Materials Injection

Introduction

Recent trends in the environmental remediation field have been away from active methods (e.g. pump and treat) and toward construction of permeable barriers and injection of materials that can enhance or augment the natural attenuation and biodegradation processes. Current research has indicated that injection of oxidizing materials or reducing agents can significantly speed up and enhance the natural biodegradation of many contaminants, lead to chemical breakdown of the contaminants, or result in their alteration to nonhazardous forms. Interest in direct push techniques has increased significantly for the remediation market due mainly to the efficiency of direct push applications.

Why Direct Push for Materials Injection?

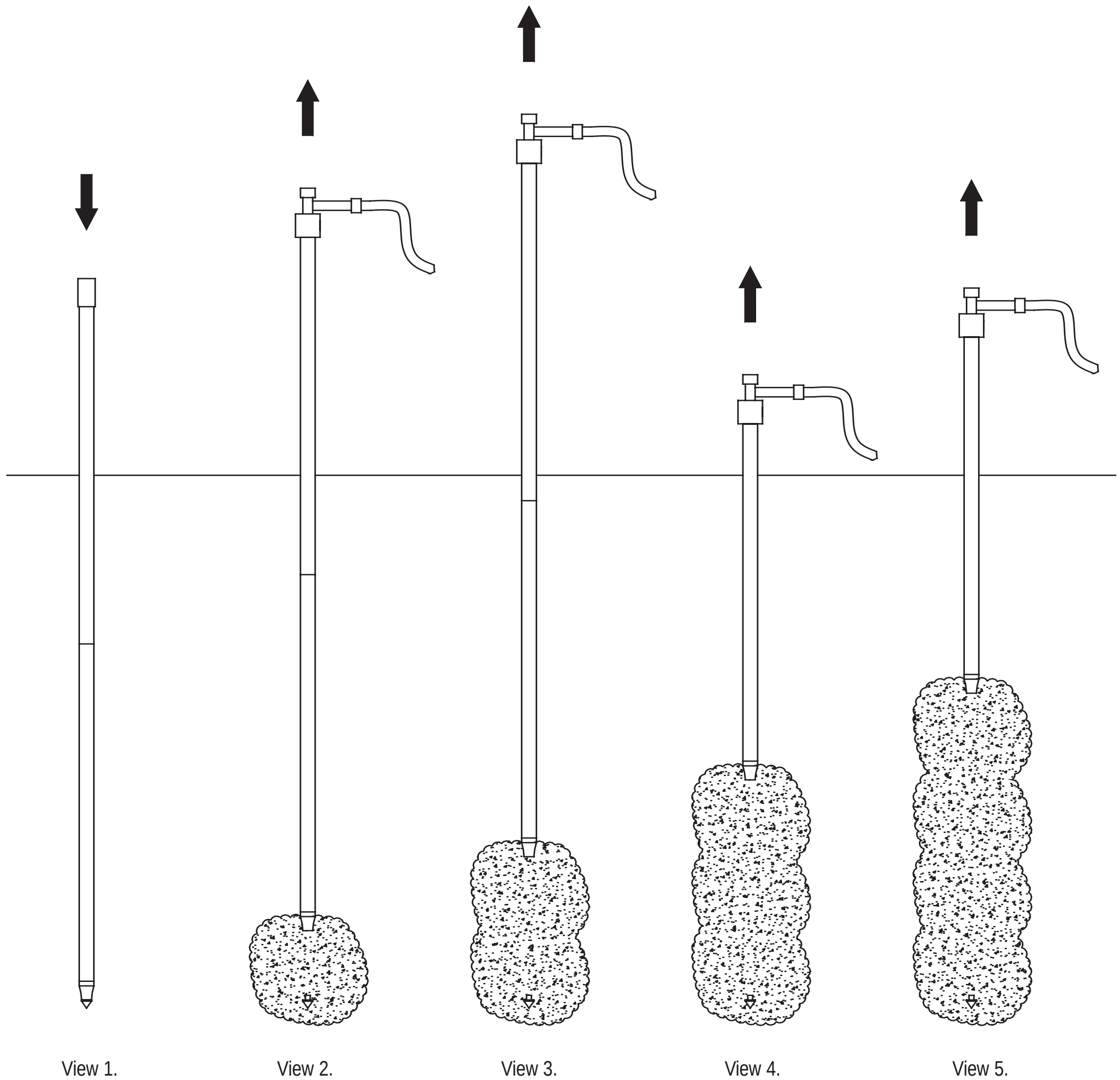
To better understand why direct push techniques are well suited for materials injection, we must first look at the way in which remediation materials are applied at a contaminated site. Most full-scale projects involve multiple injection locations that are mapped out in a grid pattern over the planned treatment area. A typical grid may include as many as 100 or more locations often spaced on 10-foot centers. Application depths are generally less than 80 feet with the majority being 40 feet or less.

Remediation materials must be applied in the right location in order to be effective. Direct push methods enable material to be injected at controlled depths and flow rates. Unlike monitoring well applications which can only occur within the fixed screened interval, direct push injections can be adjusted to cover the entire treatment zone including the capillary fringe and vadose zone.

Injection projects often take place on active industrial or commercial sites. Under such conditions, care must be taken to minimize disturbances to business activities especially when injections are located near inhabited buildings and on or near busy roads or streets.

Direct push machines are therefore suited to materials injection for the following reasons:

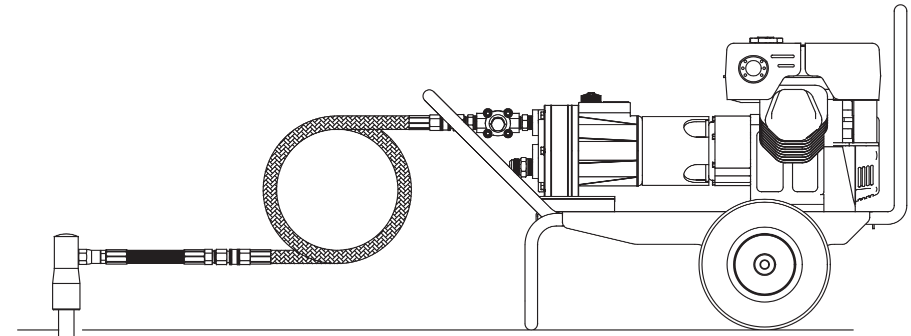
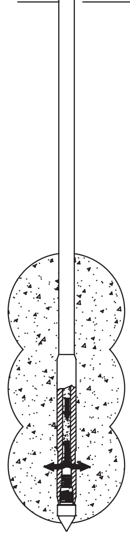
- Compact Machines Provide Enhanced Mobility
  - Off-road and limited-access sites
  - Low overhead locations
  - Indoor areas
- Low Site Impact
  - Minimal disturbance to existing property and current business activities
  - No cuttings to move and store onsite
  - Does not require installation of permanent equipment.
- Precise Targeting of Treatment Zone
  - Remediation material applied directly to target zone for accurate placement over large area
  - Capillary fringe treated without reliance on change in water level
- Cost Efficient
  - Mobility minimizes relocation and setup time
  - Rapid installation allows for many injections per day
  - No cuttings to manage onsite and pay for disposal



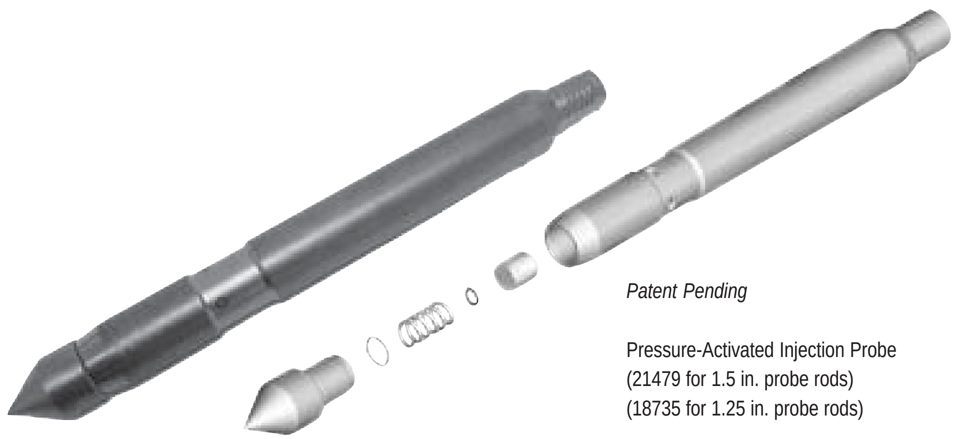
Bottom-Up Injection Procedure

The majority of injection projects today are completed using the bottom-up method. In this procedure, the tool string is driven directly to the bottom of the injection interval as shown in View 1 above. The injection pump is attached to the top probe rod (View 2) and material is injected directly through the tool string during retrieval (Views 2-5).

Injection can be performed in two ways. The first is to operate the injection pump on high speed while slowly withdrawing the tool string. This overpumping forces material out away from the probe hole in a somewhat continuous column. The second method is to raise the tool string a short distance without pumping and then operate the pump with the tool string stationary. Repeating this pull-and-then-pump cycle creates overlapping "bulbs" of material that result in the desired coverage.

Top-Down Injection / Pressure-Activated Injection Probe
and DP800 Injection Pump



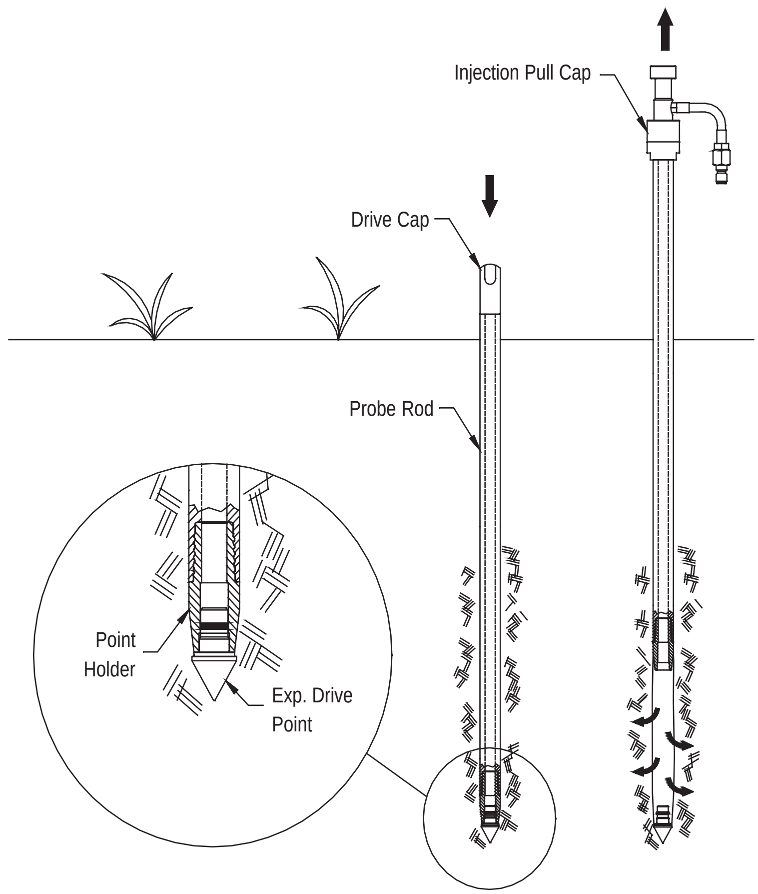
Patent Pending

Pressure-Activated Injection Probe
(21479 for 1.5 in. probe rods)
(18735 for 1.25 in. probe rods)

Top-Down Injection Procedure

Top-down injection begins by advancing the tool string to the top of the injection interval. Material is pumped through the probe rods while the tool remains stationary. The tools are then advanced to the next injection depth and material is again pumped through the stationary probe rods. This cycle is repeated to provide overlapping coverage across the entire injection interval.

Interest in top-down injection continues to increase. While this would appear to be the best injection method, it is not without its difficulties. The most common problem is clogging of the injection tip during advancement of the tool string. The Pressure-Activated Injection Probe (18735) allows for either top-down or bottom-up injection of remediation materials when using any Geoprobe® grout or injection machine. Unlike conventional injection methods, the Pressure-Activated Injection Probe ensures accurate placement of the material into the intended injection interval. The probe also acts as a backflow preventer, keeping injection material IN the ground and not ON the ground! The unique internal spool design of this probe insures that the injection ports do not clog with soil!



Bottom-Up Injection / Expendable Drive Point

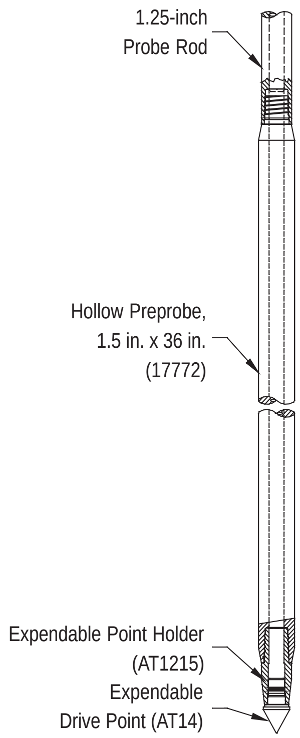
Tools for Bottom-Up Injection of Remediation Materials

The first method of bottom-up injection utilized an Expendable Point Holder (P/N AT1215) and Expendable Drive Point (AT14). The point holder threads onto the leading end of standard 1.25-inch OD probe rods and is retrieved with the rod string. The expendable point drops from the holder during injection and remains downhole.

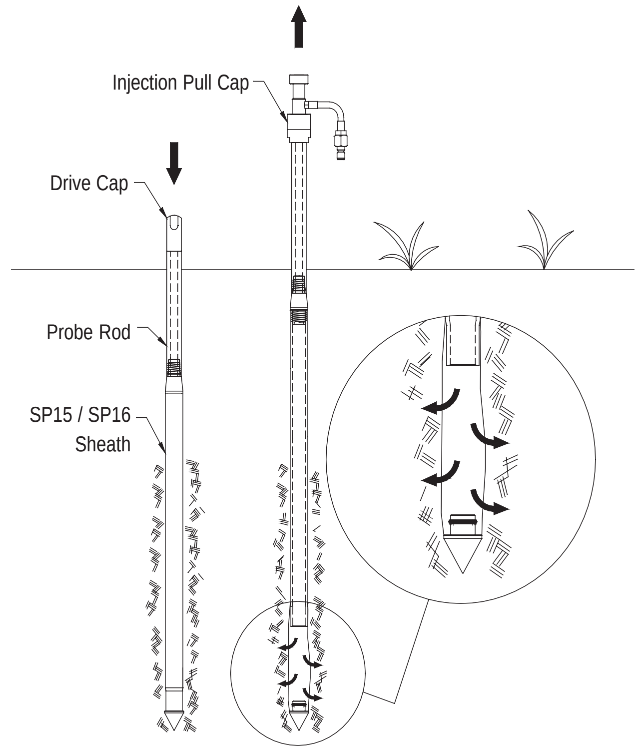
This method is still common today because of the speed and efficiency of the procedure. The tool string is driven directly to the bottom of the injection interval using a standard drive cap. An Injection Pull Cap (P/N 16697 or 16698) is then threaded onto the top probe rod and material is pumped through the tool string as rods are pulled to the surface for retrieval.

It is important that the AT14 point be used for injection as its 1.1-inch OD is smaller than that of the probe rods. This provides tight contact between the soil and probe rods above the point holder to effectively limit movement of material up along the probe rods during injection.

Operators with 1.5-inch OD probe rods may utilize a 1.5 Pin x 1.25 Box Adapter (P/N 15812) to connect the AT1215 Point Holder to the leading probe rod.



Bottom-Up Injection / Hollow Preprobe

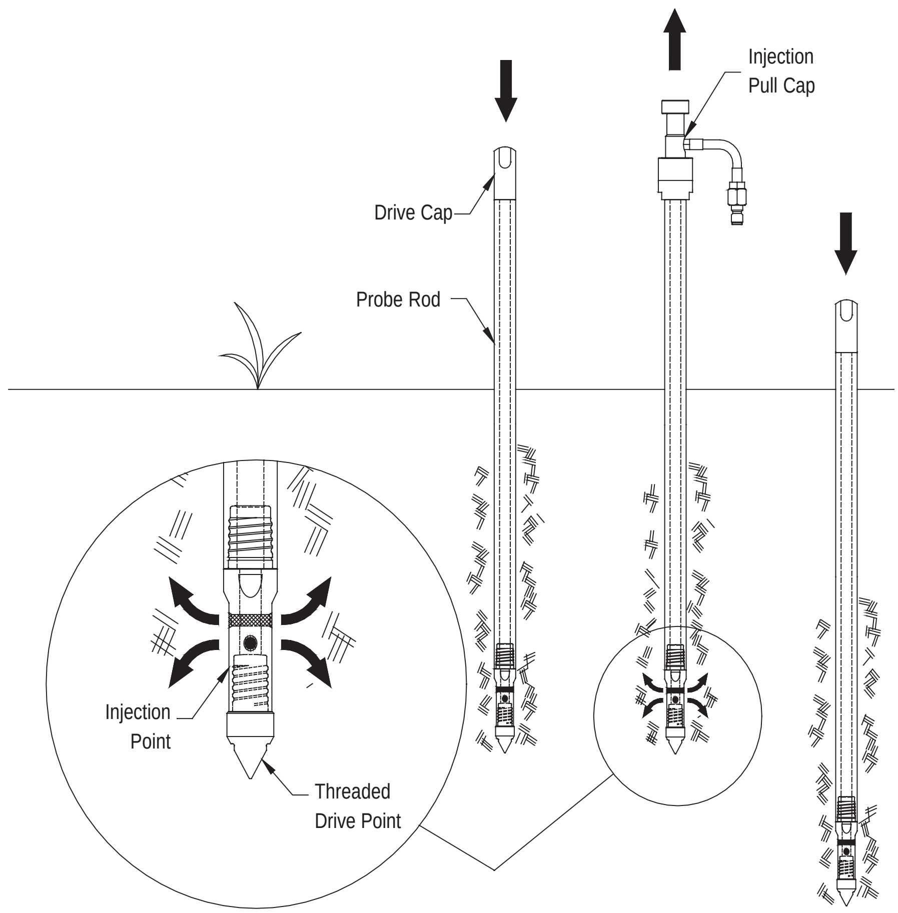


Bottom-Up Injection / SP15 or SP16 Sampler

Tools for Bottom-Up Injection of Remediation Materials

A 1.5-inch x 36-inch Hollow Preprobe (P/N 17772) is available for use with 1.25-inch probe rods when leakage occurs along the rod string. The 1.5-inch OD of the preprobe provides tighter contact between the soil and probe rods above the expendable point to better seal the rod annulus.

A Screen Point 15 / Screen Point 16 Groundwater Sampler (minus the screen) is sometimes placed at the leading end of the tool string for bottom-up injection. This is most often used by operators who already have an SP15 / SP16 sampler in their tool inventory and do not wish to stock additional items such as the preprobe or AT14 points. Because of the considerably greater cost of the SP15 / SP16 expendable points, it is wise to use probe rods and AT14 points for bottom-up injection whenever possible.



Top-Down Injection / Injection Point

Tools for Top-Down Injection of Remediation Materials

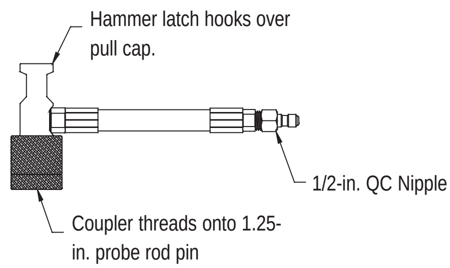
A common thought about top-down injection is to simply utilize a ported probe rod at the leading end of the tool string. Geoprobe tested this idea using ported 1.0-inch x 12-inch and 1.0-inch x 24-inch probe rods on the leading end of a 1.25-inch OD probe rod string. Both 1.0-inch rods were ported with 0.25-inch holes spaced approximately every 1.0 inches over the entire length of the rod. Tests revealed that with either length of ported rod, all but the top few ports became plugged during driving resulting in material flow only through these top 3 or 4 ports. With this information in mind, the 1.25 Pin x 1.0 Box Injection Point (P/N 17826) was developed for top-down injection.

As shown in the illustration above, the injection point is driven to the top of the proposed injection interval using a standard drive cap. The drive cap is replaced with an injection pull cap and material is pumped through the stationary tool string. The pull cap is then replaced with the drive cap and the tool string is advance to the next injection interval where the drive cap is once again replaced with the pull cap to allow pumping at the new depth.

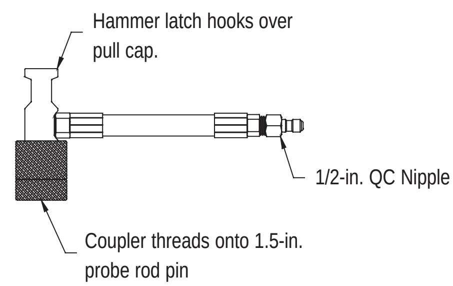
Tools for Connecting the Pump to the Probe Rods

The most important factor to consider when selecting a hose and coupler to attach the pump to the probe rods is the viscosity of the remediation material. Viscous materials require larger hoses and connections to keep backpressure at a reasonable level. Low viscosity materials can utilize smaller hoses and connections which are less costly and physically easier to work with. A few of the more common hose and coupler options are listed below.

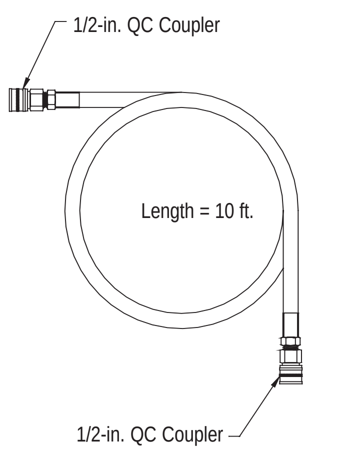
Note: "QC" is the abbreviation for Quick Connect.



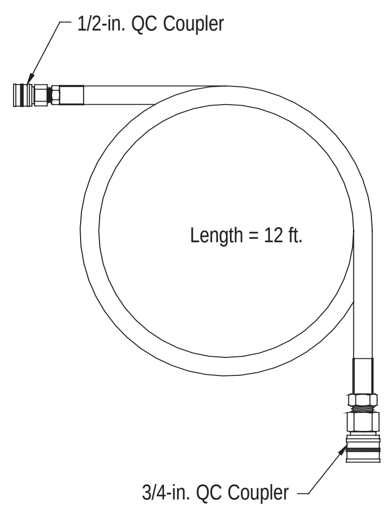
P/N: 16697
Minimum ID: Approximately 0.5 inches.
Description: Injection Pull Cap, 1.25-in. Rods



P/N: 16698
Minimum ID: Approximately 0.5 inches.
Description: Injection Pull Cap, 1.5-in. Rods

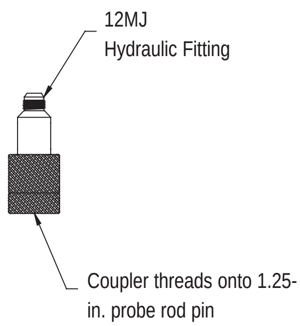


P/N: GS1051
Minimum ID: Less than 0.25 inches.
Description: High-Pressure Grout Hose Asm., 10-ft

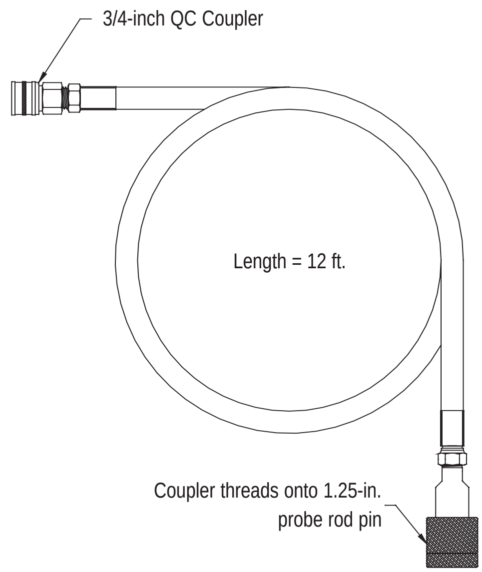


P/N: 17946
Minimum ID: Approximately 0.5 inches.
Description: Grout-Injection Hose, 1/2 QC x 3/4 QC

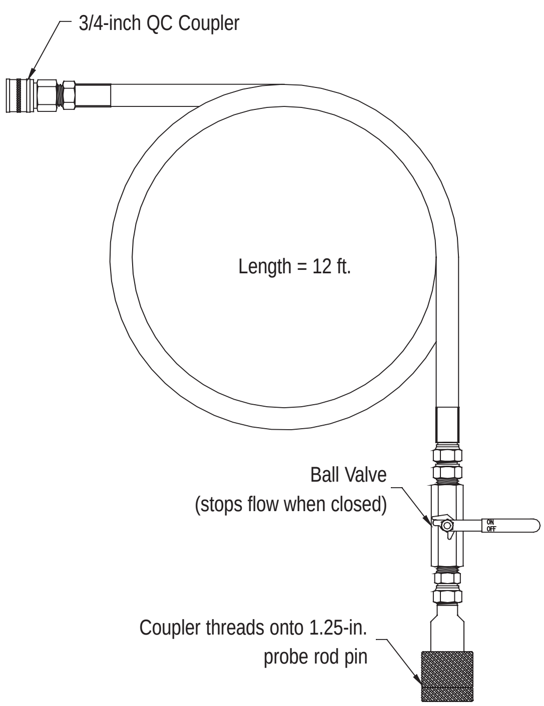
Tools for Connecting the Pump to the Probe Rods (continued)



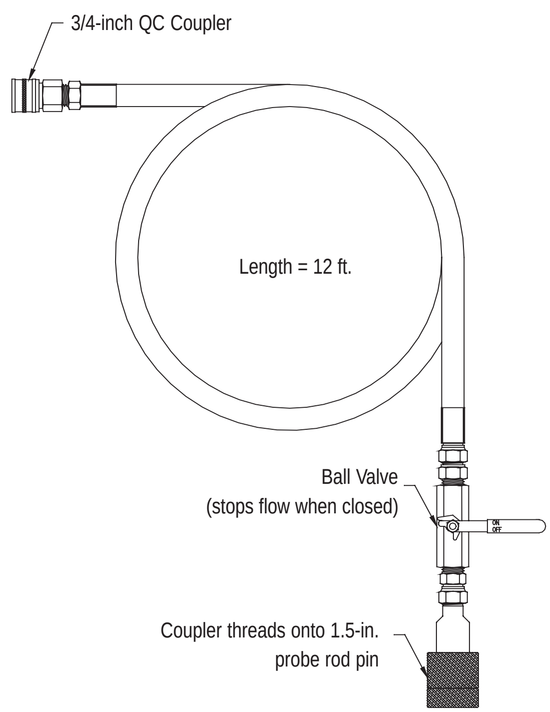
P/N: 17219
Minimum ID: Approximately 0.625 inches
Description: Injection Coupler, 1.25 Rod x 12MJ



P/N: 12580
Min. ID: Approximately 0.625 inches
Description: Grout Hose/Coupler Asm.,
w/o Valve, for 1.25-inch Rods



P/N: 13900
Minimum ID: Approximately 0.625 inches
Description: Grout Hose / Coupler Asm.,
with Valve, for 1.25-in. Rods



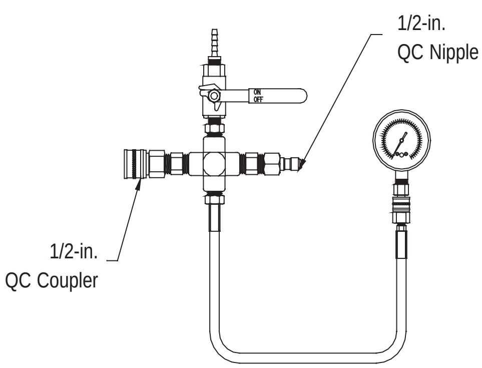
P/N: 16888
Minimum ID: Approximately 0.625 inches
Description: Grout Hose / Coupler Asm.,
with Valve, for 1.5-in. Rods

Tools for Measuring Line Pressure

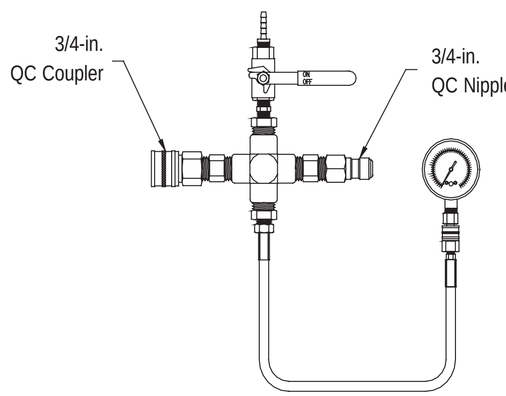
Pumping pressure can be monitored using on of the three assemblies shown below. Each assembly attaches directly to the pump outlet using quick connect couplers. The grout/injection hose is then connected to the end of the pressure gauge assembly.

The pressure gauge is connected to the end of a small flexible hose. This hose is filled with water to protect the gauge from pumped material that would otherwise clog the small orifice at the base of the gauge. Fill the hose with water and mount the pressure gauge on the side of the Grout Machine below the level of the pump outlet using a Magnetic Grout Hose Holder (P/N GS1095). This configuration traps water in the small hose to better protect the gauge. It is still necessary to periodically remove the gauge at the quick connect coupling to flush and then refill the small hose with clean water.

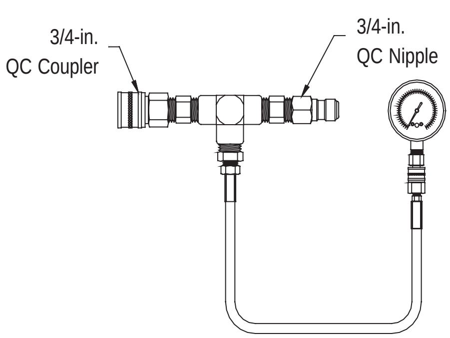
A ball valve is included on two of the assemblies. The valve enables the operator to relieve pressure from the grout/injection hose before removing the pull cap or coupler from the probe rod string. Close the valve while pumping and then open the valve to relieve line pressure once the pump is shut off. Attach flexible tubing to the barbed fitting on the end of the valve and route the open end to a suitable catch container.



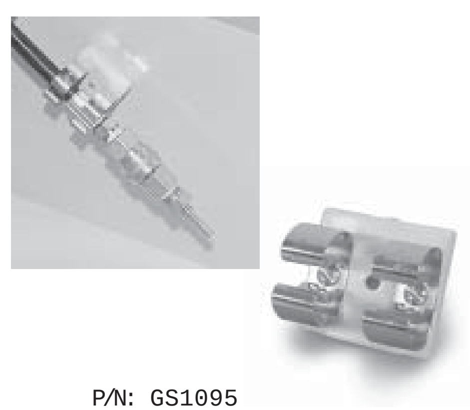
P/N: GS1090
Minimum ID: Approximately 0.5 inches
Description: Grout Pressure Gauge / Ball Valve Asm., 1/2-in. Quick Connects



P/N: 13914
Minimum ID: Approximately 0.75 inches
Description: Grout Pressure Gauge / Ball Valve Asm., with Valve, for 1.25-in. Rods



P/N: 13913
Minimum ID: Approximately 0.75 inches
Description: Grout Pressure Gauge Asm., 3/4-in. Quick Connects



P/N: GS1095
Description: Magnetic Grout Hose Holder

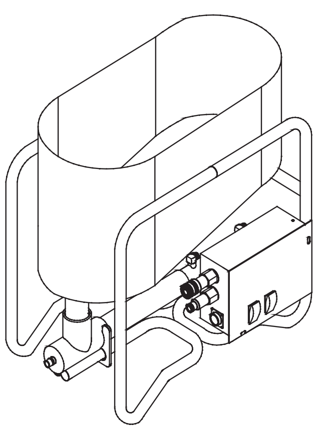
Pumping Remediation Materials

Introduction

The ability to move remediation products into the subsurface is determined by several factors. The viscosity of the material, volume of material to be injected, depth of injection interval, type of geological formations, and chemical make-up of the material being pumped all determine how a material is applied to the subsurface. The direct push industry is seeing an increase in material types being used for remediation purposes. Consequently, the need to pump these different material types into the subsurface cannot easily be done effectively and economically by just one single pump. The following section discusses pumps, pump construction, and pump options for common remediation products being used in the direct push market today.

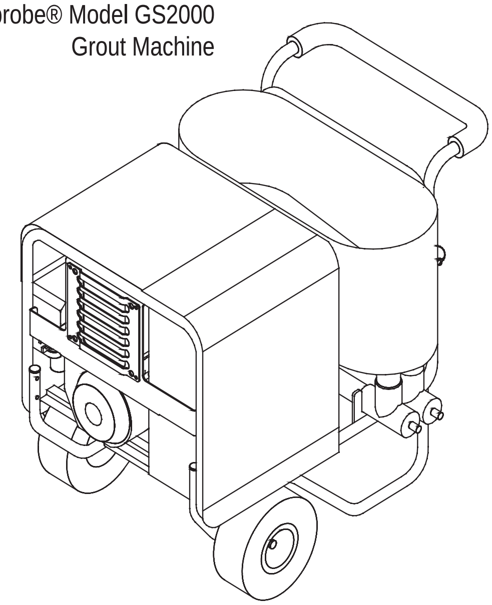
Piston Pumps

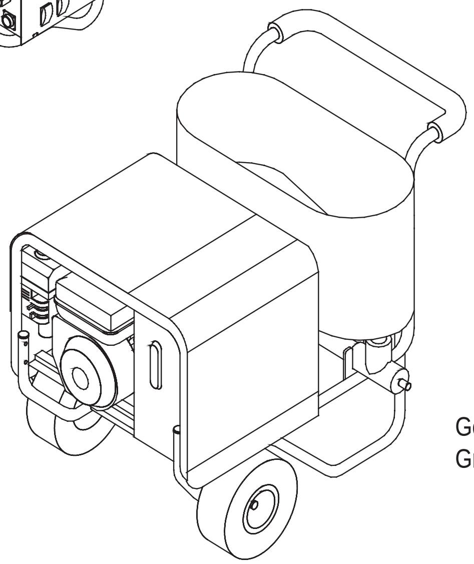
Piston pumps are commonly used everyday in the direct push and construction industry. The design of a piston pump makes it ideal for high-pressure and high material viscosity applications. Since most direct push injections are performed with small inside diameter tooling, the ability to move high viscosity materials through a small flow area is imperative. The features and configuration of the piston pump make it ideal for these conditions. Field serviceable components make maintenance and clean-up ideal for direct push sites as well.



Geoprobe® Model GS500
Grout Machine

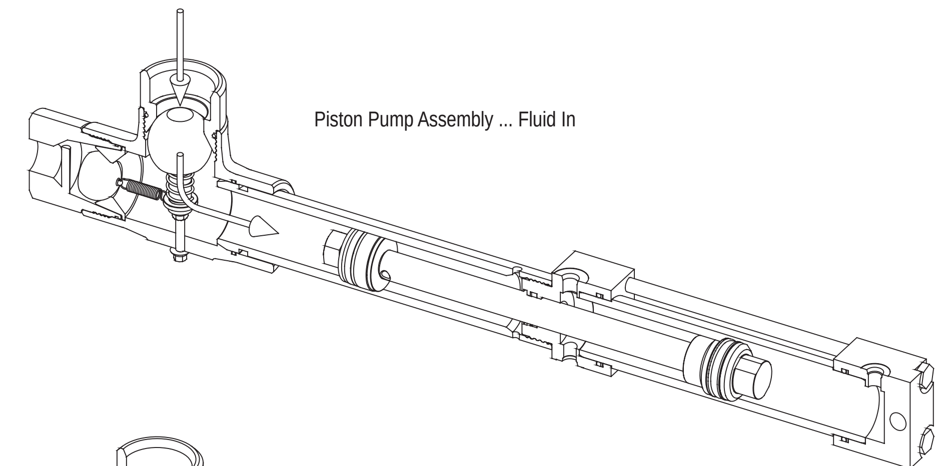
Geoprobe® Model GS2000
Grout Machine



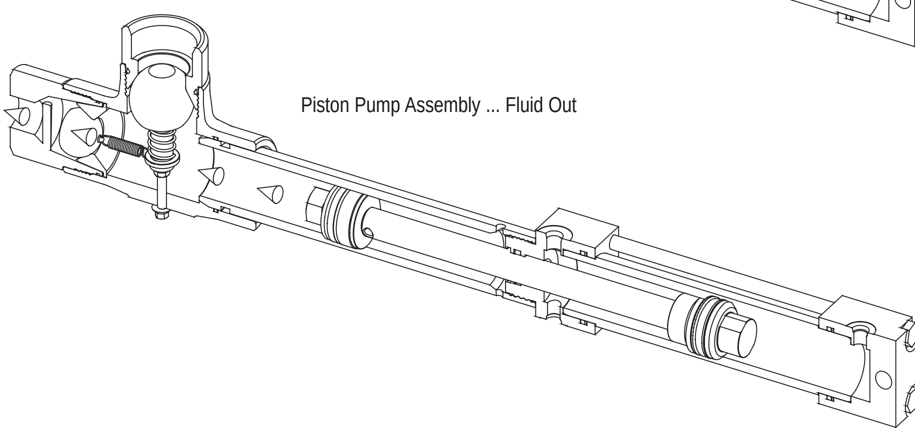


Geoprobe® Model GS1000
Grout Machine

The GS series of piston pumps offered by Geoprobe Systems all utilize the same principle of operation. Hydraulic power is used to actuate a piston in a hydraulic cylinder. This hydraulic piston is coupled to a grout piston via a piston rod. The reciprocation of the hydraulic cylinder creates the pumping action in the grout cylinder. As the cylinder retracts, it draws material out of the hopper and into the grout cylinder via the T-valve. The extension of the cylinder forces the material thru the T-valve and into the injection hose, which is connected to the tool string or tremmie tube. In the case of the GS500, hydraulic power is supplied from an external source via auxiliary supply. The GS1000 and GS2000 are powered by a self-contained gasoline engine.



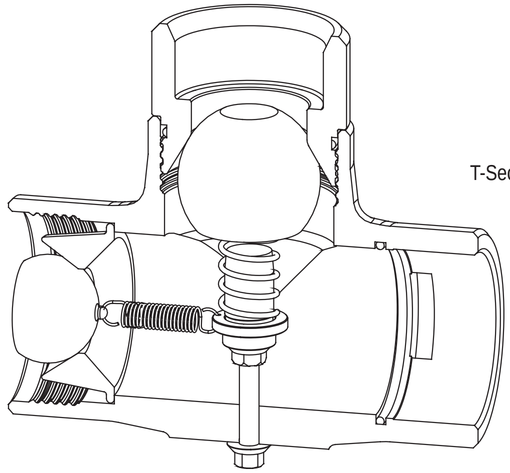
Piston Pump Assembly ... Fluid In



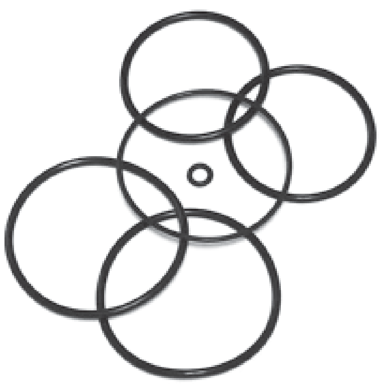
Piston Pump Assembly ... Fluid Out

The GS500 and GS1000 feature a “free floating” check ball system for applications requiring less than 1000 psi. This concept is ideal for pumping low viscosity materials at medium to low pressures. The GS2000 uses a “spring seated” check ball system with heat-treated stainless steel check balls and springs which allows the pump to operate at much higher pressures (1850 psi). The “spring seated” check balls allow the pump to operate much more efficiently than “free floating” check balls in high viscosity applications such as HRC®. The stainless steel design resists corrosion and breakdown from potassium and sodium permanganate.

An aftermarket T-valve with spring seated stainless steel check balls (16253) is available for use on GS500 and GS1000 for pumping heated HRC® in shallow applications. (40 ft. and less)



T-Section Breakaway



Viton O-ring Kit (18072)

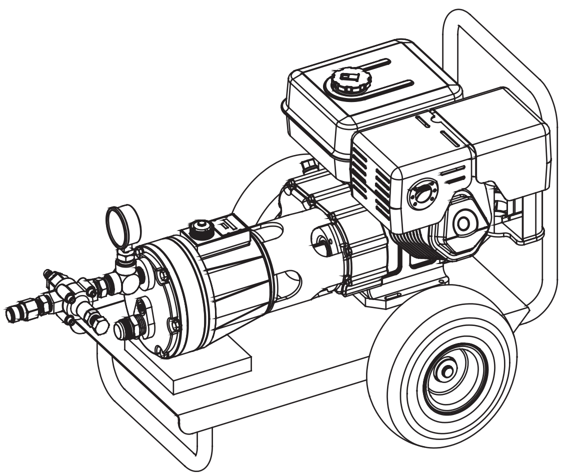
Viton Grout Piston Seal Kit (18075)

A replacement Viton grout piston seal kit (18075) and Viton O-ring kit (18072) are also available for the GS2000 for pumping potassium and sodium permanganate. The factory buna seals on the GS2000 will break down with limited exposure to any of the permanganates. It is highly recommended that any permanganates not be pumped with the GS500 or GS1000. The seals for these two pumps are not available in a material suitable for pumping permanganates, and the volume at which permanganates are usually pumped (>50 gal. per hole) is not particularly suitable for the low flow rates of the GS500 or GS1000.

Diaphragm Pump

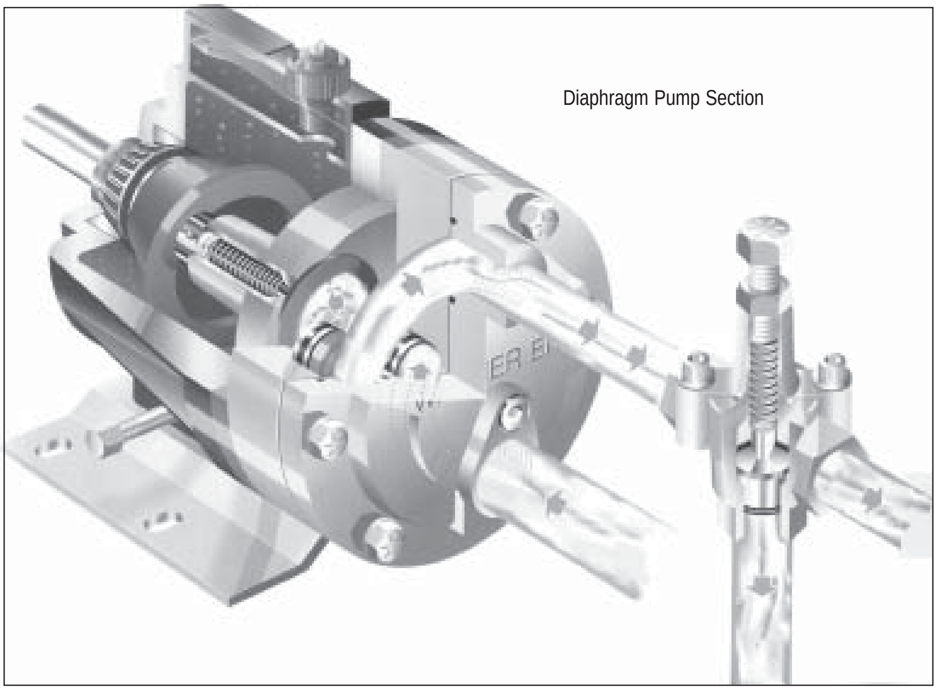
Diaphragm pumps are finding their way into direct push remediation applications due to their ability to deliver higher volumes of material without the need for high pressure. Potassium and sodium permanganate are good candidates for use with a diaphragm pump. The viscosity of the permanganates does not usually require pressures higher than 1000 psi in most formations. The injection volumes of the Permanganates are usually higher than other products, therefore a high volume, medium pressure pump is ideal.

Although the construction of most diaphragm pumps is entirely mechanical (no electrical components), they are not usually field serviceable. However, they can be easily disassembled and serviced in a shop environment. It is not recommended to use a diaphragm pump to pump materials with a high viscosity or materials that have the potential to set up or harden inside the pump. Keeping this in mind, it is not recommended to pump high solids grouts, grouts with cement, or HRC® with a diaphragm pump. Materials requiring high injection volumes and materials with a low viscosity are ideal for diaphragm pumps. This would include, but not be limited to the following: Hydrogen peroxides, permanganates, microbial products, and any abrasive slurries.



Geoprobe Model DP800 Injection Pump

The DP800 pump is designed to pump low viscosity material such as permanganates, peroxides, and microbial products. Specifically, this pump has been designed with the permanganates in mind. Pump components such as springs, valves, seals, and the diaphragms are constructed to withstand the harsh conditions caused by potassium and sodium permanganate.



The diaphragm pump of the DP800 operates using the following principle: The drive shaft (coupled to a 9HP Honda engine) is connected to a fixed-angle cam or wobble plate. As the drive shaft turns, the wobble plate moves, oscillating forward and back (converting axial motion into linear motion). Three pistons are alternately moved by the wobble plate. These pistons push oil against the back of the diaphragm on the forward stroke, causing them to flex forward and back as the wobble plate moves the pistons forward and back, thus providing the pumping action. The diaphragms are equally spaced 120 degrees apart from each other providing a low pulse flow.

Pumping Hydrogen Release Compound® (HRC®)

As previously stated, the ability of a pump to pump any given material into the subsurface depends on several factors. The viscosity of the material seems to have the most effect on how successful a material can be pumped. High viscosity (thick) materials and high pressure pumps go hand in hand. This is due to a condition called "pressure drop" or pressure loss. The pressure drop is the sum of all the losses (major and minor) in the pumping system. In the case of a direct push application, these losses are due to friction losses in hoses, probe rods, fittings, hose connections, and injection or grout pull caps. All of these losses (big and small) add up to the total pressure drop. As the viscosity of the material increases, the losses increase as well as creating the need for more energy in order to move the material into the subsurface.

HRC® can present significant problems with pressure losses since it has a very high viscosity at room temperature. As HRC® became more popular, the need for a high-pressure pump became evident. Not only did the pump need to have high pressure, but it also needed tools and peripheral items that would keep pressure drops and flow restrictions to a minimum. Thus began the development of low restriction grouting and injection tools. The injection hoses were enlarged to minimize friction loss. All 90-degree fittings were eliminated to reduce pressure losses. Pump valves and pull caps were enlarged and redesigned to allow for low restriction flow of material through the pump unit.

While reducing pressure losses in tools, and optimizing pump and valve design, the viscosity reducing effect of heating HRC® is the most significant. When the material is heated above 95 degrees Fahrenheit the ability to mix and pump HRC® is improved tenfold. Generally, it is necessary to mix the HRC® before pumping so that a homogenous mixture is being applied to the subsurface. The ability to mix HRC® at 60 degrees Fahrenheit is almost impossible, although HRC® heated to 100 degrees Fahrenheit is easily mixed with a drill and paint mixer.

Pump safety is often overlooked in direct push injection applications. Historically, injecting grout and ORC® has been done at fairly low pressures. The pressure used to pump these materials is significant enough to cause serious injury.The need for proper eye protection can not be emphasized enough.

Pumping Permanganates

Pumping permanganates requires that more attention be paid to compatibility of pump and tooling components to the permanganate material being used. The incompatibility of common seals, O-rings, hoses, and even some metals make pump selection for permanganates somewhat difficult. There are many models of high-flow pumps on the market, but their component compatibility with the permanganate family of materials is questionable. The DP800 has been designed specifically for the permanganate materials. The pump head, valves, diaphragms, and even the injection hose have been constructed out of selected materials resistant to the corrosiveness of the permanganate materials.

As stated above, pump safety is easily overlooked. Materials such as grouts, Oxygen Release Compounds® (ORC®), and HRC® are pumped without much thought of mishaps or accidents. Pump safety is especially important when pumping permanganates. Not only is the danger of a pressurized system present, but also important is the chemical makeup of the material being pumped. Potassium and sodium permanganate are oxidizers, which makes them dangerous materials to be in contact with. Placing them under pressure in a pumping system makes them even more dangerous. Once again, proper personal protection is a must.

Pump Selection

In the past, the popularity of injecting materials in direct push applications did not necessitate much thought when it came to pump selection. Today, as we see the need to pump hundreds of gallons of materials in a single direct push hole, pump selection is not only a matter of material compatibility, but also a matter of economics.

For higher viscosity materials such as high solids grouts, HRC®, or Molasses, piston pumps are almost mandatory due to the pumps ability to handle the high viscosity material. Fortunately, these same materials are usually injected in fairly low volumes making them more suitable to piston pump applications.

Low viscosity materials such as permanganates, and microbial products can be pumped with select pumps offered by Geoprobe® Systems. Since these materials are generally pumped in high volumes (>50 gallons/hole), it is not suitable to pump them with a GS series pump at 3.6 gallons per minute (max.). Alternately, these material are much more suitable for the DP800 which is capable of delivering these materials at 8 gallons per minute.

Geoprobe® Pump Comparison Data Sheet

		Grout/Injection Machine	DP800	GS500	GS1000	GS2000
		Max Output Pressure	650 psi	1000 psi	1000 psi	1850 psi
		Max Flow Rate*	8.0 gpm	2.3 gpm	2.3 gpm	3.6 gpm
Pump Compatibility	Grout	Bentonite Slurry	–	Yes	Yes	Yes
		Neat Cement	–	Yes	Yes	Yes
	Injection/Remediation Products	HRC® (heated to 100°F)	–	LC	LC	Yes
		HRC-X™ (heated to 125°F)	–	–	–	Yes
		Hydrogen Peroxide	Yes	–	–	–
		Microbial Products	Yes	–	–	–
		ORC®	–	Yes	Yes	Yes
		Potassium Permanganate	Yes	–	–	Yes•
		Sodium Permanganate	Yes			Yes•

*Pumping water

Yes: The pump is capable of pumping the material.

Yes•: The pump is capable of pumping the material if the standard seals are replace with viton seals.

LC: The pump has limited HRC® pumping capabilities providing the standard T-valve is exchanged with a spring loaded T-valve.

– : The pump is not recommended for the material

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HRC-X™ is a trademark of Regenesis Bioremediation Products, Inc., San Clemente, CA.

Minimum Pumping Time* (minutes)				
		Pump Flow Rate (GPM)		
		GS500 and GS1000	GS2000	DP800
		2.3 GPM	3.6 GPM	8.0 GPM
Volume of Material (gallons)	5 Gal	2.2	1.4	0.6
	10 Gal	4.3	2.8	1.3
	15 Gal	6.5	4.2	1.9
	20 Gal	8.7	5.6	2.5
	30 Gal	13	8.3	3.8
	40 Gal	17	11	5.0
	50 Gal	22	14	6.3
	60 Gal	26	17	7.5
	70 Gal	30	19	8.8
	80 Gal	35	22	10
	90 Gal	39	25	11
	100 Gal	43	28	13

*Based on maximum available flow rate for pumping water.

Remediation Products Commonly Injected with Direct Push Equipment

Remediation materials are injected into the subsurface to reduce the concentration of specific groups of contaminants such as chlorinated and fuel hydrocarbons. Once placed in the treatment zone, remediation materials lower contaminant concentrations either through chemical oxidation or enhanced bioremediation.

In chemical oxidation, the injected material (oxidizing agent) reacts directly with the target contaminant resulting in nontoxic end products or compounds that are more readily degradable. This is contrasted by enhanced bioremediation in which the injected material accelerates and promotes biodegradation and natural attenuation of the target contaminant by microorganisms.

Some of the more common remediation products that may be injected with direct push equipment are reviewed below.

Category: Chemical Oxidation
Product: Potassium Permanganate

- Primarily used for remediation of chlorinated solvents
- Shipped dry - purple granular crystals*
- Solubility in water = 6% solution at 20°C (68°F)*
- Normally injected at 3-5% solution
- Low Viscosity
- Not compatible with some pump components
- Strong oxidizer - special safety considerations

*Source: Carus Chemical Company (www.caruschem.com)

Category: Chemical Oxidation
Product: Sodium Permanganate

- Primarily used for remediation of chlorinated solvents
- Shipped in liquid form - dark purple solution*
- Solubility in water = 50% solution at 20°C (68°F)*
- Normally injected up to 20% solution
- Low Viscosity
- Incompatibility with pump components is as issue
- Strong oxidizer - special safety considerations

*Source: Carus Chemical Company (www.caruschem.com)

The viscosity of sodium and potassium permanganate solutions is near that of water. Because of this, minimal backpressure is created within the tool string during delivery of the solution to the subsurface.

The oxidizing effect of permanganates poses a problem that must be considered when selecting the tooling and pump for an injection project. Permanganates are not chemically compatible with the materials from which standard O-rings, pump seals, and high-pressure hoses are manufactured. These components may fail after anywhere from several days to as little as a few hours of exposure. Though dependent on the temperature and concentration of the solution, sodium permanganate is generally much more damaging to pump parts and hoses than potassium permanganate.

Viton O-rings and pump seals are compatible with sodium and potassium permanganate. Viton parts are more expensive than those made from the more common Buna material, but this is offset by the increased service life provided by Viton.

GS500 and GS1000 Grout Machines utilize piston cup seals made from urethane. Urethane cup seals quickly deteriorate in the presence of sodium permanganate. Unfortunately, this type of cup seal is not available in Viton. A neoprene fabric reinforced urethane cup seal is available, but provides only limited improvement when pumping sodium permanganate. GS2000 machines can be equipped with Viton cup seals. Viton pump seals are standard for the DP800.

Permanganate injection projects often involve the application of a significant quantity of remedial product. Volumes over 100 gallons per hole are not uncommon. Output flow should therefore be a major consideration when selecting a pump for permanganate projects. For example: A 3 gpm pump must run at full throttle for approximately 50 minutes to complete a single 150-gallon injection. Using a 6 gpm pump will cut this time in half, effectively saving 25 minutes per hole.

As listed previously, sodium and potassium permanganate are strong oxidizers that require special safety considerations when handling. The following protective gear is recommended in the Material Safety Data Sheets for sodium permanganate and potassium permanganate products available from Carus Chemical Company (www.caruschem.com):

1) Face shield, goggles, or safety glasses with side shields.

2) Rubber or plastic gloves.

3) Normal work clothing covering arms and legs plus a plastic or rubber apron. (Protective coveralls of similar materials may be preferred for probe work.)

Momentary skin contact with permanganate solutions will result in brown stains. Wash the affected area immediately with soap and clean water to avoid irritation. If clothing becomes spotted (minor exposure), wash the area with water. In the event of major contamination, remove the clothing, immediately rinse with water, and wash before reuse. Note that spontaneous ignition of contaminated cloth or paper can occur.

Category: Chemical Oxidation
Product: Hydrogen Peroxide

- Used (with catalysts) for remediation of contaminants including chlorinated and fuel hydrocarbons
- Clear, colorless, water-like appearance
- Low Viscosity
- Strong solution (>8%) for chemical oxidation
  - Heat and volume expansion (pressure) occur during decomposition
  - Reacts with iron in carbon steel probe rods
  - Incompatible with certain pump parts
- More commonly used as a dissolved oxygen source (0.5-1.0% solution) for in situ bioremediation
- Strong oxidizer - special safety considerations

Source: US Peroxide (www.H2O2.com)

The considerable heat and pressure resulting from the decomposition of strong hydrogen peroxide solutions can lead to unsafe conditions if improperly controlled. A forceful (explosive) release of downhole heat and pressure may result from improper injection techniques. Applications must therefore be designed and implemented by personnel trained and experienced in the handling and injection of hydrogen peroxide.

Category: Bioremediation
Product: Oxygen Release Compound (ORC®)

- Proprietary formulation of magnesium peroxide
- White, fine (325 mesh) powder that is hydrated onsite for injection of 35-62% solids slurry
- Viscosity raises slightly with increased solids content - 62% slurry still creates minimal backpressure
- Provides slow and sustained release of molecular oxygen which stimulates microorganisms that aerobically degrade pollutants. Result is enhanced natural attenuation of contaminants
- Remediation target often is BTEX or Vinyl Chloride
- Mild oxidizer - special safety considerations

Source: Regenesis Bioremediation Products (www.regenesis.com)

Experience with materials injection accumulated by Geoprobe® Systems began several years ago with a visit from Regenesis Bioremediation Products. Regenesis was looking for a dependable method to deliver their then-new ORC® product to the subsurface. Early field applications of ORC® were performed by lowering ORC® "socks" down existing monitoring wells. The results proved promising, but a different approach was desired to better distribute the product over an entire site.

Regenesis had tried injecting ORC® through probe rods using various types of pumps with only limited success. The most common concerns were difficulty with disassembly for cleaning, too little output pressure, or prohibitive purchase/operating costs. Geoprobe's then-new GS1000 Grout Machine appeared to provide solutions these problems. A few test holes in the backyard confirmed that ORC injection could be performed quickly and easily with Geoprobe tools and equipment.

ORC is shipped in sealed 5-gallon plastic buckets each containing 30 pounds of dry powdered product enclosed in a plastic bag. The powder is hydrated onsite using clean water and a high-speed electric or cordless drill equipped with a large spiral paint mixer. Mixing is a straight forward process of combining the powder with a measured volume of water, and then operating the drill mixer to form a smooth slurry. Some settling may occur in the bucket if the slurry is not poured directly into the pump hopper. Simply stir the slurry with a grout spatula until remixed. ORC® eventually hardens into a cement-like compound. Do not let the mixed slurry stand for more than 30 minutes before pumping.

Because ORC® is a mild oxidizer, precautions should be taken to limit contact with the powder and slurry. Situate the mixing area out in the open to provide good ventilation. Stand upwind when combining the powder and water to avoid breathing the fine ORC® particles that are easily suspended in the air. A breathing mask with HEPA filters is recommended. Chemical safety glasses and protective gloves should also be worn when mixing and injecting ORC® slurry.

Standard pump seals, O-rings, and high-pressure hoses are not adversely affected by exposure to ORC® slurry. The pump valves and hose quick connect couplers must be thoroughly cleaned with water and a scrub brush after pumping. Residual ORC® will harden overnight permanently locking quick connects and threaded pump parts in place.

Category: Bioremediation
Product: Hydrogen Release Compound (HRC®)

- Proprietary polylactate ester specially formulated for slow release of lactic acid upon hydration
- Off-white, cloudy appearance - consistency of honey
- Viscosity lowers dramatically when heated (>90°F/32°C)
- Primarily used for remediation of chlorinated hydrocarbons
- Anaerobic microbes facilitate reductive chlorination
  - HRC slowly releases lactic acid when hydrated
  - Microbes metabolize this lactic acid and release hydrogen
  - Hydrogen is then used by other microbes to strip chlorine atoms from contaminants (reductive dechlorination)
  - Remaining compounds are further biologically degraded
- anticipate the potential for eye irritation and skin irritation with large scale exposure or in sensitive individuals

Source: Regenesis Bioremediation Products (www.regenesis.com)

HRC® is shipped in sealed 4.25-gallon plastic buckets containing 30 pounds of product. HRC® is to be applied as delivered from the manufacturer. No water or glycerin may be added prior to pumping.

The high viscosity of HRC® at mild temperatures creates significant backpressure in the tool string. It is not uncommon to require upwards of 1000 psi just to move HRC® through 40 feet of 5/8-inch ID probe rods at 50°F (10°C). High viscosity also creates flow problems through the pump check valves which dramatically lower pump efficiency. The GS2000 Grout Machine was specifically designed for the higher pressures and flow concerns associated with HRC injection.

Regenesis now recommends heating HRC® in a hot water bath before pouring the material into the pump hopper. The following instructions are based on information found on the Regenesis website (www.regenesis.com).

> Place unopened buckets of HRC into an empty water tank. A Rubbermaid® fiberglass Farm Trough Stock Tank (Model 4242-00-GRAY) is typically used for this application and can hold up to 16 buckets of HRC. Hot water (approximately 130-170°F or 54-77°C) should be added to the tank after the buckets have been placed inside. HRC® is ready to be poured into the pump hopper when it reaches a minimum temperature of 95°F (35°C) which should take approximately 20-30 minutes.

Once poured into the pump hopper, a certain amount of residual HRC® will remain in the bucket. Scrape the sides and bottom of bucket and transfer this material to the hopper. There may occasionally be a thin layer of sticky granular material on the bottom of the bucket. Do not scrape this material into the hopper as it can cause problems with the pump check balls. Once the hopper is filled, the HRC® can be recirculated through the pump for approximately one hopper volume to create a uniform consistency. Do not overcirculate or add any type of liquids to decrease the viscosity of the material as this will adversely affect HRC® longevity.

Even when heated to the recommended temperature, HRC® remains viscous enough to warrant using a high-pressure hose and coupler with a relatively large ID. Geoprobe recommends one of the Grout Hose / Coupler Assemblies (P/N 12580, 13900, or 16888) described earlier in this document. These assemblies carry a minimum ID of 0.625 inches which matches the ID of both 1.25- and 1.5-inch Geoprobe® probe rods.

The MSDS for HRC® states that "One should anticipate the potential for eye irritation and skin irritation with large scale exposure or in sensitive individuals". In most cases, contact with HRC® will be more of an annoyance than a health concern. HRC® is an extremely sticky material that requires hot soapy water and lots of scrubbing to remove from the skin. Cold water is basically ineffective. Pump parts and tooling are best cleaned with the hot high-pressure water from a steam cleaner.

Category: Bioremediation

Product: Microbial Products

- Two-part injection - microbes and nutrients
  - Apply microbes during advancement - nutrients upon retraction
- Part 1: Blend of living microbes specifically formulated for site conditions
  - Naturally occurring bacteria isolated and grown for specific application
  - Facultative anaerobes - can survive aerobic and anaerobic conditions
  - Formulations available for fuel hydrocarbons, chlorinated solvents, PCBs
  - Material has appearance of "pond water" - low viscosity
  - Inject microbes without dilution (as shipped)
- Part 2: Proprietary blend of nutrients maximizes performance of microbes
  - Vtiamins, trace minerals, and specialized nutrients
  - Nutrient solution mixed in field - 1 gal of nutrients (as shipped) diluted to 55 gal before application
- Injected at 1:4 volume (microbes:nutrients)

Source: Micro-Bac International (www.micro-bac.com)

Microbial products approach remediation from a different direction than ORC® and HRC® injection. ORC and HRC® are applied to a contaminated site in order to enhance bioremediation by indigenous microbes. They accomplish this by providing oxygen or hydrogen which are generally the limiting nutrients for microbial growth in areas of high contamination. The result is a more healthy, active microbe population and an increased level of natural attenuation.

Microbial products contain naturally occurring microorganisms (generally bacteria) that have been found to flourish in the presence of certain contaminants. Microbes are selected for their ability to breakdown specific compounds and are then "grown" for application at contaminated sites. Microbial products enhance natural attentuation by establishing microorganisms that preferentially utilize the target contaminants in their metabolic processes or improve contaminant reduction as a result of materials released as by-products of their biological activities.

Facultative anaerobes are selected for microbial products to ensure their survival during aerobic/anaerobic cycling which may seriously limit the population of indigenous microbes.

After application of the microbes, a nutrient solution is injected into the subsurface. This provides a mix of vitamins, minerals, and other specialized nutrients that help “jumpstart” bacteria growth and aid in acclimation to the new environment. Injection often consists of a top-down application of microbes followed by a bottom-up application of nutrients.

The low viscosity of the microbial and nutrient solutions makes them easy to pump with Geoprobe® piston and diaphragm pumps. Centrifugal pumps should not be used as the high shear conditions and cavitation within the pump will harm the microorganisms. Microbes can easily survive the maximum 1500 psi pressure limit of Geoprobe® grout and injection machines.

Important Points to Remember When Injecting Remediation Materials

- Wear the appropriate safety gear.
- Evaluate site lithology along with contaminant location, concentration, and speciation before implementing an injection remediation plan.
- Select pumps with appropriate flow rates for the volume of material to be injected.
- Make sure pump(s), tubing, and tooling are compatible with the pumped fluid.
- Elevate supply tanks above the DP800 pump inlet to prevent cavitation.
- Always utilize O-rings at every probe rod joint.
- Lubricate O-rings before threading probe rods together.
- Lubricate O-rings before assembling T-valves for the GS500, GS1000 and GS2000 machines.
- Be careful to not pinch or kink injection hoses or tubing.
- Clean the pump and auxiliary equipment as soon as pumping is complete.
- Use a pre-probe above the injection point if necessary to prevent material from traveling up the bore hole.
- Select tool string components, such as points, pre-probes, and probe rods, so that the outer diameter combinations prevent blow by.
- Relieve fluid pressure within the tool string before disconnecting the injection hose from the tool string or pump.

Common Injection Problems and Mistakes

Several mistakes and problems that may be encountered with materials injection are listed below.

Problem: Inadequate seal between soil and tool string (leakage at ground surface).
Cause (1): Incorrect sizing of drive point - point OD is larger than probe rod OD.
Solution: Use 1.1-inch Expendable Drive Points (AT14) when possible or 1.1-inch OD Threaded Drive Point (AT142B) with adapter to appropriate probe rod.

Cause (2): Loose soil or high injection pressures require a tighter seal with soil above leading end of rod string.
Solution: Use 1.5-inch x 36-inch Hollow Preprobe (17772) above injection point or expendable point holder.

Problem: Excessive pressure loss (backpressure) through tool string.
Cause (1): Utilizing older (GS1254) Grout Pull Cap which has a restrictive minimum ID less than 1/4 inches.
Solution: Switch to an Injection Pull Cap (16697 or 16698).

Cause (2): Attempting to inject a high viscosity material with standard grout accessories.
Solution: Utilize Grout Hose / Coupler Assembly (12580, 13900, or 16888) and rod grip pull system.

Cause (3): Attempting to inject HRC® at ambient temperature.
Solution: Heat HRC in hot water bath until measured temperature reaches approximately 130-170°F (54-77°C).

Problem: Pump piston(s) cycle but do not build pressure or level of material in hopper does not go down.
Cause (1): Valve tee improperly assembled or check balls ommitted during assembly.
Solution: Reassemble following exploded view sticker on pump or procedure in Owner's Manual.

Cause (2): Pump was not cleaned properly following previous operation.
Solution: Disassemble pump and clean valve tee, check balls, and check ball seats. Replace check balls and seats if required due to presence of corrosion or residual material.

Cause (3): Granular material from bottom of HRC® bucket caused sticking check valves.
Solution: Disassemble pump and clean valve tee, check balls, and seats. Do not scrape granular material from bottom of HRC® bucket into pump hopper.

Problem: Excessive leakage from pump cylinder drain hole.
Cause (1): Cup seal(s) are worn from normal use.
Solution: Replace with new cup seal(s).

Cause (2): Cup seal(s) are incompatible with injection material and have failed.
Solution: Replace with new cup seal(s) made from compatible material. May need to switch to a different pump is compatible seals are not available.