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Results of Ultrasonic
Testing Evaluations
on
UF₆ Storage Cylinders

By
M.L. Lykins

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on UF₆ Storage Cylinders**

By
M. L. Lykins

February 1997

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Under Contract USEC-96-C-0001
to the
UNITED STATES ENRICHMENT CORPORATION

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EXECUTIVE SUMMARY

During FY96, Swain Distribution Inc. conducted wall thickness evaluations on 609 cylinders utilized for storage of 10- and 14-tons of UF₆ at PORTS and 251 cylinders at PGDP using the P-Scan system and manual ultrasonic testing measurements. A total of 723 thin-walled (5/16 in.) and 137 thick-walled (5/8 in.) UF₆ storage cylinders were evaluated at PORTS and PGDP. Forty-three thin-walled cylinders were found to have a wall thickness less than 0.250 in. The lowest wall thickness found on a thin-walled UF₆ storage cylinder during this study was 0.187 in. No thick-walled cylinders were found to have a wall thickness below 0.500 in. The minimum ANSI N14.1 minimum wall thickness for the thin-walled cylinders is 0.250 in. and 0.500 in. for the thick-walled cylinders.

In general, stacked cylinders that have been located in the bottom row were found to have a lower minimum wall thickness than those cylinders stored in the top row position. This may have been caused by variations in the time of wetness and crevice corrosion at the cylinder/support saddle interface.

INTRODUCTION

The three site cylinder management program is responsible for the safe storage of the DOE owned UF_6 storage cylinders at PORTS, PGDP and at the K-25 site. To ensure the safe storage of the UF_6 in the cylinders, the structural integrity of the cylinders must be evaluated. This report represents the latest cylinder integrity investigation that utilized wall thickness evaluations to identify thinning due to atmospheric exposure.

1 BACKGROUND

1.1 P-Scan System

The automated Projection image scanning (P-Scan) system is a nondestructive test method used to determine the remaining wall thickness of metallic objects. Swain Distribution Inc. (SDI) was first awarded a subcontract at K-25 in 1993 to conduct wall thickness evaluations on UF_6 storage cylinders using the automated P-Scan system. Cylinders were evaluated in the stacked position.¹ The scanner initially used a Focused Array Transducer System (FATS) for wall thickness measurements. After the first 21 evaluations were conducted with the FATS transducer, a second transducer (a Krautkramer-Branson MSEB transducer) was added to the system to better evaluate the wall thickness of the remaining cylinders.

The FATS transducer was developed initially to evaluate the wall thickness of metals. The FATS transducer was later modified to measure the surface profile of a metal surface. The FATS transducer measures the water path into a pit or corroded area and can provide pit depth data for corroded surfaces. On rough surfaces, the FATS transducer may not have sufficient couplant (water) to flow into the corroded area to obtain accurate measurements.

The MSEB transducer is used for the wall thickness measurements. For the P-Scan system, this transducer requires water as the couplant and a relatively smooth surface to obtain accurate wall thickness measurements. The transducer is relatively small in diameter (about 0.5 in.). If the surface of a cylinder is heavily corroded, the surface will be rough and the angle of incidence on the MSEB transducer may change during a scan.

The MSEB and FATS transducers are attached to a scanner which has magnetic wheels that adhere to the steel cylinders (Figure 1). A weld control unit is used to control the scanner during an evaluation. Cables are attached to the scanner to control the movement of the scanner. In addition, cables are attached from a P-Scan Processor (PSP-3) to the transducers to record data

from the MSEB and FATS transducers (Figure 2). The scanner is set up on a cylinder, while the operation and control of the system occur at a short distance away from the cylinder.

The scanner traverses an area on the cylinder with two-directional movement. The scanner travels back and forth in a longitudinal motion. The scanner also moves radially around the circumference of the cylinder during a scan. The movements of the scanner are automated and are controlled using the weld scanner controller. The system will travel along the full length in the longitudinal direction (9 to 12 inches, which depends on the type of scanner used) before incrementally moving to the next location in the radial direction. A typical scan would evaluate an area of about 320 sq. in.

Figure 1: Scanner used with the P-Scan system to evaluate the wall thickness of the UF₆ cylinders.

Figure 2: Weld control unit to control the scanner during an evaluation and the P-Scan Processor (PSP-3) to record the data during the evaluation.

1.2 Manual Ultrasonic Test Measurements

Manual ultrasonic test (UT) measurements are used as non-destructive methods to determine the wall thickness of the UF₆ storage cylinders. However, manual UT measurements have typically been conducted in areas of mild weathering corrosion. A dual element transducer, similar to the MSEB transducer on the P-Scan system, can be used for general manual UT measurements. The couplant used for the wall thickness measurements on the cylinders is soluble and biodegradable. The transducer is connected to an ultrasonic flaw detector that is used to convert the velocity, frequency, etc. from the transducer into a wall thickness determination.

1.3 Sampling

SDI was awarded a subcontract in FY 1996 to evaluate 10- and 14-ton mild steel cylinders at PORTS, PGDP and/or K-25 using a combination of the P-Scan system and manual UT measurements. The cylinders evaluated at PORTS were selected based on a random 10% sampling of the cylinders moved in FY 1996.²⁻⁴ In addition to the cylinders selected at random at PORTS, non-conforming cylinders (as described in the cylinder inspection procedure)⁵ were also evaluated in FY 1996 using a combination of the P-Scan system and manual UT measurements.

The cylinders evaluated at PGDP were selected from a 1-in-10 sampling plan during initial relocation activities. The 1-in-10 sampling of cylinders relocated at PGDP in FY 1996 was not continued throughout the relocation activities due to constraints in the cylinder storage areas. When the staging areas for the wall thickness evaluations were full, no other cylinders were selected for an evaluation. No cylinders were evaluated at the K-25 site in FY 1996.

2 METHODS

2.1 Location of Evaluations

The wall thickness evaluations of the cylinders were conducted after the cylinders had been placed in a staging area with the support saddles located on the outside of the stiffening rings. The saddles were placed on the outside of the stiffening rings such that the previous cylinder/support saddle interface could be evaluated with the P-Scan system. The evaluations were not conducted for cylinders in the stacked position, with the exception of about ten cylinders at PGDP.

The P-Scan thickness measurements were made over an area from the 4:30 to 7:30 o'clock position on the cylinder (assuming the valve to be at the 12 o'clock position). For bottom row cylinders, the P-Scan evaluation was conducted in the area where the support saddle had been located. This was an area where accelerated corrosion had previously been detected on bottom row cylinders.⁶ For top row cylinders, the evaluation using the P-Scan system was conducted in an area where it appeared the cylinder had suffered the most corrosion.

In addition to the P-Scan evaluation, manual UT measurements were taken at the 12 and 3 o'clock positions on the cylinder shell, as well as on the valve and plug end heads of the cylinder⁷ (Figure 3).

2.2 Surface Preparation

The surface of the cylinder to be evaluated with the P-Scan system or the manual UT measurements was cleaned to remove corrosion by-products formed on the cylinder during storage. The surface was cleaned using wire brushes, scrappers or chipping hammers when necessary. On cylinders that had paint, very little or no surface preparation was required, because there was no visible corrosion.

In general, the wall thickness measurements were obtained on smooth surfaces that had a thin, tightly adherent, oxidized surface. In some cases, on heavily corroded cylinder bottoms, the surface was irregular because of the corrosion and the accumulation of the corrosion by-products. More surface preparation was needed for the heavily corroded cylinders.

2.3 Calibration of the Equipment

2.3.1 P-Scan system

When the P-Scan system was used, the system was calibrated at the beginning and the end of each working day. The system was calibrated with a mild steel plate formed to the radius of a 48-inch diameter cylinder. The plate was fabricated to the radius of a cylinder such that the system could be configured specifically for the 10- and 14-ton cylinders. The 5/16 in. thick A285 Grade C mild steel plate was fabricated from a cylinder that had not been used in UF₆ service. Holes to various depths were drilled into the plate so that the FATS probe could be calibrated accurately. The MSEB transducer was calibrated using the thickness of the machined plate. All dimensions were verified by the Dimensional Inspection Department at the K-25 site.

Figure 3: Manual UT measurements were taken at various locations on the cylinder body and heads.

During FY 1996, the original calibration plate used for the P-Scan system was worn by the scanner such that the plate developed flat spots and it became difficult to calibrate the system. Therefore, a new calibration plate was made at PGDP using the specifications developed at the K-25 site (drawing S5E-PG0002SK2 Rev. 1). Holes of various depths and the wall thickness of the new calibration plate were verified by Code Inspection at PGDP.

It should be noted that in FY 1996, there was no thick-walled (5/8 in. thick) calibration plate used for the P-Scan system. The thin-walled (5/16 in. thick) calibration plate was used to calibrate the P-Scan system. A thick-walled calibration plate is being fabricated at the K-25 site for future work.

2.3.2 Manual Ultrasonic Tests

The Sonatest Sitiescan 120 ultrasonic flaw detector was calibrated with the dual element transducer using a mild steel calibration block that ranged in thickness from 0.15 in. to 0.38 in. The calibration of the manual system was verified after measurements were obtained.

3 RESULTS AND DISCUSSION

3.1 Wall Thickness Calculations

The data obtained using the P-Scan system was evaluated and reported by SDI. A sample of an inspection report for a cylinder is shown in the Appendix. The minimum wall thickness (MWT) for a cylinder was calculated using the maximum pit depth and the wall thickness near the location of the deepest pit. (Please note that the MWT referred to in this report is not equivalent to the required thickness for the cylinders based on ASME Section VIII Division 1 criteria.) When the results were analyzed, it was discovered that, in many cases, the wall thickness data obtained using the P-Scan system were often considerably different from the results of the manual UT measurements.

In some cases, the MWT for a cylinder, as reported by SDI, was greater than the original specifications for a new cylinder. (The procurement specification for the shell of a new thin-walled cylinder was 0.3125 in. [+0.033 in. to -0.010 in.]) For instance, the wall thickness for one of the cylinders evaluated using the P-Scan system was reported to be 0.410 in. When this wall thickness was compared to the average of the two manual UT measurements

at the 3 o'clock position for that specific cylinder, the difference was +0.100 in.

In general, the MSEB transducer indicated a wall thickness that was larger than the manual UT measurements. The difference between the two measurement techniques ranged from +0.100 in. to -0.030 in. (see Figure A-1 in the Appendix).

The cause(s) of the variation in the two results (MSEB data with the P-Scan system and the manual UT measurements) are not known. Possible contributing causes include poor contact and/or slight shifts (not perpendicular to the surface of the steel) of the MSEB transducer, as well as variations in the calibration plate. Either condition could cause variations in the signal from the MSEB transducer which, would produce less accurate data.

In addition, the differences in the data between the manual UT measurements and the P-Scan system may have been caused when the calibration plate used at the beginning of FY 1996 started to develop flat spots, as discussed previously. The average difference was -0.009 inches for the first 548 cylinders evaluated in FY 1996, with a standard deviation of 0.014 inches.

When the calibration plate could no longer be used, a new calibration plate was fabricated and verified at PGDP. The new calibration plate was used for the P-Scan evaluations starting on July 23, 1996. For the remaining 314 cylinders, the average difference between the UT measurements obtained from using the manual UT measurements and the data from the P-Scan system was -0.023 inches. The standard deviation for these differences was 0.015 inches. The high standard deviation (0.014 in.) found using either calibration plate indicated there was a large variation in the wall thickness measurements, which increased with the use of the second calibration plate.

Therefore, due to the variability in the results of the wall thickness data from the P-Scan system, the MSEB wall thickness measurements obtained with the P-Scan system were not used. For this report, the MWT for the cylinders evaluated in FY 1996 was determined using a combination of data from the P-Scan system and results from the manual UT measurements. The wall thickness used to calculate the MWT for the cylinders was obtained using the average of the two manual UT measurements taken at the 3 o'clock position on the cylinder. The two measurements at this location were selected because of the close proximity to the start of the P-Scan evaluation, the smooth surface conditions and the low amount of corrosion found in this area. The two measurements at the 12 o'clock position were not used in the MWT calculations. However, the manual UT measurements at the 12 o'clock

position were, on average, within ± 0.010 in. of the measurements obtained at the 3 o'clock position.

The minimum wall thickness (MWT) for a cylinder has been calculated using the following formula:

MWT (in.) = Average of two manual UT measurements at the 3 o'clock position (in.) - Maximum pit depth measured using the P-Scan system (in.)

(Please note that the MWT is not equivalent to the required thickness for the cylinders based on ASME Section VIII Division 1 criteria.)

3.2 Minimum Wall Thickness Data

Table 1 shows the results of the UT evaluations conducted at PORTS and PGDP in FY 1995 and FY 1996. The wall thickness for the cylinders evaluated in FY 1995 was calculated using the MSEB data obtained with the P-Scan system, whereas the cylinders evaluated in FY 1996 used a combination of the manual UT data and the P-Scan results. There is a large range in the wall thickness data for a population of cylinders from a specific cylinder storage yard, as well as between cylinders stored in the top and bottom rows. It appears that the minimum wall thickness of bottom row cylinders is less than the minimum wall thickness of corresponding cylinders stored in the top row position. This difference is due to variations in the time of wetness between the two cylinder populations.

3.3 Ultrasonic Test Results at PORTS

A total of 609 thin-walled and thick-walled cylinders were evaluated at PORTS in FY 1996 using the P-Scan and manual UT measurements. Nonconforming cylinders⁵ (such as those with heavy corrosion, dents, torn stiffening rings, etc.) were evaluated in addition to the 10% randomly selected cylinders. Therefore, the results may provide an indication as to the "worse case" storage conditions at PORTS.

Two of the P-Scan evaluations were used to conduct a second evaluation on nonconforming cylinders that appeared to have been stored previously in ground contact (a total of 611 evaluations). There were 22 cylinders (mostly thick-walled cylinders) not included in this report because previous storage information regarding the stacking configuration (top or bottom) was not recorded during the time of movement and could not be determined from previous storage information. None of the 22 cylinders had a wall thickness

below the MWT limits of 0.250 inches for thin-walled cylinders and 0.500 inches for thick-walled cylinders listed in ANSI N14.1 and ORO-651.⁸⁻⁹

Table 1: Results of Ultrasonic Evaluations Conducted on Cylinders at PORTS and PGDP in FY 1995-1996

Cylinder Yard	Year Evaluated	Number of Cylinders Evaluated		Wall Thickness (in)		Cylinder Age (years)	
		Top Row	Bottom Row	Top Row Cylinders	Bottom Row Cylinders	Top Row Cylinders	Bottom Row Cylinders
C-745B	1995	4	2	0.280-0.300	0.245-0.248	38	38
C-745F	1995	13	13	0.260-0.315	0.243-0.310	31-36	32-36
C-745G	1995	14	17	0.272-0.303	0.178-0.290	33-36	33-36
C-745K	1995	12	16	0.295-0.323	0.272-0.310	15-18	15-19
C-745L	1995	1	2	0.305	0.298-0.310	13	14
C-745C	1996	1		0.329		11	
C-745F	1996		6		0.265-0.314		36-37
C-745G	1996	137	98	0.244-0.317	0.187-0.309	18-37	5-37
C-745K	1996		6		0.294-0.316		16-37
X-745A	1996	19	41	0.267-0.310	0.257-0.309	6-34	6-39
X-745B	1996	1		0.283		22	
X-745C	1996	201	208	0.228-0.340	0.188-0.328	8-40	19-40
X-745F	1996		3		0.257-0.290		15-22
C-745C	1996	1	1	0.635	0.596	42	44
X-745A	1996	23	32	0.516-0.621	0.549-0.623	42-45	42-45
X-745C	1996	27	28	0.529-0.639	0.548-0.652	42-45	42-45
X-745E	1996		2		0.572-0.587		45
X-745F	1996		3		0.568-0.610		42

3.3.1 Thin-walled cylinders

Figures 4 and 5 show the wall thickness for the thin-walled cylinders that had been located previously in the top and bottom rows at PORTS. MWT limit indicators have been added to Figures 4 and 5 to show the wall thickness limit for ANSI N14.1 (0.250 in.)⁸ and the ASME Code Section VIII required wall thickness limit (0.219 in.) for the original design of the cylinders based on the original joint efficiency factor.¹⁰

Twenty-two thin-walled cylinders were found to have an area where the wall thickness was less than the ANSI N14.1 limit of 0.250 in.⁸ Six of the cylinders had been located previously in the top row position and the remaining cylinders had been stored previously in the bottom row (Figures 4 and 5). The wall thickness shown in Figures 4 and 5

appeared to be similar for cylinders stored previously in the top and bottom rows.

During the evaluations, it was observed that many top row cylinders were found to have a corroded area that appeared to be crevice corrosion created between the cylinder/support saddle interface. Starting in 1976, the cylinders were moved from a single-stacked position to the two-tier arrangement. Therefore, prior to 1976, all cylinders were "bottom row" cylinders.

Figure 4: Wall thickness of top row thin-walled cylinders evaluated at PORTS in FY 1996.

Three cylinders that had been stored in the bottom row had a wall thickness below the required thickness for ASME Section VIII (0.219 inches), using the original joint efficiency factor.¹⁰ A visual examination of the three cylinders was conducted on October 10, 1996. Two of the cylinders appeared to have been stored previously in ground contact. The surface of the bottom of these cylinders was rough and appeared to have accumulated corrosion by-products. The third cylinder had an area of crevice corrosion that appeared to have been created between the interface of the support saddle and the body of the cylinder. The saddle that the cylinder had been stored upon left a distinct outline on the bottom of the cylinder. Heavy corrosion by-products were found at the outline of the saddle.

Figure 5: Wall thickness of bottom row thin-walled cylinders evaluated at PORTS in FY 1996.

3.3.2 Thick-walled cylinders

Figures 6 and 7 show the results of the evaluations conducted on the top and bottom row, thick-walled cylinders using the P-Scan system, respectively. Most of the thick-walled cylinders evaluated were between 40 to 45 years old. MWT limit indicators have been added to show the ANSI N14.1 limit (0.500 in.)⁸ and the ASME Code Section VIII required wall thickness limit (0.414 in.) for the original design of the cylinders based on the original joint efficiency factor.¹⁰ (Note that the required ASME wall thickness for a 48X type cylinder is 0.506 in.¹⁰) In all cases, the measured wall thickness exceeded the design minimum allowed wall thickness.

Figure 6: Wall thickness of top row thick-walled cylinders evaluated at PORTS in FY 1996.

Very few differences were found between the top and bottom row thick-walled cylinders. The thick-walled cylinders may have been moved in 1976. In addition, many of the cylinders evaluated in FY 1996 were empty cylinders or empty cylinders with a UF₆ heel. These empty cylinders and heel cylinders may have been moved numerous times during their storage life and it is difficult to state that there is a discernible difference between top and bottom row cylinders.

Figure 7: Wall thickness of bottom row thick-walled cylinders evaluated at PORTS in FY 1996.

3.4 Ultrasonic Test Results at PGDP

A total of 251 cylinders were evaluated at PGDP using the P-Scan system in FY 1996. Figures 8 and 9 show the MWT for the thin-walled cylinders that were evaluated that had been stored previously in top and bottom row positions, respectively. The results of one cylinder evaluation from PGDP were not included in this report because the cylinder was a United States Enrichment Corporation (USEC) cylinder. The wall thickness of the USEC cylinder was 0.313 in. Two thick-walled cylinders were evaluated and both had wall thickness measurements greater than 0.590 in.

There were 21 thin-walled cylinders that had a wall thickness below the ANSI N14.1 minimum wall thickness limit of 0.250 in.⁸ All cylinders that exhibited a wall thickness below 0.250 in. came from the C-745G cylinder storage yard. Two of the cylinders had been located in the top row, while the remaining cylinders had been stored previously in the bottom row.

Six of the cylinders had a wall thickness less than the ASME Section VIII designed required thickness limit of 0.219 in. for thin-walled cylinders.¹⁰ The lowest wall thickness on a cylinder was 0.187 in. (Cylinder 14232). All of the cylinders had been stored previously in the bottom row and had corrosion by-products where the support saddle had been located. There was a distinct outline of where the support saddle had been located on the bottom of the cylinders. Two of the cylinders appeared to have had been stored in ground contact because of heavy corrosion by-products found on the bottom of the cylinders.

Most of the cylinders that had been removed from ground contact in the C-745G yard were not evaluated during this study. The investigation and repair of a suspect breached cylinder at PGDP involved a cylinder that had large amounts of corrosion by-products on the bottom of the cylinder caused from ground contact. The minimum wall thickness measurement on Cylinder 13975 using manual UT measurements was 0.175 in.¹¹

3.5 Manual Ultrasonic Thickness Measurements

Manual UT measurements were taken on the body and the heads of the cylinder. For cylinders with a weld at the 6 o'clock position, six manual UT measurements were obtained with a 0.250 in. diameter transducer. Two areas for manual UT measurements were not obtained during the study; 1) at the location on a bottom row cylinder where the stiffening ring from the top row cylinder had been located and 2) at the cylinder head/skirt interface. The

wall thickness at the interface created between the stiffening ring and the shell was to be evaluated during this study. However, measurements were not obtained because it was often difficult to locate where the point-of-contact had been located previously.

Heavy corrosion by-products had accumulated in the skirt region of both painted and unpainted skirted cylinders. It was not possible to obtain manual UT measurements in this area without first removing the corrosion by-products or the paint that had been applied in this region. The small-diameter 20 MHz transducer could not be calibrated on the Sonatest flaw detector. The 20 MHz transducer was calibrated with an USN-50 ultrasonic flaw detector and was found to provide wall thickness measurements on only a few skirted cylinders that had no heavy corrosion by-products. More wall thickness evaluations are needed in this area to better understand the corrosion that has occurred due to an increased time-of-wetness in this area.

Figure 8: Wall thickness of top row thin-walled cylinders evaluated at PGDP in FY 1996.

3.5.1 Body of the Cylinder

The manual UT wall thickness measurements taken at the 3 and 12 o'clock positions on the bodies of the thin-walled cylinders with a 0.250 in. diameter transducer ranged from 0.305 in. to 0.378 in. The manual UT wall thickness measurements taken on the body of the heavy walled cylinders ranged from 0.619 in. to 0.697 in. In general, the wall thickness values were close to the design specification of 0.3125 in. (+0.033 to - 0.010 in.) for thin-walled cylinders and 0.625 in. (+0.033 to -0.010 in.) for thick-walled cylinders. Some of the older cylinders were found to have a wall thickness above the design specification which may have been caused from the use of thicker steel plate than that specified. The wall thickness of the newer 48G type cylinders was not above the maximum original designed wall thickness limit of 0.3455 in.

Figure 9: Wall thickness of bottom row thin-walled cylinders evaluated at PGDP in FY 1996.

The P-Scan System could not be used close to the welds because of the configuration of the system. If a weld was encountered during the scan, the scanner traversed over the weld without collecting data. Manual UT measurements were taken using a 0.250 in. diameter transducer close to the longitudinal weld at the 6 o'clock position on some of the older cylinders. Three measurements were taken on either side of the weld. The average of the six wall thickness measurements taken at the bottom of the cylinder ranged from 0.321 in. to 0.376 in.

3.5.2 Heads of the Cylinder

The wall thickness on the heads on the thin-walled cylinders ranged from 0.304 in. to 0.422 in. The wall thickness of the heads on the thick-walled cylinders ranged from 0.718 in. to 0.804 in. No differences could be found between the valve end and the plug end of the cylinders. No differences were found between the center of the heads versus areas close to the valve and close to the plug.

In all cases, the thickness of the heads on the cylinders were found to be greater than the body of the cylinder. This was expected because the heads are forged from thicker steel plates. The cylinder design often gave a minimum wall thickness limit and since the heads on a cylinder are dished elliptically, the forging operation will reduce the wall thickness of the plate used for the cylinder head. To date, no appreciable differences were found in the wall thickness at locations around the cylinder heads. (Note that this does not include the cylinder head/skirt interface discussed above.)

3.6 Evaluation of the Data Obtained with the P-Scan System

The minimum wall thickness, as well as the overall size of the corroded area, can be determined from the results of the P-Scan evaluation using the computer software package (PC-Prog). This, combined with a visual examination of the cylinder describing the corroded area, can provide an indication of the size and extent of the corroded area that may be below the ANSI N14.1⁸ or the ASME Section VIII design minimum wall thickness requirements.¹⁰

3.6.1 Confirmation of P-Scan results

The results of a P-Scan evaluation was confirmed at PGDP in FY 1996. Cylinder 12888 is a 480 type 14-ton thin-walled cylinder that is 36 years old. The cylinder had been stored previously in the bottom row of the C-745G cylinder storage yard at PGDP. Cylinder 12888 was evaluated with the P-Scan system on July 15, 1996. The cylinder was reported to have a MWT of 0.198 in. on the bottom of the cylinder. The wall thickness at the 3 o'clock position, as measured with a manual UT methods was 0.338 in. (The wall thickness, as measured with the MSEB transducer on the P-Scan system and reported by SDI, was found to be 0.338 in., which was the same as the manual UT measurements at the 3 o'clock position.)

On August 13, several manual UT measurements were taken on the bottom of cylinder 12888 in the vicinity of where the wall thickness was believed to be thin. A Sonopen small diameter transducer was used by LMUS personnel to evaluate the wall thickness. The cylinder was rotated on the Ransom cylinder rotator to allow the bottom of the cylinder to be evaluated using the manual UT measurements. A carbide deburring tool attached to a drill was used to remove the corrosion products in areas considered to be heavily corroded. The wall thickness of the bottom of the valve end of the cylinder ranged from 0.199 in. to 0.320 in.¹²

4 CONCLUSIONS

The P-Scan system, combined with selected manual UT measurements, is an adequate method to evaluate the wall thickness of the UF₆ storage cylinders. The P-Scan system was used to successfully evaluate the wall thickness of 860 cylinders at PORTS and PGDP in FY 1996. A total of 474 thin-walled and 135 thick-walled cylinders were evaluated at PORTS. There were 249 thin-walled and two thick-walled cylinders evaluated at PGDP.

1. In general, bottom row cylinders were found to have a lower minimum wall thickness than top row cylinders, which may be the result of variations in the time of wetness and crevice corrosion caused at the cylinder/support saddle interface.
2. There were 22 thin-walled cylinders at PORTS that were found to have minimum wall thickness indications below the ANSI N14.1 limit of 0.250 in. Three cylinders were found to have a wall thickness indications below the worst case ASME Section VIII designed required wall thickness limit of 0.219 in. One cylinder had a wall thickness indication of 0.188 in.

3. There were 21 thin-walled cylinders at PGDP found to have a minimum wall thickness indications below the ANSI N14.1 limit of 0.250 in. Six cylinders were found to have a wall thickness indication below the worst case ASME Section VIII designed required wall thickness limit of 0.219 in. One cylinder was found to have a wall thickness indication of 0.187 in.
4. No thick-walled cylinders were found to have a minimum wall thickness below the ANSI wall thickness limit of 0.500 in. at either PORTS or PGDP.
5. The results of the P-Scan system was verified on one heavily corroded cylinder at PGDP using manual UT measurements with a small diameter transducer.

5 RECOMMENDATIONS

To improve the future wall thickness measurements on the UF₆ storage cylinders, the following actions are recommended:

1. Determine the probable cause(s) of the discrepancies between the data obtained with the MSEB transducer on the P-Scan system and the data obtained with manual UT measurements.
2. Improve the documentation recorded for the cylinders evaluated with the P-Scan system which include, but are not limited to cylinder number, previous and current location, visual appearance, surface preparation, etc.
3. Evaluate the data obtained in FY 1996 to determine the size of the corroded areas found during the P-Scan evaluations.
4. Conduct more ultrasonic thickness evaluations on cylinders that have heavy corrosion by-products, that have been stored in ground contact, to determine if the P-Scan system can be used on these cylinders.

REFERENCES

1. "Report on Ultrasonic Wall Integrity Assessment," Internal Correspondence from H.E. Philpot to V.S. Newman, et. al., February 17, 1995.
2. "Selection of Cylinders for Conducting P-Scan Evaluations," POEF-38-343-95-83, M. Lykins to T. Marshall, November 24, 1995.
3. "Selection of Cylinders for Conducting P-Scan Evaluations," POEF-38-342-96-153, M. Lykins to T. Marshall, March 19, 1996.
4. "Sampling List for 10- and 14-Ton Cylinders - Empties and Empties with Heels," POEF-38-342-96-269, M. Lykins to T. Marshall, May 22, 1996.
5. **Review of Corrosion in 10- and 14-Ton Mild Steel Depleted UF₆ Storage Cylinders,** POEF-TS-02, M.L. Lykins, August 1995.
6. "Suggested Locations for Ultrasonic Thickness Measurements on the Depleted UF₆ Mild Steel Storage Cylinders," POEF-38-343-95-58, M. Lykins to S. Pawel, August 16, 1995.
7. "Handling and Inspection of DOE 48-Inch-Diameter UF₆ Cylinders," EM&EF/EF-P2400 Rev.1, August 1, 1996.
8. "Uranium Hexafluoride-Packaging for Transport. ANSI N14.1-1990," American National Standards for Nuclear Materials, American National Standards Institute, June 1990.
9. "Uranium Hexafluoride: A Manual of Good Handling Practices," ORO-651 (Rev. 6) DE91015811, Analysas Corporation, Oak Ridge, TN, October 1991.
10. "Minimum Wall Thickness Calculations for the UF₆ Storage Cylinders Using ASME Code Section VIII," POEF-38-342-96-507, M. Lykins and M. Frazier to M. Taylor, November 5, 1996.
11. **Investigation and Repair of Suspect Breached Cylinder at Paducah, KY/EM-172,** R.R. Veazey, August 1996.
12. Verification of P-Scan Results, electronic mail Interoffice Memorandum, M. Lykins to M. Taylor, et al, November 1, 1996.
13. "Procedure for P-Scan Inspection of Uranium-Hexafluoride Cylinders," SDI-UT-095-1 Rev. 1, Swain Distribution Inc., October 5, 1995.
14. "UF₆ Cylinder Ultrasonic Testing Self-Assessment Results," LMES-1166-96-102, S. Hampton to T. Marshall, June 28, 1996.
15. **A Comparison of Wall Thickness Measurements on UF₆ Cylinders Using Scanning vs. Manual Ultrasonic Probes,** K/TSO-019, M Schmidt, et al., November 1996.

APPENDIX A

Ultrasonic Test Inspection Reports

SWAIN DISTRIBUTION INC.

P. O. Box 99, Searcy, AR 72145-0099
 211 North Rand Road, Searcy, AR 72143

501-268-5440

UF-6 Storage Cylinder P-Scan Inspection Report

Procedure No. SDI-TS-094-1 Rev. 2 Report No. SDI-96-TS- Date _____

Location _____ Technician (Name/Level) _____ Cylinder I. D. _____

X-Zero Location _____ Y-Zero Location _____

Equipment

PSP-3 407 WSC-2 1109 Scanner AWS-5

Pit Depth Measurement Probe (Probe #1) F. A. T. S. Serial No. 10-12-3

Wall-Thickness Measurement Probe (Probe #2) M. S. E. B. Serial No. 01202

Calibration Information

Calibration Standard UF-6 Cylinder Calibration Plate Wall Thickness 0.302"

Calibration Temperature _____ Cylinder Temperature _____ Thermometer I. D. _____

Actual Hole Depths	0.028"	0.045"	0.070"	0.130"	0.198"
Measured Depths					
Actual Wall Thickness	0.288"	0.248"	0.198"	0.160"	0.105"
Measured Thickness					

Inspection Results

Maximum Pit Depth _____ Wall Thickness Near Location of Maximum Pit _____

* Location of Maximum Pit was Covered / Not Covered by the Wall Thickness Measurement Probe.

Maximum Wall Thickness for Part Lengths: 1 = _____ 2 = _____ 3 = _____ 4 = _____

Maximum Pit Location: X-Coordinates _____ Y-Coordinates _____

Wall Thickness Measurement Probe Range for Part Length Containing Maximum Pit _____

Location of Wall Thickness Measurements Below 0.250":

X-Coordinates _____ Y-Coordinates _____

Valid Measurement Percentages

Wall Thickness (M. S. E. B.) _____ Pit Depth (F. A. T. S.) _____

Analysis By: (Signature/Level/Date) _____

Review By: (Signature/Level/Date) _____

P-Scan Inspection Report

SWAIN DISTRIBUTION INC.

P. O. Box 99, Searcy, AR 72145-0099
211 North Rand Road, Searcy, AR 72143

501-288-5440

UF-6 Storage Cylinder Manual U. T. Thickness Measurements

Cylinder I. D. _____ Location _____ Date _____

Equipment

Ultrasonic Instrument Sonatest Sitiescan 120 Type SS1208 Serial No. 1201503

Large Diameter Transducer J160 Size 0.250" Frequency 5.0 Mhz Serial No. B83289

Small Diameter Transducer _____ Size _____ Frequency _____ Serial No. _____

Calibration Information

Calibration Standard 0.154" thru 0.385" steps Serial No. _____ UF-07 _____

Calibration Times: In _____ Check _____ Check _____

Results

1. A _____ B _____ (contact point of adjacent rings) 2. A _____ B _____ (12 o'clock position)

3. A _____ B _____ (3 o'clock position) 4. _____ (Center of valve-end head)

5. _____ (Center of plug-end head) 6. _____ (Directly beneath the valve)

7. _____ (Directly beneath the plug) 8. A _____ B _____ C _____ D _____

E _____ (five readings in the skirt area of the cylinder head)

9. A _____ B _____ C _____ D _____ E _____ F _____ (six readings taken at the 6 o'clock position, adjacent to the weld - three on each side, in the heat affected zone area)

Note: Any non-applicable blank, due to variations in cylinder design, shall be marked "n/a".

Technician: (Signature/Level/Date) _____

Manual Ultrasonic Test Measurements Report

APPENDIX B

Variations in Ultrasonic Test Results

Figure A-1: Variation in average of manual ultrasonic test measurements at the 3 o'clock position and P-Scan MSEB wall thickness data

APPENDIX C
Observations and Findings

Observations and Findings

16. Location of P-Scan Evaluations

During the subcontract, the cylinders that were evaluated with the P-Scan system and Manual UT measurements were placed in a staging area. This staging area was situated away from the normal re-stacking operations. The cylinders were typically not stacked, with the exception of about ten cylinders evaluated at PGDP. The cylinders were placed on concrete saddles with the outer stiffening rings on the inside of the saddles. This was found to improve the evaluations by increasing the accessibility to the cylinder.

Prior to FY 1995, there had been no consistent procedures for placing the positions of the support saddles or the bottom row cylinders. The crevice created at the cylinder/support saddle interface is believed to be an area where the cylinders may experience accelerated corrosion because of the potential for retaining moisture and water in this area. Therefore, the location of the crevice corrosion created at the cylinder/support saddle interface could vary on the bottom of the cylinder. The top row cylinders should, in general, experience less problems with crevice corrosion than bottom row cylinders.

During the subcontract, it was recognized that some P-Scan evaluations had occurred at incorrect areas on some of the cylinders. For instance, the P-Scan evaluation did not traverse the corroded area created at the cylinder/support saddle interface on bottom row cylinders. The pre-job briefing held at PGDP with SDI in March 1996 described the location of the P-Scan evaluation and the location of the Manual UT measurements necessary for the cylinders. In addition, the evaluation requirements were listed in the sub-contractual agreement with SDI, as well as the SDI procedure used in FY 1996.¹³

An assessment was conducted by Quality personnel at PORTS and PGDP after the discrepancy was discovered. In general, SDI was found to follow procedures and sub-contractual requirements during the assessments.¹⁴ A visual inspection of all of the cylinders evaluated up to when the discrepancy was identified was conducted at PORTS and PGDP. The inspection was conducted to determine whether the P-Scan evaluation occurred in the correct location. The inspection identified about 100 bottom row cylinders had been evaluated in an area other than at the cylinder/support saddle interface. The problem was rectified when it was discovered. Those cylinders found to have been evaluated in incorrect areas were not evaluated a second time with the P-Scan system. Most of the cylinders had been relocated in a stacked array in a cylinder storage yard when the discrepancy was found. All of the data obtained for the evaluations has been used in this report.

For bottom row cylinders that may have experienced corrosion from ground contact, the location of the evaluation, as related to the saddle interface, may not be critical. For instance, cylinder 8539 is a 48T type 10-ton thin-walled cylinder at PORTS that appeared to have been in ground contact. The cylinder was evaluated twice in two separate areas on the bottom of the cylinder. The first time the cylinder was evaluated, the wall thickness was determined to be 0.184 in. The location of the evaluation was 54.5 in. from the valve end stiffening ring, which was not close to the cylinder/saddle interface region. The second evaluation was conducted at 14 in. from the valve end stiffening ring, which would have included the cylinder/saddle interface. The wall thickness was determined to be 0.189 in. Very little differences were found in the wall thickness along the bottom of the cylinder believed to have been stored in ground contact. (It should be noted that the data obtained during the P-Scan evaluations was difficult to interpret due to the rough surface on the cylinder created due to corrosion.)

For the suspect breached cylinder at PGDP, the wall thickness along the bottom of the cylinder was found to vary considerably.¹¹ The cylinder appeared to have experienced accelerated corrosion caused from ground contact. The wall thickness on the side of the cylinder (about the 3 o'clock position) was determined to be about 0.305 in. The wall thickness in the region where accelerated corrosion had occurred ranged from 0.175 in. to 0.311 in.¹¹ It appears that cylinders that have been stored in ground contact may have a wall thickness that can vary considerably over the corroded area.

17. Interpretation of the P-Scan data

The data generated with the P-Scan system were evaluated using a software package developed exclusively for the P-Scan system (PC-Prog). Interpretation of the data is time consuming and it relies on the experience and judgment of the individual. Throughout FY 1996, the data reported by SDI were verified by Lockheed Martin personnel (Jeff Broders at K-25 and Michael Lykins at PORTS). The verifications were conducted to determine if the wall thickness results were interpreted and reported correctly. In all cases, the results of the cylinder evaluations submitted by SDI and verified by Lockheed Martin personnel were essentially the same.

For instance, if a cylinder had been located in good storage conditions in the top or bottom row position, it is relatively easy to evaluate the data generated during an evaluation to determine the remaining cylinder wall thickness. However, if a cylinder was heavily corroded, it is more difficult to interpret the data generated during a P-Scan evaluation using PC-Prog. A heavily corroded cylinder can create more noise in the signal produced by the MSEB wall

thickness transducer. The MSEB transducer may have poor contact with the steel surface or may shift slightly (not positioned perpendicular to the surface). The wall thickness value from the MSEB transducer may then produce a value which is greater than the true wall thickness of the cylinder. The results of the P-Scan system were evaluated using small diameter transducers at K-25 in 1994.¹⁵ The study found that most of the error found with the P-Scan system was attributed to the data obtained with the MSEB transducer used to collect wall thickness measurements.

In addition, if the corrosion by-products were not removed adequately, the FATS probe could still be used to evaluate the surface of the cylinder. However, the pit depth measured would be inaccurate because the probe would be measuring inconsistencies in the corrosion by-products on the steel surface. Therefore, it is important to have a properly prepared surface before conducting an evaluation to ensure that the data obtained with the P-Scan system is both accurate and reliable.

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