

## Coke Drum Workshop



### AUT TOFD Inspection of Coke Drums

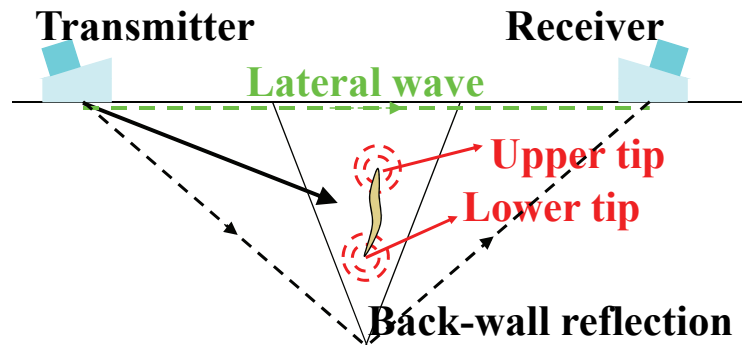
- David Bajula    Houston, Texas
- Director – Advanced NDT Services



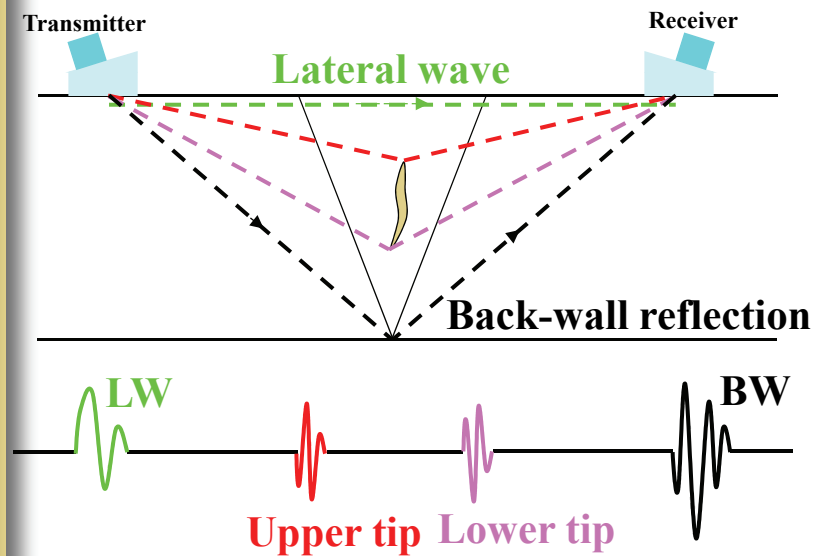
Typical Coke Drum, bulges and all, does not restrict our unique TOFD inspection.



## Typical TOFD Technique



## TOFD A-scan signals

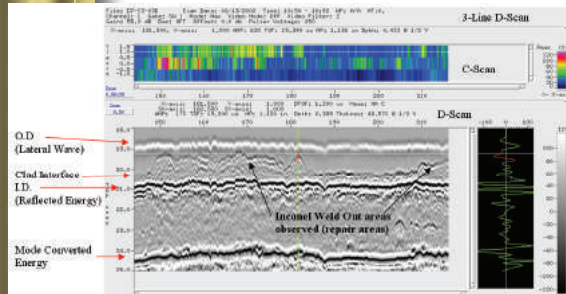


# AUT – Basic TOFD Technique

- Lateral Wave
- Longitudinal Wave (Clad & I.D. response)
  - Clad interface well defined.
- Mode Converted Energy (Shear)

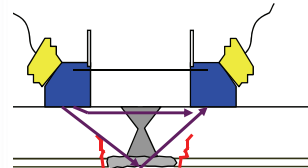


AUT System

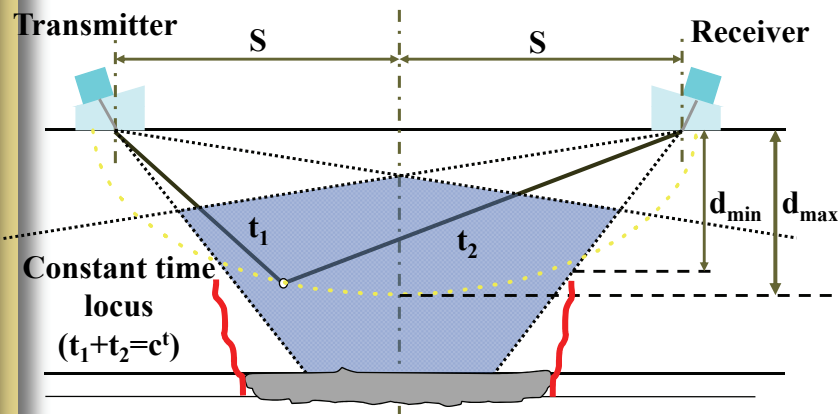


The first signal indicates the lateral wave that travels under the O.D. surface; the second represents the reflected energy from the clad interface (Inconel) and the third is the reflected energy to the I.D. surface. The fourth (last) signal is mode converted energy (shear) responses from the I.D. surface and is seldom used in the evaluation.

Essentially, the I.D. & O.D. responses establish the basis for TOFD with the volume of material saturated with sound resulting in a new full-volume examination using spectral reflection and tip diffraction signals to locate and size flaws.



## Defect position uncertain with single stroke scan



### In practice:

Maximum error on absolute depth position is within 10%.

Mistakes include NOT doing a multi-pass scan!

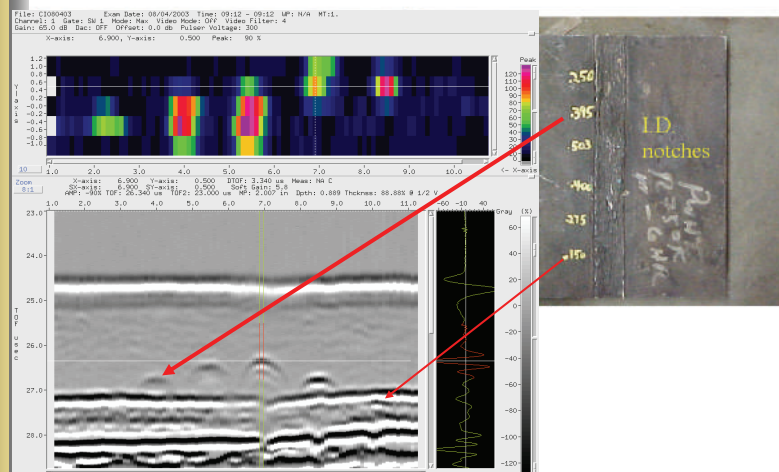
Caution for small defects situated at the back-wall or confined to the cladding.

[illegible][illegible]

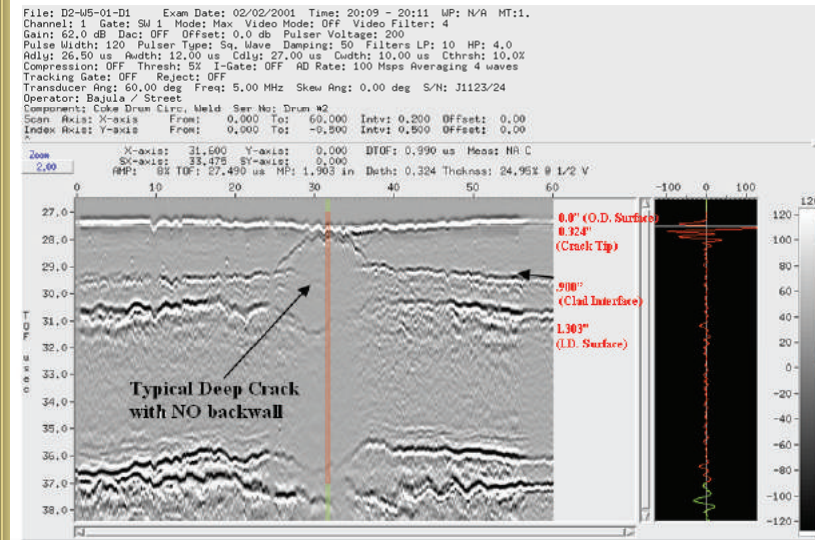
### Moderate Cracking

## Front (O.D.) Surface

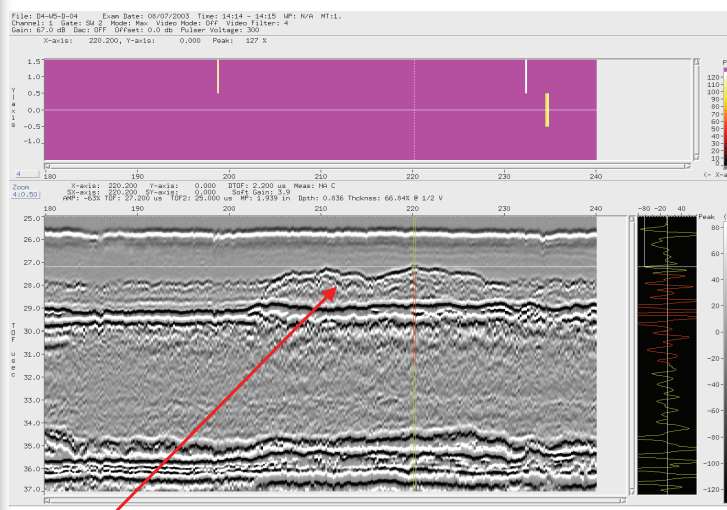
Back (I.D.) Surface



## Deep crack detected



Perfectly GOOD weld (no cracks) however almost ALL manual UT shearwave attempts will mistake this as a crack!



The above is a previous I.D. repair most likely welded out with stainless or inco.



# Even Shallow cracks are detected

## Monitoring Exams

A good AUT program is crucial for successful monitoring.

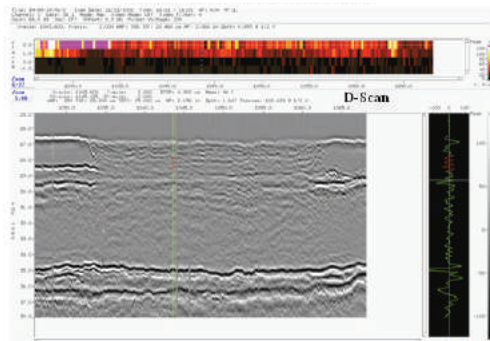
The image displays two AUT monitoring results. The top image is labeled 'Feb-03 Data' and the bottom image is labeled 'Aug-03 Data'. Both images show a cross-section of a pipe with various interfaces and a crack. The crack is located at the O.D. (Outer Diameter) and Inco repair interface. The Aug-03 image also shows a crack at the Roll bond clad interface. The images are labeled with 'O.D.', 'Inco repair interface', 'Roll bond clad interface', and 'I.D.' (Inner Diameter). The crack is labeled 'Crack (Top of)'.



**Inco weld repair from O.D. surface.**

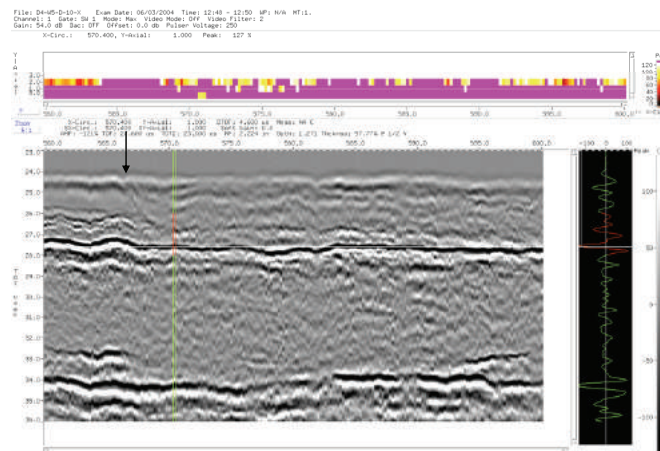
**Insulation ring is just barely out of the way**

**There is NO problem in scanning the Inco repairs or even detecting new cracking in the inco repairs!**



**The image reflects a 100% weld out from O.D with inco.**

**Scan data of an Inco Repaired Weld after several cycles...2 months.**

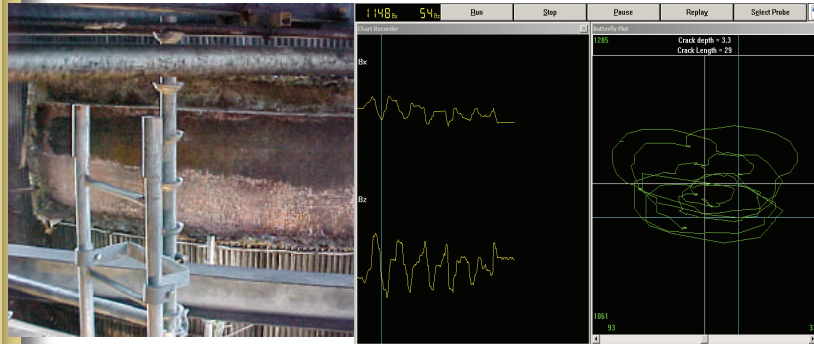


[illegible]

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## ACFM – For O.D. Cracking



Cracks are usually monitored until propagation approaches critical flaw depth or next T/A activity.

On-stream Inspection is paramount to the operation & profitability of a Coker unit.

- The AUT examinations can be performed without the usual downtime and between cycles with only minimal support.

### COKEO 6 DRUM SWITCHING SCHEDULE

| DATE        |    | DRUM 1    | DRUM 2      | DRUM 3  | DRUM 4      | DRUM 5    | DRUM 6      |
|-------------|----|-----------|-------------|---------|-------------|-----------|-------------|
| WED         | 0  | Quench    | Coking      | Warm Up | Coking      | Decoke    | Coking      |
| 2/11/2004   | 1  | Quench    | Coking      | Warm Up | Coking      | Decoke    | Coking      |
|             | 2  | Drain     | Coking      | Switch  | Switch      | Decoke    | Coking      |
|             | 3  | Decoke    | Coking      | Coking  | Strm. Strip | HU/PRG/PT | Coking      |
|             | 4  | Decoke    | Coking      | Coking  | Quench      | Warm Up   | Coking      |
|             | 5  | Decoke    | Coking      | Coking  | Quench      | Warm Up   | Coking      |
| Weld #6     | 6  | Decoke    | Coking      | Coking  | Quench      | Warm Up   | Coking      |
|             | 7  | Decoke    | Coking      | Coking  | Quench      | Warm Up   | Coking      |
| Increase    | 8  | HU/PRG/PT | Coking      | Coking  | Drain       | Switch    | Switch      |
| Drain Cycle | 9  | Warm Up   | Coking      | Coking  | Drain       | Coking    | Strm. Strip |
| 1 hour to   | 10 | Warm Up   | Coking      | Coking  | Decoke      | Coking    | Quench      |
| allow TOFD  | 11 | Warm Up   | Coking      | Coking  | Decoke      | Coking    | Quench      |
|             | 12 | Warm Up   | Coking      | Coking  | Decoke      | Coking    | Quench      |
| Weld #4     | 13 | Switch    | Switch      | Coking  | Decoke      | Coking    | Quench      |
|             | 14 | Coking    | Strm. Strip | Coking  | HU/PRG/PT   | Coking    | Drain       |
|             | 15 | Coking    | Quench      | Coking  | Warm Up     | Coking    | Decoke      |

### What is required by you:

- 1) Access to the welds
  - 1) Scaffolding
  - 2) Insulation Removal
- 2) Surface Preparation
  - 1) One time power buffing usually lasts for several exams
- 3) Expectations
  - 1) What is your repair threshold...i.e. % depth, length into carbon, clad cracking?, etc.
- 4) Time Windows for Inspections
  - 1) Typically right after quench, pause for drilling the pilot hole and then during the drill including up to the preheat
- 5) Permit, 110V Power and Water source
  - 1) Typically safe work or hot depending on plant.

### What you get!

- 1) Final Report with FULL details of cracking
  - 1) 75% confidence in cracking observed in the cladding
  - 2) 90% confidence in cracking up to .050" into the C/S
  - 3) 98% confidence in cracking .050"-.100" into the C/S
  - 4) 100% confidence in cracking >.100" into the C/S.
- 2) Detailed TOFD Images
  - 1) TOFD images for ALL scans...not just sample scans
  - 2) Full crack depth profiles in the images
- 3) ACAD
  - 1) ACAD showing scaled locations for all cracks!
- 4) Comprehensive Crack Table – full details
- 5) Ability to monitor cracks “on the go”
  - 1) Minimizing repairs of every superficial crack for a tremendous cost savings.

# Typical Field Report

## ACUREN

### ADVANCED UT EXAMINATION REPORT

| REPORT NO. | CLIENT | UNIT | CLIENT JOB | LIJ-JOB NO. | DATE            | PURCHASE ORDER |
|------------|--------|------|------------|-------------|-----------------|----------------|
| AUT-999    | Client | Unit | N/A        | AUT-999     | January 1, 2009 | 4501793771     |

| COKE DRUM | UT PROCEDURE(s) | REV | ACCEPTANCE CRITERIA                           |
|-----------|-----------------|-----|-----------------------------------------------|
| #7        | AUT-3           | 0   | ASME SEC. I, Part II, Div. 5, Subsec. NB-3200 |

| WELDS   | MAT'L                 | DIA. | NOM. T <sub>g</sub> | SURFACE COND. | SURFACE PREP  | ACCESS   |
|---------|-----------------------|------|---------------------|---------------|---------------|----------|
| #3 & #4 | 1/4" Chrome / 55 clad | 18"  | 11.70" / 100" Clad  | Flash         | Power Buffing | Scarfing |

**INTRODUCTION**

Automated (AUT) examinations were performed using TOFD techniques. The purpose of the examinations was to determine extent of potential cracking in the base material and provide a baseline AUT examination or map of eminent flaws.

The TOFD technique is capable of detecting and sizing flaws with the high accuracy ( $\pm 0.39"$  thruwall) and has the distinct advantage high productivity. Flaws can usually be characterized with TOFD however, at times Pulse-Echo and/or Shearwave examinations are used to provide additional classification. In this case, the TOFD exam serves as a "Baseline" examination to be compared with future examinations.

**EXTENT OF EXAMINATION**

Essentially, a 100% examination was performed with an automated scanner for both Circ. Welds #3 & #4. The examinations were performed as a RASTER Line-Scan (D-Scan) to accommodate the wide Inconel weld that is typical on the I.D. of a Coke Drum. Additionally, RASTER B-Scans were performed at selected locations.

**SUMMARY**

For the data collected, the TOFD indicated no SEVERE cracking ( $>50\%$  thruwall &  $>12"$  in length). However, small areas of less severe cracking were observed to propagate into the base material. Additionally, numerous cracklike indications were observed. Most were either associated with previous weld repairs or cracking indications that were limited to the cladding material or Inconel weld. Note that the TOFD energy was focused near the clad interface to enhance detection capability of clad cracking, which was limited.

Many previous repairs were observed and appear to be associated with a material interface that would be expected for an Inconel weld to base material, i.e. repairs welded out with Inconel. These are easily identified in the D-scan displays. The detection of cracking coming out of these repairs would be limited with the best chance for detection being the additional length.

See attached AUT Technique Sheet, AUT Scan Sheets and AUT Data for additional information.

| TECHNICIAN(s) | LEVEL | DATE         | APPROVED BY  | TITLE | DATE         |
|---------------|-------|--------------|--------------|-------|--------------|
| D. Bajula     | III   | Jan-01, 2009 | David Bajula | III   | Jan-01, 2009 |
| N. Ward       | II    | Jan-01, 2009 |              |       |              |

## ACUREN

### AUT CALIBRATION & TECHNIQUE SHEET

| REPORT NO. | CLIENT | UNIT | CLIENT JOB | LIJ-JOB NO. | DATE         | PURCHASE ORDER |
|------------|--------|------|------------|-------------|--------------|----------------|
| AUT-999    | Client | Unit | N/A        | AUT-999     | Jan-01, 2009 | 4501793771     |

| COKE DRUM | UT PROCEDURE(s) | REV | ACCEPTANCE CRITERIA                           |
|-----------|-----------------|-----|-----------------------------------------------|
| #7        | AUT-3           | 0   | ASME SEC. I, Part II, Div. 5, Subsec. NB-3200 |

| COMPONENT | MATERIAL                   | NOMINAL T <sub>g</sub> | SURFACE COND. | SURFACE TEMP. | INSPECTION SURFACE (S) |
|-----------|----------------------------|------------------------|---------------|---------------|------------------------|
| Weld      | 1/4" Chrome / Inconel Clad | 11.70" / 100" Clad     | Flash         | Power Buffing | Scarfing               |

| TECHNIQUE | TOFD | C-Scan | D-Scan | B-Scan | REFERENCE REFLECTOR |
|-----------|------|--------|--------|--------|---------------------|
| TOFD      | Yes  | Yes    | Yes    | Yes    | 1D Notches          |
| C-Scan    | Yes  | Yes    | Yes    | Yes    | 1" Deep 1/16" SDH   |
| D-Scan    | Yes  | Yes    | Yes    | Yes    | 1" Deep 1/16" SDH   |
| B-Scan    | Yes  | Yes    | Yes    | Yes    | 1" Deep 1/16" SDH   |

**COMMENTS:** The examinations are performed as the TOFD REFERENCE sensitivity; gain added as necessary to accommodate surface condition changes.

**UT SCOPE:** MFG. Anders      **MODEL:** IPC SN-DAS-101      **SCANNING TECHNIQUE:** ☒ LINE SCAN      ☒ RASTER

| TRANSDUCER | TYPE/MODE    | SINGLE/DUAL | SIZE | FREQUENCY (MHz) | ANGLE   | SN           |
|------------|--------------|-------------|------|-----------------|---------|--------------|
| Megasonics | Longitudinal | TOFD        | 3/8" | 5.0             | 80°/80° | J-11232-1124 |

**Basis for Technique**

This technique sheet documents the technique and basis for performing UT flaw evaluation from the O.D. surface when approved by the Level III and/or Client prior to examination.

**Basis for technique:** ☐ Calibration Block (SDH's / Notches)      ☒ Mockup (Coke Drum Block) (Notches)

Note: Inconel weld in FLUSH

☒ TOFD      ☐ AUT or MUT Shearwave & Longitudinal 0°

**COMMENTS:**

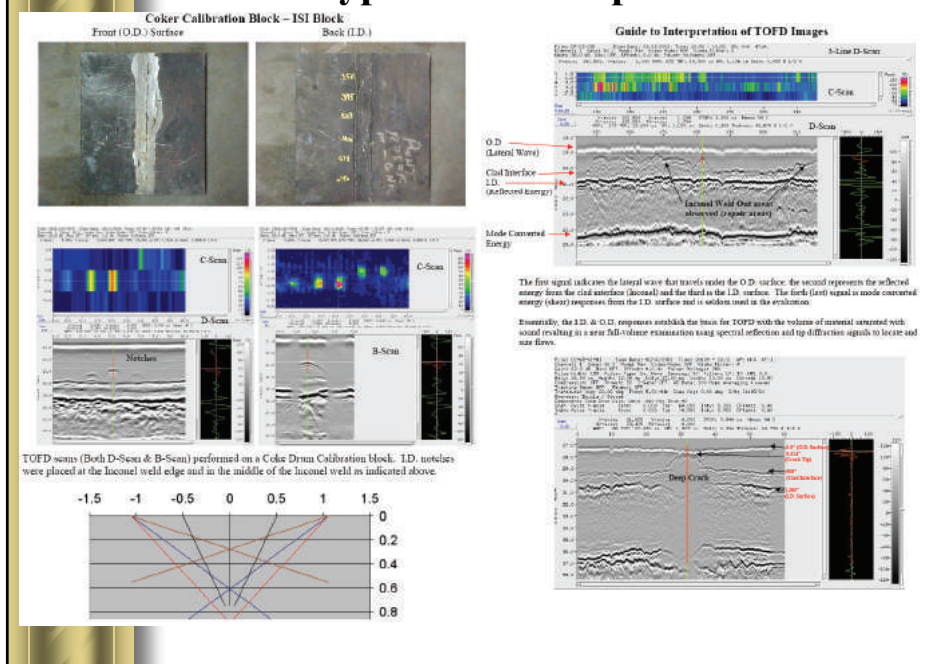
The primary technique for this inspection was TOFD executed as a raster scan.

**TECHNICIAN(s)** Bajula / Blanshan      **LEVEL(s):** III / II      **DATE:** Feb-13, 02

**APPROVED BY:** David Bajula      **LEVEL:** III      **DATE:** Feb-13, 02

**CLIENT APPROVAL:**      **TITLE:**      **DATE:**

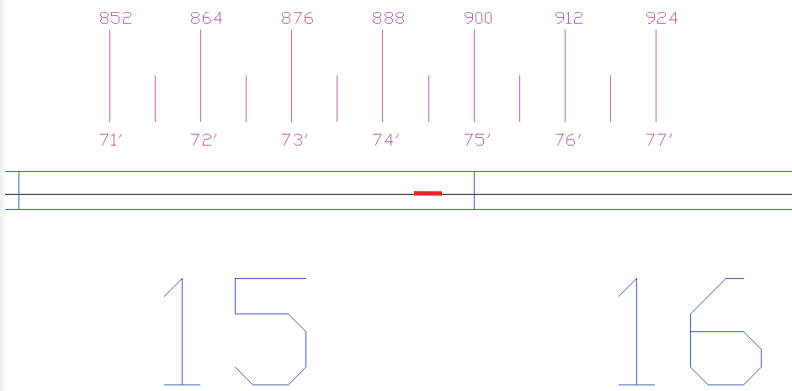
# Typical Field Report





# Typical ACAD Drawing of Drum

Drum 4  
Weld 4



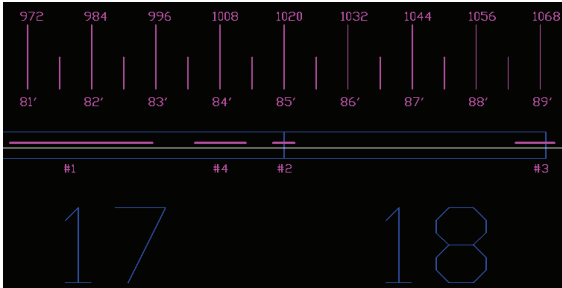
Longview Inspection  
2/29/2004

TOFD Crack Detail Summary  
Coke Drum: D4-W5 (02-26-04)

D. Bajula  
Level III

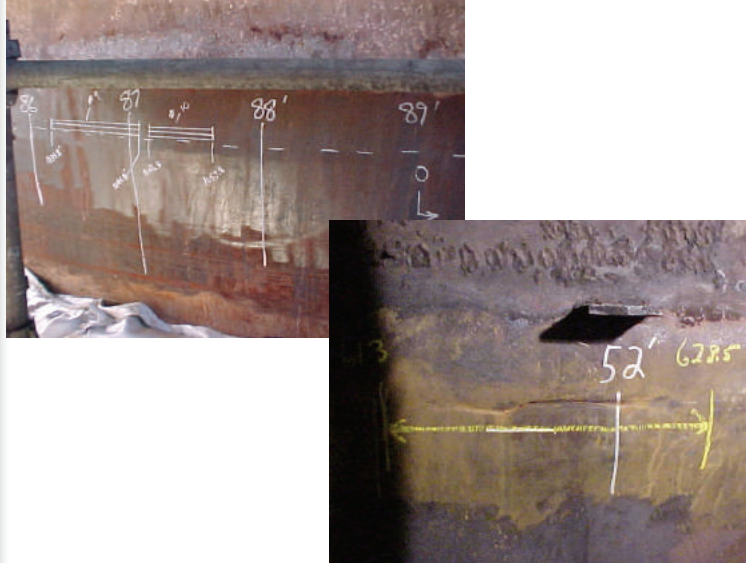
| Crk. No. | Location on Drum | AUT Exam File Name    | Location from 0° - North |         |           |         | Thick. Base Mat'l. (E) | Total Thick. (T) | TOFD Depth from O.D. (C) | Crack Depth from I.D. (T-C) | Crack Depth in Base Mat'l. (E-C) | Disposition / Comments      |
|----------|------------------|-----------------------|--------------------------|---------|-----------|---------|------------------------|------------------|--------------------------|-----------------------------|----------------------------------|-----------------------------|
|          |                  |                       | X - Circumferential      |         | Y - Axial |         |                        |                  |                          |                             |                                  |                             |
|          |                  |                       | Start                    | Stop    | Size      | Weld CL |                        |                  |                          |                             |                                  |                             |
| 1        | Northeast        | D4-W5-D-17            | 968.6"                   | 996.4"  | 26.6"     | 1.0"    | 0.945                  | 1.177            | 0.538                    | 0.639                       | 0.407                            | Previous Data               |
|          |                  | D4-W6-D-17-M1         | 969.6                    | 996.6   | 27.0"     |         | 0.945                  | 1.177            | 0.431                    | 0.746                       | 0.514                            | Crack Growth                |
|          |                  |                       |                          |         | 0.4"      |         | 0.0"                   | 0.0"             | -0.107"                  | 0.107"                      | 0.107"                           | Delta Difference            |
|          |                  | Between foot markers: |                          | 80.80'  | 83.05'    | 2.22'   |                        |                  |                          |                             |                                  |                             |
| 2        | North            | D4-W6-D-17 & 18       | 1018.0"                  | 1022.0" | 4.0"      | 1.0"    | 0.915                  | 1.194            | 0.726                    | 0.468                       | 0.189                            | Previous Data               |
|          |                  |                       | 1014.6"                  | 1022.4" | 7.8"      |         | 0.915                  | 1.194            | 0.668                    | 0.526                       | 0.247                            | Crack Growth                |
|          |                  |                       |                          |         | 3.6"      |         | 0.0"                   | 0.0"             | -0.006"                  | 0.006"                      | 0.006"                           | Delta Difference            |
|          |                  | Between foot markers: |                          | 84.55'  | 85.20'    | 0.33'   |                        |                  |                          |                             |                                  |                             |
| 3        | North            | D4-W5-D-18            | 1063.4"                  | 1070.6" | 7.2"      | 1.0"    | 0.915                  | 1.104            | 0.714                    | 0.390                       | 0.201                            | Previous Data               |
|          |                  |                       | 1064.0"                  | 1071.4" | 7.4"      |         | 0.915                  | 1.104            | 0.720                    | 0.384                       | 0.195                            | Crack Growth                |
|          |                  |                       |                          |         | 0.2"      |         | 0.0"                   | 0.0"             | 0.006"                   | -0.006"                     | -0.006"                          | Delta Difference            |
|          |                  | Between foot markers: |                          | 88.67'  | 89.28'    | 0.60'   |                        |                  |                          |                             |                                  |                             |
| 4        | North            | D4-W6-D-18            | 1003.4"                  | 1012.8" | 9.4"      | 1.0"    | 0.915                  | 1.104            | 0.688                    | 0.416                       | 0.227                            | New Crack(s) (Intermittent) |

Note: Total thickness is based on TOFD data, not 0 Deg. Crack depth in base material based on an approximated clad interface as the inco repair tends to mask the clad transition.





Details for crack locations transposed onto drum to facilitate repairs.



Any Questions??????????



1. All Coke Drums CRACK...it's not if, it's WHEN?
2. Pre T/A inspection minimizes the unknowns
3. Continuous inspections allow for better remaining life assessments.
4. All Drums can be reliably inspected with TOFD.
5. History suggests that O.D. repairs can be used to minimize downtime and eliminate entry – (subject for a different presentation)