LASER MAPPING OF COKE DRUMS – WHAT HAS BEEN LEARNED?

BY

CRAIG DUNHAM, RICK CLARK
CIA INSPECTION INC. – HANNON, ONTARIO, CANADA

PREPARED
FOR THE

AIChE SPRING NATIONAL MEETING

March 1998
New Orleans, LA

TABLE OF CONTENTS

LIST OF FIGURES

LASER MAPPING OF COKE DRUMS – WHAT HAS BEEN LEARNED?

ABSTRACT

This paper describes a variety of uses of dimensional inspection data that have been implemented by the oil refining industry to improve the overall performance and reliability of delayed coke drums. The current state of the contract inspection service that was developed to remotely inspect the internal surfaces of delayed coke drums is presented. Examples of the trends and variations observed from evaluating the data generated through internal inspections of over 120 delayed coke drums are provided.

INTRODUCTION

This paper is arranged into three sections. The first section outlines the laser based inspection technology that was employed to collect the profile data for the vessels in the analysis. The second section describes examples of trends and variations identified from evaluating the data generated from these inspections, and the third section describes a variety of uses of the inspection data that have been implemented by industry to improve the overall performance and reliability of delayed coke drums.

DESCRIPTION OF THE COKE DRUM INSPECTION SYSTEM

CIA Inspection Inc., (CIAI) offers a remote coke drum inspection service that can inspect the interior of on-line coke drums without requiring blinding or scaffolding. The inspection system is designed to remotely perform two key functions as follows:

- measure the drum internal surface contour with a laser ranging instrument and record deformations or "bulges". This replaces manual methods of holding long straightedges vertically along the drum wall and measuring distances to the wall from the straightedge.

- record a video image of the internal surface of the vessel to assist in the interpretation of the bulge map.

CIAI's **REMOTE COKE DRUM INSPECTION SYSTEM** is designed to be deployed into an empty coke drum while attached to the existing drill stem. The system can measure internal surface deformation and perform a detailed video inspection in (4) four hours. Use of this remote sensor eliminates the need to blind the drum and erect scaffolding as required for manual internal inspection. This system was designed to replace the traditional manual method of periodically entering the vessel to map the surface profile with a straight edge or wireline.

As well as automating the data collection process, the **REMOTE COKE DRUM INSPECTION SYSTEM** greatly simplifies the data reduction and analysis typically required in a comprehensive predictive maintenance program. Drum surface profile data obtained during the remote inspection is visualized using image-processing software to develop color **"bulge maps"**. Section views of any portion of the scan can be plotted for easy evaluation of areas of concern. The software allows subsequent scans to be easily compared by overlaying the profiles of the two scans on the same profile map. Comparisons of current scan profiles with historic data allow inspectors to readily track changes in drum profile. By mapping and trending the rate of change in drum profile over time, inspection personnel can identify and monitor failure prone areas externally without disrupting production.

Another feature of the Inspection Service is the **VIDEO SURVEY**. Every portion of the drum that is scanned by the laser is also video taped. The standard VHS videotape has the elevation and azimuth information permanently recorded on it, allowing easy orientation when viewing the information at a later date. This feature allows inspection personnel to remotely identify visual changes in the drums condition as well as monitoring repair areas, nozzles, thermal wells and any other feature of the drum that can be seen from traditional scaffolding.

CIAI's remote inspection method has significant advantages over conventional manual inspection methods:

- eliminates the need for entry into a coke drum. This removes the need to blind the drum, saves the scaffolding cost, reduces or eliminates down time and lost production, and improves worker safety.

- increases the number of drum inspection points by completely scanning the vertical surfaces of the entire vessel on a 1" grid. Improves the overall quality of measurements by utilizing a consistently accurate (1/8") laser range finder.

- shortens the inspection time to hours from days. This permits internal inspections to be performed on-line, between coking cycles, minimizing or eliminating production losses.

- automates the collection and storage of inspection data. Much more contour data can be collected and stored than is practical with manual methods.

- provides consistent data-reduction methods to allow quantitative information to be extracted from the vessel scan in a form that inspection personnel can readily interpret.

- allows accurate, historical comparisons of subsequent vessel scans to identify and track changes in drum profile.

- provides the remote capability to visualize the vessel surface with a high resolution video camera operating through a **14X zoom lens** picking up visual features such as **"stretch marks", "orange peel" "striations", cladding defects**, and many other informative features of the vessel surface.

Figure 1 shows the general arrangement of all elements of the inspection equipment. Note the division between hazardous and non-hazardous classifications for the site equipment.

INSPECTION RESULTS PROVIDED

DRUM SCAN DATABASE

At the completion of the site inspection, the image file database for each scanned drum is loaded into one of the site's PCs. CIAI's, **Windows based "DRUMVIEW"** software is loaded into the computer allowing the operator to access the image files for each scanned vessel. The **"DRUMVIEW"** software gives the operator a wide range of tools that can be used to interpret the condition of the vessel. Comprehensive, on-line help, covering all features of the software, is provided.

BULGE MAP

Laser distance measurements (ranges) to an accuracy of 1/8" are collected on a 1" X 1" grid over the entire vertical surface of the drum (between the tangent lines of the top and bottom drum sections). This range data is further processed by custom software to:

- "roll out" the drum cylinder to a obtain flat surface representation
- create a color visualization (contour map) of the drum, with bulge depths indicated
- add drum weld seam overlays to assist in the location and orientation of drum features

A single 8 1/2" X 11" color print of each scanned vessel is provided as a demonstration of the capabilities of the **"DRUMVIEW"** software. A typical color print is shown in Figure 2. Subsequent prints can be made with the **"DRUMVIEW"** software as necessary.

Figure 1 - General Arrangement of the Inspection System

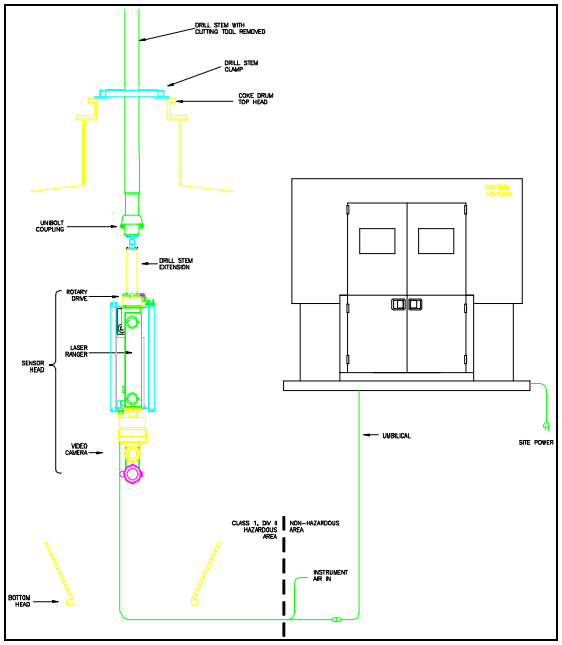
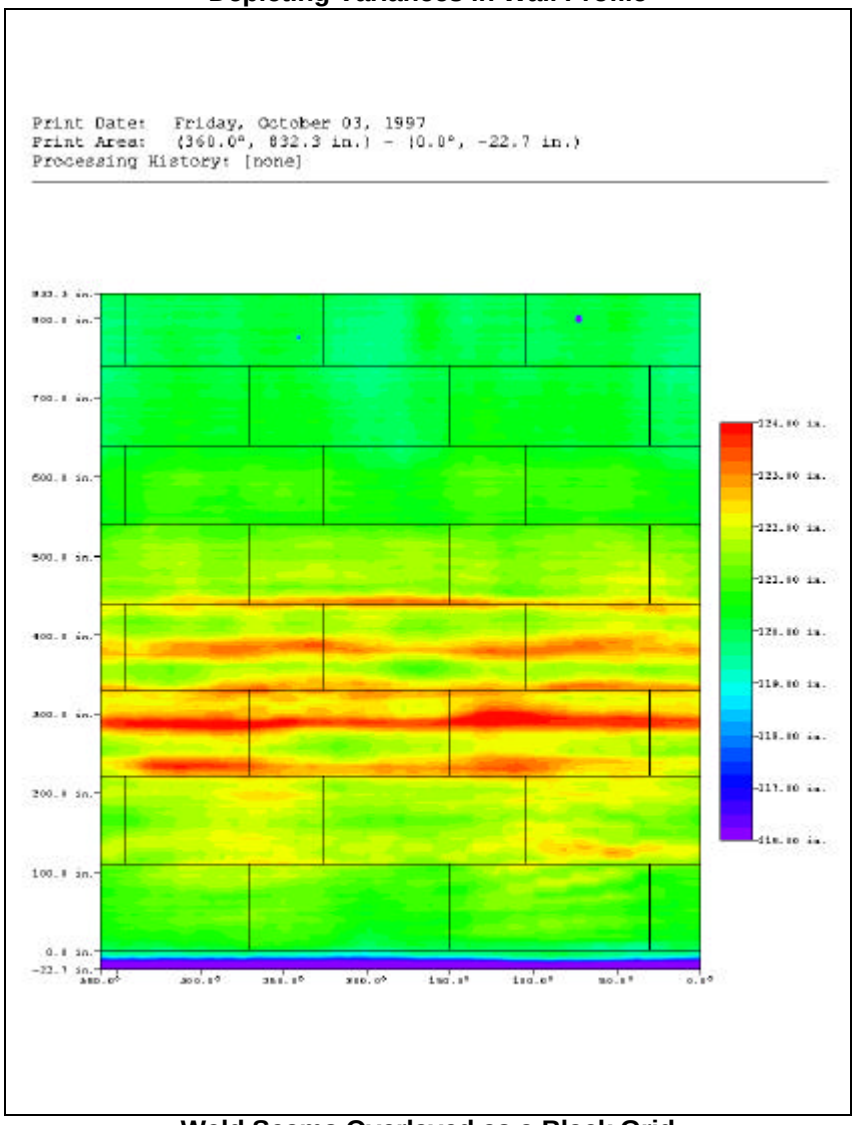


Figure 2 - Typical Color Contour Map of a Complete Coke Drum Depicting Variances in Wall Profile

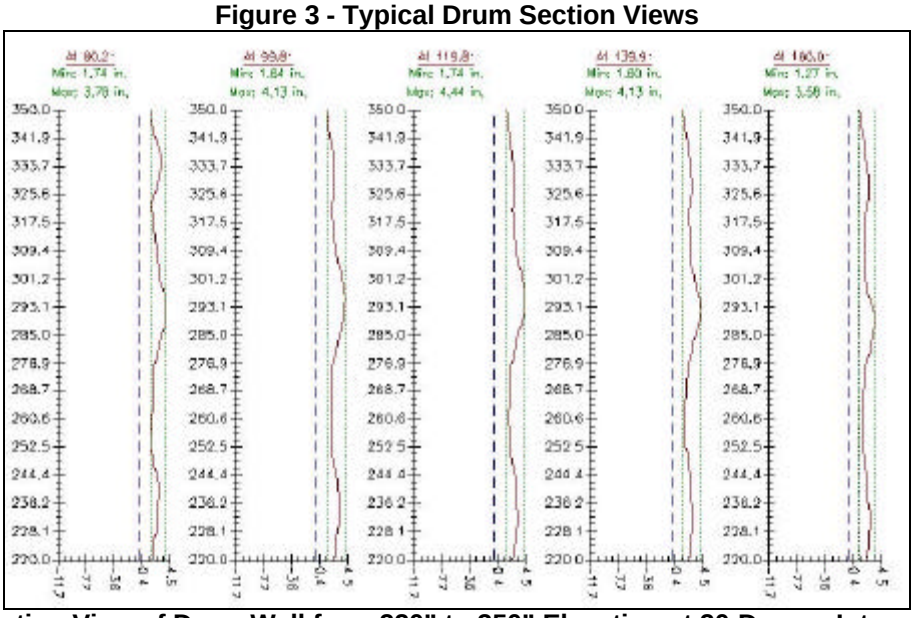


Weld Seams Overlayed as a Black Grid
Color Gradations Represent Variances in Radius of Drum

Another feature of "**DRUMVIEW**" is its ability to print out section views of any portion of the scan. A typical section graph is shown in Figure 3. Versatile software gives the operator the ability to select section lengths and orientations as necessary to fully detail any area of interest within the drum scan.

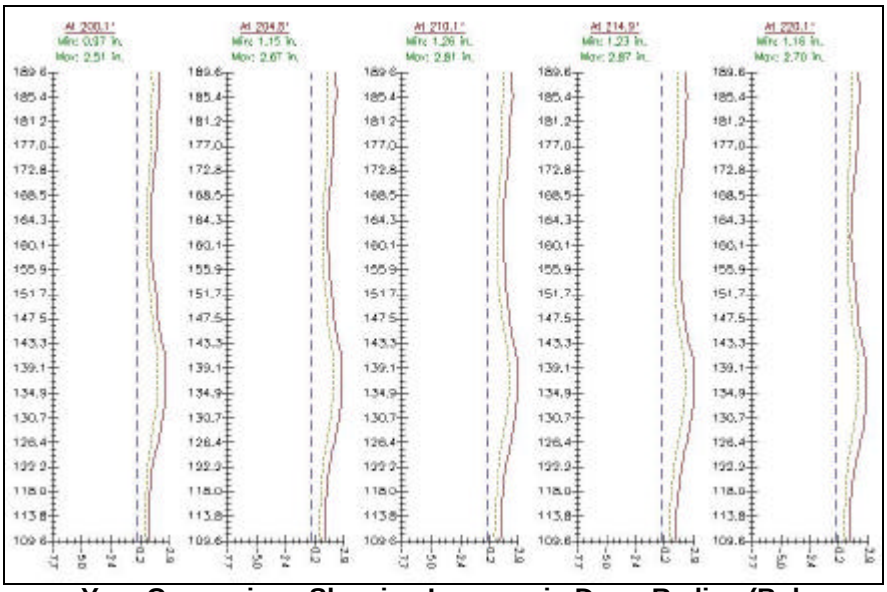
Subsequent scans of the same vessel at a later date, can be compared using custom software to evaluate changes in vessel deformations, as shown in Figure 4. In this way, inspection personnel can track changing conditions in the vessel profile.

Figure 3 - Typical Drum Section Views



Section View of Drum Wall from 220” to 350” Elevation at 20-Degree Intervals

Figure 4 - Typical Year-over-Year Section Comparison



Year over Year Comparison Showing Increase in Drum Radius (Bulge growth)

VIDEO SURVEY

The results of a color video scan of the drum interior are documented on VHS tape. Each videotape is marked with the drum number and date of the video scan. The tape is also encoded with both the vertical elevation of view as well as the angular orientation of view (in degrees from reference point).

Each video scan will become part of the permanent record of the conditions of the coke drum and can be used to assist in the interpretation of the bulge scan map. The camera used in making the video scan has a 14X zoom capability and can provide extremely detailed magnifications of the surface of the drum wall. Depending on the time allowed in the vessel, detailed scans of particular areas of interest can be recorded and stored permanently for future review.

OBSERVATIONS AND TRENDS

From over 120 coke drum inspections, CIAI has been able to identify a number of significant trends in delayed cokers.

DIMENSIONAL CHANGES

BULGES

As is generally recognized, there is a wide variation in drum state throughout the industry. CIAI has scanned some vessels, in excess of 40 years old, which exhibit very little deformation or bulging. Other vessels, of much more recent construction, exhibit significant bulging (7-8% of radius), combined with rapid bulge growth over short time periods (9-15 months). In short, there appears to be no immediately apparent correlation between the vessel age and vessel condition.

CIAI strongly suspects that variables such as vessel construction, cycle times, operating practices such as pre-heat and quench rates and feed stock characteristics have a greater impact on how the vessel ages.

With respect to vessel construction characteristics, vessels appear to fall into several distinct categories – thin wall and thick wall drums. The thinner walled drums (typically with maximum plate thickness less than ¾") tend to exhibit more and "sharper" bulges.

A further distinction can be made between drums in which the weld has higher yield than the surrounding plate, and those in which the weld has lower yield than the surrounding plate. In the former case, the weld acts like a "girdle" around the circumference of the vessel, and bulging and deformation tends to occur in the plate material between the welds. In the latter case, the weaker weld material tends to result in bulging at, or very near, the welds. In the drums where bulging has been observed at or near welds, we suspect that poor post-weld heat-treating may result in weakening of the plate material directly adjacent to the weld seam, contributing to the tendency to bulge in these areas.

In situations where bulges have occurred near welds, the bulge profiles tend to be "sharper", since a significant radial distortion is present along a relatively short vertical wall distance. The steepness of the bulge gradient in these situations can result in stress concentrations in the wall material, with obvious implications on the possibility for failure in these areas.

In those drums where CIAI has done multiple scans, a comparison of the year-over-year results generally show that the apex of the bulge "grows" faster over time than the bulge tails. This phenomenon is evident in the year-over-year comparison profiles shown in Figure 4.

SWELLING

On most older coke drums CIAI has consistently observed a general "swelling" of the vessel diameter in the lower half to two-thirds of the drum, i.e., below the outage level. In these vessels, the top of the drum is typically close to the nominal drum diameter, while the lower portion exhibits overall diameter increases of several inches, resulting in the vessel having a "coke bottle" or "pear" shape. This overall diameter increase is quite independent of any localized bulges that may also be present, and are superimposed on the general swelling. It is interesting to note that this overall swelling cannot typically be detected by manual methods of measuring drum distortion.

OVALITY

Also in most older vessels, we have regularly observed "ovality" in the drum profile, particularly above the outage level. In these vessels, the drum's cross-section is no longer circular, but has become oval or elliptical in profile, with two sides moving in, toward the center of the vessel, and the other two sides moving out, away from the centerline. Again, this ovality cannot easily be measured by manual methods.

VISUAL INTERPRETATIONS

The detailed video provided by the inspection service is capable of identifying and documenting a wide variety of visual features. The capability of the camera systems allows the operator to "zoom in" on irregularities in the surface of the vessel wall. Cladding deterioration (shown in Figure 5), blistering, "stretch marks", striations and "orange peel" have all been identified with the camera system. Previously repaired areas, plugged nozzles, thermal wells and vapor lines can be visually

inspected with this system. The capabilities of the video system are shown by sample still photos in Figure 5, Figure 6, and Figure 7.

Figure 5 - Cladding Dis-Bonding

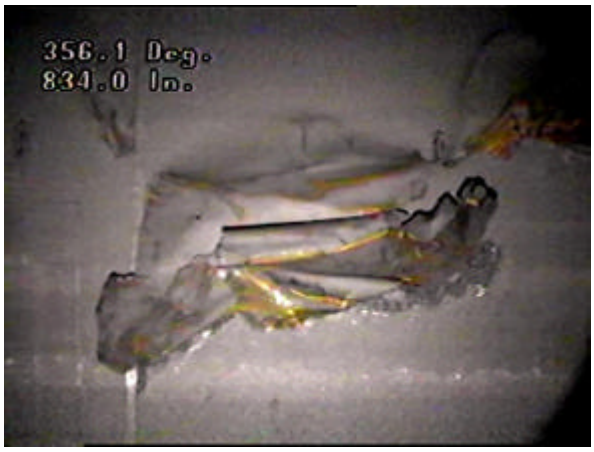


Figure 6 - Detail of Level Sensing Probe

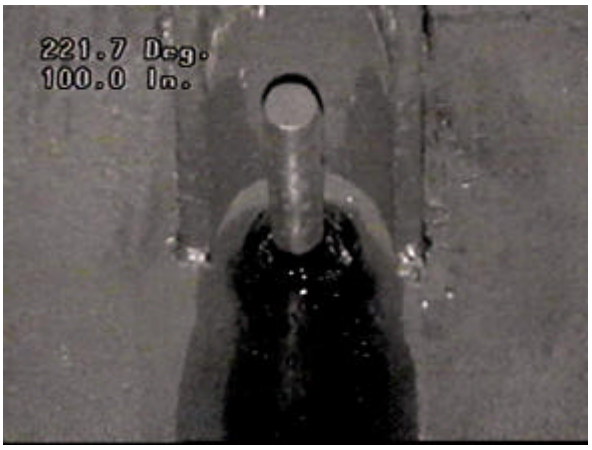
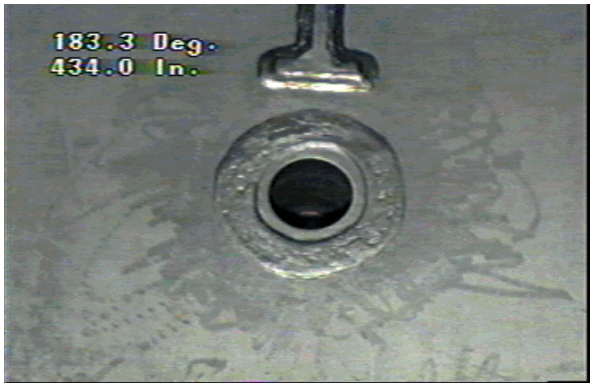


Figure 7 - Weld Detail around Pipe Inlet



USES OF THE DATA

Since the introduction of this innovative service, CIAI, working in conjunction with service providers to the industry, have developed a variety of tools and evaluative techniques, which build on the data collected by the inspection service.

BENCHMARKING

An important aspect of the service is its ability to establish a "Benchmark" or "Baseline" scan of the vessel dimensions, and then very precisely register subsequent scans to this initial data to track the rate of change of vessel profile over time. The precision afforded by the laser scanning technology enables very accurate comparison of year-over-year changes in vessel dimensions, with a confidence not possible with any manual measurement technique. This ability provides the end-user with powerful tools to determine where, and to what extent, the vessel is changing.

Initially CIAI's scans were all performed on drums that had been in service for many years, but as new drums have come on-line, the opportunity has arisen to scan drums before they have seen any significant deformation. This "as-built baseline" can be particularly useful to an operator as it identifies areas where built-in deformations might lead to future problems. It is interesting to note that some new drums have been found to have noticeable as-built imperfections even though they might meet design requirements on overall diameter and roundness.

TIME TRENDING OF PROFILES

Accurate tracking and trending of drum profiles over time is particularly important as the industry continuously pushes to increase production by shortening cycle times. This common practice results in increased stresses on the coke drums, leading to accelerated deterioration of the vessel. In some drums, CIAI has observed the same amount of diameter increase occurring over a 12-18 month period as had occurred over the entire previous life of the vessel (approximately 25 years). CIAI generally attributes this phenomena to increased stresses resulting from the shorter cycle times which these drums are now experiencing.

Determining the rate of deformation of the coke drums is a key requirement in a pro-active predictive maintenance program. With many drums in the industry approaching their end of life, this data is an essential input to formulating a remaining life estimate. Where the vessel is in its useful life depends primarily on the operating history. Since it is very difficult to correlate this history and the effect that it has on vessel condition, a more meaningful approach is to gauge how quickly it is deteriorating between subsequent laser scans. Comparative scans provide information on the rate of change of vessel profile and can be used to gauge the rate of deterioration. This deterioration rate can be theoretically extrapolated to determine retirement criteria for the operating vessel.

TURNAROUND MAINTENANCE PLANNING

Both the laser bulge map and the detailed video recorded by CIAI's inspection process are invaluable inputs to determining if further manual inspection is required during a turnaround or on an ad-hoc basis. The detailed video will often indicate areas of concern along weld seams, or around nozzles, vapor lines, and the like. The laser bulge map accurately determines those areas of greatest deformation, which can be further examined by traditional external NDE procedures.

Ideally, CIAI's inspection service may indicate that no manual inspection is required. Many refineries typically scaffold up the inside of their coke drums for manual internal inspections during major turnarounds. Use of CIAI's inspection service prior to turnarounds has, in many cases, indicated that the vessel condition is such that no entry into the drum for further inspection or repair is necessary. This results in significant cost and time savings during turnaround operations.

PATCH SIZING

In those situations where repairs or replacement of the drum's shell material is required, the precise dimensional data provided by the laser scan can be used to determine the extent of the distortion surrounding the area of interest. Since the shell is often deformed from the original fabrication through normal process operations, precise determination of the repair area dimensions can be derived from the laser map of the vessel profile. Utilizing this technique improves the quality of the repair and minimizes downtime, as the repair patch can be made in advance of the scaffolding, and will fit with minimal jacking, thereby minimizing stresses on both the repair area and the surrounding plate.

INPUT TO FURTHER ANALYSES

Determination of the location and extent of bulging is an important input into many other types of analyses that can be performed on coke drums. For example, the effective placement of strain gauges or thermocouples can be enhanced by using the laser bulge map information to identify failure prone areas prior to instrumentation. The location of this instrumentation can be made more effective with advance knowledge of the drum conditions.

Third-party firms are using the dimensional data from CIAI's laser bulge map to develop sophisticated finite element models of the real world vessel profile. This accurate information improves the theoretical model, aiding in the determination of stress profiles in the deformed vessel.

BALANCE OF LIFE MODELLING

The dimensional data provided by CIAI's service is expected to play an important role in determining the balance of vessel life. Tracking and trending the magnitude and rate of change of vessel profile over time will be used in conjunction with bulge rejection criteria, which is currently being developed, to provide an assessment of useful life remaining.

SUMMARY

CIA Inspection Inc. is part of an exciting new area of developing understanding of coke drum reliability. High fidelity, accurate dimensional measurement, and tracking of coke drum profiles, along with other state-of-the-art measurement and analysis tools, are contributing to improved reliability, and a better understanding of the operating cycle.

Additional benefits include the development of life-expectancy models, and the identification and location of failure modes on delayed cokers. The aim of all these efforts is to improve vessel reliability, which in turn improves operator safety and overall unit productivity. CIA Inspection Inc. is pleased to be part of this on-going effort within the oil refining industry to develop a greater understanding of delayed coke drum operation and performance.