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pennsylvania DEPARTMENT OF TRANSPORTATION		**DATE:** July 27, 2020

SUBJECT:

Manufacturing Specification for Reinforced Concrete Pipe
June 2020 Edition

INFORMATION AND SPECIAL INSTRUCTIONS:

The attached June 2020 Edition of the Manufacturing Specification for Reinforced Concrete Pipe (Pub. 280) represents a revised publication incorporating technical reference updates, format revisions, editorial changes, and changes from clearance transmittal comments. Modifications were circulated through the Clearance Transmittal (CT) review process under number B-18-003. A summary of key changes is attached.

This edition supersedes the May 2009 edition and is effective immediately on all projects.

Comments or questions concerning this manual may be directed to the Bureau of Project Delivery, Bridge Design and Technology Division, Structural Materials Section.

CANCEL AND DESTROY THE FOLLOWING:

Publication 280, May 2009 Edition.

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Publication 280 Manufacturing Specifications for Reinforced Pipe – 2020 Edition

Summary of Key Changes:

General:

1. Any references to out-of-date or discontinued specifications have been updated throughout.
2. References to other Publications, ASTM's and American Welding Society Codes books have been updated as required.
3. Gender Neutral compliance revisions.

Section 1 – Scope:

No significant changes.

Section 2 – Referenced Documents:

1. Added Pub 408

Section 3 – Definitions:

1. Changed lot sizes to match Qcast
2. Updated the abbreviations section

Section 4 – Classifications:

No significant changes

Section 5 – Basis of Acceptance:

No significant changes

Section 6 – Materials:

No significant changes

Section 7 – Design:

No significant changes

Section 8 – Reinforcement:

1. Clarified that lift holes are for only certain diameter pipe, per Pub 408, Section 601.
2. Clarified that weld procedure specifications (WPS) are to be submitted on TR-37 to the Chief Structural Material Engineer for review and approval.
3. Stated that resistance welding does not require a certified welder or WPS.
4. Revised the equation for pull tests to match AASHTO

Section 9 – Joints:

No significant changes

Section 10 – Fabrication:

1. Added SCM's to this section

Section 11 – Physical Requirements:

1. Removed references to PAIDD and changed to PennDOT Accepted Software.

Section 12 – Permissible Variations:

1. Internal diameter – changed the internal dimension requirement for elliptical pipe to be ±2.0%, before it only allowed for a +2.0%.

Section 13 – Workmanship, Finish, and Appearance:

No significant changes

Section 14 – Repairs:

No significant changes

Section 15 – Inspection:

No significant changes

Section 16 – Rejection:

1. Added that punched through wall lift holes are not permitted.

Section 17 – Marketing:

No significant changes

Appendix A – Design Tables and Proof Load Tables:

1. Removed reference to PAIDD.

Appendix B – Repair Procedures for Reinforced Concrete Pipe:

1. Added that reinforcing left in lift holes must be removed.
2. Added limits of spalling and break back in lift holes.

Manufacturing Specification for Reinforced Concrete Pipe

Bureau of Project Delivery
Bridge Design and Technology Division
Structural Materials Section

pennsylvania
DEPARTMENT OF TRANSPORTATION
www.penndot.gov

PUB 280 (1-22)

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Manufacturing Specification
For
Reinforced Concrete Pipe

1. SCOPE

1.1. This Specification covers reinforced concrete pipe intended to be used for the conveyance of sewage, industrial wastes, storm water, and for the construction of culverts.

1.2. This Specification covers the fabrication and acceptance of precast reinforced concrete pipe designed to conform to the Department design requirements.

1.3. Manufacturers (Fabricators) are required to submit a plant Quality Control Plan (QCP) and concrete mix design(s) to the Structural Materials Engineer, Bridge Design and Technology Division (BDTD), Structural Materials Section (SMS), at Materials Testing Laboratory (MTL), for review and approval.

NOTE: This Specification is a fabrication and purchase Specification and the fabricator must be listed in BULLETIN 15.

2. REFERENCED DOCUMENTS

2.1. AASHTO Standards:

M 6	Fine Aggregate for Hydraulic Cement Concrete
M 31	Deformed and Plain Carbon and Low-Alloy Steel Bars for Concrete Reinforcement
M 80	Coarse Aggregate for Hydraulic Cement Concrete
M 85	Portland Cement
M 148	Liquid Membrane-Forming Compounds for Curing Concrete
M 240	Blended Hydraulic Cement
M 262	Terms Relating to Concrete Pipe and Related Products
M 295	Coal Fly Ash and Raw or Calcined Natural Pozzolan for use in Concrete

2.2. ASTM Standards:

C 1417	Specification for Manufacture of Reinforced Concrete Sewer, Storm Drain, and Culvert Pipe for Direct Design
T 22	Compressive Strength of Cylindrical Concrete Specimens

T 280 Test for Concrete Pipe, Manhole Sections, or Tile

2.3. PennDOT Specifications:

Pub 145 Inspection of Prestressed/Precast Concrete Products & Concrete Products & Concrete Pipe

Pub 218 Bridge Design Standards (BD-636)

Pub 408 PennDOT Specifications

3. DEFINITIONS

3.1. For definitions of terms relating to concrete pipe, see AASHTO M 262.

3.1.1. Group of Pipe Sections:

Removed, see Section 3.1.2 for pipe lots.

3.1.2. Lot of Pipe Sections:

A "Lot" of pipe for a given concrete strength and structural design will be defined as follows for round RCP or elliptical (round equivalent) RCP for all pipe produced by the fabricator (including PennDOT, other state agencies, and commercial):

Pipe Size	Maximum Pieces per Lot*
12-15"	1000
18-36"	400
42-60"	200
>60"	200

* For quantities less than above, minimum testing frequency is 1 piece of pipe per year for each size and class of pipe manufactured during that year.

A Lot shall be all pipe dates equal to or prior to Test Specimen date, except when fabricating special design pipes requiring reduced sized test specimens (Sec. 7.2) and/or for extended delivery schedules where the pipe lot cannot be fabricated entirely prior to initial delivery to the project.

3.1.3. Running Average:

The average concrete compressive strength of all lots of pipe sections of a single concrete strength produced for the Department, generally determined as each lot is tested.

3.1.4. Proof Load:

The load carried by a pipe subjected to a three-edge bearing test, expressed in pounds per linear foot per foot of inside diameter. This proof load reflects the field service load condition for live and dead load.

3.1.5. Proof Test Load:

Three-edge bearing test load extrapolated from 0.007 inches design requirement to produce a 0.01 inches crack.

3.2. Abbreviations:

AASHTO	American Association of State Highway and Transportation Officials
BD-XXX	Bridge Design Standard Drawing (e.g. BD-636M)
BDTD	Bridge Design and Technology Division
MTL	Materials Testing Laboratory
LTS	Laboratory Testing Section
PAIDD	Pennsylvania Installation Direct Design
DM-4	Design Manual, Part 4
PTM-XXX	Pennsylvania Test Methods (e.g. PTM 606)
RC-XX	Road Construction Standard Drawing (e.g. RC-30)
RCP	Reinforced Concrete Pipe
SMS	Structural Materials Section

4. CLASSIFICATIONS

4.1. Pipe fabricated according to the classification and Specifications in BD-636M.

5. BASIS OF ACCEPTANCE

5.1. Acceptance is per item 5.1.1. The Department has the option to deviate from the required acceptance criteria of item 5.1.1 at the time of or before placement of an order. Items 5.1.2 or 5.1.3 are options that the Department may consider for use in combination with item 5.1.1. Independent of the method of acceptance, the RCP shall be designed as shown on PennDOT Standard BD-636M or the PennDOT Accepted Software.

5.1.1. <u>RCP shall be accepted on the Basis of Plant Load-Bearing Tests, Material Tests, and Inspection of Fabricated Pipe for Visual Defects and Imperfections</u> – Acceptability of the pipe in all diameters and classes, produced according to Section 3.1, passing the proof load test as shown on BD-636M or the

PennDOT Accepted Software, material tests, concrete compression tests, dimensional requirements in conformance to this Specification and inspection of fabricated pipe for defects.

5.1.2. Acceptance on the Basis of Material Tests and Inspection of Fabricated Pipe for Defects and Imperfections-Acceptance of pipe shall be on the basis of concrete compression tests, materials tests, conformance to Section 3.1, conformance to this Specification, and inspection of fabricated pipe for defects.

5.1.3. When mutually agreed in writing by the Department and the fabricator, the basis of acceptance of the concrete pipe may be made by certification. This certification shall consist of a statement by the fabricator that the concrete pipe conforms to the PennDOT design criteria, Manufacturing Design Data and to this Specification, and that the concrete and materials have been sampled, tested and conform to this Specification.

5.1.4. The Contractors/Fabricator must ensure that deviations from item 5.1.1 have been agreed upon by the Department before fabrication begins.

5.2. Age of Acceptance:

Pipe shall be considered ready for acceptance when it conforms to the requirements as indicated by the specified tests.

6. MATERIALS

6.1. All material suppliers must be listed in the appropriate PennDOT Bulletin 14 or 15.

6.2. Reinforced Concrete:

The reinforced concrete shall consist of cementitious materials, mineral aggregates, admixtures if used, and water, in which steel has been embedded in such a manner that the steel and concrete act compositely.

6.3. Cementitious Material:

6.3.1. Cement:

According to Pub 408, Section 701, cement shall conform to the requirements for Portland Cement AASHTO M 85 or shall be Portland Blast-Furnace Slag Cement or Portland-Pozzolan Cement conforming to the requirements of AASHTO M 240, except that the Pozzolan constituent in the Type IP Portland Pozzolan cement shall be Fly Ash and shall meet the requirements of Pub 408, Section 704.1(g).

6.3.2. Supplementary Cementitious Materials (SCM): E.g. Fly Ash or other SCMs.

SCMs shall conform to the requirements of Pub 408, Section 724.

6.3.3. Allowable Combinations of Cementitious Materials:

The combination of cementitious materials used in the concrete shall be one of the following:

6.3.3.1. Portland Cement only.

6.3.3.2. Mechanically Modified SCM-Cement Combinations Cement only.

6.3.3.3. A combination of Portland Cement and SCM, wherein the proportion of SCM does not exceed Pub 408, Section 704.1(c)2 and Section 724 (Portland Cement plus SCM).

6.4. Aggregates:

6.4.1 Aggregates shall conform to the requirements of Pub 408, Section 703 Type A, except that the requirement for gradation shall not apply.

6.5. Admixtures:

6.5.1 According to Pub 408, Section 711.3, admixtures may be used unless prohibited by the Department.

6.6. Steel Reinforcement:

6.6.1. Reinforcement according to Pub 408, Section 709 and consist of wire or wire fabric conforming to ASTM A 1064 or AASHTO M 31.

6.7. Aggregate Mineral Fillers (AMF):

Portions of the fine aggregate may be replaced using AMF according to Pub 408, Section 714.

7. DESIGN

7.1. Design Tables:

The diameter, wall thickness, compressive strength and reinforcement shall be as shown on BD-636M, or as provided by the PennDOT Accepted Software in Section 7.2.

7.1.1. Notes in APPENDIX A, are intended to be amplifications of tabulated requirements in BD-636M and are to be considered applicable and binding as if they were contained in the body of the Specification.

7.2. Special Designs:

7.2.1. The fabricator may request approval by the Department for special designs when diameters and installation depths are beyond those provided in the Design Tables, BD-636M.

7.2.2. Special designs shall be based on PennDOT Accepted Software, and the Design Specifications in DM4. Special designs shall include copies of any output produced by the PennDOT Accepted Software.

7.2.3. The fabricator shall submit to the Department, SMS, BDTD at MTL, Chief Structural Materials Engineer, proof of the adequacy of the proposed special design. Such proof may comprise the submission of properly certified proof load tests already made, which are found by the Department to be adequate or, if such proof load tests are not available or acceptable, the fabricator may be required to perform proof load tests to demonstrate the correctness and adequacy of the proposed design.

7.2.4. Such pipe must meet all of the test and performance requirements specified by the Department according to Section 5.

7.2.5. When the PennDOT Accepted Software is used for special design pipe, submit one copy of the computer output to the Chief Structural Materials Engineer for review and approval. Show input data and design results. Include shop drawings of the proposed pipe cross section and reinforcement layouts in sufficient detail to provide inspection. Include the following details at a minimum: State Route, Section and County; minimum concrete strength; steel areas and maximum spacing; steel yield strength; reinforcement cover and tolerances; wall thickness and tolerances; joint details; weight per lineal foot of pipe; maximum fill height and proof load.

7.3. Area

In this Specification, when the word area is not described by adjectives, such as cross-section or single wire, it shall be understood to be the cross-sectional area of reinforcement per unit lengths of pipe.

8. REINFORCEMENT

8.1. Circumferential Reinforcement:

A line of circumferential reinforcement for any given total area may be composed of two layers for pipe with wall thicknesses of less than 7 inches or three layers for pipe with wall thickness of 7 inches or greater. The layers shall not be separated by more than the thickness of one longitudinal wire plus ¼ inch. The multiple layers shall be fastened together to form a single rigid cage. If the multiple layers of a cage contain circumferential splices, the individual layers shall be rotated so that the splices are staggered. All other Specification requirements such as laps, welds, and tolerances of placement in the wall of the pipe, etc. shall apply to this method of fabricating a line of reinforcement. The design shall be based on the centroid of the layers.

8.1.1. Where one line of circular reinforcement is used, it shall be placed from 35.0 to 50.0% of the wall thickness from the inner surface of the pipe, except for wall thicknesses less than 2½ inches, the reinforcement in the wall of the pipe

shall be placed so the protective cover of the concrete over all reinforcement is a minimum of ¾ inch.

8.1.2. In pipe having two lines of circular reinforcement, each line shall be so placed that the protective covering of concrete over all reinforcement in the wall of the pipe shall be 1 inch.

8.1.3. Elliptical reinforcement shall be permitted for Elliptical pipe and quadrant reinforcement only.

8.1.4. In pipe having elliptical reinforcement with wall thicknesses 2½ inches or greater, the reinforcement in the wall of the pipe shall be so placed that the protective covering of concrete over the circumferential reinforcement shall be 1 inch from the inner surface of the pipe at the vertical diameter and 1 inch from the outer surface of the pipe at the horizontal diameter.

8.1.5. The location of the reinforcement shall be subject to the permissible variations in dimensions given in Section 12.5. Requirements for placement and protective covering of the concrete from the inner or outer surface of the pipe do not apply to that portion of a cage which is flared to extend into the bell or reduced in diameter to extend into the spigot. Reinforcement shall not be exposed on the mating side surface of the joints.

8.1.6. The spacing center to center of circumferential reinforcement in a cage shall not exceed 4 inches for pipe up to and including pipe having a 4 inch wall thickness nor exceed the wall thickness for larger pipe and shall in no case exceed 6 inches.

8.1.7. Where the wall reinforcement does not extend into the joint, the maximum longitudinal distance to the last circumferential from the inside shoulder of the bell or the shoulder of the spigot shall be 3 inches, except that if this distance exceeds one-half the wall thickness, the pipe wall shall contain at least a total reinforcement area of the minimum specified area per linear foot times the laying length of the pipe section. The minimum cover on the last circumferential near the spigot shoulder shall be ½ inch.

8.1.7.1. Where reinforcement is in the bell or spigot the minimum end cover on the last circumferential shall be ½ inch in bell or ¼ inch in the spigot.

8.1.8. The continuity of the circumferential reinforcing steel shall not be destroyed during the fabrication of the pipe. Lift eyes or holes may be provided for certain diameter pipe for the purpose of handling according to Pub 408, Section 601.

8.1.8.1. Form or core lift eyes or holes according to the fabrication method approved by the Chief Structural Materials Engineer. Test by sounding, 10.0% of each lot of cured pipe around the lift hole. If any rejections are found, test 100.0% of each lot; reject for Department use

all pipe having evidence of damage. Remove any reinforcement within the lift hole exposed during the fabricating process.

8.1.9. Welds, Splices and Development of circumferential / Reinforcement

8.1.9.1. Where pipes are not marked to show a specific orientation in the ground, any weld to, or splice of, a circumferential shall be considered to be at the point of the maximum flexural stress.

8.1.9.2. Where pipes are marked to show a specific orientation in the ground, any weld to, or splice of, a circumferential shall be considered to be at a distance determined by the orientation angle closer to the point of maximum flexural stress than the marking indicates.

8.1.9.3. Notation

$\mathbf{A_{wa}}$ = Actual Steel area of the individual circumferential wire, in^2.

$\mathbf{A_{wr}}$ = Steel area required for the individual circumferential wire for flexure (a) at the splice, for splices, or (b) at the point of maximum moment, for quadrant mat reinforcement, in^2.

$\mathbf{d_b}$ = Diameter of reinforcing wire or bar, inches

$\mathbf{D_i}$ = Inside diameter of pipe, in.

$\mathbf{F_w}$ = Embedded weld factor, See Section 8.1.11.2.2

$\mathbf{h}$ = Overall thickness of member (wall thickness), in.

$\mathbf{L_d}$ = Development length of reinforcing wire or bar, in.

$\mathbf{l_\Theta}$ = Total additional arc length beyond calculated arc lengths requiring stirrups, in.

$\mathbf{P_t}$ = Pull test strength of wire or bar at break, pounds.

$\mathbf{f_y}$ = Design yield strength of reinforcement, $lbs./in^2$

$\mathbf{f_c'}$ = Design compressive strength of concrete, $lbs./in^2$

$\mathbf{t_b}$ = Clear cover over reinforcement, in.

$\boldsymbol{\theta}$ = Orientation angle, deg.

$\mathbf{S}$ = Spacing of wire to be developed or spliced, in.

$\mathbf{V_u}$ = Factored shear force, lbs.

$\mathbf{V_c}$ = Nominal shear strength of the concrete cross section, lbs/ft.

8.1.10. Welds

For welding, submit a weld procedure specification (WPS) on Form TR-37 to the Chief Structural Materials Engineer for review and acceptance.

8.1.10.1. Manual welding of reinforcing steel shall be performed using either shielded metal arc welding (SMAW), gas metal arc welding (GMAW), or flux cored arc welding processes (FCAW). Welder and procedure qualification must be performed according to AWS D1.4 for butt splices of circumferentials. Resistance welding does not require a certified welder or WPS.

For welding limited solely to lapped splicing of circumferentials (single or double flare-V groove welds), procedure qualification testing shall be limited to demonstration that the tensile requirements of 8.1.11.2.1 and 8.1.11.2.2 will be met for production welds. Inspection, sampling and testing for procedure qualification must be coordinated with the BDTD, SMS at MTL.

Submit a weld procedure specification (WPS) to the Chief Structural Materials Engineer, BDTD, SMS at MTL, for acceptance, (see Appendix C). For procedure qualification of lapped circumferentials, not less than three samples will be tested for each diameter of wire. Where the WPS is submitted for a range of wire sizes, procedure qualification will be performed on each of the minimum and maximum wire diameters shown. The procedure qualification testing will be considered acceptable when a 90 Percent Within Limits (PWL) is achieved.

8.1.10.2. For butt splices of circumferentials or where welds are made to circumferentials, pull tests of representative specimens of the circumferential across the finished weld shall demonstrate a strength of not less than 0.75 times the design yield strength of the circumferential except as provided in 8.1.11.

8.1.10.3. At the option of the fabricator, a more detailed analysis may be made, and the requirements of this section used in lieu of 8.1.10.1.

For butt splices of circumferentials or where welds are made to circumferentials, pull tests, P_t of representative specimens of the circumferential across the finished weld shall demonstrate a strength of not less than

$$P_t = 0.75\ A_{wr}\ f_y \qquad (1)$$

or not less than

$$P_t = 0.5\ A_{wa}\ f_y \qquad (2)$$

whichever is greater.

8.1.10.4. The overall performance and acceptance of the welds in section 8.1.10 shall be accepted subject to section 11.3.1 external load crushing Strength.

8.1.11. Lapped Splices of Circumferential Reinforcement

8.1.11.1. If splices are not welded, the reinforcement shall be lapped not less than 20 diameters for deformed bars and deformed cold-worked wire, and 40 diameters for plain bars and cold-drawn wire. In addition, where lapped cages of welded-wire fabric are used without welding, the lap shall contain a longitudinal wire.

(a) If a tack weld is used for a lapped splice of circumferential, the tack weld must meet the requirements of Section 8.1.10 and Section 8.1.11.2

8.1.11.2. At the option of the fabricator a more detailed analysis may be made, and the requirements of this section used in lieu of 8.1.11.1.

8.1.11.2.1. Where lapped circumferentials are spliced by welding, they shall be lapped no less than 2 inches. Pull tests, P_t, of representative specimens shall develop not less than

$$P_t = F_W\ \ A_{wr}\ f_y \qquad (3)$$

or not less than the strength required by equation (2), whichever is the greater.

8.1.11.2.2. The embedded weld factor, F_w, relates the pull test strength of the non-embedded splice specimens to the strength of the splice embedded in the concrete of the pipe wall. Perform the pull test according to ASTM C76, Section 8.

(a) If the pull test break is in the wire, F_w shall be taken as 0.75.

(b) If the pull test break is in the weld, F_w shall be taken as 0.50.

8.1.11.3. If lapped splices of circumferentials consisting of deformed bars,

deformed wire or welded deformed wire fabric are not welded, they shall be lapped not less than L_d, where:

$$L_d = \frac{0.03\, d_b f_y A_{wr}}{\sqrt{f'_c}\, A_{wa}} \quad (4)$$

or not less than

$$0.015\, d_b \frac{f_y}{\sqrt{f'_c}} \quad (5)$$

whichever is greater. Splices of larger than #6 bars shall meet the requirements of ACI 318.

8.1.11.4. If lapped splices of circumferentials consisting of welded, smooth wire fabric are not welded, fabricate the cage according to ASTM C76 Section 8.1.8. The overlap measured between the outermost longitudinals on each side of the splice shall be no less than the spacing of the longitudinals plus 1 inch, or L_d, where:

$$L_d = 0.27 \frac{A_{wr} f_y}{s \sqrt{f'_c}} \quad (6)$$

whichever is greater.

8.1.11.5. At the option of the fabricator a more detailed analysis may be made and the following exception to the requirements of 8.1.11.3 may be applied.

If the area of circumferential reinforcement is at least twice that required for flexure, the first requirement of Section 8.1.11.3 shall not apply. The overlap measured between the outermost longitudinals on each side of the splice shall not be less than that provided in ASTM C76, or 1 inch, whichever is greater.

8.1.11.6. Alternative splice designs that differ from section 8.1.11.5 may be submitted to the Department for approval.

8.1.12. Development of Quadrant Mat Reinforcement

8.1.12.1. Circumferential quadrant mat reinforcement shall consist of welded wire fabric with 8 inch maximum cross wire spacing. When quadrant

mat reinforcement is used, the area of the main cage shall be no less than 25.0% of the area required at the point of maximum moment. The quadrant mats shall extend at least 45 degrees each side of the point of maximum moment.

8.1.12.2. At the option of the fabricator a more detailed analysis may be made and the requirements of Sections 8.1.12.3 and 8.1.12.4 used in lieu of 8.1.12.4.1.

8.1.12.3. When circumferential quadrant mat reinforcement consists of welded smooth wire fabric the following requirements shall apply:

8.1.12.3.1. The outermost longitudinals on each end of the circumferentials shall be embedded according to the following requirements:

(a) Past the point where the quadrant reinforcement is no longer required by the orientation angle, plus the greater of 12 circumferential wire diameters or ¾ of the wall thickness of the pipe, and

(b) Past the point of maximum flexural stress by the orientation angle, plus the development length, L_d, required by Equation (6).

8.1.12.3.2. The mat shall contain no less than 2 longitudinals at a distance 1 inch greater than that determined by the orientation angle from either side of the point requiring the maximum flexural reinforcement.

8.1.12.3.3. The point of embedment of the outermost longitudinals of the mat shall be at least a distance determined by the orientation angle past the point where the continuing reinforcement is no less than, double the area required for flexure.

8.1.12.4. When circumferential quadrant mat reinforcement consists of deformed bars, deformed wire or welded deformed wire fabric the following requirements shall apply:

8.1.12.4.1. Circumferentials shall extend past the point where they are no longer required by the orientation angle, plus the greater of 12 wire diameters or ¾ of the wall thickness of the pipe.

8.1.12.4.2. Circumferentials shall extend either side of the point of maximum flexural stress not less than the orientation angle, plus the development length, L_d, required by Equation (4) or (5).

8.1.12.4.3. Circumferentials shall extend at least a distance determined by the orientation angle past the point where the continuing reinforcement is no less than double the area required for flexure.

8.1.12.5. Welded wire fabric cages should be tested by LTS twice each year according to Pub 145, Part 4, Section II. Verify domestic source of the wire.

Samples of circumferentially welded wire fabric cages shall be sampled and submitted for testing by LTS each year. A minimum of ten samples are required for each wire size sampled. Do not select samples with visible undercut or other defects unless these are representative of what is being used in production.

8.2. Stirrup Reinforcement:

8.2.1. The number of lines of stirrups shall be sufficient to include the distance determined by calculation where V_u is less than V_c plus the distance l_θ as determined by formula (7). The required number of lines of stirrups shall be equally distributed on each side of the point of maximum moment, as shown on BD-636M and the PennDOT Accepted Software.

$$l_\theta = \frac{\pi\theta}{180}(D_i + 2t_b) + h \qquad (7)$$

8.2.2. Stirrups used for radial tension

When stirrups are used to resist radial tension, they shall be anchored around each circumferential of the inside cage to develop the resistance of the stirrup, and they shall also be anchored around the outside cage or embedded sufficiently in the compression side to develop the required resistance of the stirrup. If continuous prefabricated stirrup mats are used, the stirrups need to be sufficiently anchored in the compression zone of the concrete cross section so as to develop the full tensile strength of the stirrup wire. Continuous stirrup loop lengths equivalent to at least 70.0% of the wall thickness may be considered to provide adequate anchorage.

8.2.3. Stirrups used for diagonal tension

When stirrups are not required for radial tension but required for shear (diagonal tension); their longitudinal spacing shall be such that they are anchored at either, each, or every other tension circumferential. Such spacing shall not exceed 6 inches. If prefabricated stirrup mats are used, they shall be placed inside the inner cage with loops directed toward the outer cage.

8.2.4. Anchorage systems that differ from those shown in Figures 1 and 2, and their corresponding anchorage design stresses, must be submitted to the

Department, LTS, for proof of adequacy. For Bulletin 15 approval, submit independent Quality Control data for prefabricated loop type stirrup mats to verify a minimum of 65,000 psi anchorage strength is developed, as determined by appropriate tests that simulate the behavior of the stirrup in the pipe.

8.3. Longitudinal reinforcement:

Each line of circumferential reinforcement shall be assembled into a cage that shall contain sufficient longitudinal bars or members, extending the length of the pipe, to maintain the reinforcement rigidly in shape and in correct position within the form. The exposure of the ends of longitudinals, stirrups, or spacers that have been used to position the cages during the placement of the concrete shall not be a cause for rejection.

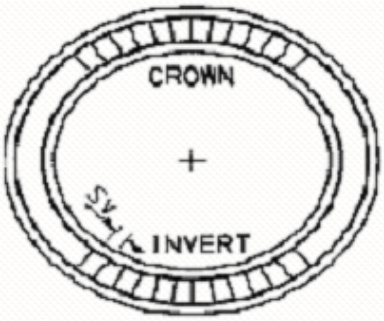
8.4. Joint Reinforcement:

8.4.1. For pipe 36 inches and larger in diameter, either the bell or spigot shall contain circumferential reinforcement. This reinforcement shall be an extension of a wall cage or may be a separate cage of at least the area per foot of that specified for the outer cage or one-half of that specified for single cage wall reinforcement, whichever is less.

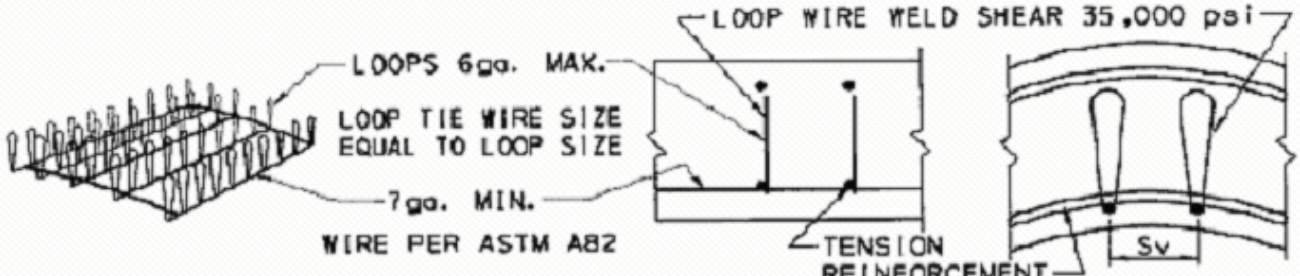
8.4.2. Where bells or spigots require reinforcement, the maximum end cover on the last circumferential shall be one-half the length of the joint or 3 inches, whichever is less.

9. JOINTS

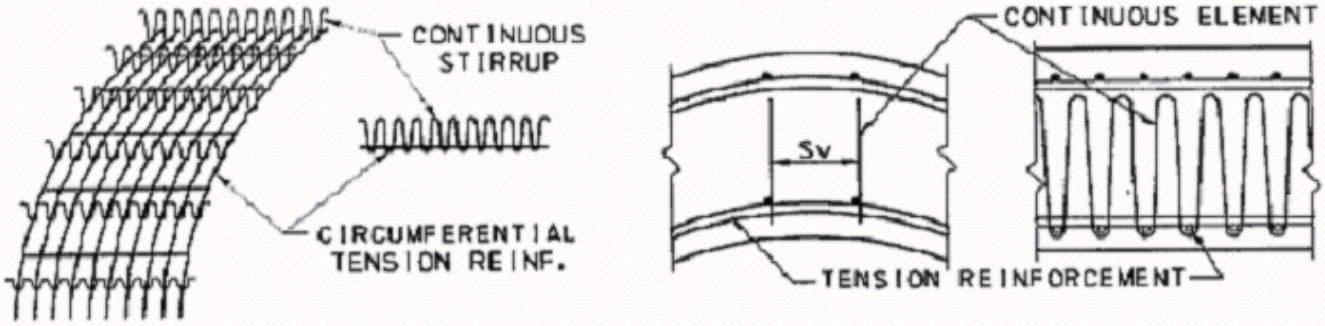
9.1. The joints shall be of such design and the ends of the concrete pipe sections so formed that when the sections are laid together they will make a continuous line of pipe with a smooth interior free from appreciable irregularities in the flow line, all compatible with the permissible variations given in Section 12.



Note: For details regarding orientation and installation of prefabricated stirrup mats, refer to Section 8.2

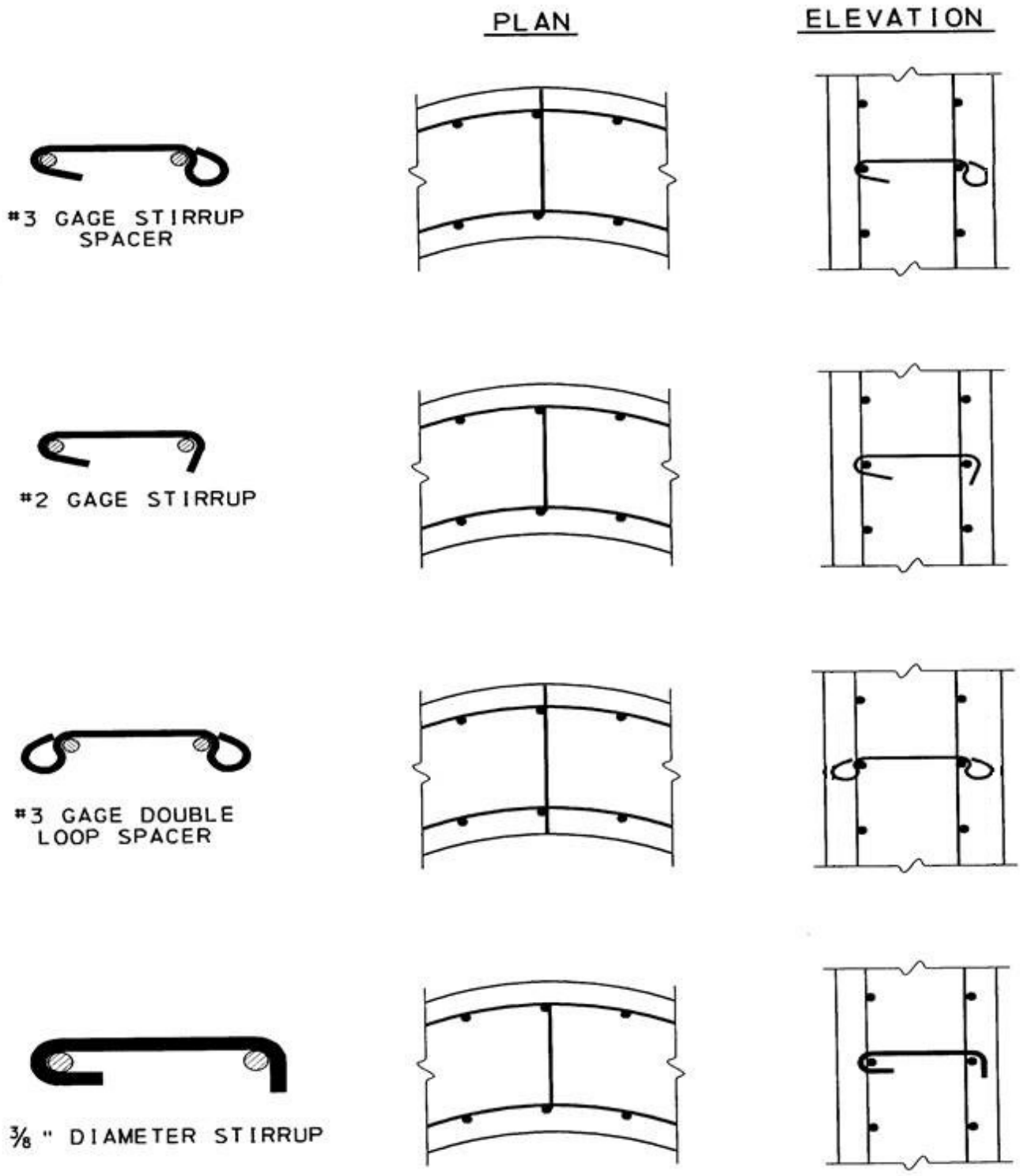


LOOP TYPE PREFABRICATED STIRRUP MATS



CONTINUOUS PREFABRICATED STIRRUP MATS

FIGURE 1



STANDARD
PIPE STIRRUP
FIGURE 2

10. FABRICATION

10.1. Mixture:

The aggregates shall be sized, graded, proportioned, and mixed in a batch mixer with such proportions of cement and water as will produce a homogeneous concrete mixture of such quality that the pipe will conform to the test and design requirements of this Specification. All concrete shall have a water-cement ratio not exceeding 0.53. All pipe fabricated under the provisions of this Specification shall contain a minimum of 470 lb. of cement (and SCM)/yd^3 of concrete unless mix designs with a lower cement (and SCM) content demonstrate that the quality and performance of the pipe meet the requirements of this Specification.

Pub 408, Section 704.1(g) Mix Designs Using Potentially Reactive Aggregates mitigation methods do not apply for mix designs for RCP, unless directed by the Chief Structural Materials Engineer.

10.1.1. Bin Scales:

Bin Scales used in proportioning cement (and SCM) and aggregates must be verified annually to their accuracy within ± 2.0% of the required weight by an acceptable certified calibration agency.

10.2. Curing:

Pipe shall be subjected to any one of the methods of curing described in 10.2 to 10.2.4, or to any other method or combination of methods approved in the QCP that will give satisfactory results. The pipe shall be cured for a sufficient length of time so that the specified proof load is obtained when acceptance is based on 5.1.1, or so that the concrete will develop the specified compressive strength at 28 days, or less when acceptance is based on 5.1.2 or 5.1.3.

10.2.1. Steam Curing

Pipe may be placed in a curing chamber, free of outside drafts, and cured in a moist atmosphere maintained by the injection of steam for such time and such temperature as approved in the QCP and needed to enable the pipe to meet the strength requirements. The curing chamber shall be so constructed as to allow full circulation of steam around the entire pipe.

10.2.2. Water Curing:

Concrete pipe may be water-cured by covering with water saturated material or by a system of perforated pipes, mechanical sprinklers, porous hose, or by any other approved method that will keep the pipe moist during the approved curing period.

10.2.3. The fabricator may, at their option, combine the methods described in 10.2.1 to 10.2.4 provided the required concrete compressive strength is attained.

10.2.4. A sealing membrane conforming to the requirements of AASHTO M 148 may be applied and should be left intact until the strength requirements are met. The concrete at the time of application shall be 10° F above the atmospheric temperature. All surfaces shall be kept moist prior to the application of the compounds and shall be damp when the compound is applied.

11. PHYSICAL REQUIREMENTS

11.1. Test Specimens:

Pipe for testing shall be furnished without charge by the fabricator and shall be selected at random by the Department and shall be pipe that would not otherwise be rejected under this Specification. The selection shall be made at the point or points designated by the purchaser when placing the order.

11.2. Tests for Extended Delivery Schedules:

For extended project deliveries, the lot will be accepted as follows: Perform a preliminary three-edge bearing test on a section according to Section 11.3. Each successive production date comprising the reduced lot will be accepted on the basis of compressive strength testing according to Section 11.4.1.(2), Acceptance Testing.

11.3. External Load Crushing Strength:

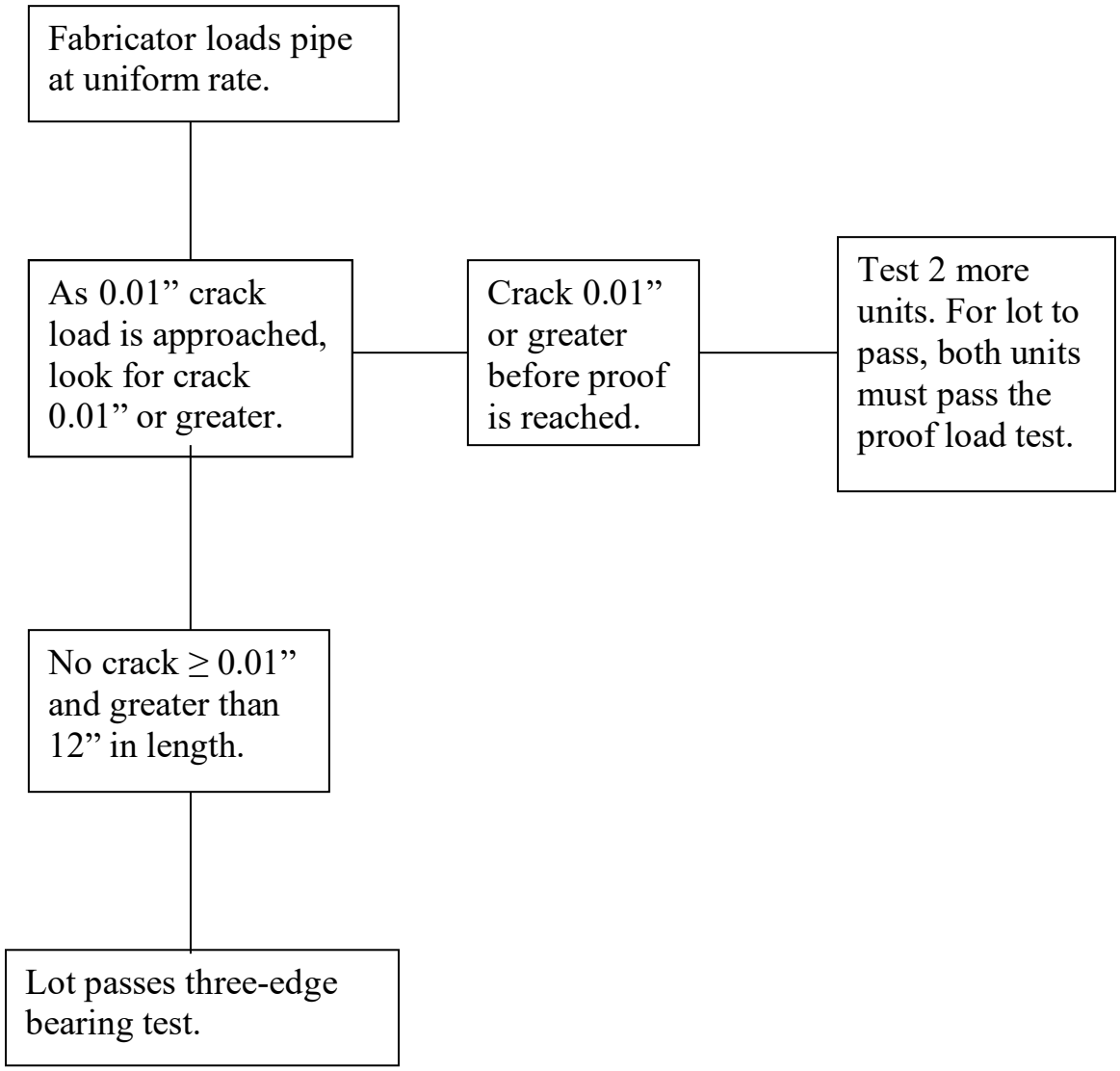
11.3.1. The load to produce a 0.01 inch crack, as determined by the three-edge bearing method described in AASHTO T 280, shall be not less than the proof load provided in BD-636M, or by PennDOT Accepted Software for each respective pipe design. Lots for which the pipe have been tested according to this Specification and that meet the proof load requirements given in 11.3.4 shall be accepted for use.

11.3.2. Retests of Pipe Not Meeting the External Load Crushing Strength Requirements – Pipe shall be considered as meeting the strength requirements when all test specimens conform to the strength requirement. The fabricator shall be allowed to retest two additional specimens for each specimen that failed, and the pipe shall be acceptable only when all of the retest specimens meet the strength requirements. If either of the additional specimen fail, the date of fabrication is rejected.

11.3.3. When acceptance is on the basis of 5.1.1, test pipe by the three-edge bearing method according to AASHTO T 280, as modified herein. Accept any test specimens which meet the 0.01 inch crack proof-load requirement

without exceeding a 0.007 inch crack width under test load and which are otherwise free from defects as listed in Section 16. Verify that 0.007 inch crack limit with a feeler gauge conforming to the requirements shown in AASHTO T 280, except having a gauge thickness of 0.007 inch.

11.3.4. The lot shall be tested to the specified design proof-load requirement as outlined below:



11.4. Concrete Test Requirements:

11.4.1. Compressive Strength:

(1) Quality Control Testing:

Compressive tests, or monitoring the design concrete strength, may be made on either standard rodded concrete cylinders or cylinders compacted and cured in a like manner as the pipe, or on cores drilled from the wall of the pipe. Cylinders and cores shall be tested according to PTM No. 604 and AASHTO T 22, respectively. The design will be considered satisfactory when at least 90.0% of the strength tests show strengths greater than the required minimum specification strength. Cylinders may be kept in a moist temperature-controlled condition to develop 28-day strengths.

(2) Acceptance Testing:

When compressive strength testing is performed for the purpose of accepting pipe lots according to section 5.1.2 and 11.2, perform compressive strength testing according to PTM No. 604 and AASHTO T 22, respectively. The compressive strength test must meet or exceed the design requirement. Specimen test results which deviate from each other by 1,000 psi or more are considered invalid.

If the concrete consistency is too stiff for compaction by rodding or internal vibrations, the following alternative method may be use:

(1) Secure a cylinder mold to the top of a vibrating table, or to the actual concrete pipe form being used to produce the pipe.

(2) Place wet-cast concrete in the cylinder mold in three equal lifts, and dry-cast or packer-head concrete according to ASTM C192.

(3) Place a cylindrical hammer on the surface of each lift with the hammer to be ¼ inch less in diameter than the inside diameter of the mold and of a weight to create a pressure of 0.353 psi on the surface of the concrete.

(4) External vibration shall be applied on each lift with a frequency of at least 800 vibrations per minute, continued until cement paste begins to ooze up around the bottom edge of the hammer.
If cores are cut from the wall of the pipe and tested they shall be cut and tested according to the requirements of AASHTO T 280. The compressive strength of each core tested shall be equal to or greater than the design strength of the concrete.

Requirements:

Pipe shall be considered as meeting the strength requirements when all test specimens conform to the strength requirements. Should any of the test specimens fail to meet the strength requirements, the fabricator shall be allowed a retest on two additional specimens for each specimen that failed, and the pipe shall be acceptable only when all of the retest specimens meet the strength requirements. When the cores cut from a section of pipe successfully meet the strength requirement, the core holes shall be plugged and sealed by the fabricator in an approved manner such that the pipe section will meet all the requirements of this Specification. Pipe sections so sealed shall be considered as satisfactory for use.

11.4.2. Absorption Test Requirements of Concrete:

The absorption of a sample from the wall of the pipe, as determined according to AASHTO T 280, shall not exceed 9.0% of the dry mass. Each sample shall be a piece broken from the wall, or a core drilled from the wall, shall have a minimum area of 9 in^2, as measured on one surface of the pipe wall, and shall be free of visible cracks. When the initial absorption sample, from a pipe fails to conform to this Specification the fabricator shall be allowed a retest on two additional samples from the same pipe for each sample that failed. The pipe shall be acceptable only when all the retest samples meet the absorption requirements. Absorption test requirements of concrete may be waived by the Department.

11.5. Test Equipment:

Every fabricator furnishing pipe under this Specification shall furnish all facilities and personnel necessary to carry out the tests described in AASHTO T 280.

12. PERMISSIBLE VARIATIONS

12.1. Internal Diameter:

The internal diameter of round 12 inches to 24 inches pipe shall vary not more the ± 1.5% from the design diameter. The internal diameter of round 27 inches and larger pipe shall not vary by more than ± 1.0% from the design diameter or ± 3/8 in., whichever is greater. The internal dimensions of elliptical pipe shall not vary more than ±2.0% from the internal dimensions shown in Fig. 3.

12.2. Wall Thickness:

The design wall thickness, or specified wall thickness, shall not vary by more than ± 5.0% or 3/16 inch, whichever is greater. A specified wall thickness more than required in the design is not cause for rejection. Pipe having localized variations in wall thickness exceeding those specified above shall be accepted if the proof load strength and minimum steel cover requirements are met.

12.3. Length of Two Opposite Sides:

Variations in the laying length of two opposite sides of the pipe shall not be more than ¼ inch for all sizes through 24 inches internal diameter, and not more than 1/8 in./ft. for all sizes larger with a maximum of ¾ inch for 90 inches internal diameter or larger, except where beveled end pipe for laying on curves is specified by the Department.

12.4. Length of Pipe:

The under run in length of a section of pipe shall not be more than 1/8 in./ft. with a maximum of ½ inch in any length of pipe. Regardless of the underrun or overrun in any section of the pipe, the end cover requirements of Section 8 and 12 shall apply.

12.5. Position of Area of Reinforcement:

12.5.1. Position:

The maximum variation in the position of the reinforcement shall be ± 10.0% of the wall thickness or ± 2 inches, whichever is greater. Pipe having variations in the position of the reinforcement exceeding those specified above shall be accepted if the three-edge-bearing strength requirements obtained on a representative specimen are met. In no case, however, shall the cover over any reinforcement be less than ¼ inch as measured to the end of the spigot or ½ inch as measured to any other surface. The preceding minimum cover limitations do not apply to mating surfaces of non-rubber gasket joints, here reinforcement shall not be exposed on the side mating surface of the joints. If convoluted reinforcement is used, the convoluted circumferential end wire may be at the end surface of the joint providing the alternate convolutions have at least 1 inch cover from the end surface of the joint.

12.5.2. Area of Reinforcement:

Reinforcement will be considered as meeting the design requirements if the area, computed on the basis of nominal area of the wire or bars used, equals or exceeds the requirements of 7.1 or 7.2. Actual area of the reinforcing used may vary from the nominal area according to permissible variations of the standard specifications for the reinforcing.

13. WORKMANSHIP, FINISH, AND APPEARANCE

13.1. Pipe shall be substantially free of fractures and surface roughness. The ends of the pipe shall be normal to the walls and center line of the pipe, within the limits of variations given in Sections 12.3 and 12.4.

14. REPAIRS

14.1. Pipe may be repaired, if necessary, because of imperfections in fabrication or damage during handling and will be acceptable if, in the opinion of the Department, the repairs are sound and properly finished and cured and the repaired pipe conforms to the requirements of this standard. Repair procedures for RC pipes are described in Appendix B.

15. INSPECTION

The quality of materials, the process of fabrication, and the finished pipe may be subject to inspection and approval by an inspector employed by the Department.

The following criteria has been developed to assign certification demerits or deviations to fabricators found to have certified and delivered pipe to Department projects not meeting the Specifications. Fabricators who accumulate three or more substantiated deviations during any continuous twelve-month period will be downgraded in their Bulletin 15 Level of Certification and may be removed from Bulletin 15. Fabricators will earn an additional certification credit over and above the base allowance of three deviations for each 100 certified deliveries to Department projects.

To earn certification credits, fabricators will be required to submit actual copies of Form CS-4171 for verification. The following general guidelines were developed to establish the relative weight of each deviation applied toward a fabricator's certification status. Based on the actual number of pipe affected, however, partial deviations may be considered cumulative.

Incident Type	No. of Deviations
▪ Diameter, out of tolerance	1
▪ Joint dimensions, out-of-tolerance, unacceptable fit	1
▪ Length of opposite sides, skewed sections	1
▪ Wall thickness, out-of-tolerance	1
▪ Unapproved repairs, unacceptable repairs (cosmetic)	½
▪ Unapproved repairs, unacceptable repairs (structural)	1
▪ Reinforcement not removed from lift holes	½
▪ Through wall cracking, exceeding the depth of the joint	1
▪ Cracking ≥ 0.003" wide AND 12" long	1
▪ Insufficient reinforcement cover	1
▪ Open texture and/or honeycombing	1
▪ Improper marking, structurally adequate	½
▪ Improper marking, structurally deficient	1
▪ Improperly substituted, structurally adequate	½
▪ Improperly substituted, structurally deficient	1
▪ Improperly certified, minor	½
▪ Improperly certified, major	1
▪ Non-Bulletin 14/15 materials used in production	1
▪ Quality Control records missing/incomplete	1

16. REJECTION

16.1. Pipe shall be subject to rejection on account of failure to conform to any of the Specification requirements. Individual sections of pipe may be rejected because of any of the following:

16.1.1. Fractures or cracks passing through the wall, except for a single end crack that does not exceed the depth of the joint.

16.1.2. Defects that indicate proportioning, mixing, and molding not in compliance with Section 10.1, or surface defects indicating honey-combed or open texture that would adversely affect the function of the pipe.

16.1.3. Damaged or cracked ends, where such damage would prevent making a satisfactory joint.

16.1.4. Any continuous crack having an unloaded surface width of 0.003 inches or more and extending for a length of 12 inches or more, regardless of position in the wall of the pipe. Any continuous crack having an unloaded surface width of 0.002 inches will be accepted. Verify the 0.003 inches crack limit with a feeler gauge conforming to the requirements of AASHTO T 280, except having a gauge thickness of 0.003 inches.

16.1.5. Punched through wall lift holes are not permitted.

17. MARKING

17.1. The following information shall be legibly marked on the inside barrel of each section of pipe.

17.1.1. The pipe designation shall be indicated as follows:

PA d t/S Max – Min

Or

PA d t/SH Max – Min

Where:

d = designated pipe internal diameter, inches

t = installation type [A = state heavy duty, B = Standard duty]

S = standard installation

SH = shoring trench box installation

Max = Maximum fill height, feet

Min + Minimum fill height, feet

Example: 24 inch pipe with a 3 inch wall thickness on a state highway with 15 feet of embankment fill where heavy duty pipe is required. This pipe could also be used for shoring condition and receive two markings as indicated below.

PA 24 A/ S 15 – 2

PA 24 A/SH 10 – 7

When dual markings are used, the lot must be tested for the greater proof load required for either the standard or shoring/trench box installation, as applicable.

17.1.2. The date of fabrication.

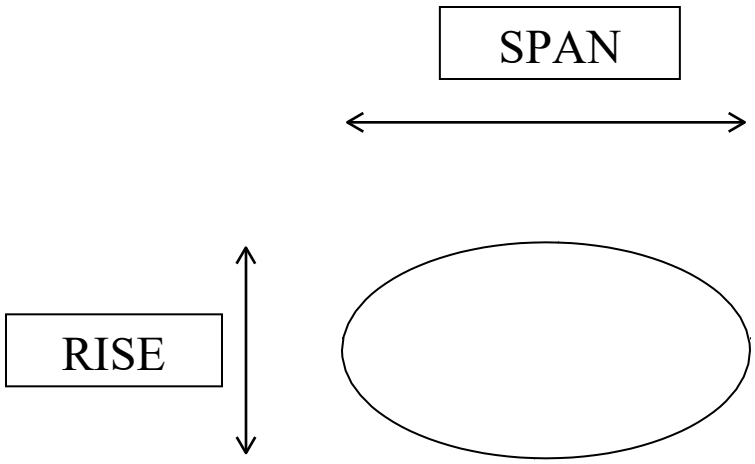
17.1.3. The name or trademark of the fabricator, and

17.1.4. Identification of plant.

17.1.5. American Concrete Pipe Association (ACPA) “Q-Cast” or National Precast Concrete Association (NPCA) stamp.

17.2. One end of each section of pipe with Elliptical or Quadrant reinforcement shall be clearly marked with the word “TOP”, during the process of fabricating or immediately thereafter, on the inside and the outside of opposite walls along the minor axis of the Elliptical reinforcing or along the vertical axis for Quadrant reinforcing.

17.3. Markings shall be indented on the pipe section or painted thereon with waterproof paint.



Approximate Equivalent Round Size, in.	Rise, in.	Span, in.
18	14.25	22.75
24	19.25	30.25
27	21.50	34.00
30	24.00	37.75
33	26.75	42.00
36	28.75	45.50
42	34.00	53.25
48	38.25	60.00
54	43.50	68.00
60	48.25	75.50
66	53.00	83.00
72	57.75	90.50
78	62.75	98.00
84	67.50	105.50
90	72.50	113.00
96	77.25	120.50
102	82.00	128.00
108	87.00	135.50
114	91.75	143.00
120	96.75	150.75

Figure 3: Cross-Sectional Shape of Elliptical Pipe
Horizontal

Note: For vertical, the rise and span are reversed

APPENDIX A - DESIGN TABLES & PROOF LOAD TABLES

NOTES:

1. Fabricate concrete pipe per this Publication and BD-636M Tables. See Instructions below for special design.
2. Test concrete pipes according to this publication, Proof Test Load Include a 1.43 factor of safety for field cracking. Testing to Ultimate is not required.
3. The design values shown in this publication make the assumption that the excavation, backfill and construction methods in the RC standards and Pub 408 are used.
4. Elliptical reinforcement is not permitted, except for quadrant reinforcement and for reinforcement of elliptical pipe.
5. Smooth welded wire fabric is used in the design of the steel areas for concrete pipe; the use of deformed wire fabric or deformed wire is also permitted.
6. Use design tables as shown on BD-636M to determine steel area; use PennDOT Accepted Software for designs not covered by these tables.
7. Steel areas shown are in in^2/ft.

INSTRUCTIONS:

- Use PennDOT Accepted Software to perform pipe designs for fill height and concrete strengths not shown in the design tables, or as indicated by double asterisks (**).

DEFINITIONS:

DIA	= INSIDE DIAMETER OF THE CONCRETE PIPE IN INCHES.
TYPE A STANDARD INSTALLATION	= HEAVY DUTY CONCRETE PIPE EMBANKMENT INSTALLATION DESIGN. (APPROX. 100 YEARS LIFE)
TYPE A SHORING/TRENCH BOX INSTALLATION	= HEAVY DUTY CONCRETE PIPE TRENCH BOX OR SHORING INSTALLATION DESIGN. (APPROX. 100 YEARS LIFE)
TYPE B STANDARD INSTALLATION	= STANDARD DUTY CONCRETE PIPE EMBANKMENT INSTALLATION DESIGN. (APPROX. 50 YEARS LIFE)
TYPE B SHORING/ TRENCH BOX INSTALLATION	= STANDARD DUTY CONCRETE PIPE TRENCH BOX OR SHORING INSTALLATION DESIGN. (APPROX. 50 YEARS LIFE)
PROOF TEST LOAD	= THREE EDGE BEARING TEST TO A LOAD EXTRAPOLATED FROM 0.007" DESIGN REQUIREMENT TO PRODUCE A 0.01" CRACK.
PROOF LOAD	= THE LOAD CARRIED BY A PIPE SUBJECTED TO A THREE EDGE BEARING TEST, EXPRESSED IN POUNDS PER LINEAR FOOT OF INSIDE DIAMETER. THE PROOF LOAD REFLECTS THE FIELD SERVICE LOAD CONDITION FOR BOTH LIVE AND DEAD LOADS
H	= DESIGN FILL HEIGHT.
f_y	= SPECIFIED YIELD STRENGTH OF REINFORCEMENT.
f'_c	= SPECIFIED COMPRESSIVE STRENGTH OF CONCRETE.

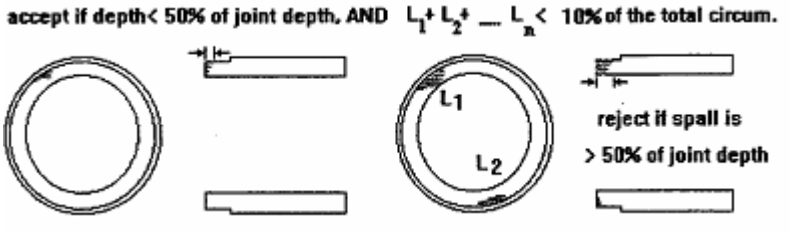
APPENDIX B – REPAIR PROCEDURES FOR REINFORCED CONCRETE PIPE

1. Spalls:

1.1. End Spalls

Occasional spalls or chips on the spigots, bell, tongue or groove which are no greater than ½ the depth of the joint in the longitudinal direction shall not be cause for rejection, provided the total length of spalls on the pipe end is not more than 10.0% of the total circumference.

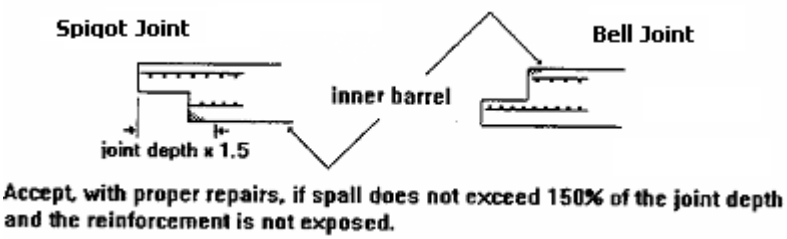
These spalls must be repaired using a Bulletin 15 approved repair material.



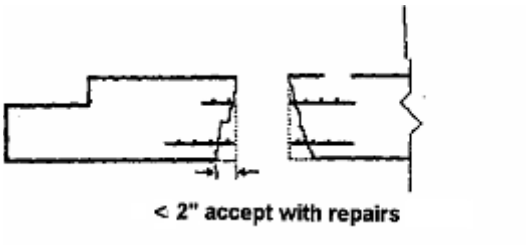
1.2. Spalls, other than damaged pipe ends

Repairs to the inner barrel will only be permitted within the acceptable limits at the spigot and bell ends of the joint as described above and as follows:

1.2.1. Spalling to the inner barrel which does not reveal the reinforcement within 1.5 times the joint depth from the end of the pipe may be repaired according to the cosmetic repair procedure identified at the end of this appendix.



1.2.2. Minor spalls less than 2 inches from the edge of the lift hole may be repaired according to the cosmetic repair procedures described at the end of this appendix. The aggregate fractured surface need not be obtained. Reinforcing steel may be visible prior to completing the repair. Minor spalls developed at the lift hole during installation may be repaired at the same time the lift hole is plugged.

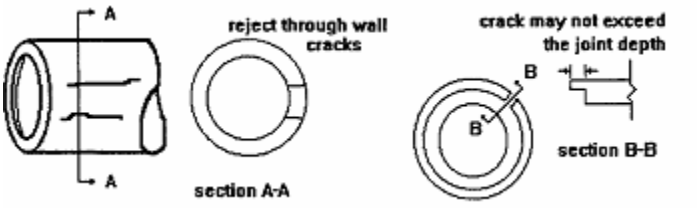


1.2.3. Spalling on the outer barrel which does not expose the reinforcement may be repaired according to the cosmetic repair procedure described at the end of this appendix. Spalling on the outer barrel which reveals the reinforcement must be repaired according to the structural repair procedure described at the end of this appendix.

2. Cracks:

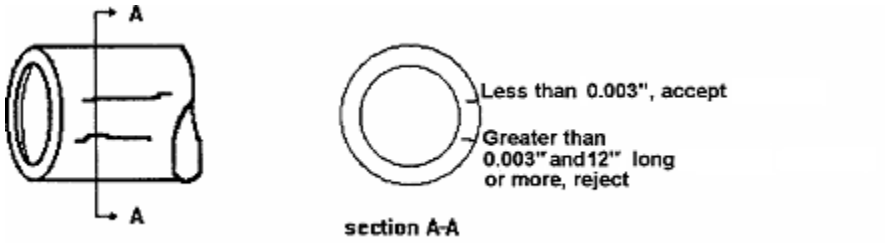
2.1. Through wall cracks:

Any pipe section exhibiting a through wall crack shall be rejected, except that a single end crack that does not exceed the depth of the joint will be permitted. Pipe sections rejected for cracks may not be repaired.



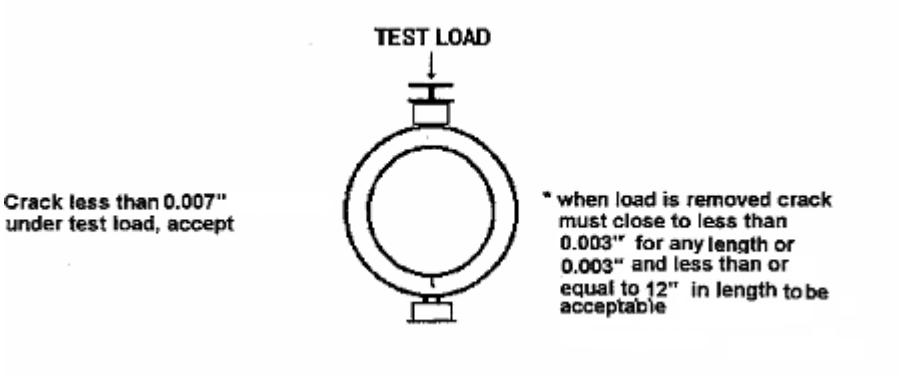
2.2. Non-through wall cracks. Untested pieces, prior to installation.

Any untested sections of pipe, other than the test specimen which was tested by the three-edge bearing method, within an approved lot and which exhibit non-through wall crack(s) having a surface width of less than 0.003 inches will be accepted. Sections exhibiting non-through wall cracks greater than or equal to 0.004 inches in width and 12 inches or more in length will be rejected.



2.3. Non-through wall cracks, tested pieces, prior to installation.

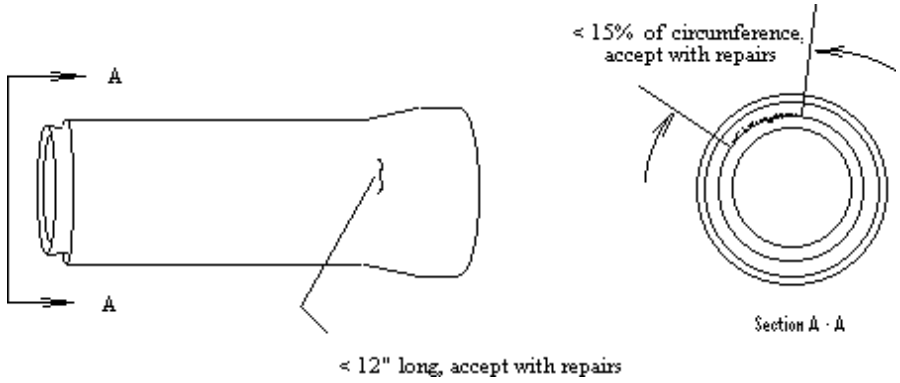
The test section for each approved lot will be accepted under the conditions of 2.2 provided the crack, under the prescribed test load, did not exceed a surface width of 0.007 inches.



2.4. Plastic 'tear' cracks

Occasionally, concrete pipe develops 'tear' cracks at their surface during initial fabrication/handling, prior to curing, when tensile stresses exceed the concrete strength. These cracks are predominantly located along the shoulder of the spigot joint where the pipe transitions to full wall depth, although minor cracking located on the outer barrel may occur less frequently. Cracks eligible for repair must meet the following criteria:

- circumferential spigot tears less than 15.0% of the circumference of the pipe
- outer-barrel wall tears less than 12 inches in length
- crack depth does not extend beyond the pipe reinforcement (after V-grooving)



Prepare the crack for repair by v-grooving along the length of the crack. Complete the repair with a Bulletin 15 approved concrete repair material (non-cosmetic), listed in Bulletin 15 which develops the minimum design strength of the pipe.

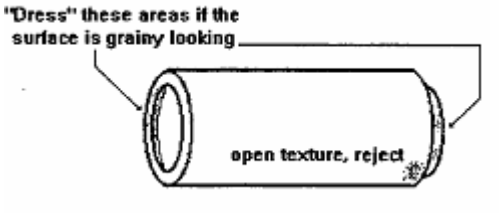
3. Fabrication Defects and Processes

3.1. Honeycombing and other mixture defects

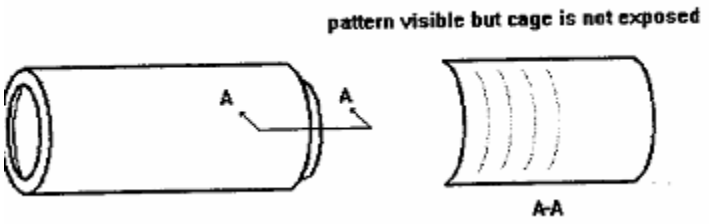
Any section exhibiting honeycombing or mixture defects that expose the reinforcing cage will be rejected.

Any section exhibiting minor surface texture defects encountered on the mating surfaces of the joint can be accepted if the surface can be completely closed with a cement slurry.

3.2. Cage shadow

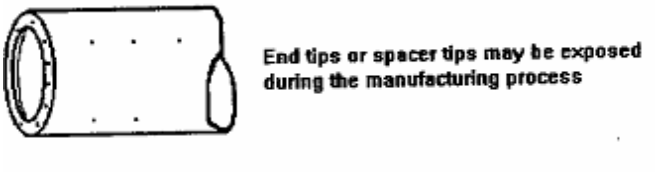


Some fabrication processes may reveal the reinforcing cage even though the section has sufficient cover. If the inspector is concerned about insufficient cover, The Structural Materials Engineer should be contacted for further review.

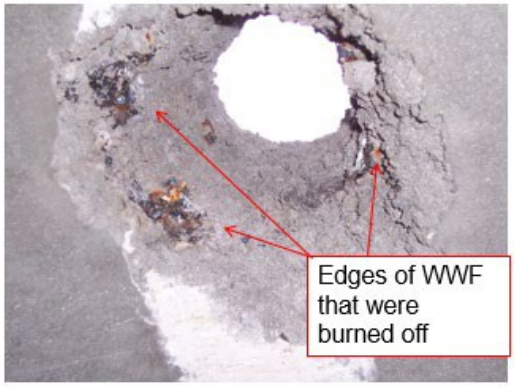


3.3. Exposed “end tips”

The presence of exposed longitudinal “end tips” of the reinforcing cage at the pipe ends or spacers on the pipe wall shall not be cause for rejection.



Reinforcing left in the lift holes must be removed. The below photos show instances where the reinforcement is visible at the outer edges of the lift holes. Both are considered acceptable. Additionally, the photo on the left shows slight spalling and break back of the lift hole. Limits of spalling and break back are provided in Appendix B, Section 1.2.2.



4. General:

   Note: Any repairs required beyond the scope of this appendix may be submitted to the Structural Materials Engineer for evaluation on a case-by-case basis. Such repair proposals should include a photograph or sketch of the affected are and a detailed repair proposal.

   The QC inspector must document additional information in the plant book when pipe sections are rejected. The date of fabrication, lot number, size, quantity and reason for rejection must be included. Rejected pipe or pipe requiring repair should be clearly marked with a colored keel or crayon in a location to prevent the defective pipe from mistakenly being shipped.

   Repairs to pipe should be performed in a workmanlike fashion, properly finished, cured and sound. Structural repairs must be witnessed by the Department inspector.

Repair Procedures – Minor chips and spalls less than 1 inch deep

- Areas to be repaired must be clean, sound and free of contaminants.
- Provide an aggregate fractured surface with a minimum surface profile of 1/8 inch.
- Saturate the repair surface with clean water to provide an SSD condition.
- Use (1) a thoroughly mixed Bulletin 15 Material according to the Manufacturer's recommendation, or (2) a mortar mix.
- Cure (1) the Bulletin 15 material according to the Manufacturer's recommendations, or (2) the mortar mix a minimum of 24 hours according to the approved QCP.

Structural Repair Procedure – Broken Joints or large barrel spalls where the reinforcement is exposed. Area: 1 inch to 6 inches depth range, maximum 120 in^2 surface area.

- Area to be repaired must be clean, sound and free of contaminants.
- Make a ¾ inch-deep vertical surface along the perimeter of the damaged area.
- Remove concrete a minimum of 1 inch beyond all exposed reinforcement.
- Provide an aggregate fractured surface with a minimum surface profile of 1/8 inch.
- Drill and insert 3/8 inch diameter steel pins on 4 inch centers for damaged areas with depths greater than 3 inches.
- Clean the repair surface and apply an approved epoxy bonding or concrete bonding agent according to the manufacturer's recommendations. This item may be deleted if the Bulletin 15 approved repair product contains a bonding agent.
- Fill the area with (1) a thoroughly mixed Bulletin 15 approved repair product and add 3/8-inch coarse aggregate to the mix according to the manufacturer's recommendations, or (2) the approved concrete mix design. **
- Cure (1) the Bulletin 15 approved repair product according to the manufacturer's recommendations, or (2) the approved concrete mix design a minimum of 24 hours according to the approved QCP.
- The repaired area will be evaluated by the Plant's Quality Control Personnel by applying a moderate blow with a 16oz. hammer at several locations of the repaired area.

** (2) is applicable only for wet cast pipe

General Notes:

- The damaged area may not exceed a length of 12 inches in any direction.
- The total surface area repaired may not exceed 200 in^2.
- The patching operation and the duration of the curing cycle are to be performed in a minimum 40^o F environment.

APPENDIX C – QUALITY CONTROL PLAN GUIDELINES FOR RC PIPE

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QUALITY CONTROL PLAN GUIDELINES FOR RC PIPE

Note: The Quality Control Plan must be developed using these requirements as a guide. Amplification of how the fabricator controls their process, using these criteria to meet specifications is required.

	Minimum Testing Frequency	Page # of QC Plan
I. Materials		
A. Cement	- Certification from Bulletin 15 source	_____
B. Reinforcement	- Certification from Bulletin 15 source	_____
C. Aggregates	- Approved Bulletin 14 sources with in plant or Quarry gradation result	_____
D. Admixtures	- Certification from Bulletin 15 source	_____
II. Prepour Inspection		
A. Rings		
• Dimensions	- Measure 25% monthly	_____
• Clean	- Review 10% daily	_____
B. Forms		
• Dimensions	- Measure 25% monthly	_____
• Clean	- Review 10% daily	_____
• Lift Hole	- Identify fabrication method	_____
C. Reinforcement		
• Wire Size/Area	- Measure 10% and record daily	_____
• Cage Diameter	- Measure 10% and record daily	_____
• Welding	- Verify WPS machine parameters, document daily	_____
• Spacer Position	- Check 10% daily	_____
III. Concrete Mix		
A. Batch Mass (Weight)	- Record 2 batch masses (weights) each shift.	_____
B. Cylinders/Cores	- Cast cylinders each day or core 3 pipe sections weekly to monitor concrete strength – each mix design	_____
IV. Curing		
Define curing method; indicate curing temperature and duration of curing period. Describe the procedure for recording the curing cycle.		_____
V. Post pour Inspection		
A. Wall Thickness	- Measure 10% and record daily	_____
B. Internal diameter	- Measure 10% and record daily	_____
C. Length of two opposite sides	- Measure 10% and record daily	_____
D. Length of Pipe	- Measure 10% and record daily	_____
E. Appearance	- Review 10% daily	
F. Position of Reinforcement	- One core weekly or measure nondestructively	_____

	Minimum Testing Frequency	Page # of QC Plan
VI. Calibration – maintain calibration certifications on file		
A. Cylinder compression machine	- Start of season	_____
B. Admixture dispensers	- Start of season	_____
C. Three edge bearing machine	- Start of season	_____
D. Scale check	- Start of season	_____
VII. Patching		
A. Outside surface	- Patch before curing pipe, if possible	_____
B. Inside surface, ends	- Use approved patching material and cure in accordance with the Manufacturer's recommendations.	_____
VIII. Documentation		
A. Straight-Line Analysis Charts	- Plot compressive strength	_____
B. Certification Shipping Form	- Form CS-4171	_____
C. Quality Control Procedures	- Record test results, post pour measurements, etc.	_____
D. Material Certifications	- Maintain on file	_____
IX. Submit an Organizational Chart, Illustrating a Quality Control Department operating and reporting to Management, independent from production		_____

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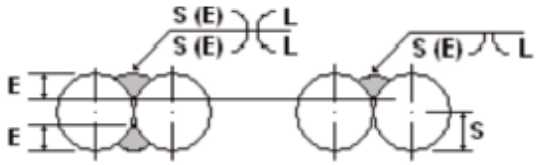
PRODUCTION JOINT WELDING PROCEDURE SPECIFICATION PROCEDURE QUALIFICATION RECORD

WPS No: _____ Date Issued: _____

Revision No: _____ Revision Date: _____

FABRICATOR NAME:	PREPARED BY:
WIRE MATERIAL SPECIFICATION:	WIRE SIZE OR RANGE: (IN.)
WELDING PROCESS: (CHECK ONE) SMAW ☐ FCAW ☐ GMAW ☐ (TRANSFER MODE: _____)	
SHIELDING GAS:	GAS FLOW RATE:
POSITION(S) OF WELDING:	
FILLER METAL SPECIFICATION:	
FILLER METAL CLASSIFICATION:	
SINGLE OR MULTIPLE PASS:	
POLARITY : (CHECK ONE) AC ☐ DC (NEGATIVE) ☐ DC (POSITIVE) ☐	
ELECTRODE EXTENSION: (ELECTRICAL STICKOUT)	
PREHEAT AND INTERPASS TEMPERATURE: **PER AWS D1.4 BASED ON BAR SIZE AND CARBON EQUIVALENCY**	

Pass No.	Elect. Size	Welding Process Variables		Joint Detail Show relevant dimensions and AWS symbols
		Amperes	Voltage	



Effective weld size (E)= 0.6S, typical

This procedure may vary due to fabrication sequence, fit-up, pass size, etc. within the Limitation of Variables.

Authorized Company Signature:_____

Additional Shop Notes:

Test Results:

For PennDOT Use Only

Example TR-37

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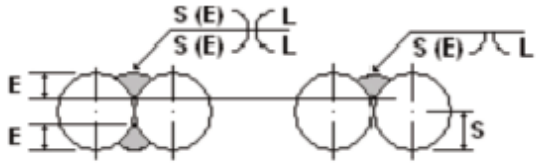
PRODUCTION JOINT WELDING PROCEDURE SPECIFICATION PROCEDURE QUALIFICATION RECORD

WPS No: _____ Date Issued: _____

Revision No: _____ Revision Date: _____

FABRICATOR NAME: Any Plant	PREPARED BY: John Doe
WIRE MATERIAL SPECIFICATION: A185	WIRE SIZE OR RANGE: (IN.) 0.1875 through 0.250 inch
WELDING PROCESS: (CHECK ONE) SMAW ☑ FCAW ☐ GMAW ☐ (TRANSFER MODE: _____)	
SHIELDING GAS: NA	GAS FLOW RATE: NA
POSITION(S) OF WELDING: Flat/Horizontal	
FILLER METAL SPECIFICATION: A5.1	
FILLER METAL CLASSIFICATION: E7018	
SINGLE OR MULTIPLE PASS: single	
POLARITY : (CHECK ONE) AC ☐ DC (NEGATIVE) ☐ DC (POSITIVE) ☑	
ELECTRODE EXTENSION: (ELECTRICAL STICKOUT) NA	
PREHEAT AND INTERPASS TEMPERATURE: **PER AWS D1.4 BASED ON BAR SIZE AND CARBON EQUIVALENCY**	

Pass No.	Elect. Size	Welding Process Variables		Joint Detail Show relevant dimensions and AWS symbols
		Amperes	Voltage	
1	1/8	100-140	10-28	 **Effective weld size (E)= 0.6S, typical**

This procedure may vary due to fabrication sequence, fit-up, pass size, etc. within the Limitation of Variables.

Authorized Company Signature: John Smith

Additional Shop Notes:

Test Results: (Attach PQR test results from lab)

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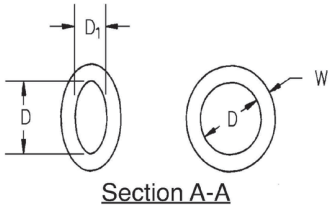
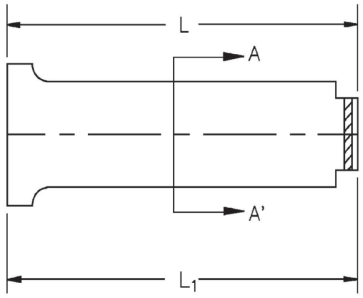
DIMENSIONAL REVIEW FOR REINFORCED CONCRETE PIPE

FABRICATOR NAME:			FORM ID: PIECE MARK:			
PLANT JOB ID:	ECMS #:	STATE PROJECT #:	SR:	SEC:	COUNTY:	S-
REVIEW TYPE:	❑ QUALITY CONTROL (QC)		❑ QUALITY ASSURANCE (QA)		❑ INDEPENDENT ASSURANCE (IA)	





Concrete Pipe Type . . . . . ❑ Circular or ❑ Elliptical

Properly Repaired . . . . . ❑ YES ❑ NO ❑ N/A

Manufacture Date: _____ Date of Post-Pour Check: _____

Quantity Made	DIA D	DIA L	Paid Marking	Wall Thick (W) inch	Steel (inch) 2/Linear Foot			
	D1 (inch)	L1 (inch)			Inner Cage	Required	Outer Cage	Required

Comments and/or Waivers: