**THIS RECOMMENDED SPECIAL PROVISION SHOULD BE USED IN CONJUNCTION WITH STANDARD DRAWINGS C-13.15**

RECOMMENDED SPECIAL PROVISION

(MA1010HDPEP, 07/24/05)

**SECTION 1010 DRAINAGE PIPE**

**1010-8 Corrugated High Density Polyethylene Plastic Pipe:** the section of the Standard Specifications is revised to read:

**1010-8 Corrugated High Density Polyethylene Pipe:**

**1010-8.01 General Requirements:**

The contractor shall submit a Certificate of Analysis, conforming to the requirements of Subsection 106.05, to the Engineer at least three weeks prior to the installation of corrugated high-density polyethylene pipe (CHDPEP). The test results and documentation will be evaluated by the ADOT Materials Group. The Department reserves the right to perform testing to ensure compliance with the specification.

For CHDPEP 12 inches in diameter and larger, the manufacturer's plant shall be certified by a testing organization approved by the ADOT Materials Group.

In addition to the requirements specified herein, CHDPEP, fittings, couplings, and ends shall conform to the requirements of AASHTO M252 for pipe sizes less than 12 inches in diameter, and AASHTO M294 for pipe sizes 12 to 60 inches in diameter.

Non-perforated pipe shall have water-resistant joints, except where watertight joints are specified on the project plans. Watertight joints may be substituted for water-resistant joints.

Watertight joints shall conform to the requirements of ASTM D 3212. Water-resistant joints shall conform to the requirements of ASTM D 3212, except that the internal water pressure test shall be conducted at 2.0 pounds per square inch, during which the joint leakage shall not exceed 200 gallons per inch of diameter per mile of pipe per day.

Magnetically-detectable plastic tape, placed in the trench 18 to 24 inches above the CHDPEP, shall have a minimum thickness of 5.5 mils and a minimum tensile strength of 5000 pounds per square inch. The tape shall be marked as to its purpose (i.e., "STORM DRAIN" or "IRRIGATION PIPE").

**1010-8.02 Field Inspection:**

For pipe 12 to 60 inches in diameter, after completion of the final fill and before any paving operation, the contractor shall dewater the installed pipe and provide the Engineer with either a video of the installation as detailed in Subsection 1010-8.03(A), a mandrel test log as detailed in Subsection 1010-8.03(B) or a physical measurement test log as detailed in Subsection 1010-8.03(C). The Engineer may waive this requirement for side drains and cross drains that are short enough to visually inspect from the end of the pipe.

The Engineer shall inspect all pipes for line and grade, joint gaps and misalignments, damage, and debris. Based on the results of the inspection and deflection testing, the Engineer may accept the installation, request an action plan from the contractor to remedy any excessive deflection, or direct the contractor to remove and replace the pipe as detailed in the table below.

If the contractor disagrees with results of the first deflection test(s), they may re-test the installation using any of the methods detailed in Subsection 1010-8.03. The contractor shall bear the cost of the re-testing; however, if the re-testing shows that deflection is no greater than 5.0% of the AASHTO minimum pipe diameter along the complete length of the pipe, the Department will reimburse the contractor for the cost of the re-test.

| **PIPE INSTALLATION** | |
|---|---|
| DEFLECTION (%) | ACTION |
| **0 – 5.0** | FULL ACCEPTANCE |
| **>5.0 – 7.0** | CONTRACTOR TO PRESENT ACTION PLAN TO ENGINEER<br>(ex. REMOVE AND RECONSTRUCT, OR REMOVE AND REPLACE)<br>RETEST |
| **>7.0** | REMOVE AND REPLACE<br>RETEST |

For pipe deflection greater than 5.0%, but less than or equal to 7.0%, the contractor shall present an action plan to the Engineer for remedying the excessive deflection. Options may include, but are not limited to, excavating the affected portion of the run and reconstructing the pipe, or removal and replacement of the affected portion. The Engineer's approval is required before the contractor may undertake any remedial efforts. For pipe deflections greater than 7% of the AASHTO minimum pipe diameter, the contractor shall remove and replace the affected length of pipe.

**1010-8.03 Inspection Procedures:**

**(A) Video Camera:**

**(1) Equipment:**

Use a pipeline video inspection camera with a laser light ring projector mounted onto and in front of the camera. The video shall be in the VHS format and provide a minimum resolution of 480 lines per inch. The videotape must have a distance marking, accurate to one foot per 100 feet. The contractor shall install a frame grabber card on the computer used to view the video image. The speed of the moving camera through the pipe shall not be greater than 30 feet per minute.

(2) **Calibration:**

Project the light or laser ring a set distance away from the camera so that the entire ring is visible in the image. Calibrate the projected light or laser ring at the beginning of the inspection by capturing the image of an object of known length or physically measuring the pipe at the location where the light or laser ring is projected.

(3) **Intervals:**

Deflection measurements shall be taken continuously for each pipe run. Deflection shall be expressed to the nearest 0.1% of the AASHTO minimum pipe diameter.

**(B) Mandrel:**

(1) **Equipment:**

The mandrel testing equipment shall be the rigid, nonadjustable type, with an odd number of legs (9 minimum) having a length not less than the nominal outside diameter of the mandrel. The diameter of the mandrel at any point shall not be less than 93% or 95% of the AASHTO minimum diameter size of the pipe being tested. The mandrel shall be fabricated of metal, fitted with pulling rings at each end, and stamped or engraved with its diameter on some segment of the mandrel other than a runner. Rope with minimal elongation characteristics (less than one foot per 100 feet) shall be used to pull the mandrel through the pipe. The rope shall be marked in one-foot increments.

(2) **Calibration:**

The mandrels' diameter shall be calibrated before and after each day's testing by use of true circular rings of diameters equal to 93% and 95% of the AASHTO minimum inside diameter of the pipe being tested. The Engineer shall be present during the calibration.

(3) **Procedure:**

The rope shall be drawn through the pipe, and then attached to the leading end of the 95% diameter mandrel. The length of the pipe run, as measured by the pull rope shall be recorded. A rope marked with one-foot increments shall also be attached to the mandrel's trailing end. The mandrel shall then be pulled through the pipe run by hand. If the 95% diameter mandrel's progress is refused the location shall be recorded. The 95% diameter mandrel shall then be run through the pipe from the opposite end until its progress is refused. That location shall be recorded.

If the 95% diameter mandrel does not pass completely through the pipe, the procedure detailed above is repeated using the 93% diameter mandrel.

### (C) Physical Measurement:

#### (1) Equipment:

Measuring devices marked with increments of 1/16 inch shall be used. These may include, but are not limited to, tape extensometers, metal measuring tapes, and wooden folding rulers with a 6-inch slide. A 24-inch level shall be used to verify vertical and horizontal control.

#### (2) Intervals:

Deflection measurements shall, at a minimum, be taken at each end of the pipe run and at intervals no greater than 5% of the pipe run (i.e., a minimum of 21 locations) based on the as-built length. Deflection measurements shall be taken vertically (6 to 12 o'clock) and horizontally (3 to 9 o'clock) at each location. The larger of the two measurements at each location shall be recorded. If a deflection greater than 5.0% of the AASHTO minimum pipe diameter is measured at any location, the Engineer shall require additional deflection measurements be taken at intervals of 1% of the pipe run, for a distance of up to 5% of the pipe run, in both directions from that location. Deflection shall be calculated as follows and expressed to the nearest 0.1%:

**% Deflection = [ (AASHTO Minimum Diameter – Measured Diameter) / AASHTO Minimum Diameter ] X 100**

Alternately, the contractor, with the Engineer's approval, may measure the pipe diameter after placement, but prior to backfilling (D1). Measurements shall, at a minimum, be taken at each end of the pipe run and at intervals no greater than 5% of the pipe run (i.e., a minimum of 21 locations) based on the as-built length. Measurements shall be taken vertically (6 to 12 o'clock) and horizontally (3 to 9 o'clock) at each location. Locations where the measurements are taken shall be marked. After completion of the backfilling, physical measurements are again taken at the marked locations. The larger of the two measurements at each location shall be recorded (D2). Deflection shall then be calculated as follows and expressed to the nearest 0.1%:

**% Deflection = [ (D1 – D2) / D1 ] X 100**

### (D) Testing Cost:

Testing costs are considered incidental to the construction and included in the unit cost of the pipe. No separate measurement or payment will be made for testing, except as specified in Subsection 1010-8.02 regarding re-testing.

# Pipe Profile Measurement Survey & Reporting Requirements

## 1.0 Digital Profiling.

### 1.1. Equipment

A combination color CCTV pipeline survey system with less than 1% "barrel distortion" , a cable distance counter, a circumferential laser ring projection system and certified measurement software shall be used to perform a measurement survey of new or existing lines as directed by ________________ . The equipment and software used must be tested and approved by a recognized independent testing group and include a tested certified accuracy of 0.5% or greater and a repeatability of 0.12% or greater.

### 1.1.2. Procedure

The measurement survey shall be accomplished using a CCTV color pipe inspection system as specified above. To determine the representative diameter of a given pipe, select a cross-section, in the pipe, evenly spaced between two points __ feet apart. The selected section should be in the barrel (away from collar or junction) and defect free. Measure internal diameter at the section. Take at least 4 measurements at the selected cross section. Ignore the section if the variance in measurements is too high and the section appears non-circular. Average the four (4) diameters and round to the nearest 1mm to arrive at the representative diameter of that line. If the pipe deformation is to great to make the above measurements then the pipe diameter as shown on the as built drawings may be used for the generation of the required reports.

A lens distortion calibration chart shall be imaged by the survey camera and recorded on the survey DVD in an MPEG2 format for 15 to 20 seconds. The measurement software shall include a lens distortion correction capability to assure the measurement accuracy regardless of the survey camera used.

A calibration target shall be imaged by the survey camera and recorded on the survey DVD in an MPEG2 format for 15 to 20 seconds. The measurement software shall have the capability to reference and calibrate to this target assuring unlimited accurate report processing of the recorded survey.

The survey system with laser ring projection head shall be placed into the pipe. The laser projection head shall be positioned, in relationship to the camera, so that the red laser ring fills 75% of the monitor screen height and the alphanumeric cable distance display does not interfere with the laser ring image. The camera and laser projection head shall be moved through the pipe at a speed not to exceed ______ feet per minute. The color video image, from the camera, shall be recorded on the survey DVD in an MPEG2 format.

### 1.2 Reports

Upon completion of the physical survey, the survey DVD and measurement software shall generate the following hard copy color reports of the survey. The Reports are to be saved as pdf's and provided to ________________on DVD in MPEG2 format.

### 1.2.1 Provide Pipe Ovality PV-Graph Report

Set ovality limit lines to 5%. Where a section of pipe exceeds this threshold, at the maximum ovality point, provide a Profile (cross-sectional) digital report with the internal diameter ring overlaid.

### 1.2.2 Provide Pipe Capacity PV-Graph Report

Set capacity limit lines to __ %. Where a section of pipe exceeds this threshold, at the maximum capacity point, provide a Profile (cross-sectional) digital report with the internal diameter ring overlaid.

### 1.2.3 Provide Flat Analysis Report

Set limit lines to __ % . Where a section of the flat graph is highlighted as red or dark blue coloring (excluding water), provide a Profile (cross-sectional) digital report with the internal diameter ring overlaid.

### 1.2.4. Minimum and Maximum Diameter (X-Y)

Set limit lines to ___ %. Where a section of pipe exceeds this threshold, at the maximum x or y diameter, provide a profile (cross-sectional) digital report with the internal diameter ring overlaid.

### 1.2.4 Saving Analyses Data

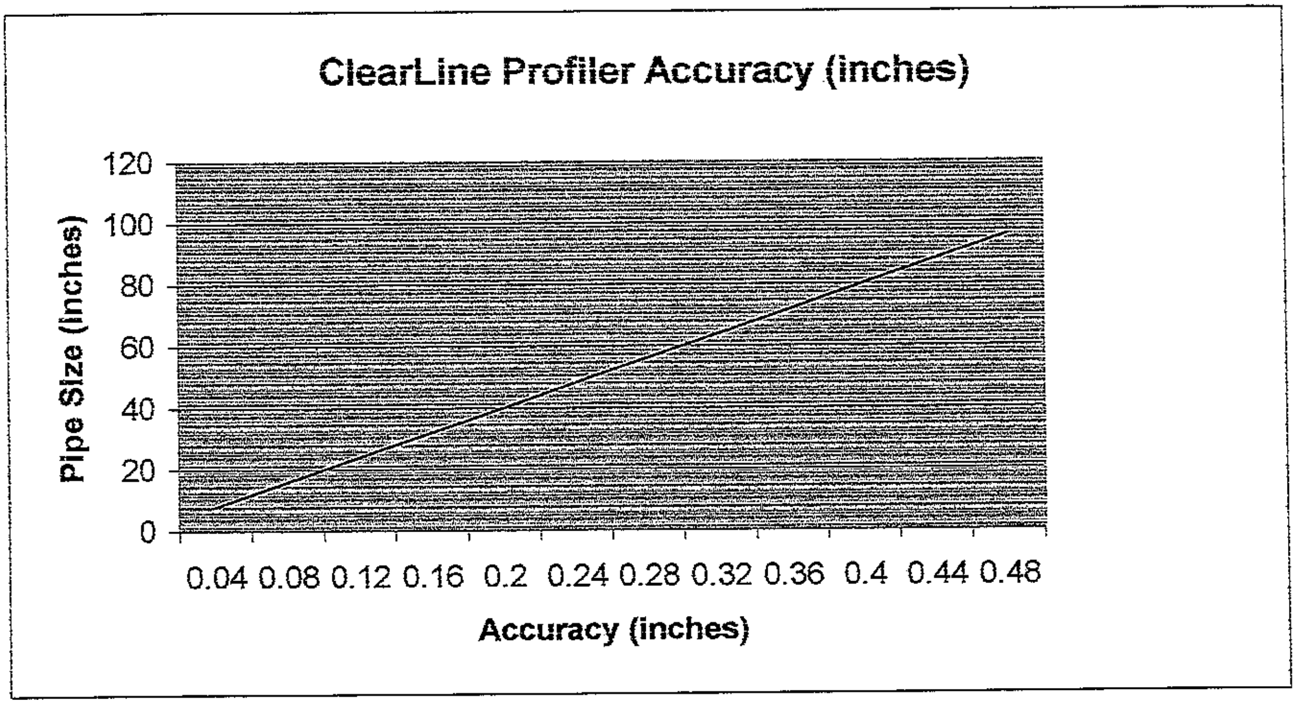
Provide one (1) copy of the of the CCTV survey recorded on DVD in the MPEG 2 format to ____________________________________ .

**Notes:** Only one cross-section is required where the above criteria have been exceeded (e.g. where both flat and ovality thresholds have been exceeded for one defect, provide only one profile).

# ClearLine Profiler Accuracy

## WRc Approved (PT/235/0904)

The WRc (ref: PT/235/0904) has certified the ClearLine Profiler to accuracy of 1mm in 200mm pipe (0.5%) for manual measurements. Similar accuracy obtained for the automated graphs (Ovality, capacity etc).




| Pipe Size (in) | Accuracy (in) | Percentage |
|---|---|---|
| 8 | 0.04 | 0.5 |
| 16 | 0.08 | 0.5 |
| 24 | 0.12 | 0.5 |
| 32 | 0.16 | 0.5 |
| 40 | 0.2 | 0.5 |
| 48 | 0.24 | 0.5 |
| 56 | 0.28 | 0.5 |
| 64 | 0.32 | 0.5 |
| 72 | 0.36 | 0.5 |
| 80 | 0.4 | 0.5 |
| 88 | 0.44 | 0.5 |
| 96 | 0.48 | 0.5 |

**Conditions:**

- Crisp clear laser profile
- Camera setup correctly (lens viewing parallel and straight, lens in centre of the pipe, lens clean)
- Profiler Configured correctly

**CCTV INTERNAL PIPE INSPECTION AND MEASUREMENT**

N.H. Bennett
Cues, 2006

The CCTV Inspection of pipelines began in the US about 1950 when Diamond Electronics Inc., a division of the Babcock & Wilcox Boiler Company, provided cameras to some electrical power generation facilities to inspect their water intake and discharge lines. As some of these facilities were municipal plants, the wastewater and storm water groups became interested in using CCTV for pipe inspection. These applications grew very little between 1950 and 1964 when national concerns developed over the costs of treating ground water infiltrating into the sewer systems through faulty joints and broken or deteriorated joint seals. In 1964 chemical grouting was introduced that used a pipe plug style packer to test the joint and if leaking inject a two part sealing fluid into it. One operational obstacle was how to you know where the joint was located and how do you place the packer in the proper position to test and seal the joint. At this time the CCTV system became a standard item in most municipal wastewater and storm water collection systems. Since the 1980's methods and types of pipe rehabilitation, including trenchless technologies, have grown at a rapid rate. One of the major requirements was for the ability to accurate measure internal pipe ovality.

All CCTV camera lenses create some distortion and non-linearity of the displayed image. This is due to a series of factors, such as the difference between lens and subject at the center verses at the edge of the display. These distortions consist of a combination of spherical distortion, pin-cushioning, and barrel distortion, and usually become most pronounced near the edges of the subject itself. Many pipe inspection cameras accentuated the barrel distortion problem by using very wide-angle lens (fisheye) to reduce their need for light to obtain a usable picture. Light falls off by the square of the distance (law of Physics), therefore if a camera had a very wide angle lens it could obtain a usable picture in the same diameter pipe using much less light than a camera that used a narrow angle lens. Larger light requirements generate heat at the camera and increase the power requirements of the system and voltage drop through the connecting cable (Ohms Law). Barrel distortion can be very misleading when looking at a pipe on the video monitor. It can be misinterpreted as being "out of specification" when in fact it is not. It is impossible to manually measure a round pipe on a video monitor with accuracy. The best option is to use a camera with 1% or less barrel distortion. If the camera used has barrel distortion and is not corrected by the software, it may provide false data in the measurement survey and potential unnecessary rehabilitation costs and/or other liabilities.

The camera itself may be a source of linearity errors. The regular spacing of pixels on a CCD Camera vary very slightly across its face. Older vacuum tube cameras are notorious for severe nonlinearity. Because of this, the use of a tube type camera is not recommended when doing internal pipe measurements.

For best picture results the inspection camera should be positioned on the centerline of the pipe being inspected. Here again we are using the lighting law to produce the best image with greatest clarity.

This will also allow the cameras automatic iris to close to its minimum opening based on sufficient and even scene lighting. If the camera is positioned near the bottom of the pipe then the iris may correct for the stronger illumination coming from the bottom of the pipe and close down. This can result in unusable images of the pipe crown and hide the defects in it. All CCTV cameras depth of field (area within focus) is controlled by its iris position. A camera with a closed iris will have a much large depth of field than that same camera with the iris open to its maximum.

In the early 1980's, European water companies began to look for more and better trenchless methods for rehabilitating failed pipes. The interruption costs of dig and replace were becoming a very sever operational and economic problem. Pipe relining processes were developed but along with their development the need to have more and accurate internal pipe measurements became mandatory. Pipe ovality was a major problem and is a required component in calculating liner thickness even today (ASTM 1216). To meet this need, several circular visible light projection systems were developed. However due to the inherent image distortion of the inspection cameras and the lack of viable imaging correction software, these systems were not readily accepted. To replace these systems, water companies and government research bodies looked into Laser profiling. After much research they determined that the technology could fill the industry needs and the state of the art in imaging software had develop solid algorithms to correct for normal camera distortions. In 2003 Laser pipe profiling was introduced, which, because of its software base and new image correction algorithms could correct for the physical inaccuracies generated by the CCTV camera systems.

Today, laser profile systems will either project a circular line around the internal circumference of the pipe or use a rotating pulse laser at a speed that appears to be a continuous line when imaged by a CCTV camera. In the Cues/Cleanflow Clearline system a projected laser system is used. A projected laser system has no moving parts to go out of alignment or is susceptible to mechanical failure. The laser projector is placed in front of the video camera at a distance so that the circular image appearing on the video monitor fills 75% of the monitor viewing area. The camera and profiler are then moved through the pipe at a speed not to exceed 30 feet per minute (NASSCO Standard). The camera images the laser circle 30 times per second. Each video image passes through a software filter to extract the laser ring information only. The software then converts the analog video image into a digital image. The software generates the precise centerlines (x-y) of the circle. From this center point a radius measurement is made every $2^0$ around the circular profile (5,400 measurements per second, 324,000 per minute). The data, from each circle, is then stored in a master database. From this database software, manipulation of the collected data will generate the ovality, capacity, x-y dimensions, a color-coded digital flat map image display and a 3-dimensional color-coded display of the inspected line. Each display is available as a hard copy report and any visible or digital image captured during the inspection can be viewed or printed as selected by the operator.

A major consideration is the accuracy of the data generated. The Clearline profiler has been independently tested by the WRc (Water Resource Council) of the UK and the IKT of Germany, and certified to have an accuracy exceeding 0.5% of the pipe diameter and a repeatability of greater than 0.12%.

The laser profile is only usable for measurements at and above the waterline. For profile data and measurement below the waterline, special narrow band SONAR has been developed. The Sonar image can be processed by the Clearline software but requires a special Sonar translation module.

Recently the industry has looked at some new non-contact measurement technology to measure the width and length of cracks in pipes as well as pipe joint separation. Again digital measurements coupled with newer pan-tilt-zoom CCTV inspection cameras have provided a solution. However, this technology requires the use of cameras without barrel distortion or the other major optical problems as described above. Digital Video Calipers are available that take the composite video image from the camera, have video monitor displayed movable crosshairs to align the item being measured between the x-x axis or y-y axis, and generates a digital distance display on the video monitor. This information can be electronically recorded on a CD/DVD or videotape or stored in a master software database. Accuracy capability again will be less than 0.5% of the measured defect, but requires control of the operating conditions and camera capabilities.

Another measurement that has been incorporated into pipeline CCTV camera systems are grade and slope measurement inclinometers. These are usually built inside the camera, get their power and transmit their measurement data over the standard camera cable. The slope data is generated within the inclinometer and sampled several times per second. From this data a hard copy printout is available from the systems alphanumeric data generator. The data will include the position (cable distance) and the angle. This data can then be transferred to a standard excel file and a grade or slope graph of the pipeline generated. Sophisticated master inspection software systems are available that generate the graph automatically and in unison with the live video image. These data can be invaluable when analyzing line problems when the line has debris or other questionable conditions.