Process Metrix Mobile Laser Contouring System (LCS) for Converter Lining Thickness Monitoring

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Process Metrix – A History of Instrumentation Development

- Insitec Measurement Systems –
  - Founded in 1985, laser-based particle size instruments
  - Close associations with gov’t labs, $5M in government research
  - 1993 - development of instrumentation for steel industry: Two color pyrometry (temperature), spectroscopy (off-gas control), range finding (refractory thickness measurement)

- Insitec sold to Malvern, PLC in 1997 –
  - Principles stay on to support technology transfer

- Process Metrix started January, 2000 -
  - Same group of people
  - Focus on steel sensors, particles, continued gov’t funding
  - LCS released in 2001
  - Next-gen particle sensor released in 2004
  - Sales growing rapidly as market penetration increases
Total Control of All Aspects of our Product

- A talented group-
  - Engineering staff include:
    - Ph.D, M.S. and B.S. degreed mechanical and chemical engineers
    - Electronics technicians
  - Process Metrix designs and builds its own:
    - Software - Microsoft Windows-based
    - Hardware -
      - 3-D CAD development tools, including Finite Element Analysis (FEA)
      - San Francisco Bay area job shops fabricate machine parts
    - Electronics -
      - In-house schematic and board layout tools, with modeling capability
      - Boards fabricated using state-of-the-art tooling in Silicon Valley
  - Each instrument is hand assembled in our factory, tested, and verified following strict quality control procedures
LCS Sales Show Rapid Market Uptake

[Graph showing units sold over time from January 2001 to January 2011, with a steady increase in sales.]
A World-Wide Installed Base Serves Converters, Ladles, EAF’s and AOD’s
Installation at Slide Gate Maintenance Station (Bao Steel, Posco, REP)
Measurement on Transfer Car (DEW, POSCO)
Basic Oxygen Furnace – Fast Measurement of the Converter for Process Control
LCS Cart - Efficient Design for Robust, Mill-Worthy Service

- Battery power (12 & 24 volt operation)
  - 2-3 hour battery life, smart charger allows operation (e.g. printing) while charging
- Fanless PC with touch screen - no keyboard
  - Automatic wireless data download to Panasonic Toughbook Laptop
- Two-axis on board inclinometer - measures cart tilt
- Retractable heat shielding for cart and personnel
- 3 USB, 1 Ethernet ports: Easy peripheral connection/ LAN connectivity
- Large diameter (40 cm/16”) wheels easily negotiate rough surfaces
Mobile Cart Version 6.0 – Simple Construction, Robust design
Achieving Fast Measurement Time with the Mobile Cart

- Purpose-built Hardware and Software For The Mill Environment-
  - Laser Tracking System automatically locates cart for each setup
  - Radio link automatically sends converter tilt information to cart from high accuracy inclinometer
  - Single mouse-click measurement control
  - Fast range measurement head - 8,000 samples/second
  - Fast data analysis (1-3s)

**GOAL: SINGLE SETUP MEASUREMENT AT ONE converter TILT**

- Measurement time - 25-30 seconds per setup
- Full converter characterization - 6 minutes at 750,000-1,000,000 points, 4-6 setups
Cart Laser Tracking System: Key to Fast, Single-Setup Measurements

- Commercially available system used in warehouse automation applications
- Cart mounted, rotating laser beacon sequentially illuminates three reflectors located behind the instrument.
- Time between reflector illuminations coupled with reflector location in defined operating area determine cart position
  - Position accuracy - 1 cm
  - Heading accuracy - 0.05 degrees
  - System updates 10 times per second - FAST
- Patented algorithm for determining position
Laser Tracking System Measures Cart Position and Heading Automatically

Reflectors mounted to building structure across charge aisle

Rotating Laser Transmitter & Receiver

Reflector

Tracking System Mounted on Cart

12 Ft (4m)
Laser Tracking– Position Determined by Timing

Sweeping laser beam

Up to 40 m

Time 1

Time 2
Converter Tilt Automatically Transmitted to Cart Using RF Link

Transmitter mounted in mill

Radio Frequency (RF) Link

Receiver located in cart

Laser Contouring System

Measure

Transmit
Documenting Accuracy

- **Tracking System**
  - Fluctuating angular values displayed during measurement indicate reflectors must be cleaned
  - Measurement taken in foot floor mount confirm measurements against survey
  - Also allow monthly validation of measurement accuracy

- **Range finding head**
  - Again, with cart in foot floor mount, measure location of center of specific reflector. Range to target in horizontal direction should be constant

- **Cart inclinometers**
  - MEMS device for high accuracy and stability
  - Calibrated using 0.01 degree accuracy level
Reliability and Performance of the Riegl Z210i-HT

- Oldest Riegl system in our customer base purchased in 2001
- 23 heads installed
  - Only two problems observed in entire fleet
- No observed performance degradation with age
- Recommended service after 5000 hours of operation (laser on time). Process Metrix provides head for exchange.
- Allowable temperature range of operation: 18-50 °C. Head shuts down automatically when outside of this range.
Measurement Spatial Resolution

- Depends on multiple factors: Point density, laser beam diameter, distance between vessel and scanner

- LCS system offers three measurement resolutions: $0.2^\circ$, $0.1^\circ$, $0.05^\circ$

<table>
<thead>
<tr>
<th>Range (m)</th>
<th>Measurement Resolution (Deg)</th>
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<tbody>
<tr>
<td>4</td>
<td>0.2</td>
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<tr>
<td>7</td>
<td>14.0</td>
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<td>12</td>
<td>24.4</td>
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<td>12</td>
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</tbody>
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- Finite beam diameter of 40 mm (or 40x20 mm) limits feature resolution
Accuracy of the Range Measurement

- Single point measurement accuracy is ±10 mm
- High point density facilitates spatial averaging for improved thickness accuracy
- For statistically independent measurements, error is reduced by $1/\sqrt{n}$, where $n$ is the number of samples
- Spatially averaging 10 measurements reduces error to less than 4 mm
- Have observed measurement repeatability error of less than 2 mm
Comprehensive Software For Data Collection and Analysis

- Data collection, instrument control and status indication
- Message logging
- Campaign Manager
- On-board error messaging
- 3-D data processing using triangle mesh
- Automatic outlier point removal
- Presentation of raw and reduced data
- 2-D Slice displays
- Bottom and wall contour displays
- Summary table

- Wear rate calculator
- Level 2 output
- Data export to CSV format
- Password-protected access control
- Bath height and slag height calculator
- Report output generator
- Surface temperature calibration and display module
- Configuration Manager
System Installation Steps

- Uncrate and assemble instrument at site
- Install tracking system reflectors
- Survey reflector and converter positions with LCS system
- Install hardware (inclinometer, foot floor mount, etc.)
- Configure software
  - Calibrate locating system
  - Input ladle/converter geometry (from as-bricked profile)
- Commission system
- Train personnel
- As vessels are relined:
  - Measure steel shell and use as thickness reference
Comprehensive Service/Support

- LCS systems include one year warranty
- After warrantee expires, Process Metrix offers a comprehensive service/support plant
- Qualified and trained engineers from our local distributors provide local service and support
- Service plan includes:
  - Twice yearly (minimum) visits to verify performance and operation
  - Unlimited telephone and website support
  - All software upgrades (as released)
  - Replacement of all systems components that fail through normal use
  - Ongoing training at customer site
In Summary….

- The LCS product is engineered for mill service and has a proven reliability record
- The system provides the highest quality data in the shortest time – Industry Wide
- Software system provide advanced functions using simple user interfaces
- System is manufactured in the USA, and includes the highest quality components available
- Service and support provided locally by our trained distributors and globally by Process Metrix engineering staff