Designation: F3220 – 17

# Standard Practice for Prioritizing Sewer Pipe Cleaning Operations by Using Transmissive Acoustic Inspection[1]

This standard is issued under the fixed designation F3220; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This practice covers procedures for assessing the blockage within gravity-fed sewer pipes using transmissive acoustics for the purpose of prioritizing sewer pipe cleaning operations.[2] The assessment is based on an acoustic receiver measuring the acoustic plane wave transmitted through the pipe segment under test in order to evaluate the blockage condition of an entire segment and to provide an onsite assessment of the blockage within the pipe segment. (**1**, **2**, **3**, **4**, **5**)[3]

1.2 The scope of this practice covers the use of the transmissive acoustic inspection as a screening tool. The blockage assessment provided by the acoustic inspection should be used to identify and prioritize pipe segments requiring further maintenance action such as cleaning or visual inspection, or both. Thereby, also identifying the pipe segments which are sufficiently clean and do not require additional maintenance action.

1.3 This standard practice does not address structural issues with the pipe wall.

1.4 The inspection process requires access to the manhole (MH) from ground level. It does not require physical access to the sewer line by either the equipment or the operator.

1.5 This standard practice applies to all types of pipe material.

1.6 The inspection process requires access to sewers and operations along roadways or other locations that are safety hazards. This standard does not describe the hazards likely to be encountered or the safety procedures that must be carried out when operating in these hazardous environments.

1.7 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Terminology

2.1 *Definitions:*

2.1.1 *authority, n*—party responsible for the generation and verification of performance to job specification(s) and contract requirements.

2.1.2 *blockage assessment, n*—the aggregate blockage within a pipe segment between two adjacent MHs.

2.1.3 *closed circuit television (CCTV), n*—a closed circuit pipeline inspection television system including a camera, camera transporter, integrated lighting, central control system, video monitor, and recording device.

2.1.4 *coordinated universal time (UTC), n*—is the primary international time standard for regulating clocks and time.

2.1.5 *geographic information system (GIS), n*—system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data.

2.1.6 *global position system (GPS), n*—space-based navigation system that provides location and time information anywhere on or near the earth where there is an unobstructed line of sight to four or more GPS satellites.

2.1.7 *manhole (MH), n*—vertical shafts intersecting a sewer that allows entry to the sewer for cleaning, inspection, and maintenance.

2.1.8 *pipe segment, n*—the section of a sewer line between two adjacent MHs.

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[1] This practice is under the jurisdiction of ASTM Committee F36 on Technology and Underground Utilities and is the direct responsibility of Subcommittee F36.20 on Inspection and Renewal of Water and Wastewater Infrastructure.

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[2] The transmissive acoustic inspection is covered by Patent US8220484B2. Interested parties are invited to submit information regarding the identification of an alternative(s) to this patented item to the ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

[3] The boldface numbers in parentheses refer to a list of references at the end of this standard.

2.1.9 *segment's acoustic fingerprint (SAF), n*—acoustic feature set which characterize a pipe segment. The acoustic feature set is used in classifying the blockage assessment. (**2, 6**)

2.2 *Abbreviation:*

2.2.1 *ID*—identification

## 3. Summary of Practice

3.1 Transmissive acoustic inspection operational procedure is based on measuring the signal received from an active acoustic transmission through a pipe segment. Fig. 1 depicts the general configuration of a transmissive acoustic inspection. The acoustic transmitter generates sound waves just below the entrance to the MH which couple into the connecting sewer line segments. The sound wave propagates in the air gap above the wastewater flow from the speaker to the receiving microphone attached to the acoustic receiver located at the adjacent MH. The acoustic receiver measures the acoustic plane wave from the transmitted signal in order to evaluate the blockage condition of an entire segment and provides an onsite blockage assessment. Both the speaker and the microphone are placed just within the opening of the MH and should never come in contact with the wastewater flow. The operators have no requirement for confined space entry.

3.2 Transmissive acoustic inspection principle of operation is based on the observation that a pipe segment is a natural acoustic waveguide. Commonly encountered sanitary sewer defects, such as roots, grease, pipe sags, and pipe breakages naturally absorb or reflect acoustic energy. These defects change a segment's acoustic properties and produce a measurable impact on the received signal at the microphone, that is, the segment's acoustic fingerprint (SAF). Each segment has an individual SAF representative of its current state. Transmissive acoustic inspection measures and assesses the SAF to determine the Blockage Assessment, that is, an estimate of the aggregate blockage within the pipe segment between the acoustic transmitter and acoustic receiver.

## 4. Significance and Use

4.1 *Significance:*

4.1.1 Collection system maintenance requires allocating cleaning resources to the right place prior to system failure (sanitary sewer overflows, mainline blockages, and building backups). Transmissive acoustic inspection provides a tool to assist in allocating cleaning resources by prioritizing pipe segments based on their blockage assessment and thereby facilitating efficient cleaning resource allocation.

4.1.2 This standard practice provides minimum requirements and suggested practices regarding the transmissive acoustic inspection of gravity-fed sewer line blockage assessment to meet the needs of maintenance personnel, engineers, contractors, authorities, regulatory agencies, and financing institutions.

4.2 *Limitations and Appropriate Uses:*

4.2.1 The blockage assessment provided by the transmissive acoustic inspection may not resolve the type of blockage(s) within the pipe segment nor resolve the location(s) of the blockage(s) within the pipe segment.

4.2.2 Due to the physics associated with transmissive acoustic inspection, the blockage assessment may be confounded due to:

*(1)* Structural designs resulting in poor acoustic coupling,

*(2)* Pipe segments completely filled with water, for example, full pipe sag or inverted siphon, and

*(3)* Transient conditions within the pipe, for example, active lateral discharge or temporary flow surcharges.

These issues are addressed as part of the performance criteria specified in X1.5.

4.2.3 Due to physics associated with acoustics and trade-offs in equipment design for conducting transmissive acoustic inspection, there are limitations based on the following pipe segment attributes:

*(1)* Pipe diameter,

*(2)* Pipe segment length,

*(3)* MH depth, and

*(4)* Flow levels.

Inspections conducted outside the manufacturer's recommended ranges for these pipe segment attributes may result in the transmissive acoustic blockage assessment deviating from the performance criteria specified in X1.5.

4.2.4 Inspections conducted between non-adjacent MHs, for example, skipping an intermediate MH, may result in the transmissive acoustic blockage assessment deviating from the performance criteria specified in X1.5.

## 5. Procedure

5.1 If the work is to be conducted by an outside contractor, apart from the provisions generally included in an inspection

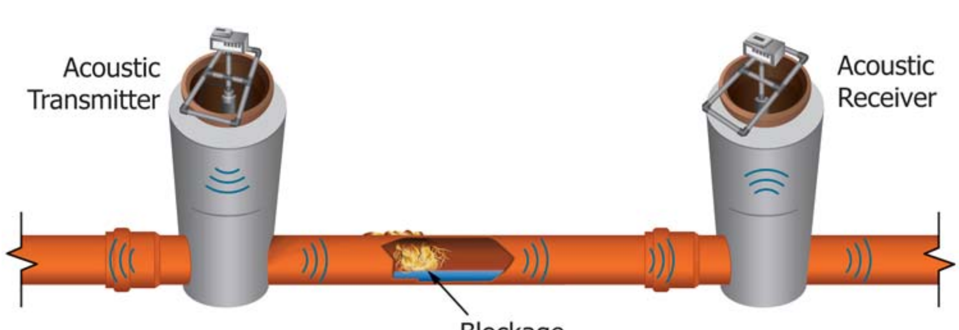


**FIG. 1 Transmissive Acoustic Inspection System Operation**

services contract, the transmissive acoustic inspection contract should define and assign responsibilities for the following items:

*(1)* Access to the site of work is to be provided to the extent that the authority is legally able to so provide or, if not so able, a written release from responsibility for the performance of work at sites where access cannot be made available;

*(2)* MH numbering system for all areas of the project;

*(3)* Location, exposure, and accessibility of all MH should be provided; and

*(4)* Geographic Information System (GIS) maps should be provided, when available.

5.2 The transmissive acoustic inspection procedure detailed in this practice is based on the transmissive acoustic inspection equipment meeting the minimum requirements detailed in Appendix X1.

5.3 The transmissive acoustic inspection should only be conducted for pipe segments which meet the manufacturer's recommended specifications for: pipe diameter, pipe segment length, MH depth, and flow levels.

5.4 The transmissive acoustic inspection shall be conducted using the following procedure for each pipe segment under test. The acoustic transmitter and the acoustic receiver shall be placed on adjacent MHs by their respective field operators. The transducers (microphone and speaker) shall be placed within the MH, as illustrated in Fig. 1.

5.5 The inspection shall follow the manufacturer's recommendation for the equipment with the procedure outlined as follows:

5.5.1 Based on the authority's policy for providing a pipe segment's length, the acoustic receiver operator enters the length of the pipe segment under test. This parameter is used in assessing the blockage assessment. The pipe segment's length should be based on the authority's GIS data, when available, and when deemed to be sufficiently accurate as specified by the manufacturer's requirements, for example, pipe segment's length is entered to within ±50 ft.

5.5.2 The field operators initiate the automated test. The test shall be started on both the acoustic transmitter and acoustic receiver within the time interval specified by the equipment manufacturer.

5.6 Following each inspection, the field operator shall record the following: acoustic receiver identification (ID), unique blockage assessment ID, upstream MH ID, downstream MH ID, pipe segment's location information, blockage assessment, date, and time. The operator's recorded data duplicate and augment the data recorded electronically by the transmissive acoustic inspection equipment and is used in the data registration quality control (7.3 and 7.4).

5.7 The transmissive acoustic inspection equipment operation shall be verified on a daily basis prior to use. Only the verification procedure specified by the equipment manufacturer shall be used. The verification results will be electronically recorded by the transmissive acoustic inspection equipment.

5.8 On a daily basis, the data recorded electronically by the transmissive acoustic equipment shall be uploaded for report generation and data registration quality control.

## 6. Report

6.1 A report shall be produced as described in 6.2 through 6.4. The objective of the report is to provide clear and concise information to assist in prioritizing cleaning operations on the pipe segments inspected.

6.2 *Daily Verification Report*—A table listing the operation verification results. The table is based on data recorded electronically by the transmissive acoustic inspection equipment. Each table entry will include: the date, the time, and the results of the equipment operation verification. If an operation verification fails, then the table entry will indicate the corrective measures taken as well as an additional operation verification entry to show that the corrective measures were successful.

6.3 *Summary of Pipe Sections Tested*—A table of pipe sections tested shall be produced that shows the name/number of the upstream and downstream MHs, the distance between MHs as specified by the authority's GIS data (when available), the distance between MHs as measured by using the inspection equipment global position system (GPS) location estimates, the pipe length specified by the operator in the field as recorded by the equipment, the acoustic receiver device ID, measurement timing verification, the blockage assessment ID, the blockage assessment based on the operator specified pipe length in the field, and the blockage assessment based on the corrected pipe length. In addition, the table shall indicate whether the:

*(1)* Pipe segment location was verified, that is, location was verified by correlating the field operator recorded information with the transmissive acoustic inspection equipment GPS location estimates and the authority's GIS data;

*(2)* Pipe segment was tested based on skipping an intermediate MH due to the intermediate MH not being located or not being accessible; and

*(3)* Pipe segment was not tested based on not being able to locate or access two adjacent MHs.

6.4 *Field Recorded Electronic Data*—The following reports will be provided based on the data recorded by the transmissive acoustic inspection equipment:

6.4.1 A table of the unedited Field Recorded Electronic Data, as illustrated in Fig. 2. The table will include for each pipe segment evaluated: unique measurement identification, coordinated universal time (UTC), GPS location, operator pipe length setting, blockage assessment, and acoustic receiver status. The authority will have access to the unedited Field Recorded Electronic Data.

6.4.2 Graphical representation shall be provided of the data as illustrated in Fig. 3.

6.4.3 When the authority's GIS data is available, the graphical representation should provide a color coding to indicate whether or not the MH was accessible by the field operators. Different colors or symbols should be used for the MH locations to indicate: the MH was accessible, the MH was unable to be located, or the MH was not accessible.

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| | Meas. ID | RX Oper. ID | RX Hw ID | TX Oper. ID | TX Hw ID | Date/Time * =estimated | Meas. Dur. (sec) | Oper. Pipe Lng (ft) | Eval. Pipe Lng (ft) | Meas. Status | Pipe Status | Field Assess | GPS Assess | Notes | Rx Lat/Lon | Tx Lat/Lon |
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**FIG. 2 Transmissive Acoustic Inspection Field Recorded Data and Post Processing Blockage Reassessment Based on Pipe Length Evaluated Using GPS and GIS Data**

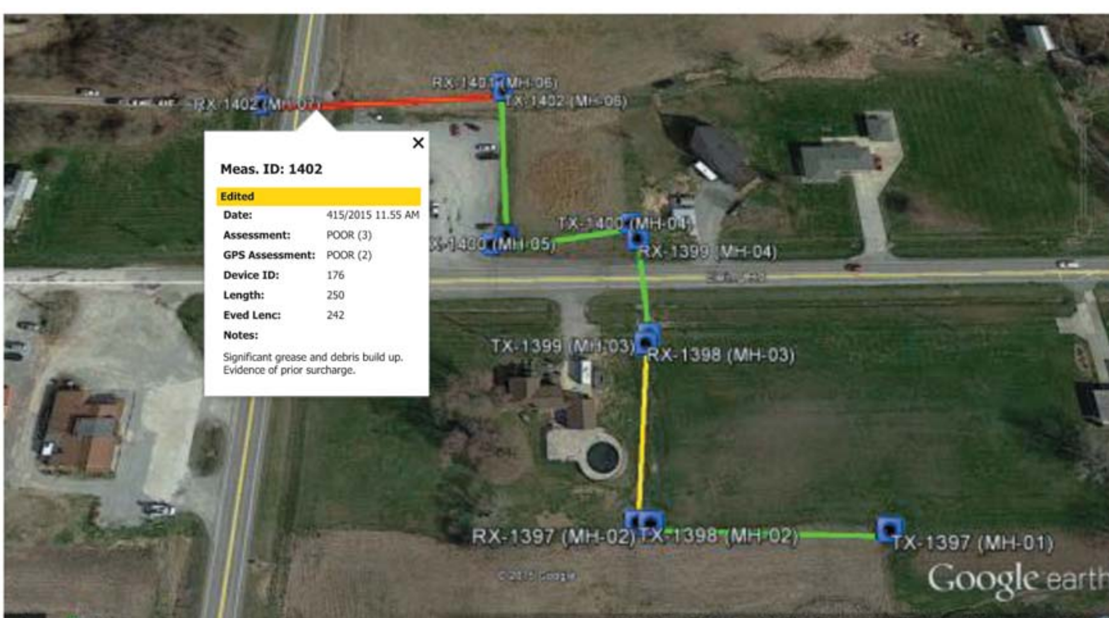


**FIG. 3 Geographical Representation of Transmissive Acoustic Inspection**

## 7. Quality Control

7.1 *Equipment Operation Verification*—The transmissive acoustic inspection equipment operation shall be verified on a daily basis prior to use. Only the verification procedure specified by the equipment manufacturer shall be used.

7.2 *Measurement Timing Verification*—For each pipe segment tested, the acoustic transmitter shall be verified to be transmitting over the time interval during which the acoustic receiver is assessing the pipe segment's blockage.

7.3 *Measurement Location Verification*—For each pipe segment tested, the location of the measurement shall be verified to ensure the blockage assessment is associated with the correct pipe segment. The verification process shall use the field operator's recorded information with the transmissive acoustic inspection equipment GPS information and the authority's GIS data.

7.4 *Pipe Length Verification and Reassessment*—For each pipe segment tested, the pipe length entered by the field operator to perform the inspection shall be verified. If the pipe length used is not within the tolerance specified by the equipment manufacturer, then the blockage assessment shall be re-evaluated using the SAF data and the corrected pipe length.

## 8. Keywords

8.1 acoustic inspection; blockage assessment; cleaning operations; combined sewer; condition assessment; maintenance operation; prioritizing cleaning; sanitary sewer; wastewater collection system

# APPENDIX

**(Nonmandatory Information)**

## X1. TRANSMISSIVE ACOUSTIC INSPECTION EQUIPMENT

X1.1 Allocating cleaning resources impacts the collection system performance as depicted in the graph in Fig. X1.1. The graph is a scatter plot of overflows/100 miles versus percentage system cleaned based on self-reporting from sixteen municipalities' annual performance reports (**2**). Linear regression indicates a strong correlation between cleaning effort and overflow reduction. Due to the inherent random nature of the underlying mechanisms that build up to overflows, there is likely a diminishing return with more cleaning. Therefore, as the percentage of the system cleaned increases, an even larger proportion of unnecessary cleaning will be conducted. Transmissive acoustic inspection provides a tool to assist in allocating cleaning resources by prioritizing pipe segments based on their blockage assessment and thereby facilitating efficient cleaning resource allocation.

X1.2 The transmissive acoustic inspection practice is based on equipment that meets the following minimum requirements for the acoustic receiver, acoustic transmitter, and the blockage assessment performance criteria.

### X1.3 Acoustic Transmitter

X1.3.1 Signal generating subsystem and transducer (speaker) capable of generating the acoustic signal to assess the SAF at the acoustic receiver.

X1.3.2 GPS subsystem that automatically estimates the location of the acoustic transmitter at the time of a blockage assessment and is used in stamping each measurement with UTC.

X1.3.3 Electronic storage for recording UTC, location, and acoustic transmitter status for a minimum of 100 measurements.

X1.3.4 Wireless interface to allow recorded measurements to be communicated to the acoustic receiver.

X1.3.5 User interface allowing operator control and status of the acoustic transmitter.

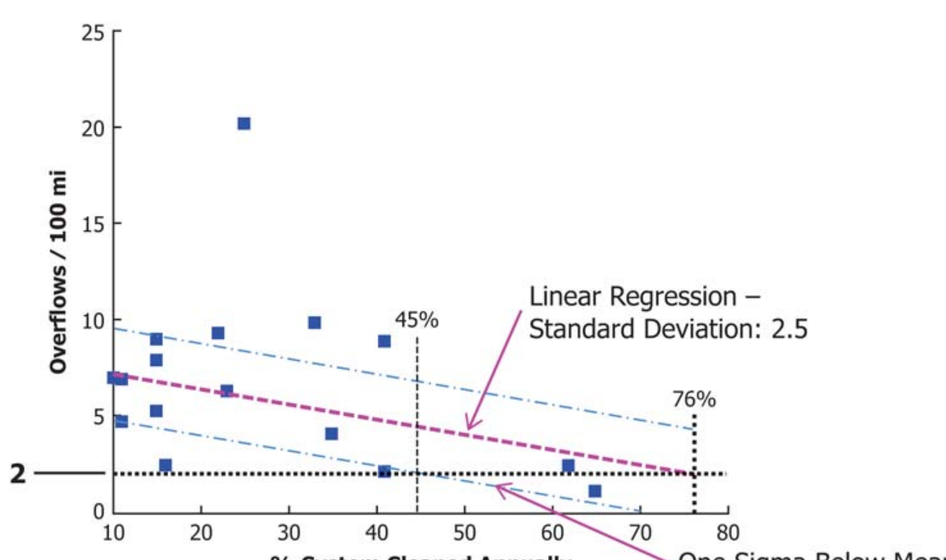


**FIG. X1.1 Comparison of Sixteen Municipalities' Performance in Maintaining Their Collection System's Overflow Rates Based on Percentage of System Cleaned Annually**

## X1.4 Acoustic Receiver

X1.4.1 Signal processing subsystem and transducer (microphone) capable of receiving the acoustic signal and to assess the SAF based on the signal transmitted from the acoustic transmitter.

X1.4.2 GPS subsystem that automatically estimates the location of the acoustic receiver at the time of a blockage assessment and is used in stamping each measurement with UTC.

X1.4.3 Electronic storage for recording unique measurement identification, UTC, location, operator pipe length setting, blockage assessment, and acoustic receiver status for a minimum of 100 measurements.

X1.4.4 Electronic storage for recording SAF data for a minimum of 100 measurements. The SAF data enables reassessment.

X1.4.5 Wireless interface to allow recorded measurements to be communicated from the acoustic transmitter.

X1.4.6 Wireless or wired interface, or both, to provide electronic interface to networked computer, tablet, or mobile device, or combinations thereof, to allow measurement stored in the acoustic receivers electronic storage to be extracted and saved.

X1.4.7 User interface allowing operator control and status of the acoustic receiver.

## X1.5 Blockage Assessment Performance Criteria

X1.5.1 The blockage assessment performance criteria is established to address the industry's objective for a cost effective tool for prioritizing cleaning operations. When the equipment is used as specified, the transmissive acoustic inspection should be a conservative estimator for pipe segments' blockage assessment as outlined in this section.

X1.5.2 Prior to developing the performance criteria, factors impacting the transmissive acoustic inspection performance are reviewed. These factors are divided into two categories: factors which can be addressed by equipment design and others which cannot.

X1.5.3 The transmissive acoustic inspection equipment is designed to discriminate between degrees of aggregate blockage within a pipe segment. This is based on the algorithm at the receiver interpreting the outcome the aggregate blockage within a pipe has had on the acoustic energy received, that is, the SAF. Pipe segment attributes, such as pipe segment length, pipe diameter, MH depth and flow levels, effect the SAF and are not correlated with the blockage. Over a specified range for each of the pipe attributes, the effect on the acoustic energy is predictable with limited variability. Therefore the effect of the pipe attributes can be addressed in the transmissive acoustic inspection equipment design. As indicated in 4.2.3, operating the equipment outside the manufacturer's specified limits for the pipe attributes may affect the blockage assessment reliability and can cause the blockage assessment to deviate from the performance criteria stated in X1.5.6.

X1.5.4 Measurement conditions can occur which are not predictable. As an example, if during a transmissive acoustic inspection a lateral is discharging, then the curtain of water obstructs the acoustic wave. This can result in the blockage assessment being lower than would be measured based solely on the obstructions within the pipe segment. Under this condition, the transmissive acoustic inspection cannot discriminate between the lateral discharge and an actual blockage. 4.2.2 lists additional measurement conditions which may confound the transmissive acoustic inspection resulting in a possible inconsistent blockage assessment. These conditions add to the variability in the transmissive acoustic blockage assessment.

X1.5.5 *Summarizing*—The blockage assessment performance criteria is developed to bound the variability in the assessment by comparing it to a known assessment tool in the industry, closed circuit television (CCTV). Comparing a CCTV based blockage assessment to the transmissive acoustic blockage assessment requires a consistent framework. Since the transmissive acoustic inspection can only provide a survey grade assessment of the aggregate blockage within a pipe segment, the detailed inspection results provided by CCTV need to be mapped/interpreted from the same perspective. This mapping requires a subjective human assessment of the degree of aggregate blockage within the pipe segment using the same scoring range as the transmissive acoustic inspection.

$$D = Y - X \quad \text{(X1.1)}$$

where:

*X and Y* are defined as the transmissive acoustic blockage assessment and the CCTV based blockage assessment, respectively.

Given the ranges for $X$ and $Y$ are 0 to 10 with zero (0) indicating complete blockage and ten (10) indicating an essentially clean segment, then the range of $D$ is from -10 to 10. For $D<0$, implies the CCTV based blockage assessment is less than the transmissive acoustic blockage assessment and for $D<<0$, the outcome is a False Negative meaning the CCTV based blockage assessment indicated the pipe segment under test was likely more blocked than the transmissive acoustic blockage assessment. For $D>0$, the CCTV based blockage assessment is greater than the transmissive acoustic blockage assessment, and for $D>>0$ a False Positive outcome meaning the CCTV based blockage assessment indicated the pipe segment under test was likely to be less blocked than the transmissive acoustic blockage assessment. Blockage assessments which are classified as false negatives are more likely to result in overflows and those classified as false positives may result in unnecessary cleaning. (7)

X1.5.6 Using the previous development, the performance criteria for the transmissive acoustic blockage assessment are defined as follows:

$$\text{Criteria I:} \quad P_r[D \geq -2] = P_r[Y - X \geq -2] > 0.9 \quad \text{(X1.2)}$$

with 90 % confidence, and

$$\text{Criteria II:} \quad P_r[D \geq 4] = P_r[Y - X \geq 4] < 0.4 \quad \text{(X1.3)}$$

with 90 % confidence.

Criteria I governs the false negative outcome for the blockage assessment and Criteria II governs the false positive outcome. Criteria I is more restrictive than Criteria II; this is in line with the objective for Transmissive Acoustic Inspection to be a conservative estimator.

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