Designation: E947 – 22

Standard Specification for Sampling Single-Phase Geothermal Liquid or Steam for Purposes of Chemical Analysis[1]

This standard is issued under the fixed designation E947; 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 specification covers the basic requirements for equipment and the techniques to be used for the collection of uncontaminated and representative samples from single-phase geothermal liquid or steam. Geopressured liquids are included.

1.2 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.3 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *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. Referenced Documents

2.1 *ASTM Standards:*[2]

D1192 Guide for Equipment for Sampling Water and Steam in Closed Conduits (Withdrawn 2003)[3]

E1675 Practice for Sampling Two-Phase Geothermal Fluid for Purposes of Chemical Analysis

3. Application

3.1 The equipment specification covers only that equipment which is commonly used for the sampling of single-phase geothermal liquid or steam. It does not cover specialized equipment required for, and unique to, a specific test or method of analysis. The specification covers items such as valves, fittings, tubing, cooling coils and condensers, sample containers, and sample probes, but excludes equipment used in specific testing and analysis.

3.2 The sampling procedure applies to sampling of single-phase steam or liquid streams, including single-phase steam or liquid streams separated from two-phase flow as described in Practice E1675, dry saturated steam, superheated steam, and pumped geothermal liquid. The sampling procedure is not applicable to the collection of liquid droplets and entrained solids in steam (steam quality and purity), which must be collected by isokinetic sampling utilizing different equipment and techniques. The single-phase steam sampling specification applies to vapor-phase species in the steam only (noncondensable gases, HCl and boric acid). The single-phase liquid sampling specification applies to fully dissolved species in the liquid only, including noncondensable gases if no gas bubbles are present (gas breakout).

3.3 For most geothermal and geopressured fluids tested by the procedures outlined in this specification, both liquid and steam samples may be collected.

4. Sample Probes

4.1 Sampling probes shall be used to extract liquid or steam from the main part of the geothermal flow rather than using a wall-accessing valve and pipe arrangement. This allows a representative sample to be collected of a homogeneous, single-phase fluid. The probes are not designed for multi-phase sampling or sampling under isokinetic conditions (see Fig. 1). Consideration should be given to the force generated by any specific combination of probe diameter and system pressure and to the limitations and safety of sliding seals. A combination of probe tip bead and safety chain are recommended to restrict forcible ejection of the probe from the line being sampled. In some cases, a permanently installed sampling probe is preferred.

4.2 Sample probes shall be designed to extract representative samples from homogeneous single-phase fluid flow. Special attention during construction of the probe shall be given to

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[1] This specification is under the jurisdiction of ASTM Committee E44 on Solar, Geothermal and Other Alternative Energy Sources and is the direct responsibility of Subcommittee E44.15 on Geothermal Field Development, Utilization and Materials.

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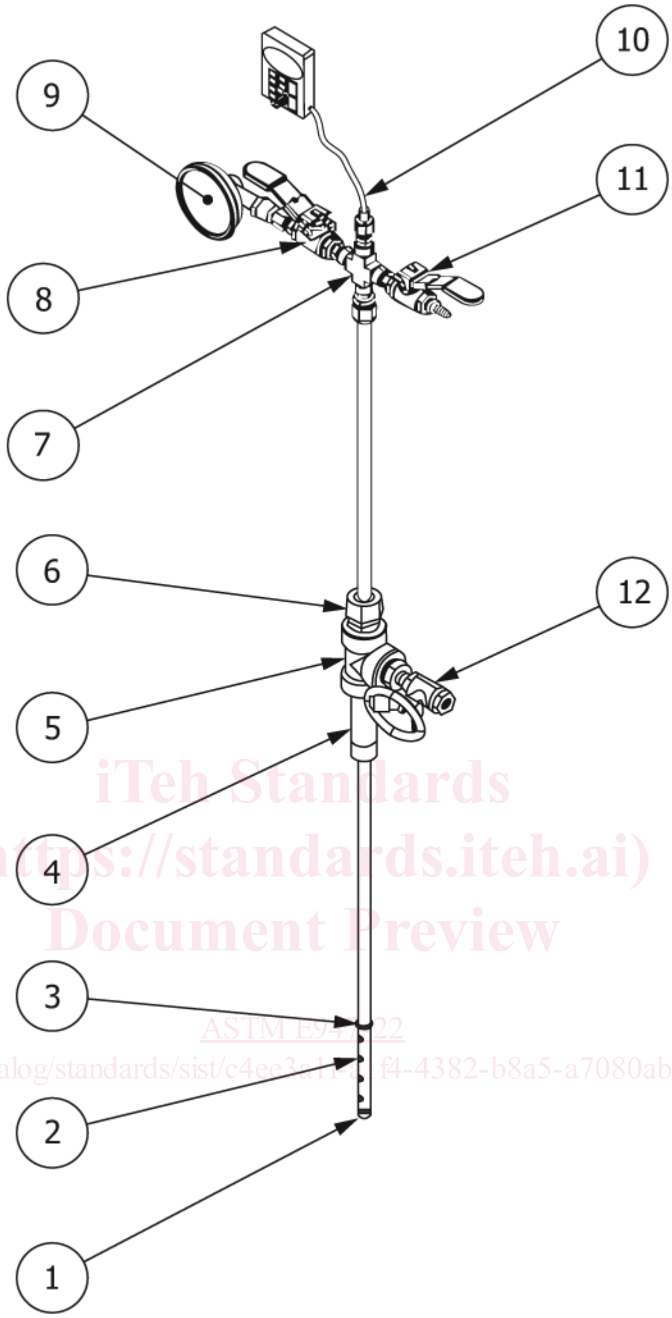
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.



(1) Welded probe tip, 12.7 mm (½ in.) diameter probe
(2) Sample holes, 6.4 mm (¼ in.) diameter, 4 each
(3) Welded bead safety stop
(4) Pipe nipple, 19.0 mm (¾ in.) NPT
(5) Probe tee, 19.0 mm (¾ in.) NPT
(6) Packing gland with PTFE or flexible graphite sliding seal element, 12.7 mm (½ in.) bore size
(7) Probe cross, 6.4 mm (¼ in.) NPT
(8) Pressure port valve, 6.4 mm (¼ in.) NPT, PTFE seals
(9) Pressure gauge, vibration dampening, range 0 kPa to 2000 kPa (0 psig to 300 psig)
(10) Thermocouple, Type K, transition joint, 3.175 mm (⅛ in.) sheath, length sufficient to reach tip of probe, signal cable
(11) Sample Port Valve, 6.4 mm (¼ in.) NPT, PTFE seals, #6 Male AN/JIC fitting
(12) Vent port valve, 6.4 mm (¼ in.) NPT, PTFE seals

Material specification: All metal components made from UNS S30400, S31600, S30403, or S31603. Alternative materials, such as N06625 may be appropriate when sampling conditions are likely to cause stress corrosion cracking.

FIG. 1 Single-Phase Sampling Probe

the stresses that the probe will later be subjected to during insertion into, and operation in, a pressurized flowing system.

4.2.1 The sampling probe shaft should be constructed of UNS S30400, S31600, S30403, or S31603 tubing, or another suitable material. Its outer diameter should be 9.5 mm (0.375 in.) to 12.7 mm (0.500 in.) with a wall thickness of at least 1.25 mm (0.049 in.).

4.2.2 The probe shaft must be of sufficient length to reach the center of the pipeline.

4.3 The probe shall be equipped with a sliding seal mechanism that will allow the probe shaft to slide into and out of the flow stream, while under pressure.

4.3.1 The temperature and pressure rating of the sliding seal shall be at least 1.5 times greater than that of the fluid or vapor to be sampled.

4.4 The sampling probe shaft passes through the sliding seal and access valve in order that liquid or steam can be sampled from the central stream of the flow line. Thereafter, the sample contacts only surfaces that the operator can verify are non-contaminating and non-absorbing.

5. Valves, Gauges, and Fittings

5.1 Valves which control access to the sampling point shall have straight throats (frequently designated as ball, plug, and gate valves). Gate valves and ball valves shall be full-port style. This permits a probe to be inserted directly into the flow.

5.2 The sample probe shall be equipped with at least one full-port shut-off valve on the downstream end so that the sampling line may be isolated when necessary.

5.3 For single-phase liquid sampling, the throttling devices such as valves, capillary tubes, or orifices, if used, shall be placed at the sample outlet of the cooler or condenser. A head column such as that recommended for normal water and steam sampling (Specification D1192, for Equipment for Sampling Water and Steam) shall not be used because it provides a mechanism for gas separation and escape prior to sample collection.

5.4 Equipment adequate to determine the pressure and temperature of the mainstream liquid or steam flow may be utilized.

5.4.1 Temperature measurements are made with a resistance temperature detector (RTD) or a Type-K thermocouple. 4-wire RTD probes are preferred due to the large linear range and stable signal. Minimum accuracy of the meter should be at least ±0.6 °C (±1 °F). Meters and temperature probes should be calibrated at the same intervals as the pressure transducers to ensure consistency between the measurements of pressure and temperature. All meters and probes require permanent identification numbers so that field data and calibration data can be traced to each specific instrument.

5.4.1.1 The temperature sensing element shall be housed in a sealed, ungrounded sheath of sufficient length to reach the inlet end of the probe. The sheath shall be constructed from the same material as the probe, or other suitable inert material.

5.4.1.2 The sheath must be of small enough diameter so as not to occlude more than 20 % of the interior cross-sectional area of the probe shaft.

5.4.2 Pressure measurements are made with a calibrated digital pressure transducer. A pressure-snubbing device is recommended to minimize the pressure spikes and surges common in geothermal flow lines. Minimum accuracy of the gauge should be ±1 % of full-scale. The gauge should be calibrated at monthly intervals when in routine use and every six months for intermittent use. All gauges require permanent identification numbers so that field data and calibration data can be traced to each specific instrument.

5.5 Sample ports on the probe often need to be replumbed, and fittings may need to be replaced. A selection of pipe fittings including reducer bushings, pipe nipples, couplings, and elbows, plus those needed for sample equipment maintenance, is required on site.

6. Sampling Lines

6.1 Sampling lines shall be as short as practical and of sufficient strength to prevent structural failure.

6.2 Standard sample lines are perfluoroalkoxy alkane (PFA) tubing with UNS S30400, S31600, S30403, or S31603 overbraid rated to 1378 kPag and 243 °C (500 psig and 470 °F). Joint Industry Council/Army-Navy (JIC/AN) type fittings attach hoses to the probe outlet and condenser/cooler inlet. Hoses are dedicated to either steam or liquid service to prevent cross-contamination.

6.2.1 The inner diameter of hose used for liquid sampling should not exceed 9.5 mm (0.375 in.).

6.2.2 The inner diameter of hose used for vapor sampling should not exceed 6.4 mm (0.250 in.).

6.2.3 When sampling pressure exceeds 1378 kPag, UNS S30400, S31600, S30403, or S31603 tubing should be used (6.4 mm to 9.5 mm (0.25-in. to 0.375-in.) outside diameter), although it is less convenient. Convoluted, flexible stainless steel hose is specifically excluded due to potential entrapment and contamination problems caused by the internal convolutions. Alternative materials such as N06625 may be appropriate when the fluid being sampled is likely to have high concentrations of halides.

7. Sample Cooler

7.1 The tube through which the sample flows shall be continuous through the cooling location so there will be no possibility of sample contamination or dilution from the cooling water. The internal diameter of the tube is suggested to be no larger than that of the sample probe so that storage within the coil is low and the time lag of sample through the cooling phase will be a minimum.

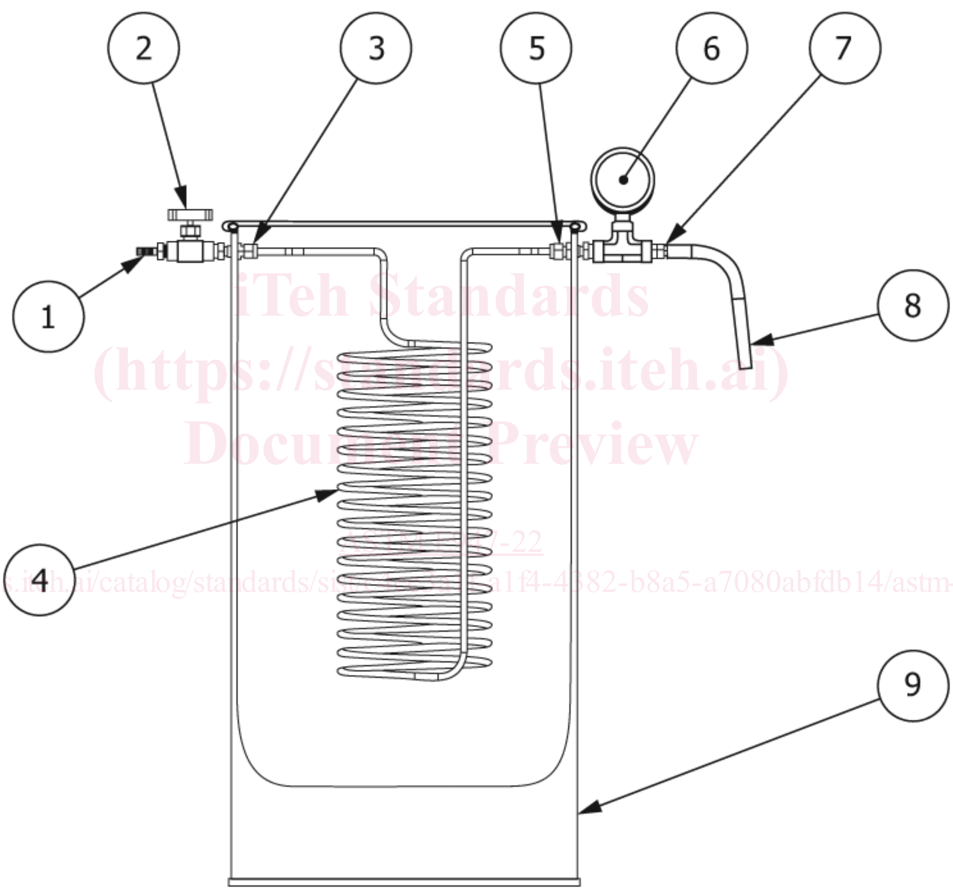
7.2 When the temperature of the sample is above the boiling point of water, it may be advantageous to use a precooler containing water to lower the temperature of the sample before it enters the cooler. The temperature of the sample can then be controlled by the flow rate and the temperature of the final cooling bath (frequently an ice water bath).

7.3 The steam cooling coil has a regulating valve at the inlet. Regulating the flow at the condenser inlet maintains fluid velocity on the condensate and prevents fluid holdup inside the condenser. The outside diameter of the steam cooling coil is typically 6.4 mm (0.250 in.). Outside diameters larger than 6.4 mm (0.250 in.) should not be used, as larger tubing sizes decrease fluid velocities and increase residence times within the tubing. (See Fig. 2.)

7.3.1 The steam cooling coil is arranged as a downward spiral with the inlet at the top. This maintains the thermal gradient in the cooling container, allowing the coolant at the surface to boil and radiate as much heat as possible, while preserving the cooler fluids at the bottom of the vessel. The cooled sample fluid exits through a straight tube rising to the top of the cooler.

7.3.2 In cases where the noncondensable gas concentration in steam exceeds approximately 5 % by weight, the outlet of the steam condenser coil should be at an elevation below the inlet with a continuous down-slope in the tubing from inlet to outlet. This allows the small volume of condensate to drain freely out of the condenser and prevents hold-up within the coils. Smaller diameter coils may be necessary if noncondensable gas concentrations exceed 5 % by weight. In these cases, tubing with an outer diameter of 3.2 mm (0.125 in.) will maintain flow velocities without excessive restriction of fluid flow.

7.3.3 It is necessary to ensure the cooling system for steam collection is free of leaks where atmospheric gases could enter the system and contaminate the sample. Effective ways to check for leaks are to pressurize the system or subject it to vacuum and monitor any change in pressure over a few minutes of time. If there is no change in pressure from the initial pressurization, then the system is free of leaks and adequate for sampling.



(1) JIC fitting, 6.4 mm (¼ in.) NPT × S.A.E. 37° sample inlet
(2) Regulating valve, 6.4 mm (¼ in.) NPT
(3) Bulkhead fitting, 6.4 mm (¼ in.) NPT × 6.4 mm (¼ in.) Swagelok
(4) 6.1 m × 6.4 mm (20 ft × ¼ in.) O.D. tubing, 0.9 mm (0.035 in.) wall
(5) Bulkhead fitting, 6.4 mm (¼ in.) NPT × 6.4 mm (¼ in.) Swagelok
(6) 101.6 kPa × 206.8 kPa (30 in. Hg × 30 psi) vacuum/pressure gauge
(7) Gauge tee, 6.4 mm (¼ in.) NPT and hose adapter, 6.4 mm (¼ in.) NPT × 6.4 mm (¼ in.) hose barb
(8) Plastic[4] tubing, 9.5 mm (⅜ in.) O.D., 4.8 mm (3⁄16 in.) I.D. sample outlet
(9) 30 L to 76 L (8-gal to 20-gal) drum with perforated lid

Material specification: All metal components made from UNS S30400, S31600, S30403, or S31603. Alternative materials, such as N06625 may be appropriate when sampling conditions are likely to cause stress corrosion cracking.

FIG. 2 Steam Sample Condenser

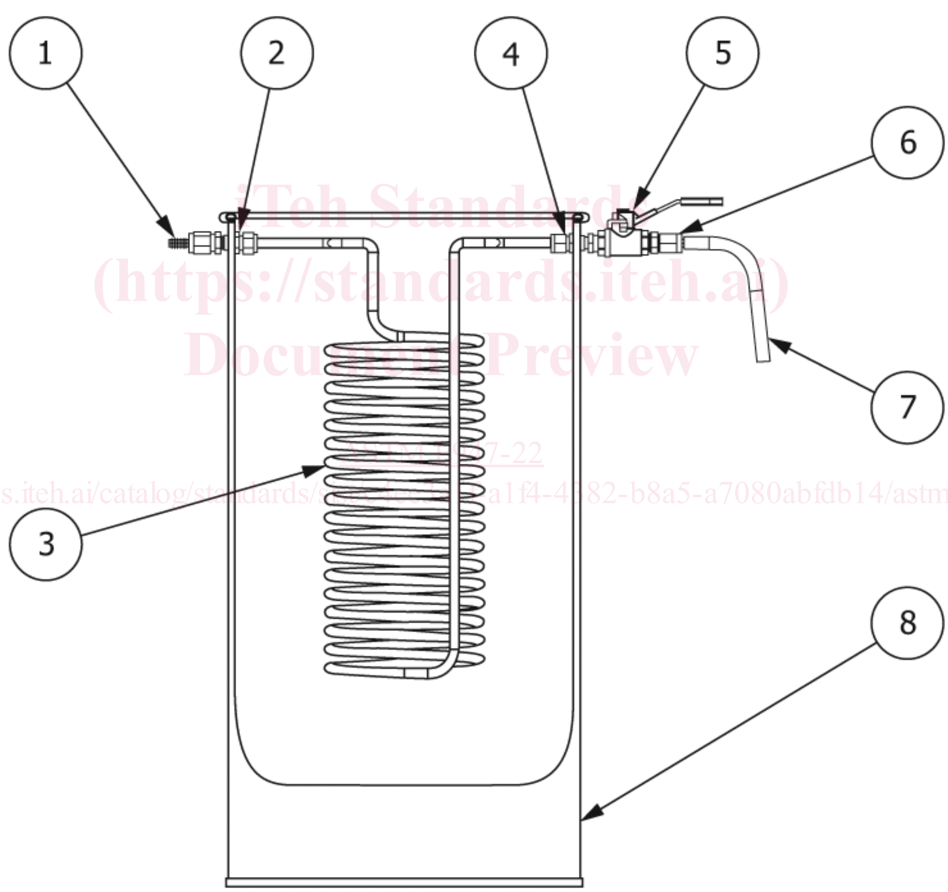
7.4 The liquid cooling coil has a regulating valve at the outlet. Regulating the flow at the condenser outlet maintains pressure on the liquid as it cools and prevents flashing of liquid inside the condenser which could result in gas break-out or chemical deposition, or both. The outside diameter of the liquid cooling coil is typically 6.4 mm (0.250 in.). In cases where the liquid contains substantial quantities of particulate matter, 9.5 mm (0.375 in.) outside diameter tubing coils may be used to minimize cooling coil plugging problems. Outside diameters larger than 9.5 mm (0.375 in.) should not be used, as larger tubing sizes increase the risk of contamination and chemical deposition during liquid sampling due to low fluid velocities and longer residence times within the tubing. (See Fig. 3.)

7.4.1 The liquid cooling coil is arranged as a downward spiral with the inlet at the top. This maintains the thermal gradient in the cooling container, allowing the coolant at the surface to boil and radiate as much heat as possible, while preserving the cooler fluids at the bottom of the vessel. The cooled sample liquid exits through a straight tube rising to the top of the cooler.

7.5 Cooling is achieved by an ice/water bath surrounding the coils or by a continuous overflow of cooling water running into the vessel holding the coils. Alternate configurations may include a water-tight jacket around the coils through which a constant source of cooling water flows. A source of coolant may be a glycol/water mixture circulated through the condenser jacket and an external fan-cooled heat exchanger.

7.6 Plastic[4] Sample tubing located at the exit of the cooler for steam and liquid sample collection should be 4.8 mm (0.188 in.) inside diameter by 9.5 mm (0.375 in.) outside

[4] Tygon, a registered trademark product of Norton Co., has been used for this purpose.



(1) JIC fitting, 6.4 mm (¼ in.) NPT × S.A.E. 37° sample inlet
(2) Bulkhead fitting, 6.4 mm (¼ in.) NPT × 6.4 mm (¼ in.) or 9.5 mm (⅜ in.) Swagelok
(3) 6.1 m × 6.4 mm or 9.5 mm (20 ft × ¼ in. or ⅜ in.) O.D. tubing, 0.9 mm (0.035 in.) wall
(4) Bulkhead fitting, 6.4 mm (¼ in.) NPT × 6.4 mm (¼ in.) or 9.5 mm (⅜ in.) Swagelok
(5) Sample valve, ball valve, 6.4 mm (¼ in.) NPT
(6) Hose adapter, 6.4 mm (¼ in.) NPT × 6.4 mm (¼ in.) hose barb
(7) Plastic[4] tubing, 9.5 mm (⅜ in.) O.D., 4.8 mm (3⁄16 in.) I.D. sample outlet
(8) 30 L to 76 L (8-gal to 20-gal) drum with perforated lid

Material specification: All metal components made from UNS S30400, S31600, S30403, or S31603. Alternative materials, such as N06625 may be appropriate when sampling conditions are likely to cause stress corrosion cracking.

FIG. 3 Liquid Sample Cooler

diameter. Heavy wall plastic[4] tubing is required for use under vacuum during steam sample collection and pressure during in-line filtration of liquid samples.

8. Example of Sampling Train

8.1 Examples of fully assembled sampling trains for steam and liquid are shown in Fig. 4 and Fig. 5.

9. Materials and Lubricants

9.1 *Lubricants:*

9.1.1 No lubricant shall be used in the collection containers, or their valves and seals, where it could contact the sample and bias the components of interest. This is particularly important if minor constituents are to be measured.

9.1.2 Other valves and moving parts in the sampling equipment that contact the sample should be lubricated to the minimum extent consistent with service life.

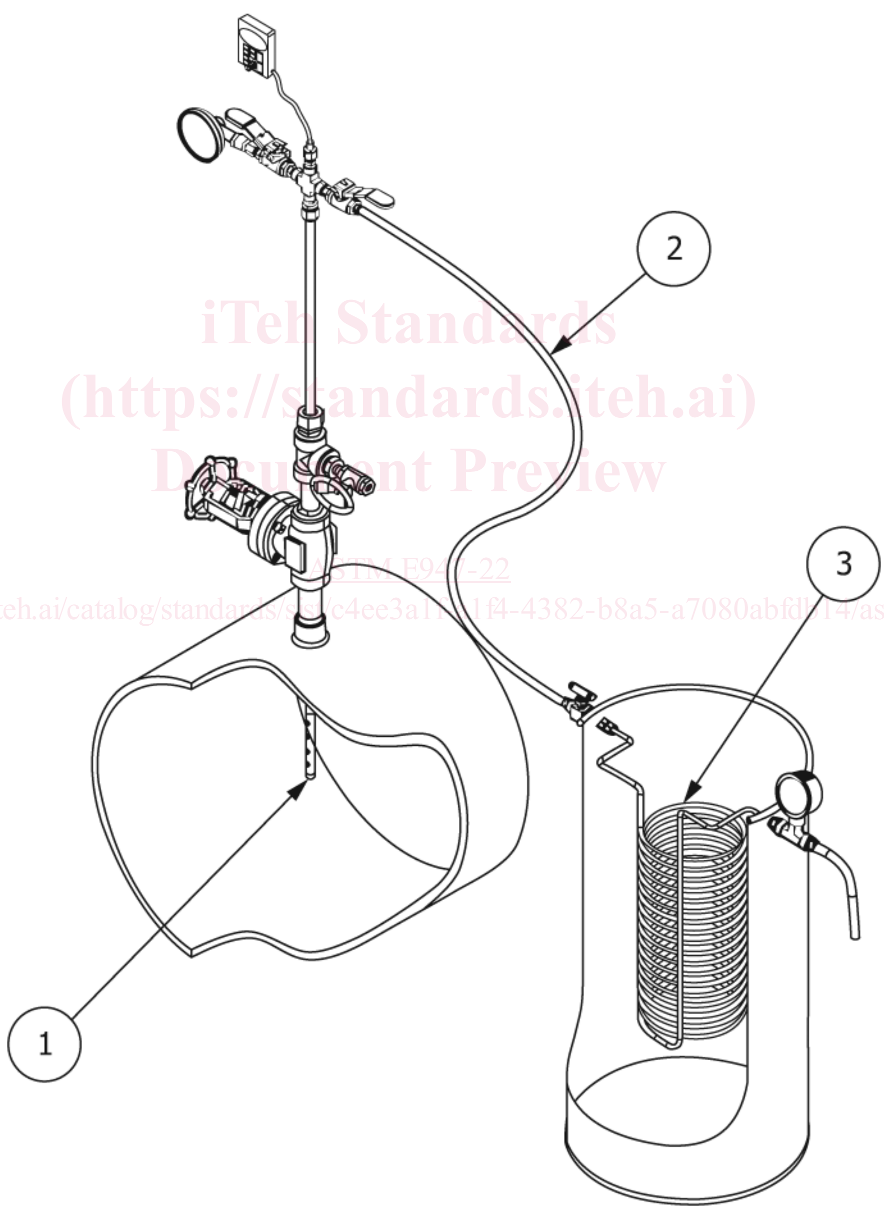
9.2 *Materials:*

9.2.1 In all cases, the sampling equipment shall be made of materials resistant to corrosion by the sample and that will not bias the results. Stainless steel, glass, and polymers are examples of materials that are generally satisfactory.

9.2.2 Copper-based alloys should be avoided.

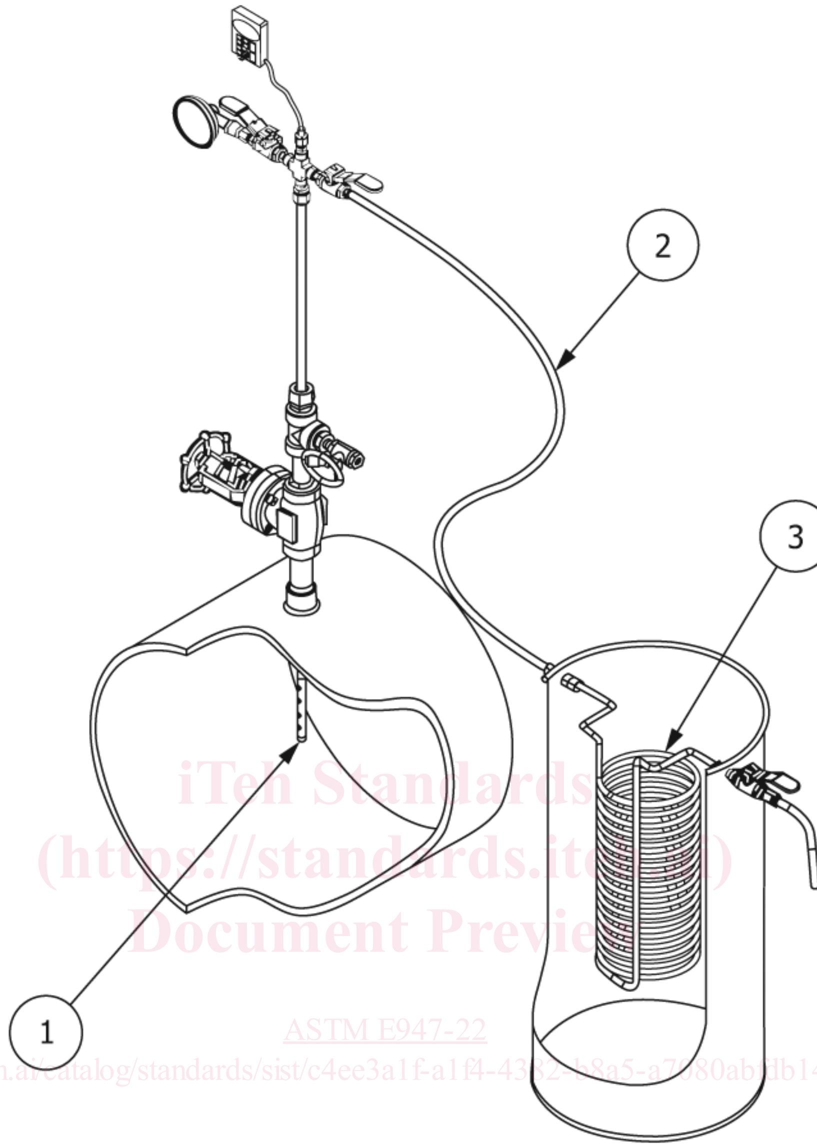
10. Sample Location

10.1 Sample locations vary and are dependent upon the samples to be collected. Generally, sample ports must be



(1) Probe tip, inserted to center of flow, holes facing into flow
(2) Sample hose
(3) Steam sample condenser

FIG. 4 Sampling Probe and Steam Condenser (Cutaway View)



(1) Probe tip, inserted to center of flow, holes facing into flow
(2) Sample hose
(3) Liquid sample cooler

FIG. 5 Sampling Probe and Liquid Sample Cooler (Cutaway View)

located on flowing pipelines that are confirmed to be single-phase liquid or single-phase steam.

10.2 Since samples are collected from the center of the flowing pipeline, the orientation of sample ports on single phase flow pipelines is limited only to orientations that provide adequate access to insert and remove the probe. In most cases, ports should have at least 2 m (6 ft) of clearance from obstructions such as floors, walls, or other pipes.

10.3 The sample ports must be at least 26 mm (1 in.) in diameter and configured with a full-open port ball or gate valve. This is necessary to ensure the probe can pass through the port and into the flow. Scale and debris often reduce the effective inner diameter of the port, therefore smaller ports are not recommended.

10.4 Sample ports should always be located on portions of the pipeline containing flowing fluids and should never be located on portions of pipelines containing stagnant fluids. The physical and chemical composition of the pipeline fluids can change significantly from heat loss and chemical reactions in the trapped fluids.

11. Sampling Procedure

11.1 *Probe Installation:*

11.1.1 If sampling liquid, tighten all fittings from sample probe to liquid cooler outlet. If sampling steam, tighten all fittings from sample probe to steam condenser outlet, then verify the sampling assembly is leak-free following the steps outlined in 7.3.3.