

Practical Application of Bulk Slurry Metrology

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CMP Users Group

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INTRODUCTION

- **Celerity R&D Lab**
 - **Liquids process simulation**
 - **Reduced & full scale**
 - **Material for presentation obtained through testing**
 - **Liquid lab move from Tempe, AZ to Allen, TX**
 - **Proximity to other Celerity R&D facilities**

DISCUSSION TOPICS

- **CMP Slurry**
 - **Brief overview**
 - **Manufacture & usage challenges**
- **Bulk Distribution**
 - **Basics**
 - **CMP slurry handling**
 - **Effects of steps**
- **Metrology Applications**
 - **Key areas to monitor**
 - **Examples**

CMP SLURRY

- **Overview**
 - **Solid & liquid mixture**
 - **Physical composition**
 - **Targeted planarization**
 - **Specific particle element & size**
 - **Differing ratios of solids to liquids**
 - **Chemical component function**

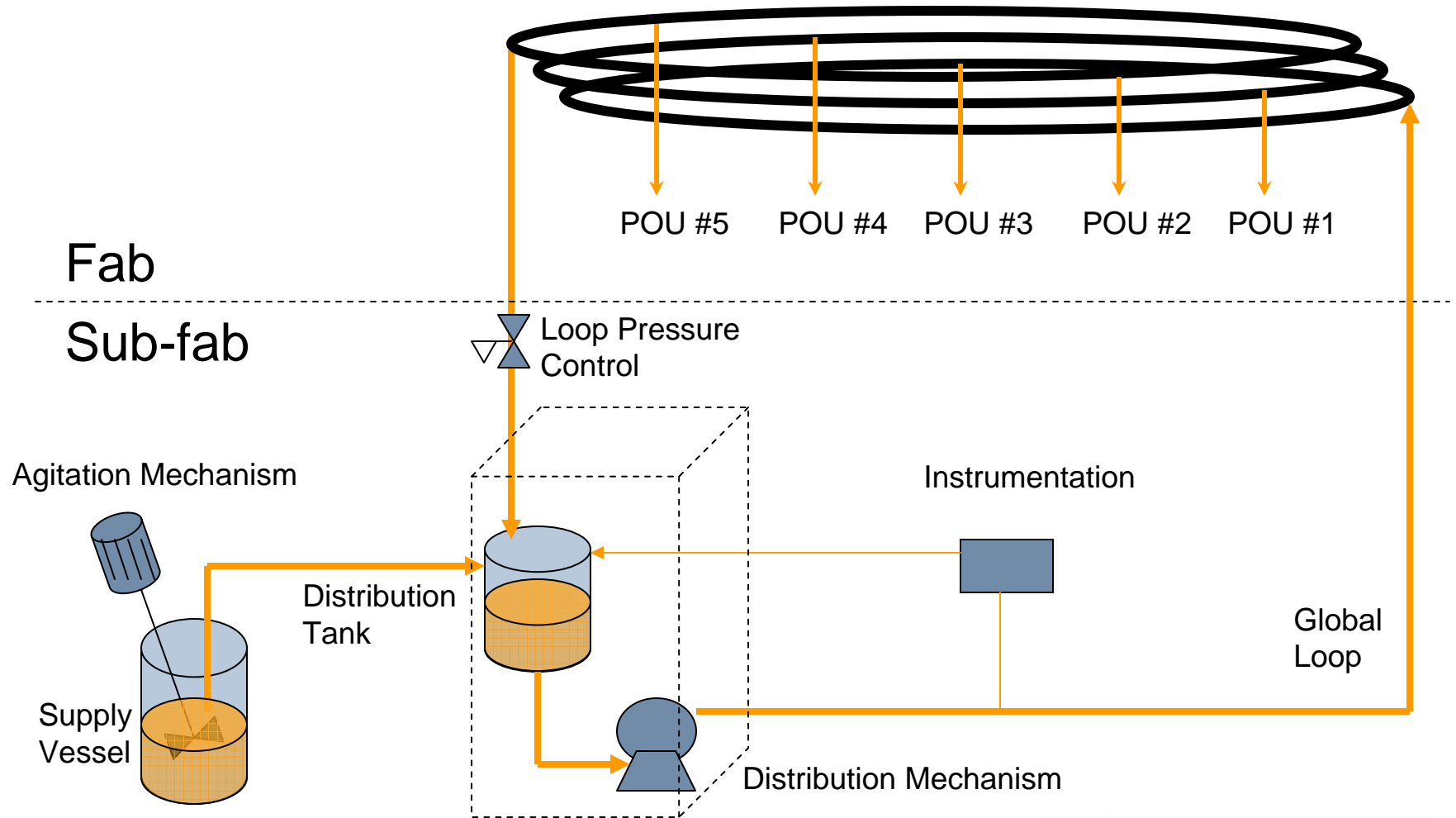
CMP SLURRY CHALLENGES

- **Complex Systems**
 - **70 - 99 wt% DI water**
 - **1 – 30 wt% solids**
 - **< 5 wt% various chemicals**
- **Manufacturing Complexity**
 - **Specific recipes**
 - **Variation in input quality, blending, particle dispersion methods**
- **Post Manufacture Variation (End User)**
 - **Dilution**
 - **Blending**

BULK DISTRIBUTION

- **Common Delivery Method to Polishers**
- **Advantages of Bulk Distribution:**
 - **Efficiency**
 - **Space**
 - **Process**
 - **Capital**
- **Different approaches per manufacturer**
- **Similar function**

BULK DISTRIBUTION OVERVIEW



BULK DISTRIBUTION SUPPLY

- **Transportation**
 - **Delivered via drums, totes**
 - **Typically not a factor in quality**
 - **Maintain temperature limits**
- **Storage**
 - **Climate controlled**
 - **Duration of storage**
 - **Expiration (slurry manufacturer defined)**

BULK DISTRIBUTION PREPARATION

- **Supply Preparation**
 - **Slurry dependent**
 - **Idle Time**
 - **Stratification**
 - **Sedimentation**
 - **Agitation**
 - **Pump Circulation**
 - **Powered mixer**
 - **Drum tumbler**

BULK DISTRIBUTION PREPARATION

- **Under Handling**
 - **Insufficient agitation**
 - **Non-homogenous mixture**
 - **Solids remain in supply vessel**
 - **Unpredictable results**
 - **Yield affected**
 - **Recommended agitation times**
 - **Solved by:**
 - **Larger mixers, different impeller selection**
 - **Larger pumps, higher circulation flow rates**

BULK DISTRIBUTION PREPARATION

- **Over Handling**
 - **Excessive agitation**
 - **Difficult to identify**
 - **Visual cues: foaming, air entrainment**
 - **Particle agglomeration**
 - **Filters affected**
 - **Yield affected**
 - **Solved by:**
 - **Gentler agitation method**
 - **Smaller pumps, shorter time, and lower circulation flow rates**

BULK DISTRIBUTION USAGE

- **Usage Scheduling**
 - **Raw material handling**
 - **Reduced storage time**
 - **Optimized agitation time**
- **Distribution Tank & Batch Sizing**
 - **Optimal system scaling**
 - **Systems often sized for future usage**
 - **Pumps run below optimum range of performance curves**
 - **Slurry runs risk of over agitation in low volume large system**
 - **Slurry runs risk of excessive turnovers for large volume low utilization**

BULK DISTRIBUTION NEED FOR OPTIMIZATION

- **Distribution Tank & Batch Sizing**
 - Limits on changes to design flexibility
 - Batch size optimization
 - Frequency optimization
- **Local Circulation Time**
 - Dependent on call for batches from the distribution loop
- **Global Circulation Time**
 - Dependent on consumption
 - Sedimentation concern
 - Agglomeration concern
 - Number of tank turnovers

BULK DISTRIBUTION NEED FOR OPTIMIZATION

- **Distribution Components Affect**
 - **Local & Global distribution**
 - **Distribution mechanism**
 - **Pumps**
 - **Flow Path**
 - **Tubing**
 - **Valves**
 - **Restrictions**
 - **Tank Design**
 - **Blending Method**
 - **Time required to blend**

METROLOGY

- **Understanding Slurry Condition during Distribution**
- **Quantify Critical Variables**
- **Monitoring Techniques**
 - **Benchtop**
 - **Sample extraction**
 - **External measurement**
 - **Process**
 - **In-line single**
 - **In-line continuous**

METROLOGY TECHNIQUES

- **Benchtop**
 - **Proven methods**
 - **Internal & external lab analysis**
 - **Examples include:**
 - **Gravimetric (density, solids concentration)**
 - **Titration**
 - **Viscosity**
 - **Particle concentration (diluted samples)**

METROLOGY TECHNIQUES

- **Process**
 - **In-line single**
 - **Samples collected directly off process loop and measured individually**
 - **Typically automated versions of benchtop methods**
 - **Examples include**
 - **Titration**
 - **Particle concentration (diluted samples)**

METROLOGY TECHNIQUES

- **Process**
 - **In-line continuous**
 - **Samples collected directly off process loop and measured continuously**
 - **Constant data stream, may include time averaging**
 - **Examples include**
 - **Refractive Index**
 - **Particle concentration (raw sample)**
 - **pH**
 - **Viscosity**
 - **Conductivity**
 - **Density**

METROLOGY APPLICATION

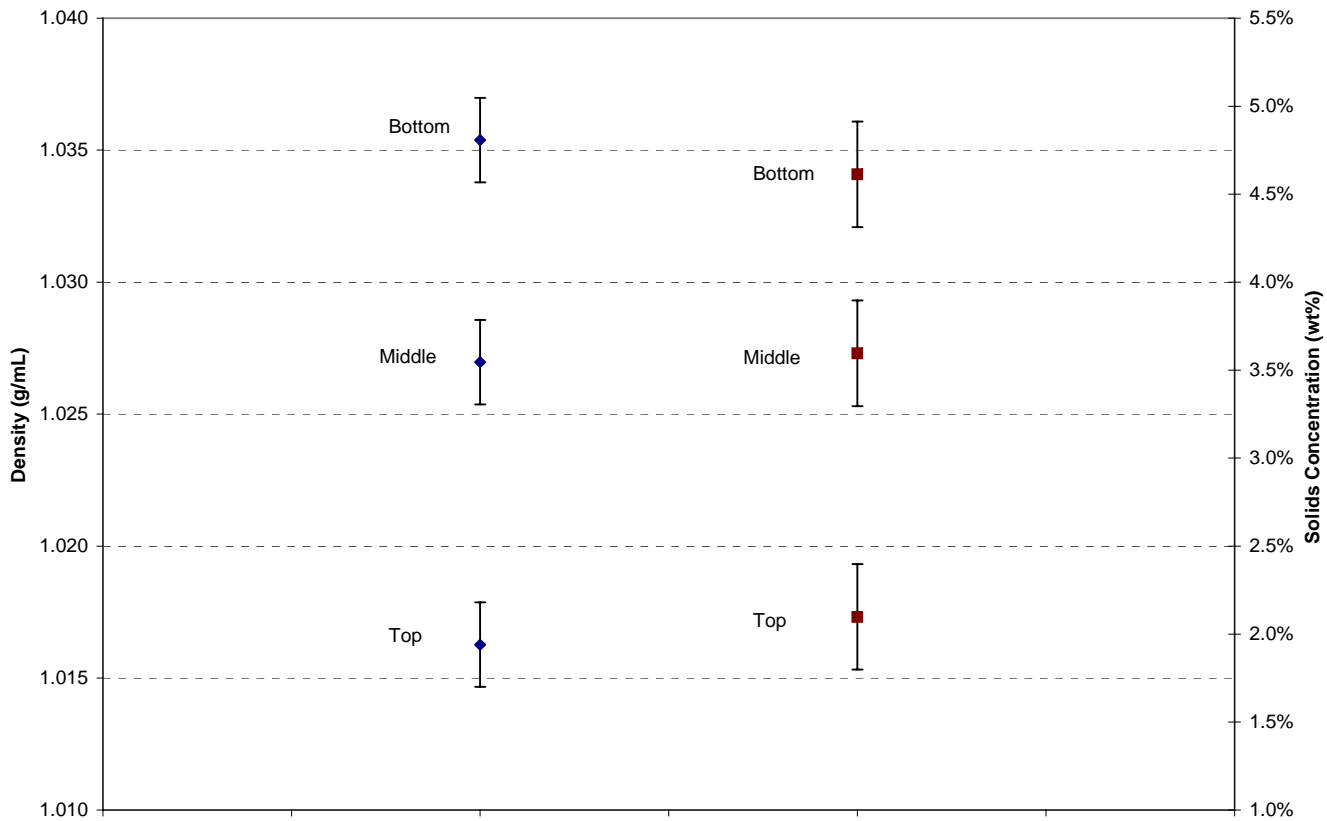
- **How Techniques Are Applied**
 - **Incoming Quality**
 - **Supply Preparation**
 - **Local Loop Circulation**
 - **Blending**
 - **Global Loop Circulation**
 - **Consumption**

METROLOGY APPLICATION

- **Incoming Quality**
 - **Samples collected for benchtop measurement of drum or tote before agitation**
 - **Best used for historical information tracking**
 - **Can catch gross deviations from the norm (i.e. frozen samples, drum seal broken) or COA**
 - **Establishing site storage requirements**
 - **Establishing vessel mixing requirements**
 - **Density**
 - **Solids concentration**
 - **Particle concentration**

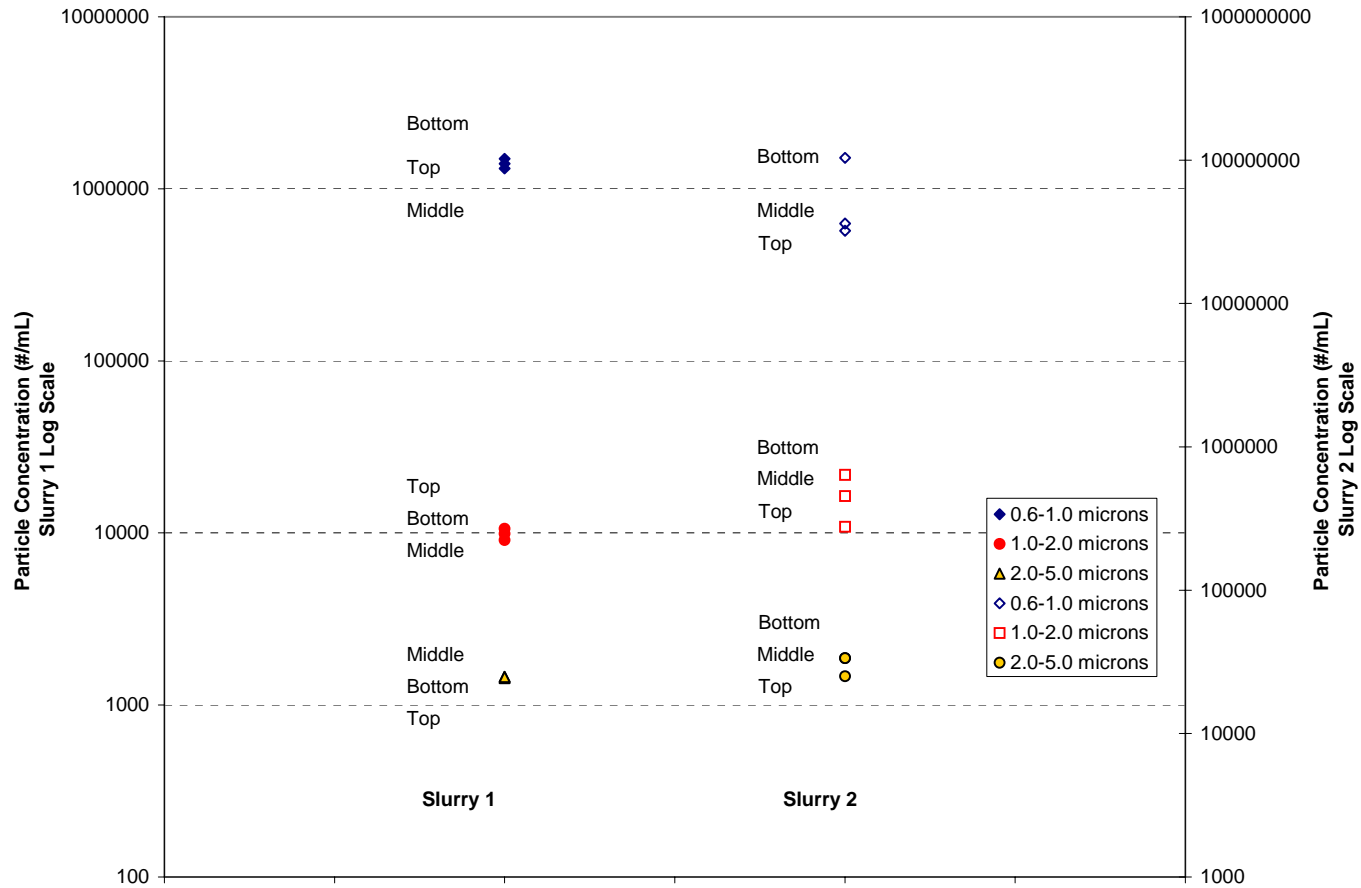
BENCHTOP METROLOGY – INCOMING QUALITY

▪ Incoming Drum Example – Density & Solids Concentration



BENCHTOP METROLOGY – INCOMING QUALITY

▪ Incoming Drum Example – Particle Concentration

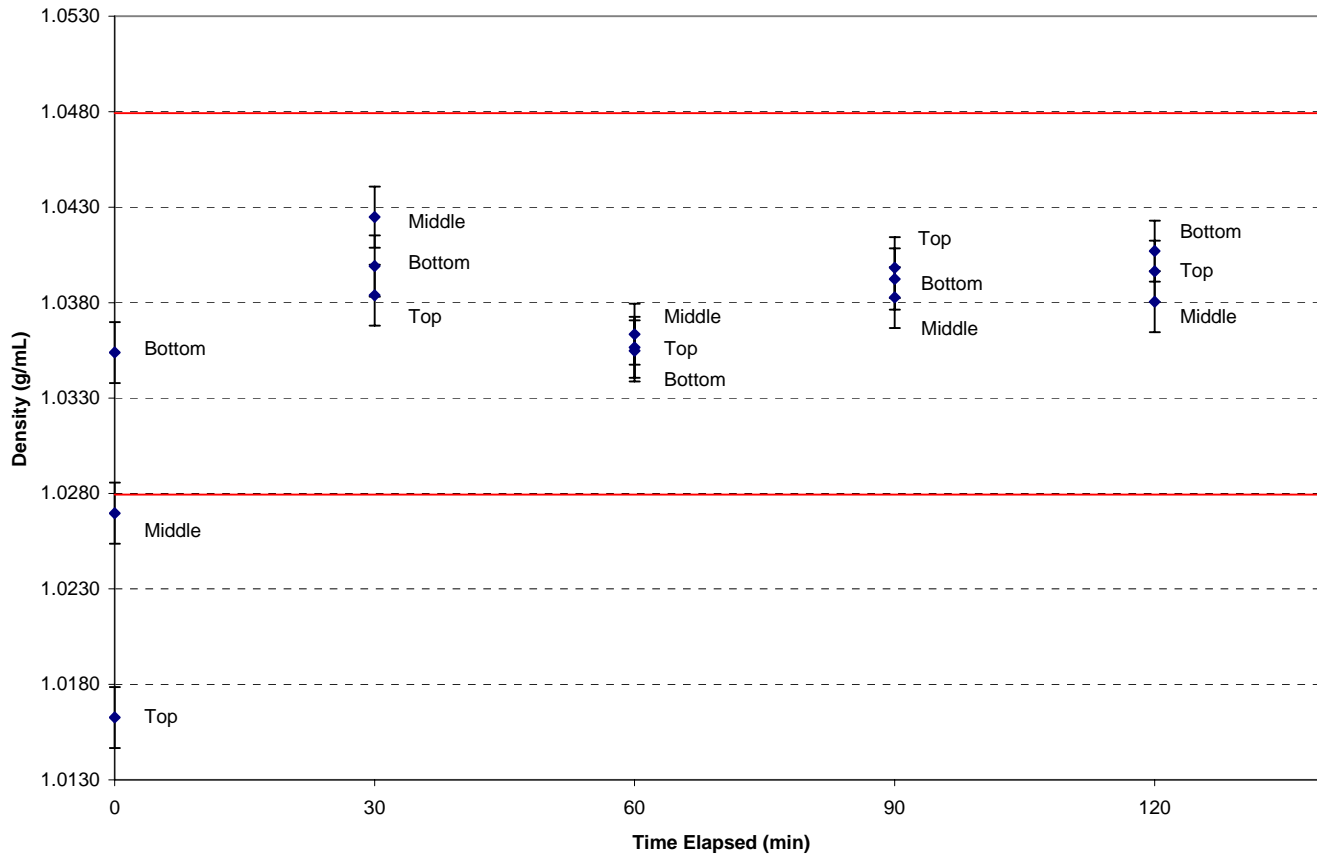


METROLOGY APPLICATION

- **Supply Preparation**
 - **Samples collected for benchtop measurement of drum or tote during agitation**
 - **Determination of uniformity**
 - **Determination of agglomeration**
 - **Amount of time to agglomeration**
 - **Alternate mixing methods**
 - **Low pitch impeller blades or low velocity powered mixing**
 - **Drum tumbler or drum shaker**

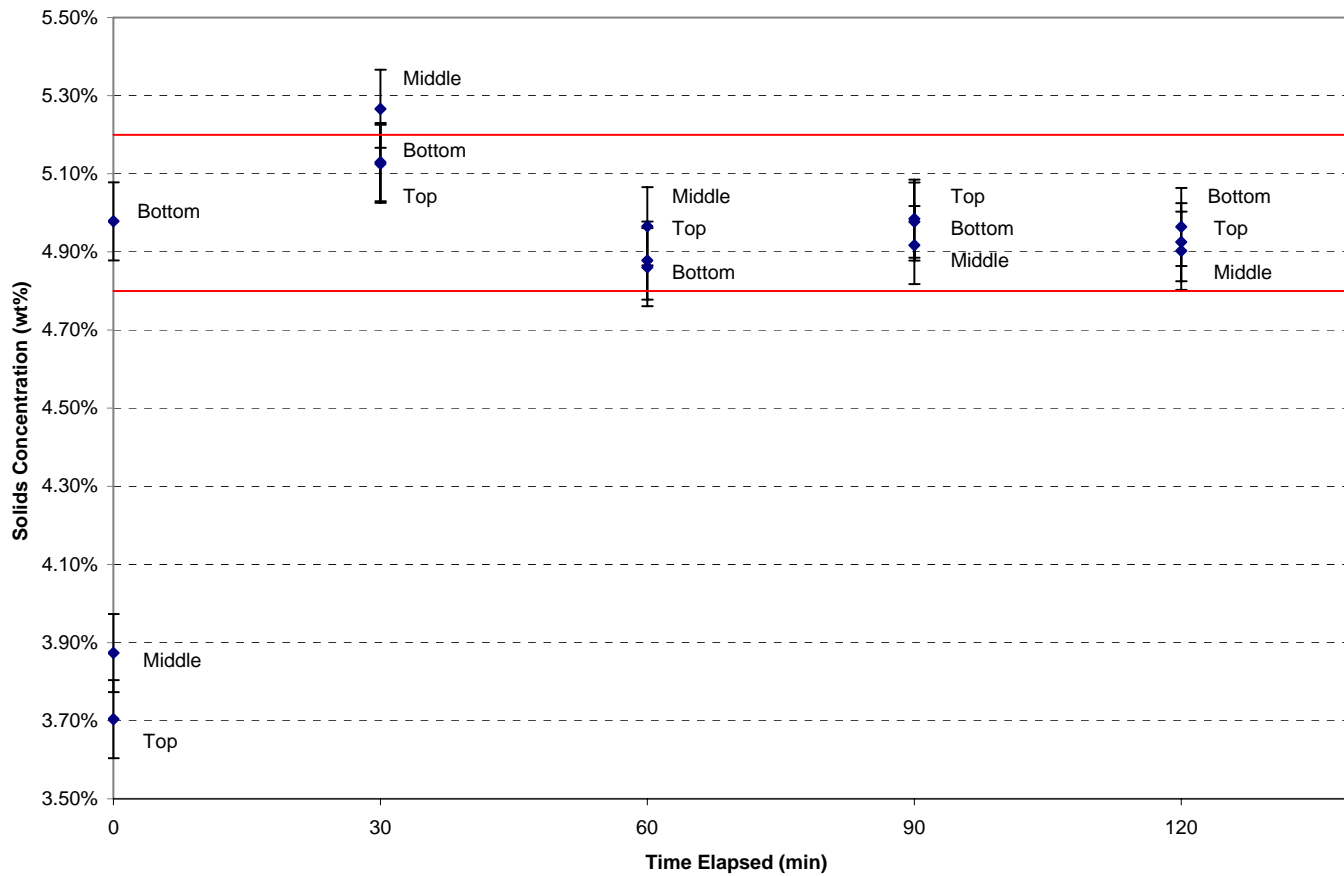
BENCHTOP METROLOGY – SUPPLY PREPARATION

▪ Drum Agitation Example – Density



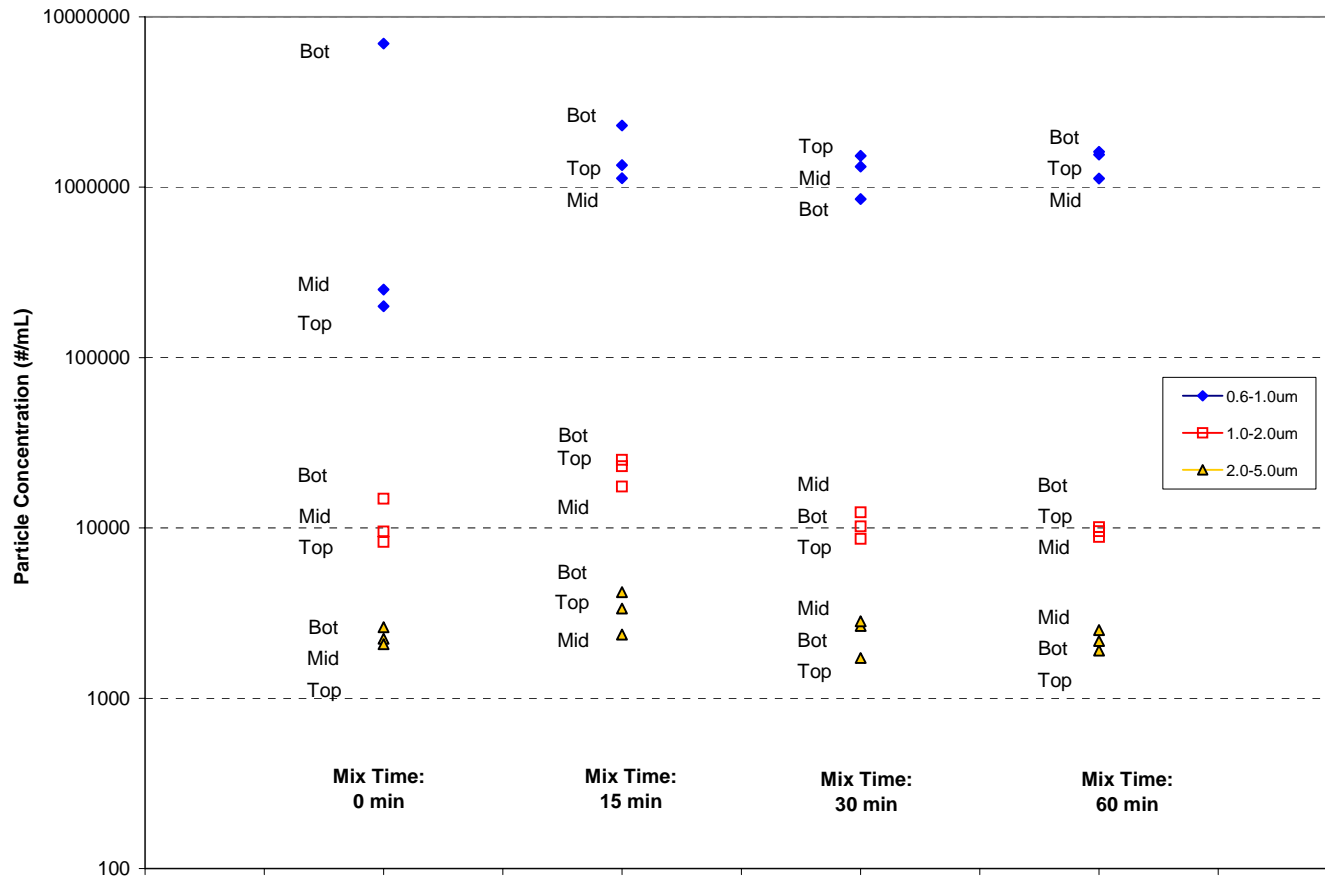
BENCHTOP METROLOGY – SUPPLY PREPARATION

▪ Drum Agitation Example – Solids Concentration



BENCHTOP METROLOGY – SUPPLY PREPARATION

▪ Drum Agitation Example – Particle Concentration

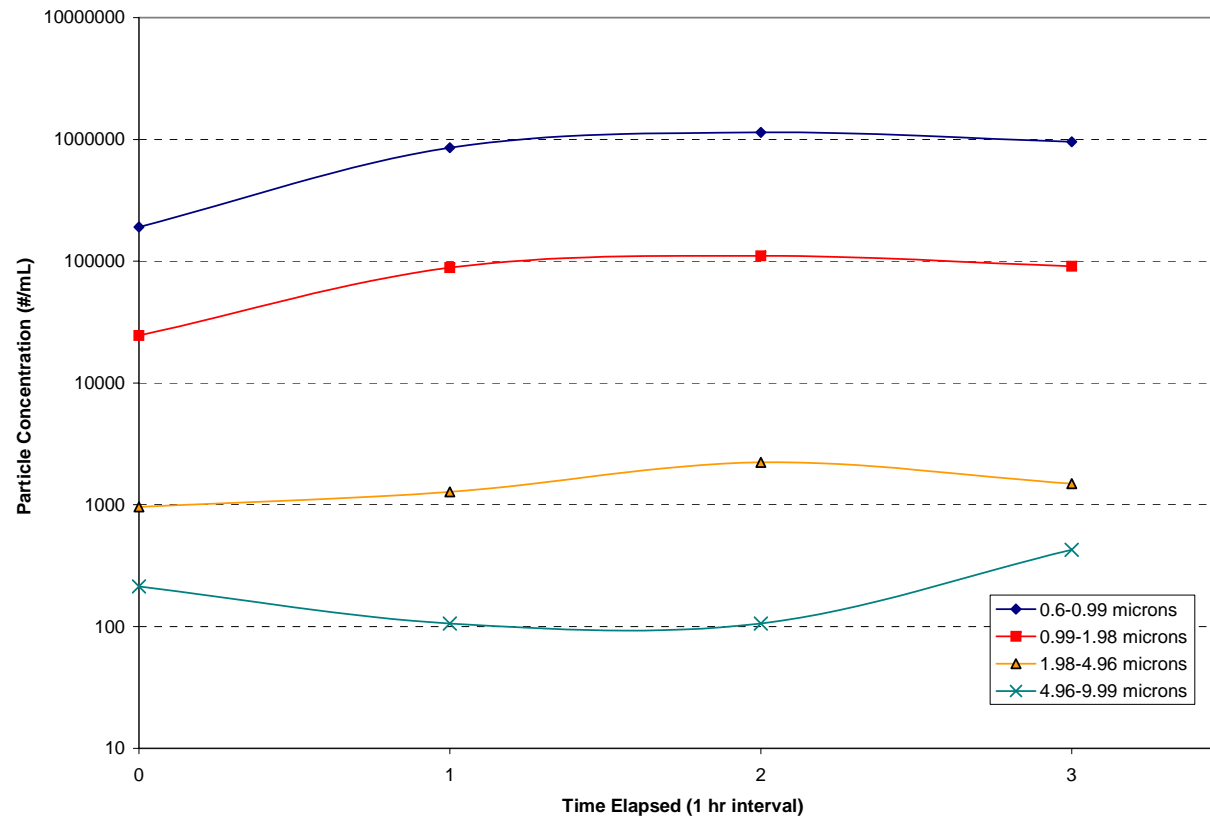


METROLOGY APPLICATION

- **Local Loop Circulation**
 - **Raw Material**
 - **Verification of uniformity**
 - **In-line measurement of density, pH, conductivity, refractive index**
 - **Blending**
 - **Consistency of batches**
 - **Scale, level, or flow meter measurement**
 - **In-line measurement of density, pH, conductivity, refractive index, viscosity**

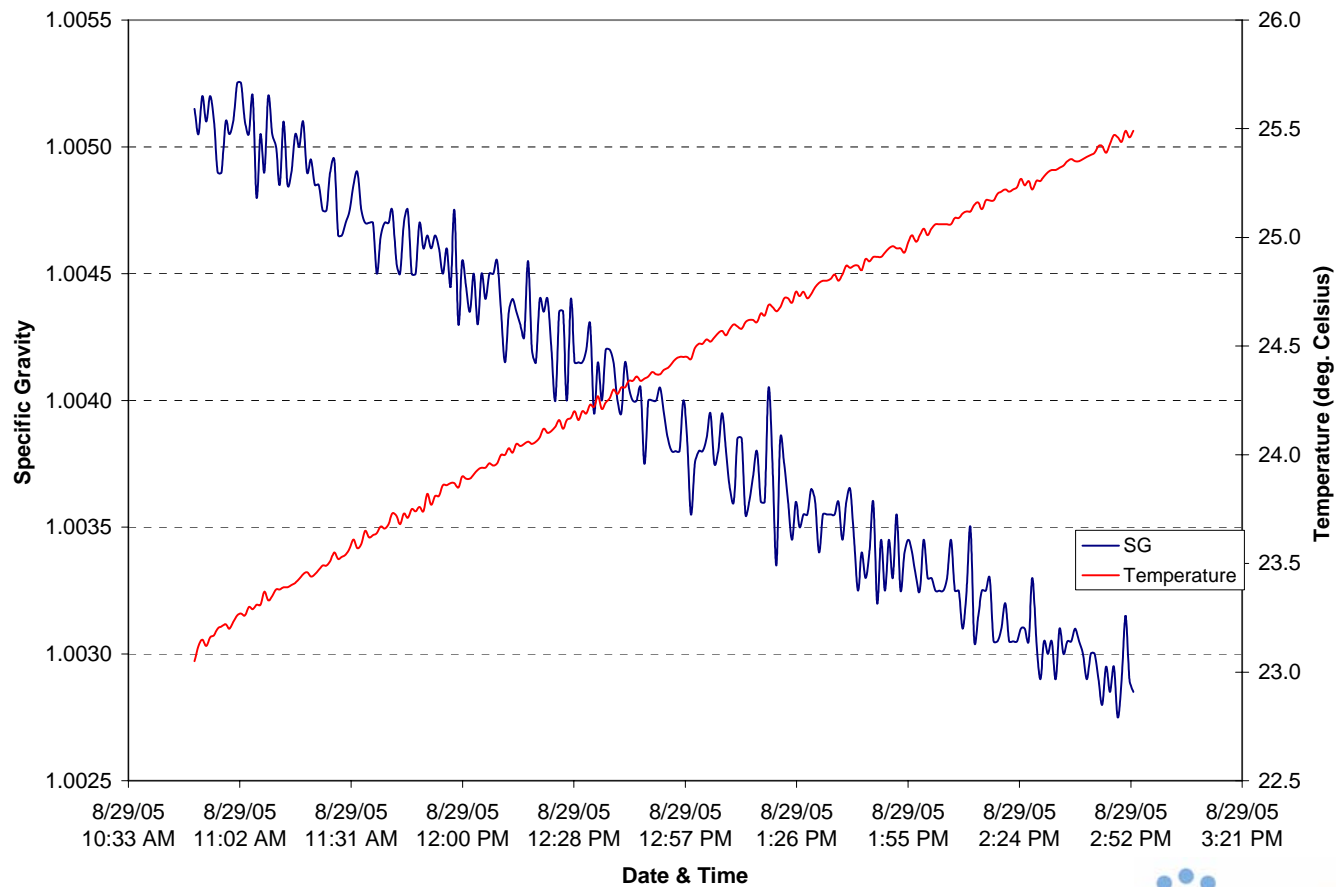
IN-LINE METROLOGY – LOCAL LOOP RAW

- Local Loop Example – Raw Material Uniformity Particle Concentration



IN-LINE METROLOGY – LOCAL LOOP BLENDING

▪ Local Loop Example – Blend Batch Specific Gravity

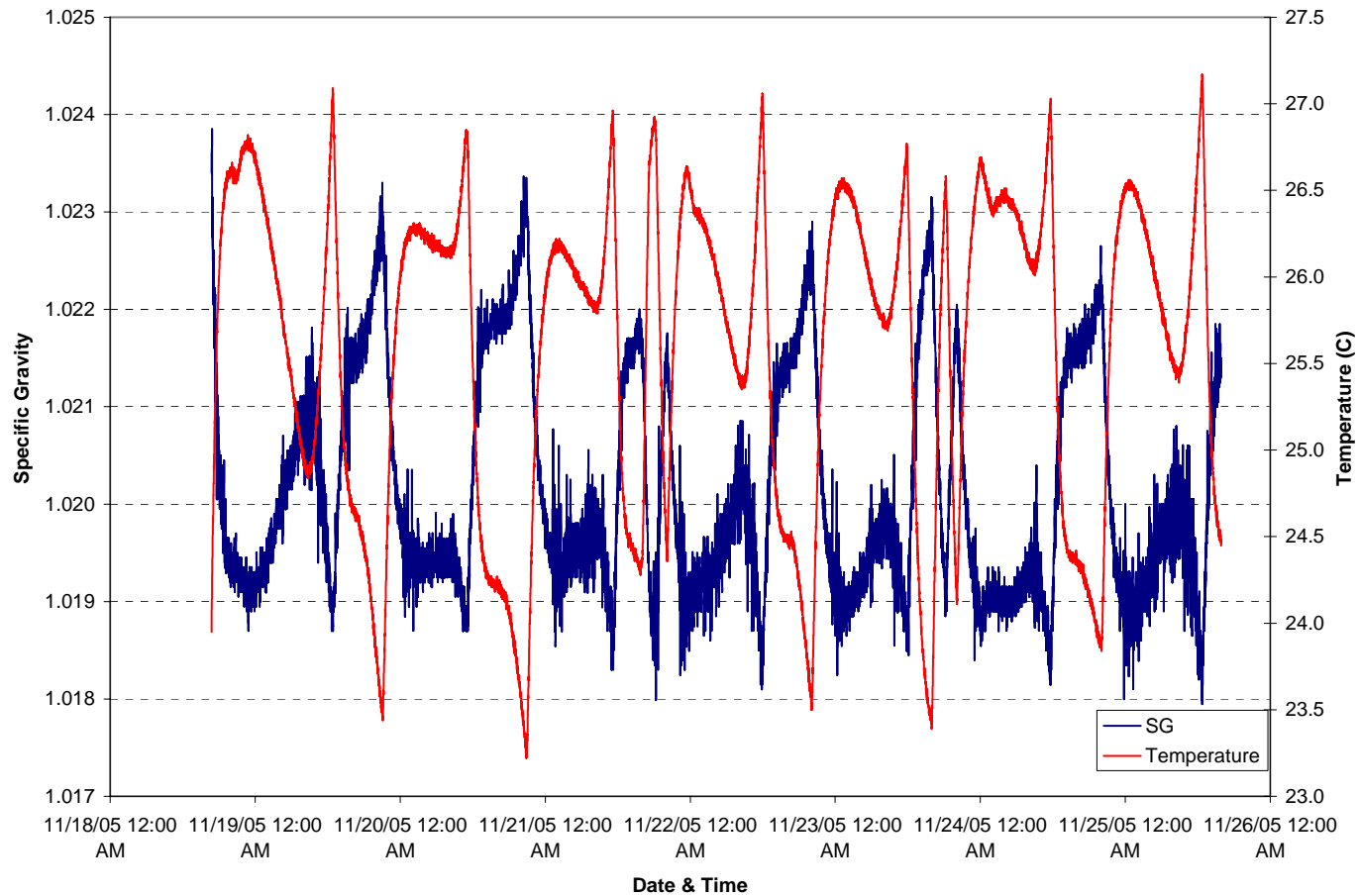


METROLOGY APPLICATION

- **Global Loop Circulation**
 - **Slurry quality during usage**
 - **Mixture uniformity**
 - **In-line measurement of density, particle concentration**
 - **Particle agglomeration**
 - **In-line sample measurement of particle concentration**
 - **Chemical concentration**
 - **In-line continuous measurement of conductivity, pH, refractive index, viscosity, spectroscopy**
 - **In-line sample measurement of chemical through titration**

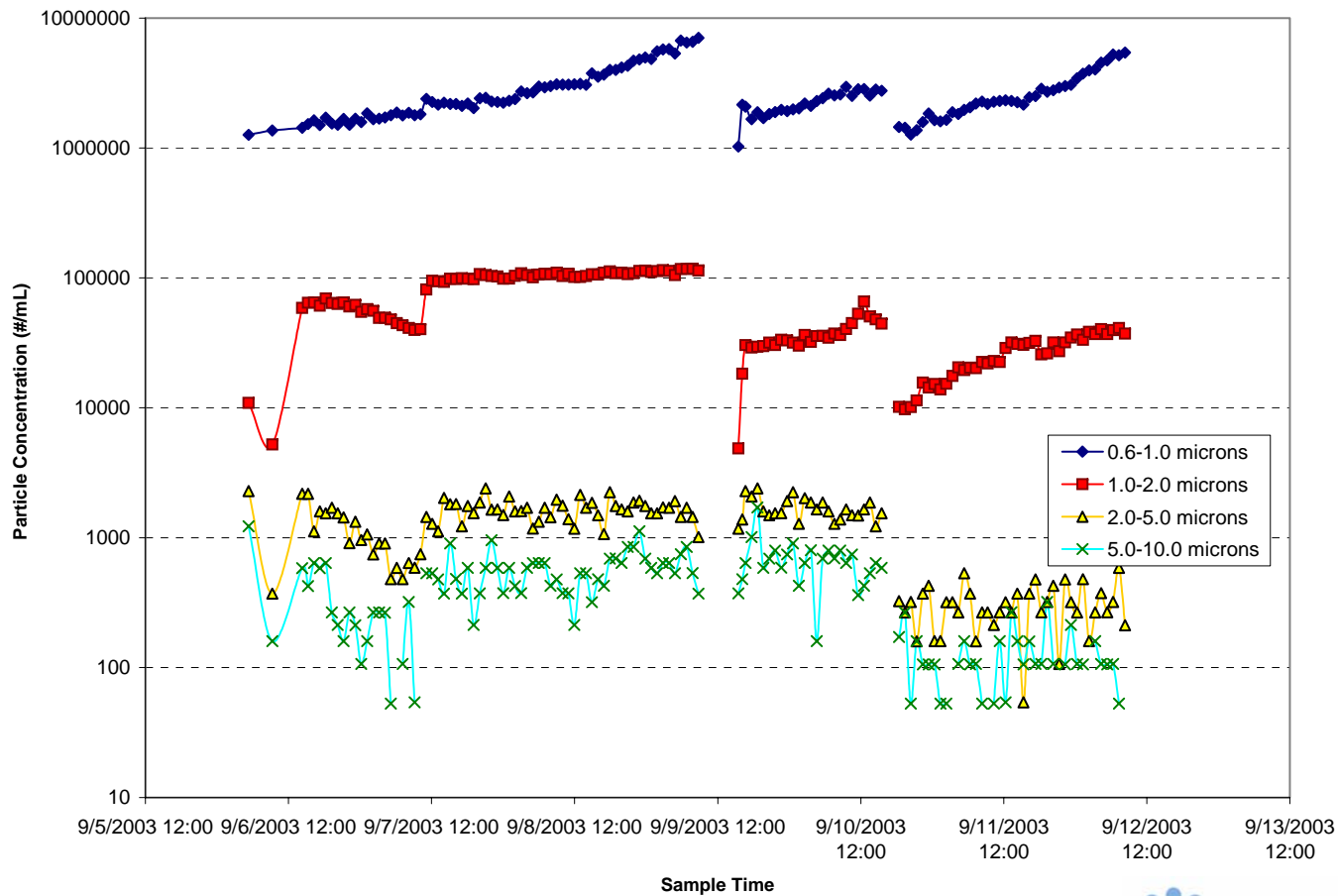
IN-LINE METROLOGY – GLOBAL LOOP

Global Loop Example – Mixture Uniformity



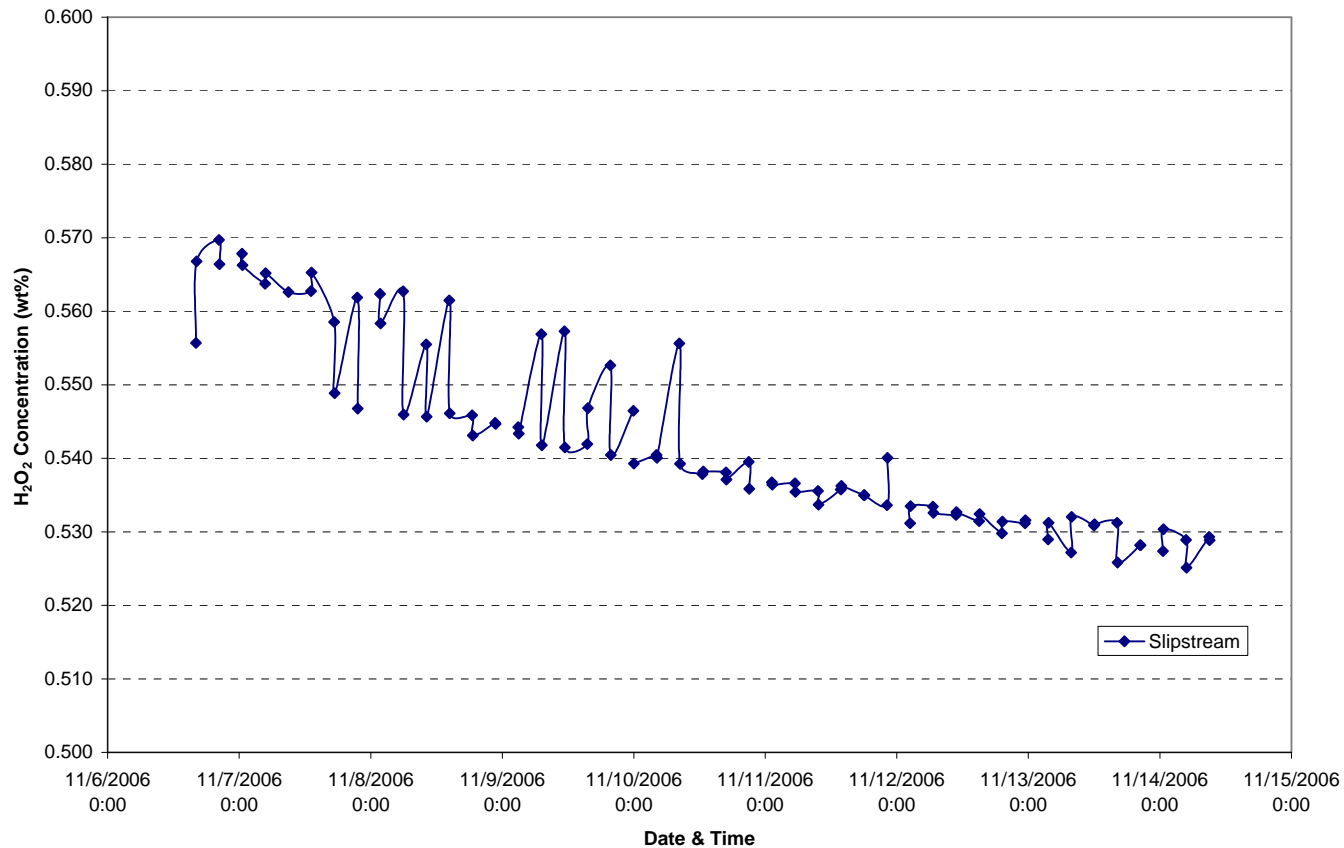
IN-LINE METROLOGY – GLOBAL LOOP

Global Loop Example – Particle Agglomeration



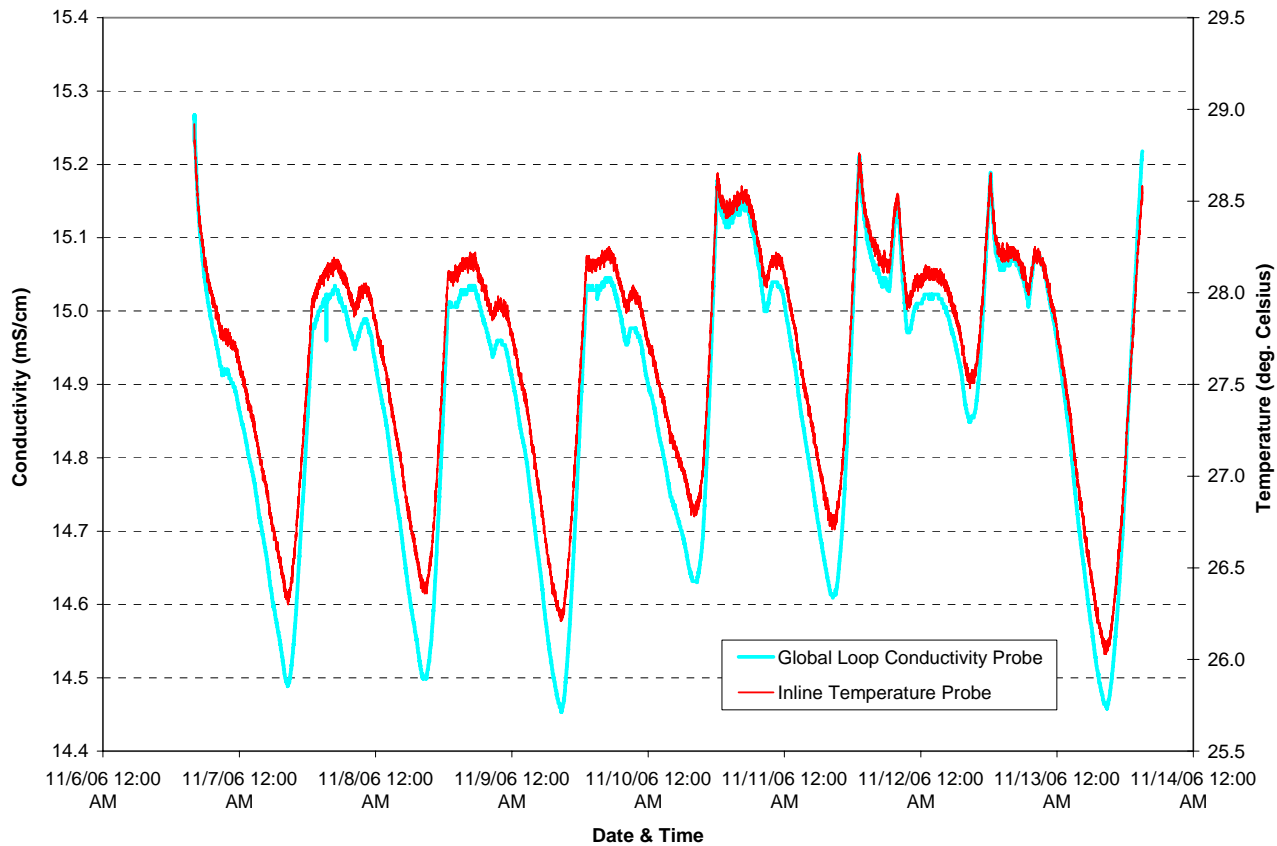
IN-LINE METROLOGY – GLOBAL LOOP

- Global Loop Example – Chemical Concentration Titration



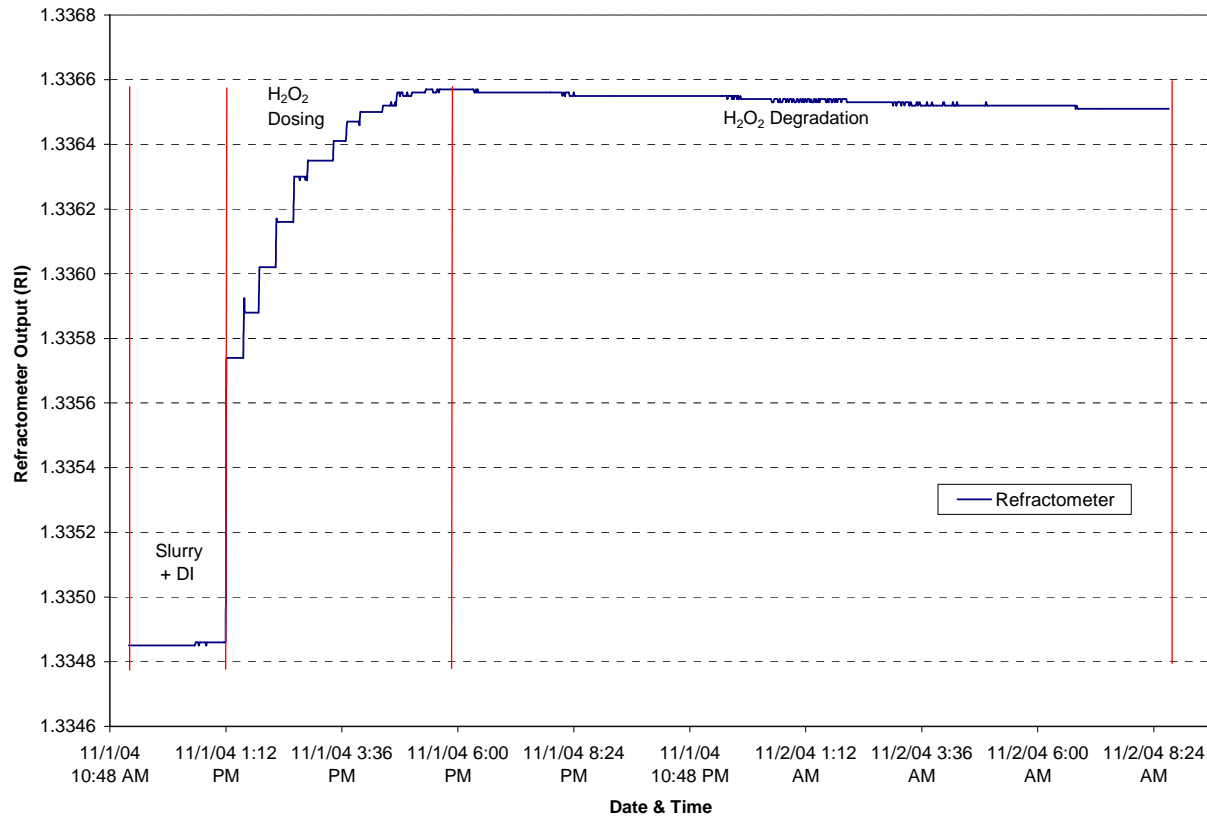
IN-LINE METROLOGY – GLOBAL LOOP

- Global Loop Example – Chemical Concentration Conductivity



IN-LINE METROLOGY – GLOBAL LOOP

- Global Loop Example – Chemical Concentration Refractive Index

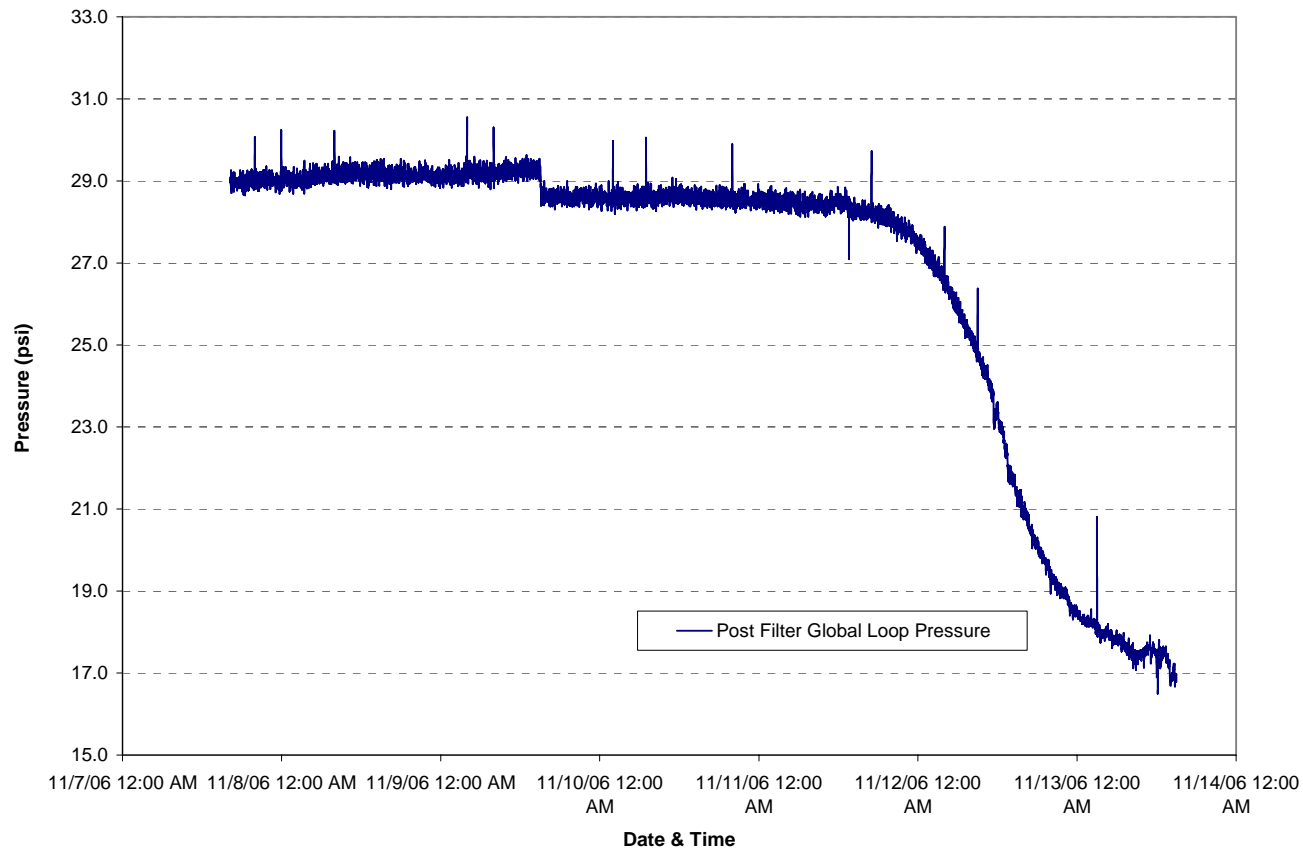


METROLOGY APPLICATION

- **POU Consumption**
 - **Maintain bulk process properties**
 - **In-line continuous measurement of pressure and flow rate**
 - **Feedback to pumps and backpressure control**
 - **Track filter condition**
 - **In-line continuous measurement of pressure**
 - **In-line sampling of particle concentration**
 - **Blending**
 - **Monitoring or control of blended output using in-line devices**

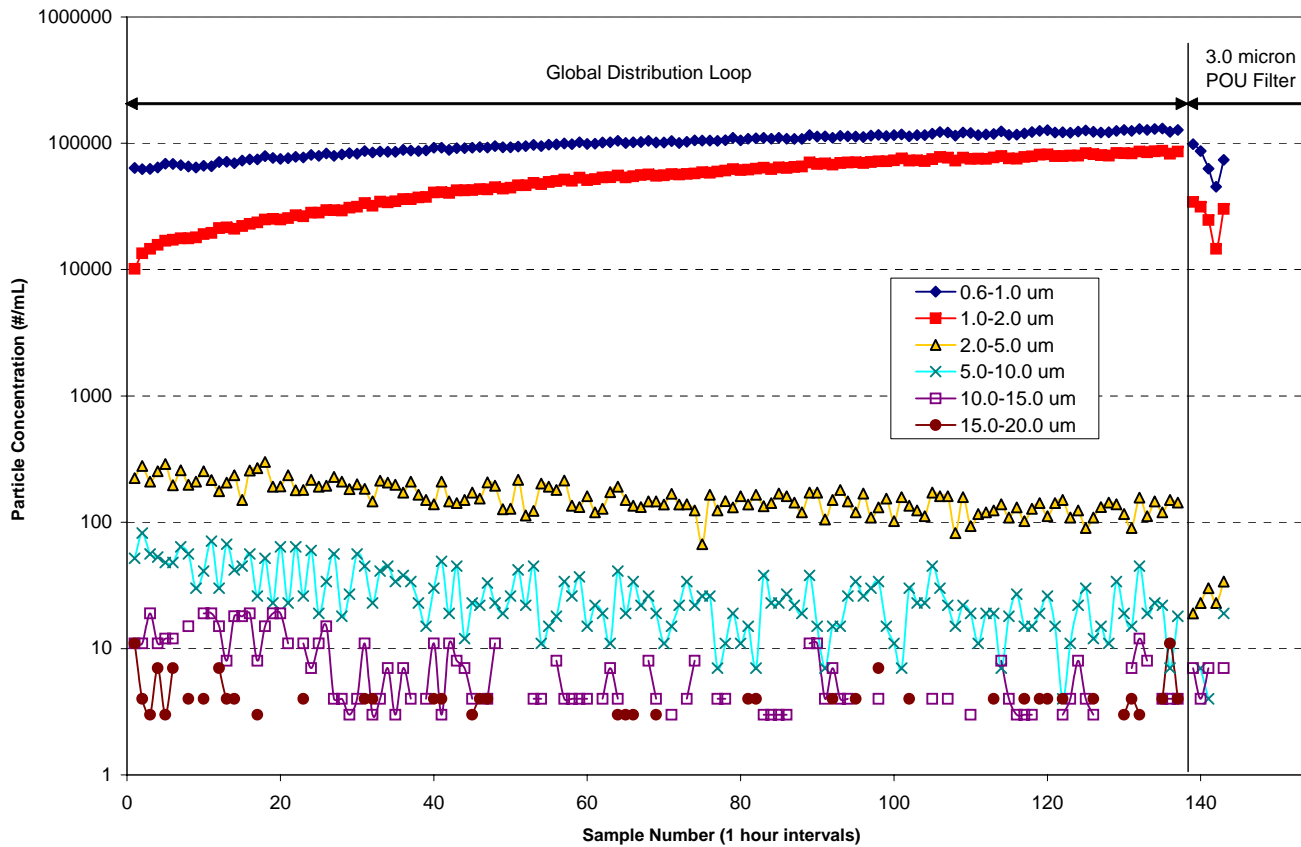
IN-LINE METROLOGY – POU

- POU Consumption Example – Pressure



IN-LINE METROLOGY – POU

POU Consumption Example – Filter Condition



CONCLUSIONS

- **Complexities of CMP Slurry**
 - **Production**
 - **Constituents**
 - **Pot-life**
- **Difficulties in Processing Slurry**
 - **Equipment**
 - **Usage**
- **Greater Understanding of Processes Through Metrology**
 - **Online & offline techniques targeting specific performance metrics**
- **Processing Consistency Results in Yield Consistency**