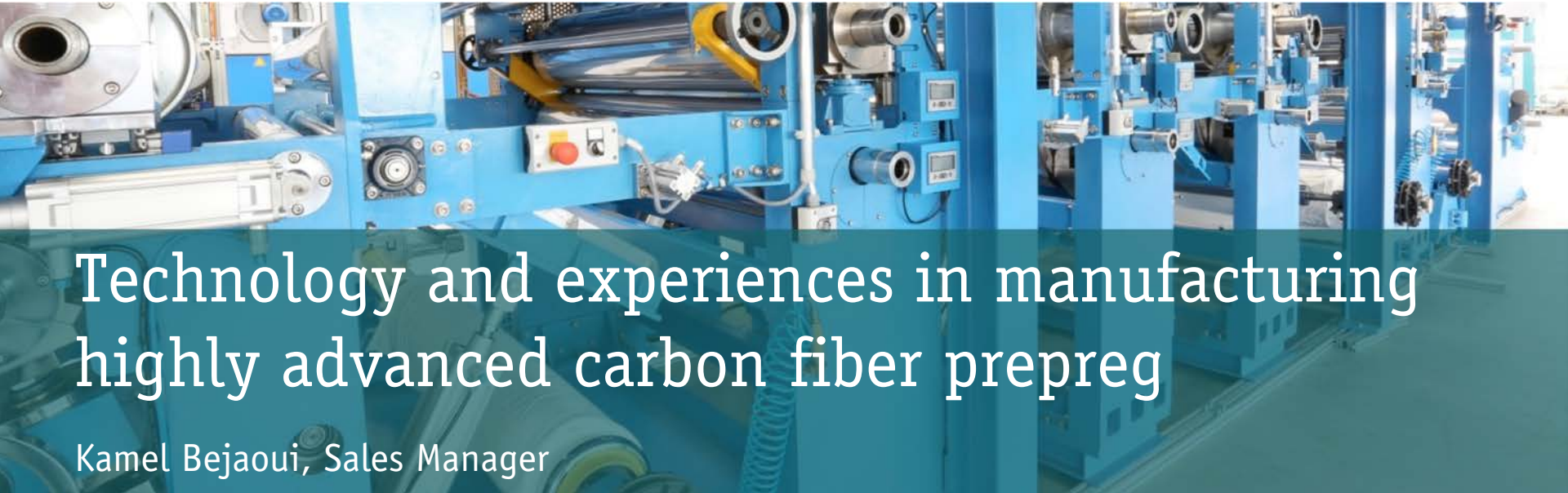




Technology and experiences in manufacturing highly advanced carbon fiber prepreg

Kamel Bejaoui, Sales Manager

Summary

Introduction

Technology
background

Spreading
technology

Coating
technologies

Impregnation
technologies

Curing / High
temperature
systems

Pilot line
layout

Proof
of concept

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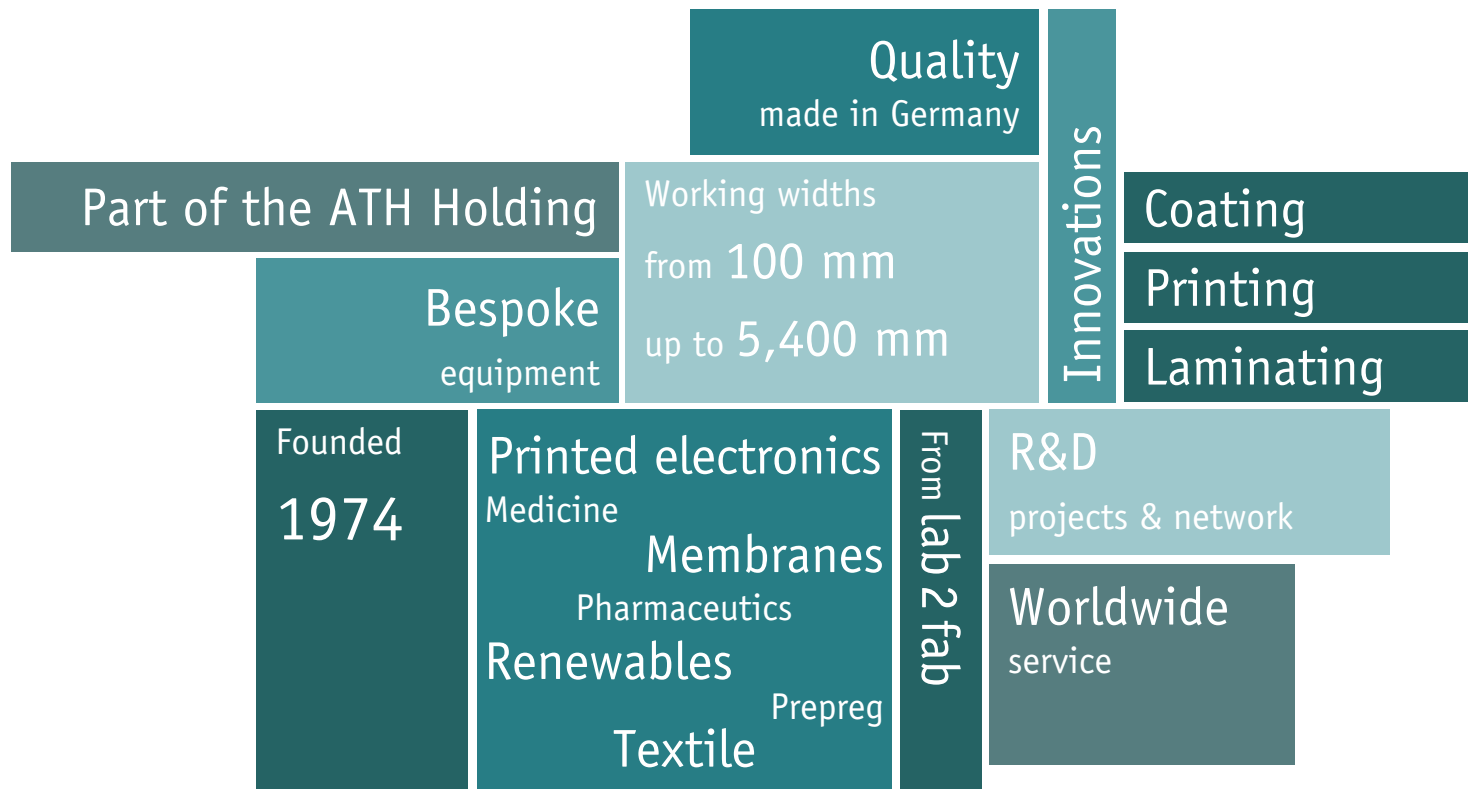
Impregnation
technologies

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layout

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of concept

Overview



Group of companies



- ✓ Founded 1903
- ✓ Approx. 200 employees
- ✓ Located in Hamburg



- ✓ Founded 1995
- ✓ Approx. 50 employees
- ✓ Located in Norderstedt



- ✓ Founded 1974
- ✓ Approx. 50 employees
- ✓ Located in Dormagen

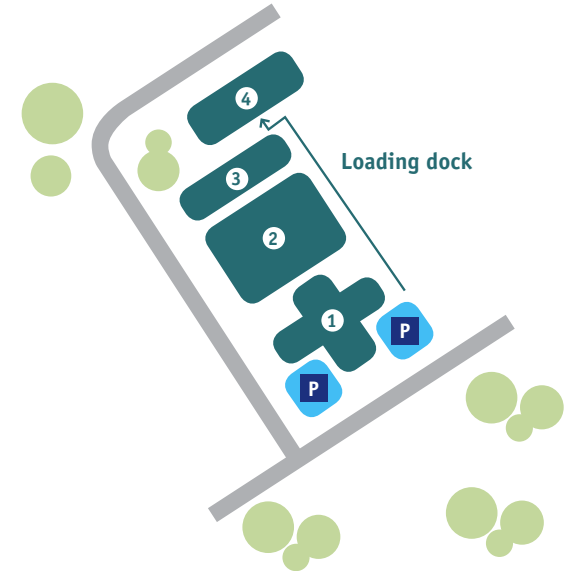


- ✓ Founded 1919
- ✓ Approx. 140 employees
- ✓ Located in Hamburg

Represented worldwide



Headquarter in Dormagen



- ① Head office
- ② R&D centre
- ③ Assembly
- ④ Loading dock
- P Visitor parking

Vision – from lab 2 fab



Lab



Pilot



Production

Coatema equipment platform strategy for lab 2 fab

Our work in associations – global networking



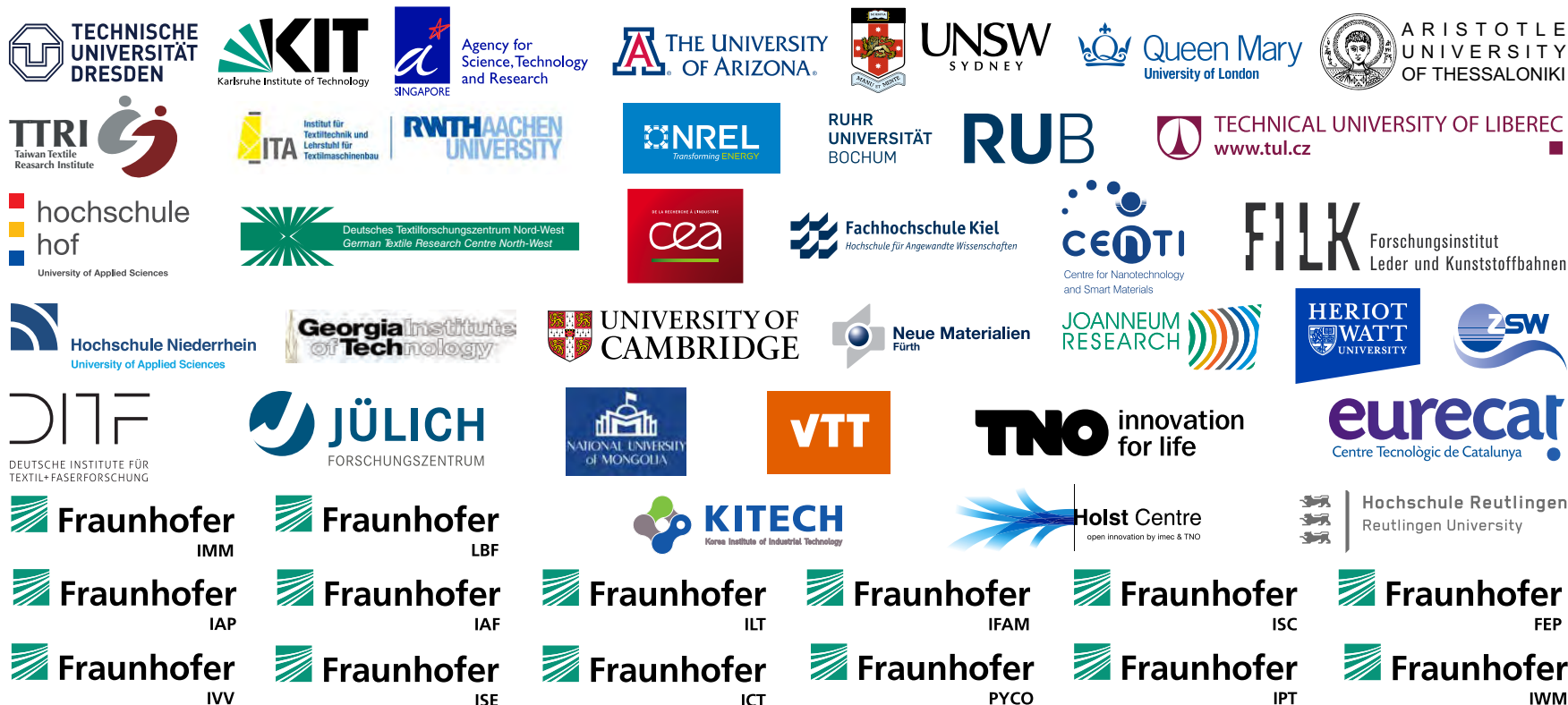
Board Member:
OE-A

Advisory Board:
Fraunhofer ITA

Coatema customers



R&D customers



R&D projects overview 2020

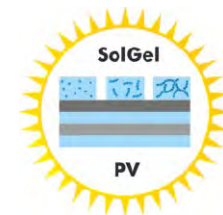


Oled Solar

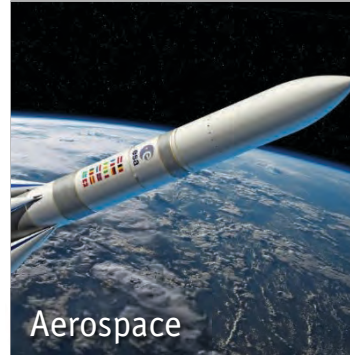
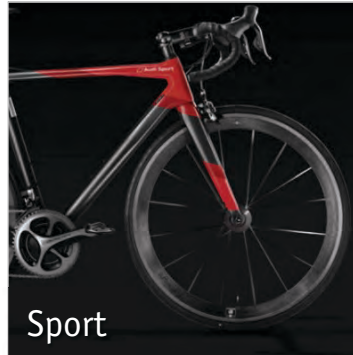


PEPcat

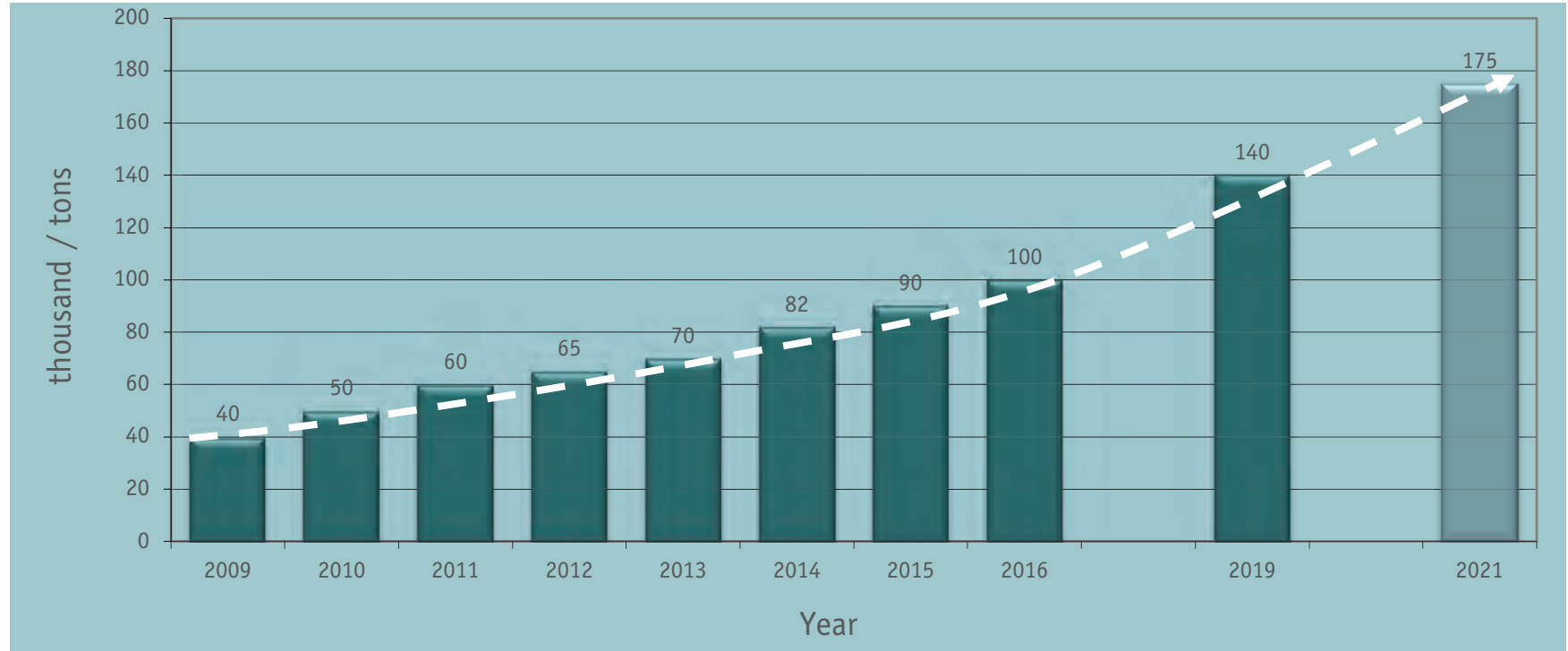
E-Nanoprint Pro



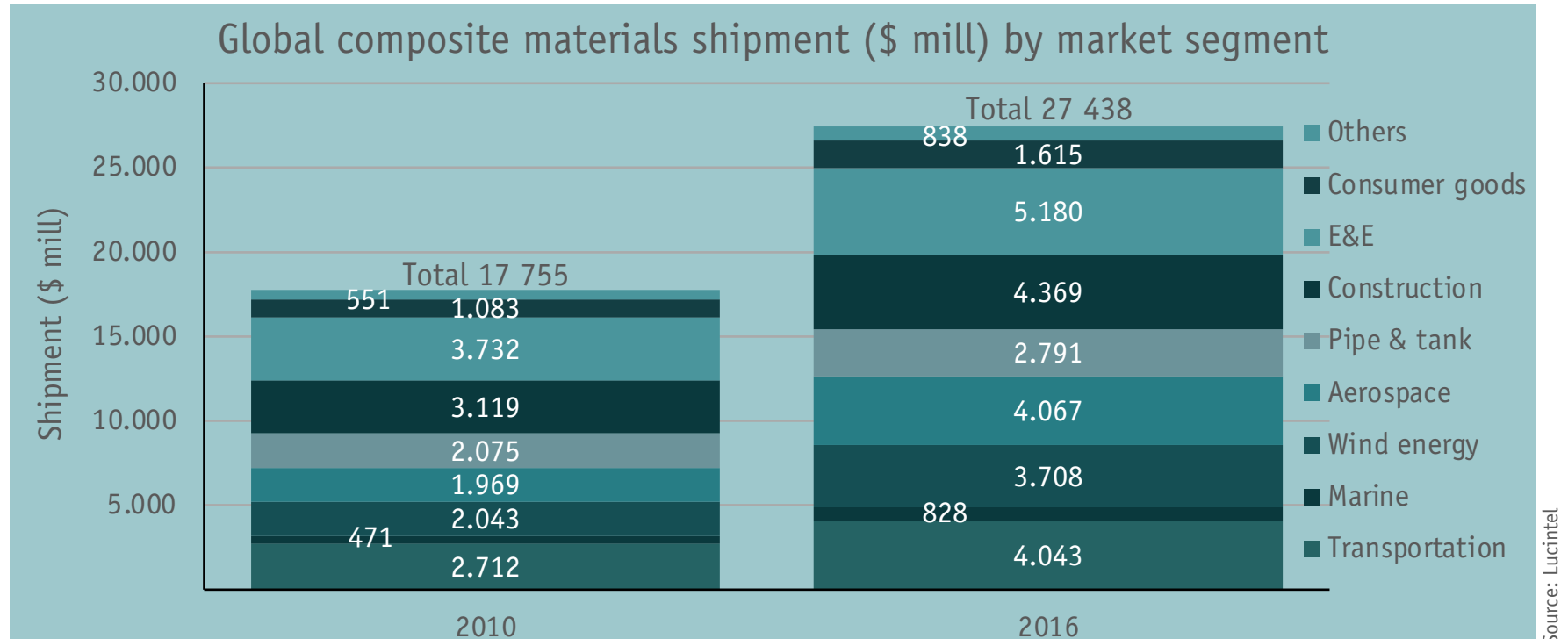
The market for prepreg



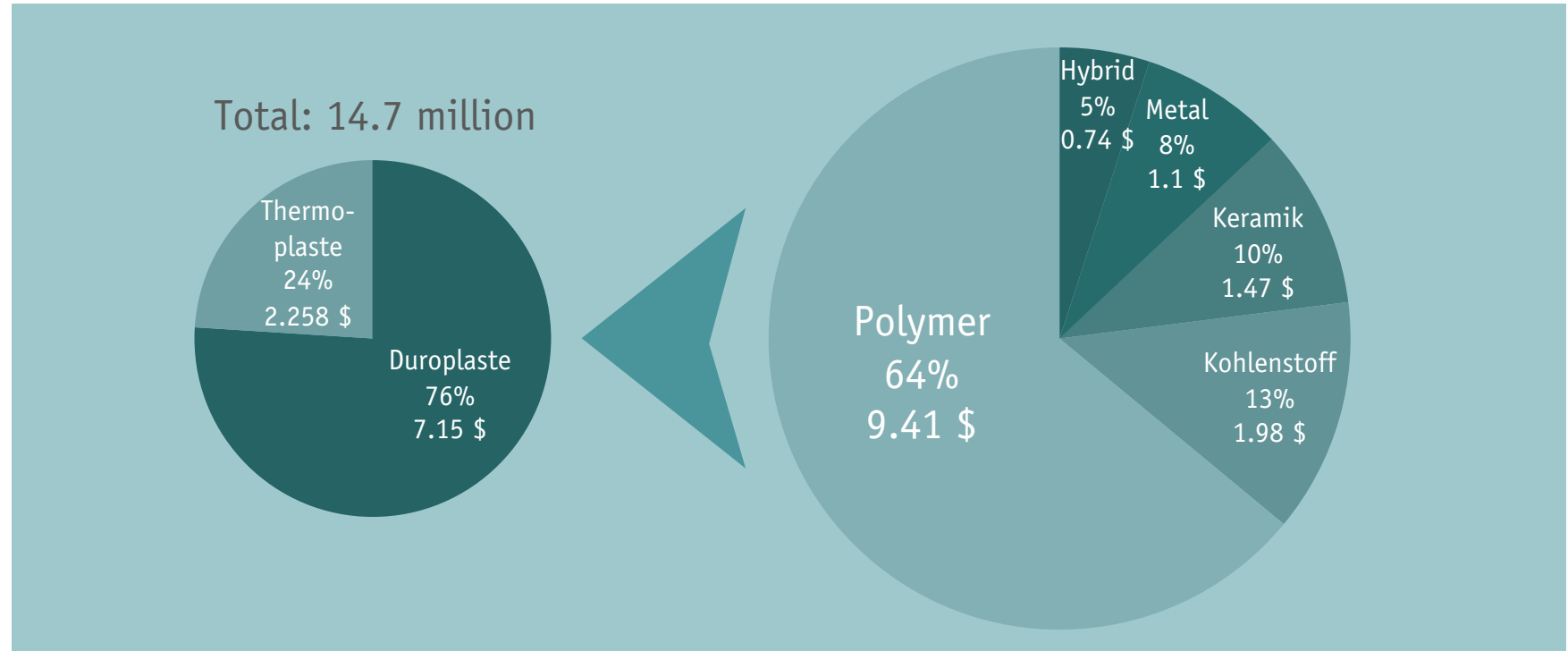
The market for prepreg – the market in total



The market for prepreg – the market in total



Current turn over in Bill. US\$ for different matrix materials (2013)



Source: Acmite Market Intelligence e.K.

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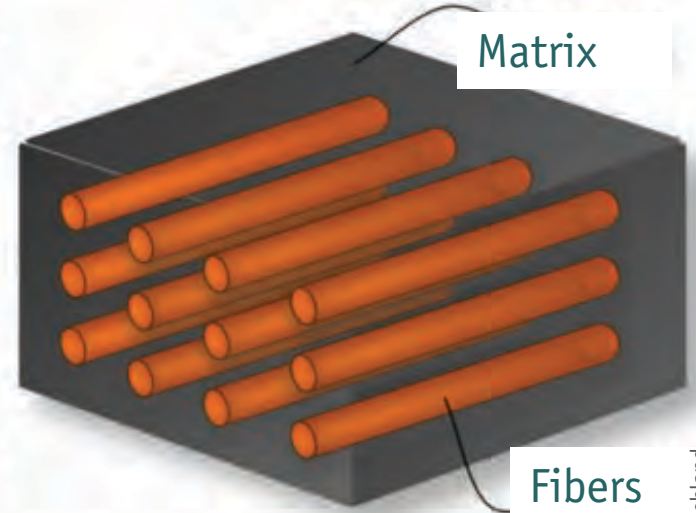
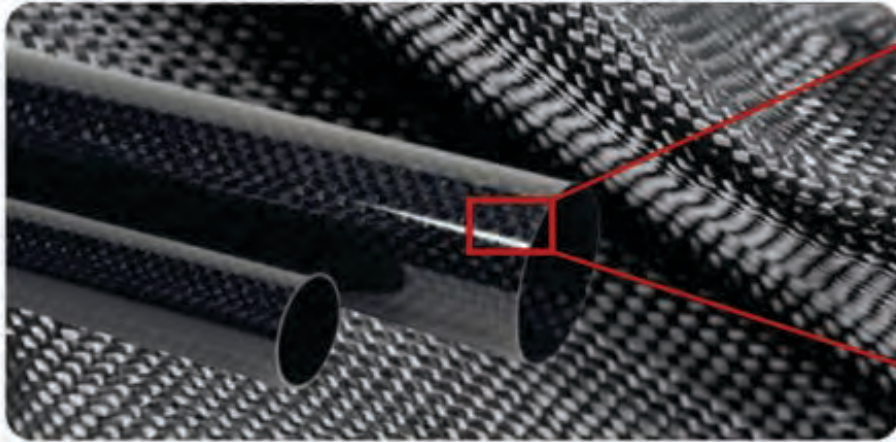
Impregnation
technologies

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of concept

Prepreg



Source: Carbon-Deutschland

Types of material

Today there are 3 major composite systems

✓ Thermosetting (duroplastic) resins:

A polymer that cannot be remolten or reformed once it has been cured.
Curing creates a molecular cross-linking, which is irreversible.

Version B-stage: ✓ Curing stops at incomplete crosslinking
✓ Final curing to complete crosslinking after shaping

✓ Thermoplastic resins:

A polymer in which the molecules are not cross-linked, or they are cross-linked to a weaker degree. A thermoplastic polymer can be reshaped or reformed by reheating the polymer.

✓ Hybrid systems

Fibres and substrates

Reinforcement – man made fibres

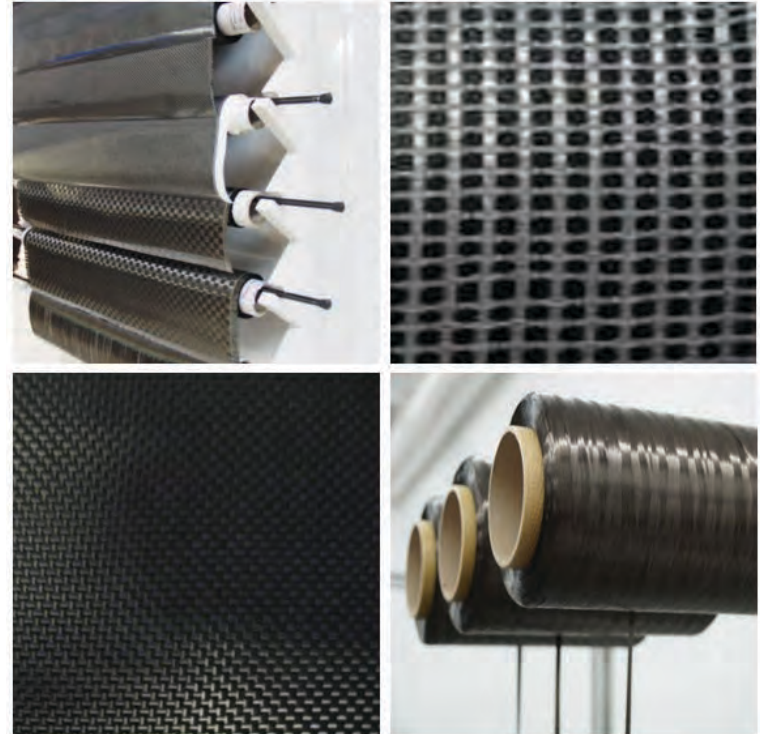
- ✓ Carbon
- ✓ Glass
- ✓ Polyamide (Nylon R)
- ✓ Aramid (Kevlar R)
- ✓ Basalt



Rovings and textile structure

Rovings and textile structure of the substrate

- ✓ Uni- and Bi-directional structures
- ✓ Woven substrates
- ✓ Multi-directional fibers construction
 - ✓ Layer (cross) structures
 - ✓ Sewed knitted structures
 - ✓ Nonwovens
- ✓ Products with more than one orientation direction, this is influenced by the later desired strength direction



Thermosetting materials

Thermosetting (duroplastic) resins:

- ✓ Solvent based epoxy resins also as chemical or physical B-stage
- ✓ Hotmelt and solvent free epoxy resins
- ✓ Phenol systems solvent or water based
- ✓ Cyanate Ester systems
- ✓ Polyester / vinyl ester / acrylic resin
- ✓ 1K and 2K products (mostly resins)



Disadvantages:

Rigid, not meltable, recycling problems

Specs for thermosetting materials

Specs for thermosetting (duroplastic) systems:

- ✓ **Variation of the coating weight both sides**
10 – 300 g/m²
- ✓ **Range of viscosity**
100 – 50 000 mPas
- ✓ **Temperature range**
40 – 250 °C, standard application temperature 60 – 120 °C
- ✓ **Speed range for different production processes**
average speed 50 – 80 m/min for film coating process
average speed 5 – 15 m/min for combined coating and laminating lines
average speed 5 – 25 m/min for impregnation average speed
- ✓ **Temperature accuracy**
± 1K roller surface temperature and dryer accuracy

Thermosetting materials advantages

- ✓ High amount of formulations are possible for every demand
- ✓ Specials are possible
- ✓ Durable and long live time
- ✓ Shiny systems for visible parts
- ✓ High temperature resistance for Cyanate ester systems till 350 °C

Thermoplastic materials

Thermoplastic systems

- ✓ PE Polyethylen
- ✓ PP Polypropylen
- ✓ PC Polycarbonat
- ✓ POM Polyoxymethylen
- ✓ PEEK Polyetheretherketon
- ✓ PA Polyamide
- ✓ PEI Polyetherimid
- ✓ PTFE Polytetrafluorethylen

→ **Disadvantages:**
high viscosities, change of systems for appliance, not finally certified

Specs for thermoplastic materials

Specs for thermosetting systems

powder like materials

- ✓ solvent thermoplastic resins
- ✓ extruded thermoplastic resins

Variation of the coating weight

- ✓ 10 to 300 g/m²

Range of viscosity

- ✓ 100 – 200 000 mPas depending on coating or extrusion technology

Temperature range

- ✓ 80 – 400 °C ± 1K

Speed range

- ✓ Average speed range for impregnation 0.1 – 10 m/min.

Advantages for thermoplastic materials

- ✓ High toughness
- ✓ High formability for 3D applications
- ✓ Low density additional weight reducing
- ✓ Quick hardening possibilities
- ✓ Mistakes are correctable
- ✓ Plenty of times heatable and formable

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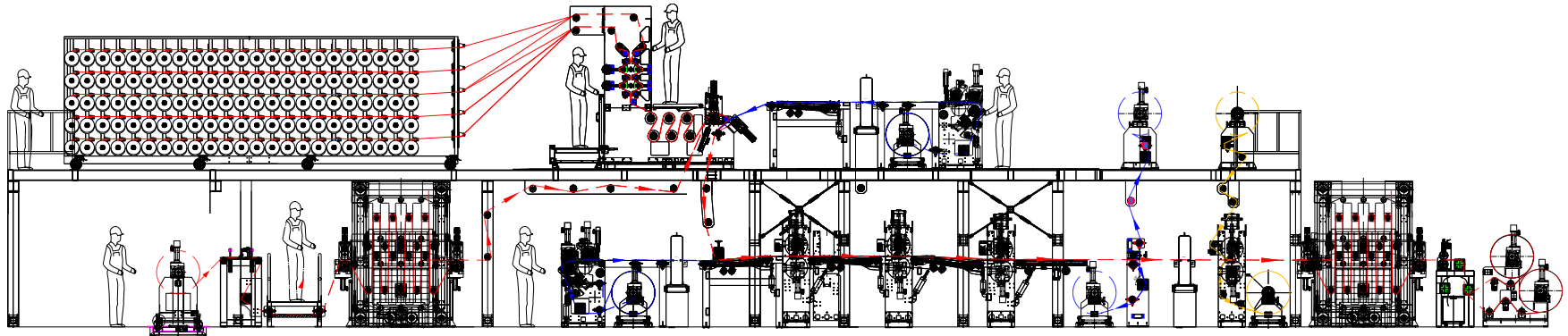
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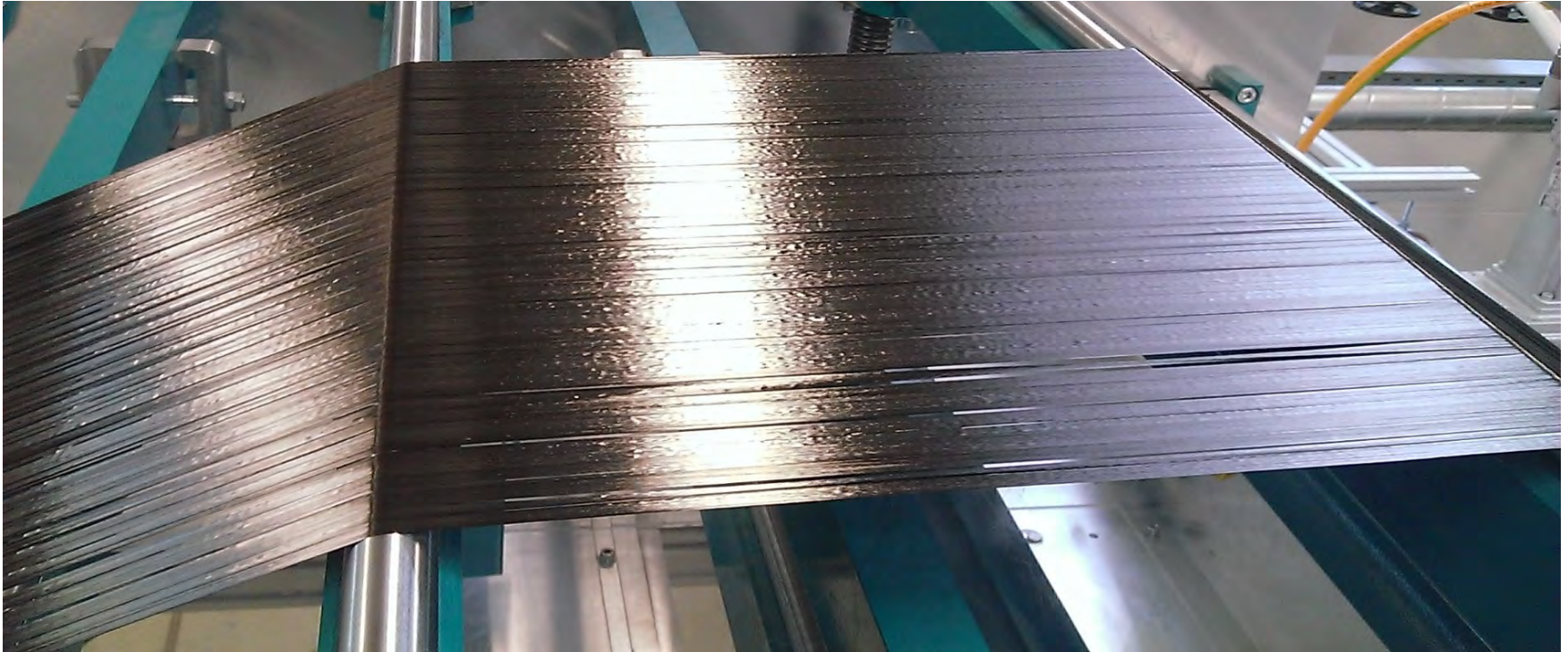
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of concept

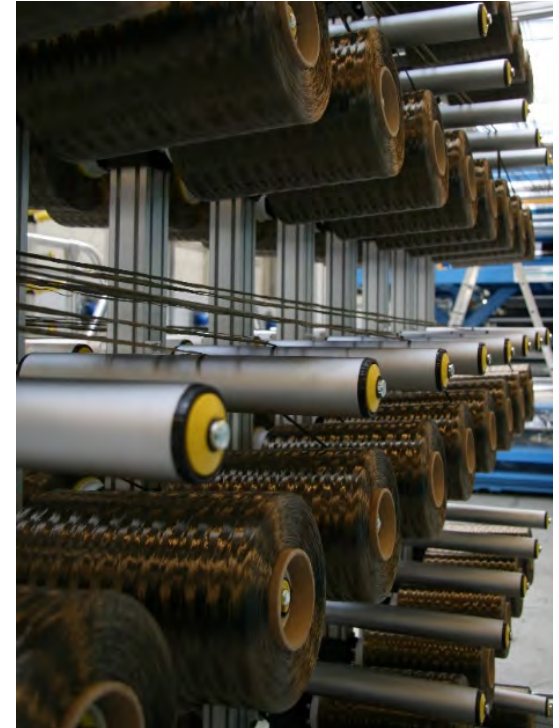
1. Spreading of fibre
2. Coating the resin
 - a) Thermosetting (duroplastic) resins
 - b) Thermoplastic resins
3. Impregnation into the matrix



Spreading technology



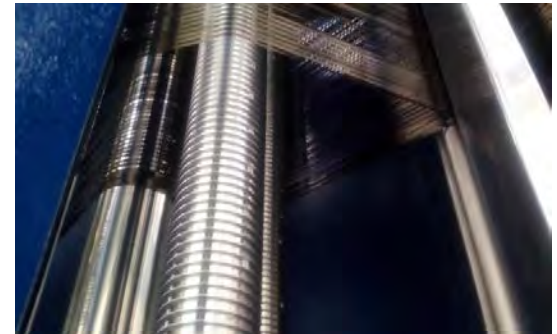
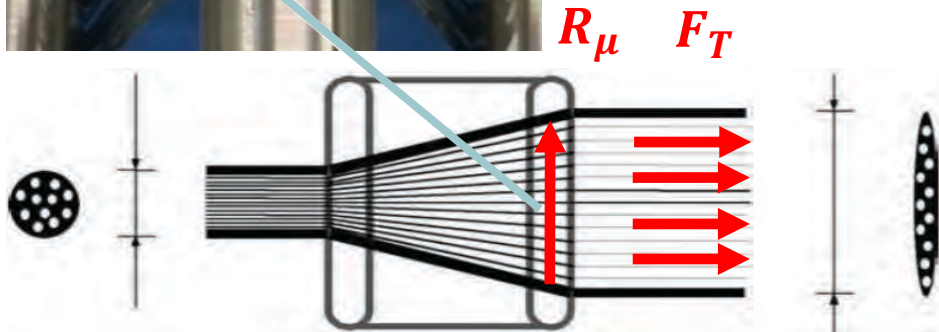
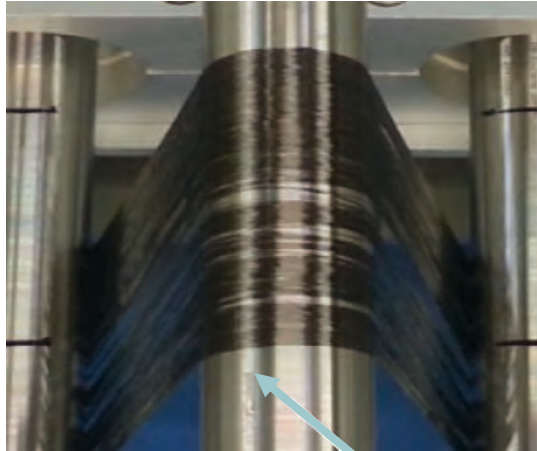
Creel station for carbon bobins



Substrate weight depending on roving fineness and number

		UD-Width mm	Carbon 1k	Carbon 3k	Carbon 6k	Carbon 6k	Carbon 6k	Carbon 12k	Carbon 12k	Carbon 12k	Carbon 12k	Carbon 24k	Carbon 24k	Carbon 24k	Carbon 24k	Carbon 50k	Carbon 50k	Carbon 50k	Carbon 50k
Filament Number			1.000	3.000	6.000	6.000	6.000	12.000	12.000	12.000	12.000	24.000	24.000	24.000	24.000	50.000	50.000	50.000	50.000
Fineness (tex)	g/1000m		67	200	400	400	400	800	800	800	800	1.600	1.600	1.600	1.600	3.500	3.500	3.500	3.500
Roving Number	pro 1 m		300	200	150	200	250	62	100	125	166	62	83	94	125	34	43	63	71
Substrate weight	g/m ²		20	40	60	80	100	50	80	100	133	100	133	150	200	120	150	220	250
Roving Number	for DU width	600	180	120	90	120	150	37	60	75	100	37	50	56	75	21	26	38	43
Spreading	mm		3,33	5,00	6,67	5,00	4,00	16,00	10,00	8,00	6,02	16,00	12,03	10,67	8,00	29,17	23,33	15,91	14,00
		UD-Width mm	Carbon 1k	Carbon 3k	Carbon 6k	Carbon 6k	Carbon 6k	Carbon 12k	Carbon 12k	Carbon 12k	Carbon 12k	Carbon 24k	Carbon 24k	Carbon 24k	Carbon 24k	Carbon 50k	Carbon 50k	Carbon 50k	Carbon 50k
Filament Number			1.000	3.000	6.000	6.000	6.000	12.000	12.000	12.000	12.000	24.000	24.000	24.000	24.000	50.000	50.000	50.000	50.000
Fineness (tex)	g/1000m		67	200	400	400	400	800	800	800	800	1.600	1.600	1.600	1.600	3.500	3.500	3.500	3.500
Roving Number	pro 1 m		300	200	150	200	250	62	100	125	166	62	83	94	125	34	43	63	71
Substrate weight	g/m ²		20	40	60	80	100	50	80	100	133	100	133	150	200	120	150	220	250
Roving Number	for DU width	1200	360	240	180	240	300	75	120	150	199	75	100	112	150	41	51	75	86
Spreading	mm		3,33	5,00	6,67	5,00	4,00	16,00	10,00	8,00	6,02	16,00	12,03	10,67	8,00	29,17	23,33	15,91	14,00

Spreading process



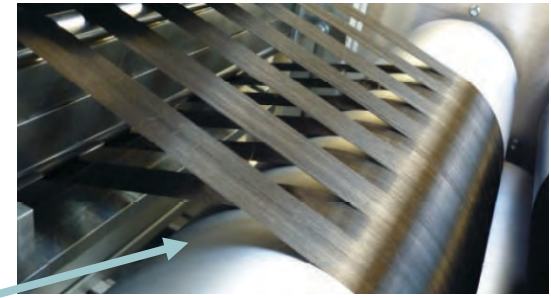
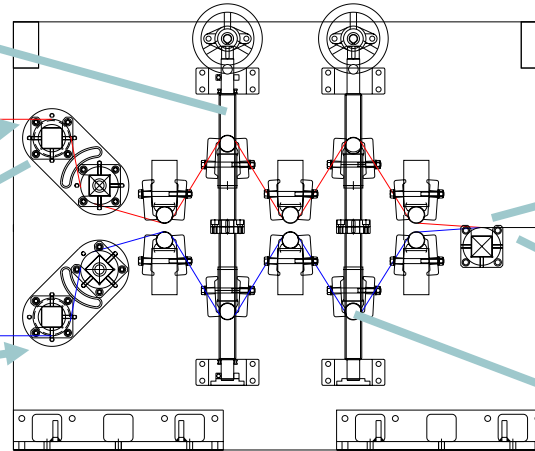
Spreading process



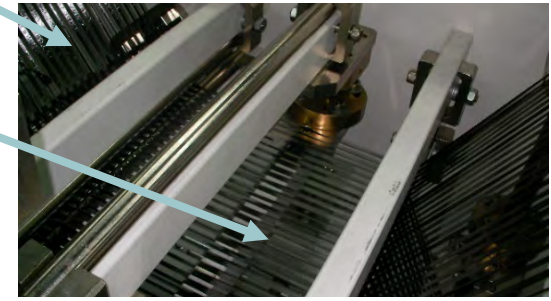
Top spreading rods



Positioning roller

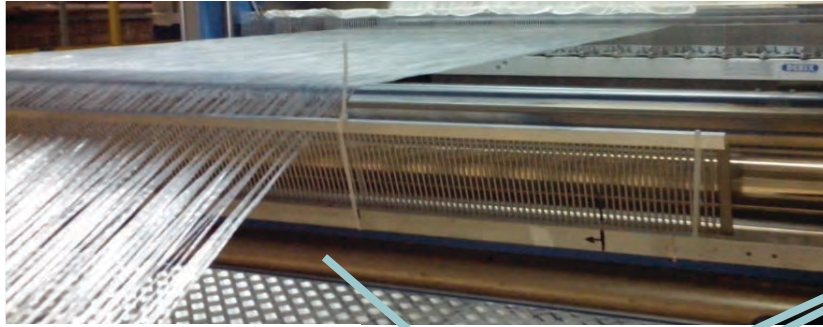


Transfer roller



Bottom spreading rods

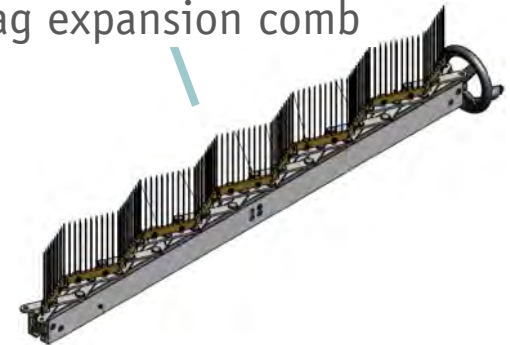
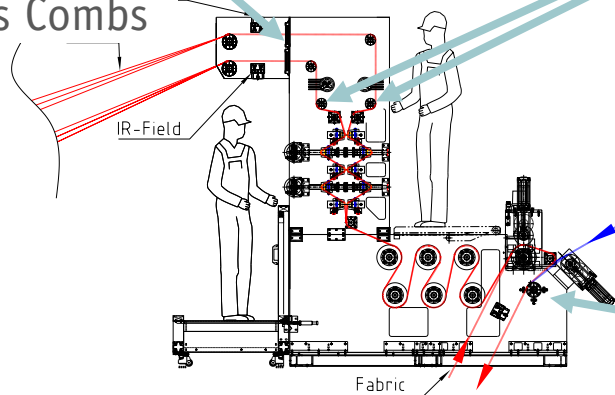
Spreading device



Two units Combs

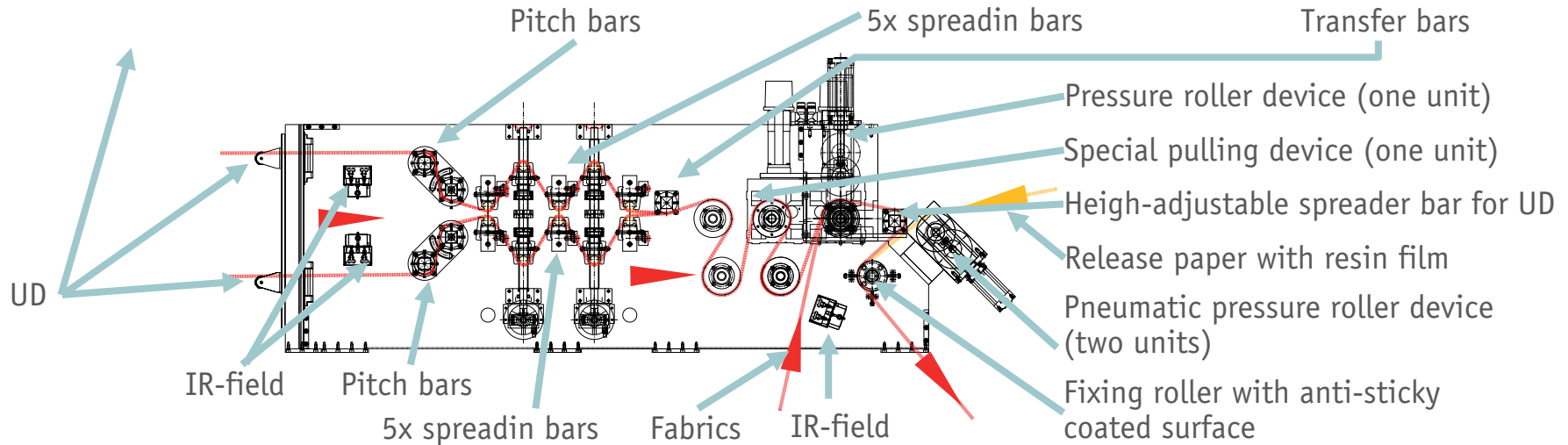
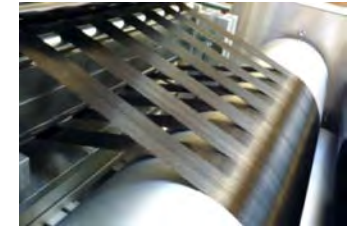


Two units Zig zag expansion comb

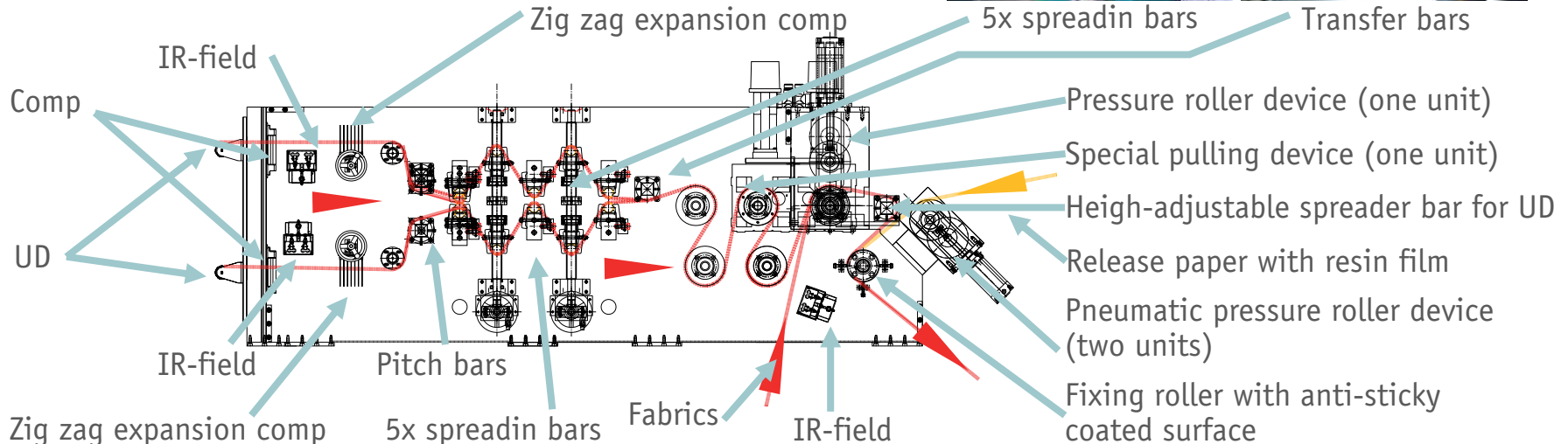
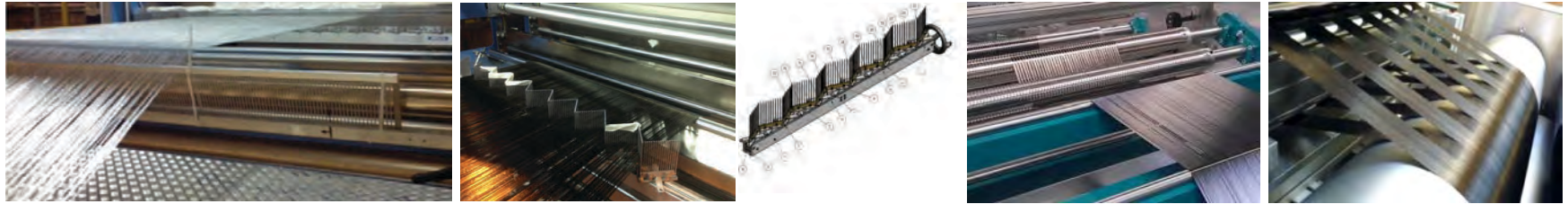


Roller with teflon coated surface

Spreading device with pitch bars



Spreading device with zig zag expansion comb



Additional possibilities

- ✓ Ultrasonic devices
- ✓ Vibrations bars
- ✓ Cooled bars for higher traction force
- ✓ Topocrom surface of the bars for reducing traction

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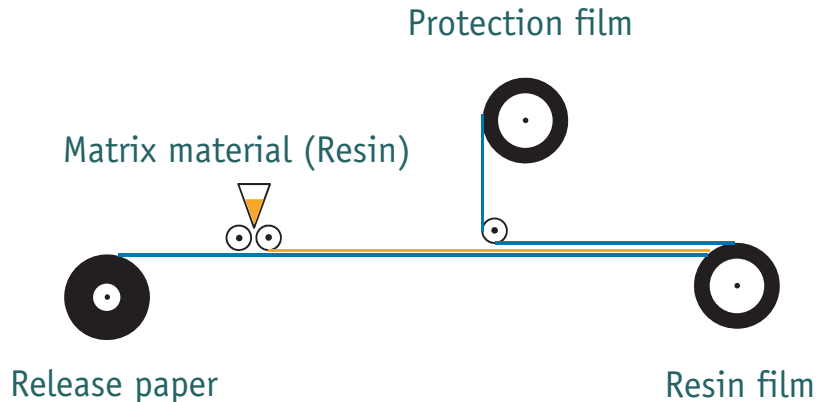
Proof
of concept

Substrate weight depending on roving fineness and number

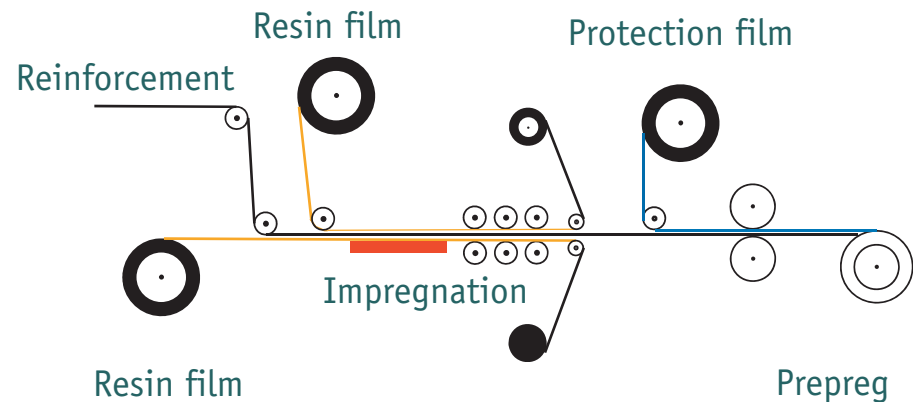
- ✓ 12K spreading per roving to 8 mm add up to 100 g/m²
- ✓ 12K spreading per roving to 10.7 mm add up to 75 g/m²
- ✓ 24K spreading per roving to 8 mm add up to 200 g/m²
- ✓ 24K spreading per roving to 10.7 mm add up to 150 g/m²
- ✓ 24K spreading per roving to 16 mm add up to 100 g/m²

Film transfer method

Step1: Matrix film coating

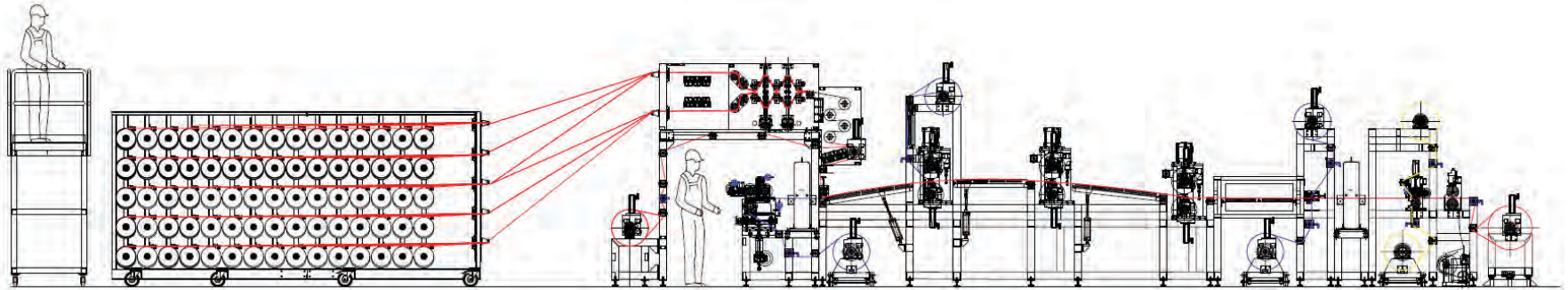


Step2: Prepreg impregnation



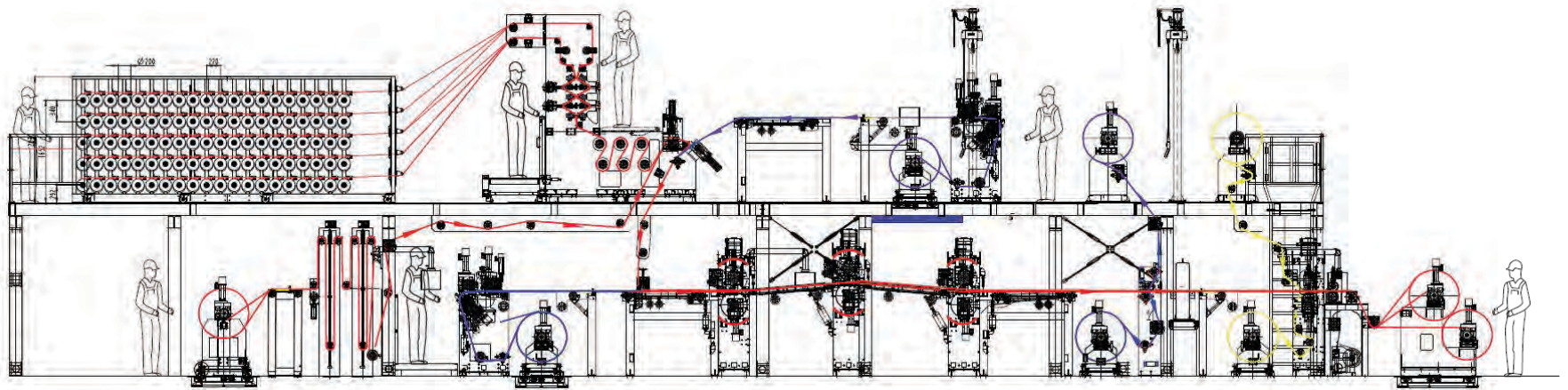
Film transfer method

Lab prepreg coating line



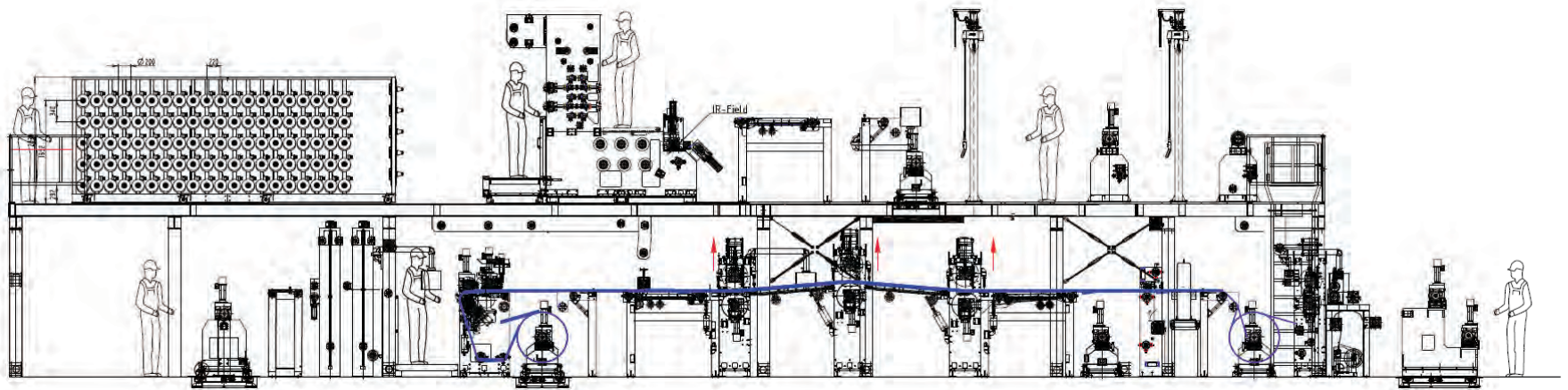
Film transfer method

1 Step process



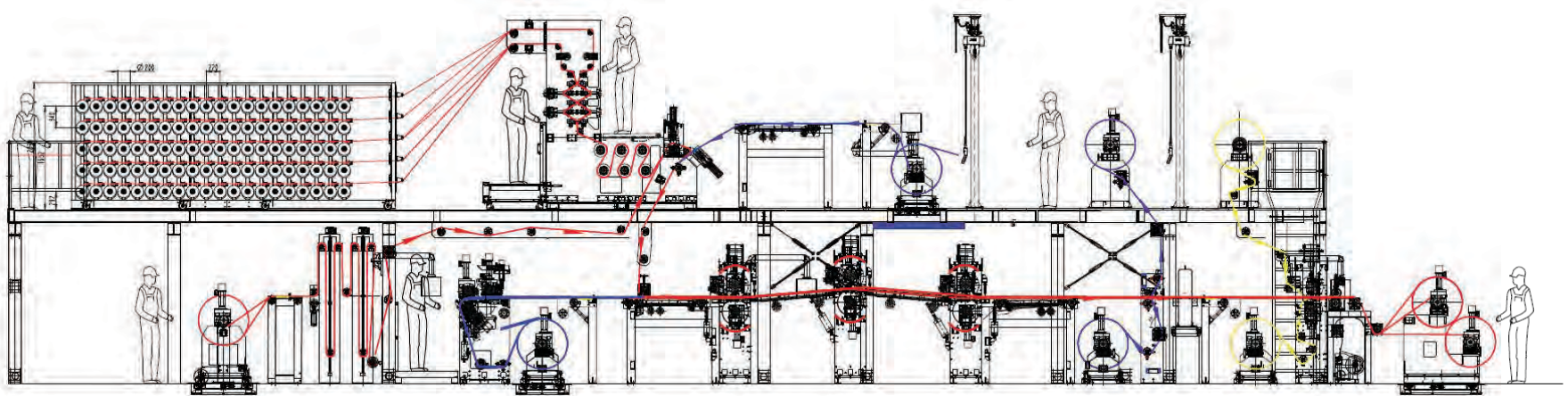
Film transfer method

2 Step process: resin-film coating



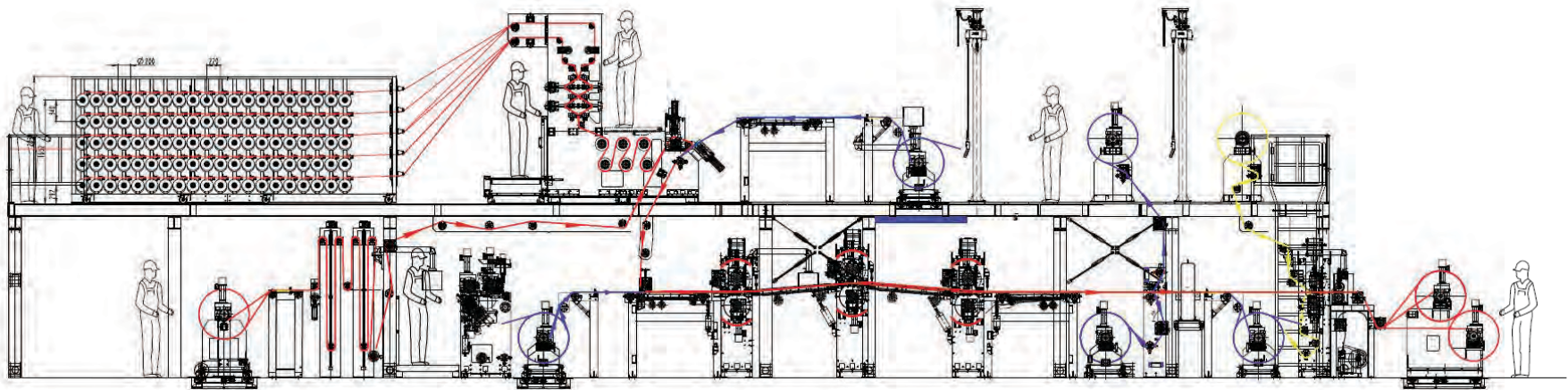
Film transfer method

2 Step process: 1. direct – 2. indirect

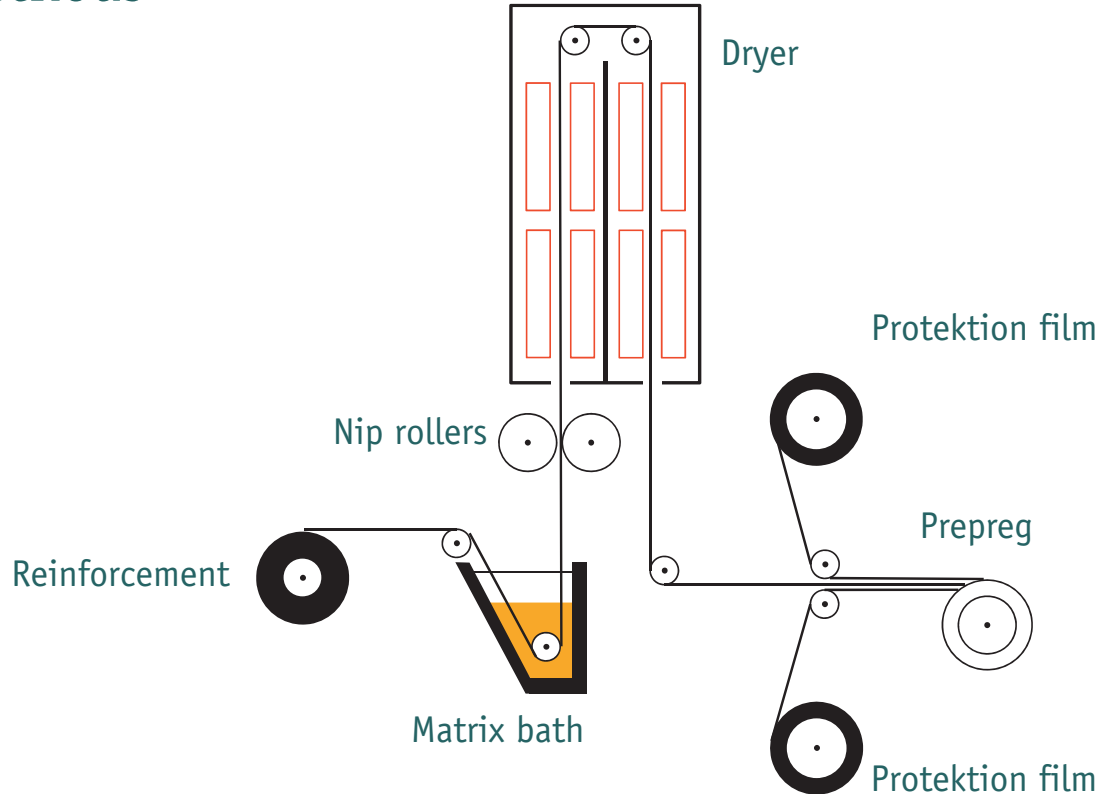


Film transfer method

2 Step process: 1. indirect – 2. indirect

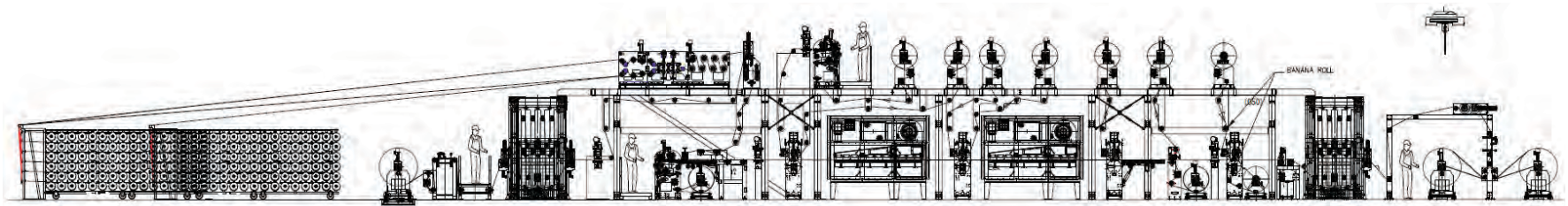


Solvent methods

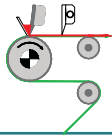


Film transfer method

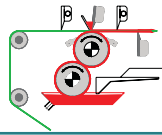
1 Step process for solvent



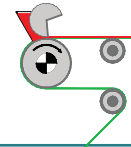
Coating systems



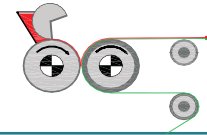
Knife system



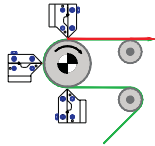
Double side system



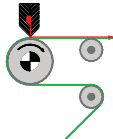
Commabar system



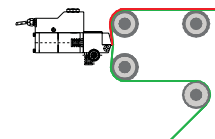
Reverse commabar system



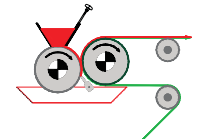
Slot die system



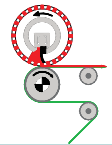
Curtain coating system



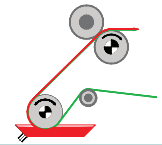
Hotmelt slot die system



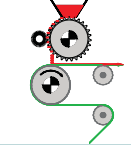
Case knife system



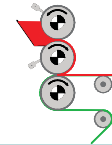
Rotary screen system



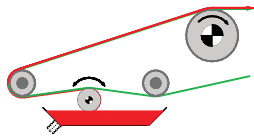
Dipping system (Foulard)



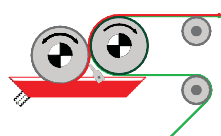
Powder scattering system



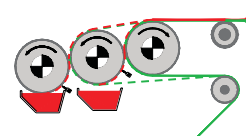
Reverse roll system



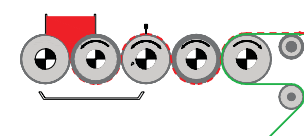
Micro roller system



2 Roller system

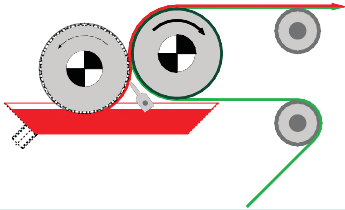


3 Roller combi system

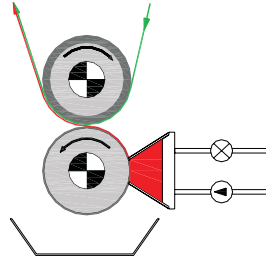


5 Roller system

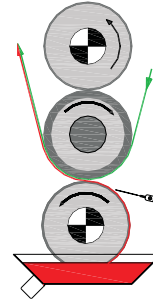
Printing systems



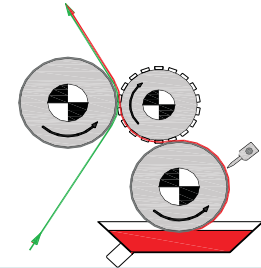
Engraved roller system



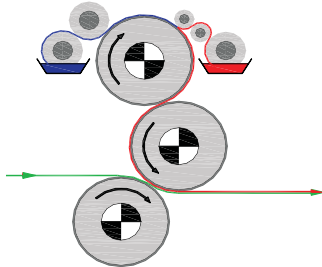
Gravure roller system



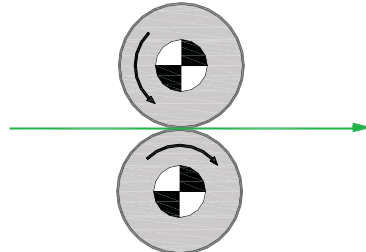
Gravure indirect system



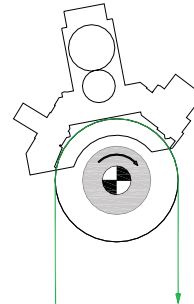
Flexography system



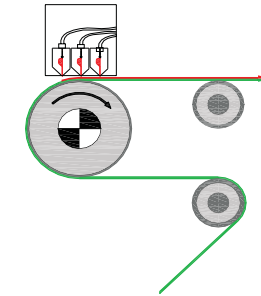
Offset lithography system



Hot embossing system



Nanoimprint system

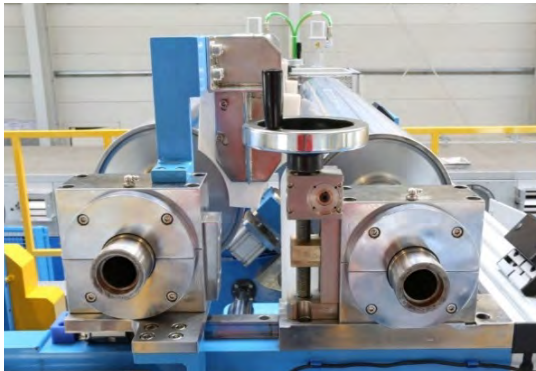


Inkjet system

Indirect coating – concept:

- ✓ Coating is being done on a carrier film
- ✓ Easy to pre-meter the coating thickness
- ✓ Transport on a support carrier to the next steps
- ✓ High accuracy
- ✓ Reproducibility

Indirect coating



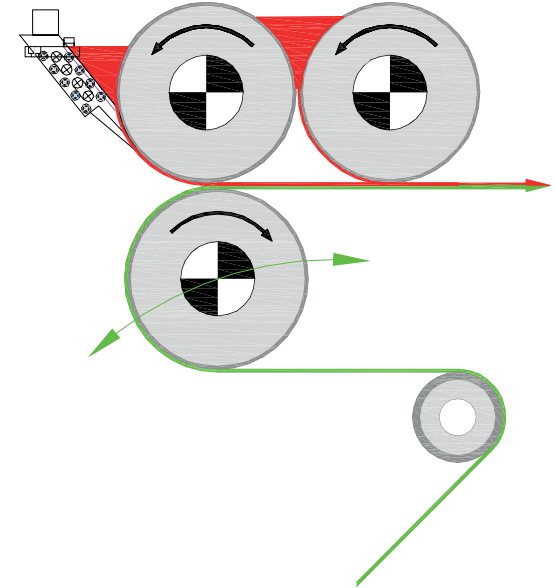
**Modular coating system
for prepreg**

Viscosity

✓ 100 – 200 000 mPas

Temperature range

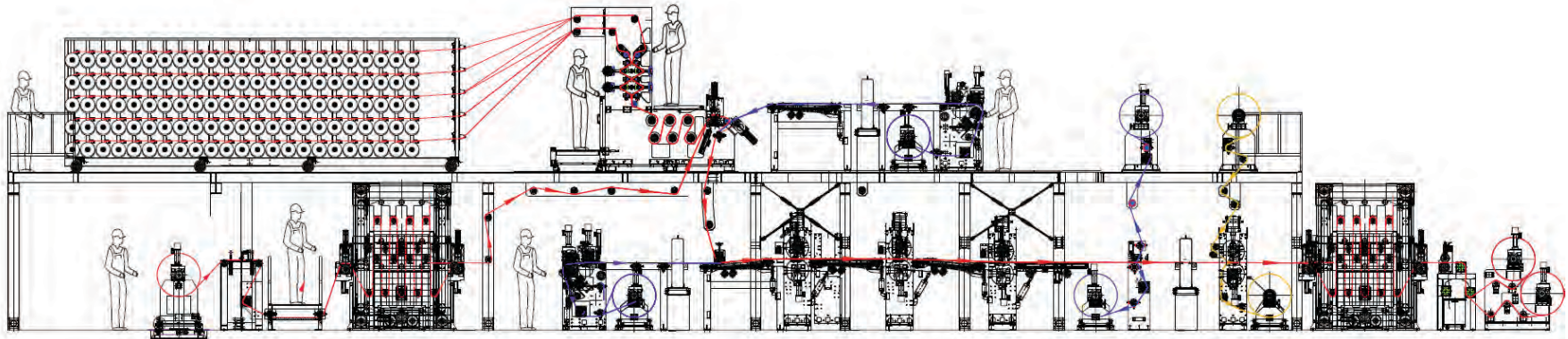
✓ RT – 250°C



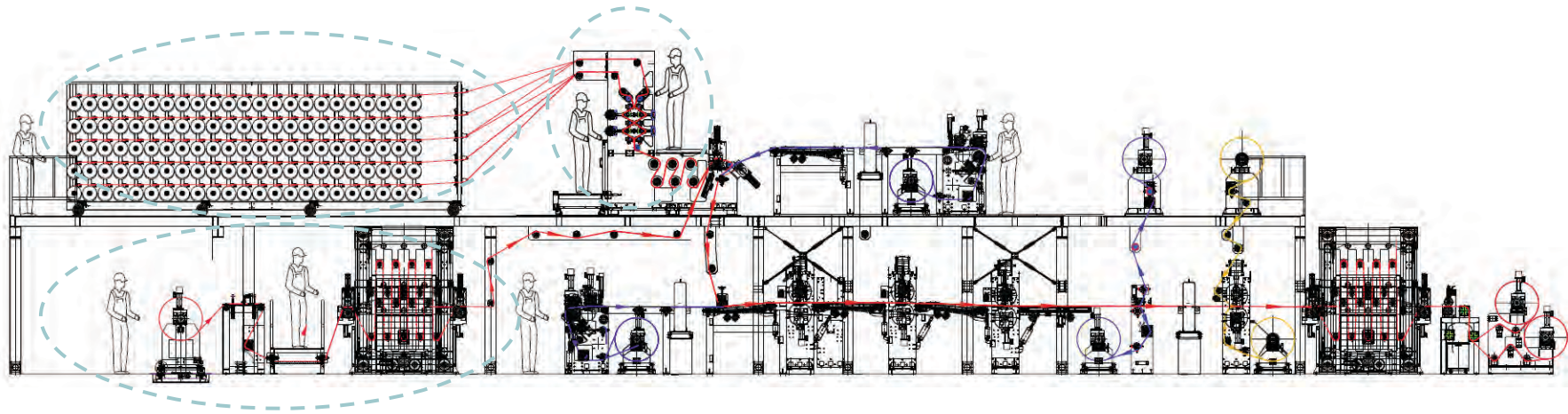
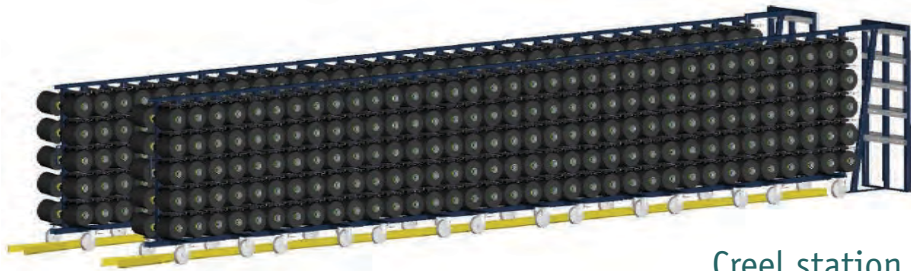
Thermosetting technology



1. Spreading of fibre
2. Coating the resin
 - a) Thermosetting (duroplastic) resins
 - b) Thermoplastic resins
3. Impregnation into the matrix



Technology background – layout for thermosetting production line



Technology background – layout for thermosetting production line



Coating system 1



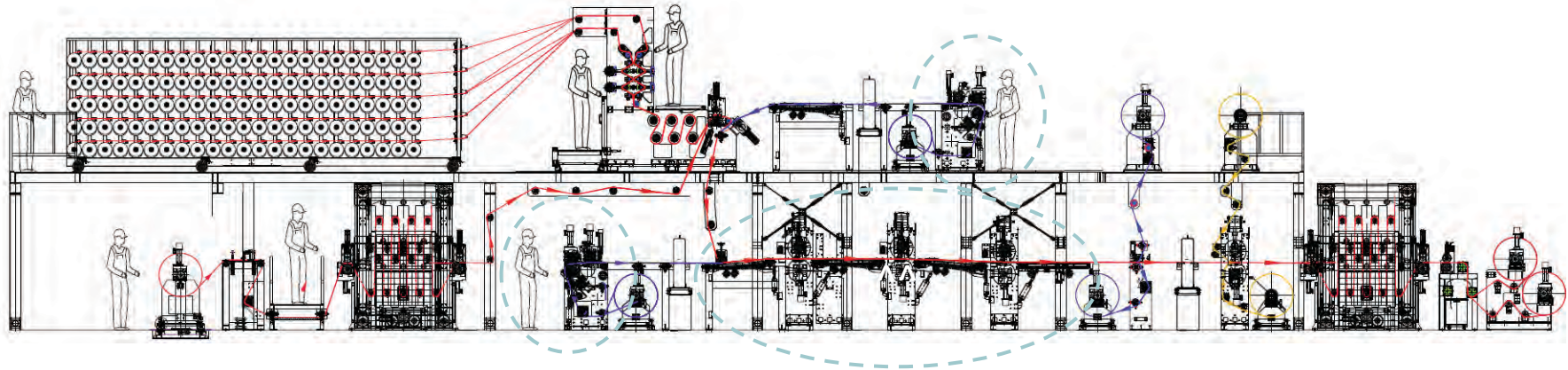
Coating system 2



Hot calender



Heating table



Technology background – layout for thermosetting production line



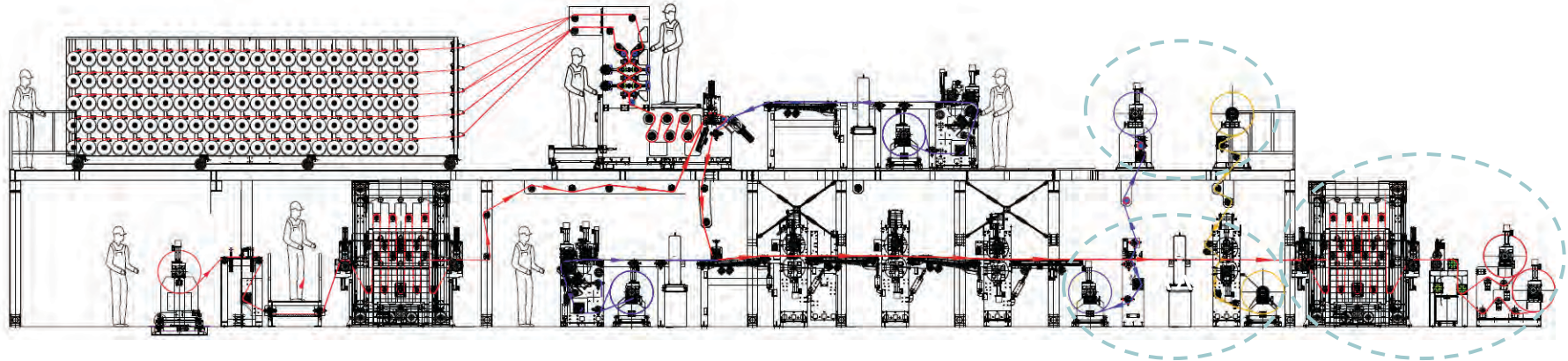
De-lamination + Lamination station



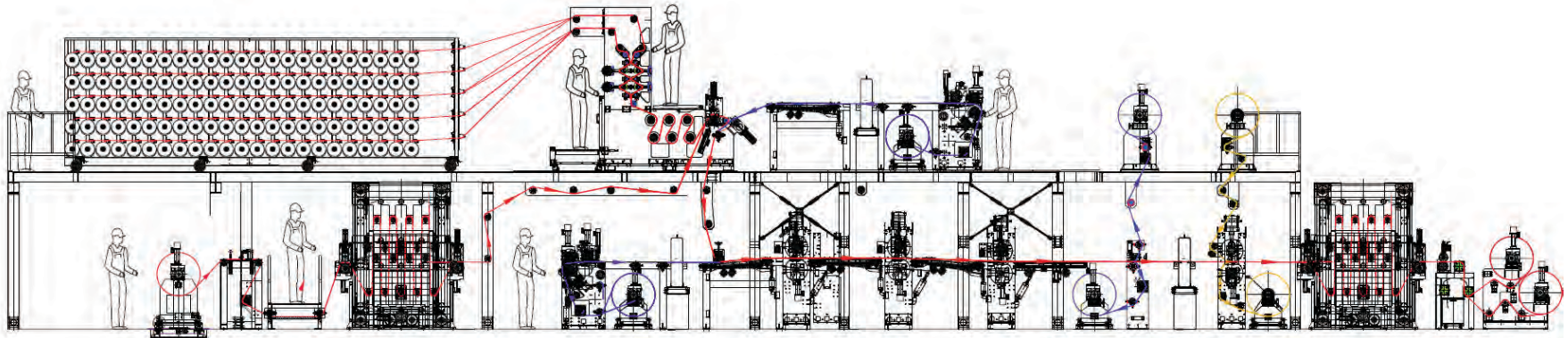
Winding-station

Cutting device

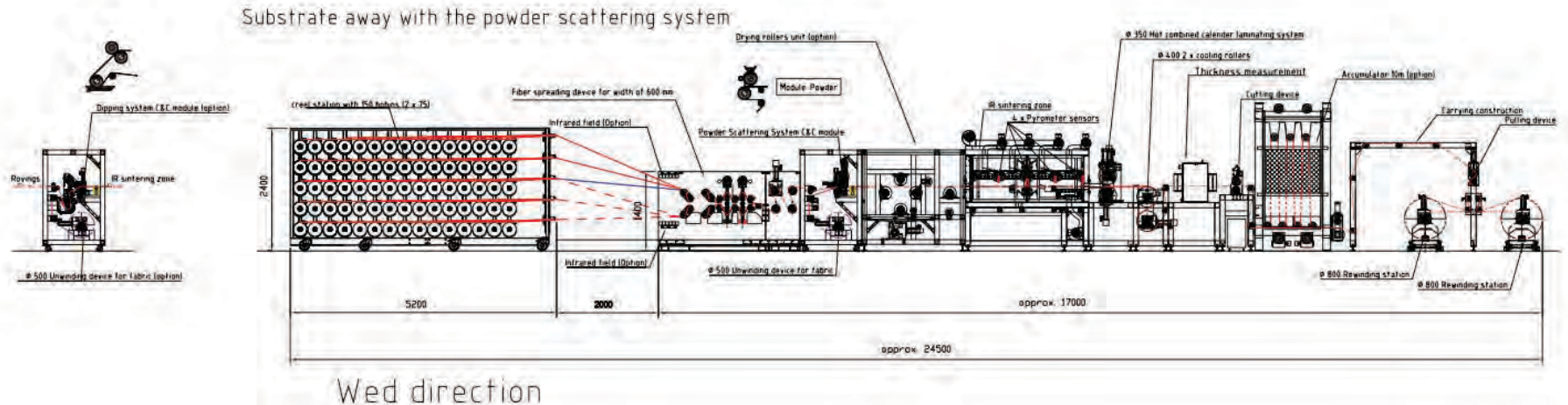
Rewinding station



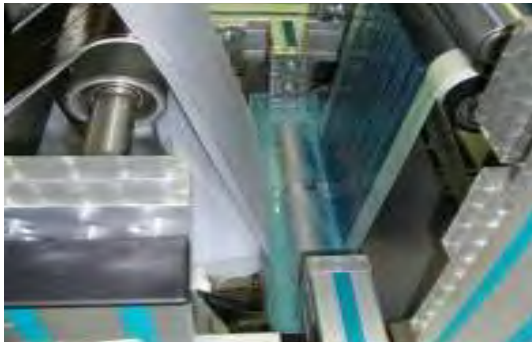
1. Spreading of fibre
2. Coating the resin
 - a) Thermosetting (duroplastic) resins
 - b) Thermoplastic resins
3. Impregnation into the matrix



Production line layouts – thermoplastic process



Dipping / Foulard



Variation of the impregnation weight

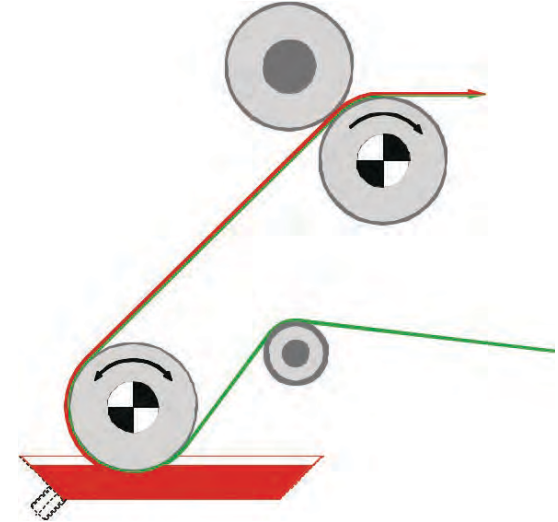
- ✓ Depending on the fabric / UD tape

Range of Viscosity

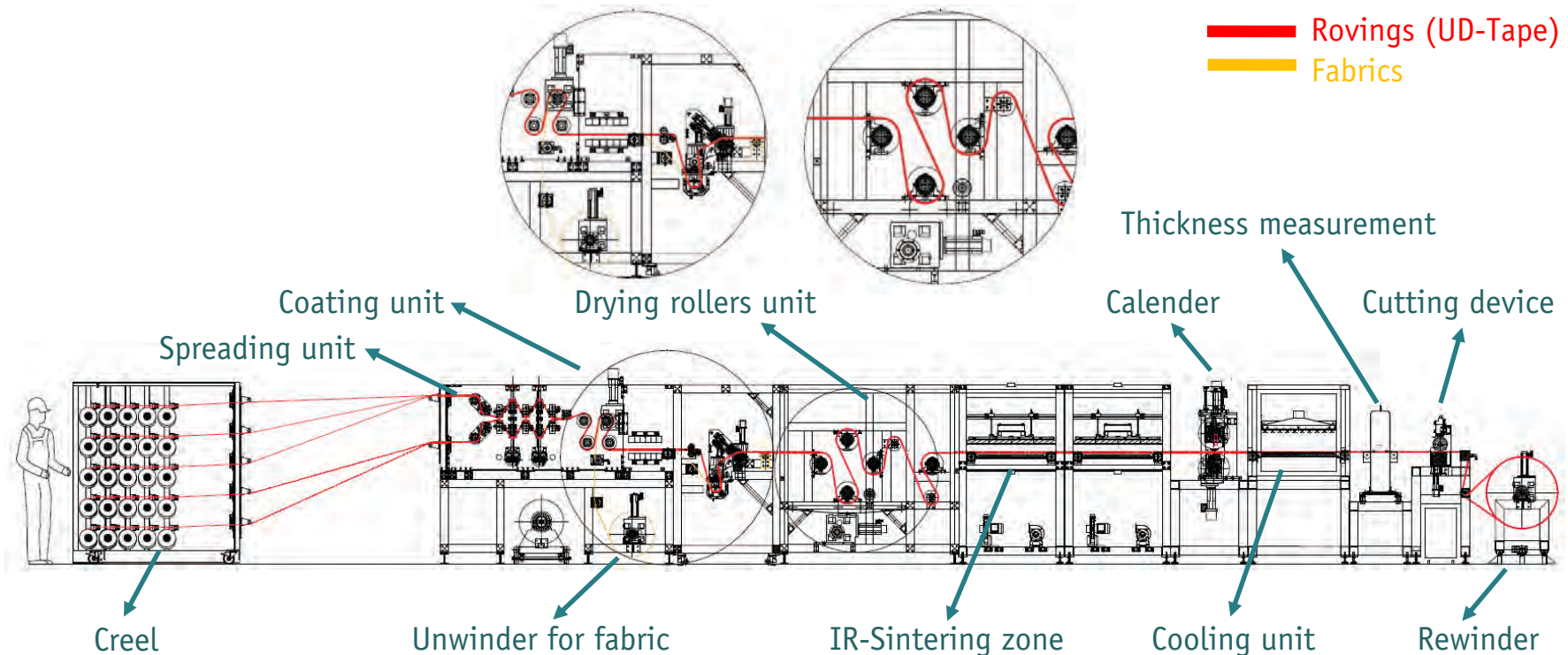
- ✓ 100 – 10 000 mPas

Temperature range

- ✓ RT – 250°C



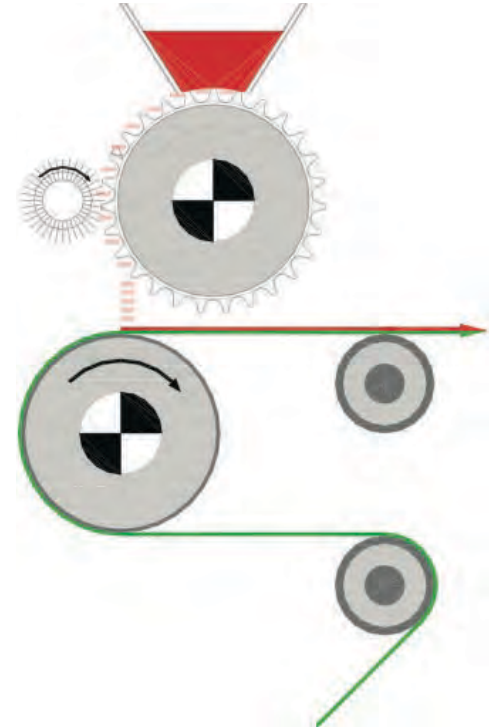
Dipping / Foulard prepreg line



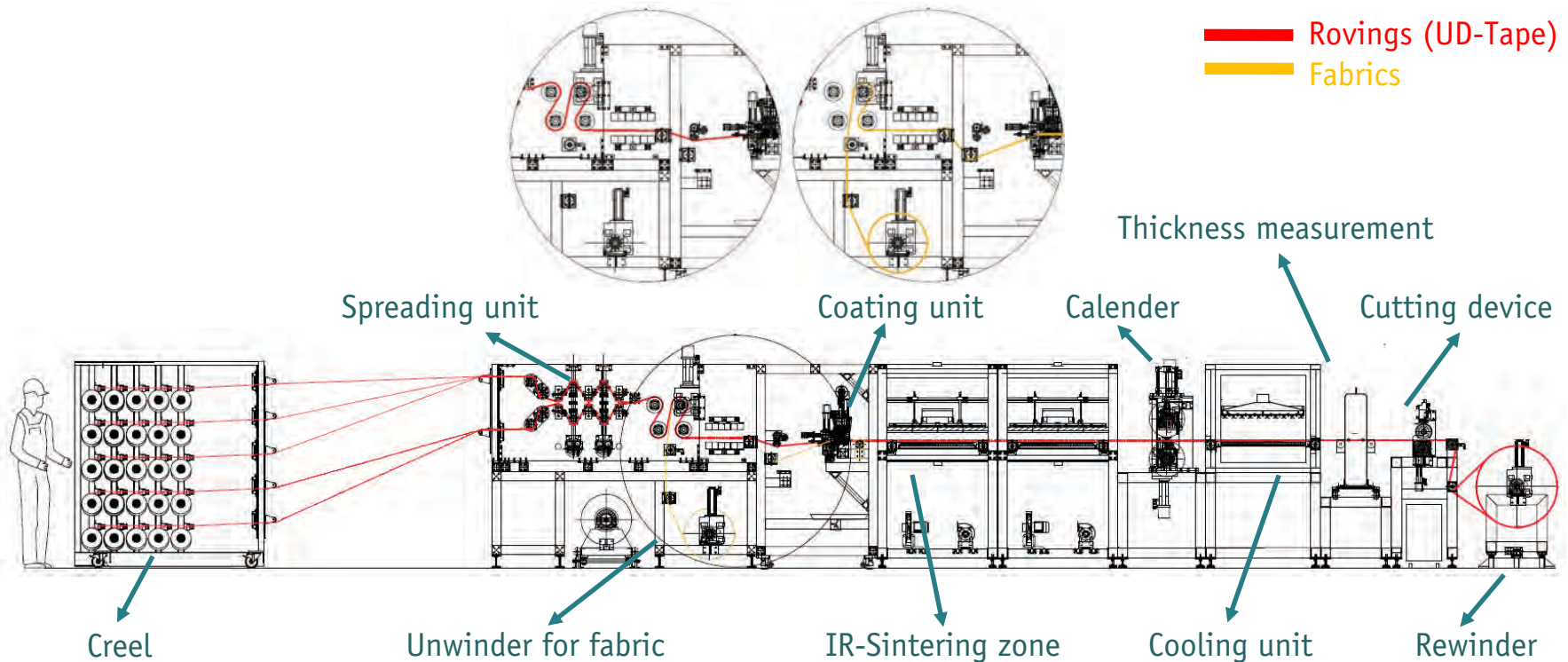
Powder Scattering



**Variation of the
impregnation weight**
✓ 10 – 300 g/m²



Powder scattering prepreg line



Hotmelt / Extrusion



Variation of the impregnation weight

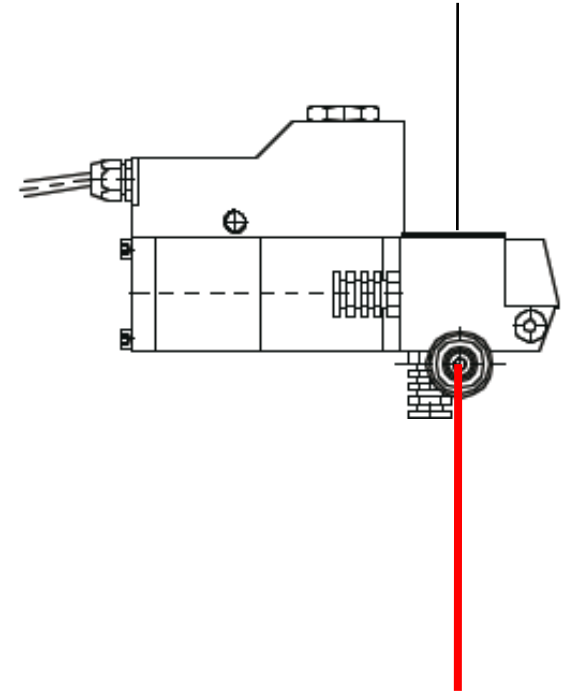
- ✓ Depending on the fabric / UD tape

Range of Viscosity

- ✓ 100 – 10 000 mPas

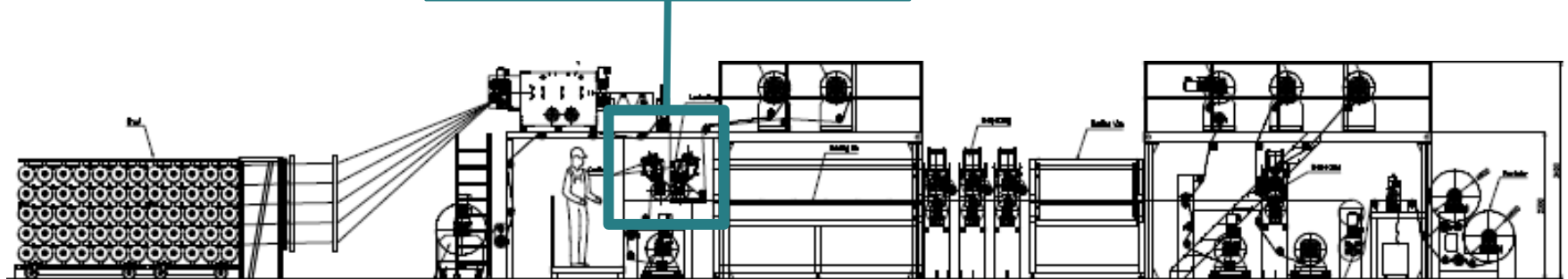
Temperature range

- ✓ RT – 400°C



Extrusion die / Hotmelt

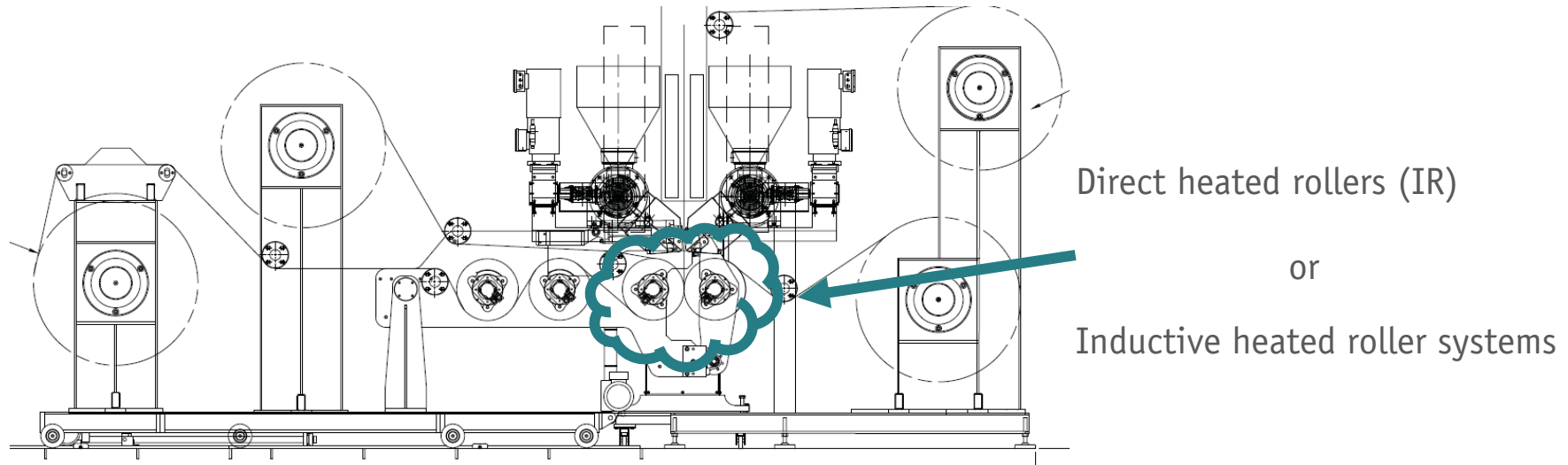
Double Side Extrusion of thermoplastic resins



Curing / High temperature systems

For the curing / impregnation process of high-tech polymers (PEEK, PEK, PTFE) temperatures from room temperature up to 400°C are needed

→ Therefor special high temperature roller systems (>300°C) are applied



Summary

Introduction

Technology
background

Spreading
technology

Coating
technologies

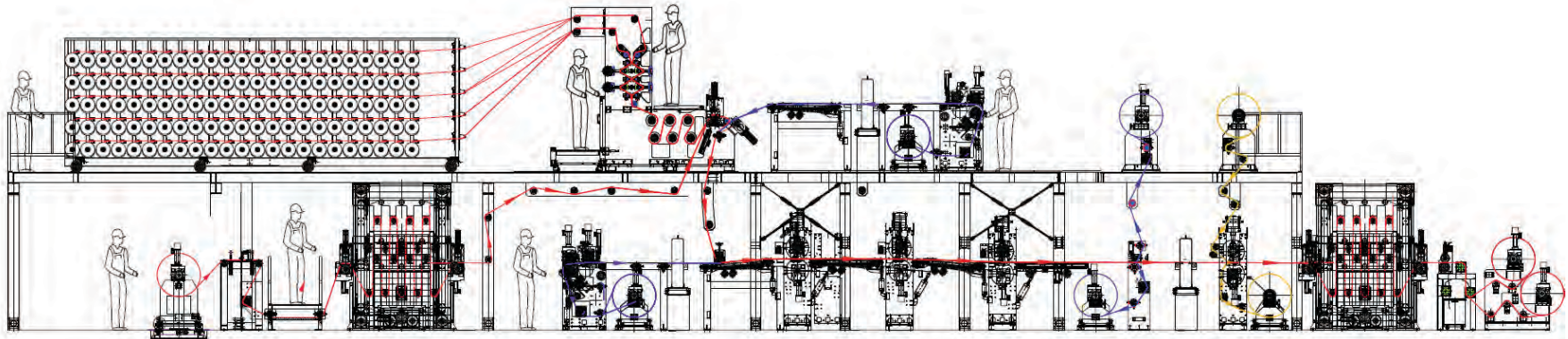
Impregnation
technologies

Curing / High
temperature
systems

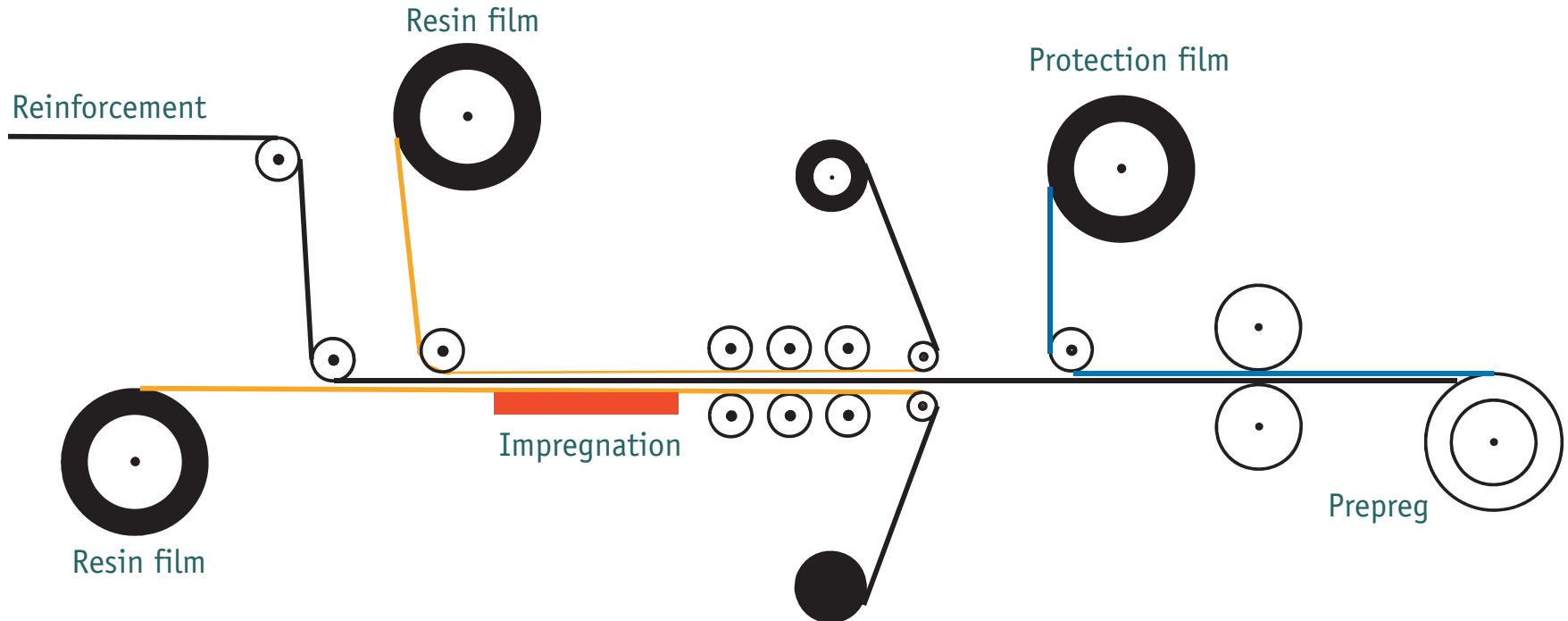
Pilot line
layout

Proof
of concept

1. Spreading of fibre
2. Coating the resin
 - a) Thermosetting (duroplastic) resins
 - b) Thermoplastic resins
3. Impregnation into the matrix



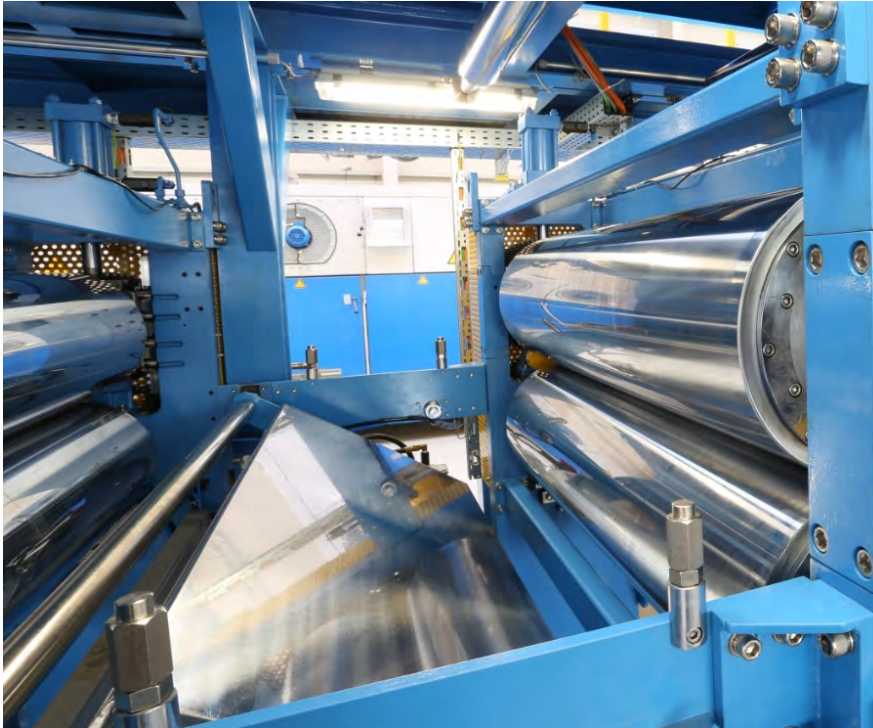
Impregnation technologies



Impregnation zone



High precise calender systems with heating table



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of concept

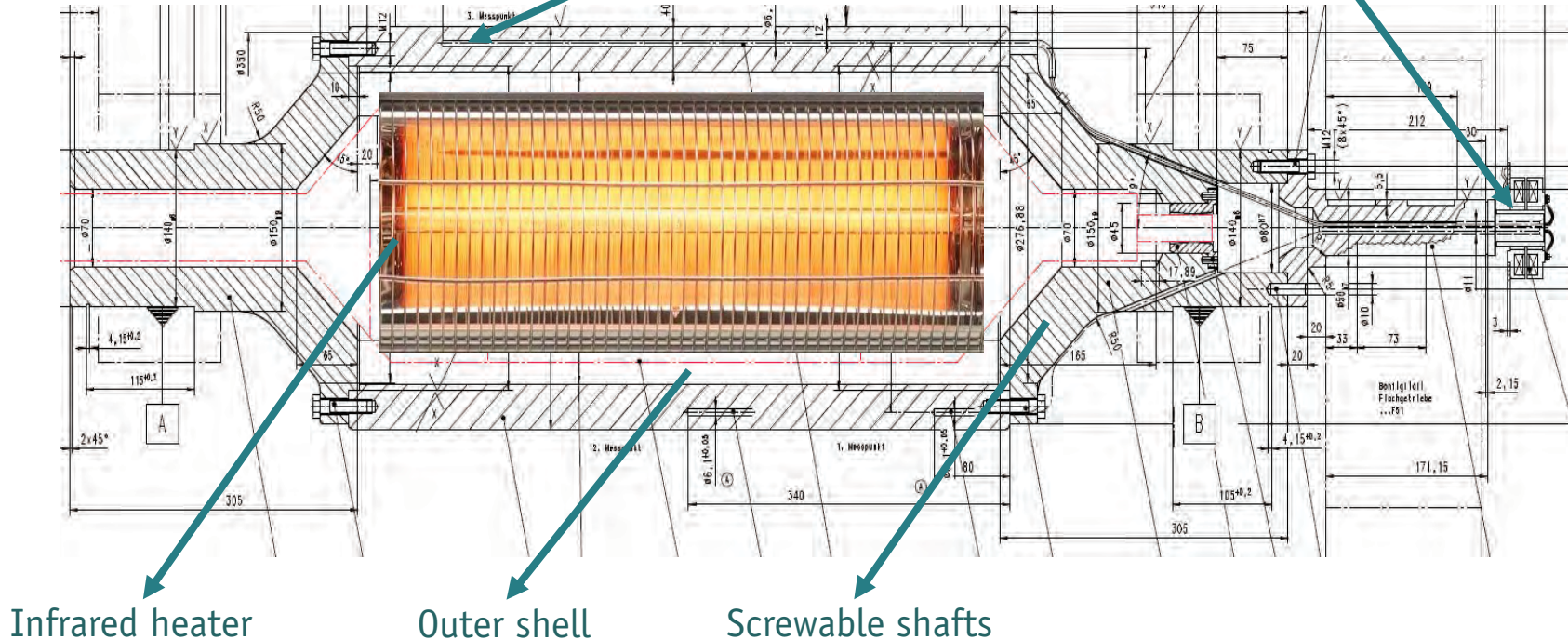
Roll design parameters

- ✓ Geometrical Dimensions
 - ✓ Diameter, surface width (WOB), journals
- ✓ Media
 - ✓ Type, flow amount, flow speed, pressure, temperature range
- ✓ Roll material for shell, journals and interior
 - ✓ Stainless steel, carbon steel, 42CrMo4 with hardened surface
- ✓ Tolerances
 - ✓ True running, cylindricity, surface roughness
- ✓ Surface coating
 - ✓ Chrome, teflon, ceramic, rubber, etc...

Direct heated roller (IR)

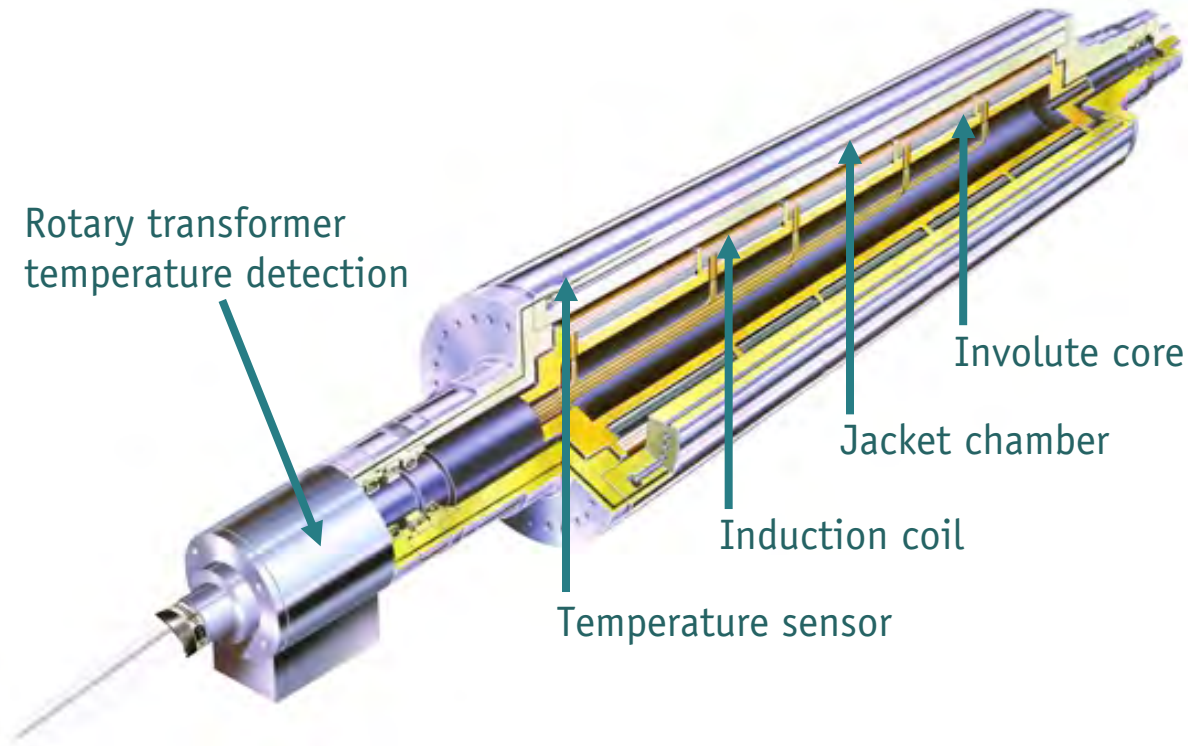
Drilling for PT 100 temperature sensor

Rotary feedthrough for electrical connections

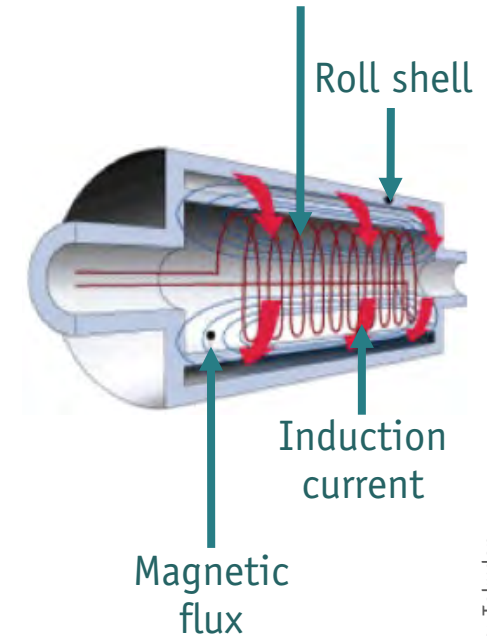


Source: Wumag texroll

Direct heated roller (IR)

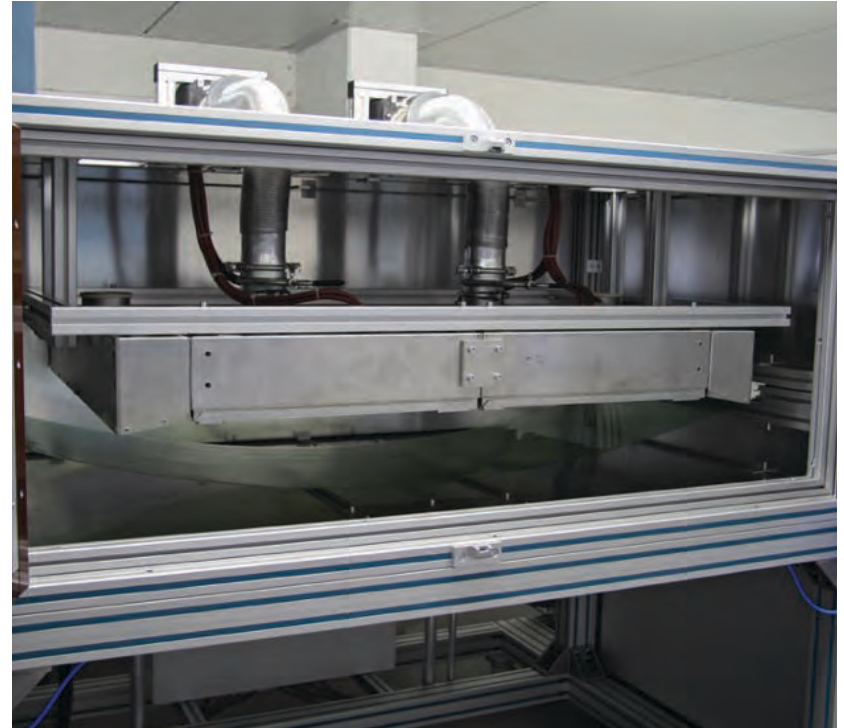


Rotary transformer temperature detection



Source: Tokuden

Drying with IR technology

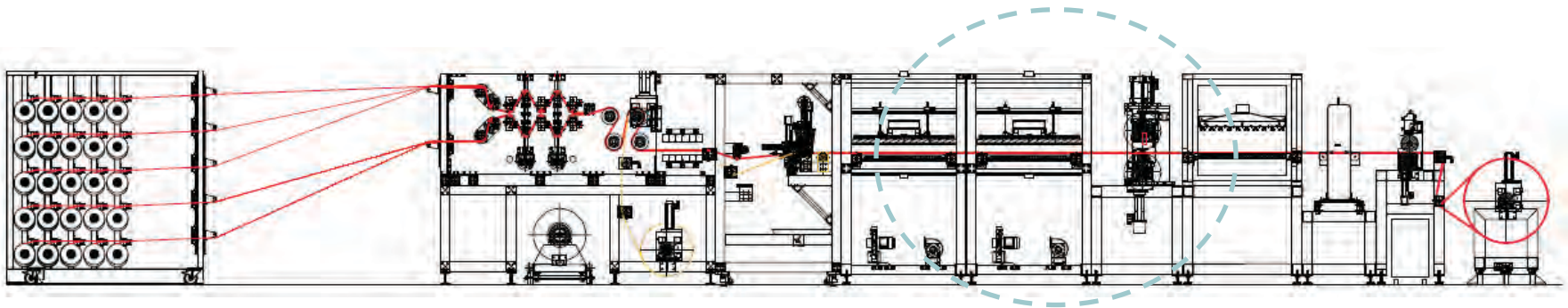


Drying with IR technology



Production line layouts – thermoplastic process

High precise calender systems with IR-sintering dryers



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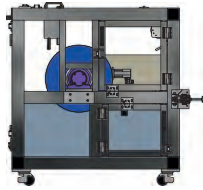
All line layouts in Click&Coat™ design



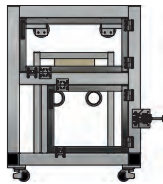
Here are a few benefits of the Click&Coat™ approach:

- ✓ Over 40 coating, printing and ancillary modules available
- ✓ Award winning C&C design for connecting and aligning modules
- ✓ Easy three – wire electrical connectors
- ✓ Siemens S7 software solution
- ✓ Fast set up time for new processes or increased through-put
- ✓ Over 40 coating and printing systems for plug in and out
- ✓ Patented C&C design for connecting the modules

Click&Coat™ your own ideas



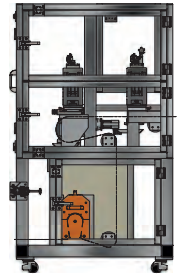
Winder



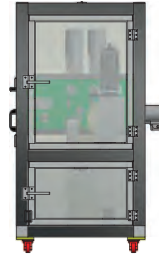
Corona



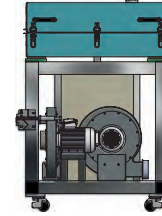
Podestral



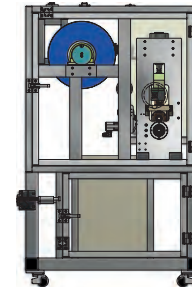
Coating



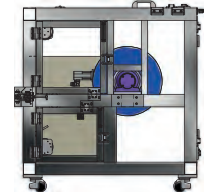
Inkjet



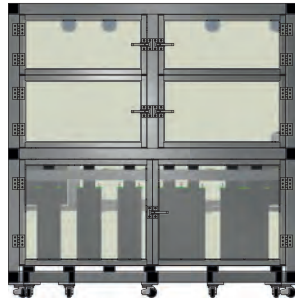
Dryer



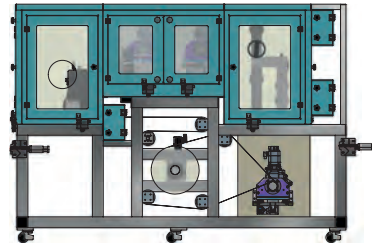
Laminator



Rewinder



Chemical treatment bath



Inert Coating and
laminating



Registration
control



Turning
device

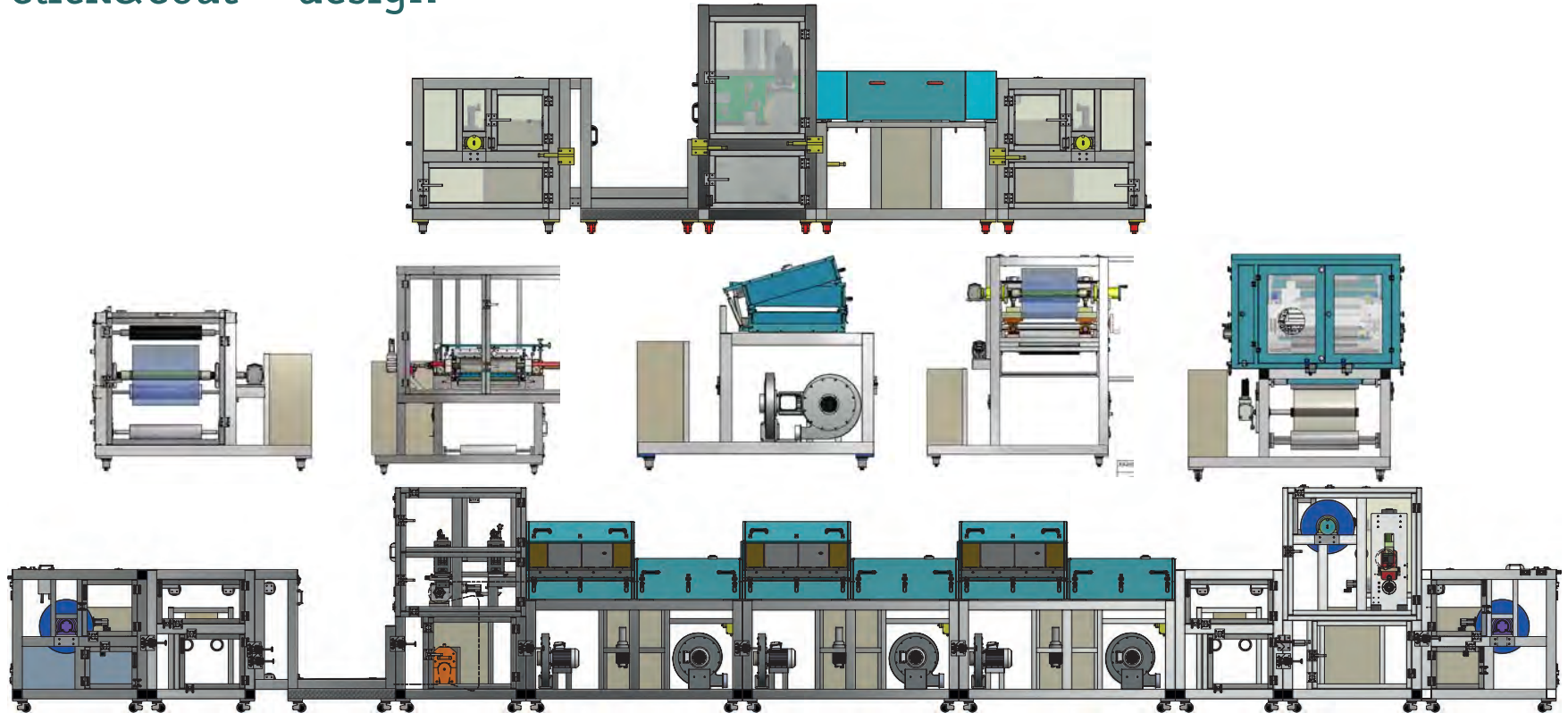


Lamination

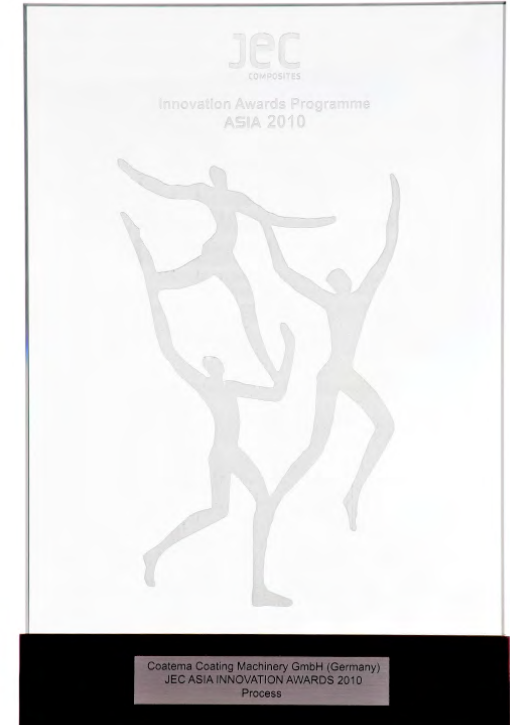


Cutting

Click&Coat™ design



Click&Coat™ for Prepreg production



Click&Coat™ for Prepreg production



Click&Coat™ for Prepreg production



Click&Coat™ for Prepreg production



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Production line layouts – thermoplastic process



Production line layouts – thermoplastic process



Production line layouts – thermoplastic process



Production line layouts – thermoplastic process



Production line layouts – thermoplastic process



Bridging the gap

Needed for success in prepreg processes:

- ✓ Pilotscale to Production scale product portfolio is key, Coatema is offering this.
- ✓ Reproducible results in every step of scale?
- ✓ Reality check if the approach is really scalable?
- ✓ Is the approach an approach for the real life production environment or is it rocket science?
- ✓ Are economies of scale reachable and when?
- ✓ High temperature thermoplastic prepregs are the future, development needed here.
- ✓ Coatema can demonstrate high temperature thermoplastic applications, ask us.

Do not hesitate to contact us!



Anything missing?

Let us know and we will make it happen!

Our R&D centre is worldwide the most versatile centre for coating, printing and laminating.

Sales department:
sales@coatema.de

Thank you



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Phone +49 (0) 21 33 97 84 - 0 | info@coatema.de

