Monitoring Technology for Early Detection of Internal Corrosion for Pipeline Integrity

Southwest Research Institute

Project No. 14.05529

DOE Contract DE-FC26-02NT41319

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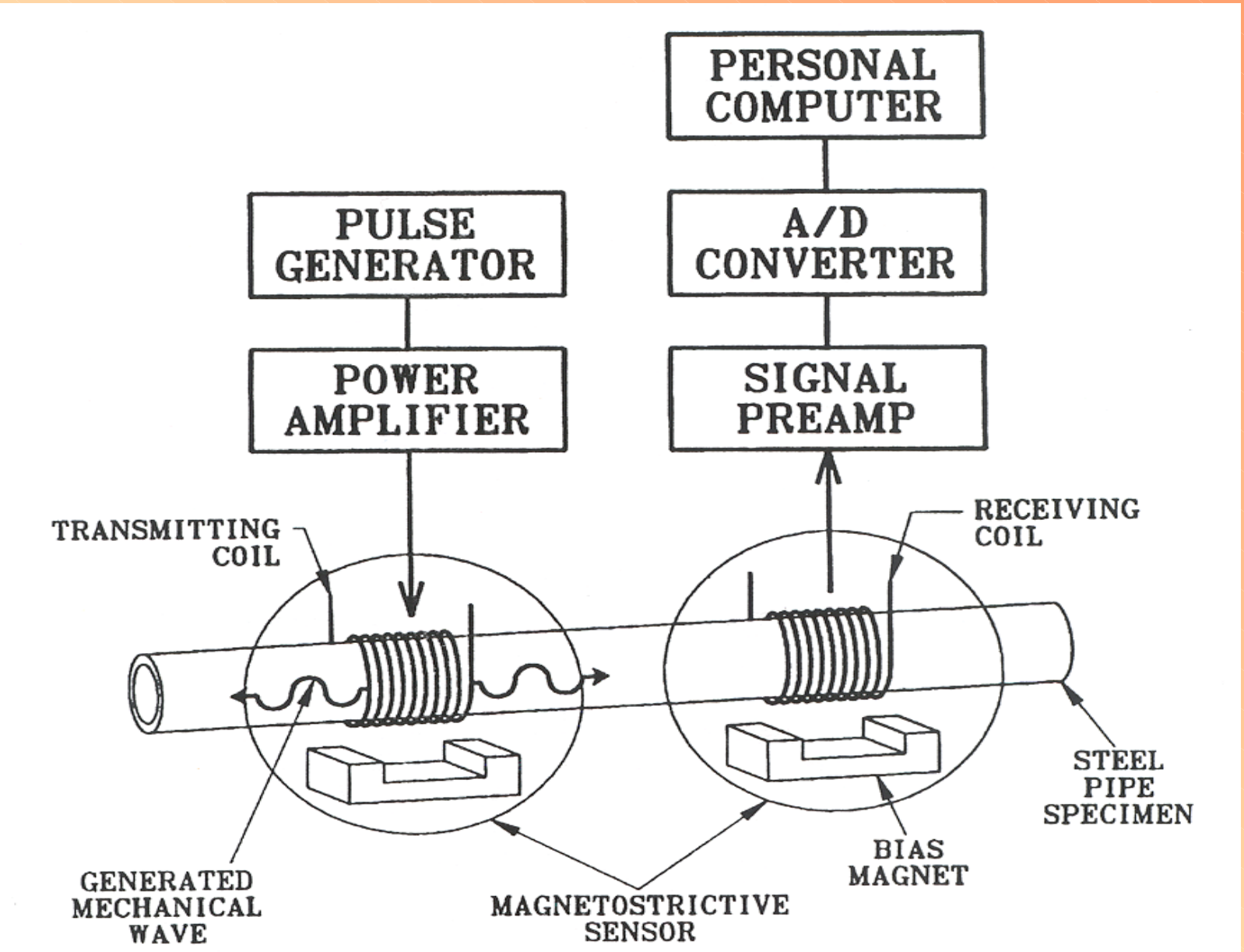
OBJECTIVE

Demonstrate that the magnetostrictive sensor (MsS) technology can be used to inspect and monitor buried pipeline for initiation and growth of corrosion. Monitoring is based upon obtaining data periodically from an MsS sensor fixed to the pipe.

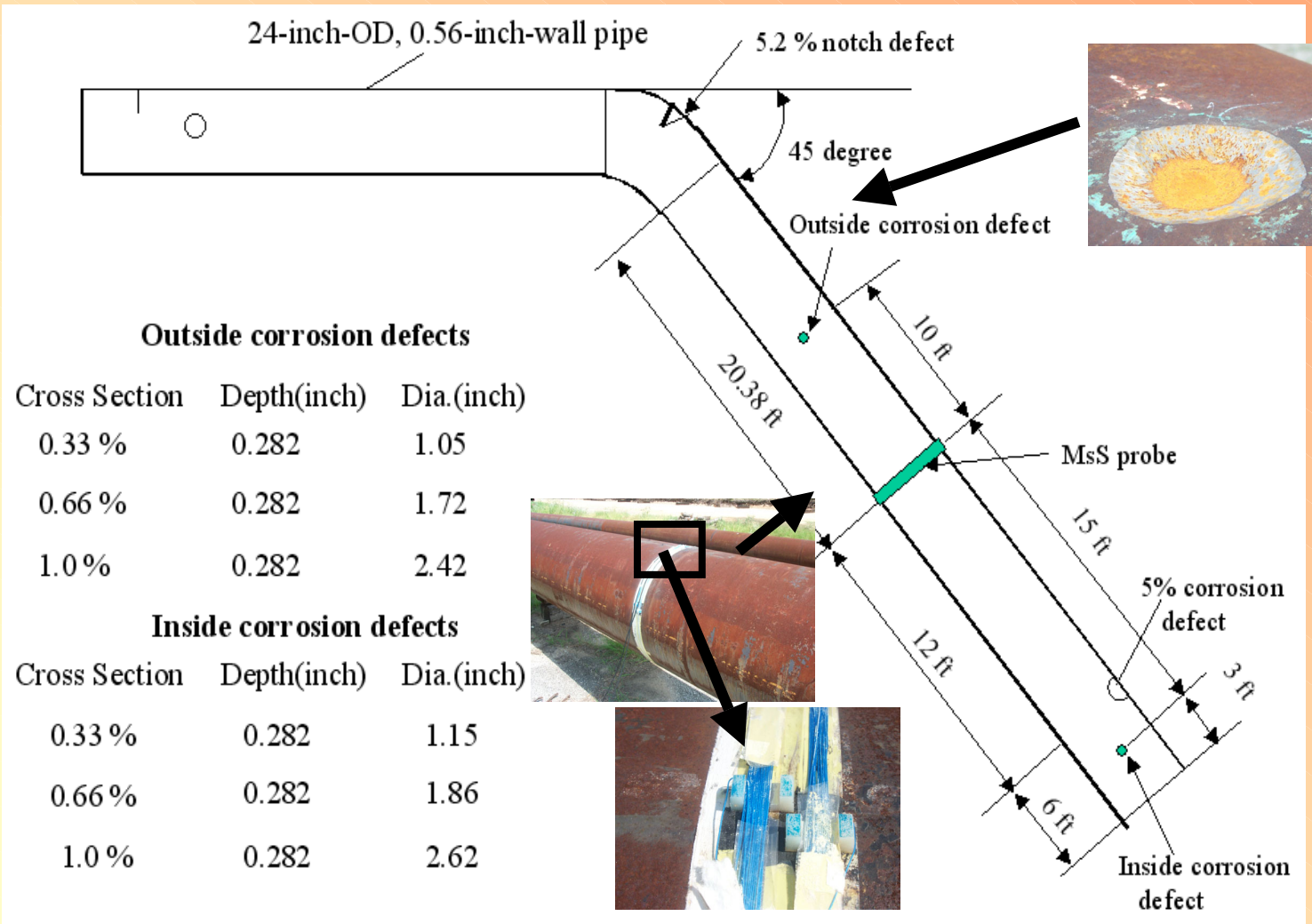
TECHNICAL APPROACH

- Laboratory demonstration of the MsS technology as a monitoring tool
  - Implant simulated flaws in real pipe
  - Collect data as defects are changed
- Optimization of the MsS technology
- Field demonstration of the MsS technology for monitoring corrosion

DESCRIPTION OF METHOD



LABORATORY TESTING



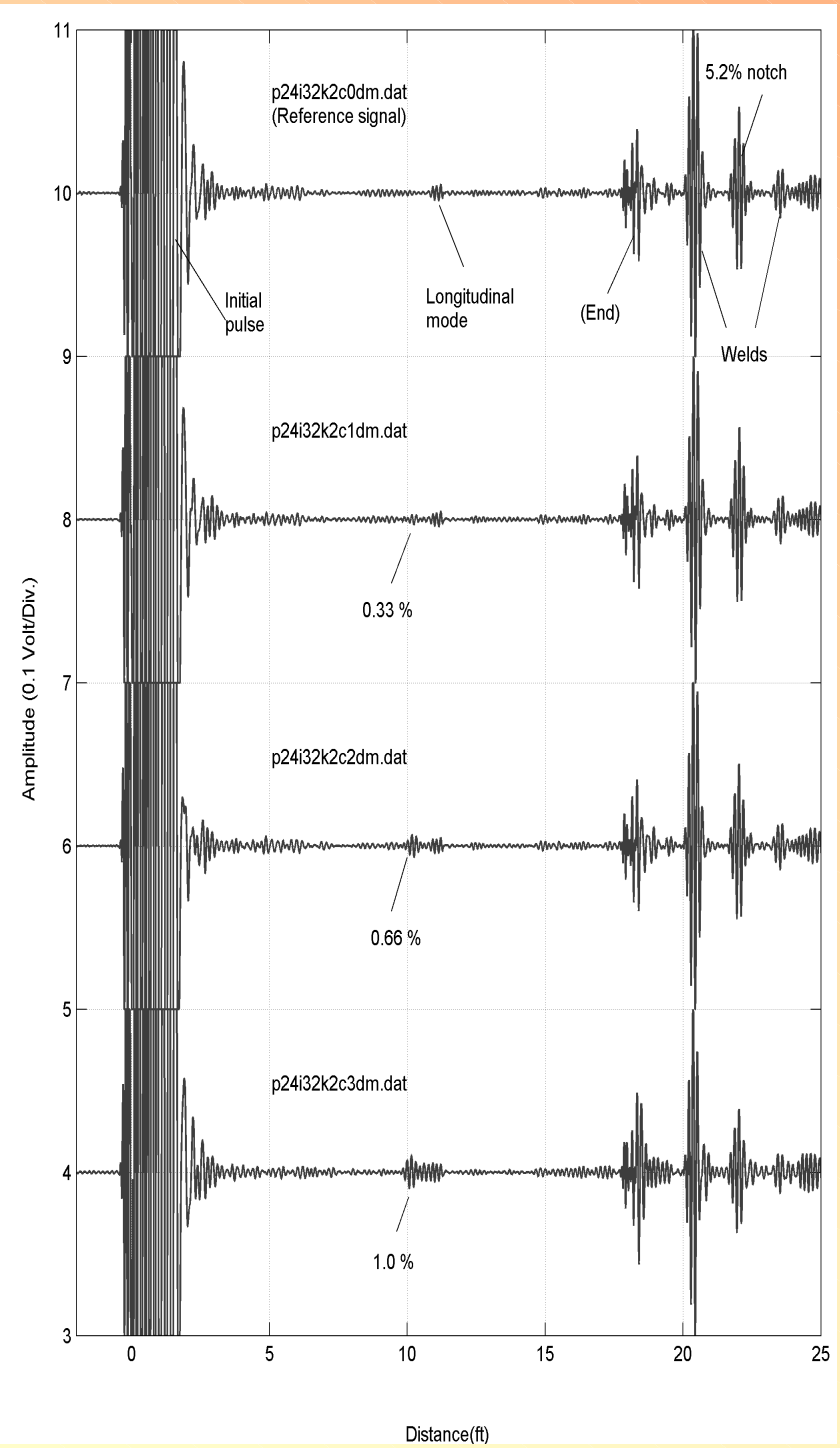
Outside corrosion defects

Cross Section	Depth(inch)	Dia.(inch)
0.33 %	0.282	1.05
0.66 %	0.282	1.72
1.0 %	0.282	2.42

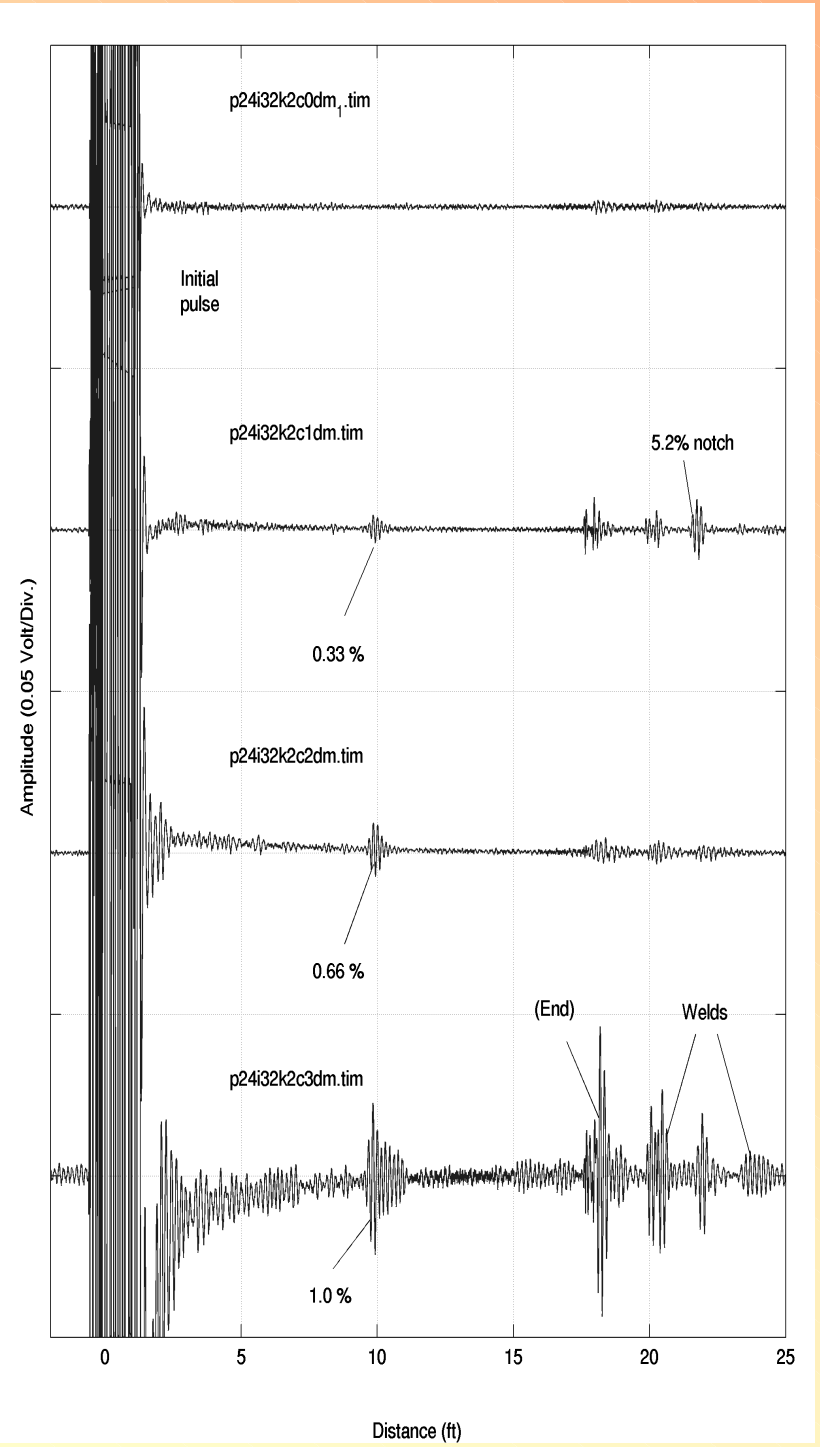
Inside corrosion defects

Cross Section	Depth(inch)	Dia.(inch)
0.33 %	0.282	1.15
0.66 %	0.282	1.86
1.0 %	0.282	2.62

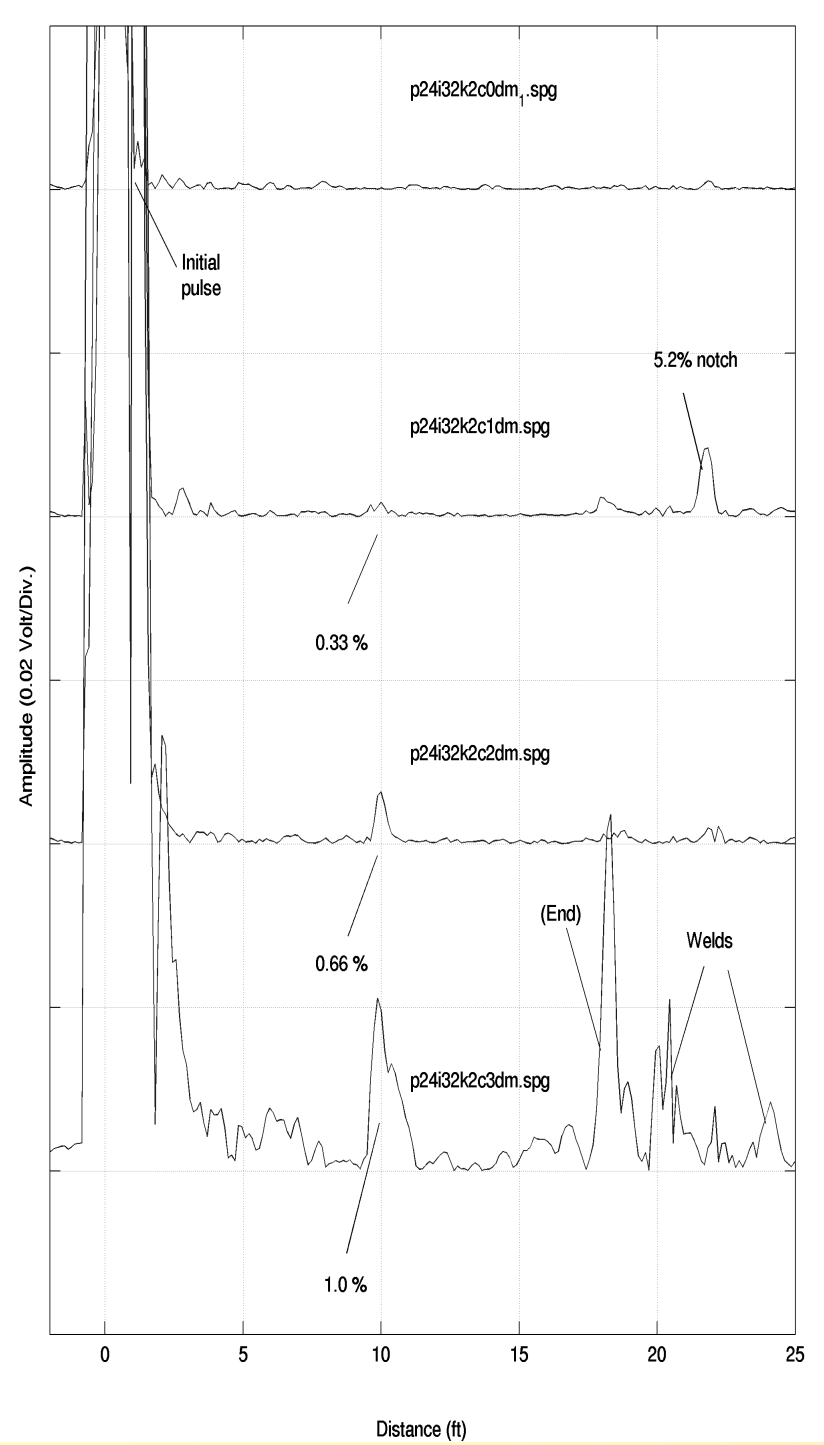
Layout of the test pipe used for initial evaluation of MsS monitoring technology



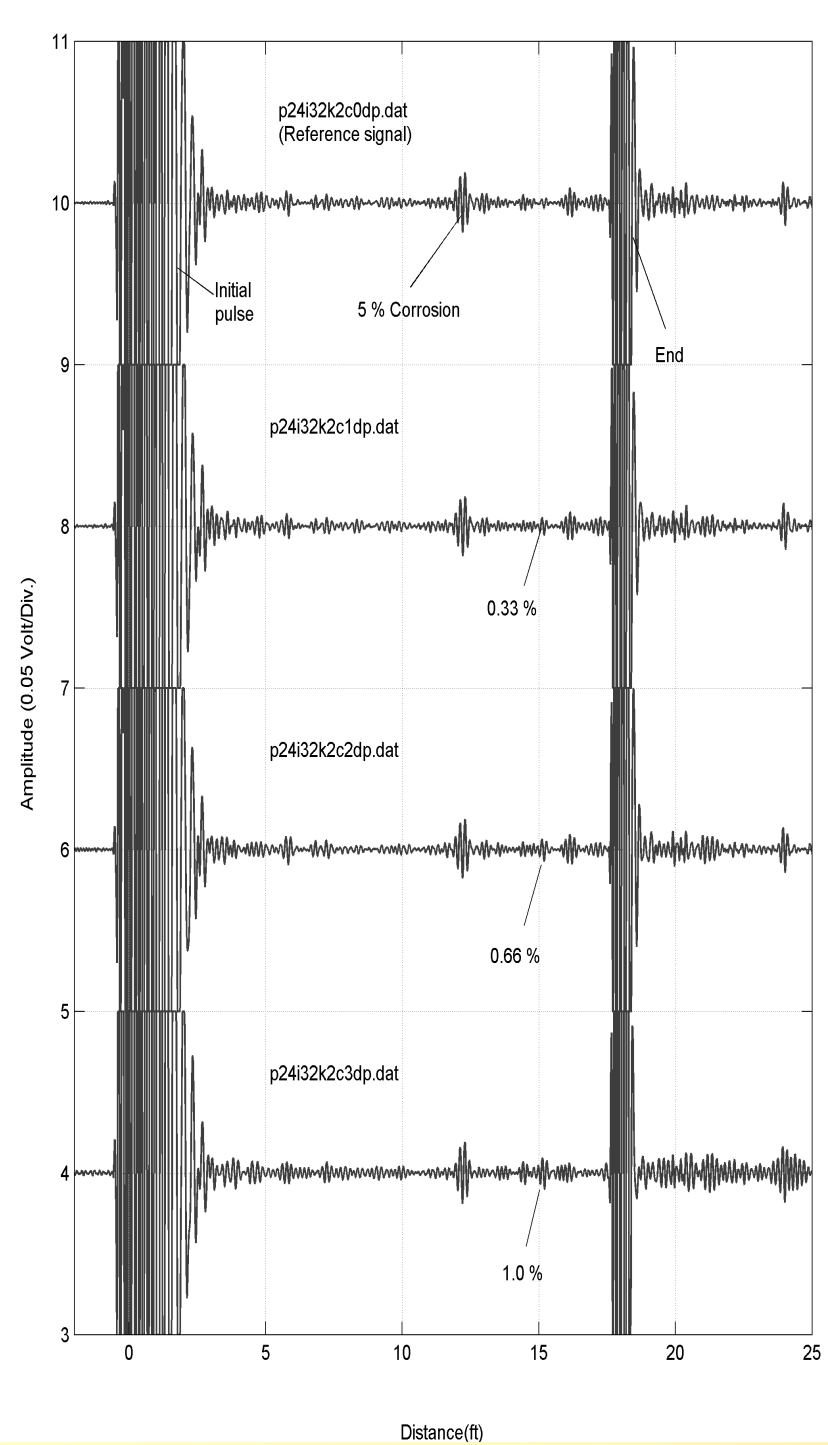
INSPECTION DATA OBTAINED FROM VARIOUS OD DEFECTS



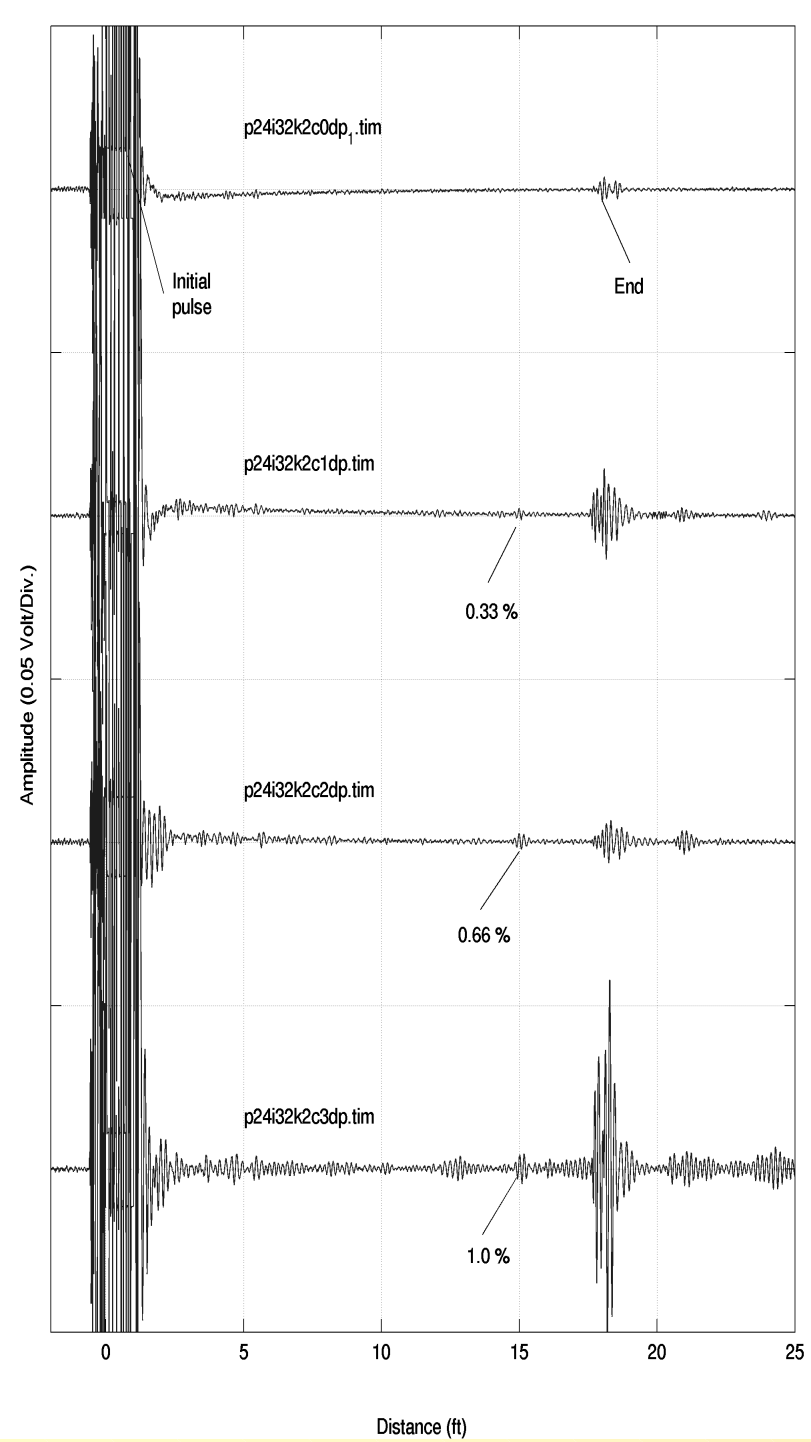
MONITORING DATA OBTAINED FROM OD DEFECTS



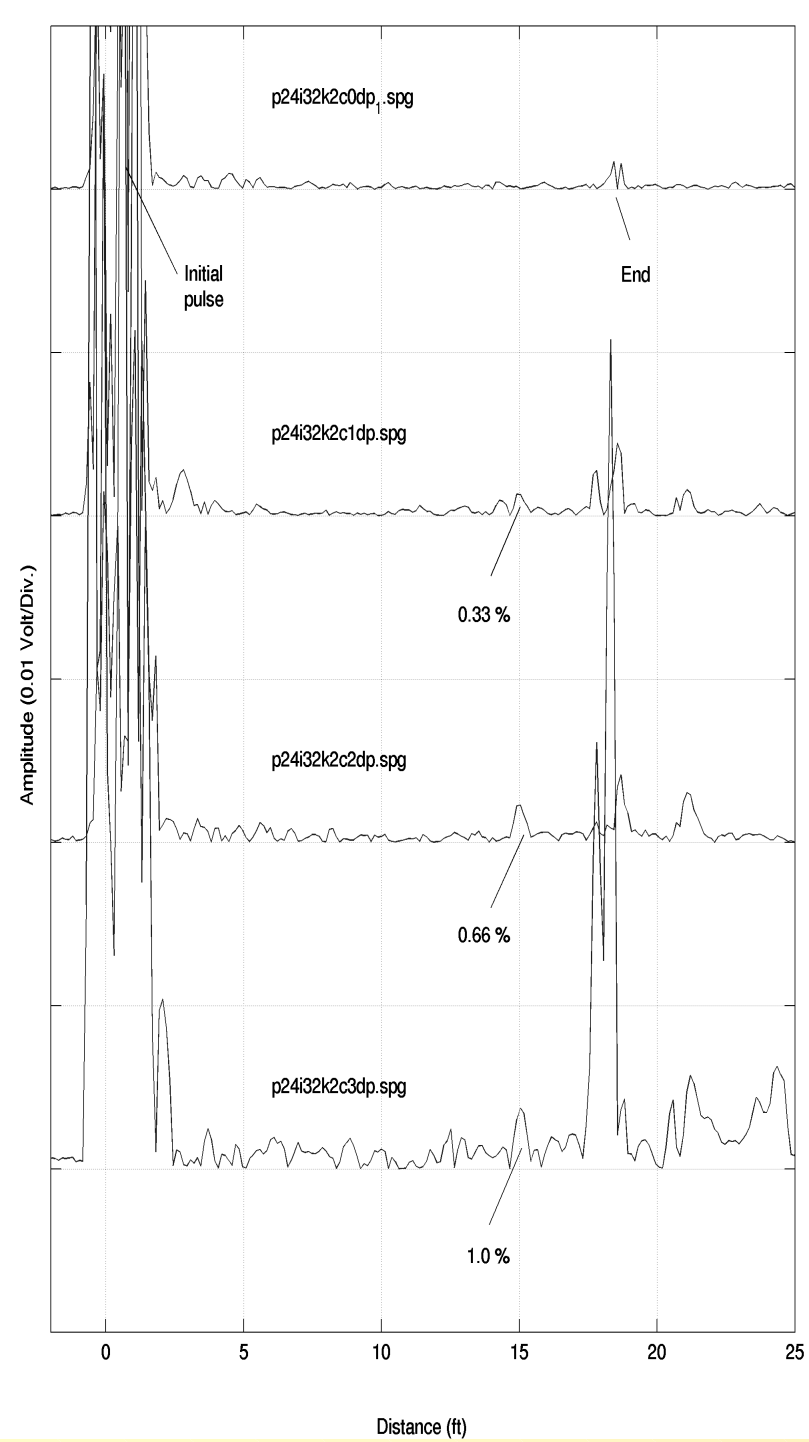
MONITORING DATA OBTAINED FROM OD DEFECTS (cont'd)



INSPECTION DATA OBTAINED FROM VARIOUS ID DEFECTS

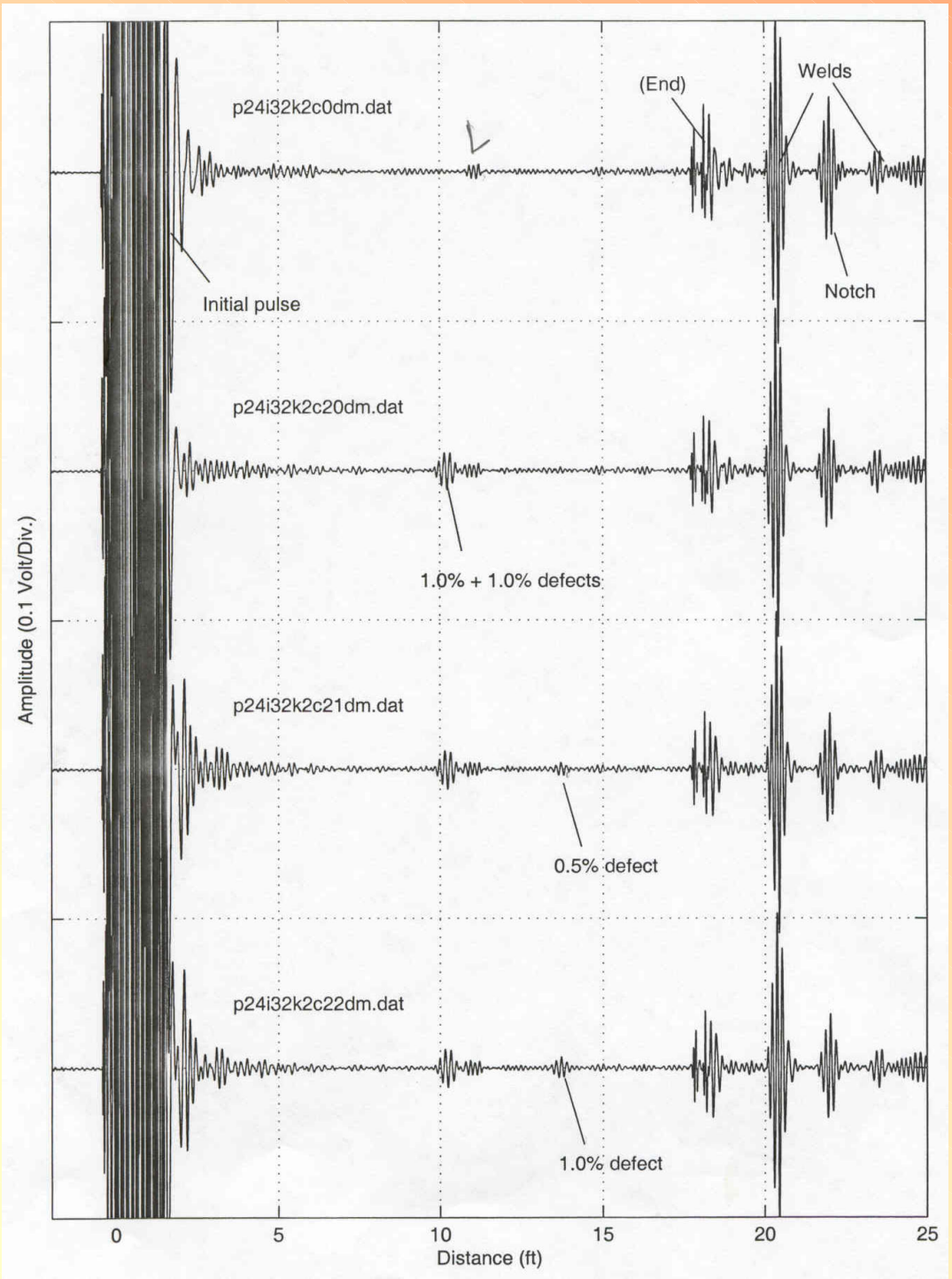


MONITORING DATA OBTAINED FROM ID DEFECTS



MONITORING DATA OBTAINED FROM ID DEFECTS (cont'd)

One Time Reference Adjustment

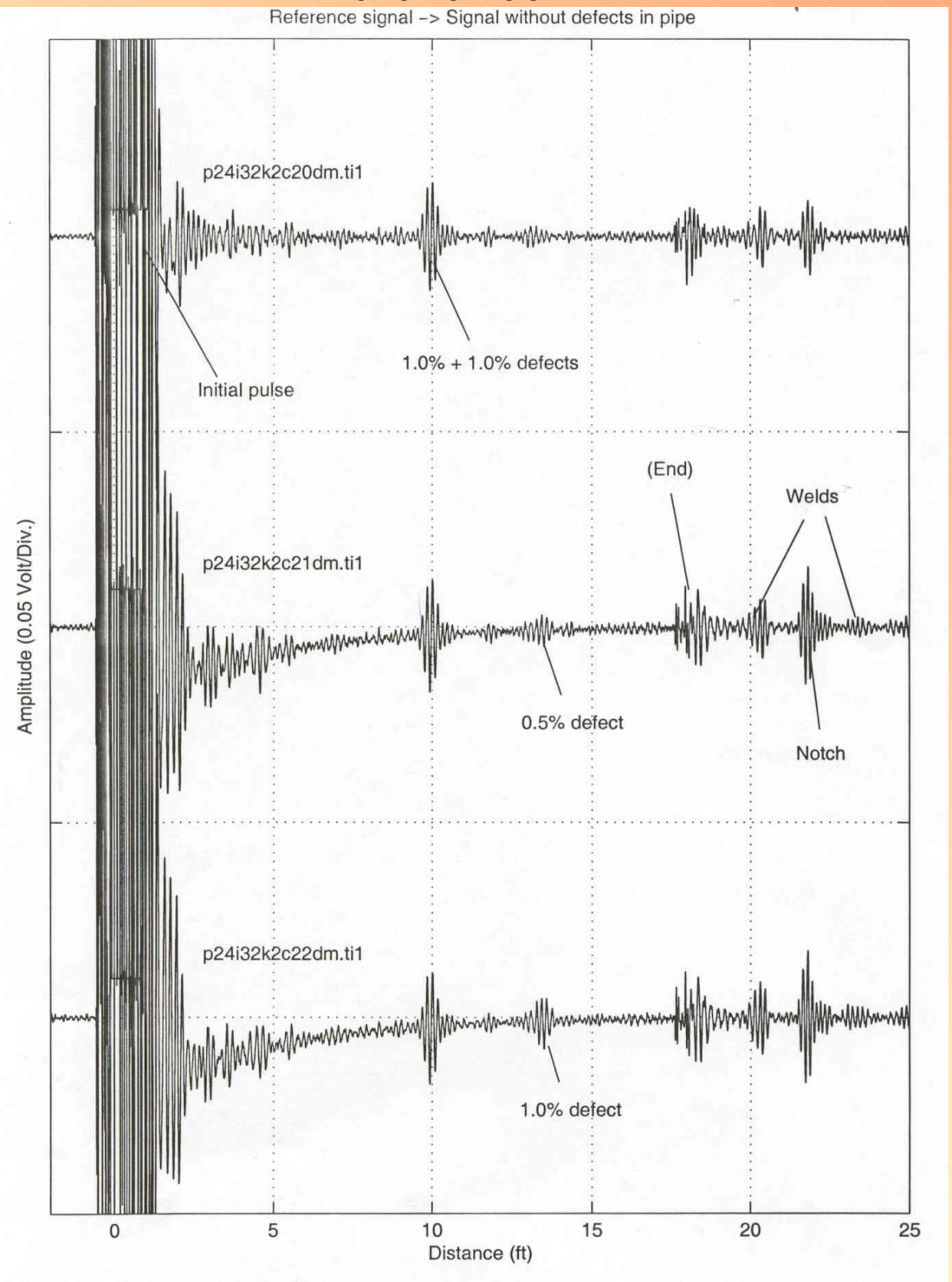


Ref. 1

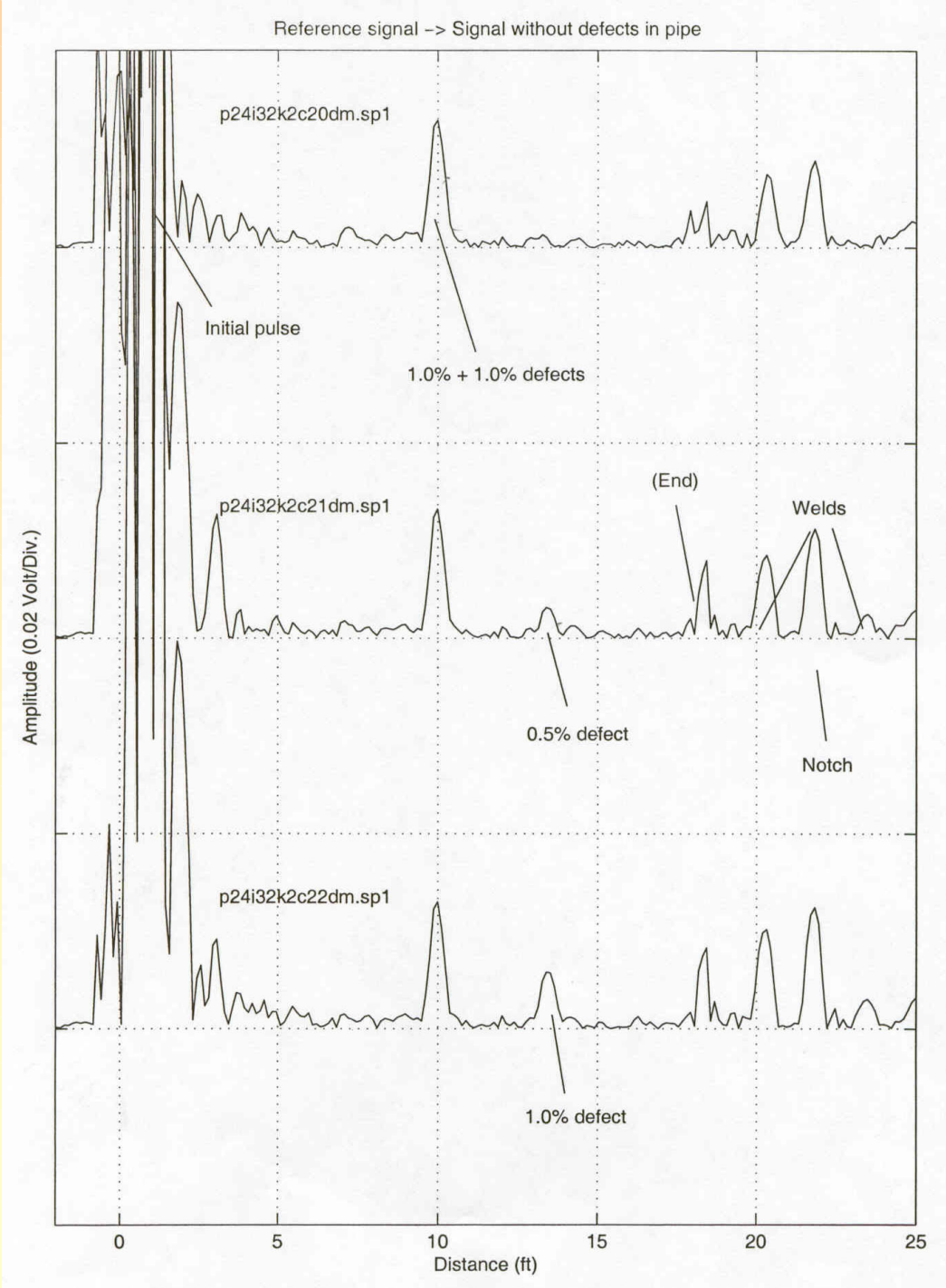
Ref. 2

MORE MONITORING DATA

Reference 1

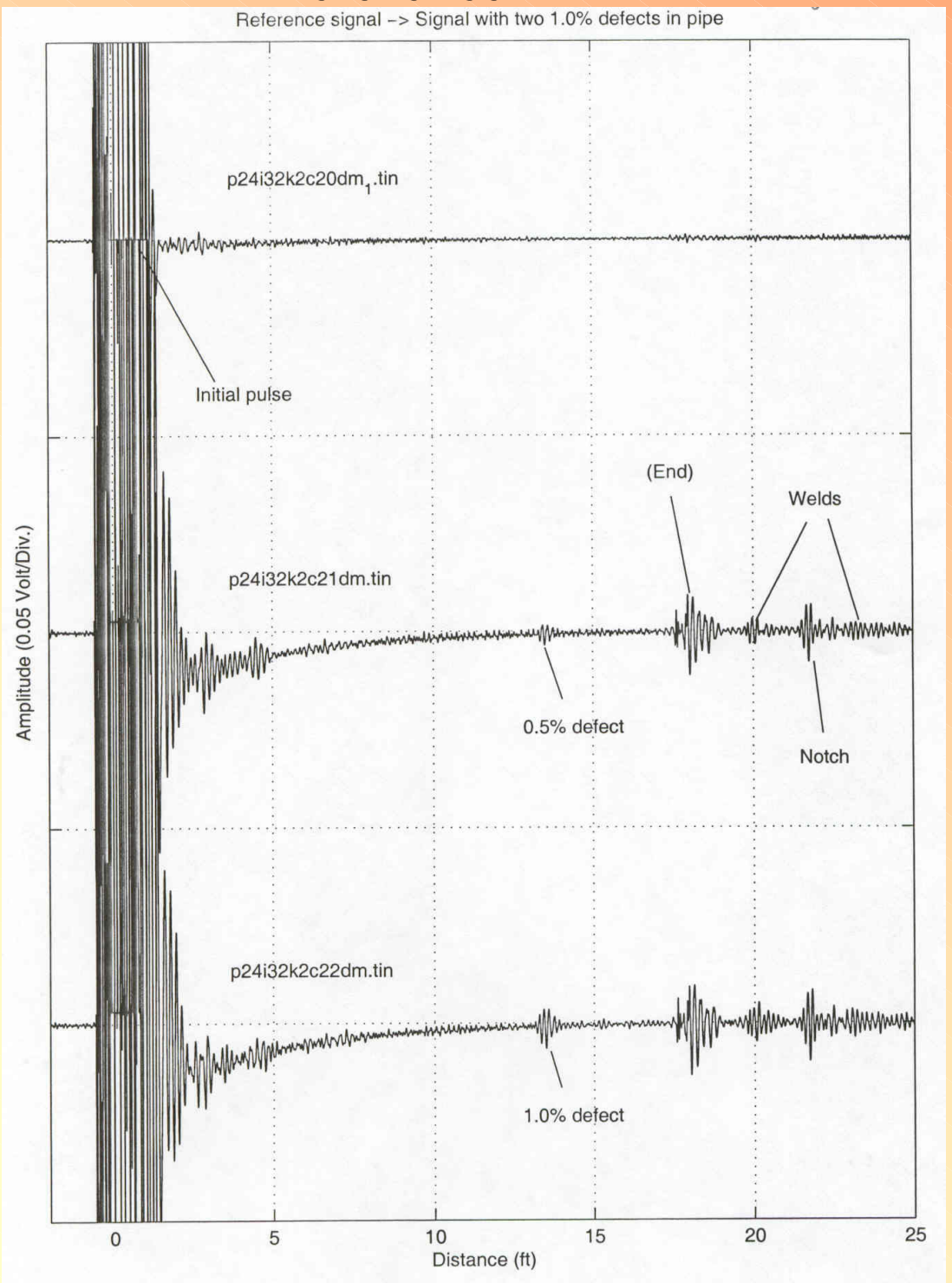


MORE MONITORING DATA (cont'd)

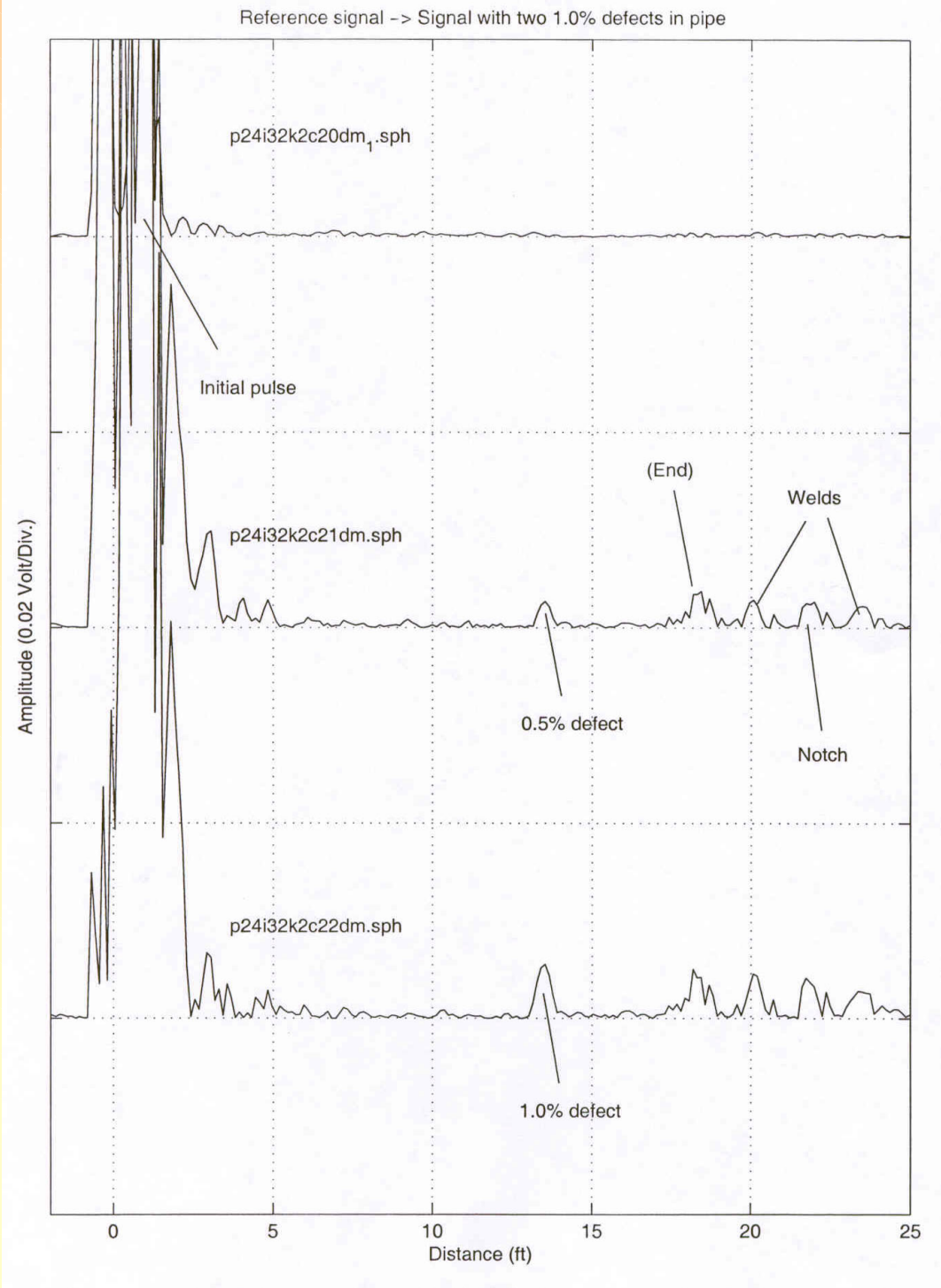


MORE MONITORING DATA (cont'd)

Reference 2



MORE MONITORING DATA (cont'd)



MORE MONITORING DATA (cont'd)

ISSUES ASSOCIATED WITH FIELDING TECHNOLOGY

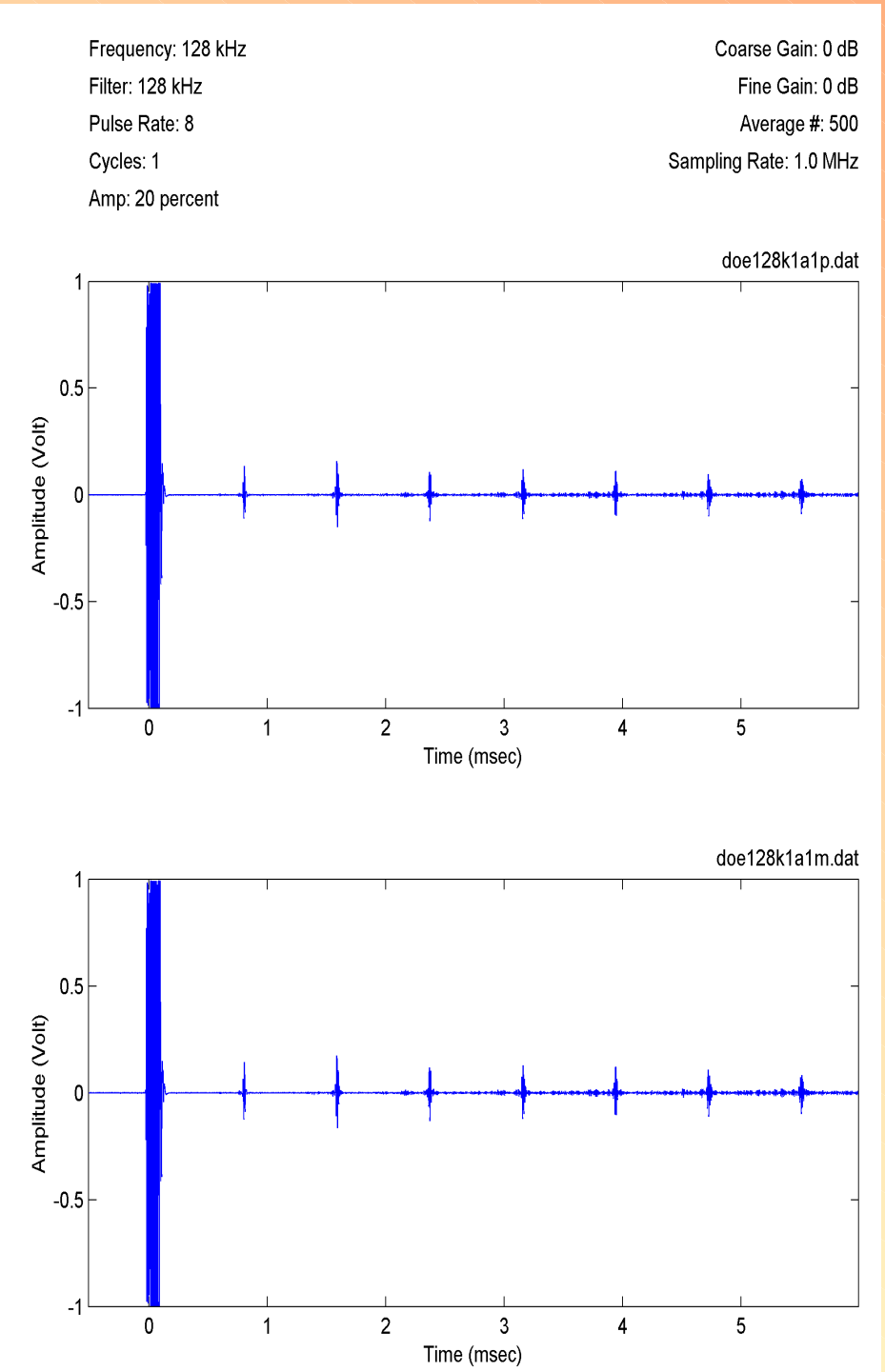
- Bonding to nickel foil MsS
- Environmental protection for the MsS
- Tar coating effects

EVALUATION OF ADHESIVES

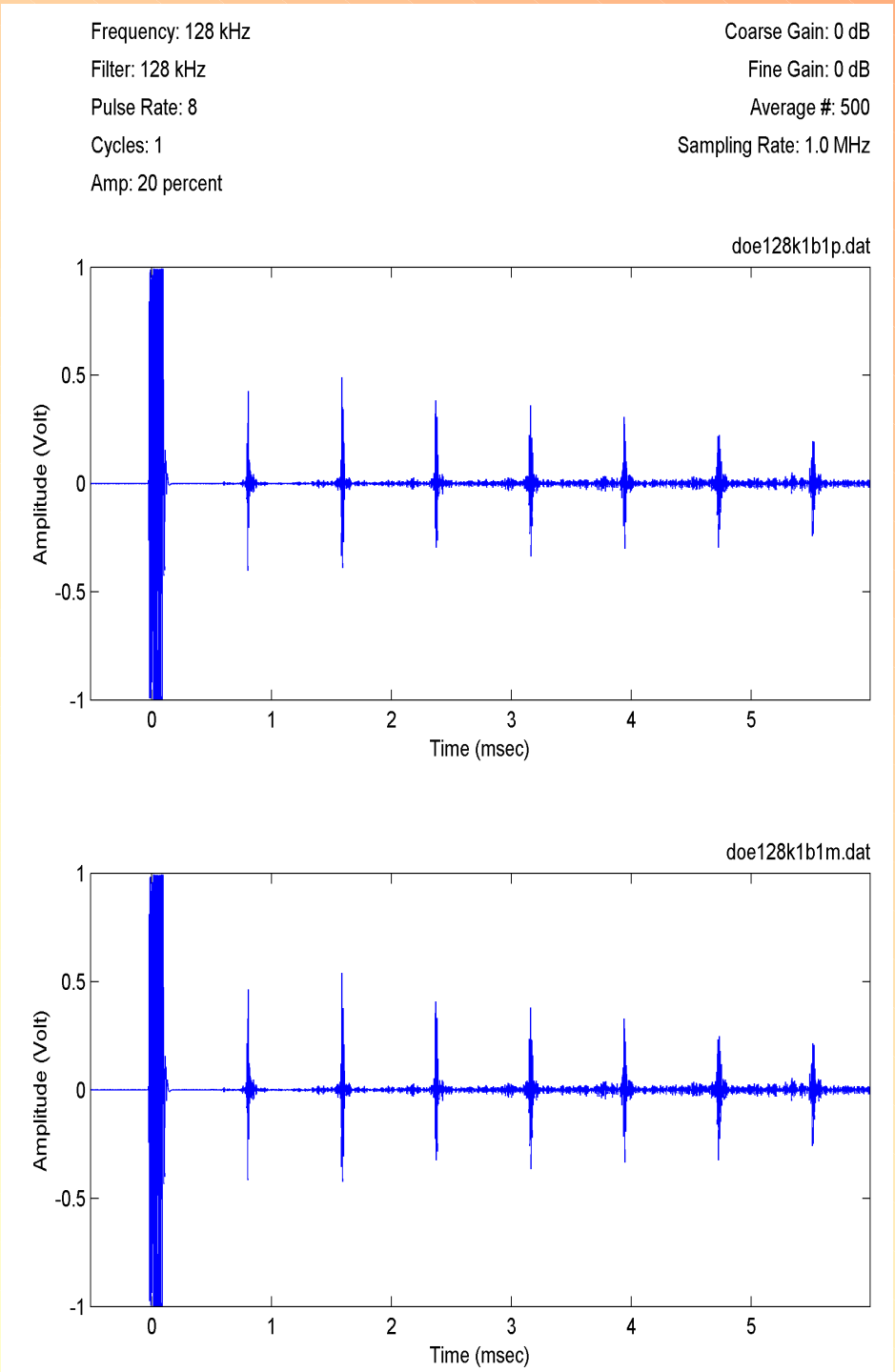
- Validate that they can effectively couple the shear-wave mode
- Verify reasonable cure time and temperature range
- Determine any special handling requirements

Sample ID	Epoxy Manufacturer	Estimated Strength	Other Comments	Couples T-Mode
1A	Devcon 5 Minute		Viscous mixture that is easy to apply to pipe and nickel with tongue depressor. Cures in 5 minutes and this means good preparation is needed before applying to the pipe	Yes
1B	Clock Spring 440A	>1,200 psi shear	1 part activator to 10 parts adhesive makes thick mixture that is easy to apply to the pipe with tongue depressor. Initial cure in approximately 3 hours with final cure in 24 hours. Has an offensive odor. Bond quality and ability to couple torsional waves was good within 24 hours, but maximized between 3 and 7 days.	Yes
2A	3M Scotchweld DP-100		Similar Devcon 5-minute epoxy. Easy to apply with tongue depressor	Yes
2B	3M Super 77		Spray adhesive. Easy to apply, no mixing required	Poor Coupling
3A	Bond-It 7040		Mix two equal parts, makes white viscous gel, easy to apply with tongue depressor, requires 24-hour cure time	Yes
3B	Cotronics Durabond 454	10,000 psi tensile	Mix 2 parts of resin with 1 part of hardener, makes very thick paste, easy to apply with tongue depressor but difficult to produce a thin bond line, requires 24-hour cure time	Yes
4A	Cotronics Duralco 4540N	10,000 psi tensile	Requires applicator gun, viscosity like thick paint, 16-hour cure time	Did not bond well
4B	Cotronics Duralco 4461N	9,500 psi tensile	Requires applicator gun; viscosity like thin oil, therefore, difficult to apply in real pipe application; may produce thin bond line, 16-hour cure time	Yes
5A	Cotronics Duralco 4537 N	6,000 psi tensile	Requires applicator gun, easy to apply with tongue depressor, 1- to 4-hour cure time	Yes
5B	Aeropoxy ES6220	3,000 psi tensile	Mix equal parts of A and B, viscosity like thick paint, similar to Devcon 5-minute epoxy, cure time is 5 minutes	Yes
6A	Aeropoxy PR2032/ PH3660	45,870 psi Tensile	Mix 3 parts 2032 to 1 part 3660, viscosity like water, 18- to 24-hour cure time, would be difficult to apply on real pipe application	Yes
6B	Aeropoxy ES6279	7,200 psi Tensile	Mix equal parts of A and B, makes thick paste, easy to apply with tongue depressor, 6- to 8-hour cure time, requires eye and hand protection	Yes
7A	Epic Resins R1603/ H5002	2600 to 2940 psi shear	Mix 2 parts of 1603 to 1 part of 5002, viscosity like thin paint, spreads easily with tongue depressor, cure time is 7 days	Yes
7B	Epic S7005	700 psi shear	Mix 2 parts of A to 1 part of B, makes creamy white mix, cures in 10 to 12 hours	Yes
8A	Epic S7033	2660 to 2940 psi shear	Mix equal parts of A and B, makes very stiff mixture similar to peanut butter, will not stick to pipe, cures in 2 to 4 days	Yes
8B	Epic S7045		Mix equal parts of A and B, 8 to 12-hour cure time, makes thick liquid that is easy to apply with tongue depressor	Yes
9A	Clock Spring HT180	1,200 psi shear	Mix 2 parts of A to 1 part of B, makes thick liquid that is easy to apply with tongue depressor, very strong odor, cure time is unknown	Yes
9B	Armstrong A-31	2350 psi shear	Mix 3 parts of A to 1 part of B, viscosity similar to butter, 16 to 24-hour cure time, easy to apply using a tongue depressor	Yes
10A	Armstrong A-1	3,000 psi tensile	Mix 100 parts of A-1 to 4 parts of Activator, 7-day cure time at room temperature, easy to apply with tongue depressor	Yes
10B	Armstrong A-3	3070 psi tensile	Mix 100 parts of A-3 to 4 parts of Activator, 7-day cure time at room temperature, easy to apply with tongue depressor	Yes

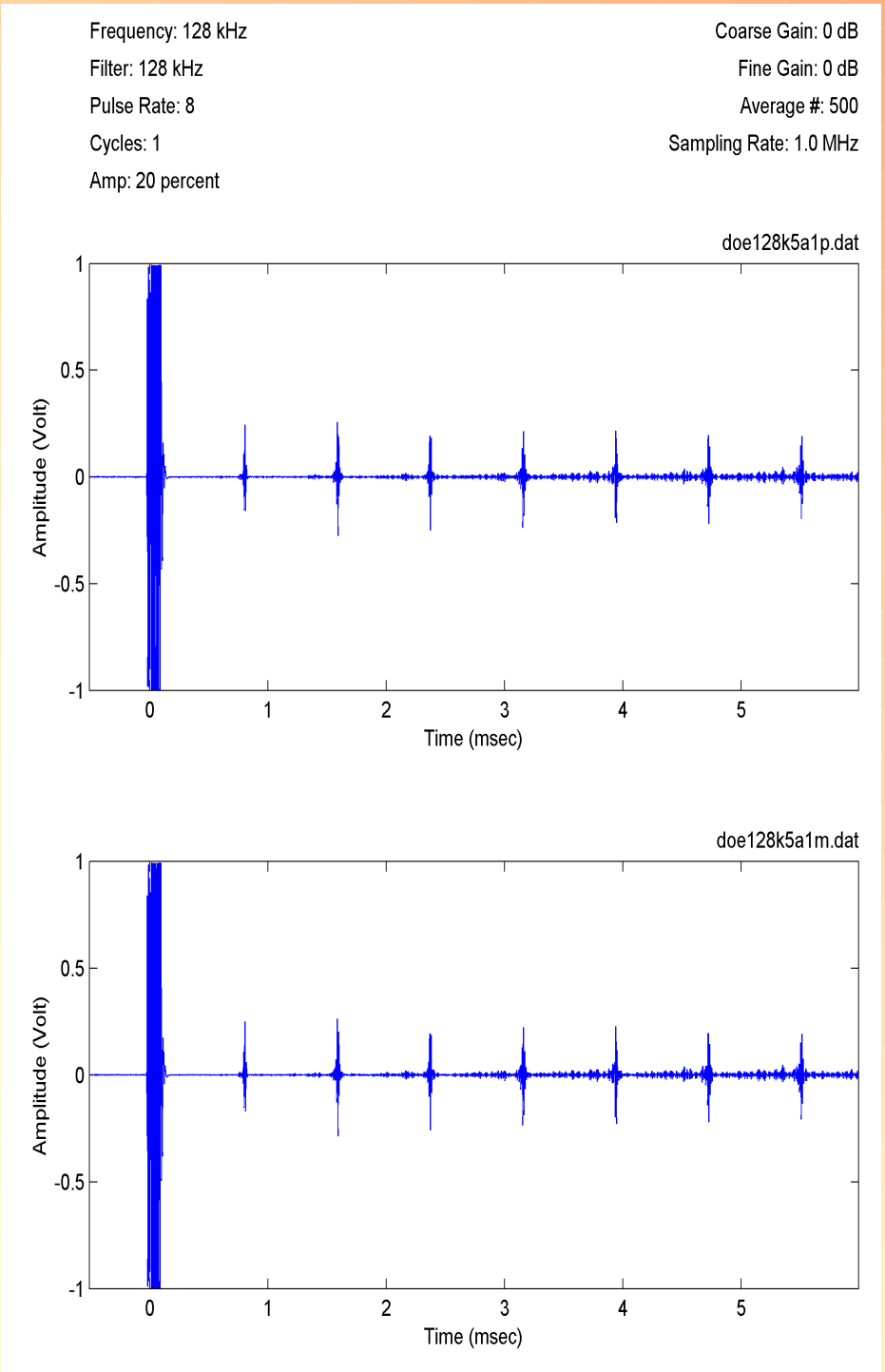
LIST OF ADHESIVES AND COMMENTS



EXAMPLE WAVEFORM OBTAINED WITH DEVCON 5-MINUTE EPOXY



EXAMPLE WAVEFORM OBTAINED WITH CLOCK SPRING MA440 EPOXY



EXAMPLE WAVEFORM OBTAINED WITH COTRONICS DURALCO 4537N EPOXY

CONCLUSIONS FROM EVALUATION OF ADHESIVES

Best Adhesives	Advantages	Disadvantages
Devcon 5 Minute	Short curing time so the nickel foil is easy to align	Unknown long-term adhesive properties for buried pipe environments
Clock Spring 440A	Good long-term adhesive properties with history for actual buried pipe environment	Cure time is too long
Cotronics Duralco 4537N	Good long-term adhesive properties	Unknown long-term adhesive properties for buried pipe environments

FIELD TEST SITE

Preliminary test site is the El Paso gas line in the Houston, Texas area.

WORK TO BE CONDUCTED IN THE NEXT YEAR

- Optimize sensor and sensor application
- Finalize sensor installation procedure
- Apply MsS sensor to test site pipeline and collect reference data
- Bury pipeline
- Collect monitoring data at various intervals
- Write final report