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An American National Standard

Standard Practice for Sampling Steam[1]

This standard is issued under the fixed designation D 1066; 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 the sampling of saturated and superheated steam. It is applicable to steam produced in fossil fired and nuclear boilers or by any other process means that is at a pressure sufficiently above atmospheric to establish representative sample flow. It is also applicable to steam at lower and subatmospheric pressures for which means must be provided to establish representative flow.

1.2 For information on specialized sampling equipment, tests or methods of analysis, reference should be made to the *Annual Book of ASTM Standards*, Vols 11.01 and 11.02, relating to water.[2,3]

1.3 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the inch-pound units are shown in parentheses. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

1.4 *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:*

A 269 Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service[4]

A 335/A 335M Specification for Seamless Ferritic Alloy-Steel Pipe for High Temperature Service[4]

D 1129 Terminology Relating to Water[3]

D 3370 Practices for Sampling Water in Closed Conduits[3]

D 5540 Practices for Flow Control and Temperature Control for On-Line Water Sampling and Analysis[3]

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms used in this practice, refer to definitions given in Practice D 1129.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *isokinetic sampling*—a condition wherein the velocity of the sample entering the port or ports of the sample nozzle(s) is the same as the velocity in the stream being sampled.

3.2.2 *sample cooler*—a small heat exchanger designed to provide cooling/condensing of small process sampling streams of water or steam.

3.2.3 *sampling*—the withdrawal of a representative portion of the steam flowing in the boiler drum lead or pipeline by means of a sampling nozzle and the delivery of this portion of steam in a representative manner for analysis.

3.2.4 *saturated steam*—a vapor whose temperature corresponds to the boiling water temperature at the particular existing pressure.

3.2.5 *superheated steam*—a vapor whose temperature is above the boiling water temperature at the particular existing pressure.

4. Summary of Practice

4.1 This practice describes the apparatus, design concepts and procedures to be used in extracting and transporting samples of saturated and superheated steam. Extraction nozzle selection and application, line sizing, condensing requirements and optimization of flow rates are all described in detail. Condensed steam samples should be handled in accordance with Practices D 3370 and D 5540.

5. Significance and Use

5.1 It is essential to sample steam representatively in order to determine the amount of impurities, including moisture, in it. An accurate measure of the purity of steam provides information, which may be used to determine whether the purity of the steam is within necessary limits to prevent damage or deterioration of subsequent equipment, such as turbines, etc. Impurities in the steam may be derived from

[1] This practice is under the jurisdiction of ASTM Committee D19 on Water , and is the direct responsibility of Subcommittee D19.03 on Sampling of Water and Water-Formed Deposits, Surveillance of Water and Flow Measurement of Water Samples.

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[2] *Annual Book of ASTM Standards*, Vol 11.01.

[3] *Annual Book of ASTM Standards*, Vol 11.02.

[4] *Annual Book of ASTM Standards*, Vol 01.01.

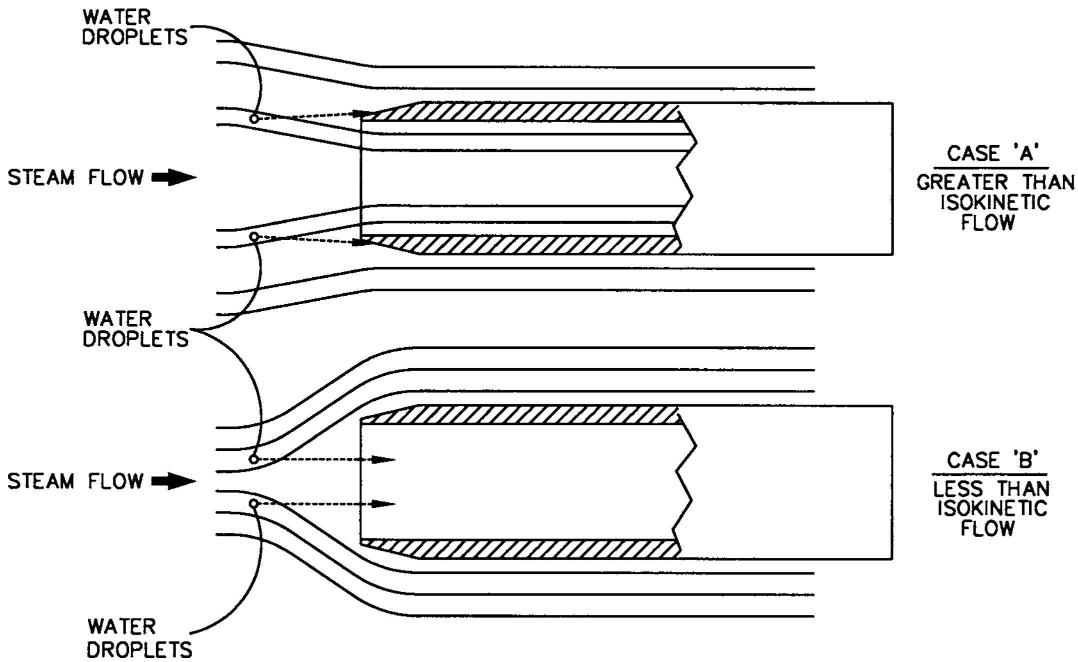

FIG. 1 Effect of Nono-Isokinetic Sampling

boiler water carryover, inefficient steam separators, natural salt solubility in the steam and other factors.

6. Interferences

6.1 *Saturated Steam*— Sampling of steam presents difficult extraction and transport problems that affect the representativeness of the sample.

6.1.1 Isokinetic sampling requires that the velocity of the fluid entering the sample nozzle port(s) is the same as the velocity of the stream being sampled at the location of the sample nozzle. When the sample is not extracted isokinetically the contaminants in the steam are not properly represented in the sample. The effects of non-isokinetic sampling are illustrated in Fig. 1 and can make the sample unrepresentative.

6.1.2 Traditionally, saturated steam samples with initial steam velocities above 11m/s (36f/s) were considered to provide adequate turbulent flow to ensure transport of most particulates and ionic components. More recent studies **(1)(2)**[5] find that because many sample lines are long and uninsulated, steam samples are frequently fully condensed prior to reaching the sample station. Partially or fully condensed samples usually have a velocity too low to prevent excessive deposition and the sample becomes nonrepresentative of the source. Detailed design of the sample line to control vapor and liquid velocity can minimize this interference but cooling of saturated steam samples at the source is recommended to assure a representative sample. See Practice D 3370 for further information on factors that affect liquid sample transport.

6.2 *Superheated Steam*—Most contaminants can be dissolved in superheated steam. However as steam pressure and temperature are reduced the solubility of many contaminants is decreased and the contaminants deposit on the inner surfaces of the sample line **(3)**. This condition has been found to be prevalent only in regions of dry wall tube where the temperature of the tube wall exceeds the saturation temperature of the steam.

6.2.1 Interference also occurs when the transport tube temperature is at or below the saturation temperature. The steam loses superheat and dissolved contaminants deposit on the tube wall. The sample is no longer representative. Superheated steam samples shall be cooled or desuperheated in the sample nozzle or immediately after extraction to ensure a representative sample. See 7.1.3.3 and 7.2.4.

7. Materials and Apparatus

7.1 *Extracting the Sample*:

7.1.1 *Saturated Steam*— Since saturated steam is normally sampled as a two-phase fluid, made up of steam and small droplets of water, isokinetic sampling shall be employed. Since steam velocities vary with boiler load it normally is not practical to sample isokinetically throughout the load range. Normally, the load of interest is full load or a guaranteed overload. The sampling system shall be designed to provide isokinetic sampling at this design load.

7.1.1.1 At low velocities, the moisture in wet steam forms a film along the inside surface of the steam line that entrains impurities **(4)**. Table 1 shows the minimum steam flow required for representative samples at various steam pressures.

7.1.2 *Superheated Steam*—Superheated steam is usually regarded as a single phase fluid. Unless particulates are being measured, isokinetic sampling is not required. Most impurities in superheated steam are present in vaporous form and are thoroughly mixed with the steam vapor. However, an oxide layer forms on the steam side of superheater and reheater lines and gets thicker with increased service. Since the physical properties of the oxide are different from the parent metal,

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

TABLE 1 Minimum Saturated Steam Line Conditions at Point of Sampling

Saturated Steam Pressure		*Minimum Steam Flow*	
psig	(kPa)	ft/s	(m/s)
100	(690)	195	(59.6)
200	(1379)	141	(42.8)
300	(2068)	114	(34.8)
400	(2758)	95	(29.1)
500	(3447)	83	(25.3)
700	(4826)	70	(21.2)
1000	(6895)	54	(16.6)
1500	(10342)	36	(11.0)
2000	(13790)	26	(7.9)
2500	(17237)	18	(5.5)
2800	(19300)	13	(4.1)

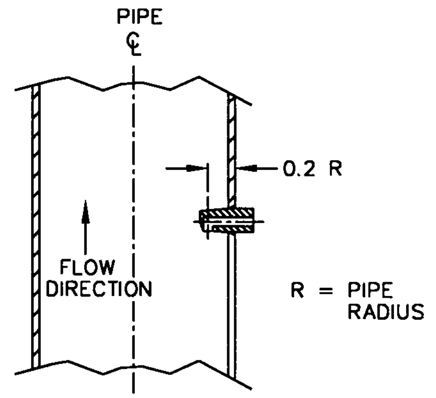

FIG. 2 Single Port Nozzle

changing pressure and temperature cause the oxide layer to crack and exfoliate **(3)**. The exfoliated material can retain significant amounts of impurities, such as sodium, which can be leached into the sample when the material contacts the liquid phase of the sample **(5)** **(6)**.

7.1.2.1 Because the dissolved contaminants in high pressure superheated steam deposit on the inner surfaces of the nozzle and sample lines as the sample desuperheats, superheated steam samples shall be rapidly desuperheated or condensed near the point of extraction. See 7.2.4.

7.1.3 *Sampling Nozzles*— Stratification of suspended solids in horizontal steam pipes can influence the composition of the steam samples. To minimize the effects of stratification it is recommended that steam sampling nozzles be located in long vertical pipes. To ensure that all water droplets are carried in the flow stream, downward flow is preferred. Nozzles which must be located in a horizontal pipe should be near the top of the pipe **(1)**. Sampling nozzles can be either of a single port or multiport configuration as specified or recommended by the boiler manufacturer or design engineer.

7.1.3.1 *Single Port Nozzles*—A single port nozzle which is positioned at a known distance from the inner surface can also be used when it is at a location where a predictable velocity gradient exists. Normally this would be at a location where fully developed turbulent flow exists which enables the determination of velocity at any location in the steam line. Single port nozzles are most frequently located at a distance from the pipe wall where the actual velocity equals the average velocity, typically 0.2 R of the pipe **(1)(6)**. Fig. 2 depicts this typical single port nozzle. This type of single port nozzle can be easy to install and provides good results at a reasonable cost. Fig. 3 shows another single port nozzle used to sample saturated steam in superheater supply tubes.

7.1.3.2 *Multi-Port Nozzles*—Multi-port nozzles which sample at various locations across the pipe cross section can also be used. These nozzles may be used only at locations where the velocity profile across the pipe can be determined **(1)**. Ports shall be located so that each port samples from an equal fraction of the cross-sectional area of the pipe being sampled. Since the steam velocity varies across the pipe section, each port diameter must be sized to result in isokinetic sampling with the proper fraction of sample collected from each port. Table 2 and Fig. 4, Fig. 5, and Fig. 6 detail information on port location, port sizing and internal passage sizing for multi-port nozzles.

7.1.3.3 *Sampling Nozzles for Superheated Steam*—The nozzles described for use with saturated steam can also be used for superheated steam. However, isokinetic sampling is normally not required for superheated steam unless particulates are measured.

7.1.3.4 In order to minimize the deposition of contaminants from superheated steam several experts currently recommend injecting condensed and cooled sample directly into the superheated steam sampling nozzle **(1)**. Due to concern for induced thermal stresses, few power plants have installed nozzles with integral condensate injection. An acceptable alternative is to condense the sample immediately after extraction. See 7.2.4 for sample line and condensing design criteria.

7.1.3.5 *Materials and Installation*—Sampling nozzles shall be adequately supported and shall be designed to prevent failure due to flow-induced vibration, thermal stress cycling and other possible causes. Nozzles are most often made of AISI 316 **(7)** or other austenitic stainless steel or alloy 600 **(1)(6)**. Weld joints used for dissimilar metals are subject to high thermal stresses due to different coefficients of thermal expansion. Care should be used in weld rod selection and inspection of all dissimilar metal weld joints.

7.1.3.6 Sample ports shall be drilled cleanly, using the standard drill size nearest to the calculated port diameter. The port inlet ends shall not be chamfered or rounded, and the outlet ends shall be free of burrs. The smallest recommended port diameter is 3.18 mm (1⁄8) in. Port diameters of less than 2.38 mm (3⁄32) in. are subject to plugging and shall not be used. Total port area shall be determined to maintain isokinetic sampling in the nozzle port(s) at the desired sampling rate and design steam load.

7.1.3.7 At least one shut off valve (commonly referred to as a root valve) shall be placed immediately after the point from which the sample is withdrawn so that the sample line may be isolated. In high pressure applications two root valves are often used. The valve(s) selected should be rated for the pressure/temperature of the sample source.

7.2 *Transporting the Sample*:

7.2.1 *General*—Sample lines should be designed so that the sample remains representative of the source. See 6.1 and 7.1.1.