ASTM
INTERNATIONAL

Standard Practice for
Flow Control and Temperature Control for On-Line Water Sampling and Analysis[1]

1. Scope

1.1 This practice covers the conditioning of a flowing water sample for the precise measurement of various chemical and physical parameters of the water, whether continuous or grab. This practice addresses the conditioning of both high- and low-temperature and pressure sample streams, whether from steam or water.

1.2 This practice provides procedures for the precise control of sample flow rate to minimize changes of the measured variable(s) due to flow changes.

1.3 This practice provides procedures for the precise control of sample temperature to minimize changes of the measured variable(s) due to temperature changes.

1.4 The values stated in either SI or inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 *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.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]
D 1066 Practice for Sampling Steam
D 1129 Terminology Relating to Water
D 1192 Specification for Equipment for Sampling Water and Steam in Closed Conduits [3]
D 3370 Practices for Sampling Water from Closed Conduits
D 3864 Guide for Continual On-Line Monitoring Systems for Water Analysis

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, refer to Terminology D 1129.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *crud deposition*—deposition on interior surfaces of sample tubing or other hardware of fine insoluble particles of iron oxides and other byproducts of metallic corrosion that are present throughout the system. The term "crud" is generally used for all types of fouling.

3.2.2 *sample conditioning*—reduction of the temperature and pressure of a flowing sample from process conditions to a controlled temperature and pressure, and maintenance of a constant flow rate both in incoming sample lines and through on-line analyzers.

3.2.3 *sample cooler*—a small heat exchanger designed to cool small streams of water or steam.

3.2.4 *temperature compensation*—adjustment of the analyzer measured value for variation in temperature of the sample from a preestablished value by the use of electronic adjustment or data manipulation.

4. Summary of Practice

4.1 This practice covers the system design, operating procedures, and selection of equipment to help ensure the appropriate flow and temperature control for analysis of water and steam samples. This control is essential to ensure the accuracy and repeatability of on-line analyzers. Variations in types of analysis, sample characteristics, and their effect on sample conditioning are included.

4.2 The equipment and procedures described in this practice are intended to represent current state-of-the art technology available from major manufacturers of sample conditioning equipment. Refer to Practices D 1066 and D 3370, Specification D 1192, and Guide D 3864 for additional information on sampling.

5. Significance and Use

5.1 Sample conditioning systems must be designed to accommodate a wide range of sample source temperatures and pressures. Additionally, efforts must be made to ensure that the resultant sample has not been altered during transport and conditioning and has not suffered excessive transport delay.

Studies have shown that sample streams will exhibit minimal deposition of ionic and particulate matter on wetted surfaces at specific flow rates (1–5). [4]

5.1.1 To ensure that the physical and chemical properties of the sample are preserved, this flow rate must be controlled throughout the sampling process, regardless of expected changes of source temperature and pressure, for example, during startup or changing process operating conditions.

5.2 The need to use analyzer temperature compensation methods is dependent on the required accuracy of the measurement. Facilities dealing with ultra-pure water will require both closely controlled sample temperature and temperature compensation to ensure accurate measurements. The temperature can be controlled by adding a second or trim cooling stage. The temperature compensation must be based on the specific contaminants in the sample being analyzed. In other facilities in which some variation in water chemistry can be tolerated, the use of either trim cooling or accurate temperature compensation may provide sufficient accuracy of process measurements. This does not negate the highly recommended practice of constant temperature sampling, especially at 25°C, as the most proven method of ensuring repeatable and comparable analytical results.

5.3 A separate class of analysis exists that does not require or, in fact, cannot use the fully conditioned sample for accurate results. For example, the collection of corrosion product samples requires that the sample remain at near full system pressure, but cooled below the flash temperature, in order to ensure a representative collection of particulates. Only some of the primary conditioning criteria apply in this case, as in others. Temperature compensation is not applicable since the material being analyzed is not in a liquid state.

6. Interferences

6.1 Samples can be degraded by the loss of ionic or particulate components, introduction of contaminants by components or leaks, changes of sample flow rate through an analyzer, excessively long sample lines, sample temperature changes, and inaccurate temperature compensation of on-line analysis equipment.

6.2 Studies (3–5) have shown that the loss of ionic and particulate components is minimized by maintaining the water sample velocity at 1.8 m/s in the sample tubing transporting the sample. The turbulent flow at 1.8 m/s (6 ft/s) presents a stable condition of deposition and removal. Changes in sample flow rate or flow rates beyond a median range of approximately 1.8 m/s can upset this equilibrium condition.

6.3 Saturated steam and superheated steam samples present difficult transport problems between the source and the primary sample cooling equipment (4). Saturated steam samples with transport velocities typically above 11 m/s (36 ft/s) provide adequate turbulent flow to ensure the transport of most particulates and ionic components. Excessively large or small steam sample lines can affect the sample quality and quantity significantly. If the sample tubing has too large an inside

diameter, the steam velocity may be too low to transport the condensed portion of the steam along with the vapor. If the sample tubing has too small an inside diameter, the pressure drop may be excessive, reducing the quantity of sample available at the sample panel. In the case of super-heated steam, significant ionic deposition can occur in the sample tubing transport as the steam desuperheats. This can affect sample analysis accuracy significantly. Superheated samples should use a process to inject cooled sample into the sample line at or near the nozzle outlet to desuperheat the sample so as to minimize deposition in the initial portion of the tubing run.

6.4 Samples may become contaminated by products introduced into the stream by the tubing, valves, or other associated conditioning hardware. To minimize contamination of the sample, high-grade tubing, such as AISI Type 316 SS, must be used. Cobalt contamination from valve hardening material can introduce significant error in transition metal analysis by ion chromatography.

6.5 Air leakage into sample lines can affect pH, conductivity (specific, cation, and degassed), and especially dissolved oxygen measurements.

6.6 The operation of a sample system includes periodically taking grab samples and adding and removing on-line analyzers. The accuracy of the analyses can be affected if the flow rate through any on-line analyzer changes because of these procedures. The same is true if these actions change the flow rate in the incoming sample line to the system.

6.7 Changing the temperature of the sample flowing through an on-line analyzer can alter the accuracy of the analysis. Sample temperature can change because of a change in flow rate through the heat exchangers, because of a change of flow rate of the cooling water in the heat exchangers, or from a change in temperature of the heat exchanger cooling water supply. Every effort should be made to ensure constant sample temperature. The ideal sample temperature is $25 \pm 0.5°C$ ($77 \pm 1°F$) because this is the standard for comparing readings of temperature-sensitive analyses.

6.8 Electronic compensation is able to compensate for the deviations in sample temperature for a known chemical matrix (contamination). If an unknown source of contamination is introduced, the analyzer may not be programmed, or programmable, to respond to the new solution. An error is introduced as a result. The further the sample temperature deviates from 25°C (77°F), the greater the error.

6.9 In sliding pressure or cycling power plants, or both, in which sample inlet pressures vary, the sample flow methodology detailed in this practice should be modified to automate the flow control process to ensure constant sample flow for high-accuracy analysis.

7. Apparatus

7.1 *Sample Tubing*— Tubing should be high quality such as AISI Type 316 SS and be sized to maintain appropriate flow to minimize sample analysis errors. The tubing inside diameter is the critical dimension. Heavy-wall tube with an appropriate inside diameter size selected to provide proper flow rate (see 6.2) can be used for construction strength.

7.2 *Primary Sample Coolers*—Heat exchangers, designed to handle high-pressure and high-temperature samples and

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[4] The boldface numbers in parentheses refer to the list of references at the end of this practice.

provide efficient cooling with approach temperatures of below 1°C (2°F), should be selected. Generally, AISI Type 316 SS is an appropriate sample tube material; however, other material selections may be necessary based on incoming sample temperature and cooling water impurities, that is, chlorides.

7.3 *Pressure Reducers*—Pressure reduction is accomplished with a variable orifice. A high-quality needle valve performs well for source pressure less than 34.5 bar (500 psig). A variable rod-in-tube device performs well for pressures 34.5 bar and greater because it is basically non-wearing and minimizes sample dissociation during pressure reduction.

7.4 *Pressure Regulating Device*—To maintain constant sample pressure at the inlet to each analyzer train, a variable or fixed back pressure regulating valve or a head cup may be used.

7.5 *Secondary or Trim Sample Cooler*—Similar to the primary sample cooler, this heat exchanger should be a device capable of maintaining a sample outlet temperature within 0.5°C (1°F) of the incoming cooling water temperature to ensure constant outlet temperature, even with significant variations in sample flow or heat load.

7.6 *Sample Flow Indicator(s)*—A non-valved rotameter or other flow indication device in the main sample line or flow indication device, or both, in all branch lines (analysis, grab, and bypass) is typically used. A method of measuring total sample flow in accordance with recommended velocities must be used (see 6.2 and 8.4).

7.7 *Temperature Indicator*—A mechanical or electronic indication of sample temperature must be provided to help the operator monitor sample conditions and confirm the efficiency of the heat exchangers.
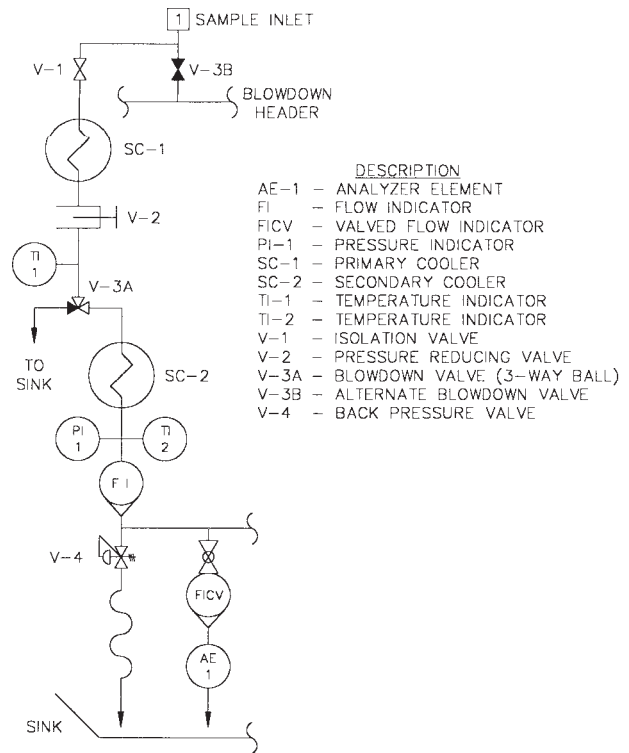
8. Procedure

8.1 *Procedure for Establishing Constant Flow*:

8.1.1 Confirm that the sample tube transporting the sample is sized properly to ensure the sample velocities noted in 6.2 and 6.3. Keep the sample lines as short as possible (particularly steam) to eliminate alteration of the sample prior to the primary cooling point.

8.1.2 Flow control of the sample streams involves two stages. The first is reduction of the pressure from the source to a lower value and establishment of the desired flow in the incoming line. The second is maintenance of the reduced pressure at a constant value so that flow through the analyzers will remain constant.

8.1.3 Hold the reduced sample pressure constant by passing it through a back pressure regulating valve that maintains the inlet pressure constant. The valve opens to let more water through if the inlet pressure tends to increase. The valve closes if the inlet pressure decreases, maintaining the inlet pressure but reducing the flow through it. A head cup will also achieve similar constant flow results. Use the constantly flowing discharge from the back pressure valve for grab samples. Pipe the analyzers in parallel to the constant pressure zone. Thus, once the valved flow meter (FICV) controlling the flow to an analyzer sensor is set, the flow through the analyzer will remain constant as long as the inlet pressure remains constant. See Fig. 1.

8.2 *Procedure for Establishing Constant Temperature*:

DESCRIPTION
AE-1 — ANALYZER ELEMENT
FI — FLOW INDICATOR
FICV — VALVED FLOW INDICATOR
PI-1 — PRESSURE INDICATOR
SC-1 — PRIMARY COOLER
SC-2 — SECONDARY COOLER
TI-1 — TEMPERATURE INDICATOR
TI-2 — TEMPERATURE INDICATOR
V-1 — ISOLATION VALVE
V-2 — PRESSURE REDUCING VALVE
V-3A — BLOWDOWN VALVE (3-WAY BALL)
V-3B — ALTERNATE BLOWDOWN VALVE
V-4 — BACK PRESSURE VALVE

NOTE 1—Fixed back pressure regulating valves (V4) are available and eliminate the need to adjust back pressure and readjust the flow. This fixed pressure regulating valve provides the added benefits of acting as a sample relief valve and grab sample discharge.

NOTE 2—In ultra-pure water applications, it is not uncommon for the sample flow indicator (FI) to be placed in the sample bypass line and the valved flow meter(s) (FICV) to be placed after the analyzer elements to avoid the possibility of air inleakage, which could affect sample quality.

FIG. 1 Schematic of a Typical Sample Line

8.2.1 Temperature reduction and control of the sample is best accomplished in two stages: primary and secondary cooling. If only one stage of cooling is used, the temperature of each sample will be constant with constant flow, but each sample will have a different temperature because of different source temperatures and pressures supplied to the primary sample cooler. Using a second stage of cooling will bring the temperature of all the samples to the same constant temperature (recommended at 25°C (77°F)). Refer to 6.7 and 6.8.

8.2.2 Refer to the first stage of cooling as primary cooling. The bulk of the heat in each sample is removed in this sample cooler (heat exchanger). A highly efficient sample cooler is desirable so that the temperature of the sample leaving the cooler will be as close as possible to the cooling water temperature. This is particularly true of the steam samples with short sample lines, since a portion of the cooler capacity is used up condensing the steam before the condensate can be cooled.

NOTE 1—Steam samples (particularly high-pressure samples) that have long sample lines ahead of the primary cooler can have a substantial portion of the steam condensed prior to the sample reaching the cooler.

8.2.2.1 Since the sample cooler has a fixed amount of heat transfer area, the temperature of the sample leaving the cooler will remain constant if the sample flow is kept constant, and

both the cooling water temperature and flow are kept constant. However, each sample will have a different discharge temperature.

8.2.3 The variable orifice is always located after the first stage of cooling. Since the temperature of the sample is below the saturation point, the sample will not flash across the orifice.

8.2.4 The second stage of cooling is referred to as secondary or trim cooling. By using a close approach cooler for each line and controlling the temperature of the cooling water closely ($\pm\frac{1}{2}$ °F (0.5°C)), the temperature of all of the samples can be brought within a close tolerance of each other. Since the bulk of the heat has been removed from most of the samples, and only a small amount has been added in reducing the sample pressures, a relatively modest amount of heat remains to be removed. A mechanical refrigeration system, with proper temperature controls, is the most common source of controlled temperature cooling water. In some areas, use local clean water sources that do not exceed the sample control temperature for secondary cooling. This kind of system still needs the quality of temperature control supplied by a refrigeration system.

8.3 *Example*:

8.3.1 Fig. 1 shows a flow schematic of a typical sample line. The procedure for conditioning an incoming sample for on-line analysis includes purging the sample line, checking for proper temperature, establishing the proper flow of sample from the source, and setting the proper flow to each on-line analyzer.

8.3.2 Check V2, the variable orifice, to be sure it is in the closed position. Position V3A (three-way ball valve) to divert flow into the sink. Open V1. Open V2 gradually until a high flow is established. Do not let the sample temperature (TI1) exceed 200°F (93°C). The high flow rate will loosen particulate matter in the sample line and flush it into the sink. The crud

will typically come in bursts and can be seen in the sink. When the stream has remained clear for a short while, close V2 and reposition V3A.

8.3.3 Open V2 until the flow shown by FI, total sample flow indicator (rotameter), reaches the desired rate. Adjust V4 to the desired back pressure while observing PI (typically approximately 23 psig). V2 and V4 may have to be readjusted a few times to reach the desired combination of flow and pressure. Now, as each analyzer valved flowmeter (FICV) is opened, the discharge from V4 will decrease by the same amount, without changing the flow through FI.

8.3.4 If the temperature of the secondary cooling water source is set properly, the controlled temperature (T2) of each sample should be within 0.5°C (1°F) of each other.

8.3.5 During operation, a burst of crud may occasionally come down the sample line and plug the variable orifice. If this occurs, change the position of V3A to the sink and open V2 until the crud blows through. Close V2, readjust V3A, and then reestablish the proper flow through FI.

8.3.6 V3B is an alternate position for a sample flush (blowdown) valve. In this case, the hot sample is allowed to flash across the valve into a header, which transports the mixture of steam and water to a safe disposable area. The disadvantages of this approach are that the sample line downstream of the isolation valve (V1) is not flushed and the operator cannot see when the line is finally clean. Also, flashing across the valve seat is a violet process. This can require excessive maintenance of the valve.

9. Keywords

9.1 crud; flow control; ionic deposition; on-line analysis; pressure reduction; sample conditioning; sample cooler; temperature compensation; temperature control

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