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ON-SITE DISPOSAL FACILITY LEACHATE CONVEYANCE SYSTEM LEAK INVESTIGATION REPORT GRAVITY LINE SECTION

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

APRIL 1999

U.S. DEPARTMENT OF ENERGY

FERNALD AREA OFFICE

20110-RP-0003
REV. 0
FINAL

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ON-SITE DISPOSAL FACILITY LEACHATE CONVEYANCE SYSTEM LEAK INVESTIGATION REPORT GRAVITY LINE SECTION

Document # 20110-RP-0003

Revision 0

April 1999

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REVISION SUMMARY

Revision	Date	Description of Revision
0	April 1999	Initial Issuance of OSDF LCS Leak Investigation Report 20110-RP-0003

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LIST OF ABBREVIATIONS AND ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CQA	Construction Quality Assurance
CQC	Construction Quality Control
DCN	Design Change Notice
DOE	U. S. Department of Energy
EOR	Engineer of Record
EPA	United States Environmental Protection Agency
FDF	Fluor Daniel Fernald
FEMP	Fernald Environmental Management Project
HDPE	High Density Polyethylene
OEPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
RCI	Request for Clarification of Information
SDR	Standard Dimension Ratio

EXECUTIVE SUMMARY

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The Fernald Environmental Management Project (FEMP) is a 1,050-acre facility located approximately 18 miles northwest of Cincinnati, Ohio. The FEMP is owned by the U.S. Department of Energy (DOE) and was operated as a uranium processing facility from 1951 to 1989. Since 1989, the FEMP has been undergoing environmental remediation in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). As part of the cleanup remedy, an on-site disposal facility (OSDF) is being constructed to permanently dispose of 2.5 million cubic yards of contaminated soil and debris from the FEMP. The OSDF will consist of eight individual areas of waste placement; these areas are called cells.

The engineering design of the OSDF, including the leachate conveyance system, went through a formal review process at the 30 percent, 60 percent, 90 percent, and final stages of the design development. Each stage consisted of a review by Fluor Daniel Fernald (FDF), DOE, U.S. Environmental Protection Agency (EPA), and Ohio Environmental Protection Agency (OEPA). All comments were formally addressed and resolved before the OSDF design drawings were issued for construction.

The OSDF includes a leachate collection and conveyance system which collects water that comes into contact with the waste (this water is called leachate) and then transports the water via underground pipes to the Advanced Wastewater Treatment facility for treatment. This leachate conveyance system consists of a gravity pipeline that extends from each OSDF cell to a manhole (one manhole per cell) and then continues to a central pump station (called the Permanent Lift Station) which pumps the leachate to the treatment facility. The pipeline from the Manhole No. 1 to the Permanent Lift Station is approximately 3,600 feet in length, 800 feet of which is permanent and 2,800 feet of which is temporary. In accordance with regulations, the pipe used to convey leachate is a double-walled pipe. A double-walled pipe is actually a pipe within a pipe: a smaller 6-inch inside pipe carries the leachate (this is called the carrier pipe) and a larger 10-inch outside pipe (called the containment pipe) provides secondary containment in case there is a leak in the smaller pipe.

The double-walled High-Density Polyethylene (HDPE) plastic pipe was delivered to the job site in 40-foot sections. This pipe was first joined into 200- to 400-foot long sections using several different HDPE joining methods (butt fusion joints, electrofusion couplings, and extrusion welds). These sections were then lowered into a trench and joined to each other to form the complete gravity pipeline of the OSDF leachate conveyance system. Following construction, the pipe was subjected to hydrostatic pressure testing. Leaks were detected during this testing and were repaired prior to operation. After successful completion of final hydrostatic testing, the leachate conveyance system became operational in December 1997.

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In January 1999, water accumulation was found in Manhole No. 3 during a routine inspection of the gravity pipeline. In order to determine the source of the accumulated water, numerous tests were performed including dye tests and video camera inspection of the inside of the pipes. Four leaks in the gravity pipeline were discovered as a result of these tests (see Figure 1 in Section 3.0 of this report).

- Leak #1 was located in Excavation #2 which was northwest of the West Impacted Stockpile; the leak was at a 10-inch electrofusion coupling on the containment pipe.
- Leak #2 was located in Excavation #3 which was west of OSDF Cell 3; the leak was at a 6-inch electrofusion coupling on the carrier pipe.
- Leak #3 was located in Excavation #4 which was southeast of the FEMP shipping and receiving building; the 10-inch containment pipe had a tear in the pipe wall.
- Leak #4 was also located in Excavation #3 (south of Leak #2); the leak was at a 6-inch electrofusion coupling on the carrier pipe.

As leaks were discovered, the sections of pipe containing the leaks were removed so that they could be evaluated as to the cause of the leaks. Initial findings indicated that three of the four leaks were located at electrofusion couplings (one of the three HDPE joining methods). In addition, the carrier pipe was found to have an oval shape instead of a round shape as it had at installation. Leak investigation activities in the field took place from February to March 18, 1999; at that time field work was put on hold until a more detailed investigation of the causes of the leaks could be performed.

An investigation team was formed in March 1999 at the request of the FDF Leadership Team. The scope of the investigation team was to evaluate and examine the gravity pipeline and to determine the probable causes of the leaks. Based on the research of the investigation team, additional information was requested from GeoSyntec, the engineering contractor for the design and construction of the OSDF. GeoSyntec provided the following information to the investigation team:

- as-built documents associated with the leak investigation including a drawing showing the location of electrofusion couplings, butt fusion joints, and low points within the pipeline and records illustrating the results of the hydrostatic testing, including lengths of each pipe tested and the date of testing

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- draft revised hydrostatic testing procedures on March 15 and March 16, 1999 for the 6-inch carrier pipe and the 10-inch containment pipe

- analysis of 6-inch carrier pipe deformation (ovality) including a determination of the existing condition of the pipe and a recommendation of suitability for future use

- analysis of electrofusion coupling failures and recommendations for replacement and/or repair

Following a review of construction records, visual inspection of the removed sections of pipeline, interviews with personnel involved in the construction and leak investigation activities, and review of the additional information provided by GeoSyntec, the investigation team reports the following findings and conclusions:

- The original design specified a pipe with a certain wall thickness (called Standard Dimension Ratio [SDR] 11). Through formal change procedures, the pipe to be used was changed to one with a thinner wall (called SDR 26).

- Hydrostatic testing of the 10-inch containment pipe was performed while the 6-inch carrier pipe was empty (i.e., not pressurized). This caused the oval condition in the SDR 26 carrier pipe. Based on the review of GeoSyntec's analysis, the investigation team determined that the oval carrier pipe is still functional for gravity pipeline operation.

- One electrofusion coupling that was removed from the gravity pipeline indicated minimal preparation of the pipe surface prior to joining, which resulted in poor bonding in the fusion zones. Proper preparation of the HDPE pipe surfaces is important for adequate fusion.

- A different method for joining the double-walled pipe, called the fixed end method, was used on some of the electrofusion couplings. The fixed end method made joining pipe sections difficult.

- The electrofusion couplings were welded using a machine that was preprogrammed by the manufacturer. The default melt time was not correct for the thickness of HDPE pipe being used and resulted in the joints being overmelted.

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- One leak (Leak #3) was found in an area where the side of the pipe was damaged by construction equipment. The tear and resulting leak were most likely caused by construction equipment coming into contact with the pipe during original installation.

Based on these findings, the investigation team presented the following lessons learned:

- Procedures for hydrostatic testing need to be specific to the configuration of the pipe assembly being used.

- Due to increased installation difficulty, minimize the use of electrofusion couplings.

- Establish construction "hold points" for electrofusion coupling installation so that a quality check can be performed.

- Use a documented approval process for revising methods of installation.

- Maximize the installation of HDPE pipe in only one direction. When HDPE pipe is installed in one direction, there is always a free end and the butt fusion joining method can be used.

The determination and evaluation of repair options for the gravity pipeline of the OSDF Leachate Conveyance System was not included in the scope of the investigation team. These issues are being evaluated separately by a team comprised of personnel from DOE, FDF, and GeoSyntec.

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1.0 INTRODUCTION

This report presents a summary of the initial construction and testing of the OSDF leachate conveyance system, the discovery of leaks, and documents the findings and conclusions of the investigation team. A separate report, entitled *Evaluation of Leachate Transmission System, On-Site Disposal Facility*, has been prepared by GeoSyntec and presents detailed technical information on the construction of the leachate conveyance system and the evaluation of the leaks. The GeoSyntec document is being issued simultaneously with this report. Appropriate references to the GeoSyntec document are included in this report.

Numerous technical terms are used throughout this report to explain the construction of the leachate conveyance system. The following definitions are provided to assist the reader in understanding the detailed information presented in this and the GeoSyntec report:

General Engineering Terms:

Construction Quality Assurance Final Report

A Construction Quality Assurance Final Report is prepared at the completion of a project, or at the completion of a component of a large project. The report generally includes inspection reports, quality control data, laboratory test results, as-built drawings, and design changes. The report is prepared and certified to be correct by the Engineer of Record.

Design Change Notice (DCN)

A document used to identify, formalize a request for, or provide changes to an approved design drawing, specification, or other document. When approved, a DCN has the same authority as a revision to the affected document.

Engineer of Record (EOR)

A licensed Professional Engineer registered in the state in which the work is being performed. For the construction of the OSDF leachate conveyance system, GeoSyntec was the Engineer of Record.

Request for Clarification of Information (RCI)

A document used to request a clarification or interpretation of design documents.

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Leachate Conveyance Terms:

double-walled pipe (also called dual-containment pipe)

A smaller pipe seated inside of a larger pipe.

leachate

Liquid that has come into contact with or been released from waste material.

Permanent Lift Station

An underground tank located at the lowest point of the gravity pipeline in which liquids are pumped to a higher elevation (lifted) and forced through the remainder of the pipeline using mechanical pumps.

Pipeline Terms:

gravity pipeline

A pipeline in which liquids are transported by the force of gravity without the use of mechanical pumps.

high-density polyethylene (HDPE)

Plastic that is produced under high temperature and extremely high pressure; HDPE is usually black in color and is available in varying thicknesses.

hydrostatic testing

Test of strength and leak resistance of a pipe by internal pressurization with a liquid.

Standard Dimension Ratio (SDR)

$$SDR = \frac{pipe\ diameter}{minimum\ wall\ thickness}$$

An SDR 11 pipe has a wall thickness of 0.6 inches and an SDR 26 pipe has a wall thickness of 0.25 inches

Methods of Pipe Joining:

butt fusion joint

The joining of two plastic pipes by heating the ends until they are molten and then pressing them together to form a homogenous bond

electrofusion coupling

A method of joining plastic pipes in which a coupling is placed over the ends of the pipes and electric current is applied which melts and joins the components.

extrusion weld (or "backwelding")

A ribbon of molten plastic is placed over the edge of the seam; when it solidifies it joins and seals the two pieces of plastic.

2.0 SCOPE OF INVESTIGATION

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Following the discovery of leaks in the gravity pipeline of the leachate conveyance system, an investigation team of engineers was formed on March 12, 1999 at the request of the FDF Leadership Team. The scope of the investigation team was to evaluate and examine the gravity pipeline and to determine the probable causes of the leaks. The gravity line is defined in three different sections:

- Section 1 — The permanent gravity pipeline from penetration boxes located in OSDF cells 1, 2, and 3 to Manhole No. 1, Manhole No. 2, and Manhole No. 3
- Section 2 — The permanent gravity pipeline from Manhole No. 1 to Manhole No. 2 and to Manhole No. 3
- Section 3 — The temporary gravity pipeline from Manhole No. 3 to the Permanent Lift Station

The results of the investigation for Section 2 (permanent) and Section 3 (temporary) are presented in this report. The evaluation of Section 1, the permanent gravity pipeline, from the OSDF cells to the manholes, will be issued as an addendum to this report.

Through daily meetings, individual discussions with appropriate personnel, and examination of construction, engineering, and quality assurance records, the investigation team gathered information on the initial installation and testing of the leachate conveyance system, the discovery and field investigation of the leaks (including examining the leaking sections of pipe that were removed), and the procedures and processes used during construction. In addition to the members of the investigation team, parties involved in the daily meetings and individual discussions included FDF construction personnel from both the OSDF and leachate conveyance system projects, OSDF project team members, FDF quality assurance personnel, FDF management, and representatives from GeoSyntec, DOE, EPA, and OEPA. The discussions focused on the history of the project and involved those people most closely associated with each particular portion of the project.

Following the daily meetings and individual discussions, the investigation team directed its attention to the methods and procedures for installing electrofusion couplings and conducting hydrostatic testing of the gravity pipeline. These issues were identified as the possible causes of the leaks based on problems encountered during installation. Detailed data was collected and evaluated on the installation of electrofusion couplings and performance of hydrostatic testing.

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Based on the research of the investigation team, additional information was requested from GeoSyntec, the Engineer of Record for the design and construction of the OSDF. GeoSyntec performed the following activities and provided the following information to the investigation team:

- Attended meetings at the FEMP and participated in conference calls with the members of the investigation team.
- Gathered information concerning submittals that were approved by GeoSyntec field representatives regarding construction of the gravity pipeline, initial hydrostatic testing procedure, and videos taken of the pipeline during the leak investigation.
- Developed as-built documents associated with the leak investigation including a drawing showing the location of electrofusion couplings, butt fusion joints, and low points within the pipeline and records illustrating the results of the hydrostatic testing, including lengths of each pipe tested and the date of testing.
- Drafted revised hydrostatic testing procedures on March 15 and March 16, 1999 for the 6-inch carrier pipe and the 10-inch containment pipe.
- Confirmed calculations based on using a pipe with a Standard Dimension Ratio of 26 (SDR 26); calculations addressed loading conditions, hydrostatic testing pressures, and pipe buckling pressures.
- Performed an analysis of 6-inch carrier pipe deformation (ovality) including a determination of the existing condition of the pipe and a recommendation of suitability for future use.
- Analyzed electrofusion coupling failures and made recommendations for replacement and/or repair.
- Evaluated the need for increased monitoring of the leachate conveyance system.
- Analyzed previous methods used for leachate detection within the leachate conveyance system; recommended improvements for earlier detection

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- Summarized all the above activities in a report entitled *Evaluation of Leachate Transmission System, On-Site Disposal Facility,* hereinafter referred to as the GeoSyntec Report).

As stated earlier, the GeoSyntec report discussed in the last bullet item is being issued concurrently with this report. Prior to issue, the investigation team performed a peer review of GeoSyntec's report and provided comments for incorporation into the final document.

The lessons learned identified in Section 5.0 of this report may be expanded and issued as a separate document in the future. In addition, this investigation report will be submitted to the FDF Occurrence Reporting Department for development of a Root Cause Analysis document.

Determining and evaluating options for the future use of the leachate gravity line was not included in the scope of the investigation team. A brief description of the options is presented in Section 9.0 of the GeoSyntec report. These options are being evaluated separately by a project team consisting of personnel from DOE, FDF, GeoSyntec, OEPA, and a consultant to EPA.

3.0 HISTORY

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3.1 CONTRACTOR ROLES AND RESPONSIBILITIES

There are a number of different companies that were involved in the oversight and construction of the leachate conveyance system. They are GeoSyntec, Village Building Services, Inc., and Wise Service, Inc. Each of these companies were under contract with FDF. The purpose of this section is to clarify the roles and responsibilities of each of these companies as they relate to the design, construction, testing, and operation of the leachate conveyance system.

Fluor Daniel Fernald

FDF was responsible for project management, review of the OSDF and leachate conveyance system designs, quality assurance oversight, health and safety oversight, and construction oversight.

GeoSyntec Consultants, Inc.

The major roles of GeoSyntec included developing the engineering design, performing as the Engineer of Record, reviewing and approving design change notices, and performing as the Construction Quality Assurance (CQA) consultant. Specifically, GeoSyntec's roles and responsibilities included:

1. Provide all engineering design services, professional consulting, reports, calculations, drawings, and specifications necessary to obtain FDF, DOE, EPA, and OEPA approval for construction and maintenance of the OSDF
2. Certify design drawings by a professional engineer registered in Ohio
3. Provide written input on Construction Quality Assurance Plan that summarizes the quality control tests required within the various specifications required for design, construction, waste placement, and closure of the OSDF
4. Review all shop drawings and calculations submitted by the construction contractor
5. Inspect construction workmanship, materials, and equipment and reporting on their conformity or nonconformity to the approved drawings and specifications
6. Assist in the interpretation of Certified for Construction documents, and revision of these documents to address actual field conditions
7. Evaluate design change notices and/or nonconformances
8. Oversight, review, and evaluation of construction testing/certification
9. Technical assistance with change orders and claims
10. Attend weekly construction progress meetings
11. Assist with start-up

12. Final site certification at the end of each construction phase, including testing, records, and final documents (including "as-built" drawings and specifications)
13. Field testing and laboratory services during construction of the OSDF
14. Establish and maintain a formal quality assurance program acceptable to FDF.

Village Building Services, Inc.

Village Building Services was the construction contractor for the leachate conveyance system. They were responsible for furnishing labor, supervision, administration, tools, equipment, and materials to construct the leachate conveyance system. The work included the installation of underground HDPE piping, associated manholes, lift station, submersible lift pumps, instrumentation, electrical components, and overhead power line. Village Building Services subcontracted ISCO Industries to fabricate and supply pipe and conduct training. ISCO Industries, in turn, subcontracted Central Plastics Company to supply couplings and melting machines.

Wise Services, Inc.

Wise Services has a standing contract with FDF and is responsible for providing labor resources at the request of and under the supervision of FDF. Wise Services was utilized in December 1997 to assist in the repair of leaks that were discovered after initial hydrostatic testing, but before the leachate conveyance system was operational.

3.2 DESIGN CHANGE PROCESS

Because field conditions may change during the course of a project, changes to the original, engineered design based on field conditions are not uncommon. Field changes need to be reviewed and evaluated to ensure that the original intent of the design is not compromised. Since design changes occurred during the installation of the leachate gravity pipeline, the following description of how design changes are documented is provided.

As questions arise concerning the design, a Request for Clarification of Information (RCI) or a Design Change Notice (DCN) is generated. An RCI requests only information or definition of a given portion of the design and may lead to the generation of a DCN. A DCN proposes changes to the original design.

The RCIs and DCNs are subject to a review and comment process before final approval. Construction cannot proceed with design changes until a DCN is approved.

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The FEMP uses a formal system for tracking RCIs and DCNs. All are given a unique identification number and copies of all documents are kept on file on site with Engineering/Construction Document Control for reference. For a list of the RCIs and DCNs and complete copies of the documents, refer to Section 2.3 of the GeoSyntec report.

3.3 SUMMARY OF LEACHATE GRAVITY LINE INSTALLATION

The installation of the leachate gravity line began in late July 1997 and was completed in December 1997. To facilitate the 1999 investigation activities, the investigation team requested a description of the installation activities from FDF Construction personnel. The following is a brief summary of the installation activities. Refer to the GeoSyntec report for further information and details of the installation of the gravity pipeline.

The 6-inch/10-inch double-containment leachate pipe was fabricated in 40-feet sections by ISCO Industries in Louisville, Kentucky. The pipe was delivered to the site with the 6-inch carrier pipe seated within the 10-inch containment pipe. ISCO Industries also provided training and equipment for joining the sections of pipe. The 40-foot sections were fused in the field in 200- to 400-foot lengths on the bank of the trench excavation using butt fusion techniques. After the sections were fused together, they were placed into the trench. Pipe was installed simultaneously in different locations by multiple crews. The crews proceeded in different directions until the pipelines met.

After the pipe was placed in the trench, the longer sections of pipe were joined using an electrofusion coupling joint. An electrofusion coupling was used to connect the 6-inch pipe as well as the 10-inch pipe at the same location along the pipeline (referred to as a double electrofusion coupling configuration).

After joining the longer sections of pipe, the pipe was leveled, aligned, and backfilled. The pipe was then subjected to hydrostatic testing, which was monitored by GeoSyntec, to ensure the pipes were not leaking. When the pipe passed the final hydrostatic testing, the trench was completely backfilled to specified levels and grades.

3.4 CONSTRUCTION QUALITY ASSURANCE FINAL REPORT

The construction activities necessary to install the leachate conveyance system gravity pipeline were monitored by GeoSyntec for conformance with the design requirements. GeoSyntec performed Construction Quality Control (CQC) and Construction Quality Assurance (CQA) activities to confirm

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that the construction materials and methods were in compliance with the certified for construction drawings, technical specifications, CQA Plan, and approved changes.

A final report, dated January 1998 (ECDC #10724), was submitted by GeoSyntec to FDF. The "Construction Quality Assurance, Final Report, On-Site Disposal Facility, Phase I and Leachate Conveyance System" states, "The results of CQA activities undertaken by GeoSyntec as described in this report indicate that Phase I and the Leachate Conveyance System of FEMP OSDF were constructed in accordance with the specifications and Construction Drawings, which were prepared by GeoSyntec consultants, Atlanta, Georgia, as approved by FDF, DOE, OEPA, and USEPA". The final CQA Report is signed and sealed by a GeoSyntec professional engineer registered in the State of Ohio.

3.5 IDENTIFIED PROBLEMS

The following is a brief summary of the events involved in identifying the leakage problems occurring in the gravity pipeline in early 1999. For detailed information and chronological events associated with the investigative effort, refer to Section 4.3 of the GeoSyntec report.

During a routine inspection of the gravity line, water accumulation was found in Manhole No. 3, which was north of the Equipment Wash Facility. The source of the accumulated water was not immediately evident. FDF performed dye testing, excavation, and video camera taping of the gravity pipeline to investigate the pipeline. These tests identified four leaks in the gravity pipeline. Details and sequence of the investigative effort are given in Section 4.3 of the GeoSyntec report.

As leaks were located, sections of the pipeline were removed and replaced to repair the leak. In addition, one removed coupling was subjected to x-ray analysis to evaluate the pipe surface preparation. Various repairs and line modifications were made in February and March of 1999. For a detailed discussion of repairs and hydrostatic testing during this time frame refer to Section 4.3 of the GeoSyntec report. Leak investigation activities in the field took place until March 18, 1999; at that time field work was put on hold until a more detailed investigation of the causes of the leaks could be performed.

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4.0 FINDINGS AND CONCLUSIONS

The following text presents the conclusions and findings of the investigation team. The conclusions and findings were based on review of field information (DCNs, RCIs, daily logs, etc.), meetings with different parties involved in the design and construction of the leachate gravity line, discussions with manufacturers and suppliers, and inspections of pipe that had been removed from the system. For a plan view of area see Figure 1. For a location of joints see Figures 2, 3, and 4.

4.1 HYDROSTATIC TESTING PROCEDURES/OVALITY

Findings

The 6-inch carrier pipe had deformed to an oval shape from Manhole No. 1 to the permanent lift station, except at points of the electrofusion coupling. There was no documentation available stating the condition of the carrier pipe during hydrostatic testing of the 10-inch containment pipe, however, the carrier pipe was assumed to be empty. With the 6-inch carrier pipe empty, the annular space between the 6-inch and 10-inch pipe exerted a pressure on the 6-inch pipe and exceeded the pipe's buckling capacity (see Calculation A in Appendix B to this report). Hence, the 6-inch pipe deformed to an oval shape. The field samples of pipes removed were measured showing a 9 to 16 percent range in ovality (see Calculation B in Appendix B). GeoSyntec's report presents a detailed review and analysis of the ovality and its effect on the continued use of the 6-inch line.

Conclusions

The ovality of the 6-inch carrier pipe resulted when the buckling pressure of the SDR 26 pipe was exceeded during hydrostatic testing of the 10-inch containment pipe. The ovality does not affect the ability of the constructed system to meet the design intent, including the hydraulic capacity. The long-term implications of exceeding the buckling capacity on the carrier pipe in the permanent section of the leachate conveyance pipeline may require follow-up analysis. Section 6 of GeoSyntec's report presents a detailed review and analysis of the effect of containment pipe pressure on carrier pipe integrity.

4.2 ELECTROFUSION COUPLINGS

Electrofusion coupling leaks due to various contributing causes were observed. A summary of all electrofusion couplings and 12-inch sleeves (See Figure 5 for use of sleeve) installed as of March 29, 1999 is presented in Table 1. Also refer to Figures 2, 3, and 4 of this report for physical locations of all joints. Contributing causes for Leaks #1, #2, and #4 are presented below.

TABLE 1
SUMMARY OF ELECTROFUSION COUPLINGS AND SLEEVES
As of 3/29/99

General Location	Length of Pipeline	Number of Electrofusion Couplings 6 Inch	Number of Electrofusion Couplings 10 Inch	Number of Sleeves 12 Inch
Manhole No. 1 to Manhole No. 2	400 feet	4	4	1
Manhole No. 2 to Manhole No. 3	400 feet	3	4	1
Manhole No. 3 to Permanent Lift Station	2,800 feet	24	15	8
TOTAL	**3,600 feet**	**31**	**23**	**10**

Leak #1

Leak #1 was identified at a 10-inch electrofusion coupling in Excavation #2

Findings

During hydrostatic testing to determine the location of a leak in the 10-inch containment pipe, there was evidence that the pipe was leaking near a cleanout. The leak was located on the south side of the cleanout. The leaking coupling was removed and subjected to x-ray examination along with a non-leaking coupling. The x-ray of the non-leaking coupling indicated proper fusion over the entire surface. The x-ray of the leaking coupling showed a small area of incomplete fusion at the bottom of the coupling (the side that faced the bottom of the trench).

Conclusions

The x-ray of the leaking coupling indicated the presence of debris in the area of incomplete fusion. This was most likely the cause of the leak.

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Leak #2

Leak #2 was identified at a 6-inch electrofusion coupling in Excavation #3.

Findings

This leak occurred in the 6-inch carrier pipe located at a cleanout west of OSDF Cell 3, and was identified by video. There was also a small gap (estimated to be 1/16-inch) between the end of the pipe and the coupling. Minimal fusion over a narrow contact area on the pipe was observed.

Conclusions

The minimal fusion was adequate to pass the 1997 hydrostatic leak test. Subsequent pipe movement, due to either thermal expansion and contraction and/or ground movement, most likely caused the pipe end to pull away from the coupling, thus promoting a failure in the joint. The visual inspection showed a glossy surface which indicates inadequate pipe surface preparation.

Leak #3

Refer to Section 4.3 of this report "Equipment Damage" for a discussion of the findings and conclusions associated with Leak #3.

Leak #4

Leak #4 was identified at a 6-inch electrofusion coupling in Excavation #3.

Findings

An air pressure test was used to discover Leak #4 at a 6-inch electrofusion coupling located south of the cleanout and Leak #2. A 15-foot section of dual containment pipe was removed. This section of pipe contained three sets of couplings (three 6-inch electrofusion couplings and three 10-inch electrofusion couplings). The middle 6-inch pipe and 10-inch pipe couplings were both vertically misaligned. The coupling arrangement used was the "fixed end method" (see Figure 6). In addition, inadequate surface preparation in this area was also noted.

Conclusions

The leak at the carrier pipe was most likely caused by the vertical misalignment of the 6-inch electrofusion coupling. The inadequate surface preparation may have also contributed to the leak.

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Fixed End Method for Electrofusion Couplings

Findings

During the course of the installation, a different method for joining the dual containment pipe, called the fixed end method, was used without being formally submitted, reviewed and approved. This method was observed in the field by GeoSyntec and FDF construction personnel and no objections to the method were raised, which indicates that approval of the method would have most likely been granted had it been submitted for formal approval. A more thorough description of the fixed end method is provided in Section 3.5.3 of the GeoSyntec report.

A number of fixed end method joints were made with 6-inch and 10-inch electrofusion couplings (see Figure 6). In a correspondence dated August 25, 1998 (attached in Appendix A), Central Plastics Company, the electrofusion couplings supplier, raised concerns about the installation and techniques used to make fixed end method joints.

Conclusions

The assembly of double-wall containment piping by the fixed end method made joining pipe sections difficult because visual verification of engagement could not be performed effectively on the 6-inch pipe (see Figure 6). Joints presented in Figure 5 , the sleeve detail per ISCO SK-0197-006 R1, is the approved submittal for this type of joint. This sleeve detail was used satisfactorily at ten locations in the gravity pipeline.

Long Melt Time

Findings

Every coupling sample from the field displayed a deformation in the melt zone on the interior of the pipe. This condition indicated that the pipe melt temperature was too high or that the fusion time was too long. A manufacturer's program set the fusion time and temperature for the welding. Each electrofusion coupling had a barcode which would provide information to the melting machine so that the correct program was used. The machine used during repairs was the Friamat Machine manufactured by Friatec Co.

The fusion machine used in the initial installation of the leachate conveyance system was programmed to detect proper pipe alignment, melt time, and engagement. The machine will report an error code if the pipes are misaligned, overmelted, or not engaged. There are no available records that document the presence of error codes during installation of electrofusion couplings.

Conclusions

During a discussion with the Friamat machine manufacturer's representative, he indicated that the standard setting of the machines are typically for SDR 9 to SDR 17 pipe. The manufacturer also indicated that the use of SDR 26 pipe required the machine to have fusion time manually input. No field documentation existed indicating manual programming of the machine used to install the electrofusion couplings on the pipeline in 1997. Thus, melt times and machine settings during original installation were unknown. Following examination of the removed joints, while visible deformation exists on the interior of the pipe in the coupling fusion zone, the degree of deformation is not believed to have contributed to the failed couplings. The long-term implications of the increased melt time will require additional research by a polymer scientist.

4.2 EQUIPMENT DAMAGE

Leak #3

Leak #3 was identified at a 10-inch containment pipe in Excavation #4.

Findings

In an effort to retrieve the video camera lodged in the 6-inch pipe, Leak #3 was discovered. The exterior surface of the pipe had scratches and scrapes for approximately three feet on either side of the leak. The leak originated from a tear in the pipe which was approximately 1-inch long. A centralizer was located adjacent to the leak, which acted as a hinge point causing the pipe to weaken. Discussions with personnel and a review of the photographs taken during excavation of the pipe for leak investigations indicate that a backhoe was used to remove fill to within approximately 1 foot of the top and along the sides of the pipe. The last foot of fill was then removed manually.

Conclusions

The tear and resulting leak were most likely caused by construction equipment coming into contact with the outer surface of the pipe during the original installation.

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5.0 LESSONS LEARNED

A brief summary of lessons learned are covered in this section. Lessons learned are presented as a checklist of items to assist in future work concerning the design and installation of the HDPE dual containment pipe.

5.1 HYDROSTATIC TESTING PROCEDURE

The lesson learned is that the procedures submitted for approval need to be specific to the configuration of the pipe assembly being used. The pressure used and the sequence of application of pressures should match the pipe configuration being installed.

5.2 ELECTROFUSION COUPLINGS

The lessons learned in the use of electrofusion couplings are as follows:

- Due to increased installation difficulty, minimize the use of electrofusion couplings; use butt fusion welds where possible.
- Establish a process for construction "hold points" for electrofusion coupling installation. At each hold point, installation must stop and a quality check be performed to ensure proper surface preparation, alignment, melt times, etc. Installation cannot proceed without approval from the Engineer of Record.
- Precautions must be taken to eliminate misalignment and seating problems of the carrier and containment pipes.
- Confirm that the correct fusion time for the pipe being used is programmed into the fusion machine.
- Use a documented approval process for revising methods of installation.

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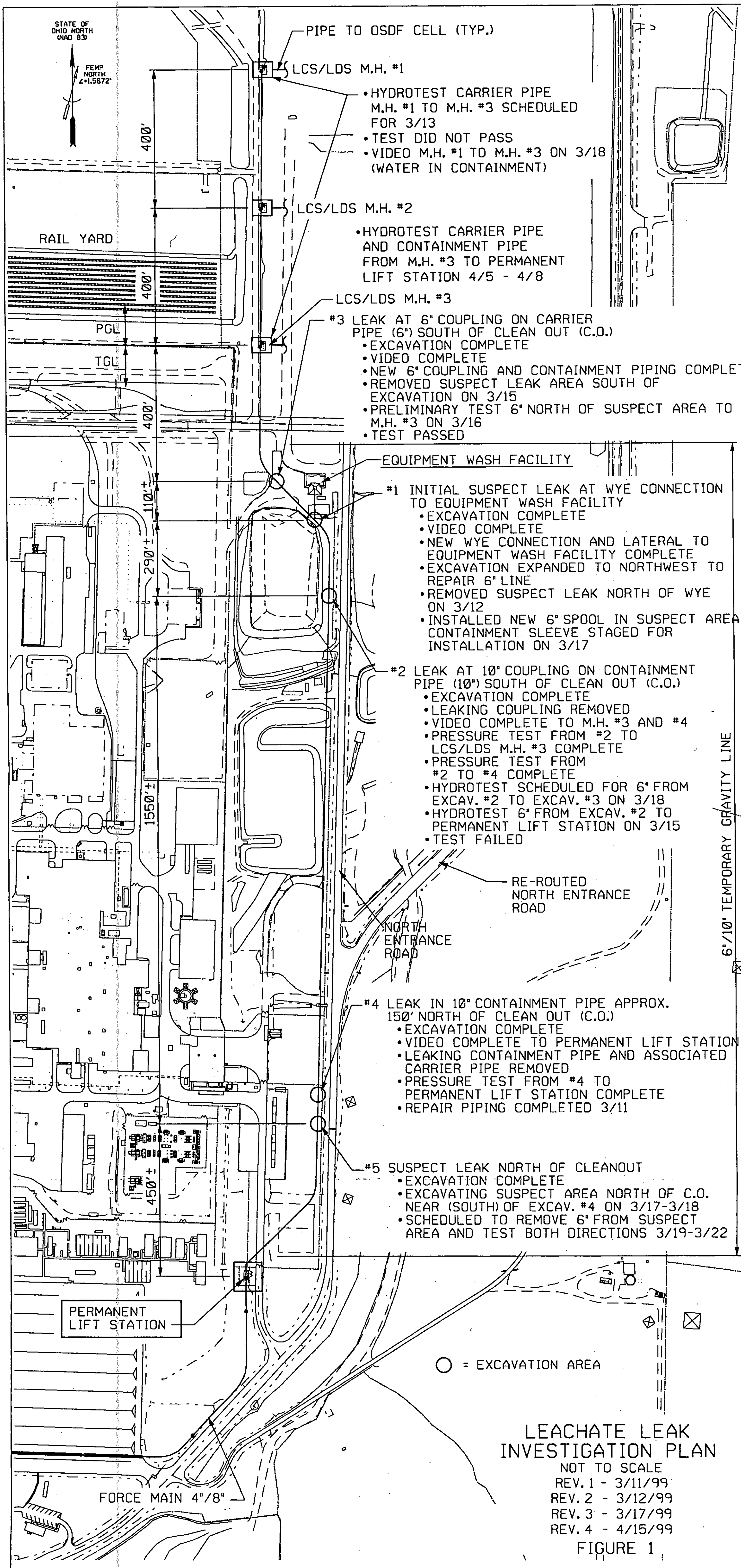
5.3 DESIGN CHANGES IN SELECTION OF MATERIALS

The lesson learned in design changes for the selection of materials and new sizes of pipes is to make sure the Engineer of Record evaluates the effect of all changes. FDF should ensure that a more thorough review of substantive DCNs is performed by the Engineer of Record.

5.4 PIPE INSTALLATION

The lesson learned for HDPE pipe installation is to maximize the installation of pipe in only one direction. When HDPE pipe is installed in one direction there is always a free end and the butt fusion joining method can be used.

Develop a back-up system such as visual inspection to eliminate over-reliance on the fusion machine to ensure the pipes are properly joined.



LEACHATE LEAK INVESTIGATION PLAN

NOT TO SCALE

REV. 1 - 3/11/99

REV. 2 - 3/12/99

REV. 3 - 3/17/99

REV. 4 - 4/15/99

FIGURE 1

2193

27

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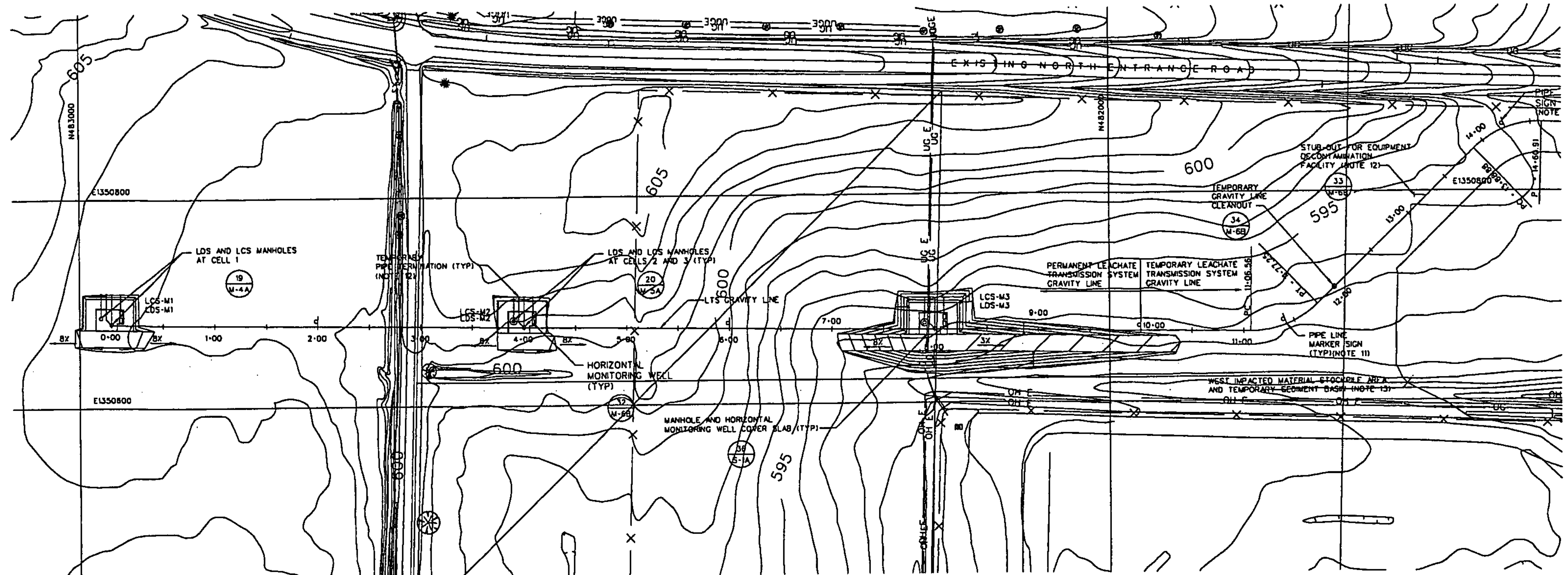


1 PLAN
LEACHATE TRANSMISSION SYSTEM

LEGEND

- 600 — EXISTING GROUND ELEVATION (FEET)
- 600 — FINISHED GROUND ELEVATION (FEET)
- POWER POLE
- PIPE LINE MARKER SIGN
- TEMPORARY GRAVITY LINE CLEANOUT
- LEACHATE TRANSMISSION SYSTEM MANHOLES (LDS AND LCS) AND HORIZONTAL MONITORING WELL COVER SLAB

LEGEND - JOINT IDENTIFICATION

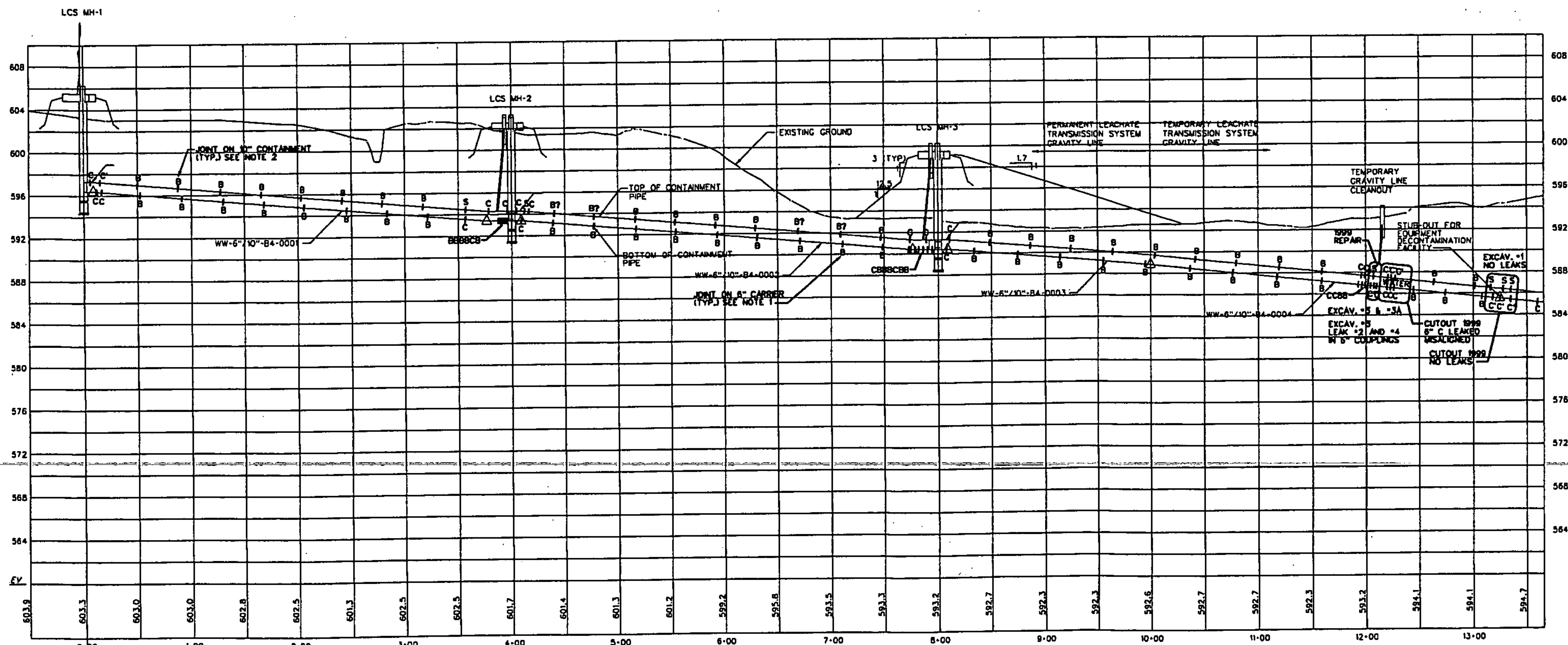
B - BUTT FUSION JOINT
C - ELECTROFUSION (EF) COUPLING
C' - ELECTROFUSION COUPLING W/BACKWELD
S - PIPE SLEEVE EXTRUSION WELDED
4B - FOUR BUTT JOINTS CLOSELY SPACED
B? - NO SURVEY NOTES - ASSUMED BUTT JOINT BASED ON PHOTOS AND FIELD NOTES

JOINT IDENTIFICATION NOTES:

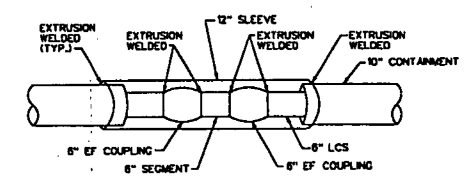
1. PIPE VIDEO TAPE EXAMINATIONS WERE USED TO DETERMINE APPROXIMATE LOCATIONS OF JOINTS FOR THE 6-in. CARRIER PIPE.
2. PIPE LOCATION SURVEYS, CONSTRUCTION PHOTOS AND FIELD NOTES WERE USED TO DETERMINE APPROXIMATE LOCATIONS OF JOINTS FOR THE 10-in. CONTAINMENT PIPE. SOME PIPE AREAS REMAIN INCOMPLETE.
3. JOINT LOCATIONS AT THE TEMPORARY CLEANOUTS, ESPECIALLY THE 10-in. CONTAINMENT PIPE, ARE APPROXIMATE AND CURRENTLY INCOMPLETE.

NOTE:

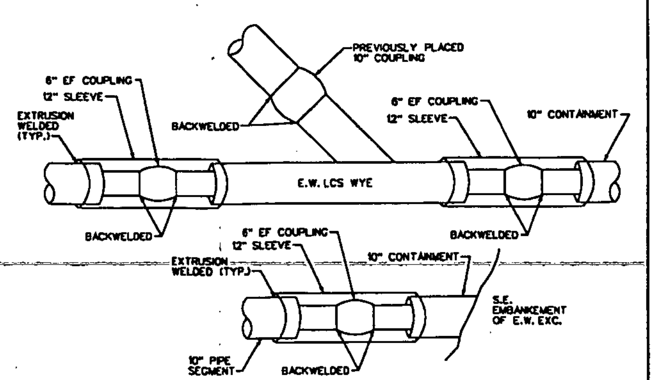
1. DRAWINGS INTENT IS FOR JOINT IDENTIFICATION ONLY. EXISTING BACKGROUND FROM GEOSYNTEC DESIGN DWG G-8A. FOR LOCATION OF LINE, BY GRID COORDINATES, SEE AS BUILT DRAWINGS.



2 PROFILE
LEACHATE TRANSMISSION SYSTEM



REPAIR @ C.O. @ STA. 12+00 (APPROX.)



EW-LCS REPAIR @ STA. 13+20 (APPROX.)

LEACHATE CONVEYANCE SYSTEM
LEAK INVESTIGATION
PLAN AND PROFILE DATA
3/29/99
FIGURE 2

2193

LEGEND

——600——	EXISTING GROUND ELEVATION (FEET)
——600——	FINISHED GROUND ELEVATION (FEET)
(symbol)	POWER POLE
(symbol)	PIPE LINE MARKER SIGN
(symbol)	TEMPORARY GRAVITY LINE CLEANOUT

LEGEND - JOINT IDENTIFICATION

B - BUTT FUSION JOINT
C - ELECTROFUSION (EF) COUPLING
C' - ELECTROFUSION COUPLING W/BACKWELD
S - PIPE SLEEVE EXTRUSION WELDED
4B - FOUR BUTT JOINTS CLOSELY SPACED
B? - NO SURVEY NOTES - ASSUMED BUTT JOINT BASED ON PHOTOS AND FIELD NOTES

JOINT IDENTIFICATION NOTES:

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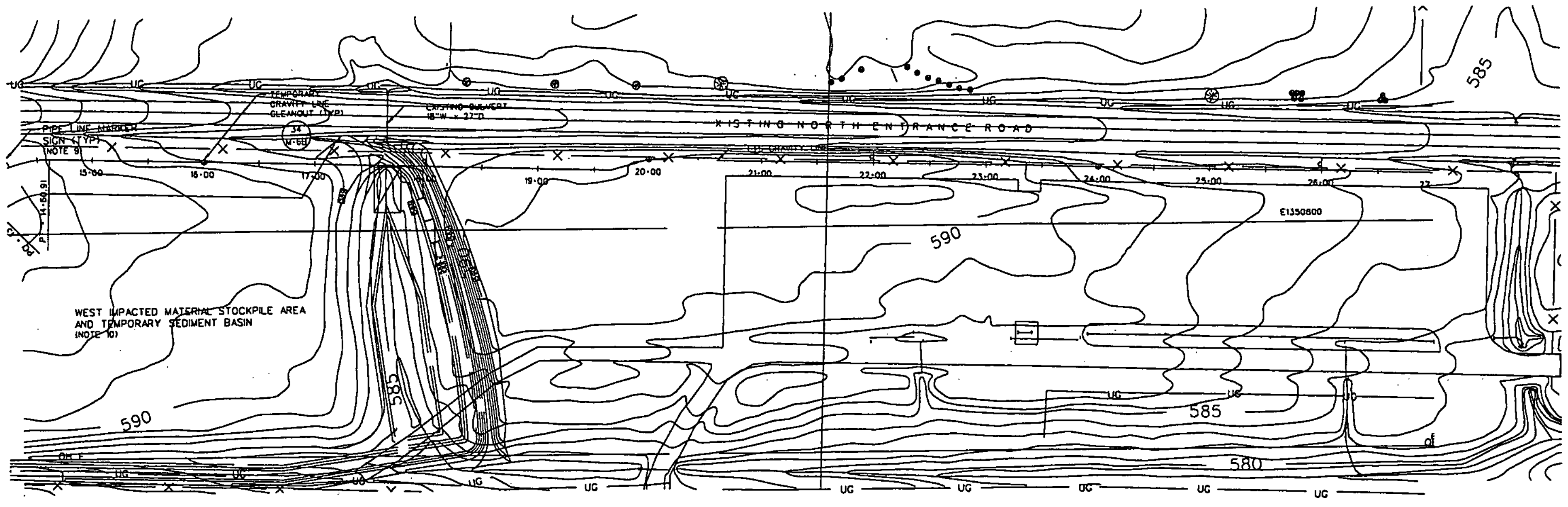
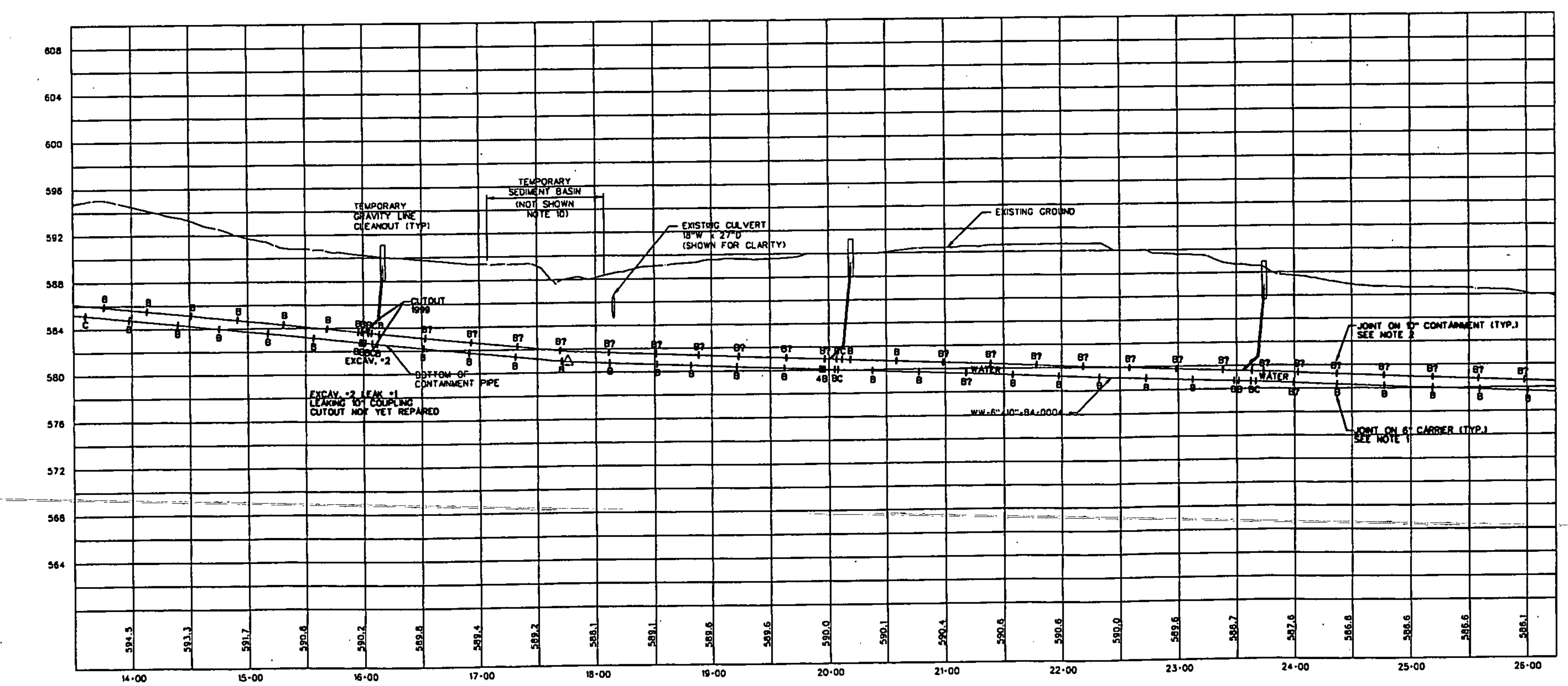
2. PIPE LOCATION SURVEYS, CONSTRUCTION PHOTOS AND FIELD NOTES WERE USED TO DETERMINE APPROXIMATE LOCATIONS OF JOINTS FOR THE 10-in. CONTAINMENT PIPE. SOME PIPE AREAS REMAIN INCOMPLETE.
3. JOINT LOCATIONS AT THE TEMPORARY CLEANOUTS, ESPECIALLY THE 10-in. CONTAINMENT PIPE, ARE APPROXIMATE AND CURRENTLY INCOMPLETE.

NOTE:

1. DRAWINGS INTENT IS FOR JOINT IDENTIFICATION ONLY. EXISTING BACKGROUND FROM GEOSYNTEC DESIGN DWG G-8B. FOR LOCATION OF LINE, BY GRID COORDINATES, SEE AS BUILT DRAWINGS.



3 PLAN
LEACHATE TRANSMISSION SYSTEM



4 PROFILE
LEACHATE TRANSMISSION SYSTEM

LEACHATE CONVEYANCE SYSTEM
LEAK INVESTIGATION
PLAN AND PROFILE DATA
3/29/99
FIGURE 3

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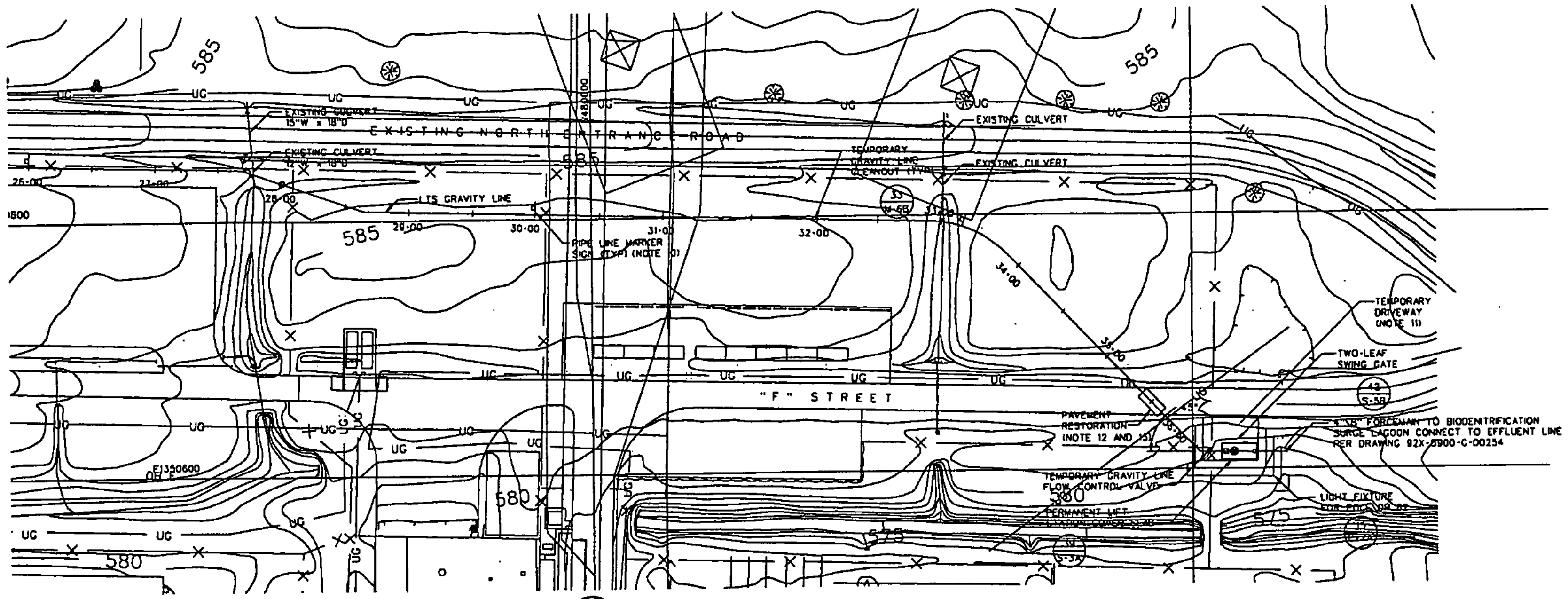
LEGEND

- 600 — EXISTING GROUND ELEVATION (FEET)
- 600 — FINISHED GROUND ELEVATION (FEET)
- POWER POLE
- PIPE LINE MARKER SIGN
- TEMPORARY GRAVITY LINE CLEANOUT
- SECURITY FENCE



5 PLAN
LEACHATE TRANSMISSION SYSTEM

LEGEND - JOINT IDENTIFICATION

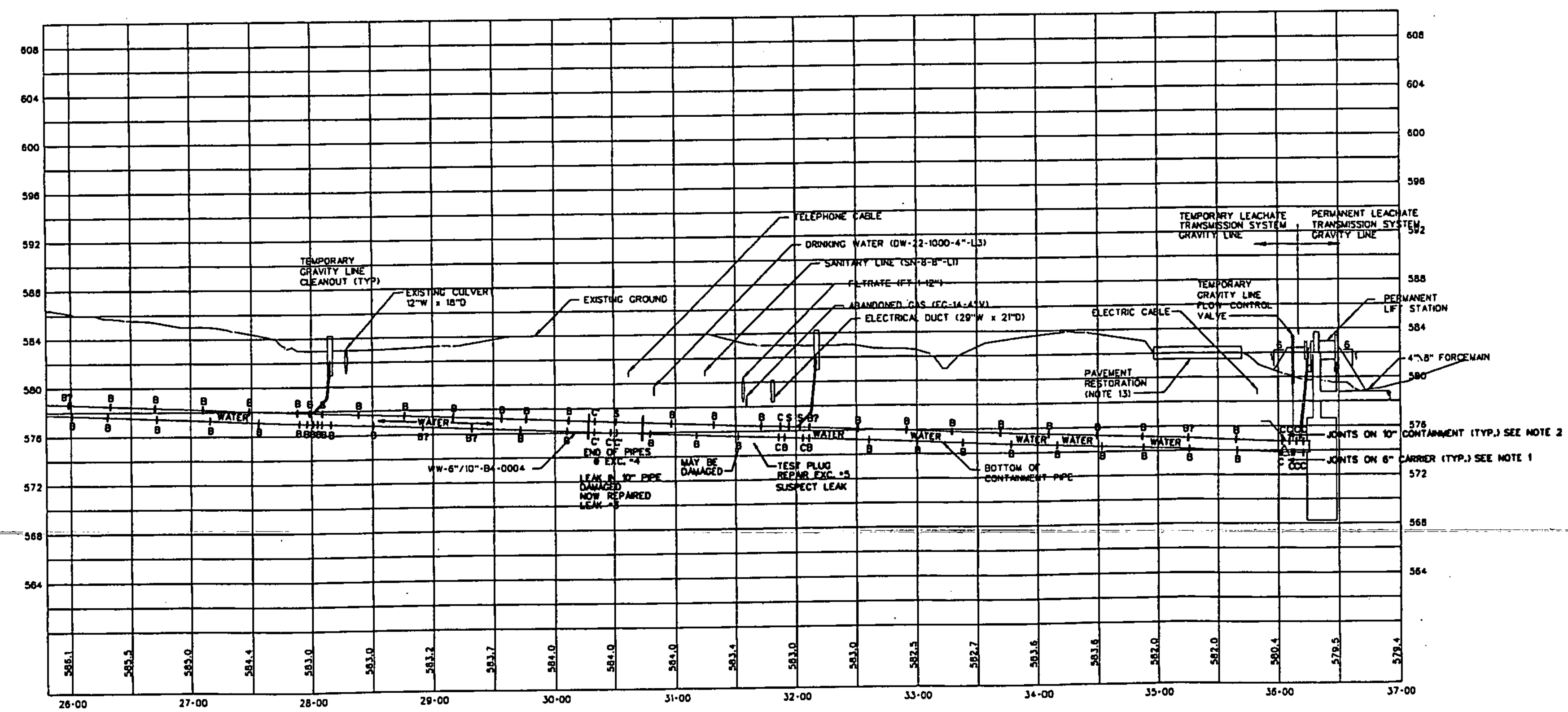
- B - BUTT FUSION JOINT
- C - ELECTROFUSION (EF) COUPLING
- C' - ELECTROFUSION COUPLING W/BACKWELD
- S - PIPE SLEEVE EXTRUSION WELDED
- 4B - FOUR BUTT JOINTS CLOSELY SPACED
- B? - NO SURVEY NOTES - ASSUMED BUTT JOINT BASED ON PHOTOS AND FIELD NOTES

JOINT IDENTIFICATION NOTES:

1. PIPE VIDEO TAPE EXAMINATIONS WERE USED TO DETERMINE APPROXIMATE LOCATIONS OF JOINTS FOR THE 6-in. CARRIER PIPE.
2. PIPE LOCATION SURVEYS, CONSTRUCTION PHOTOS AND FIELD NOTES WERE USED TO DETERMINE APPROXIMATE LOCATIONS OF JOINTS FOR THE 10-in. CONTAINMENT PIPE. SOME PIPE AREAS REMAIN INCOMPLETE.
3. JOINT LOCATIONS AT THE TEMPORARY CLEANOUTS, ESPECIALLY THE 10-in. CONTAINMENT PIPE, ARE APPROXIMATE AND CURRENTLY INCOMPLETE.

NOTE:

1. DRAWINGS INTENT IS FOR JOINT IDENTIFICATION ONLY. EXISTING BACKGROUND FROM GEOSYNTEC DESIGN DWG G-8C. FOR LOCATION OF LINE, BY GRID COORDINATES, SEE AS BUILT DRAWINGS.

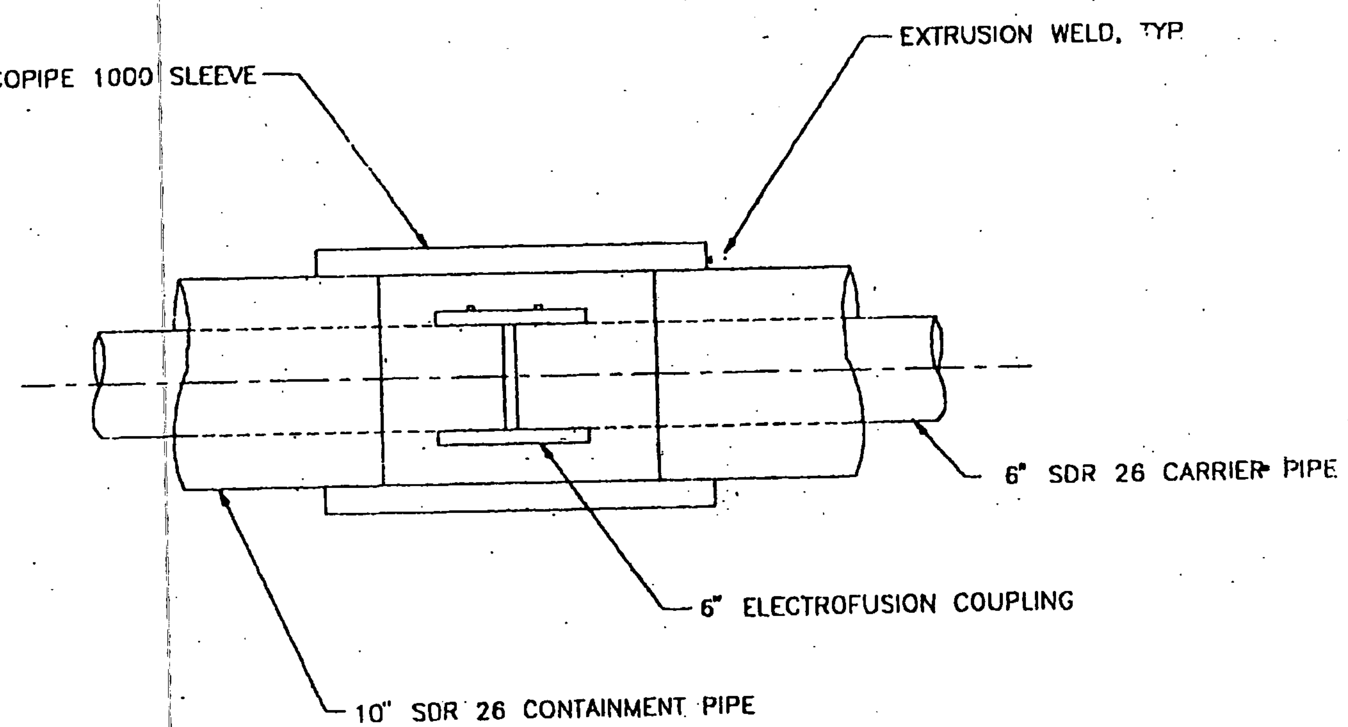


6 PROFILE
LEACHATE TRANSMISSION SYSTEM

SUMMARY

LINE	LENGTH	# OF ELECTROFUSION COUPLINGS 6"	10"	12" SLEEVES
M.H. 1 TO M.H. 2	400'	4	4	1
M.H. 2 TO M.H. 3	400'	3	4	1
M.H. 3 TO PLS	2824'	24	15	8
TOTAL	3624'	31	23	10

LEACHATE CONVEYANCE SYSTEM
LEAK INVESTIGATION
PLAN AND PROFILE DATA
3/29/99
FIGURE 4



ISCO ISCO INDUSTRIES, INC. 926 BAXTER AVE. BOX 4545 LOUISVILLE, KY. 40204 (502)583-8591	VILLAGE BUILDING SERVICES
	CLEANOUT CONNECTION
	DATE: 8/4/97 SPH
	SK-0197-006 R1

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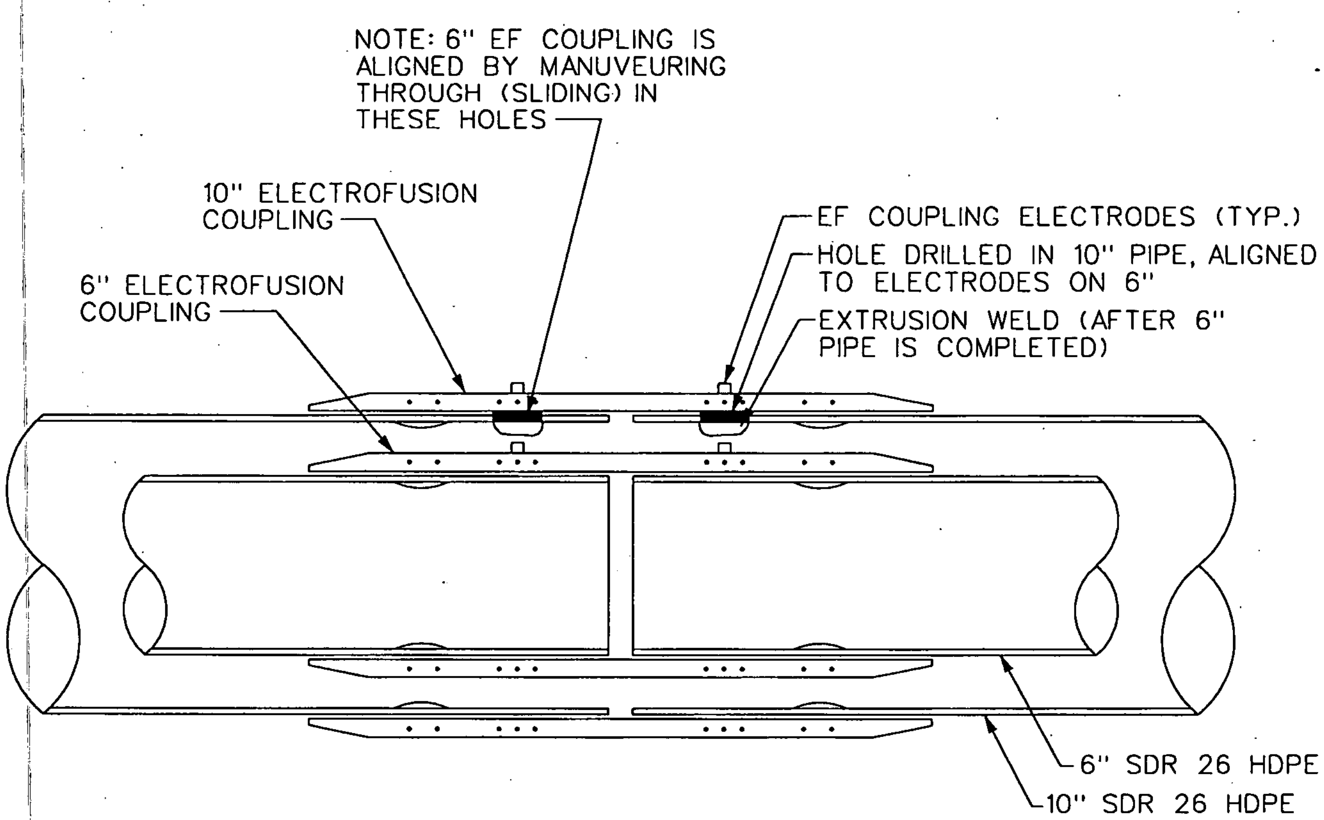
Sheet 8 of 10

FIGURE 5



GRAVITY LEACHATE LINE
EXISTING FIXED END METHOD

NOTE:
THE ABOVE DETAIL IS HISTORICAL EVIDENCE OF JOINT. IT IS NOT THE APPROVED (OR SUBMITTED) PROCEDURE.

FIGURE 6

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APPENDIX A

CORRESPONDENCE FROM CENTRAL PLASTICS 8/25/98

3/14/99 VCJ

E. KUBRIN

CENTRAL PLASTICS COMPANY
1901 West Independence
P.O. Box 3129
Shawnee, Oklahoma 74801
Phone: (405) 273-6302
Engr. Fax: (405) 878-4935

Rick E. Springer, P.E.
Product Engineering Manager
Direct Phone: (405) 878-3946
Direct Fax: (405) 878-5946
Email: rspringer@centralplastics.com

SEP 01 1998

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August 25, 1998

Mr. Rick McGuire
Fluor Daniel Fernald
P.O. Box 538704
Cincinnati, OH 45253-8704

Reference: Village Building Services
Leachate Conveyance System
Fernald, OH
Subcontract No.: FSC 589
VBS Job No.: 0197

Dear Mr. McGuire:

Attached please find a copy of our failure analysis report concerning the failures experienced by Village Building Services on a dual containment system at the above referenced job site.

Two sets of failed joints (a set consisting of one 6" coupler on the carrier pipe and one 10" coupler on the containment pipe) were subjected to numerous tests in our Engineering Lab. Our resulting conclusion is that the joints failed due to improper installation techniques, consisting of insufficient pipe preparation and the introduction of holes in the 10" pipe located directly under the fusion zone resulting in insufficient interfacial pressure.

It is our understanding that Village Building Services experienced only 12 failures of the 10" couplers during their installation, and subsequently repaired those by extrusion welding the couplers to the pipe. Apparently, there were no failures of the 6" couplers. Based on the results of our analysis, we believe that <u>all</u> joints created using these installation techniques are suspect and could potentially fail due to any number of factors including (but not limited to) pipe expansion/contraction and ground movement.

Both the contractor Village Building Services and our distributor ISCO Industries have been notified of these findings.

If you have any questions or comments concerning this report or it's content please let me know.

Sincerely,

Rick E. Springer, P.E.
Product Engineering Manager

Copy: Phill Pourchot
Bob Sehorn
Rocky Wade
Dane Johnson
Terry Stiles
Terry Stiles
Rick Hart
Clay Hamilton
Jimmy Kirchdorfer, Jr. - ISCO

CENTRAL PLASTICS COMPANY
ENGINEERING TEST REPORT

Subject:	Evaluation of 10"IPS and 6"IPS Electrofusion Couplings Returned By Village Building Services, Inc. Due to Leaks
Prepared By:	Clay Hamilton - Technical Services Manager
Date:	June 10, 1998
File Number:	FA-98-010

I. Introduction

The scope of this project was to evaluate two 10"IPS electrofusion couplings used on a dual containment line that were leaking and determine the cause of the leaks. Also included in this study were two 6"IPS electrofusion couplings that were joining the carrier pipe situated inside the 10" containment pipe. The fittings were installed on a leachate conveyance system at the US Department of Energy Fernald Environmental Management Project at Fernald, Ohio.

II. Background

The 10"IPS containment pipe for the leachate conveyance system was pressurized to 15 psig. During this pressure test, leaks were detected in the 10" electrofusion coupling joints. Repairs were made to some of the 10" couplings via extrusion welding around the ends of the couplings. Two samples were returned to Central Plastics for evaluation as to the cause of the leaks.

III. Procedure

The couplings were labeled in two sets: Set A consisted of 1-10"IPS electrofusion coupling (A-10) and 1-6"IPS electrofusion coupling (A-6). Set B consisted of 1-10"IPS electrofusion coupling (B-10) and 1-6"IPS electrofusion coupling (B-6). The part numbers and lot numbers of each fitting were recorded as well as the coil resistance and identification resistance of each coupling (if able to measure) were also recorded.

Pressure Testing:

A pressure test was conducted on one of the 10" couplings (A-10). The other couplings did not have enough exposed pipe to butt fuse end caps onto for the pressure test. Caps were fused to the exposed sections of 10" pipe. The assembly was pressurized to 30 psig and leak detection fluid was used to isolate any leaks. At 30 psig, a sectional area of the coupling was leaking. The leaking area was marked and photographs were taken of the leaking coupling.

Destructive Testing:

The destructive testing that was performed on couplings consisted of both bend/strip testing and joint crush testing.

* For a bend/strip test, thin sections are cut from the dissected coupling/pipe joint. One half of the thin section is secured and the other is bent from 90° to 180° around. This allows a good visual view of the overall joint area. It also shows how well the fitting is bonded to the pipe and the strength of the joint itself.

* The crush test (see Appendix 2) was performed according to ASTM F1055 Sec. 9.4.1 *Joint Crush Test.* The pipe sections were situated in the jaws of a hydraulic press and crushed to reveal the strength of the electrofusion joint.

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IV. Results / Discussion

Coupling A-10:

Pressure Test: The A-10 coupling joint was visually inspected and found to have holes drilled in through the 10"IPS polyethylene pipe (see Appendix A-3a). The holes in the pipe were approximately 1.08" in diameter and located directly under the fusion zones of the 10"IPS electrofusion coupling. The ends of the pipe were capped off and air pressure was applied through a transition fitting that was inserted into one of the 10"IPS butt fusion caps (see Appendix A-3b). Leak detection fluid was applied to the areas around the coupling. Air pressure was increased and a leak was detected.

Destructive Tests: The coupling was cut in half along the area where the holes were cut into the 10"IPS polyethylene pipe (see Appendix A-3c and A-3d). As a result of the holes being drilled in the 10"IPS pipe, molten polyethylene material from the coupling was able to flow into the openings resulting in an overall decrease of interfacial joining pressure. Portions of the dissected coupling were subjected to a joint crush test and failed the test when the coupling totally disengaged from the pipe. Additional sections were cut from the joint area and subjected to broad width and thin width bend tests. In all bend tests the coupling separated from the pipe with no bonded areas detected. This was due to no scraping of the pipe surface (see Appendix A-3e).

Coupling A-6:

Pressure Test: No pressure test was performed on coupling A-6 as the pipe length on one side of the coupling was not long enough to fuse another section of pipe or a butt fusion cap.

Destructive Tests: The coupling was cut in half. One half of the joint was subjected to a crush test. The fitting failed the joint crush test with the fitting totally separating from the pipe with no bonded areas detected. The other half of the coupling joint was subjected to a broad width and a thin width bend test. In all bend tests the coupling separated from the pipe with no bonded areas detected. The fitting failed the bend test.

Coupling B-10:

Pressure Test: No pressure test was performed on coupling B-10 as the pipe length on one side of the coupling was not long enough to fuse another section of pipe or a butt fusion cap.

Destructive Tests: Coupling B-10 also had holes drilled into the 10"IPS pipe directly under the fusion areas of the coupling (see Appendix A-3f). The coupling was cut in half and subjected to both joint crush and bend tests. Portions of the dissected coupling were subjected to a joint crush test and failed the test when the coupling totally disengaged from the pipe. Additional sections were cut from the joint area and subjected to broad width and thin width bend tests. In all bend tests the coupling separated from the pipe with no bonded areas detected. This was due to no scraping of the pipe surface.

Coupling B-6:

Pressure Test: No pressure test was performed on coupling B-6 as the pipe length on one side of the coupling was not long enough to fuse another section of pipe or a butt fusion cap.

Destructive Tests: The coupling was cut in half. One half of the joint was subjected to a crush test. The fitting failed the joint crush test with the fitting totally separating from the pipe with no bonded areas detected. The other half of the coupling joint was subjected to a broad width and a thin width bend test. In all bend tests the coupling separated from the pipe with no bonded areas detected. The fitting failed the bend test.

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V. Conclusion

10"IPS Electrofusion Couplings:

On the basis of our findings, the cause for the leaking 10"IPS electrofusion couplings was due to two factors. One factor was that holes were drilled in the 10"IPS PE pipe directly under the fusion zones on the 10" couplings resulting in a drastic loss of interfacial fusion pressure. This fusion pressure is critical in order to form a good, sound electrofusion joint. There are three elements in making a polyethylene joint, Heat, Pressure, and Time. From our analysis of the 10" couplings, one of the key elements (pressure) was substantially reduced and in isolated areas was basically eliminated.

The second factor was that there was no preparation of the PE pipe. One of the most important steps in electrofusion joining is to **properly** prepare the polyethylene pipe by scraping off the outer surface. The outer surface / skin of polyethylene pipe acts like a barrier preventing the materials in the coupling and pipe from fusing properly, thus forming the joint. The outer surface of polyethylene pipe contains oxidation as well as die lubricants which are used in the extrusion process. Any foreign matter on the pipe's surface acts as contaminants preventing the joining of the two polyethylene components (pipe and fitting).

6"IPS Electrofusion Couplings:

The 6" couplings were not originally part of the analysis, however, since they were included in the returned sets of couplings they were evaluated by destructive testing. The 6" couplings (A-6 and B-6) were destructively tested in the same manner as the 10" couplings. The evaluations of the crush and bend/strip tests on the 6" couplings revealed that the 6"IPS polyethylene pipe was not prepared at all. Only minor surface scratches were noticeable, probably due to the pipe being dragged. The outer surface of the 6"IPS pipe had not been scraped. The main concern for these joints is the long term quality of the joints since the pipe was not scraped. Since the pipe was not scraped, there was no joining of polyethylene materials between the couplings and the pipe. Basically only a compression joint, not a fusion joint, exists between the pipe and fittings. Even though the joints passed an initial pressure test, the long term performance of the joints is questionable. Over time, with seasonal changes and changes in the ground temperature, the pipe will expand and contract. This expansion and contraction of the polyethylene pipe will cause the joints to weaken and probably leak.

Overall Conclusion:

The overall conclusion as to why the 10"IPS electrofusion couplings leaked was due to no preparation of the pipe surface and a substantial loss of joining pressure due to the holes being cut into the 10"IPS pipe directly under the fusion zones of the 10"IPS couplings.

Appendices: A-1. Coupling Information Chart
A-2. Referenced standards and procedures.
A-3. Photographs

Appendix A-1

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Coupling Information Chart

Fitting Number	Coil Resistance (ohms)	ID Resistance (ohms)	Work Order Number	Run Date
A-10	0.816	118	M047830	9/97
A-6	0.650	454.2	M026280	6/97
B-10	0.820	118	M047830	9/97
B-6	0.652	454.8	M026280	7/97

Appendix A-2

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A-2a-1 to A-2a-2:
ASTM F1055: Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing, Section 9.4.1 *Joint Crush Test*

A-2b-1 to A-2b-3:
ASTM F1290: Standard Practice for Electrofusion Joining Polyolefin Pipe and Fittings

A-2c-1 to A-2c-3:
Central Plastics Electrofusion Operation And Training Manual: Standard Joining Procedures.

joining as in 8.1.1, may be made on unpressured pipe specimens.

9. Test Methods

9.1 *Minimum Hydraulic Burst Pressure Test:*

9.1.1 Select four fittings at random and prepare specimens in accordance with Section 8. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2.

9.1.2 Test the specimens in accordance with Test Method D 1599.

9.1.3 Failure of the fitting or joint shall constitute specimen failure.

9.1.4 Failure of any one of the four specimens shall constitute failure of the test. Failure of one of the four specimens tested is cause for retest of four additional specimens, joined at the failed specimens joining temperature. Failure of any of these four additional specimens constitutes a failure of the test.

9.2 *Sustained Pressure Test:*

9.2.1 Select four fittings at random and prepare specimens in accordance with Section 8 of this specification. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2.

9.2.2 Test the specimens in accordance with Test Method D 1598. All tests shall be conducted at 80 ± 2°C. The assemblies are to be subjected to pipe fiber stresses of 580 psi (4.0 mPa) for 1000 h or 670 psi (4.6 mPa) for 170 h. Joint specimens shall not fail within these time periods. Any failures within these time periods must be of the pipe, independent of the fitting or joint and must be of a "brittle" type pipe failure, not "ductile." If ductile pipe failures occur, reduce the pressure of the test and repeat until 170- or 1000-h results or pipe brittle failures are achieved.

9.2.3 Failure of the fitting or joint shall constitute specimen failure.

9.2.4 Failure of any one of the four specimens shall constitute failure of the test. Failure of one of the four specimens tested is cause for retest of four additional specimens, joined at the failed-specimens-joining temperature. Failure of any of these four additional specimens constitutes a failure of the test.

9.3 *Tensile Strength Test:*

9.3.1 Select four fittings at random and prepare specimens in accordance with Section 8 with the exception that it is permissible, on pipe sizes above 4 in. (102 mm) IPS, if limits of tensile machine will not allow 25 % elongation with pipe specimens of three-pipe diameters, to test with free pipe lengths of 20 in. (304-mm) minimum. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2.

9.3.2 Test the specimens using the apparatus of Test Method D 638. Test at a pull rate of 0.20 in. (5.0 mm) per min. ±25 %.

9.3.3 Failure of the fitting or joint as defined in 5.3, shall constitute specimen failure.

9.3.4 Failure of any one of the four specimens shall constitute failure of the test. Failure of one of the four specimens tested is cause for retest of four additional specimens, joined at the failed specimens joining temperature. Failure of any of these four additional specimens constitutes a failure of the test.

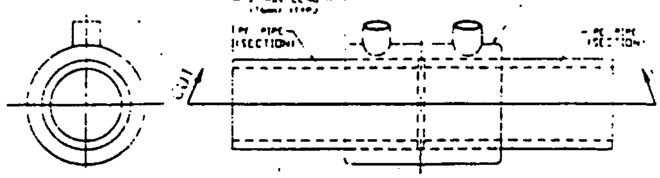

FIG. 1 Preparation of Coupling Specimen for Crush-Test

9.4 *Joint Integrity Tests*—Socket type joints and saddles illustrations of joint crush tests are offered in 9.4.1 and 9.4.2 as test methods which are useful as an evaluation of bonding strength between the pipe and fitting. Similar test evaluations as agreed upon between purchaser and seller are of equal value in performing such evaluations and may be substituted with such agreements.

9.4.1 *Joint Crush Test:*

9.4.1.1 Select four fittings at random and prepare specimens in accordance with Section 8. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2 (Note 3).

NOTE 3—It is permissible to utilize in joint integrity testing, specimens from the quick-burst tests conducted in 9.1 after visually determining that neither the joint area nor the pipe segment to be crushed was a part of the failure mode in the quick-burst test.

9.4.1.2 Slit socket joints longitudinally as illustrated in

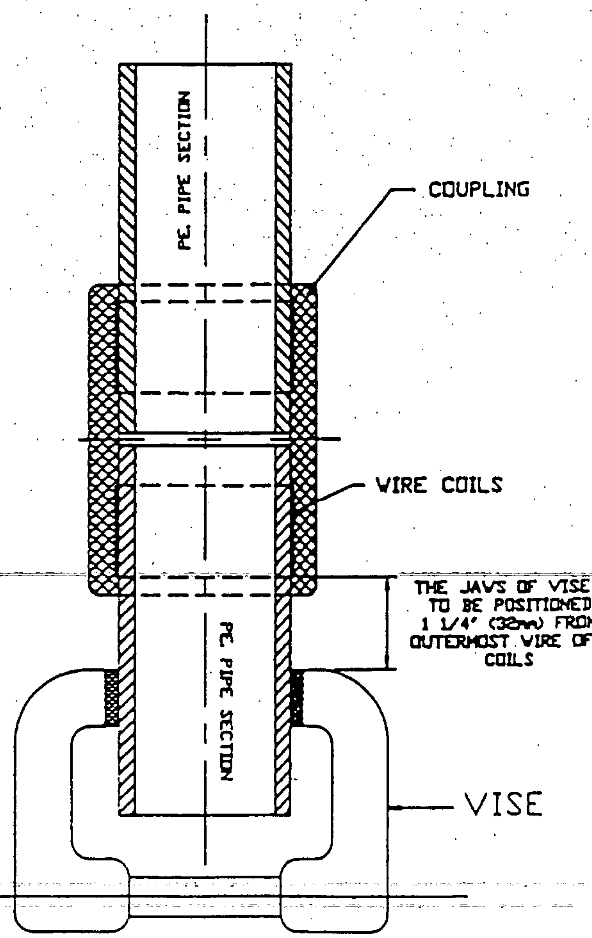

FIG. 2 Coupling Crush Test Arrangement

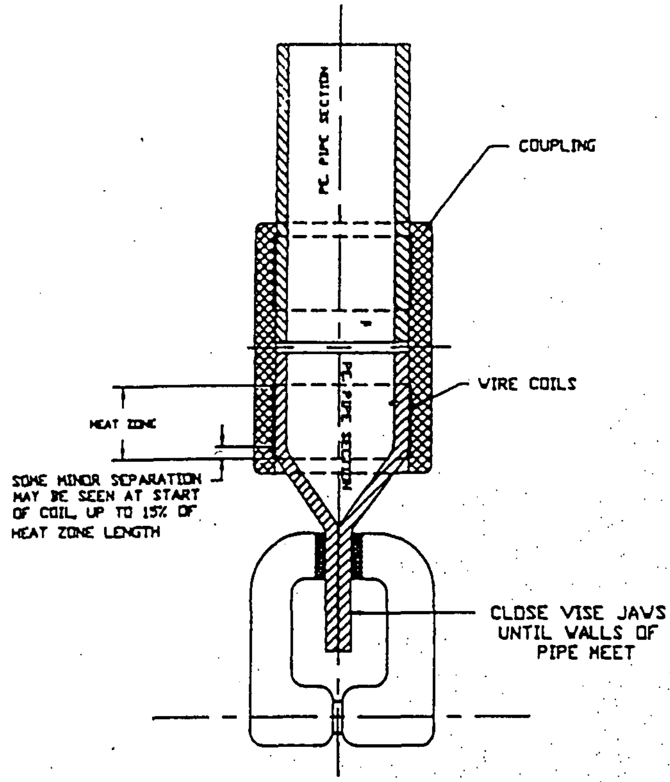

FIG. 3 Coupling Crush Test

Fig. 1 as near the centerline of the pipe as practical. Pipe lengths extending out of the socket may be cut back to a minimum of 3 in. (76 mm) for ease of placing in a vise.

9.4.1.3 Place each specimen half in a vise such that the outermost wire of coil is within 1.250 ± 0.125 in. (32 ± 3 mm) of vise jaws, with the jaws closing only on the pipe portion of the specimen (Fig. 2).

9.4.1.4 Tighten the jaws of the vise on the pipe until the inner walls of the pipe meet (Fig. 3). Repeat crush test on both halves and each end of specimen, at all ends, where a joint exists.

9.4.1.5 Separation of the fitting from the pipe at the fusion interface constitutes a failure of the test. Some minor separation at the outer limits of the fusion heat source up to 15 % of the fusion length may be seen. This does not constitute a failure. Ductile failure in the pipe, fitting, or the wire insulation material, is acceptable as long as the bond interface remains intact.

9.4.1.6 Failure of any one of the four specimens shall constitute failure of the test and is cause for retest of four additional fittings, joined at the same temperature as the failed specimens. Failure of any of these four additional specimens constitutes a failure of the test.

9.4.2 *Saddle Type Joints (Not Full-Wrap Design):*

9.4.2.1 Select four fittings at random and prepare specimens in accordance with Section 8. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2 (see 9.4).

9.4.2.2 Pipe lengths extending from saddle joint may be cut back clear up to the outer edges of the saddle for convenience of handling, if desired, however, it is not necessary. The length of the pipe extending beyond the saddle is not important to this test (Fig. 4).

9.4.2.3 Place the specimen in vise jaws as shown in Fig. 5, such that vise jaws are within ½ in. of saddle bottom and the jaws will close only on the pipe portion of the specimen. Saddle designs incorporating a bottom half saddle will need the bottom half removed for this test. Saddle designs incorporating a full-wrap single piece saddle are to be tested as in 9.4 socket type joints (Figs. 2 and 3).

9.4.2.4 Tighten the jaws of the vise on the pipe until the inner walls of the pipe meet (Fig. 6).

9.4.2.5 Separation of the fitting from the pipe at the fusion interface constitutes a failure of the test. Some minor separation at the outer limits of the fusion heat source up to 15 % of the fusion length may be seen. This does not constitute a failure. Ductile failure in the pipe, fitting, or the wire insulation material, is acceptable as long as the bond interface remains intact.

9.4.2.6 Failure of any one of the four specimens shall constitute failure of the test and is cause for retest of four additional fittings, joined at the same temperature as the failed specimens. Failure of any of these four additional specimens constitutes a failure of the test.

9.5 *Evaluation for Voids*—When dissecting electrofusion joints for the integrity tests in 9.4, or any reason, voids at or near the fusion interface may be exposed. The voids, should they be present, are a phenomenon of the electrofusion process, due to trapped air and shrinking during the cooling

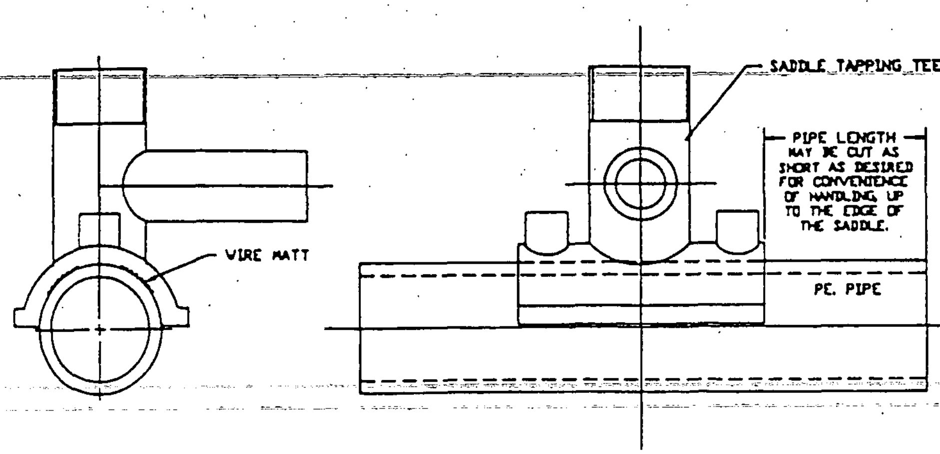

FIG. 4 Preparation of Saddle Specimen for Crush Test

ASTM Designation: F 1290 – 93

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American National Standard

Standard Practice for Electrofusion Joining Polyolefin Pipe and Fittings[1]

This standard is issued under the fixed designation F 1290; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice describes general procedures for making joints with polyolefin pipe and fittings by means of electrofusion joining techniques. These should be regarded as general procedures and not as a substitute for the installation procedures specified by the manufacturers. Manufacturers should be requested to supply specific recommendations for joining their products.

NOTE 1—Reference to the manufacturer in this practice is defined as the electrofusion fitting manufacturer.

1.2 The techniques covered are applicable only to joining polyolefin pipe and fittings of related polymer chemistry, for example, polyethylenes to polyethylenes using a polyethylene electrofusion fitting. Consult the manufacturer's recommendations for compatibility of the electrofusion fitting with the specific pipe or fitting material to be joined.

1.3 The electrofusion joining technique described can produce sound joints between polyolefin pipe and fittings, provided that all products involved (that is, pipe and fittings) meet the appropriate ASTM specifications.

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

F 412 Terminology Relating to Plastic Piping Systems[3]

F 1055 Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing[3]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise specified.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *control box*—the apparatus placed between the power source and the electrofusion fitting to regulate energy input to the fitting.

4. Significance and Use

4.1 Using the procedures in Sections 8 and 9, the manufacturer's instructions and equipment, pressure-tight joints can be made between manufacturer-recommended combinations of pipe that are as strong as the pipe itself.

5. Operator Experience

5.1 Skill and knowledge on the part of the operator are required to obtain a good quality joint. Each operator shall be qualified in accordance with recommended procedures and any regulatory agency or industry organization that has jurisdiction over these practices.

5.2 These procedures require the use of electrical and mechanical equipment. The person responsible for the joining of polyolefin pipe and fittings should ensure that recommended procedures developed for the electrofusion fittings involved, including the safety precaution to be followed, are issued before joining operations commence. It is especially important that the operator be aware of specific instructions regarding the use of electrical equipment in the presence of a potentially explosive environment.

6. Electrofusion Joining Processes

6.1 Electrofusion is a heat-fusion joining process where a heat source is an integral part of the fitting. When electric current is applied, heat is produced, melting and joining the components. Fusion occurs when the joint cools below the melt temperature of the material. The specified fusion cycle used requires consideration of the properties of the materials being joined, the design of the fitting being used, and the environmental conditions. See Specification F 1055 for performance requirements of polyethylene electrofusion fittings.

6.2 Adequate joint strength for field testing is attained when the fitting is not disturbed or moved until the joint material cools (Note 2). Bond strength can be affected if the joint is not allowed to cool sufficently.

NOTE 2—Polybutylene undergoes a crystalline transformation for several days after cooling below its melt temperature. Although this phenomenon has an effect on the ultimate physical properties of the material, its effect on testing of joints has not been found to be significant. If there is any question concerning the effects of crystallization, tests should be conducted on joints that have been conditioned for different periods of time in order to establish the conditioning-time relationship.

7. Classification

7.1 *Technique 1: Coupling Type*—The electrofusion coupling technique involves heat fusion of pipes with a tubular fitting with pipe sections inserted in each end of the fitting.

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[1] This practice is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.20 on Joining.

Current edition approved March 15, 1993. Published July 1993. Originally published as F 1290 – 90. Last previous edition F 1290 – 90.

[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

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The coupling contains an internal heat source. The heat source can be: (*1*) a resistance wire coil located on the inner surface of the fitting, or (*2*) the fitting itself can be made of an electrically conductive material. When electric current is applied, heat is produced in the fitting melting the inside of the fitting and the outside of the pipe. The melted material from the two components flow together and fuse as the joint cools. A device should be used to secure the joint and hold it in axial alignment during the joining process. The device may be either an external clamp or one which is integral to the coupling.

7.2 *Technique 2: Saddle Type*—The electrofusion saddle technique involves heat fusion of a saddle fitting to the outer surface of a pipe. The heat source is located on the fusion surface of the concave base of the saddle fitting and can be either: (*1*) a resistance wire coil, or (*2*) a conductive polymer. When electric current is applied, heat is produced at the interface of the pipe and fitting, melting the surface of the two components. The fusion bond occurs when the melted materials of the two components flow together and cool below the melting temperature of the material. During the fusion process, a clamping device should be used to hold the fitting in place on the pipe. This device may be either an external clamp or one that is integral to the saddle fitting itself.

8. Apparatus

8.1 *General Recommendations:*

8.1.1 *Power Source*—An adequate source of electricity is required. Consult the manufacturer's recommendations for the type of power (ac or dc), input voltage, frequency (Hertz) and power output (KW) required for proper fusion of fittings. A transformer may be required if the source voltage differs from the voltage recommended by the manufacturer.

8.1.2 *Extension Cord*—If the power source is remote from the installation site, an extension cord may be required. Select an extension cord of sufficient conductor size to deliver the required voltage to the control box.

8.1.3 *Control Box*—A control box is required to deliver the appropriate amount of energy to the electrofusion fitting. Semi-automatic and fully automatic control boxes may incorporate either timers or sensing circuits which monitor temperatures, current, or pressures in the fittings during the fusion process. Not all control boxes are compatible with all electrofusion fittings. Consult the manufacturer to determine the compatibility of control boxes not made by the same manufacturer as the fitting.

8.1.4 *Alignment Devices*—Various types of alignment devices are available and may be required for a particular fitting. The alignment device should prevent movement of the components being joined during the fusion and cooling cycles.

8.1.5 *Surface Preparation Equipment*—The purpose of surface preparation is to remove surface contamination and oxidation from pipe or fitting spigot (Note 3).

NOTE 3—Surface preparation is very important to assure total fusion.

8.1.5.1 *Tools*—A surface cleaning tool is required for certain fitting designs to remove the outer layer or skin of material on the pipe or fitting spigot surface prior to fusion. Tools used for that purpose are commonly called scrapers. Only qualified procedures and approved tools should be used. Emery cloth or sandpaper is not recommended.

8.1.6 *Miscellaneous*—The following equipment may be useful to assist in the electrofusion joining procedure:

8.1.6.1 *Tubing Cutter*—Used to obtain square end cuts on pipe.

8.1.6.2 *Marking Pen*—Used to mark the fitting location on the pipe surface for certain fitting designs. It may be useful to mark the pipe to define the boundaries before scraping or abrading the pipe surface.

8.1.6.3 *Wiping Cloth*—A clean, dry, non-synthetic, lint-free cloth or paper towel should be used for removing surface preparation residue from the joining surfaces. Considerations of the hazards of static electricity should be applied in selection of a wiping cloth material.

9. Joining Procedure

9.1 Precaution—Fusion quality can be affected if extreme weather conditions exist. Therefore, the ambient temperature limits should be considered when making field joints. Observe normal precautions in the use of electrical equipment, especially in wet environments.

9.2 *Technique 1: Coupling Procedure:*

NOTE 4—When fittings are to be used to repair pipe under conditions where line pressure buildup is anticipated, pressure should be blocked off or vented to prevent excessive pressure buildup during the joining and cooling cycle.

9.2.1 Cut the pipe ends squarely and remove burrs or shavings. Clean and dry the pipe by wiping with a clean paper towel or cloth.

9.2.2 Remove the outer surface of the pipe using recommended procedure and tools. Avoid gouging or removing excessive material from the pipe surface. Care should be taken to maintain the specified minimum wall for the pipe.

NOTE 5—For certain non-pressure applications, removal of the pipe outer surface material may not be required. Consult the manufacturer for recommendations.

9.2.3 If pipe inserts are supplied with the electrofusion fitting, install these inserts into the pipe ends.

NOTE 6—Care should be taken to ensure that fitting and pipe joint surfaces are properly handled and maintained free of contamination, such as dirt, debris, or other sources of contamination such as oil from the operator's hands which could have a deleterious effect on joint quality.

9.2.4 Center the fitting on the pipe ends. The gap between the pipe ends should not exceed the recommended value.

9.2.5 Secure the fitting and pipe in place to prevent movement during the fusion and cooling cycles using the recommended alignment tool.

9.2.6 Attach leads from the control box to the fitting. Follow recommended procedures to ensure leads are connected and working properly.

9.2.7 Activate the fusion cycle in accordance with the installation instructions. When the cycle is complete, follow the recommended procedures for disconnecting the leads from the fitting.

9.2.8 Allow the assembly to cool before removing the alignment tool. Consult instructions for recommended cooling procedures.

9.2.9 *Joint Acceptance*—Assure the fusion cycle was com-

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pleted without interruption for the prescribed time for fitting type and size being joined.

9.3 *Technique 2: Saddle Procedure:*

9.3.1 Clean and dry the joining surface of the pipe by wiping with a clean paper towel or cloth.

9.3.2 Remove the outer surface of the pipe using recommended procedure and tools. Surface preparation is only required in the area where the fitting is to be installed. Avoid gouging or removing excessive material from the pipe surface. Be careful not to alter the contour of the pipe during this procedure.

9.3.3 Position the saddle fitting on the prepared surface of the pipe. Secure the fitting in place to prevent movement during the fusion and cooling cycles. Handle the fitting carefully to avoid contamination of the fusion surfaces (Note 6).

9.3.4 Attach leads from the control box to the fitting. Follow recommended procedures to ensure that the leads are connected and working properly.

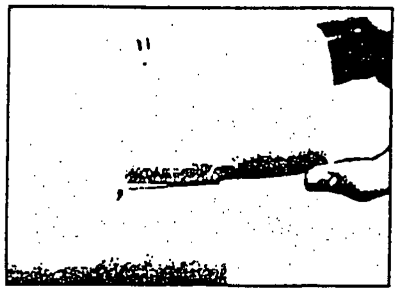
9.3.5 Activate the fusion cycle in accordance with the installation instructions. When the cycle is complete, follow the recommended procedures for disconnecting the leads from the fitting.

9.3.6 Allow the assembly to stand until it is cool before removing pipe from the alignment or clamping device. Consult instructions for recommended cooling procedures.

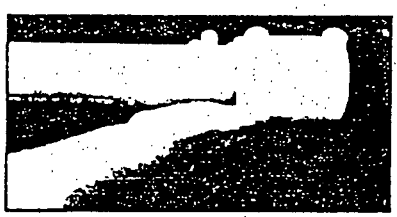
9.3.7 *Joint Acceptance*—Assure the fusion cycle was completed without interruption for the prescribed time for fitting type and size being joined.

6. Continue scraping until only a virgin surface remains.

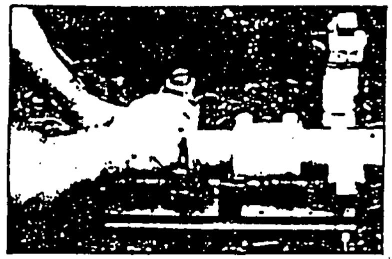
   Caution: Avoid all possible recontamination of the prepared surface. Do not touch inside of fitting or scraped pipe surfaces with your hands as perspiration and body oils could contaminate jointing areas and affect joint performance.



7. To determine stab depth, measure half the length of the coupling and mark the pipe ends an equivalent length. For ease of installation, a stab depth indicator and internal fitting stops are a molded part of Central Electrofusion couplings and reducers.



8. Slide fitting onto pipe until pipe ends meet with the stops in the I.D. of the fitting. Check measurement mark for proper stab depth.



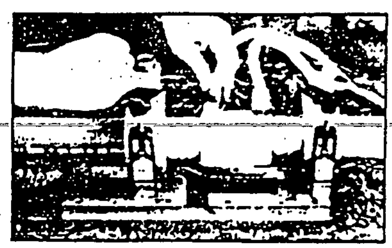
9. Maintaining stab depth, place into the proper clamping tool to secure the pipe from movement during the fusion cycle. For best results, alignment clamps should be placed as close to the fitting as possible.

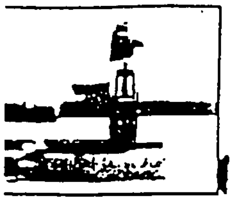
10. The sequence processor should be connected to an adequate AC power source (110 volt).

    Note: If utilizing a generator, the generator should be engaged before plugging the sequence processor in.

    Refer to the Electrical Data shown on page 12 for the precise electrical requirements of the size and type of Central Electrofusion fitting being joined.

11. The sequence processor will automatically run a quick diagnostic check of its operational functions (voltage input/output, etc.). When diagnostic check is complete "Attach Fitting" will appear on the visual display.





·ads from fitting. ce should remain ɹre pipe and fitting ımmended cooling ɿoving clamp, ad- g time should be e subjecting the ɩding, burying. g, or similar handl- ll stress.

12 for the recom- ɩg times for the of Central Elec- g being joined.

event of out-of- is important to ɜquate and even eved around the rence of the pipe. stopper can be ɪnd of the pipe to g the area to be

Appendix A-3

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graphs:

g A-10 showing holes cut into 10"IPS polyethylene pipe and extruded material flow

ıling A-10 showing leak detection foaming due to leak.

g A-10 showing the cross sectional view of the extruded material through the holes ylene pipe.

of the holes with extruded material.

owing no pipe preparation on the 10" pipe as well as no bonding between the fitting

g B-10 showing the holes cut into the 10" pipe as well as the extruded material flow

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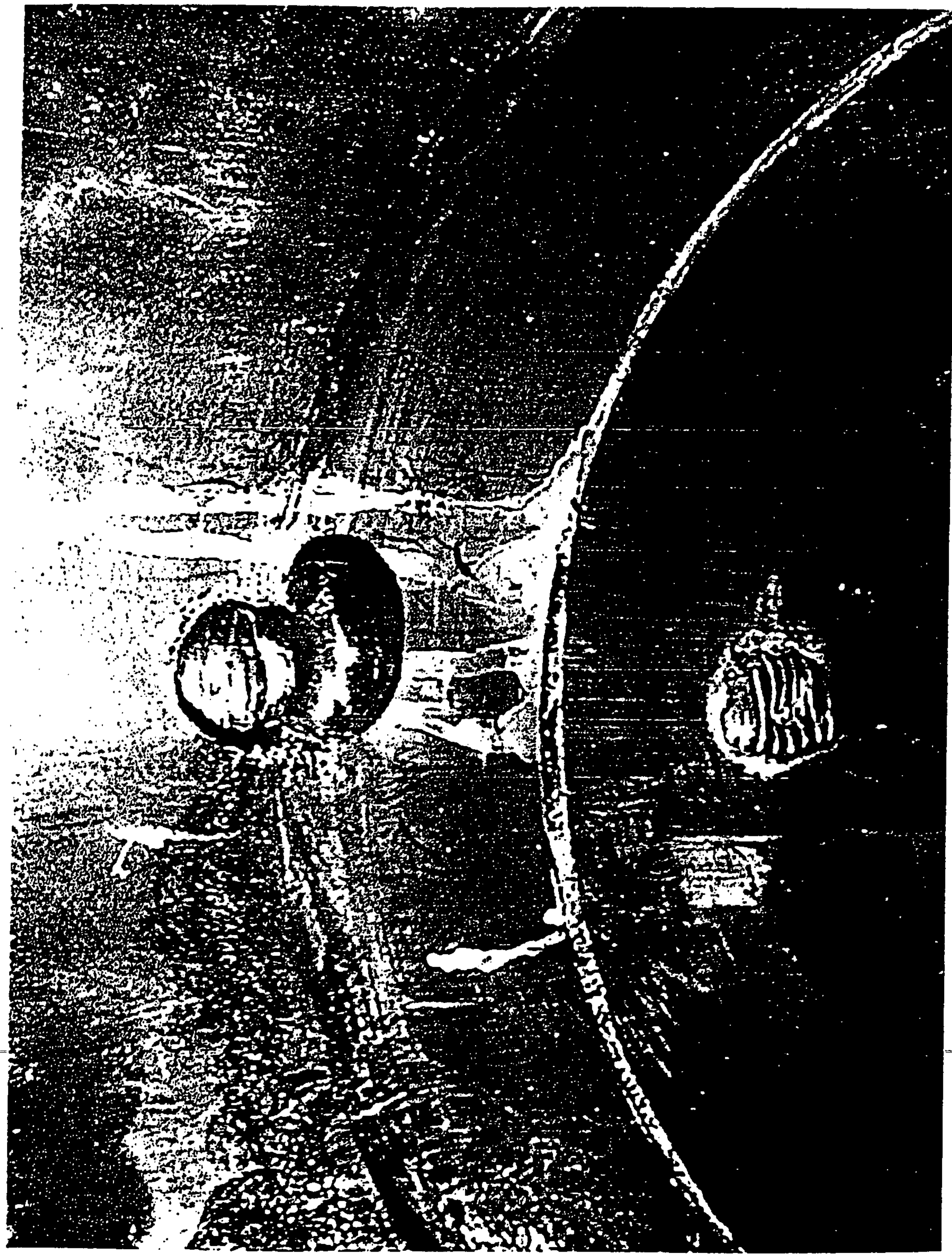

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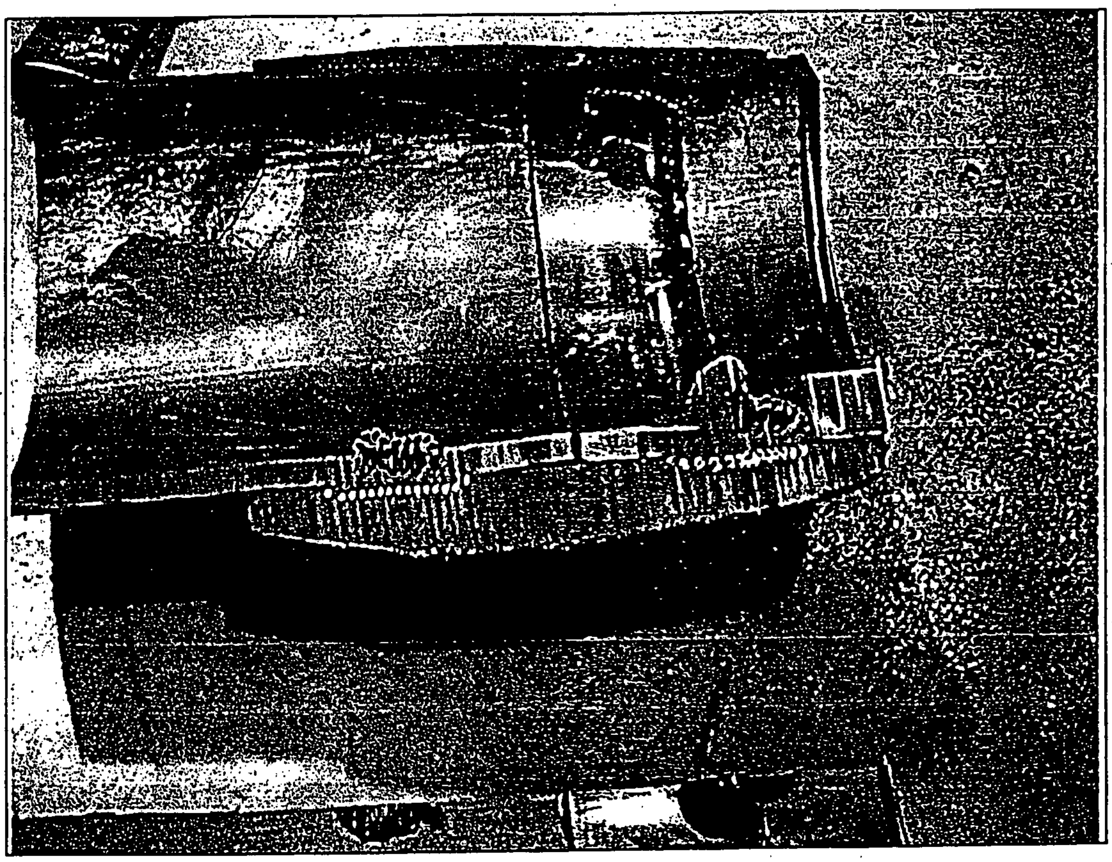

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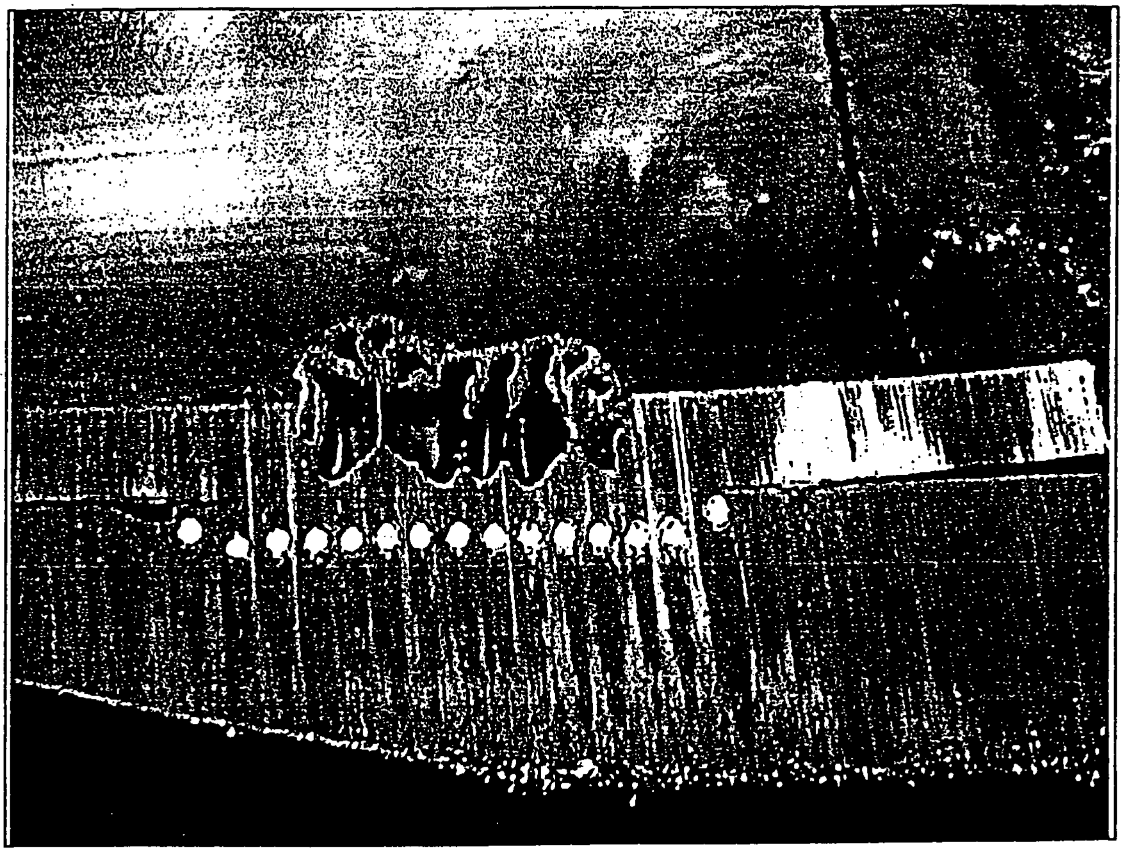

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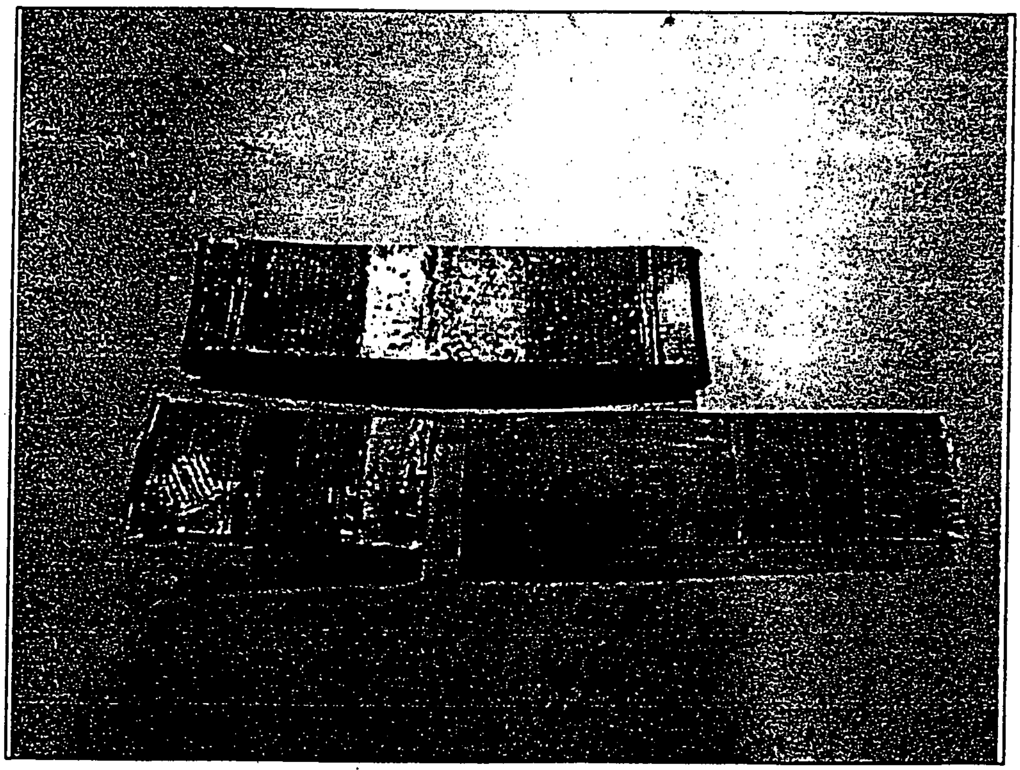

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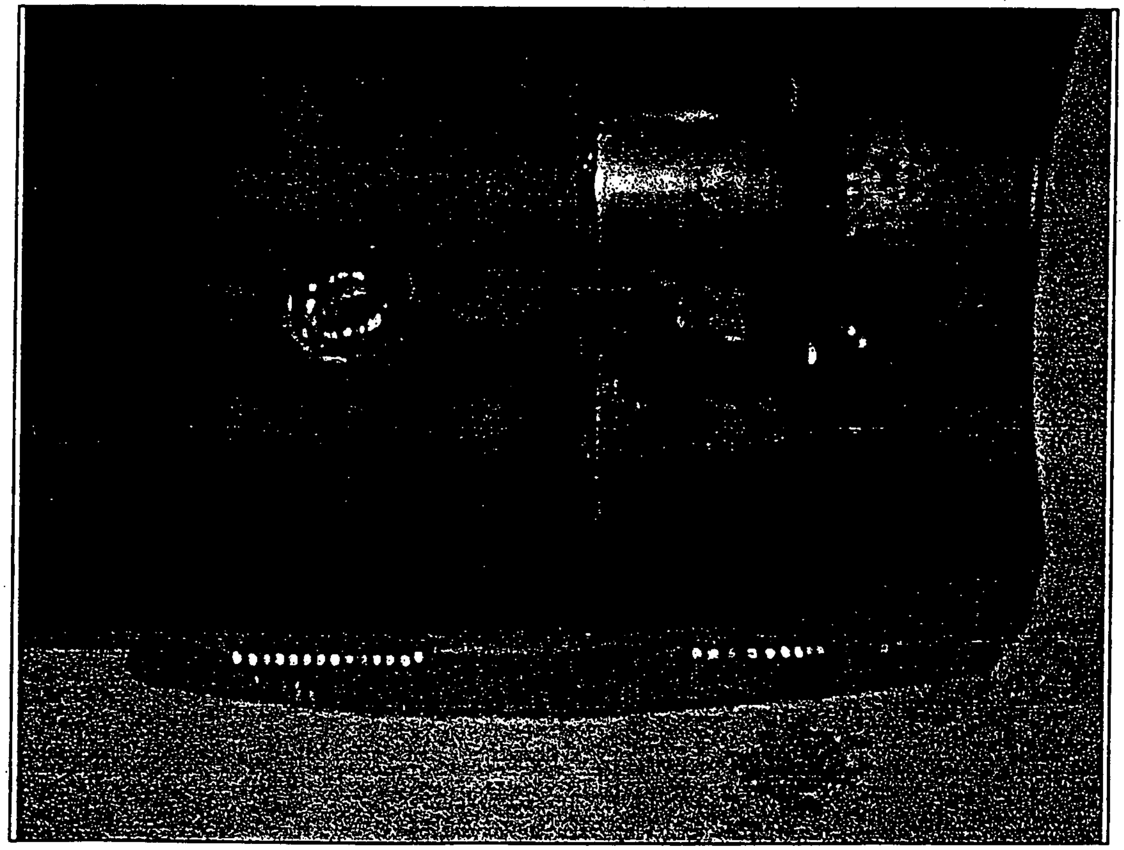

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APPENDIX B

CALCULATIONS

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2. Hydro test

   Per test records P test = 15 psi

3. Total pressure
   P total = P static + P test = 7.2 +15 = 22.2 psi

4. Pipe Buckling Capacity of 6-inch carrier.

Per Driscopipe Systems Design p. 37

P critical = (2.32E)/(SDR)^3
where;
E is the modulus of elasticity of HDPE = 130,000 psi for 1000 series pipe
SDR = 26 for the 6-inch carrier

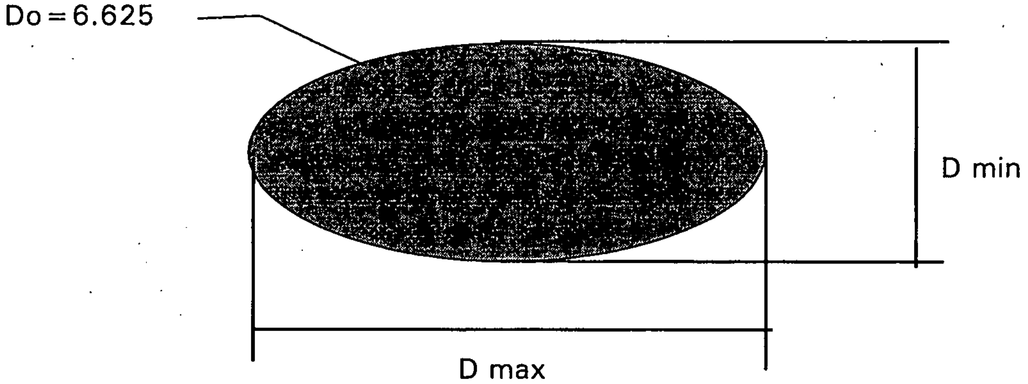
and
P critical = (2.32E)/(SDR)^3 = (2.32 x 130000)/(26)^3 = 17.2 psi

6. Comparison of total P to critical buckling.

P total = 22.2 psi > 17.2 psi = P critical
Hence, the hydrostatic pressure exceeds the pipe's buckling capacity and the pipe will start to buckle to an oval shape.

B. Leachate Investigation-Pipe Ovality Determination
By: EJK Date: 3/12/99

Measurement of HDPE pipe samples from field removed pipe.



6-inch SDR 26 CARRIER PIPE

Sta./leak	Dmax	Dmin	%Ovality (Dmax/Do)
16+00	7.375"	5.75"	111.3%
Leak #4	7.5"	5.5"	113.2%
Leak#1	7.375"	5.75"	111.3%
Leak #4	7.625"	5.375"	115.1%
12+23	7.25"	6"	109.4%

% ovality is per p.25 of Driscopipe Systems Design manual.