NONDESTRUCTIVE TESTING OF WASTE DRUM INTEGRITY

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ABSTRACT

An investigation of methods for measuring the wall thickness of low level transuranic (TRU) waste drums revealed that the ultrasonic pulse echo method provided a rapid and accurate evaluation. An assessment based on 400,000 individual measurements could be performed in a two minute examination period with an accuracy of about ± 0.025 mm (± 0.001 in.) of true wall thickness. However, variations in thickness of the external coat of paint can introduce a high side error and recommendations are made for correcting this error if necessary. A selection of conventional ultrasonic instruments and transducers was evaluated to identify the optimum combination for drum testing. Required equipment parameters, a bubbler for coupling sound into the drum wall, and desirable instrument improvements are identified. Surface irregularities such as dents, scratches, labels, loose paint and rust cause loss of some data. Recommended adaptations in the ultrasonic instrumentation and drum surface cleaning may provide improved capability for these problem areas.

The unique characteristics of the waste drum used at various Department of Energy (DOE) sites are documented. Several specimens were obtained and a selection was artificially corroded for characterizing tester performance.

INTRODUCTION

Nondestructive testing techniques were evaluated and laboratory investigations were performed for evaluating the integrity of waste drums that contain low level TRU waste. These drums have been stored on above ground asphalt pads since 1971 and it is necessary to assure the waste container (drum) integrity prior to shipment of the waste to a permanent nuclear waste repository. Described measurements of wall thickness can be made nondestructively that will evaluate possible structural deterioration of a container. Such examinations focus on the need for previously stored waste to meet Waste Acceptance Criteria (WAC) before they can be accepted by the Waste Isolation Pilot Plant (WIPP) repository.[1] This investigation concentrates mainly on transducers, instruments, performance of ultrasonic equipment for the measurement of drum wall thickness, and the identification of representative waste drum types. The Nondestructive Testing (NDT) instruments evaluated were limited to commercially available equipment with specific tailoring potential for this application.

SUMMARY AND CONCLUSION

The investigation identified the ultrasonic pulse echo technique as a feasible method for ensuring waste drum integrity. However, adaptations to this ultrasonic method may be needed because some regions of a drum wall could not be tested. Both ultrasonic and eddy current techniques were initially considered and the eddy current method was rejected because a practical system could not be accomplished within the scope of this work. The ultrasonic system evaluates the drum integrity accurately and swiftly. Approximately 20 circumferential scans can be performed on the sides and ends of a drum in two minutes, with greater than 20,000 individual thickness measurements being made during each revolution. A total drum wall integrity assessment could be nominally based on 400,000 such ultrasonic interrogations with a demonstrated accuracy of about ± 0.025 mm (± 0.001 in.) of true wall thickness. The ultrasonic technique lends itself to production testing such that an estimated 100 drums a day could be handled with one test system. The NDT equipment has computer compatible outputs that could be utilized to document the examination results for WIPP acceptance.

A possible drawback inherent with the ultrasonic test method is that water must contact the drum in order to transmit ultrasound into the drum wall. To minimize this problem, a water bubbler was designed and successfully demonstrated which reduced the amount of water contact with a drum. Other problems are caused by irregularities on the drum's surface such as dents, seams, labels and rust which cause loss of some, but probably not a critical amount, of wall thickness data. Circuits or software techniques could enhance the test results by rejecting erroneous data caused by these anomalous conditions. Cleaning a drum surface with a blast of shop air to remove loose rust on a heavily corroded surface significantly improved the extent of the surface area examination. Variations in drum paint thickness introduce a wall thickness measurement inaccuracy. Depending upon accuracy needed in the final drum acceptance criteria, a possible solution to this problem could be provided by an independent measurement of paint thickness using readily available eddy current technology. It was also noted that a more thorough assessment can be obtained on 16 gauge drums as compared to 18 gauge drums because the thinner wall drums have more dents and surface distortions.

The unique characteristics of various TRU waste drums presently in service were identified by contacting users at DOE sites. These characteristics are documented, and representative waste drum samples were obtained for evaluating the ultrasonic test system. Some drum samples were subjected to accelerated corrosion for demonstrating the ability of the test equipment to measure drum wall thinning.

In total, this nondestructive test technique has demonstrated a capability to evaluate the structural integrity of low level waste drums that have been stored in temporary retrieval sites. The information generated about the measuring systems capability can now be assessed against the need, as repository requirements are more completely identified. In order to have the necessary examination capability in a timely manner, this effort should be continued as recommended. Specifically tailored ultrasonic instruments and hardware fabricated to an equipment specification (Appendix I) should be demonstrated as a system. If improved ultrasonic measurement in regions of dents, seams or external corrosion is needed or if a backup eddy current system using magnetic saturation is needed, such work should be initiated as soon as possible.

TEST CONCEPT, THROUGHPUT AND DRUM HISTORY

The elementary concept of measuring wall thickness can be explained by reference to Fig. 1. An ultrasonic transducer transmits a pulse of sound into the wall and then detects the resulting echo from the back wall. The formula relates thickness of wall to the length of time it takes an ultrasonic pulse to echo off the back surface. Since the velocity of sound in steel is relatively constant, measuring the time required for an ultrasonic round trip provides a signal proportional to thickness. For thin components 0.51 - 1.90 mm (0.020 - 0.075 in.), the echo bounces back in less than one microsecond. With suitable tailoring, ultrasonic instruments can detect these relatively short intervals and provide a reliable thickness measurement.

Logistics for Testing Drums

The logistics for inspecting stored waste containers indicate that an examination throughput of about 100 drums/day may be required. This translates into the testing of one drum every two minutes. The required equipment parameters (Appendix I) for accomplishing these examinations were predicated on the basis of this testing throughput rate. It is not uncommon for a bank of two or three ultrasonic testers to be used in a production operation. Scaling up to meet greater testing requirements, if needed, is entirely feasible for this type of instrumentation.

Waste Drums

From 1970 to 1980, the waste storage drums for low level TRU waste have all been standard Department of Transportation (DOT) steel drums mostly of the 55 gallon size, but including a few 30 gallon and other odd sizes. In the past, the various DOE Sites have bought drums based on DOT specifications with modifications for specific paints or coatings to meet individual site needs. The drums described in Table I are about 0.571 m (22-1/2 in.) in diameter by about 0.860 m (34.0 in.) high with a drum wall thickness of either 16 or 18 gauge steel. Initially, the lighter gauge 55 gallon steel drums, designated DOT 17-E and 17-H, were used, some of which were reconditioned. In later years the DOE Sites have virtually all changed to the heavier 16 gauge DOT 17-C drums. In addition to using heavier gauge drums, some sites like Rocky Flats and Bettis are presently also using an internal 2.3 mm (0.090 in.) thick polyethylene liner.

The exterior and interior surface finishes include a wide variety of paints and coatings. Recent Hanford coatings included a black exterior paint and an interior 450°F baked epoxy-phenolic resin; however, both interior and exterior surfaces are now galvanized with zinc. Rocky Flats uses a white exterior paint, no internal paint, and a polyethylene interior liner; other sites use different combinations. Basic drum sizes, shapes, hoop and chime configurations are typically specified in ANSI MH2.4 and CFR Title 49 Article 178.112-116. The mechanical integrity of the drum is such that waste drums have been stacked five to six drums high on end or side on above ground asphalt pads that are covered with plywood, polyethylene and finally 0.97 m (3 ft.) of soil.

Representative samples of new and used drums were obtained from Hanford, Rocky Flats and Bettis for evaluation of the test equipment on the laboratory ultrasonic test bed. In addition, the effort was broadened to include the capability of contact ultrasonics for measuring wall thickness of an M-III storage bin as described in Appendix II.

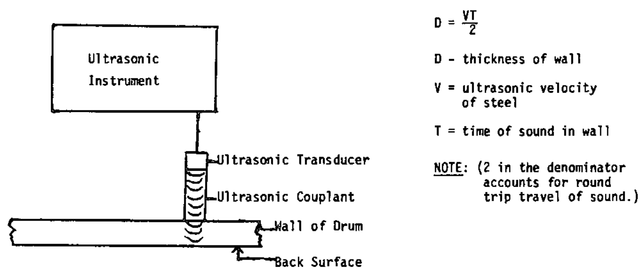

Fig. 1. Schematic of Ultrasonic Thickness Measurement. (NOTE: The above formula relates thickness of wall to the length of time it takes the ultrasonic pulse to make the round trip from entrant surface to back surface and return to the entrant surface.)

THICKNESS MEASURING

Ultrasonic Testers

A selection of four off the shelf ultrasonic thickness measuring instruments were evaluated for measuring drum wall thickness. They were evaluated on a laboratory test bed as shown in Fig. 2. This test bed includes a computer for controlling transducer position, a water filled immersion tank, a transducer manipulation bridge, a drum rotating turntable, two "C" scan recorders and a strip chart recorder (not shown). Corrosion drum specimen #II is shown in test position on the turntable and a completed C scan showing the extent of corrosion in this drum is on the polar recorder. This was a flexible and satisfactory test facility for the investigations.

Interface Gate

For high speed scanning, a water path coupling must be used to transmit sound from transducer into drum. The length of the water path will vary because of changing distance between transducer and drum surface as a drum rotates. Such variations in water path dictate the necessity of using interface or interpulse gating. When operated in the interface gate mode, the UT device measures transit time (distance) from when the sound first enters the part until its return to this surface. Interpulse gating measures time between selected echos.

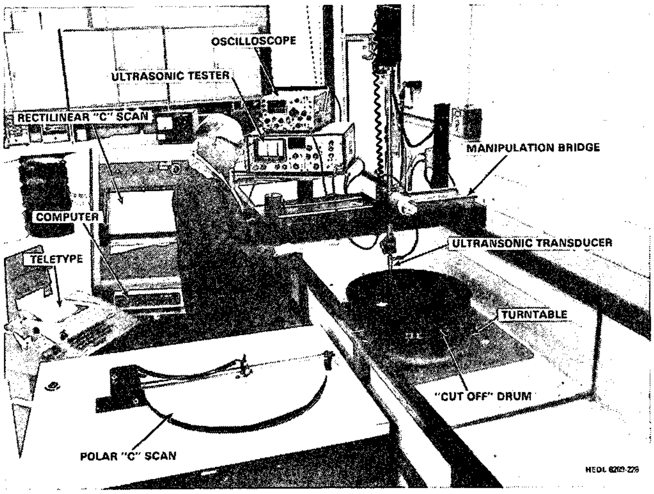

Fig. 2. Ultrasonic Test Bed

Two of the available laboratory instruments were not suitable for this application because they had only main bang gating and did not have interface or interpulse gating. The other two units have interface gating and thus are potentially suitable for this application. However, one of these latter two instruments has a gain stability problem that caused significant thickness measurement error. Also, observation of the back surface echos indicated a substantial loss of signal when the sound beam passed over minor surface irregularities such as small scratches. Loss of back surface echo means loss of wall thickness data and such loss must be minimized in this application. UT testers can readily be obtained with automatic gain circuits which should correct at least part of this problem.

The fourth ultrasonic instrument experienced less loss of signal when the sound beam passed over surface irregularities. Thus, it had better tolerance to sudden thickness changes, scratches or paint runs and did exhibit a measuring efficiency of better than 95% on DOT 17C drums. It also features a broadband receiver response to 75 mHz desirable for operation with high frequency transducers. Thus, in this investigation, the fourth broadband instrument provided the best data and was used in performing most of the work.

Ultrasonic Transducers

The most important feature of a transducer for this application is shortness of driving pulse (main bang) combined with good sensitivity for detecting reflected echos. These needs point to a high frequency, highly damped, focused transducer with a relatively short focal length for measuring the thin drum wall. The following transducers were evaluated for shortness of main bang and measurement accuracy using an ultrasonic standard E drum II described in this paper.

10 mHz	13mm (1/2 in.) dia.	unfocused
2.25 mHz	6.4mm (1/4 in.) dia.	unfocused
5 mHz	19mm (3/4 in.) dia.	64mm (2-1/2 in.) focal length
5 mHz	13mm (1/2 in.) dia.	unfocused
7 mHz	13mm (1/2 in.) dia.	unfocused
10 mHz	6.4mm (1/4 in.) dia.	unfocused
10 mHz	13mm (1/2 in.) dia.	38mm (1-1/2 in.) focal length
10 mHz	13mm (1/2 in.) dia.	38mm (1/2 in.) focal length
15 mHz	9.5mm (3/8 in.) dia.	51mm (2 in.) focal length
25 mHz	6.4mm (1/4 in.) dia.	38mm (1-1/2 in.) focal length

As expected, the 25 mHz transducer provided the best combination of sharp echo pulses and high sound collection efficiency. The second best transducer was the 13 mm (1/2 in.) dia. flat (unfocused) 10 mHz unit. However, it suffered from loss of signal due to surface irregularities. A plastic lens focused at 38 mm (1-1/2 in.) was added, but this addition did not significantly improve transducer performance. The best overall transducer evaluated for this application was the 25 mHz unit with a 32 mm (1-1/4 in.) water path coupling length obtained from a commercially available source.

Bubbler for Coupling Ultrasound to Drum

When preparing containers for WIPP storage, it is not desirable to immerse the drums in water in order to obtain an ultrasonic coupling medium. An ultrasonic bubbler fabricated from DELRIN* provided an acceptable method for using ultrasound without immersing the test object. A minimum water flow of 1 gal/min. (50 ml/sec) was required to sustain the water column against a drum surface. Ultrasonic operation and mounting of transducer were identical to the immersion technique. The threaded end of the transducer fastened into a manipulator and provided mechanical support and positioning. The diameter of the bubbler body was relatively small 25.4 mm (1 in.) dia. so that the bubbler can be manipulated into position to test an inside surface of a bottom chime. Possible trapped air in the bubbler escaped through a small side fitting and a threaded insert plugs off the end and reduced the amount of water flow needed. This bubbler provided excellent ultrasonic coupling and was fully functional for drum wall measurement.

SYSTEM CALIBRATION

A wall thickness standard E drum II with four 12.7 mm (1/2 in.) dia. flat bottom holes (FBH) to cover the drum wall range of interest was fabricated. This standard was used for calibration and evaluation of the ultrasonic and eddy current testers. The basic material is galvanized steel 1.9 mm (0.075 in.) thick and the holes were located on 50.8 mm (2 in.) centers in the 76.2 mm (3 in.) by 304.8 mm (12 in.) piece. The holes were fabricated to different depths to obtain a range of remaining wall material as tabulated below.

* A trademark of Dupont Company.

Top FBH	1.9 mm (0.072 in.) nominal, 0.025 mm (0.001 in.) range from 1.82-1.84 mm (0.0715-0.0725 in.)
Next FBH	1.7 mm (0.068 in.) nominal, 0.025 mm (0.001 in.) range from 1.73-1.75 mm (0.068-0.069 in.)
Next FBH	1.5 mm (0.059 in.) nominal, 0.025 mm (0.001 in.) range from 1.47-1.51 mm (0.058-0.0595 in.)
Bottom FBH	1.0 mm (0.040 in.) nominal, 0.025 mm (0.001 in.) range from 1.00-1.03 mm (0.0395-0.0405 in.)

The standard was used frequently to calibrate the ultrasonic tester and a typical recorder trace is shown in Fig. 3. Note that the FBHs are thinner at the edges than in the center, thus have a range of depth. The UT system readily detected this range of thickness variation which illustrates graphically the accuracy and relatively sharp area resolution capability of ultrasound.

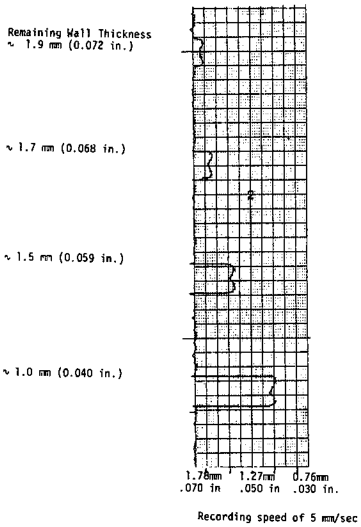

Fig. 3. Recording of Wall Thickness Standard E Drum II Using the Bubbler for Coupling Ultrasound

Sensitivity of Transducer Alignment

A seam or dent causes loss of data because the drum surface is not perpendicular to the sound beam. The sound scatters and an echo does not reflect back to the transducer. A simple experiment indicates the magnitude of this problem. The E drum II standard was tilted off from perpendicular and the angle measured. Significant signal loss occurred when the surface was misaligned more than 1°. This sensitivity to misalignment readily explains signal loss over dented areas and seams where several degrees of surface distortion occur. It was noted that the 25 mHz focused transducer exhibited the least sensitivity to such tilt. Improving transducer coupling for more efficient transmission and collection of the ultrasonic beam is a fertile area for upgrading ultrasonic tester performance.

EXAMINATION OF DRUMS

The broadband ultrasonic tester successfully measured wall thickness of several representative specimens. The simplest case was a 16 gage drum lid with no corrosion and no inside coating of paint (a Rocky Flats drum lid). In this measurement, the interface reflection was from bare steel and the echo was from a paint-metal interface. A recording (Fig. 4) shows the measurement across the inside of the drum lid that is very uniform indicating a lid thickness of ∿ 1.45 mm (0.057 in.). A manual micrometer measurement confirmed that the steel thickness of this lid was 1.45 mm (0.057 in.). The small signal irregularities noted were at least partially due to dirt on the surface. Hand rubbing the surface eliminated one small signal perturbation and reduced another. A second thickness measurement from the other side of this lid through the exterior coat of paint is also shown in Fig. 4. Note that the measured thickness is greater due to the paint, ∿ 1.52 mm (0.060 in.) and is more variable because of uneveness in the paint coating through which the sound must travel. The paint caused the ultrasonic thickness measurement to be increased by about 0.076 mm (0.003 in.) while micrometer measurements indicated the paint was 0.025-0.051 mm (0.001-0.002 in.) thick.

Effect of Exterior Paint

Outside paint thickness is included in ultrasonic wall thickness measurements and it causes a high side error. Ultrasonic velocity in paint is from 1/3 to 1/2 that of steel; thus the sound takes proportionally longer to travel through the paint. A possible solution to this inaccuracy problem would be to measure paint thickness separately and then subtract a paint thickness correction term from the UT measurement. This would yield a more accurate net thickness value. Paint thickness could be measured by a lift-off eddy current method using a commercially available instrument. The correction for a 0.025 mm (0.001 in.) paint thickness is relatively minor. However, for paint 0.18 mm (0.007 in.) thick as reported found on some drums, the correction would be significant.

Ultrasound was able to penetrate all coatings attempted and provide measurements of the overall drum wall thickness. The inner coating does not significantly affect a thickness measurement. The sound is reflected at this interface and does not have to penetrate an inner coating of paint in order to obtain a measurement. Contents of a drum would also have no significant effect on wall thickness measurement. Water inside a drum will cause a slight reduction in amplitude of an ultrasonic echo, but this does not affect thickness measurement accuracy.

Measurement of Wall Thinning

A second 16 gauge drum lid was subjected to artificial corrosion of selected areas. Nitric and hydrochloric acids etched away selected areas of the wall material. Preparation of the five areas were as follows:

Area	Preparation
1	Only paint removed
2	∿ 0.254 mm (0.010 in.) of steel removed
3	> 0.381 mm (0.015 in.) of steel removed
4	> 0.508 mm (0.020 in.) of steel removed
5	> 0.762 mm (0.030 in.) of steel removed

This lid was then ultrasonically scanned from the outside surface to obtain a "C" scan. The greater the depth of corrosion, the darker was the recording. The recording image intensity and shape matched the shape and depth of the corrosion. The area of removed paint does not show up on the recording. This was expected. Again, whether the inside surface is bare or is painted does not significantly affect reflection of an ultrasonic pulse. Similarly the area with paint removed does not show up on a comparable strip chart recording of this specimen (Fig. 5).

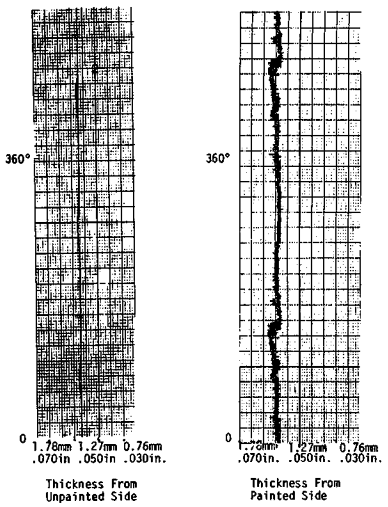

Fig. 4. Measurement of Steel Wall Thickness of a New Drum Lid. (Measured in a circular path about 381 mm (15 in. dia.) Recording trace starts to repeat itself every 18 major chart divisions. On left trace the small indications are from roughness or dirt on unpainted steel surface.) (On right trace the paint caused an increase and more variability in thickness measurement.)

As shown, there is good correlation between micrometer and ultrasonic measurements of remaining wall thickness of this lid. The ultrasonic tester with its relatively sharp area resolution capability indicates a short range of depth variation for each zone of corrosion except for the zone of deepest corrosion. In this zone, the extent of metal thinning was below the range of the instrument. Causes of such limitations are discussed in a following section. Within its range, the ultrasonic measurement of wall thickness through the exterior paint on the lid was within about ± 0.025 mm (± 0.001 in.) of the comparative micrometer data.

Effect of Outside Surface Rust

A third lid was rusted naturally on the outside surface. This provided an indication of how an outside coating of rust affects a measurement. The inside surface of this 16 gauge lid was not corroded. Recordings of two thickness measurements were made at 406 mm (16 in.) and 508 mm (20 in.) dia. on the lid. Two major regions of erratic ultrasonic tester response were indicated in each recording and they were caused by the outside surface rust. Rust scatters or stops the ultrasonic beam causing false thick and thin wall thickness indications.

The lid was subsequently cleaned with a blast of shop air (80 psig) (6.52×10^5 Pa) and remeasured. The air blast removed substantial amounts of rust and reduced the region of erratic indications by about 40%. Results of air blast cleaning indicate that a technique with a more effective cleaning action is needed to remove rust scale and loose paint prior to measuring drum wall thickness.

16 Gauge Drum

Several drum specimens were tested on the ultrasonic test bed and wall thickness of both the bottom end and the sides were measured. Shown in Fig. 6 are the measurements made on drum #II which had severe corrosion over 1/4 of the end area. Recorded wall thickness indicates the precise repeatability that can be obtained ultrasonically. Note how precisely the measurements repeat every 360°.

Remaining Wall Thickness Ultrasonic	Micrometer	Area
0.81 mm 0.032 in. (saturated)	0.74 mm 0.029 in.	5
0.94-1.04 mm 0.037-0.041 in.	0.99 mm 0.039 in.	4
1.12-1.19 mm 0.044-0.047 in.	1.168 mm 0.046 in.	3
1.27-1.35 mm 0.050-0.053 in.	1.32 mm 0.052 in.	2
1.52-1.55 mm 0.060-0.061 in.	1.55 mm 0.061 in.	1

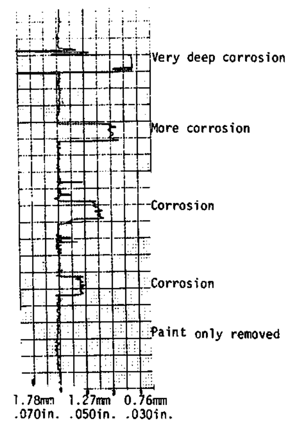

Fig. 5. Ultrasonic Thickness Measurement of Artificially Corroded Drum Lid and Comparative Micrometer Thickness Measurements.

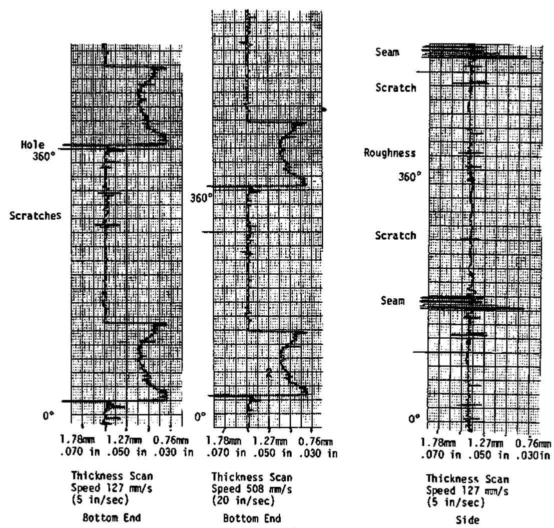

Fig. 6. Wall Thickness Measurement of Side and Bottom End of a 16 Gauge Corroded Drum #II at Two Scanning Speeds. (Scan of bottom end was a circular path about 318mm (15 in.) dia. This bottom end had corrosion over 25% of the end area. Recording trace starts to repeat itself every 18 major chart divisions.)

The recordings show severe corrosion on the bottom end of the drum and no corrosion on the side of the drum as it should. In one area of the bottom, the rust extended completely through the wall leaving a hole (marked "hole" in the upper left of Fig. 6). To ultrasound a hole is a loss of signal and the measurement gate completely opens up like it does for an infinitely thick object and causes a sharp signal to the left on the recording. For improved recording an electronic circuit could be added to test for such loss of signal and cause incorrect measurements made during this condition to be deleted. Besides the corrosion there were indications from scratches, surface roughness and the side seam as indicated. Some relatively simple signal processing could be employed to reject incorrect data caused by a seam or surface roughness. Overall, the recording provides a representative thickness measurement better than 95% of the time. Unfortunately, measurements are not obtained in the seam area because the sound is reflected away from the transducer. Obtaining measurements in the seam area at the same time the other wall areas are tested is beyond the capability of the laboratory instruments available for this investigation. Demonstrating greater capability for this area would probably require a modest amount of transducer developmental effort for improved transmitting and collecting of the ultrasonic beam.

18 Gauge Drums

Measurement of 18 gauge drums is basically more difficult because the material is thinner (∿ 1.22 mm) (0.048 in.) and consequently weaker and has more and deeper dents. The measuring efficiency for drum #I (DOT 17E) was only about 33% while that for drum #III (DOT 17H) was about 90%. Good measurements are more difficult to obtain on a drum with many dents and end buckling. On a statistical basis, the UT system does provide some basic data on these drums, operating at measurement rates up to 10,000 measurements/sec or 1,200,000 attempts each two minutes. Even with a 10% efficiency, a thickness assessment would be based on 120,000 valid measurements. However, this leaves dent, seam and buckled areas, possible critical ones, without measurement. With some development work, the efficiency of sound transmission and collection could be significantly improved and the resulting measuring efficiency greatly increased.

Scan Speed and Resolution Capability

A drum integrity examination must be performed rapidly and thoroughly. Fig. 6 also shows examination speeds of 127 mm/s (5 in/sec) and 508 mm/s (20 in/sec). Note that no significant data was lost and that no significant reduction in sensitivity occurred at the faster examination speed. This happens because ultrasonic interrogation occurs four thousand times each second which corresponds to making a thickness measurement every 0.127 mm (0.005 in.) along the scan path at the highest speed. Measurements are made at even closer intervals at slower speeds. Besides being thorough, the ultrasonic beam has good area resolution and sharpness of the beam was indicated as follows: An area 1.6 mm (1/16 in.) square was marked off with tape and successful thickness measurements were made through this relatively small opening. These results indicate the small area resolution and relatively fast scan speed that can be achieved with this ultrasonic method.

Correlation with Physical Measurement

On the end of drum #II a region was scanned between two holes 28.6 mm (1-1/4 in.) apart that were made during the artificial corrosion of this drum. Ultrasonic measurements agreed well with hand measurements made with a pin anvil micrometer considering the difficulty in making micrometer measurements on a corroded, uneven surface.

	Micrometer	UT Reading
1.	1.46mm (0.0575 in.)	1.5mm (0.059 in.) corroded areas
2.	1.51mm (0.0595 in.)	1.5mm (0.059 in.) corroded areas
3.	1.41mm (0.0555 in.)	1.32mm (0.052 in.) corroded areas
4.	0.79mm (0.0310 in.)	0.97mm (0.038 in.) corroded areas

Measurement #4 was below the tester range. An equipment lower limit occurs when the echo pulses have a finite width of about 0.2 μ sec. (width at half maximum amplitude). With thinner material, the time for sound to travel round trip through the material becomes short, ∿ 0.4 μ seconds compared to the pulse duration of 0.2 μ seconds. Below ∿ 0.97 mm (0.038 in.) wall thickness the available equipment could not resolve individual echo pulses. Measurements of thinner material would require conventional equipment specifically adjusted or tailored for such application. An Instrument Company representative indicated that instrument #4 could be adjusted to reliably measure down to a 0.381 mm (0.015 in.) wall thickness.

Preparation of Drum Corrosion Samples

Three cut off drum samples were subjected to accelerated corrosion using nitric and hydrochloric acids. The corrosion depth ranged from slight to completely through the wall in a manner very similar to natural corrosion. Tops of the drums were cut off at a height of 0.381 mm (15 in.) (just above the bottom hoop) for handling ease in the ultrasonic tester. Drum samples and extent of corrosion are identified as follows:

I - An EH Yellow drum (reconditioned) that has about half of the bottom corroded

II - A DOT 17C drum that has a corroded 1/4 pie section in the bottom

III - A DOT 17H drum that has hoop as well as bottom corrosion

These samples represent a good selection of corroded drums that effectively simulate "natural" corrosion.

Initial Eddy Current Effort

Early in this investigation, attempts to measure steel wall thickness with commercially available eddy current instruments were not successful. Most eddy current instruments do not operate in the low frequency range needed to penetrate through the drum wall (≲ 100 Hz). Laboratory testing indicated that variations in magnetic characteristics of drum steel cause background noise that seriously mask out signals from thickness variations.

An approach taken by some eddy current equipment manufacturers is to minimize magnetic effects by magnetic saturation of the test article. This method requires special expensive equipment and fixturing beyond the scope of this investigation. However, the eddy current saturation technique is an alternative approach that could possibly provide a backup method for measuring drum wall thickness.

Drum	Contractor/Location	Specification Date	Thickness Gauge	Outer Coating
17-C	ARHCO (Hanford)	5/11/77	16[a]	Alkyd Paint
17-C	Rockwell (Hanford)	2/3/81	16	Zinc Galvanized
17-C	Rockwell (Rocky Flats)	8/5/80	16	White Paint
17-C	Monsanto	1/23/75	16	White Paint
17-C	EG & G (Idaho)	7/18/78	16	White Paint
17-H	Rockwell (Hanford)	10/23/79	18	Yellow Paint
17-H	ARHCO (Hanford)	9/11/72	--	--

The drums are ∿ 0.572 m (22-1/2 in.) diameter with a height of ∿ 0.86 m (34 in.) height.

(a) 16 gauge drums have a nominal thickness of 1.52 mm (0.0598 in.) and a minimum thickness of 1.35 mm (0.0533 in.).

18 gauge drums have a nominal thickness of 1.21 mm (0.0478 in.) and a minimum thickness of 1.09 mm (0.0428 in.).

Table I. Waste Drum Specifications and Characteristics

APPENDIX I

REQUIRED EQUIPMENT PARAMETERS

Basic thickness measurement for insuring drum integrity will be performed by an ultrasonic pulse-echo tester. About 20 circumferential examinations on sides and ends will be performed on a drum in two minutes. Measurements can be made in critical areas such as close to the bottom chime. At least 20,000 individual ultrasonic interrogations will be made for each revolution of a drum. Thus, a drum wall integrity assessment will nominally be based on some 400,000 individual measurements. Automation of operation, positioning of transducer, evaluation of data, analysis of data and interpretation of results will be accomplished under computer control.

It is assumed that this system will have either a dedicated or shared computer to enhance the data and provide needed control and documentation. The raw data would be enhanced by removing incorrect input from bumps, seams and labels and by refinement that removes paint caused errors. Detailed component requirements are:

Ultrasonic Instrument

1. range - 0.50 to 1.9mm (0.020 to 0.075 in.)
2. sync - interface or inter-echo
3. display - video plus gate and thickness
4. receiver - 50 to 30 mHz broad band
5. gain - automatic gain feature
6. pulser - broad band pulser output ∿ 300 volts nominal
7. repetition rate - 4 or 10 kHz switch selectable
8. outputs - analog and TTL compatible BCD (3-1/2 digits)
9. repeatibility - 0.0025 mm (0.0001 in.) of thickness measurement
10. mechanical - compatible with overall instrumentation
11. smart circuit - test condition of gate to reject data[a]

Ultrasonic Probe

1. transducer - 25 mHz, 6.35 mm (1/4 in.) dia. and 38.1 mm (1-1/2 in.) focal length
2. bubbler - ∿ 25.4 mm (1 in.) dia. with water flow rate of 3.78ℓ/min (1 gal/min)

Probe Motion

1. electrical - signal cable for wet application
2. mechanical - conventional bridge controls for computer controlled transducer
3. drum rotation - drum rotation turntable
4. drum cleaning - capable of up to 508 mm (20 in.) sec. surface speed

Eddy Current Instrument

1. range - 0.0025 to 0.025 mm (.0001 to .010 in.) paint on steel
2. display - thickness (4 digits)
3. outputs - analog + I/O for computer
4. transducer - surface scanning probe
5. repeatibility - 0.0025 mm (.0001 in.) of thickness measurement
6. mechanical - compatible with overall instrumentation

Drum Handling

Not specifically addressed because drum handling will be part of facility equipment.

Computer Hardware

A dedicated mini-computer for control of instrumentation or possible time sharing on a large computer for analysis and documentation.

Computer Software

Programs for control of test instruments, interpretation, signal enhancement, analysis and documentation.

APPENDIX II

WASTE BIN MEASUREMENTS

Investigation of wall thickness measurements for bin waste containers indicates that the exterior paint causes a significant increase in the indicated wall thickness measurements. A series of ten repeat measurements were made at four locations on the bin using the contact method. Comparison with micrometer measurements indicated that the ultrasonic measurements were about 0.152 mm (0.006 in.) too large. With the paint removed, there was no such error in the ultrasonic measurement. A 0.076 mm (0.003 in.) thickness of epoxy-phenolic paint appears to be 0.229 mm (0.009 in.) thick in an ultrasonic measurement causing a 6% high side error. A possible solution would be to separately measure paint thickness in order to subtract it from a total thickness to obtain the actual steel thickness measurement.

Additional work indicated (1) that the container's internal tarmastic coating had neglible effect on thickness measurement. (2) That a seam weld on the bottom of the tank did not interfere with wall thickness measurements. (3) That unbonded paint or rust prevents a measurement because the UT cannot couple through an unbond. (4) That a good UT measurement was accomplished through an epoxy type paint (70% epoxy, 30% phenolic resin).

REFERENCES

1. WIPP-DOE-069, Rev. 1, TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant, September 1981.

(a) "Smart" circuits will reject false thickness reading or alternatively a software program will reject them.