February 3, 2009

To: Kelly Dappen
Product Administration
Headquarters

From: J. F. Evans
Sr. Research Engineer

Subject: Aluminized Type 2, The First 50 Years

RI No. 090017, Report No. 1 - Final

The following detailed site assessments can be posted on the web or forwarded in to customers in relevant geographic locations

BACKGROUND

During 1952-3 Armco collaborated with state departments of transportation which installed of Type 2 Aluminized corrugated steel pipes (T2 CSP) in various locations. Two reports were published documenting T2 CSP durability in 1983 and 1996 summarizing the 30 and 43 year status. This Research Investigation represents the third report summarizing the status of the remaining 22 sites following more than 50 years in service. Ten of the sites assessed in 1996 were removed from service due to changes in land use. The site in Sangamon Co. Illinois was completely submerged due to locally heavy rains prior to the time of the assessment, while a site in Marshall Co. IA had to be relined and grouted due to damage on the galvanized half of this tandem site.

This report contains state by state compilations of site assessments conducted over 4 years starting in 2002. A total of 22 pipes in 9 states were located and examined. Each site assessment includes the location, site description, list of samples procured, visual observations and environmental parameters. The environmental parameters of interest include soil resistivity, soil pH, chloride and sulfate content, and water (when available) resistivity and pH.

SITE ASSESSMENT SAMPLING AND TESTING

Soil: ‘A’ position was designated above the water line, contacting the pipe. ‘B’ position was designated near the invert, less than 6” from the pipe. All soil chemistry and resistivity data was gathered on the B position sample.

Water: When available water was procured at the invert. Several sites were dry, and no sample could be obtained. In San Juan Co. WA, the pipes were dry when sampling in mid-September, but the local county personnel explained that during the rainy season (November through March) these culverts have water running continuously.

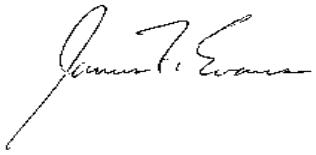
Trepan: Pipe samples were cut as close to the 6 o’clock position as practical. The coupon center point is on a corrugation crest. The metallographic section

attempts to characterize the surface as fairly and accurately as possible. The original pipe thickness was determined using a hand held micrometer on a pristine section of the original pipe with free aluminum coating present on both sides. At sites where pristine Type 2 ends were unavailable for measurement, the trepans were measured in locations where free aluminum coating was present on both sides. Deepest pit depth was measured using a micrometer equipped with pointed caliper ends. Several pitted positions on the trepan were measured but only the deepest pit was recorded.

Observations describe pipe conditions and are usually supported by the images included in the site assessment.

CONCLUSIONS

The pipe conditions after 50 years in service provided enough data to conservatively extrapolate service life estimates beyond 75 years for 16 gage Type 2 Aluminized. Using pit depth penetration, it is reasonable and conservative to expect the service life for 16 gage Type 2 Aluminized Corrugated Steel Pipe (0.062" nominal thickness) to be 100 years for environmental conditions with a narrower pH range from 6.0 to 8.0 and minimum resistivity of 1500 ohm.cm or environments with pH 5.0 to 8.0 and minimum resistivity of 5000 ohm.cm. The 75 year estimated service life for 16 gage Type 2 Aluminized in pH range 5.0 to 9.0, with 1500 ohm-cm minimum resistivity was validated soundly.



James F. Evans
Sr. Research Engineer
Carbon Steel Product Research

JFE/RI No. 090017cover letter/jj

ATTACHMENTS

1. ALT2 Site Assessment Summary and 7 summary reports compassing site assessments in the states of CA, CO, IL, IA, KS, MO, NM, WA

REFERENCES

1. L. Bednar "Aluminized Steel Type 2 Corrugated Steel Pipe Durability Update: 1996"

2. Research Daybook 7494 p.1 through 19.

Site and Laboratory Summaries for Illinois

Site Location: Greene County, IL. Site 1 1.0 mi. NE of Hillview-Eldred blacktop, 10 paces SW of residential driveway
Description: 36" dia. ALT2 in good condition, visually round – no apparent ovality or buckling. Estimate 5 days since previous rainfall.
Sampling: 3 Soils from A, B and C positions, 1 water, 1 ALT2 trepan.
Observer: James DuBoise, PE Illinois DOT
Observations: Good condition, no buckling, still round. Almost no red rust at the 6'o'clock position. Approximately 5 days since last rainfall per J. DuBoise.
Parameters:
Soil resistivity: 1930ohm.cm; pH: 7.0; chlorides: 40 ppm, sulfates: 68ppm
Water; water resistivity: 550 ohm.cm; pH: 6.9 stagnant puddle near inlet

Images from Greene County Site:

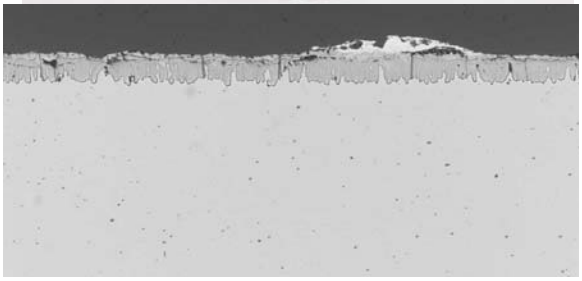
Site and Laboratory Summaries for Illinois

Trepan Evaluation: The top images represent the coupon 'as received'. The coupon was then bead blasted to remove loose oxides and an images were recorded of the remaining surface. Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.114".
Micrometer results: Ball: 0.113", 0.114", 0.113" Point: 0.096" (0.018"deep)
Based on conservative pit penetration extrapolations, the projected service life of 16 gage T2 CSP will exceed 100 years in this environment.

Images of Type 2 Aluminized trepan from Site 1:

ALT2 water side

ALT2 soil side



140X

140X

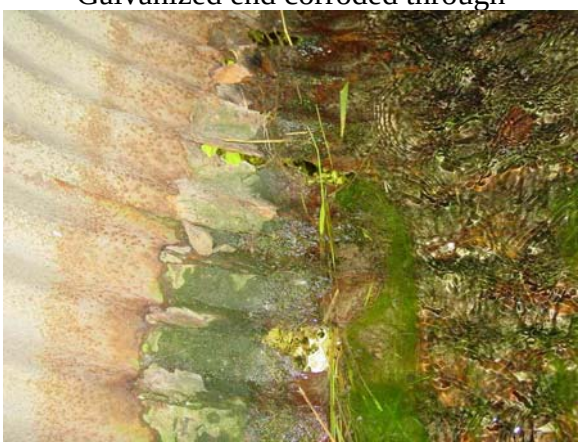
Site and Laboratory Summaries for Illinois

Site Location: Morgan County, IL. Site 2 1.0 mi. south, 2.5 mi. west of Prentice, IL. 30 paces east of residential driveway. South end is ALT2 (inlet), north side is galvanized.
Description: 36" dia. ALT2 in very good condition on south end of pipe. Galvanized on north end of pipe corroded completely through at bottom.
Sampling: 2 Soils from A positions at each end, 1 water sample flowing @1.5" deep in pipe, 1 ALT2 trepan. No galvanized sample taken.
Observer: James DuBoise, PE Illinois DOT
Observations: Free aluminum coating is visible around the complete circumference. Previous trepan holes not corroded further. Sample taken at 6:30 position. Galvanized end is corroded completely through at bottom of pipe. The exposed crown on the galvanized end is rusted with no remaining zinc. Estimate 5 days since previous rainfall per J. DuBoise.
Parameters:
Soil resistivity: 2860ohm.cm; pH: 7.0; on ALT2 end. Chlorides: 10ppm, sulfates: 33ppm
Soil resistivity: 1820ohm.cm; pH: 6.9; on galv end. Chlorides: 10ppm, sulfates: 28ppm
Water pH: 6.6; resistivity: 1370 ohm.cm

Images from Morgan County Site:

Aluminized end

Galvanized end corroded through



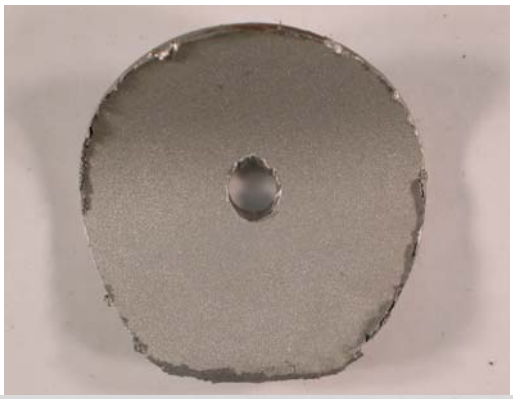
Site and Laboratory Summaries for Illinois

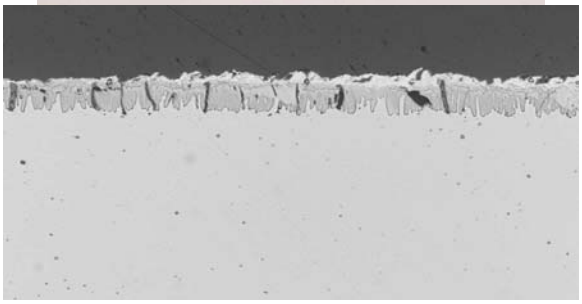
Trepan Evaluation: The top images represent the coupon 'as received'. The coupons were then bead blasted to remove loose oxides and images were recorded of the remaining surface. Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.113".
Results Ball: 0.112", 0.112", 0.113" Point: 0.111" (0.002"deep – very few small pits)
Based on conservative pit penetration extrapolations, the estimated service life of 16 gage T2 CSP will exceed 100 years in this environment.

Images of Type 2 Aluminized trepans from Site 2:

ALT2 water side

ALT2 soil side





140X

140X

Site and Laboratory Summaries for Illinois

Site Location: **Sangamon County, IL**, north of Buckhart, IL north on E. Buckhart Rd.for 1.0 mile, jog to right and north on Young Rd. 0.5 miles. Pipe goes under Young Rd. east/west. Site was completely submerged due to high water.
Observer: James DuBoise, PE Illinois DOT
No Observations or samples procured

Image from Sangamon County Site:

Site and Laboratory Summaries for Iowa

Site Location: Marshall County, IA, Site 3. 3.2 mi. north of State Center, IA under S52 Road.
Description: 36" dia. ALT2/Galv tandem in good condition, runs east/west under a north south road (S52).visually round – no apparent ovality or buckling.
Sampling: 6 Soils from A, B and C positions on both ends, 0 water, 1 ALT2 & 1 Galv trepan.
Observations: Good condition, no buckling, still round on both ends. ALT2 in very good condition. Sampled at the 6'o'clock position. Galvanized end rusted and discolored with a heavy oxide layer @ 18" of pipe bottom, not perforated just heavily pitted. Surroundings are very densely vegetated with tall thick grass covering the entire slope from the road to the crops.
Environmental Parameters:
ALT2 end: Soil resistivity: 1270 ohm.cm; pH: 6.6; Chlorides: 10ppm, sulfates: 27ppm
Galv. end: Soil resistivity: 1490 ohm.cm; pH: 6.8; Chlorides: 20ppm, sulfates: 45ppm
No water samples available at this site.

Images from Marshall County Site 3:

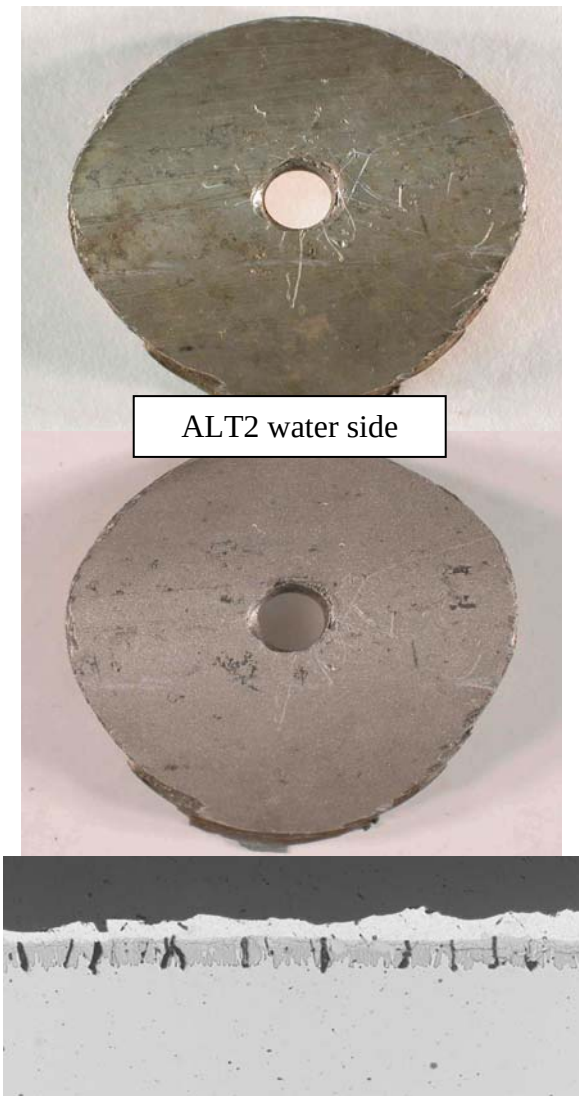
Galvanized end

Aluminized end

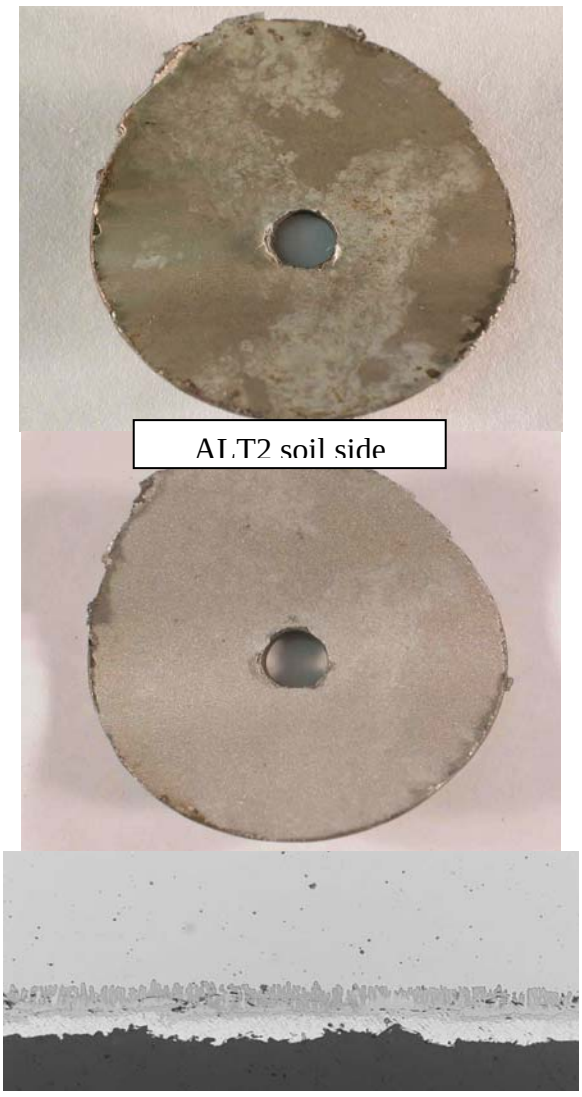
Site and Laboratory Summaries for Iowa

Site 3 Trepan Evaluation ALT2: The top images are of the coupon as removed after rinsing off loose dirt and debris. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. No pitting evident.
Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.115".
Micrometer results: Ball: 0.114", 0.115", 0.115" Point: 0.112" (0.003"deepest pit)
Based on conservative pit penetration extrapolations, the service life of 16 gage T2 CSP will exceed 100 years.

Images of ALT2 trepans from Site 3: all 6 o'clock pipe positions



140X



140X

Site and Laboratory Summaries for Iowa

Site Location: Marshall County, IA, Site 4. 0.1 mi. north of E29 on S52.
Description: 36" dia. ALT2/Galv tandem in good condition, east/west under a north south road (S52) visually round, no apparent ovality or buckling. Similar to previous Marshall Site 3.
Sampling: 6 Soils from A, B and C positions on both ends, 0 water, 1 ALT2 & 1 Galv trepan.
Observations: Good condition, no buckling, still round on both ends. ALT2 (outlet) in very good condition although it was beneath 12" of soil. Some free aluminum was still visible. Sampled at the 6'o'clock position. Galvanized end (high side) was beneath 6" of dirt. It was rusted and discolored with a heavy oxide layer @ 20" of pipe bottom, not perforated just heavily pitted. Surroundings are very densely vegetated with tall thick grasses covering the entire slope from the road to the crops, similar to all Marshall Co. Sites in Iowa.
Environmental Parameters:
ALT2 end: Soil resistivity: 1830 ohm.cm; pH: 6.9; Chlorides: 30ppm, sulfates: 31ppm
Galv. end: Soil resistivity: 1660 ohm.cm; pH: 7.0; Chlorides: 40ppm, sulfates: 44ppm
Water pH: no water was available at this site.

Images from Marshall County Site 4:

Galvanized end

Aluminized end

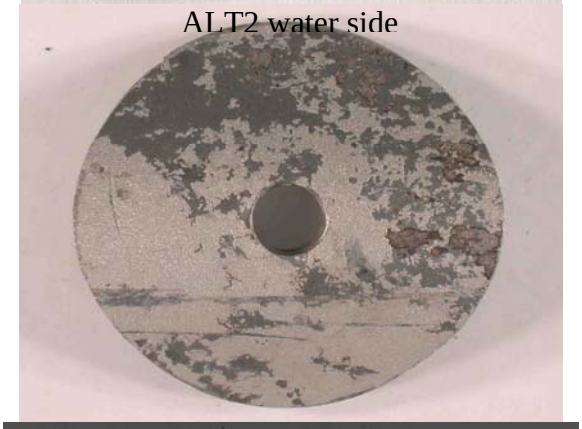
Site and Laboratory Summaries for Iowa

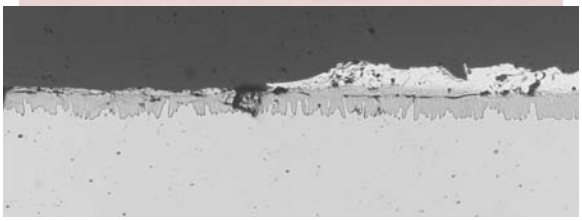
Site 4 Trepan Evaluation ALT2: The top images are of the coupon as removed after rinsing off loose dirt and debris. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Some shallow small pits were visible on the water side.
Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.116".
Micrometer results: Ball: 0.116", 0.115", 0.116" Point: 0.112" (0.004"deep)
Based on conservative pit penetration extrapolations, the service life of 16 gage T2 CSP will exceed 100 years.

Images of trepan from Site 4: all 6 o'clock pipe positions

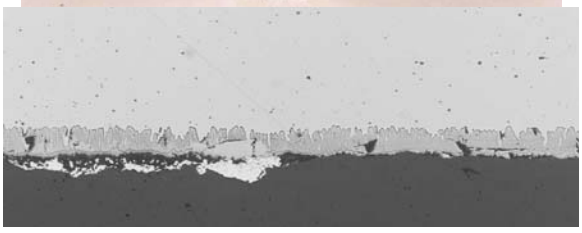
ALT2 water side

ALT2 soil side





140X



140X

Site and Laboratory Summaries for Iowa

Site Location: Marshall County, IA, Site 5. 1.4 mi. south of E29 on S52.
Description: 36" dia. ALT2/Galv tandem in good condition, east/west under a north south road (S52) visually round, no apparent ovality or buckling. Similar to other Marshall Co. sites.
Sampling: 6 Soils from A, B and C positions on both ends, 0 water, 1 ALT2 & 1 Galv trepan.
Observations: Good condition, no buckling, still round on both ends. ALT2 (outlet) in very good condition although it was beneath 2" of soil. Some free aluminum was still visible. Sampled at the 6'o'clock position. Galvanized end (inlet) was engulfed in heavy brush and undergrowth. It was rusty and discolored @ 12" of pipe bottom, not perforated, pretty good condition for galvanized. Surroundings on both ends were very densely vegetated with tall thick grasses covering the entire slope from the road to the crops, similar to all the Marshall Co. sites.
Environmental Parameters:
ALT2 end: Soil resistivity: 1040 ohm.cm; pH: 7.1; Chlorides: 140ppm, sulfates: 97ppm
Galv. end: Soil resistivity: 1570 ohm.cm; pH: 6.6; Chlorides: 10ppm, sulfates: 78ppm
Water pH: no water was available at this site.

Image from Marshall County Site 5:

Galvanized end

Aluminized end

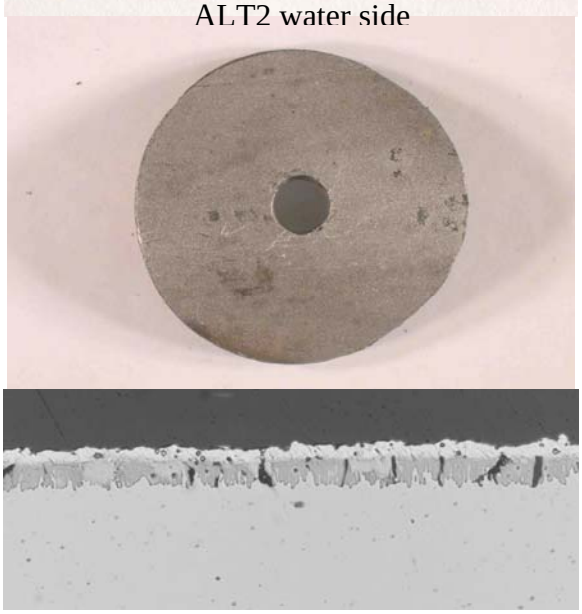
Site and Laboratory Summaries for Iowa

Site 5 Trepan Evaluation ALT2: The top images are of the coupon as removed after rinsing off loose dirt and debris. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Few very lite, shallow pits mostly on the soil side.
Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.113".
Micrometer results: Ball: 0.111", 0.111", 0.112" Point: 0.110" (0.003"deepest pit)
Based on conservative pit penetration extrapolations, the projected service life of 16 gage T2 CSP will exceed 100 years.

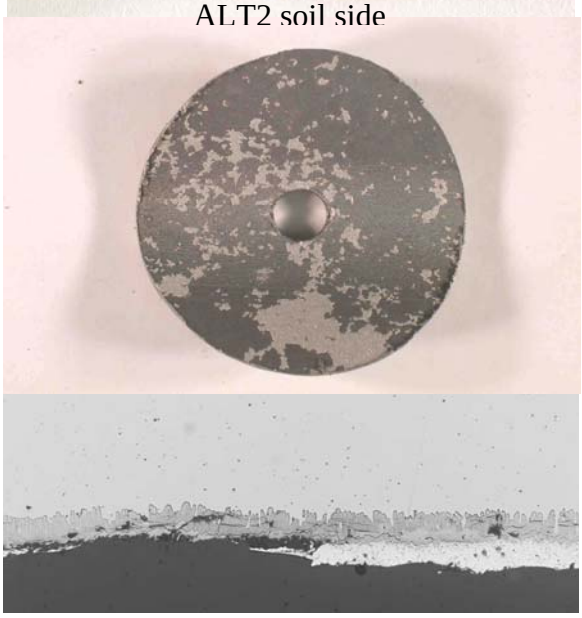
Images of ALT2 trepans from Site 5: all 6 o'clock pipe positions

ALT2 water side

ALT2 soil side



140X

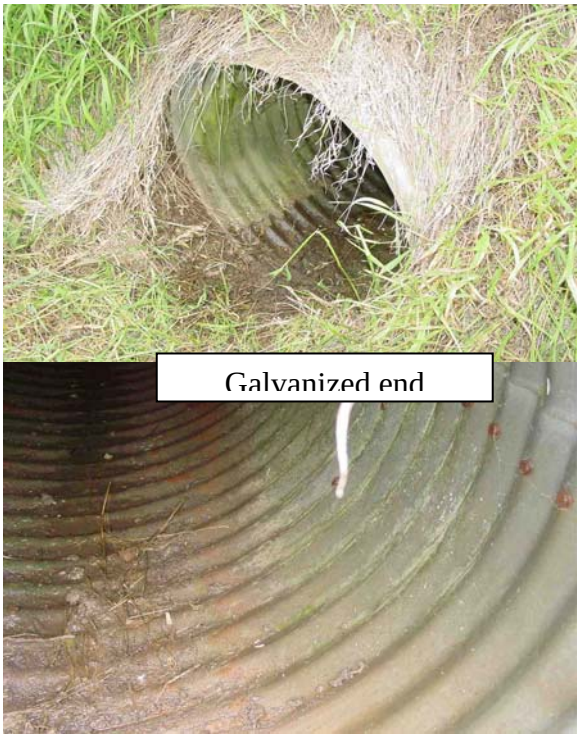


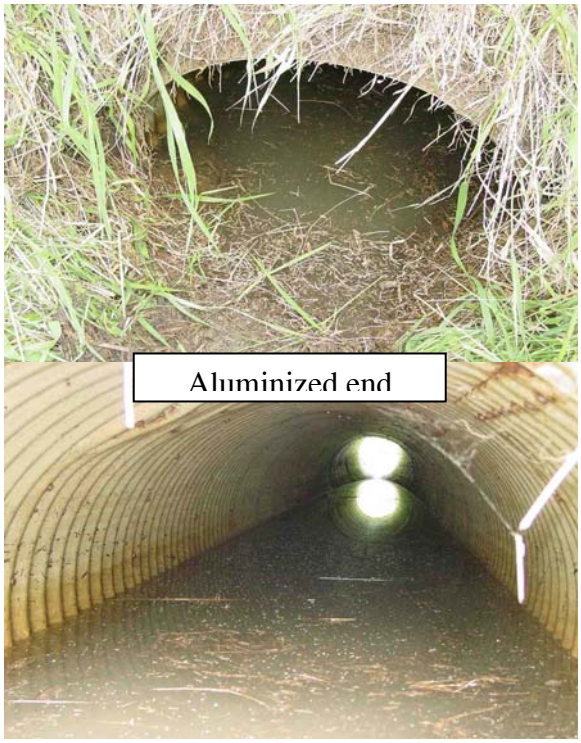
140X

Site and Laboratory Summaries for Iowa

Site Location: Marshall County, IA, Site 6. 0.8 mi. north of E29 on S52.
Description: 36" dia. ALT2/Galv combination, east/west under a north south road (S52). Aluminized end (outlet) is too deeply buried/submerged to trench and sample. Galvanized end (inlet) is rusted and pitted but not perforated, no apparent ovality or buckling.
Similar to other Marshall County sites.
Sampling: 4 Soils from A, B and C positions on the Galvanized end, one from the A position on the Aluminized end and 1 water sample from the standing water on the Aluminized end as well. Only galvanized trepan procured from pipe.
Observations: Good condition, no buckling apparent. ALT2 (outlet) is mostly buried and submerged under mud and standing water, too much to drain and trench. Galvanized end (inlet) was rusty @ 14" of pipe bottom, not perforated, pretty good condition for galvanized. Surroundings on both ends were very densely vegetated with tall thick grasses covering the slopes from the road to the crops, similar to other Marshall County sites.
Parameters:
ALT2 end: Soil resistivity: 1860 ohm.cm; pH: 7.1; Chlorides: 10ppm, sulfates: 76ppm
Galv. end: Soil resistivity: 1570 ohm.cm; pH: 6.6; Chlorides: 10ppm, sulfates: 59ppm
Water sample: Resistivity: 1790ohm.cm, pH: 6.6; stagnant condition

Images from Marshall County Site 6:





Site and Laboratory Summaries for Iowa

Site Location: Marshall County, IA, Site 7. 1.2 mi. north of E29 on S52.
Description: 36" dia. ALT2/Galv combination, east/west under a north south road (S52). Aluminized end (inlet) has been extended, difficult to photograph because approximately 12' has been added to pipe length due to road slope accommodations. Galvanized end (outlet) was not sampled due to extensions on the pipe. No ovality or buckling is visible looking through the pipe. Similar to other Marshall County sites.
Sampling: 5 Soils from A, B and C positions on the Aluminized end, two from the A & B positions on the Galvanized end and 1 water sample from the standing water on the Aluminized end was procured. Only an Aluminized trepan was procured from pipe.
Observations: Good condition, no buckling apparent.
Surroundings on both ends were very densely vegetated with tall thick grasses covering the slopes from the road to the crops, similar to other Marshall County sites.
Environmental Parameters:
ALT2 end: Soil resistivity: 1330ohm.cm; pH: 7.0; Chlorides: 30ppm, sulfates: 88ppm
Galv. end: Soil resistivity: 1820ohm.cm; pH: 6.3; Chlorides: 20ppm, sulfates: 66ppm
Water sample: Resistivity: 710ohm.cm; pH: 6.7; stagnant condition

Images from Marshall County Site 7:

Galvanized end

Aluminized end

Site and Laboratory Summaries for Iowa

Site 7 Trepan Evaluation ALT2: The top images are of the coupon as removed after rinsing off loose dirt and debris. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Moderate to heavy pitting on the water side, and lite pitting on the soil side.
Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.105".
Micrometer results: Ball: 0.096", 0.101", 0.094" Point: 0.074" (0.031"deep)
Based on conservative pit penetration extrapolations, the 16 gage service life would remain 75 years, low resistivity water and soil likely contributed to the poorer performance.

Images of ALT2 trepans from Site 7 at six o'clock pipe position

ALT2 water side

ALT2 soil side

140X

140X

Site and Laboratory Summaries for Missouri

Site Location: Lafeyette County, Mo, Site 8 1.5 miles west of Rt. 13 on FF Rd. @ 50 yards west of a small farm access which was on the north side of FF.

Description: 36" dia. Galvanized (inlet) ALT2 (outlet) combination. Estimate 7 days since previous rainfall. Rocky soil and the presence of abrasive debris upstream have visibly pitted the 6 o'clock position of this pipe.

Sampling: Three soil samples were procured from the A and B positions on ALT2 end and only the A position on the Galvanized end due to cement headwall. One water sample, 1 ALT2 trepan and 1 fragment from the perforated Galvanize end was also collected.

Observations: ALT2 is in good condition, no buckling, still round. Previous hole saw cuts are intact with no appreciable 'creep'. Narrow path between 5:30 and 6:30 position appears to be without coating. Alloy appears exposed from 4:30 to 7:30 position. Galvanized end is completely perforated from 5 to 7 o'clock position. Fairly rocky soil on both ends of the pipe.

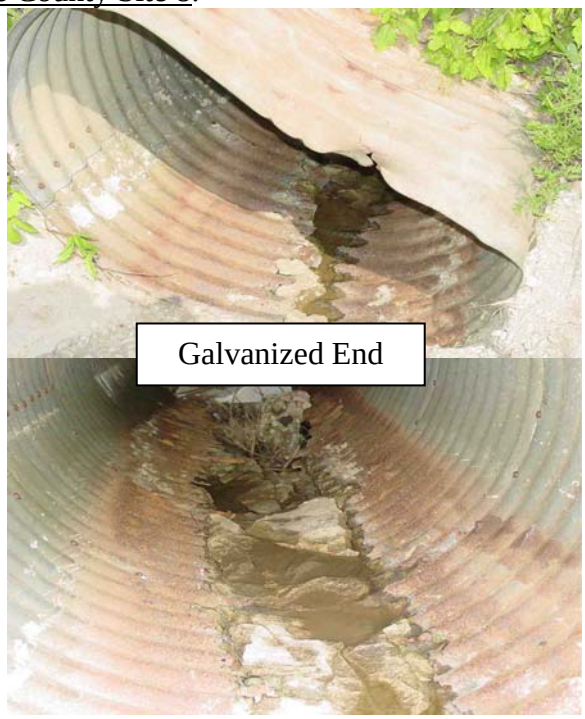
Environmental Parameters:

ALT2 end: Soil resistivity: 1830ohm.cm; pH: 7.4; Chlorides: 40ppm, sulfates: 48ppm

Galv. end: Soil resistivity: 6010ohm.cm; pH: 7.1; Chlorides: 10ppm, sulfates: 25ppm

Water: pH: 6.6; resistivity: 1520 ohm.cm

Images from Lafeyette County Site 8:



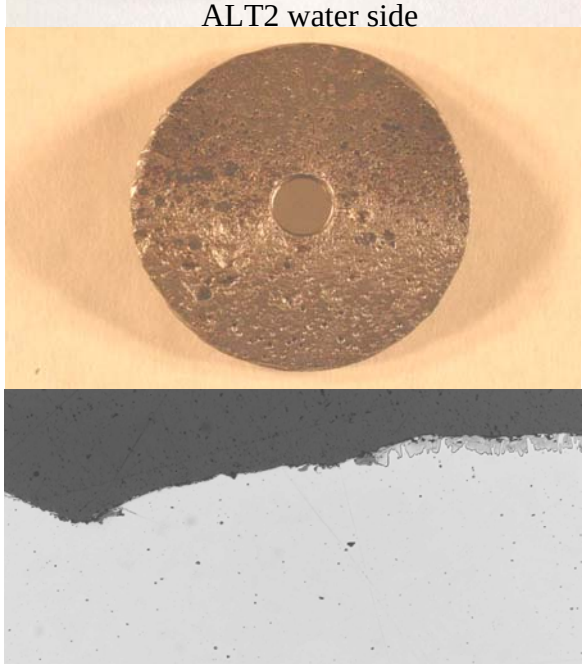
Site and Laboratory Summaries for Missouri

Site 8 ALT2 Trepan Evaluation: The top images are the coupon as removed after rinsing off loose dirt and debris. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Lite to moderate pitting is present on the top surface.
Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.107",
Micrometer results: Ball: 0.099", 0.103", 0.101" Point: 0.090" (0.017"deep)
Based on conservative pit penetration extrapolations, the service life of 16 gage T2 CSP would remain 75 years in this environment. The main detractor appears to be pitting due to abrasion.

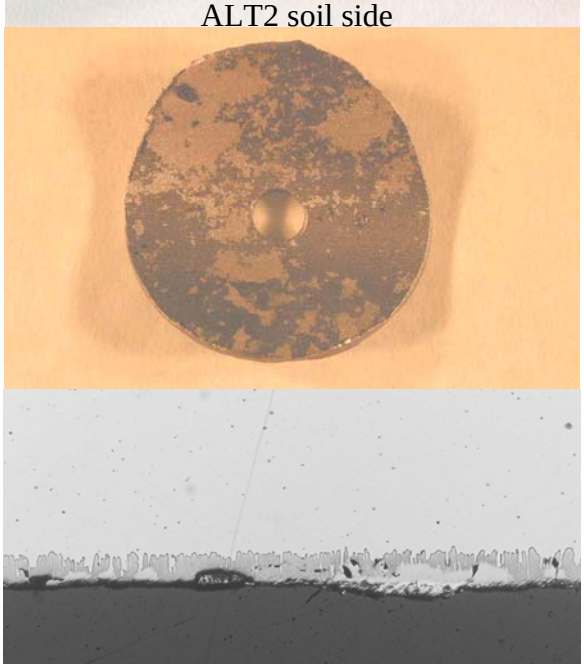
Images of ALT2 trepan from Lafeyette Co. Site 8: ALT2 soil side

ALT2 water side

ALT2 soil side



140X

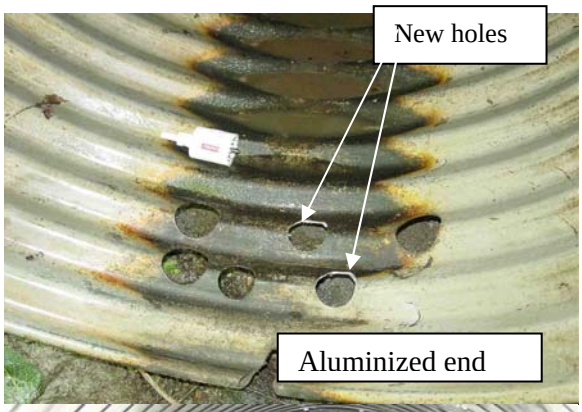


140X

Site and Laboratory Summaries for Missouri

Site Location: Lafeyette County, MO, Site 9 1.0 mi. west of Rt 13 on FF. In large wooded ditch, 40' west of stabilized utility pole which is on the north side of FF.
Description: 30" dia. 14 gage ALT2 tandem with 14 gage Galvanized (inlet).
Sampling: 2 Soil samples from A and B positions on the ALT2 end, 1 water sample from water standing on the ground beneath the ALT2 end and 1 ALT2 trepan. No galvanized sample taken, image only. Could not obtain galvanized soil sample due to the concrete headwall and rocky surface beneath the perforated pipe.
Observations: Free aluminum coating is visible around most of circumference. ALT2 pipe was in good condition with some red rust at the 6 o'clock position approximately 9" wide at bottom. Previous saw cuts from the 30 year and the 42 year durability studies are intact with no creep evident. Galvanized end of pipe corroded completely through from 5 to 7 o'clock position exposing a washed out rocky surface beneath. No soil sample was procured.
Environmental Parameters:
ALT2 end: Soil resistivity: 1770ohm.cm; pH: 7.2; Chlorides: 30ppm, sulfates: 75ppm
Water: Resistivity: 990 ohm.cm, pH: 6.4; stagnant

Images from Lafeyette County Site 9:



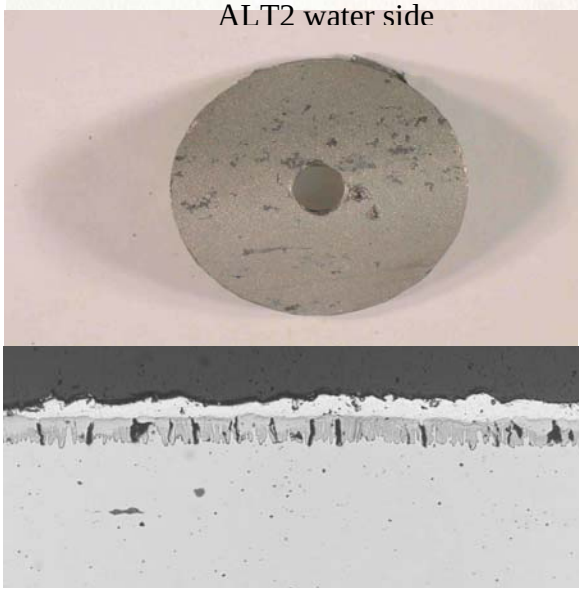
Site and Laboratory Summaries for Missouri

Site 9 ALT2 Trepan Evaluation: The top images are of the coupon removed from the lowest point on the pipe after rinsing off loose dirt and debris. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Almost no pitting is present on the top or bottom surfaces. Removal of the red rust revealed that Type 2 coating was still intact and the red rust appears to be 'leached on' from the remnants of the rusty upstream galvanized pipe. Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.083".
Micrometer results Ball: 0.082", 0.083", 0.082" Point: 0.082" (no pitting)
Based on conservative pit penetration extrapolations, the service life of 16 gage ALT2 material would be in excess of 100 years.

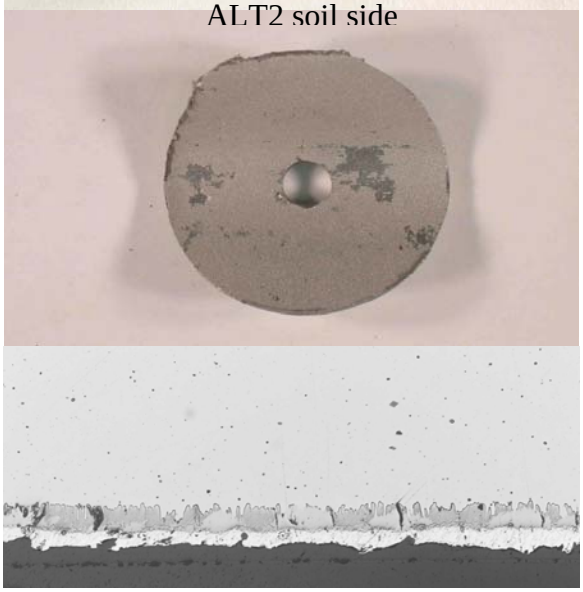
Images of ALT2 trepan from Lafeyette Co. Site 9:

ALT2 water side

ALT2 soil side



140X



140X

Site and Laboratory Summaries for Missouri

Site Location: Carter County, MO, Site 10 5.8 mi. north of bus.60 on Hwy D.
Description: 36" dia. 12 gage ALT2 installed inline with 12 gage Galvanized (uphill end).
Sampling: 2 soil samples from the A position at the ALT2 and galvanized ends. No trepans taken, only images. The pipe was half full of silt and rocky debris.
Observations: Qualitatively, the aluminized end showed slightly less evidence of red rust. Upon looking into the half filled culvert (lower left image) the visible upper arch on the aluminized end was intact with some red rust at the joints. This culvert is overdue for maintenance, it was not possible to determine the pipe condition below grade on either end.
Environmental Parameters:
ALT2 end: Soil resistivity: 1420ohm.cm; pH: 6.7; Chlorides: 10ppm, sulfates: 35ppm
Galv. end: Soil resistivity: 4720ohm.cm; pH: 6.7; Chlorides: 90ppm, sulfates: 44ppm
The galvanized end was closer to the shoulder of the road which would explain the higher chloride levels likely from road salt. Water sample: none, site dry

Image from Carter County Site 10:

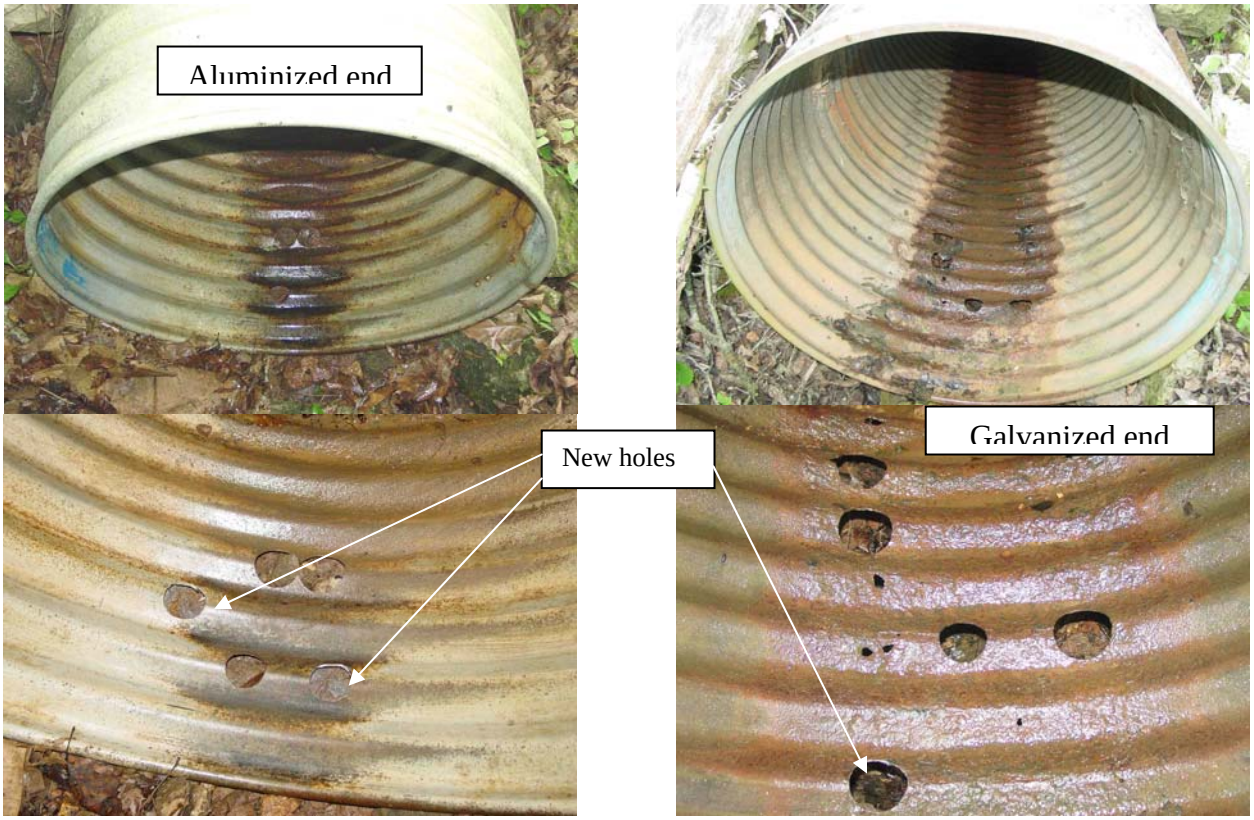
Aluminized end

Galvanized end

Site and Laboratory Summaries for Missouri

Site Location: Carter County, MO, Site 11 5.7 mi. north of bus. 60 on Hwy D. Near Site 10.
Description: 30" dia. 14 gage ALT2 (uphill end) installed inline with 14 gage Galvanized pipe.
Sampling: 4 Soils from A and B positions on the ALT2 and galvanized end, no water sample as the site was dry. 1 ALT2 and 1 galvanized trepan both cut from 2" off the six o'clock position.
Observations: Free aluminum coating is visible around most of circumference. ALT2 pipe was in good condition with some red rust at the 6 o'clock position approximately 6" wide at bottom. Previous saw cuts from the 30 year and the 42 year durability studies are intact with no creep evident on both ends. Galvanized end of pipe has some scattered perforations and red rust at the 6 o'clock position approximately 14"wide. Fairly dense vegetation and leafy ground cover was evident around both ends of the pipe, especially the upstream end, likely reducing abrasion.
Environmental Parameters:
ALT2 end: Soil resistivity: 1830ohm.cm; pH: 6.5; Chlorides: 20ppm; sulfates: 55ppm
Galv. end: Soil resistivity: 3220ohm.cm; pH: 6.7; Chlorides: 30ppm: sulfates: 41ppm
Water sample: none

Images from Carter County Site 11:



Site and Laboratory Summaries for Missouri

Site 11 ALT2 Trepan Evaluation: The top images are of the coupon removed from the lowest point on the pipe after rinsing off loose dirt and debris. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Almost no pitting is present on the top or bottom surfaces. Removal of the red rust revealed that Type 2 coating was still intact on the downstream side of the corrugation's water side and completely intact on the soil side. Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.083"
Micrometer results Ball: 0.082", 0.083", 0.083" Point: 0.078" (minor pitting on the upstream water side only)
Based on conservative pit penetration extrapolations, the service life of 16 gage ALT2 material would be in excess of 100 years.

Images of ALT2 trepan from Carter Co. Site 11

ALT2 water side

ALT2 soil side

140X

140X

Site and Laboratory Summaries for Kansas

Site Location: **Dickinson County, KS**, **Site 12**; 0.2 mile east of Dove Rd. (east access to Carlton, KS) on Hwy 4.
Description: 36" dia. 12 gage Galvanized (inlet) ALT2 (exit) in-line combination.
Sampling: 2 Soils from B positions on ALT2 and galvanized ends. No water, 1 ALT2 trepan and 1 Galvanize trepan.
Observations: ALT2 is in good condition, no buckling, still round, some scaling on the bottom where pipe was beneath the soil. The only red rust is where pipe was damaged by DOT mowers. Galvanized end is completely rusted from 8 o'clock to 4 o'clock position and perforated.
Environmental Parameters:
ALT2 end: Soil resistivity: 1640ohm.cm; pH: 7.1; chlorides: 20ppm, sulfates: 45ppm
Galv. end: Soil resistivity: 1700ohm.cm; pH: 6.6; chlorides: 20ppm, sulfates: 26ppm
Water: none available

Images from Dickinson County Site 12:

Aluminized end

Galvanized end

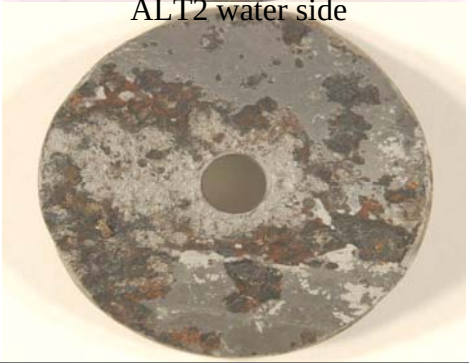
Site and Laboratory Summaries for Kansas

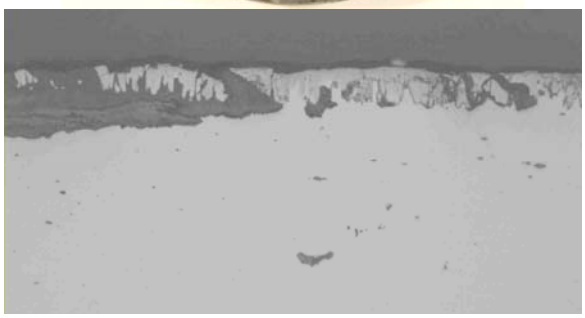
Site 12 ALT2 Trepan Evaluation: The top images are the coupon as removed after rinsing off loose dirt and debris. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Lite to moderate pitting is present on the top surface near the peak. Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.112".
Micrometer results: Ball: 0.111", 0.093", 0.098"; Point: 0.088" (0.024"deep)
Based on conservative pit penetration extrapolations, the service life of 16 gage T2 CSP will exceed 100 years.

Images of ALT2 trepan from Dickenson Co. Site 12:

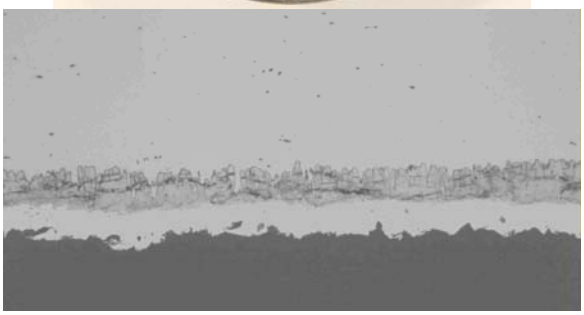
ALT2 water side

ALT2 soil side





140X



140X

Site and Laboratory Summaries for Kansas

Site Location: **Pratt County, KS**, **Site 13** 1.5 mi. east of US 281 on K64. Pipe is located in semi-residential area with minimal overburden above pipe.
Description: 30" dia. ALT2 in-line with Galvanized (upstream) pipe.
Sampling: 2 soil samples from the B positions at each end, no water sample (dry), ALT2 and galvanized trepans procured.
Observations: Both ends looked good. Previous trepan holes not corroded further on either end. Sample taken at 6:30 position. Galvanized end has some red rust from the 5 to 7 o'clock position.
Environmental Parameters:
ALT2 end: Soil resistivity: 3290ohm.cm; pH: 6.9; Chlorides: 30ppm; sulfates: 103ppm
Galv. end Soil resistivity: 3000ohm.cm; pH: 5.9; Chlorides: 50ppm; sulfates: 23ppm
Water: none

Images from Pratt County Site 13:

Aluminized end

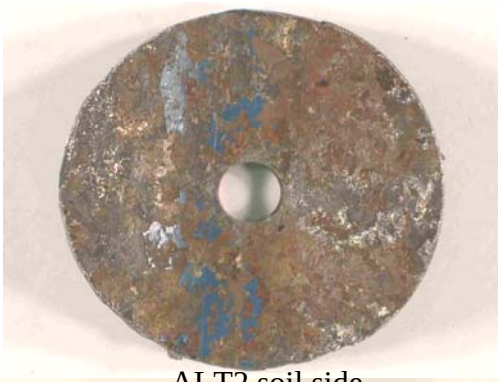
Galvanized end

Site and Laboratory Summaries for Kansas

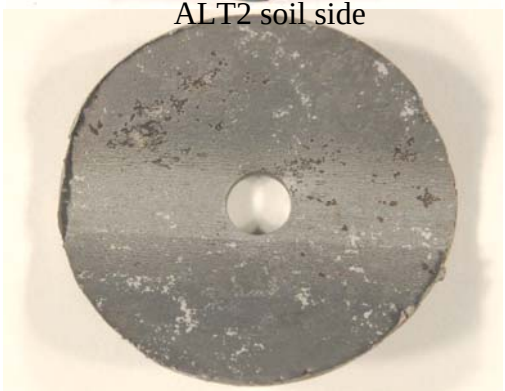
Site 13 ALT2 Trepan Evaluation: The top images are the coupon as removed after rinsing off loose dirt and debris. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Lite to moderate pitting is present on the top surface near the peak. Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.082”
Results Ball: 0.081”, 0.081”, 0.082” Point: 0.066” (0.016”deep)
Based on conservative pit penetration extrapolations, the service life of 16 gage T2 CSP will exceed 100 years.

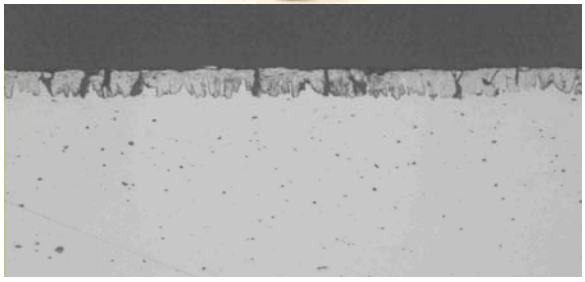
Images of ALT2 trepan from Pratt Co. Site 13:

ALT2 water side



ALT2 soil side





140X

140X

Site and Laboratory Summaries for Kansas

Site Location: Decatur County, KS, Site 14

Description: This site included two parallel 36" culverts of 12 gage pipe. The north ends (inlet) were aluminized while the south ends were galvanized.

Sampling: Soil samples were procured from the A and B positions contacting the pipe, no water was present, and trepans were procured from the 6o'clock position on all four pipe ends.

Observations: Both ends looked pretty good. Aluminized end still has good free aluminum coating intact. Previous trepan holes had not corroded further on either end. Samples were taken at 6:00 position. Galvanized end has red rust from the 4 to 8 o'clock position. Not perforated.

Environmental Parameters:

East ALT2 end: Soil resistivity: 1890ohm.cm; pH: 6.5; Chlorides: 40ppm; sulfates: 25ppm
East Galv end: Soil resistivity: 2830ohm.cm; pH: 6.5; Chlorides: 40ppm; sulfates: 24ppm
Water: none
West ALT2 end: Soil resistivity: 2070ohm.cm; pH: 6.6; Chlorides: 20ppm; sulfates: 30ppm
West Galv end: Soil resistivity: 1660ohm.cm; pH: 6.5; Chlorides: 70ppm; sulfates: 35ppm
Water: none

Images from Decatur County Site 14 ALT2 end:

east pipe aluminized end

west pipe aluminized end

Site and Laboratory Summaries for Kansas

Images from Decatur County Site 14 GALV end:

west pipe galvanized end

east pipe galvanized end

east pipe galvanized end

east pipe galvanized end

Site and Laboratory Summaries for Kansas

Site 14 East ALT2 Trepan Evaluation: The top images are the coupon as removed after rinsing off loose dirt and debris. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Lite pitting is present on the bottom surface and on the top very near the peak.

Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.110".

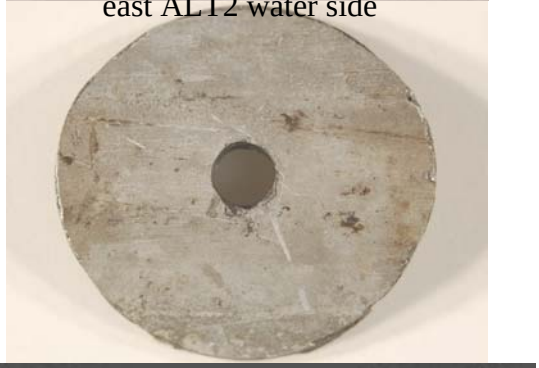
Micrometer results Ball: 0.110", 0.109", 0.109" Point: 0.106" (0.004")

Based on conservative pit penetration extrapolations, the service life of 16 gage T2 CSP will exceed 100 years.

Images of East ALT2 trepan from Decatur Co. Site 14:

east ALT2 water side

east ALT2 soil side



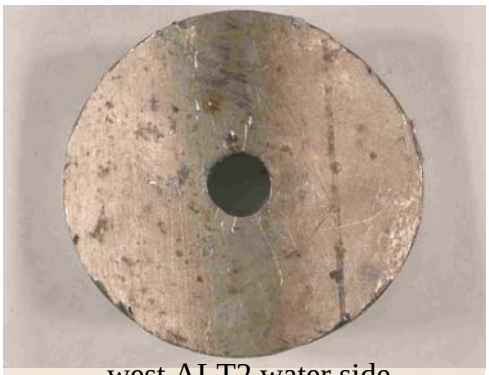
140X

140X

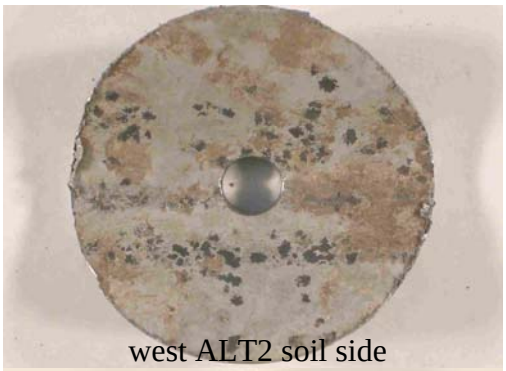
Site and Laboratory Summaries for Kansas

Site 14 West ALT2 Trepan Evaluation: The top images are the coupon as removed after rinsing off loose dirt and debris. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Lite pitting is present scattered on the top and bottom surfaces. Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.110".
Micrometer results: Ball: 0.107", 0.108", 0.108", 0.109" Point: 0.105" (0.005")
Based on conservative pit penetration extrapolations, the service life of 16 gage T2 CSP will exceed 100 years.

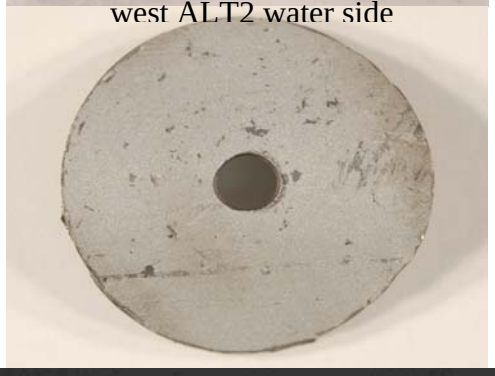
Images of West ALT2 trepan from Decatur Co. Site 14:

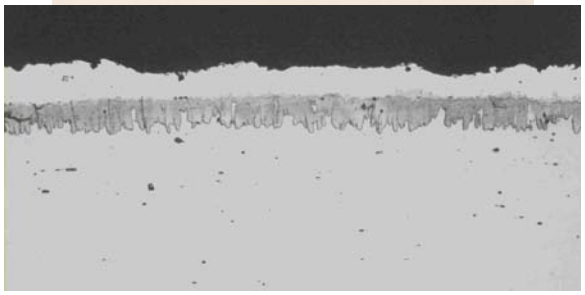


west ALT2 water side

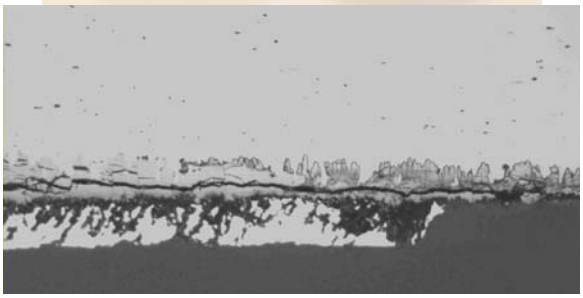


west ALT2 soil side





140X

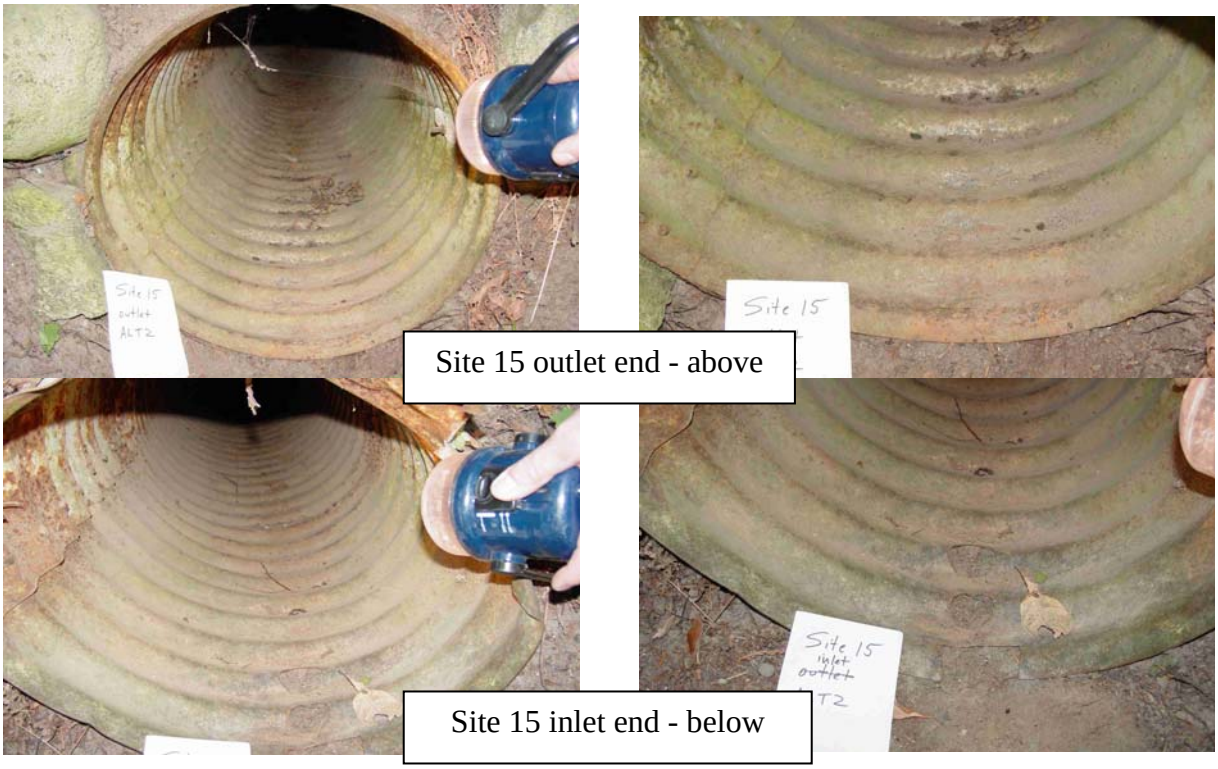


140X

Site and Laboratory Summaries for Washington State

Site Location: San Juan County, WA, Site 15 Road number 140, end of mile 1. Referred to as "Bob Henry's culvert". Aluminized pipe only – no galvanized sections.
Description: 18" dia. ALT2. Currently dry, remains dry most of the summer months. Has water continuously from November to March. Loamy soil with thick vegetation all around. Overall good condition. Rust was visible on upper corrugations inside the pipe, but no appearance of ovality.
Sampling: Two soil samples were procured from the A and B positions on the inlet end of the pipe. One trepan was procured from the 6 o'clock position. No water was available.
Observers: Russ Harvey, Fred Richardson and Joel Thorson of San Juan County Highway Dept.
Observations: ALT2 is in good condition. Previous hole saw cuts are intact with no appreciable 'creep'. Portions of a narrow path between 5:30 and 6:30 position appear to be without coating. Moss appears to be growing over the oxide on the lower half of the pipe.
Environmental Parameters:
Soil resistivity: 17,160 ohm.cm; pH: 5.3; Chlorides: 10ppm, sulfates: 27ppm
Water sample: none, site dry

Images from San Juan County Site 15:



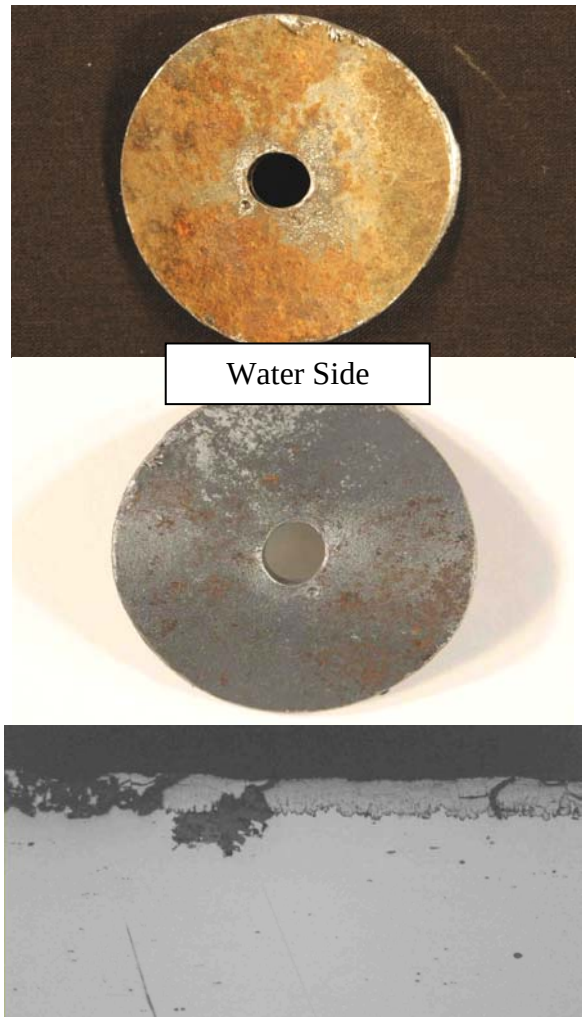
Site 15 outlet end - above

Site 15 inlet end - below

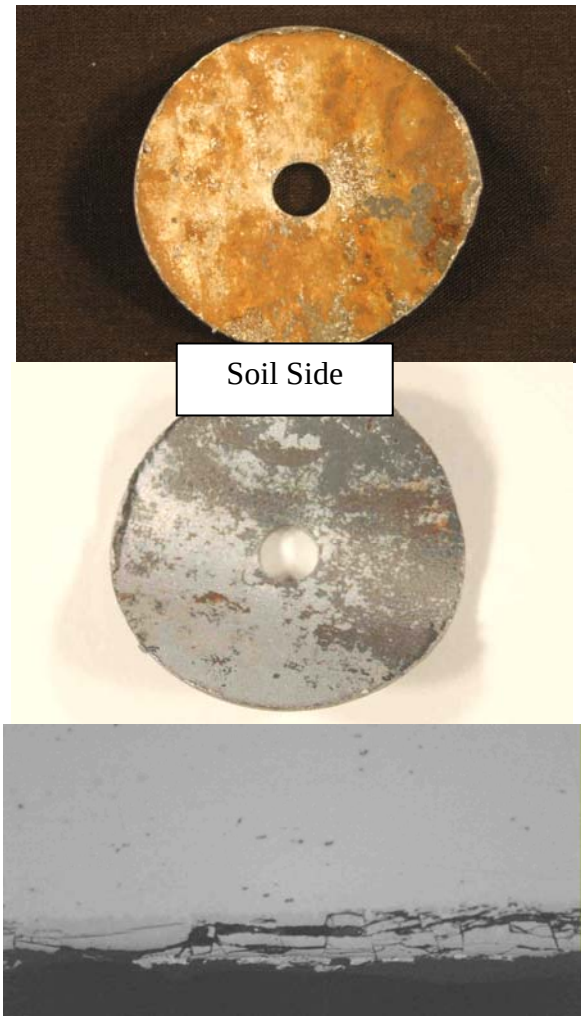
Site and Laboratory Summaries for Washington State

Site 15 ALT2 Trepan Evaluation: The top images are the coupon as removed after rinsing off loose dirt, debris and moss. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Light to moderate pitting is present on the upstream corrugation of the water side.
Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.065".
Results Ball: 0.065", 0.066", 0.065"; Point: 0.055" (0.010" deep)
Based on conservative pit-penetration extrapolations, the service life of 16 gage material would be in excess of 100 years.

Images of ALT2 trepan from San Juan Co. Site 15:



140X



140X

AK Steel Site and Laboratory Summaries for Washington State AK Steel

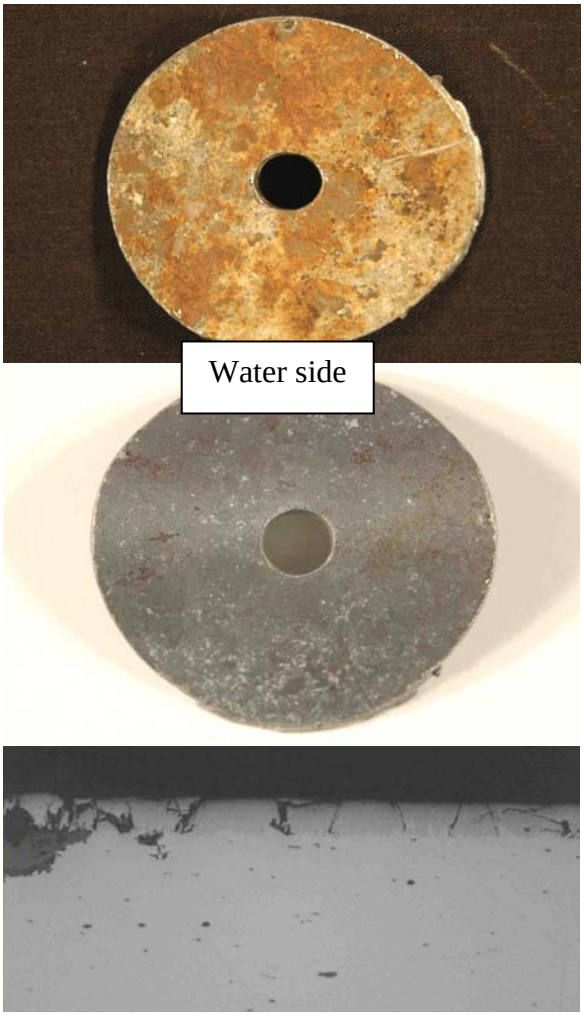
Site Location: San Juan County, WA, Site 16 On road 141, 0.5 miles west of road 140. The pipe has a tag with "#2, A" bolted to the crown on the inlet end.
Description: 18" dia. 16 gage ALT2. Currently dry, remains dry most of the summer months. Has water continuously from November to April per county observers. Loamy soil with thick vegetation all around. Overall good condition.
Sampling: 2 Soils from A and B positions, no water sample and one ALT2 trepan.
Observers: Russ Harvey and Joel Thorson of San Juan County Highway Maintenance
Observations: The remnant of aluminized coating was obscured by moss and oxide similar to other Waldron Island sites. No ovality was noted.
Environmental Parameters:
Soil resistivity: 8,720 ohm.cm; pH 6.0; Chlorides: 30ppm, sulfates: 47ppm
Water sample: none, site dry

Image from San Juan County Site 16:

Site and Laboratory Summaries for Washington State

Site 16 ALT2 Trepan Evaluation: The top images are of the coupon removed from the 6 o'clock position in the pipe after rinsing off loose dirt, debris and moss. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Light pitting is present on the soil side, but the water side is smooth. Removal of the red rust revealed that the smooth iron-aluminide alloy layer was intact.
Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.067".
Results Ball: 0.065", 0.064", 0.065" Point: 0.053" (0.014" deep)
Based on conservative pit penetration extrapolations, the service life of 16 gage ALT2 material would be in excess of 100 years.

Images of ALT2 trepan from 16:



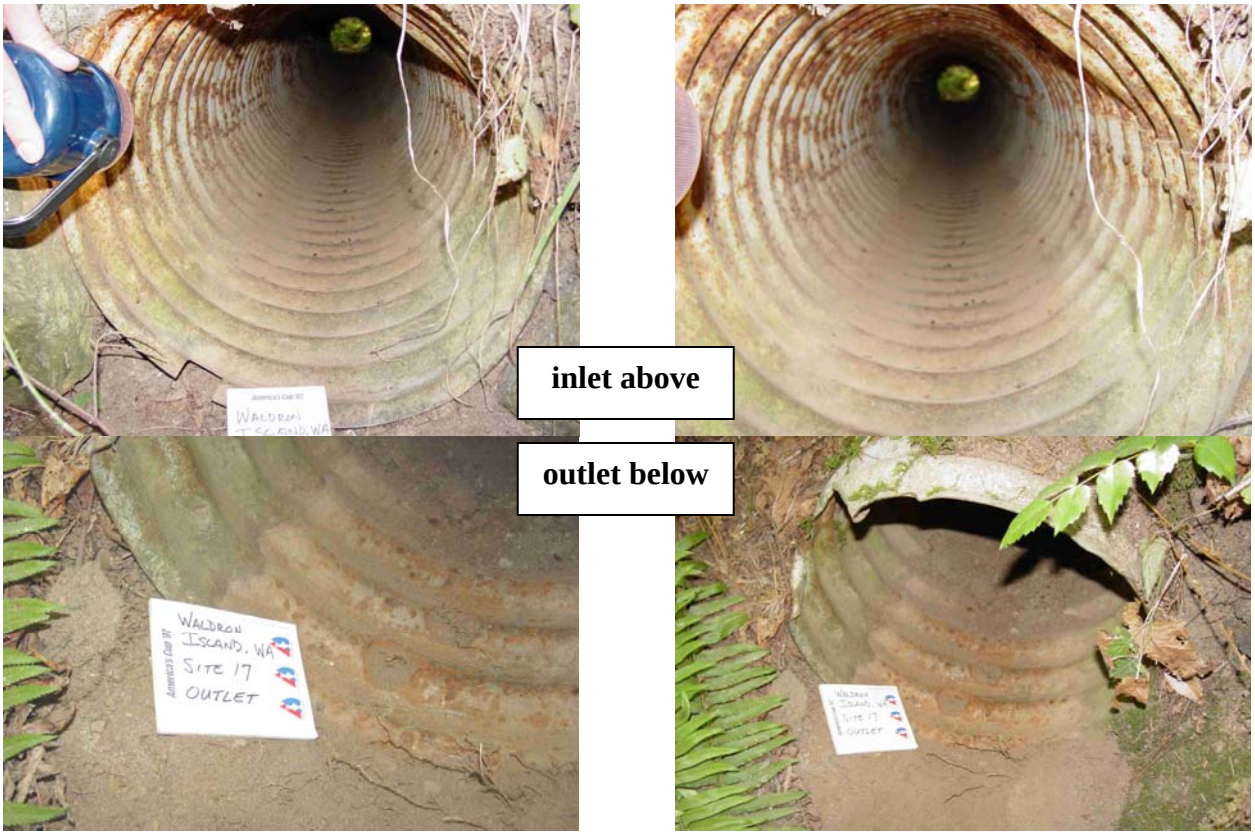
140X

140X

Site and Laboratory Summaries for Washington State

Site Location: San Juan County, WA, Site 17 Road 141-1; 0.7 mi. west of Road 140.
Description: 18" dia. 16 gage ALT2 installed N-S cross culvert at the end of the county Rd. Currently dry, remains dry most of the summer months. Has water continuously from November to April per Joel Thorson. Loamy soil with thick vegetation all around. Overall good condition.
Sampling: 2 soil samples from the A and B position. One trepan taken from each end. The outlet end had 2" of silt and decayed vegetation settled on the lower invert. The outlet trepan was in very close proximity to Site 18, which could not be resampled due to the small diameter (12") pipe and the location of previous holes at the 6 o'clock position.
Observers: Russ Harvey and Joel Thorson of San Juan County Highway Maintenance
Observations: The remnant of aluminized coating was obscured by moss and oxide similar to other Waldron Island sites. No ovality was noted.
Environmental Parameters:
Soil resistivity: 16160 ohm.cm; pH: 5.3; Chlorides: 20ppm, sulfates: 27ppm
Water sample: none, site dry

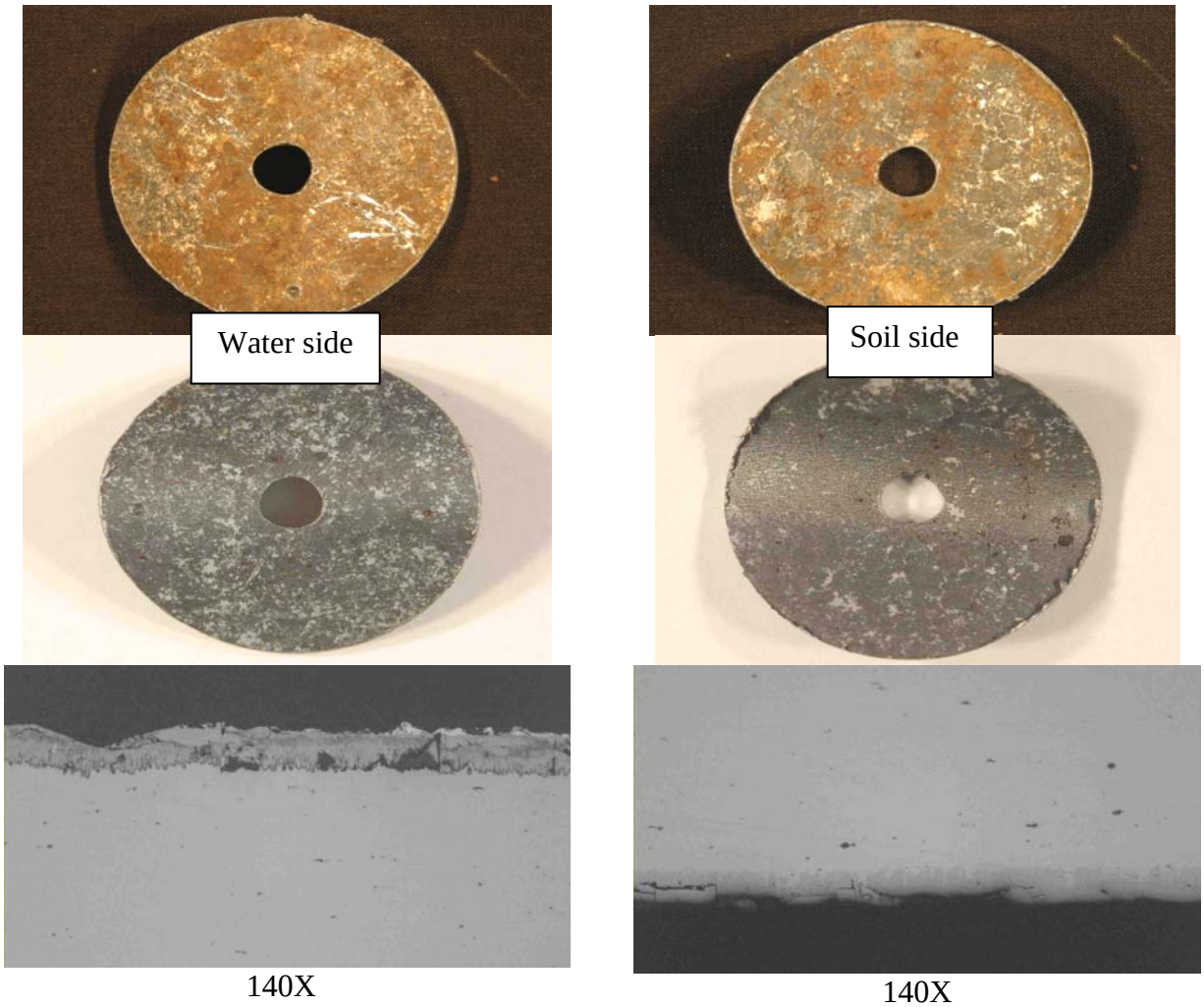
Images from San Juan County Site 17:



Site and Laboratory Summaries for Washington State

Site 17 Inlet ALT2 Trepan Evaluation: The top images are of the coupon removed from 6 o'clock position on the pipe after rinsing off loose dirt, debris and moss. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Almost no pitting is present on the top or bottom surfaces. Removal of the red rust revealed that some of the free aluminum component of the Type 2 coating was intact.
Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.067".
Results Ball: 0.066", 0.065", 0.065" Point: 0.057" (0.010" deep)
Based on conservative pit penetration extrapolations, the service life of 16 gage ALT2 material would be in excess of 100 years.

Images of ALT2 trepan from site 17 inlet:



AK Steel Site and Laboratory Summaries for Washington State AK Steel

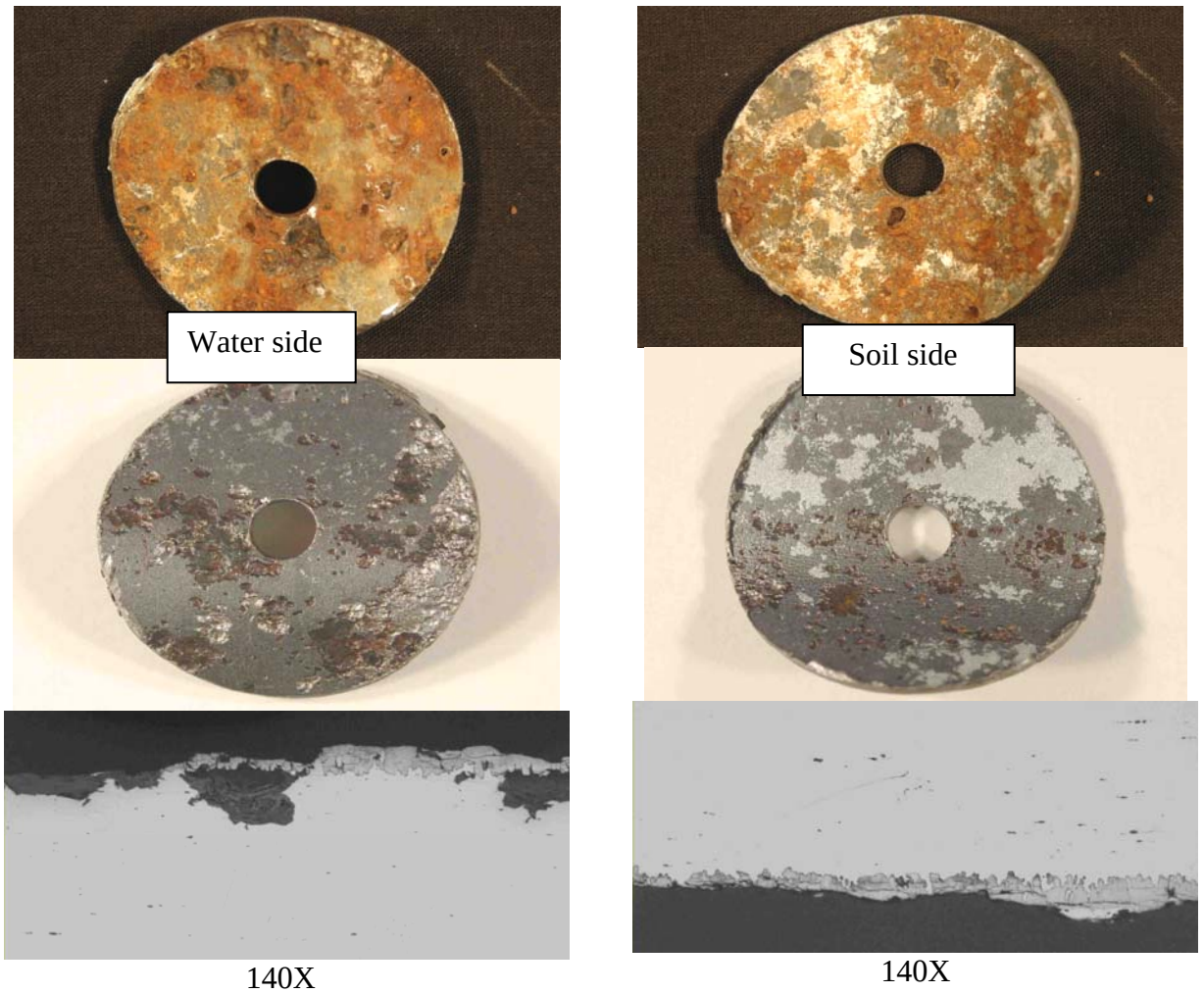
Site 17 Outlet ALT2 Trepan Evaluation: The top images are of the coupon removed from 6 o'clock position on the pipe after rinsing off loose dirt, debris and moss. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Moderate pitting is present on the water and soil sides. Removal of the red rust revealed that portions of the alloyed iron-aluminide component of the Type 2 coating remained. The soil side still had patches of free aluminum coating remaining.

Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.066".

Results Ball: 0.065", 0.064", 0.065" Point: 0.041" (0.025" deep)

Based on conservative pit penetration extrapolations, the service life of 16 gage ALT2 material would be in excess of 100 years.

Images of ALT2 trepan from site 17 outlet:



AK Steel Site and Laboratory Summaries for Washington State AK Steel

Site Location: San Juan County, WA, Site 18 Road 141-1; 0.7 mi. west of Road 140. This pipe is perpendicular, and very close in proximity to site 17.
Description: 12" dia. 16 gage ALT2 installed E-W parallel to the county road for a private road. This pipe was perpendicular to the pipe sampled at Site 17. Currently dry, remains dry most of the summer months. It also has water continuously from November to April per Joel Thorson. Loamy soil with thick vegetation all around. Overall good condition.
Sampling: One soil sample taken from the B position. No trepan could be procured due to the small diameter (12") pipe and the locations of previous holes at the 6 o'clock position.
Observers: Russ Harvey and Joel Thorson of San Juan County Highway Maintenance
Observations: The remnant of aluminized coating was obscured by moss and oxide similar to other Waldron Island sites. No ovality was noted.
Environmental Parameters:
Soil resistivity: 21,310 ohm.cm; pH: 5.8; Chlorides: 10ppm, sulfates: 67ppm
Water sample: none, site dry

Images from site 18 :

Site and Laboratory Summaries for California

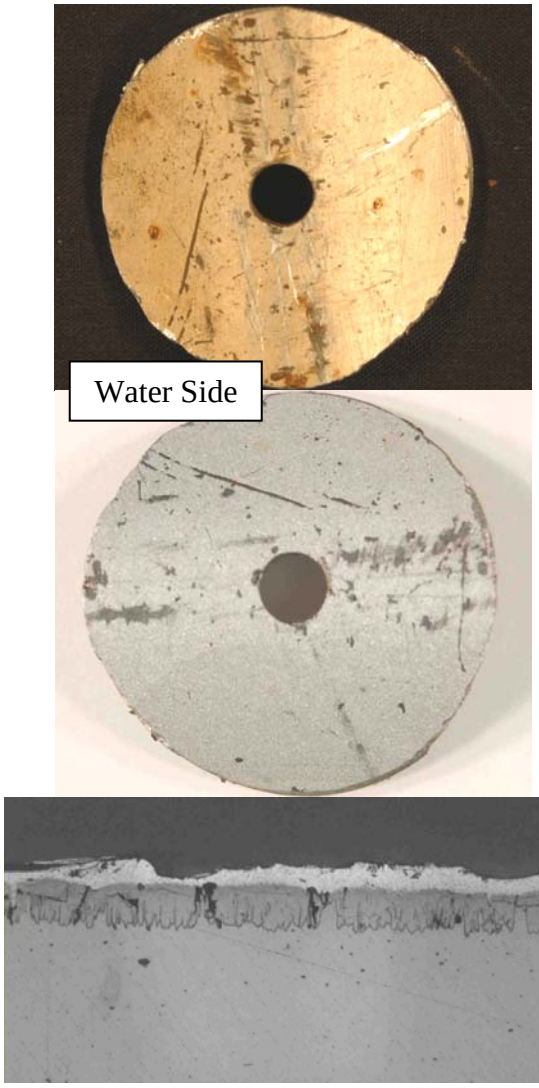
Site Location: El Dorado County, CA, Site 19 Pipe is 6.3 miles east of Georgetown, CA having a culvert marker "6.31".
Description: 18" dia. ALT2 on the inlet end. The galvanized outlet was not accessible. Currently dry, no recent rainfall. Pipe is silted to approximately 1/2 full. It has a low overburden and some ovality is evident in the middle of the road. The aluminized end is in good condition. The pipe end is only 2 feet from the edge of the pavement. Not much nearby vegetation.
Sampling: Two soil samples were procured from the A and B positions on the inlet end of the pipe. One trepan was procured from the 6 o'clock position. No water was available.
Observations: ALT2 is in very good condition. Previous hole saw cuts are intact with no appreciable 'creep'.
Environmental Parameters:
Soil resistivity: 6,430 ohm.cm; pH: 6.6; Chlorides: 20ppm, sulfates: 24ppm
Water sample: none, site dry

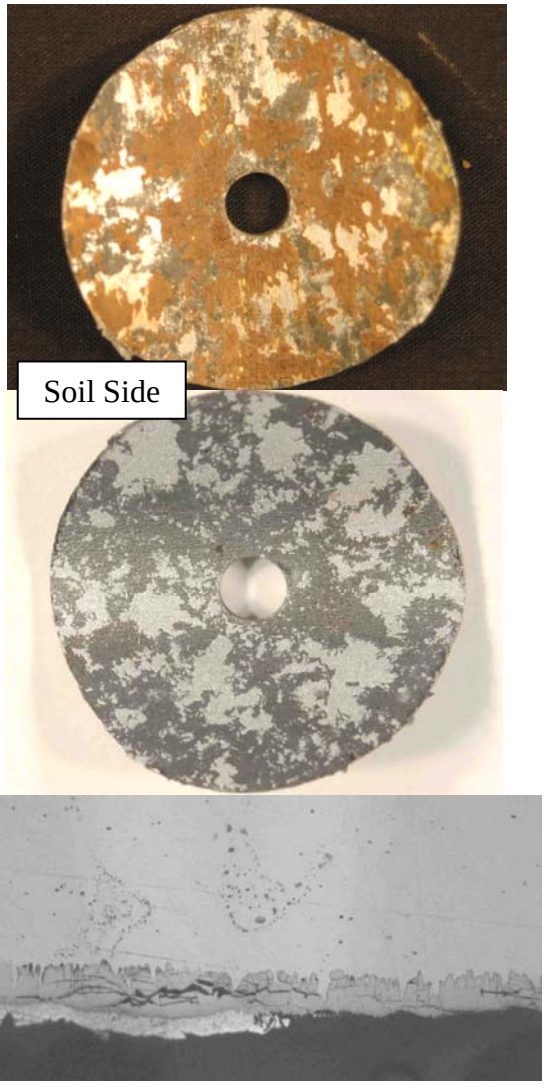
Images from El Dorado County Site 19:

Site and Laboratory Summaries for California

Site 19 ALT2 Trepan Evaluation: The top images are the coupon as removed after rinsing off loose dirt, debris. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Water side is smooth. Some minimal pitting is present on the soil side. The iron-aluminide alloy layer still remains on most of the soil side.
Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.068".
Results Ball: 0.068", 0.068", 0.067"; Point: 0.061" (0.007" deep)
Based on conservative pit-penetration extrapolations, the service life of 16 gage material would be in excess of 100 years.

Images of ALT2 trepan from El Dorado Co. Site 19:





140X

140X

Site and Laboratory Summaries for California

Site Location: San Benito County, CA, Site 20 One mile north of Hwy 101 on Cole road. Very near 510 Cole Road. Culvert Marker 1142.
Description: 30" dia. 14 gage ALT2 pipe with a 20 foot galvanized extension added in 1968. The galvanized extension had no remaining zinc from the 5 to 7 o'clock positions. The pipe is currently dry. A lot of leaf decay is present in the pipe. Overall good condition – no ovality. The original galvanized end was cantilevered out the west side and perforated. It not sampled due to the steep landscape.
Sampling: Soil from the B position, one ALT2 trepan, and no water sample.
Observations: The aluminized coating was still present on the water side with patches of oxide on the crests. No ovality was noted.
Environmental Parameters:
Soil resistivity: 630 ohm.cm; pH 5.1; Chlorides: 810ppm, sulfates: 18ppm
Water sample: none, site dry

Images from San Benito County Site 20:

previous holes

Site and Laboratory Summaries for California

Site 20 San Benito Co. ALT2 Trepan Evaluation: The top images are of the coupon removed from the 6 o'clock position in the pipe after rinsing off loose dirt, debris and moss. The coupon was then bead blasted to remove loose oxides and the lower images were recorded. Moderate to heavy pitting is present on the soil side, but the water side is smooth. Removal of the red rust revealed very little coating was intact on the soil side.

Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.081".

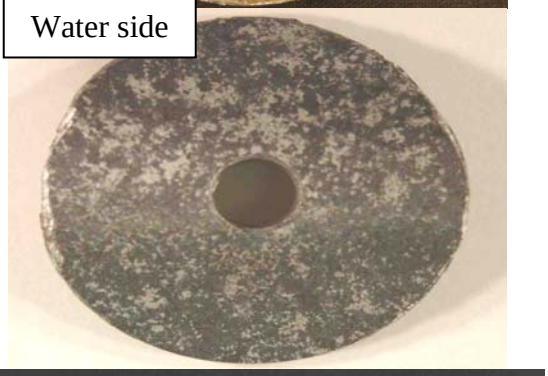
Results Ball: 0.080", 0.081", 0.079" Point: 0.057" (0.024" deep)

Based on conservative pit penetration extrapolations, the service life of 16 gage ALT2 material would remain 75 years. The low resistivity and high chloride content of the soil collected near the pipe entrance was much more reactive than the soil measurements taken at the 42 year time frame. This may be an indicator of some change in the upstream landscape.

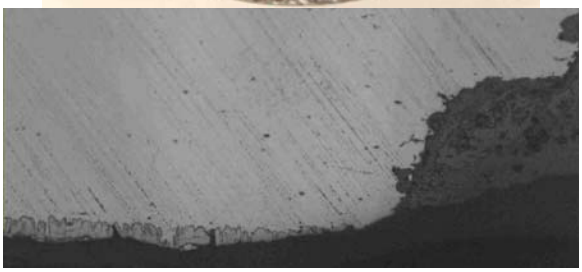
Images of ALT2 trepan from 20 San Benito Co.:

Water side

Soil Side



140X



140X

Site and Laboratory Summaries for Colorado & New Mexico

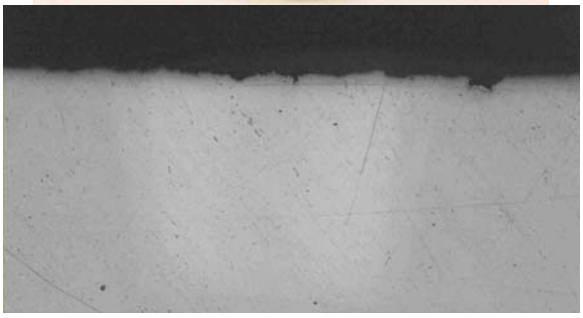
Site Location: Bernalillo County, NM. Site 21, 150 yards south of Woodward on Broadway. Pipe is a culvert beneath the entrance to Ever-Ready Oil Co. plant parallel to Broadway, very near a yellow fire hydrant.
Description: 30" dia. 14gage ALT2 that is silted to within 4" of the top of the pipe. Excavation revealed pipe in good condition. Estimate 7 days since previous rainfall per K. Fetter.
Sampling: 2 Soils from A, B positions, no water, 1 ALT2 trepan.
Observations: Pipe appeared in fair condition; however no coating was visible at the 6 o'clock position. In case of a significant rain event, this pipe is too full of silt to be effective.
Parameters:
Soil resistivity: 2750ohm.cm; pH: 7.7; chlorides: 30 ppm, sulfates: 102 ppm
Water: none available

Images from Bernalillo County Site:

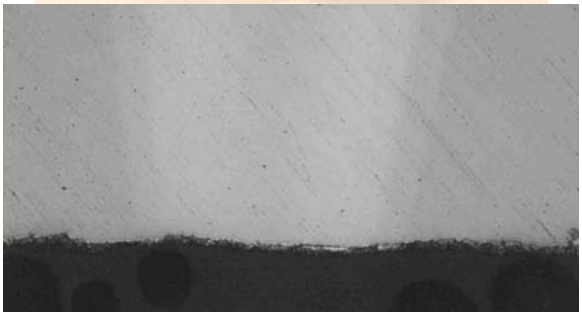
Site and Laboratory Summaries for Colorado & New Mexico

Trepan Evaluation: The coupon was washed and photographed as received (top 2 images) then bead blasted to remove loose oxides and the bottom images were recorded.
Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.084”
Micrometer Results Ball: 0.079”, 0.080”, 0.079” Point: 0.062” (0.022”deep)
Based on conservative pit penetration extrapolations, the service life of this pipe may be in excess of 75 years, however this CSP is too full of silt and sand to be an effective culvert.

Images of trepan from Site 21:



75X



75X

Site and Laboratory Summaries for Colorado & New Mexico

Site Location: Fairplay, CO. Site 22 North entrance to the Sinclair Gas Station and Silverheels Minimart on the west side US Hwy 285 in Fairplay Colorado. This location was originally an entrance to a Conoco Bulk plant.
Description: 24" dia. ALT2 in very good condition on both ends with concrete headwalls.
Sampling: Soil from B position, no water sample, 1 ALT2 trepan.
Observations: Free aluminum coating is visible around the complete circumference. Previous trepan holes were not corroded further. Sample taken at 6:00 position.
Parameters:
Soil resistivity: 3218ohm.cm; pH: 6.4; Chlorides: 10ppm Sulfates: 126ppm
Water: none, site dry

Images from Fairplay Colorado Site:

North end of pipe

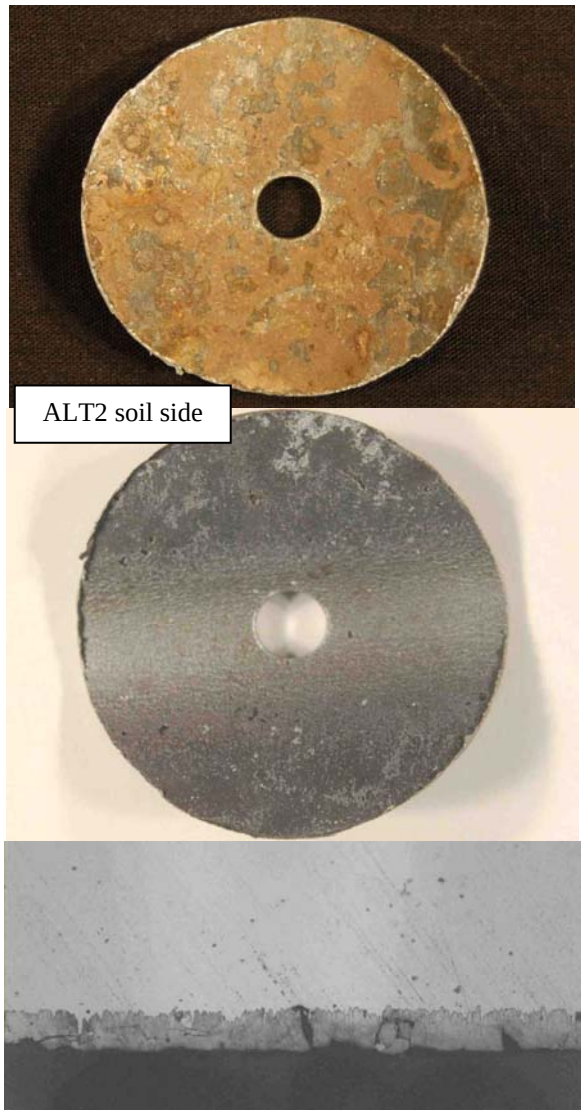
South end of pipe

Site and Laboratory Summaries for Colorado & New Mexico

Trepan Evaluation: The coupon was washed and photographed as received (top 2 images) then bead blasted to remove loose oxides and the bottom images were recorded.
Micrometer readings were taken after bead blasting using a ball micrometer (general thickness) and a point micrometer (deepest pit depth). Starting thickness: 0.066”
Micrometer Results Ball: 0.065”, 0.065”, 0.064” Point: 0.059” (0.007”deep – few small pits)
Based on conservative pit penetration extrapolations, the service life of this pipe would be in excess of 100 years.

Images of trepan from Site 22:

140X



140X