Designation: D 4448 – 85a (Reapproved 1992)

Designation: D 4448 – 01

INTERNATIONAL

Standard Guide for
Sampling Ground~~w~~-Water Monitoring Wells[1]

This standard is issued under the fixed designation D 4448; 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 guide covers~~ procedures for obtaining valid, representative samples from groundwater monitoring wells. The scope is limited to~~ sampling equipment and procedures and "in the field" preservation, and it does not include well location, depth, well development, design and construction, screening, or analytical procedures that also have a significant bearing on sampling results.This guide is intended to assist a knowledgeable professional in the selection of equipment for obtaining representative samples from ground-water monitoring wells that are compatible with the formations being sampled, the site hydrogeology, and the end use of the data.

1.2 This guide is only intended to provide a review of many of the most commonly used methods for~~ samp~~ collecting ground-water quality samples from monitoring wells and is not intended to serve as a ground-water monitoring plan for any specific application. Because of the large and ever increasing number of options available, no single guide can be viewed as comprehensive. The practitioner must make every effort to ensure that the methods used, whether or not they are addressed in this guide, are adequate to satisfy the monitoring objectives at each site.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are provided for information only.

1.4 *This standard does not purport to address all of the safety problems, 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. ~~Summary of Guide~~

~~2.1 The equipment and procedures used~~Referenced Documents

2.1 *ASTM Standards:*

D 4750 Test Method for~~ sampling~~ Determining Subsurface Liquid Levels in a~~ monitoring well depend on many factors. These include, but are not limited to, the design and construction of the well, rate of groundwater flow, and the chemical species of interest. Sampling procedures will be different if analyzing for trace organics, volatiles, oxidizable species,~~ Borehole or~~ trace metals is needed. This guide considers all of these factors by discussing equipment and procedure options at each stage of the sampling sequence. For ease of organization, the sampling process can be divided into three steps: well flushing, sample withdrawal, and field preparation of samples.~~

~~2.2 Monitoring wells must be flushed prior to sampling so that the groundwater is sampled, not the stagnant water in the well casing. If the well casing can be emptied, this may be done although it may be necessary to avoid oxygen contact with the groundwater. If the well cannot be emptied, procedures must be established to demonstrate that the sample represents groundwater.~~ Monitoring~~ an indicative parameter such as pH during flushing is desirable if such a parameter can be identified.~~

~~2.3 The types of species that are to be monitored as well as the concentration levels are prime factors for selecting sampling devices **(1,2).**~~ Well (Observation Well)[2] ~~The sampling device and all materials and devices the water contacts must be constructed of materials that will not introduce contaminants or alter the analyte chemically in any way.~~

~~2.4 The method of sample withdrawal can vary with the parameters of interest. The ideal sampling scheme would employ a completely inert material, would not subject the sample to negative pressure and only moderate positive pressure, would not expose the sample to the atmosphere, or preferably, any other gaseous atmosphere before conveying it to the sample container or flow cell~~

D 5088 Practice for~~ on-site analysis.~~

---

[1] This guide is under the jurisdiction of ASTM Committee D~~-~~34 on Waste Management and is the direct responsibility of Subcommittee D34.01 on Sampling and Monitoring.

Current edition approved Aug.~~ 23 and Oct. 25, 1985.~~ 10, 2001. Published~~ May 1986.~~ November 2001. Originally published as D 4448–85. Last previous edition D 4448–85a (1992).

~~[2] The boldface numbers in parentheses refer to a list~~

[2] *Annual Book* *of~~ references at the end of this guide.~~* *ASTM Standards*, Vol 04.08.

~~2.5 The degree and type~~ Decontamination of ~~effort and care that goes into a sampling program is always dependent on the chemical species of interest and the concentration levels of interest. As the concentration level of the chemical species of analytical interest decreases, the work and precautions necessary~~ Field Equipment Used at Nonradioactive Waste Sites[2]

D 5792 Practice for ~~sampling are increased. Therefore, the sampling objective must clearly be defined ahead~~ Generation of ~~time. For example,~~ Environmental Data Related to ~~prepare equipment for sampling for mg/L (ppm) levels~~ Waste Management Activities: Development of ~~Total Organic Carbon (TOC) in water is about an order of magnitude easier than preparing to sample~~ Data Quality Objectives[3]

D 5903 Guide for ~~µg/L (ppb) levels of~~ Planning and Preparing ~~a trace organic like benzene. The specific precautions to be taken in preparing to sample~~ Ground-Water Sampling Event[4]

D 6089 Guide for ~~trace organics are different from those to be taken in sampling~~ Documenting a Ground-Water Sampling Event[4]

D 6452 Guide for ~~trace metals. No final Environmental Protection Agency (EPA) protocol is available~~ Purging Methods for Wells Used for Ground-Wa~~mp~~ter Quality Investigations[4]

D 6517 Guide for Field Preservation of ~~trace organics. A short guidance manual~~ Ground-Water Samples[4]

2.2 ~~**(3)** and an EPA document **(4)** concerning monitoring well sampling, including considerations for trace organics, are available.~~

~~2.6 Care must be taken not to cross contaminate samples or monitoring wells with sampling or pumping devices or materials. All samples, sampling devices, and containers must be protected from the environment when not in use. Water level measurements should be made before the well is flushed. Oxidation-reduction potential, pH, dissolved oxygen, and temperature measurements and filtration should all be performed on the sample in the field, if possible. All but temperature measurement must be done prior to any significant atmospheric exposure, if possible.~~

~~2.7 The sampling procedures must be well planned and all sample containers must be prepared and labeled prior to going to the field.~~ *EPA Standards:*

EPA Method 9020A

EPA Method 9022

3. ~~S~~Terminology

3.1 *Definitions:*

3.1.1 *low-flow sampli~~e~~ng*—a ground water sampling technique where the purge and ~~Use~~

~~3.1 The quality~~ sampling rates do not result in significant changes in formation seepage velocity.

3.1.2 *minimal purge sampling*—the collection of ~~groundwater has become an issue~~ ground water that is representative of ~~national concern. Groundwater monitoring wells are one of~~ the ~~more important tools for evaluating~~ formation by purging only the ~~quality~~ volume of ~~groundwater, delineating contamination plumes, and establishing~~ water contained by the ~~integrity of hazardous material management facilities.~~

~~3.2 The goal in~~ sampling ~~groundwater monitoring wells~~ equipment (that is, tubing, pump bladder).

3.1.2.1 *Discussion*—This sampling method should be considered in situations where very low yield is a consideration and results from this sampling method should be scrutinized to ~~obtain samples~~ confirm that ~~are truly representative of the aquifer or groundwater in question. This guide discusses the advantages~~ they meet data quality objectives (DQOs) and ~~disadvantages~~ the work plan objectives.

3.1.3 *passive sampling*—the collection of ~~various well flushing, sample withdrawal, and sample preservation techniques. It reviews~~ ground-water quality data so as to induce no hydraulic stress on the aquifer.

3.1.4 *water quality indicator parameters*—refer to field monitoring parameters that include but are not limited to ~~be considered in developing a valid sampling plan.~~ pH, specific conductance, dissolved oxygen, oxidation-reduction potential, temperature, and turbidity that are used to monitor the completeness of purging.

4. ~~Well Flushing (Purging)~~

~~4.1 Water that stands within~~Summary of Guide

4.1 The equipment and procedures used for sampling a monitoring well ~~for a long period~~ depend on many factors. These include, but are not limited to: the design and construction of ~~time may become unrepresentative~~ the well, rate of ~~formation water because chemical or biochemical change may cause water quality alterations~~ ground-water flow, and ~~even if it is unchanged from~~ the ~~time it entered the well, the stored water~~ chemical species of interest. Sampling procedures may ~~not~~ be ~~r~~ diffe~~p~~rent if analyses for trace organics, volatiles, oxidizable species, or trace metals are needed. Thi~~v~~s guide considers all of ~~formation water~~ these factors by discussing equipment and procedure options at ~~the time~~ each stage of ~~sampling, or both. Because~~ the ~~representativeness~~ sampling sequence. For ease of ~~stored water is questionable, it should~~ organization, the sampling process can be ~~excluded from samples collected from a monitoring well.~~

~~[3] Viton is a trademark~~

[3] *Annual Book of ~~E. I. du Pont de Nemours & Co., Wilmington, DE 19898 and has been found suitable for this purpose.~~ ASTM Standards,* Vol 11.04.

[4] *Annual Book of ASTM Standards,* Vol 04.09.

~~4.2 The surest way~~ divided into three steps: well purging, sample withdrawal, and field preparation of~~ accomplishing this objective is to remove all stored water from~~ samples. Certain sampling protocols eliminate the~~ casing~~ first step.

4.2 The sampling must be well planned and all sample containers must be prepared prior to~~ sampling. Research with a tracer in a full scale model 2 in. PVC well **(5)** indicates that pumping 5~~ going to~~ 10 times~~ the~~ volume of~~ field. These procedures should be incorporated in the~~ well via an inlet near~~ approved work plan that should accompany the~~ free water surface is sufficient~~ sampling crew so that they may refer to it for guidance on sampling procedures and analytes to be sampled (see Guide D 5903).

4.3 Monitoring wells must be either purged to remove~~ all the stored~~ stagnant water in the~~ casing. The volume of the~~ well~~ may~~ casing or steps must be~~ calculated~~ taken to~~ include~~ ensure that only water meeting the~~ well screen~~ DQOs and~~ any gravel pack if natural flow through these~~ the work plan objectives is~~ deemed insufficient to keep them flushed out.~~

~~4.3 In deep or large diameter wells having~~ withdrawn during sampling (see Practice D 5792). When well purging is performed, it is accomplished by either removing a~~ volume~~ predetermined number of~~ water so large as to make~~ well volumes or by the removal of ground water until stable water quality parameters have been obtained. Ideally this purging is performed with minimal well drawdown and minimal mixing of the formation water~~ impractical, it may be feasible~~ with the stagnant water above the screened interval in the casing. Passive sampling and the minimal purge methods do not attempt to~~ lower a pump or pump inlet to some point well below~~ purge the water~~ surface,~~ present in the monitoring well prior to sampling **(1)**.[5] The minimal purge method attempts to purge only the~~ volume below~~ sampling equipment. Each of these methods is discussed in greater detail in Section 6.

4.4 The types of chemical species that~~ point then withdraw~~ are to be sampled as well as the~~ sample from a deeper level. Research indicates this approach should avoid most contamination associated with stored water~~ reporting limits are prime factors for selecting sampling devices ~~**(5, 6,7)**~~**(2, 3)**.~~ S~~ **The sampling device and all materials and devices the~~ casing above the purge point with a packer may make this approach more dependable by preventing migration of stored~~ water~~ from above. But the packer~~ contacts must be~~ above the top~~ constructed of~~ the screened zone,~~ materials that will not introduce contaminants or~~ stagnant water from above~~ alter the~~ p~~ analytes of c~~k~~oncern in any way. Material compatibility is further discussed in Section 8.**

4.5 The method of sample co~~w~~llection can vary wit~~o~~h the~~ purged zone through~~ parameters of interest. The ideal sampling scheme employs a completely inert material, does not subject the~~ well's gravel/sand pack.~~

~~4.4 In low yielding wells,~~ sample to pressure change, does not expose the~~ only practical way~~ sample to~~ remove all standing water may be~~ the atmosphere, or any other gaseous atmosphere before conveying it to~~ empty~~ the sample container or flow cell for on-site angalysis. Since~~ i~~ these ideals are not always~~ possible to remove all water, it may~~ obtainable, compromises must be ~~advisable to let~~ made by the knowledgeable individual designing the sampling program. These co~~v~~ncer~~ (r~~ns should be~~f~~ documented in the data quality objectives (DQOs) of the sampling plan (see Practice D 5792) **(4)**.

4.6 The degree and~~ empty it again at least once. If introduction~~ type of~~ oxygen~~ effort and care that goes into a sampling program is always dependent on the~~ aquifer may be~~ chemicals of~~ concern, it would be best not to uncover~~ concern and their reporting levels as documented in the~~ screen when performing~~ project's DQOs. As the~~ above procedures. The main disadvantage~~ reporting level of~~ methods designed to remove all~~ the chemical species of analytical interest decreases, the~~ stored water is that large volumes may need to~~ precautions necessary for sampling generally increase. Therefore, the sampling objective must clearly be~~ pumped~~ defined ahead of time in~~ certain instances. The main advantage is that~~ the DQOs. The specific precautions to be~~n~~ taken in preparing to sample for~~ contamination of samples with stored water is minimized.~~

~~4.5 Another approach~~ trace organics are different from those to be taken in sampling for trace metals. A draft U.S. EPA guidance document **(5)** concerning monitoring well~~ f~~ sampling, including cons~~h~~iderations for trace organics, is available to~~ m~~ pro~~n~~vide additional guidance.

4.7 Care must be taken not to contaminate samples or~~ more indicator parameters such as pH, temperature, or conductivity~~ monitoring wells. All samples, sampling devices, and~~ consider the well to~~ containers must be~~ flushed when the indicator(s) no longer change. The advantage of this method is that pumping can be done~~ protected from~~ any location within the casing and the volume~~ possible sources of~~ stored water present has no direct bearing on the volume of water that must~~ contamination when not in use. Water level measurements should be~~ pumped. Obviously,~~ made according to Test Method D 4750 before placing, purging, or sampling equipment in~~ a low yielding well,~~ the well~~ m~~. Redox potential, turbidity, pH, specific conductance, DO (dissolved oxygen), and temperature measurements should all be~~ emptied before~~ performed on the~~ parameters stabilize. A disadvantage of this approach is that there is no assurance~~ sample in~~ all situations that~~ the~~ stabilized~~ field, if possible, since these parameters ~~represent formation water. If significant drawdown has occurred, water from some distance away may~~ change too rapidly to be ~~pulled into the screen causing~~ conducted by a~~ steady parameter reading but not a representative reading. Also, a suitable indicator parameter and means~~ fixed laboratory under most circumstances. Field meter(s) or sondes equipped with flow-through cells are available that are capable of continuously monitoring these parameters during purging if they are being used as water quality indicator parameters. These devices prevent the~~ field must be available.~~

~~4.6 Gibb **(4,8)** has described a time-drawdown approach using a knowledge~~ mixing of oxygen with the~~ well hydraulics to predict the percentage of stored water entering~~ sample and provide a~~ pump inlet near the top~~ means of~~ the screen at any time after flushing begins. Samples are taken~~ determining when the~~ percentage is acceptably low. As before, the advantage is~~ parameters have

---

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

stabilized. Certain measurements that~~ well volume has no direct effect in the duration~~ are used as indicators of~~ pumping. A current knowledge of the well's hydraulic characteristics is necessary to employ this approach. Downward migration of stored water due to effects other than drawdown (for example density differences) is not accounted for in this approach.~~

~~4.7 In any flushing approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be used. Excessive drawdown distorts the natural flow patterns around a well~~ biological activity, such as ferrous iron, nitrite, and~~ can cause contaminants that were not present originally to~~ sulfite, may also be~~ drawn into~~ conducted in the~~ w~~ field since they rapidly oxidize. All temperature measurements must be done prior to any significant atmospheric exposure.

5. ~~Materials~~Significance and ~~Manufacture~~ Use

5.1 The~~ choice~~ quality of ground water has become an issue of national concern. Ground-water monitoring wells are one of the more important tools for evaluating the quality of ground water, delineating contamination plumes, and establishing the integrity of hazardous material management facilities.

5.2 The goal in sampling ground-water monitoring wells is to obtain samples that meet the~~ construction~~ DQOs. This guide discusses the advantages and disadvantages of various well sampling methods, equipment, and sample preservation techniques. It reviews th~~ou~~e variables that need to be~~ based upon~~ considered in developing a~~ knowledge~~ valid sampling plan.

6. Well Purging

6.1 Water that stands within a monitoring well for a long period of~~ what compounds~~ time may become unrepresentative of formation water because chemical or biochemical change may alter water quality or because the formation water quality may change over time (see Guide D 6452). Even if it is unchanged from the time it entered the well, the stagnant water may not be representative of formation water at the time of sampling. There are two approaches to purging that reflect two differing viewpoints: to purge a large volume of ground water and to purge a minimum of, or no ground water before collecting a sample. The approach most often applied is to purge a sufficient volume of standing water from the casing, along with sufficient formation water to ensure that the water being withdrawn at the time of sampling is representative of the formation water. Typically, three to five well volumes are used. An alternative method that is gaining acceptance is to minimize purging and to conduct purging at a low flow rate or to eliminate purging entirely.

6.2 In any purging approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be used. Excessive drawdown distorts the natural flow patterns a~~m~~round the well. Two potential negative effects are the introduction of ground water that is not representative of water quality immediately around the monitoring well and artificially high velocities entering the well resulting in elevated turbidity and analytical data that reflects the absorption of contaminants to physical particles rather than soluble concentrations in ground water. It may~~ interact via leaching, adsorption, or catalysis. In some situations, PVC or some other plastic~~ also result in cascading water from the top of the screen that can result in changes in dissolved gasses, redox state, and ultimately affect the concentration of the analytes of interest through the oxidation of dissolved metals and possible loss of volatile organic compounds (VOCs). There may also be~~ sufficient.~~ a lingering effect on the dissolved gas levels and redox state from air being introduced and trapped in the sandpack. In~~ others, an all glass apparatus may~~ no instance shall a well be~~ necessary.~~

~~5.2 Most analytical protocols suggest that~~ purged dry. If available, the field notes or purge logs generated during previ~~e~~ous sampling or development of the well as well as construction logs should be reviewed to assist in the selection of the most appropriate sampling~~ and storing samples for trace organics analysis (µg/L levels) must~~ method.

6.3 The most often applied purging method has an objective to remove a predetermined volume of stagnant water from the casing prior to sampling. The volume of stagnant water can either be~~ constructed~~ defined as the volume of~~ glass~~ water contained within the casing and screen, or~~ TFE–fluorocarbon resin, or both. One suggestion advanced by~~ to include the~~ EPA~~ well screen and any gravel pack if natural flow through these is deemed insufficient to keep them flushed out. Research with a tracer in a full scale model 2-in. polyvinyl chloride (PVC) well **(6)** indicates that pumping 5 to 10 times the~~ monitoring~~ volume of the well~~ be constructed so that only TFE–fluorocarbon tubing be used~~ via an inlet near the free water surface is sufficient to remove all the stagnant water in the ca~~t~~sing. This approach (with three to five casing volumes purged) was suggested by the U.S. EPA **(7)**.

6.4 In deep or large diameter wells having a volume of water so large as to make removal of all the water impractical, it may be feasible to lower a pump or pump inlet to some poin~~g~~t well below the water surface, purge only the volume below that~~ extends~~ point then withdraw the sample from a~~ few feet~~ deeper level. Research indicates this approach should avoid most contamination associated with stagnant water **(6, 8)**. Sealing the casing above the purge point with a packer may make this approach more dependable by preventing migration of stagnant water~~ table to~~ from above. But the packer must be above the to~~m~~p of the screened zone, or stagnant water from above the packer may flow into the purged zone through the well's gravel/sand pack.

6.5 An alternate method is based on research by Barcelona, Wehrmann, and Varlien **~~(3,5)~~(1) and Puls and Powell (2)~~A~~. Their research suggests that purging at rates less than 1 L/min (approximately 0.25 gal/min) provides more reproducible VOCs and metals analytical results than purging at high rates. This method is based on the premise that at very low pumping rates, there is little mixing of the water column and laminar ground-water flow through the screen provides a more consistent sample. This sampling method also produces less turbid samples that may eliminate the need for filtration when collecting metals. This method is~~ now commercially available, PVC~~ commonly referred to as low-flow sampling.**

6.6 The low-flow sampling approach is most applicable to wells capable of sustaining a yield approximately equal to the pumping rate. A monitoring well~~ casings are currently~~ with a very low yield may not be applicable to this technique since it may be difficult to reduce the~~ most popular. If adhesives are avoided, PVC~~ pumping rate sufficiently to prevent mixing of the water column in the well~~ casings are acceptable~~ casing in~~ many cases although their use may still lead~~ such a well. The water level in the well being sampled should be continuously monitored using an electronic water-level indicator during low-flow sampling. Such a water-level indicator could be set below the water surface after sufficient water has been withdrawn to~~ some problems~~ fill the pump, tubing, and flow cell. The water-level indicator would then produce a continuous signal indicating submersion. When the well is purged, if the water level falls below the water-level indicator probe, the signal indicates that the water level has fallen below the maximum allowable drawdown and the pumping rate should be decreased. Pumping is started at approximately 100 mL/min discharge rate and gradually adjusted to match the well's recharge rate. The selection of~~ concern. At present,~~ the type of ~~background presented by PVC~~ pump is dependent on site-specific conditions and~~ interactions occurring between PVC and groundwater are not well understood. Tin,~~ DQOs. The bladder pump design is most commonly used in this sampling method, however, the~~ form~~ depth limitation of~~ an organotin stabilizer added to PVC,~~ this pump may necessitate the use of a gas-driven piston pump in some instances.

6.7 A variation on the above purging approaches is to monitor one or more indicator parameters until stabilization of the selected parameter(s) has been achieved. Stabilization is considered achieved when measurements a~~k~~re within a pre-defined range. This range has been suggested to be approxim~~PVC~~ately 10 % over two successive measurements made 3 min~~g~~ apart by the U.S. EPA **(4)**. More recent documents **(9)**

~~5.3 Since~~ have suggested ranges ±0.2°C for temperature, ±0.1 standard units for pH, ±3 % for specific conductance, ±10 % for DO, and ±10 mV for redox potential. A disadvantage of the~~ most significant problem encountered~~ stabilization approach is that there is no assurance in~~ trace organics sampling, results from~~ all situations that the stabilized parameters represent formation water. These criteria should therefore be set on a site by site basis since if set too stringent, large volumes of~~ PVC adhesives in monitoring well construction, threaded joints might avoid~~ contaminated purge water may be generated without ensuring that the ~~problem **(3,5)**. Milligram per litre (parts per million) levels of compounds such as tetrahydrofuran, methyl-ethyl-ketone, and toluene are found to leach into groundwater~~ samples~~ from monitoring well casings sealed with PVC solvent cement. Pollutant phthalate esters **(8,10)** are often found~~ are any more representative. In a low yielding formation, this could result in~~ water samples at ppb levels;~~ the~~ EPA~~ well being emptied before the parameters stabilize. Also, if significant drawdown has~~ found them on occasion at ppm levels in their samples. The ubiquitous presence of~~ occurred, water from some distance away may be pulled into the screen causing a steady parameter reading but not a representative reading. If these~~ phthalate esters is unexplained, except to say~~ criteria are properly selected, the volume of investigative derived waste water may be reduced.

6.8 The indicator parameters that~~ they~~ may be~~ leached from plastic pipes, sampling devices,~~ monitored include pH, temperature, specific conductance, turbidity, redox potential, and~~ containers.~~

~~5.4 TFE–fluorocarbon resins are highly inert and have sufficient mechanical strength to permit fabrication~~ DO. A combination of~~ sampling devices~~ a pump and~~ well casings. Molded parts are exposed~~ field meter(s) or sondes equipped with a flow-through cell is ideal for this purpose since it allows the monitoring of one or more of these parameters on a continuous basis without exposure to~~ high temperature during fabrication which destroys any organic contaminants.~~ the atmosphere. A typical flow-through cell application is shown in Fig. 1. The~~ evolution~~ pump used in this technique may be any pump capable of~~ fluorinated compounds can occur during fabrication, will cease rapidly, and does not occur afterwards unless the resin~~ producing a steady flow such as a peristaltic or bladder pump. If a submersible pump is used, the hydra~~t~~ulic pressure developed in the flow-through cell may be sufficient to~~ its melting point.~~

~~5.5 Extruded tubing~~ force the probes out of~~ TFE-fluorocarbon for sampling may contain surface traces of an organic solvent extrusion aid.~~ their position. This~~ can~~ problem may be~~ removed easily~~ eliminated by installing a tee connector in the~~ fabricator and,~~

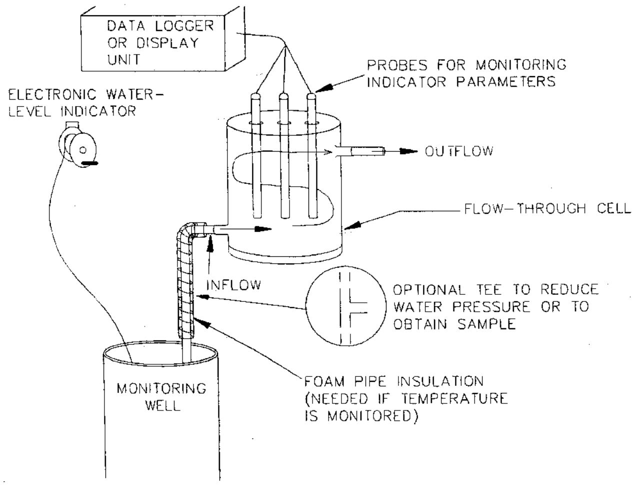

FIG. 1 Flow-Through Cell

~~once removed by flushing, should not affect~~ discharge line to allow only a portion of the ~~sample. TFE-fluorocarbon FEP~~ flow to enter the flow-through cell. Another concern with the low-flow sampling method is sorption onto the tubing. Studies have indicated that at flow rates of 0.1 L/min (0.026 gal/min), low-density polyethylene (LDPE) and ~~TFE-fluorocarbon PFA resins do not require this extrusion aid~~ plasticized polypropylene tubings are prone to sorption and ~~may~~ TFE-fluorocarbon should be ~~suitable for sample~~ used. This is especially a concern if tubing ~~as well. Unsintered thread-sealant tape~~ lengths of ~~TFE-fluorocarbon is available in an "oxygen service" grade~~ 15 m (50 ft) or longer are used **(10)**.

6.9 Gibb and ~~contains no extrusion aid and lubricant.~~

~~5.6 Louneman, et al.~~ Schuller **(11)** ~~allude to problems caused by~~ have described a ~~lubricating oil used during TFE-fluorocarbon tubing extrusion. This reference also presents evidence that a fluorinated ethylene-propylene copolymer adsorbed acetone~~ time-drawdown approach using knowledge of the well hydraulics to ~~a degree that later caused contamination~~ predict the percentage of stagnant water entering a ~~gas sample.~~

~~5.7 Glass and stainless steel~~ pump inlet near the top of the screen at any time after flushing begins. Samples are ~~two other materials generally considered inert in aqueous environments. Glass~~ collected when the percentage is ~~probably among~~ acceptably low. As before, the ~~best choices though it~~ advantage is ~~not inconceivable it could adsorb some constituents as~~ that well volume has no direct effect on the duration of pumping. A current knowledge of the well's hydraulic characteristics is necessary to employ this approach. Downward migration of stagnant water due to effects other ~~contaminants~~ than drawdown (for example, ~~Na, silicate, and Fe). Of course, glass sampling equipment must be handled carefully in the field. Stainless steel~~ density differences) is ~~strongly and easily machined~~ not accounted for in this approach.

6.10 An alternative to ~~fabricate equipment. Unfortunately, it~~ purging a well before sampling is ~~not totally immune~~ to collect a water sample within the screened zone without purging. These techniques are based on studies that ~~could release metallic contaminants. Stainless steel contains various alloying metals, some of~~ under certain conditions, natural ground-water flow is laminar and horizontal with little or no mixing within the well screen **(12, 13)**. To properly use these ~~(for example Ni) are commonly used as catalysts for various reactions. The alloyed constituents of some stainless steels can~~ sampling techniques, a water sample must be ~~solubilized by~~ collected within the ~~pitting action~~ screened interval with little or no mixing of ~~nonoxidizing anions such as chloride, fluoride, and in some instances sulfate, over~~ the water column within the casing. Examples of these techniques include minimal purge sampling which uses a ~~r~~ dedicated sampling pump capable of ~~pH conditions. Aluminum, titanium, polyethylene,~~ pumping rates of less than 0.1 L/min, discrete depth sampling using a bailer that allows ground water entry at a controlled depth, (for example, differential pressure bailer **(14)**), or diffusion sampling. These sampling techniques are discussed in 8.1.10.

7. Materials and ~~other corrosion resistant~~ Manufacture

7.1 The choice of materials ~~have been proposed by some as acceptable materials, depending on groundwater quality and~~ used in the ~~constituents~~ construction of ~~interest.~~

~~5.8 Where temporarily installed~~ sampling ~~equipment is used, the sampling device that is chosen~~ devices should be ~~non-plastic (unless TFE-fluorocarbon), cleanable~~ based upon knowledge of ~~trace organics, and must~~ what compounds may be ~~cleaned between each monitoring well use~~ present in ~~order to avoid cross-contamination of wells~~ the sampling environment and ~~samples. The only way to ensure that~~ how the ~~d~~ sample materials may interact via leaching, adsorption, or catalysis. A second concern is ~~indeed "clean" and acceptable is to analyze laboratory water blanks and field water blanks~~ that ~~have been soaked in and passed through the sampling device to check for the background levels that~~ corrosion or degradation may ~~result from~~ compromise the structural integrity of the sampling ~~materials~~ device. In some situations, PVC or ~~from field conditions. Thus,~~ other plastic may be sufficient. In others, an all ~~samplings for trace materials~~ TFE-fluorocarbon apparatus may be necessary. The potential presence of nonaqueous phase liquid (NAPL) should also be ~~accompanied by samples which represent~~ a consideration since its presence would expose the ~~field background (if possible), the~~ sampling equipment ~~background, and the laboratory background.~~

~~5.9 Additional samples are often taken in the field and spiked (spiked-field samples) in order~~ to ~~verify~~ high concentrations of potential solvents. No one material is ideal in that ~~the sample handling procedures are valid. The American Chemical Society's committee~~ each material will, to some degree absorb or leach chemicals or may degrade on ~~environmental improvement has published guidelines for data acquisition~~ exposure to a chemical.

7.2 The advantages and ~~data evaluation which should be useful~~ disadvantages of these materials for sampling equipment are summarized in ~~such environmental evaluations **(10,12)**~~ Table 1.

7.3 *PVC*:

7.3.1 If adhesives are avoided, PVC is acceptable in many cases although their use may still lead to some problems if trace organics are of concern or NAPL is present **(15)**. At present, interactions occurring between PVC and ground water are not well understood. Tin, in the form of an organotin stabilizer added to PVC, may enter samples taken from PVC **(16)**.

7.3.2 The structural integrity concerns with PVC increase with the concentration of PVC solvents in ground water. As such, NAPLs that are PVC solvents are a primary concern. Potential NAPLs that are of a concern for PVC and other commonly used plastics are listed in Table 2. Degradation of these materials is primarily by solvation, which is the penetration of the material by the solvent that ultimately causes softening and swelling that can lead to failure. Even in lower concentrations, however, PVC solvents may deteriorate PVC. Methylene chloride, which is a very effective PVC solvent, will soften PVC at one tenth its

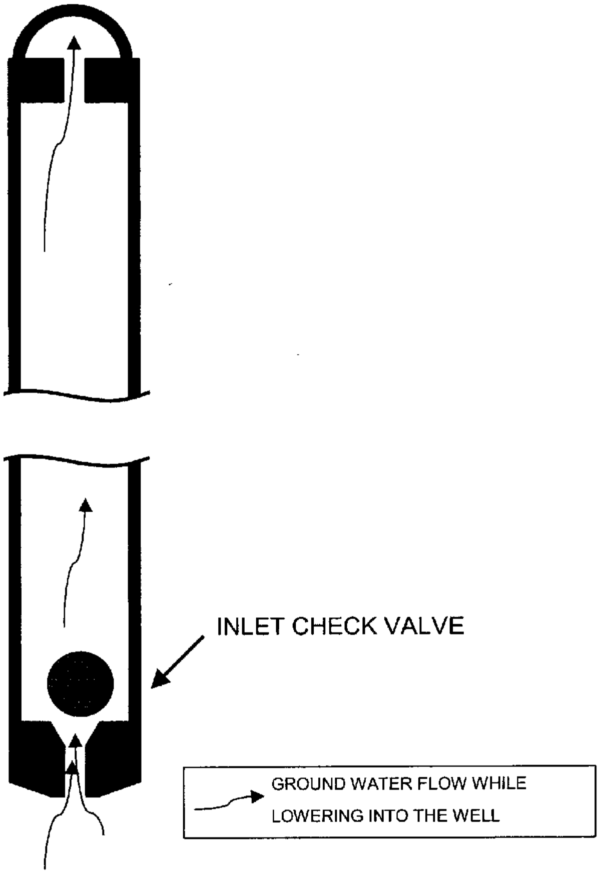

FIG. 2 Single Check Valve Bailer

solubility limit while trichloroethylene, which is a less effective solvent, will begin to soften PVC at six tenths its solubility limit **(17)**.

7.4 *TFE-Fluorocarbon Resins*:

7.4.1 TFE-fluorocarbon resins are highly inert and have sufficient mechanical strength to permit fabrication of sampling devices. Molded parts are exposed to high temperature during fabrication that destroys any organic contaminants. The evolution of fluorinated compounds can occur during fabrication, will cease rapidly, and does not occur afterwards unless the resin is heated to its melting point. Relative to PVC and stainless steel, TFE-fluorocarbon is less sorptive of cations **(18)**.

7.4.2 Extruded TFE-fluorocarbon tubing may contain surface traces of an organic solvent extrusion aid. This can be removed easily by the fabricator and, once removed by flushing, should not affect the sample. TFE-fluorocarbon fluorinated ethylene propylene (FEP) and TFE-fluorocarbon perfluoroalkoxy (PFA) resins do not require this extrusion aid and may be suitable for sample tubing as well. Unsintered thread-sealant tape of TFE-fluorocarbon is available in an "oxygen service" grade and contains no extrusion aid and lubricant.

7.5 *Glass and Stainless Steel*:

7.5.1 Glass and stainless steel are two other materials generally considered inert in aqueous environments. Glass is generally not used, however, because of difficulties in handling and fabrication. Stainless steel is strong and easily machined to fabricate equipment. It is, however, not totally immune to corrosion that could release metallic contaminants (see Table 1). Stainless steel contains various alloying metals, some of these (that is, Nickel) may catalyze reactions. The alloyed constituents of some stainless steels can be solubilized by the pitting action of nonoxidizing anions such as chloride, fluoride, and in some instances sulfate, over a range of pH conditions. Aluminum, titanium, polyethylene, and other corrosion resistant materials have been proposed by some as acceptable materials, depending on ground-water quality and the constituents of interest.

7.5.2 Where temporarily installed sampling equipment is used, the sampling device that is chosen should be able to be cleaned of trace organics, and must be cleaned between each monitoring well use to avoid cross-contamination of wells and samples. Decontamination of equipment PVC and stainless steel constructed sampling equipment exposed to organic chemicals, pesticides or nitroaromatic compounds generally can be successfully accomplished using a hot detergent solution followed by a hot water rinse. Equipment constructed of LDPE and TFE-fluorocarbon should also be hot air dried or oven dried at approximately 105°C to remove residual pesticides and organic contaminants, respectively **(19, 20)**. A common method to verify that the device is "clean" and acceptable is to analyze a sample (equipment blank) that has been soaked in or passed through the sampling device,

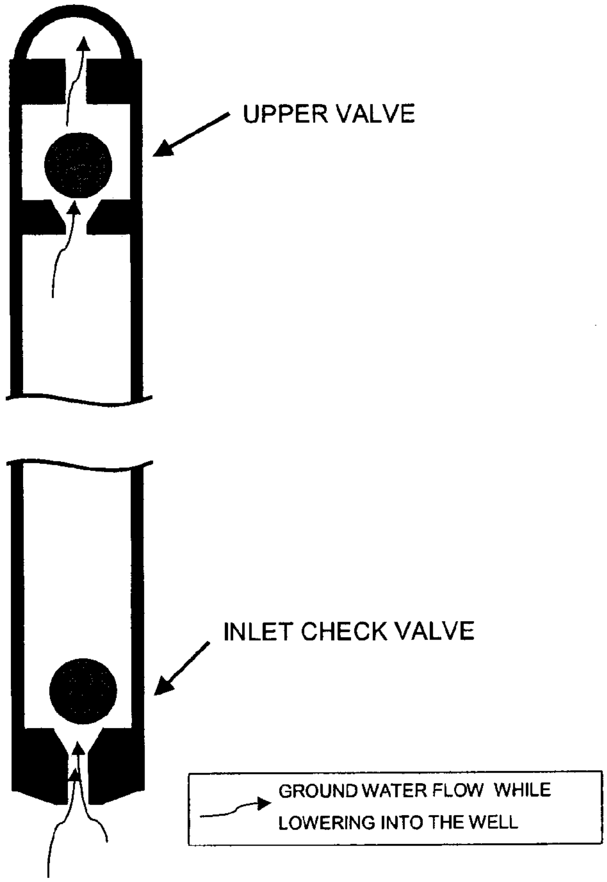

FIG. 3 Double Check Valve Bailer

or both, to check for the background levels that may result from the sampling materials or from field conditions. Thus, all samplings for trace materials should be accompanied by samples that represent the sampling equipment blank, in addition to other blanks (field blank and trip blank). Decontamination procedures are further discussed in Practice D 5088.

7.6 Additional samples are often collected in the field and spiked (spiked-field samples) in order to verify that the sample handling procedures are valid. The American Chemical Society's committee on environmental improvement has published guidelines for data acquisition and data evaluation, which should be useful in such environmental evaluations **(21)**.

8. Sampling Equipment

~~6~~8.1 The choice of sampling technique must be based on an understanding of the hydrogeology of the site under investigation and the end use of the data. Since each technique has its advantages and disadvantages, no one technique can be chosen as the best overall technique. Since different techniques will likely yield different results, it is best to be consistent throughout an investigation to facilitate the comparison of data values over time. There is a fairly large choice of equipment presently available for~~ groundwater sampling from single screened wells and well clusters.~~ ground-water sampling. The sampling devices can be categorized into the following~~ eight~~ nine basic types~~.~~ as described in the following sections:

~~6~~8.1.1 *Down-Hole Collection Devices*:

~~6~~8.1.1.1 Bailers, messenger bailers, or thief~~ samplers **(13,14)** are~~**(22, 23)** are examples of down-hole~~ devices that probably provide valid samples once the well has been flushed.~~ collection devices. They are not practical for removal of large volumes of water but are relatively inexpensive permitting their dedicated use and are widely used. These devices can be constructed in various shapes and sizes from a variety of materials. They do not subject the sample to pressure extremes.

~~6.1.1.2 Bailers do expose part of the sample to the atmosphere during withdrawal. Bailers used for sampling of volatile organic compounds should have a sample cock or draft valve in or near the bottom of the sampler allowing withdrawal of a sample from the well below the exposed surface of the water or the first few inches of the sample should be discarded. Suspension lines for bailers and other samplers should be kept off the ground and free of other contaminating materials that could be carried into the well. Down-hole devices are not very practical for use in deep wells. However, potential sample oxidation during transfer of the sample into a collection vessel and time constraints for lowering and retrieval for deep sampling are the primary disadvantages.~~

~~6.1.1.3 Three down-hole devices are the single and double check valve bailers and thief samplers. A~~

8.1.1.2 A schematic of a single check valve unit is illustrated in Fig.~~ 1.~~ 2. The bailer may be threaded in the middle so that additional lengths of blank casing may be added to increase the sampling volume. TFE-fluorocarbon~~ or~~, stainless steel, and PVC

TABLE 1 TypMaterical Contasiner and Preservation Rs In Sequirlemencts fior a Ground-W Of Sater Monmplitoring Progra Equipment (76)

~~Sample and~~Measure~~ment~~erial		~~Volume Required (mL)~~	
~~Metals As/Ba/Cd/Cr/Fe Pb/Se/ Ag/Mn/Na~~		~~1000–2000~~	P/G (spe
Polytetrafluoroethylene		~~1000–2000~~	• Virgin P
~~high purity nitric acid to pH <2~~	~~6 months~~		
	• Ideal material in corrosive environments where inorganic compounds are of interest		
~~Mercury~~		~~200–300~~	~~P/G (spe~~
		~~200–300~~	~~P/G (spe~~
~~Radioactivity alpha/ beta/radium~~		~~4000~~	P/G (s p
		~~4000~~	• Potentia tensile ar resistanc string as **70, 71)**
~~high purity nitric acid to pH< 2~~	~~6m onths~~		
	• Potential problems with obtaining a seal between the casing and the annular sealant because of PTFEs low coefficient of friction and antistick properties as compared to other plastics **(71)**		
~~Phenolics~~		~~500–1000~~	~~G~~
		~~500–1000~~	~~G~~
~~cool, 4°C H_2SO_4 to pH <2~~	~~28 days~~		
	• Expensive		
~~Miscellaneous~~		~~1000–2000~~	~~P~~
		~~1000–2000~~	~~P~~
~~cool, 4°C~~			
Polyvinylchloride	• Leaching of compounds of tin or antimony, which are contained in original heat stabilizers during polymer formulation, could occur after long exposure		
~~Fluoride~~		~~300–500~~	PVC prim MEK (me (methylis into grour the water preferred
		~~300–500~~	• When u of volatile glues, su (methylet cyclohexa Therefore sealed wi
	~~28days~~ • Cannot be used where pure product or high concentrations of a PVC solvent exist		
~~Chloride~~		~~50–200~~	P/~~G~~
		~~50–200~~	• There is
			P/~~G~~
	~~28 days~~ • Maximum string length of 2-in. (~5-cm) diameter threaded PVC casing should not exceed 2000 ft (~610 m) **(72)**		
~~Sulfate~~		~~100–500~~	P/~~G~~
		~~100–500~~	• P/~~G~~
	~~28day s~~ • PVC can volatilize CFCs into the atmosphere within the unsaturated zone, which can be a potential problem for studies of gas and moisture transport through the unsaturated zone		
~~Nitrate~~		~~100–250~~	~~P/G~~
		~~100–250~~	~~P/G~~
	~~48 hours~~		
Coliform			
		~~100~~	~~P/G~~
	~~6 h~~		
Stainless steel	• Generally has high corrosion resistance, which differs with type		
~~Conductivity~~		~~100~~	~~P/G~~

TABLE 2 Chemical Compatibility Table For Selected NAPL (78)

Chemical	PTFE (Teflon)	PP (Polypropylene)	PVC (Type I)	PVC (Type II)	304 Stainless	316 Stainless	Carbon Steel
Benzene	R	X	U	U	G	G	G
Carbon Tetrachloride	R	U	X	U	E	E	G
Dichlorobenzene	R	R	U	U	. . .	G	. . .
Dichloroethane (DCA)	R	X	U	U	G	G	G
Dichloroethylene (DCE)	R	R	U	U	G	G	. . .
Diesel Fuel	R	R	R	. . .	E	E	G
Ethyl Benzene	R	U	U	U	S	G	U
Gasoline	R	X	R	. . .	G	G	G
Hydraulic Oil (petro.)	R	X	R	. . .	R	R	. . .
Hydraulic Oil (synthetic)	R	X	R	. . .	R	R	. . .
Jet Fuels	R	X	R	R	G	G	G
Kerosene	R	R	R	R	G	G	G
Motor Oil	R	X	R	R	G	G	G
Napthalene	R	R	U	U	E	E	G
Tetrachloroethylene (PCE)	R	U	U	U	E	E	G
Toluene	R	R	U	U	E	E	E
Trichloroethylene (TEC)	R	R	U	U	G	G	G
Xylenes	R	R	U	U	G	G	G

For Metals
E < 2 mills Penetration/Year
G < 20 mills Penetration/Year
S < 50 mills Penetration/Year
U > 50 mills Penetration/Year
(1 mill = 0.001 in.)
R = Resistant (No corrosion rate reported)

For All Non-Metals
R = Resistant
U = Unsatisfactory
X = Conflicting Data, at least one reference reported unsatisfactory

are the most common materials used for construction ~~**(15).**~~

~~6.1.1.4 In~~**(24)**.

8.1.1.3 In operation, the single check valve bailer is gently lowered into the well~~,~~ to a depth just below the water surface, water enters the chamber through the bottom, and the weight of the water column closes the check valve upon bailer retrieval. The specific gravity of the ball should be about 1.4 to 2.0 so that the ball almost sits on the check valve seat during chamber filling. Upon bailer withdrawal, the ball will immediately seat without~~ any samples~~ sample loss through the check~~ valve. A similar technique involves lowering a sealed sample container within a weighted bottle into the well. The stopper is then pulled from the bottle via a line and the entire assembly is retrieved upon filling of the container **(14,16).**~~

~~6.1.1.5 A~~ valve.

8.1.1.4 A double check valve bailer allows point source sampling at a specific depth ~~**(15,17).** An~~**(25, 26)**. The double check valve bailer is also effective at collecting dense, non-aqueous phase liquid (DNAPL) from the bottom of a monitoring well. An example is shown in Fig.~~ 2.~~ 3. In this double check valve design, water flows through the sample chamber as the unit is lowered. A venturi tapered inlet and outlet ensures that water passes~~ freely~~ through the unit with limited restriction. When a depth where the sample is to be collected is reached, the unit is retrieved. Because the difference between each ball and check valve seat is maintained by a pin that blocks vertical movement of the check ball, both check valves close simultaneously upon retrieval. A drainage pin is placed into the bottom of the bailer to drain the sample directly into a collection vessel to reduce the possibility of air oxidation.

8.1.1.5 A top-filling bailer is a closed bottom tubular device, opened on top and provided with a loop or other fixture to attach to the drop line. The~~ acrylic model in Fig. 2~~ top-filling bailer is~~ threaded at~~ gently lowered below the water surface in the well and water pours into the bailer from the top. Although this variation on the bailer design results in greater agitation of the sample, it may be used to collect a sample of light, non-aqueous phase liquid (LNAPL) by lowering it just below the surface of the LNAPL and allowing the~~ addition~~ bailer to skim the LNAPL from the surface of th~~r~~e water column.

8.1.1.6 The differential pressure bailer is a sealed canister body with two small diameter tubes of different heights built into its removable top **(14)**. The bailer is usually constructed of stainless steel to provi~~n~~de suffic~~r~~ient weight to allow it to sink relatively quickly to the desired sampling depth. Once the bailer's downward progress is stopped, differences in hydrostatic pressure between the two tubes allows the bailer to fill through the lower tube as air is displaced through the upper tube. This type of bailer minimizes the exposure of the sample to air especially if fitted with internal 40 mL vials for direct sample bottle filling.

8.1.1.7 Special care must be taken to minimize exposing the sample to the atmosphere during the transfer of the sample from the bailer to the sample bottle. There are several approaches to overcome this issue. Bottom-emptying bailers used for sampling of VOCs, for example, should have an insertable sample cock or draft valve cock (often referred to as a bottom or bailer emptying device) in or near the bottom of the sampler allowing withdrawal of a sample from the bailer with minimal atmosphere exposure.

~~6~~8.1.1.~~6~~8 Suspension lines for bailers and other samplers should be kept off the ground and free of other contaminating materials that could be carried into the well. A plastic sheet may be spread out on the ground around the monitoring well for this purpose. Disposable TFE-fluorocarbon, PVC, polyethylene, and polypropylene bailers are available which offer time savings and all but eliminates the potential for cross contamination during sampling.

8.1.1.9 Sample oxidation is a concern with single check valve and top filling bailers. Sample oxidation might occur during the extended time it takes to bail a sample if water levels are a great depth below the ground surface or if there is a delay in the transfer of the sample from the bailer to the sample bottles. Using point source bailers, however, minimizes the oxidation problem.

8.1.1.10 Another approach for obtaining point source samples employs a weighted messenger or pneumatic change to "trip" plugs at either end of an open tube (for example, tube water sampler or thief sampler) to close the chamber **(~~18~~27)**~~.~~. Foerst, Kemmerer, and Bacon samplers are of this variety **~~(14,17,19)~~(23, 24, 26). A~~ simple~~ number of thief or messenger devices are available in various materials and~~ inexpensive pneumatic sampler was recently described by Gillham~~ shapes. Differential pressure bailers ~~(20). The device (Fig. 3) consists~~(14) also provide a point source sample but do not require manual tripping.**

8.1.2 *Bladder Pumps*:

8.1.2.1 Bladder pumps consist of a~~ disposable 50 mL plastic syringe modified~~ flexible membrane enclosed by~~ sawing off~~ a rigid housing. Water enters the~~ plunger and~~ pump cavity through an inlet, usually located on the~~ finger grips. The syringe is then attached to a gas-line by means~~ bottom of~~ a rubber stopper assembly. The gas-line extends to~~ the~~ s~~ pump. Compressed gas either from a compre~~,~~ssor or air cylinder is~~ used to drive~~ injected into a bladder within the~~ stem-less plunger, and~~ pump cavity forcing the check valve on the inlet to~~ raise~~ close and~~ lower~~ the~~ syringe into~~ sample up through a second check valve at the~~ hole. When~~ top of the ~~g~~ pump and into a dis~~-~~charge line (Fig. 4). Water is~~ pressurized,~~ prevented from re-entering the~~ rubber plunger is held at~~ bladder by the~~ tip of the syringe.~~ top check valve. The~~ sampler~~ bladder is then~~ lowered into~~ depressurized, allowing the pump to refi~~n~~ll. The process is repeated to cycle the water to the surface. Sampl~~l~~es taken from depths of 122 m (400 ft) have been reported.

8.1.2.2 A variety of design~~,~~ modifications and materials are available **(29, 30)** however, TFE-fluorocarbon bladders, either PVC, TFE-fluorocarbon resin or stainless steel bodies and fittings are most common. An automated controller system is used to control the~~ d~~ time between pressurization cycles and regulate pressure.

8.1.2.3 Bladder pumps have a distinct advantage over gas displacement pumps in that there is~~ reached,~~ no contact with the~~ p~~ driving gas. Disadvantages include the large gas volumes required, and difficulty in decontaminating the~~ gas-line~~ pump. This pump design is~~ reduced~~ most applicable to~~ atmospheric (or slightly less)~~ dedicated well installations and~~ water enters the syringe.~~ where low pump rate or flow rate (less than 0.5 L/min) are required. The~~ sampler is then retrieved~~ flow rate from~~ the installation and the syringe detached from the gas-line. After the tip~~ a bladder pump is~~ sealed,~~ dependent on the~~ syringe is used as a short-term storage container. A number~~ dimensions of~~ thief or messenger devices are available in various materials and shapes.~~

~~6.1.2~~ the bladder pump, controller settings, gas pressure, and total dynamic head.

8.1.3 *Suction Lift Pumps*:

~~6~~8.1.~~2~~3.1 Three types of suction lift pumps are the direct line, centrifugal, and peristaltic. A major disadvantage of any suction pump is that it is limited in its ability to raise water by the head available from atmospheric pressure.~~ Thus, if the surface of the water is more than about 25 ft below the pump, water may not be withdrawn.~~ The theoretical suction limit is about 10.4 m (34 ft), but most suction pumps are capable of maintaining a water lift of only~~ 25 ft or less.~~

~~6.1.2.2 Many suction pumps draw the water through some sort of volute in which impellers, pistons, or other devices operate to induce a vacuum. Such pumps are probably unacceptable for most sampling purposes because they are usually constructed of common materials such as brass or mild steel and may expose samples to lubricants. They often induce very low pressures around rotating vanes or other such parts such that degassing or even cavitation may occur. They can mix air with the sample via small leaks in the casing, and they are difficult to adequately clean between uses. Such pumps are acceptable for purging of wells, but should not generally be used for sampling.~~

~~6.1.2.3 One exception to the above statements is a peristaltic pump. A peristaltic pump is a self-priming, low volume suction pump which consists of a rotor with ball bearing rollers~~ 7.6 m (25 ft) **~~(21).~~** ~~Flexible tubing is inserted around the pump rotor and squeezed by heads as they revolve in a circular pattern around the rotor. One end of the tubing is placed into the well while the other end can be connected directly to a receiving vessel. As the rotor moves, a reduced pressure is created in the well tubing and an increased pressure (<40 psi) on the tube leaving the rotor head. A drive shaft connected to the rotor head can be extended so that multiple rotor heads can be attached to a single drive shaft.~~

~~6.1.2.4 The peristaltic pump moves the liquid totally within the sample tube. No part of the pump contacts the liquid. The sample may still be degassed (cavitation is unlikely) but the problems due to contact with the pump mechanism are eliminated. Peristaltic pumps do require a fairly flexible section of tubing within the pumphead itself. A section of silicone tubing is commonly used within the peristaltic pumphead, but other types of tubing can be used particularly for the sections extending into the well or from the pump to the receiving container. The National Council of the Paper Industry for Air and Stream Improvement~~ **~~(22)~~** ~~recommends using medical grade silicone tubing for organic sampling purposes as the standard grade uses an organic vulcanizing agent which has been shown to leach into samples. Medical grade silicone tube is, however, limited to use over a restricted range of ambient temperatures. Various manufacturers offer tubing lined with TFE-fluorocarbon or Viton[3] for use with their pumps. Gibb~~ **~~(1,8)~~** ~~found little difference between samples withdrawn by a peristaltic pump and those taken by a bailer.~~

~~6.1.2.5 A direct method of collecting a sample by suction consists of lowering one end of a length of plastic tubing into the well or piezometer. The opposite end of the tubing is connected to a two way stopper bottle and a hand held or mechanical vacuum pump is attached to a second tubing leaving the bottle. A check valve is attached between the two lines to maintain a constant~~

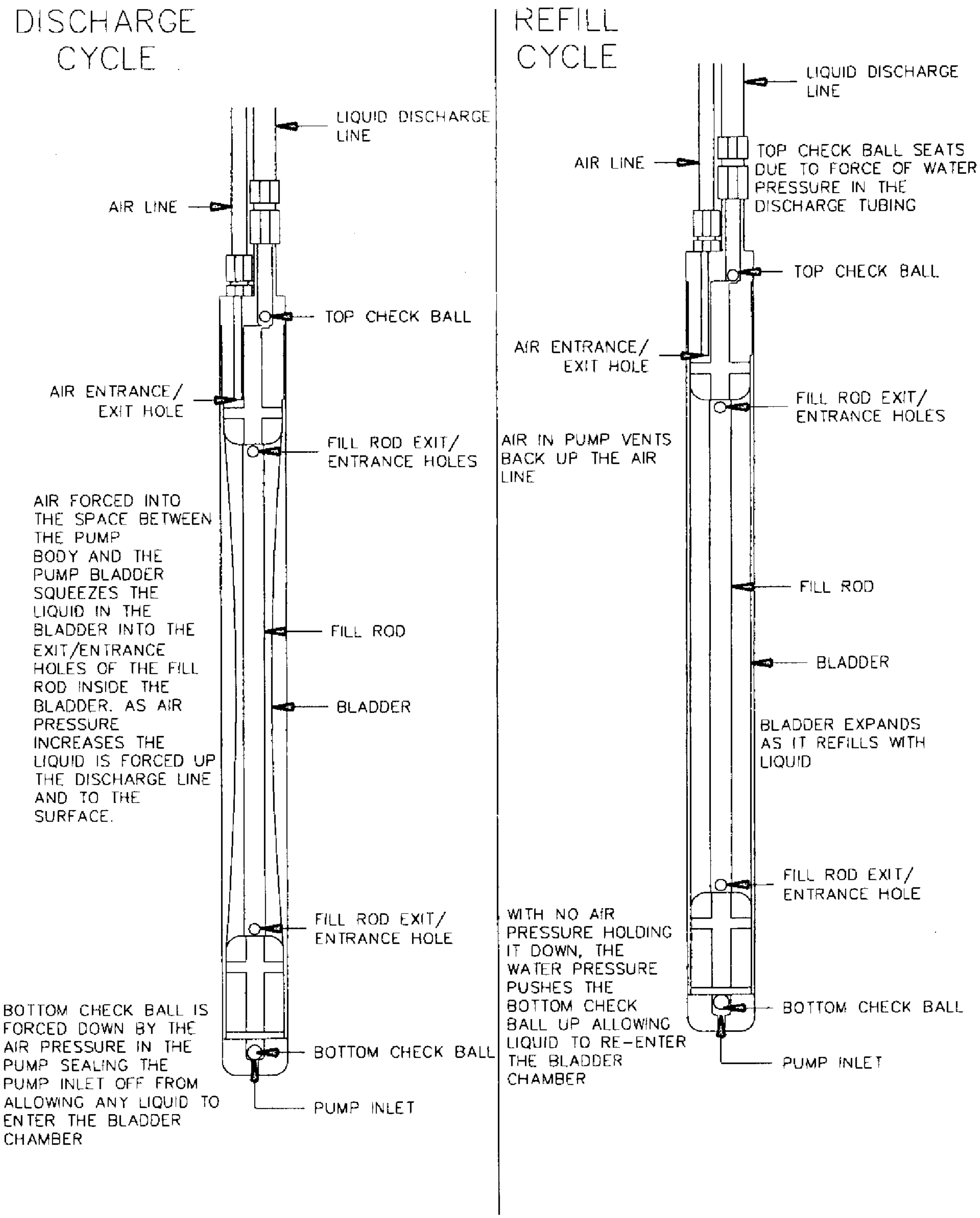

FIG. 4 Squeeze Type Bladder Pump

~~vacuum control. A sample can then be drawn directly into the collection vessel without contacting the pump mechanism~~ ~~**(5,23,24)**~~**(31)**.

~~6~~8.1.~~2~~3.~~6~~2 ~~A~~Many suction pumps draw water through a volute in which impellers, pistons, or other devi~~f~~ces operate to indu~~g~~ce a vacuum. Such pumps are probably unacceptable for most sampling purposes because they are usually constructed of non-inert materials such as brass or mild steel and may expose samples to lubricants. They often induce very low pressures around rotating vanes or other such parts such that degassing or potentially cavitation may occur. They can mix air with the sample via small leaks in the casing, and they are difficult to adequately clean between uses. Such pumps may be accept~~t~~a~~c~~ble for purging of wells, but should not generally be used for sampling.

8.1.3.3 An exception to the above statements is a peristaltic pump (also known as a rotary peristaltic pump). A peristaltic pump is a self-priming, low-volume suction pump that consists of~~ plastic~~ a rotor with rollers **(32)**. Flexible tubing~~ that~~ is~~ lowered~~ inserted around the pump rotor and squeezed by rollers as they rotate. One end of the tubing is placed into the~~ well. A foot valve~~ well (a weighted end may be used) while the other is~~ usually attached~~ connected directly to a receiving vessel. As the~~ end of~~ rotor moves, reduced pressure is created in the well tubing~~ to assist in priming~~ and an increased pressure on the tube leaving the rotor head. Pumping rates may be controlled by varying the speed of the rotor or by changing the size of the pump head, which contains the pump rotor.

8.1.3.4 The peristaltic pump moves the liquid totally within the sample tube. No part of the pump contacts the liquid. The ~~maximum lift~~ sample may be degassed (cavitation is~~ about 4.6 m (15 ft)~~ unlikely), but the problems due to contact with the pump mechanism are eliminated. Peristaltic pumps do require a fairly flexible section of tubing within the pump head itself. A section of silicone tubing is commonly used within the peristaltic pump head, but other types of tubing can be used particularly for the sections extending into the well or from the pump to the receiving container. The National Council of the Paper Industry for Air and Stream Improvement **(33)** recommends using medical grade silicone tubing for VOC sampling purposes as the standard grade uses an organic vulcanizing agent which has been shown to leach into samples. Var~~r~~ious manufacturers offer tubing lined with TFE-fluorocarbon or Viton[6] for use with their pumps. Plasticized polypropylene tubings and LDPE should be avoided if flow rates less than 0.1 L/min (0.025 g/min) are used ~~**(23,25,26)**~~**(10). The extraction rate with this method can range from 0.04 to 30 L/min (0.01 to 8 gal/min) (34)**.

~~6~~8.1.~~2~~3.~~7~~5 There is disagreement on the applicability of peristaltic pumps for the collection of groundwater samples. Research by Tai, et al **(35)** has shown that peristaltic pumps provide adequate recovery of VOCs. The U.S. EPA **(4)** does not recommend its use because of studies that suggest that VOCs may be lost during sampling **(36)**.

8.1.3.6 A direct method of collecting a sample by suction consists of lowering one end of a length of plastic tubing into the well or piezometer. The opposite end of the tubing is connected to a two-way stopper bottle and a hand held or mechanical vacuum pump is attached to a second tubing leaving the bottle. A check valve is attached between the two lines to maintain a constant vacuum control. A sample can then be drawn directly into the collection vessel without contacting the pump mechanism **(37, 38)**.

8.1.3.7 A centrifugal pump can be attached to a length of plastic tubing that is lowered into the well. A foot valve is usually attached to the end of the well tubing to assist in priming the tube. The maximum lift is about 4.6 m (15 ft) for such an arrangement **(37, 38, 39)**.

8.1.3.8 Suction pump approaches offer a simple sample retrieval method for shallow monitoring wells. The direct line method is~~ extremely~~ portable though considerable oxidation and mixing may occur during collection. A centrifugal pump will agitate the sample to an even greater degree although pumping rates of 19 to 151~~ Lpm~~ L/min (5 to 40 g~~p~~al/min) can be attained. A peristaltic pump provides a lower sampling rate with less agitation than the other two~~ pumps. The withdrawal rate of peristaltic pumps can be carefully regulated by adjustment of the rotor head revolution.~~

~~6.1.2.8 All~~ pumps, as discussed in 8.1.3.4.

8.1.3.9 All three systems can be specially designed so that the water sample contacts only the TFE-fl~~o~~uorocarbon or silicone tubing prior to sample bottle entry.~~ Separate~~ Dedicated tubing is recommended for each well or piezometer sampled. Each of these methods that relay on suction can change solution chemistry by causing degassing which may result in loss of volatile compounds and dissolved gasses and this should be a consideration in their application **(34)**.

~~6~~8.1.~~3~~4 *Electric Submersible Pumps*:

~~6~~8.1.~~3~~4.1 A submersible pump consists of a sealed electric motor that powers a piston, impeller, or helical single thread~~ worm at a high rpm.~~ worm. Water is brought to the surface through~~ an access~~ a discharge tube.~~ Such~~ Similar pumps~~ have been~~ are commonly used in the water well industry~~ for years~~ and many designs exist ~~**(5,26)**~~**(40).**

~~6~~8.1.~~3~~4.2 Submersible pumps provide relatively high discharge rates for water withdrawal at depths beyond suction lift capabilities. A battery operated unit 3.6 cm (1.4 in.) in diameter and with a 4.5~~ Lpm~~ L/min (1.2 g~~p~~al/min) flow rate at 33.5 m (110 ft) has been developed ~~**(27)**~~ **(41). Another submersible pump has an outer diameter of 11.4 cm (4.5 in.) and can pump water from 91 m (300 ft). Pumping rates vary up to 53.0~~ Lpm~~ L/min (14 g~~p~~al/min) depending upon the depth of the~~ pump~~ total dynamic head (42~~8~~).**

~~6~~8.1.~~3~~4.3 A submersible pump provides higher extraction rates than many other methods. Considerable sample agitation results, however, in the well and in the~~ collection~~ discharge tube during~~ transport.~~ sampling. The possibility of introducing trace metals

---

[6] Viton is a trademark of E. I. du Pont de Nemours & Co., Wilmington, DE 19898 and has been found suitable for this purpose.

into the sample from pump materials also~~ exists. Steam cleaning~~ exists; however, submersible pumps designed specifically for environmental work do exist. These pumps are constructed of relatively inert materials such as stainless steel, TFE-fluorocarbons and Viton. Decontamination procedures are discussed in Practice D 5088. Recent research, however, has suggested that steam cleaning followed by rinsing with unchlorinated, deionized water~~ is suggested~~ should be used between samplings when analysis for~~ organics in the parts per million (ppm) or parts per billion (ppb) range~~ VOCs is required **~~(29)~~ (43). Complete decontamination of submersible pumps is difficult and should be confirmed by the collection of equipment blanks.**

~~6~~8.1.4.4 Submersible pumps have several disadvantages that should be considered. The silt and fine sand commonly present in monitoring wells may cause excessive wear to internal impellers and staters. These pumps also commonly require a high-amperage 120/220-V power source and a reel and winch system that limit their mobility. Submersible pumps may also not be suitable for collecting liquids containing VOCs or dissolved gasses because of their potential to degas the sample.

8.1.5 *Gas-Lift Pumps*:

~~6~~8.1.~~4~~5.1 Gas-lift pumps use compressed air to bring a water sample to the surface. Water is forced up an eductor pipe that may be the outer casing or a smaller diameter pipe inserted into the well annulus below the water~~ level~~ **~~(30,31)~~ (44, 45).**

~~6~~8.1.~~4~~5.2 A similar principle is used for a unit that consists of a small diameter plastic tube perforated in the lower end. This tube is placed within another tube of slightly larger diameter. Compressed air is injected into the inner tube; the air bubbles through the perforations, thereby lifting the water sample via the annulus between the outer and inner tubing **~~(32)~~(45). In practice, the eductor line should be submerged to a depth equal to 60 % of the total submerged eductor length during pumping ~~(26)~~(40). A 60 % ratio is considered optimal although a 30 % submergence ratio is adequate.**

~~6~~8.1.~~4~~5.3 The source of compressed gas may be a hand pump for depths generally less than 7.6 m (25 ft). For greater depths, air compressors, and pressurized air~~ bottles, and air compressed from an automobile engine~~ cylinders have been used. When air compressors are used, an air-oil filter must be installed to minimize the introduction of oil to the well.

~~6~~8.1.~~4~~5.4 As already mentioned, gas-lift methods result in considerable sample agitation and mixing within the well, and cannot be used for samples which will be tested for~~ volatile organics.~~ VOCs or dissolved gasses (for example, DO, methane). The eductor pipe or weighted plastic tubing is a potential source of sample contamination. In addition, Gibb~~ (8)~~ **~~uncovered difficulties~~(11) expressed concerns in sampling for inorganics. These~~ difficulties~~ concerns were attributed to changes in redox, pH, and species transformation due to solubility constant changes resulting from stripping, oxidation, and pressure changes.**

~~6.1.5~~

8.1.6 *Gas Displacement Pumps*:

~~6~~8.1.~~5~~6.1 Gas displacement or gas drive pumps are distinguished from gas-lift pumps by the method of sample transport. Gas displacement pumps force a discrete column of water to the surface via mechanical lift without extensive mixing of the pressurized gas and water as occurs with air-lift equipment. The principle is shown schematically in Fig.~~ 4.~~ 5. Water fills the chamber. A positive pressure is applied to the gas line closing the sampler check valve and forcing water up the sample line.~~ By~~ The cycle is repeated by removing the~~ pressure the cycle can be repeated.~~ pressure. Vacuum can also be used in conjunction with the gas **~~(30)~~(46). The device can be permanently installed in the well ~~(33,34,35)~~(47, 48, 49) or lowered into the well ~~(36,37)~~(50, 51).**

~~6~~8.1.~~5~~6.2 A more complicated two stage design constructed of glass with check valves made of TFE-fluorocarbon has been constructed **~~(38,39)~~(52, 53). The unit was designed specifically for sample testing for trace level organics. Continuous flow rates of up to~~ 2.3 Lpm (0.6 gpm)~~ 38 L/min (10 gal/min) are~~ possible with a 5.1 cm (2 in.) diameter unit.~~**

~~6.1.5.3 Gas~~ possible.

8.1.6.3 Gas displacement pumps~~ have also been developed with multiple functions. The water sample in Fig. 5 provides piezometric data measurements with an internally mounted transducer~~ **(40)**~~. A sample with its transducer exposed externally for piezometric measurements is illustrated in Fig. 6~~ **(41)**~~. The sensor can activate the gas source at the surface to cause sample chamber pressurization at the predetermined depth. Another design can be used as a water sampler or as a tool for injecting brine or other tracers into a well~~ **(42)** ~~.~~

~~6.1.5.4 Gas displacement pumps~~ offer reasonable potential for preserving sample integrity because little~~ of the~~ driving gas comes in contact with the sample as the sample is conveyed to the surface by a positive pressure. There is, however, a potential loss of dissolved gasses~~ or~~ and contamination from the driving gas and the housing materials.

~~6.1.6 *Bladder Pumps*:~~

~~6.1.6.1 Bladder pumps, also referred to as gas-operated squeeze pumps, consist of a flexible membrane enclosed by a rigid housing. Water enters the membrane through a check valve in the vessel bottom; compressed gas injected into the cavity between the housing and bladder forces the sample through a check valve at the top of the membrane and into a discharge line (Fig. 7). Water is prevented from re-entering the bladder by the top check valve. The process is repeated to cycle the water to the surface. Samples taken from depths of 30.5 m (100 ft) have been reported.~~

~~6.1.6.2 A variety of design modifications and materials are available~~ **(43,44)** ~~. Bladder materials include neoprene, rubber, ethylene propylene terpolymer (E.P.T.), nitrile, and the fluorocarbon Viton.[3] A bladder made of TFE-fluorocarbon is also under development~~ **(45)**~~. Automated sampling systems have been developed to control the time between pressurization cycles~~ **(46)** ~~.~~

~~6.1.6.3 Bladder pumps provide an adaptable sampling tool due primarily to the number of bladder shapes that are feasible. These devices have a distinct advantage over gas displacement pumps in that there is no contact with the driving gas.~~

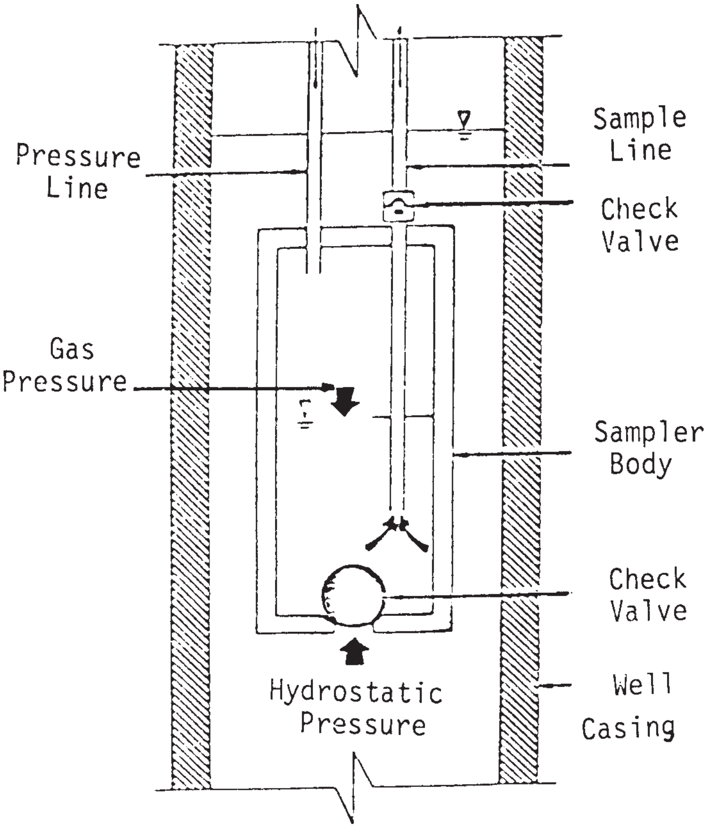

FIG. 5 The Principle of Gas Dispalcement Pumping

~~Disadvantages include the large gas volumes required, low pumping rates, and potential contamination from many of the bladder materials, the rigid housing, or both.~~

~~6.1.7~~

8.1.7 *Gas Driven Piston Pumps*:

~~6.1.7.1 A simple and inexpensive example of a gas driven piston pump is a syringe pump **(47)**. The pump (Fig. 8) is constructed from a 50 mL plastic syringe with plunger stem removed. The device is connected to a gas line to the surface and the sample passes through a check valve arrangement to a sampling container at the surface. By successively applying positive and negative pressure to the gas-line, the plunger is activated driving water to the surface.~~

~~6.1.7.2 A~~

8.1.7.1 A double piston pump powered by compressed air is illustrated in Fig. ~~9.~~ 6. Pressurized gas enters the chamber between the pistons; the alternating chamber pressurization activates the piston ~~which~~ that allows water entry during the suction stroke of the piston and forces the sample to the surface during the pressure stroke **(54~~8~~)**. Pumping rates between ~~9.5~~ 0.16 and ~~30.3 L/hr (2.5 to 8 gal/hr)~~ 0.51 L/min (0.04 and 0.13 gal/min) have been reported from 30.5 m (100 ft). Depths in excess of 457 m (1500 ft) are possible.

~~6~~8.1.7.~~3~~2 The gas piston pump provides continuous sample withdrawal at depths greater than is possible with most other approaches. Nevertheless, contribution of trace elements from the stainless steel and brass is a potential problem and the quantity of gas used is significant.

~~6~~8.1.8 *Packer Pump Arrangement*:

~~6~~8.1.8.1 A packer pump arrangement provides a means by which two expandable "packers" isolate a sampling unit between ~~two~~ packers within a well. Since the hydraulic or pneumatic activated packers are ~~wedged~~ pressed against the casing ~~wall or screen,~~ wall, the sampling unit will obtain water samples only from the isolated well portion. The packers are deflated for vertical movement within the well and inflated when the desired depth is attained. Submersible, gas lift, and suction pumps can be used for sampling. The packers are usually constructed ~~from some type~~ of a rubber ~~or rubber~~ compound **(54~~8~~-5~~1~~7)**. A packer pump unit consisting of a vacuum sampler positioned between ~~two~~ packers is illustrated in Fig. ~~10~~ 7 **(5~~2~~8)**.

~~6~~8.1.8.2 A packer assembly allows the isolation of discrete sampling points within a well. A number of different samplers can be situated between the packers depending upon the analytical specifications for sample testing. Because access to the interval between packers is blocked once the packers are inflated, the selection of sampling devices is limited to sampling pumps. Vertical movement of water outside the well casing during sampling is possible with packer pumps but depends upon the pumping rate and subsequent disturbance. Deterioration of the expandable materials will occur with time with the increased possibility of undesirable organic contaminants contributing to the water sample.

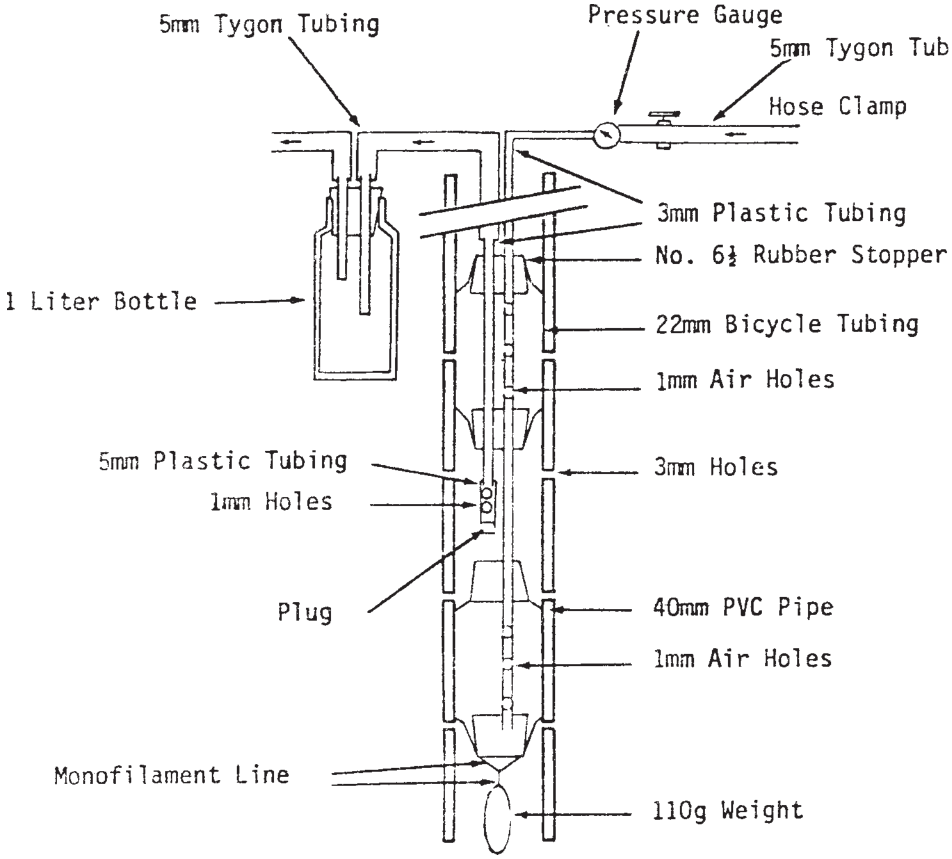

FIG. 7 Pac~~ken fro~~ Pum~~ R~~p Arrange~~f (4).~~ ment

Taken from Ref **(79)**

~~7. Sample Containers and Preservation~~

~~7.1 Complete and unequivocal preservation~~

8.1.9 *Inertial-Lift Pumps*:

8.1.9.1 The inertial-lift pump consists of~~ samples, whether domestic wastewater, industrial wastes, or natural waters, is practically impossible. At best, preservation techniques only retard~~ a foot valve at the~~ chemical~~ end of a flexible tube. The tube and~~ biological changes that inevitably continue after the sample~~ foot valve is~~ removed from~~ inserted into the~~ source. Therefore, insuring the timely analysis of a sample should be~~ well with one end of the~~ foremost considerations~~ tube remaining at the surface. The tube is then rapidly moved in a continuous up-and-down motion. Each upward stroke lifts the~~ sampling plan schedule. Methods of preservation are somewhat limited and are intended~~ water column in the tubing a distance equal to~~ retard biological action, retard hydrolysis of chemical compounds and complexes, and reduce~~ the~~ volatility~~ stroke length. At the end of~~ constituents. Preservation methods are generally limited~~ the upstroke, the water continues to~~ pH control, chemical addition, refrigeration and freezing. For~~ move slightly upward by inertia. On the down stroke, the foot valve opens allowing fresh water~~ samples, immediate refrigeration just above freezing (4°C~~ to enter the tube. This process continues resulting in~~ wet ice) is often~~ a flow to the~~ best preservation technique available, but it~~ surface.

8.1.9.2 The inertial-lift pump is~~ not the only measure nor~~ capable of operating efficiently at depths to 30 m (100 ft). It is~~ it applicable~~ effective in~~ all cases. There may be special cases where it might be prudent~~ small diameter wells or direct-push technology probes which are typically 12.5 mm (½-in.) diameter. The pumping rate ranges from 0 to~~ include a recording thermometer in the sample shipment~~ 7.6 L/min (0 to~~ verify~~ 2 gal/min) **(34)**, depending on the~~ maximum and minimum temperature to which~~ rate of the~~ samples were exposed. Inexpensive devices for this purpose are available.~~

~~7.2 All bottles~~ up and~~ containers must be specially pre-cleaned, pre-labelled,~~ down pumping stroke and~~ organized in ice-chests (isolating samples and sampling equipment from~~ the~~ environment) before one goes into the field. Otherwise, in any comprehensive program utter chaos usually develops in the field or laboratory.~~ tube diameter. The~~ t~~ equipment used in~~ the field~~ this pump is~~ very valuable and should~~ inexpensive enough to be~~ spent on taking field notes, measurements, and in documenting samples,~~ dedicated to a well with the exception of the pump handle or motor drive that do not~~ on labelling and organizing samples. Therefore,~~ contact the~~ sampling plan should include clear instructions~~ sample.

8.1.9.3 The inertial-lift pump, however, has several disadvantages. It is difficult to operate in deep, large diameter wells. Although a motor drive can overcome this limitation, the~~ sampling personnel concerning~~ incorporation of a motor drive limits the

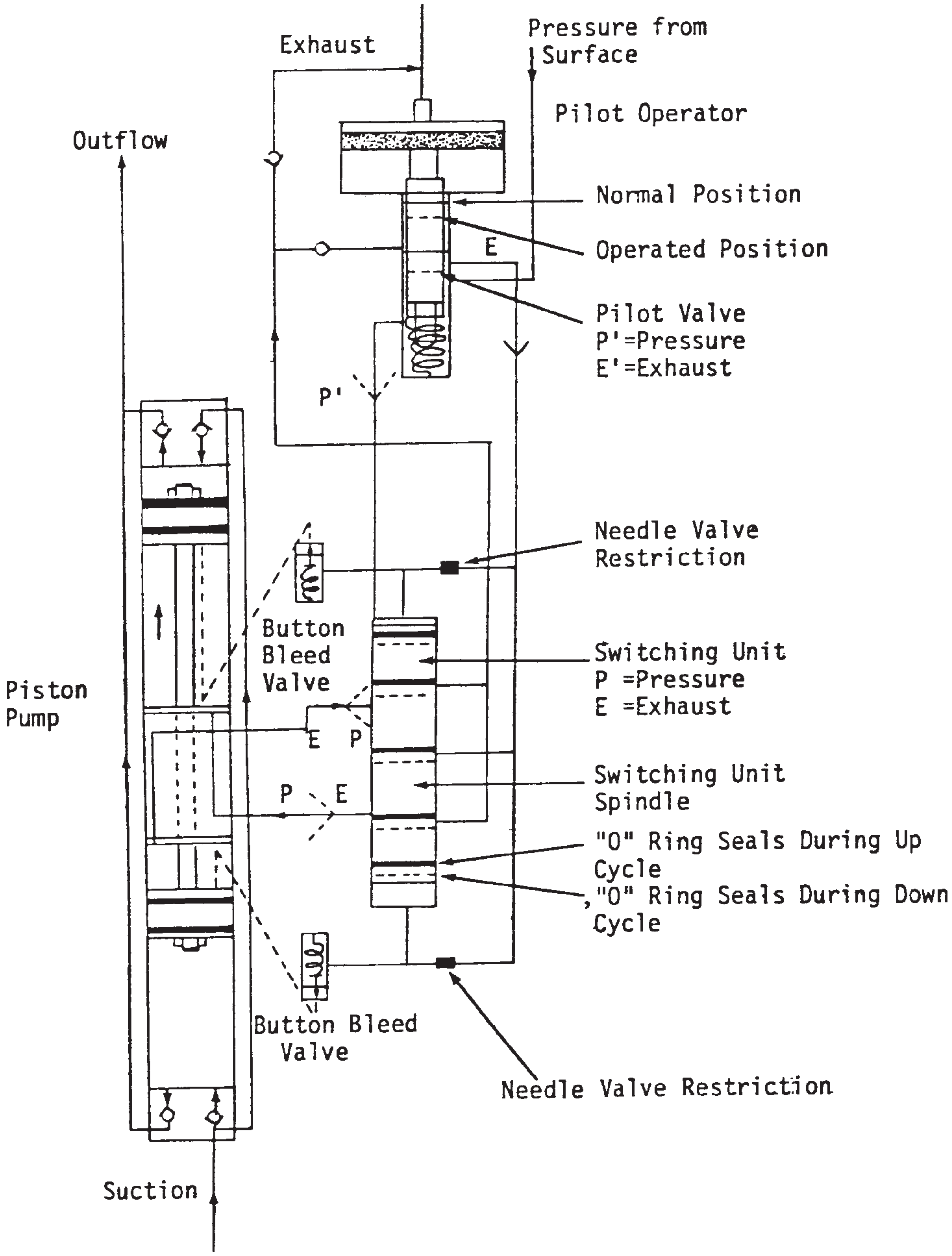

FIG. 6 Gas-Driven Piston Pump

~~information required in~~ portability of the ~~field data record logbook (notebook),~~ equipment. The foot valve must be selected to match the ~~information needed on container labels for identification,~~ casing material since it will tend to ride against the ~~chain-of-custody protocols,~~ casing and potentially will either damage the ~~methods~~ casing or wear out. The discharge tubing must be stiff for ~~preparing field blanks and spiked samples. Example of detailed plans and documentation procedures have been published~~ ~~**(14,53)**~~~~.~~

~~7.3 The exact requirements for~~ the ~~volumes of sample needed and the number of containers~~ pump to ~~use may vary from laboratory to laboratory.~~ operate properly. This ~~will depend on~~ makes the ~~specific analyses~~ tubing awkward to install and remove from a monitoring well.

8.1.10 *Minimal Purge, Discrete Depth, and Passive Sampling*—Sampling techniques that do not rely on, or require only minimal purging may be ~~performed, the concentration levels~~ used if a particular zone within a screened interval is to be sampled or if a well is not capable of yielding sufficient ground water for purging. These techniques include minimal purge, discrete depth sampling, and passive sampling.

8.1.10.1 A dedicated pump is used for minimal purge sampling so that only enough water is purged through the ~~individual laboratory protocols. The manager~~ pump so that the volume of water contained by the ~~sampling program should make no~~

~~assumptions about~~ pump and discharge tube is removed before sampling. No attempt is made to purge the ~~laboratory analyses. He~~ casing, screen, or formation. This volume should ~~discuss~~ be minimized by the ~~analytical requirements~~ selection of small diameter tubing and the ~~sampling program in detail with the laboratory coordinator beforehand.~~ smallest possible pump chamber. This initial volume of discharged water is ~~especially the case~~ discarded since ~~some analyses and preservation measures must be performed at~~ it had prolonged contact with the ~~laboratory as soon as possible after~~ sampling device.

8.1.10.2 The discrete depth sampler is often non-dedicated. It is lowered very slowly to the ~~samples arrive. Thus, appropriate arrangements must be made.~~

~~7.4 There are a number~~ depth of ~~excellent references available which list~~ the ~~containers and preservation techniques appropriate for~~ screen where a water ~~and soils **(13,14,50,54-56**. The "Handbook for Sampling and Sample Preservation of Water and Wastewater"~~ sample is ~~an excellent reference and perhaps~~ drawn into the sam~~o~~pling chamber. This~~t~~ is accomp~~r~~lished either manually by usi~~v~~ng a triggering mechanism such as a cable or automatically such as with a differential pressure bailer **(14)**. Discrete depth samplers, however, must be used with great caution because of the potential of mixing of the water column in the well casing while lowering the sampler to its sampling depth.

8.1.10.3 Passive sampling, using diffusion samplers (a water-filled membrane), is based on the principle of molecular diffusion of VOCs from the ground water into the sampler. (Research is currently being conducted by the U. S. Geological Survey to evaluate diffusion samplers for the collection of non-VOC parameters, however, study results have not been published.) The samplers must remain in the borehole for an adequate time for the water initially within the sampler to equilibrate with that in the borehole. The diffusion sampler typically consists of water-filled, low-density polyethylene tubing, which acts as a semi-permeable membrane. The sampler is attached to a weighted line, and lowered to a predetermined depth within the screened interval. Since the sample is depth specific, multiple samplers may be strung together to provide samples from different depths within the well. After adequate residence time has elapsed, the sampler(s) are removed from the well, punctured and the sample transferred into sample bottles. The samples are preserved and submitted to the laboratory for analysis. In a study of this technique, a minimum of 11 days was required to achieve equilibration **(59, 60)**. Concerns about the applicability of this sampling method to specific VOCs have been raised, however, no detailed evaluation of this issue has been published. In a comparison of sampling techniques, samples collected by the diffusion method were found to be biased lower than samples collected using a low-flow method **(61)**, however, this difference was attributed to issues with the laboratory or to the depth-specific nature of diffusion samplers.

9. Sample Containers and Preservation

9.1 The order of sample container filling, method of filling, selection of sample container type, and preservation method should be provided in the sampling and analysis plan. Generally, the order of sample container filling should proceed from most volatile to least volatile compound.

9.2 Complete and unequivocal preservation of samples, whether domestic wastewater, industrial wastes, or natural waters, is practically impossible. At best, preservation techniques only retard the chemical and biological changes that inevitably continue after the sample is removed from the source. Therefore, insuring the timely analysis of a sample should be one of the foremost considerations in the sampling plan schedule. Methods of preservation are somewhat limited and are intended to retard biological action, retard chemical reactions and complexes, and reduce the volatilization of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration, and freezing. For water samples, immediate refrigeration just above freezing (4°C in wet ice) is often the best preservation technique available, but it is not the only measure nor is it applicable in all cases. There may be special cases where it might be prudent to include the temperature to which the samples were exposed. Inexpensive devices for this purpose, such as a recording thermometer, are available for this purpose. A water-filled bottle may be included in the sample-shipping container for temperature measurement by the laboratory receiving the samples.

9.3 All bottles and containers must be specially pre-cleaned, and organized in ice chests (isolating samples and sampling equipment from the environment) before one goes into the field. The time in the field is very valuable and should be spent on taking field notes, measurements, and in documenting samples, not on labeling and organizing samples. Therefore, the sampling plan should include clear instructions to the sampling personnel concerning the information required in the field data record logbook (notebook), the information needed on container labels for identification, the chain-of-custody protocols, and the methods for preparing field blanks and spiked samples. Examples of detailed plans and documentation procedures have been published **(23, 62, see Guide D 6089)**.

9.4 The exact requirements for the volumes of sample needed and the number of containers to use may vary from laboratory to laboratory. This will depend on the specific analyses to be performed, the concentration levels of interest, the individual laboratory protocols, and the required QC samples. Since a well may not be capable of yielding adequate sample volume, a minimum required sample volume should be provided to the sample crew. The manager of the sampling program should make no assumptions about the laboratory analyses. He should discuss the analytical requirements of the sampling program in detail with the laboratory coordinator beforehand. This is especially the case since some analyses and preservation measures must be performed at the laboratory as soon as possible after the samples arrive. Thus, appropriate arrangements must be made.

9.5 There are a number of excellent references available which list the containers and preservation techniques appropriate for water and soils **(22, 23, 29, 58, 63-65)**. Some of this information is summarized in Table X1.1 and Guide D 6517, however, different regulatory programs have specific requirements that must be met.~~5~~

9.6 Sample containers for ~~trace organic~~ VOC samples require special cleaning and handling considerations **~~(57)~~ (66). The**

sample container for purgeable organics consist of a screw-cap vial (25 to 125 mL) fitted with a TFE-fl~~o~~uorocarbon faced silicone septum. The vial is sealed in the laboratory immediately after cleaning and is only opened in the field just prior to pouring a sample into it. The water sample then must be sealed into the vial headspace free (no air bubbles) and immediately cooled (4°C) for shipment. Multiple samples ~~(usually about four taken from one large sample container)~~ are taken because leakage of containers may cause losses, may allow air to enter the containers, and may cause erroneous analysis of some constituents. Also, some analyses are best conducted on ~~independent protected samples.~~

~~7.6 The purgeable samples must~~ independently preserved samples. The sampling program for VOCs should include at a minimum trip blanks. Trip blanks and field spikes should also be ~~analyzed by the~~ considered for low level analysis.

9.7 The laboratory must analyze the purgeable samples within 14 days after ~~collection, unless they are to be analyzed for acrolein or acrylonitrile (in which case they are to be analyzed within 3 days).~~ collection. For samples for solvent extractions (extractable organics-base neutrals, acids ~~and~~, pesticides, herbicides), the sample bottles are narrow mouth, screw cap quart bottles or half-gallon bottles that have been precleaned, rinsed with the extracting organic solvent and oven dried at 105°C for at least 1 h. These bottles must be sealed with TFE-fluorocarbon lined caps (Note 1). Samples for organic extraction must be extracted within 7 days and analyzed within ~~30~~ 40 days after ~~extraction. Special pre-cleaned, solvent rinsed and oven-dried stainless steel beakers (one for each monitoring well) may be used for transferring samples from the sampling device to the sample containers.~~ extraction.

NOTE 1—When collecting samples, the bottles should not be overfilled or prerinsed with sample before filling because oil and other materials may remain in the bottle. This can cause erroneously high results.

~~7~~9.~~7~~8 For a number of ground-water parameters, the most meaningful measurements are those made in the field at the time of sample collection or at least at an on-site laboratory. These include the water level in the well (see Test Method D 4750) and parameters that ~~sometimes~~ can change rapidly with storage. A discussion of the various techniques for measuring the water level in the well is contained in a NCASI publication **(~~5~~67)** and detailed procedures are outlined in a U.S. Geological Survey publication **(~~5~~68, 69)**. Although a discussion of ~~these~~ water level measuring techniques is beyond the scope of this guide, it is important to point out that accurate measurements must be made either before a well is ~~flushed~~ purged or ~~only~~ after it has had sufficient time to recover. Parameters that can change rapidly with storage include ~~specific conductance,~~ pH, turbidity, redox potential, ~~dissolved oxygen,~~ DO, and temperature. Specific conductance, although most accurately determined in a laboratory setting, often is measured in the field where it is used as an indicator parameter to determine the completeness of purging. For some of the other parameters, the emphasis in ground-water monitoring is on the concentration of each specific dissolved component, not the total concentration of each. Samples for these types of measurements should be filtered through 0.45 µm membrane filters ideally in the field or possibly at an on-site laboratory as soon as possible. Analyses often requiring filtered samples include ~~all~~ metals, radioactivity parameters, ~~total~~ dissolved organic carbon, dissolved ~~orthophosphate (if needed),~~ orthophosphate, and total dissolved phosphorous ~~(if needed)~~ **~~(13,14)~~ (22, 23). If metals are to be analyzed, filter the sample prior to acid preservation. If concerns related to the loss of mobile colloidal material by filtering is a consideration, sampling protocol should be modified to limit sample turbidity during collection so that filtering is not necessary. This is often done by using very low purge and sample flow rates. For ~~TOC organics,~~ total organic carbon (TOC), the filter material should be tested to assure that it does not contribute to the TOC. The type or size of the filter to be used is not well ~~understood.~~ determined. However, if results of metal, TOC or other parameters that could be ~~e~~ affected by solids are to be compared, the same filtering procedure must be used in each case. Repeated analytical results should state whether the samples were filtered and how they were filtered.**

~~7~~9.~~8~~9 Shipment and receipt of samples must be coordinated with the laboratory to minimize time in transit or weekend delivery receipt. All samples for organic analysis (and many other parameters), should be maintained at 4°C (±2°C) **(65)** during storage and shipping and should arrive at the laboratory within one day after ~~it is shipped and~~ shipment. Sample receipt should be ~~maintained at about 4°C with wet ice. The best way~~ verified to ~~get them~~ provide an opportunity to ~~the laboratory in good condition is~~ trace a lost shipment or to ~~send them in sturdy~~ resample if breakage occurs during shipment.

9.10 A commonly used shipping container is an insulated ice chest~~s~~ (cooler~~s~~) equipped with bottle dividers. ~~24-h~~ An overnight courier service is recommended, if personal delivery service is not practical. Care must be taken in packaging the ice so that no leakage occurs. Such leakage may damage sample labels or, if it escapes the sample cooler, may be misconstrued to be hazardous liquid by the courier. Sample paperwork, including the chain-of-custody, should be enclosed in a sealed plastic bag and taped to the inside lid of the shipping container to protect it from water. Sample containers may be sealed in plastic bags to protect sample labels from water damage from melting ice or sample leakage from other bottles.

9.11 Many courier services have strict shipping requirements for samples that are "hazardous." The courier service should be contacted prior to field activities if there is a concern about how to ship a sample.

10. Keywords

10.1 diffusion sampling; ground water; low flow; low stress; minimal purge; monitoring; purge; sampling; stabilization; well

APPENDIX

(Nonmandatory Information)

X1. SAMPLE HANDLING PROCEDURES FOR GROUND WATER MONITORING PARAMETERS

X1.1 See Table X1.1 for procedures for handling samples.

TABLE X1.1 Sample Handling Procedures For Ground Water Monitoring Parameters (77)

Parameter[A]	Bottle Type[A]	Preservative	Volume Required for Analysis, min (mL)[B]	Storage Time[C] (with Preservation, where applicable), max
pH	P,G	None, analyze immediately for field measurement	25	ASAP ($\leq$48 h) for lab measurement
Specific Conductance	P,G	Cool (4°C)	100	28 days
Alkalinity and Bicarbonate	P,G	Cool (4°C)	100	14 days
COD	P,G	Analyze ASAP ($\leq$48h) or add H_2SO_4 to pH<2; cool (4°C)	100	28 days
TDS	P,G	Cool (4°C)	100	7 days
TSS	P,G	Cool (4°C)	100	7 days
Chloride	P,G	None	50	28 days
Fluoride	P	None	300	28 days
Nitrate	P,G	Analyze ASAP ($\leq$48h) or add H_2SO_4 to pH<2; cool (4°C)	100	28 days
Sulfate	P,G	Cool (4°C)	50	28 days
Ammonia	P,G	Analyze ASAP ($\leq$48h) or add H_2SO_4 to pH<2; cool (4°C)	500	28 days
Mercury	P,G	HNO_3 to pH<2	100	28 days
Metals, Dissolved (Including Ca, Mg, K, Na)	P,G	Filter on site; HNO_3 to pH<2	200	6 months
Metals, Total (Including Ca, Mg, K, Na)	P,G	HNO_3 to pH<2	100	6 months
Phenols	P,G	Add H_2SO_4 pH<2; cool (4°C)	500	28 days
Hardness	P,G	HNO_3 to pH<2	100	6 months
Volatile Organic Compounds (VOC)	G, TFE-lined cap	Add HCL to pH<2; cool (4°C)	2 × 40 ml	14 days
Total Organic Carbon (TOC)	G, TFE-lined cap	Add H_2SO_4 or HCL to pH<2; cool (4°C)	40	28 days
Total Organic Halogen (TOH)	Amber glass, TFE-lined cap	H_2SO_4 to pH<2 and cool (4°C) for EPA 9020A; cool (4°C) for EPA 9022	250	28 days
Turbidity	P, borosilicate glass	Cool (4°C)	100	48 h

[A] P = Plastic (polyethylene or equivalent); G = Glass; G, TFE-lined cap = Glass screw-cap vials sealed with Teflon-faced silicone septa.
[B] Individual laboratories may request more than the minimum volume.
[C] ASAP = As soon as possible.

REFERENCES

(**1**) ~~Gibb, J. P., Schuller, R. M., Griffin, R. A.,~~ ~~*Monitoring Well Sampling*~~*Barcelona, Michael J., Wehrmann, H. Allen, and* ~~*Preservation Techniques*~~ *Varljen, Mark D., “Reproducible Well-Purging Procedures and VOC Stabilization Criteria for Ground-water Sampling,” Ground Water,* ~~*EPA-600/9-80-101, 1980.*~~ *Vol 32, No. 1, 1994, pp. 12-22.*

(**2**) ~~Pettyjohn, W. A., Dunlap, W. J., Cosby, R. L., Keeley, J.~~Puls, Robert W., ~~“Sampling~~ and Powell, R. M., “Acquisition of Representative Ground Water Quality Samples for ~~Organic Contaminants,”~~ Metals,” *Ground Water Monitoring Review*, ~~Vol 19, (2), March/April 1981,~~ 1992, pp. ~~180–189.~~ 16-176.

(**3**) ~~Dunlap, W. J., McNabb,~~Gibb, J. ~~F., Scalf, M. R., Cosby,~~ P., Schuller, R. ~~L.,~~ M., and Griffin, R. A., ~~*Sampling for Organic Chemicals*~~*Monitoring Well Sampling and* ~~*Microorganisms in the Subsurface*~~ *Preservation Techniques*, ~~*EPA-600/2-77-176, NTIS PB 276 679, August 1977, 35 pp.*~~ *EPA-600/9-80-101, 1980.*

(**4**) ~~Scalf, M. R., McNabb, J. F., Dunlap, W. J., and Cosby, R. L.,~~ ~~*Manual of Ground Water*~~*Data Quality* ~~*Sampling Procedures, National Water Well Association, NTIS PB-82 103 045, 1981.*~~ *Objectives Process for Hazardous Waste Site Investigations, EPA QA/G-4HW, EPA/600/R-00/007, U.S. EPA, January 2000.*

(**5**) ~~“A Guide to Groundwater Sampling,”~~ ~~*NCASI*~~*RCRA Ground-Water Monitoring Draft Technical* ~~*Bulletin*~~ *Guidance*, ~~*No. 362, January 1982.*~~ *Office of Solid Waste, U.S. EPA, 1992.*

(**6**) Humenick, M. J., Turk, L. J., Coldrin, M.,“Methodology for Monitoring Ground Water at Uranium Solution Mines,” *Ground Water*, Vol 18 (3), May–June 1980, p. 262.

(**7**) *RCRA Technical Enforcement Guidance Document*, OSWER-9950.1, 1985.

(**8**) Marsh, J. M., and Lloyd, J. W., “Details of Hydrochemical Variations in Flowing Wells,” *Ground Water*,~~ Volume~~ Vol 18 (4), July~~–~~-August 1980, p. 366.

(**~~8~~9**) Nielsen, David M., Nielsen, Gillian L., “Technical Guidance on Low-flow Purging & Sampling and Passive Sampling,” *NEFS-TG001-99*, Nielsen Environmental Field School, Galena, OH, 1999.

(**10**) Parker, Louise V., and Ranney, Thomas A., “Sampling Trace-Level Organics with Polymaric Tubing,” *Dynamic Studies Special Report*, 97-2, 1997.

(**11**) Gibb, J. P., Schuller, R. M., and Griffin, R. A., “Collection of Representative Water Quality Data from Monitoring Wells,” *Proceeding of the Municipal Solid Waste Resource Recovery Symposium*, EPA-600/9-81-002A, March 1981.

(**~~9~~12**) Powell, R. M., and Puls, R. W., “Passive Sampling of Ground Water Monitoring Wells without Purging: Multilevel Well Chemistry and Tracer Disappearance,” *Journal Contam. Hydrol.*, 12, 1993, pp. 51-77.

(**13**) Kearl, P., Korte, N., and Cronk, T., “Suggested Modifications to Ground Water Sampling Procedures based on Observations from the Colloidal Borescope,” *Ground Water Monitoring Review* Vol 12, No. 2, 1992, pp. 155-166.

(**14**) Smyth, R. E., and Wayne, T., “New Sampling Device Provides Laboratory Verification,” Part 1 of 2, Publication of Sibak Industries, Limited, Inc., presented at the Waste Testing and Quality Assurance Symposium, Arlington, VA, August 1999.

(**15**) McCaulou, Douglas R., Jewett, D. G., Huling, S., “Compatibility of NAPLs and Other Organic Compounds with Materials used in Well Construction, Sampling, and Remediation,” *Ground Water Monitoring and Remediation*, 1996, pp. 125-131.

(**16**) Boettner, E. A., Gwendolyn, L. B., Zand, H., and Aquino, R., *Organic and Organotin Compounds Leached from PVC and CPVC Pipe*, NTIS P8 82-108 333, 1982.

(**~~10~~17**) ~~Junk, G.~~Parker, Louise V. , and Ranney, Thomas A.,~~ Svec, H. J., Vick, R. D., Avery, M. J., “Contamination~~ “Effect of~~ W~~ Concentration on Sorption of Dissolved Organics by~~ Synthetic Polymer Tubes,” *Environmental Science*~~ *PVC, PTFE, and*~~ *Technology*~~ *Stainless Steel Well Casings,” Ground Water Monitoring Review, Vol*~~ *8 (13) 1100, December 1974.*~~ *14, No. 3, 1994, pp. 139-149.*

(**~~11~~18**) ~~Louneman, W.~~Ranney, Thomas A.,~~ Bufalini, J. J., Kuntz, R. L.,~~ and~~ Meeks, S. A.,“ Contamination from Fluorocarbon Films,” *Environmental Science*~~ *Parker, Louise V., “Sorption and*~~ *Technology*, Vol 15 (1), January 1981.~~ Leaching of Trace Level Metals by Polymeric Well Casings,” Special Report 96-2, 1996.

(**~~12~~19**) Parker, Louise V., and Ranney, Thomas A., “Decontaminating Materials Used in Groundwater Sampling Devices,” Special Report 97-25, 1997.

(**20**) Parker, Louise V., and Ranney, Thomas A., “Decontaminating Groundwater Sampling Devices,” Special Report 97-25, 1997.

(**21**) ASC Committee on Environmental Improvement, “Guidelines for Data Acquisition and Data Quality Evaluation in Environmental Chemistry.” *Analytical Chemistry*, Vol 52, 1980, pp. 2242–2249.

(**~~13~~22**) *Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities*, EPA/530/SW-611, August 1977.

(**~~14~~23**) *Handbook for Sampling and Sample Preservation of Water and Wastewater*, U.S. Dept. of Commerce NTIS PB-259 946, September 1976.

(**~~15~~24**) Timco Manufacturing Co., Inc., “Variable Capacity Bailer,” *Timco Geotechnical Catalogue*, Prairie du Sac, WI, 1982.

(**~~16~~25**) deVera, E., Simmons, B., Stephens, R., and Storm, D., *Samplers and Sampling Procedures for Hazardous Waste Streams*, Environmental Protection Agency, EPA-600/2-80-018, 1980, p. 51.

(**~~17~~26**) Morrison, R., *Ground Water Monitoring Technology*, Timco Manufacturing Co., 1982, p. 276.

(**~~18~~27**) Eijelkamp, “Equipment for Soil Research,” *General Catalogue*, Geisbeek, The Netherlands, 1979, pp. 82–83.

(**~~19~~28**) Wood, W., “Guidelines for Collection and Field Analysis of Ground-Water Samples for Selected Unstable Constituents,” *Techniques of Water-Resources Investigations of the United States Geological Survey*, Chapter D2, 1976, p. 24.

(**~~20~~29**) Gilham, R. W., “Syringe Devices for Groundwater Monitoring,” *Ground Water Monitoring Review*, Vol 2 (2), Spring 1982, p. 36.

(**30**) *Remote Sampler Model 200*, Markland Specialty Engineering, Ltd., Etobicoke, Ontario, Bulletin 200/78, 1978.

(**31**) Herzog, B., Pennino, J., and Nielsen, G., “Ground-Water Sampling,” *Practical Handbook of Ground-Water Monitoring*, Nielsen, D. M., ed., Lewis Publishers, Chelsea, MI, 1991, pp. 449-499.

(**32**) Masterflex, *Masterflex Pump Catalogue*, Barnant Corp., Barrington, IL, 1981.

(**~~22~~33**) “Guidelines for Contracting Sampling and Analyses for Priority Pollutants in Pulp and Paper Industry Effluents,” *NCASI Stream Improvement Technical Bulletin*, No. 335, August 1980.

(**~~23~~34**) Federal Remediation Technologies Roundtable, Field Sampling and Analysis Technologies Matrix Version 1.0, http://www.frtr.gov/site/, revised February 6, 1999.

(**35**) Tai, D. Y., Turner, K. S., and Garcia, L. A., “The Use of a Standpipe to Evaluate Ground Water Samplers,” *Ground-Water Monitoring Review*, Winter, 1991, pp. 125-132.

(**36**) Imbrigiotta, T. E., Gibs, J., Fusillo, T. V., Kish, G. R., and Hochreiter, J. J., “Field Evaluation of Seven Sampling Devices for Purgeable Organic Compounds,” *Ground-Water Contamination: Field Methods*, Collins, A. G. and Johnson, A. J., eds., ASTM STP 963, ASTM, Philadelphia, 1988, pp. 258-273.

(**37**) Allison, L., “A Simple Device for Sampling Ground Water in Auger Holes,” *Soil Science Society of America Proceedings*~~ 35: 844–45, 1971. ~~, No. 35, 1971, pp. 844–845.

(**~~24~~38**) Willardson, L., Meek, B., and Huber, M., “A Flow Path Ground Water Sampler,” *Soil Science Society of America Proceedings*~~ 36: 965–66, 1972.~~ , No. 36, 1972, pp. 965–966.

(**~~25~~39**) Wilson, L., *Monitoring in the Vadose Zone: A Review of Technical Elements and Methods*, U.S. Environmental Protection Agency, EPA-60017-80-134, 1980, p. 180.

(**~~26~~40**) Driscoll, F. G., *Ground Water and Wells*, Johnson,~~ E. E.,~~ Filtration Systems, Inc., St. Paul, MN, 198~~0~~6, p.~~ 440.~~ 1189, Table 21.6, and p. 324.

(**~~27~~41**) Keck, W. G., and Associates, *New “Keck” Submersible Water Sampling Pump for Groundwater Monitoring*, Keck, W. G. and Associates, East Lansing, MI, 1981.

(**~~28~~42**) McMillion, L., and Keeley, J. W., “Sampling Equipment for Ground-Water Investigation,” *Ground Water*, Vol 6, 1968, pp. 9–11.

(**~~29~~43**) Industrial and Environmental Analysts, Inc., *Procedures and Equipment for Groundwater Monitoring*, Industrial and Environmental Analysts, Inc., Essex Junction, VT, 1981.

(**~~30~~44**) ~~Trescott, P., and Pinder, G., “Air Pump for Small-Diameter Piezometers,” *Ground Water* , Vol 8, 1970, pp. 10–15.~~

~~(**31**)~~ Sommerfeldt, T., and Campbell, D., “A Pneumatic System to Pump Water From Piezometers,” *Ground Water*, Vol 13, 1975, p. 293.

(**~~32~~45**) Smith, A., “Water Sampling Made Easier with New Device,” *The Johnson Drillers Journal*, July~~–~~-August 1976, pp. 1~~–~~-2.

(**~~33~~46**) Trescott, P., and Pinder, G., “Air Pump for Small-Diameter Piezometers,” *Ground Water*, Vol 8, 1970, pp. 10–15.

(**47**) Morrison, R., and Ross, D., “Monitoring for Groundwater Contamination at Hazardous Waste Disposal Sites,” *Proceedings of 1978 National Conference on Control of Hazardous Material Spills*,~~ April 13,~~ Miami Beach, FL, April 13, 1968, pp. 281–286.

(~~**34**~~**48**) Morrison, R., and Brewer, P. “Air-Lift Samplers for Zone-of-Saturation Monitoring,” *Ground Water Monitoring Review*, Spring 1981, pp. 52–54.

(~~**35**~~**49**) Morrison, R., and Timmons, R., “Groundwater Monitoring II,” *Groundwater Digest*, Vol 4, 1981, pp. 21–24.

(~~**36**~~**50**) Bianchi, W. C., Johnson, C., Haskell, E., “A Positive Action Pump for Sampling Small Bore Holes,” *Soil Science Society of America Proceedings*, Vol 26, 1961, pp. 86–87.

(~~**37**~~**51**) Timmons, R., Discussion of “An All-Teflon Bailer and~~ An~~ an Air-Driven Pump for Evacuating Small-Diameter Ground-Water Wells,” by~~ D. Buss~~ Buss, D., and~~ K.~~ Bandt, K., *Ground Water*, Vol 19, 1981, pp. 666–667.

(~~**38**~~**52**) Timco Manufacturing Co., Inc., “Gas Lift Teflon Pump,” *Timco Geotechnical Catalogue*, Prairie du Sac, WI, 1982.

(~~**39**~~**53**) Tomson, M., King, K., and Ward, C., “A Nitrogen Powered Continuous Delivery, All Glass Teflon Pumping System for Groundwater Sampling from Below 10 Meters,” *Ground Water*, Vol 18, 1980, pp. 444–446.

(~~**40**) *Pneumatic Water Sampler*, Slope Indicator Co., Seattle, WA, 1982.~~

~~(**41**~~**54**) ~~Petur Instrument Co., Inc., *Petur Liquid Sampler*, Petur Instrument Co., Inc., Seattle, WA, 1982.~~

~~(**42**) Idler, G., “Modification of an Electronic Downhole Water Sampler,” *Ground Water*, Vol 18, 1980, pp. 532–535.~~

~~(**43**) *Remote Sampler Model 200*, Markland Specialty Engineering, Ltd., Etobicoke, Ontario, Bulletin 200/78, 1978.~~

~~(**44**) Middleburg, R., “Methods for Sampling Small Diameter Wells for Chemical Quality Analysis,” *Presented at the National Conference on Quality Assurance of Environmental Measurements*, Nov. 27–29, Denver, CO, 1978.~~

~~(**45**) *Air Squeeze Pump*, Leonard Mold and Die Works, Denver, CO, 1982.~~

~~(**46**) *Automatic Sampler Controller: Markland Model 105 and 2105*, Markland Specialty Engineering, Ltd., Etobicoke, Ontario, Bulletin 105/78, 1981.~~

~~(**47**) Gillham, R. W., and Johnson, P. E., “A Positive Displacement Ground-Water Sampling Device,” *Ground Water Monitoring Review*, Vol 1 (2), Summer 1981, p. 33.~~

~~(**48**)~~ Signor, D., “Gas-Driven Pump for Ground-Water Samples,” *U.S. Geological Survey, Water Resources Investigation 78–72*, Open File Report, 1978.

(~~**49**~~**55**) *Tigre Tierra HX Pneumatic Packer*, Tigre Tierra, Inc., Puyallup, WA, 1981.

(~~**50**~~**56**) Cherry, R., “A Portable Sampler for Collecting Water Samples from Specific Zones in Uncased or Screened Wells,” *U.S. Geological Survey*, Prof. Paper 25-C, 1965, pp. 214–216.

(~~**51**~~**57**) Grisak, G., Merritt, W., and Williams, D., “Fluoride Borehole Dilution Apparatus for Groundwater Velocity Measurements,” *Canadian Geotechnical Journal*, Vol 14, 1977, pp. 554–561.

(~~**52**~~**58**) Galgowski, C., and Wright, W., “A Variable-Depth Ground-Water Sampler,” *Soil Science Society of America Proceedings*, Vol 44, 1980, pp. 1120–1121.

(~~**53**~~**59**) ~~*Samplers*~~*Vroblesky, D. A., and*~~ *Sampling Procedures for Hazardous Waste Streams*,~~ *Hyder, W. T., “Diffusion Samplers as an Inexpensive Approach to Monitoring VOCs in Ground Water,”* ~~USEPA MERL Laboratory, Cincinnati, OH, EPA-600/2-80-018, January 1980.~~ *Ground Water Monitoring Review* 12, No. 3, 1992, pp. 177-184.

(~~**54**~~**60**) Gefell, M. J., Hamilton, L. A., and Stout, D. J., “Comparison between Low-flow and Passive-diffusion Bag Sampling Results for Dissolved Volatile Organics in Fracture Sedimentary Bedrock,” Proceedings of the Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Remediation Conference and Exposition, Nov. 17-19, 1999, Houston, TX, pp. 304-315.

(**61**) Parsons Engineering Science, Inc., “Technical Report for the Evaluation of Groundwater Diffusion Samplers,” prepared for the Air Force Center for Environmental Excellence, Technology Transfer Division, 1999.

(**62**) ~~*Methods for Chemical Analysis of Water*~~*Samplers and*~~ *Wastes*, EPA-600/4-79-020, USEPA EMSL~~ Sampling Procedures for Hazardous Waste Streams, U.S. EPA MERL Laboratory, Cincinnati, OH,~~ March 1979.~~ EPA-600/2-80-018, January 1980.

(~~**55**~~**63**) ~~*Federal Register*~~*Methods for Chemical Analysis of Water and Wastes*,~~ Vol 44, No. 244, Dec. 18, 1979, pp. 75050–75052.~~ EPA-600/4-79-020, U.S. EPA EMSL Laboratory, Cincinnati, OH, March 1979.

(~~**56**~~**64**) *Standard Methods for the Examination of Water and Wastewater*, APAA, 14th ed., Washington, DC, 1976, pp. 38–45.

(~~**57**~~**65**) U.S. EPA, “Test Methods for Evaluation Solid Wastes, Physical/Chemical Methods (SW846),” Third Edition, September 1986; Final Update I, July 1992; Final Update IIA, August 1993; Final Update II, September 1994; Final Update IIB, January 1995, and Final Update III, December 1996.

(**66**) *Handbook for Analytical Quality Control in Water and Wastewater Laboratories*, EPA-600/4-79-019, U.S. EPA EMSL Laboratory, Cincinnati, OH, March 1979.

(~~**58**~~**67**) “A Guide to Groundwater Sampling,” *NCASI Technical Bulletin*, No. 362, National Council for Stream and Air Improvement, Research Triangle Park, NC, January 1982.

(**68**) U.S. Department of Interior, “Groundwater,” Chapter II, *National Handbook of Recommended Methods for Water Data Acquisition*, 1980.

(**69**) *Subsurface Characteristics and Monitoring Techniques,* Desk Reference Guide, EPA/1625/R-93/0036, 1993.

(**70**) Dablow, J. F. III, Persico, Daniel, and Walker, G. R., “Design Considerations and Installation Techniques for Monitoring Wells Cased with ″Teflon″ PTFE,” in *Ground-water Contamination-Field Methods*, Collins, A. G., and Johnson, A. I., eds., American Society for Testing and Materials, *Special Technical Publication 963*, Philadelphia,1988, pp. 199-205.

(**71**) Aller, Linda, Bennett, T. W., Hackett, Glen, Petty, R. J., Lehr, J. H., Sedoris, Helen, Nielson, D. M., and Denne, J. E., *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells*, National Water Well Association, Dublin, OH, 1989, p. 398.

(**72**) Nielsen, D. M., and Schalla, Ronald, “Design and Installation of Ground-Water Monitoring Wells,” in *Practical Handbook of Ground-Water Monitoring*, Nielsen, D. M., ed., Lewis Publishers, Chelsea, MI, 1991, pp. 239-331.

(**73**) Schmidt, G. W., “The Use of PVC Casing and Screen in the Presence of Gasoline on the Ground Water Table,” *Ground Water Monitoring Review*, 7, No. 2, 1987, p. 94.

(**74**) Johnson, R. C., Jr., Kurt, C. E., and Dunham, G. F., Jr., “Well Grouting and Casing Temperature Increases,” *Ground Water*, Vol 18, No. 1, 1980, pp. 7-13.

(**75**) Parker, L. V., “Suggested Guidelines for the use of PTFE, PVC and Stainless Steel in Samplers and Well Casings,” in *Current Practices in Ground Water and Vadose Zone Investigations*, Nielsen, D. M., and Sara, M. N., eds., Special Technical Publication 1118, American Society for Testing and Materials, Philadelphia, 1992, pp. 217-229.

(**76**) Adapted from Lapham, Wayne W., Wilde, Franceska D., Koterba, Michael T., *Guidelines and Standard Procedures for Studies of Ground-Water Quality*, U.S. Geological Survey Water-Resources Investigations Report 96-4233, 1997.

(**77**) From Standard Methods for the Examination of Water and Wastewater, 18th Edition, 1992, p. 1-22, Methods for Chemical Analysis of Water and Wastes, March 1983 Revision, p. xvi-xx, or EPA Test Methods for Evaluating Solid Waste, SW-846, 3rd Edition.

(**78**) Adapted from McCaulou, Douglas R., Jewett, David G., and Huling, Scott G., "Compatibility of NAPLs and Other Organic Compounds with Materials Used in Well Construction, Sampling, and Remediation," *Ground Water Monitoring Review*, Fall 1996, Vol 16, No. 4, pp. 125-131.

(**79**) *Samplers and Sampling Procedures for Hazardous Waste Streams*, U.S. EPA, MERL Laboratory, Cincinnati, OH, EPA–600/2–80–018, January 1980.

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).