Coatings Trends & Technologies

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rheonics

High-Quality and 'Greener' Coatings with Automated Viscosity Monitoring and Control

Track – 3: Coating Process Engineering
September 8, 2021

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Rheonics - Introduction

- **Rheonics** is a global automation provider of robust plug and play instruments for viscosity and density monitoring, two of the key physical properties of a process fluid.
- Based on resonant sensor technology developed over 3 decades at **ETH Zurich**. Strong IP portfolio (11 granted, multiple pending)
- Rheonics viscometers and density meters meet a wide variety of measurement challenges in the most **demanding and aggressive environments**.

Roadmap of the presentation

1

The ‘Why’ of viscosity

- Paint and coating properties influenced by viscosity
- Coating applications

2

The ‘How’ of viscosity

- Traditional viscosity measurement techniques and their limitations
- Balanced torsional resonator ‘inline’ viscometer as an alternative
- A gateway to complete viscosity automation in coating = inline viscometer + controller + software

3

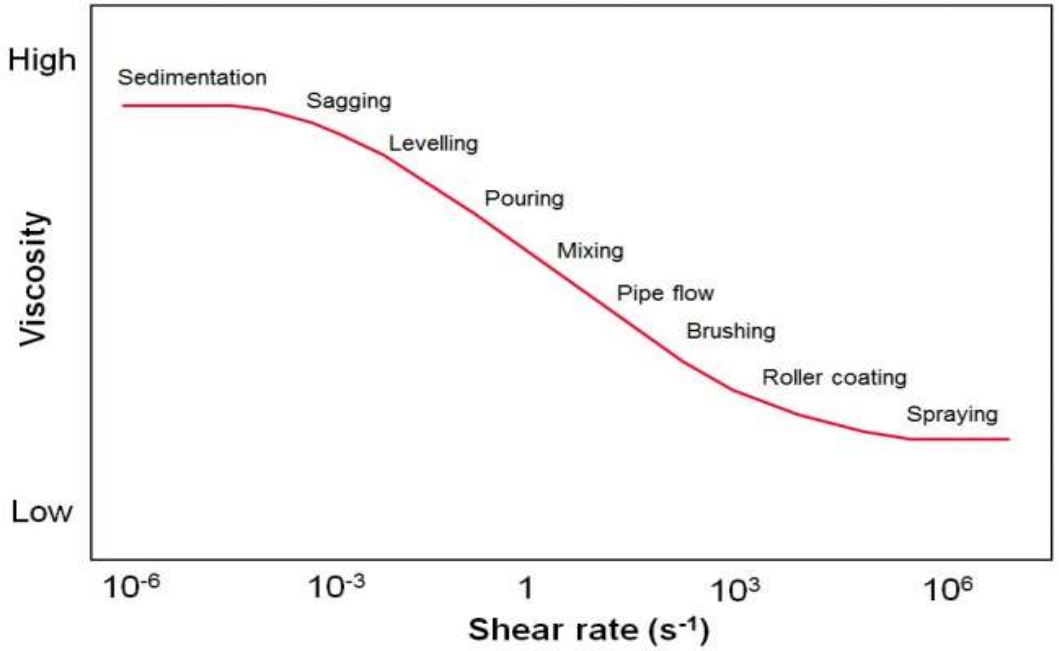
Impact

- Technical impact
- Business impact
- Sustainability impact
- Case Studies – How viscosity automation leads to ‘greener’ operations

Why measure viscosity in a coating process?

- Viscosity is a measurement of the ***flow characteristics*** of the coating fluid.
- Effective indicator of ***concentration of coating solids*** in the fluid, which is the basis for the thickness and uniformity of the film.

A good composition alone cannot guarantee production of smooth and defect free coated surfaces....



Typical shear rates encountered in common coating processes| Source: Malvern Instruments

Performance Criterion influenced by viscosity

- Sag resistance
- Levelling behaviour
- Paint transfer efficiency

Viscosity is an indicator of ....

- Flow behaviour
- Concentration of solids
- Homogeneity of the formulation

Coating characteristics affected by viscosity

Optimizing and maintaining the right viscosity throughout the coating process can assure the desired characteristics of the coating, depending on the end-use requirements:

- **Film thickness and deposition**
- **Finished surface qualities**
- **Stability**
- **Adhesion**
- **Color match**
- **Thermal and chemical characteristics**

Industrial applications

Battery Electrode Coating

Automotive Coating

Anti-corrosion coating

Wire coating

Coil coating

Contact Lens printing

Viscosity – Your First Port of Call for Correcting Coating Defects

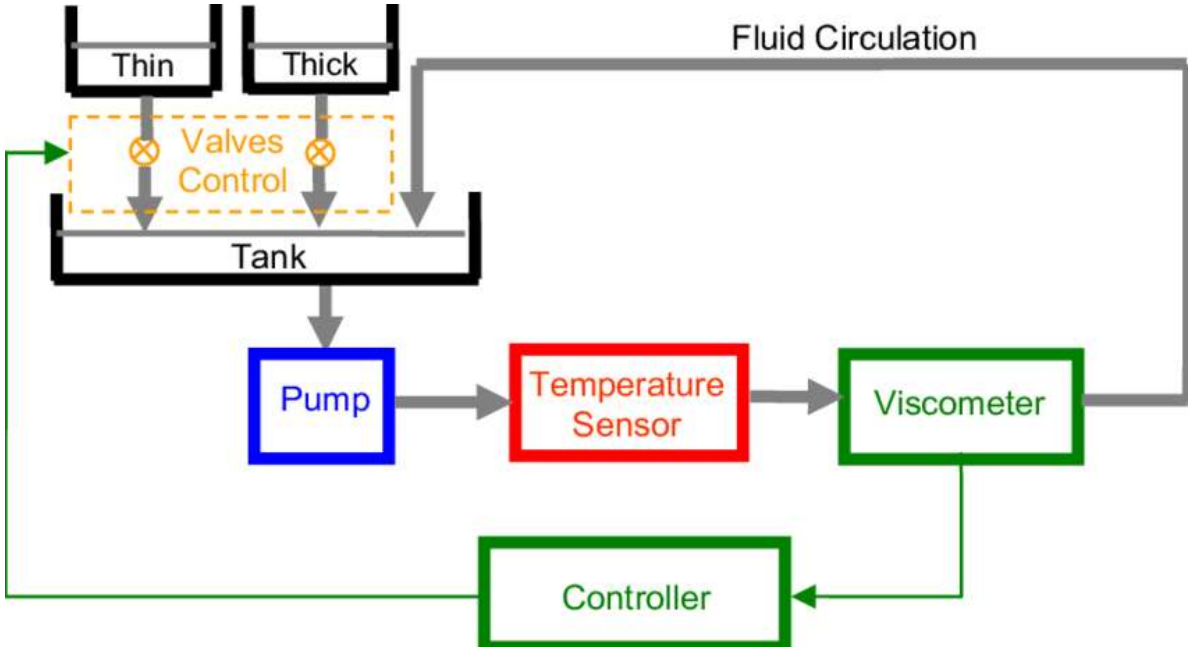
High viscosity coatings can be problematic to spray, pickup or deposit onto a substrate. A low viscosity coating can potentially level well, filling in holes or streaks in the coating, but can also lead to unwanted creep/spreading.

The root cause of the following coating defects trace back to incorrect viscosity:

Coating Defects: How they can be alleviated with viscosity management

PROBLEM	CAUSES	SOLUTION
ORANGE PEEL	Nozzle held too far away from the surface; shop temperature is too high to alter the viscosity; spray nozzle is clogged.	Inline viscosity measurement will flag up clogging and temperature compensated viscosity will avoid the issue
MOTTLED SURFACE	Inadequate mixing	Inline viscosity measurement shows large variations
RUNS OR SAGS	Excessive viscosity → slow drying, too thick finish coat	Inline viscosity control prevents excessive viscosity
COLOR VARIATIONS	Uncorrected fluctuations in viscosity → variations in color density and coating thickness	Viscosity monitoring shows viscosity fluctuations, automatic control reduces their impact
SOLVENT POP	Inadequate control of paint viscosity and temperature prior to application	Automatic control of viscosity avoids use of excess solvent, reducing the chances of entrapment
AIR ENTRAPMENT	Inadequate monitoring of paint line conditions	Inline viscometer alerts operators to the bubbles and foam in fluid lines
BLISTERS	Viscosity of the surface of the film increases to a high level, trapping volatile solvents	Optimizing solvent use and ensuring correct viscosity of coating through inline viscometer avoids this issue

Putting measurement data to use: Quantify. Monitor. Control.



An example of viscosity feedback control system

Source: Chang, Woo & Monovoukas, Christos & Tanaka, Michael & Fronczak, Norbert. (2007). Automatic viscosity-controlled production of photoresist - art. no. 65193N. Proceedings of SPIE - The International Society for Optical Engineering. 6519. 10.1117/12.717976.

- Process optimization begins with measurement.
- When correct viscosity is attained, maintaining it consistently is key to success in coating process.
- Proper viscosity control assures the quality and lifetime of the coat, helping meet the highest demands on the quality and productivity of the coating process.

Current methods for viscosity measurement

Despite its importance to product quality, coating viscosity is still measured by century-old methods that interface poorly with emergent Industry 4.0 standards.

Current methods require manual sampling and testing.

Resonant sensor technology and a predictive tracking controller offer a simple and efficient bridge to bring coating viscosity management up to the modern standards that prevail in today's highly automated coating operations.

Traditional methods and their limitations

Coating material viscosity is still measured by old methods. They involve manual sampling and offline testing. Two main methods are:

- Efflux cups
- Rotational viscometers

Limitations

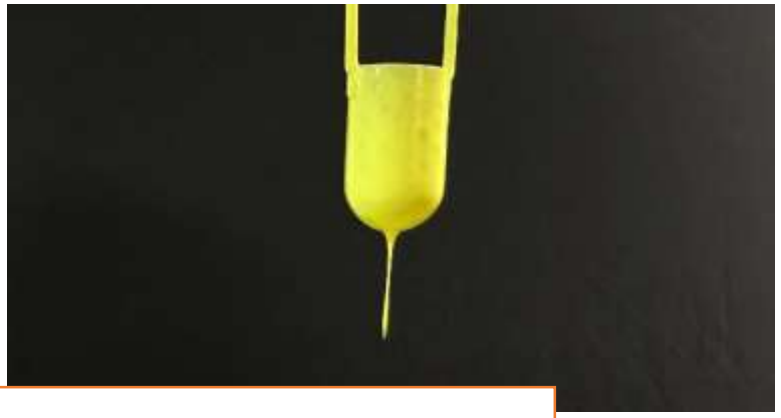
- Samples don’t represent actual condition of process fluid
- Need experienced operators
- Can’t supply the data needed for inline process control

Efflux cup

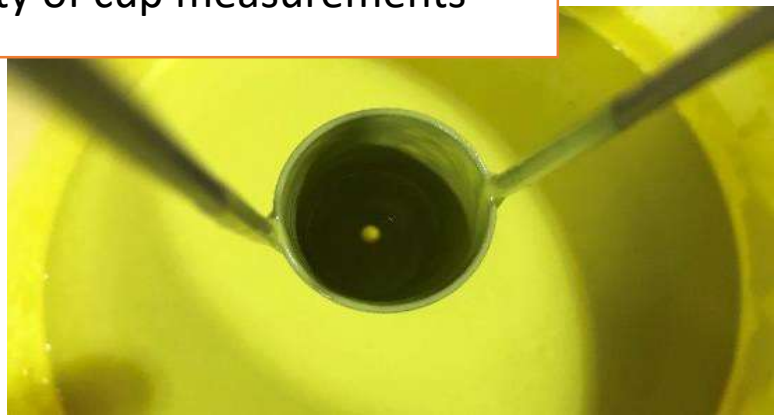
Rotational viscometer

Are cups suitable for viscosity checks?

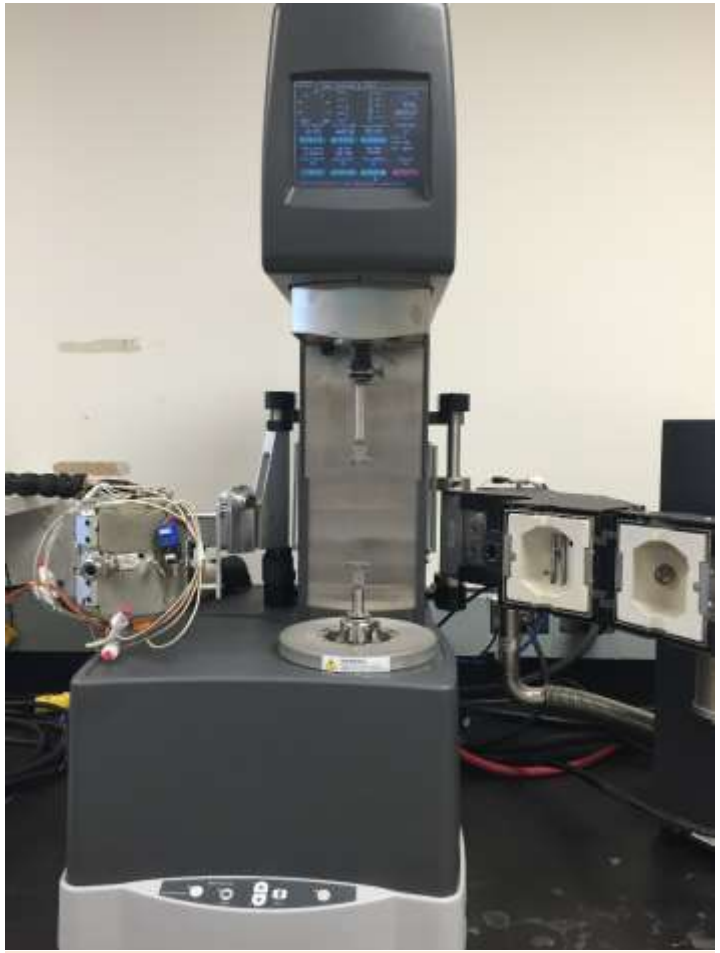
- Accuracy issues
- Cleaning issues
- Frequent calibration with a standard DIN cup
- Viscosity in ‘cup seconds’
- No temperature control or compensation
- Where do you dip the cup in the tank?
- How do you store the data and do long-term optimizations
- When do you start and stop recording the time?
- Non-repeatable even with experienced operators



The many uncertainties in procedures, as well as wear and deposits on cups, contribute to less than optimal accuracy and repeatability of cup measurements



Rotational viscometers and rheometers: Limitations of lab measurements

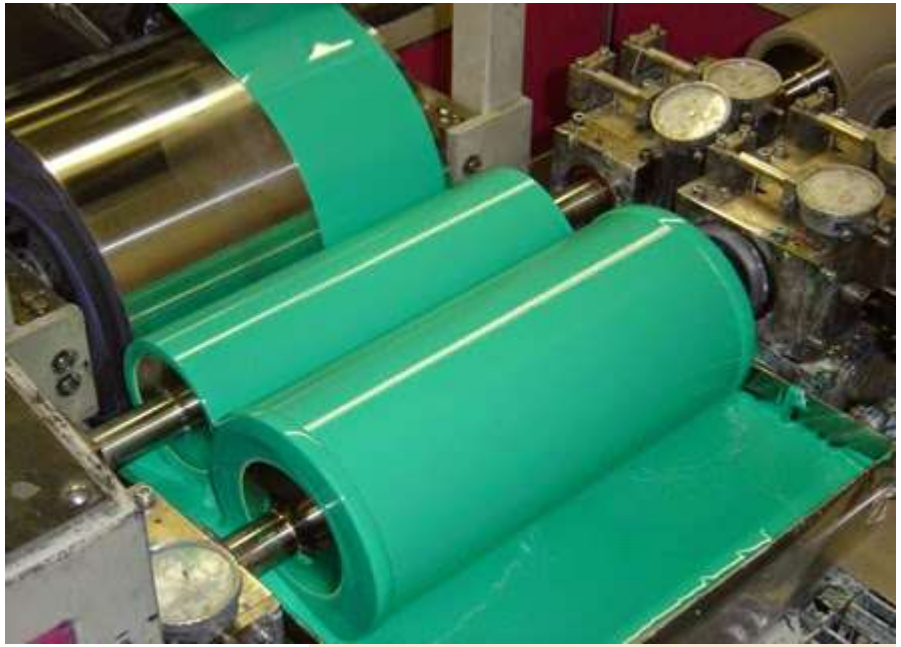


Rheometer

Rotational viscometer

- Measurements **cannot** be made under actual use conditions
- Affected by temperature, shear rate, humidity and other variables
- Difficult to decide what parameters are relevant
- Necessary sampling rates not well established
- Issues with repeatability and reproducibility
- Data not easily available for long-term optimization.

Delay between measurement and action



Coil Coating Process | Source: SRISOL

Sample collected from circulation sent to lab for analysis

Elapsed time = ?

Are traditional measurement devices suitable for use in coating lines?

While offline measurements may be useful in characterizing the right viscosity for the application, they are not useful for monitoring and controlling viscosity in a process environment for the following reasons:

- They are not easily adaptable to real-time, inline control of coating viscosity, which is affected by temperature, shear rates, humidity and other external factors.
- Measurements must be recorded manually into the automation processes involved.
- Dependent on operator’s skill for reliable readings.
- Rotational viscometers need labs for analysis.
- Delay between measurement and action; by the time the laboratory reports on the sample, it no longer reflects the actual coating viscosity in tank or in circulation.

Vibrational Instruments – Reliable alternatives?

Vibrational viscometers from different manufacturers

Advantages	• Can be plugged in the tank/circulation line directly • Real-time behaviour of the coating formulation can be monitored • Do not rely on operator's expertise
Limitations of current products	• Frequent calibration required • Difficult to set up and maintain • Many are sensitive to outer vibrations and shocks • Large size and mass makes them difficult to mount, and susceptible to damage through inadvertent contact with surrounding equipment

Desirable features of a viscometer for industrial coating applications

- Inline sensor to make direct viscosity measurements on the coating formulation
- Needs no re-calibration
- Easily cleanable
- Provides reliably repeatable measurements
- Fast response to viscosity changes to spot process fluctuations as they happen
- Produces log of viscosity data for process analysis
- An intuitive user software interface to visualize the process data
- Enable viscosity control automation in coating lines, to keep pace with the already high degree of process automation
- Provide a path to full automation

A ‘Balanced resonator’ inline viscometer: The technology meeting the requirements

- Inline viscometer measures the viscosity in the circulation line: No offline sampling!
- Compact form for easy, unobtrusive installation
- Wide measurement range – works with coating of any viscosity
- Extremely repeatable measurements
- Responsive, stable measurements – not influenced by shocks or vibrations during operation

Revolutionizing viscosity control in coating applications

Thinking beyond cup seconds

Revolutionising the way coaters control quality

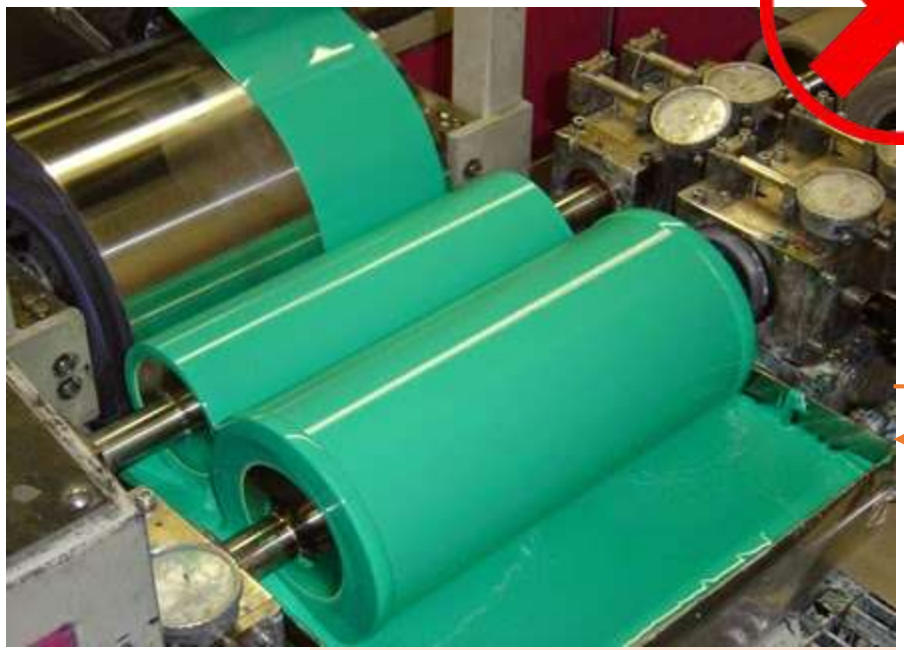
Measuring viscosity with cups is unreliable, inaccurate, time-intensive even with experienced operators. It's a huge bottle neck for scaling up volumes by continuous processes.

Inline viscometer

The Autonomous way: Continuous viscosity monitoring by the inline device

- No operator intervention required
- Measurement is continuous, without having to worry about sampling or accuracy
- The inline sensor provides 1 reading per second!

Long delay: Coating fluid in circulation may no longer have same viscosity as sample

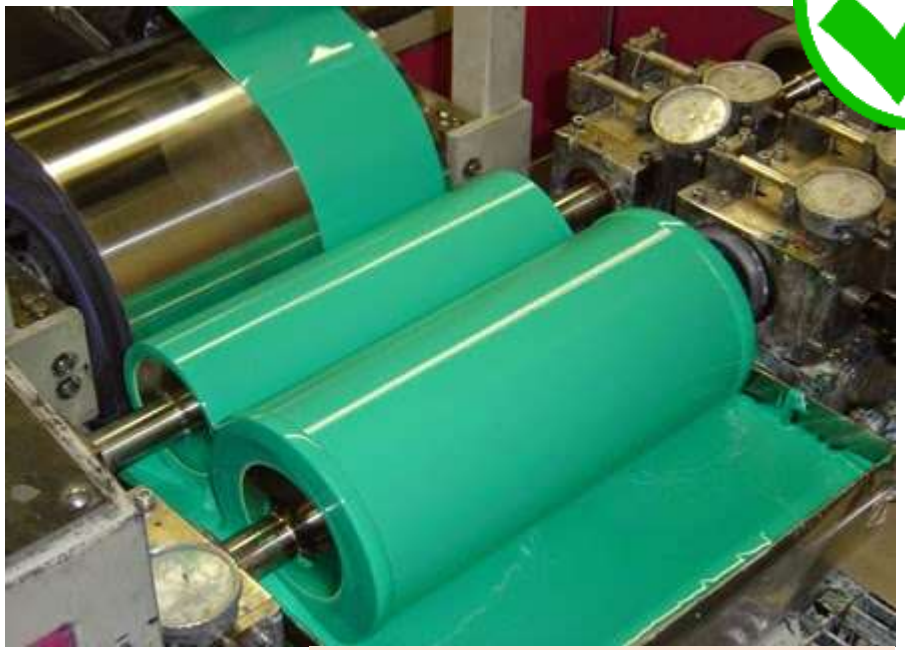


Coil Coating Process | Source: SRISOL

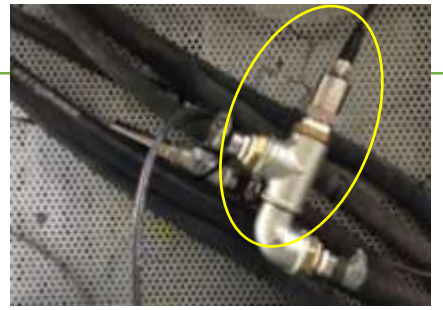
Sample collected from tank sent to lab for analysis

Elapsed time between viscosity change and corrective action may be hours

No delay : Reads the actual viscosity of the coatings in the circulation line



Coil Coating Process | Source: SRISOL



MEASURE
inline resonant viscometer

EVALUATE
Digital viscometer electronics

CONTROL
Predictive control system

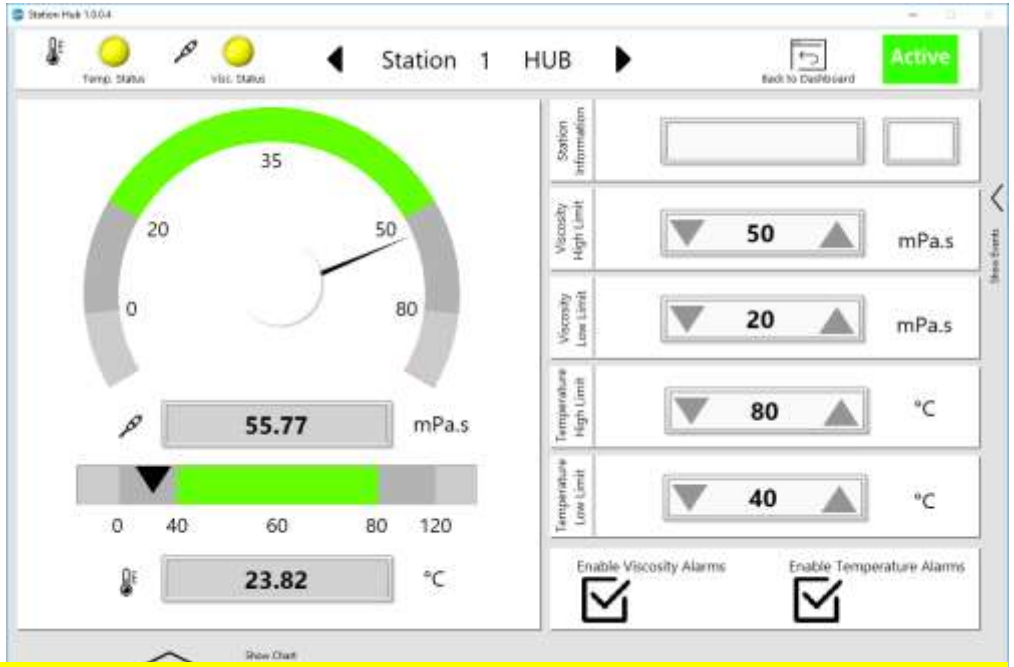
Directly make real-time measurements on the coating formulation, and act on it

Qualities of the inline viscosity measurement and control device

- ***Needs no re-calibration, cleaning or maintenance:*** An inline sensor should be permanently calibrated and maintenance free over an expected lifetime of 25 years
- ***Works with all types of coating formulations:*** Sensor must work reliably with all coat types including solvent, water-borne and UV. Same accuracy and reliability over whole viscosity range.
- ***Built-in temperature monitoring to enable temperature compensation of viscosity:*** The sensor reading should allow compensation of the viscosity readings for changes in temperature.
- ***Compact sensor form factor*** to enable easy integration in the coating circulation line.
- ***Extremely dependable and reliable data:*** The sensor's viscosity data should be extremely repeatable and reproducible. Operators must be able to rely on trends, changes, disturbances for making process decisions
- ***Measurements are unaffected by vibrations***, temperature variations or machinery.

Showing the installation of an inline viscometer in an ink delivery system

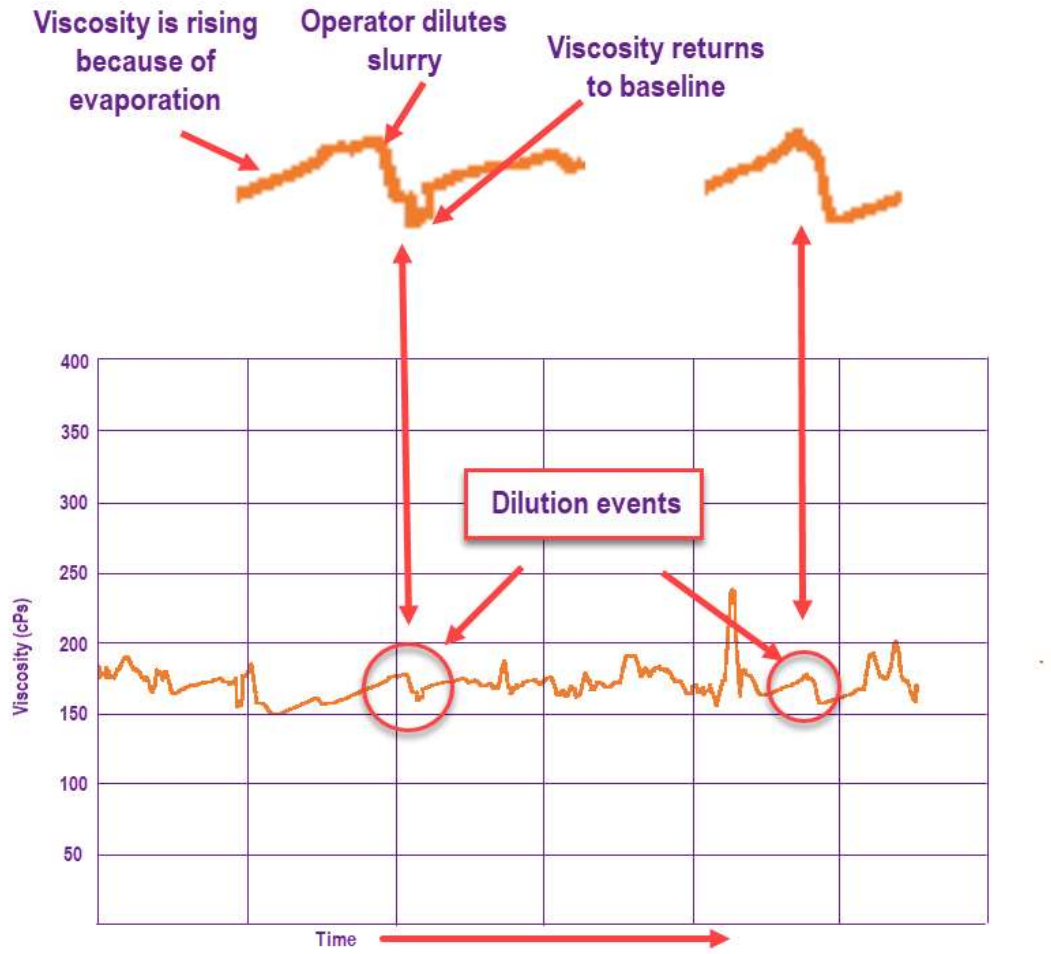
Visualizing process data from a real-time instrument



Process Insights – Using the software accompanying the advanced inline viscometer

- ***A real-time instrument*** enables the high data rate of of ca. 1 reading per second required for tight viscosity control. Measurements in digital form enable automatic entry into the factory automation system without error-prone human intervention.
- ***Gateway to viscosity automation with digital viscosity data:*** Digital output, unattended operation, and high measurement reliability make an inline sensor ideally suited to coating automation. Operator can be satisfied that coating process today can be duplicated and multiplied to support high and consistent quality throughout.

Typical use case of the process viscometer in coating application

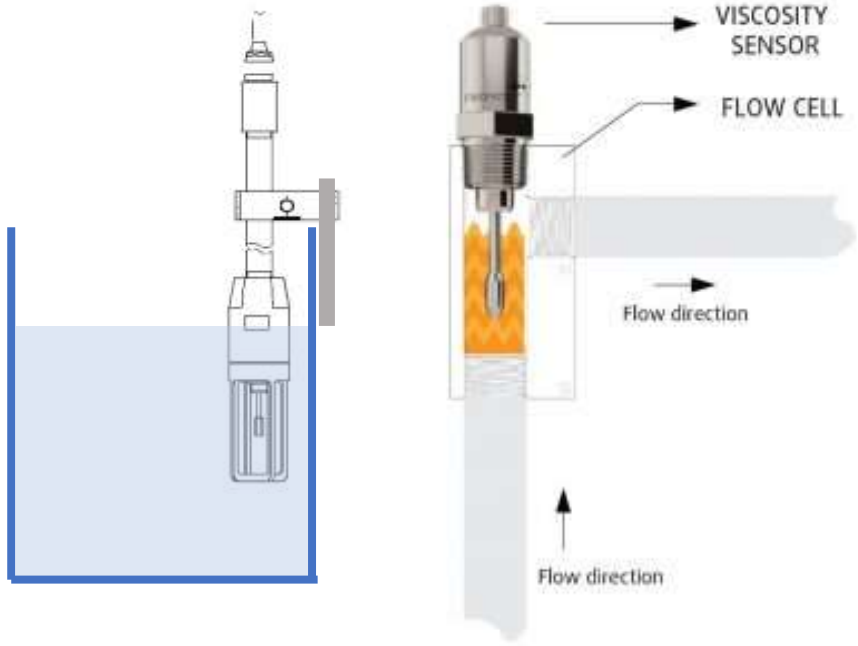


Application: Casting by multilayer coating of a wax assembly

- The inline sensor shows when coating formulation is getting thicker due to evaporation.
- Operator compensates adding thinners
- The software shows trend of coat viscosity – helps predict problems before they happen. Operator can take corrective action if viscosity deviates from control limits.
- Displays and logs viscosity data. Log can be used for analyzing and supporting data-driven quality improvements.
- Measurements available in digital form, so viscosity can be recorded and entered into the factory automation system without human intervention.

Sensor installed to autonomously monitor viscosity with built-in display

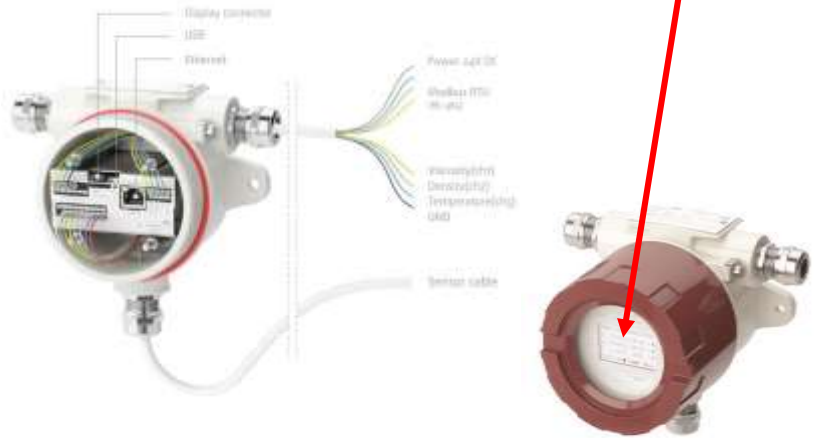
1. Install sensor in coating fluid reservoir, or in a circulation line



2. Connect sensor to electronics

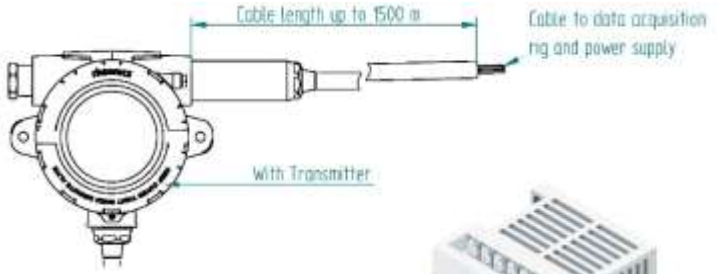
Electronics with built-in display

Connect sensor probe to sensor electronics.
Power electronics.



Sensor electronics can be wired to customer's PLC for viscosity control

Connect sensor electronics to PLC

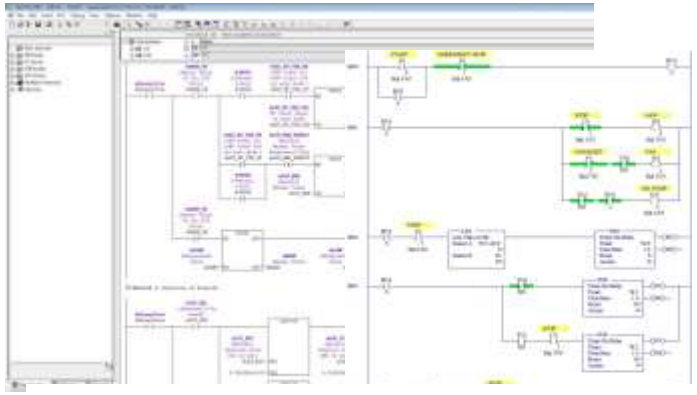


Connect using:

- 4-20mA
- Modbus
- Ethernet IP

Customer PLC

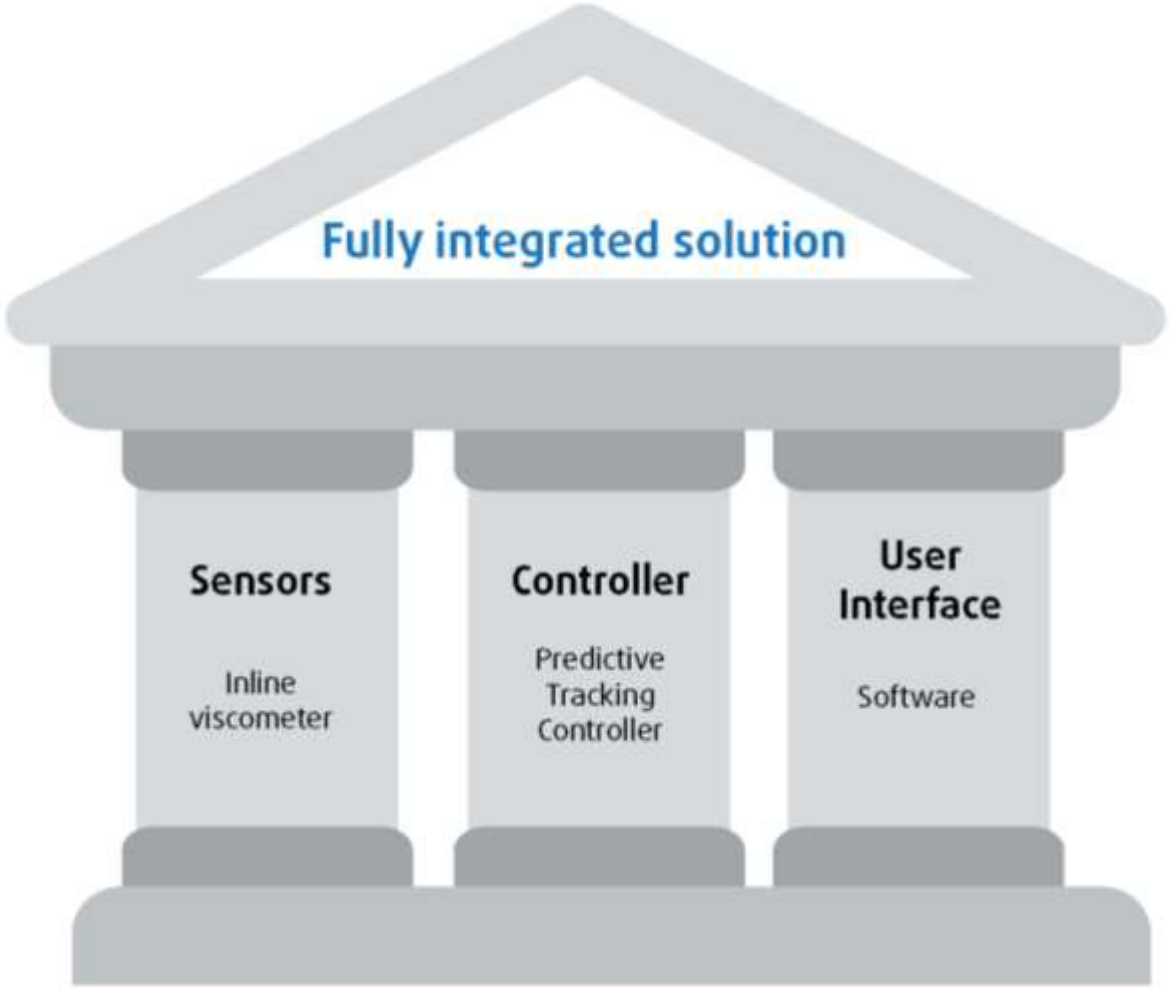
Program PLC to monitor and control viscosity



Generally performed by customer automation engineers

Foundations of a fully automated, closed-loop control system option

Coating Tracking and Control System

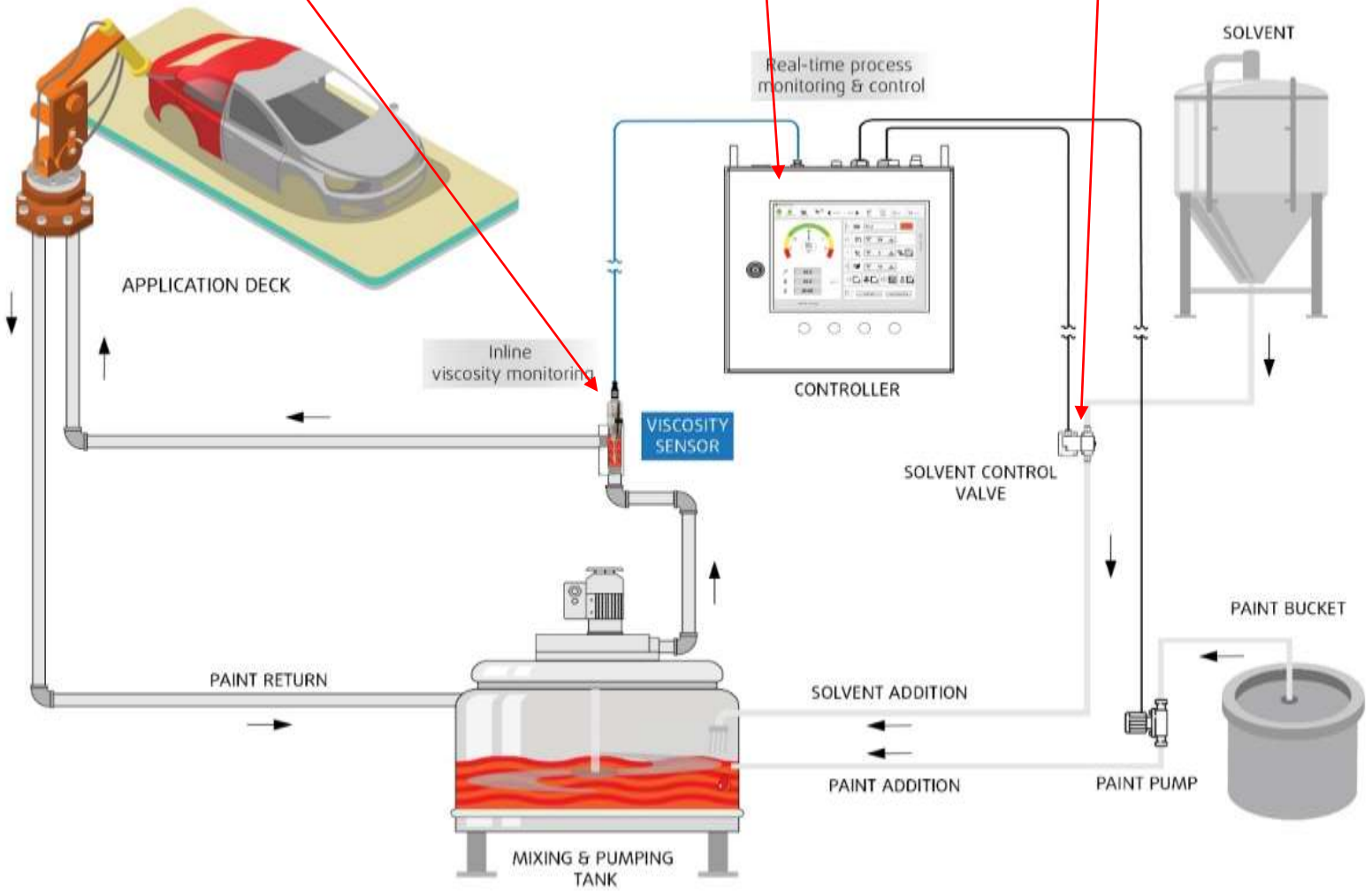


1 Inline viscometer is located directly in the supply line and transmitting coat viscosity to main control cabinet in real-time.

2 Predictive Tracking **Controller** ensures precise control of viscosity. Operator HMI gives one touch viscosity lock functionality.

3 **Dilution control valve** connected to main control cabinet with feed line of diluent from central tank to each mixing tank.

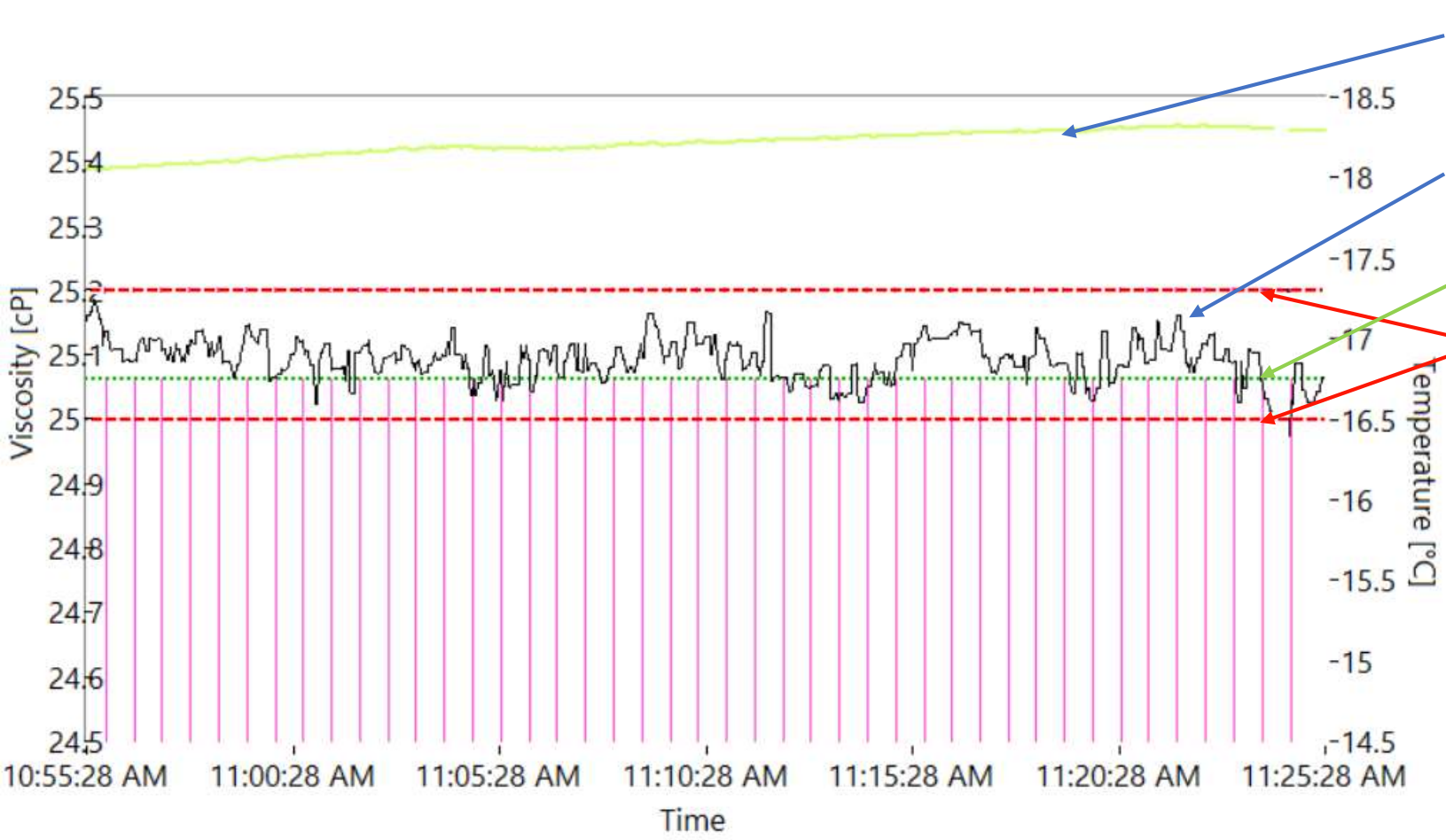
How does the closed-loop coating tracking and control system work?



Fully integrated control system components

1. Inline viscometers
2. Predictive Tracking Controller
3. Solvent Control Valve

Control stability for maintaining consistently uniform viscosity....



Temperature Compensated Viscosity Vs Time.

Temperature compensated viscosity variation is **less than 0.2 mPaS** throughout the complete print run; which is unattainable with any other sensor or traditional instruments.

Unlocking full automation

Realizing the value of true automation in coating.

The integrated system's controller is installed in a heavy stainless steel housing, which is equipped with its own industrial PC and touch screen displays. The operator can choose a viscosity set point from the touch screen interface, and lock the system to that set point.

- ***The Software comes with operator focused interface:*** User interface of the software enables one-click setting of viscosity.
- ***Industry 4.0 ready - enables full automation of coating!***

Predictive Tracking **Controller** in a stainless steel housing

Inline integration of **viscometers** in coating circulation lines

An integrated viscosity control system ensures consistent coating quality ...

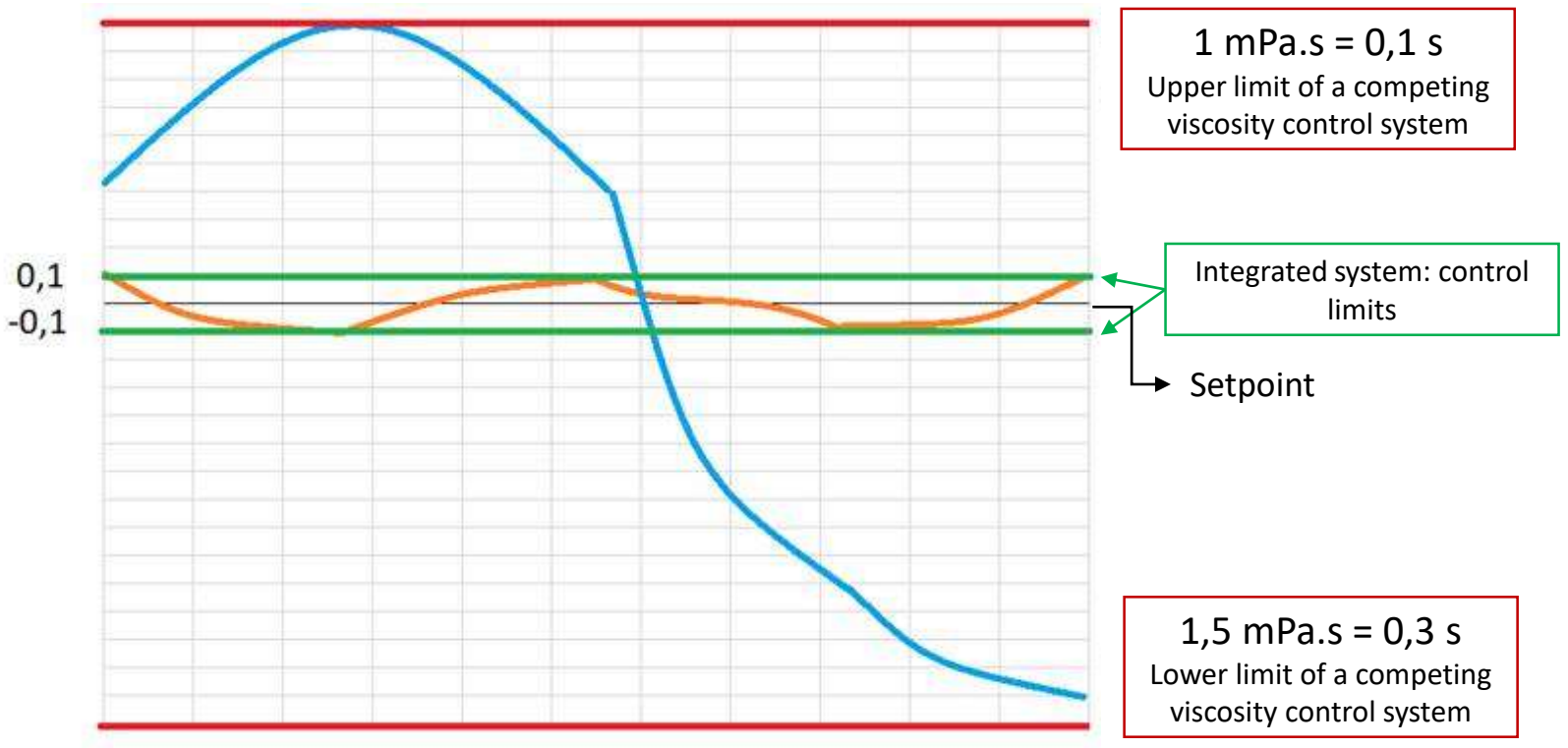


Exhibit – 1. Viscosity control accuracy, Rheonics System Vs. Competitor

Process Challenge without viscosity control

Inconsistent coating quality

How this system solves it?

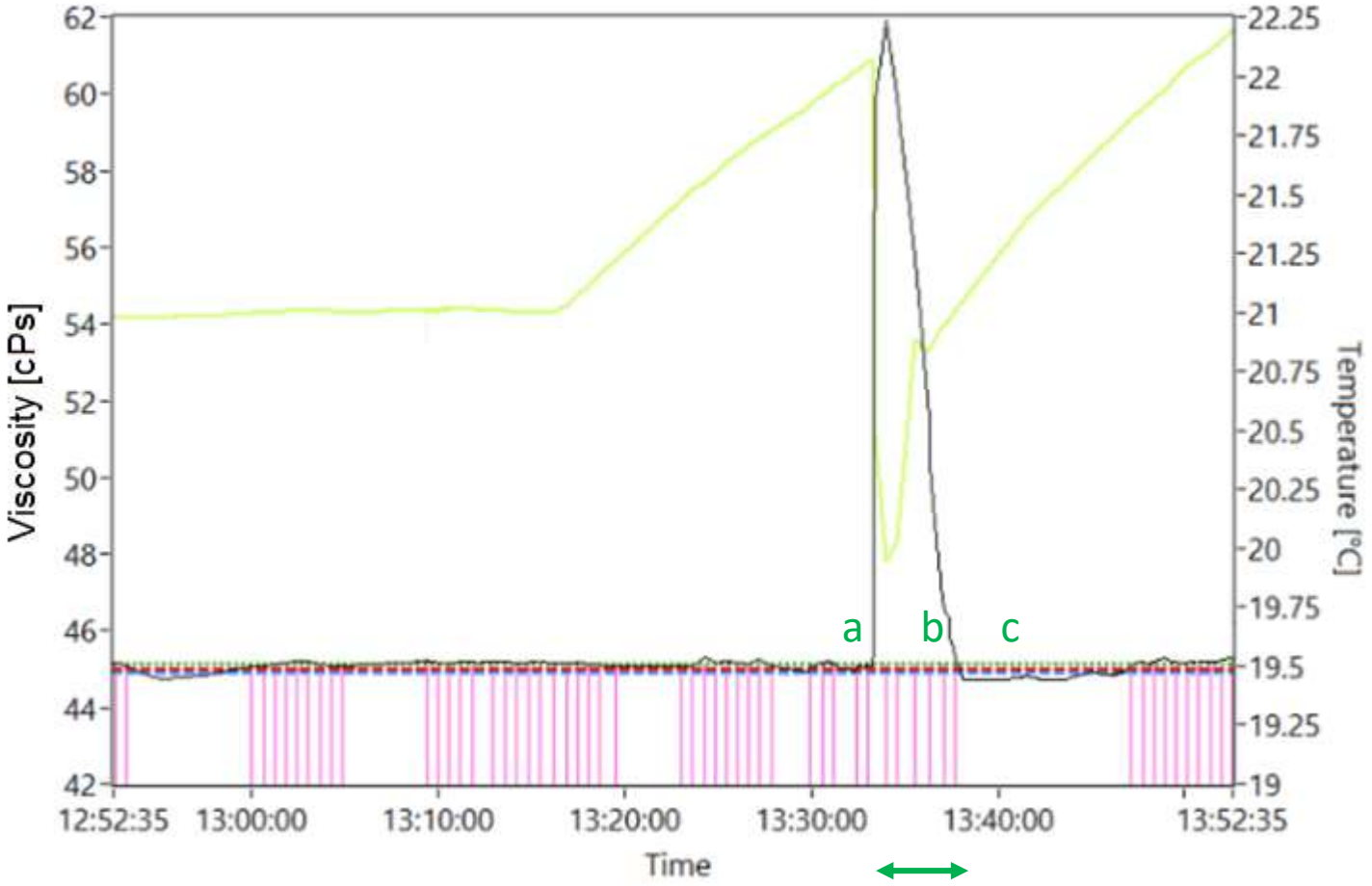
An advanced system's high precision and accuracy ensures minimum fluctuations in viscosity which results in consistent quality

Note:

Orange line shows ***ink viscosity control with the proprietary viscosity control system***

Blue line shows ink viscosity control of a competing, industry leading solution

Fast system responsiveness ensures minimum thinners consumption...



An integrated control system brings new ink to setpoint within 5 minutes

Response of the system to adding a large volume of cool ink to a system running at 21 deg. C. The spike in viscosity is because of cool ink addition.

Process challenge without viscosity control

Over consumption of solvent and increased solvent emissions.

How this system solves it?

The automated system brings viscosity to the setpoint quickly with minimal overshoot and without overdilution, without any human intervention.

Impact: Technical, Business and Sustainability

Technical Impact	• Superior quality, due to consistency in coating operations • Complete tracking and traceability of every job • Automated corrective actions for ensuring product consistency • More agility in dealing with new variants in production and compliance • Industry 4.0 connectivity enabling data-driven decision making and fault analysis
Business Impact	• Efficient operations – reduction in personnel hours • Improved productivity – faster, automated system • Higher Profitability • Reduced costs due to reduction in materials consumption • Easy scalability of operations
Sustainability Impact	• Reduced scrap, rejects • Lesser material and dilent/solvent consumption • Optimum energy consumption in pumping, agitation and application • Lesser VOCs emissions • Safer and cleaner workplace for operators and employees • Reduction in setup times and significantly easier cleaning procedures

Case #1: Integrated System deployed in printing press and laminating machines

1. Solvent consumption reduction

Proprietary integrated solution commissioned in Laminating Machines – April 2020

Solvent Consumption Data on laminating machine								
	2013	2014	2015	2016	2017	2018	2019	2020
Ratio (Solvent: Adhesive)	2,05	1,94	1,96	1,93	1,96	2,09	2,02	1,22

Proprietary integrated solution commissioned in Printing Press – June 2018

Solvent Consumption Data on printing press								
	2013	2014	2015	2016	2017	2018	2019	2020
Ratio (Solvent: Ink)	1,26	1,05	1,23	1,02	1,00	0,57	0,84	0,65

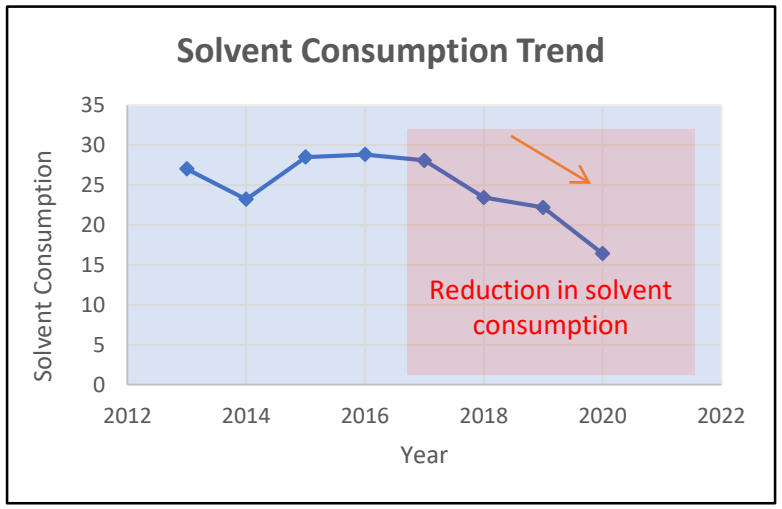
Note: There is a **~ 40% reduction in solvent consumption** after the proprietary closed-loop viscosity control system integration in customer application.

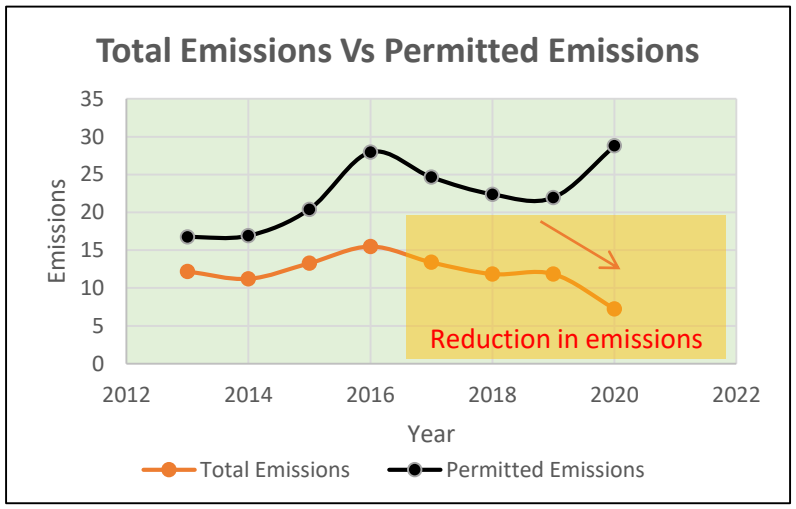
Solvent consumption per unit adhesives & per unit ink data reported by a customer after commissioning of the proprietary integrated viscosity control solution (Source – Maasmond B.V., Netherlands).

2. Emissions reduction

Proprietary integrated solution commissioned in Maasmond B.V. Operations – June 2018

	2013	2014	2015	2016	2017	2018[1]	2019	2020[2]
Solvents consumption	27.045	23.239	28.532	28.848	28.112	**23.442**	**22.197**	**16.420**
Total emission	12.193	11.214	13.281	15.487	13.389	**11.841**	**11.841**	**7.240**
Permitted emission	16.727	16.896	20.400	27.971	24.655	22.388	21.954	28.798





Notes:

1. First system commissioned on printing press ink stations in June 2018
2. The second system commissioned on the laminator units in April 2020

Solvent consumption and emissions data reported by a customer after commissioning of the proprietary integrated viscosity control solution (Source – Maasmond B.V., Netherlands)

Case #2: Understanding VOC emission costs of adding extra thinners to coats

Consequences for total VOC emissions if “just a little extra” thinner is added to an industrial coating

		Quantity (Q) (gallons)	VOCs concentration (C) (lbs/gallon)	VOCs emissions (Q*C) (lbs)
Paint	Low-VOC epoxy: 75 % solids, 25% volatiles are VOCs. 1.8 lbs/gallon VOCs	1000	1.8	1800
Extra Thinner	7 lbs/gallon VOCs	100	7	**700** ▲40.00%

Source: How “Just a Little Thinner” Impacts VOC Emissions in Industrial Coatings By: Dwayne Lum | May 18, 2021 in Coating Science

VOC emissions “cost” for protecting 200,000 ft² of steel from corrosion rose from 1,800 lbs VOCs by 700 lbs (to 2,500 lbs) —a nearly 40% increase!

A fast-response control system ensures the addition of thinners/diluents is kept to an absolute minimum, dosing only as much is required.

Future of printing and coating: Focus on the **environment**

Roadmap of coating companies calls for safer, environment friendly, sustainable operations.

1. Continuing measures to ***minimize solvent consumption*** in coating/printing operations to reduce volatile organic compounds (VOCs) and air pollutants (HAPs)
2. ***Moving from solvent-based to water-based coatings***

Environmental hazards of VOCs and HAPs

- Soil, air and water pollution
- Ozone layer depletion
- Negative health effects on exposure

Facilitating automation goals with an integrated viscosity control system

Goals of viscosity automation	How do the advanced process control solutions contribute?
Knowledge transfer from experienced operators to an automated system	• Existing procedures can be programmed into the controller • Specific protocols can be memorized and recalled for repeat jobs
Viscosity automation brings coating process control up to Industry 4.0 standards	• Accurate, transparent viscosity control removes last barrier to full automation
Easy integration into coating lines	• A fully integrated supports seamless integration into existing processes and factory data systems • Monitoring, logging and self-check functions contribute to operator independence • Integration into factory data systems provides a path to data-driven process optimization

Conclusions

- A reliable inline viscometer with an integrated control system brings accurate, repeatable coating viscosity control up to the standards required of *modern industrial automation*.
- It removes the subjectivity and long time delays of traditional methods, making possible inline, real-time monitoring and control of coating viscosity.
- The integrated solution of viscometers and the control system improves both coat quality and consistency, reducing waste and rejects, while streamlining the viscosity measurement and control process.
- Viscosity automation solution not only adds technical and business excellence to coating operations, but also transforms them sustainably.

rheonics

inline process
density and viscosity
monitoring

Thank you for your attention!

We look forward to working with coating professionals and applying our knowledge of sensors to ensure data-driven QC and **‘greener’ coating operations.**

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