HARGIS + ASSOCIATES, INC.
HYDROGEOLOGY • ENGINEERING

La Jolla Gateway
9171 Towne Centre Drive, Suite 375
San Diego, CA 92122
Phone: 858.455.6500
Fax: 858.455.6533

November 13, 2013

VIA FEDERAL EXPRESS STANDARD AND EMAIL

Mr. William F. Jeffers, PE
Hazardous Substances Engineer
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
DEPARTMENT OF TOXIC SUBSTANCES CONTROL
9211 Oakdale Avenue
Chatsworth, CA 91311-6520

Re: Planned Flow Survey and Depth Discrete Sampling Program,
City of Fullerton Production Well No. 9, Former Raytheon Company
(Formerly Hughes Aircraft Company) Site, 1901 West Malvern Avenue, Fullerton, California

Dear Mr. Jeffers:

This letter has been prepared by Hargis + Associates, Inc. (H+A) on behalf of the Raytheon Company (Raytheon) to inform the Department of Toxic Substances Control (DTSC) regarding a planned flow survey and depth discrete sampling program to be conducted at the City of Fullerton's production well No. 9 (Well 9). This program is being conducted as a voluntary effort in coordination with the City of Fullerton and the Orange County Water District (OCWD).

Well 9 is located on the north boundary of the Fullerton Airport (Figure 1) and is routinely used for municipal water supply. Well 9 is approximately 1,080 feet deep and was constructed with 7 separate screen intervals. A depth discrete flow survey and water sampling program has been developed to evaluate the percentage of water contributed by the various screens and the water quality associated with each screen interval. The information that will be collected will allow assessment of potential future well modifications that supports and enhances continued production of groundwater that meets drinking water quality standards and meets the City of Fullerton's water supply requirements.

Flow survey and sampling services will be provided by BESST, Inc. under contract to H+A. BESST, in conjunction with the U.S. Geological Survey, has developed a small-diameter, downhole, vertical flow measuring tool that can be deployed at various depths within the casing and screen. By comparing measurements at different depths while the well is being pumped, the relative flow contribution of each screen interval can be calculated. Following the flow survey, a small-diameter sampling device will be deployed and depth discrete water samples will be collected between each screen interval to assess the vertical distribution of water quality within the well while it is being pumped. Based on these results, the quality of the water being contributed by each screen can be calculated.

The following provides a brief description of Well 9 and the approach to the well survey and sampling program.

Other Offices:
Mesa, AZ
Tucson, AZ

Well 9 Construction

Well 9 was drilled in 1984 to a total depth of 1,135 feet. The drillers log indicates that nominal 20-inch diameter casing (~19¼-inch inner diameter [ID]) was installed from land surface to 350 feet and was grouted in-place with neat cement to provide a sanitary seal. The 20-inch casing necks down to 16-inch casing between 350 and 355 feet. Sixteen-inch blank casing and separate wire wrap screen sections extend to a total depth of 1,080 feet.

The drillers log indicates that the lower portion of the well below 355 feet was completed with nominal 16-inch casing (~15¼-inch ID) and 7 wire wrap screen intervals as follows:

- 435 to 515 feet
- 555 to 575 feet
- 615 to 635 feet
- 660 to 720 feet
- 750 to 850 feet
- 940 to 960 feet
- 980 to 1,080 feet

A well schematic has been prepared based on the information in the drillers log indicating general well construction details and screen intervals (Figure 2).

Well 9 is currently fitted with a nominal 16-inch shaft driven turbine pump with 15¼-inch diameter bowls set on 190 feet of 12-inch column pipe. A 2-inch diameter access tube extends through the concrete pump base that allows access into the 20-inch casing. It is assumed that this access tube is sufficient to allow entry and removal of the survey tools and that there is sufficient clearance to pass by the turbine pump.

Task 1 – Verify Well Access

Prior to conducting the flow survey, a field engineer from BESST will verify that there is sufficient access to conduct the survey by running a dummy (with similar dimensions as the survey equipment) into the well, past the turbine pump. The current static water level and current depth to the bottom of the well will also be verified. In addition, a depth discrete sample would also be collected from below the uppermost screen interval of Well 9 while the well is not operating. This sample would be collected if there is a downward gradient in the area based on water level data measured in nearby monitor wells as follows. Water levels will be measured the week before and the day the BESST field engineer runs the dummy in Well 9 in the following monitor wells: nested monitor well MW-35 cluster (there are three screens in this well, the deepest of which is Unit B); monitor wells MW-33 and MW-36 (the two closest Unit B monitor wells); and OCWD test well (the second screened interval in this monitor well is completed in roughly the same interval as the top screen in Well 9). If there is a downward gradient from zones above Unit B to Unit B, a groundwater sample will be collected in the blank casing immediately below the uppermost screen zone in Well 9. The sample will be analyzed for volatile organic compounds (VOCs) using U.S. Environmental Protection Agency (EPA) Method 524.2 (Table 1). The sample will be collected using the depth discrete sampling method specified in Task 4 for VOCs.

In the event that the clearance is too tight to allow entry of the survey tools, the program will be suspended and various alternatives will be evaluated to achieve the required access. Potential options include:

- Raising and shifting the pump discharge (including motor and column pipe) sideways and setting it on blocks to allow access to the top of the casing.
- Pulling the pump and installing a smaller-diameter test pump.

Any required well/pump modifications must be approved by the City of Fullerton and will be conducted by a qualified licensed drilling/pump contractor that has an established working relationship with the City of Fullerton. Potential contractors include:

- Layne Christensen
- Tri-County Pump

In the event that well and/or pump modifications are required, the selected contractor will be retained directly by H+A. Once adequate clearance has been achieved, the following flow survey and sampling tasks will be sequentially conducted.

Task 2 – Pre Flow Survey Assessment

At present, Well 9 is temporarily shut down due to City water supply logistics, but can be pumped, as needed, to support the well survey and sampling. Prior to conducting the flow survey, Well 9 will be operated at its normal pumping rate for a period of at least 5 days. During this time, the pumping water level in the well will be measured, the flowrate recorded, and a water sample will be collected from the pump discharge sampling port on a daily basis to verify the well-specific capacity and confirm that the water contains low concentrations of 1,1-dichloroethene (1,1-DCE) that have historically been detected in the well. The water samples will be analyzed for VOCs using EPA Method 524.2 on a 24-hour turnaround basis. In the event that after 5 days 1,1-DCE is not detected in the most recent daily sample, the well will continue pumping and the sample interval will be increased to every other day until 1,1-DCE is detected.

Task 3 – Downhole Flow Survey

Once it is confirmed that 1,1-DCE is present in the well discharge, a downhole flow survey will be conducted using a dilute rhodamine tracer dye that is National Sanitation Foundation (NSF) approved for use in potable water supplies. General Standard Operating Procedures for the downhole survey are provided (Attachment 1). Equipment and related tubing introduced to the well will be decontaminated by spraying with a bleach solution. Immediately prior to conducting the flow survey, the well discharge will be diverted to waste (adjacent equalization basin) and will remain to waste for the duration of the flow survey.

The flow survey involves setting a tool to the target measurement depth. The turbine pump will be turned off for a short period as the tool passes by the pump intake and then restarted. Once the flowrate and drawdown have restabilized, the flow measurements will commence. A minimum of two flow measurements will be made in each section of blank casing and optionally within the longer screen intervals. The tool emits an instantaneous pulse of rhodamine dye which travels upward in the casing to the pump intake and is discharged from the well. Although rhodamine dye is NSF 60 approved for use in potable water supply systems at dilute concentrations on an infrequent basis, the well discharge will be diverted to waste during the flow survey to prevent introduction of dye into the water supply distribution system.

The time required for the dye pulse to travel from the tool to the detector at the wellhead will be measured and recorded. The process is repeated at the other target depths. The difference in travel time is proportional to the upward water velocity between the target depths and knowing the casing ID the relative water flow up the casing can be calculated. The incremental contribution to the total flow from each screen is then calculated. This information will be used to assess to what extent each screen contributes to the well's overall capacity. It will also be used in conjunction with the depth discrete sampling data described below to assess the relative water quality contributed by each screen.

During the flow survey, the discharged water will not pass through the inline flow meter at the wellhead as the water bypasses the flow meter when water is pumped to waste, so the total flowrate cannot be monitored directly. However, the pumping water level will be monitored every hour (using the air line at the wellhead) to assess potential changes in well pumping rate during the survey.

Task 4 – Depth Discrete Water Quality Sampling

Depth discrete water samples will be collected within the blank casing above six of the seven screen intervals. A sample will be collected from the wellhead, which is representative of all seven of the screened intervals. A depth discrete sample may also optionally be collected within the lower screen interval using a small-diameter sampling pump or pressurized sampler depending on the compounds to be analyzed. General Standard Operating Procedures for depth discrete sampling are provided (Attachment 2). Prior to lowering the sample device into the well, the sampler and tubing will be cleaned and rinsed with a chlorine bleach solution.

Sampling will be conducted while the well is being pumped in the normal operating mode. Samples of the well discharge will be collected for VOCs just prior to starting and immediately following completion of the depth discrete sample collection each day to verify that no significant change in water quality occurred during the sampling event.

Depth discrete samples will be collected using two different sampling devices. Samples for VOC analysis will be collected using a pressurized bailer sampling device. Samples for inorganic analysis will be collected using the pressurized bailer if the sample submergence is adequate; otherwise, a small-diameter gas-operated sampling pump will be used.

Samples will be collected using the pressurized bailer by pressurizing the bailer and tubing at land surface and lowering the pressurized sampler to the target depth. The pressure is then released, allowing the sampler and tubing to fill with water from the target depth. The sampler will be re-pressurized and retracted from the well. At land surface, the pressure is released and sample containers will be immediately filled with water from the bottom of the bailer. Prior to collecting subsequent samples, the tubing and sampler will be purged with nitrogen gas.

Inorganic samples may be collected using the small-diameter gas-operated sampling pump attached to dual Teflon-lined tubing. The pump is initially lowered to the target sample depth, allowing the tubing to fill with water. The dual tubing and pump will then be completely purged of water two times using nitrogen gas. Water will then be pumped from the target depth by alternately applying pressurized nitrogen to the gas injection tubing, forcing water to land surface up the water discharge tubing. Water samples will then be collected and the pump lowered to the next target depth and the process repeated.

Proposed target sampling depths are indicated on Figure 2. Water samples will be analyzed by CalScience Environmental Laboratories. Samples will be analyzed for VOCs, 1,4-dioxane, general minerals, nitrate, selenium, manganese, and iron using appropriate EPA methods (Table 1). In addition, water samples for California Assessment Manual (CAM) metals will be collected immediately above the bottom screen and from the well discharge at the end of the sampling program. A detailed sample and analyte list indicating the EPA method to be used is provided in Table 1.

The following quality assurance / quality control (QA/QC) samples will be collected:

- one duplicate sample from the wellhead (final wellhead sample);
- one VOC duplicate sample from downhole sample depth (sample 7);
- one rinsate sample for VOC analysis from the pressurized bailer following the initial decontamination procedure;
- VOC daily trip blank sample; and
- VOC and 1,4-dioxane daily field blank samples.

Samples will be analyzed on a standard turnaround time.

Task 5 – Data Evaluation

Data will be evaluated in conjunction with the City of Fullerton and OCWD to assess which zones may be contributing the 1,1-DCE that has been detected in the discharge from Well 9. Depending on the percentage contribution of flow to the well, the screen interval(s) which exhibit higher 1,1-DCE concentrations may be packered off or otherwise sealed off in the future.
It is anticipated that additional well testing would be conducted if sealing off a portion of the well appears viable. This testing would likely consist of setting a temporary packer and test pump . A separate work plan would be prepared prior to conducting the packer testing program.

Schedule and Reporting

It is anticipated that the proposed survey and sampling will be conducted in December pending contractor availability and completion of necessary planning and access activities. Within approximately 30 days of receipt of final analytical results, a brief Technical Memorandum will be prepared and submitted to the City of Fullerton and OCWD, summarizing the results of the survey and providing recommendations regarding future modification/operation and testing of Well 9.

HARGIS + ASSOCIATES, INC.

If you have any questions or require additional information, please contact us.

Sincerely,

HARGIS + ASSOCIATES, INC.

Christopher G.A. Ross, PG 4594, CHG 221 Principal Hydrogeologist	Roger A. Niemeyer, PG 3616, CHG 43, CEG1071 Principal Hydrogeologist

CGAR/RAN/ama

Attachments: Table 1. Analytical Schedule

Figure 1. Site Location (City of Fullerton Well No. 9) (H+A Dwg No. 410-9106A)
Figure 2. Schematic Construction Diagram, Fullerton Well #9 (H+A Dwg No. 710-0797A)

Attachment 1. BESST Standard Operating Procedure for Dye Tracer
Attachment 2. BESST Standard Operating Procedures for Depth Discrete Sampling

cc w-attachments: Mr. Paul E. Brewer, Raytheon Company (via Email & U.S. Mail)
Mr. Dave Mark, Orange County Water District (via Email & U.S. Mail)
Mr. Dave Schickling, City of Fullerton (2 copies) (via Email & U.S. Mail)
Mr. Chad Blais, City of Fullerton (via Email & U.S. Mail)

532_A01_05_Prod Well 9 Smplng Prgrm

TABLE 1
ANALYTICAL SCHEDULE

SAMPLE CONTAINER REQUIREMENTS

	METHOD	CONTAINER	PRESERVATION
VOCs	EPA 524.2	3 x 40 ml VOA	HCl / Ascorbic Acid
1,4-Dioxane	EPA 8270C(M) ID	1-L Amber glass	none
Metals (ICP/MS)	EPA 6020	250 ml HDPE	HNO_3
Mercury	EPA 7470A		
Bicarb/Carb	SM 2320B	250 ml Poly	none
Anions	EPA 300.0	250 ml Poly	none

ANALYTICAL DETAILS / SAMPLE LOCATION

		Reporting Limit	Method Detection Level	Unit	Method	SAMPLE LOCATION
VOCs	Various	1,1-DCE - 0.50 Other various	1,1-DCE - 0.048 Other various	ug/L	EPA 524.2	Pre-Survey; wellhead and depth discrete
1,4-Dioxane	1,4-Dioxane	1.0	0.28	ug/L	EPA 8270C(M) ID	Wellhead and depth discrete
CAM Metals	Antimony	0.001	0.0000995	mg/L	EPA 6020	Final wellhead sample and depth discrete sample 7
	Arsenic	0.001	0.000386	mg/L	EPA 6020	
	Barium	0.001	0.0000986	mg/L	EPA 6020	
	Beryllium	0.001	0.00029	mg/L	EPA 6020	
	Cadmium	0.001	0.000128	mg/L	EPA 6020	
	Chromium	0.001	0.000402	mg/L	EPA 6020	
	Cobalt	0.001	0.0000919	mg/L	EPA 6020	
	Copper	0.001	0.00014	mg/L	EPA 6020	
	Lead	0.001	0.0000898	mg/L	EPA 6020	
	Mercury	0.0005	0.0000453	mg/L	EPA 7470A	
	Molybdenum	0.001	0.000127	mg/L	EPA 6020	
	Nickel	0.001	0.000132	mg/L	EPA 6020	
	Selenium	0.001	0.000168	mg/L	EPA 6020	Wellhead and depth discrete
	Silver	0.001	0.000111	mg/L	EPA 6020	Final wellhead sample and depth discrete sample 7
	Thallium	0.001	0.000101	mg/L	EPA 6020	
	Vanadium	0.001	0.000149	mg/L	EPA 6020	
	Zinc	0.005	0.000479	mg/L	EPA 6020	
Anion	Bicarbonate (as CaCO3)	1.0	0.85	mg/L	SM 2320B	Wellhead and depth discrete
	Boron	0.05	0.00676	mg/L	EPA 6020	
	Carbonate (as CaCO3)	1.0	0.85	mg/L	SM 2320B	
	Chloride	1.0	0.12	mg/L	EPA 300.0	
	Fluoride	0.10	0.025	mg/L	EPA 300.0	
	Sulfate	1.0	0.19	mg/L	EPA 300.0	
	Nitrate (as N)	0.10	0.025	mg/L	EPA 300.0	
Cation	Calcium	0.1	0.00665	mg/L	EPA 6020	Wellhead and depth discrete
	Iron	0.05	0.00926	mg/L	EPA 6020	
	Magnesium	0.1	0.00278	mg/L	EPA 6020	
	Potassium	0.1	0.00744	mg/L	EPA 6020	
	Sodium	0.1	0.00303	mg/L	EPA 6020	
	Manganese	0.001	0.000139	mg/L	EPA 6020	

FOOTNOTES

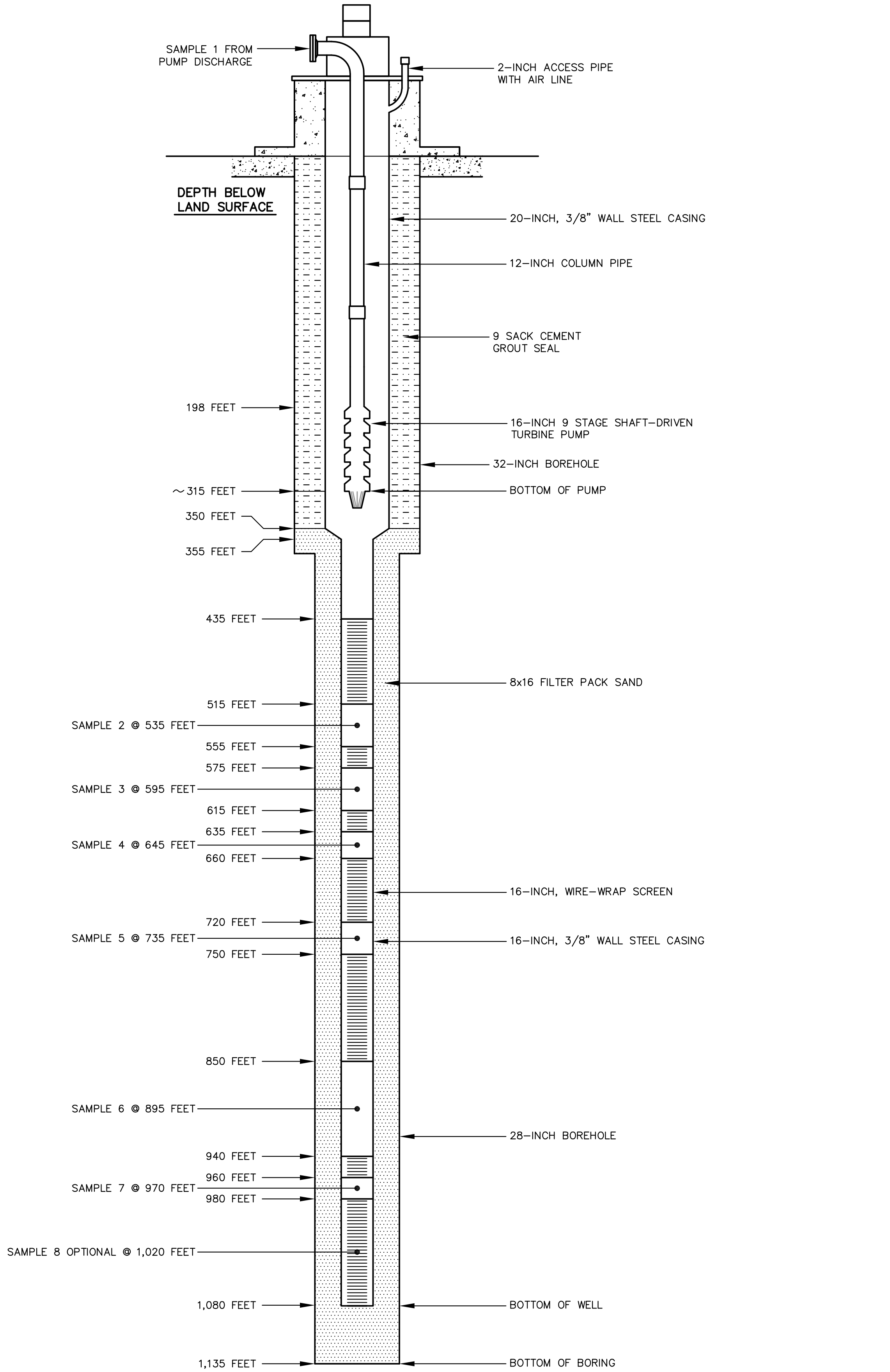
L = Liter
mg/L = Milligrams per liter
ml HDPE = Milliliters high-density polyethylene
ug/L = Micrograms per liter
HNO_3 = Nitric Acid
HCl = Hydrochloric Acid
VOA = Volatile Organics Analysis
VOCs = Volatile Organic Compounds

Nov 05, 2013 – 4:27pm ADH – T:\2013\500-599\532 Raytheon\Hydrogeology\H+A BaseMaps\410-9106.dwg

11/13	RPT NO. 532.31	410–9106	A

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

FIGURE 1. SITE LOCATION



Nov 05, 2013 - 11:45am ADH - T:\2013\500-599\532 Raytheon\Hydrogeology\WellDiag\710-0797.dwg

11/13	RPT NO. 532.03	710-0797	A

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

FIGURE 2.
SCHEMATIC CONSTRUCTION DIAGRAM
FULLERTON WELL #9

ATTACHMENT 1

BESST STANDARD OPERATING PROCEDURE
FOR
DYE TRACER

BESST INC.
GLOBAL SUBSURFACE TECHNOLOGIES

Standard Operating Procedures

Dye Tracer Flow Meter Profiling and HydroBooster™ Groundwater Sampling

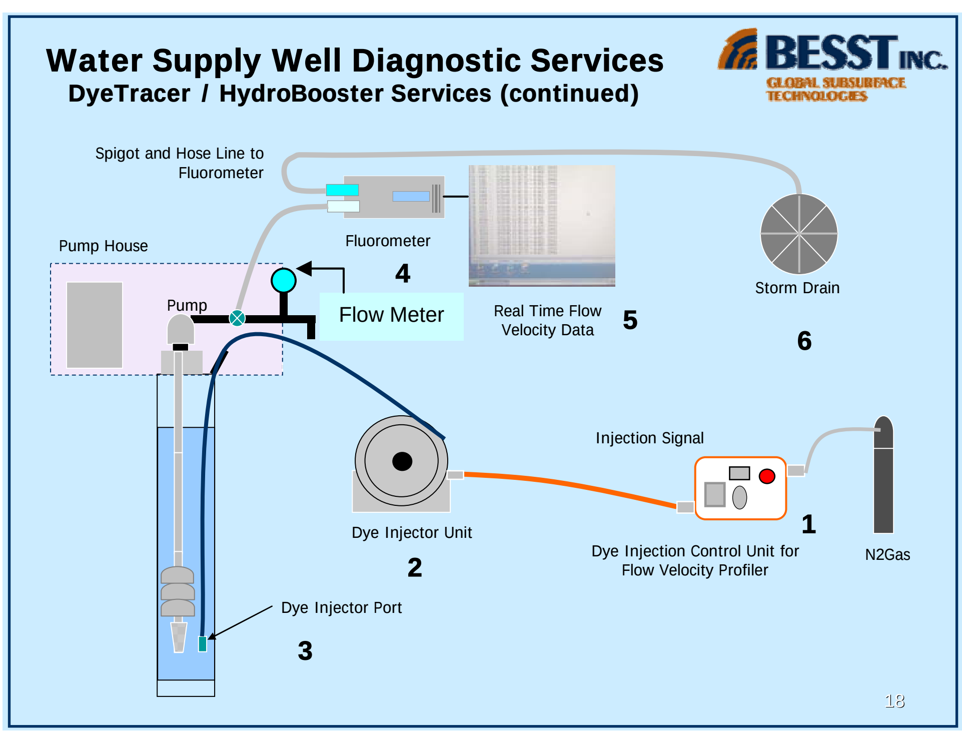
1. Dye Tracer Flow Velocity Profiling – General Description

The Dye Tracer Flow Velocity Profiling System (DT) is a USGS method and apparatus patented technology and was constructed and is operated by BESST, Inc. under exclusive license from the USGS. The technology has the ability to provide a dynamic flow velocity profile from virtually any type of production, remediation or monitoring well without first having to remove the pump from the well. The end result of the method produces a quantitative groundwater production profile of water influx along a well screen under dynamic flow pumping conditions along the entire well screen. The velocity and production profiles generated by this technology are comparable to profiles generated by spinner logging tools under dynamic flow conditions. The setup schematic for the Dye Tracer (DT) system is presented in Figure 1.

The DT system is composed of six main components:

a. Flexible Dye Injection Hose w/ Injection Nozzle
b. Motorized Hose Spool for deploying and retrieving the dye injection tubing w/ nozzle
c. Injection Pump / w/ Pneumatically Controlled Solenoid for the injection pump and Valve Switching Unit
d. Injection Control Unit
e. 10-AU Fluorometer from Turner Designs
f. Rhodamine Red Dye (NSF 60 Approved)

Figure 1: Schematic of Dye Tracer Flow Velocity Profiling System



1.1 Planning and Field Preparation

The first step in operation of the DT system is access to the well of interest. Preparation consists of communication between the consultant, water purveyor and BESST in order to determine the most suitable access points into the well – between the pump column and interior well casing wall. Schematics of the pump and pump house and multiple photos of the well head are typically reviewed before the start of any project. Once reviewed, a planned approach is agreed to before commencement of work.

The DT tubing and injection nozzle typically ranges between ½-inch to ¾-inch in diameter. The small diameter and flexibility of the tubing and nozzle assembly make it possible to bypass the pump column, down-hole impeller bowls and / or electric pump motors. A key factor in successfully inserting the injection tubing and nozzle is the attachment of a small diameter steel cable or weighted chain to a metal loop located and attached just below the injection nozzle. The weight attachment makes it possible to move the DT tubing up and down in the well without turning off the pump.

In typical applications, the DT tubing is lowered through a mechanical counter that indicates the depth of the injection nozzle. The injection process can be started near the top of the pump or impeller bowls or from the bottom of the well screen. Injection points are typically laid out on a 10- to 20-foot vertical grid in order to obtain enough data points to vertically profile production along the well screen.

Prior to well injection, 50 ml of Rhodamine Red (RR) (from Bright Dyes, Inc.) is injected into a 5-Gallon bottle of DI water. The solution from the RR bottle is then fed by the injection pump (IP) to the injection line until the line is completely filled with the RR solution. When released into a well, each second of injection by the Injection Control Unit (ICU) is equivalent to approximately 20 ml of RR released from the injection nozzle (IN). Figure 2 below shows a typical setup for the DT system at a production well location in northern Nevada.

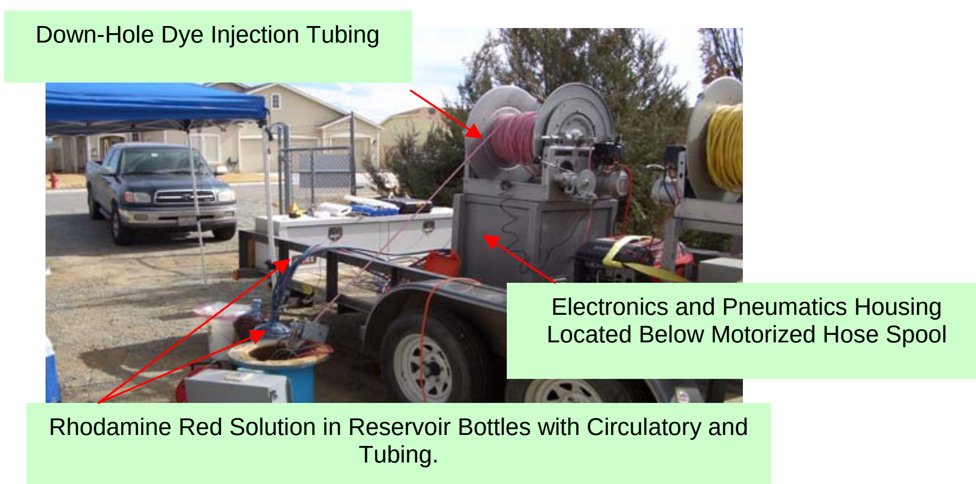


Figure 2: Typical trailer setup for Dye Tracer Flow Velocity Profiling System – at a location in northern, Nevada.

While the system is in non-injection mode and idling, the RR solution is circulated in the RR reservoir bottle to prevent air bubbles from entering the liquid and being injected into the well. Additionally, an electronic float sensor is placed within the RR reservoir bottle to prevent air from being drawn into the injection line. As a result, when the RR solution is drawn down to the lower third of the RR bottle, the injection pump automatically shuts off. More RR solution is then added to the bottle before RR injection is continued. Introduction of air into the injection line is undesirable since air bubbles can cause delays in the return time of the RR to the fluorometer.

1.2 General Description of Equipment

The fluorometer used for the velocity profiling is a Model 10-AU from Turner Designs and is shown in Figure 3. The 10-AU Fluorometer measures the concentration of various analytes in samples of interest via fluorescence. In the case of dynamic flow velocity analysis for wells, the analyte of interest is artificially introduced in order to measure the peak concentration return times of rhodamine red from the release point to the fluorometer via the discharge path of the pumping well. The return concentrations are typically in the part per billion range. Light or exciting light from a light source within the fluorometer is passed through a color filter specific to rhodamine red, that transmits light of the chosen wavelength range (color). The wavelength of the exciting light that falls on the sample is set by the choice of the light source and the excitation filter. The emitted light radiates in a sphere from the light source and is directed towards the 10-AU detector through an emission filter. The purpose of the emission filter is to prevent any scattered exciting light from reaching the detector (photomultiplier tube) and to pass the emitted color that is specific to the analyte of interest. The concentration of the RR solution is directly proportional to the signal response received by the fluorescing light emitted by the rhodamine red that is received by the detector. The concentration is typically reported on an analog display panel located on the front of the 10-AU (Turner Designs, 1996).

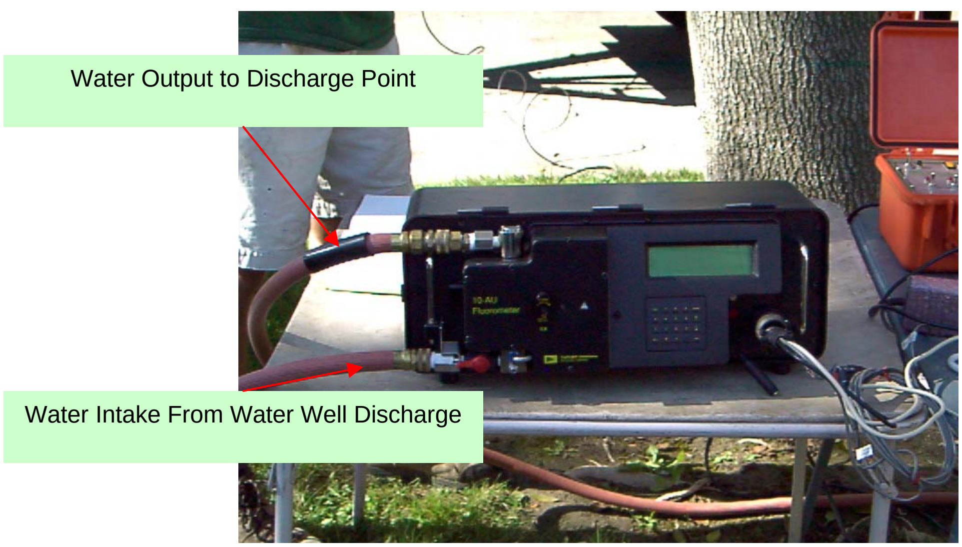


Figure 3: Model 10-AU fluorometer from Turner Designs.

To-the-second consistency of injection time, and bubble free RR injection solution is the key to establishing meaningful and reproducible results for defining dynamic flow velocity measurements in any well under study. Figure 4 shows a BESST, Inc. injection control unit for tightly regulating injection pulse times. Figures 5 and 6 provide a more detailed look of the circulatory system of the dye injector.

Figure 4: Dye Injection Control Unit for to-the-second regulation of dye injection pulses.

Figure 5: Electrical and Pneumatics components inside housing are controlled by the Dye Injection Control Unit (Figure 4). The housing contains injection pump, injection pressure regulator, pneumatically controlled valve switching solenoid, fuse box, electrical circuits and primary and secondary valve control units.

Figure 6: Bottle to right contains primary RR reservoir. When the large oval red button is depressed on the Dye Injection Control Unit (Figure 4), the RR solution is fed from the red tube, then to the injection pump, and finally through the injection nozzle and into the well. When the injection pump is idling, the RR solution circulates through the blue tube and red tube in the primary RR reservoir bottle. The secondary RR bottle receives excess RR that is not used during an injection pulse.

1.3 Injection Procedure

Prior to the first dye injection, the well of concern is typically pumped at the specified pumping rate for the flow velocity test until draw down stabilization inside the well has been reached. Periodic readings are recorded from a flow meter attached to the discharge line. Ideally, the flow meter is attached to the discharge line at a distance of at least 10 feet from the well head in order to minimize the effect of pipe fluid turbulence on the flow meter reading.

The first step in the dye injection process is to lower the injection tubing and nozzle through a mechanical counter to the first injection point in the well. Often times, the injection process starts from the well bottom – since the weighted end of the injection tubing is used to verify the actual well depth. Therefore, as a matter of convenience, the first injection point is typically near the bottom of the well. The injection points are then executed along a vertical ascending grid. At the point of dye injection, the release time is manually noted in a field log. Each release time is selected from a scrolling time and concentration log which appears on a laptop screen – the laptop being directly connected to the fluorometer. The communication of this information through the laptop is facilitated through the laptop's default communication software called Hyperlink. An example of the laptop display is shown in Figure 7 below.

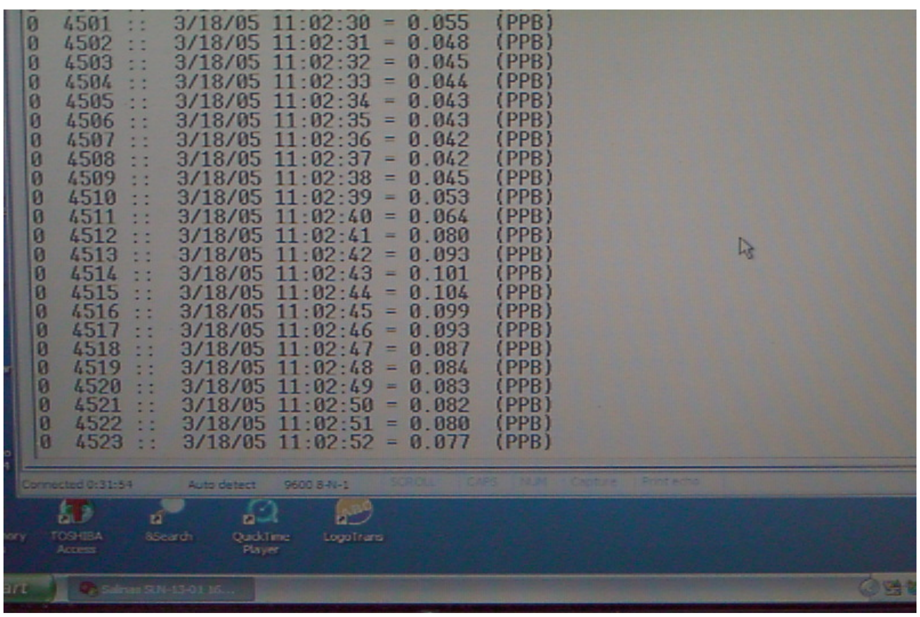


Figure 7: Streaming Laptop Hyperlink Communication Display from AU-10 Fluorometer. Date, time and concentration value are reported and stored in continuous scrolling format.

Figure 8: Laptop connected to 10-AU

1.4 Data Requirements
During the course of completing the vertical dye injection grid, some of the injection points are repeated in order to establish travel time and velocity reproducibility. Once all of the injection points are completed, the data is entered into an Excel spreadsheet with built-in data calculations that facilitate the generation of the flow profile – using the Excel chart function. The basic equation (Izbicki, 2000) used for calculating flow velocity is:

$Q = (V\pi r^2)$

where,

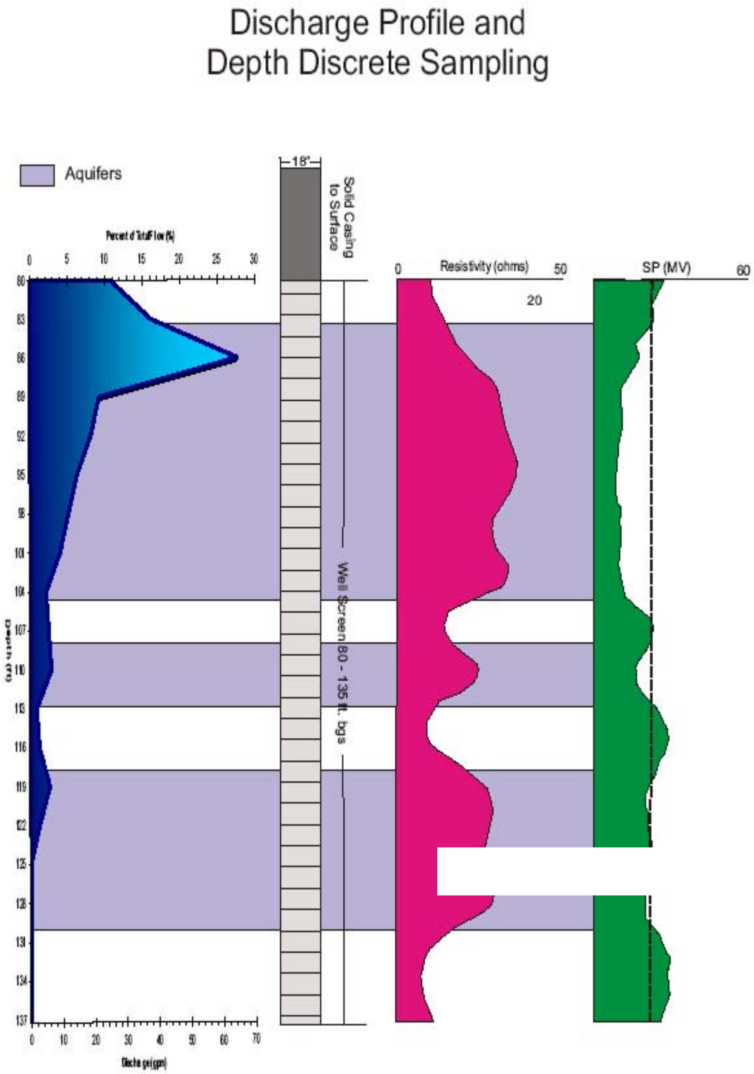
$V = (d_2 - d_1) / (t_2 - t_1)$

Q = flow in gallons per minute (gpm)
d = injection depth
d_2 = injection depth # 2
d_1 = injection depth # 1
t = travel time of peak tracer concentration from release point to detector
t_2 = return time for rhodamine red peak to fluorometer detector for d_2 injection point
t_1 = return time for rhodamine red peak to fluorometer detector for d_1 injection point

Other factors that are required for the solution and interpretation of the results are well diameter, pump diameter, pump column diameter and length, depth of pump intake, well screen interval(s), and length of well screen located above the pump. Other pieces of information that can play a role in the interpretation of the results are driller's logs from when the well bore was drilled and any geophysical logs such as resistivity short and long normal, spontaneous potential (SP), gamma ray, neutron, caliper, video surveys and others.

As far as data plotting, there are various types of valid presentation formats. One type of format (presented in Figure 9) plots depth on the y-axis, percent flow on the top x-axis and GPM discharge on the bottom x-axis. Additionally, lithologic and geophysical information are presented in co-plots to the right in order to correlate lithologic and geophysical properties to production.

Figure 9: Blue curve displays flow profile of production well – where injection depth points are shown along y-axis. Top x-axis shows percent contribution with depth and bottom x-axis shows discharge with depth in GPM. Magenta shaded curve displays resistivity in ohms and green-shaded curve shows spontaneous potential (SP) in millivolts (MV).



2. HydroBooster™ Groundwater Sampling – General Description

The HydroBooster™ pump is a high-lift gas displacement pump that was designed by BESST, Inc. for the USGS for collecting groundwater samples from active production wells without having to remove the pump (USGS, 2004). The HydroBooster™ pump spans from 6 to 18-inches in length (depending on model) and ranges in diameter from ½-inch to 7/8-inch. The pump can be connected to any type of tubing (i.e. Teflon, polyethylene, nylon, etc.). For high pressure applications, the tubing can consist of regular nylon, or even nylon reinforced with fiber glass or Kevlar for ultra high pressure applications to 3,000+ feet BGS. Figure 10 shows an example of a HydroBooster™ application at a site in the California Central Valley for a production well under study for vertical distribution of nitrate contamination.

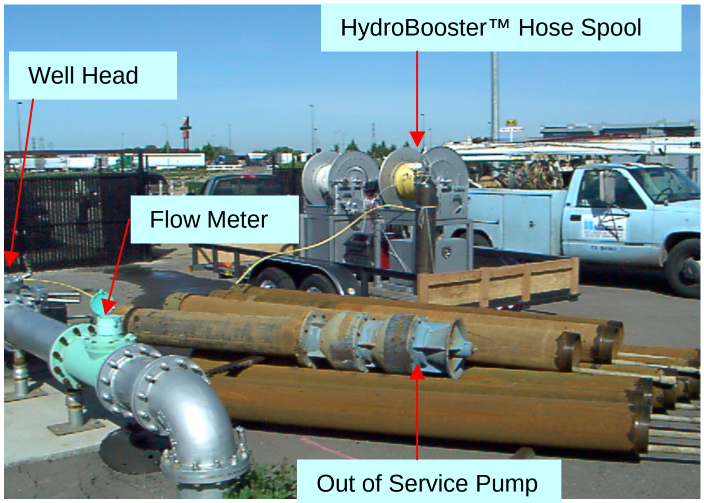


Figure 10: Setup of the HydroBooster system at a groundwater production well in the California Central Valley. Groundwater samples were collected in conjunction with running a smaller electric pump inside the well. The main pump was removed sometime prior to the testing and is shown in foreground (blue housing). The production well was under study for vertical distribution of nitrate contamination. Note the flexibility of the HydroBooster system leading up to the well head.

As with the Dye Tracer Flow Velocity Unit, the tubing for the HydroBooster™ system is flexible, permitting access into various types of production well settings without having to remove the pump. Various types of small diameter BESST pumps used for groundwater sampling in production wells (as well as small diameter and Westbay Multi Port wells) is shown in Figure 11.

Figure 11: HydroBooster Pumps

3. Decontamination of Flow Meter and Groundwater Sampling System

Cleaning and decontamination of the flow meter and groundwater sampling system begins with use of a hot water steam cleaner. The entire rig is hosed down with the steam cleaner. Following the steam cleaning, all of the tubing is removed and placed into a hot water washer where the tubing is washed with disinfecting detergent to a temperature of 180 degrees F.

When the profiling rig reaches the site, all of the various equipment are prepared for use. Nitrile gloves are used in the handling of the tubing and all of the other parts that go into the well. Just prior to the tubing, weights, injection nozzle and pump entering the well, the field scientists use a Hanson Sprayer to disinfect the components with an anti-bacterial solution consisting of a mixture of one-half gallon of household bleach per 5 gallons of fresh water. **Since chlorine is volatile the solution is always prepared in open, well ventilated areas. It is dangerous to work with chlorine solutions in confined areas.**

ATTACHMENT 2

BESST STANDARD OPERATING PROCEDURES
FOR
DEPTH DISCRETE SAMPLING

BESST Inc.

Standard Operational Procedure SI004

Pressurized Minibailer Sampling

Prepared by BESST Inc.

Revised by Meredith Wong

TABLE OF CONTENTS

1.0 Purpose and Application

The purpose of this Standard Operating Procedure is to establish a uniform process for minibailer sampling. The pressurized minibailer is used for depth dependent sampling without pump removal. This technology is typically utilized for VOC sampling or when access issues impede the use of a HydroBooster. The laboratory analysis of the sampling is combined with a dynamic or ambient flow profile to determine analyte concentrations in water entering the well at different depths.

2.0 Health and Safety Information

2.1 Pressure – Handling and using pressurized gas at any pressure is dangerous. Often, it is not contact with the pressurized gas itself that can cause serious injury but the materials which transport the gas such as the tubing or devices operated by the pressurized gas. All operators should have full understanding of how to use the nitrogen tank regulator. Of highest concern is keeping the fittings used to connect the parts of the minibailer sampling system in good repair to prevent blow-outs from these points. Fittings should not be disconnected while the system is pressurized (unless they are quik release) and gas tanks should always be secured using ties or stored horizontally on a flat surface.

2.2 Chemical Exposure – All samples should be treated as though they contain an organic, inorganic or biological contaminant that will cause the sampler harm or illness. Many of the dangers of handling groundwater samples are from chronic exposure to small levels as opposed to acute exposure; all sampling should be conducted in a way to eliminate or minimize exposure to the sampling product. Additionally, purge and sample water should be adequately prevented from running into nearby waterways or storm drains. Chemical information on sample preservatives and cleaning agents used should be studied and appropriately addressed (see section 3.10 for cleaning products used). Safety Glasses, appropriate gloves (Nitrile, for example), and splash guards including aprons and long sleeves/pants should be used when necessary.

2.3 Trip/Slip/Fall – Precautions must be taken to avoid tripping and fall hazards, especially due to the exposed lines used to connect to the compressed gas source and extended sampling lines. High risk areas should be recognized and contained to prevent unnecessary movement through these areas. Preferred walkways should be clear and kept free of hazards. Deploying tubing in an out of an oil-lubricated well causes a layer of oil to form on the work surface, which can pose a risk of slipping.

2.4 Lifting – Handling the pressurized gas sources and extensive tubing pose significant lifting hazards. Team Lift and extra care should be exercised when handling heavy equipment to minimize injury and strain.

2.5 Pinch Points – Contact should be avoided with moving parts to prevent pinching and injury. The sausage weights should be handled by holding the weights themselves, taking care not to catch fingers between the weights. Gears and other moving components should be avoided when the winch is in operation.

2.6 Personal Protective Equipment (PPE) – All operators must wear slip resistant safety-toe boots/shoes to prevent injuries due to dropped devices and slippery surfaces. Additional PPE is covered in Supplies and Equipment (section 3.11).

3.0 Theory

The minibailer is comprised of flexible sheathed ¼” tubing (typically nylon) and a one way valve. The tubing is first pressurized with compressed N_2 gas, which closes the check valve at the bottom, and lowered into the well. When the desired sampling depth is reached, the tubing is depressurized (the gas is released up hole). Water then enters through the valve and fills the tubing until the height of water in the tubing is in line with the water level of the well. At this point, the hydrostatic pressure is equal on both sides of the valve and water stops moving into the line. Hydrostatic pressure can be calculated with the following relationship:

$$p = \rho g h \qquad (1)$$

p: hydrostatic pressure

ρ: fluid density

g: acceleration due to gravity

h: vertical height of fluid from valve to water level

The density of water and gravitational acceleration are the same on either side of the valve; therefore, when the vertical height of water above the valve is equal on both sides, the hydrostatic pressure is also equal.

Equation 1 is also used to calculate the minimum pressure required in the line to prevent water from pushing the valve open and entering the tubing as it is lowered to the desired depth:

$$p = \rho g h$$

$$= 1000\frac{kg}{m^3} \times 9.8\frac{m}{s^2} \times h$$

$$= 9800\frac{Pa}{m} \times h \times (1.450337 \times 10^{-4}\frac{psi}{Pa}) \times (.3048\ \frac{m}{ft})$$

$$\text{Minimum pressure} = .434\frac{psi}{ft.} \times h$$

When the tubing has filled to the water line, it is once again pressurized with compressed N_2 gas. The pressure of the gas fully seats the valve and keeps the VOCs dissolved in the sample water. The tubing must be retrieved to the surface each time water is collected to keep the sample pressurized throughout the bailing process. Comparison of VOC concentrations in water collected from the same source using different sampling methods has shown that failing to pressurize the system during sampling causes VOCs to escape the solution, while keeping the sample pressurized as it is retrieved prevents VOCs from exiting the water.

The expected volume of sample water can also be calculated using the depth of the valve and the inner cross sectional area of the tubing:

$$v = \pi(\frac{D}{2})^2 h \qquad (4)$$

$$\frac{mL}{ft} = \pi(\frac{D}{2})^2 \times (\frac{12in}{ft}) \times (\frac{16.3871\ mL}{in^3})$$

v: volume of water sample

h: depth from nozzle to water level (ft. of head)

D: inner diameter of tubing

The chart on the following page displays expected sample volumes by feet of head and tubing size.

Tubing ID	1/8 in	13/16 in	1/4 in
Feet of Head	mL/cycle	mL/cycle	mL/cycle
1	2.4	5.4	9.7
20	48	109	193
40	97	217	386
60	145	326	579
80	193	434	772
100	241	543	965
120	290	652	1158
140	338	760	1351
160	386	869	1544
180	434	977	1737
200	483	1086	1931
220	531	1195	2124
240	579	1303	2317
260	627	1412	2510
280	676	1520	2703
300	724	1629	2896
320	772	1737	3089
340	820	1846	3282
360	869	1955	3475
380	917	2063	3668
400	965	2172	3861
420	1014	2280	4054
440	1062	2389	4247
460	1110	2498	4440
480	1158	2606	4633
500	1207	2715	4826
520	1255	2823	5019
540	1303	2932	5212
560	1351	3041	5406
580	1400	3149	5599
>600	>1448	>3258	>5791

Table 1. Expected sample volume based on feet of submergence and tubing size.

4.0 Equipment and Supplies

3.1 Flexible, sheathed ¼” tubing line with check valve

3.2 Motorized hose spool for deploying and retrieving the tubing

3.3 Compressed nitrogen gas and regulator

3.4 ¼” in tubing for gas line, three way valve, and quik release fittings

3.5 Sausage weights and quick link

3.6 Mechanical counter, clamps, and saw horse

3.7 Sample collection bottles, bucket, cup

3.8 Tools: vice grips, knife/cutter, 10 mil pipe tape, wrenches (large and small), swage tool

3.9 Fittings: ¼” unions, ¼” ferrules, ¼” hex nuts, cable ferrules, extra valves/poppets/o-rings

3.10 Alconox, Simple Green, bleach, trash bags, paper towels/rags

3.11 Personal protective equipment: slip resistant boots (steel or composite toe), sturdy gloves, latex gloves, hearing protection

5.0 Procedural Steps

Before the sampling begins:

-Create a sampling plan using the well information and flow profile (if dynamic)

-Have the well pumped until it reaches drawdown stabilization (if dynamic)

5.1 Attach valve to the end of the tubing. The valve should be placed such that the open end of the poppet is at the top of the valve and the other end of the poppet seals onto the o-ring at the bottom.

5.2 Attach the sausage weights to the end of the valve with a chain link.

5.3 Attach the counter to the reel of tubing using clamps. Rest the counter on a saw horse/dowel for support.

5.4 Using a pressure regulator and ¼” line, connect a line from the gas tank to a 3 way valve. Attach another ¼” line to the bottom of the 3 way valve. Use quik release fittings to join the line to the end of the bailer.

5.5 Open the gas tank and pressurize the bailer line to at least .434 psi/ft. of sample depth. Check the pressure level in the line by closing the gas tank but keeping everything connected; the low pressure gauge on the regulator will indicate the pressure in the bailer line. When the desired pressure in the line has been reached disconnect the quik release fitting.

5.5 Zero the counter when the tubing is at ground level. First measure the distance from the opening to the ground, following the path of the tubing. Then, zero the counter when the nozzle is at the opening, let it drop the distance measured, and zero the counter once again.

5.6 Lower the tubing to the first sampling depth, disinfecting the tubing with alconox is it enters the well for the first time.

5.7 Release the pressure in the bailer by turning the knob on 3 way valve to the open end, then connecting the line back up to the bailer. Wait for the tubing to fill up with water. The line is full when air is no longer being displaced out the end of the bailer—this can be verified by submerging the open end of the 3 way valve in water and waiting until air bubbles stop forming. It may be useful to connect a short ¼" line to the open end of the valve to dip in water.

5.8 Pressurize the line again by turning the knob on the 3 way valve to face the gas line. Disconnect the line from the bailer.

5.8 Retrieve the tubing to the surface. This can be done with the winch or by hand. Take care not to catch the tubing on sharp points in the well. The pulling force of the winch can damage the tubing if it is caught or dragging. If using the winch, hold the tubing and push or pull it slightly as it is pulled out of the well. The tubing will tighten up if it gets stuck, at which point stop the winch and handle the tubing manually until it hangs freely. If necessary, eliminate a sharp entry point with tape or fiberglass enforced tubing.

5.9 Depressurize the line when it is fully out of the well, but not all the way--leave a few psi. The sound of the gas as it exits the line is a good indication of the amount of pressure left in the line—wait until it quiets down significantly and then turn the knob on 3 way valve halfway to stop the line.

5.10 Detach the valve from the bailer using vice grips, bending the tubing to control the exit velocity of the sample water.

5.11 Collect the sample.

5.12 If the next sample is at a new depth, air dry the line by running gas (around 100 psi) through one end until it comes out the other end dry. This will take a few minutes. Replace the valve on the bailer line.

5.14 Collect samples at all depths in the sampling plan. Multiple trips to the same depth may be necessary if the volume does not fill the sample bottle.

Stainless Steel Blatymini (Miniaturized Blatypus Pump)
Standard Operating Procedures

BESST Inc. 50 Tiburon Street, Suite #7, San Rafael, CA 94901
Phone (415)453-2501 / Fax (415)453-2509 / cell: 415.302.7354
nheller@besstinc.com / www.besstinc.com

Table of Contents

Procedural Order To Follow

Section 1: Blatymini (Short Cycle Mode) Using Control Box

For Manual and Motorized Hose Reel Operation

1. Attach the **regulator** with **gas line** to the nitrogen tank
2. Attach the **gas line** from **regulator** to **gas-in** fitting on control box. Attach another tube from **gas-out** fitting on control box to **3-way valve** on tube spool.
3. Make sure control box is **OFF** and plug it in.
4. Attach **sample return line** by screwing on hex nut to male tube-connector on side of tube spool opposite motor and 3-way valve assembly (not pictured).

For Motorized Hose Reel Operation

1. Attach deep cycle (car) battery or other 12v DC 70 Amp power source to positive and negative **motor leads** on tube spool.
2. Plug **control switch** into black plug mounted on the tube spool.
3. Engage **motor clutch** by pulling out on black handle, this will allow motor to drive tube spool.

For Manual and Motorized Hose Reel Operation

1. Deploy **pump** system to desired depth for purging/sampling (using control switch for motorized system), or by disengaging clutch (pushing it in) and manually lowering tubing into well.
2. Begin purging/sampling per procedures described in section 2 for Blatymini mode or section 3 for Hydrobooster mode.

Figure 1: Blatymini / Blatypus Timer Control Unit

Section 2: Purging and sampling in <u>Blatymini mode (Short Cycle Breathing Mode)</u>

1. Once the pump is at depth, wait for the entire tube bundle to fill up with water. To ensure the system is full place the end of the sample return line in a bottle of water, it will bubble as the line fills up, and once it stops bubbling the line should be completely full and ready to begin pumping.
2. Make sure the **3-way valve (attached to the regulator)** is in the **purge/sample** position in order for gas to flow through the control box from the gas line to the pump.
3. Calculate lift pressure for a given pump depth using the following (mean sea level) calculation: *depth of water below ground surface: in PSI/ft = 1PSI /2.31 ft / in PSI/Meter = 7.55 PSI/Meter / in kPa/Meter = 52 kPa/Meter. Note: It is critically important to realize at this point that we are explaining how to purge and sample the well using the Blatymini Short Cycle Pumping Mode.*
4. Maximum Working Pressure capacity of Nylon Gas-In Line and Sample Return Line Tubing = 850 PSI. Burst strength of Nylon Gas-In Line and Sample Return Line Tubing = 1,600 PSI. Maximum Working Pressure of Nylon Packer Inflation Line = 900 PSI. Burst Strength of Nylon Packer Inflation Line = 1,800 PSI.
5. How do you decide the appropriate on/off cycle to use for the short cycle Blatymini mode? There are a number of factors that come into play. First, calculate the depth to water. Second, calculate the depth of pump submergence below water. Third, determine the type of formation material around the outside of the screen and your estimation of how easily the formation will recharge the well during pumping. So, these are the factors that you first think about when deciding how many seconds on and how many seconds off you will set on the timer control unit. The next step is that you have give it a try. Its' somewhat empirical since you're not absolutely sure how fast the formation will recharge the well and your Blatymini pump with tubing. However, once you have figured out the most practical time settings, then you need to permanently record your findings on a field work sheet – so that you and others will know the starting point for the timer control unit settings the next time the pump is at this well and the selected depth. If the well is only meant for a single time use, then it is still quite useful to record this information since your field crew will get a sense of the recharge time cycle for the given type of formation materials.
6. Here are some general rules of thumb for selecting time settings:
    1. When depth to water is shallow, and there is 10 feet or less submergence of the pump below first water, and the surrounding formation is sandy, then you should select the shortest on-time possible (about 1 second). The off cycle (recharge time) should take approximately 10 to 20 seconds (max).
    2. Same situation as in example (1), but this time the surrounding formation is clay. The off cycle could take several minutes.
    3. Depth to water is shallow, but the pump is placed at a somewhat deep depth below first water (say about 50 to 100 feet or more), then the on cycle can be much longer (on the order of 5 to 20 seconds). One important idea to keep in mind is that for every second of on-cycle there is about a 6 foot (2 meter) descent in the water level depth inside the gas-in line. So, if the on-cycle time is 10 seconds but the pump is only 50 feet below water, then within 10 seconds of on-cycle, the water level inside the gas-in line will have descended about 60 feet – that is 10 more feet than there is depth available. In this case, the gas-in line will be dewatered and could be manifested as a sputtering of water and gas at the ground surface. This would indicate that the number of seconds set for the on cycle would be decreased (perhaps to 5 seconds).
    4. Same as Scenario #3, but this time the surrounding formation consists of tight clay. As you can see, tight clays largely effect the off-cycle time. It could be minutes – or even hours for groundwater to recharge the pump and tubing. Therefore, patience is key.
7. *What we've learned is that pumping cycle times vary in relation to pumping head, pump depth, and recharge rate in well. You will need to adjust the on/off times to attain optimum flow. If the well has a very high or low recharge rate, the off time could be considerably lower or higher, respectively.*
8. Turn on control box using the **power switch (Figures 1 and 2)**
9. Typically, the system will need to go through multiple on/off cycles before any water flows from the sample return line. The process may take 5 to 10 or more minutes depending on depth of pump and amount of head within well.
10. If water flows out of sample return line until air blows out, the purge cycle is either too long, or the recharge cycle is too short, adjust the cycles until water exits sample return with no air. For a see figure 4a-c for an explanation of how Blatypus mode works.

11. **IMPORTANT:** Each time the pump is set at a new depth you must purge the system twice completely before sampling in order to ensure a pure sample. NOTE: To Quick-Purge System completely of water in HydroBooster Mode, follow instructions in Sections 3. In the HydroBooster Mode there must be one continuous pulse that empties the entire system so that it can fill entirely with water from the new sample depth. To achieve this you must purge in the Hydrobooster mode covered in Section 3.

Section 3: Setting up the system for Hydrobooster Mode (With or Without control box)

1. The HydroBooster Mode is also referred to as the Quick-Purge Mode. The HydroBooster Mode can be run with or without the timer control unit. Personally, I like to use the timer control unit for convenience and the "hands-off" capability that it provides. The timer control unit provides an automated function that makes it possible for the field crew to tend to other business within close proximity to the well. When not using the timer control unit the gas-in line is connected directly to a 3-way valve that is attached to the nitrogen regulator line gauge. There is a black handle on the 3-way valve that you turn back and forth. When you want gas pressure, you turn on the line. When you want to release the gas pressure, you rotate the valve in the opposite direction and bleed off the pressure. So, when not using the timer control unit, the directions are as follows:
2. Attach regulator with gas-line to nitrogen tank
3. Attach the 3-way valve to the line gauge of the regulator (not the tank pressure gauge).
4. Attach gas-in line directly to the 3-way valve.
5. Make sure that the know on top of the nitrogen tank, the valve handle on the 3-way valve and the handle on the nitrogen regulator are all in the close position.
6. To release pressure from the nitrogen tank, do so in this order.
    a. Open nitrogen tank knob ¼ to ½ turn (counter clockwise).
    b. Rotate clockwise the handle on the nitrogen tank regulator to the desired pressure. Do so slowly as to avoid damaging the spring inside the regulator.
    c. When the desired line pressure is indicated on the nitrogen tank line gauge, then slowly open the handle on the 3-way valve to release the gas pressure into the gas-in line. Within a short period of time, you will begin to see groundwater exiting from the sample return line.
7. Calculating the pressure for the HydroBooster Mode is different than the Blatypus Mode. For the HydroBooster Mode we are purging all of the water from the gas-in and sample return line – to the point where you see a sputtering spray exiting the sample return line. The total lift distance for removing all of the water from the sample return line must be calculated from the pump depth. The formula is as follows: ((Depth to Pump / 2.31 ft/PSI) x 1.1). The coefficient of 1.1 is to compensate for the head loss due to friction in the sample return line. As an example, if the pump is located at 450 feet bgs, then lift pressure is equal to: ((450ft/2.31ft/PSI)x1.1) = 214.29 PSI (215 PSI). This formula does not apply to the snorkel tubing since it is simply a hydrostatic feed line and groundwater rises under its own hydrostatic pressure to equuilibrium.
8. Upon viewing the spray, the black handle on the 3-way valve is rotated 180 degrees to release all of the nitrogen gas pressure.
9. As the gas pressure is released through the 3-way valve you will hear a loud hiss. At the same time you are listening to the hiss, take the end of the sample return line and place it inside a bottle of water with the end of the line submerged. If you observe a rapid stream of bubbles in the water bottle, then it means that the sample return line is refilling quickly (and implies that the gas-in line is filling quickly as well – since both lines fill simultaneously during recharge. If you do not see bubbles or there is a fairly rapid cessation of bubbles after you turn the handle on the 3-way valve to the gas-release position, then it probably means that the formation around the well screen in the sample depth zone is quite tight. In this case, recharge could take a long time – hence one of the conveniences of using the timer control unit as opposed to manual control of the purge cycle.
10. Once the first purge is complete you now want to execute a second purge and requires repeating the previous steps.
11. Typically, once the second purge cycle is complete, the timer control unit can be switched back to the Blatypus Short Cycle mode for sample collection.

Figure 2. Control Box Diagram

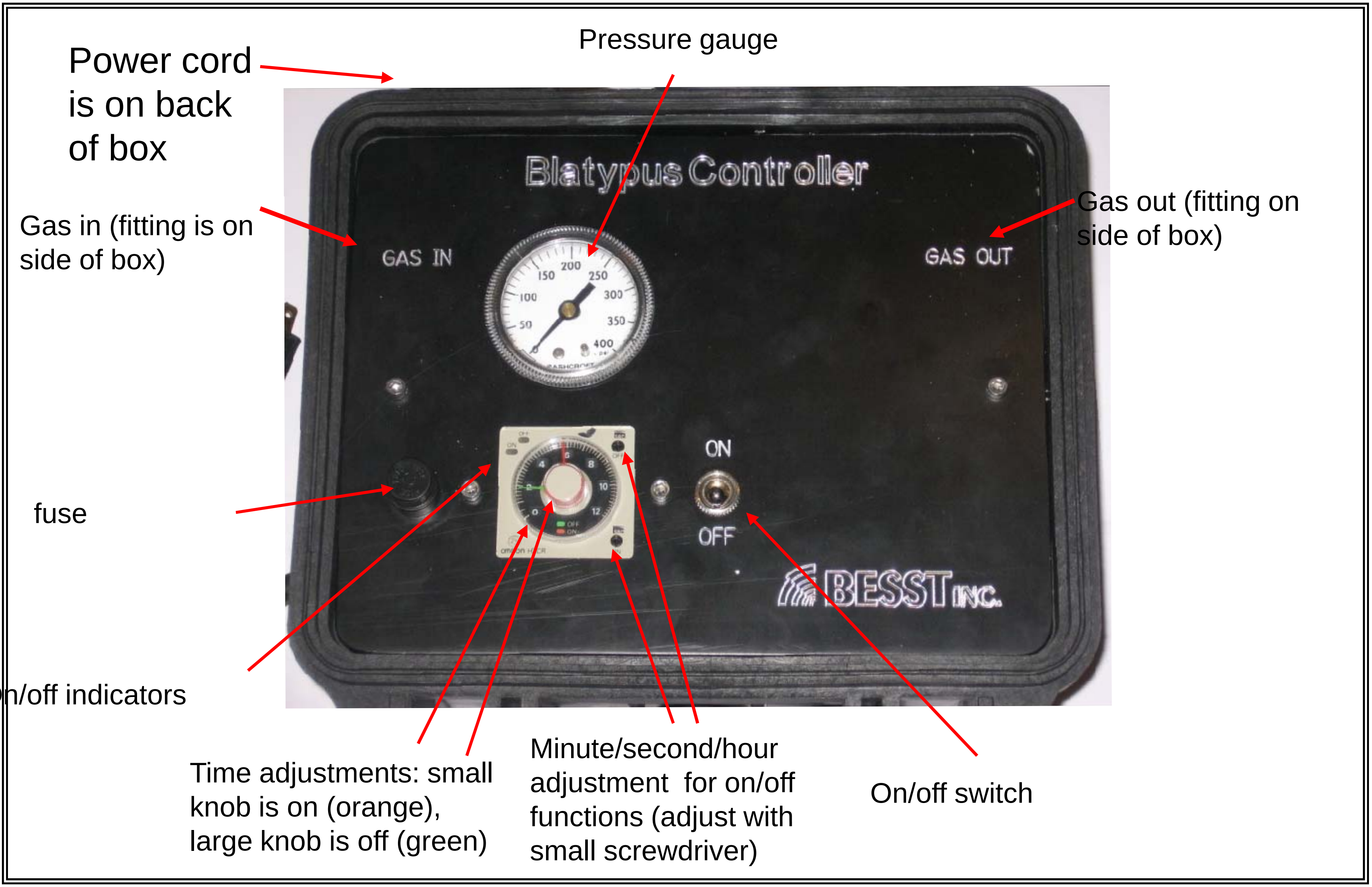


Figure 3-4 Reel Assembly and 3-Way Valve Function

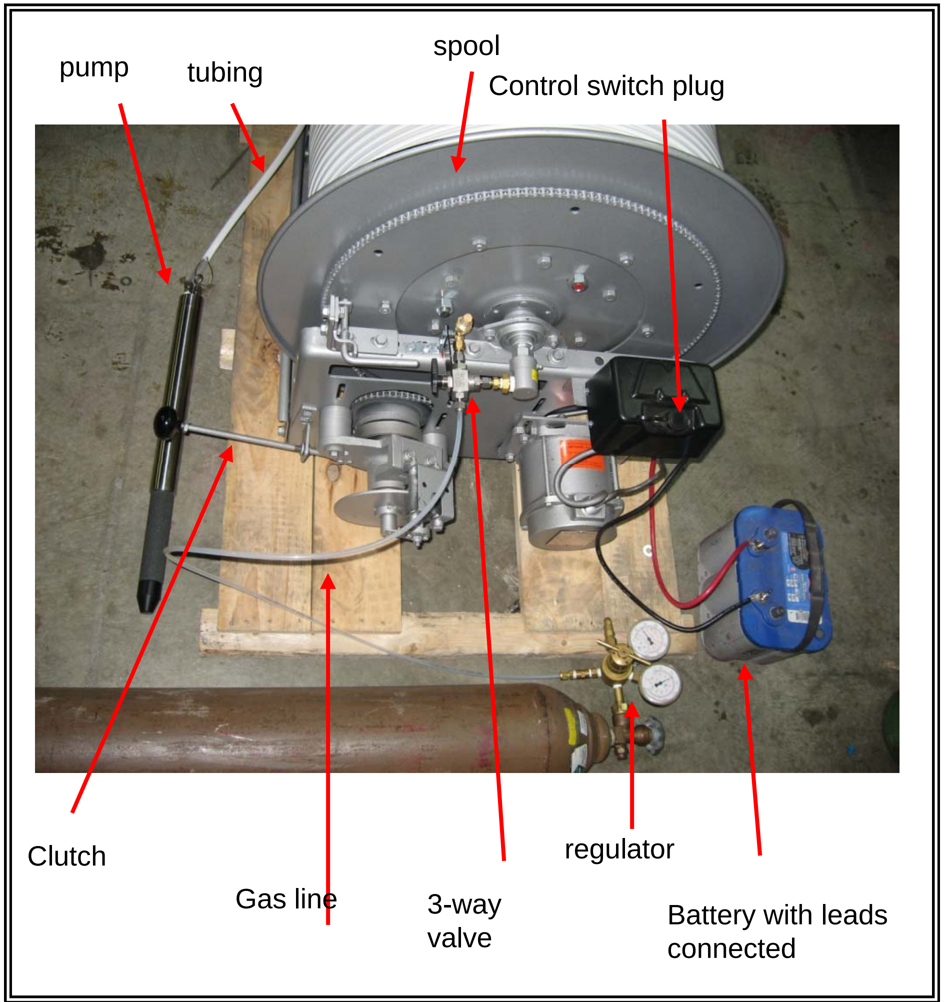


Figure 3. Reel assembly

Note: in Figure 3 counter/stabilizer assembly is not shown, but will arrive bolted onto the front of the frame, and control switch is not shown, which is used for raising or lowering the pump. Pump is shown set up in Hydrobooster mode.

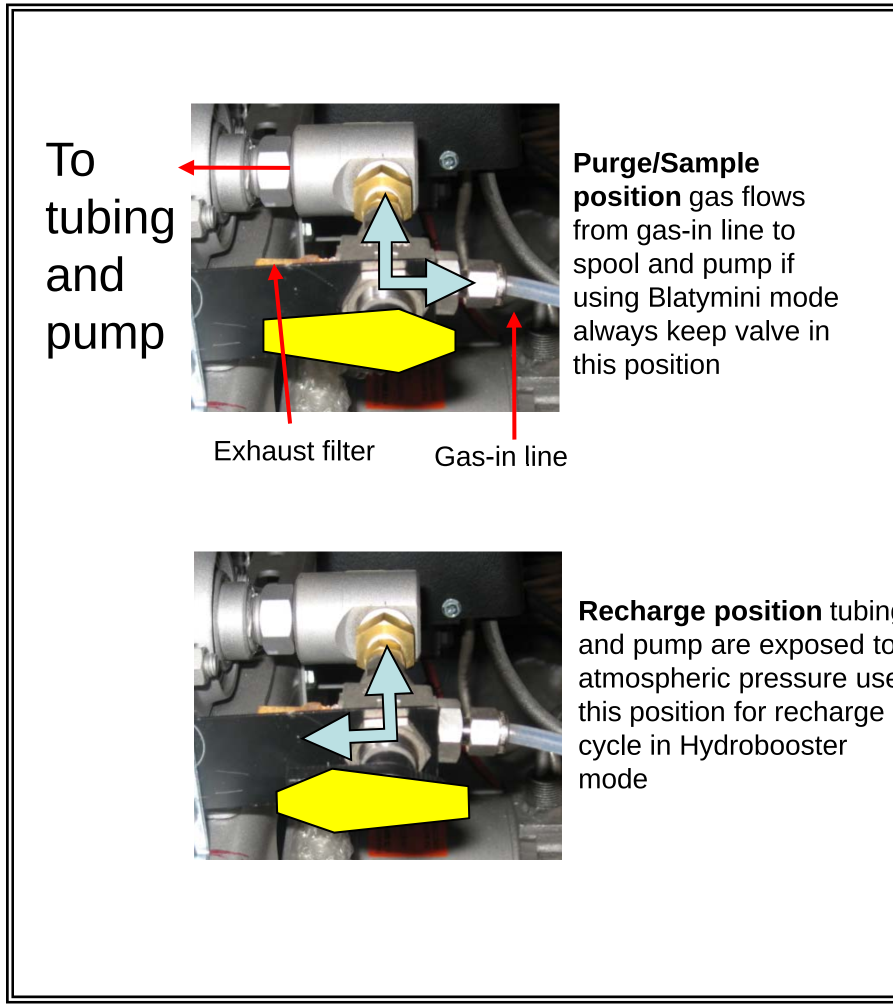


Figure 4. Three way valve function

Figures 4 a-c Blatypmini Pumping Schematic

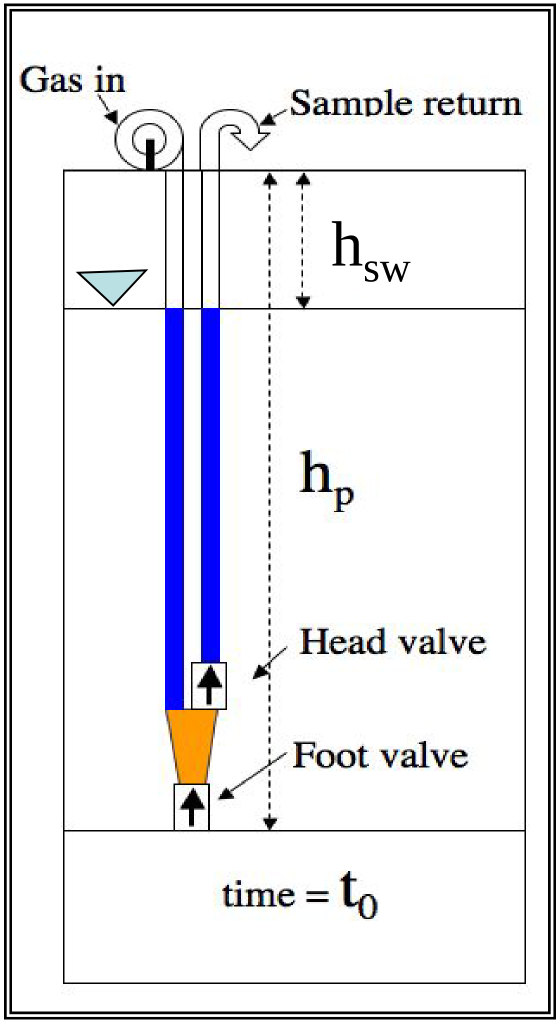


Figure 5a

At time t_0 water flows up through head and foot valve to static water level

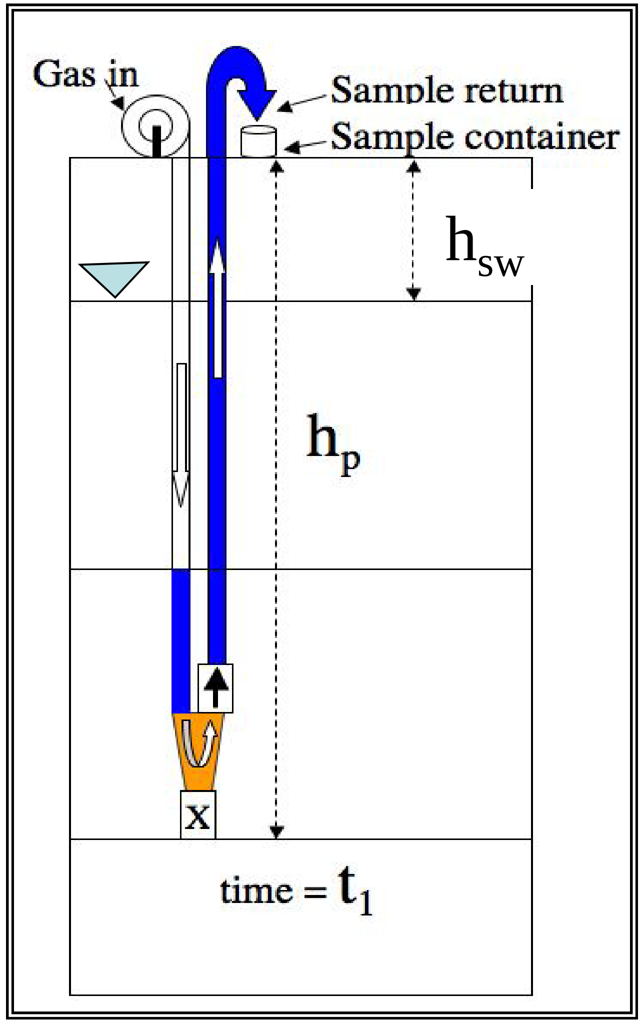


Figure 5b

At time t_1 the purge/on cycle begins, the foot valve closes and water is pushed up through the sample return line

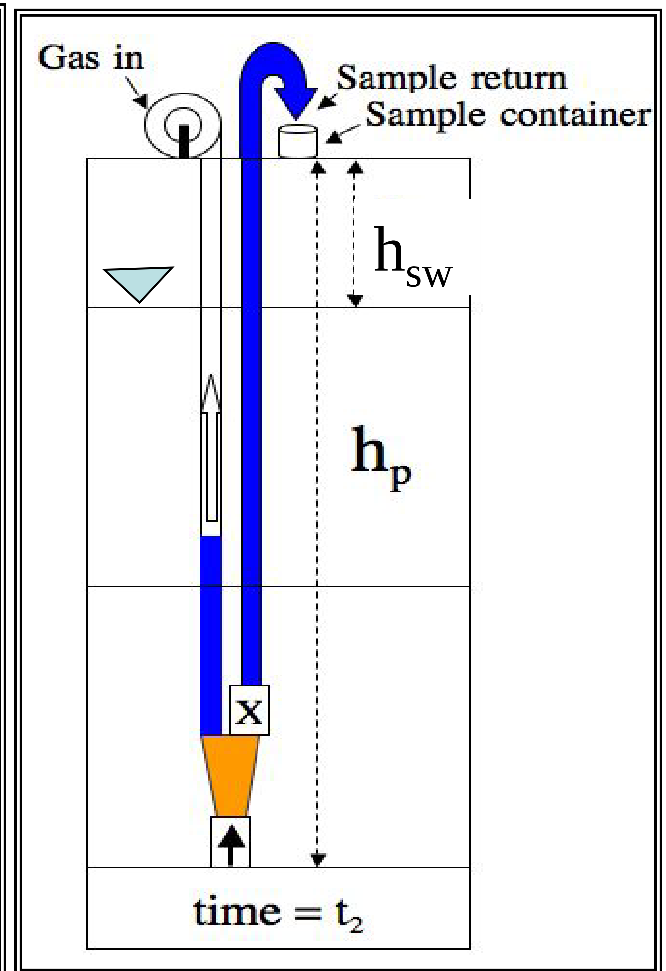
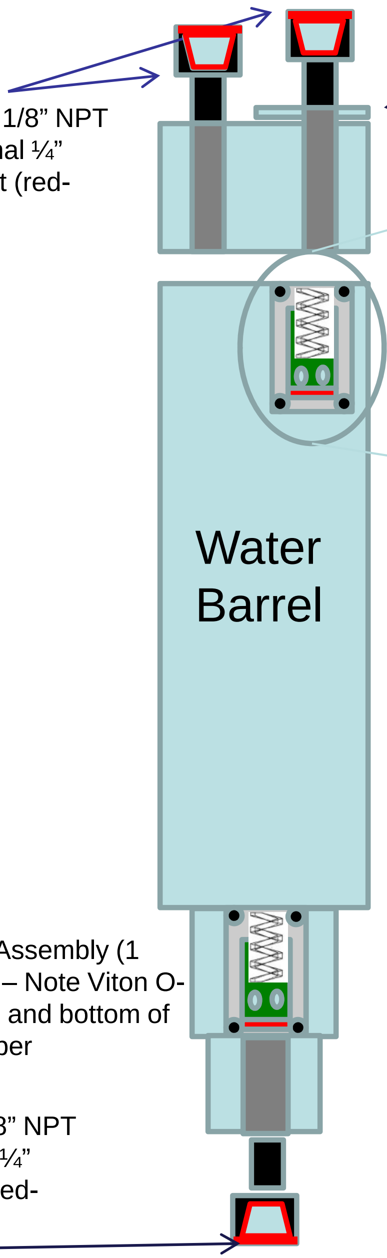
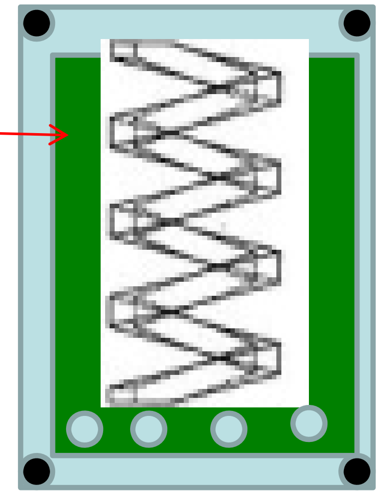


Figure 5c

At time t_2 the recharge cycle begins, the gas line is exposed to atmospheric pressure and refills while the head valve holds the column of water in the sample return line

Figure 6: Blatypus Pump

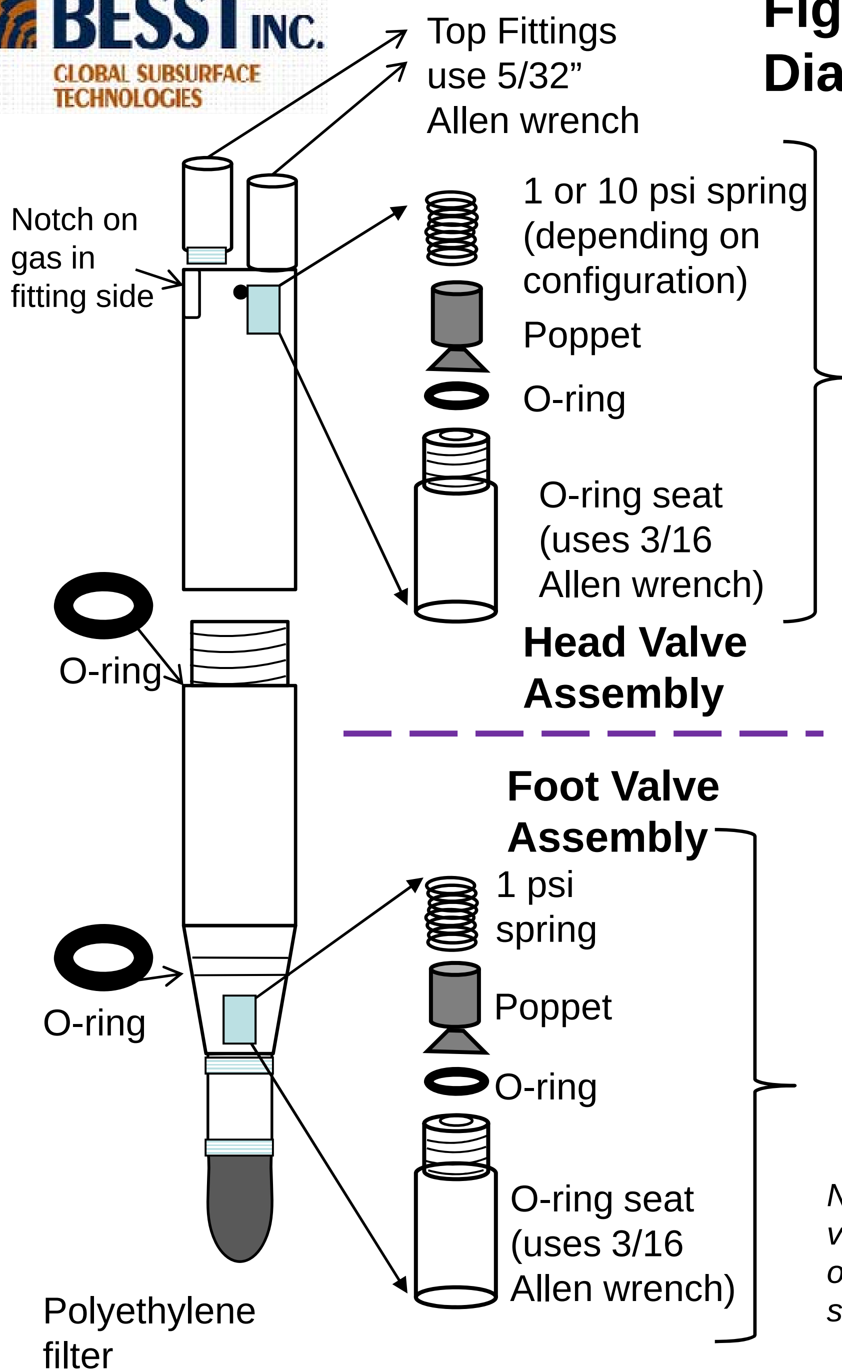




Points To Remember:

1. Holes at bottom of poppet face into borehole or well.
2. Spring always goes inside of poppet
3. One o-ring at the top and one o-ring at the bottom of each valve chamber. This is a Viton O-Ring.
4. If no air or water discharges from sample return line, then sample return and gas lines are switched. Reverse positions of lines at ground surface. Disconnect the gas line from the downstream connection on the outside of the timer-controller unit. This line now becomes your sample return line. Take the former sample return line and connect it to the downstream end of the timer controller unit. This is your new gas-in line.
5. If there is air coming out of the sample return line it can mean one of two things:
    1. Poppet inside of foot-valve chamber is stuck in open position due to grit inside foot-valve chamber. The grit is either wedged between the poppet and the inside wall of the valve chamber or there is grit build-up on the o-ring and the bottom of the poppet cannot seat properly and form a water tight seal. Could be a combination of both.
    2. The –o-ring has lost its' elasticity due to saline pitting and breakdown of the elastomer.
    3. The poppet is upside down in the valve chamber.
    4. There is no spring in the valve chamber.
    5. The spring is located on the bottom of the poppet and the poppet is upside down.

Figure 7: Blatymini Pump Assembly Diagram - Schematics



1) The top fittings should be tightened until snug, not dead tight.

2) The O-ring Seats can be tightened until dead tight. Take care to keep the o-ring straight around the o-ring seat lip so that it can create a good seal when tightened. Once they are tight, insert a small piece of strong wire or a skinny allen key above the poppet. Push down firmly on the allen key to seat the o-ring into the o-ring seat to make a tight seal. The poppet should then travel freely when pushed, and the poppet valve should hold pressure. (See next page for o-ring seating procedure.)

3) Once the valve assemblies are tightened down and the o-rings seated, screw the head and foot pump body pieces together until hand tight. Tubing can be inserted into top fittings , and pump can be pressure tested and used. (See appendix 1 for pressure testing procedure)

Note: head and foot valve poppets, o-rings, and o-ring seats are identical

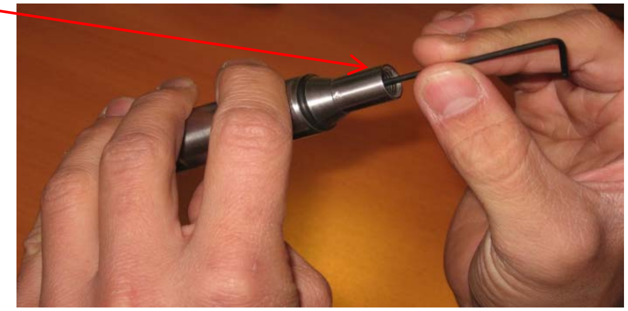
BESST INC. GLOBAL SUBSURFACE TECHNOLOGIES

Figure 8:Blatymini Pump Assembly Diagram - Photos

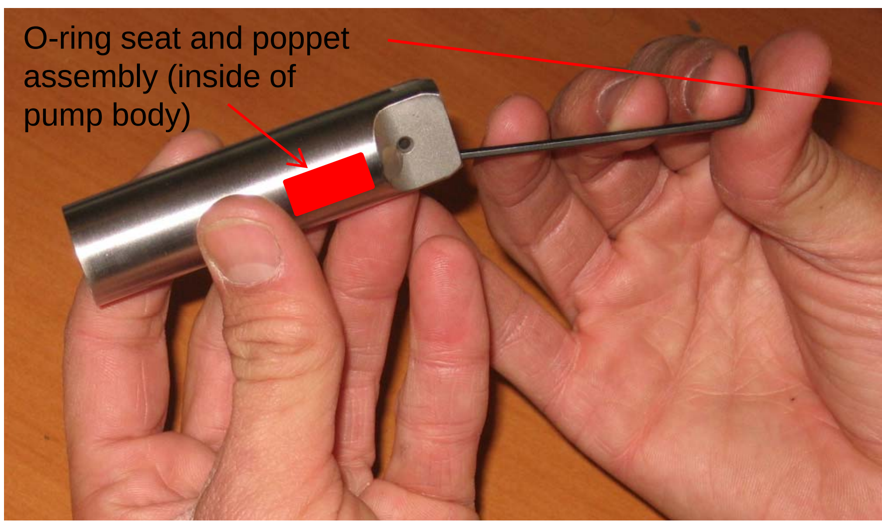
O-ring seat and poppet assembly

Step 1: insert allen key behind poppet

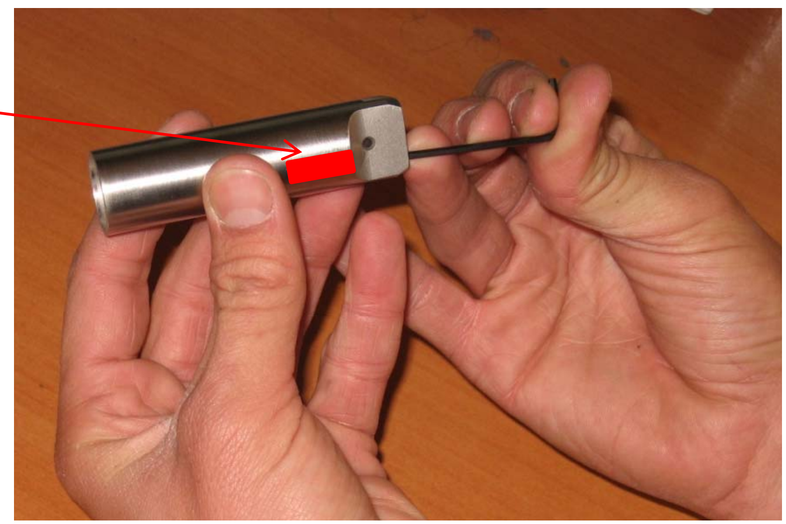
Step 2: press firmly on back of poppet to seat o-ring into place



Step 3: checking to make sure poppet moves freely

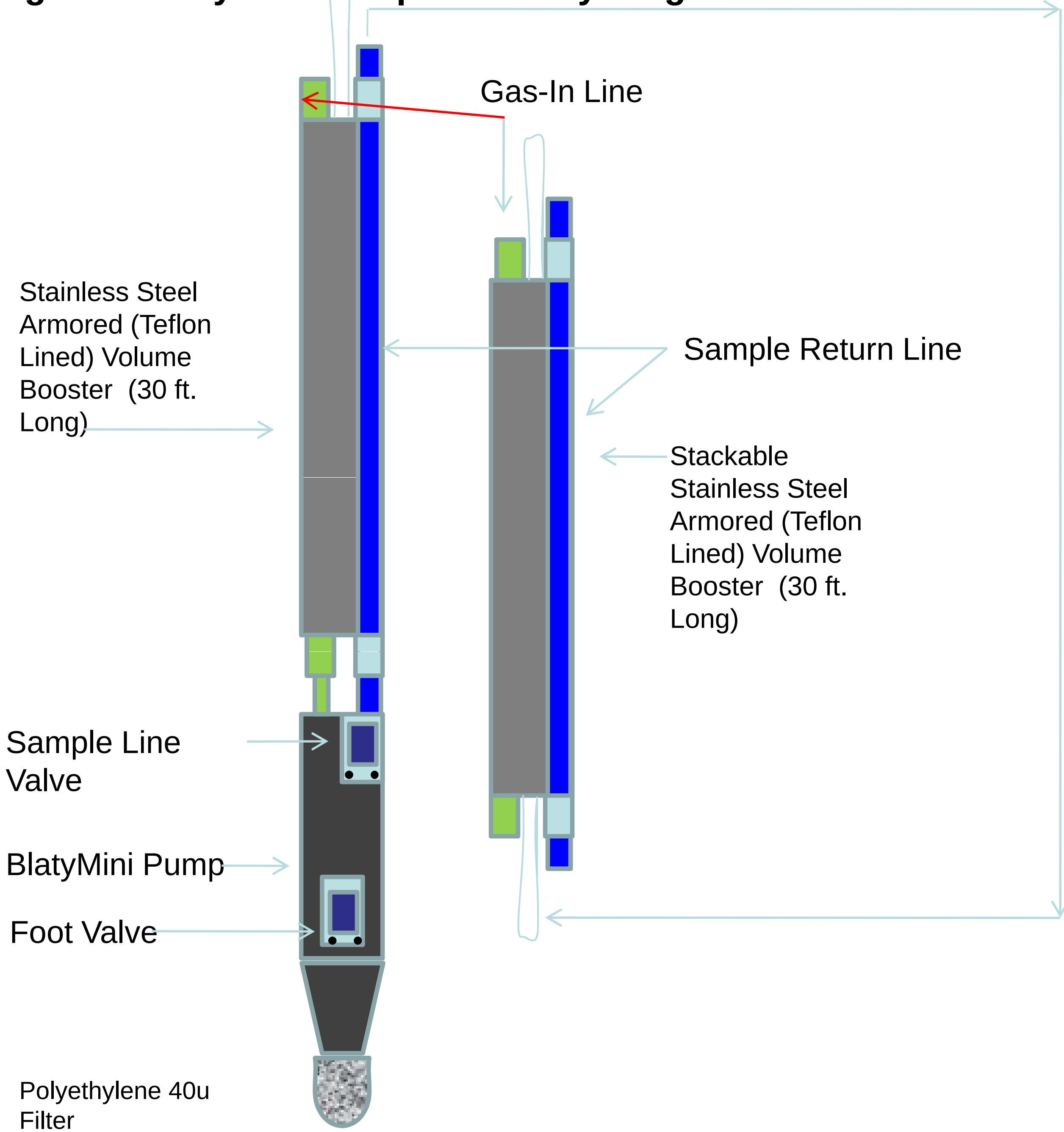


Step 1: insert allen key behind poppet in head (sample return line) valve.



Step 2-3: pressing firmly on poppet to seat o-ring into place. For step three insert the allen key in below the poppet valve to make sure it travels freely (see above step three).

Figure 9:Blatymini Pump Assembly Diagram – Volume Booster Option



The purpose of the Volume Booster Assembly (VBA) is to add a larger volume of water in wells where insufficient head is available for standard air-lift development. It can be operated with the Blatypus or BlatyMini pumps.

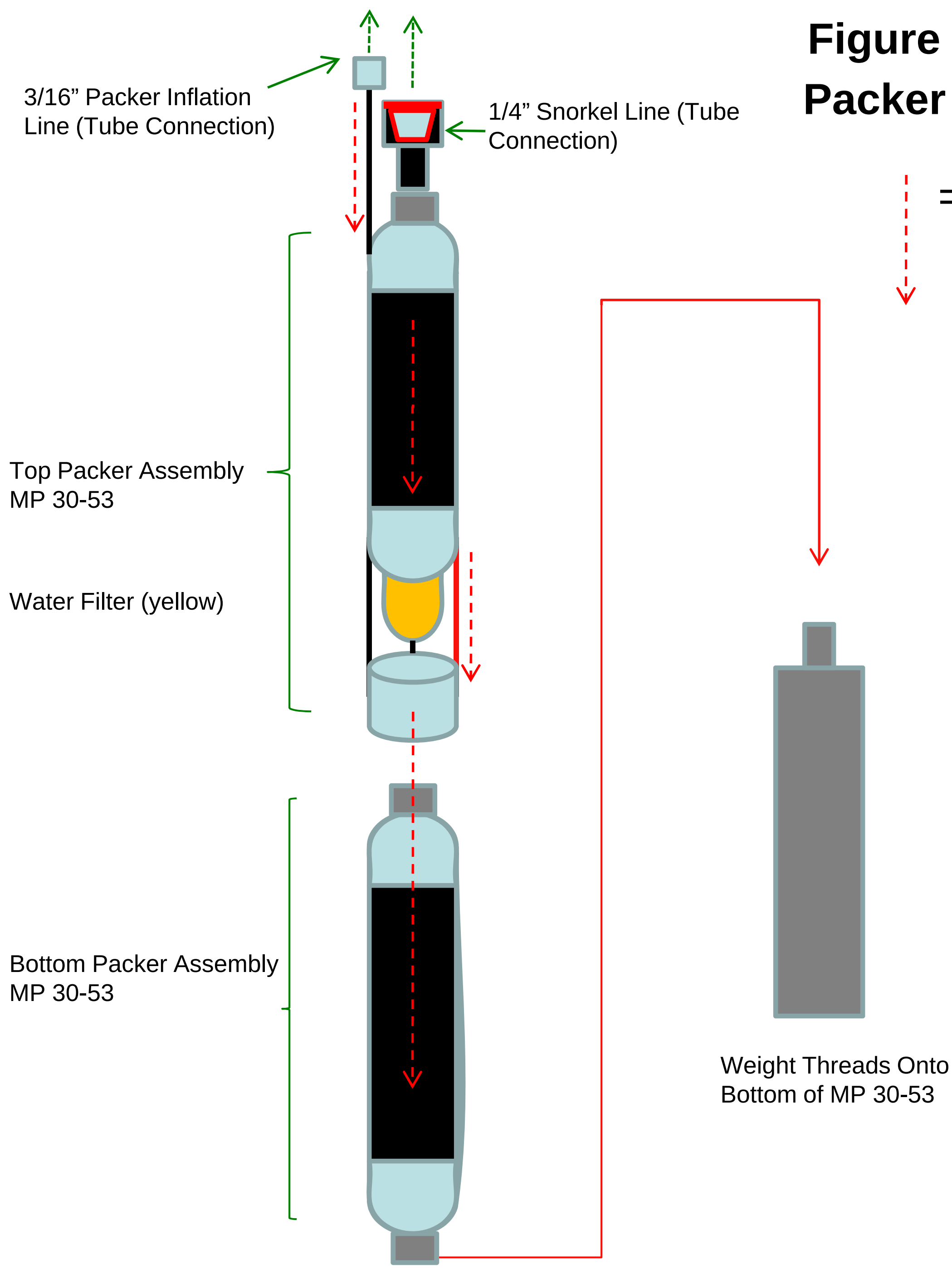
The internal volume of the VBA is about 80 ml/ft. Therefore, if there is 30 feet of head within the VBA then the maximum purge volume per pump stroke is 2,400 ml or 2.4 liters of water.

In this case, the process would involve pumping a long stroke until all of the water is evacuated from the system – and then allowing it to recharge after all of the water is blown out. This would be evidenced by sputtering at the ground surface of air and water.

If sand does get into the BlatyMini or Blatypus pump, then the pumps can be easily disassembled and cleaned out.

Figure 10 – Mini Straddle Packer Option

Packer Assembly : MP 30 – 53 mm



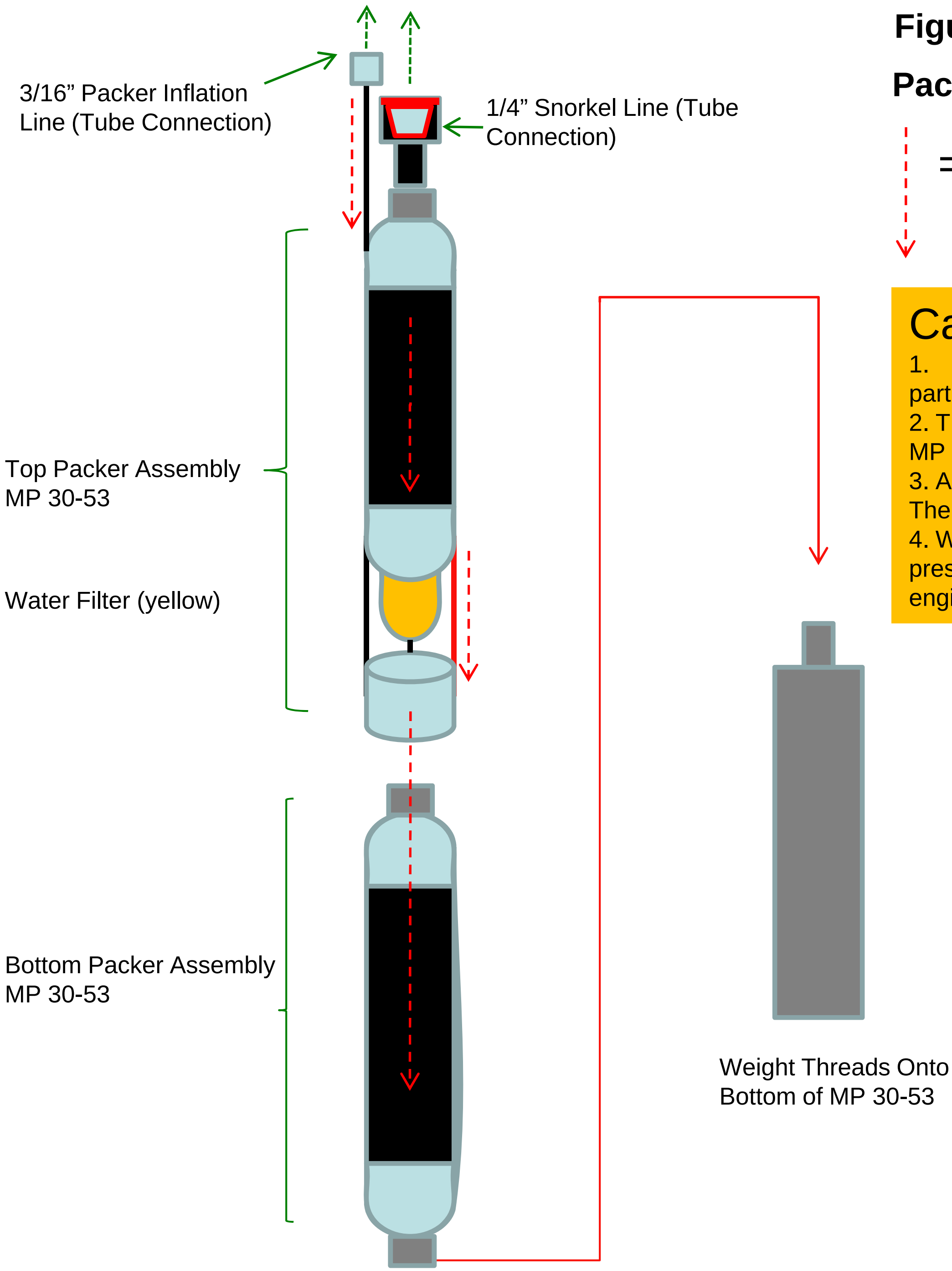
= Packer Inflation Flow Path

- To convert pounds per square inch to kilopascals, multiply the PSI value by 6.894
- To convert kilopascals to pounds per square inch, multiply the kpa value by 0.145
- LAC PVC Riser Pipe Inside Diameter = 1.875 Inches (Imperial Units)
- LAC Riser Pipe ID = 47.62 mm (Metric Units)
- Estimated Maximum Confined Inflation Pressure For MP 30-53 (From Bottom Chart) = 62.5 (100)Kpa = 906.25 PSI
- Example:
  - Packer Depth = 250 Meters (817.5 feet)
  - Depth To Water = 0 Meters (0 feet)
  - Inflation Pressure (Assuming 0.55 PSI/ft assuming higher specific gravity for saline water) = 817.5 x 0.55 = 449.63 PSI
  - Sealing Pressure: Add another 50 PSI to seal against inside wall of PVC riser pipe. Therefore, total pressure = 499.63 PSI (500 PSI)

Figure 11 – Mini Straddle Packer Option

Packer Assembly : MP 30 – 53 mm

= Packer Inflation Flow Path

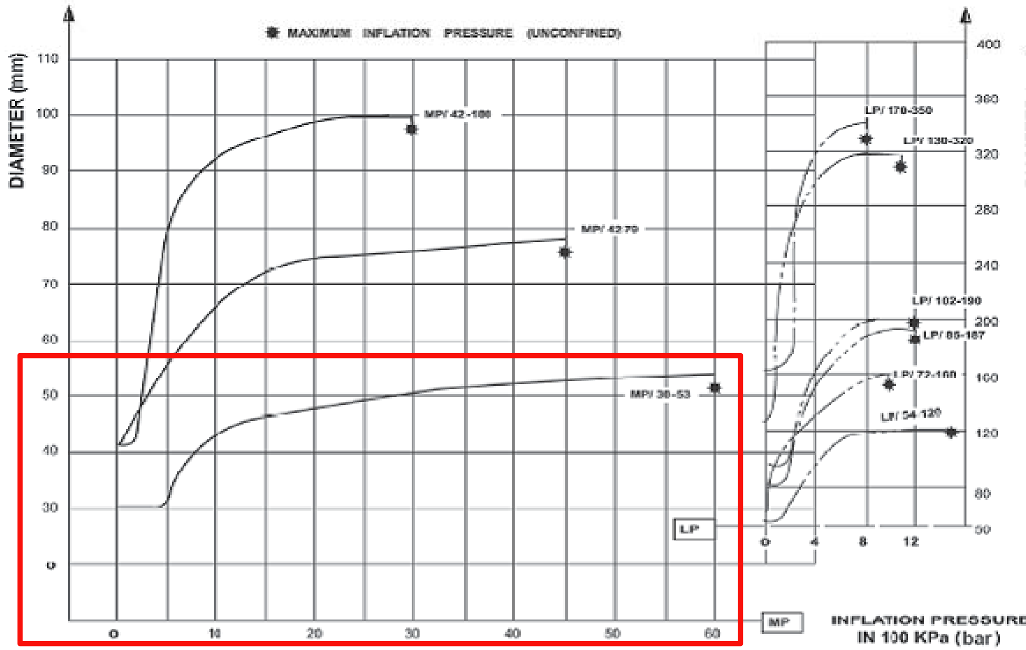


Careful!!

1. Avoid dewatering zone between packers – particularly at deeper depths and higher inflation pressures.
2. The estimated maximum confined inflation pressure for the MP 30-53 is about 906 PSI.
3. At your maximum application depth of 450 meters (1,471 feet) The estimated confined inflation pressure to be used is 810 PSI.
4. When adding another 50 PSI for the sealing pressure the total pressure applied to the MP 30—53 packer is 860 PSI and is within engineered pressure tolerances for the packer assembly.

Figure 12 – Mini Straddle Packer Option

Packer Assembly : MP 30 – 53 mm



Curves of packer inertia when inflated in unconfined condition

TYPE	35 (1 3/8)	40 (1 37/64)	45 (1 25/32)	50 (1 31/32)	60 (2 23/64)	70 (2 3/4)	80 (3 9/64)	100 (3 15/16)	120 (4 23/32)	140 (5 1/2)	160 (6 19/64)	180 (7 3/32)	200 (7 7/8)	220 (8 21/32)	240 (9 7/16)	260 (10 15/64)	280 (11 1/32)	300 (11 13/16)	320	
MP/30-53	110	90	70	55																
MP/42-79			130	110	70	60														
MP/42-100			130	105	65	50	30													
LP/54-120					130	90	65	30												
LP/72-160							80	50	30	20										
LP/85-187								100	70	40	30									
LP/102-190									95	75	55	45								
LP/130-320										75	55	45	35	25	20	15				
LP/170-350												60	50	40	35	30	25	20	15	15

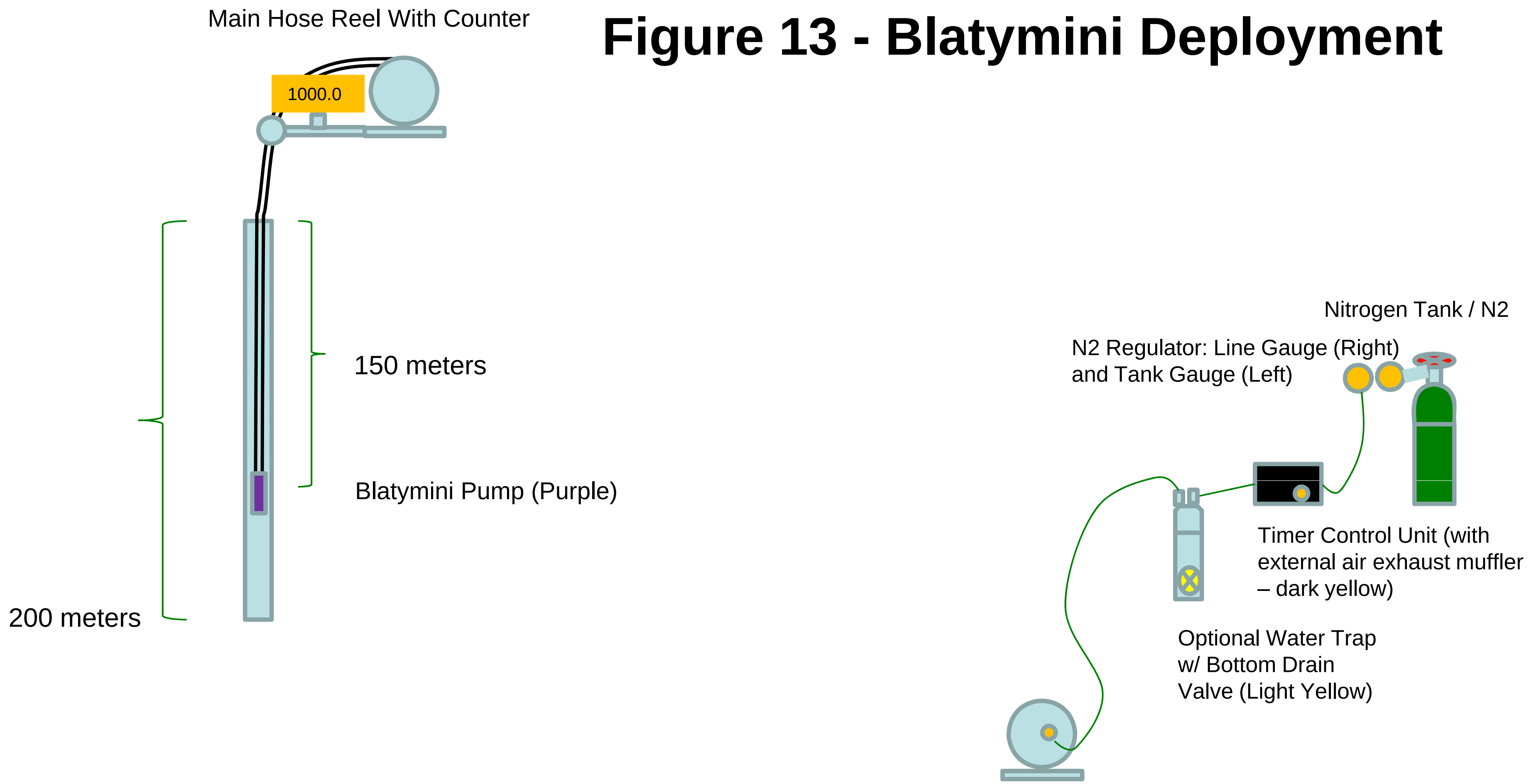
Diameter in millimeters (inches) — DIAMETER

Pressure (x 100 kPa)

Working pressure (confined), in 100 kPa (bar), versus borehole diameter, in millimeters

- To convert pounds per square inch to kilopascals, multiply the PSI value by 6.894
- To convert kilopascals to pounds per square inch, multiply the kpa value by 0.145
- LAC PVC Riser Pipe Inside Diameter = 1.875 Inches (Imperial Units)
- LAC Riser Pipe ID = 47.62 mm (Metric Units)
- Estimated Maximum Confined Inflation Pressure For MP 30-53 (From Bottom Chart) = 62.5 (100)Kpa = 906.25 PSI
- Example:
  - Packer Depth = 250 Meters (817.5 feet)
  - Depth To Water = 0 Meters (0 feet)
  - Inflation Pressure (Assuming 0.55 PSI/ft assuming higher specific gravity for saline water) = 817.5 x 0.55 = 449.63 PSI
  - Sealing Pressure: Add another 50 PSI to seal against inside wall of PVC riser pipe. Therefore, total pressure = 499.63 PSI (500 PSI)

Figure 13 - Blatymini Deployment



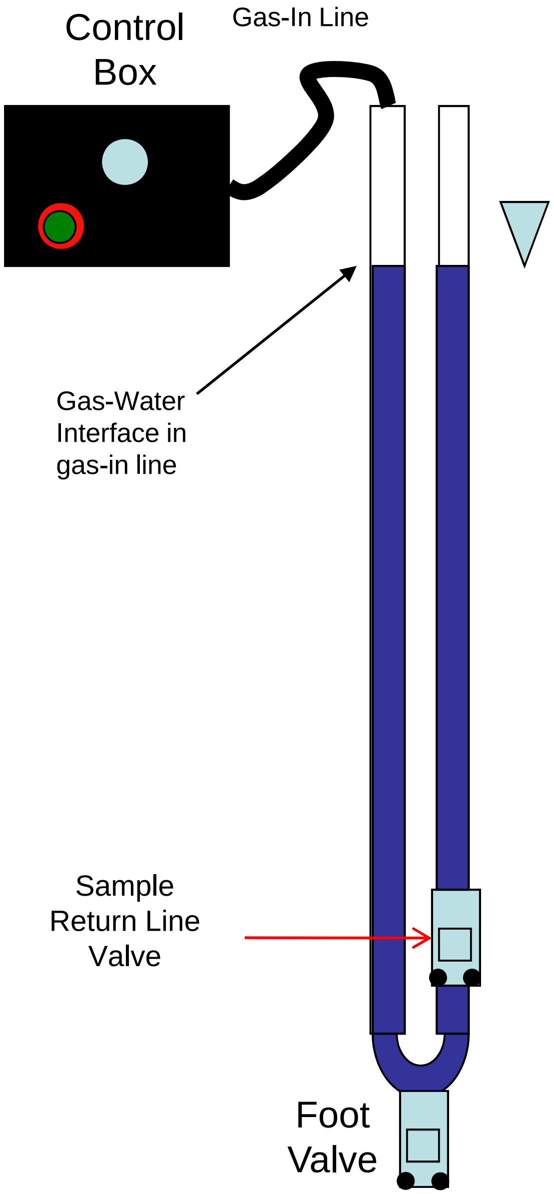


Figure 14 – Pumping Operation

Overview

The Blatypus Pump is a two-valve pump that is excellent for VOC and inorganic water sampling – and is similar in design to Bladder Pumps – with the exception that there is no bladder. The absence of a bladder actually serves as an advantage in comparison to bladder and electric submersible pumps and studies by Cheery et al show that a two-valve bladderless pump is as effective for VOC sampling as a bladder pump. First, elimination of the bladder removes the depth lift constraints that are characteristic to bladder pumps. Second, the absence of a bladder removes the possibility of a key-component failure during repeated use and high pressure purging and sampling.

A timer unit is used to control the pumping cycles of the Blatypus pump and is very similar in function to those made by other companies such as QED, Solinst and Geotech. However, the BESST timer-control unit has some distinct advantages over the other systems. First, the control unit can be operated to pressures of 750 PSI. Second, the timer adjustment is not limited to 60 seconds of off-time or on-time for the pump cycle. The BESST timer control unit can be programmed for seconds, minutes, hours and days. Third, BESST also manufactures a high pressure timer control unit that can be operated to 1,500 PSI (for depths up to 3,000 feet bgs.). For Blatypus applications of 600 feet or deeper a stainless steel Blatypus is required.

General Operation

For every second of on-pressure from the control box into the gas-in line, there is a descent of the gas-water interface of about 6 to 8 feet. Let's say you're working in a very permeable formation with rapid recharge to the pump intake and gas in tubing, and let's also assume that you have plenty of hydraulic head (submergence) of the pump intake below static water (first water). The Blatypus works on the basis of a "foot-jack" principle the same as a car jack. As your leg moves up and down on the peddle of the car jack, the foot depression and raising always goes to the same low and high point each time (the gas-in line water/gas interface). The car on the other hand keeps rising higher and higher (the water in the sample return line).

The procedure is simple when dealing with high permeability and plenty of submergence. When working at depth with less submergence and tight formations, you have to be careful not to have too many on-seconds set on the timer-control unit. Otherwise, the water/gas interface in the gas-in line with descend to the foot valve either quickly or over a number of on/off cycles and the result will be a mixture of air and water in the sample return line.

See next page for further details.

Figure 15 – Pumping Operation

In the scenario to the right, the operator sets the on-time to 1 second on and 5 seconds off. In this example, the gas-water interface at static water level is represented by the black-dashed line. The red dashed line represents the descent of the gas/water interface by about 8 feet over a one-second-on interval. The simultaneous compliment to this descent is an 8-foot rise in the sample return line (shown by the dashed green line). Each on/off cycle raises the water in the sample return line by about 8 feet. When the off cycle on the timer kicks in, the gas/water interface in the gas-in line is allowed to return to the static point in preparation for the next on cycle. So, the water level in the gas-in line just goes up and down between the black and red dashed lines while the water level in the sample return line ratchets to the ground surface – resulting in a continuous pulsating flow.

This scenario is experienced most often in very permeable formations with fast recharge and adequate submergence of the pump intake below static water level.

The scenario on the next page demonstrates what happened when working in tight formations and deep wells with little submergence – where the operator uses too much on time and not enough off time on the timer control unit.

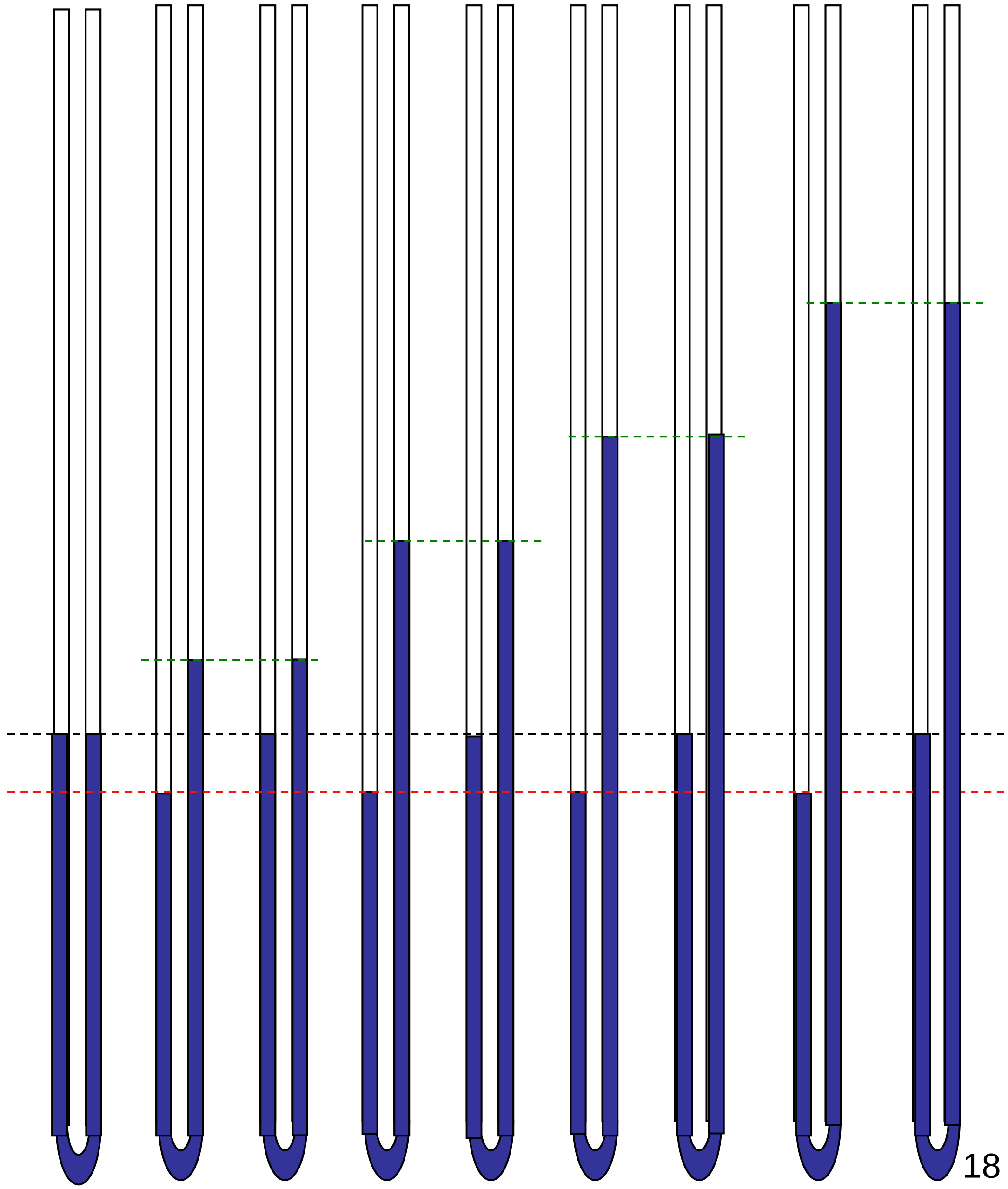


Figure 16 – Pumping Operation

If, on the other hand, there is too much on-time and not enough off-time for water recharge of the gas-in line, there is a progressive downward ratcheting of the gas/water interface in the gas-in line until, eventually, the gas-in line becomes dewatered. As a result, the sample return line will all flow a continuous water stream briefly or until the sample return line runs out of continuous water. Then, the field scientist will observe a gas-water mixture coming out of the sample return line (after continuous flow of water in the sample return line runs out).

The operator will note that there is a sputtering from the sample return line. This problem is all derived from not allowing enough recharge time in the gas-in line. This often happens in tight formations and deep wells with reduced submergence of the pump intake point. The key is to be patient and to MINIMIZE THE ON TIME AS MUCH AS POSSIBLE AND MAXIMIZE THE OFF TIME FOR FULL RECHARGE (I.E. 1 SEC. ON / 20 SECS OFF).

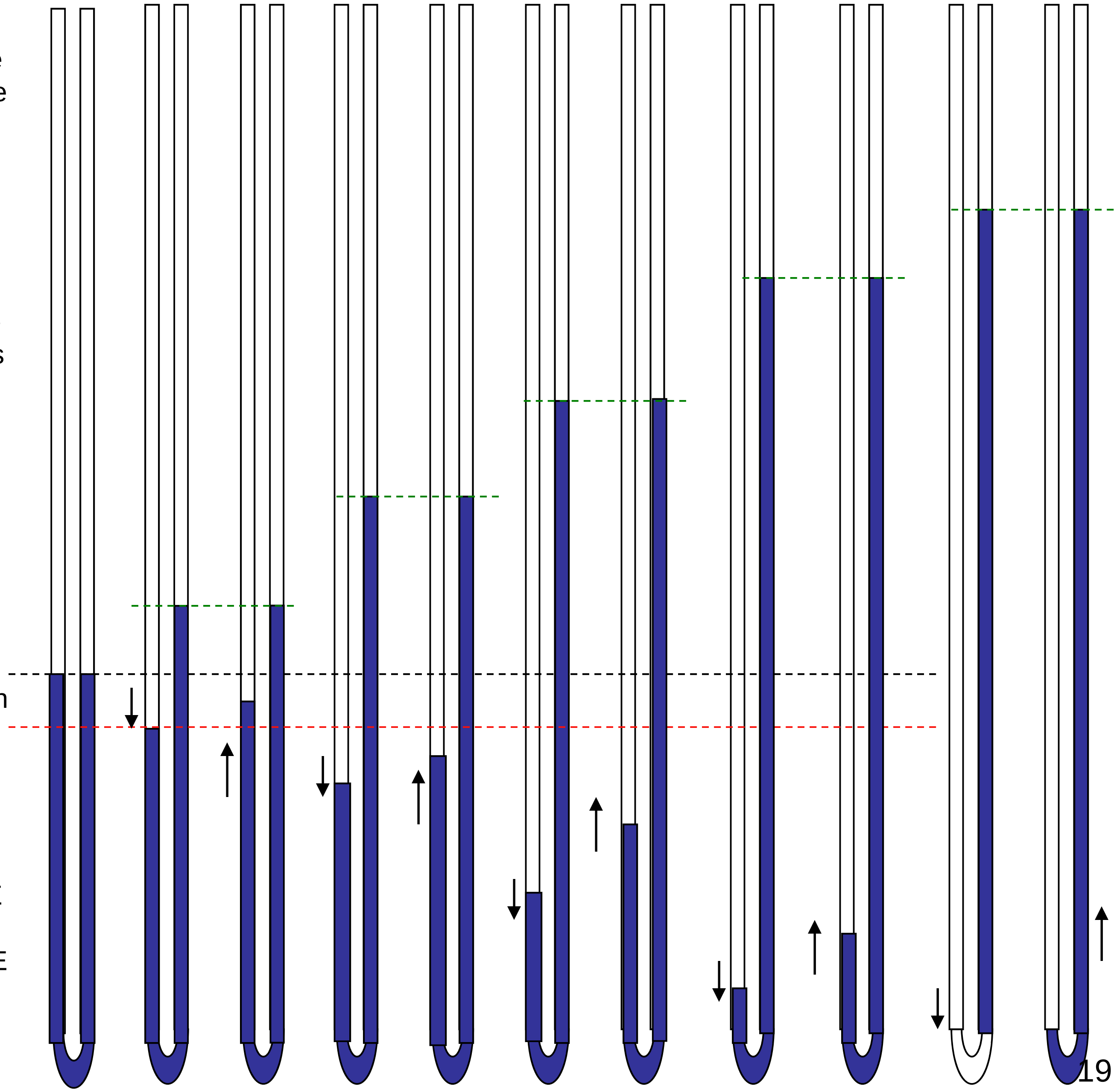


Figure 17

Water Trap