Online Turbidimeter Calibration and Verification Guidance

Iowa Department of Natural Resources

Turbidity meters (known as turbidimeters) are used to measure the clarity of water. A properly calibrated turbidimeter allows a system to judge the effectiveness of treatment and ensure the water being delivered to customers is safe. Iowa Administrative Code 567—Chapter 43 requires turbidity measurements to be performed on representative samples of the system's filtered water (Combined Filter Effluent or CFE) every four hours (or more frequently) that the system serves water to the public. Continuous turbidity monitoring may be substituted for grab sample monitoring if the public water supply validates the continuous measurement for accuracy on a regular basis using a turbidity protocol approved by the department and audited for compliance during sanitary surveys. Chapter 43 also requires continuous monitoring of turbidity on each individual filter (Individual Filter Effluent or IFE). IFE data must be recorded at least every 15 minutes.

Major elements of a turbidity protocol shall include, but are not limited to: sample measurement location, method of calibration, calibration standards, calibration frequency, method of verification, verification frequency, documentation procedures, data collection procedures, data recording frequency, and data reporting procedures. This document is intended to provide guidance in the development of a turbidity protocol with verification that meets the requirements described above.

Common Definitions

Calibration – is a procedure which checks or adjusts instruments accuracy by comparison with a defined primary standard or reference.

Verification – is a procedure which is used to check whether or not an instrument's calibration is within certain limits.

Primary Standard – is a standard used to calibrate the instrument response with respect to analyte concentration. Formazin and the stabilized form of formazin are the most common types of primary standard. Also available is a commercially manufactured liquid suspension of Styrene divinylbenzine polymer (SDB) such as ProCal. Formazin standards may be user-prepared in the lab or purchased in various stabilized pre-prepared forms such as StabilCal. User-prepared solutions typically do not have a very long shelf life compared to pre-prepared stabilized form of formazin and must be discarded after one week or per the manufacturer's instructions. SDB solutions are more costly but remain stable almost indefinitely.

Secondary Standard – is a standard that the manufacturer or an independent testing laboratory has certified will give instrument calibration results equivalent to the results obtained when the instrument is calibrated using a primary standard within certain limits. Examples of secondary standards are liquid latex, SDB, or Gelex solutions that are sealed in a sample container. They may also include glass rods, plates, or plastic cylinders and mirror devices designed for use in a specific manufacturer's instrument such as a Hach ICEPIC. A secondary standard is used for instrument verification and should be checked periodically against a primary standard.

Sample Measurement Location

Continuous reading turbidimeters should be located as close as possible to the sample tap and be tapped at a location that is representative of process performance. The CFE sample tap must be

located at a point that includes effluent from all filters. The CFE sample should represent the performance of the filters and not be subject to negative interference due to additional settling in a clearwell or positive interference due to precipitation of iron, manganese, or post floc due to pH adjustment. For IFE turbidity samples, the sample collection tap must be on the filtered water line prior to confluence with water from another filter.

The protocol must include the following information:

- The location(s) in the process stream where turbidity data being used for compliance is collected.
- Instrument type, make, model, method, etc.

Method of Calibration and Verification

Calibration and Verification should follow manufacturer's procedures for a particular instrument. Calibration must be done utilizing a primary standard, whereas verification can be done using either a primary or secondary standard.

There are two basic verification methods - wet or dry. The dry verification method is performed using a dry calibration device such as an ICEPIC or Glass Rod Secondary Standard. Wet verification is performed utilizing a premade or user prepared standard. Online turbidimeter performance may also be verified by comparison against another properly calibrated instrument. However, this method is not recommended due to the potential for error.

The protocol must include the following information:

- Detailed written procedure or reference to the manufacturer's procedures being utilized for calibration and verification.
- Type of standards being utilized for both calibration and verification.
- If user prepared standards are being used, include a written procedure for preparation.

Calibration and Verification Frequency

Turbidimeters must be calibrated at least as often as recommended by the manufacturer, but no less than every 90 days and after any significant maintenance or repair such as bulb replacement or cleaning the instrument body. The calibration of each turbidimeter used for compliance must be verified at least once per week with a primary standard, secondary standards, or the manufacturer's proprietary calibration confirmation devise or by a method approved by the department. Calibration at least every 90 days and verification at least once per week are required by rule.

To be considered an acceptable verification, turbidity measurements greater than 0.5 NTU must be within +/- 10% of the reading assigned to the standard or reference material. Turbidity measurements 0.5 NTU or less must be within +/- 0.05 NTU or less of the reading assigned to the standard or reference material. If the verification is not within the acceptable range, the turbidimeter must be recalibrated.

The protocol must include the following information:

- The utility's schedule for routine calibration and verification and any other instances in which calibration and/or verification would be needed.

Data Collection, Documentation, and Reporting

Daily and long term data collection, storage, and handling procedures are an integral component of any monitoring program. Electronic plant turbidity data logs should be created in an easily accessible format (e.g., csv, xlsx) and be located in a directory that is easily accessible to operators. Electronic turbidity data logs should include accurate time/date stamp and be tagged to identify the plant operating conditions (i.e., filter-to-clearwell, filter-to-waste, backwash, and out-of-service). Ideally, sorting functionality should be included to allow the operator to review historical data related to a specific plant operating condition (e.g., filter-to-clearwell data only). Electronic data should be backed up routinely.

Rules require IFE, CFE, and calibration/verification data to be reported on the Monthly Operation Report (MOR). MORs and all data generated to comply with the self-monitoring requirements, including but not limited to recorder charts, logbooks, bench sheets, SCADA records, and electronic files, must be maintained at the facility for no less than 5 years.

The protocol must include the following information:

- How turbidity data being used for compliance purposes is collected (e.g., grab sampling vs continuous monitoring, instrument type, method, location, etc.)
- The frequency in which turbidity data is collected and documented. For continuous instrumentation, the protocol should indicate at what frequency data sent to SCADA is recorded in the data historian (e.g., 5, 10, 15 minute intervals).
- How turbidity values being reported on MOR are obtained from the data collected (e.g., are the values manually pulled off of a daily trend line, operator logs, or generated from the logged SCADA data at some specified interval.)
- How maximum daily values for IFE and CFE are determined.
- Description of any other data related quality control practices completed by staff (e.g., any protocols for reviewing data spikes, excluding data from reporting either manually or in SCADA programming such as during filter start-up or backwash and when filters are off, etc.)
- Description of where and how historical data is stored to allow for easy retrieval for future review.
- Procedure for documenting calibration/verification information (e.g., the name of the person conducting calibration/verification, calibration/verification data, and any adjustments or maintenance made to the instrument in the instrument's logbook).

Other Items for Consideration

Turbidity and other water quality data is used to evaluate performance, make data based decisions for process control, and for regulatory compliance. Therefore, ensuring this data is as accurate and consistent as possible is critical. The accompanying checklists were developed by the Region 6/7 Area Wide Optimization Program Workgroup and include additional items that can affect data integrity. These items should be considered when a utility is evaluating their compliance and operational monitoring program.

For More Information

Contact your Regional DNR Field Office:

FO1 (Manchester): 563-927-2640
FO2 (Mason City): 641-424-4073
FO3 (Spencer): 712-262-4177
FO4 (Atlantic): 712-243-1934
FO5 (Windsor Heights): 515-725-0268
FO6 (Washington): 319-653-2135

Online Nephelometric Turbidimeter w/90° Detector (*Example: Hach 1720E*)

- ☐ ***Turbidimeter must be calibrated per manufacturer's specifications at least once every 90 days and after any significant maintenance or repair (check calibration/verification history)**
- ☐ ***Turbidimeter calibration is verified at least weekly (turbidity measurements greater than 0.5 NTU must be within +/- 10% of the reading assigned to the reference material. Turbidity measurements 0.5 NTU or less must be within +/- 0.05 NTU)**
- ☐ Sample tap is a sufficient distance downstream of chemical feed points to ensure adequate mixing and sufficient reaction time (in turbulent flow conditions 10 x pipe diameters is suggested, in laminar flow conditions more than 100 × pipe diameters is suggested)
- ☐ Sample line tapped into larger process pipe and sample tap orientation is "good" or "best" per Figure 1
- ☐ Sample tap location is appropriate for measuring desired parameters (e.g., filter-to-waste sample location is representative of filter-to-waste sample).
- ☐ Sample line length is not excessive (i.e., as close and direct as reasonably possible)
- ☐ Sample line does not have excessive elevation changes
- ☐ Sample pumping is to be avoided, if possible
- ☐ Sample flow rate to turbidimeter is between 200 and 750 mL/min and is verified quarterly (samples with high turbidity should operate at as high as flow rate as possible and without a bubble trap, while samples with low turbidity should operate at as low as flow rate as possible)
- ☐ Turbidimeter is installed indoors or in a location that is isolated from vibration, heat, and direct sunlight
- ☐ Turbidimeter head is securely seated on the turbidimeter body
- ☐ Turbidimeter body, bubble trap, and photocell window (do not disassemble or scratch) is thoroughly cleaned and rinsed as needed, or prior to calibration (see user's manual for details)
- ☐ Verify that the reading on the display of the online analyzer is the same as what is being shown on SCADA
- ☐ Turbidimeter photocell contains a small air bubble
- ☐ Turbidimeter output mode is set to "HOLD" during calibration and maintenance activities
- ☐ Turbidimeter error mode is set to "TRANSFER" during normal operation and transfer value is set to 0.00 or 20.00 NTU
- ☐ Turbidimeter date and time stamp is verified during calibration and after power outages
- ☐ Turbidimeter sample line is inspected during calibration and replaced as needed (raw water sample lines will need to be replaced more frequently that filtered water sample lines)
- ☐ Turbidimeter lamp assembly is replaced at least once per year (per manufacturer's specifications)
- ☐ Turbidimeter data log interval (DATALOG INTRVL) is at desired setting (≤1 minute is recommended)
- ☐ Turbidimeter output signal span is set to 0.00 to 5.10 NTU
- ☐ Turbidimeter bubble reject (BUBBLE REJECT) setting is at desired setting (enabled, or yes, is recommended)
- ☐ Turbidimeter signal averaging setting (SIGNAL AVG) is at desired interval (30 second interval is recommended)
- ☐ Turbidimeter offset value (OFFSET) is at desired setting (0.00 NTU is factory default)

Note: Items in bold(*) are required per 567 IAC 43.5(4)"a"(1)

Online Laser Turbidimeter (*Example: Hach FilterTrak 660sc*)

- ☐ ***Turbidimeter must be calibrated per manufacturer's specifications at least once every 90 days and after any significant maintenance or repair (check calibration/verification history)**
- ☐ ***Turbidimeter calibration is verified at least weekly (turbidity measurements greater than 0.5 NTU must be within +/- 10% of the reading assigned to the reference material. Turbidity measurements 0.5 NTU or less must be within +/- 0.05 NTU)**
- ☐ Sample tap is a sufficient distance downstream of chemical feed points to ensure adequate mixing and sufficient reaction time (in turbulent flow conditions 10 x pipe diameters is suggested, in laminar flow conditions more than 100 × pipe diameters is suggested)
- ☐ Sample line tapped into larger process pipe and orientation is adequate (see Figure 1)
- ☐ Sample line length is not excessive (i.e., as close and direct as reasonably possible)
- ☐ Sample flow rate to turbidimeter is between 100 and 750 mL/min (samples with high turbidity should operate at as high as flow rate as possible, while samples with low turbidity should operate at as low as flow rate as possible)
- ☐ Turbidimeter is installed indoors in location that is isolated from vibration, heat, and direct sunlight
- ☐ Turbidimeter head is securely seated on the turbidimeter body
- ☐ Turbidimeter is cleaned at least once per month and prior to calibration (see user's manual for details)
- ☐ Turbidimeter output mode is set to "hold" during calibration and maintenance activities
- ☐ Turbidimeter data log interval (DATALOG INTRVL) is at desired setting (≤1 minute is recommended)
- ☐ Turbidimeter bubble reject (BUBBLE REJECT) setting is at desired setting (enabled, or yes, is recommended)
- ☐ Turbidimeter signal averaging setting (SIGNAL AVG) is at desired interval (30 second interval is recommended)
- ☐ Turbidimeter offset value (OFFSET) is at desired setting based on calibration (0 mNTU is factory default)

Note: Items in bold(*) are required per 567 IAC 43.5(4)"a"(1)

Turbidity Instrumentation Data Integrity Checklists

Benchtop Turbidimeter (*Example: Hach 2100 Series*)

- ☐ ***Turbidimeter is calibrated per manufacturer's recommendations (e.g., Hach 2100Q should be calibrated at 20, 100, and 800 NTU and then verified at 10 NTU)**
- ☐ ***Turbidimeter calibration is verified at least once per week using secondary standards (e.g., Gelex), which should be ±5% of the value recorded on the secondary standard vial**
- ☐ Turbidimeter is located on stable, level surface that is free of vibration
- ☐ Turbidimeter is not located in direct sunlight or near a heat source
- ☐ Turbidimeter and standards are both at ambient temperature during calibration
- ☐ Sealed vial standards (e.g., StablCal) standards are stored at approximately 40°F, if used less than once per month
- ☐ Turbidimeter is left "on" 24 hours a day if it is used regularly (per manufacturer's recommendation)
- ☐ Turbidimeter is "on" at least 30 minutes (ratio on) and 60 minutes (ratio off) prior to analysis
- ☐ Silicone oil is used on sealed vial standards and sample vials prior to calibration/analysis (see user's manual for procedure)
- ☐ Vials are placed in the cell holder with the triangle on the vial aligned with the reference mark on the sample cell holder
- ☐ Sample cells are not dirty, scratched, or damaged (see user's manual for cleaning procedure)
- ☐ Sample cells are free of condensation (common when water temperature is cooler; see user's manual)
- ☐ Sample cells are filled with distilled or deionized water during storage
- ☐ Sample cells are indexed and matched (see user's manual for procedure)
- ☐ Samples are mixed by gentle inversion prior to analysis
- ☐ Air bubbles are removed, if present (see user's manual for various techniques)
- ☐ Samples are analyzed immediately after they are collected (changes in temperature and settling can occur)
- ☐ Turbidimeter ranging setting (RANGE) is set to "automatic" (recommended by manufacturer)
- ☐ Turbidimeter signal averaging setting (SIGNAL AVG) is "on" (recommended by manufacturer)
- ☐ Turbidimeter ratio setting (RATIO) is "on" (recommended by manufacturer)

Note: Items in bold(*) are required per 567 IAC 43.5(4)"a"(1)

Online Nephelometric Laser Turbidimeter w/360° x 90° Detector *(Example: Hach TU5300 sc, Hach TU5400 sc)*

- ☐ ***Turbidimeter must be calibrated per manufacturer's specifications at least once every 90 days and after any significant maintenance or repair (check calibration/verification history)**
- ☐ ***Turbidimeter calibration is verified at least weekly (turbidity measurements greater than 0.5 NTU must be within +/- 10% of the reading assigned to the reference material. Turbidity measurements 0.5 NTU or less must be within +/- 0.05 NTU)**
- ☐ Sample tap is a sufficient distance downstream of chemical feed points to ensure adequate mixing and sufficient reaction time (in turbulent flow conditions 10 x pipe diameters is suggested, in laminar flow conditions more than 100 × pipe diameters is suggested)
- ☐ Sample line tapped into larger process pipe and sample tap orientation is "good" or "best" per Figure 1
- ☐ Sample tap location is appropriate for measuring desired parameters (e.g., filter-to-waste sample location is representative of filter-to-waste sample).

- ☐ Sample line length is not excessive (i.e., as close and direct as reasonably possible)
- ☐ Sample line does not have excessive elevation changes
- ☐ Sample pumping is to be avoided, if possible
- ☐ Sample line pressure does not exceed 87 psi
- ☐ Sample flow rate to turbidimeter is between 200 and 500 mL/min and is verified quarterly (samples with high turbidity should operate at as high as flow rate as possible and without a bubble trap, while samples with low turbidity should operate at as low as flow rate as possible); if equipped, confirm flow rate on flow sensor
- ☐ Turbidimeter is installed indoors or in a location that is isolated from vibration, heat, and direct sunlight
- ☐ Turbidimeter is not installed in immediate proximity of televisions, radios, computers, or other electronic equipment. This instrument is sensitive to electromagnetic and electromechanical interference.
- ☐ Turbidimeter is installed in a vertical position and is level
- ☐ Vial is cleaned at least once every three months
- ☐ Vial is replaced at least every two years
- ☐ Desiccant cartridge is replaced at least every two years or as identified by instrument notification
- ☐ Turbidimeter is calibrated per manufacturer's specifications at least once every three months during normal operation and after any significant maintenance or repair (check calibration/verification history)
- ☐ Verify that the reading on the display of the online analyzer is the same as what is being shown on SCADA
- ☐ Turbidimeter output mode is set to "HOLD" during calibration and maintenance activities
- ☐ Turbidimeter error mode is set to "TRANSFER" during normal operation and transfer value is set to 0.00 or 20.00 NTU
- ☐ Turbidimeter calibration is verified at least once every week
- ☐ Turbidimeter date and time stamp is verified during calibration and after power outages
- ☐ Turbidimeter sample line is inspected during calibration and replaced as needed (raw water sample lines will need to be replaced more frequently that filtered water sample lines)

- ☐ Turbidimeter data log interval (DATALOG INTRVL) is at desired setting (≤ 1 minute is recommended). The default setting for this instrument is 10 minutes, which is greater than desired.
- ☐ Turbidimeter output signal span is set to 0.00 to 5.1 NTU
- ☐ Turbidimeter bubble reject (BUBBLE REJECT) setting is at desired setting (enabled, or yes, is recommended)
- ☐ Turbidimeter signal averaging setting (SIGNAL AVG) is at desired interval (30 second interval is recommended)
- ☐ Turbidimeter offset value (OFFSET) is at desired setting (0.00 NTU is factory default)

Note: Items in bold(*) are required per 567 IAC 43.5(4)"a"(1)

Figure 1: Sample Location in Process Stream

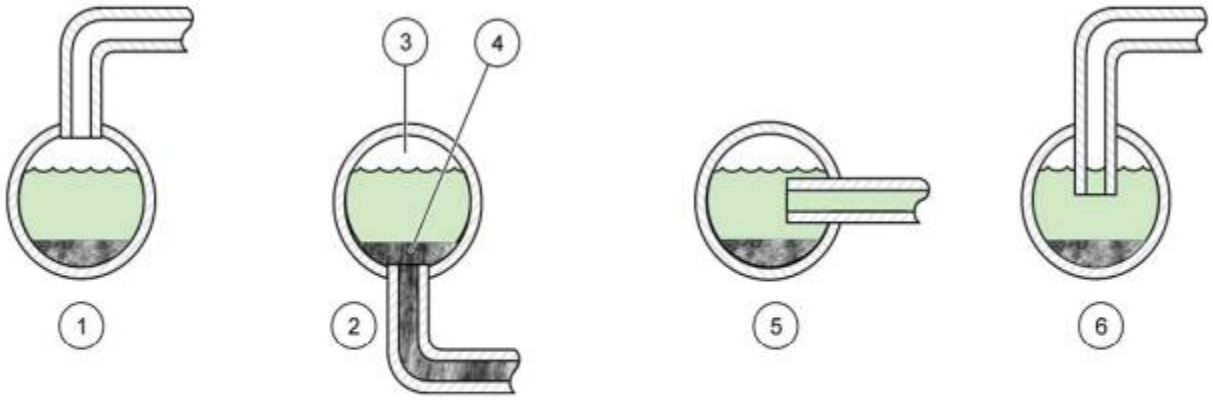

Figure 6 Sample line location in the process stream

1	Poor	**4**	Sediment (typical)
2	Poor	**5**	Good
3	Air (typical)	**6**	Best

Image Source: Hach Company (2014)
NOTE: Tap may include a quill that extends the tap into the center of the pipe.