Foundry 4.0 – Effective shell building needs real-time viscosity monitoring and control of ceramic slurries

Investment Casting Institute
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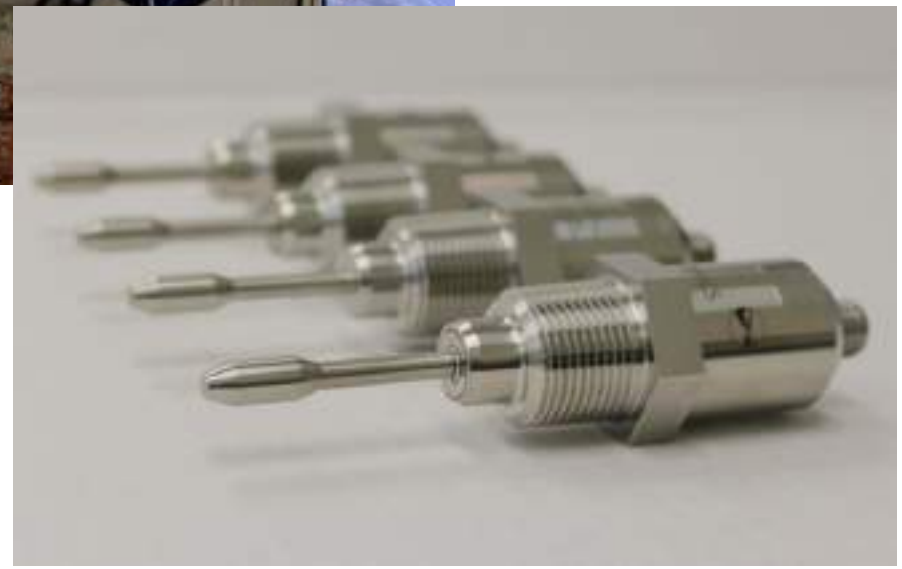
https://rheonics.com

rheonics

Rheonics - Introduction

- Rheonics was founded to solve the issue of lack of robust plug and play instruments for viscosity and density monitoring, two of the key physical properties of a process fluid.
- To achieve the vision of a no-hassle, easy to use inline viscometer, the founders brought together a team of experts from leading universities and global companies to build advanced intelligent fluid process monitoring instruments.
- Our sensors have been used by machine builders and fabricators for monitoring and controlling the quality of ceramic slurry. In investment casting, we see an application that has been on the look-out for a viscosity and density sensor that can help achieve the perfect dip coated parts for casting. Rheonics sensor met that need creating industry 4.0 enabled process optimization of the dip coating process.



Outline of the presentation

1. **Importance of viscosity for shell building**
   - Why slurry viscosity is important in shell building?
   - An evaluation of traditional methods for controlling slurry viscosity
   - Factors affecting a viscosity measuring device selection for slurry application

2. **A reliable inline viscometer for slurry viscosity management**
   - Rheonics SRV viscometer as an alternative
   - Advantages of SRV for slurry viscosity management
   - Beyond measurement to real-time control

3. **Real-time slurry viscosity measurement and control in the shell room**
   - Sensor mounting options
   - Integrated solution: sensor, controller and control valves
   - A gateway to complete viscosity automation in shell building, Slurry Track = sensor + controller + software
   - Benefits for the users and technology outcomes for the industry

Part 1

Importance of viscosity for shell-building

- Why slurry viscosity is important in shell building?
- An evaluation of traditional methods for controlling slurry viscosity
- Factors affecting a viscosity measuring device selection for slurry application

Viscosity: Importance in shell building

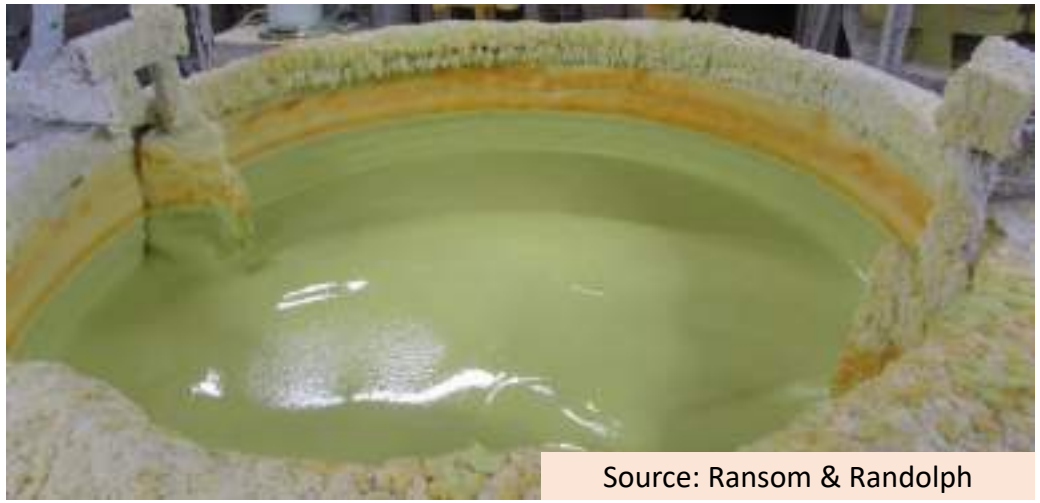
- Measure of a fluid’s resistance to flow
- Quantifies the thickness or thinness of a fluid
- Determines the thickness of the layer that remains after each dipping process
- Uniformity of the coated slurry layer on the wax assembly
- Tighter control of slurry viscosity has been found to contribute to the ease and quality of shell building, as well as the quality of the finished cast goods.

Source: Multistation SAS / MK technology

Slurry Viscosity and shell quality

- A good slurry composition alone cannot guarantee production of smooth and defect free shell if the slurry is prepared in an inadequate manner.
- Viscosity of the slurry is a measurement of the ***flow characteristics*** of the slurry.
- ***Particle size distribution***, represented by the slurry viscosity, affects important attributes of the final shell.
- It is an important determinant of the ***layer thickness and adhesion***, i.e. how much of it will remain on the wax assembly during the dipping and draining cycles.

Source: ICI / investmentcasting.org



Source: Ransom & Randolph

Shell properties affected by slurry

Several literature and studies to investigate the effect of controllable shell building process variables on the shell properties cited viscosity as an important input variable.

Shell properties affected by viscosity of the slurry:

- Layer & final thickness
- Surface finish
- Permeability
- Strength
- Edge coverage
- Edge strength
- Bending strength
- Thermal characteristics

Shell defects that are caused by improper slurry viscosity

Slurry Preparation Problems:

1. Penetration
2. Buckle
3. Bubbles

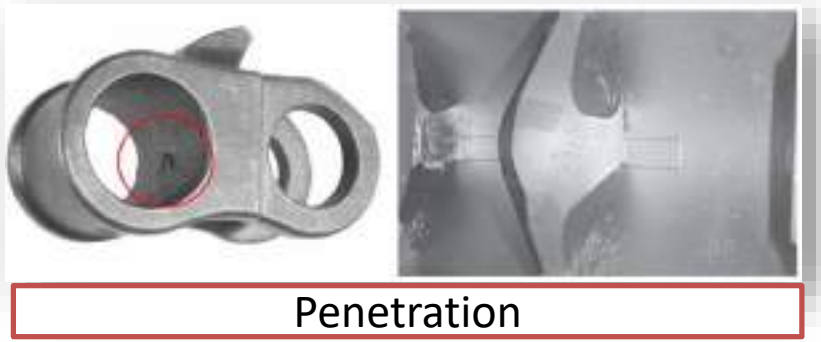
Slurry Maintenance Problems:

4. Excess Metal/ Bridging effects

Shell Drying Problems:

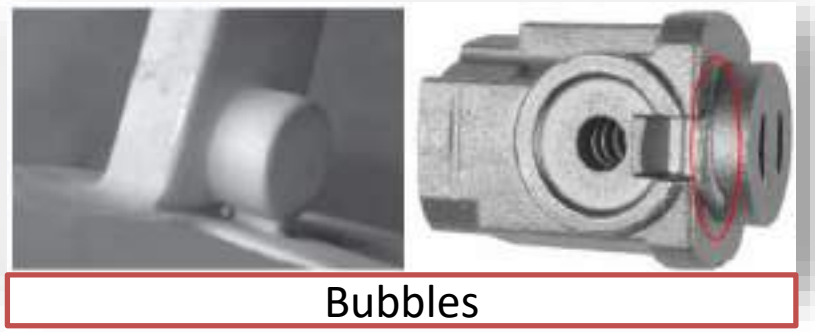
5. Spall

Buckle



Penetration

Excess Metal



Bubbles

Spall

Source:

Atlas of Casting Defects, An Investment Casting Institute Publication, December 2017
Atlas of Shell Defects, An Investment Casting Institute Publication, February 2004

Requirements from a viscosity device from the casters' perspective

The search for viscometer for slurry applications has been long, with researchers highlighting key requirements:

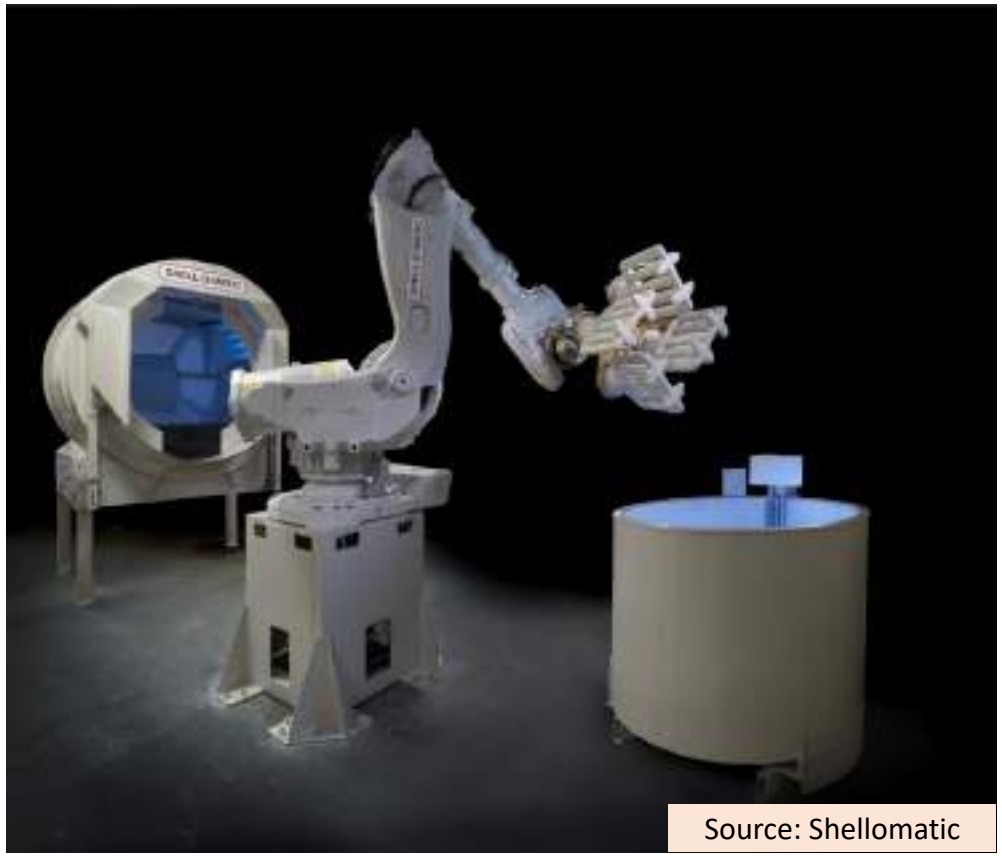
- Takes **continuous measurements** of actual viscosity during shell forming process
- **Avoid delay** for sampling and evaluation of measurements
- Requires **no calibration**
- Should be "transparent" to the **operator**, requiring no special knowledge, operation, or evaluation of results
- Should provide measurements that can be used by **automation** of processes

Current methods for viscosity measurement

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

Current methods require manual sampling and testing.

Rheonics SRV and **SlurryTrack technology** offer a simple and efficient bridge to bring slurry management up to the modern standards that prevail in today's highly automated shell rooms.



Source: Shellomatic

Showing the installation of the Rheonics SRV viscometer in a shell building slurry drum

Traditional methods and their limitations

Slurry viscosity is still measured by old methods. The involve manual sampling and testing in laboratories, two main methods are:

- Efflux cups
- Rotational viscometers

Limitations

- Offline, needs sampling
- Need experienced operators
- Can’t supply the data needed for inline process control

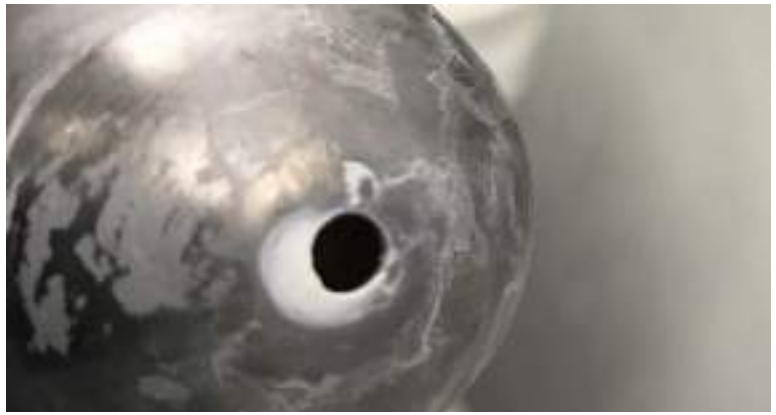
Source: Gardco

Source: Brookfield

Source: Thermo HAAKE

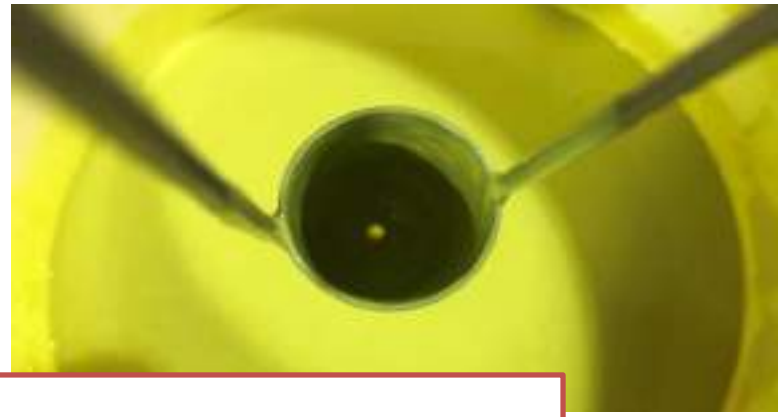
Are cups suitable for viscosity checks?

- Accuracy issues
- Cleaning issues
- Frequent calibration with a standard DIN cup
- Slurry viscosity in ‘cup seconds’



Source: Ransom & Randolph

- 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

- 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
- How do you store the data and do long-term optimizations?

Source: Gradco/Brookfield

Delay between measurement and action:

Source: IPCL India

Sample collected from slurry tank sent to lab for analysis

Elapsed time = ?

Source: Brookfield

Suitability of traditional measurements for shell room use

- Neither of these methods is easily adaptable to real-time, inline control of slurry viscosity
- Measurements must be recorded manually into the automation processes involved
- Rotational viscometers need labs for analysis.
- By the time the laboratory reports on the sample, it no longer reflects the actual slurry condition in tank

Summary: Limitations of offline measurement techniques

- **Efflux cups:**
  - **Inaccurate:** depend on the operator's judgement. Repeatability is seldom under 1 seconds.
  - **No temperature control :** although viscosity is highly temperature-dependent.
- **Rotational viscometers:**
  - **Rely on operators' expertise:** Lab viscometers are delicate, and require skilled operators
  - **Not a real-time indicator of slurry in the process:** Samples sent to the lab are not the same as the material currently in the slurry tank, since the measurement may be made hours after the sample is drawn.

Neither method is readily adaptable to inline, real-time viscosity control. Measurements must be recorded by hand, and then entered into data processing and control systems

Vibrational Instruments – Reliable alternatives?

Advantages	• Can be plugged in the slurry drum directly • Real-time behaviour of the slurry 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

Source: Sofraser, Hydramotion, Nametre (GAS)

Desirable features of a shell room viscometer

- Inline sensor to make direct viscosity measurements on the ceramic slurry
- Does not require re-calibration and must be easily cleanable
- Provides repeatable measurements – to support process quality as well as information for process improvement
- Fast, reliable response to slurry viscosity changes to enable immediate operator intervention if necessary
- Produces log of viscosity data and an intuitive interface (software) to visualize the process data
- Enable viscosity control automation in shell rooms, to keep pace with the already high degree of process automation
- Provide a path to full shell-room automation

Part 2

A reliable inline viscometer for slurry viscosity management

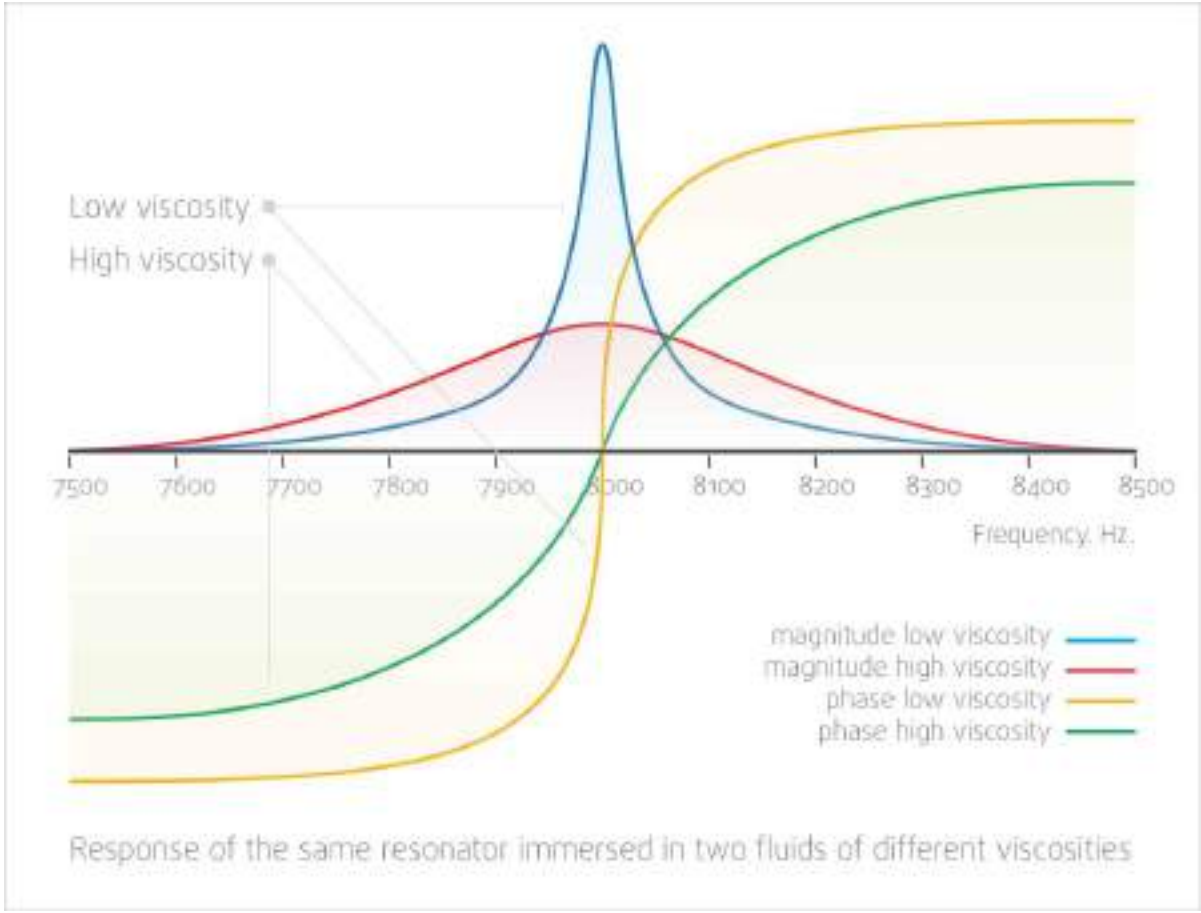
- Rheonics SRV viscometer as an alternative
- Advantages of SRV for slurry viscosity management
- Beyond measurement to real-time control

Rheonics SRV: The viscosity technology revolution for this application

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

Balanced Torsional Resonator: The game changer in viscometer technology

- Rheonics SRV viscosity technology makes use of an ultra-stable torsionally balanced mechanical resonator (US patent 9,267,872) whose oscillations are damped by the viscosity of the slurry.
- The more viscous the fluid, the higher the mechanical damping of the resonator. By measuring the damping, the product of viscosity and density is estimated.
- The resonator is excited and sensed by means of an electromagnetic transducer mounted in the sensor's body.
- Damping is measured by Rheonics patented gated phase-locked loop technology .
- Based on these two key technologies, the SRV viscosity sensor delivers stable, repeatable and highly accurate measurements.



Sensor Operating Principle

Read more: https://rheonics.com/whitepapers/

Rheonics SRV: Revolutionizing slurry viscosity control in shell room

Source: Digital Fire

The traditional way

Measuring viscosity with cups is unreliable, inaccurate, time-intensive even with experienced operators.

The Autonomous way:
Continuous viscosity monitoring by Rheonics SRV viscometer

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

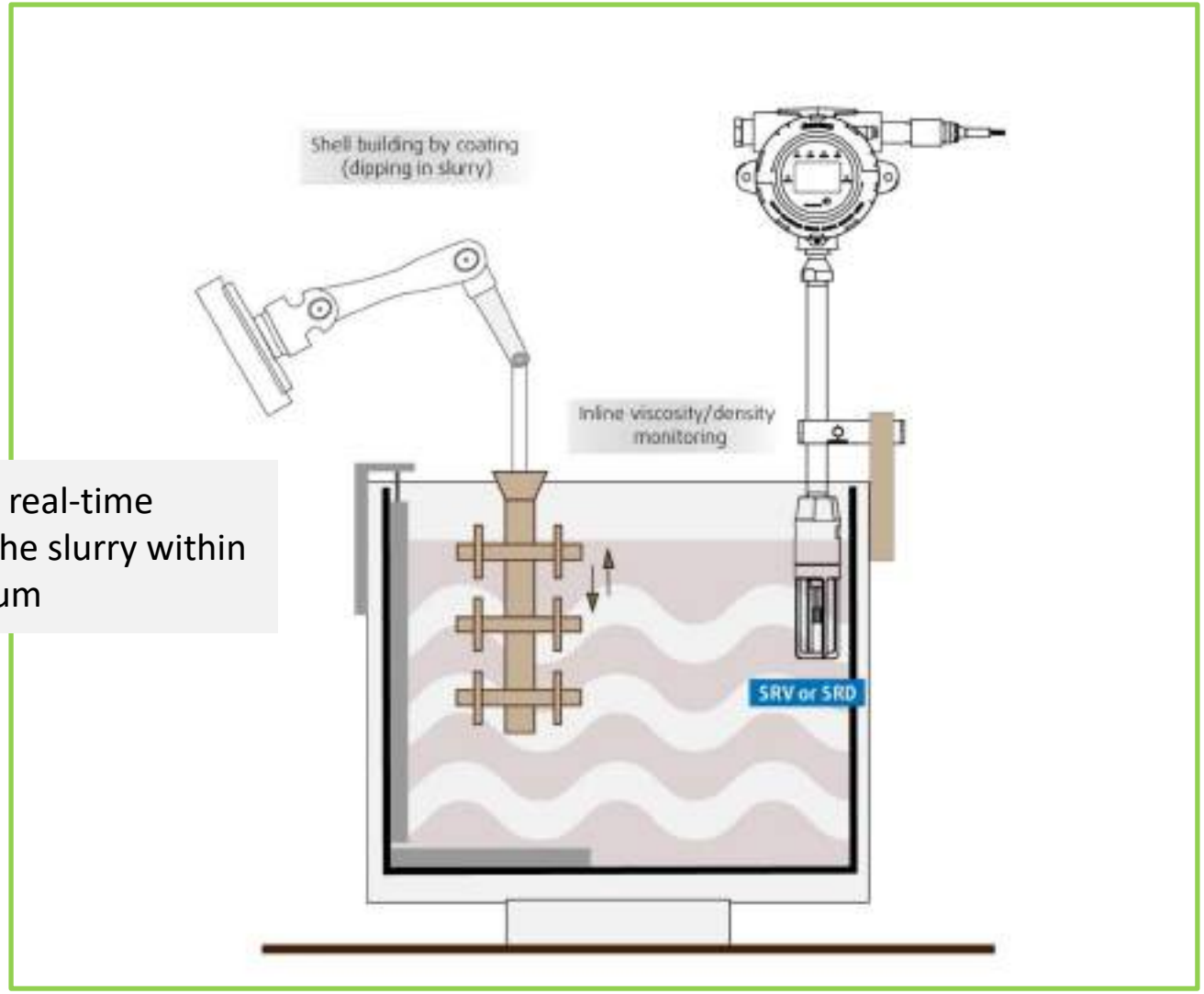
Long delay: Slurry in drum may no longer have same viscosity as sample

Sample collected from slurry tank sent to lab for analysis

Elapsed time may be hours

No delay : Reads the actual viscosity of the slurry in the drum

Directly make real-time measurements on the slurry within the drum



SRV – Truly revolutionary technology for slurry quality control

- ***No more manual handling or offline sampling of slurry:*** Replaces cup measurements and offline lab measurements.
- ***Independent of operators skills or judgement***
- ***Sensor needs no re-calibration, cleaning or maintenance:*** Sensor is permanently calibrated and maintenance free over the expected 25 years lifetime of the sensor.
- ***Extremely dependable and reliable data:*** SRV's viscosity data is extremely repeatable and reproducible. Operators can fully the viscosity data (trends, changes, disturbances) for making process decisions, reliably and dependably.
- ***Provides a direct, stable link between slurry viscosity and casting quality:*** Operators can focus the shell building job instead of slurry measurements.
- ***Works with all types of slurries:*** SRV works reliably with all slurry types and coats. Same accuracy and reliability over whole viscosity range.
- ***Built-in temperature monitoring enables temperature compensation of viscosity***

SRV – Build it into the machine instead of building the machine around it

- SRV's ***compact form factor*** means lower footprint and easy integration in the slurry drum.
- ***Simple sensor integration*** reduces installation cost.
- ***Measurements are unaffected by vibrations***, temperature variations or shell room machinery.

SRV – Typical use case inside the shell room

- SRV shows when slurry is getting thicker due to evaporation.
- Operator compensates adding diluent.
- SRV shows trend of slurry 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 the slurry 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.

Showing the installation of the Rheonics SRV viscometer in a shell building slurry drum

SRV with tank mount adapter: Rugged sensor made for tough environments

SRV is provided with a tank mount adapter that allows quick install in the drum and prevents damaging its sensing element through inadvertent impacts with other equipment, as well as with unmixed clumps of slurry ingredients.

SRV's tank mount adapter components

The SRV with its tank mount adapter are installed in the slurry tank, with a cable connecting it to the SlurryTrack system.

SRV hooked to tank mount adapter for installation in slurry drum

Part 3

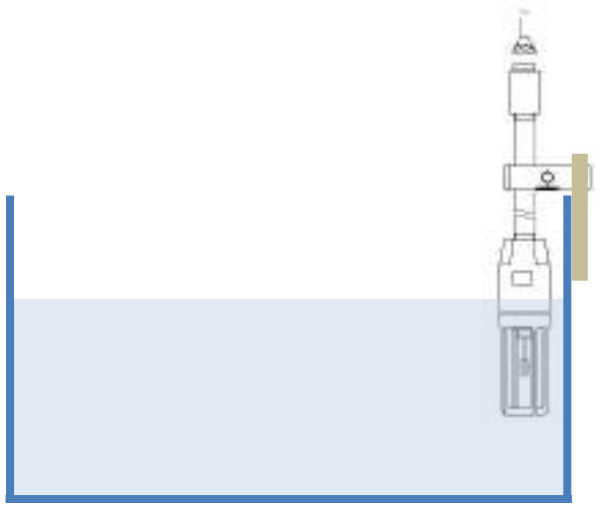
Real-time slurry viscosity management for shell building

- Sensor system installation options
- Integrated solution: sensor, controller and control valves
- A gateway to complete viscosity automation in shell building, Slurry Track = sensor + controller + software

SRV installed to autonomously monitor viscosity with built-in display

1. Install sensor in slurry drum

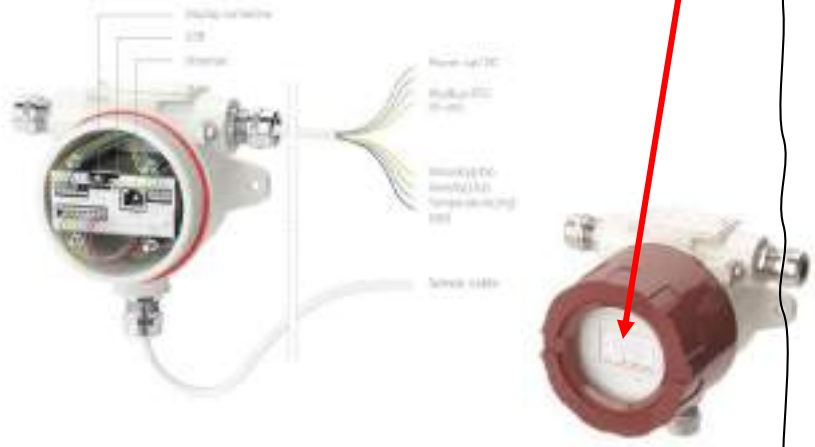
Install SRV probe in slurry tank using tank mount adapter



2. Connect sensor to electronics

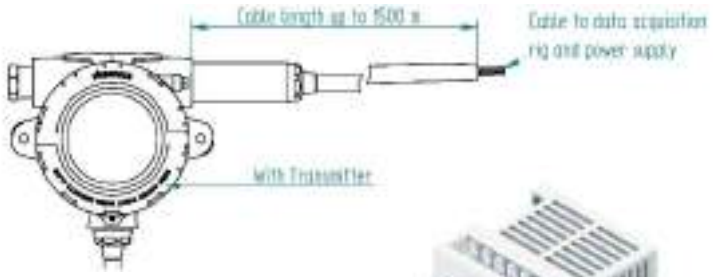
Connect SRV probe to sensor electronics. Power electronics.

SRV electronics with built-in display



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

Connect sensor electronics to PLC

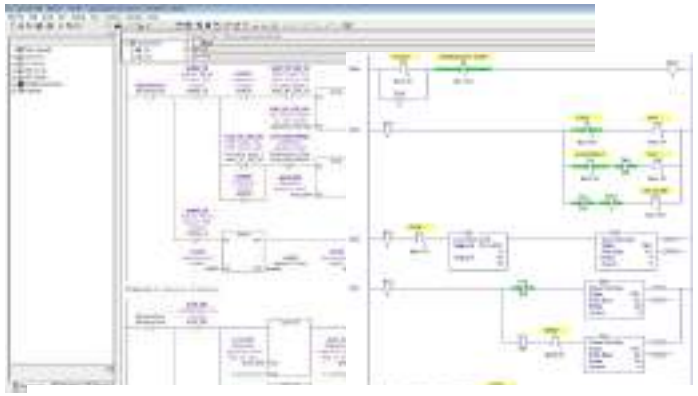


Connect using:

- 4-20mA
- Modbus
- Ethernet IP

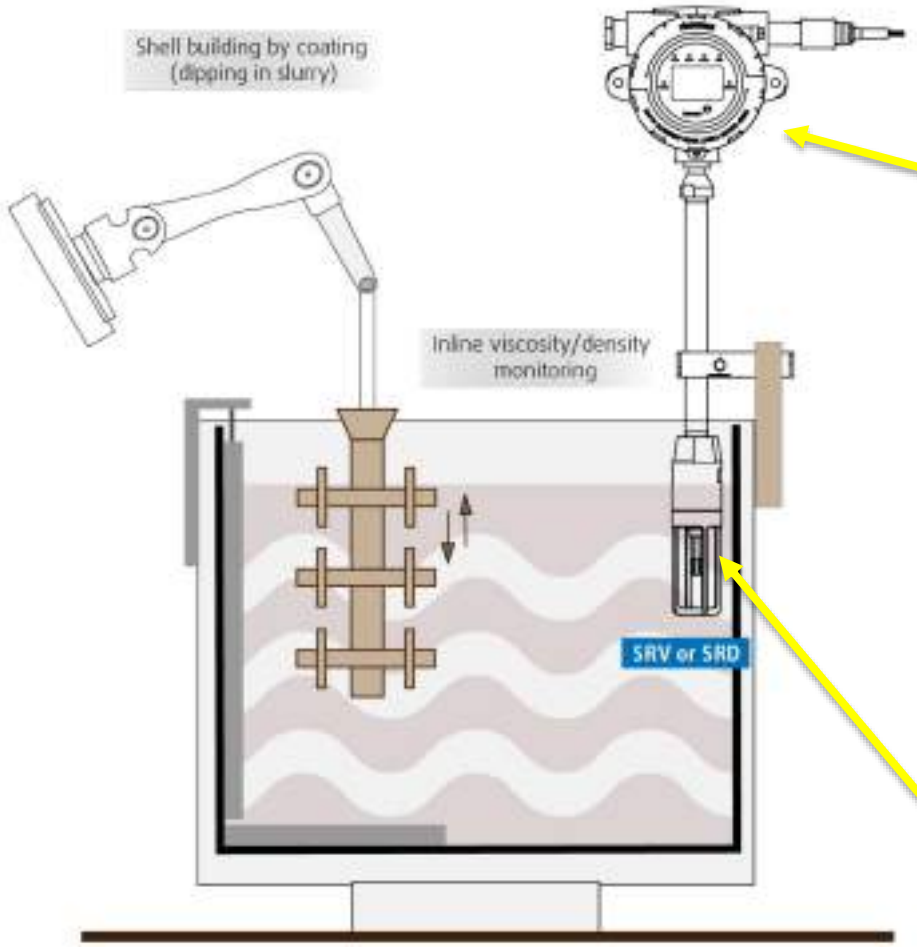
Customer PLC

Program PLC to monitor and control viscosity



Generally performed by customer automation engineers

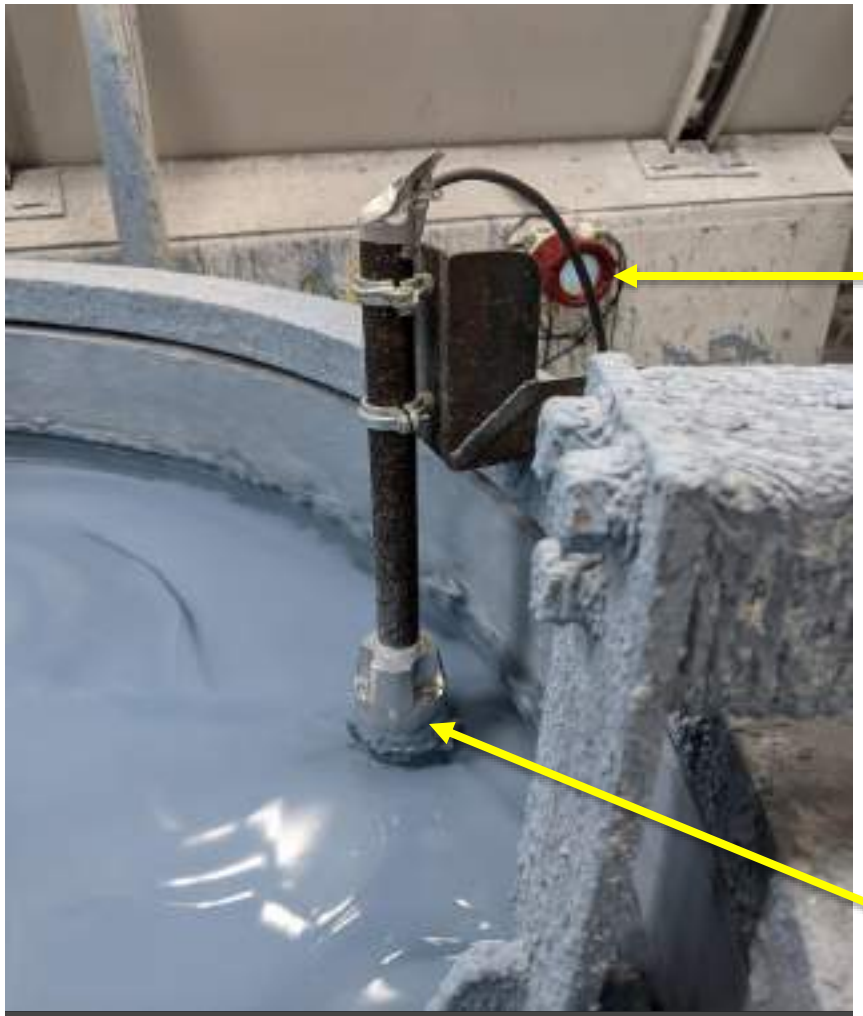
SRV with integral transmitter housing and display



Electronics
(SME-DRM)

SRV
Viscometer

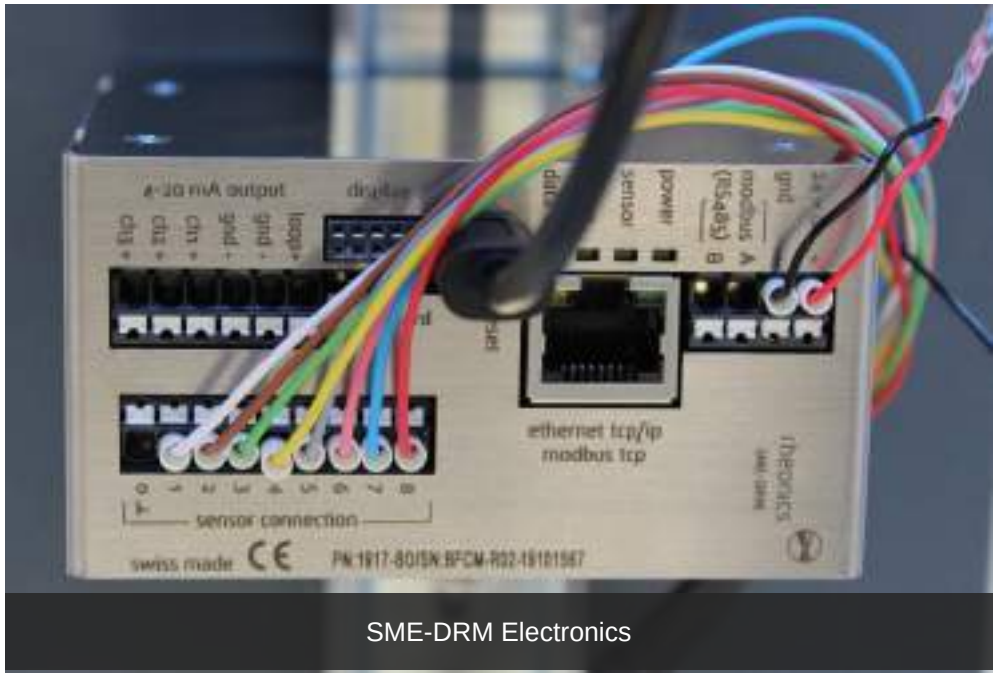
SRV is connected to remote electronics by a cable



Showing the installation of the Rheonics SRV viscometer in a shell building slurry drum

Electronics (SME-DRM)

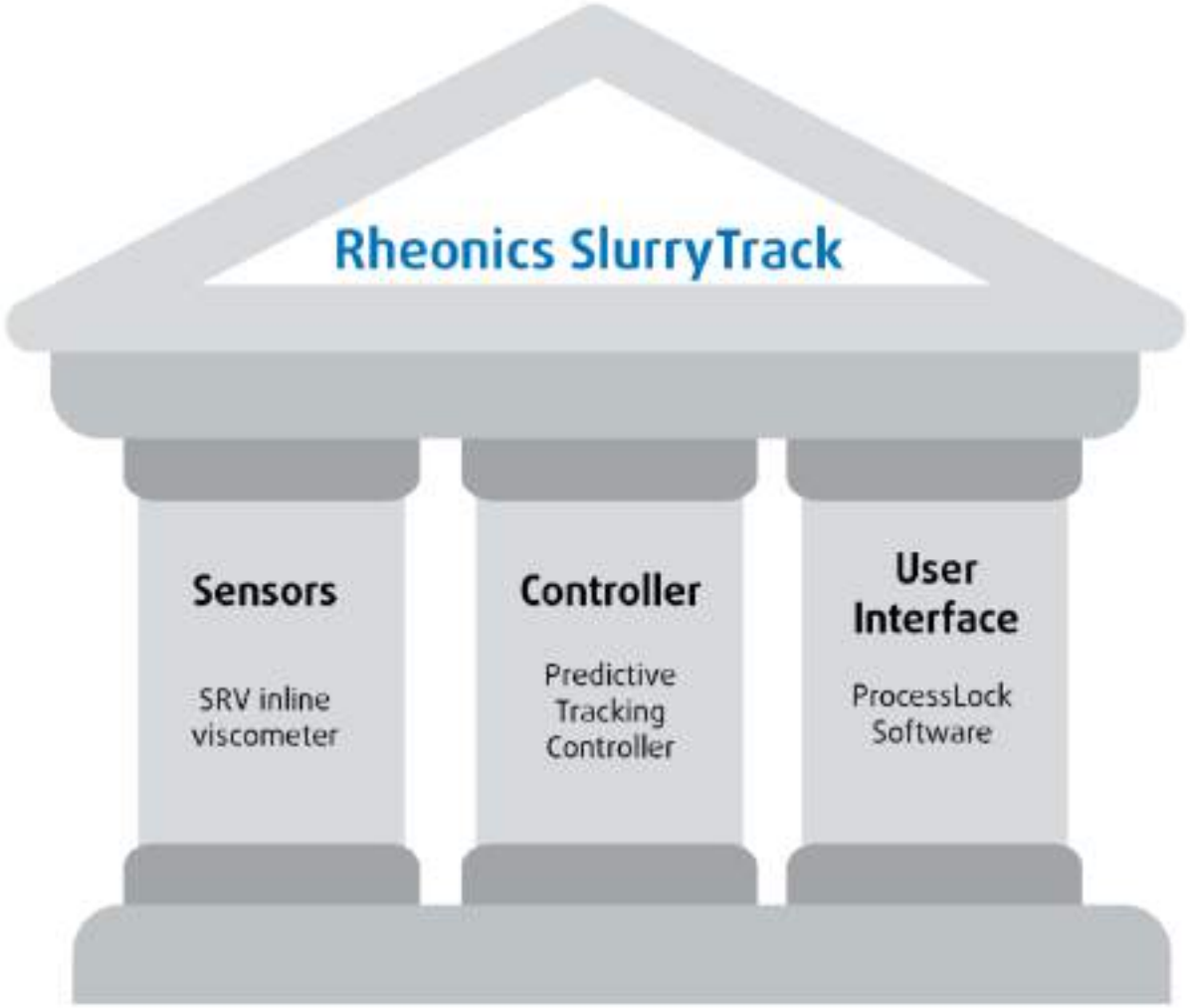
SRV Viscometer



SME-DRM Electronics

The SRV is connected to the SME-DRM electronics, which is connected to the customer PLC (using 4-20mA channels).

Full system integration for monitoring and control: Rheonics SlurryTrack



Rheonics SlurryTrack for monitoring and control

Rheonics **SRV Sensor** with its *tank mount adapter* is directly mounted on the slurry tank/drum.

MEASURE

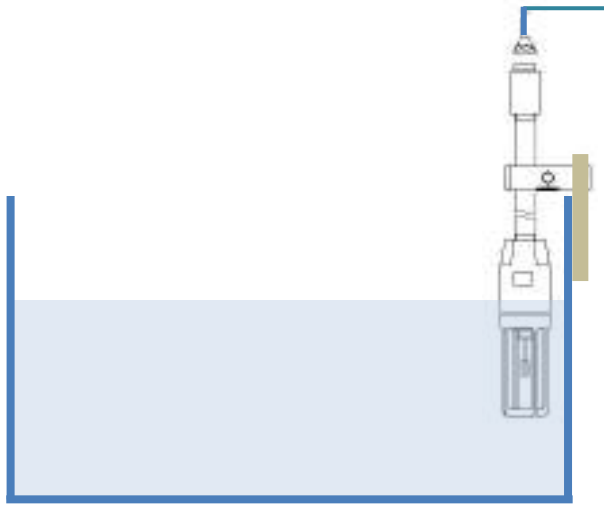
SlurryTrack predictive tracking controller that receives the SRV's viscosity measurement, compares it to the viscosity set point, and actuates a **solenoid valve** that doses diluent–typically water–into the slurry tank/drum to restore it to the set viscosity.

CONTROL

SlurryTrack for monitoring and data acquisition

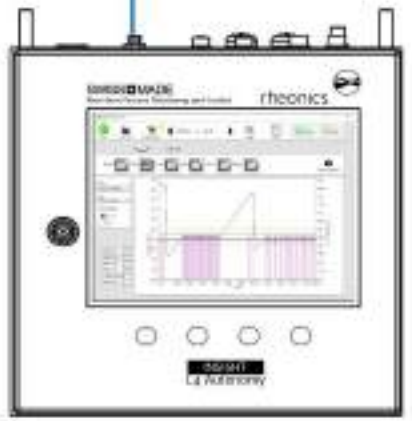
STEP 1

Install SRV probe in slurry tank using tank mount adapter



STEP 2

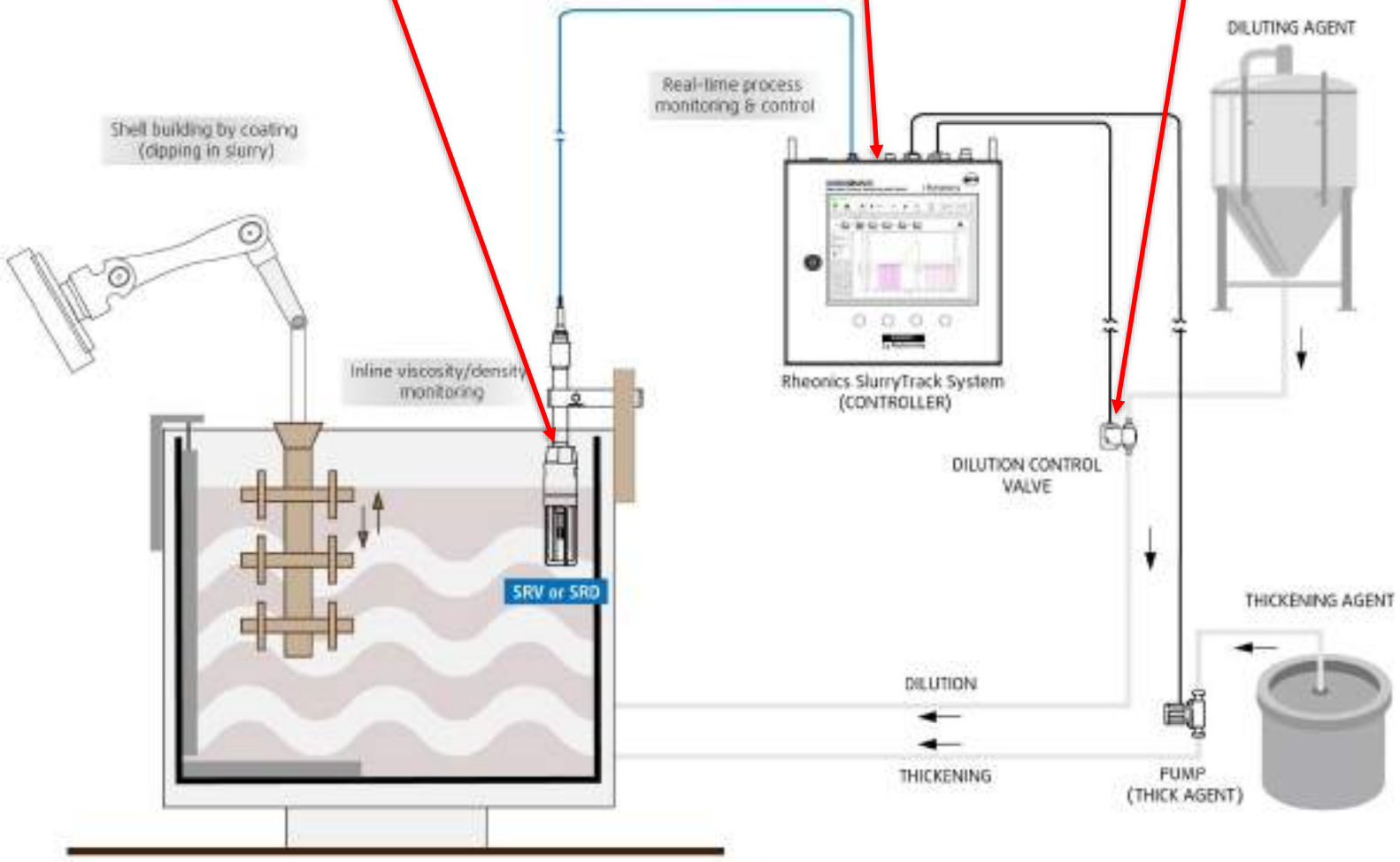
Connect SRV probe to RPS-A system. Power and operate.



Rheonics SlurryTrack System (CONTROLLER)

How does the RST work?

1. Rheonics **SRV Sensor** is located directly in the slurry tank, monitoring and transmitting slurry viscosity to main control cabinet in real-time.
2. Rheonics Predictive Tracking **Controller** ensures precise control of slurry 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 slurry tank.



RST control system components

1. Rheonics SRV viscometers
2. Rheonics Predictive Tracking Controller
3. Dilution Control Valve

SlurryTrack PTC: Unlocking full automation in the shell room

Realizing the value of true automation inside the shell room.

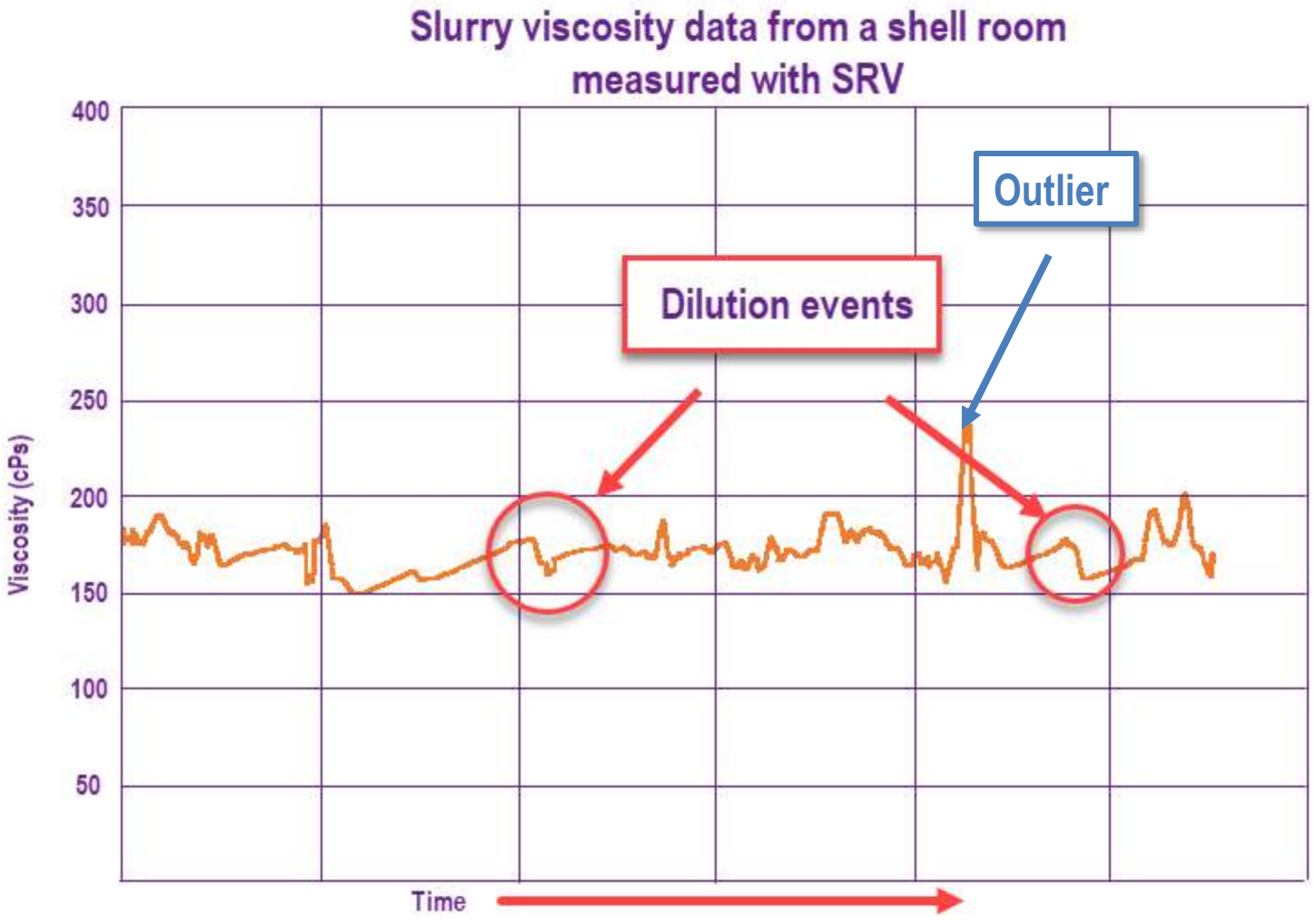
The SlurryTrack system is installed in a heavy stainless steel housing, which is equipped with its own industrial PC and touch screen displays. The operator can choose a viscosity set point from the touch screen interface, and lock the system to that set point.

- ***The ProcessLock Software comes with operator focused interface:***
  User interface of the **ProcessLock** enables one-click setting of slurry viscosity.

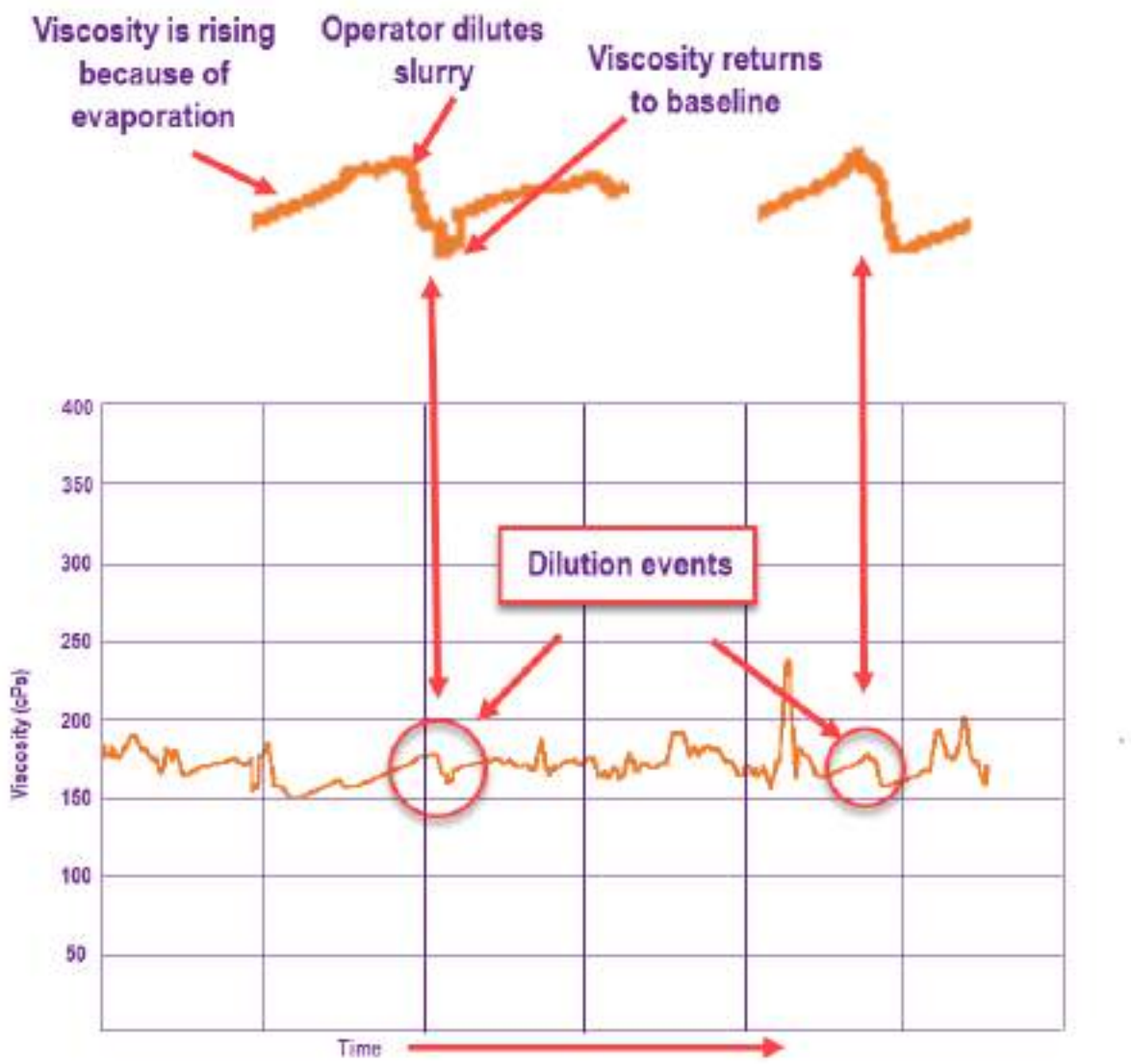
- ***Foundry 4.0 ready - enables full automation of shell rooms:***
  ProcessLock software measures, tracks and logs every variable. Data is available to the PLC and factory data acquisition systems. Plant managers, quality personnel and production supervisors get powerful interface to directly view process data, or to review it through process logs.

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

Typical SRV data trend from a shell room – 7 days data



Typical SRV data trend from a shell room – 7 days data



Shell rooms of the future – Rheonics facilitating automation goals

Goals of viscosity automation	How does SlurryTrack, ProcessLock and SRV contribute?
Knowledge transfer from experienced operators to an automated system	• Existing procedures can be programmed into SlurryTrack controller • Specific protocols can be memorized and recalled for repeat jobs
Viscosity automation brings slurry control up to Industry 4.0 standards	• Accurate, transparent viscosity control removes last barrier to full automation
Easy integration into existing shell room systems	• SlurryTrack 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

SlurryTrack – Customer experience and technology outcomes

User Benefits reported by our customers	• Superior shell quality, due to uniform coating • Efficient operations – reduction in man hours by 40% • Improved productivity – faster, automated system = more molds • Higher Profitability • Reduced costs • Easy scalability of operations
Technology Outcomes for Investment Casting Industry	• Reduced scrap, rejects, diluent consumption • Reduction in setup times and significantly easier cleaning procedures • Safer and cleaner workplace • Complete tracking and traceability of every job • Industry 4.0 connectivity enabling data-driven decision making and fault analysis

Conclusions

- Rheonics SRV with SlurryTrack brings accurate, repeatable slurry 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 slurry viscosity.
- SlurryTrack improves both shell quality and job-to-job consistency, reducing waste and rejects, while streamlining the viscosity measurement and control process.

In doing so, it frees the operators to concentrate on what they do best: applying their art and experience to producing the best possible castings in an increasingly automated world of industry

rheonics

inline process
density and viscosity
monitoring

Thank you for your attention!

We look forward to working with the casting professionals and applying our knowledge of sensors to ensuring data driven quality control.

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Appendix Slides

Precise viscosity control

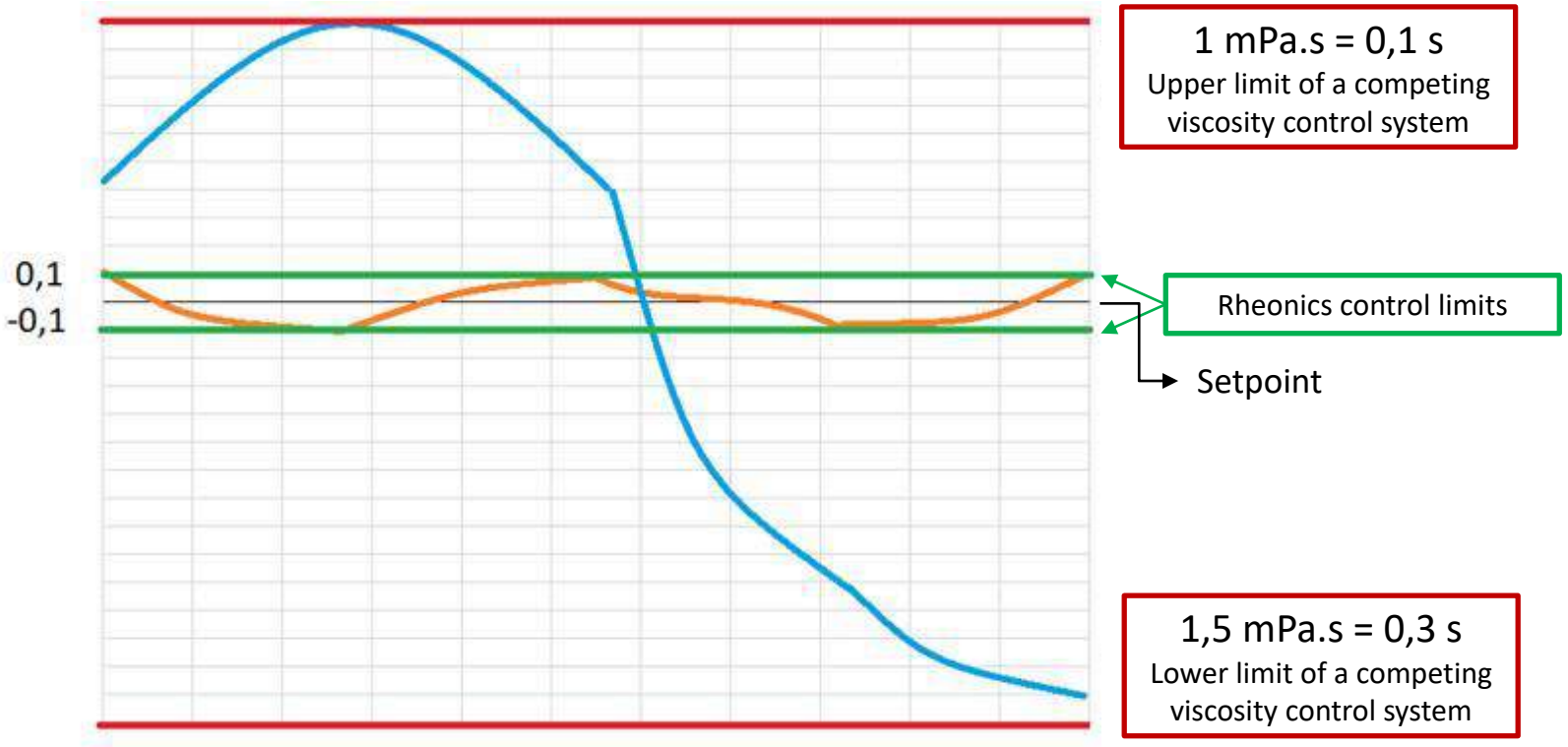


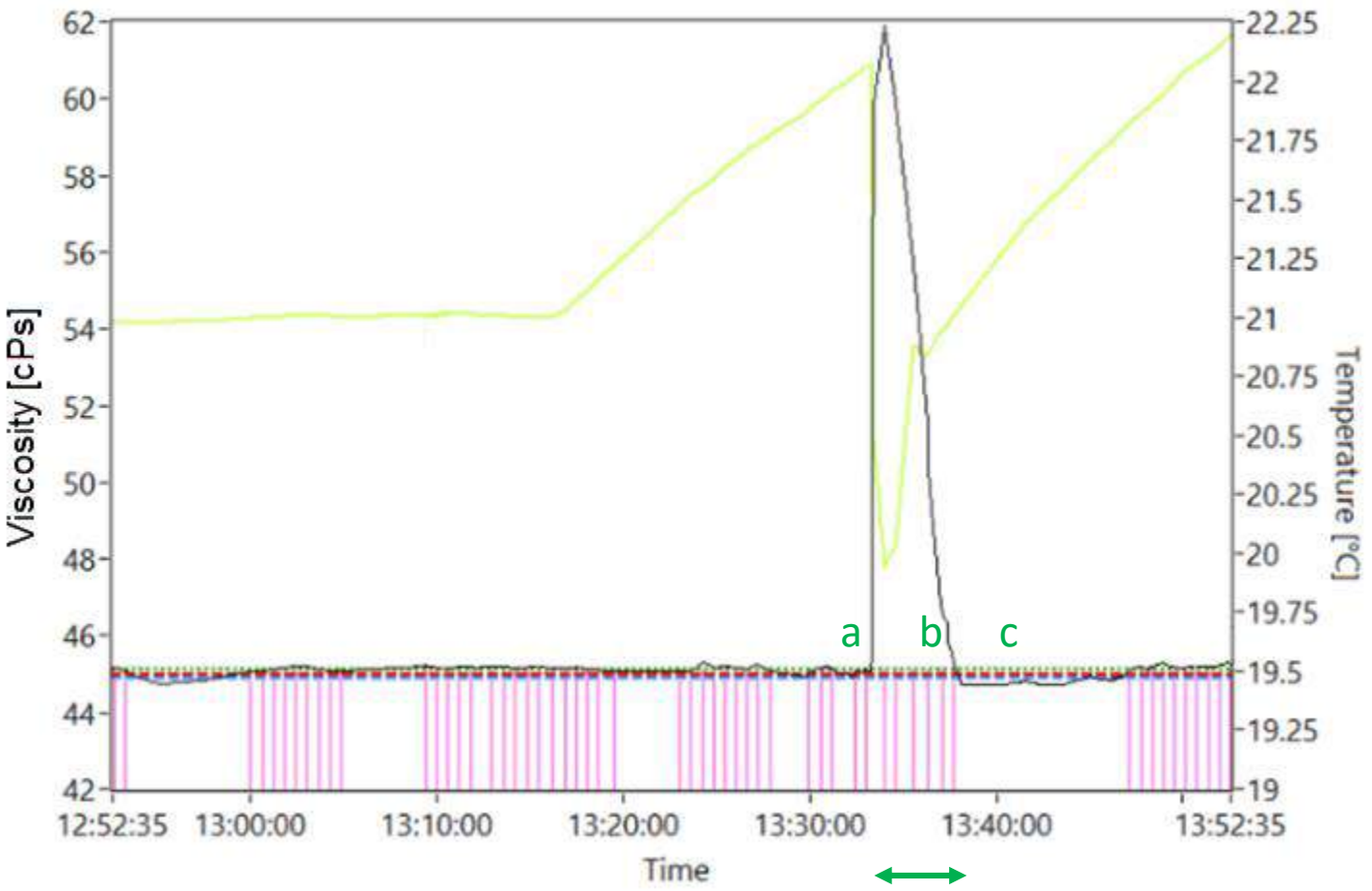
Exhibit – 1. Viscosity control accuracy, Rheonics SlurryTrack Vs. Competitor

Note:

Orange line shows ***viscosity control with Rheonics Sensors***

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

System responsiveness



Rheonics integrated system brings viscosity to setpoint within 5 minutes

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

InkSight viscosity control system ensures *rapid recovery of the temperature compensated viscosity to the setpoints*.

- On addition of new thickener (a), SlurryTrack brings the viscosity to the setpoint quickly (b), with minimal overshoot and without overdilution (c).
- The dosing of diluent to make viscosity adjustment is completely autonomous: no manual intervention is required.
- The operator does not need to worry about slurry's viscosity prior to addition, since the system can automatically adjust the viscosity very fast and accurately.

Shell rooms of the future - Industry 4.0, data-driven processes and digitalization

- Summarizing the benefits of the real-time viscosity management in the shell room
- Foundry 4.0: Process data at the center for short term and long term casting products quality improvements
- Shell rooms of the future: Possibilities with the Rheonics technology

Benefits of viscosity management

Factors that make viscosity management important during the shell building process

1. **Investment shell and casting quality:** Tight viscosity control improves surface roughness, thermal conductivity, chemical reactivity, permeability and shell strength by enabling consistent and repeatable shell properties
2. **Reducing costs by reducing waste:** Over-mixing can not only affect the quality of end product but waste materials, time and energy. Viscosity management in the mixing process can identify the endpoint reliably and accurately, thus leading to significant reduction in rejects and waste.
3. **Efficiency:** Hassle free, real time monitoring of mix viscosity eliminates the costly and time-consuming laboratory analysis, which often results in delayed response to changes in the slurry properties. Ensuring consistency throughout the coating process significantly reduces reject rates saving cost and time and assists in continuous casting processes.
4. **Automation:** Automatically monitoring and controlling slurry preparation and coating process takes out a manual task that is prone to errors and relieves operators to focus on the quality of the final product. This improves the productivity and enhances capacity.

Investment casting – Need for viscosity automation?

- Investment casting is labour-intensive and time-intensive
- There are excellent opportunities for automation for a safer, cleaner and more productive workplace.
- By automating the dipping process with robots, casters can increase their production capacity by 50% and free up operators time.
- Slurry quality control (real-time viscosity sensing) can elevate the degree of automation and ensure that the shell building process requires minimal operator intervention to consistently produce top quality shells over the years. The data from the sensor can be used to actuate the robots dipping and draining cycles in the short term and lead to quality improvements in longer term.

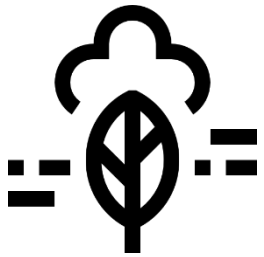
Source: Intercast

Source: Franklin Bronze

Outcomes | Inline viscosity management lets the operator ….

ENVIRONMENT

Reduce Diluent consumption



Optimized automatic dosing compensates exactly for evaporation, eliminating excess diluent consumption. Software keeps track of all events such as setpoint violations, alarms averages per-color solvent consumption and the number of doses.

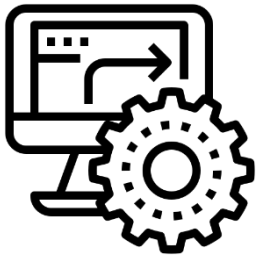
SAFETY

Achieve better operator safety

With SRV, operators do not need to make manual measurements eliminating all contact with slurry. Furthermore, any new addition of diluent does not need pre-dilution, as system automatically and rapidly brings slurry to the proper viscosity.

PRODUCTIVITY

Completely Automate operations



In some investment casting companies, systems in for shell building are already automated iwth robots. SlurryTrack+SRV completes the circle by bringing fully automating slurry viscosity control – one of the most crucial factors in achieving highest shell quality with minimal operator intervention.

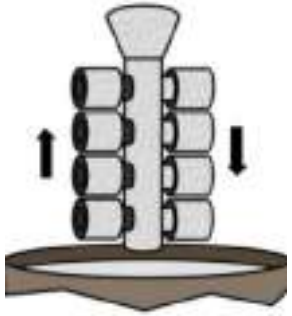
RESPONSIVENESS

Make data-driven decisions

Collected data is available for process optimization, quality control and proactive maintenance. Data allows detecting process deviations and facilitates root cause analysis. Rheonics solutions are designed to empower casters with maximum actionable data.

Outcomes | Inline viscosity management gives the operators ….

Highest Shell Quality



Viscosity is the single most important variable for shell quality and properties. SlurryTrack system helps maintain the highest quality, defects-free standards through tight and accurate viscosity control.

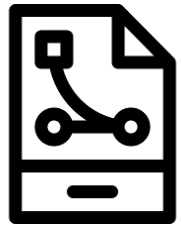
More efficient operations

SlurryTrack increases productivity and supports expansion of production capacity by automation. Operators do not need to make time-intensive and error prone manual measurements of viscosity.

Reduced costs

By ensuring correct slurry properties throughout a run, tight viscosity control reduces shell defects, waste and rejects. Diluent consumption and inclusion scraps are significantly reduced while improving productivity.

Easy scalability



Expand capacity by integrating a sensor on every slurry tank and the data reflects on the same dashboard. Knowledge transfer is a breeze making the capacity expansion feasible.

Foundry 4.0 - Future of shell rooms

Drivers for manufacturers' embrace of Foundry 4.0

1. **Automated corrective actions for ensuring product consistency (Short-term loop).** Closed control loops through sensor-based, in-line quality inspection reduce waste and increase yield through early process deviation detection, root cause analysis, and automatic correction.
2. **Big data provides robust evidence to base decisions for greater efficiency (Long-term loop).** The data provided by the process monitoring equipment enables them to tweak various process parameters and optimise the manufacturing process. Interconnection and information transparency allow for operators to make decisions both inside and outside of production facilities, thus enabling decentralization of decisions.
3. **More agility in dealing with new product variants in production, compliance and product provenance.** Casting manufacturers get a more accurate picture of how the new slurry formulations will behave and how they might need to adjust current systems and control parameters.
4. **Higher customer satisfaction and adapting to customer requests.** Industry 4.0 solutions can impact casting companies by driving closer interactions with their customers. The technology, data, and information that can help transform manufacturing operations can also make processes and systems more responsive to customer needs.

EXAMPLE - Shell rooms using process data – IFaCOM approach at EMA, Rolls Royce

Foundry	Europea Microfusioni Aerospaziali (EMA), part of the Rolls Royce group, Morra de Sanctis (AV), Italy
Products	Precision investment castings foundry for the production of turbine blades, vanes for modern jet-engines to civil and defense aerospace and power generation engines.
Approach	Intelligent Fault Correction and self Optimizing Manufacturing systems (EU 7th Framework Programme) Deployed multiple sensors for process data acquisition and corrective action during shell building

Short term optimization of quality	**Long term optimization of product quality**
Focussed monitoring and control: A robust control of the industrial manufacturing. Real-time control of the shell making process through the introduction of new sensors and new equipment for corrective actions and the automation of manual measurement processes.	**Multiple sensors data**: continuously updated sensor data coming from the in-line sensors mentioned above and the post process analyses (silica content, shell mechanical hardness, adhesion of primary to secondary shell layers, pH, etc.). **Statistical and cognitive systems**: Statistical Process Control (SPC) & Neural Networks data analysis of acquired and constantly updated dataset with the aim to find the correlations between the measured Key Process Variables and the Target Variable (output quality parameter) for long-term optimization.

Involved:

Shell rooms of the future – IFaCOM approach

Intelligent Fault Correction and self Optimizing Manufacturing systems

To achieve more effective control on the ceramic shell mold and particularly a more effective correction of the ceramic primary slurry that ensure the best final quality of the superalloy components in the long run.

3 main levels on which the IFaCOM approach is based:

- closed loop control of vital parameters based on in-process real-time measurements
- medium time process tuning and optimization based on analysis of complex data sets
- optimized machine system for long-range performance improvement.

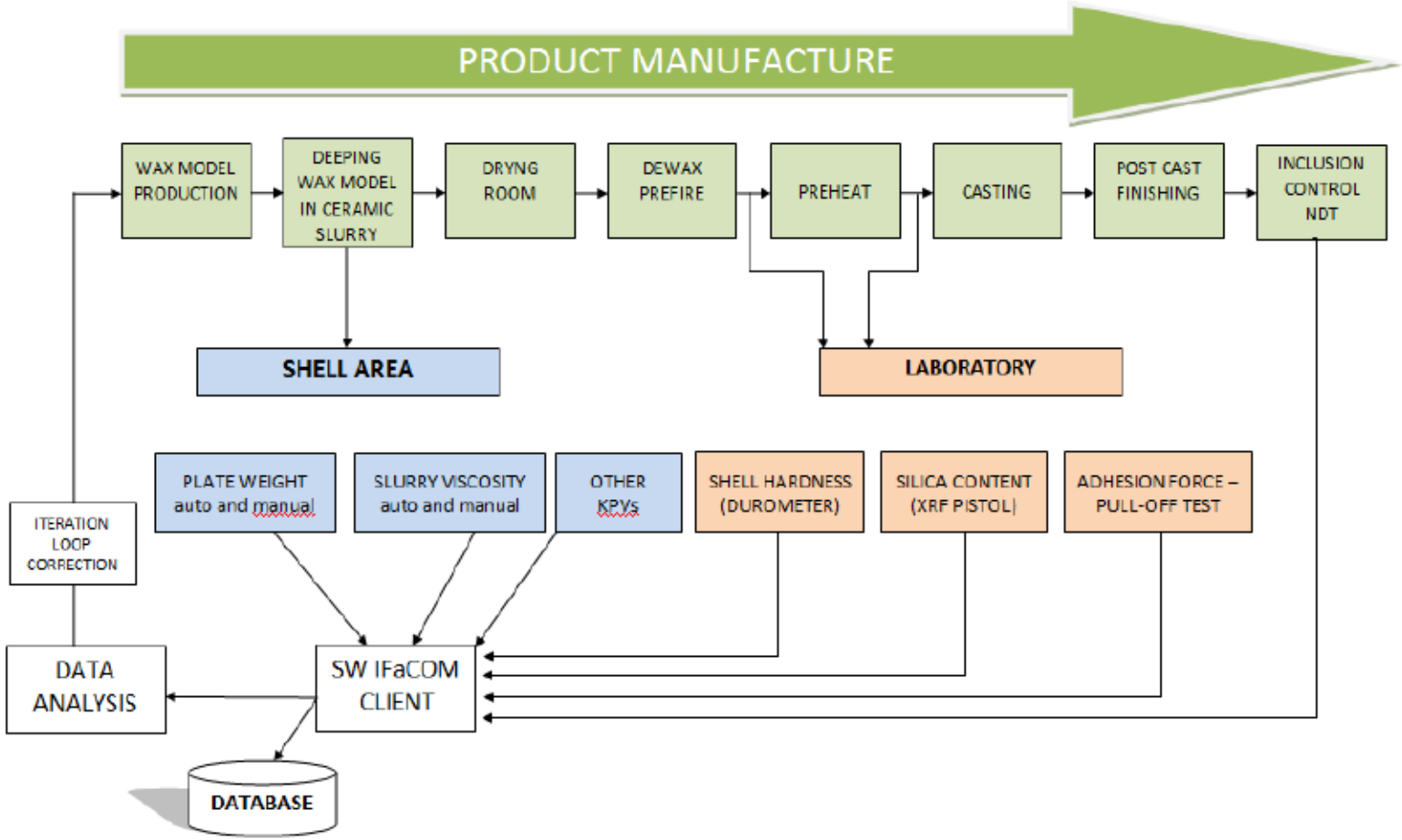


Figure 25: IFaCOM focus, the shell making process

Source: CORDIS EU Research, https://cordis.europa.eu/docs/results/285/285489/final1-ifacom-final-publishable-summary-report.pdf

Shell defects that are caused by improper slurry viscosity (1/2)

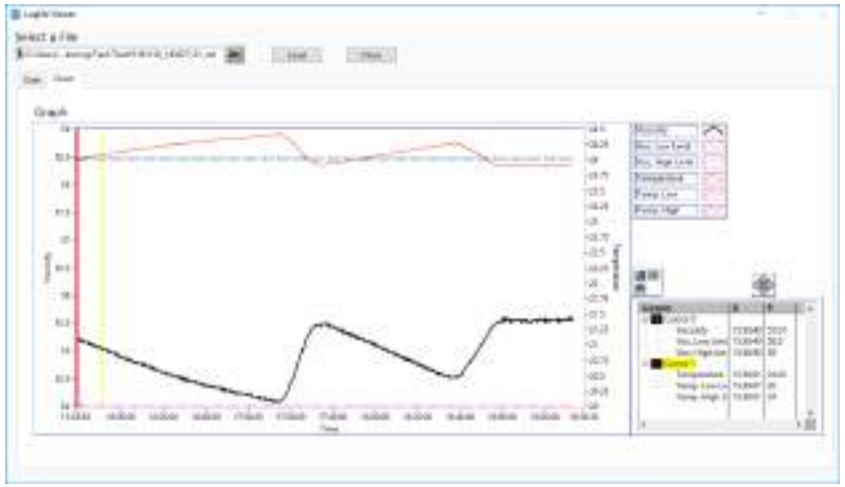
Defect	Causes	Correction
Penetration | Slurry Preparation Problems Metal penetrates into the primary layer during casting. Pinholes or air pockets in the primary layer fill with metal during casting	• Incomplete slurry mixing • Prime slurry layer too thin	• Ensure the slurry is completely mixed before using in production • Increase slurry viscosity or reduce slurry drain time.
Buckle | Slurry Preparation Problems The bond strength of the primary layer to the wax patter is insufficient and the primary layer buckles (lifts) off the pattern. The bond strength can be insufficient for a number of reasons including stress on the primary layer as it shrinks during drying.	• Too much or too little slurry on interior surfaces	• Decrease/Increase slurry viscosity or increase/decrease draining time.
Bubbles | Slurry Preparation Problems Air trapped against the wax pattern by the primary slurry layer	• Incomplete pattern wetting	• Use pre-wet or lower prime coat viscosity

Shell defects that are caused by improper slurry viscosity (2/2)

Defect	Causes	Correction
Excess Metal/Bridging Defects | Slurry Testing and Maintenance Problems Thin or weak areas of the shell fail during dewax or casting allowing metal to leak into the void in the shell.	• Incomplete slurry wetting	• Lower the slurry viscosity or use prewet solutions
Spall | Shell Drying Problems The layer to layer bond in the shell construction is not strong enough and the ceramic fractures off the mold surface during dewaxing, mold preheating or casting and falls into the mold cavity.	• Prime coat slurry too thick	• Reduce prime coat viscosity

Source:
Atlas of Casting Defects, An Investment Casting Institute Publication, December 2017
Atlas of Shell Defects, An Investment Casting Institute Publication, February 2004

ProcessLock Software: Automatic, single click viscosity control of slurry



Rheonics Software Screenshots from SlurryTrack System

Operator independent measurement – Software built for the Operators, by operators

Conventional viscosity measurement systems require intensive operator intervention distracting operators from their core mission. ProcessLock software takes over measurement and control functions placing the full power of todays highly sophisticated machines in the hands of the operator. It removes the last hurdle to producing the best shells.

User focused interface

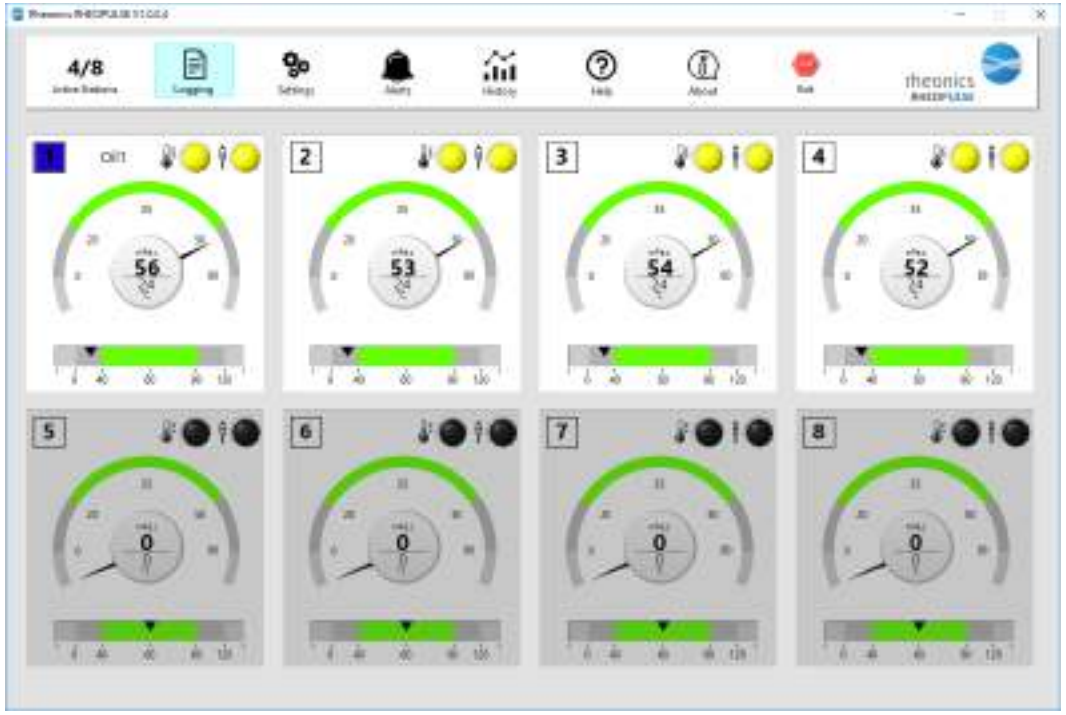
Operators worldwide told us, they wanted to “set it and forget it”. We rolled their vision into the single-click processlock “AUTO” control button. That single button places the full power of the SlurryTrack in the hands of the operator. The dosing of dilents or thickeners are adaptively automated.

Seamless integration with machine and factory data system

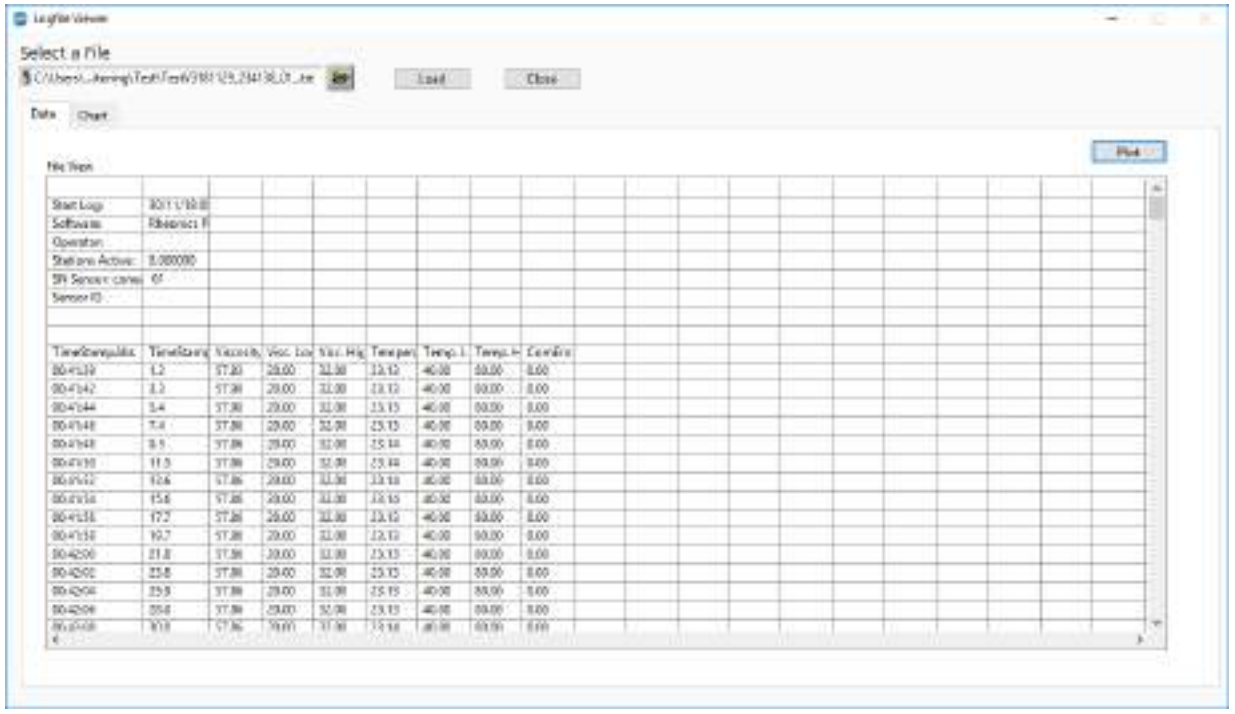
ProcessLock Software monitors, logs and analyzes every aspect of the slurry system, carrying out advanced analytics, self-diagnosis, forensics to spot potential problems before they happen. All these data and analytics is shared with machine PLC and factory data acquisition systems in industry standard protocols. Rheonics software can communicate bi-directionally with machine and factory AI systems, enabling plant managers, quality assurance specialists and production supervisors to not only monitor but actively guide the production in their plants.

ProcessLock Software: Process data at fingertips for analysis

SRV’s repeatability, supported by the Controller and ProcessLock software, ensures that today’s slurry is the same as yesterday’s, and tomorrow’s the same as today’s



Monitor multiple slurry tanks on a single dashboard.



The software ensures complete traceability and registers all data to support analysis and improvement efforts.

rheonics

inline process
density and viscosity
monitoring

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