Development of CIA's Remote Robotic Crack Detection Service

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Today's Presentation

- Brief Background on CIA

- ACFM Development

- Field Trials

- Next Steps

CIA Background

- CIA invented the concept of laser scanning for coke drums in 1990
- Over 1000 inspections for 75 clients in 22 countries
- Comprehensive service - laser scan & zoom video of all circ welds, follow-up ACFM
- Performed between coking cycles – typically under 4 hours
- Immediate results – final report written and usually delivered to client before leaving site
- Partner in coke drum reliability

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CIA Comprehensive Coke Drum Inspection Program

- 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
- Comprehensive reliability program helps manage drum life – key to preventing drum failure

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Inspection Results

➤ Is This A Crack?

➤ If so, how deep and how long is it?
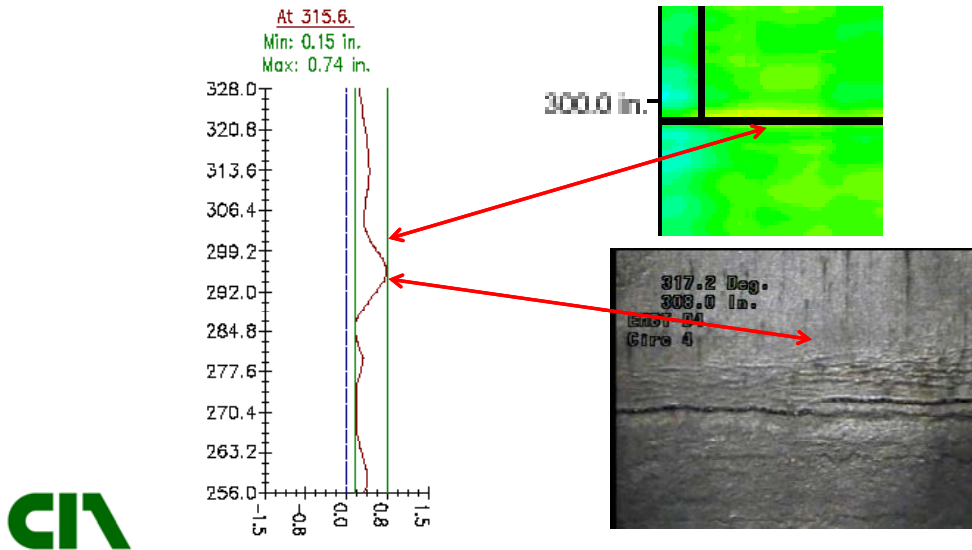
Development of Remote Robotic Crack Detection

- CIA identified there was a need to quantify crack type indications in a quick, cost effective and accurate way in conjunction with our existing on-line service

- Standard UT methods usually require shutdown or extended cycle times, difficult to manage, expensive

- Took 18+ years of laser & visual inspection experience and developed new technique

- Chose ACFM - Alternating Current Field Measurement

What is ACFM?

- Developed by TSC in England
- Originally developed for sizing fatigue cracks on underwater welds
- Used as replacement for magnetic particle and penetrant testing
- Electromagnetic technique for detecting & sizing surface breaking defects
  - Works through coatings, works at welds, underwater, on hot or cold surfaces and on all metals

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What is ACFM?

- ACFM operates by inducing a locally uniform AC field into the test surface. This field flows in a thin skin in the surface of the material and is disturbed by the presence of <u>surface breaking defects</u>.

- These changes are detected by two sensors mounted in the probe which measure the magnetic field resulting from the applied electric field

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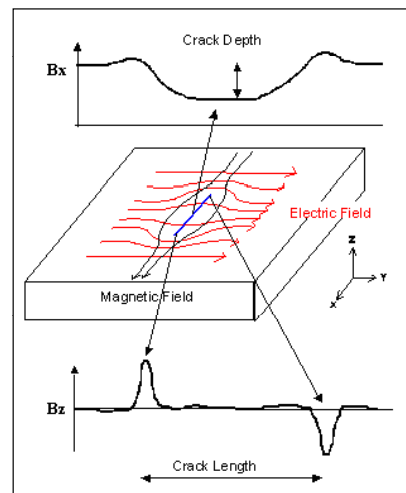
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Development of ACFM for Coke Drums

- Deploy ACFM probe remotely from drill stem similar to existing inspection system & used in conjunction with laser scanner – retracting boom

- Crawler mounted probe placed inside coke drum wall directly at areas of interest to allow quick local surveys

- 16 sensor pair probe (4.25" wide) customized by TSC for use in coke drums & tuned to detect defects as small as 0.330 inches in length & 0.04 inches in depth

- Several field trials – top entry, bottom entry, crawler & probe

ACFM Equipment
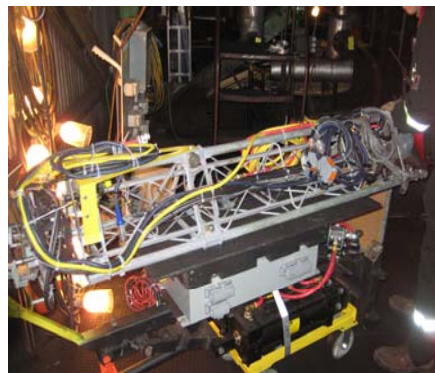
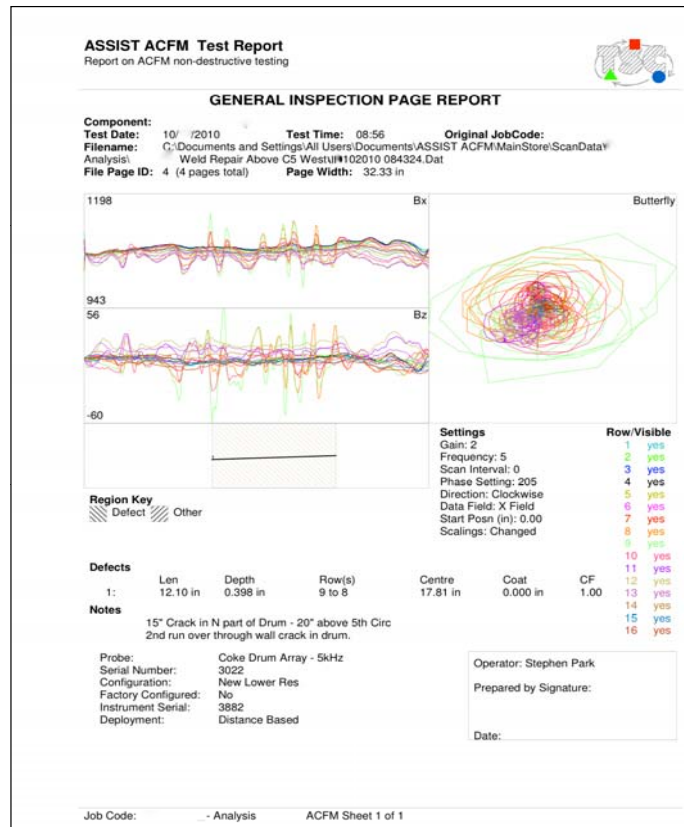# Video – Crawler on drum wall

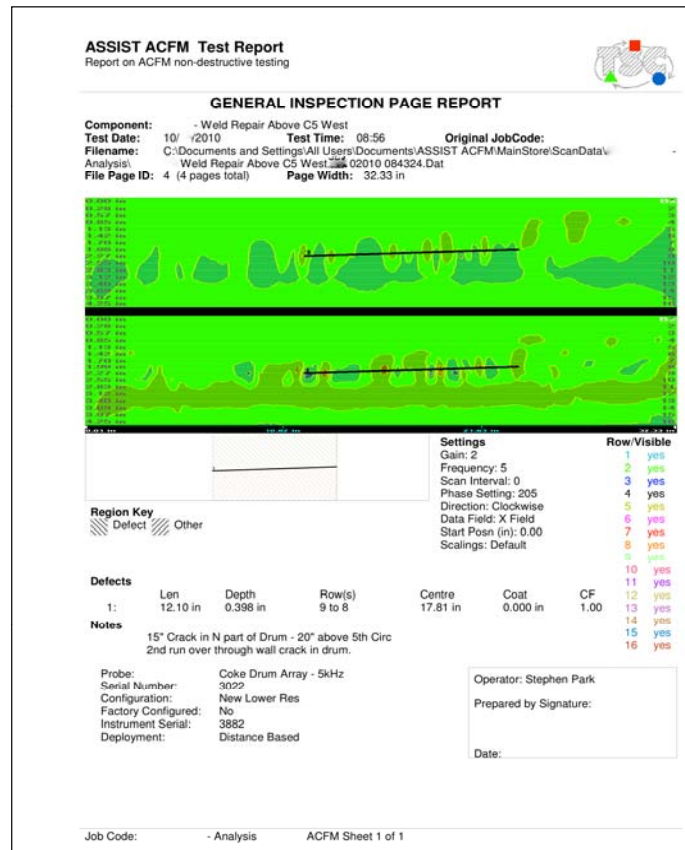194.4 deg

Field Trial Results

- October 2010
  - Refinery in Canada
  - Drum was out of service (crack repair)
  - Swing stage built inside drum – ACFM probe & crawler driven across known, verified indications
  - Collect data & correlate findings with existing indications (correlated with grind out depths at indication sites)

Field Trial – crawler on drum wall

GENERAL INSPECTION PAGE REPORT

Component: - Weld Repair Above C5 West
Test Date: 10/ /2010   Test Time: 08:56   Original JobCode:
Filename: C:\Documents and Settings\All Users\Documents\ASSIST ACFM\MainStore\ScanData\
Analysis\   Weld Repair Above C5 West   02010 084324.Dat
File Page ID: 4   (4 pages total)   Page Width: 32.33 in

Settings	Row/Visible	
Gain: 2	1	yes
Frequency: 5	2	yes
Scan Interval: 0	3	yes
Phase Setting: 205	4	yes
Direction: Clockwise	5	yes
Data Field: X Field	6	yes
Start Posn (in): 0.00	7	yes
Scalings: Default	8	yes
	9	yes
	10	yes
	11	yes
	12	yes
	13	yes
	14	yes
	15	yes
	16	yes

Region Key
Defect   Other

Defects

	Len	Depth	Row(s)	Centre	Coat	CF
1:	12.10 in	0.398 in	9 to 8	17.81 in	0.000 in	1.00

Notes
15" Crack in N part of Drum - 20" above 5th Circ
2nd run over through wall crack in drum.

Probe: Coke Drum Array - 5kHz
Serial Number: 3022
Configuration: New Lower Res
Factory Configured: No
Instrument Serial: 3882
Deployment: Distance Based

Operator: Stephen Park

Prepared by Signature:

Date:

Job Code: - Analysis   ACFM Sheet 1 of 1

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Analysis – Field Results

- **Repeatability** - same area, examined multiple times, should produce near identical results when examined by the same analyst
  - Of 3 areas where multiple readings were taken (1 x 4, 2 x 2 readings), the maximum difference was 0.098" and the average (using the max) was 0.059" in crack depth

- **Internal Consistency -** same data is analyzed by different trained users the results should be similar
  - Of 11 matching readings, average difference was 0.036", maximum was 0.084" in crack depth

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Analysis – Field Results

- **External Consistency -** When defects are analyzed by another technique, results should be close, with allowances for limitations of each technique in specific situations
  - Of 7 areas with comparable results, the average difference was 0.063" in crack depth
- **Reliability -** No defects of a specific minimum size should be missed. For coke drums a starting point is defects longer than 0.75 inches and deeper than 0.1 inches.
  - Other than very short (< 0.5") point defect flaws, no defects were missed. Some shallow defects were reported where no LDP was present.
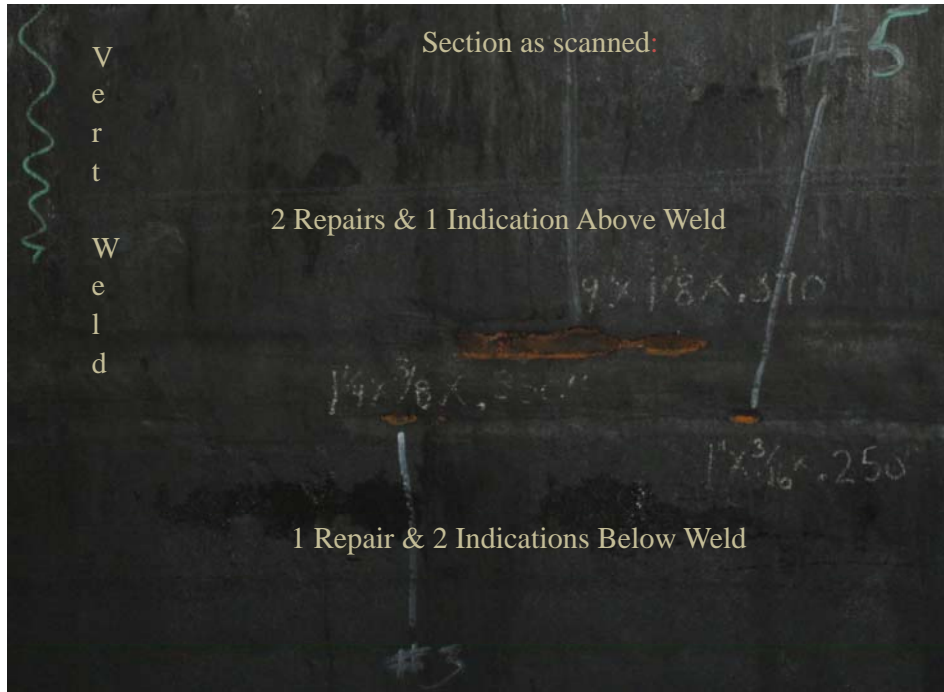 - One defect was reported as 0.340" instead of 0.110" in depth due to its proximity to a repair.

Further Verification – March 2012

- March 2012 – refinery in Canada
- Collect more field data and validate different types of crack indications
- Went into drum on scaffold with crawler and collected more data
- Specifically effects of large indications mixed with weld repairs – what works?
- Other UT data compared to ACFM – in progress

Client identified area

Section as scanned:

2 Repairs & 1 Indication Above Weld

1 Repair & 2 Indications Below Weld

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CIA results

Section after sandblasting:

2 Repairs & 1 Indication Above Weld

1 Repair & 2 Indications Below Weld

Page	Defect ID	Defect Length	Defect Depth	Probe Rows	Inches to Defect Start	Client Identifier	Client Findings	Meas ured Depth	ACFM / Measure Delta
8	28	2.84	0.87	12	19.06	C303	1.25" long x .375" wide spall	0.282	-0.195
8	8	9.43	0.324	5	14.22	C304	10" long by 1.125 wide spall	0.380	-0.057
8	11	9.43	0.381	8	14.78	C304	10" long by 1.125 wide spall	0.380	0.601
8	30	1.27	0.86	11 to 12	23.93	C305	1.0" long x .183" wide spall	2.35	-0.149

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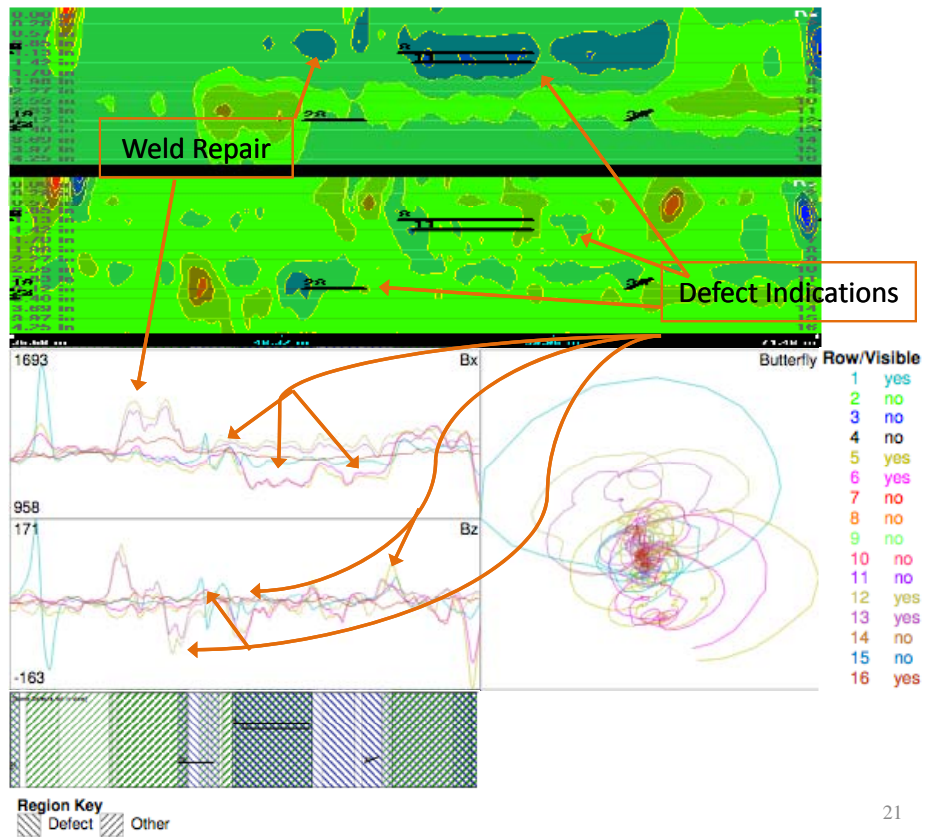
Results – Lessons learned

- Able to extract useful information even in repair areas which are inherently difficult to inspect with any technique due to differential metallurgy, inclusions, undercut and general roughness.

- Need for good visuals in these areas so drum cleaning should be emphasized in areas where known weld repairs have been completed.

- ACFM is a viable method for evaluating crack type indications internally

- No technique is uniquely qualified to inspect under all conditions.

Applying ACFM to Coke Drums

Candidates for ACFM:

- Mid life stage drums – starting to see bulges and crack type indications

- Drums with visible crack type indications (after verification by video inspection)

- Drums that have crack type indications that are not in areas of repair (affected by different metallurgy/repair methods)

- Stress cracking of the cladding – cracks beyond that?

- Shutdown of drum is not an option – need verification first and need it fast

- Planning for further repairs - pre-turnaround planning

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Summary

- CIA has a long & successful track record for developing & implementing innovative technologies for coke drums

- ACFM is a work in progress – industry acceptance & experience

- "Screening tool" – used to verify surface breaking defects

- This is the first step – quick, remote, non-intrusive

- Robotic crack detection is next breakthrough technology that will enhance drum knowledge

CIA

ACFM Development

- Industry contributors to this development:

  - Mechanical Integrity (PetroChem Inspection Services)
  - TSC Inspection Services
  - ConocoPhillips
  - Chicago Bridge & Iron
  - Flint Hills Resources
  - Suncor Energy

CIA – Coke Drum Management through Knowledge

www.cia-inspection.com