

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

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USA





Process Metrix – A History of Instrumentation Development

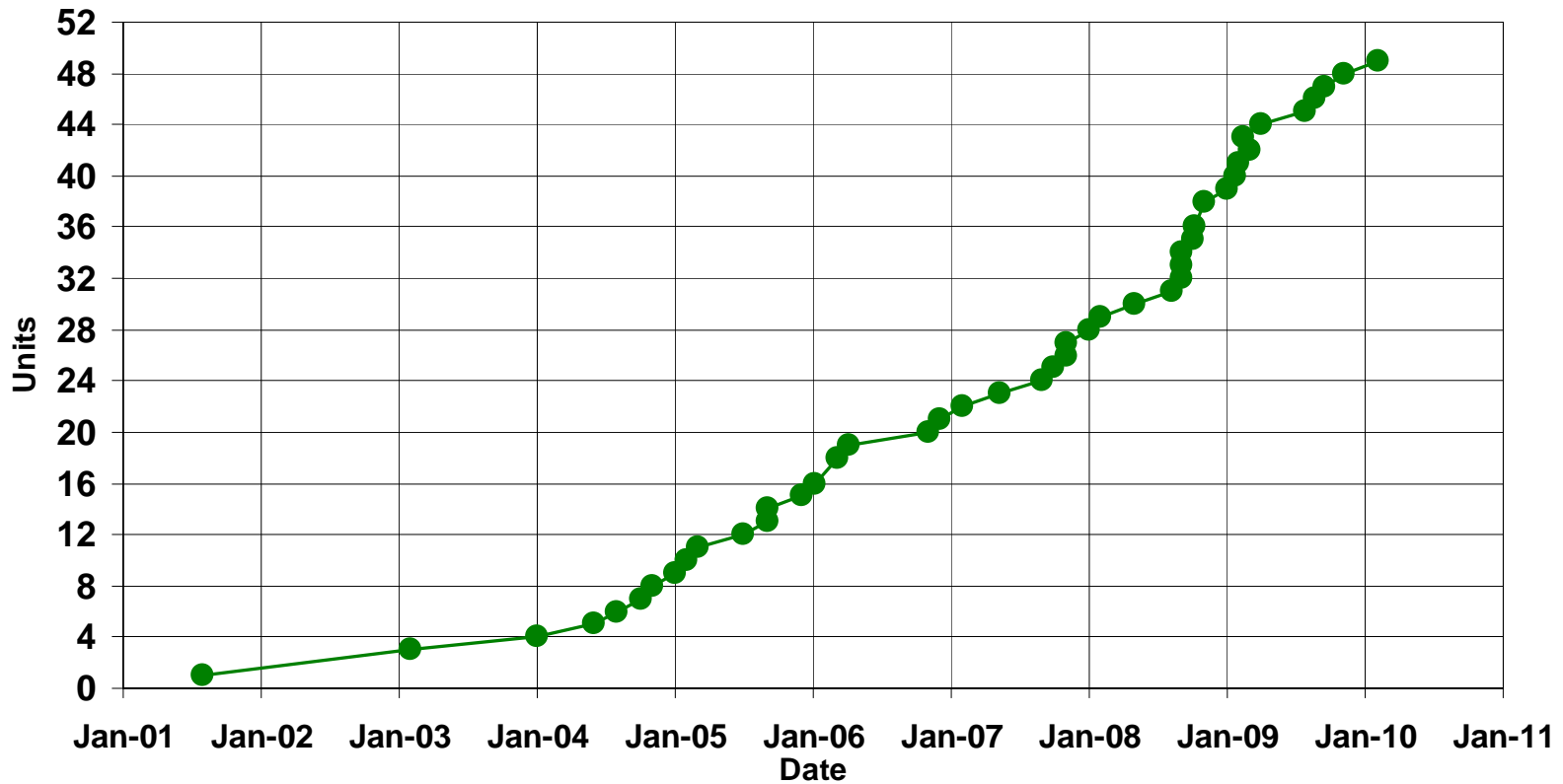
- Insitec Measurement Systems –
 - Founded in 1985, laser-based particle size instruments
 - Close associations with gov't labs, \$5M in government research
 - 1993 - development of instrumentation for steel industry: Two color pyrometry (temperature), spectroscopy (off-gas control), range finding (refractory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



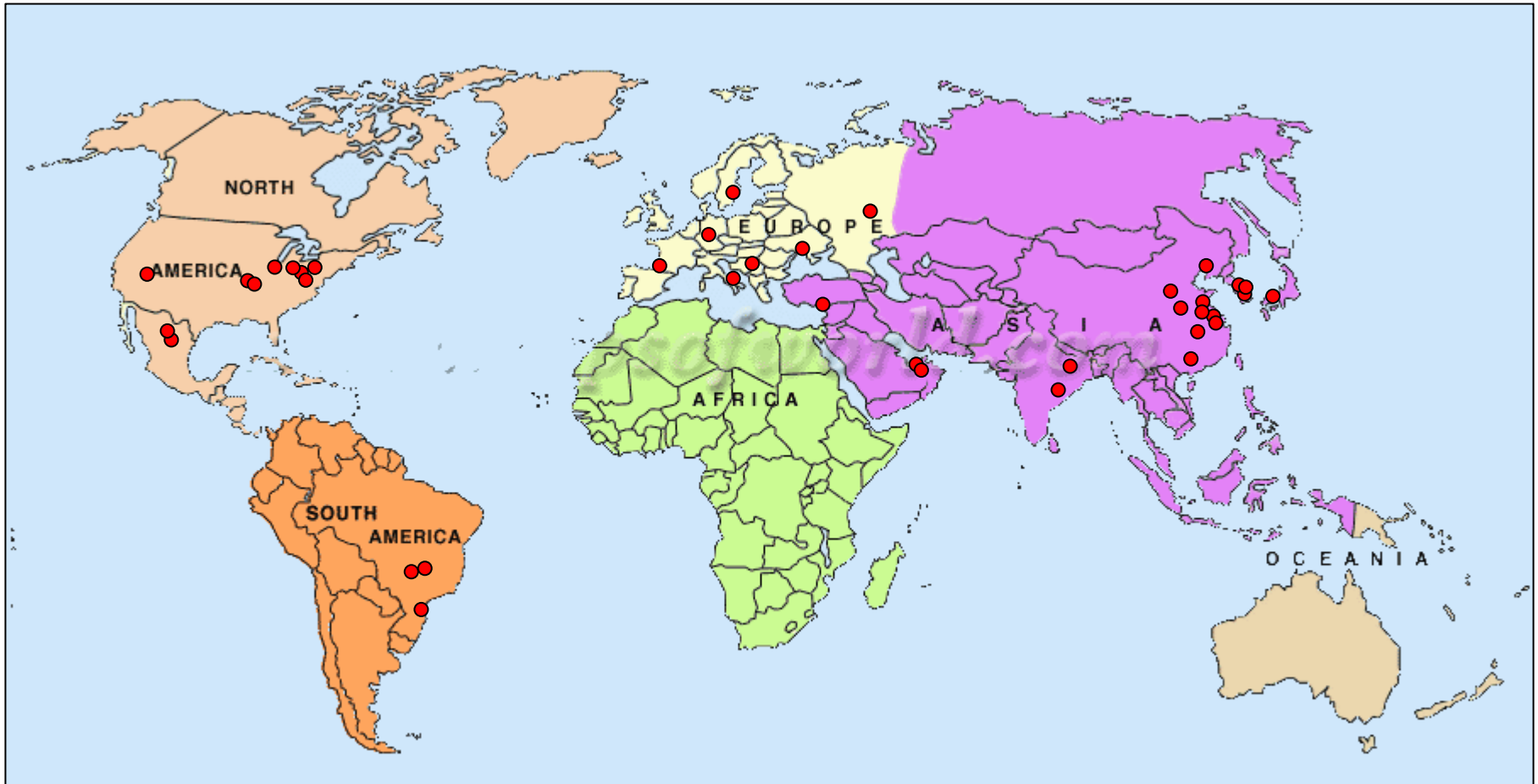
Total Control of All Aspects of our Product

- 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

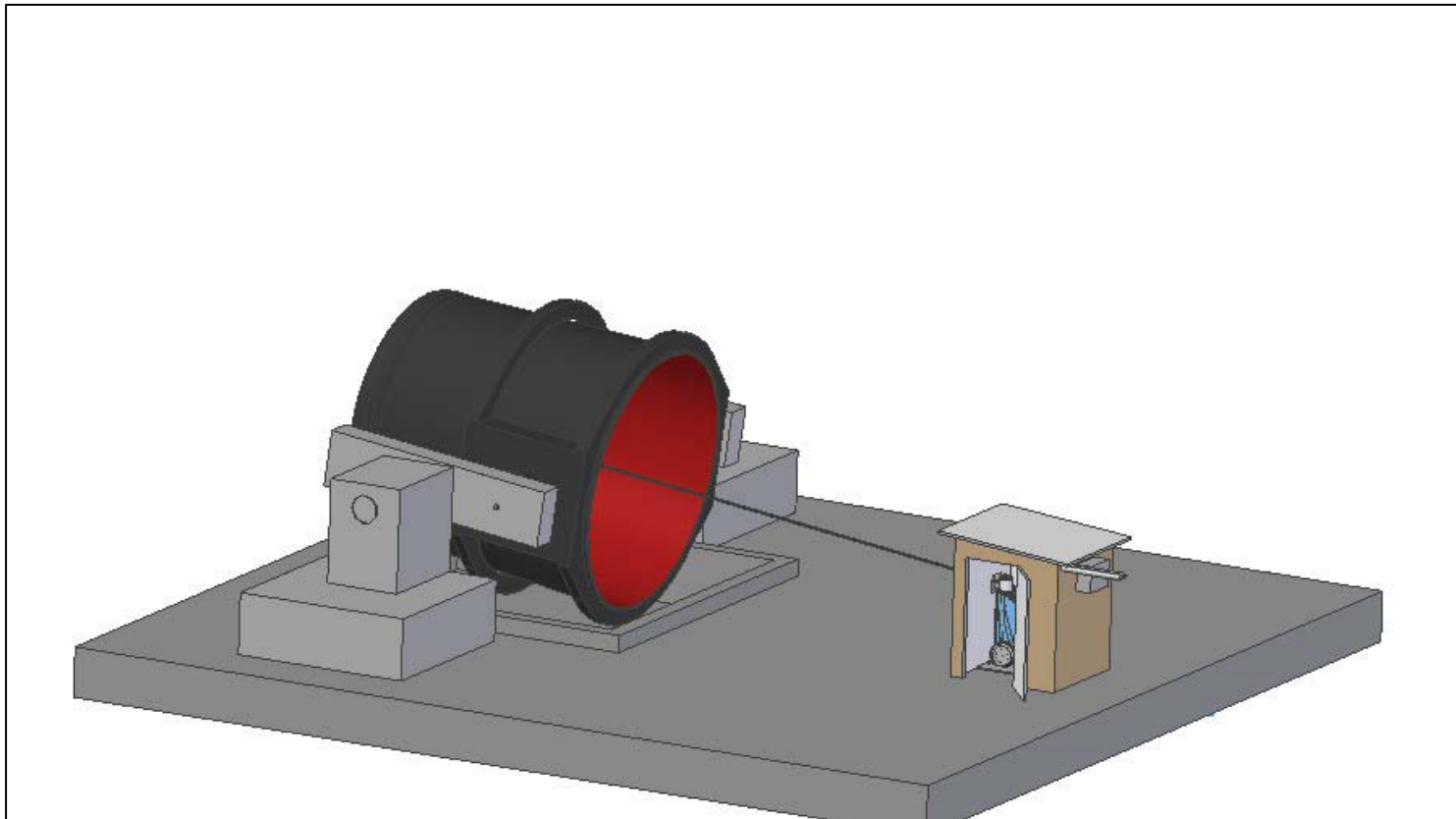
LCS Sales Show Rapid Market Uptake



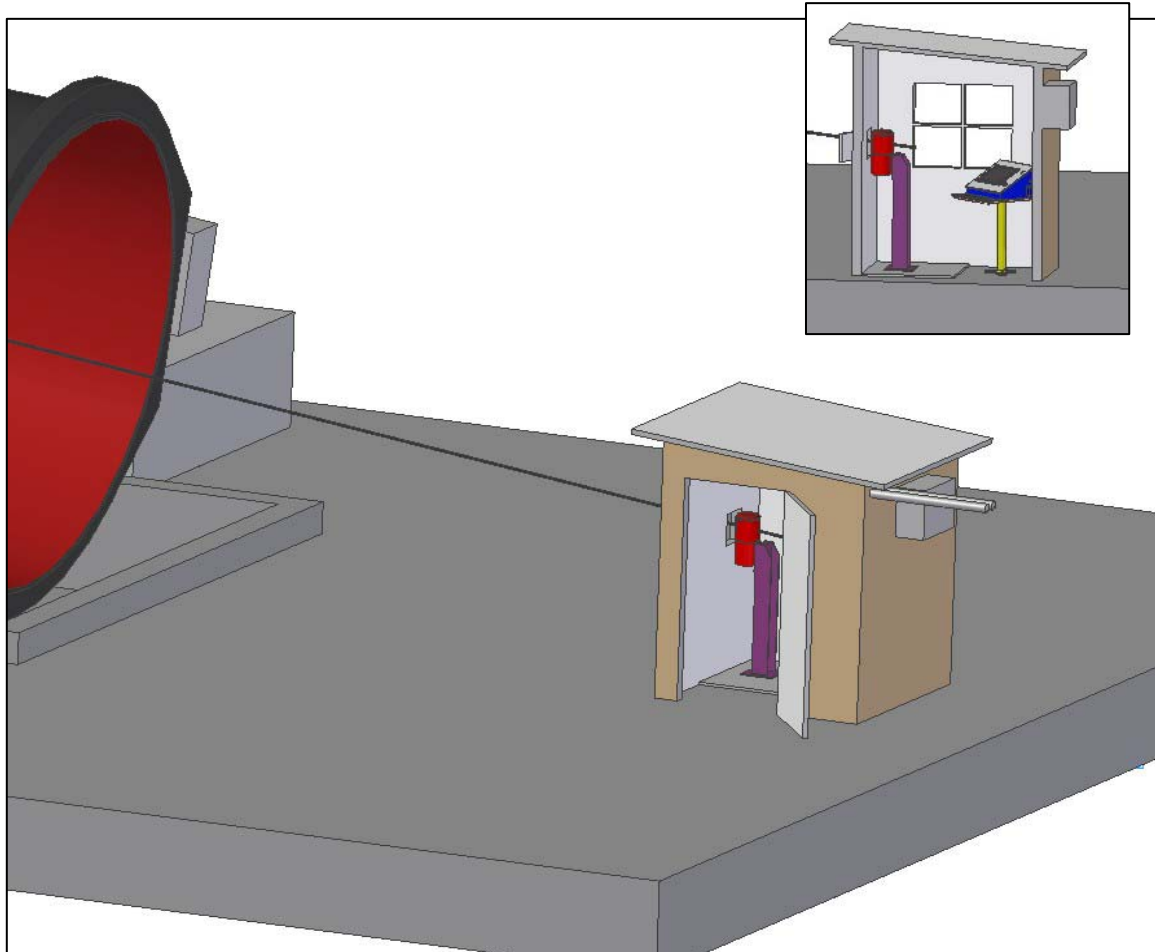
A World-Wide Installed Base Serves Converters, Ladles, EAF's and AOD's



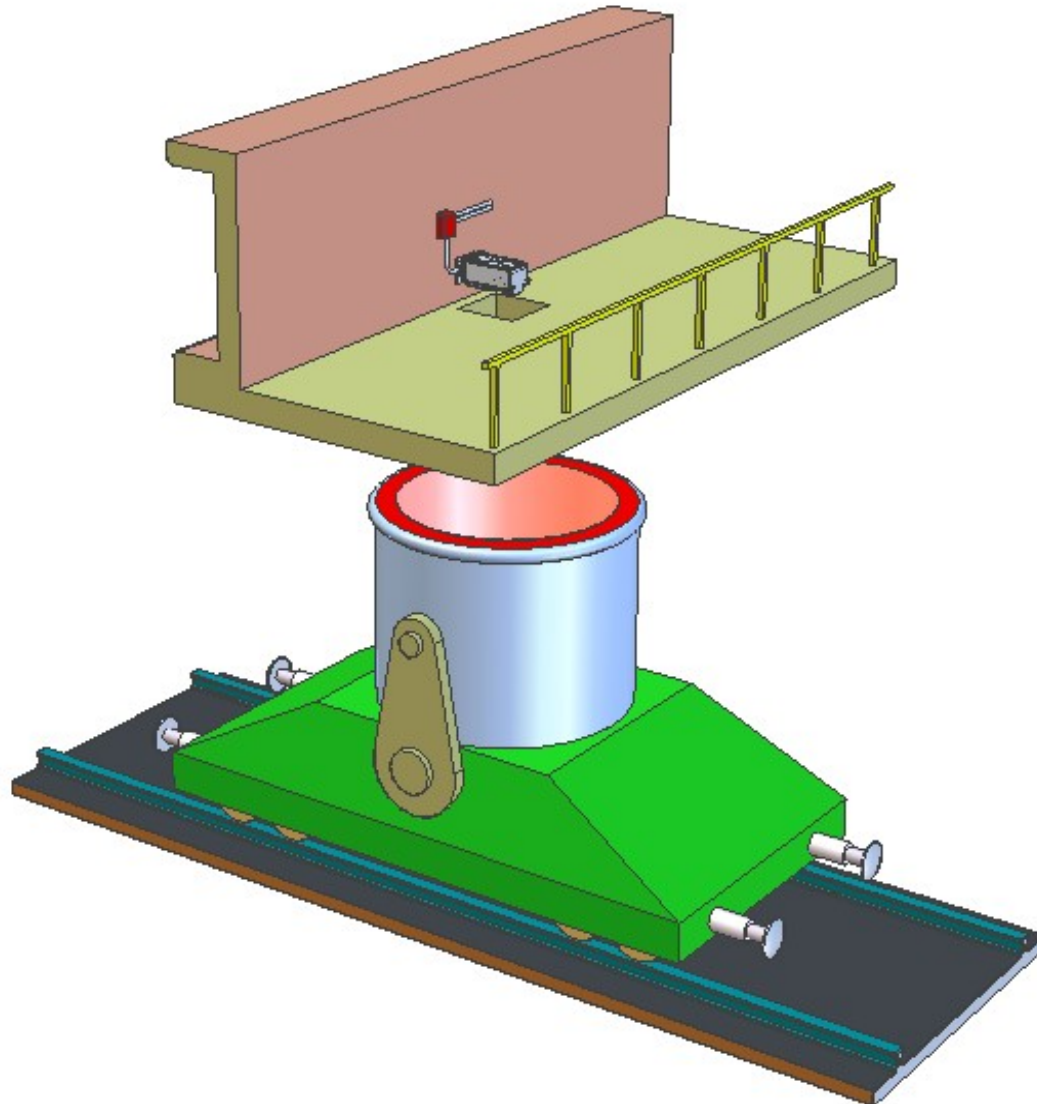
Installation at Slide Gate Maintenance Station (Bao Steel, Posco, REP, Tubos Reunidos)



Installation at Slide Gate Maintenance Station (Bao Steel, Posco, REP, Tubos Reunidos)



Measurement on Transfer Car (DEW, POSCO)





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° , 0.1° , 0.05°

Point Spacing (mm) vs. Resolution and Range			
	Measurement Resolution (Deg)		
Range (m)	0.2	0.1	0.05
4	14.0	7.0	3.5
7	24.4	12.2	6.1
12	41.9	20.9	10.5



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 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



Tracking Campaign History

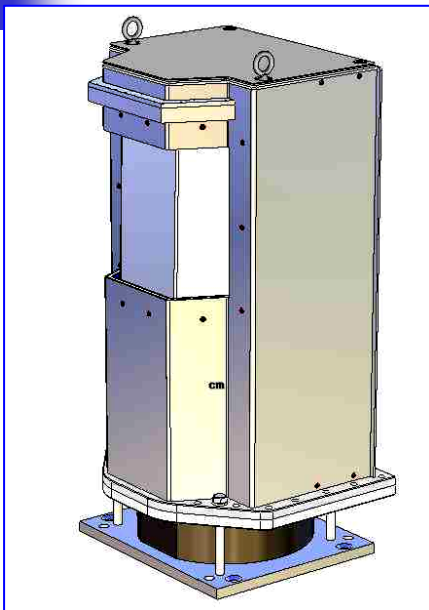
- Software has capability to output data in .csv format
- Can be sent to Level 2 system
- Use this information to
 - Develop wear rate analysis,
 - Review wear history
 - Correlate operations with wear



Fixed-Head LCS System Components

- Principle Components of Laser System:
 - Riegl scanning laser range finder
 - Water cooled/heated laser enclosure with pneumatically actuated door
 - Control electronics
 - Computer (Windows OS), printer
 - Ethernet communication link to control electronic
 - Purpose-built software

Riegl Z210i-HT Scanning Laser Range Finder for Ladle Measurement



- Incorporates Riegl measurement head – same head as used in mobile system
 - 5 mm range uncertainty
 - $\pm 40^\circ$ vertical field of view, $0^\circ - 350^\circ$ horizontal
 - 8,000 Hz data acquisition
 - Water cooled and optically filtered for high heat load
 - Can be mounted in any orientation
- Water-cooled enclosure, pneumatically actuated door
- Fast: Data acquisition typically 20 seconds, 10 second data reduction





Reliability and Performance of the Riegl Z210i-HT

- Oldest Riegl system in our customer base purchased in 2001
- 40+ 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 if system under service contract.
- Allowable temperature range of operation: 18-50 °C. Head shuts down automatically when outside of this range.

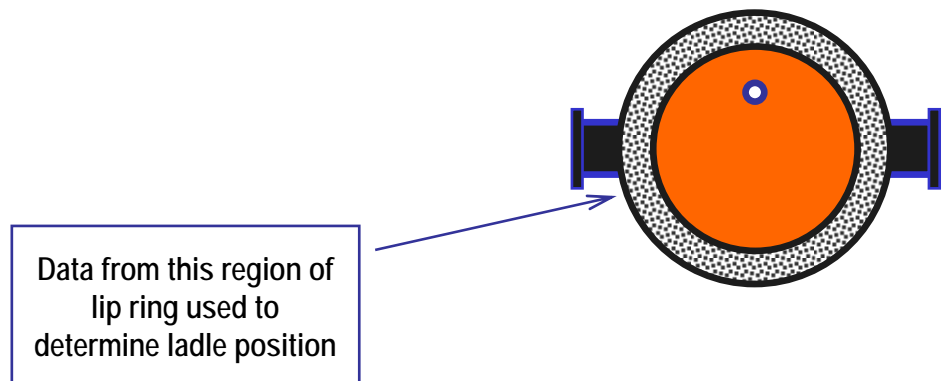


Key Considerations for Ladle Applications

- Thin lining in ladle requires high accuracy ranging head (5 mm uncertainty)
- Must know position of ladle to similar accuracy
- Installation location must include the current ladle work flow:
 - Slide gate maintenance station
 - Transfer car
 - Pre-heater station
- Reference measurement of newly-bricked **HOT** ladle crucial for accuracy
- Campaign manager (software) tracks each ladle to allow assessment of ladle thickness over time

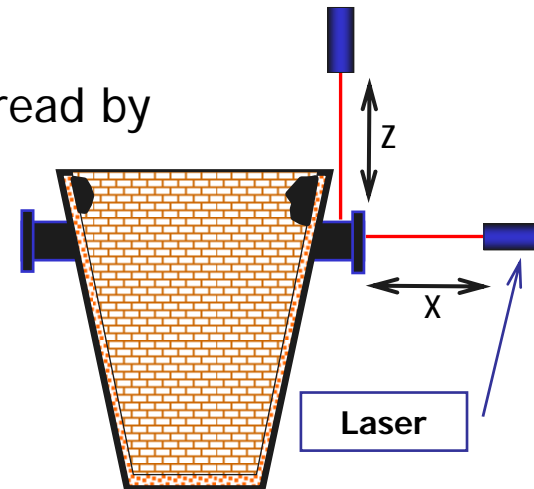
Determining Ladle Position – Method 1: Image Analysis

- Use range data from ladle lip to determine ladle position
 - Completely automated process, fast, easy measurement
 - Requires that the lip ring be nominally free of slag/steel
 - All or a portion of the lip ring plates must remain flat (no deformation due to heat, etc.)
 - Large number of scanned points on lip ring give high accuracy positioning



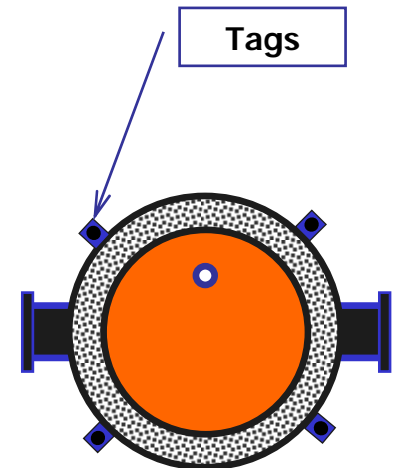
Determining Ladle Position - Method #2: Instrumented Ladle Stand

- Use single-point laser range finders to determine ladle position in ladle stand
 - Typically requires several degrees of freedom be fixed (i.e. rotations are more difficult to measure)
 - Fast, automated
 - Output of laser range finders automatically read by LCS system



Determining Ladle Position - Method #3: Scanned Tags

- Tags on ladle used to determine ladle position
 - Tags scanned during measurement
 - Completely automated for fast, easy measurement
 - Three tags needed to locate ladle
 - Tags must be kept clean
 - Typically two removable, two attached





RFID for Total Lade Tracking in the Mill

- RFID tracks ladle number, heat number (other information) as ladle moves through mill
- Passive RFID tag stores 1064 bits of information
- RFID write station at slide gate maintenance point writes updated heat number to ladle
- Integrate with plant Level II control
- RFID read stations located throughout mill (LCS measurement station, caster, etc.) receive ladle information when ladle is in range

Measurement Repeatability: 1-2mm

Lining thickness difference (mm)

Distance from Ladle Lip (m)

0.2	0.3	0.0	3.0	1.0	4.3	2.3	-0.7	2.3	1.3	1.0	3.0	2.0
0.4	0.0	0.3	-0.3	-0.3	0.3	0.3	-0.7	0.7	-0.3	0.3	0.7	1.0
0.6	4.0	2.7	2.3	1.7	2.0	2.0	1.3	1.7	1.7	1.3	2.3	1.7
0.8	3.7	0.7	0.3	0.0	1.7	3.7	-1.0	0.3	1.0	-0.3	2.3	0.3
1.0	1.0	0.7	2.7	0.0	0.7	0.7	1.3	1.0	1.3	0.3	-0.3	0.0
1.2	0.7	0.3	1.3	-1.0	2.0	1.7	-0.7	0.0	0.3	0.3	0.3	2.0
1.4	2.7	1.0	-0.7	1.0	0.0	0.3	1.7	1.7	1.7	-1.7	0.0	0.0
1.6	0.3	0.7	-0.7	-2.0	0.0	0.3	-0.3	0.3	0.0	-0.3	0.7	0.3
1.8	0.7	1.3	0.7	0.3	1.3	2.0	0.3	1.3	0.3	0.0	1.0	-0.3
2.0	2.3	0.3	-0.3	-0.7	0.7	1.3	1.0	2.0	1.3	0.0	-0.3	0.3
2.2	0.3	1.3	0.0	0.3	1.0	0.7	2.3	1.3	1.0	1.7	1.7	1.0
2.4	1.3	1.3	-0.3	1.3	0.0	0.3	-1.0	1.3	2.0	0.7	0.7	1.3
2.6	0.7	0.3	0.0	1.0	0.7	-0.3	2.0	2.0	-0.3	-0.7	0.3	1.0
2.8	1.0	1.0	0.3	-0.7	-0.3	-0.3	0.7	0.0	0.7	0.0	0.7	1.3
3.0	1.7	1.0	0.0	-1.0	0.7	-0.3	1.3	0.3	0.0	-0.3	1.3	0.3
3.2	0.7	1.0	0.7	0.0	0.3	-1.0	0.3	0.7	2.3	0.0	0.3	2.0
3.4	3.0	1.0	0.7	-0.7	-1.0	2.7	-2.0	0.3	-0.3	1.0	1.3	2.3
	180°	210°	240°	270°	300°	330°	0°	30°	60°	90°	120°	150°

Data collected from a series of measurements made on a single ladle in transfer car

Angular Position in Ladle (90-270=trunion)



Comprehensive Service/Support

- Comprehensive warranty on all system components
- Process Metrix offers a comprehensive service/support plant
- Qualified and trained engineers provide local service and support.

Developers of the system provide service, or direct those who do

- 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



System Installation Steps

- Install required facilities (power, water cooling, Ethernet)
- Install instrument, computer, electronics
 - Connect facilities, verify operation
 - Install hardware/fiducials required to locate ladle
- Configure software:
 - Input survey data
 - Ladle geometry (from as-bricked profile)
- As ladles are relined:
 - Measure steel shell and use as thickness reference
 - Measure newly relined ladle before first heat (replaces as-bricked profile)
- Train personnel

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 trained engineers from PMC