GMA ZAVARIVANJE LEGURA NIKLA

GMA WELDING NICKEL ALLOYS

Christoph MATZ [1)]

Ključne riječi: zavarivanje, kladiranje, plinovi, legure nikla, primjena, CRONIGON®

Key words: welding, cladding, gases, Nickel alloys, application, CRONIGON®

Sažetak: Zavarivanje s CRONIGON® plinovima umjesto čistog argona kod GMA-zavarivanja legura nikla dovodi do povećanja performansi procesa (komada ili m^2) poboljšava kvalitetu, smanjuje popravke, štedi dodatni materijal ili skraćuje pomoćne procese zavarivanja (bolja stabilnost procesa).

Abstract: Usage of CRONIGON® -welding gases instead of straight argon in GMA-welding of Ni-alloys results in an added value by increased process performance (pieces or m^2), improved quality, less rework, savings in filler metal or reduced auxiliary process time (better process stability).

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1. FIELDS OF APPLICATION FOR NICKEL ALLOYS

- Chemical and petrochemical industry
- Industrial furnaces
- Power industry and environmental care
- Oil and gas production
- Off-shore technology
- Automotive industry
- Aeronautics and space industry

2. CLASIFICATION BY DEMAND / APPLICATION

Corosion:

Reducing acids:sufurous acid, phosphoric acid, hydrochloric acid, organic acids

- Oxidizing acids: nitric acid and other oxidizing agents, urea production
- Hot alkaline (KOH, NaOH) and brines (KCl, NaCl)
- Seawater and chloride-containing cooling water
- Hot gases and combustion products (heat-resistant materials)

Mechanical load:

- At very high temperatures (creep – resisting materials)

Nickel alloys – typical alloy systems

Nickel
+ Water, seawater, brines, alkaline
- sulfurous-, nitric and phosphoric acid (inorganic acids), acetic acid (organic acid)

Nickel-Copper
+ Seawater, thinned HCl, hydrofluoric acid, saline solutions, caustic soda
- hihhly concentrated acids (e.g. sulfurous acid, nitric acid, phosphoric acid)

Nickel-Molybdenum
+ good overall resistance

Nickel-Chromium-Iron
+ High-temperature-alloys
- Limited wet corrosion propertis

Nickel-Chromium-Molydbenum
+ Outstanding resistance in virtually all corrosive agents

Nickel-Chromium-Iron-Molydbenum-Copper
+ Higher resistance than austenitic steels, esp. in sulfurous and phosphoric acid
- Lower resistance than Ni-Cr-Mo

3. GENERAL RULES FOR WELDING NICKEL ALLOYS

- Absolute neatness and cleanlines of the workplace
- Use of seperate and special tools
- Cleaning of the work piece directly prior to welding (degreasing)
- Weld preparation preferably with machining
- Adjust welding parameters (e.g. pulse time or voltages)
- Observe interpass temperatures
- The use of modern pulsed arc power source is strongly recommended
- Keep contact with the alloy manufacturer

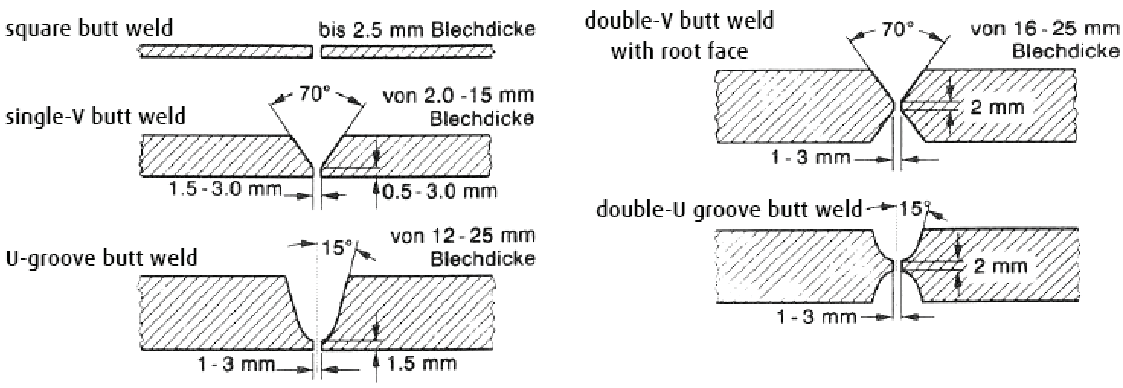
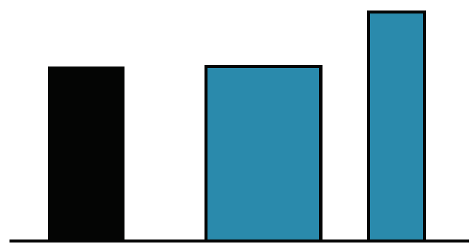


Figure 1. Seam preparation used in Ni-alloy welding

t_P [ms]	2	3	1,5	Wire-Ø 1.2 mm
u_P [V]	35	35	40	



CrNi-Steel		Ni-alloy	
	v_W	slower	faster
	Pos.	PA PB	PA PB PC
		w h	w h q

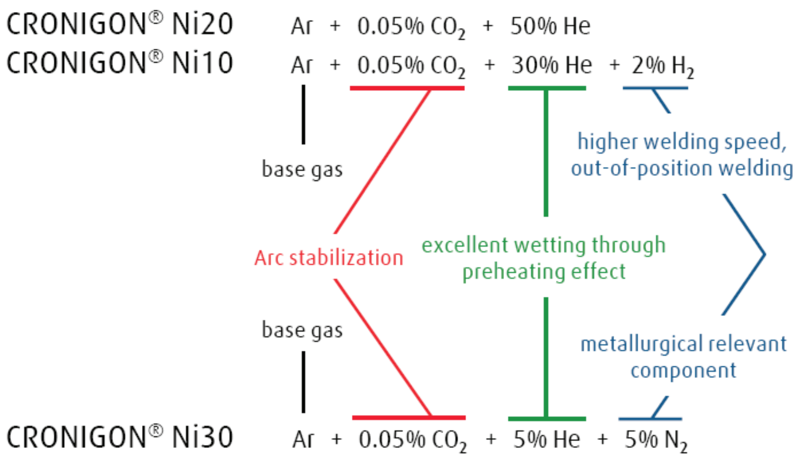
Ideal pulse shape is tuned with respect to
- Base metal
- Welding gas
- Wire-Ø
- Position

Pulse frequency
- is set using t_B or directly
- depends on wire feed speed

Power source
- preprogrammed
- freely adjustable

Figure 2. MAG welding of Ni-alloys – Power source adjustment

4. EFFECTS OF SHIELDING GAS COMPONENTTS



Parent metal:
Nicrofer 5923hMo
(alloy 59, 2.4605)

Filler metal:
Nicrofer S5923
(FM59, 2.4607),
Ø1.2mm

v_{Wire} = 9 m/min
v_W = 60 cm/min

MAG_p - bead-on-plate runs

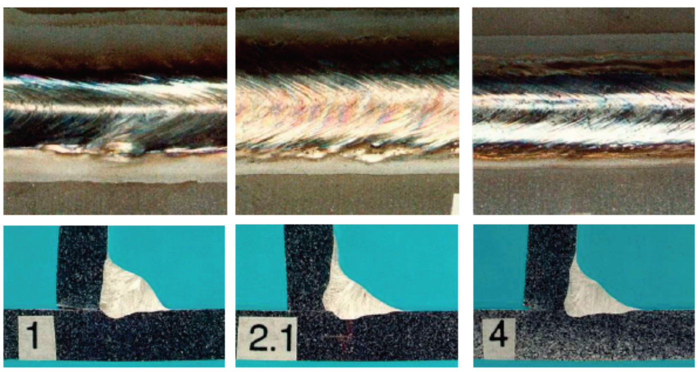
Welding gas	Argon	VARIGON® He50	CRONIGON® Ni20	CRONIGON® Ni10
U_p [V]	37,5	40	41,5	39,5
t_P [ms]	3,0	3,0	3,0	3,0
t_B [ms]	6,0	3,5	5,5	5,5
I_P [A]	200	210	200	215
I_G [A]	40	40	40	40

Figure 3. Welding gas influence on arc stability and surface quality

Parent- and filler metal:
Nicrofer 5923
(alloy 59 + FM59)

Welding process:
MAG_p

Plate thickness:
5 mm



Welding gas	Argon	VARIGON® He50	CRONIGON® Ni10
v_W	25 cm/min	35 cm/min	50 cm/min
v_{Wire}	5 m/min	5 m/min	5 m/min

Figure 4. Welding gas influence on penetration and welding speed

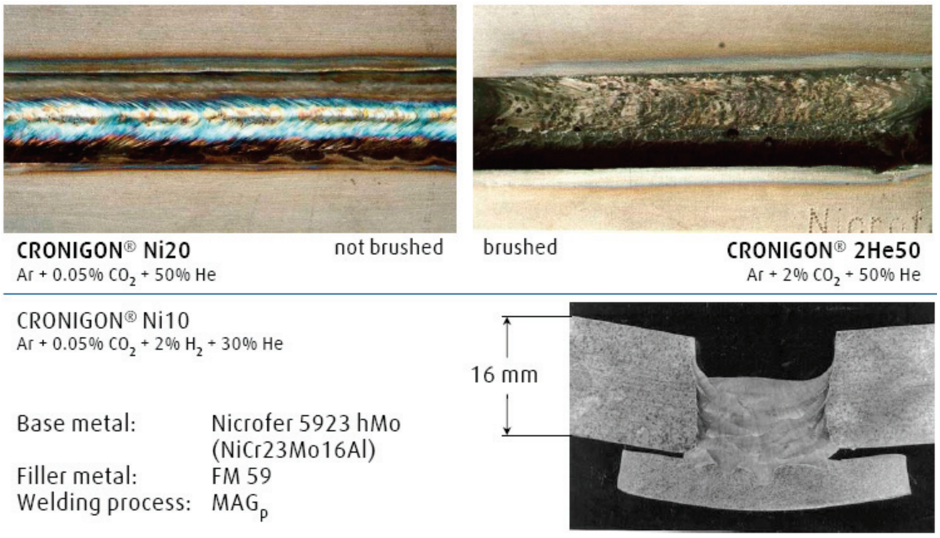


Figure 5. Mag welding of Ni-alloys-shieding gas influence

5. NI-ALLOYS – WELDING GAS OVERVIEW

<u>TIG / Plasma</u>

- Argon
- Argon / Hydrogen (H_2- content usually 2-10%)
- Argon / Helium (He- content usually 10-50%)
- Argon / Nitrogen (N_2- content usually 1-3%)

<u>MAG</u>

- CRONIGON® Ni10 (30%He + 2%H_2 + 0,05%CO_2 + Ar)
- CRONIGON® Ni11 (15%He + 2%H_2 + 0,05%CO_2 + Ar)
- CRONIGON® Ni20 (50%He + 0,05%CO_2 + Ar)
- CRONIGON® Ni10 (5%He + 5%N_2 + 0,05%CO_2 + Ar)

6. MATERIAL TESTED

So far CRONIGON® Ni10 was successfully tested on:

- alloy B-2 (2.4617, NiMo28)
- alloy 625 (2.4856, NiCr22Mo9Nb)
- alloy 59 (2.4605, NiCr23Mo16Al)
- alloy 718 (2.4663, NiCr23Co12Mo)
- FM 82 (2.4806, UNS: N06082, SG-NiCr20Nb)

and several others.

7. CLADDING OF FINNED TUBES FOR WASTE INCINERATION PLANTS

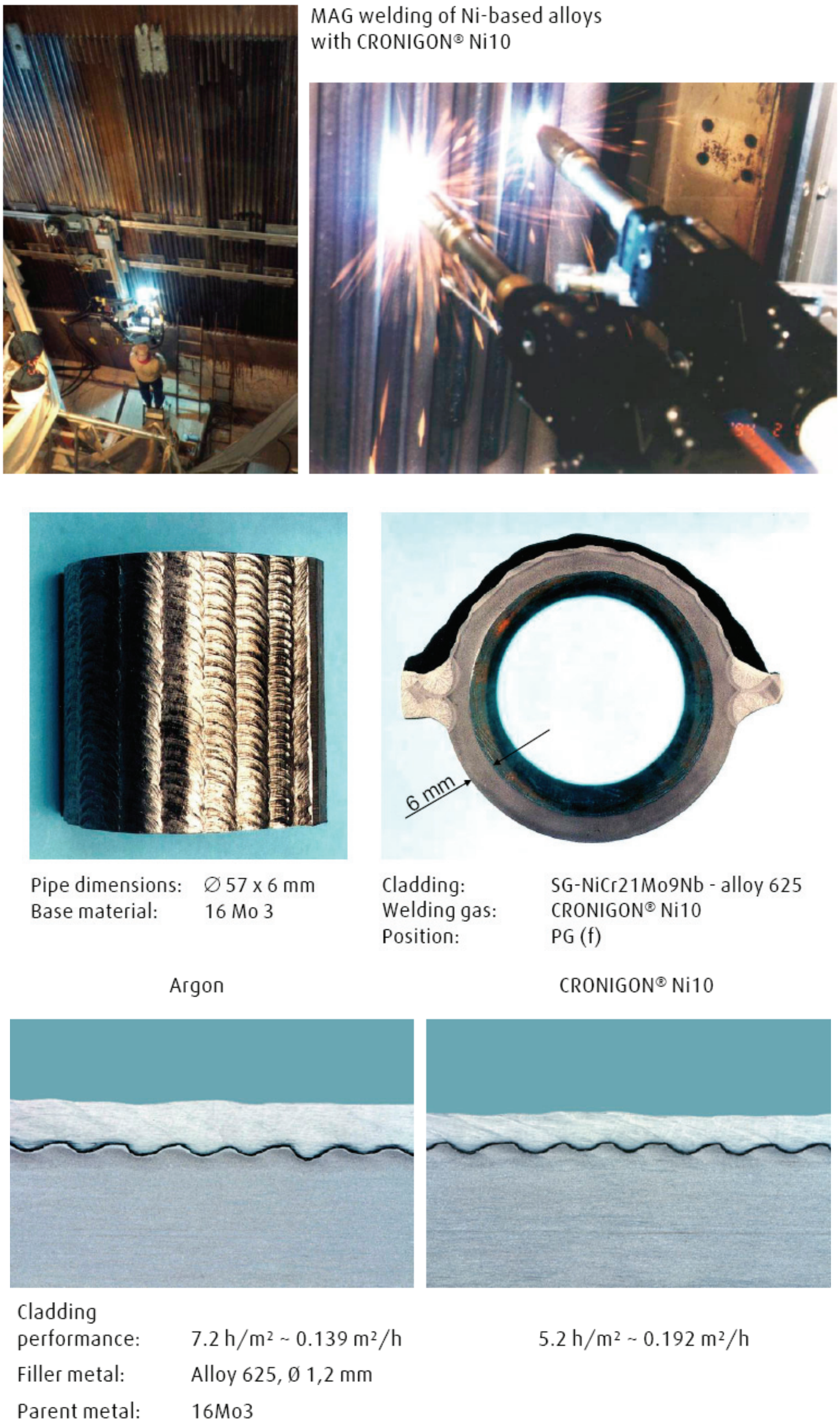


Figure 6. Cladding of finned tubes for waste incinetarion plants

8. WELDING GAS INFLUENCE IN CMT-WELDING

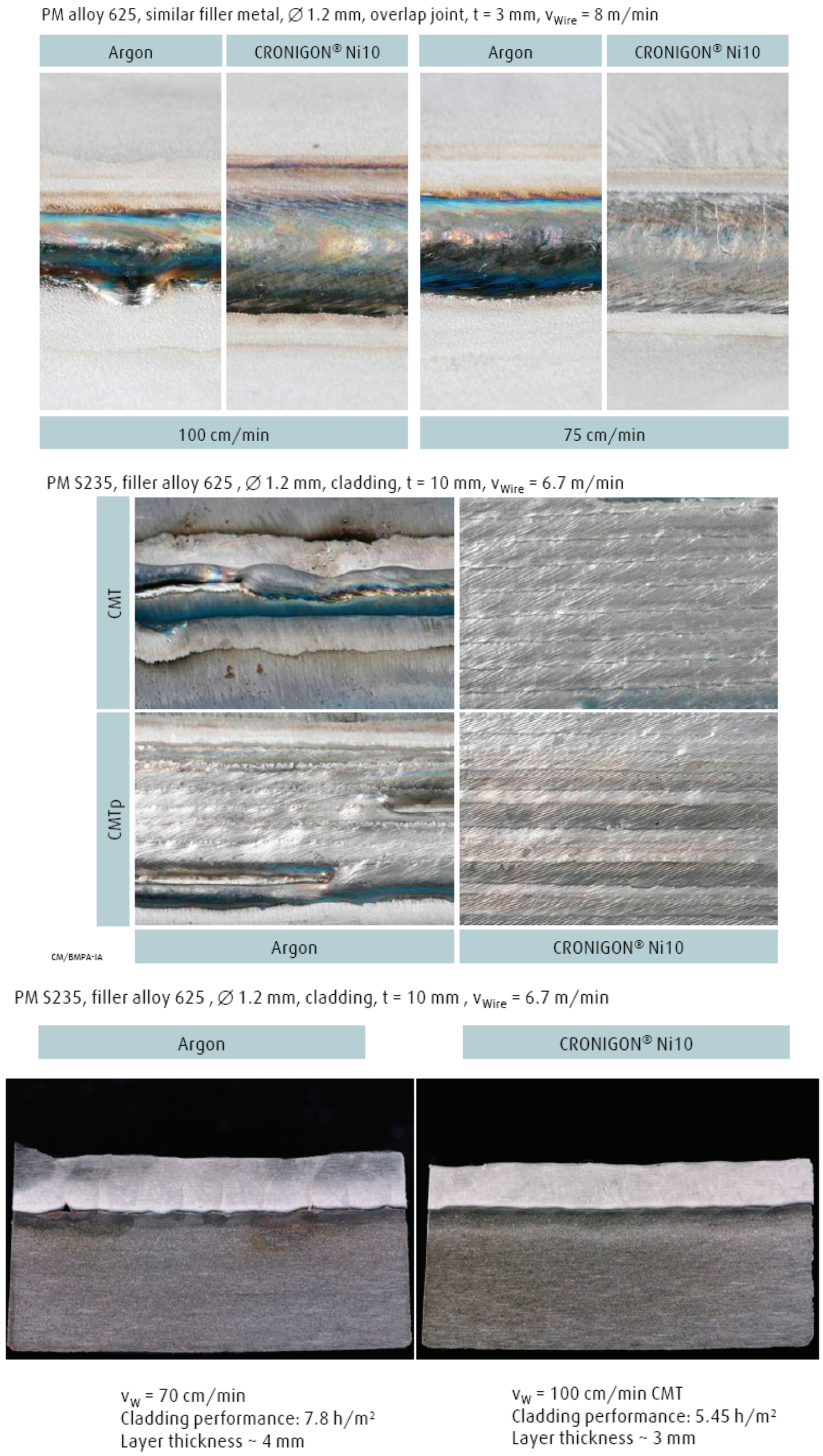


Figure 7. Welding gas influence in CMT-welding

9. U/I – ANALYSIS

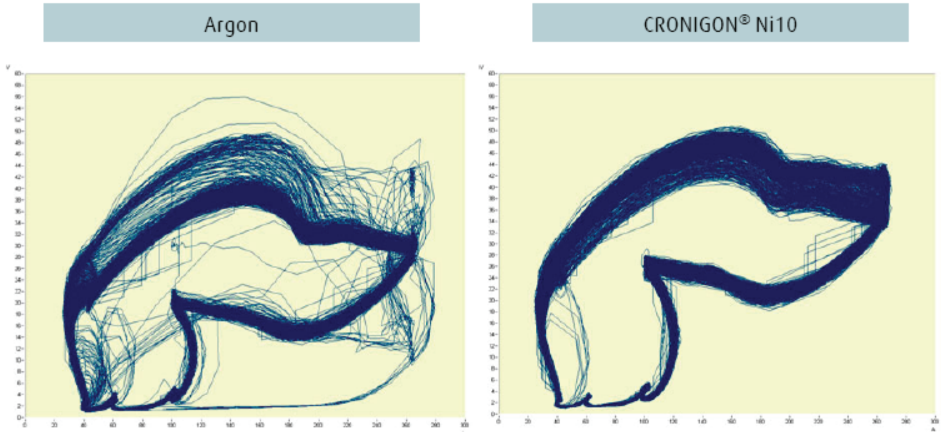


Figure 8. U/I Analysis

10. SUPPLAY SOLUTION: i-GAS PRINCIPLE FOR CRONIGON® Ni10/1

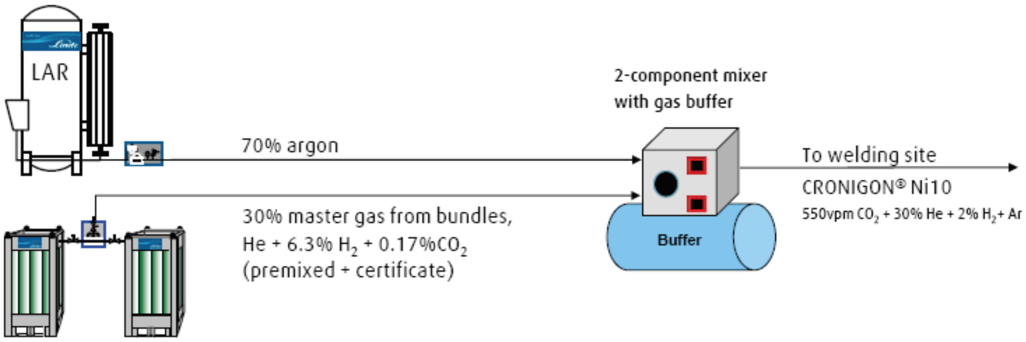


Figure 9. Supply solution: i-GAS principle for CRONIGON® Ni10/1

- The giggest part of the welding gas is taken from the "cheap" already existing argon pipeline.
- The relatively small amount of helium hydrogen and CO_2 is taken from cylinders or bundles as a premixed "Master-Gas".
- The 4-component welding gas is made with a standard 2-component gas mixing device
- A CO_2 meter to monitor the exact amount of the CO_2- doping also informs about He and H_2 content of the gas mix

11. SUPPLAY SOLUTION: i-GAS PRINCIPLE FOR CRONIGON® Ni10/2

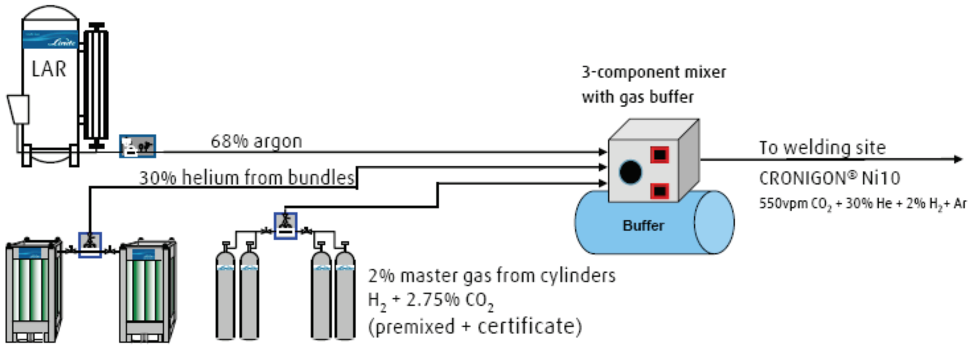


Figure 10. Supply solution: i-GAS principle for CRONIGON® Ni10/2

a. Advantage: Much greater flexibility for He and H_2-contents
b. Drawback: Higher handling sffort, more complicated 3-component gas mixer
c. A CO_2 meter to monitor the exact amount of the CO_2- doping also informs about H_2 content of the gas mix

12. WRAP-UP

All quality requirements in MAG-welding of Ni-alloys under CRONIGON® -welding gases:

- mechanical-technological values
- corrosion resistance
- crack-resistance
- flexibility during application
- spatter free droplet transfer

were met

Improved economy of MAG_p and welding processes with regulated short-arc (CMT, coldArc®, STT etc.) by using CRONIGON® -welding gases:

- higher welding speed respectively cladding perfomance
- increased machine uptime(stabilized process, less prone to interference)
- reduction of rework (spatter removal, smoothing of welds)
- reduced filler metal consumption (more precise control over cladding thickness)
- less repair welding (savings in work hours, grinding devices and expensive filler metal).

Usage of CRONIGON® -welding gases instead of straight argon in GMA-welding of Ni-alloys results in an added value by increased process perfomance (pieces or m^2), improved quality, less rework, savings in filler metal or reduced auxiliary proces time (beter process stability).

13. REFERENCES

[1] Ammann, Th., Heinemann, J.: Influence of shielding gases on corrosion properties of nickel alloy weldments. Linde Gas publication, 2005.

[2] Geipl, H.: "Process for shielded arc welding and shielding gas therefor." European Patent EP 0 639 427 (1997).

[3] Geipl, H.: Pulsed MAGM welding of nickel alloy. Linde Gas publication, 1997.

[4] Heubner, U., Klöwer, J.: Nickelwerkstoffe und hochlegierte Sonderedelstähle. Eigenschaften - Verarbeitung - Anwendungen. ThyssenKrupp VDM publication. Expert-Verlag, 2002.

GMA welding of nickel alloys.

Dipl.-Ing. EWE Christoph Matz

SBZ 2009 Slavonski Brod, 11.-13.11.2009

Fields of application for Nickel alloys

- Chemical and petrochemical industry
- Industrial furnaces
- Power industry and environmental care
- Oil and gas production
- Off-shore technology
- Automotive industry
- Aeronautics and space industry

Classification by demand / application

THE LINDE GROUP

Corrosion:

- Reducing acids:
  sulfurous acid, phosphoric acid, hydrochloric acid, organic acids
- Oxidizing acids:
  nitric acid and other oxidizing agents, urea production
- Hot alkaline (KOH, NaOH) and brines (KCl, NaCl)
- Seawater and chloride-containing cooling water
- Hot gases and combustion products
  (heat-resistant materials)

Mechanical load:

- At very high temperatures
  (creep-resisting materials)

Nickel alloys - typical alloy systems

THE LINDE GROUP

Nickel

\+ Water, seawater, brines, alkaline

\- sulfurous-, nitric and phosphoric acid (inorganic acids), acetic acid (organic acids)

Nickel-Copper

\+ Seawater, thinned HCL, hydrofluoric acid, saline solutions, caustic soda

\- highly concentrated acids (e.g. sulfurous acid, nitric acid, phosphoric acid)

Nickel-Molybdenum

\+ good overall resistance

Nickel-Chromium-Iron

\+ High-temperature-alloys

\- Limited wet corrosion properties

Nickel-Chromium-Molybdenum

\+ Outstanding resistance in virtually all corrosive agents

Nickel-Chromium-Iron-Molybdenum-Copper

\+ Higher resistance than austenitic steels, esp. in sulfurous and phosphoric acid

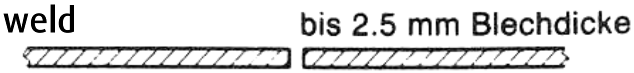
\- Lower resistance than Ni-Cr-Mo

General rules for welding Nickel alloys

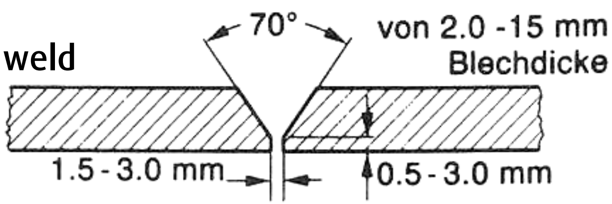
- Absolute neatness and cleanliness of the workplace
- Use of separate and special tools
- Cleaning of the work piece directly prior to welding (degreasing)
- Weld preparation preferably with machining
- Adjust welding parameters (e.g. pulse time or voltages)
- Observe interpass temperatures
- The use of modern pulsed arc power sources is strongly recommended
- Keep contact with the alloy manufacturer

Seam preparation used in Ni-alloy welding

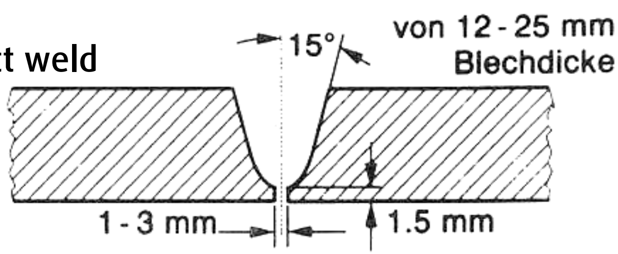
square butt weld



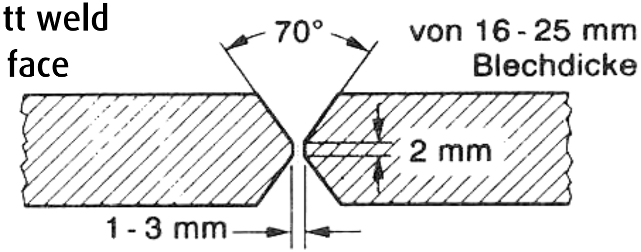
single-V butt weld



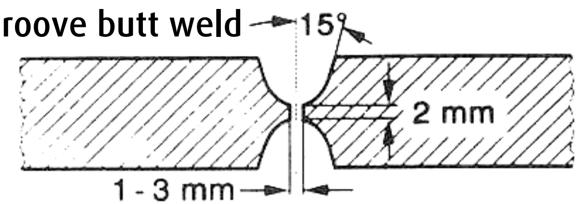
U-groove butt weld



double-V butt weld
with root face

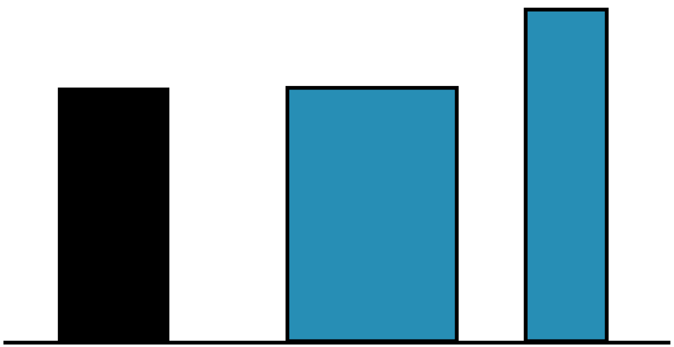


double-U groove butt weld



MAG welding of Ni-alloys - Power source adjustment

t_P [ms]	2	3	1,5	Wire-Ø 1.2 mm
u_P [V]	35	35	40	



CrNi-Steel		Ni-alloy	
	v_W	slower	faster
	Pos.	PA PB	PA PB PC
		w h	w h q

Ideal pulse shape is tuned with respect to

- Base metal
- Welding gas
- Wire-Ø
- Position

Pulse frequency

- is set using t_B or directly
- depends on wire feed speed

Power source

- preprogrammed
- freely adjustable

Effects of shielding gas components

CRONIGON® Ni20 — Ar + 0.05% CO_2 + 50% He

CRONIGON® Ni10 — Ar + 0.05% CO_2 + 30% He + 2% H_2

- Ar: base gas
- 0.05% CO_2: Arc stabilization
- He: excellent wetting through preheating effect
- 2% H_2: higher welding speed, out-of-position welding
- 5% N_2: metallurgical relevant component

CRONIGON® Ni30 — Ar + 0.05% CO_2 + 5% He + 5% N_2

Welding gas influence on arc stability and surface quality

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Parent metal:
Nicrofer 5923hMo
(alloy 59, 2.4605)

Filler metal:
Nicrofer S5923
(FM59, 2.4607),
Ø1.2mm

v_{Wire} = 9 m/min
v_W = 60 cm/min

MAG_p – bead-on-plate runs

Welding gas	Argon	VARIGON® He50	CRONIGON® Ni20	CRONIGON® Ni10
U_p [V]	37,5	40	41,5	39,5
t_P [ms]	3,0	3,0	3,0	3,0
t_B [ms]	6,0	3,5	5,5	5,5
I_P [A]	200	210	200	215
I_G [A]	40	40	40	40

Welding gas influence on penetration and welding speed

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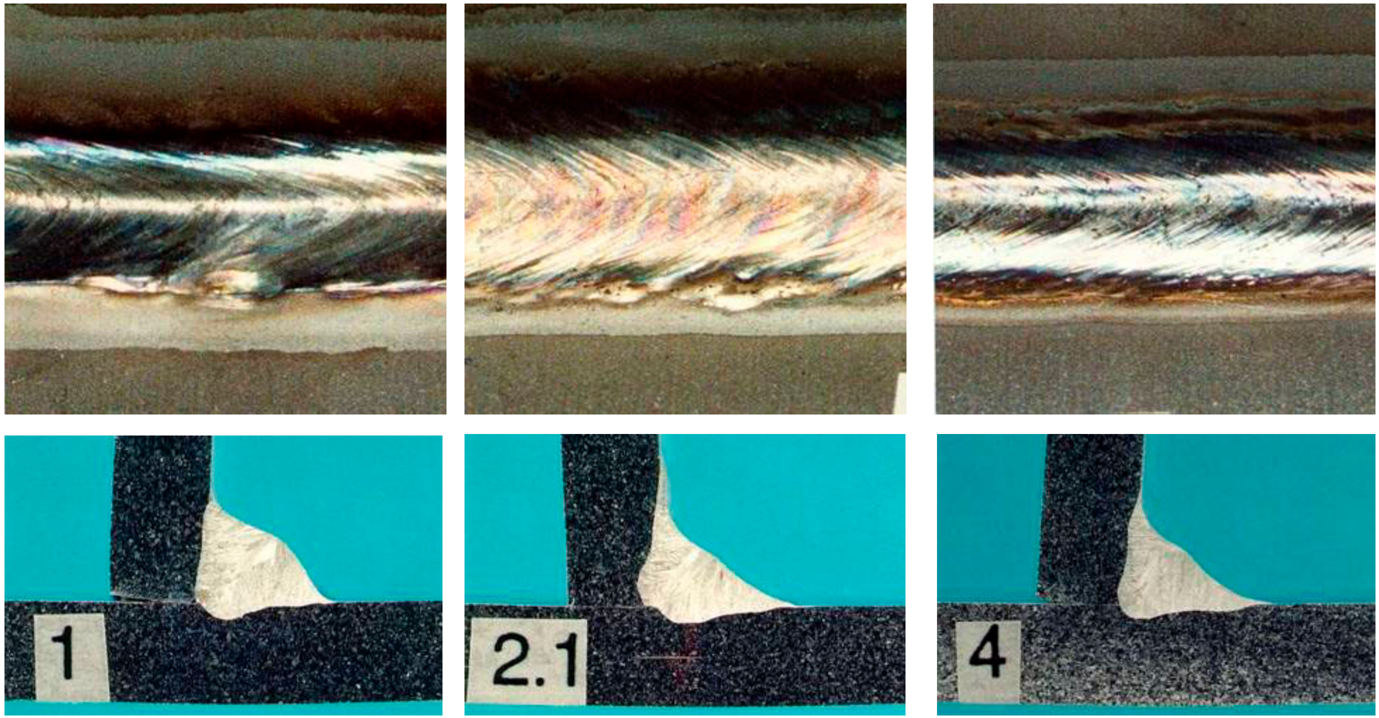
Parent- and filler metal:
Nicrofer 5923
(alloy 59 + FM59)

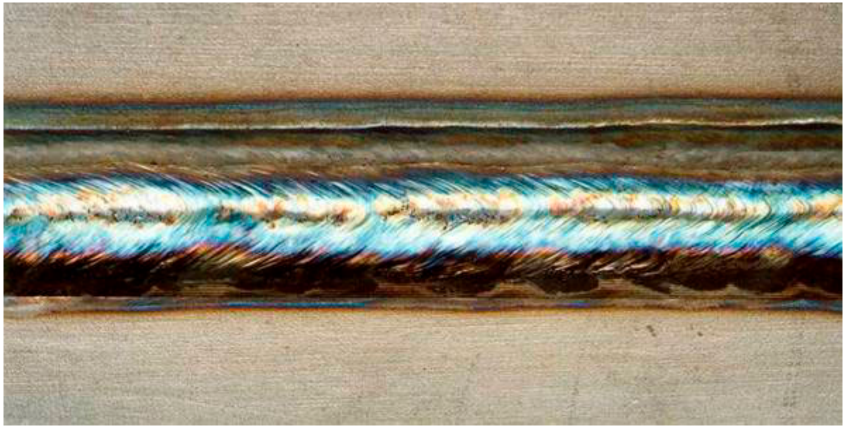
Welding process:
MAG_p

Plate thickness:
5 mm



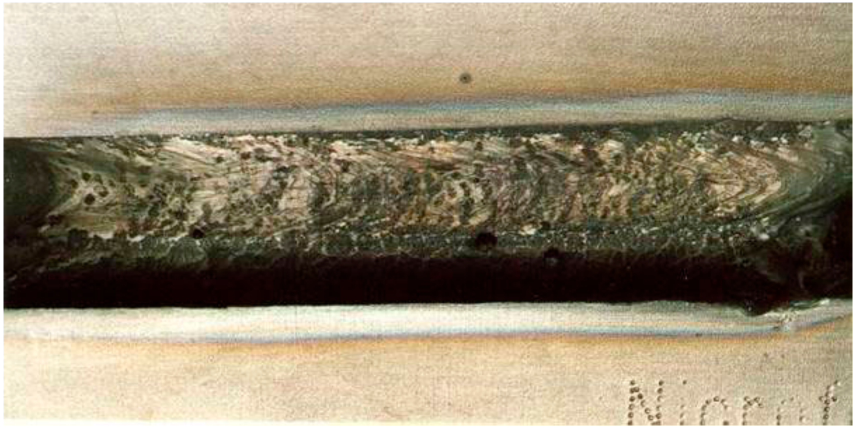
Welding gas	Argon	VARIGON® He50	CRONIGON® Ni10
v_W	25 cm/min	35 cm/min	50 cm/min
v_{Wire}	5 m/min	5 m/min	5 m/min

MAG welding of Ni-alloys - shielding gas influence



CRONIGON® Ni20
Ar + 0.05% CO_2 + 50% He

not brushed

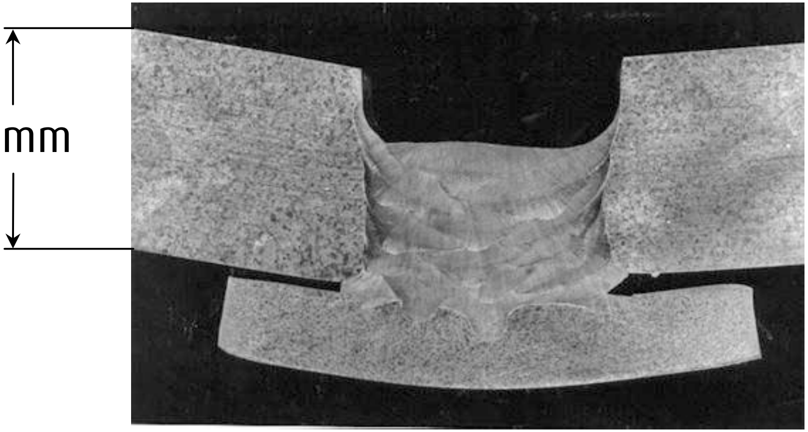


brushed

CRONIGON® 2He50
Ar + 2% CO_2 + 50% He

CRONIGON® Ni10
Ar + 0.05% CO_2 + 2% H_2 + 30% He

Base metal:	Nicrofer 5923 hMo (NiCr23Mo16Al)
Filler metal:	FM 59
Welding process:	MAG_p



Ni-alloys - Welding gas overview

TIG / Plasma

- Argon
- Argon / Hydrogen (H$_2$-content usually 2-10%)
- Argon / Helium (He-content usually 10-50%)
- Argon / Nitrogen (N$_2$-content usually 1-3%)

MAG

- CRONIGON® Ni10 (30% He + 2% H_2 + 0.05% CO_2 + Ar)
- CRONIGON® Ni11 (15% He + 2% H_2 + 0.05% CO_2 + Ar)
- CRONIGON® Ni20 (50% He + 0.05% CO_2 + Ar)
- CRONIGON® Ni30 (5% He + 5% N_2 + 0.05% CO_2 + Ar)

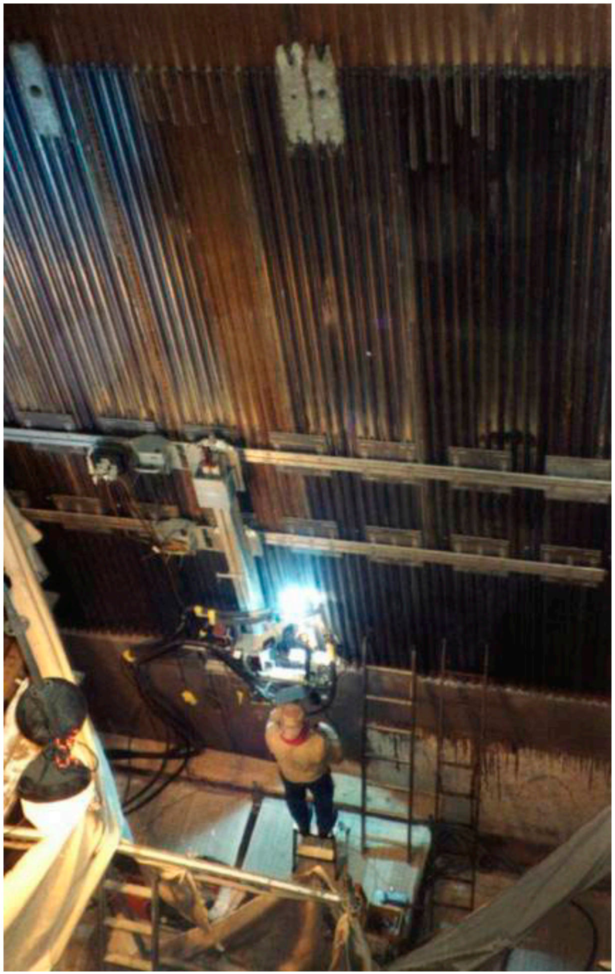
Materials tested

So far CRONIGON® Ni10 was successfully tested on:

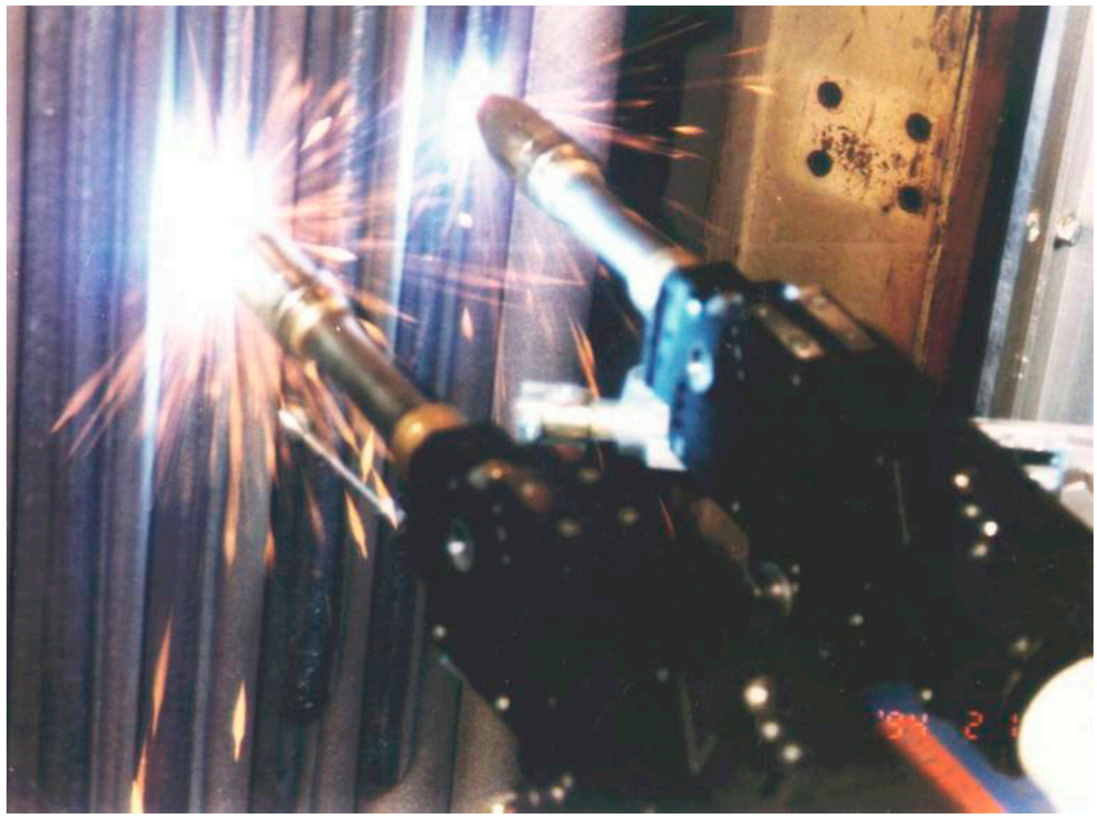
- alloy B-2 (2.4617, NiMo28)
- alloy 625 (2.4856, NiCr22Mo9Nb)
- alloy 59 (2.4605, NiCr23Mo16Al)
- alloy 718 (2.4663, NiCr23Co12Mo)
- alloy 617 (2.4663, NiCr23Co12Mo)
- FM82 (2.4806, UNS: N06082, SG-NiCr20Nb)

and several others.

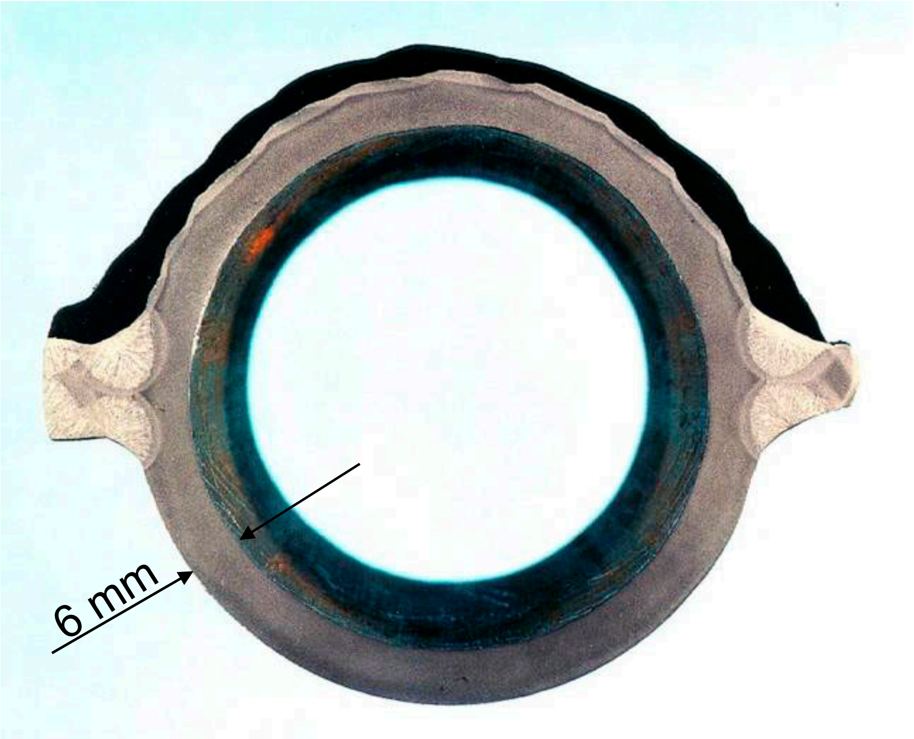
Cladding of finned tubes for waste incineration plants



MAG welding of Ni-based alloys
with CRONIGON® Ni10



Cladding of finned tubes for waste incineration plants



Pipe dimensions:	∅ 57 x 6 mm
Base material:	16 Mo 3

Cladding:	SG-NiCr21Mo9Nb - alloy 625
Welding gas:	CRONIGON® Ni10
Position:	PG (f)

Cladding of finned tubes for waste incineration plants

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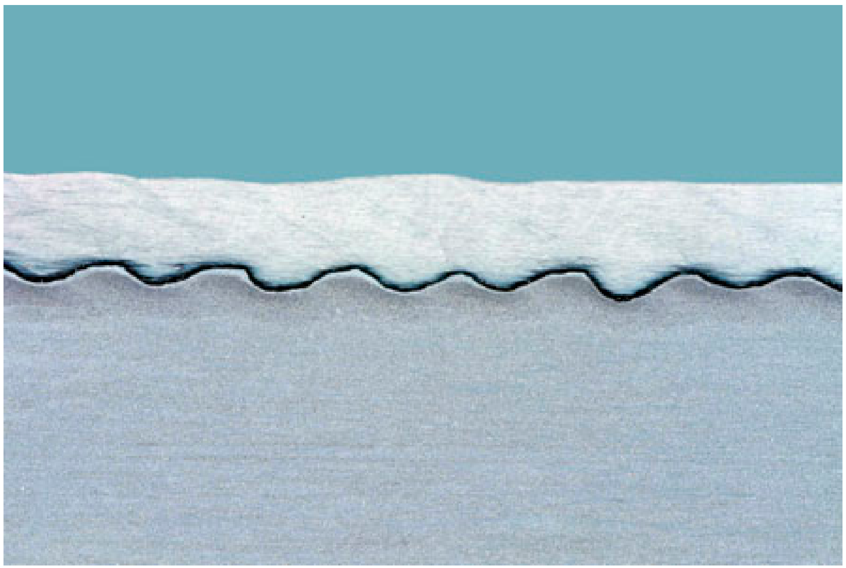
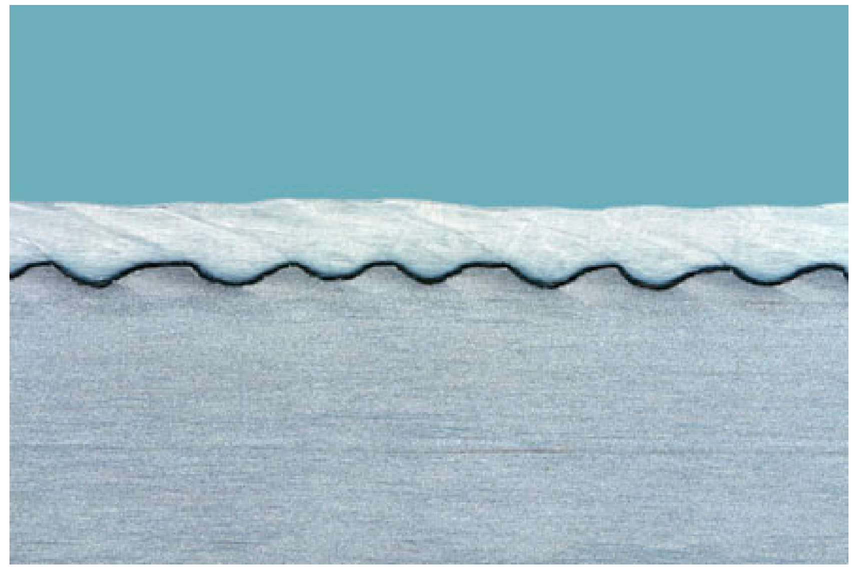
Argon



CRONIGON® Ni10

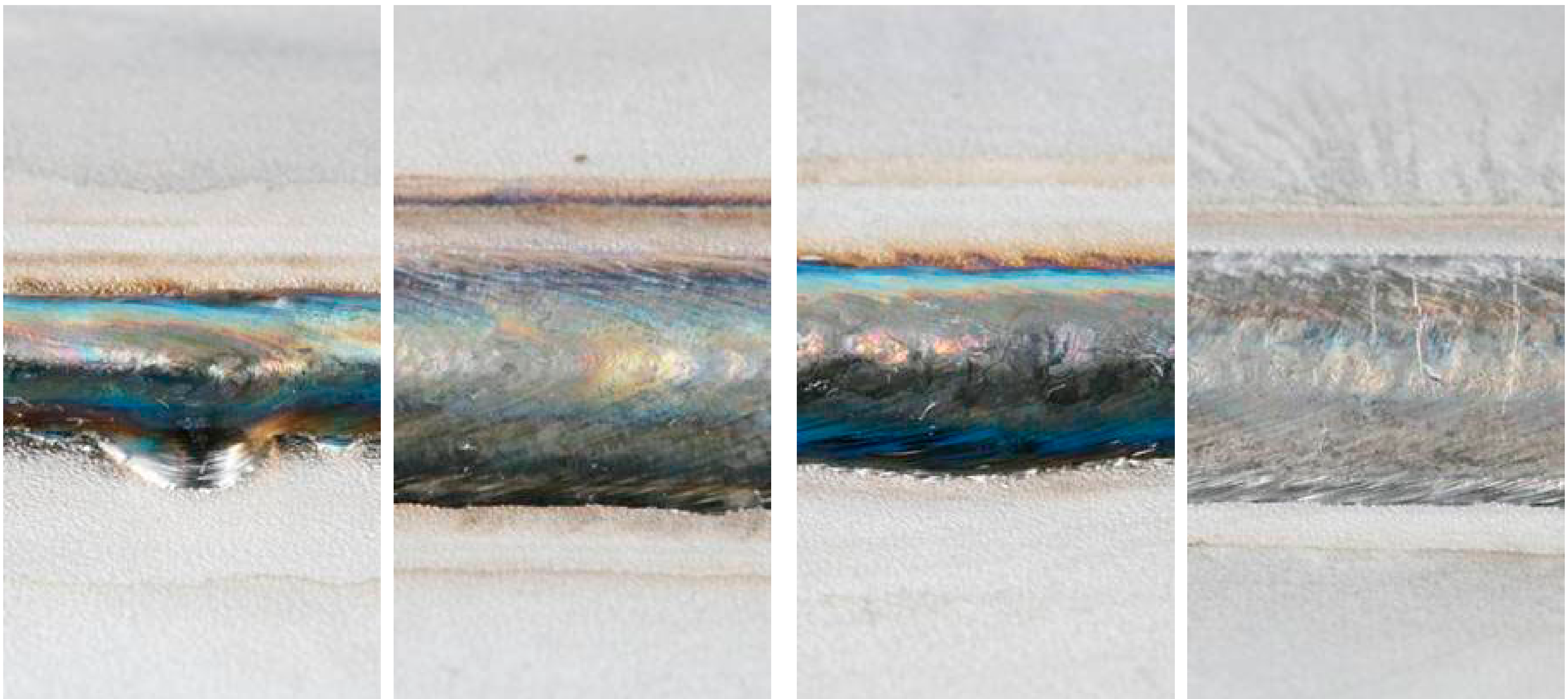


	Argon	CRONIGON® Ni10
Cladding performance:	7.2 h/m² ~ 0.139 m²/h	5.2 h/m² ~ 0.192 m²/h
Filler metal:	Alloy 625, Ø 1,2 mm	
Parent metal:	16Mo3	

Welding gas influence in CMT-welding

PM alloy 625, similar filler metal, ∅ 1.2 mm, overlap joint, t = 3 mm, v_{Wire} = 8 m/min

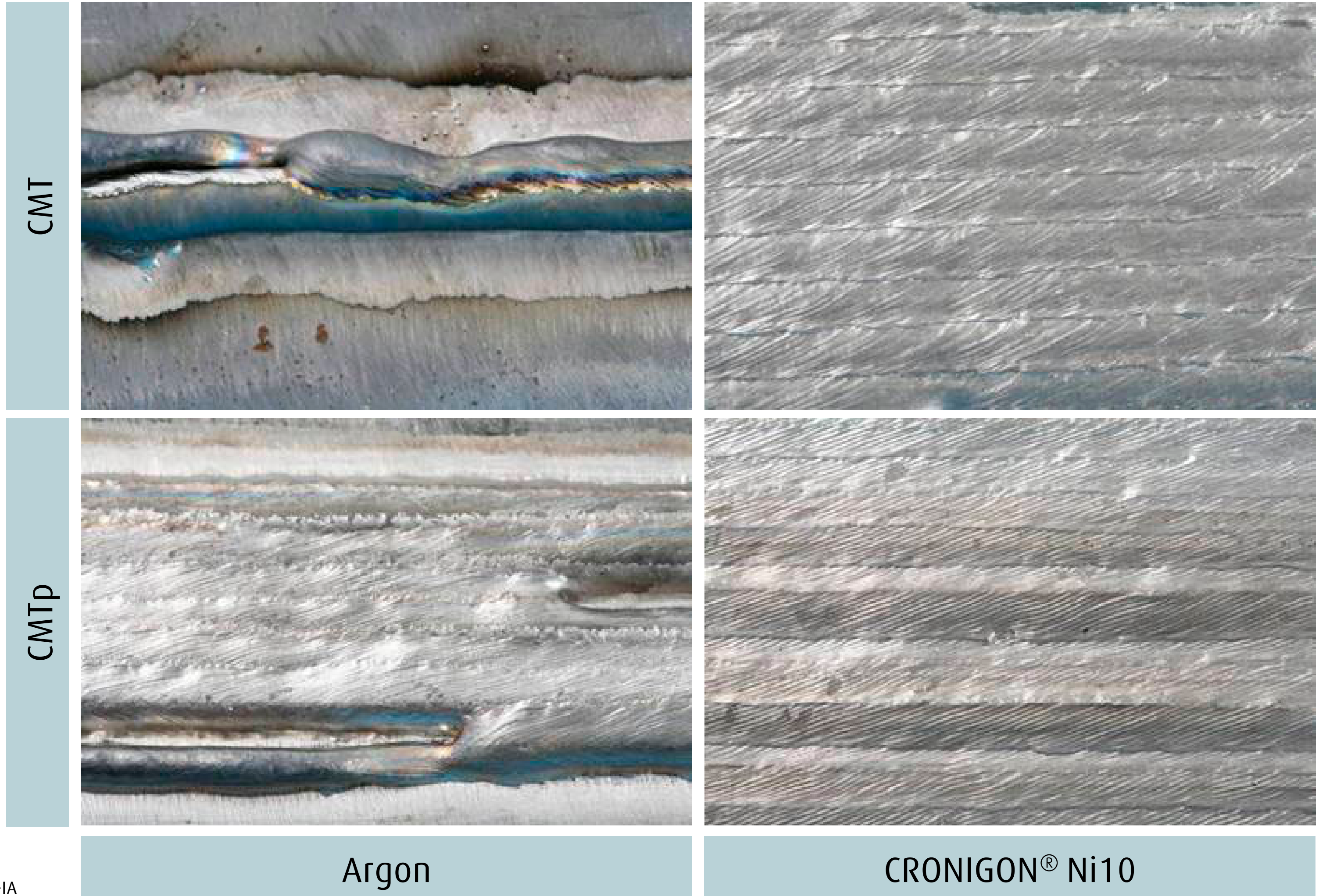
Argon	CRONIGON® Ni10	Argon	CRONIGON® Ni10



100 cm/min	75 cm/min

Welding gas influence in CMT-welding

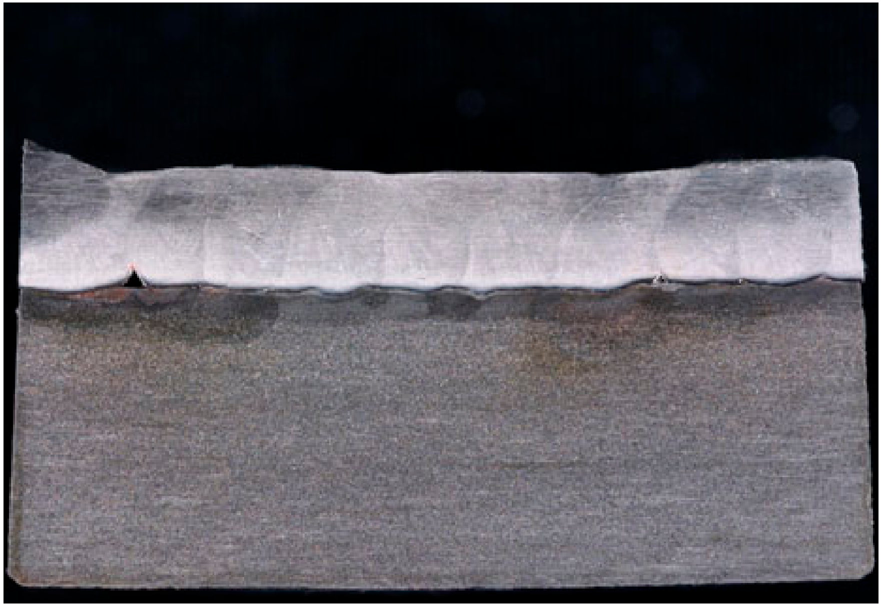
PM S235, filler alloy 625 , ∅ 1.2 mm, cladding, t = 10 mm, v_{Wire} = 6.7 m/min

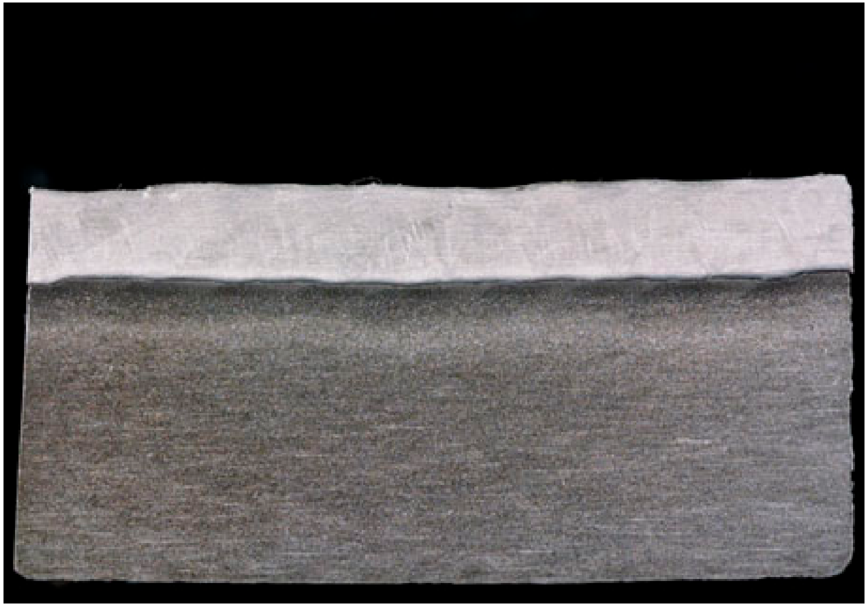


Welding gas influence in CMT-welding

PM S235, filler alloy 625 , ∅ 1.2 mm, cladding, t = 10 mm , v_{Wire} = 6.7 m/min

Argon	CRONIGON® Ni10



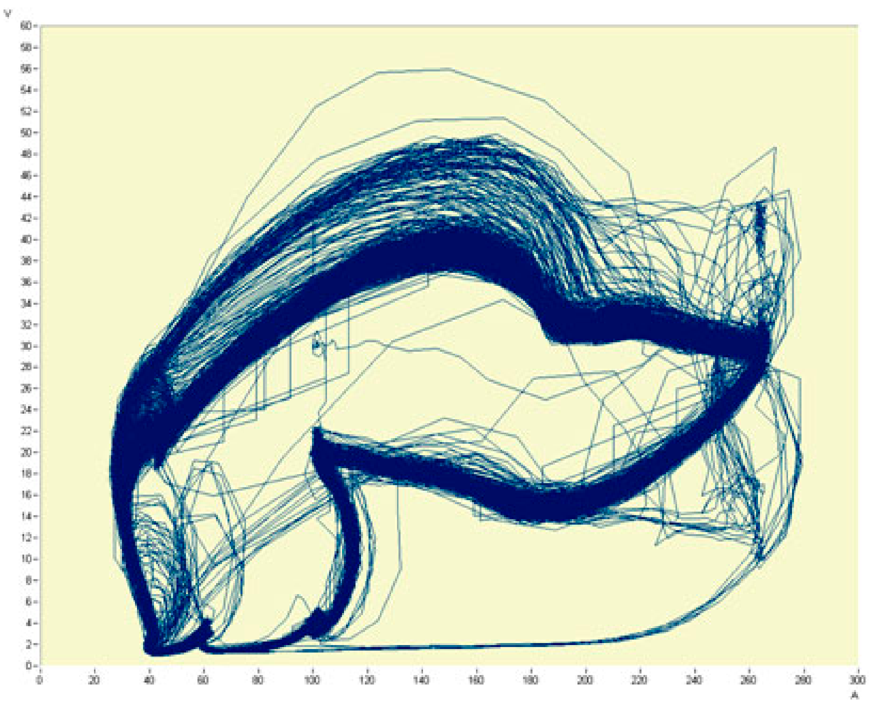


v_W = 70 cm/min
Cladding performance: 7.8 h/m²
Layer thickness ~ 4 mm

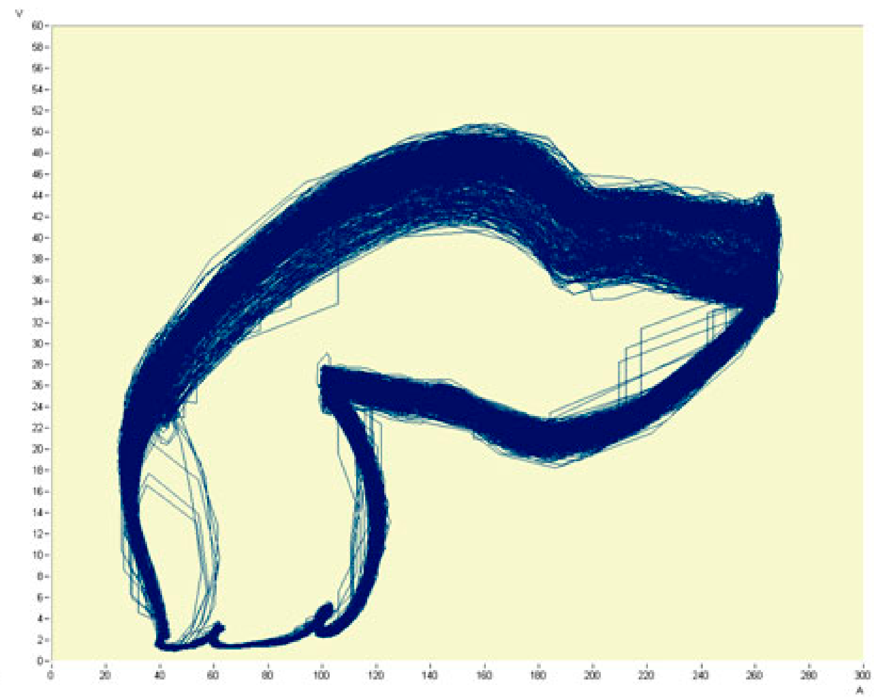
v_W = 100 cm/min CMT
Cladding performance: 5.45 h/m²
Layer thickness ~ 3 mm

U/I-analysis

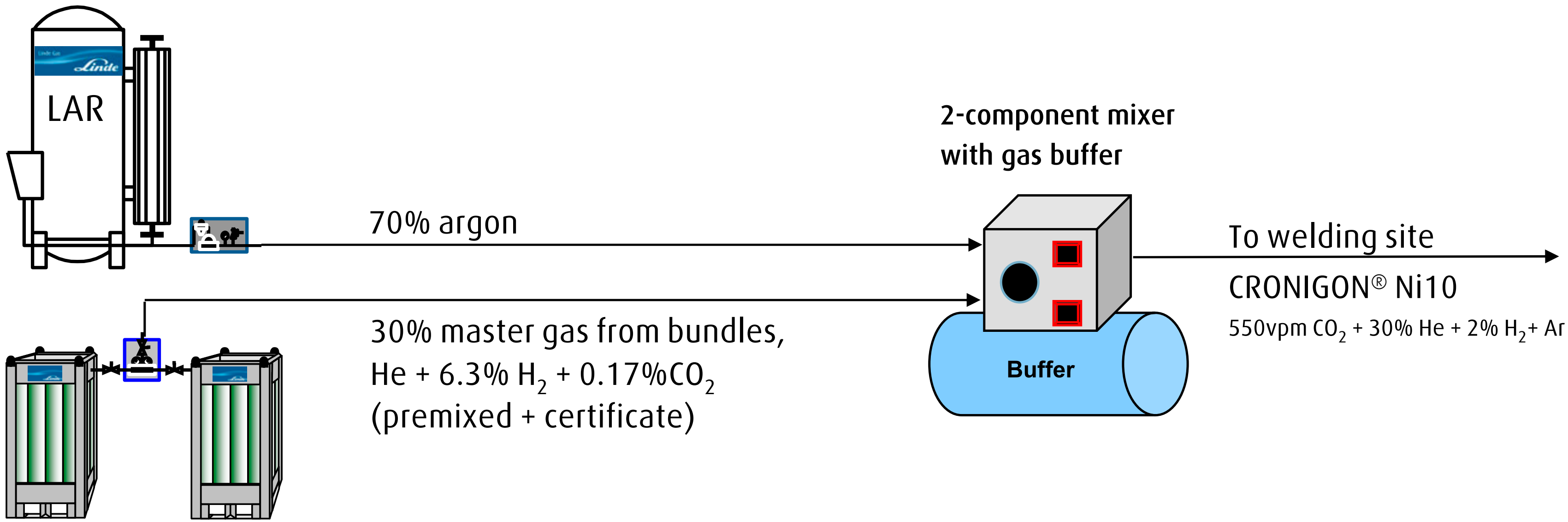
Argon



CRONIGON® Ni10



Supply solution: i-GAS principle for CRONIGON® Ni10 /1



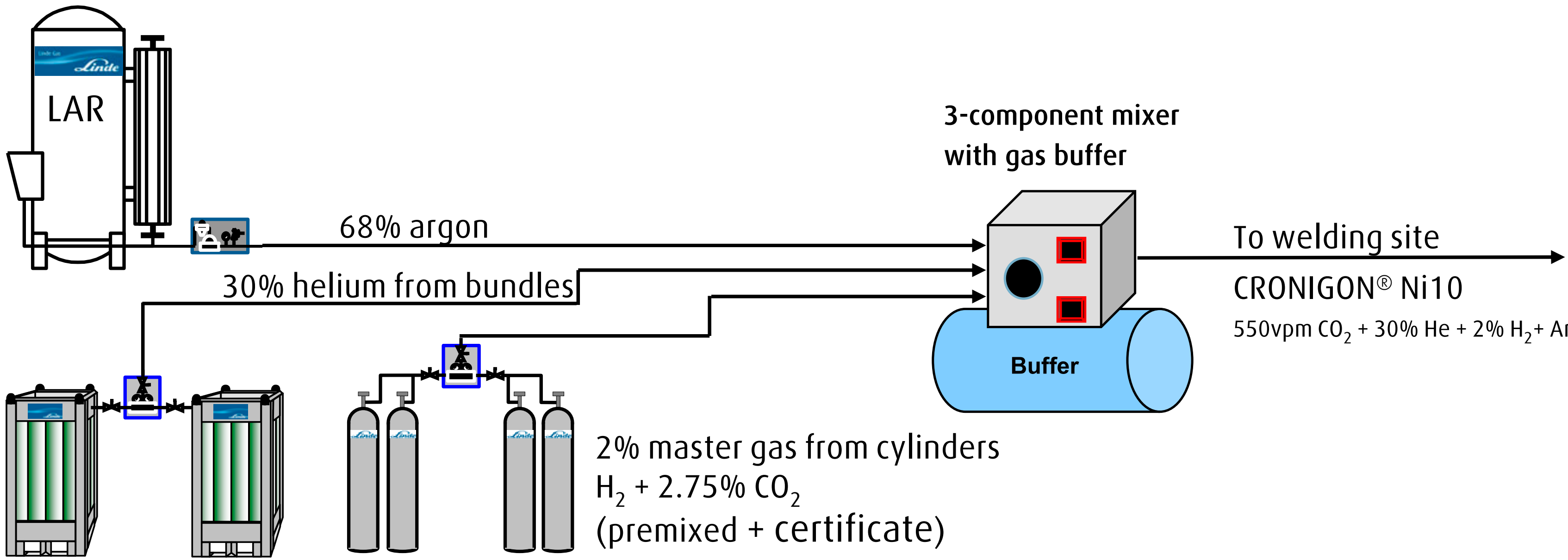
⇒ The biggest part of the welding gas is taken from the „cheap" already existing argon pipeline.

⇒ The relatively small amount of helium, hydrogen and CO_2 is taken from cylinders or bundles as a premixed "Master-Gas".

⇒ The 4-component welding gas is made with a standard 2-component gas mixing device

⇒ A CO_2 meter to monitor the exact amount of the CO_2-doping also informs about He and H_2 content of the gas mix

Supply solution: i-GAS principle for CRONIGON® Ni10 /2



⇒ Advantage: Much greater flexibility for He and H_2-contents

⇒ Drawback: Higher handling effort, more complicated 3-component gas mixer

⇒ A CO_2 meter to monitor the exact amount of the CO_2-doping also informs about the H_2 content of the gas mix

Wrap-up

THE LINDE GROUP

Linde

All quality requirements in MAG-welding of Ni-alloys under CRONIGON®-welding gases

- mechanical-technological values
- corrosion resistance
- crack-resistance
- flexibility during application
- spatter free droplet transfer

were met

Improved economy of MAG_p and welding processes with regulated short-arc (CMT, coldArc®, STT etc.) by using CRONIGON®-welding gases

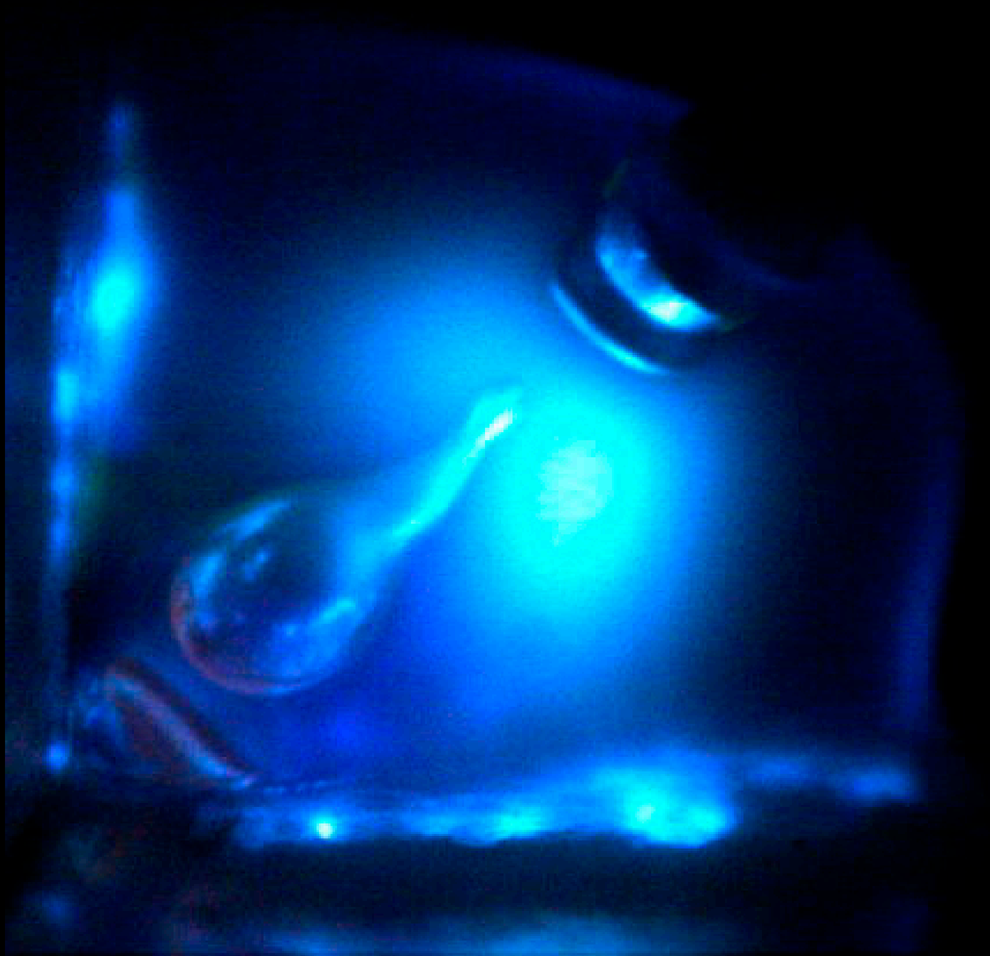
- higher welding speed respectively cladding performance
- increased machine uptime (stabilized process, less prone to interference)
- reduction of rework (spatter removal, smoothing of welds)
- reduced filler metal consumption (more precise control over cladding thickness)
- less repair welding (savings in work hours, grinding devices and expensive filler metal)

Wrap-up

Usage of CRONIGON®-welding gases instead of straight argon in GMA-welding of Ni-alloys results in an added value by increased process performance (pieces or m^2), improved quality, less rework, savings in filler metal or reduced auxiliary process time (better process stability)

This value added outweighs by far the higher cost of the adopted welding gas

Overall improved performance and economy



Thank you very much for your attention