CIA Inspection (US), Inc.

COKE DRUM LIFE IMPROVEMENT
A COMBINED APPROACH

COKING .COM
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Today's Presentation

Distortion Monitoring

Remote Internal Visual Inspection

Coke Drum Management Through Knowledge

Strain Gage Measurement

Acoustic Emission Testing

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Owner/Operator's Dilemma

- How to:
  - manage capital asset in responsible and cost effective manner
  - optimize process control to maximize throughput
  - improve reliability and reduce maintenance costs
  - maximize drum life
  - effectively plan for vessel replacement

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Coke Drum Design

- Typically designed and built to the ASME "Boiler and Pressure Vessel Code" Section VIII, Division I
- Generally not designed for low cycle fatigue
- Traditionally designed with horizontally-arranged courses varying in thickness from bottom to top

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Coke Drum Realities

- Drums operate under severe conditions of cyclic heating and forced cooling
- Variable nature of the process results in a wide variety of experiences for drums of similar design

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Coke Drum Failures

- Ultimate failure mechanism is crack initiation in plate-plate welds due to low cycle fatigue
- Almost all cracking occurs on circumferential welds
- Drums fail in a leak-before-break failure mode

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Through-wall Crack

Extensive through-wall cracking started from inside

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Coke Drum Inspection/ Monitoring

- Most direct method of crack determination:
  - Visual or dye penetrant inspection from inside
  - Ultrasonic inspection from outside
- Impractical to perform 100% inspection
- Predictive/preventive approach must be utilized

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Coke Drum Inspection/ Monitoring

- Distortion Monitoring
- Remote Internal Visual Inspection
- Strain Gage Measurement
- Acoustic Emission Testing

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Distortion Monitoring

- Remote laser surface profiling performed between cutting and refilling
- Laser based range imaging system collects laser distance measurements of entire vertical surface of vessel
- Color contour map shows bulge profiles and other distortions
- Allows drum comparison over time
- Custom designed software "Drumview" interprets the drum scan data

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Distortion Monitoring

- Regular laser profiling of coke drums allows operators to:
  - Focus further inspection efforts on welds near deformed areas
  - Compare degree of deformity among their different drums
  - Compare change in drum deformities over time
  - Compare site specific results with industry wide trends
  - Model effects of a typical quench cycle using finite element modeling tools

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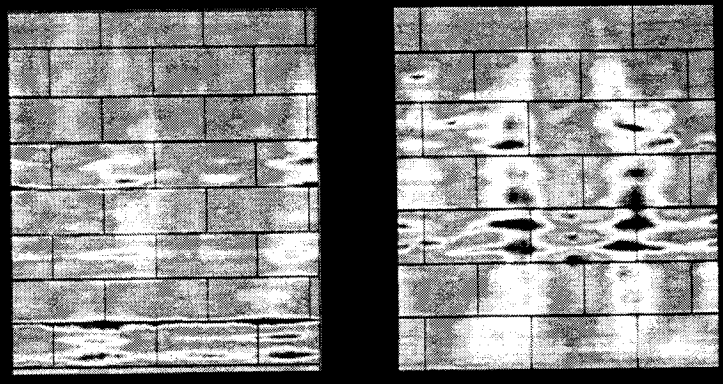
Typical Bulge Maps



Mid Life Drums

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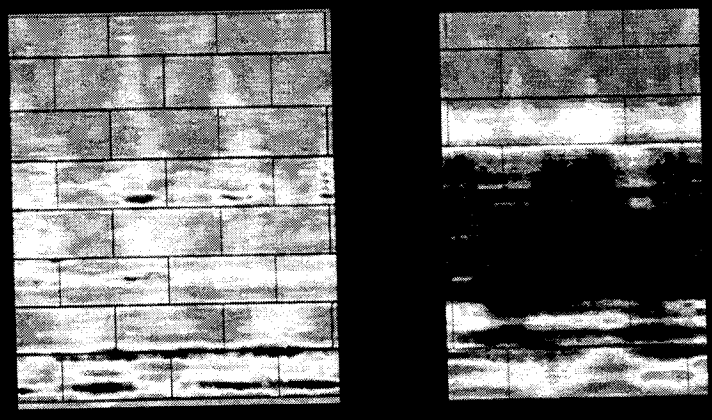
Typical Bulge Maps



Late Stage Drums

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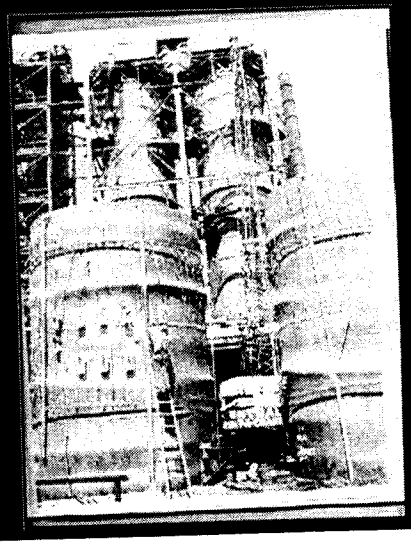
Coke Drum Shell Bulging



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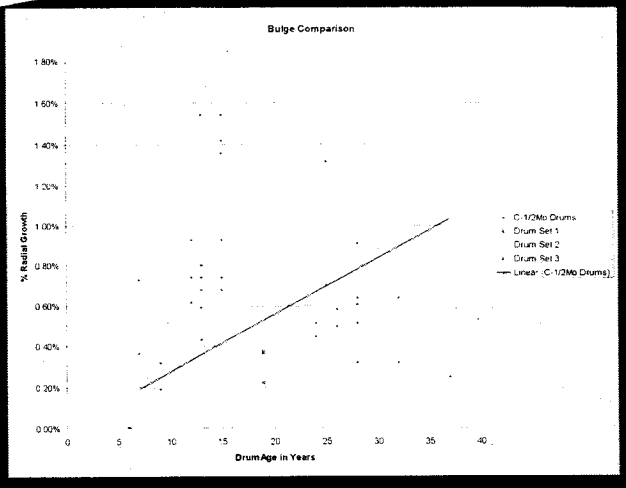
Drum Trending



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Remote Internal Visual Inspection

- Remote video inspection performed between cutting and refilling
- Color video camera with a high resolution zoom lens used to identify surface flaws
- Videotape registered with same elevation and azimuth as laser scan
- All findings recorded on VHS tape and documented and reported by API certified inspector in report format

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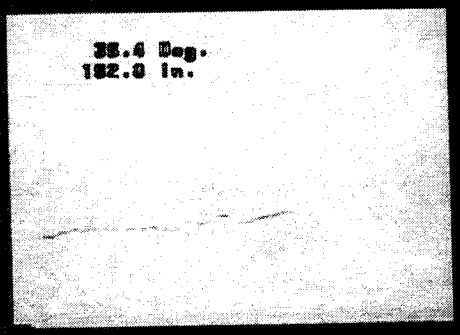
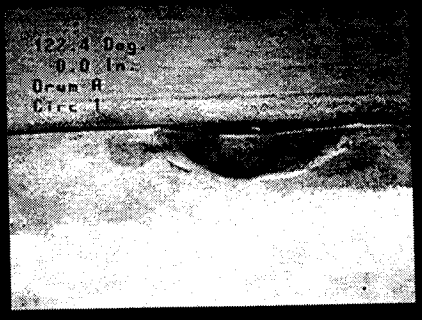
Visual Inspection Findings

Visible crack in circ weld



Cladding failure



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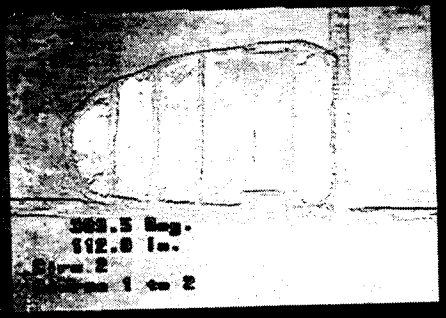
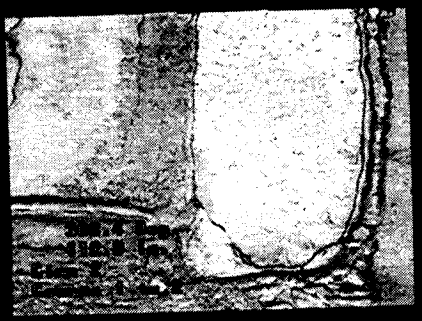
Visual Inspection Findings

Cladding repair



Crack in overlay



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Further Monitoring

- Depending on findings from laser & remote visual inspection, additional activities/ approaches can be undertaken
  - Engineering analysis
  - Materials evaluation and testing
  - On-line monitoring of damage
  - Fitness for service
  - Operational control and optimization
  - Recommendations on repair/replace procedures

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Strain Gauging

- With Stress Engineering:
  - Use laser image dimensions to properly place strain gauges in areas of most stress/strain
  - Data provides complete corrections to strains from temperature-induced error, calculation of bi-axial Principal Stress results, including Stress Intensity
  - Extrapolations made from database to predict remaining useful life of drum

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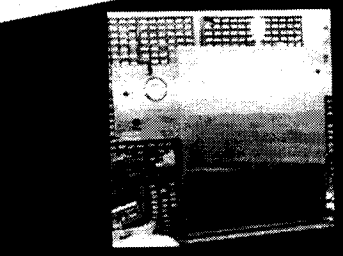
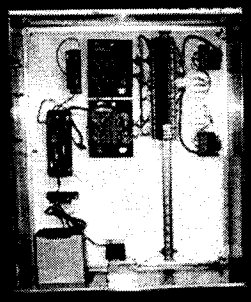
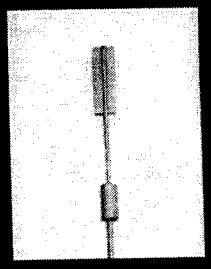
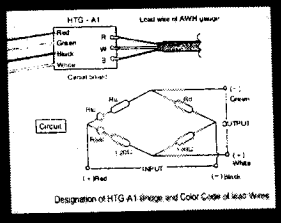
Strain Gage Monitoring









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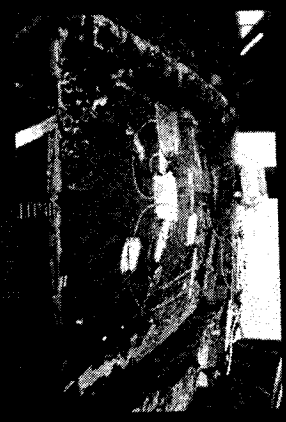
Strain Gage Locations on Shell



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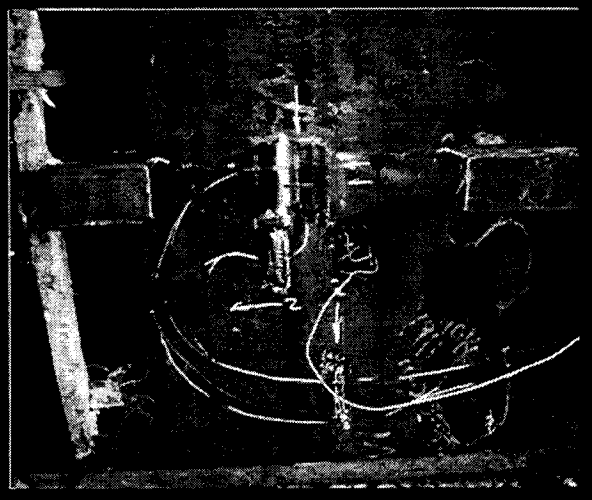
Strain Gage Locations at Skirt



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Output from Strain Gage Measurement

- Operational intelligence to reduce fatigue damage
- Fatigue crack growth prediction
- Low cycle fatigue damage accumulation
- Remaining life assessments

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Dimensional Assessment for Replacement

- With CB&I:
  - In conjunction with laser inspection dimensional data can aid in the correct custom can replacement
  - Drumview "export" feature can help manufacture proper fit-up - bulging and ovality
  - New coke drum inspection to meet code qualifications

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Improved Replacement Techniques

- Replacement Scenarios
  - A section of vertical wall
  - The cylindrical portion of the drum
  - The entire drum
- Drum profile information helps:
  - to define location of section to replace as many bulged areas as possible
  - to define interface with remaining portion of original drum

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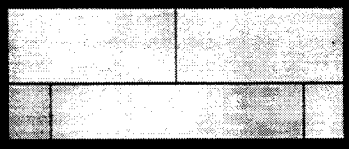
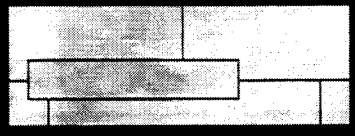
Improved Replacement Techniques



Section of laser scan showing distortion at circ weld



Section of laser scan after repair showing location of "repair patch"

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New Look at Coke Drum Design

- Design shell and skirt for low cycle fatigue
- Design using "actual" measured thermal transients, rates and strain ranges
- Utilize uniform thickness walls of high yield strength plate
- Match yields between plates and welds
- Flush grind weld caps
- Arrange course plates vertically

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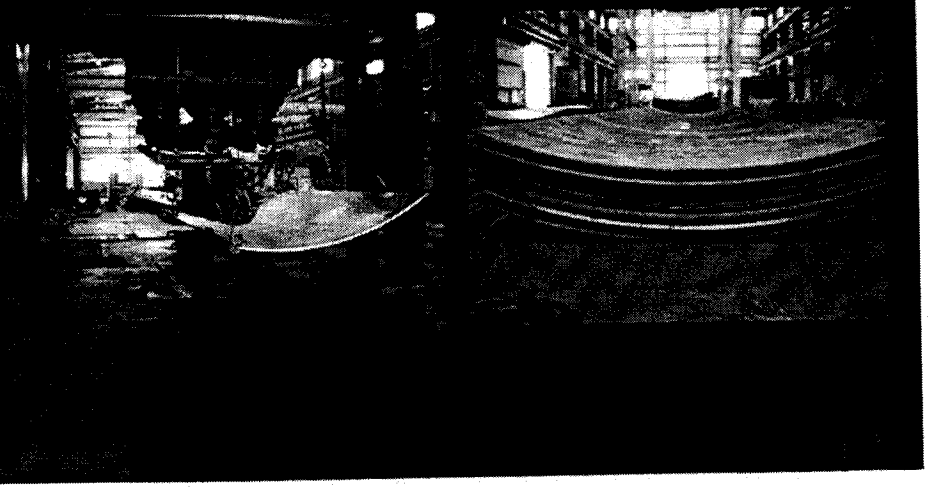
New Coke Drum Design



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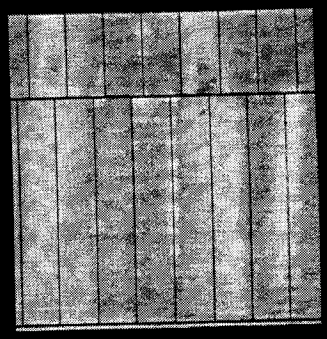
New Coke Drum Design

New Drum Fabrication
Conventional Design



New Drum With
Vertical Plate Technique

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Weld Repair Plan & Procedures

- Develop repair and replace procedures for defective areas of coke drums
- Recommend correct inspection and repair techniques
- Provide on-site consultation and if necessary can provide supervised contract welders to ensure the best possible repair is performed using the correct procedure

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Summary

- Coke drum life improvement is a combined approach
- CIA with alliance partners can help improve the reliability of your coke drums
- Improved reliability means improved profitability

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