



UGI Utilities, Inc.
460 North Gulph Road
King of Prussia, PA 19406

Post Office Box 858
Valley Forge, PA 19482-0858

(610) 337-1000 Telephone
(610) 992-3258 Fax

August 23, 2011

VIA FEDERAL EXPRESS

Rosemary Chiavetta, Secretary
Pennsylvania Public Utility Commission
Commonwealth Keystone Building
400 North Street
Harrisburg, PA 17120

RECEIVED

AUG 23 2011

PA PUBLIC UTILITY COMMISSION
SECRETARY'S BUREAU

**Re: Application of UGI Utilities, Inc. – Gas Division for approval of the installation of a eight (8”) inch gas pipeline under the tracks of the East Penn Railroad, LLC, where the tracks cross the right-of-way of SR 1055 (Galen Hall Road), West Cocalico Township, Lancaster County, Pennsylvania.
Docket No. A-**

Dear Secretary Chiavetta:

Enclosed for filing, please find an original and three copies of the above-captioned application of UGI Utilities, Inc. – Gas Division. In accordance with Commission policy concerning rail highway crossings, there is no filing fee required for this application. Copies of this application have been filed upon the persons indicated on the attached Certificate of Service. Expedited consideration of this application is requested, as UGI Utilities, Inc.- Gas Division would like to commence work on this project by September 1, 2011.

Should you have any questions concerning this application, please feel free to contact me.

Very truly yours,

Mark C. Morrow

Counsel for
UGI Utilities, Inc. – Gas Division

BEFORE THE
PENNSYLVANIA PUBLIC UTILITY COMMISSION

IN RE: APPLICATION OF UGI :
UTILITIES, INC. – GAS DIVISION :
FOR APPROVAL OF THE INSTALLATION :
OF AN EIGHT INCH GAS PIPELINE :
UNDER THE TRACKS OF EAST PENN :
RAILROAD, LLC WHERE THE TRACKS :
CROSS THE RIGHT-OF-WAY OF SR 1055 :
(GALEN HALL ROAD), WEST :
COCALICO TOWNSHIP, LANCASTER :
COUNTY, PENNSYLVANIA. : Docket No. A -

RECEIVED

AUG 23 2011

PA PUBLIC UTILITY COMMISSION
SECRETARY'S BUREAU

To the Pennsylvania Public Utility Commission:

1. The name and address of applicant is:

UGI Utilities, Inc.
2525 North 12th Street
Reading, PA 19612-2677

2. The name and address of applicant's attorney is:

Mark C. Morrow (Attorney I.D. 33590)
460 North Gulph Road
King of Prussia, PA 19406
Tel.: 610.768.3628
Fax.: 610.992.3258
E-mail: morrowm@ugicorp.com

3. The applicant is a public utility that provide natural gas distribution service in Pennsylvania.
3. Applicant desires to install a proposed eight-inch (8") PE gas pipeline by a continuous directional bore beneath the tracks of Penn Eastern Rail Lines, Inc. where such tracks cross SR 1055 (Gallen Hall Road), within the PennDOT right-of-way in West Cocalico Township, Lancaster County, Pennsylvania. An application to the engineering consultant working for Penn Eastern Rail Lines, Inc., showing the location of the proposed crossing amongst other things, in attached as Exhibit A. Installing the eight-inch (8") PE gas pipeline will not require any surface excavation within thirty (30') feet of the center line of the track of Penn Eastern Rail Lines, Inc. at the crossing, and will instead be accomplished by a directional horizontal boring of

a hole beneath the tracks at the crossing maintaining a minimum depth of at least fifteen (15') feet.

4. No utilities currently have underground facilities in the crossing. Public utilities, municipalities, corporations, or property owners concerned in or affected by the proposed alteration of the crossing are:

Steve Sampson
Contract Administrator for
Penn Eastern Rail Lines, Inc.
ReLTEK, LLC
651 High Street
Suite 203
Burlington, NJ 08016

Michael Forester
County Permit Supervisor
Penn DOT – District 8-0
Lancaster County Maintenance Office
2105 Lincoln Highway East
Lancaster, PA 17602

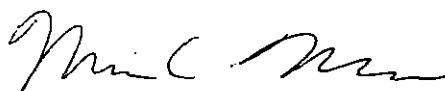
Rebecca Buchanan
Lancaster County Conservation District
1383 Arcadia Road, Room 200
Lancaster, PA 17601

Henry Freed
WEST COCALICO TOWNSHIP
156B W Main St. PO Box 244
Reinholds, PA 17569

6. Applicant has not had to acquire property to make the installation of the proposed gas line possible.
7. Applicant agrees to bear all the costs incurred in furnishing material and performing the work necessary to install and thereafter maintain the proposed gas line.
8. Applicant avers that this crossing is necessary and proper since the proposed pipeline is required to convert the residential developments of Village Hollow and Sunrise Gardens from propane to natural gas.
9. Applicant requests expedited approval of this application so that work on this project may begin on September 1, 2011.

WHEREFORE, UGI Utilities, Inc. requests respectfully that the Commission approve this application.

Respectfully submitted,

A handwritten signature in black ink, appearing to read "Mark C. Morrow". The signature is written in a cursive style with a horizontal line underneath it.

Mark C. Morrow
460 North Gulph Road
King of Prussia, PA 19406
Tel. 610.768.3628
Fax: 610.992.3258
morrowm@ugicorp.com

Counsel for
UGI Utilities, Inc. – Gas Division

Dated: August 23, 2011

EXHIBIT A

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AUG 23 2011

PA PUBLIC UTILITY COMMISSION
SECRETARY'S BUREAU



Consulting Engineering
Environmental Services
Construction Inspection

McTISH, KUNKEL & ASSOCIATES

3500 Winchester Road, Suite 300, Allentown, PA 18104
610-841-2700 • FAX 610-841-2709
e-mail: info@mctish.com • www.mctish.com

M.J. McTish, PE., Ret.
P.F. Kunkel, PE., Ret.

M.P. McTish, PE.
D.J. McTish, P.G.
J.P. Ryan, PE., PLS
J.J. Porter

T.S. Benner, PE.
M.E. Himmelwright, PE.
B.L. Bolinger
R.L. Moyer, PE., PLS
D.R. Heyne, S.E.T.
B.D. Bomdt, PE.
L.A. Martin, PE.
J.L. Stekar, PE.

June 23, 2011

ReLTEK, LLC.
Operations Group
1314 Oxmead Road
Burlington, NJ 08016
Attn: Steve Sampson - Applications

Subject: **UGI 8" Gasline Crossing of the
Penn Eastern Rail Lines**
SR 1055 (Galen Hall Road)
West Cocalico Township, Lancaster County

Dear Steve:

Enclosed are the three (3) copies of the items required for review and approval of a right-of-way occupancy for the purposes of allowing UGI Utilities, Inc. to cross under the existing railroad.

Should you have any questions, or require any additional information, please do not hesitate to contact me.

Very truly yours,

McTISH, KUNKEL & ASSOCIATES


Joseph V. Civitella
Senior Project Designer

JVC
06324-reltek-ltr.wpd
enclosures

ReLTEK use only

File #: _____
Date Received: _____

ReLTEK

APPLICATION FOR RIGHT of WAY OCCUPANCIES

APPLICATION FEE: A non-refundable fee of \$750.00 is due with submission of this application.

This application fee does not include any fees for: (a) special handling, (b) engineering review, (c) document preparation, (d) rents, (e) Railroad Protective Insurance, (f) preparation of estimates, (g) flagmen/watchmen costs/expenses or (h) construction costs incurred by the land owner. Payment of all additional fees is due prior to construction. Construction cost estimates for land owner's portion of the project may be requested, and will be prepared at the sole cost and expense of Applicant.

All applications are to be submitted in accordance with ReLTEK Specifications for Right of Way Occupancies. Failure to conform to these specifications may result in delays, additional costs, return or denial of your application. Construction drawings should be no larger than 11" x 17" in size. Larger size drawings are accepted in special circumstances, with prior approval of ReLTEK.

No work on land owner's property may proceed until Applicant is in receipt of a fully executed Occupation Agreement and has received authorization from land owner's engineering representative. No verbal approvals are granted or implied.

Name of Applicant: UGI Utilities, Inc.
(Exact name to be shown on Occupancy Agreement)

Applicant is: Individual Corporation* Municipality Other: _____
* State of Incorporation PA

Applicant's Mailing Address:
UGI Utilities, Inc.
2121 City Line Road
Bethlehem, PA 18017

Send Document to: (If different than Applicant's address)

Attention: Tony Sayegh
Title: Sr. Engineer

Attention: _____
Title: _____

Telephone #: (610) 807-3114

Telephone #: () _____

Location of Occupancy:

Name of Land Owner over which occupancy is applied: Penn Eastern Rail Lines, Inc.
 City Town Village: Reinhold, Township: West Cocalico
County: Lancaster, State: PA. Footage (2,270 ') and direction (N (S)E/W)
from Mile Post #: 7 or center line of Public Highway Crossing or Bridge: _____
(Name / Number)

Occupation to be located within confines of Dedicated Highway (right of way lines must be shown on plan)

Highway Name or Number: SR1005 Galen Hall Road AAR DOT #: _____
(AAR DOT# is posted near crossing)

(CONTINUED ON NEXT PAGE)

Type of Facilities:

- Pipe: Gravity Pressure (Non-Flammable) Pressure (Flammable)
 Wire / Cable: Aerial Undergrade (in conduit) Overhead
 Telephone (# of pairs: _____) Electrical (voltage: _____) Fiber Optic
 Phase of electrical circuits: _____ Number of electrical circuits: _____ Number of Poles: _____
 Crossing Angle: 118 ° Longitudinal (Total footage of occupancy: _____)
 Revision to existing facilities (*Copy of original agreement must be included with application*)

Method of pipe/conduit installation:

- Open Cut Bore & Jacking Jacking Tunneling Other Directional Bore

SEND COMPLETED APPLICATION TO:

ReLTEK, LLC
1314 Oxmead Road
Burlington, NJ 08016

Attention: Occupancy Agreements

Email: occupancies@rektek.com

APPLICANT'S CHECK LIST

- 1) Review Specifications.
- 2) Proper name and mailing address of Licensee.
- 3) Application fee.
- 4) Location data
- 5) Plan and Profile drawings (no larger than 11" x 17").
- 6) Pipe Data Sheet.
- 7) Depth of bury.
- 8) Method of installation.
- 9) Distance from face of launching and receiving pits.
- 10) Location of manholes and valves.
- 11) Size, voltage, type and number of: wires, cables or Fiber Optic Cables
- 12) Wire/Cable vertical clearance from sag to top of rail or highest grade of ROW if no tracks are present
- 13) Distance from poles to centerline of track, path or trail or centerline of ROW if no improvements are present
- 14) Pole configuration.
- 15) Angle of crossing.
- 16) Number of tracks (if crossing is over railroad).
- 17) Length of longitudinal occupancy.
- 18) R/W lines of Dedicated Highway (for crossings within public highways).
- 19) Bridge Footing of Dedicated Highway Bridge.
- 20) Bridge Attachment for Dedicated Highway Bridge.

****Warning**:**

Extreme caution is to be used in excavation due to the possible existence of other underground facilities along land owner's right of way. Any damage to existing facilities will be the sole responsibility of the Applicant. In compliance with State law, prior to commencing work, the contractor shall notify appropriate State "One Call" service.

PIPE DATA SHEET

| | CARRIER PIPE | CASING PIPE |
|--|--------------|-------------|
| CONTENTS TO BE HANDLED | Natural Gas | |
| NORMAL OPERATING PRESSURE | 60 psi | |
| NOMINAL SIZE OF PIPE | 8" | |
| OUTSIDE DIAMETER | 8.625" | |
| INSIDE DIAMETER | 7.87" | |
| WALL THICKNESS | 0.639" | |
| WEIGHT PER FOOT | 8.43 lbs. | |
| MATERIAL | PE | |
| PROCESS OF MANUFACTURE | Extruded | |
| SPECIFICATION | PE 2406 | |
| GRADE OR CLASS | - | |
| TEST PRESSURE | 100. PS19 | |
| TYPE OF JOINT | Fused | |
| TYPE OF COATING | - | |
| DETAILS OF CATHODIC PROTECTION | - | |
| DETAILS OF END SEALS OR PROTECTION | - | |
| METHOD OF INSTALLATION | Bore | |
| CHARACTER OF SUBSTRATE AT CROSSING LOCATION | - | |
| APPROXIMATE GROUND WATER LEVEL | - | |
| SOURCE OF INFORMATION ON SUBSURFACE CONDITIONS (BORINGS, TEST PITS, ETC) | - | |



Consulting Engineers
Environmental Scientists
Construction Inspectors

GP-5 Utility Line Crossing
Pipe Deflection Calculation Method

McTish, Kunkel & Associates

Allentown • Pittsburgh • Montoursville

McTish, Kunkel and Associates evaluated the capacity of an 8" diameter pipe to withstand the loads due to earth pressure and the Copper E-80 locomotive live load. The criteria as set in *Specifications for Pipeline Occupations of Railroad Property* by ReLTEK call for a maximum deflection of 3% of the diameter of the pipe. In this case, that deflection was limited to 0.259 inches.

The Specifications for flexible pipe calls for the deflection to be calculated according to Spangler's Iowa formula with the following parameters:

Deflection Lag Factor = 1.5
Modulus of Soil Reaction = 1080 psi
Bedding Constant = 0.096
Soil Loading Constant = 0.13

Live loading plus impacts were estimated according to Section 10.A(3), Table 1 in the *Specifications*. Loading to earth pressure was based on a soil density of 120 pcf per Section 10.A(2) in the *Specifications*.

The deflection was also computed according to the criteria as presented in Chapter 6 of the *PE Design Manual*, prepared by the Plastics Pipe Institute. The *Manual* said that finite element computer programs can make more accurate predictions than the original Spangler Iowa Formula. But the improvements in precision are lost in construction variability. According to the *Manual*, the Modified Iowa Formula remains the most frequently used method of determining deflection.

MKA computed deflections according to both the Iowa Formula and the Modified Iowa Formula. The Iowa Formula predicted a deflection of 0.269 inches and the Modified Iowa Formula predicted a deflection of 0.249 inches. The deflection according to the Iowa Formula is 3.9% greater than allowable. But the Modified Iowa Formula, specifically for solid wall plastic pipe, predicts a deflection of less than the limit. Averaging the two values results in a deflection of 0.259 inches, the same as the limit.

Given the average value of the two computations, it is our engineering judgment that the proposed plastic pipe meets the deflection criteria of the railroad and should be approved for installation.



Consulting Engineers
Environmental Scientists
Construction Inspectors

McTish, Kunkel & Associates
Allentown • Pittsburgh • Montoursville

**GP-5 Utility Line Crossing
Pipe Deflection Calculations**

By: JJT

Checked: KSC/SER

Compute Deflection of 8" ID PE Pipe Underneath Penn Eastern Rail Lines Track. Use Criteria from ReLTEK Specifications.

Pipe information

| | | |
|---|--------|------------------------|
| DI = Inside Pipe Diameter = | 7.847 | inches |
| OD = Outside Pipe Diameter = | 8.625 | inches |
| R = Pipe Radius = | 3.924 | inches |
| Tw = Wall Thickness of Pipe = | 0.639 | inches |
| I = Pipe Wall Moment of Inertia = Thickness ³ / 12 = | 0.0217 | in ⁴ / inch |

Input Items

Live Load Information from ReLTEK, Chapter 10, Table 1

| | | |
|---|-----|-----|
| Live Load + Impact for Cooper E-80 Loading for 14 feet of fill = | 800 | psf |
| Live Load + Impact for Cooper E-80 Loading for 16 feet of fill = | 625 | psf |
| Average Values Above for Live Load + Impact for 15 feet of fill = | 713 | psf |

Load Due to Soil Pressure

| | | |
|---|------|-----|
| Soil Density (ReLTEK, Chapter 10, Section A2) = | 120 | pcf |
| Pressure at 15 feet of Fill = 15 * 120 = | 1800 | psf |

Input Items for Spangler Iowa Equation (from ReLTEK, Chapter 10, Section 4)

| | | |
|--|---------|----------|
| DL = Deflection Lag Factor = | 1.500 | |
| K = Bedding Constant = | 0.096 | |
| E' = Modulus of Soil Reaction = | 1080 | psi |
| Allowable Deflection of Pipe (percentage of Pipe Diameter) = | 3.000 | % |
| Allowable Deflection = 3.000% * 8.625 = | 0.259 | inches |
| E = Elastic Modulus of the Pipe Material = | 21,000 | psi |
| Reference: PE Pipe Handbook, Chapter 3, Table B.1.1, Page 99 | | |
| W = Earth Load on Pipe = 7.847 * (713 + 1,800) / 144 = | 136.942 | lbs / in |

Compute Deflection Based on Spangler Equation

Reference: Spangler Equation PDF, Page 3

$\Delta = (DL * K * W * R^3) / (E * I + 0.061 * E' * R^3)$
Terms from the Spangler Iowa Equation



Consulting Engineers
Environmental Scientists
Construction Inspectors

McTish, Kunkel & Associates

Allentown • Pittsburgh • Montoursville

**GP-5 Utility Line Crossing
Pipe Deflection Calculations**

By: JJT

Checked: KJCSER

| | | |
|----------------------|---------------------------------------|----------|
| $DL * K * W * R^3 =$ | $1.500 * 0.096 * 136.942 * 3.924^3 =$ | 1191.023 |
| $E * I =$ | $21,000 * 0.0217 =$ | 457 |
| $0.061 * E' * R^3 =$ | $0.061 * 1,080 * 3.924^3 =$ | 3979.006 |

| | |
|--|---------------------|
| Deflection = $1,191.023 / (457 + 3,979.006) =$ | 0.269 inches |
|--|---------------------|

Spangler's Equation for Solid Wall and ASTM F894 Pipe in Plastic Pipe Manual, Chapter 6

| | |
|--|------------|
| Kbed = Bedding Factor = | 0.096 |
| LDL = Deflection Lag Factor = | 1.500 |
| PE = Vertical Soil Pressure Due to Earth Load = | 1800 psf |
| PL = Vertical Soil Pressure Due to Live Load = | 713 psf |
| E = Apparent Modulus of Elasticity of Pipe Material = | 21,000 psi |
| E' = Modulus of Soil Support = | 1080 psi |
| Fs = Soil Support Factor = | 1.00 |

Reference: PE Pipe Handbook, Chaptre 6, Table 3.8, Page 215 and Table 3.10, Page 216

| | |
|--|------------------------|
| I = Pipe Wall Moment of Inertia = $t^3 / 12 =$ | 0.0217 in ⁴ |
| OD = Outside Diameter = | 8.6250 inches |
| DR = Dimension Ratio = $OD / Tw = 8.625 / 0.639 =$ | 13.4977 |
| MD = Mean Diameter = $OD - Wall Thickness = 8.625 - 0.639 =$ | 7.986 inches |
| Ring Stiffness Constant = $RSC = 6.44 * E * I / Mean Diameter^2 =$ | 46.1072 |

Reference: PE Pipe Handbook, Chaptre 6, Eq 3-12, Page 212

For Solid Wall Pipe

Reference: PE Pipe Handbook, Chapter 6, Eq 3-10, Page 211

| | |
|---|----------|
| $Kbed * LDL * PE + Kbed * PL =$ | 327.648 |
| $2 * E / 3 =$ | 14000 |
| $(1 / (DR - 1))^3 =$ | 0.000513 |
| $.061 * Fs * E' =$ | 65.880 |

Compute Value of Terms in Brackets In the Equation

| | |
|--|-------|
| $= (327.648 / (14,000.000 * 0.000513 + 65.880)) =$ | 4.485 |
|--|-------|

| | |
|---|---------------------|
| Deflection = $MD * Terms in Brackets / 144 =$ | 0.249 inches |
|---|---------------------|

The Marston load theory was used to evaluate the total vertical load, W , on the pipe:

$$W = CWB^2$$

where:

- C = load coefficient
- w = weight of backfill material, pounds per cubic foot
- B_c = outside width of pipe, feet

The load coefficient varies with the type of backfill material and depth of burial, and, in the embankment condition, is also affected by the projection ratio and the settlement ratio. The settlement ratio is a rational concept, but impossible to evaluate in advance of construction, and, therefore, is considered a semi-empirical constant. Recommended values for the settlement ratio were determined from a very small number of flexible pipe installations.

In 1955, after discovering that the modulus of passive resistance could not possibly be a property of soil because its dimensions were not those of a true modulus, Spangler and Dr. R. K. Watkins proposed a modulus of soil reaction, E' , defined as:

$$E' = eR$$

The modified Iowa Formula, as used today, is therefore:

$$\Delta X = \frac{D_1KW}{EI/R^3 + (0.061)E'}$$

If the Iowa Formula is rearranged as:

$$\Delta X = \frac{(D_1KW)}{(EI/R^3) + (0.061)E'}$$

The following terms can be introduced to describe the three separate factors that affect the pipe deflection:

- D_1KW = load factor
- EI/R^3 = ring stiffness factor
- $0.061 E'$ = soil stiffness factor

And the modified Iowa Formula represented as:

$$\Delta X = \frac{\text{Load Factor}}{\text{Ring Stiffness Factor} + \text{Soil Stiffness Factor}}$$

LOAD FACTOR

The load factor incorporates the parameters that have to do with the magnitude and distribution of the soil pressures on a buried pipe. The pipe deflection is directly proportional to the load factor and, yet, less is known about its components than any others in the Iowa Formula. Changes in construction procedures or bedding could vary the actual load factor more than 100 percent from the load factor calculated in the design phase.

Deflection Lag Factor

Spangler originally stated, "The deflection lag factors observed in the experiments range from 1.38 to 1.46, and in no instance was equilibrium completely attained. Therefore, 1.5 is suggested as a conservative value for design use for standard corrugated-pipe culverts installed without strutting or predeforming," and after further investigation, "The deflection lag factor cannot be less than unity and has been observed to range upward toward a value of 2.0. A normal range of values from 1.25 to 1.50 is suggested for design purposes." The U. S. Bureau of Reclamation, however, after review of many projects, concluded that, "The actual value, however, depends on when the immediate deflection is measured, the volume change rate of the soil, and the load on the soil. D_1 is basically an empirical factor and ranges from 1 to 8 in observed tests."

Bedding Constant

The bedding constant, K , is dimensionless, and varies with the bedding angle, α (Figure 1), as presented in Table 2. The angle of bedding describes the load resisting area of the bedding under the pipe. As the angle of bedding increases, the loaded area increases and the pipe deflects less. No further study has been done on this constant since its conception in 1941, even though it can influence the deflection predicted by the Iowa Formula by as much as 25 percent.

Earth Load

The Marston theory is the most common method of calculating the earth load, W , on the pipe and is recommended by Spangler for the Iowa Formula. In the Marston theory, the load depends on whether the pipe is in a trench or embankment (or combination), the type of backfill soil, the settlement of the pipe in relation to the backfill material, and the distance that the pipe projects into the natural soil foundation. Virtually all corrugated steel pipe research and experience has been on highway culverts constructed as positive projection embankment installations, where good side fill compaction is relatively easy to achieve. Conversely, there is a lack of research and experience on corrugated steel pipe installed in trench conditions.

Table 2. Bedding Angle—Constant Relationships.

| BEDDING ANGLE | BEDDING CONSTANT |
|---------------|------------------|
| 0° | 1.00 |
| 15° | 1.10 |
| 30° | 1.20 |
| 45° | 1.30 |
| 60° | 1.40 |
| 75° | 1.50 |
| 90° | 1.60 |

c. The values shown in Table 1 shall be used for the vertical pressure on a buried structure for the various heights of cover.

Table 1
Live loads, including impact, for various heights of cover for a Cooper E-80 loading.

| Height of Cover Load | | | |
|----------------------|---------|----------|---------|
| feet | (meter) | lb/sq ft | (kPa) |
| 2 | (0.6) | 3800 | (162.8) |
| 3 | (0.9) | 3150 | (150.8) |
| 4 | (1.2) | 2850 | (136.5) |
| 5 | (1.5) | 2550 | (122.1) |
| 6 | (1.8) | 2250 | (107.7) |
| 7 | (2.1) | 1950 | (93.4) |
| 8 | (2.4) | 1700 | (81.4) |
| 9 | (2.7) | 1500 | (71.8) |
| 10 | (3.0) | 1300 | (62.2) |
| 12 | (3.7) | 1000 | (47.9) |
| 14 | (4.3) | 800 | (38.3) |
| 16 | (4.9) | 625 | (29.9) |
| 18 | (5.5) | 500 | (23.9) |
| 20 | (6.1) | 400 | (19.2) |
| 25 | (7.6) | 250 | (12.0) |
| 30 | (9.1) | 150 | (7.2) |

d. To determine the horizontal pressure caused by the railroad loading on a sheet pile wall or other structure adjacent to the track, the Boussinesq analysis shall be used. The load on the track shall be taken as a strip load with a width equal to the length of the ties, 8½ feet (2.6 m). The vertical surcharge, q (psf), caused by each axle, shall be uniform and equal to the axle load divided by the tie length and the axle spacing, 5 feet (1.5 m). For the E-80 loading this results in;

$$q = 80,000 / (8.5 \times 5) = 1882 \text{ psf. } (q = 356 / (2.591 \times 1.524) = 90.1 \text{ kPa})$$

The horizontal pressure due to the live load surcharge at any point on the wall or other structure is p_h and can be calculated by the following:

$$p_h = (2q/\gamma)(\gamma - \sin \alpha (\cos^2 \alpha))$$

e. The vertical and horizontal pressures given above shall be used unless an alternate design method is approved by Railroad. Proposals to use an alternate design method must include acceptable references and a statement explaining the justification for choosing the alternate method.

(4) Design Assumptions

a. To design a casing pipe or an uncased carrier pipe for the external loads on Railroad's right-of-way, the following design assumptions shall be used, unless site conditions indicate more conservative values are required:

Flexible Pipe (Steel, DIP, CMP, Tunnel Liner Plate)

Steel Pipe (Bored and jacked in place)

Spangler's Iowa formula shall be used for design with:

- (a) Deflection lag factor - $Df = 1.5$
- (b) Modulus of soil reaction - $E' = 1080 \text{ psi (7.45 MPa)}$
- (c) Bedding constant - $K_b = 0.096$
- (d) Soil loading constant - $K_u = 0.13$
- (e) Allowable deflection of pipe - 3% of pipe diameter

Ductile Iron Pipe (Open Cut)

ANSI Specification A 21.50 shall be used for design with:

- (a) Pipe laying condition = Type 3
- (b) Earth load - ANSI A 51.50 prism method

Corrugated Steel Pipe & Corrugated Structural Steel Plate Pipe (Open Cut)

AREMA Chapter 1, Part 4, Sections 4.9 & 4.10 shall be used for design with:

- (a) Soil stiffness factor - $K = 0.33$
- (b) Railroad impact as per Section 4.1.3.b. of this specification.

Tunnel Liner Plate (Turneled)

AREMA Chapter 1, Part 4, Section 4.16 shall be used for design with:

- (a) Soil stiffness factor - $K = 0.33$
- (b) Railroad impact as per Section 4.1.3.b. of this specification.

Rigid Pipe (RCP, Vitrified Clay Pipe and PCCP)

Reinforced Concrete Pipe, Vitrified Clay Pipe & Prestressed Concrete Cylinder Pipe (Open Cut)

American Concrete Pipe Association design manual shall be used for design with:

- (a) Marston load theory used for earth load
- (b) Bedding (Load Factor) - $L_f = 1.9$
- (c) Factor of safety - $FS = 1.25$ for RCP $FS = 1.50$ for VCP
- (d) Railroad impact as per Section 4.1.3.b. of this specification.

Appendix B

Apparent Elastic Modulus

B.1 – Apparent Elastic Modulus for the Condition of Either a Sustained Constant Load or a Sustained Constant Deformation

B.1.1 – Design Values for the Base Temperature of 73°F (23°C)

TABLE B.1.1
Apparent Elastic Modulus for 73°F (23°C)

| Duration of Sustained Loading | Design Values For 73°F (23°C) ^(1,2) | | | | | |
|-------------------------------|--|-----|--------|-----|--------|-----|
| | PE 2XXX | | PE3XXX | | PE4XXX | |
| | psi | MPa | psi | MPa | psi | MPa |
| 0.5hr | 62,000 | 428 | 78,000 | 538 | 82,000 | 565 |
| 1hr | 59,000 | 407 | 74,000 | 510 | 78,000 | 538 |
| 2hr | 57,000 | 393 | 71,000 | 490 | 74,000 | 510 |
| 10hr | 50,000 | 345 | 62,000 | 428 | 65,000 | 448 |
| 12hr | 48,000 | 331 | 60,000 | 414 | 63,000 | 434 |
| 24hr | 48,000 | 317 | 57,000 | 393 | 60,000 | 414 |
| 100hr | 42,000 | 280 | 52,000 | 359 | 55,000 | 379 |
| 1,000hr | 35,000 | 241 | 44,000 | 303 | 48,000 | 317 |
| 1 year | 30,000 | 207 | 38,000 | 262 | 40,000 | 276 |
| 10 years | 26,000 | 179 | 32,000 | 221 | 34,000 | 234 |
| 50 years | 22,000 | 152 | 28,000 | 193 | 29,000 | 200 |
| 100 years | 21,000 | 145 | 27,000 | 186 | 28,000 | 193 |

- (1) Although there are various factors that determine the exact apparent modulus response of a PE, a major factor is its ratio of crystalline to amorphous content – a parameter that is reflected by a PE's density. Hence, the major headings PE2XXX, PE3XXX and, PE4XXX, which are based on PE's Standard Designation Code. The first numeral of this code denotes the PE's density category in accordance with ASTM D3350 (An explanation of this code is presented in Chapter 5).
- (2) The values in this table are applicable to both the condition of sustained and constant loading (under which the resultant strain increases with increased duration of loading) and that of constant strain (under which an initially generated stress gradually relaxes with increased time).
- (3) The design values in this table are based on results obtained under uni-axial loading, such as occurs in a test bar that is being subjected to a pulling load. When a PE is subjected to multi-axial stressing its strain response is inhibited, which results in a somewhat higher apparent modulus. For example, the apparent modulus of a PE pipe that is subjected to internal hydrostatic pressure – a condition that induces bi-axial stressing – is about 25% greater than that reported by this table. Thus, the Uni-axial condition represents a conservative estimate of the value that is achieved in most applications.

It should also be kept in mind that these values are for the condition of continually sustained loading. If there is an interruption or a decrease in the loading this, effectively, results in a somewhat larger modulus.

In addition, the values in this table apply to a stress intensity ranging up to about 400psi, a value that is seldom exceeded under normal service conditions.

in the Iowa Formula in 1941. R. Watkins⁽⁵⁾ modified this equation to allow a simpler approach for soil characterization, thus developing the Modified Iowa Formula. In 1964, Burns and Richards⁽⁶⁾ published a closed-form solution for ring deflection and pipe stress based on classical linear elasticity. In 1976 M. Katona et. al.⁽⁷⁾ developed a finite element program called CANDE (Culvert Analysis and Design) which is now available in a PC version and can be used to predict pipe deflection and stresses.

The more recent solutions may make better predictions than the Iowa Formula, but they require detailed information on soil and pipe properties, e.g. more soil lab testing. Often the improvement in precision is all but lost in construction variability. Therefore, the Modified Iowa Formula remains the most frequently used method of determining ring deflection.

Spangler's Modified Iowa Formula can be written for use with solid wall PE pipe as:

$$(3-10) \quad \frac{\Delta X}{D_M} = \frac{1}{144} \left(\frac{K_{BED} L_{DL} P_E + K_{BED} P_L}{\frac{2E}{3} \left(\frac{1}{DR-1} \right)^3 + 0.061 F_S E'} \right)$$

and for use with ASTM F894 profile wall pipe as:

$$(3-11) \quad \frac{\Delta X}{D_I} = \frac{P}{144} \left(\frac{K_{BED} L_{DL}}{\frac{1.24(RSC)}{D_M} + 0.061 F_S E'} \right)$$

*Large diameter
pipes*

WHERE

- ΔX = Horizontal deflection, in
- K_{BED} = Bedding factor, typically 0.1
- L_{DL} = Deflection lag factor
- P_E = Vertical soil pressure due to earth load, psf
- P_L = Vertical soil pressure due to live load, psf
- E = Apparent modulus of elasticity of pipe material, lb/in²
- E' = Modulus of Soil reaction, psi
- F_S = Soil Support Factor
- RSC = Ring Stiffness Constant, lb/ft
- DR = Dimension Ratio, OD/t
- D_M = Mean diameter ($D_I + 2z$ or $D_O - t$), in
- z = Centroid of wall section, in
- t = Minimum wall thickness, in
- D_I = pipe inside diameter, in
- D_O = pipe outside diameter, in

Deflection is reported as a percent of the diameter which can be found by multiplying 100 times $\Delta X/D_M$ or $\Delta X/D_I$. (When using RSC, the units of conversion are accounted for in Equation 3-11.)

Apparent Modulus of Elasticity for Pipe Material, E

The apparent modulus of PE is dependent on load-rate or, duration of loading and temperature. Apparent elastic modulus values for high and medium density PE may be found in Table B.1.1 in Chapter 3 Appendix. These values can be used in Spangler's Iowa Formula. It has long been an industry practice to use the short-term modulus in the Iowa Formula for thermoplastic pipe. This is based on the idea that, in granular embedment soil, deformation is a series of instantaneous deformations consisting of rearrangement and fracturing of grains while the bending stress in the pipe wall is decreasing due to stress relaxation. Use of the short-term modulus has proven effective and reliable for corrugated and profile wall pipes. These pipes typically have pipe stiffness values of 46 psi or less when measured per ASTM D2412. Conventional DR pipes starting with DR17 or lower have significantly higher stiffness and therefore they may carry a greater proportion of the earth and live load than corrugated or profile pipe; so it is conservative to use the 50-year modulus for DR pipes that have low DR values when determining deflection due to earth load.

Vehicle loads are generally met with a higher modulus than earth loads, as load duration may be nearly instantaneous for moving vehicles. The deflection due to a combination of vehicle or temporary loads and earth load may be found by separately calculating the deflection due to each load using the modulus appropriate for the expected load duration, then adding the resulting deflections together to get the total deflection. When doing the deflection calculation for vehicle load, the Lag Factor will be one. An alternate, but conservative, method for finding deflection for combined vehicle and earth load is to do one calculation using the 50-year modulus, but separate the vertical soil pressure into an earth load component and a live load component and apply the Lag Factor only to the earth load component.

Ring Stiffness Constant, RSC

Profile wall pipes manufactured to ASTM F894, "Standard Specification for Polyethylene (PE) Large Diameter Profile Wall Sewer and Drain Pipe," are classified on the basis of their Ring Stiffness Constant (RSC). Equation 3-12 gives the RSC.

(3-12) $RSC = \frac{6.744 EI}{D_M^3}$

WHERE

E = Apparent modulus of elasticity of pipe material @73°F (See Chapter 3 Appendix)

I = Pipe wall moment of inertia, in^4/in ($t^3/12$, if solid wall construction)

Z = Pipe wall centroid in

D_I = Pipe inside diameter in

D_M = Mean diameter ($D_I + 2z$ or $D_O - t$), in

t = Minimum wall thickness, in

Modulus of Soil Reaction, E'

The soil reaction modulus is proportional to the embedment soil's resistance to the lateral expansion of the pipe. There are no convenient laboratory tests to determine the soil reaction modulus for a given soil. A. Howard ⁽⁶⁾ determined E' values empirically from numerous field deflection measurements by substituting site parameters (i.e. depth of cover, soil weight) into Spangler's equation and "back-calculating" E' . Howard developed a table for the Bureau of Reclamation relating E' values to soil types and compaction efforts. See Table 3-7. In back-calculating E' , Howard assumed the prism load was applied to the pipe. Therefore, Table 3-7 E' values indirectly include load reduction due to arching and are suitable for use only with the prism load. In 2006, Howard published a paper reviewing his original 1977 publication from which Table 3-7 is taken. For the most part the recent work indicates that the E' values in Table 3-7 are conservative.

Due to differences in construction procedures, soil texture and density, pipe placement, and insitu soil characteristics, pipe deflection varies along the length of a pipeline. Petroff ⁽⁷⁾ has shown that deflection measurements along a pipeline typically fit the Normal Distribution curve. To determine the anticipated maximum deflection using Eq. 3-10 or 3-11, variability may be accommodated by reducing the Table 3-7 E' value by 25%, or by adding to the calculated deflection percentage the correction for 'accuracy' percentage given in Table 3-7.

In shallow installations, the full value of the E' given in Table 3-7 may not develop. This is due to the lack of "soil confining pressure" to hold individual soil grains tightly together and stiffen the embedment. Increased weight or equivalently, depth, increases the confining pressure and, thus, the E' . J. Hartley and J. Duncan ⁽⁸⁾ published recommended E' values based on depth of cover. See Table 3-8. These are particularly useful for shallow installations.

Chapter 7, "Underground Installation of PE Pipe" covers soil classification for pipe embedment materials and preferred methods of compaction and installation for selected embedment materials. Some of the materials shown in Table 3-7 may not be appropriate for all pipe installation. One example would be fine-grained soils in wet ground, which would not be appropriate embedment, under most circumstances, for either profile pipe or pipes with high DR's. Such limitations are discussed in Chapter 7.

TABLE 3-7
Values of E' for Pipe Embedment (See Howard ⁴)

| Soil Type: pipe Embedment Material (Unified Classification System) ¹ | E' for Degree of Embedment Compaction, lb/in ² | | | |
|---|---|--|---|--|
| | Dumped | Slight, <85% Proctor, <40% Relative Density | Moderate, 85%-95% Proctor, 40%-70% Relative Density | High, >85% Proctor, >70% Relative Density |
| Fine-grained Soils (LL > 50) ² Soils with medium to high plasticity; CH, MH, CH-MH | No data available: consult a competent soils engineer, otherwise, use E' = 0. | | | |
| Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with less than 25% coarse grained particles. | 50 | 200 | 400 | 1000 |
| Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with more than 25% coarse grained particles; Coarse-grained Soils with Fines, GM, GC, SM, SC ³ containing more than 12% fines. | 100 | 400 | 1000 | 2000 |
| Coarse-grained soils with Little or No Fines GW, GP, SW, SP ³ containing less than 12% fines | 200 | 1000 | 2000 | 3000 |
| Crushed Rock | 1000 | 3000 | 3000 | 3000 |
| Accuracy in Terms of Percentage Deflection ⁴ | ±2% | ±2% | ±1% | ±0.5% |

¹ ASTM D-2487, USBR Designation E-3

² LL = Liquid Limit

³ Or any borderline soil beginning with one of these symbols (i.e., GM-GC, GC-SC).

⁴ For ±1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

Note: Values applicable only for fills less than 50 ft (15 m). Table does not include any safety factor. For use in predicting initial deflections only; appropriate Deflection Lag Factor must be applied for long-term deflections. If embedment falls on the borderline between two compaction categories, select lower E' value, or average the two values. Percentage Proctor based on laboratory maximum dry density from test standards using 12,500 ft-lb/cu ft (598,000 J/m²) (ASTM D-698, AASHTO T-99, USBR Designation E-11). 1 psi = 6.9 KPa.

TABLE 3-8
Values of E' for Pipe Embedment (See Duncan and Hartley⁽²⁾)

| Type of Soil | Depth of Cover, ft | E' for Standard AASHTO Relative Compaction, lb/in ² | | | |
|--|--------------------|--|------|------|------|
| | | 85% | 90% | 95% | 100% |
| Fine-grained soils with less than 25% sand content (CL, ML, CL-ML) | 0-5 | 500 | 700 | 1000 | 1500 |
| | 5-10 | 600 | 1000 | 1400 | 2000 |
| | 10-15 | 700 | 1200 | 1600 | 2300 |
| | 15-20 | 800 | 1300 | 1800 | 2600 |
| Coarse-grained soils with fines (SM, SC) | 0-5 | 600 | 1000 | 1200 | 1900 |
| | 5-10 | 800 | 1400 | 1800 | 2700 |
| | 10-15 | 1000 | 1500 | 2100 | 3200 |
| | 15-20 | 1100 | 1600 | 2400 | 3700 |
| Coarse-grained soils with little or no fines (SP, SW, GP, GW) | 0-5 | 700 | 1000 | 1600 | 2500 |
| | 5-10 | 1000 | 1500 | 2200 | 3300 |
| | 10-15 | 1050 | 1600 | 2400 | 3600 |
| | 15-20 | 1100 | 1700 | 2500 | 3800 |

Soil Support Factor, F_s

Ring deflection and the accompanying horizontal diameter expansion create lateral earth pressure which is transmitted through the embedment soil and into the trench sidewall. This may cause the sidewall soil to compress. If the compression is significant, the embedment can move laterally, resulting in an increase in pipe deflection. Sidewall soil compression is of particular concern when the insitu soil is loose, soft, or highly compressible, such as marsh clay, peat, saturated organic soil, etc. The net effect of sidewall compressibility is a reduction in the soil-pipe system's stiffness. The reverse case may occur as well if the insitu soil is stiffer than the embedment soil; e.g. the insitu soil may enhance the embedment giving it more resistance to deflection. The Soil Support Factor, F_s , is a factor that may be applied to E' to correct for the difference in stiffness between the insitu and embedment soils. Where the insitu soil is less stiff than the embedment, F_s is a reduction factor. Where it is stiffer, F_s is an enhancement factor, i.e. greater than one.

The Soil Support Factor, F_s , may be obtained from Tables 3-9 and 3-10 as follows:

- Determine the ratio B_d/D_o , where B_d equals the trench width at the pipe springline (inches), and D_o equals the pipe outside diameter (inches).
- Based on the native insitu soil properties, find the soil reaction modulus for the insitu soil, E'_N in Table 3-9.
- Determine the ratio E'_N/E' .
- Enter Table 3-10 with the ratios B_d/D_o and E'_N/E' and find F_s .

TABLE 3-9
Values of E'_N , Native Soil Modulus of Soil Reaction, Howard¹⁰

| Native In Situ Soils | | | | |
|--|------------------|---|-----------------|--------------|
| Granular | | Cohesive | | E'_N (psi) |
| Std. Penetration ASTM D1586 Blows/ft | Description | Unconfined Compressive Strength (TSF) | Description | |
| > 0 - 1 | very, very loose | > 0 - 0.125 | very, very soft | 50 |
| 1 - 2 | very loose | 0.125 - 0.25 | very soft | 200 |
| 2 - 4 | loose | 0.25 - 0.50 | soft | 700 |
| 4 - 8 | medium | 0.50 - 1.00 | medium | 1,500 |
| 8 - 15 | slightly compact | 1.00 - 2.00 | stiff | 3,000 |
| 15 - 30 | compact | 2.00 - 4.00 | very stiff | 5,000 |
| 30 - 50 | dense | 4.00 - 8.00 | hard | 10,000 |
| > 50 | very dense | > 8.00 | very hard | 20,000 |
| Rock | | | | 50,000 |

TABLE 3-10
Soil Support Factor, F_s

| E_p/E_s | B/D_0 1.0 | B/D_0 2.0 | B/D_0 2.5 | B/D_0 3.0 | B/D_0 4.0 | B/D_0 5.0 |
|-----------|----------------|----------------|----------------|----------------|----------------|----------------|
| 0.1 | 0.16 | 0.30 | 0.60 | 0.80 | 0.90 | 1.00 |
| 0.2 | 0.30 | 0.45 | 0.70 | 0.85 | 0.92 | 1.00 |
| 0.4 | 0.50 | 0.60 | 0.80 | 0.90 | 0.95 | 1.00 |
| 0.8 | 0.70 | 0.80 | 0.90 | 0.95 | 1.00 | 1.00 |
| 0.8 | 0.85 | 0.90 | 0.95 | 0.98 | 1.00 | 1.00 |
| 1.0 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1.5 | 1.30 | 1.15 | 1.10 | 1.05 | 1.00 | 1.00 |
| 2.0 | 1.50 | 1.30 | 1.15 | 1.10 | 1.05 | 1.00 |
| 3.0 | 1.75 | 1.45 | 1.30 | 1.20 | 1.08 | 1.00 |
| 5.0 | 2.00 | 1.60 | 1.40 | 1.25 | 1.10 | 1.00 |

Lag Factor and Long-Term Deflection

Spangler observed an increase in ring deflection with time. Settlement of the backfill and consolidation of the embedment under the lateral pressure from the pipe continue to occur after initial installation. To account for this, he recommended applying a lag factor to the Iowa Formula in the range of from 1.25 to 1.5. Lag occurs in installations of both plastic and metal pipes. Howard^{10, 11} has shown that the lag factor varies with the type of embedment and the degree of compaction. Many plastic pipe designers use a Lag Factor of 1.0 when using the prism load as it

AFFIDAVIT

Tony Sayegh, being duly sworn according to law, deposes and says that he is a Project Leader for UGI Utilities, Inc.; that he is authorized to and does make this affidavit for it; that the facts set forth in the foregoing document are true and correct to the best of his knowledge, information and belief; that he expects the said UGI Utilities, Inc. to be able to prove the same at any hearing hereof; and that he makes this affidavit subject to the penalties of 18 Pa.C.S. §4904 (relating to unsworn falsification to authorities).



Tony Sayegh

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CERTIFICATE OF SERVICE

I hereby certify that I have, this 23st day of August, 2011 served a true and correct copy of the foregoing document in the manner and upon the persons listed below in accordance with requirements of 52 Pa. Code §1.54 (relating to service by a participant):

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Michael Forester
County Permit Supervisor
Penn DOT – District 8-0
Lancaster County Maintenance Office
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Rebecca Buchanan
Lancaster County Conservation District
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156B W Main St. PO Box 244
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Manager, Rail Safety Division
Bureau of Transportation & Safety
Pennsylvania Public Utility Commission
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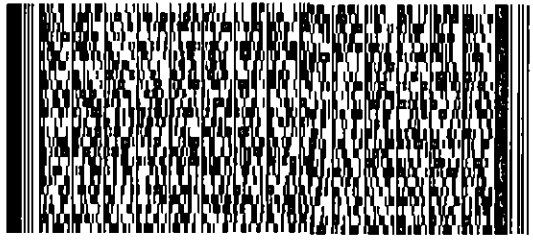
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