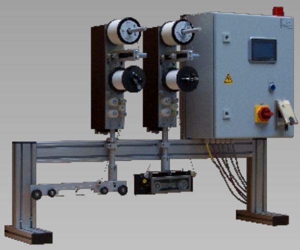
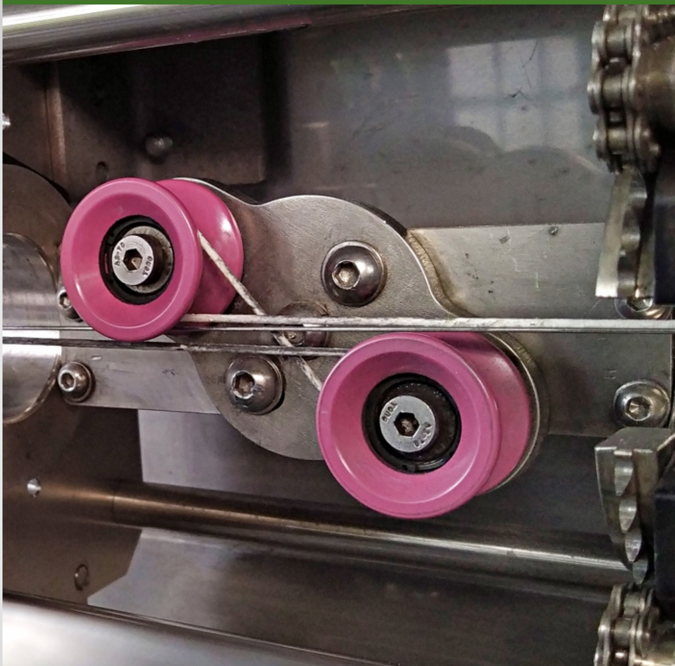
Boockmann Engineering GmbH

2021





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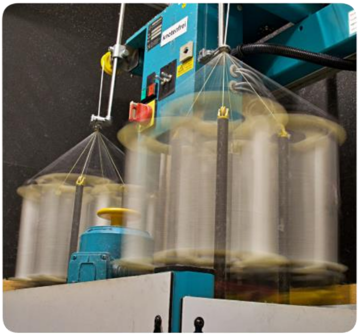
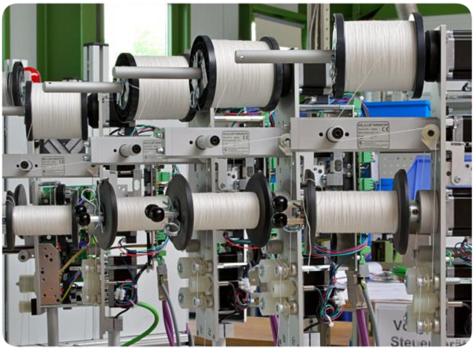
I. History:

1983	Founders: Annedore and Gerhard Boockmann Company Location: Sonnenstraße 14, Niederlauer-Unterebersbach Sales of wire enamels and consulting for electro varnishes and resins Founded as “Boockmann GmbH”
1984	Equipping laboratory workplaces
1985-1987	Development of Magnet Wire Enamels
1988-1989	Installation of the first patented emission-free and energy-saving impregnating plant with EEC technology Patent for impregnating plant with EEC technology and process air treatment
1990	New company building, Unterebersbach
1991	Patent for solvent-free lubricating technology for magnet wires (HELILUB®)
1993-1998	Industrialization of the HELILUB® technology about 2.000 lines at work
2002	Inauguration of the first production hall in Steinach
2003-2006	Basic patent applied for HELICORD® system for wire cleaning and cable processing
2006	Development of an automatic looping unit for PLC-controlled HELICORD® process
2007	Inauguration of the second production hall in Steinach
2008	Development of the HELICORD® machine NB58 for 2-step abrasive cleaning
2009	Implementation and certification of DIN ISO 9001 und ISO TS16949
2011	Inauguration of the third production hall in Steinach
2012	HELICORD® machine for finish application directly before the winder Development of solvent-supported extractive welding wire finish HELICORD® W NB37F001
2013	Improvement in HELILUB® lubrication of fine and ultra-fine wire
2014	New business unit “LabTech” Development of Welding Test Unit Development of Multi-Wire-Cleaning Machine for treatment of multi-wire, fine-wire and strip surface Renamed to “Boockmann Engineering GmbH”
2019	Inauguration of the fourth production hall in Steinach





II. HELILUB®

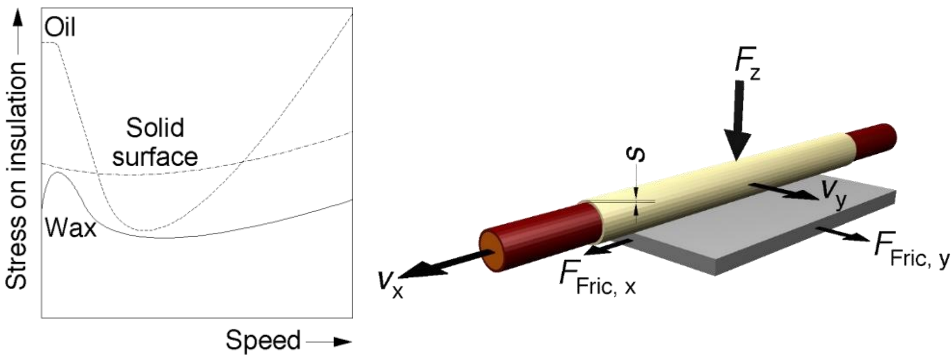
1 Basics of Magnet Wire Lubrication

Magnet wire processing requires lubrication for the following reasons:

- Protecting wire and insulation
- Increasing production speed
- Protecting winding tools
- Increasing density of windings

1.1 Mechanics of Magnet Wire Handling

Imagining an enameled wire which is pressed to a plane with a load F_z, the friction force to overcome in order to move the wire is a function of F_z. For dry, solid sliding surfaces, the friction force is independent of the speed v of the movement (fig. 1), which is also true for wires lubricated with wax or wax-like materials. Lubrication with oil or grease results in viscous floating which is dependent on the speed of movement.



Sliding on solid surface: $F_{Fric} = f(F_z)$

Floating on viscous oil: $F_{Fric} = f(1/s; v)$

$s = f(1/F_z; v)$

Fig. 1: Lubrication and friction force

For high winding speeds and winding density, often a solid dry sliding surface is required. This can be achieved, with limited success, by self-sliding enamels or, more successfully, by polishing with solid sliding agents, mainly paraffin and waxes.

Oily lubricants tend to drain out of the delivery spool. Like grease or high amounts of relatively low melting wax, oil absorbs dust, and coatings with these materials cannot withstand the high specific pressures between crossing wires due to their viscous behavior. Thus their application is mainly preferred for the insertion technique in motor production etc..

The coefficient of friction, as well as the sliding properties, windability, and insertability each show optima depending on lubricant quantity. Unfortunately, these optima often are not located in the same range of quantity and thus must be determined by experience.

Wire insulation		Coeff. of friction with ester wax lubrication	Coeff. of friction with paraffin lubrication
Ester-Imide	-	0.11	0.13
Ester-Imide	Amide-Imide	0.09	0.11
Ester-Imide	Amide-Imide with internal lubrication	0.07	0.09
Various, PUR included	PA-6.6 Overcoat	0.06	0.08
Self-bonding varnish	-	0.14	0.16

Table 1: Dynamic coefficient of friction for different combinations of insulating and lubricating materials determined according to Parussel [4]

The dynamic coefficient of friction, measured between a wire and a steel plate (Parussel [4]), is indicated in table 1 for different enamel materials and waxes. It is a material property of the applied lubricant, influenced by the wire insulation material.

Due to the strong dependence of the coefficient of friction from the lubricant amount on the wire surface (figure 2), the quantity applied to the surface must be controlled within narrow limits. Additionally the lubricating process influences reliability and uniformity of the lubrication.

1.2 Reasons for New Lubrication Methods

Solvent-based lubricants consist of nearly 99 % of volatile organic compounds (VOC), which are usually released by ventilation systems of factories (fig. 3).

Since governmental regulations (e.g. the European VOC regulation 1999-13-EC [5]) limit the amount of VOC emissions also specifically from magnet wire production, manufacturers can eliminate an important emission source by using solvent-free lubrication.

Additionally, with respect to ISO 14000, customers increasingly require programs for environmental protection from their magnet wire suppliers.

Furthermore, applied liquids including solutions of solid lubricants get stripped off the wire surface due to increased centrifugal forces on fast-turning guide rolls in high VD enameling machines, with an impact on process reliability and quality.

Solvent-free magnet wire lubrication reduces worker's health concerns from fumes and prevents severe workplace accidents as well as fire hazard.

In addition solvent induced attack on the wire enamel as well as on plastic spools are avoided.

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Fig. 3: Fumes released during solvent-based wire lubrication

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1.3 <u>Comparison of Technologies for Metering and Application of Lubricants on Magnet Wire</u>

Magnet wire manufacturers are trying to better meet enhanced lubrication requirements of their customers. Being influenced by e.g. ISO 9001 or IATF 16949, users of magnet wire have individual and very specific demands regarding the type and quantity of the lubricant as well as consistency of lubrication. Some customers even require the possibility of recorded constant supervision of the lubricating process for magnet wire production.

Numerous possibilities of machinery, process and materials for lubrication of winding wires exist. Table 2 provides a comparative overview on various technical solutions.

The HELILUB® method first reported in 1993 [1], using pre-impregnated yarns, overcomes the problems of all felt systems by providing high consistency and reliability of lubricant application, and allows to constantly supervise the lubrication. Due to the easy change of lubricant quantity and material, the magnet wire producer can adjust the lubrication exactly to very specific customer requirements and offer customized products.

		Materials						
Dosage Principle	Means of polishing	Solutions 0.1 - 2% solids, conventional	Concentrates 5 – 50 % solids, dispersions	Water dispersion	Self-sliding enamels	Melts of lubricants	HELILUB®, Impregnated Yarns	Lubricant vapors
Level/ Capillarity	Felts	+						
Rollers	Felts	+	○	+		○		
Rollers	Rollers	+	+(1)			+(1)		
Valves	Felts	+	+(1)	○		+(1)		
Pump	Felts	+	+(1)	+		+(1)		
Pin	Felts Future: Rollers	+	+(1)			+(1)		
Yarn speed	Yarn	+	+	+			+	
Vapor temperature	Not necessary							+
Dual coat enameling	Not applicable				+			
(1) If heated reservoir and felts available							+ Good ○ Possible	

Table 2: Materials and devices for dosage and polishing for magnet wire lubrication [2]

Most important with respect to the lubricating process are the principles of applying a metered quantity (dosage) and the principles of polishing. This may limit the selection of applicable materials and their embodiment or aggregate state, as listed in table 2.

In table 3 a selection of important characteristics (e.g. with respect to environmental and safety impact, lubrication process and cost) of the different magnet wire lubrication methods is listed and rated.

Generally, it turns out that the technical ranking of the HELILUB® process is equal or superior to all other methods. The higher investment costs for HELILUB® will be compensated by the advantages of high precision, reliability and supervision of the lubrication even for high V×D enameling machines.

	Conventional felt solution, level or roller dosage	Solution felt pump dosage	Water felt	Internal	Vapor	Melt felt magnetic valve or pneumatic pump dosage	Melt felt pin dosage	HELILUB® Yarn
Environmental protection	–	–	+	+	+	+	+	+
Fire hazard	–	–	+	+	○	○	○	+
Health risks	–	–	+	+	○	○	○	+
Easy change of lubricant	–	–	–	– –	–	– / ○ (1)	–	+
Quantity supervision	–	–	–	n/a	–	– –	– –	+
Quantity adjustment	–	○	○	n/a	○	○	○	+
Fine and ultra-fine wires	○	○	–	?	+	–	–	+
Low wire temperature	○	○	–	+	+	○ (2)	○ (2)	+
High wire temperature	+	+	+	n/a	– –	+	+	+
High VD	– (5)	– (5)	– (3, 5)	○	– ?	○	○	+
Tolerance for particle contamination	○	○	○	n/a	?	–	○	+
Reliability of polishing	–	–	–	+	+	–	–	+
Investment cost calculated on 3 year return of investment per average kg of wire (US-cent/kg)	0.2	1	1	n/a (4)	2	1 - 3	1	2
Material per average kg of wire lubricant, polishing, energy (US-cent/kg)	1	1	0.1	0.3	0.3	0.2	0.2	1

(1) If single dosage and application
(2) With pre-heating or concentrates
(3) Wetting and drying problems
(4) Low if dual coat applicator available
(5) Spraying loss of lubricant due to fast turning rolls

+ Good
n/a Not applicable
○ Possible
? No information
– Difficult
– – Not possible

Table 3: Comparison of different lubrication methods [2]

2 Principle of the HELILUB® Process

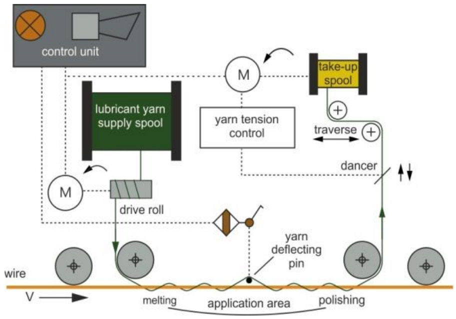


Fig. 4: Schematic of the HELILUB® process

The HELILUB® process is based on the application of lubricant to the surface of magnet wire by an impregnated cellulose yarn, wrapped around the wire several times and moved slowly in the same direction as the wire. The amount of lubricant applied is controlled by the calibration of the yarn and polished onto the wire surface by the yarn tension and speed difference between yarn and wire. The lubricant is extracted from the lubricating yarn using the wire temperature after the enameling oven. The lubricant quantity applied can be calculated from the difference in weights per meter of the lubricating yarn before and after the process.

HELILUB® offers the possibility to apply a large variety of lubricants, even high melting or insoluble ones, and to easily calculate and adjust the lubricant quantity.

It provides the following advantages:

- Exact lubricant dosage
- Easy calculation
- Easy to control
- Lowest coefficient of friction at high enameling speeds
- Constant supervision of lubrication
- Reliability in production on large delivery spools
- Lubrication interruption alarm

3 Calculation of Lubricant Metering and Yarn Consumption:

The applied quantity usually is around 20 mg/m², but can range from less than 6 to about 200 mg/m². The required process parameters are calculated as follows:

Symbol	Meaning	Data for example	Unit
M	Quantity of lubricant applied on the wire surface	18.5	mg/m²
G	Difference in weight of yarn per meter before and after application	60	mg/m
d	Diameter of the drive roll	17	mm
n	Rotation speed of the drive motor	1	min^{-1}
V	Wire speed	175	m/min
D	Wire diameter	0.375	Mm
F	Corrective factor for variable drive motor speed	1	

Table 4

Lubricant dosage: $M = \frac{G \times d \times n \times F}{V \times D}$

$$M = \frac{60 \times 17 \times 1 \times 1}{175 \times 0.315} \frac{mg}{m^2} = 18.5 \frac{mg}{m^2}$$

Yarn consumption: $q \approx \frac{V \times D \times M \times 3}{1000}$

$$q \approx \frac{55 \times 18.5 \times 3}{1000}$$
$$\approx 3 \frac{kg}{line \times year} \approx 12 \frac{Spools}{line \times year}$$

4 Industrial Installations of the HELILUB® Process

Figure 5a shows lubricators NB52G for standard applications. Models for wires with lower temperature (fig. 5b) and for fine wires (fig. 5c) are also available. The HELILUB® technology can be adapted to all magnet wire sizes and enameling machines, even with vertical wire run. It is also applicable for the special demands of the production of hermetic motors and sealed relays. All types of lubricators are easy to install.

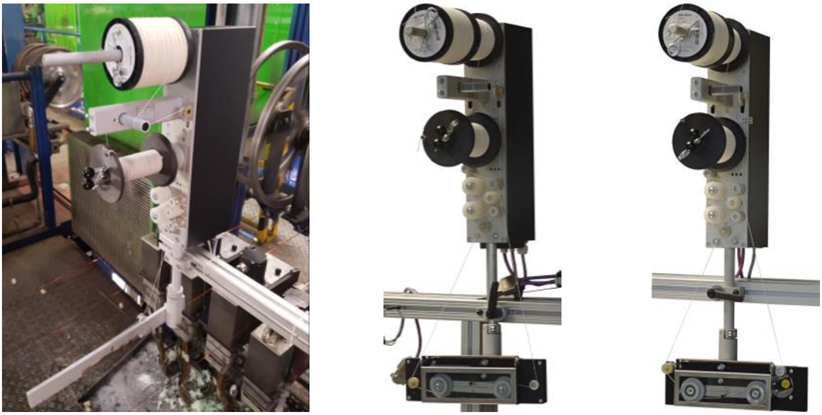


Fig. 5: a) HELILUB® model 2016 applicators NB52 for standard applications b.) NB53G6 for wires with lower temperature and c) NB53G0 for fine and ultra-fine wire.

4.1 Lubrication of Low Temperature Wire

Low wire temperature occurs mainly in vertical machines, and prevents proper lubricant transfer and dispersion.

Using felts this is a permanent problem, even when applying solutions of lubricants, because application felts get clogged and lubricant transfer is reduced or even interrupted.

Figure 6 shows the principle and figure 5b shows a photograph of a cold wire HELILUB® applicator which overcomes these problems. It uses heated rolls and increased friction between wire and yarn in order to melt and equalize the lubricant on the complete surface nearly independently from ambient and wire temperature, provided that the latter is not lower than 10°C below the melting point of the wax.

Since cold wire lubricators can be mounted directly before the take-up spool, the variation of lubricant quantity due to losses caused by deposit of lubricant from the wire on wire guide pulleys can be reduced considerably.

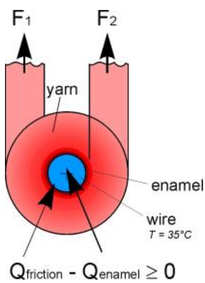


Fig. 6: Cold wire lubricant application

4.2 Lubrication of Fine and Ultra Fine Wire

Lubrication of fine and ultra-fine enameled wire with diameters below 0.15 mm, compared to lubrication of medium-sized diameters (0.15 - 1mm), is particularly critical. Fine wire is almost always coated with solderable or even self-bonding enamels. These coatings are very sensitive towards any impact of solvents. Applying oil as a lubricant does not provide as good friction properties, especially at high wire or winding speed, as wax applied correctly from solutions or melt. On the other hand, a local over-concentration of wax is critical, as windings on the spool may adhere to each other and cause wire elongation or even breaks. Punctual accumulations of wax often appear in solvent-free lubrication by means of felts, when wax particles deposit on the felt at the wire outlet side or on pulleys, then are carried along by the wire. Besides that, the desired very even and thin coating of 4 to 10 mg/sqm is difficult to obtain due to the low heat capacity of fine wire, which does not provide sufficient time for consistent flow and wetting before solidification of the wax.

4.2.1 HELILUB® for Fine and Ultra Fine Wire

Figure 7 shows the principle of a HELILUB® fine wire application zone and figure 5c a photograph of a fine wire lubricator. In this case the lubricant-impregnated yarn is not wrapped around the wire, but the wire just touches the surface of the yarn which is wound around heated rolls (fig. 8 and 9).

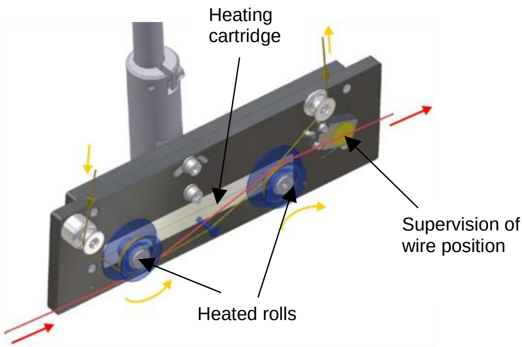


Fig. 7: Scheme of fine wire lubricant application zone

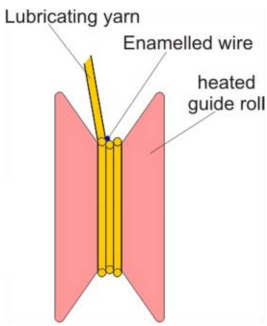


Fig. 8: Heated roll with HELILUB® application zone for fine wire lubrication

This HELILUB® setup for fine wire combined with appropriate yarn string-up (see pictures in fig. 9) provides good consistency, low coefficient of friction even with small lubricant quantities, no kinks, neither elongation nor wire breaks, no solvent attack to enamel and spools as well as precisely calculable lubrication due to elimination of drip losses.

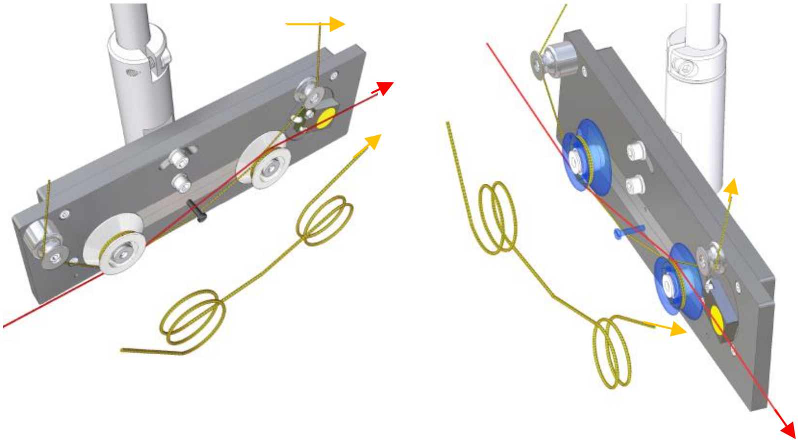


Fig. 9: How to correctly string-up the HELILUB® applicator for fine wire lubrication

4.3 Examples for Industrial Installations

The process is well introduced in the industry, with several thousand lines running worldwide. The following fig. 10 to 13 show examples of industrial installation of four generations of applicators.

a 1992, ACEBSA; VD 10, 6 mm wire distance;

b 1995, SICME NEL; VD 30,

Fig. 10: Multi-line installations of the first generation of applicators NB50G with only one common motor for the fix yarn speed and the take-up by means of a friction clutch. The applicators were supplied and supervised by a multi-line control box with collective error alarm function.

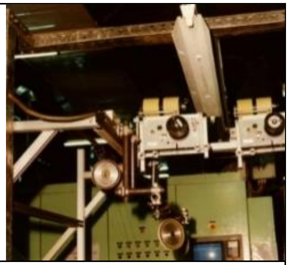


Fig. 11: 1995, SICME; VD 30, 6 mm; second generation single line applicator NB51 with integrated power supply, traverse range and error alarm

		
a 1996: vertical oven; VD 30	b 2005: Italia Impianti; VD 100, narrow wire spacing; installation with a 4-line control box with integrated collective error alarm function	c 2009: SICME NEM; VD 60,; these lubricators were supplied and supervised by a PLC-based control box NB50E606 with two-line text display, yarn slip supervision and detailed error alarm function

Fig. 12: Installations of third generation applicators, here NB52 for warm wire. These applicators had individual synchronous motors for yarn speed, take-up and traverse range.

		
a NB52 (model 2016) for warm wire lubrication	b NB53G0 (model 2016) for fine and ultra-fine wire lubrication	c NB53G6 (model 2016) for cold wire lubrication

Fig. 13: Fourth generation applicators from model year 2016

With each development step process reliability, equipment durability and ease of use were improved. In addition to detailed fault detection, like wire or yarn breaks and yarn slippage, the latest model 2016 provides:

- Robust, reliable and long-life step motors
- Less slippage, no formation of loops or tightening and installation in any position due to active yarn release

- Easier yarn string-up
- Continuous yarn tension at take-up
- µ-processor control with storage of settings (lubricator continues to operate independently in case of interrupted CAN-Bus connection)
- µ-processor-controlled power supply and control units NB50E70x (model 2016) for 1 – 8 devices with a graphic touch screen and integrated OPC-UA server for process data transfer to a superordinate line control available
- CAN-Bus data exchange for process settings and status signals

  Applicable also for cleaning bare wire of small diameters in opposite run mode (up to yarn tension of 6 N).

5 µ-Processor Control and Process Data Documentation of the HELILUB® Process

Current HELILUB® applicators can be operated by means of a control box type NB50E70x (model 2016), equipped with µ-processor main board and an operator panel. This allows the operator to set individual parameters for each lubricator and even to store parameter sets as recipes. The control calculates, regulates and supervises the individually required yarn speed according to equation 1. Thus, not only the correct wire position and movement of the yarn is supervised, but also yarn slippage, and the temperature of an optionally installed process zone with heated yarn guide pulleys.

Furthermore, data from the control unit can be provided to a superordinate control which collects and evaluates errors and process data in order to allow comprehensive and traceable process data documentation (figure 19).

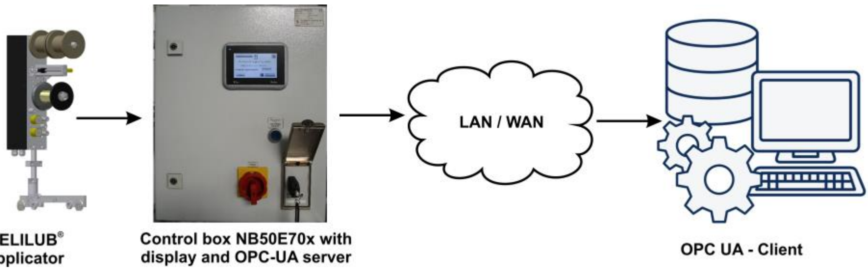


Fig. 19: Scheme of µ-processor control and process data documentation for the l ubricant yarn process

6 HELILUB® Machines

6.1 Microprocessor-controlled HELILUB® Applicators

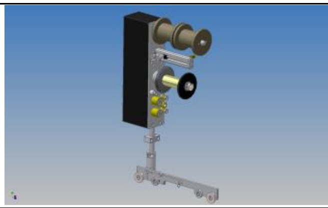
		
1	Model number	NB52G1…
2	VxD range	5 to about 200 (for lubricant application from 5 to 150 mg / m²)
3	Recommended application	for hot wires (refer to 7.), for multi-line enameling machines
4	Mounting instructions	Close to oven exit (refer to 7)
5	Wire spacing of the enameling machine	Minimum 50 mm, respectively above 12 mm and 140 mm alternating
6	Range of wire diameter (mm)	0.15(*) to 2 (12 AWG to 35 AWG(*))
7	Required wire temperature	Higher than 10°C above the melting point of the lubricant, but lower than 120°C (wax evaporation)
8	Process monitoring	Device connection (power supply/CAN-Bus) Wire breakage by inductive-sensor-supervised yarn guide hook (range of sensitivity 2 – 15 cN) Yarn tension before and after lubricant application (yarn breakage) Yarn slippage by rotation speed of the guide roll
9	Release tension (N)	0.5 – 6
10	Take-up tension (N)	2 – 6
11	Dimensions (mm)	Height: about 570 (min.) – 770 (max.), dependent on the length of the supporting tube Width: about 80 Depth: about 450
12	Weight (kg)	6
13	Connections	Power supply: 3-core cable with 3-pin plug CAN-Bus: 2-core cable with CAN-Bus plug Optional wire speed signal: pulses + 24 VDC (max. 4 kHz)
14	Input power supply (V DC)	24 (min. 22 to max. 30) **Attention! Out of this range, the correct operation of the device is not guaranteed.**
15	Max. power consumption	60 W
16	Suitable control devices	NB50E7xy (model 2016)
17	Maximum length of power supply and CAN-Bus cable (m)	Power supply: 50 (cross section 1,5 mm²) CAN-Bus: 300 (cross section 0,35 mm²) for max. ten connected applicators
18	Special applications	-
19	Operating temperature (°C)	+ 10 to + 45
20	Storage and transport temperature (°C)	-20 to +60
21	Relative air humidity (%)	5 to 70 (at 25°C, not condensing; indoor use only)
22	Environmental air pressure (hPa)	860 - 1080

Table 5

(*) for thin wires with PUR enamels the type of lubricator has to be decided after preliminary tests

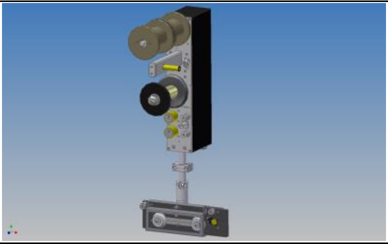
		
1	NB53G0…	NB53G5/G6…
2	5 to about 200 (for lubricant application from 5 to 150 mg / m²)	
3	Yarn lubricant applicator for low temperature ultra-fine wire for multi-line enameling machines	Yarn lubricant applicator for low temperature medium diameter wire for multi-line enamelling machines
4	At the oven exit or also directly at the winder (refer to 7)	
5	Minimum 61 mm	
6	Ultrafine up to about 0.3 mm(*) (above 28 AWG(*))	about 0.18 to 2 mm (33 AWG to 12 AWG)
7	20°C below the melting point of the lubricant or warmer	
8	Device connection (power supply/CAN-Bus) Wire position: capacitive sensor (wire breakage) Yarn tension before and after lubricant application (yarn breakage) Yarn slippage by the speed of the yarn guide roll Temperature	Device connection (power supply/CAN-Bus) Friction by yarn tension (range of sensitivity 200 – 1000 cN) Contact between wire and yarn (wire breakage) Yarn tension before and after lubricant application (yarn breakage) Yarn slippage by rotation speed of the guide roll Temperature
9	0.5 – 6	
10	2 – 6	
11	Height: 620 (min.) – 670 (max.) dependent on the length of the supporting tube Width: about 136 Depth: about 270	
12	6	
13	Power supply: 3-core cable with 3-pin plug CAN-Bus: 2-core cable with CAN-Bus plug Optional wire speed signal: pulses + 24 VDC (max. 4 kHz)	
14	24 (min. 22 to max. 30) **Attention! Out of this range, the correct operation of the device is not guaranteed.**	
15	100 W	
16	NB50E7xy (model 2016)	
17	Power supply: 50 (cross section 1,5 mm²) CAN-Bus: 300 (cross section 0,35 mm²) for max. ten connected applicators	
18	Post-process re-lubrication of sub-standard wire Pre-treatment of wire before coil winding machines	
19	+ 10 to + 45	
20	-20 to +60	
21	5 to 70 (at 25°C, not condensing; indoor use only)	
22	860 - 1080	

Table 5 (continued)

(*) for thin wires with PUR enamels the type of lubricator has to be decided after preliminary tests

6.2 Control Units for HELILUB® Applicators Model 2016

			
1	Device model numbers	NB50E701	NB50E704
2	Range of application	Control of HELILUB® applicators (model 2016) NB52… and NB53…	
3	Max. number of HELILUB® applicators	1	4
4	Mounting instructions	Wall installation by means of 4 screws, opening angle of the door. 120°, opening radius: 400 mm	
5	Operator’s interface/HMI	Touchscreen 4,3“; 800x480 Pixel	
6	Authorization, security	Electronic access keys with different levels	
7	Acoustic alarm	92 dB at 1 m distance; alternating sound; interruptible	
8	Optical alarm	Red blinking light; non-interruptible; can be quit only by eliminating the error	
9	Input power supply	100 - 240 VAC / 50/60 Hz; 6 A pre-fuse	
10	Input power consumption (W)	~500	
11	Output power supply for HELILUB® applicators	24 V DC, 4 A per HELILUB® applicator	
12	Connection to the HELILUB® applicators	Power supply: 3 conductor cable and 3-pin connector CAN-Bus network: shielded 2 conductor cable with sub-D 9-pin CAN-Bus connector)	
13	Max. length of cables for power supply and CAN-Bus (m)	Power supply: 50 (cross section 1,5 mm²) CAN-Bus: 300 (cross section 0,35 mm²)for max. ten connected applicators	
14	Optional interfaces	Ethernet (VNC), MODBUS RTU (with superordinate control)	
15	Special features	Monitoring of yarn slippage	
16	Operating temperature (°C)	+ 10 - + 45	
17	Storage/transport temperature (°C)	- 20 - + 60	
18	Relative air humidity (%)	5 to 70 (at 25°C, not condensing)	
19	Air pressure (hPa)	860 – 1080	
20	Ca. dimensions H × W × D (mm)	400 x 200 x 200	590 x 500 x 210
21	Weight (kg)	2.8	~ 20

Table 6

			
1	NB50E706	NB50E708	NB50E710
2	Control of HELILUB® applicators (model 2016) NB52… and NB53…		
3	6	8	10
4	Wall installation by means of 4 screws, opening angle of the door. 120°, opening radius: 400 mm		
5	Touchscreen 4,3"; 800x480 Pixel		
6	Electronic access keys with different levels		
7	92 dB at 1 m distance; alternating sound; interruptible		
8	Red blinking light; non-interruptible; can be quit only by eliminating the error		
9	100 - 240 VAC / 50/60 Hz; 6 A pre-fuse		
10	~500	~1000	
11	24 V DC, 4 A per HELILUB® applicator		
12	Power supply: 3 conductor cable and 3-pin connector CAN-Bus network: shielded 2 conductor cable with sub-D 9-pin CAN-Bus connector)		
13	Power supply: 50 (cross section 1,5 mm²) CAN-Bus: 300 (cross section 0,35 mm²)for max. ten connected applicators		
14	Ethernet (VNC), MODBUS RTU (with superordinate control)		
15	Monitoring of yarn slippage		
16	+ 10 - + 45		
17	- 20 - + 60		
18	5 to 70 (at 25°C, not condensing)		
19	860 – 1080		
20	590 x 500 x 210	590 x 600 x 210	
21	~ 20	~ 25	

Table 6 (continued)

7 HELILUB® Consumables

Product number	Basis	Melting range (°C)	Tensile strength (cN)	Weight of lubricant (mg/m)	Weight of lubricating Yarn (mg/m)	Range of application
NB21M001	Blend of paraffin with ester wax	53 - 58	~1000	~ 70	~ 140	Standard with applicator NB52G1… and for fine wires with applicator NB53G0…
NB23M003	Blend of paraffin with ester wax	53 - 58	~ 3000	~ 160	~ 300	Standard for higher VD or for larger quantity of lubricant
NB23K203	Hydroxyester wax	49 - 51	~ 3000	~ 160	~ 300	For all hermetic motors, also for HFC (134 a)
NB23S003	Blend of paraffin with ester wax	53 - 58	~ 3000	~ 160	~ 300	Wax with softer plasticity, better consistency of the coefficient of friction due to easier polishing

Table 7

Upon request the following lubricant bases are also available:

Beeswax: lowest coefficient of friction at low application quantities, also suitable for food industry (depending on national laws)

Paraffin: preferred for self-bonding wires, also suitable for food industry (depending on national laws)

References

1. Boockmann, G. and R. Fichtner. “Nonpolluting Solid Lubrication of Enamelled Wires”. Proceedings of Electrical Electronics Insulation Conference and Electrical Manufacturing & Coil Winding Conference, Chicago 1993. IEEE Publication 93CH3219-3, pp. 165-171

2. Boockmann, G., K. Boockmann, R. Fichtner: “Innovation for Magnet Wire Lubrication”. Proceedings of Electrical Insulation Conference and Electrical Manufacturing & Coil Winding Conference, Chicago 1997. IEEE Publication 97CH36075, pp. 195-201

3. Boockmann, G., K. Boockmann, R. Fichtner: “Magnet Wire Lubrication Technology”; Proceedings of Electrical Manufacturing & Coil Winding Conference ‘98, Cincinnati 1998

4. W. Parussel “Defining the Surface Smoothness of Varnished Wires” Electrotechnical Periodical, pp 692 695, December 1961

5. European Community: “COUNCIL DIRECTIVE 1999/13/EC of March 11 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations”, Official Journal of the European Communities, Brussels, 29.03.1999, pp. L85/1 – L85/22

6. MAG: Company brochure “Vapolub” MAG - Maschinen und Apparatebau Aktiengesellschaft, Puntigamerstraße 127, A-8055 Graz, Austria and Ferjancsik, Zsombor. “Vermeidung von Lösemittelemissionen bei der Gleitmittelbeschichtung von Elektrodrähten bei der Firma Eldra”. Thesis at the Technische Universität Graz, 1996

III. HELICORD®

1 HELICORD® Principle

Following the principle of our logo, the HELICORD® principle is based on friction between a fast-moving wire and a textile cord wound around a wire, strand or insulated cable multiple times, moving rather slowly under push-pull-controlled conditions. This creates a multiple 360° contact between a constantly renewed cleaning medium (i. e. the cord) and the wire.

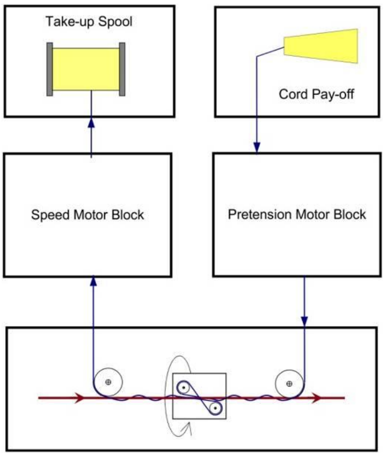


Fig. 30: Flow chart of the HELICORD® process

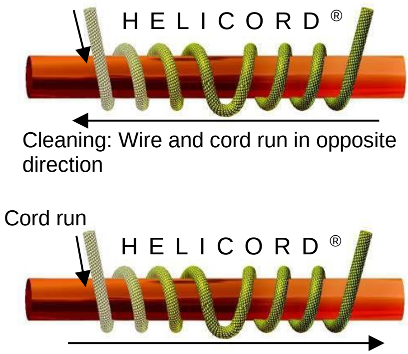


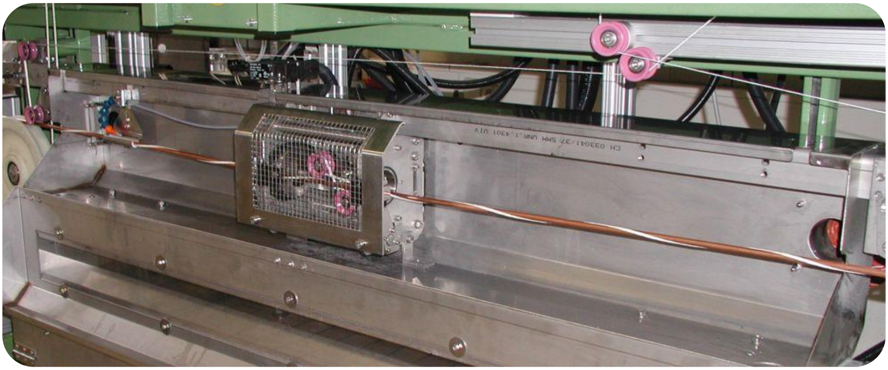
Fig. 31: Wire and cord running in opposite (top) and same (bottom) direction

The friction applied to the wire equals the difference between cord tensions before and after the process zone. It is determined by the cord pre-tension, i.e. the tension on the cord supply side, and the number of loops of cord around the wire when the machine is operated in fixed-number-of-loops mode; or by the cord pre-tension on the cord supply side and tension on the cord take-up side when the machine is operated in friction-controlled mode.

Friction power on the wire increases linearly with the wire speed. This means the friction energy per wire surface unit and thus also efficiency is independent of the wire speed (refer to BE1437 „Essentials of the HELICORD® Process“) and can be run at drawing speeds.

Although for coating only applications, cord and wire are run in the same direction, whereas for cleaning applications, wire and cord are run in opposite directions, cleaning and coating in the same process may be

possible, depending on the exact requirements of the application in question.
The HELICORD® process, machines and consumables were developed beginning in 1996 and protected for Boockmann GmbH by patents from 2000 on. In the following years, it became an industrial standard for a large number and variety of applications and is now in use in over 300 production lines.


Picture 1

1.1 Why the Efficiency of HELICORD® is Independent from Wire Speed (Compared to Other Technologies)

1. HELICORD® Treatment:

The cleaning power (or friction power in the case of HELICORD®) increases proportionally to the wire speed. The friction energy applied per surface unit is calculated according to:

$$\frac{\text{Friction force} \times \text{Wire speed}}{\pi \times \text{Wire - Ø} \times \text{Wire speed}} = \frac{\text{Friction power}}{\text{Wire surface/Time}} = \frac{\text{Friction energy}}{\text{Wire surface}}$$

⇨ The friction energy applied per wire surface unit is ***independent*** from the wire speed.

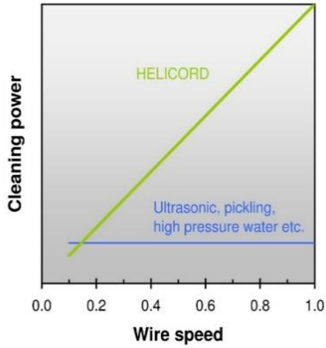


Fig. 25

⇓

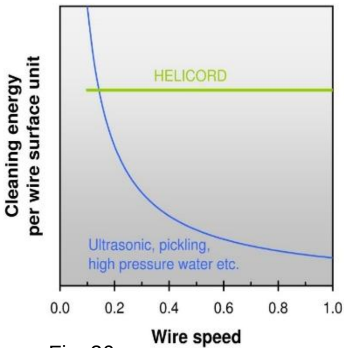


Fig. 26

2. Ultrasonic Treatment:

The cleaning power is the applied ultrasonic power, which is proportional to the power input, but constant at different wire speeds. The ultrasonic energy applied per surface unit is calculated according to:

$$\frac{\text{Ultrasonic power}}{\pi \times \text{Wire - Ø} \times \text{Wire speed}} = \frac{\text{Ultrasonic power}}{\text{Wire surface/Time}} = \frac{\text{Ultrasonic energy}}{\text{Wire surface}}$$

⇨ The ultrasonic energy applied per wire surface unit is **inversely proportional** to the wire speed.

Remark: In many applications, ultrasonic energy can only affect the wire surface partially, since most of it is absorbed by floating particles before.

3. Chemical Treatment (Pickling/Etching):

The chemically induced abrasion of material per time unit (understood as cleaning power) is independent from the wire speed. Thus the degree of cleaning of a specific wire length is determined by its exposure time in the bath.

⇨ The amount of material eroded per wire surface unit is **inversely proportional** to the wire speed.

4. High Pressure Water Cleaning:

The available cleaning power of the water jets is constant at different wire speeds.

⇨ The cleaning energy per wire surface unit is **inversely proportional** to the wire speed.

1.2 Why the Efficiency of HELICORD® is Independent of Time (Compared to Other Technologies)

1. HELICORD® Treatment:

Because of the constant movement of the cord, the wire is always in contact with fresh, clean cord at the end of the process zone.

⇨ The efficiency of the HELICORD® process is ***independent*** of the time.

2. Ultrasonic Treatment:

The cleaning liquid is constantly contaminated with soluble and solid residues removed from the wire surface.

In order to avoid useless absorption of ultrasonic energy, floating particles have to be filtered out continously.

Despite such a costly filtration, the intensity of cleaning constantly decreases due to the accumulation of (soluble) pollutants, until the liquid is exchanged.

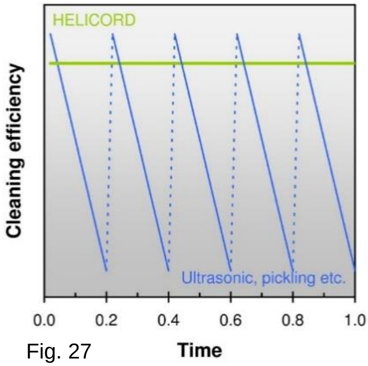


Fig. 27

⇨ The efficiency of ultrasonic cleaning shows a **saw-tooth**-like behaviour when plotted against time.

3. Chemical Treatment (Pickling):

The chemical bath is constantly polluted with non-reactive, solid residues as well as it is used up increasingly by the chemical reaction with the wire surface. Accordingly, the intensity of cleaning constantly decreases until the chemical bath is exchanged.

⇨ The efficiency of chemical cleaning shows a **saw-tooth**-like behaviour.

4. High Pressure Water Cleaning:

The circulating water is constantly contaminated with soluble and solid residues removed from the wire surface. Despite costly filtration, the intensity of cleaning constantly decreases due to the accumulation of pollutants until the liquid is exchanged.

⇨ The efficiency of high pressure water cleaning shows a **saw-tooth**-like behaviour.

Remark to points 2 – 4: The dependence of time of the efficiency of these processes could be moderated by continuous addition of cleaning liquid following a counterflow principle. That would cause high costs and therefore did not assert itself in industrial practice.

1.3 Essentials of Abrasive Cleaning

Abrasive cleaning considerably reduces the amount of hydrocarbons on the wire surface originating mainly from drawing soaps. Also loosely adhering particles are removed.

Abrasive cleaning prior to further wire processing requires a subsequent cleaning step in order to remove especially residual abrasive grains and other pollutants.

For abrasive two-step treatment of wire, a HELICORD® machine NB58 has to be used as follows:

In the first step, an abrasive cord (see also „Abrasive Cord Overview“, BE1524) removes loosely adhering particles and solid drawing lubricant residuals.

In the second step, a dry braided cord (see also “Overview of Dry Cords”, BE1414) and possibly metered small quantities of cleaning liquid is used for final cleaning.

The second step can also be used to apply a wire finish: Either an impregnated cord (see “HELICORD® - W Overview of Cords”, BE1518) and solvent, or a dry cord (see above mentioned BE1414) with metering of liquid finishing material is used.

Fig. 28:Two-step HELICORD® machine NB58

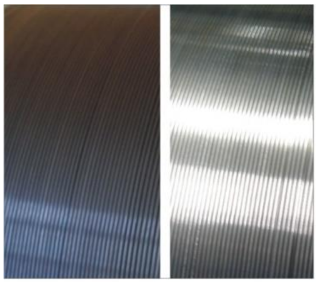


Fig. 29: Wire appearance after two-step HELICORD® treatment

Application Range:

- Solid wire with heavy contamination with residuals from drawing soaps
- Preparation of wire for copper-coating
- Simultaneous cleaning and finish application to solid stainless steel wire
- Simultaneous cleaning and finish application to mild steel welding wire

2 Applications of HELICORD®

2.1 HELICORD® in the Welding Wire Industry

2.1.1 Reasons for Using HELICORD® in the Welding Wire Industry

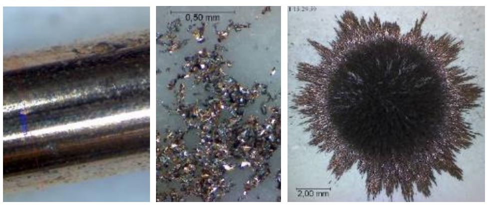
Welding wire finishing is a type of wire surface treatment developed specifically to improve welding properties and performance of welding wire. The most important factors are cleaning and application of active components. Coatings can improve factors such as plasma stability, feedability, corrosion resistance and ignition behavior.
The HELICORD® process provides a very advanced method of welding wire finishing. The unique advantage of this technology is the possibility of cleaning and applying a coating in one process step.

In the welding wire industry, the following applications are most common:

- Wiping off excess drawing lubricants or feed-aid media
- Removing excess drawing oil from Al-wire
- Abrasive treatment for removing large quantities of Ca-stearates, especially from filled wire
- Removing drawing lubricant residues before copper-plating
- Application of oil as feed-aid on solid wire
- Application of anti-corrosive waxes on mild steel filled wire
- Application of feed-aid dispersions containing e.g. graphite or molybdenum disulfide (and similar)

2.1.2 Types of Welding Wire and Their Particular Properties and Improvement Possibilities by HELICORD® Surface Treatment

Removal of particles (Fig. 32) and surface contaminants, as well as achieving specific, consistent sliding properties are most critical for any type of welding wire surface finishing. Particles and drawing lubricant residues will block the liner or contact tip of a welding gun, causing plasma interruptions or micro-fusing with wire stops, finally resulting in interruptions in welding. In order to avoid redundancy, the following table only presents the particular properties and requirements specific to each type of welding wire, and the appropriate, recommended HELICORD® processes.



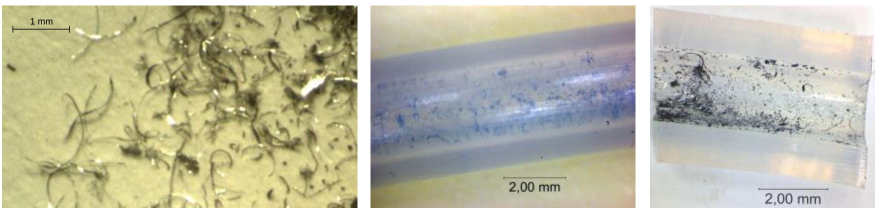
a. b. c.

Fig. 32: Particles (b) taken off a commercial copper-coated wire G4Si1 (a) using a polyamide-based cord (a). About 750 g of particles were taken off 800 m of wire. The copper-colored particles are magnetic (c), and thus must be copper-coated ferrous particles. Apparently the wire was not cleaned sufficiently before copper coating.

Type of Welding Wire	Typical Properties and Most Common Issues	Solution	Recommended Treatment
copper-coated, steel (low- or non-alloyed, cored with welded seam or solid)	only occasional contact issues due to too many loosely adherent particles	removal of particles by liquid-supported cleaning	1-step HELICORD® treatment for removal of particles and simultaneous liquid-supported application of a wax-type finish containing corrosion inhibitors suitable for ferrous and non-ferrous metals and plasma stabilizer
	feeding issues in long liners	liquid-supported extractive application of wax-type lubricants	
	corrodes easily	liquid-supported extractive application of corrosion inhibitors suitable for ferrous and non-ferrous metals, supported by application of wax as a lubricant	
	arc instability	liquid-supported extractive application of high potassium finish for plasma stabilization	
	feeding issues in the contact tip caused by particles	removal of particles by liquid-supported cleaning or/and coating with anti-wear component	
copper-free, steel (low- or non-alloyed, cored with welded seam or solid)	high tendency to fuse in the contact tip	liquid-supported extractive application of a finish acting as a separating agent (NB82C300)	2-step HELICORD® treatment for (possibly abrasive) removal of drawing lubricant residues and particles, and liquid-supported extractive application of a wax-based lubricant containing corrosion inhibitors for ferrous metals, plasma stabilizer and a separating agent (NB82C300)
	improvement of sliding properties needed	liquid-supported extractive application of wax-type lubricants after abrasive pre-treatment	
	contact issues due to drawing lubricant residues	dry removal of drawing lubricant residues by abrasive pre-treatment	
	corrodes easily	liquid-supported extractive application of corrosion inhibitors	
stainless steel, solid (high alloy or Ni-based)	bad quality of the weld seam caused by drawing lubricant residues	2-step HELICORD® treatment: step 1: abrasive pre-treatment step 2: liquid-supported extractive application of lubricant and simultaneous removal of drawing lubricant residues (NB80Z000)	

<table>
<tr><th>Type of Welding Wire</th><th>Typical Properties and Most Common Issues</th><th>Solution</th><th>Recommended Treatment</th></tr>
<tr><td rowspan="4">cored wire with open (not welded) butt or overlap seam (high-, low- or non-alloyed)</td><td>sharp edge of the seam causes feeding issues and contact tip erosion</td><td rowspan="2">lubrication after abrasive pre-treatment</td><td rowspan="3">2-step HELICORD® treatment for abrasive cleaning, and liquid-supported extractive application of lubricant (NB82C300)</td></tr>
<tr><td>feeding issues in very long liners</td></tr>
<tr><td>corrodes easily</td><td>application of lubricant and corrosion inhibitors after abrasive pre-treatment</td></tr>
<tr><td>diffusible hydrogen</td><td colspan="2">2-step HELICORD® treatment consisting of abrasive pre-treatment and liquid-supported cleaning</td></tr>
<tr><td rowspan="3">aluminum, solid</td><td>porosity caused by high amount of hydrocarbons</td><td colspan="2" rowspan="3">1-step HELICORD® treatment for particle removal and application of anti-wear agent after washing</td></tr>
<tr><td>cold welding between wire layers on the spool</td></tr>
<tr><td>feeding issues caused by self-supported particle formation in the liner</td></tr>
<tr><td>special alloys, e.g. Zn spray wire or Cu alloys, solid</td><td>feeding issues in the contact tip caused by particles</td><td colspan="2">1-step HELICORD® treatment for particle removal and application of corrosion inhibitors and anti-wear agents</td></tr>
</table>

Table 8



a. b. c.

Fig. 33: Aluminum welding wire: Long particles taken off a Ø 0.9 mm aluminum wire (a), that had been shaved before final drawing. Particles (b), (c) stuck in a PTFE liner that had been cleaned on the inside.These particles create more particles in an avalanche effect, blocking the liner and contact tip.

2.1.3 Alternative Processes

In the following chapters, the above-mentioned HELICORD® processes for improvement of welding wire properties will be explained in detail and remarks about industrial applications will be made: Chapter 2.1.3.1 will focus on cleaning processes, chapter 2.1.3.2 will focus on application of active components onto the wire surface.

a.

b.

Fig. 34: Braided round (a) and flat (b) cord wound around a Ø 1.2 mm wire.

2.1.3.1 Cleaning Processes

2.1.3.1.1 1-step Dry Cleaning

Using an NB57 HELICORD® machine (see chapter 4) and round (NB65…, NB67…) or flat (NB87…, NB88…) braided cords (see Fig. 34), liquid contaminants, e.g. drawing emulsions or oils, and loose metal particles can be wiped off the wire surface. It is also possible to wipe off an excess of solid drawing lubricant residues to a certain extent or, using suitable process parameters, to distribute them more consistently on the surface.

2.1.3.1.2 1-step Liquid-Supported Cleaning

Adding small amounts (a few ml/min) of cleaning liquids (water with tenside or organic solvents) onto cord and wire, cleaning of the wire surface can be intensified. On rough surfaces, the use of liquids also increases surface penetration.

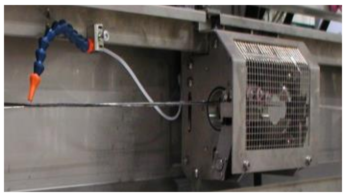


Fig. 35: Metering outlet in a HELICORD® process zone (including the looping unit)

2.1.3.1.3 Dry Abrasive Cleaning

Cords impregnated with abrasive particles (Al_2O_3), designed to grind or polish the wire surface, have been proven successful in removing adherent particles or large amounts of dry drawing lubricant residues coming off as powder, and smoothing the edge of the open seam of cored wire. Round and flat abrasive cords (Fig. 36) impregnated with polishing grains of different grit sizes are available. Setting the optimum value of friction force is another critical factor.

In a second process step, residual contaminants and polishing particles remaining on the wire surface after the first process step can be wiped off, dry or supported by use of a cleaning liquid.
For abrasive cleaning, typically a 2-step HELICORD® machine NB58 is used (see chapter 4).

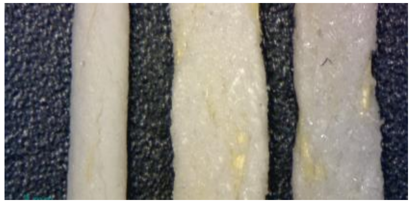
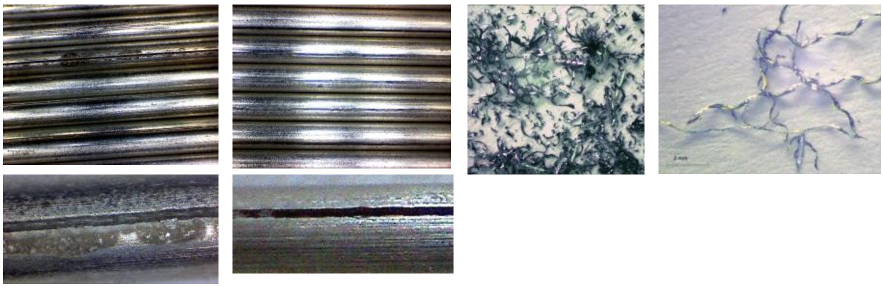


Fig. 36: Viscose-aramide-based abrasive cords with Al_2O_3 particles: round with small grains (left), flat with medium-sized grains (middle) and large grains (right)



a. b. c.

Fig. 37: Open seam of a 309 LT stainless steel FCW, Ø 1.2 mm in different magnifications before (a) and smoothed after (b) abrasive cleaning. Long spiral particles (c) collected during abrasive cleaning in different magnifications.

2.1.3.1.4 Liquid-Supported Abrasive Cleaning

In order to avoid clogging the cord when cleaning abrasively, water-based or organic cleaning liquids could be added to the process, if need be at an excess rate. Suitable and sufficiently durable cords are still being developed. As described in chapter 2.1.3.1.3, residual contaminants and polishing grains must be wiped off the wire surface in the second process zone of a HELICORD® machine NB58 (see chapter 4).

2.1.3.2 Application Processes

2.1.3.2.1 Application of Liquid Finishing Materials

Consistent application of liquid finishing materials, such as oils, is possible using a pump to precisely meter said liquids onto a dry cord in the process zone of a HELICORD® machine. The metering amount is controlled proportionally to the wire speed. Cord and wire are preferably run in opposite directions in order not only to coat the wire, but also to clean it more efficiently at the same time. Setting a fixed number of loops (instead of running the machine in friction-controlled mode) for this application will keep the loops from „wandering“ and thus ensures that their position will not change in relation to the position of the metering outlet.

2.1.3.2.2 Extractive Application Processes

A clear advantage of solid finishing materials (waxes or film-forming materials) is their better adherence compared to oil-based or other liquid finishing materials which is why, even at high wire speeds, they will not spray off at wire guide pulleys due to centrifugal forces. Once applied, their distribution on the wire surface is consistent over time, whereas liquid finishing materials have a tendency to flow even on wire spools, due to centrifugal forces on the winder, or due to gravitation and capillarity during storage. Also, dust will stick to liquid-coated surfaces much better than to surfaces with a solid finish.

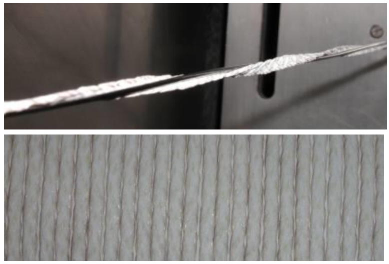

a.
b.

Fig. 38: Pre-impregnated cord for application of PTFE: in the process zone, wrapped around the wire (a), and on a supply spool(b). Extraction can be improved by using solvent.

The following chapters will give details on how to apply soluble, dispersible or meltable solid finishing materials to the wire surface out of pre-impregnated cords.

2.1.3.2.2.1 Solvent-supported Extractive Application

Polar or non-polar solvents, or mixtures thereof, can be used for extraction of finishing materials out of pre-impregnated cords, similar as for liquid-supported cleaning (chapter 2.1.3.1.2). The amount of liquid used must be sufficient to dissolve a sufficient amount of finishing components to be applied to the wire out of the cord. However, as the friction heat occurring in the process improves solubility of organic finishing materials, the amount of liquid required is still relatively small (as compared to other processes using solvents in the wire industry).
Any solvent should evaporate mostly before the first wire guide pulley after the wire leaves the process zone in order to prevent the finishing material from spraying off at the pulley. The amount of solvent used must be accordingly low, or the evaporation rate sufficiently high.
The HELICORD® machine is operated with a fixed number of loops and with wire and cord running in opposite directions for the same reasons as in chapter 2.1.3.2.1.
When using flammable solvents, the process zone and main unit, which holds the used cord on the take-up spool, must be evacuated sufficiently

under controlled conditions in order to avoid formation of flammable vapor concentration.

2.1.3.2.2.2 Heat-supported Extractive Application

In order to avoid using organic solvents, it is possible to use cords pre-impregnated with meltable finishing materials. In a heated process zone, the finishing material is melted on the cord and applied to the wire surface in a liquid state. It should solidify before the first wire guide pulley after the wire leaves the process zone in order to prevent the finishing material from spraying off at the pulley.
Wire and cord can run in the same or opposite directions. Running wire and cord in opposite directions in addition to applying of a welding wire finishing material also provides more reliable removal of loosely adherent particles at the same time. The extraction rate, however, will be lower than when running cord and wire in the same direction.

2.1.3.2.2.3 Extraction by Friction

Extraction just by friction between the wire and cord is possible. The degree of extraction, however, is lower than of liquid- or heat-supported extraction. It usually results in a very low variance in the amount of finishing material applied.
The friction force is most critical for this application. It is determined by the difference between the cord tension and pre-tension and can be set within the limitations of the machine.

2.1.3.3 Possible Setups

Basic Model	Specific Equipment	Application/Remarks
NB57 / NB55 (1-step HELICORD® machine = one process zone)	- fixed process zone - length of process zone 1 or 1.6 m - total length of machine in-line (depending on length of the process zone) ca. 1.5 or 2.1 m	- Finishing (liquid or wax- / polymer-based finishing materials suitable for solvent-supported extraction) and simultaneous particle removal, if applicable
	- traversing process zone, can be connected to the traverse of a spooler (for narrow places of installation) - length of process zone 1 or 1.6 m - total length of machine (depending on length of the process zone) ca. 1.4 or 1.9 m	
	- aluminum machine frame for installation on a drum coiler or similar - fixed process zone - length of process zone 1.6 m - 2nd operating panel (optional) - total length of machine in-line 2.1 m	- Finishing (liquid or wax-based finishing materials suitable for solvent-supported extraction) and simultaneous particle removal, if applicable - fits Lämneå Bruk drum spooler
NB58 (2-step HELICORD® machine = two process zones)	- machine frame with two successive process zones - 2nd process zone fixed - length of 2nd process zone 1 or 1.6 m - total length of machine (depending on length of the 2nd process zone) ca. 3.3 or 3.9 m	- Abrasive wire surface treatment for removal of particles and solid drawing lubricant residues, and to smoothen the edge of cored wire with open seam in the 1st process zone - Final cleaning, dry or liquid-supported, and possibly simultaneous application of liquid or wax- / polymer-based finishing materials suitable for solvent-supported extraction
	- machine frame with two successive process zones - 2nd process zone traversing, can be connected to the traverse of a spooler (for narrow places of installation) - length of 2nd process zone 1 or 1.6 m - total length of machine (depending on length of the 2nd process zone) ca. 3.3 or 3.9 m	
	- machine frame with two process zones atop each other (for limited space, suitable only for smaller wire diameters) - 2nd process zone fixed - length of process zone 1.6 m each - total length of machine ca. 2.6 m	

Basic Model	Specific Equipment	Application/Remarks
	- machine frame with two atop each other process zones (for limited space, suitable only for smaller wire diameters) - 2nd process zone traversing, can be connected to the traverse of a spooler (for limited space availability of installation) - length of process zone 1.6 m each - total length of machine ca. 2.6 m	

Table 9: Overview of HELICORD® machines

2.1.3.4 Applications in the Industry

The following table presents some examples of welding wire finishing applications, giving information on the type of wire, wire diameter, wire speed and the most important HELICORD® parameters and process data.

List of abbreviations:
D_D = wire diameter in [mm]
v_D = wire speed in [m/s]
F_V = cord pre-tension in [N]
F_C = cord tension in [N]
v_C = cord speed in [cm/min]
M = metering amount of liquid („drip rate") in ml/min

Application	Parameter Zone 1	Parameter Zone 2
1-step liquid finish (oil) application on copper-coated welding wire before the precision spooler D_D = 1.0 – 1.4 mm, v_D = 25 - 35 m/s	cord: NB87V002 v_C = 10 cm/min customer-specific oil M = 1 ml/m² wire and cord run in opposite directions	
1-step finish application on copper-free welding wire D_D = 1.2 mm, v_D = 20 m/s	cord: NB82C301 (ke59/126) v_C = 10 cm/min customer-specific oil M = 1 ml/m² wire and cord run in opposite directions	
2-step cleaning, removing dry drawing lubricants and particles from solid stainless steel welding wire D_D = 1.2 mm, v_D = 10 -15 m/s	cord: NB77V002 v_C = 10 cm/min wire and cord run in opposite directions	cord: NB88V002 v_C = 10 cm/min customer-specific pickling liquid M = 1 ml/m² wire and cord run in opposite directions

Application	Parameter Zone 1	Parameter Zone 2
2-step finishing treatment on solid stainless steel welding wire: abrasive removal of dry drawing lubricants and particles; application of low hydrocarbon finish D_D = 0.8 – 1.6 mm,	cord: NB78F001 or NB78F002 v_C = 10 cm/min wire and cord run in opposite directions	cord: NB38V001 v_C = 10 cm/min wire and cord run in opposite directions
finish application on Al-welding wire D_D = 0.8 – 1.6 mm, v_D = 10 m/s	cord: NB37F006 Isopar/Isobutanol 1:1 M = 1 ml/m^2 wire and cord run in opposite directions	
finish application and simultaneous removal of particles from zinc spray wire D_D = 2.0 – 2.5 mm, v_D = 5.5 m/s	cord: NB37F004 v_C = 10 cm/min NB10H008, M = 1 ml/m^2 wire and cord run in opposite directions	
1-step egalization of drawing lubricants (graphite, MoS_2) on cored wire D_D = 1.0 – 1.6 mm, v_D = 20 m/s	cord: NB67V014 v_C = 10 cm/min Isopar/Isobutanol 1:1 M = 1 ml/m^2 wire and cord run in opposite directions	
2-step finishing treatment on mild steel cored wire with open seam: abrasive removal of dry drawing lubricants; application of molten wax D_D = 1.2 mm, v_D = 10 -15 m/s	cord: NB78F002 v_C = 10 cm/min wire and cord run in opposite directions	cord: NB67V002 v_C = 10 cm/min wire and cord run in opposite directions
1-step removal of dry drawing lubricants and particles before ultrasonic cleaning from solid welding wire D_D = 1.2 mm, v_D = 20 m/s	cord: NB87V002 v_C = 10 cm/min wire and cord run in opposite directions	
2-step removal of Na stearates 7 dry drawing lubricant and particles from solid mild steel welding wire D_D = 1.2 mm, v_D = 10 -15 m/s	cord: NB77V001 F_V = 20 N, F_C = 140 N v_C = 30 cm/min wire and cord run in opposite directions	cord: NB67V002 F_V = 20 N, F_C = 60 N v_C = 40 cm/min wire and cord run in opposite directions
Finish application and simultaneous removal of particles from Ni-based welding wire D_D = 1.0 – 1.6 mm, v_D = 10 m/s	cord: NB88V001 v_C = 10 cm/min customer-specific finishing liquid, wire and cord run in opposite directions	

Application	Parameter Zone 1	Parameter Zone 2
2-step finishing treatment on solid stainless steel welding wire: abrasive removal of dry drawing lubricants and particles; PTFE application D_D = 1.2 mm, v_D = 10 -15 m/s	cord: NB78F002 F_V = 20 N, F_C = 110 N v_C = 20 cm/min wire and cord run in opposite directions	cord: NB38F001 F_V = 10 N, F_C = 65 N v_C = 30 cm/min customer-specific finishing liquid, wire and cord run in opposite directions
2-step removal of dry drawing lubricants and particles from solid stainless steel welding wire D_D = 1.6 mm, v_D = 30 m/s	cord: NB77V002 v_C = 10 cm/min wire and cord run in opposite directions	cord: NB88V001 v_C = 10 cm/min customer-specific pickling liquid, M = 1 ml/m^2 wire and cord run in opposite directions
1-step finish application and simultaneous removal of particles from stainless steel welding wire D_D = 1.0 mm, v_D = 20 m/s	cord: NB38F001 v_C = 10 cm/min wire and cord run in opposite directions	
1-step abrasive cleaning of stainless steel cored wire E308 LT-1 D_D = 1.2 mm, v_D = 5 m/s	cord: NB78F002 F_V = 20 N, F_C = 90 N v_C = 20 cm/min wire and cord run in opposite directions	
1-step finish application and simultaneous removal of particles from stainless steel welding wire D_D = 1.2 mm, v_D = 25 m/s	cord: NB38F001 F_V = 20 N, F_C = 90 N v_C = 30 cm/min wire and cord run in opposite directions	
2-step finishing treatment on solid copper-free welding wire: abrasive removal of dry drawing lubricants and particles; PTFE application D_D = 1.2 mm, v_D = 10 -15 m/s	cord: NB78F002 wire and cord run in opposite directions	cord: NB37F004 wire and cord run in opposite directions

Table 10

2.2 HELICORD® in the Cable Industry

2.2.1 General Applications

Both drawing lubricant residues and metal particles from drawing and stranding can severely disturb the extrusion process in cable production, and have a highly negative impact on performance of the finished product in the field. Therefore most applications in the cable industry are cleaning applications.

As most bare wire is made of copper or copper alloys and other soft metals, cleaning usually requires a one-step process, using only soft dry cords. Abrasive cleaning as part of a two-step process is necessary only very rarely in this part of the wire industry, mostly on rather specific alloys.

If cleaning is required in order to improve an extrusion process, it should be done directly before the extruder in order to avoid secondary contamination or formation of new particles in spooling and re-spooling. In the case of stranded wire, this is particularly critical, as every pulley touching and thus putting pressure on the strand will squeeze out contaminants from the inside of the strand towards the surface again, recontaminating the surface after cleaning.

On single wire, cleaning can be facilitated by using solvents to help dissolve lubricant residues and lower adhesion of particles to the wire surface. Solvents used include various types of organic solvents, but also tensides in water-based solutions. On stranded wire, solvents should not be used at all, as they will creep inside the strand and make contaminants „wander" from the inside towards the surface within very short time, even if used right before the extruder, and disturb the extrusion process.

In the cable industry, the following applications are most common:

- Removal of copper dust after rod break-down, especially before resistance annealer in order to prevent contamination of all following steps by copper dust
- Cleaning of conductors before extruder head from dust and spikes for solid wire and strands up to Ø 30 mm e. g. for very thin insulation, high frequency cables, antenna cables, communication cable, high voltage submarine cables
- Cleaning of plastic-insulated conductors before second insulation layer cover for winding wire of submarine pumps, e.g. on oil platforms
- Cleaning of copper tubes before extruder for submarine fiber optics
- Application of very thin PTFE-coating on insulated conductors as anti-adhesive and release agent (replacement of talcum powder)
- Application of insulation-compatible waxes on bare strands for adjustment of insulation adhesion
- Cleaning of conductors before enameling
- Cleaning of superconductors as preparation for enameling or plating

- Removing lubricant from an enameled superconductor
- Cleaning of protection steel tube for fiber optics
- Removal of faulty prints from cable surface
- Removal of drawing lubricants from superconductors before annealing
- Cleaning of superconductor surface after intermediate annealing
- Removing oily particles from braided shielding
- Coating with primer for improved adhesion

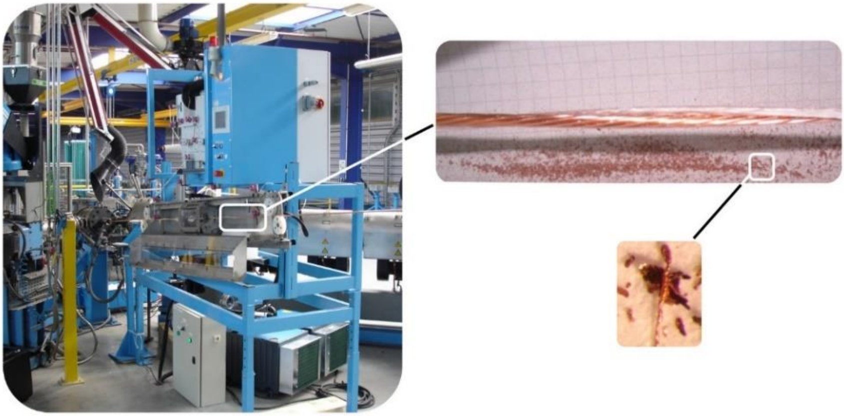


Fig. 39

2.2.2 Misprint Removal

Misprints on cable jackets may occur on one to five per mill of the cable production of any given producer. Discarding of these finished products would cause considerable economical loss as well as other expenses for scrapping and recycling. Therefore, removing the misprint and reprinting the cable jacket usually pays back.

Up to now, such misprints were removed semi-automatically at best, but in many cases manually at accordingly high labor cost. Additionally, the direct contact of operators with volatile organic solvents, necessary for removing the printing ink, should be avoided for health and hazard reasons.

Removal of misprints can be better achieved by using HELICORD®-technology:

- Multiple 360° contact between cable and cleaning media
- Effective cleaning by cable and cord running in opposite directions, and continually refreshed cleaning media
- Adjustable liquid metering at up to five outlets in the process zone
- No Permanent supervision by operator required in normal operation

- Process zone and housing of the basic unit prepared for connection of exhaust ventilation (interlock of liquid metering with exhaust ventilation is necessary)
- Cable speed up to 70 m/min, limited only by the required time of exposure to the solvent
- Health and hazard protection of the machine operator

Cables up to diameters of about 10 mm can be treated in a process zone of 1.6 m length, cables up to 18 mm in a process zone of 3 m length.

2.2.3 PTFE Application

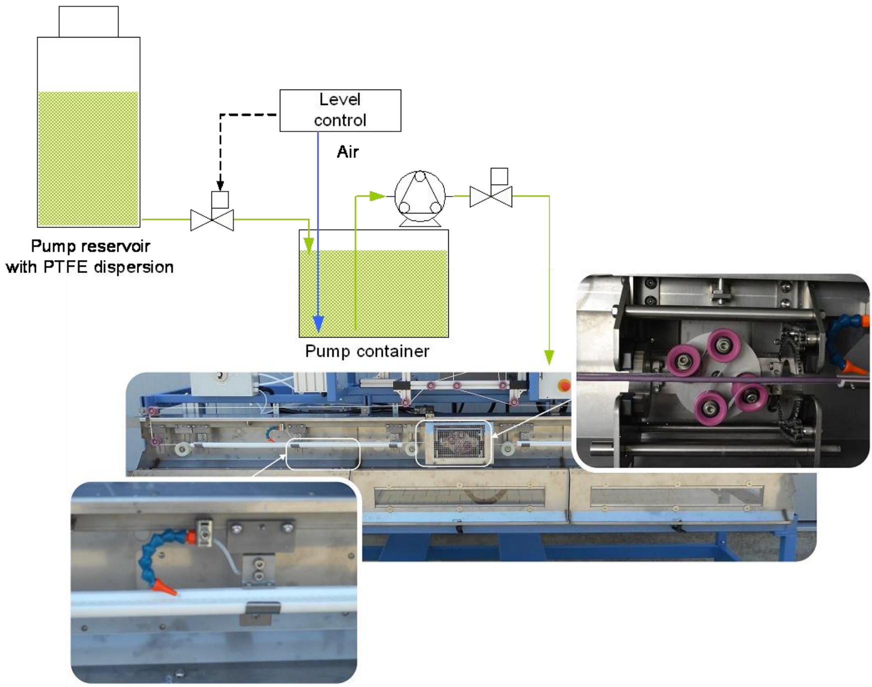


Fig. 41

Insulated conductors are often encapsulated into electrical windings. At the exit from the encapsulating compound, the insulation could break. Conductors coated with PTFE reduce this risk. Moreover, in many cable applications a defined strip force of the jacket is required. This is obtained by application of release agents to the insulated conductors. Talcum, which is commonly used, besides dust formation has the disadvantage that in many cases the strip force cannot be precisely adjusted. PTFE coatings have better performance properties.

However, aqueous PTFE dispersions cannot be handled by common metering pumps, because they coagulate under shear stress, and pumps as well as valves are quickly clogged.

HELICORD® machines NB57 can be equipped with a peristaltic pump that meets the particular requirements of this application in order to bring the PTFE dispersion into the HELICORD® process zone under low pressure and minimal shear force without coagulating in the tubes and valves.

By use of HELICORD® with a peristaltic pump, adhesion and strip force can now be reduced more easily than ever before due to precise metering of an aqueous PTFE dispersion to the insulated single conductors of the cable.

The HELICORD® principle is based on controlled friction between conductor and cord and leads to coagulation of the PTFE on the conductor. The multiple 360° looping provides consistent application to the whole conductor or cable surface and compensates the low but inevitable pulsation of the peristaltic pump at low metering amounts.

If necessary, the pump container and reservoir can be equipped with stirrers in order to prevent settling of the dispersion.

2.3 HELICORD® in Other Industries

2.3.1 General Applications

- Cleaning precision stainless steel wire
- Lubrication of precision stainless steel wire
- Application of waxes or PTFE dispersion on wire for the food industry
- Application of primers for drawing lubricants
- Cleaning wire before chemical or electrolytical plating
- Finishing / cleaning silver-clad wire for medical use
- Removing loose particles from plated wire
- Preparation before plasma annealer

2.3.2 Magnet Wire Cleaning with HELICORD® before Enameling

Earlier Issues with Bare Wire Cleaning before Tube Annealers

Picture 2

- Without additional capstan, wire gets elongated or even breaks due to softening by heat
- Re-pollution of the wire during annealing and cooling
- For a long time, no adapted HELICORD® devices were available with respect to
  - narrow wire spacing
  - required friction forces
  - economical questions for multi-line applications

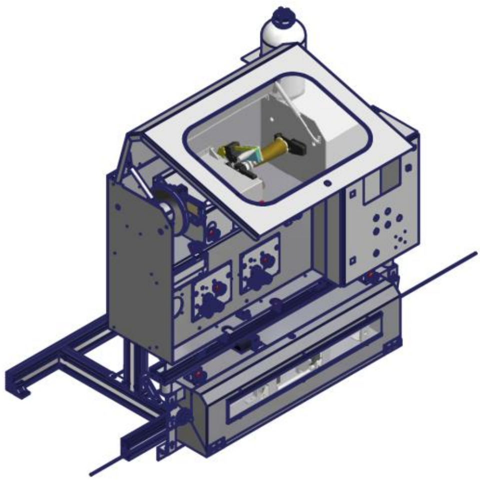
Installation between Annealer and First Enamel Application

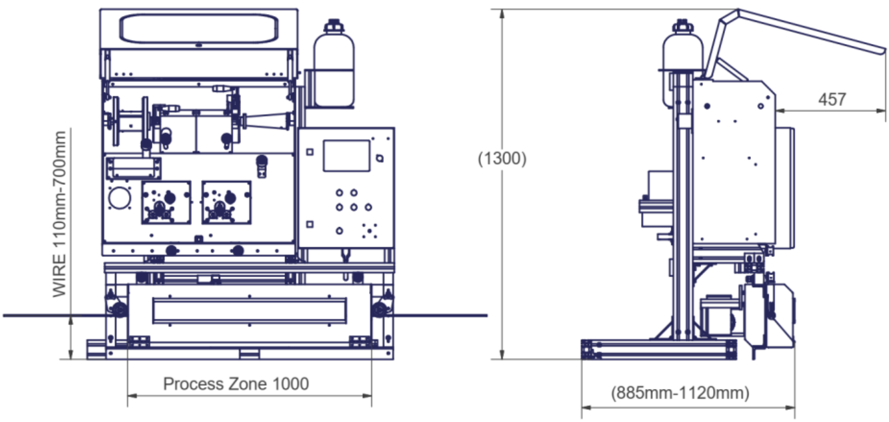
- Cleaning contaminants from drawing, annealing and cooling off the wire
- Avoids carry-over of contamination to and agglomeration in the enameling section
- Reducing high voltage failure counts by a factor of up to 10
- Improved enamel adhesion on the wire
- No wire elongation or even cracks at reasonable friction forces

3 HELICORD® Machines

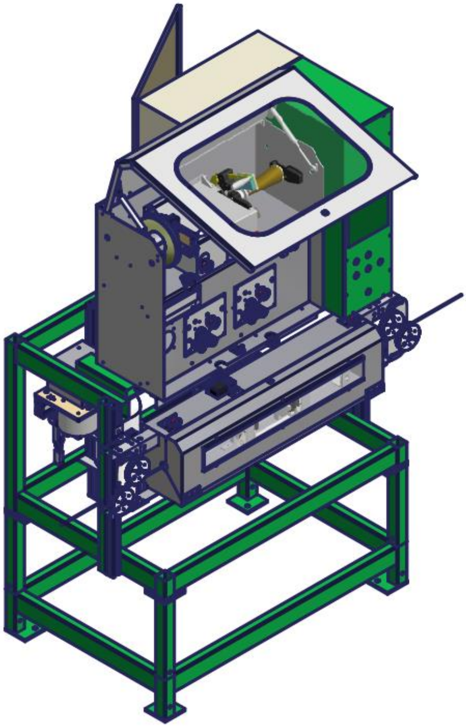
3.1 HELICORD® - Standard Models

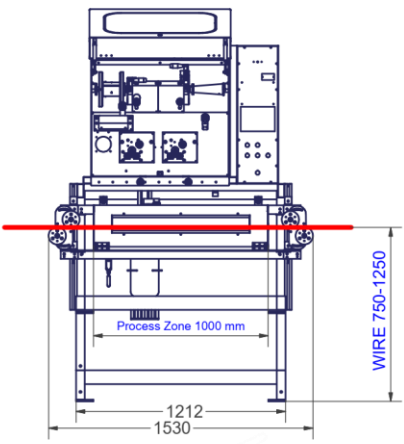
NB55 – for installation on a drum spooler

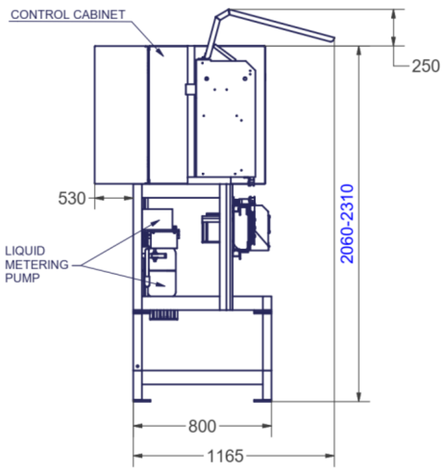




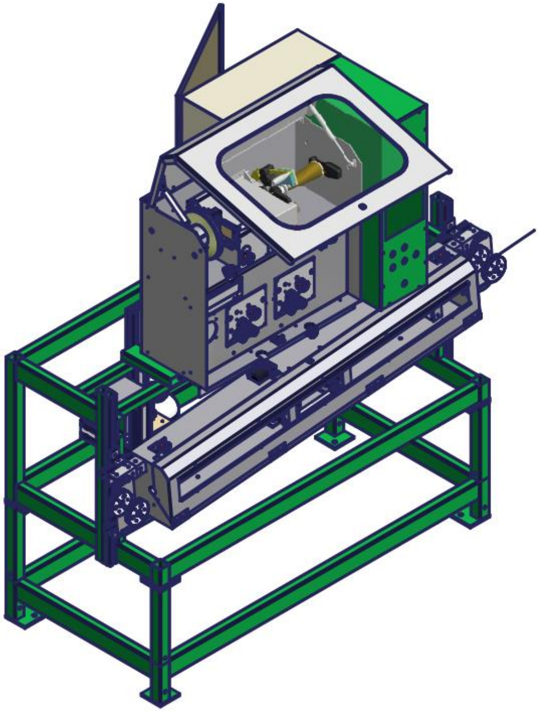
NB57 – 1200

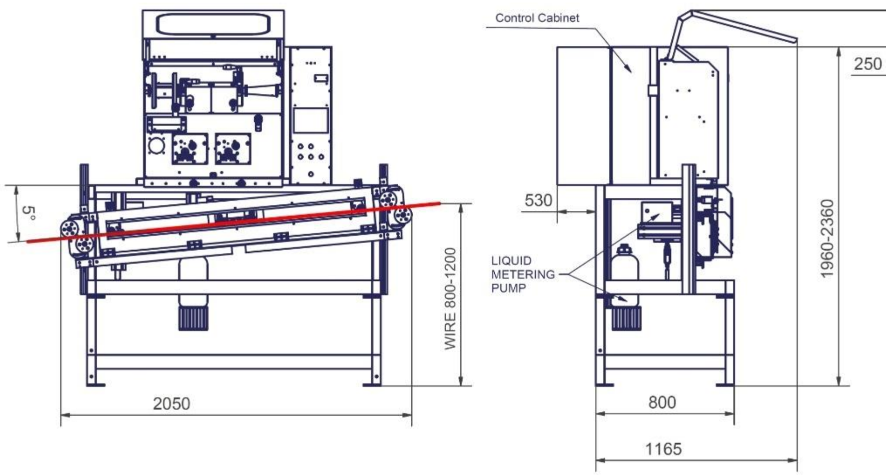



Process Zone 1000 mm
WIRE 750-1250
1212
1530

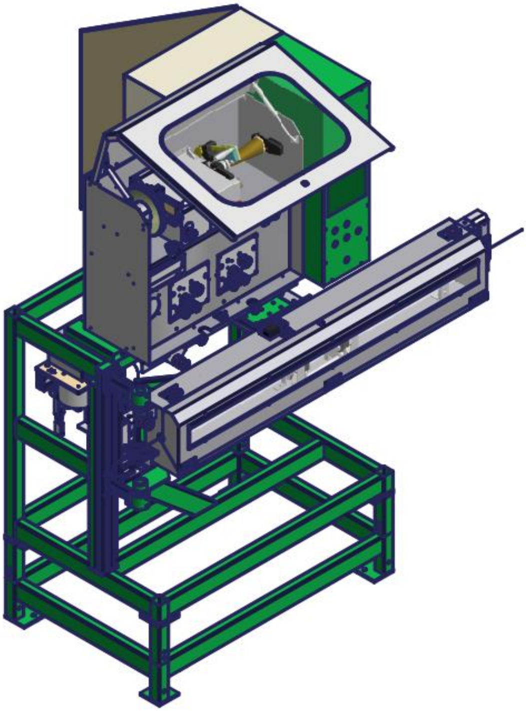

CONTROL CABINET
250
530
LIQUID
METERING
PUMP
2060-2310
800
1165

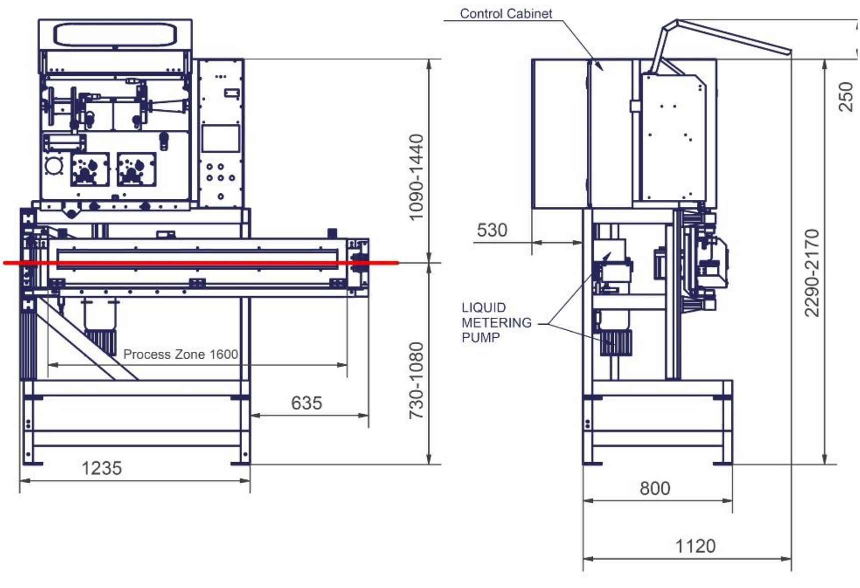
NB57 – 1700



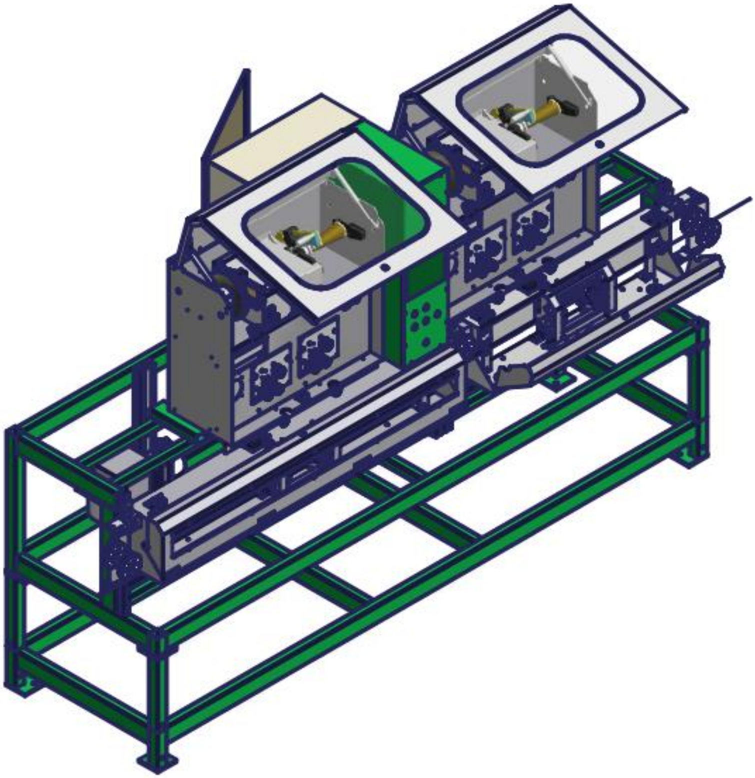

5°
WIRE 800-1200
2050
Control Cabinet
250
530
1960-2360
LIQUID
METERING
PUMP
800
1165

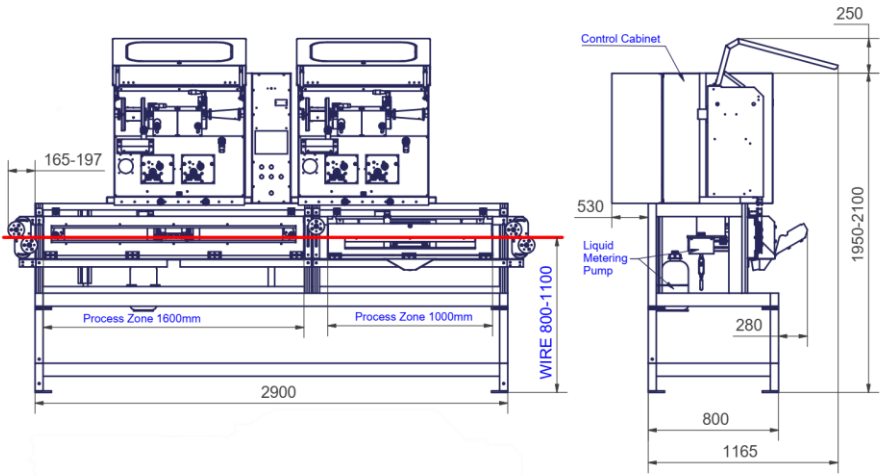
NB57W (passively traversable process zone)



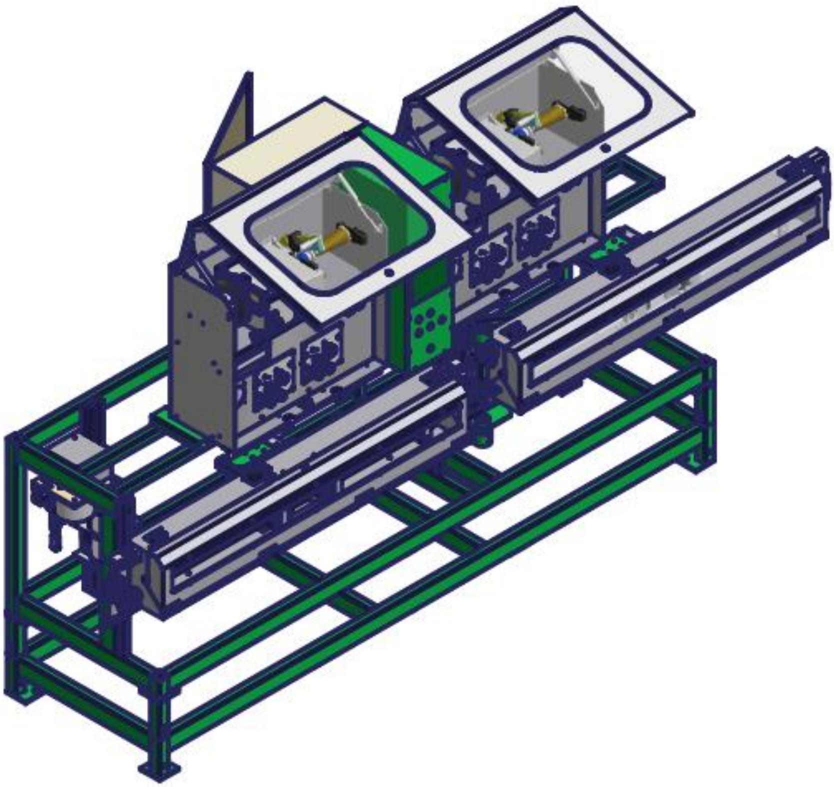


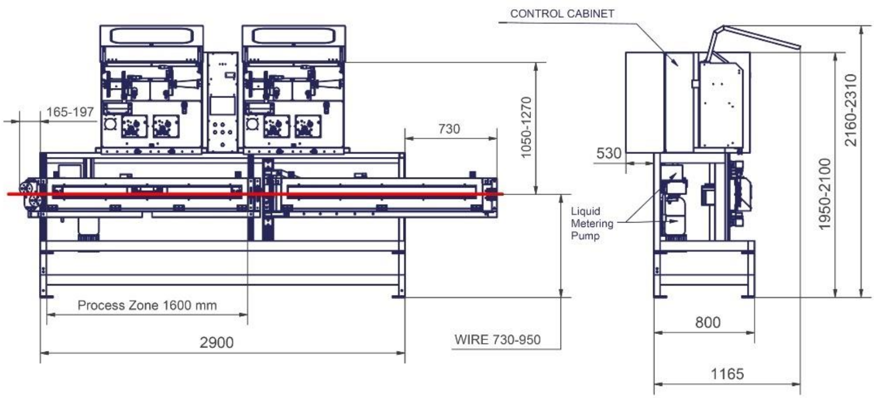
NB58 – streched form





NB58W – stretched form (passively traversable second process zone)





3.2 HELICORD® NB57 for removing misprints

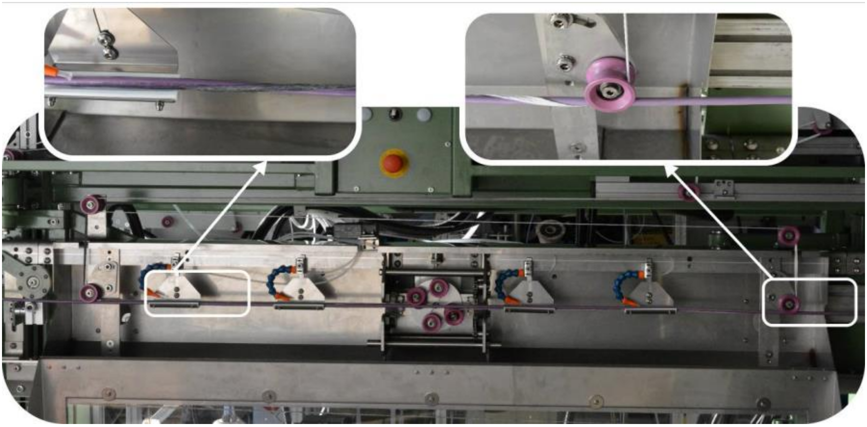


Fig. 42: HELICORD® machine NB57 with special looping unit and multiple liquid metering outlets for removal of misprints from cable jackets. Display details before (left) and after (right) removal of the misprint

Technical Data:

Equipment	- Process zone with dust cover, length 1.6 or 3.0 m - Anti-statically stainless steel cord and cable guide pulleys and support rolls - Automatic looping unit - µ-processor-controlled - Liquid metering device with outlets in up to 5 positions - Steel frame - Connection to the production line is possible
Application	Removal of soluble ink misprints from cable jackets (PVC, PUR)
Technical Data	
Recommended cable diameter (mm) for length of the process zone 1.6 m 3.0 m	≤ 10 mm ≤ 18 mm
Recommended cable speed (m/min)	30 – 60 (depending of the required time of exposure to the solvent)
Preferred friction force (N)	about 40
Applied organic solvents	mostly acetone, MEK (methyl ethyl ketone)
Maximum cord pretension (N)	100
Adjustable metering quantity (ml/min)	2.0 to 10.0 (for each nozzle)
Adjustable cord speed (cm/min)	10 - 120
Control	All parameters are µ-processor-controlled, and displayed on operator touch panel
Power connection	16 A, 3 P+N+E, 380 V, 50 Hz (other options on request)
Power consumption (W)	max. 500
Input signal of cable speed from the line control	0 – 10 VDC
Connection of external control	optional
Acoustic Alarm	110 dB in 1 m distance, 2,500 to 3,000 Hz, alternating current, acknowledgeable
Optical Alarm	Red flashing light
Dimensions H × W × D (mm) for process zone length: 1.6 m 2.6 m	2,400 – 2,600 × 2,100 × 1,330 2,400 – 2,600 × 3,000 × 1,330
Operating temperature	+ 10 to + 45°C
Storage and transportation temperature	– 20 to + 60°C
Relative air humidity	5 to 70 % at 25°C (not condensing)
Environmental air pressure	860 to 1,080 hPa

Table 11

3.3 HELICORD® NB57 for PTFE application

Technical Data:

Equipment	- Process zone, length 3 m, with dust cover - Automatic looping unit - µ-processor-controlled - Metering unit with low shear stress for aqueous PTFE dispersions - Steel frame
Application	Application of aqueous PTFE dispersions to insulated conductors
Technical data	
Range of application	Conductor or cable jacket up to diameters of about 25 mm
Line speed (m/min)	About 50 to 200 (according to current experience)
Friction force (N)	about 40
Applicable PTFE dispersion	NB10H027, NB10H037
Max. cord tension at pay-off (N)	100
Adjustable flow rate (ml/min)	1 to 40
Adjustable speed of HELICORD® (cm/min)	10 to 120
Control	All parameters are µ-processor-controlled, and displayed on the operator-panel.
Connection power	16 A, 3 P+N+E, 380 V, 50 Hz (other options on request)
Power consumption (W)	max. 500
Input signal of cable speed from the line control	0 to 10 VDC
Connection of external control	optional
Acoustic Alarm	110 dB in 1 m distance, 2,500 to 3,000 Hz acknowledgeable
Optical Alarm	Red flashing light about 85 flashes/minute
Dimensions H × W × D (mm)	2,095 – 2,235 x 3,300 x 910
Operating temperature	+ 10 to + 45°C
Storage and transportation temperature	– 20 to + 60°C
Relative air humidity	5 to 70 % at 25°C (not condensing)
Environmental air pressure	860 to 1080 hPa

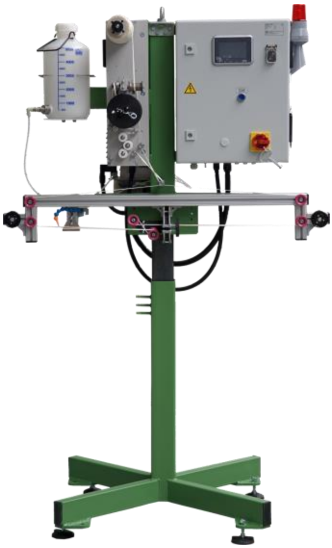
Table 12

Picture 3

3.4 HELIFIL Machines

HELIFIL machines provide:

- Active cord release for constant pretension and minimum slippage
- Service-reduced, high torque stepping motors for friction forces up to 35 N
- Continuous cord tension control at take-up
- Individual µ-processor control, programmable via CAN-bus data exchange
- Power supply: 24 VDC/1.5 A
- Two drive rolls and a pressure roll provide constant cord speed at minimum slippage
- Opposite wire and cord run
- Cord tension monitored by force sensor
- Adaptable to a wide range of wire diameters and speeds
- Suitable for dry wiping, or solvent-supported cleaning (optional pump required)
- Small unit for applications where limited space is available
- Suitable for small wire diameters and friction forces less than 35 N

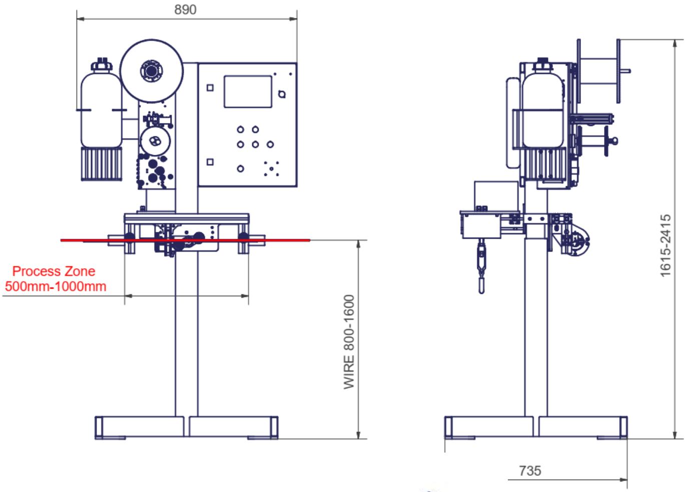


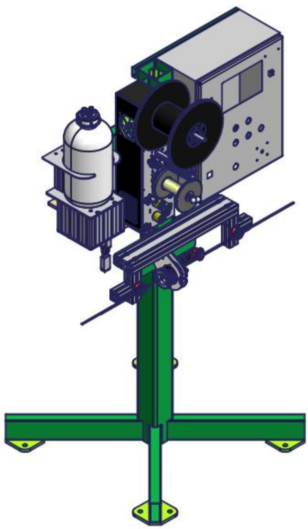
Picture 4

Technical Data

Recommended wire diameter (mm)	soft metals: 0.3 – 3.0; other options for smaller diameters available upon request
Max. cord tension (N)	35
Cord tension at pay-off (N)	0.5 - 6
Max. cord tension at take-up (N)	0.5 - 6
Adjustable cord speed (cm/min)	1 - 100

Table 13





4 HELICORD® and HELIFIL Consumables

4.1 HELICORD® – Overview of Dry Cords

	NB65V014	NB67V002	NB80N001	NB87V002	NB87V006	NB88V001	NB80Z000	NB80Z002
Type of braiding								
Flat	-	-	X	X	X	X	X	X
Round	X	X	-	-	-	-	-	-
Textile basis								
Viscose	-	X	-	-	X	-	X	X
Aramide	-	X	-	X	X	X	X	X
Polyamide	X	-	X	X	-	X	-	-
Range of application								
Dry cleaning	X	X	X	X	X	X	X	X
Liquid-supported cleaning	-	-	X	X	X	X	X	X
Aluminum welding wire	-	X	-	-	X	-	-	X
Ferrous welding wire	-	X	X	X	X	X	X	X
Solid wire	X	X	X	X	X	X	X	X
Stranded wire	X	-	X	X	-	X	X	X
For cleaning before high temperature extrusion and extrusion on pre-heated wire: special types of cord available upon request								
Technical data								
Minimum cord length per cone [m]	1,700	920	770	1,640	1,440	740	829	3,300
Total weight of the cord [mg/m]	~ 1,190	~ 2,410	~ 3,050	~ 1,575	~ 2,320	~ 3,215	~ 3,300	~ 1000
Packing unit	carton (4 cones)							

Table 14

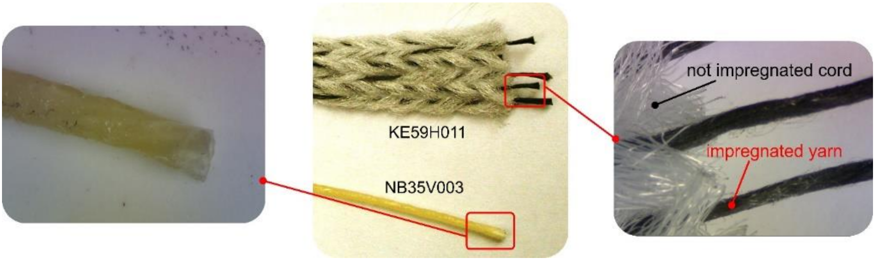
4.2 HELICORD® – Overview of Abrasive Cords

	NB77V009	NB77V011	NB78F001
Flat	-	-	X
Round	X	X	-
Viscose	X	X	X
Aramide	X	X	X
Polyamide	-	-	-
Range of application			
	Non, low- or high-alloyed steel wire, solid wire or flux-cored wire with open or closed seam, Not recommended for plated (e. g. copper-coated) wire!		
Technical data			
Grit size	F150/F360	F360	F40/F80
Cord length per spool [m]	1,550	1,550	930
Total weight of the cord [mg/m]	~ 2,800	~ 2,600	~ 4,100
Packing Unit	carton (2 spools)		

Table 15

4.3 Welding Wire Finish Cords

HELICORD® W cords were designed for application of finish materials onto wire surface. Their braided design provides wear resistance and high tensile strength. Using different individually impregnated fibers and/or impregnating the finished cords, even non miscible compounds can be combined. They can be extracted by means of solvents or heating.



Picture 5: Heat-extractable HELICORD® NB35Vxx versus liquid-extractable HELICORD® W, showing individual impregnated yarns in the braid

The special advantage of HELICORD® W is the possibility to clean and lubricate simultaneously due to the fact that HELICORD® W process allows operation with wire and cord running in opposite directions.

Thus, loose and loosely adherent particles and scales from the drawing process or other preceding process steps are thoroughly removed. This improves the properties of welding wire regarding lifetime of the liner and contact nozzles.

	NB37F004	NB81V000	NB82K300	NB82C300
Flat	X	X	X	X
Round	-	-	-	-
Viscose	-	X	X	X
Aramide	X	X	-	-
Polyamide	X	-	X	X
Wax-like lubricant	X	-	X	X
Lubricant with low hydrocarbon content	-	X	-	-
Corrosion inhibitor	X	-	X	X
Plasma stabilization	X	-	X	X
Separating agent	-	-	-	X
Steel (low-alloyed and non-alloyed)	X	-	X	X
Steel (high-alloyed)	X	-	-	-
Aluminum	-	X	-	-
Cord length per cone/spool [m]	1,070	1,260	700	700
Total weight of the cord [mg/m]	~ 2,560	~ 2,390	~ 5,300	~ 6,750
Packing unit	Carton (4 cones)			

Table 16

5 Liquid Consumables

General Information

We offer a number of liquid consumables for various applications.
In the cable industry, dispersions are used as slide, strip or feed aids.
Welding Wire Finish dispersions and oils are liquid lubricants for welding wire surface preparation. The formulae were designed specifically for improvement of copper-coated low alloy and mild steel wire. They improve the welding properties of wires with respect to:

- **Feedability**

Due to the base material - a thin, low-volatile fatty acid derivative or PTFE - a good coefficient of friction, i.e. low feed resistance of the coated wire is achieved.

- **Storage Stability**

The decrease of feedability of oil-lubricated welding wire upon storage is a well-known phenomenon caused by oxidation and volatility of the oil, whereas PTFE coatings are almost inert. Boockmann's oil-based Welding Wire Finishes contain an antioxidant delaying the degradation of sliding properties caused by oxidation of the lubricant during storage under exposition to air. The decline of feedability caused by volatility of the lubricant cannot be changed by use of additives. This decline becomes evident to a measurable degree upon open storage over more than 6 months. Only vapor-impermeable packaging, such as aluminum compound foil, will help.

- **Corrosion Protection**

Another group of additives has anti-corrosive influence not only on the copper surface, but also on the iron base which is not completely protected by the copper coating. These anti-corrosive agents delay the first appearance of rust points from several hours to up to more than one week in warm and humid climate. Thus, it will be possible to leave the wire spool unprotected on the welding machine, e.g. during the weekend, also in tropical climate.

- **Welding Arc Stabilization**

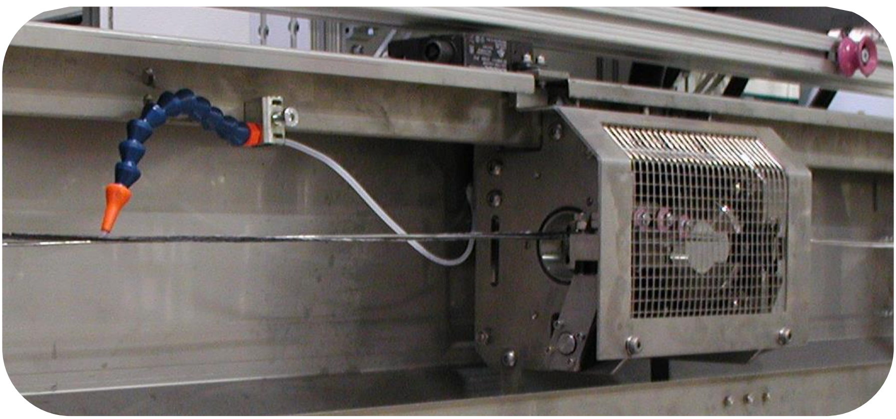
An additive stabilizes the electrical discharge. For wire with such a coating, the noise level and spray welding inception voltage are measurably lower. Thus, the energy input into the melt will be reduced and welding of thinner sheets enhanced. Spattering of the melt is also reduced. This leads to less vibration of the handle, reduced formation of deposit in the gas nozzle, and especially loss of material by spattering of several percent of the material used is reduced considerably. The monetary savings of material overcompensate the higher cost of the lubricant.

Application Process of Welding Wire Finish

Welding Wire Finish dispersions and oils can be applied in the skim pass after copper-coating or by conventional application means (wiper, pump-felt, roller-felt, spray methods). During application by HELICORD® process, besides better uniformity, removal of loose particles (from the drawing process or copper-coating) can be achieved simultaneously, thus improving welding properties with respect to clogging of the liner and deposit in the contact tip.

Product number	Type of liquid	Chemical basis	Components	Applications
NB10H020	Finish oil	Ester oil	Ca. 6,3 % Potassium, corrosion protection	Finishing of Copper-coated welding wire
NB10H027	Dispersion	De-ionized water	20 % PTFE	Slide, strip and feed aid for bare and already insulated conductors and cables
NB10H037			10 % PTFE	

Table 20



Picture 15

IV. Liquid Metering Pumps

1 Metering Pump NB41B780

1.1 Principle

The metering pump unit NB41B780 is based on a self-priming radial peristaltic or hose pump for pumping neutral aqueous liquids or dispersions.
This principle is based on the outside of a hose lying against the circular segment inner wall of the pump head, pinched off from the inside by rollers rotating on a rotor.
As a result, the pinch-off moves along the hose and propels the pumped medium.
The metering pump NB41B780 consists of the following main components:

- Peristaltic pump with drive motor (5) with variable speed control.
- Removable pump container (6) made of stainless steel with a filling capacity of 1.5 liters
- Level control for the pump container
- Reservoir bottle (7) with a filling capacity of 5 liters
- Control box with control and operator display
- Aluminum frame for mounting the metering pump and its components

1.2 Dimensions

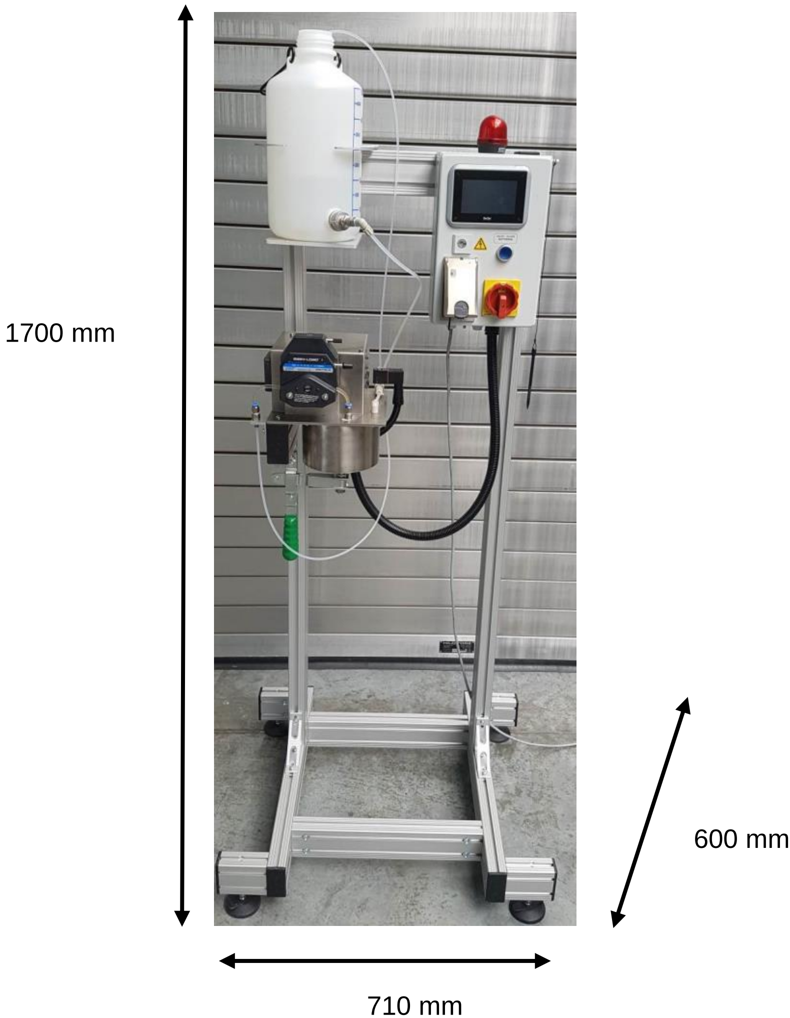


Bild B.1: NB57G003

1.3 ***Technical Data***

Application	Metering pump for applying an aqueous PTFE dispersion to bare and insulated wires and cables preferably in combination with a HELICORD® machine.
Operator's interface	Touchscreen 4"
Adjustable flow rate (ml/min)	0 bis 10 rpm (~ 0 bis 100 ml/min)
Applicable range of viscosity	≤ 1,000 mPa•s
suitable pH range	4 - 10
Compatible liquids	aqueous PTFE dispersions
Power supply (1P + N + PE)	230 VAC, 16 A pre-fuse
Fuse	T 4 A
Input signal	Digital wire speed signal 24 V DC (Pulse), max. 4.000/sec
Acoustic Alarm	Level monitoring (110 dB in 1 m distance, 2,500 to 3,000 Hz, acknowledgeable)
Optical Alarm	Red flashing light
Dimensions H × W × D (mm)	1700 x 710 x 600
Net Weight (kg)	45
Capacity Reservoir	~ 5.0
Capacity Pumpcontainer	~ 1.5
Operating temperature	+ 10 to + 45°C
Storage and transportation temperature	– 20 to + 60°C
Relative air humidity	5 to 70 % at 25°C (not condensing)
Environmental air pressure	860 to 1,080 hPa

Table 21

2 **Application notes**

- The compatibility of the pump and its components with media other than aqueous neutral PTFE dispersions must be evaluated and approved. Otherwise, malfunction or damage are possible.
- The metering quantity of the peristaltic pump can be set via the touchscreen display in rpm of the rotor in the pump head. It can be adjusted proportionally to a frequency signal from a sensor (e.g. wire speed) or an external control (e.g. HELICORD® equipment NB55 and NB57).
- The pump container can be removed for emptying and cleaning.

V. Skim-Pass Dispersion NB10H038

Task:

The copper layer of both chemically and electrolytically copper-coated welding wire is not compacted. It appears dull due to loose copper particles. Therefore, a final drawing step, the so-called skim pass, is necessary. Lubricants used are oils and dispersions. They may not be too viscous so as not to destroy the weak adhesion between copper and iron.

The viscosity of our water-dilutable skim pass dispersion can easily be adjusted for specific requirements by adding water. The values in the table below refer to the most typically used concentration; a higher viscosity version is available upon request. Our dispersion contains a highly effective additive for corrosion protection.

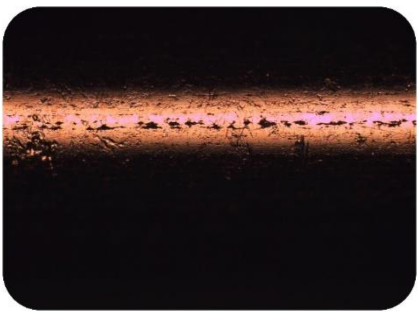
Technical Data:

Property	Unit	Typical value
Appearance		Low viscous, light-toned, opaque
Density (20 °C)	g/cm³	1,00
Solids content (1 g in a tray Ø 5 cm, 2 h, 140 °C)	%	40 +/- 1
Flash point	°C	67
Viscosity (20 °C, DIN 53211, 4 mm)	sec	40 +/- 2
pH value		7 – 8

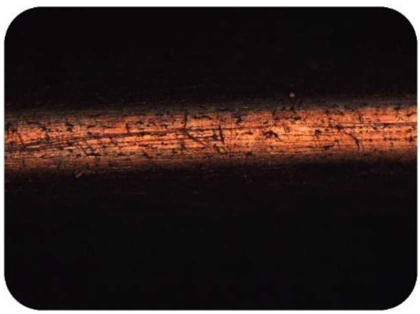
Table 17

An important manufacturer of copper-coated welding wire prefers our product after comparative testing, due to the evaluation as follows:

“The wire drawing lubrication by using NB10H038 oil is good, and have a bright surface, the copper layer is dense, strong anti-corrosion ability.” (excerpt from conclusions, “Test report of wire polishing oil”)



Picture 6: Surface of copper-coated welding wire (Ø 1.18 mm) after the skim pass using NB10H038 and corrosion test



Picture 7: Surface of copper-coated welding wire (Ø 1.18 mm) after the skim pass using a conventional dispersion and corrosion test

VI. Multi Wire Cleaning Machine

Field of application:

For treatment of multi wire, fine wire and strip surface a multi wire cleaning machine is now available. It can be used to

- wipe off metal dust and particles as well as oily or other contamination from the surface of wire and strip, or
- evenly apply lubricant or a release agent as well as other functional substances.

The preferred field of application is the surface treatment of wire for strands with an individual diameter of 0.1 to 0.8 mm. Single wires of a diameter of 0.3 mm or bigger are preferably to be treated by HELICORD® because of the multiple 360° loops and higher process reliability. Furthermore, thin rectangular shaped wire, flat conductors, metal strips of a thickness up to 0.5 mm and widths of up to 300 mm can be treated. The material to be treated can be steel, copper, aluminum or other non-ferrous metal. The wire or strip can be bare or metallized.

Short description

The strand to be cleaned is fed through two parallel fleece strips pressed together by an adjustable force against the feed direction in the process zone (see picture 8).

For adjustment to the wire diameter, different strengths of fleece are available.

Picture 8: Multi wire cleaning machine

Picture 9: Fleece run

For an intensive contact between fleece and wire or strip as well as for setting the friction force, four rollers are arranged in pairs in the process zone and adjustable against each other in height.

Both fleece strips are fed through the process zone from the supply spool under dancer-controlled tension at a constant speed and wound onto a take-up spool.

Properties

The multi wire cleaning machine and HELICORD® technology have many advantages in common:

- energy input independent of wire speed for each unit of surface area
- continuous supply of fresh cleaning medium and the possibility of adding cleaning liquids or application (e. g. lubricants, anti-corrosives etc.)
- regulation of the fleece speed and possibly of the dosage quantity proportional to the speed of the strand during start-up or slowing down of the production line.

In order to use the entire surface of the fleece strip, the angle between the longitudinal axes of the fleece and process zone can be adjusted.

When cleaning rectangular profile wire or strips it is necessary to consider that for wire of a diameter of more than 0.5 mm, the sides where the two fleece layers touch are not treated properly due to the principle.

The machine is microprocessor-controlled. A touch panel is used as operator interface showing the operating status as well as possibly appearing error messages, and to enter setpoints for fleece tension and fleece speed.

In order to replace the fleece supply spool and to insert strips to be treated, the upper and lower part of the machine connected by a hinge joint can be opened (see picture 9).

Technical data

1	Speed of wire or strip	≤ 20 m/s
2	Wire diameter	0.1 – 0.8 mm (AWG 20 to 38)
3	Height of the run of the wire or strip	1.0 – 1.2 m (adjustable)
4	Dimensions of fleece	Width: 300 mm Thickness: approx. 1 mm Length: 100 m Core diameter of the spool: 71 mm Outer diameter of the spool:320 mm
5	Adjustment range of fleece speed	1 – 1.000 mm/min
6	Adjustment range of pretension fleece	2 – 20 N
7	Electric outlet	115 – 230 VAC / 50 (60) Hz, 1 A
8	Primary protection	4 A
9	Input signal for speed of wire or strip from line control	0 – 10 VDC
10	Acoustic alarm	110 dB in 1 m distance, 2500 to 3000 Hz, acknowledgeable
11	Optical alarm	Red flash light
12	Dimensions H × B × T (mm)	1.600 – 1.800 × 1.000 × 700
13	Operating temperature	± 10 to + 45°C
14	storage and transport temperatures	– 20 to + 60°C
15	Relative air moisture	5 to 70 % at 25°C (non-condensing)
16	Ambient air pressure	860 to 1080 hPa

Table 18

VII. Labtech

1 Device for Determination of the Static Coefficient of Friction of Wire Surfaces

Basic Considerations

Both in the laboratory and in production, a quick evaluation of sliding properties of wire surfaces is often needed. The static coefficient of friction (µ) can be used as a first indication.
Boockmann's compact device for measuring the static coefficient of friction provides a quick and easy measurement and thus allows fast judgement of production conditions and parameters.

Measurement Principle

Condition I: $F_H < F_R$

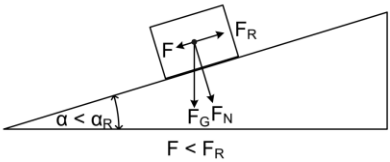


Fig. 43

Condition II: $F_H \geq F_R$

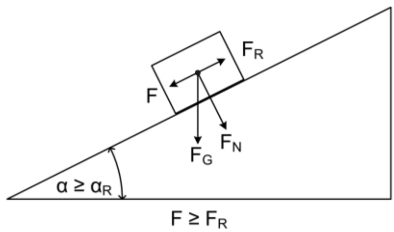


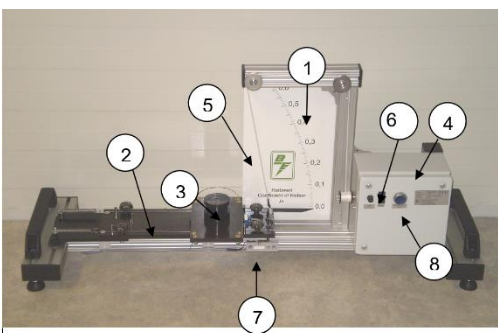
Fig. 44

F_N = Normal force
F_H = Downhill slope force
F_G = Gravitational force (sliding plate)
F_R = Friction force
µ = Coefficient of friction

$$\mu = \frac{F_R}{F_N}$$

For the condition $F_H = F_R$, the friction force is determined by increasing the angle β until the sliding plate starts moving (Condition II).

Equipment



Picture 10

Legend:

1 - Scale
2 - Inclination plate
3 - Sliding plate with a weight
4 - Control Box
5 - Rope
6 - Main switch
7 - Micro switch
8 - Reset measurement button

Measurement

After the wire is positioned correctly and the measurement is started, the inclination plate (2) moves upwards and stops automatically when the sliding plate (3) starts moving (picture 11). The coefficient of friction µ (*µ=tanβ)* can be read on the scale (1)

Picture 11

A minimum of 5 measurements is made, and from them the arithmetical average of μ is calculated.

Technical Data Sheet		
Product no.		NB40B955
Recommended wire diameter		0.10 to 2.5 mm
Mains voltage		115 to 230 V AC
Fuse		T 2.5 A
Total power consumption		~ 50 W
Operating environment	Temperatures	+10°C to +45°C
	Relative air humidity	5 to 70 % at 25 °C, not condensing
	Air pressure	860 to 1080 hPa
Measurement (W x H x D)		1010 x 500 x 310 mm
Weight		~ 10 kg
Measuring range		0.0 to 0.6
Accuracy		± 0.01

Table 22

2 Test Unit for Determination of Hydrocarbons on Wire Surfaces

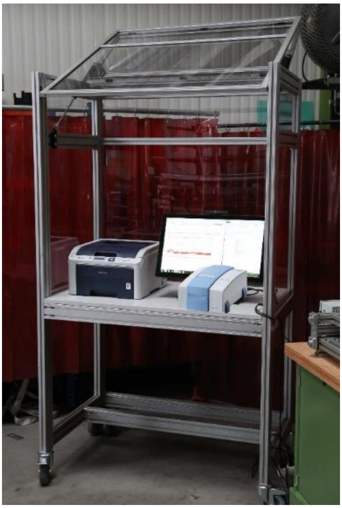
Hydrocarbons (CH) can influence the surface properties of wire and its processing considerably. Therefore the knowledge of type and amount of organics on the wire surface, either contamination or functional coating, is important for wire manufacturers, processors and industrial end-users for quality assurance.

More simple infrared measurement systems applied in the wire industry work with a fixed wavelength and only allow the quantitative determination of a specific hydrocarbon based on the calibration set in the factory.

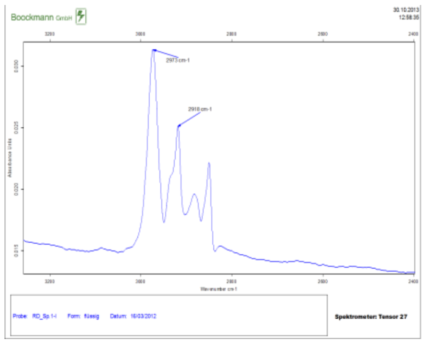
In contrast, the test unit presented here records the full spectrum in the MIR range

- either in the transmitted light through a cuvette containing the measuring solution
- or optionally by an „ATR“ unit in total reflection at the wire itself or by a wipe on a suitable CH-free medium.

Amount and type of pure hydrocarbons on wire surfaces can be determined by suitable computer-assisted analysis. The determination of mixtures of CH or additions of inorganic components is limited.



Picture 12: Enclosure, IR spectrometer, computer for evaluation and color laser printer



IR spectrum: CH absorption used for evaluation

Two configuration data sets with the associated calibration curves for the IR spectrometer are delivered with the CH test unit for quality-ensuring determination of the amount of known hydrocarbons. They enable even non-professionals to successfully operate the machine by following an easy-to-understand measuring instruction.

The CH test unit converts the determined concentration of the solvent on the basis of the entered data and provides results in terms of the amount of lubricant per square meter of the wire surface.

The test unit provides the following additional features like for example:

- extension of the library of IR spectra included in the delivery
- setup of customized libraries
- computer-supported substance identification by comparing spectra (with references created before) in the libraries
- method setup for substance specific quantification
- diverse functions for spectra editing and evaluation

Included in the delivery of the test unit are:

- work table with dust cover (with ventilation hook-up)
- FTIR spectrometer (measuring range for wave numbers of 375 – 7.500 cm^{-1}) with
- transmission unit with holder for cuvettes
- 10 mm quarz cuvettes set
- 5 ml pipette
- test tube holder
- 200 test tubes
- configuration data sets to determine the amount of specific hydrocarbons
- optional: ATR-unit
- computer with Windows operating system and pre-installed software for spectra evaluation
- spectra library with organic substances frequently used in welding wire manufacturing
- measuring standards (BE standard 151, BE standard 154, BE standard 156) for quantitative and qualitative determination of substances
- color laser printer
- analytical scales
- dosage pipette

3 Digital Microscope for Wire Surface Examination

Target

Surface damages on wire, such as

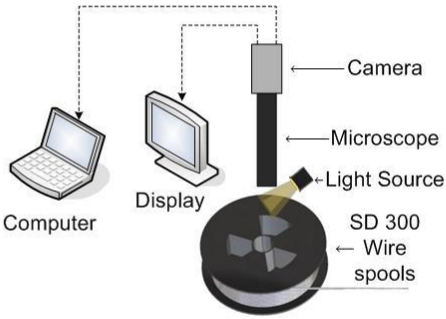
- roughness from rod or strip
- scratches from pulley flanges
- scratches from precision winding
- micro cracks due to too high deformation ratio or slippage of the wire on capstan rolls

are generated in different steps of the production process.

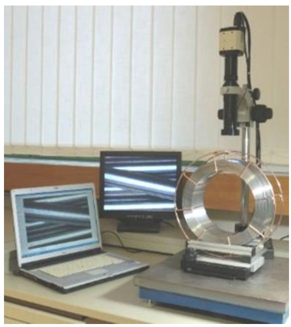
In order to avoid this and systematically improve the wire surface quality, raw material quality and process conditions, especially of drawing and rolling, must be adjusted. To do so, it is necessary to examine and evaluate the wire surface carefully in each production step.

Solution

The digital microscope provides, at reasonable cost, the possibility to visually inspect the wire surface on sample pieces or directly on spools (figure 45b). Comparing the surface after different stages of production, ideally the particular process during which a specific type of surface damage is generated, can be verified.



a.



b.

Fig. 45: Schematic (a) and photograph (b) of the setup

The digital microscope setup consists of

- Reflected-light microscope with 11-fold optical zoom
- 15" XGA color monitor
- Object table with stand column

- Precision xy-cross table with additional holders for
  a. wire spools (up to dimension of SD 300, see picture 1b) and
  b. wire segments Ø 0.5 to 3 mm and 200 mm length (figure 2); 360° observation by wire rotation around its longitudinal axis
- LED ring light for vertical lighting
- LED spot light (2.3 W) for inclined lighting
- High resolution camera with direct and USB video output

and comes with a CD with basic PC software that allows storing individual pictures and short videos.

Options

- Two additional lenses providing magnifications 90x - 1,000x (about 45 mm focal distance) and 22x - 250x (about 180 mm focal distance) available. [Remark: The higher the focal distance, the higher is the depth of sharpness.]
- Software for enhancement of depth of sharpness
- PC or notebook with Microsoft Windows operating system

Technical Data

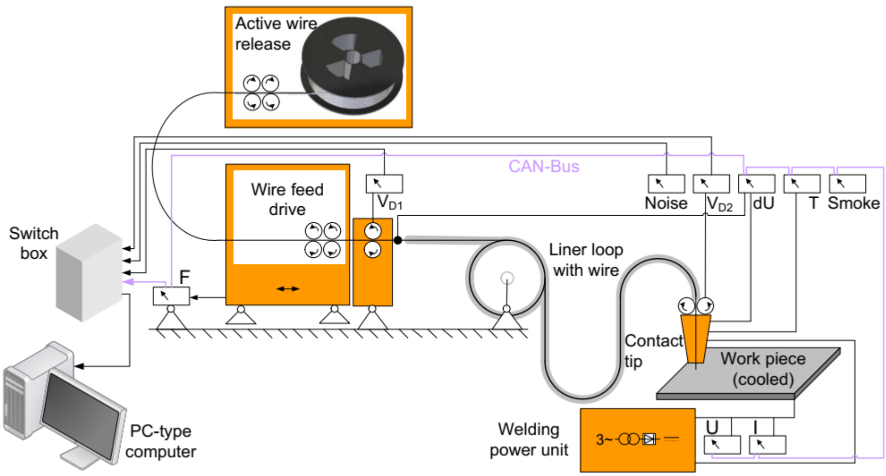
Microscope		
Magnification (with respect to a 15" monitor)		45× to 500×
Focal distance (microscope to object) (mm)		90
Video Camera		
Resolution	Direct video output (pixel)	1,024 × 768 (XGA)
	USB output to PC (pixel)	1,600 × 1,200 (UXGA)
Power supply		100 - 240 V / 50 – 60 Hz (P + N), max. 1.0 A
Monitor		
Screen size (inch)		15
Resolution (pixel)		1,024 × 768
Power supply		100 - 240 V / 50 – 60 Hz (P + N + PE), max 1.5 A
Object table		
Lateral dimensions (mm)		400 × 400
Height of stand column (mm)		about 560
Precision xy-cross table		
Lateral dimensions (mm)		180 × 155
Lateral working range (mm)		65 × 76

Table 19

4 Welding Test Unit

Picture13

The welding wire test unit allows the objective assessment of welding wire properties by operator-independent experimental welds under controlled and repeatable conditions. That provides information on systematic further development and quality assurance. During welding, measurements like feedability and voltage loss in the contact tip are recorded. The moving work piece allows long-time tests, so that variations in wire surface quality regarding particles, roughness and consistency as well as performance in the contact tip and contact tip wear can be detected.



Picture 14

The following measurements are recorded by the computer of the welding test unit and displayed as a chart on the screen:

- feeding force (F)
- welding current (I)
- welding voltage (U)
- voltage loss in the contact tip (dU)
- noise level during welding
- temperature curve of the contact tip (T)
- wire speed after wire feed (VD1)
- wire speed before contact tip (VD2)
- smoke density

The chart shows measurement curves of a customary stainless steel welding wire in need of improvement. The simultaneous fluctuations of the feeding force and the welding current curve show micro-arcs and welds in the contact tip. They finally lead to complete fusing of the wire with the contact tip and interruption of the measurement. The high and very irregular voltage loss probably is caused by contamination of the wire surface.
The voltage loss of a good copper-plated wire is less than 25 mV, that of a good blank normal steel wire less than 100 mV.

Testing curves (flux-cored stainless steel welding wire with a diameter of 1.2 mm):

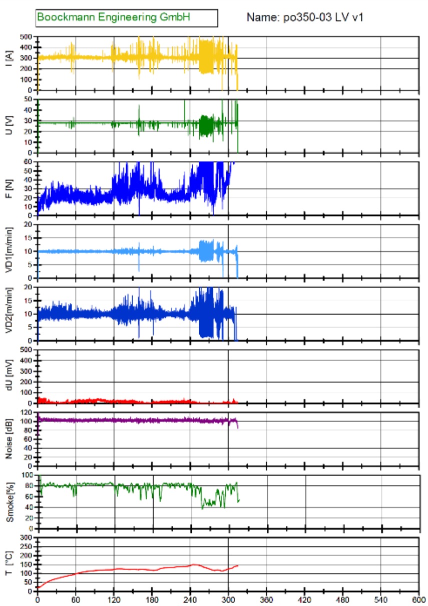


Fig. 46: Commercially available product

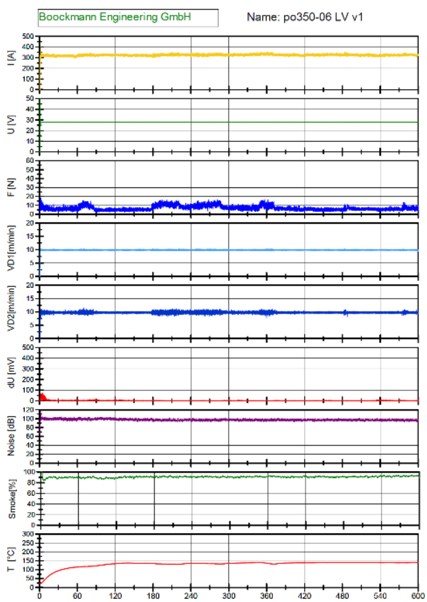


Fig. 47: Wire from a) after welding wire finishing with HELICORD®

Further properties:

- The welding current can be set up to 500 A during permanent operation.
- Measuring data are recorded at up to 1 kS/s and an analog digital converter resolution of up to 12 bit.
- The welding speed can be set up to 1,000 mm/min.
- The operator is guided through the measurement by HMI.
- The measurement report can be printed by the color laser printer included in the delivery.

Notes:

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