (< 8 mm) and with short welding times (< 100 ms)
- Disadvantages:
  - severe oxidation of the weld zone
  - increased pore formation
  - and irregular weld bead



ARC Welding elements

Studs (EN ISO 13918)

Type DD

Type PD

Type RD

Type UD

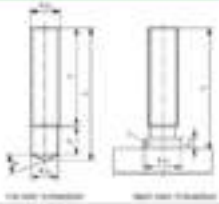
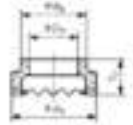
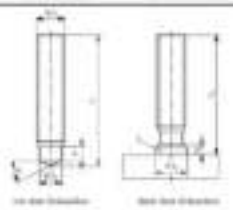
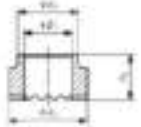
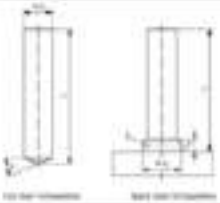
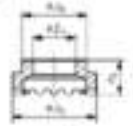
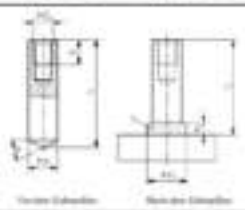
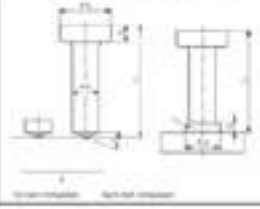
Type ID

Type SD

Ceramic ferrule

ARC Welding elements

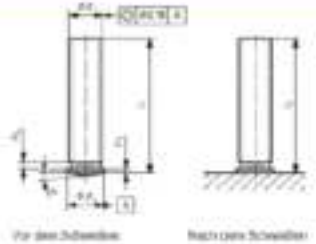
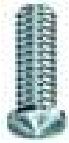
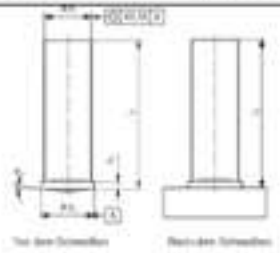
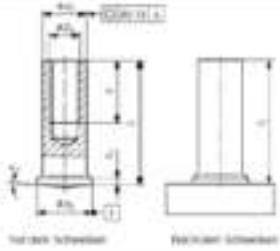
Studs (EN ISO 13918)

Type of Studs			Symbol for Studs	Symbol for Ceramic Ferrules
drawn arc stud welding with ceramic ferrule or shielding gas	threaded stud (pitch)		PD	 P F
	threaded stud with reduced shaft		RD	 RF
	unthreaded stud		UD	 UF
	stud with internal thread		ID	
	shear connector		SD	

features: ignition cone angle (~23 °) / CF: ignition cone with aluminum ball

SC Welding Elements

Studs (EN ISO 13918)

Type of studs			Symbol for studs
short-cycle drawn arc stud welding	threaded stud (pitch) with flange		 PS
	unthreaded stud		US
	stud with internal thread		IS

features:

- small ignition cone angle (~7°)
- flange

Welding Parameters

Welding parameters ISO 14555

Parameters	Effect
Welding Current I [A]	Size of the melt pool Fluidity of the melt
Welding Time t [ms]	Penetration Size of the melt pool
Lift L [mm]	Geometry of the melt pool Porosity
Protrusion P [mm]	Formation of the melt seam
Plunging speed / Damping	Shape of melt seam

Welding Parameters

Welding parameters - Power unit

Welding current [I]

- depending on the stud dimensions, the welding current is between 300 and 3,000 A

- for **normal stud welding** of unalloyed steel, Position PA:
  I [A] = 80 x D [mm] ..... for studs up to 16 mm diameter
  I [A] = 90 x D [mm] ..... for studs over 16 mm diameter

  for **stainless steel**: current ~10% less

- for **Short-Cycle drawn arc stud welding**:
  current as high as possible is set
  I [A] = min. 100 x D [mm]

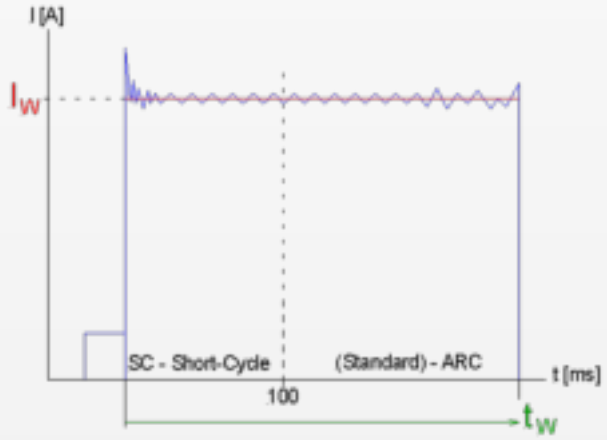
Welding Parameters

Welding parameters - Power unit

Welding time [t]

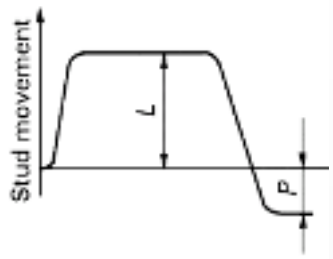
- for **normal stud welding** (mild steel, Position PA):
  t_W [ms] = 20 x D [mm] ..... for studs up to 12 mm diameter
  t_W [ms] = 40 x D [mm] ..... for studs over 12 mm diameter

- for **Short-Cycle drawn arc stud welding:**
  t_W [ms] < 100

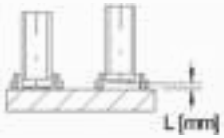


Welding Parameters

Welding parameters – Weld gun

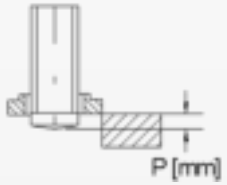


Lift [L]



- Is between (0.8) 1.5 and 8 mm
- is proportional to the stud diameter
- Coated surfaces: the lift must be greater than it is normally
- greater lift increases the arc length and therefore the arc voltage; the magnetic deflection of the arc also increases (arc blow effect)

Protrusion [P]



- Is approximately 1 to 8 mm and proportional to the stud diameter
- Depends on: - the desired shape of the weld collar
  - the shape of the stud base and
  - the collar area of the ring (when welding with CF)

Welding parameters – Weld gun

Plunging speed

- for studs with a diameter up to 14 mm: approximately 200 mm/s
  for larger studs: approximately 100 mm/s so as to prevent the weld pool splashing

Polarity

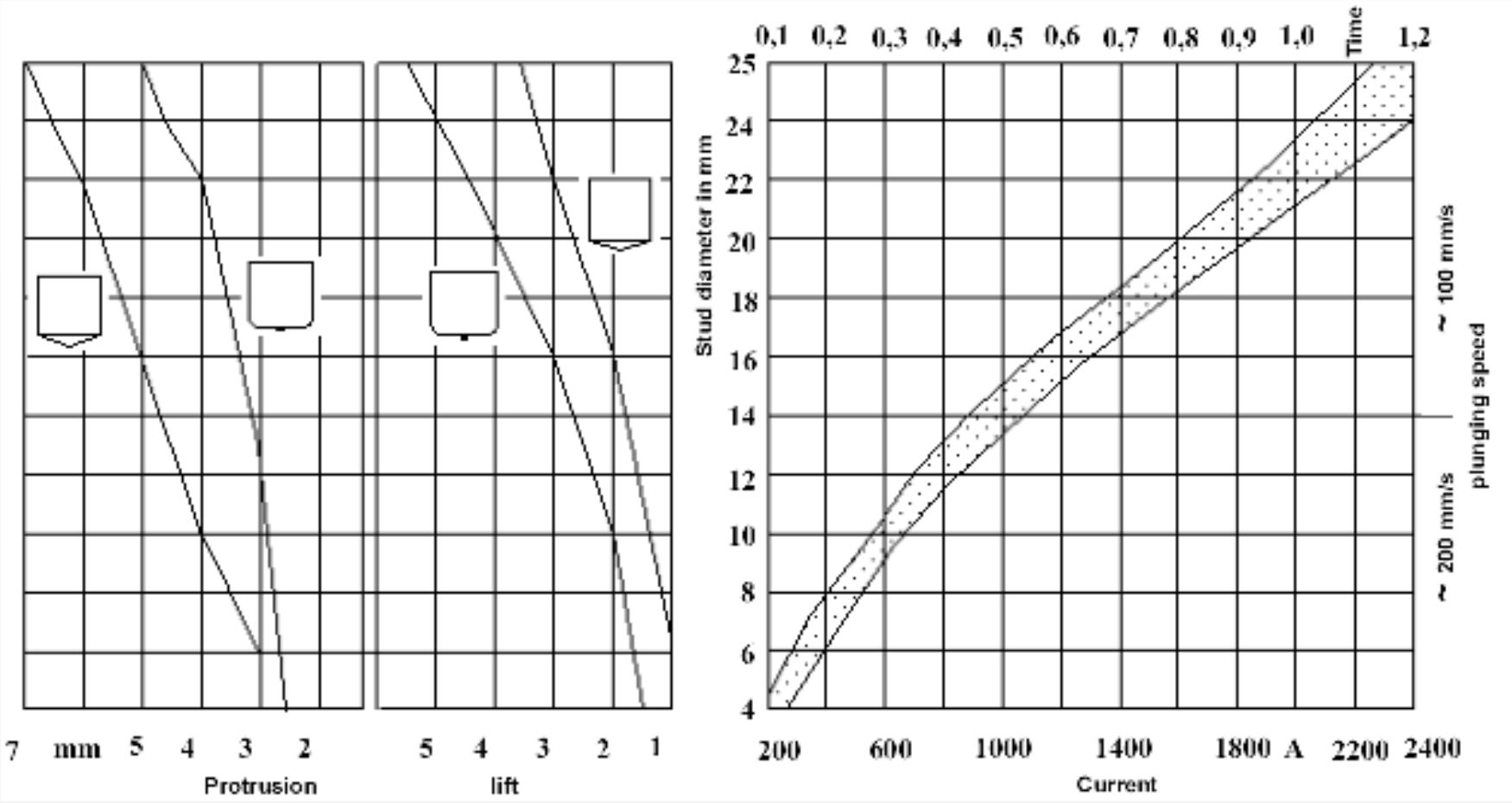
- Steel: the **stud** is connected to the **negative pole** and the parent metal is the positive pole
- Aluminum: opposite polarity has proven successful for special metals

Arc voltage

- values of between 20 V and 40 V
- surface impurities such as oil or grease increase the arc voltage
  shielding gases reduce the arc voltage

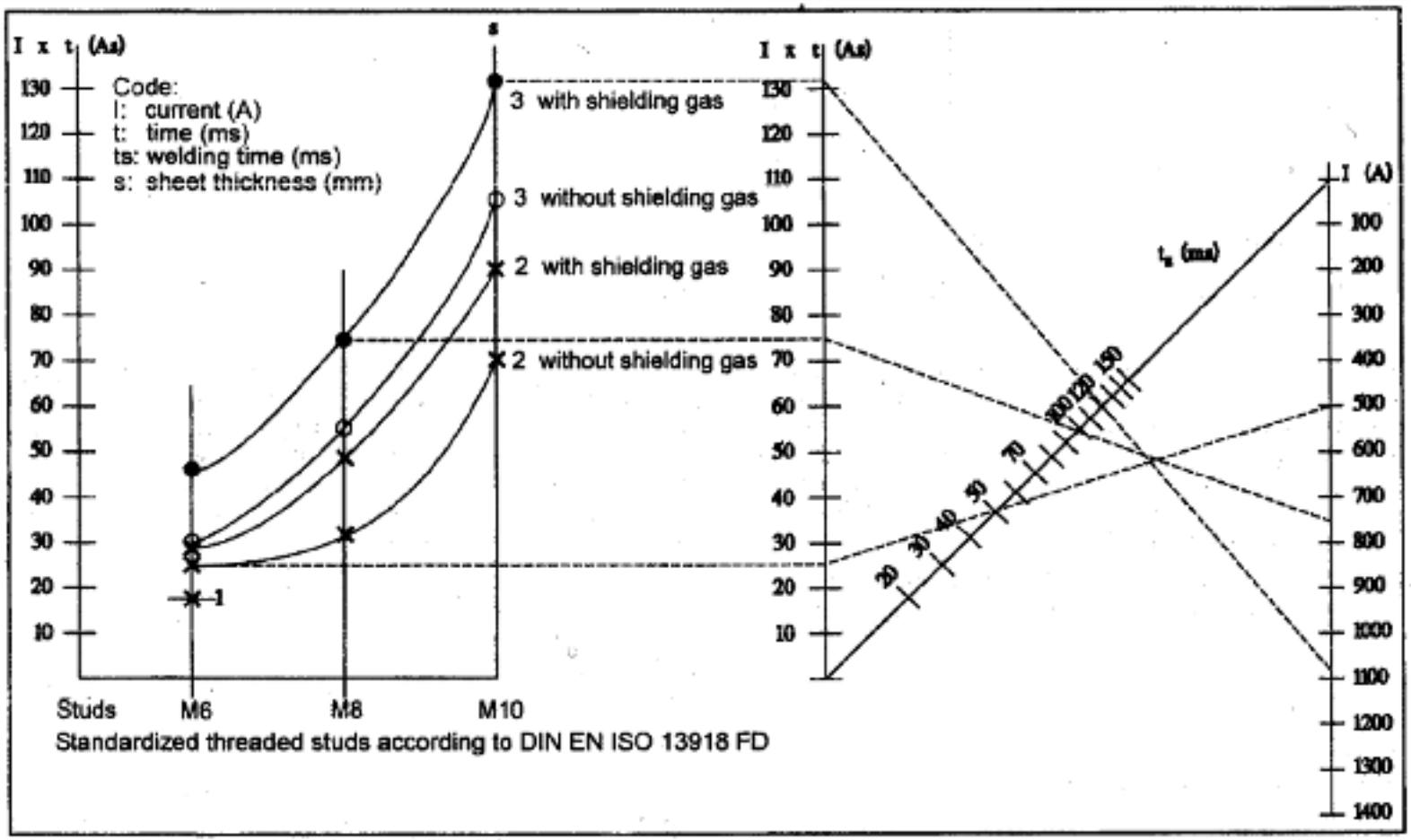
Welding Parameters

ARC Welding parameters (DVS)



Welding Parameters

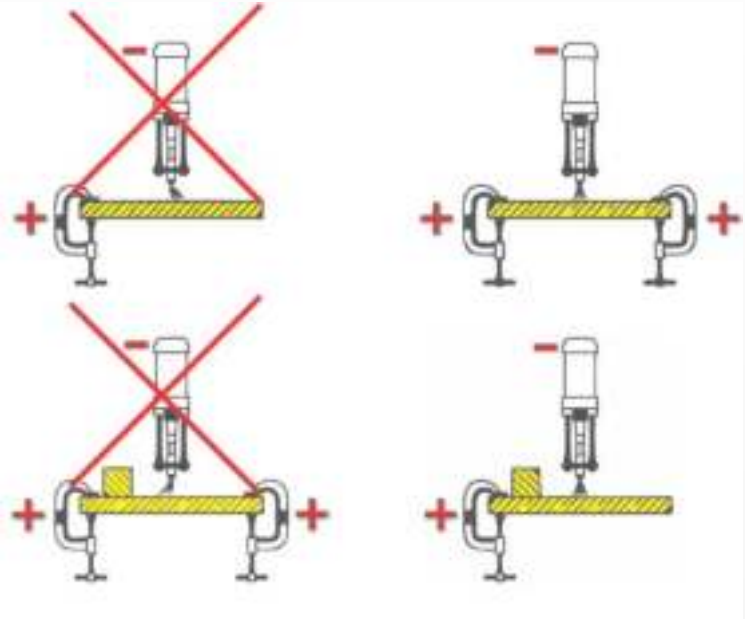
SC Welding parameters (DVS)



Example 1: Stud M10, metal sheet thickness 3 mm, with shielding gas, 132 As: 1100 A / 120 ms
Example 2: Stud M8, metal sheet thickness 3 mm, with shielding gas, 75 As: 750 A / 100 ms
Example 3: Stud M6, metal sheet thickness 2 mm, without shielding gas, 25 As: 500 A / 50 ms

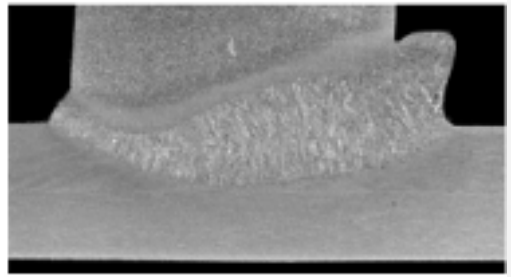
Welding Parameters

Welding parameters – Arc blow



Ceramic Ferrule

Shielding Gas



Macro-Cut

Material Combinations

Material and Weldability

Stud material	Work piece / Parent metal			
	Mild steel ($R_{eH} \leq 460$ N/mm²) **Fine-grain structural steel** ($R_{eH} > 360$ N/mm **C≤ 0,2%**	**Fine grain steel** ($R_e > 360$ N/mm²) **Vanadium alloy Cr-Mo-(Ni) steel** Mo ≤ 0,7%, V ≤ 0,1%	**Austenitic (stainless) steel AISI 300 series 405, 410, 430**	**Aluminium & Al-Mg-Alloys** (Mg ≤ 3.5%) **5000-series**
4.8 (weldable) AISI 1006 to 1020	**a**	b	b ²	-
AISI 300 series	b/**a** [1]	b	**a**	-
EN AW - AlMg 3 (EN AW – 5754) EN AW - AlMg 5 (EN AW – 5019)	-	-	-	b

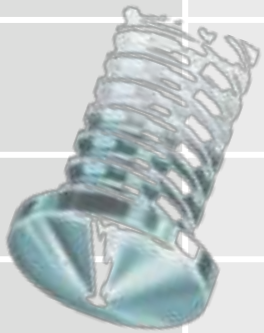
1) Up to ∅ 10 mm in position PA and shielding gas
2) Only short-cycle

a) Highly weldable for any application (e.g: force transfer)
b) Weldable with limits for force transfer
c) Weldable with limits only for heat transfer
- not weldable

ARC / SC Process

Process characteristics

Welding method	Drawn Arc
Power source	Inverter / Transformer (Capacitor)
Power supply	400/460/480V / 50-60Hz (115/230V, single phase)
Welding time	5 ms – 1.5 s
Welding current	max. 3,000 A
Welding diameter	Ø 2 – 25 mm M3 - M24
Stud design	Cone angle
Material	Mild steel, stainless steel Aluminium
Sheet metal thickness	> 1 mm



ARC / SC Process

Process characteristics

Process reliability	Average - High
Visual criteria:	Weld seam
Automation	Possible (up to 12 mm)
Centering for assembling	Difficult
Application Industrial - Jobside Application Automotive Industry Insulation	 Yes Yes HVAC **H**eat, **V**entilation, **C**lima, **A**ircondition

ARC Process

ARC – Advantages

- **Simple adjustment** of the welding parameters (Welding current, welding time, Lift, Protrusion)
- **Wide working range: stud diameter 2 – 25 mm**
- Tolerates surface curvature and imperfections (e.g. light rust, scale, grease and some coatings) burns through parent material laminations
- Gives neat and controlled weld seam
- The only method of stud welding large diameters

SC Process

SC - Advantages

- **Simple adjustment** of the welding parameters (Welding current, welding time, Lift, Protrusion)
- **Working range: stud diameter 2 – 12 mm**

- **Automation is easily possible up to 12 mm** stud diameter
- Can utilise low cost "CD" studs
- This process is more tolerant than CD of uneven or dirty surfaces
- Ferrules are not required - however shielding gas improves weld quality
- This process also lends itself to multi-gun applications

Quality

Applications / Quality check




No defect (with flat bead)	**No defect** (preferably composite, compliant with the requirements by Eurocode 4)	**Pores**	**Shrinkage cracks** (insufficient immersion of the stud)
Welding parameter setting correct	Welding parameter setting correct	Welding current (Energy) to low	Wrong setting at the weld gun / weld gun defect

The shear connectors used in composite construction require specific inspections and quality control

- Testing procedures are specified in the contract documents or by a local building authority
- ISO 14555 / AWS D1.1 specifies the tests and inspections for shear studs

Quality

Process parameters (ARC/SC)

Welding Process and Method

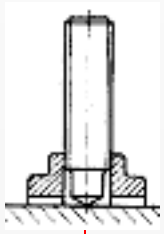
Drawn arc, short cycle

Welding Equipment

Power unit
(Transformer, Inverter, Capacitor*)
Ground cable (length, cross section)
Welding Gun / Welding head

Design / Geometry

Angle
Aluminium-ball
Ceramic ferrule



Welding parameters

Welding Current
Welding time
(*Charging Voltage)
Plunging Speed
Lift (Arc Voltage)
Protrusion
Damping
Gas (flow rate)

Physics

Energy
Current
Resistance
Inductivitance
Magnetism (Arc Blow)

Material

Parent metal	
Studs	ISO 13918
Material combination	ISO 14555
Thickness, Surface	
Shielding Gas:	ISO 14175

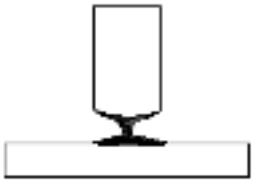
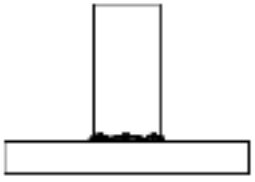
Extent of Examination and Testing

ARC

Visual examination: all studs

Check:

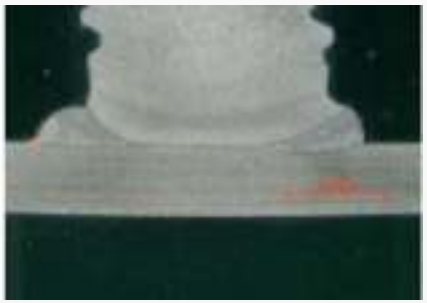
- the **uniformity of shape** and
- the **size of the collar**

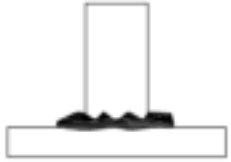
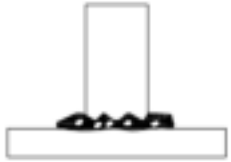
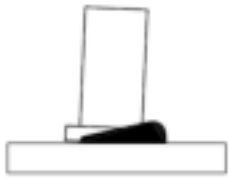
No.	Appearance	Assessment	Recommended corrective actions
Visual examination			
1	Collar regular, bright and complete. Length after weld within tolerances. 	Acceptable (parameters are correct).	None.
2	Reduced diameter weld. Length too long. 	Insufficient protrusion (plunge) or lift. Insufficient centering. Welding power too high. Damping activity too strong.	Increase protrusion (plunge) or lift. Check centering of ceramic ferrule. Reduce current and/or welding time. Reduce damping activity.
3	Reduced, irregular and greyish collar. Length too long. 	Weld energy too low. Ceramic ferrule is moist. Lift too short.	Increase current and/or welding time. Dry out ferrules in oven. Increase lift.

Extent of Examination and Testing

Short-Cycle
Visual examination: all studs
Check:

- the **uniformity of shape** and
- the **size of the collar**



No.	Appearance	Assessment	Recommended corrective actions
Visual examination			
1	Regular collar, no visual defects. 	Acceptable (parameters are correct).	None.
2	Partial weld. 	Weld energy too low. Polarity incorrect.	Increase current and/or welding time. Correct polarity.
3	Large irregular collar. 	Welding time too long.	Reduce welding time.
4	Pores in collar. 	Welding time too long. Current too low. Oxidation of weld pool. Surface contaminated.	Reduce welding time. Increase current. Provide suitable shielding gas. Clean the surface.
5	Collar off centre with undercut. 	Effect of arc blow.	See Table A.8.

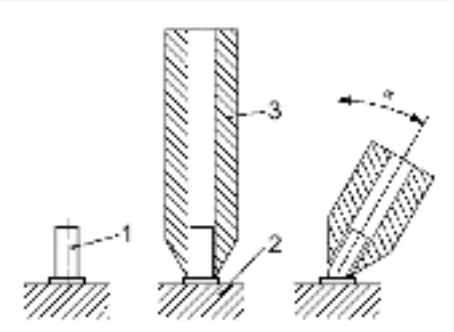
Extent of Examination and Testing

Bend testing

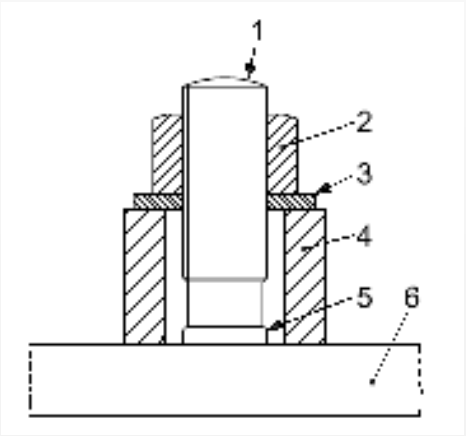
- Bending angle: 60°
- Serves as a simple bench test for approximate checking of the chosen data
- The weld is subjected to bending in a undefined manner
- Passed the test: **No cracks** are found in the weld after bending

Tensile testing

- By using a suitable tension device the welded studs were pulled axially until fracture



1	stud
2	work piece
3	tool
α	bending angle

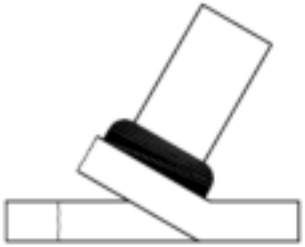
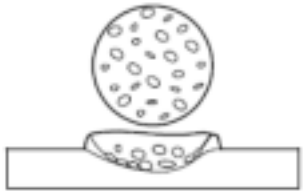
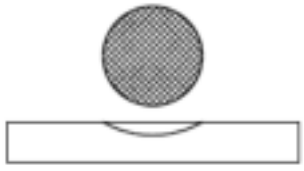


1	stud
2	steel nut
3	washer
4	sleeve
5	collar
6	work piece

Quality

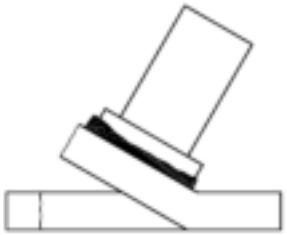
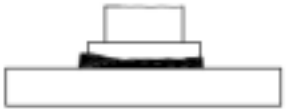
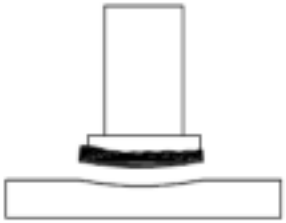
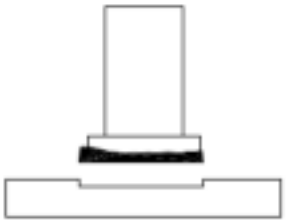
Bend Testing (Fracture examination)

ARC

Fracture examination			
6	Tearing of parent material. 	Acceptable (parameters are correct).	None.
7	Fracture above collar after sufficient deformation. 	Acceptable (parameters are correct).	None.
8	Fracture within the weld. High porosity. 	Weld energy too low. Unclean surface. Material not suitable for stud welding.	Increase current and/or welding time. Clean the surface. Select suitable material.
9	Fracture in HAZ. Greyish fracture surface without sufficient deformation. 	Carbon content of parent material too high. Cooling rate too high.	Select suitable material. Increase welding time. Preheating may be necessary.

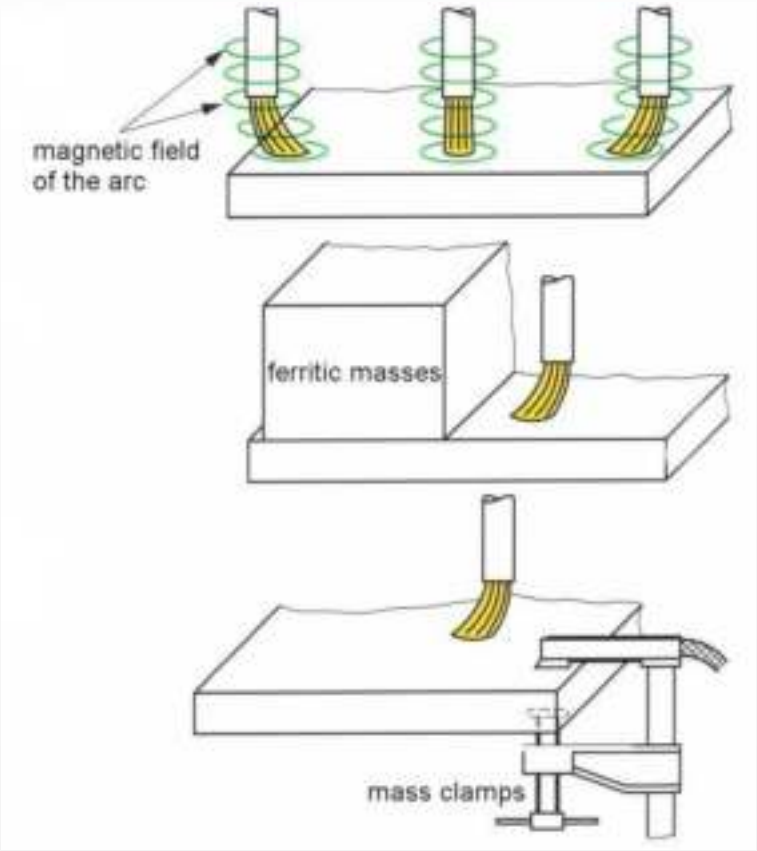
Bend Testing (Fracture examination)

Short-Cycle

No.	Appearance	Assessment	Recommended corrective actions
Fracture examination			
6	Tearing of parent material. 	Acceptable (parameters are correct).	None.
7	Fracture above collar after sufficient deformation. 	Acceptable (parameters are correct).	None.
8	Fracture in HAZ. 	Carbon content of parent material too high. Parent material not suitable.	Select suitable material.
9	Lack of penetration. 	Heat input too low. Incorrect weld polarity.	Increase heat input. Correct weld polarity.

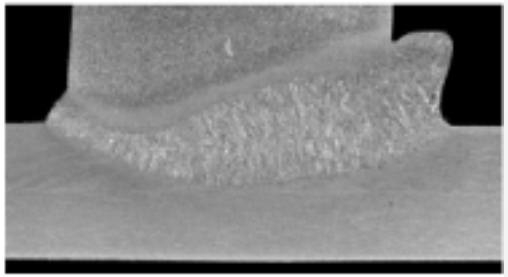
Quality

Welding Practice - Magnetic Arc Blow



Ceramic ferrule

Shielding gas



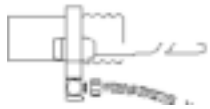
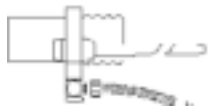
Macro-etched slice

ARC Stud Welding

Application and handling

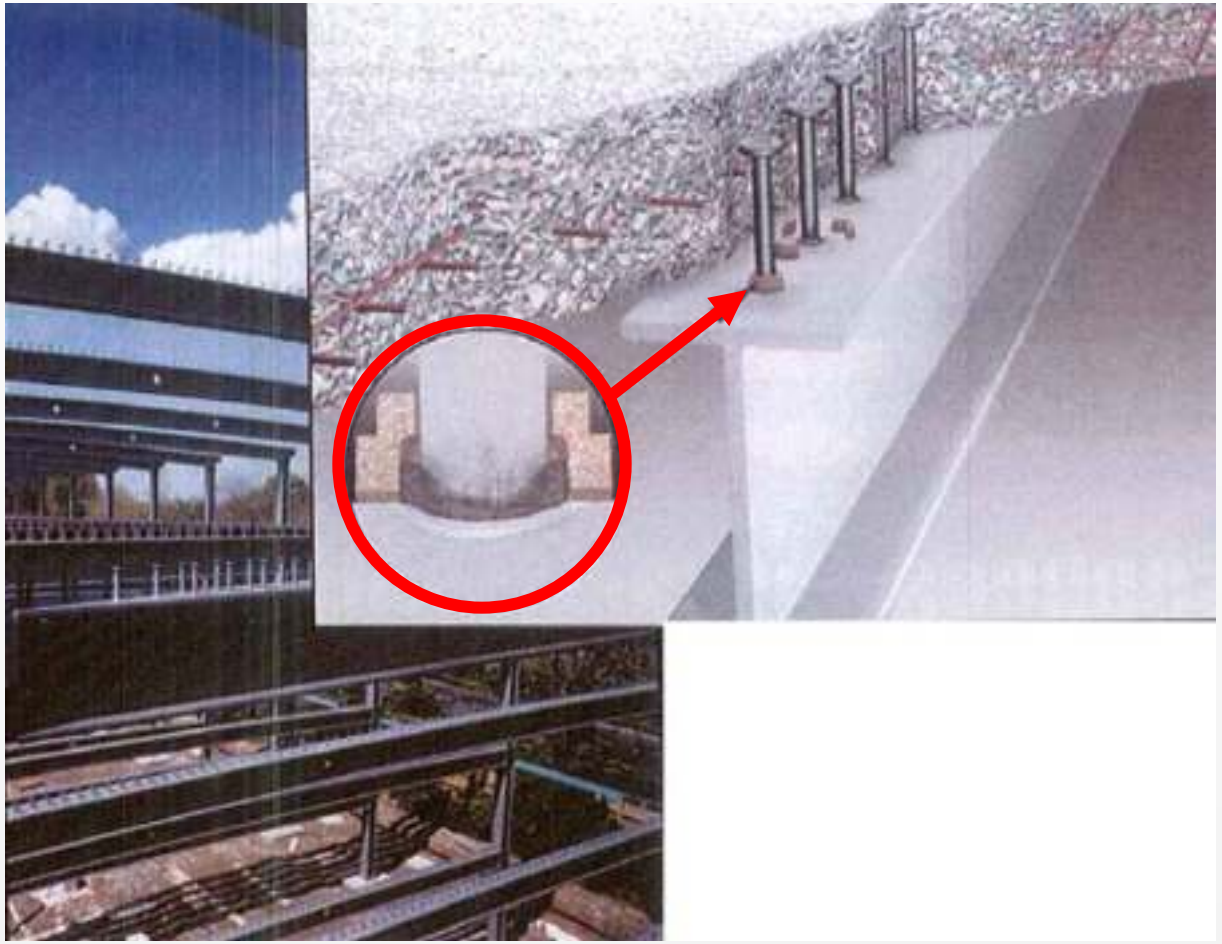
ARC Stud Welding

Application and handling

Weld gun	Market	Application	Recommended Power Unit	Accessories
A 12	Industry	 	IT 1002, IT 2002 IT 50, IT 90, IT 130	 Centering device  centering tube  Tripod - ceramic  Tripod – Shielding gas
A 16	Industry Heavy Duty		IT 1002, IT 2002, IT 3002 IT 50, IT 90, IT 130	 Tripod - ceramic  Tripod – Shielding gas
A 22 **A 25**	Industry Heavy Duty		IT 2002, IT 3002 IT 90, IT 130	 Tripod - ceramic  Tripod – Shielding gas

ARC / SC - Verfahren

Applikations



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