LEGACY PARKWAY
SEGMENT 1

INSTRUMENTATION SUBMITTAL
AND
OPERATION AND MAINTENCE MANUALS
SUBMITTAL NO. CEI-001349-01

PREPARED FOR:
A&W HIGHWAY CONTRACTORS JV SEG 1
3737 WEST 2100 SOUTH
WEST VALLEY CITY, UT 84120

PREPARED BY:
COLORADO ENGINEERING AND INSTRUMENTATION
12860 WEST CEDAR DR. SUITE 208
LAKEWOOD, CO. 80228
DECEMBER 1, 2006

LEGACY PARKWAY
SEGMENT 1
INSTRUMENTATION SUBMITTALS
OPERATION AND MAINTENCE
MANUALS

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COMPANY OVERVIEW

Colorado Engineering and Instrumentation, Inc. (CEI) is dedicated to providing high quality, responsive and economical service to our clients. The firm is structured to deliver superior work at competitive prices of a project in order to produce cost effective practical solutions for our clients. This team effort gets fast-track projects completed on time and within budget.

CEI was established in 1986 to support field projects in the engineering and scientific areas. In the twenty (20) years since incorporation, we have successfully completed over 100 projects for more than 50 clients. Our clientele includes mining companies; hazardous waste disposal facilities; utilities; local, state, and federal agencies; and consulting engineering firms.

Headquartered in Lakewood, Colorado, CEI maintains a professional group of geotechnical, civil, mining and environmental engineers and specialists. Our specialists and technical personnel are experienced and trained in a full range of instrumentation for engineering, mining, environmental, and civil application. The list bellow illustrates a sampling of the wide scope of professional and technical services and the various products available from CEI.

- Environmental Engineering
- Geotechnical Engineering
- Geotechnical Scientific Instrumentation
- Engineering and Scientific Field Support

CEI is a small disadvantaged business (SDB) concern as defined in the Small Business Act. The corporation is 8a certified with the Small Business Administration and has DBE/MBE certifications with the State of Colorado, City and County of Denver, City of Los Angeles, State of Arizona, State of Massachusetts, and State of Utah.

CEI is experienced in all types of dams including rock fill, earth, RCC, concrete, and Lock and Dams.

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Instrumentation, Inc.
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Foundation monitoring for excavations.

Tunnel stabilization and monitoring.

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EXCELLENCE IN WORK EXPERIENCE

Colorado Engineering and Instrumentation, Inc. (CEI) is a Native American-Denver based firm headquartered in Lakewood, Colorado. Since our inception in 1986, CEI has provided services in the following areas:

Rock and Soil Instrumentation:

- Vibrating Wire Pressure Transducers and Temperature Sensors
- Thermocouples
- Tie-Back Load Cells
- Total Pressure Cells
- Strain Gages – Weldable Embedment
- Inclinometer Systems
- Settlement Sensors and Systems
- Concrete Stress Cells
- Tape Extensometers
- Borehole Extensometers

Water Level Monitoring and Sampling Systems:

- Remote Data Acquisition Systems (Multi or Single Channel)
- Submersible Pressure Sensor
- Portable Pumping Test Units
- Underground Storage Tank Leak Detection
- Dedicated Sampling System Design

Mine and Tailings Pond Instrumentation:

- Electro - Conductive Systems
- Data Acquisition for Remote Monitoring
- Pneumatic and Vibrating Wire Pressure Transducers
- Settlement Points, Plates, Targets, Etc.
- Standpipe and Water Monitoring Piezometers

Roadways, Railways, Waterways, and Tunnels:

- Load Cells – High and Low Pressure
- Extensometers – Borehole
- Tiltmeters
- Survey Monuments and Targets
- Cable Trays and Raceways
- Data Acquisition – Telephone, Satellite, and Radio
- Piezometers – Standpipe, Vibrating Wire, Pneumatic, Etc.

CUSTOMIZED MATERIALS FOR YOUR NEEDS

Colorado Engineering and Instrumentation, Inc. (CEI) is a proven manufacture and supplier of monitoring wells completion products. By providing custom fabricated PVC products such as flush threaded casing and screens, protective covers, and miscellaneous PVC adapters CEI has demonstrated it's versatility in meeting the needs for environmental monitoring. The following items are provided for your specific needs.

Sample of the ASTM Threads

Flush Threaded Casing:

- PVC
- Stainless
- Teflon
- Fiberglass

PVC Well Screens:

- PVC Pipe – ¾" through 6"
- Slot Spacing – 1/8", 3/26", ¼", and Larger
- Slot Widths - .010" through .250"
- Custom Slotting over Specified Intervals

Sample of the Well Products CEI carries.

Well Protection:

- Watertight Flush Surface Covers with Tamper Deterrent Bolts
- Non-watertight Flush Mounted Covers
- Locking Steel with Well Covers
- Master Locks (Keyed Alike)

Sample of the Well Protection CEI carries.

Well Products:

- Silica Sand – 8/12, 10/20, 20/40, 6/9
- Bentonite
    - Pellets – ¼", 3/8", ½"
    - Tablets – 3/8"
    - Granular
    - Grout for High Efficiency Seal
- Centralizers for All Diameter Pipe
- Porous Stone Filters
- Porous Plastic Filters

Monitoring Well Materials:

- Flush Threaded Caps and Plugs
- Slip Caps and Plugs
- Well Points
- Threaded Adaptors
- Couplings
- Submersible Pumps
- 2" Diameter Cycling Pumps

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REMEDIATION EXPERIENCE

Environmental and Geotechnical Engineering Services

Colorado Engineering and Instrumentation, Inc. (CEI) provides geotechnical field support services to mining, natural resources, and land reclamation engineering projects. CEI also provides concept design, fabrication, installation, and maintenance of instrumentation and monitoring system to the engineering, environmental and a remedial design capability in environmental and restoration of mining wastes, soils and groundwater, and decontamination and decommissioning of facilities.

Sister Bar Installation

CEI employs multi-disciplinary engineering and technical staff who support industrial and government clientele who can provide engineering and specific services in the areas of environmental assessment, construction, mining, oil and gas, and in environmental, safety, and health including, OSHA/MSHA Training.

Geotechnical Engineering

CEI provides geotechnical engineering studies of physical and strength properties for in-situ and disturbed materials. These studies are the basis for the design for structural foundations on civil projects. Projects range from one story dwellings to multi-story commercial structures, reservoir impoundments, regulatory mandated landfill designs and closure, and for hard and soft rock mining. CEI can provide the management and oversight for geotechnical site assessment, field exploration projects and data analysis and interpretation.

Pulling Cable

Geotechnical Instrumentation

CEI has specialized in geotechnical instrumentation since 1986. We have served mining, dam construction, tunnel, hazardous waste, and waterway industries. With out highly trained field personnel we are a leader in field services. We are fully qualified in the installation of:

- Vibrating Wire Transducers
- Vibrating Wire Piezometers
- Pneumatic Piezometers
- Stand Pipe Piezometers
- Inclinometer Systems
- Settlement Monitors
- Settlement Plates
- String Motion Recorders
- Data Acquisition System
- Satellite Telemetry
- Weirs
- Flow Meters
- Total Pressure Cells
- Conductivity Sensors
- Crackmeters
- Strain Gauges
- Extensometers
- Movement Monuments
- Load Cells
- Thermocouples
- Thermistors
- Tilt Meters
- Flumes
- Survey Targets

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CEI has the capability to design and manufacture custom instrumentation and in our shop located in Lakewood, Colorado.

Engineering and Scientific Field Support

Construction is an integral part of civil projects, environmental restoration, land reclamation and facility upgrade and remediation. CEI can provide professional and qualified engineering technician support in the conduct of small or large scale projects. Staff can oversee or participate in the conduct for activities that include landfill construction, surface and groundwater testing, and sampling, chain of custody, analytical laboratory shipping, hazardous site investigations/remediation support, facility assessments and compliance technicians experienced in regulatory compliance, standard operating procedures, construction standards and reporting and maintaining schedule. All CEI staff are certified and trained in health and safety procedures.

Concrete Core Drilling

Project Experience

CEI performed remediation services on the following projects:

*SEE SHEETS THAT FOLLOW

Joint Meter Installation

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Colorado Engineering & Instrumentation, Inc
Project Summary

	Project Location (State)	Data Acquisition Systems	Inclinometer Systems	Total Pressure Cells	Settlement Monitors	Movement Monitors	Weirs	Extensometers	Vibrating Wire Piezometers	Strain Gages	Stand Pipe Piezometers	Pneumatic Piezometers	Strong Motion Recorders	Load Cells	Settlement Plates	Thermistors/Thermocouples	QA/QC Services	Tiltmeters	Leek Detection Systems	Force Transducers	Flow Recorders
Wood Gulch Dam	NV								X							X					
Eagle Mine	CO										X	X			X						
Yamcola Dam	CO	X							X							X					
Taylor Draw Dam	CO								X							X					
Quail Creek Dam	UT											X				X					
Mclaughlin Tailings Mine	CA								X		X					X	X				
Gibrlater Dam	CA					X	X		X		X	X				X					
Deer Flats Dam	ID						X		X							X					
New Wadell Dam	AZ						X														
Theodore Roosevelt Dam	AZ	X	X		X	X		X	X				X	X		X					
Winfield Locks & Dam	WV	X	X		X	X					X					X		X			
Siegrist Dam	PA	X				X			X		X	X				X					
Little Rock Dam	CA				X				X				X			X					
Rischard Dam	CO	X			X	X			X		X							X			
Coolidge Dam	AZ	X						X													
Lake Allen Henry Dam	TX		X		X	X						X									
Grouse Creek Mine	ID		X		X	X			X		X					X					
Cripple Creek Mine	CO								X												
Fish Creek Reservoir	CO						X		X		X										
Barrick Tailings Disposal	NV								X							X			X		
Maggie Creek Dam	NV				X	X						X									
Eagle Mine	CO				X							X									
Hudson River II Dam	GA											X									
Steinker Dam	UT					X	X														
Colorado Department of Transportation	CO		X							X					X						
Barrick Gold Strike	NV	X							X										X		
Mona Dam	UT	X				X			X												
Gross Dam	CO	X							X												

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Bartlett Dam	AZ					X			X												
Dworshak Dam	ID	X				X	X		X												
Toker Dam (Africa)						X			X							X					
McKay Dam	OR					X										X					
Tie Hack Dam	WY							X	X												
Middle Fork Dam	CO															X					
Barker Dam	CO											X									
Rob Roy Dam	WY										X										
Climax Molybdenum Mine Tailings Dam	CO								X												
Thompson Creek Mine	ID	X	X		X						X	X									
Sibutad Mine (Philippines)																	X				
Lutheran Hospital	CO																X				
Ghan Corp	CO																X				
U.S. Air Force	CO																X				
Omni Custom Builders	CO																X				
Coeur Rochester Mine	NV																X				
Western Waste Disposal	NV																X				
Corona County Landfill	CA																X				
Tambo Mine (Chile)																	X				
St. Joe State Park Dam	MO																X				
Bristle Cone & Pinion Canyon Dam	CO				X						X										
Ridgeway Dam	CO	X			X		X	X	X			X		X							
Rocky Flats Nuclear Plant	CO	X																			
Sleeper Mine	NV	X																	X		
Jackson Lake Dam	WY	X	X			X	X		X						X	X					
Copperstone Mine	AZ								X												
Senac Dam	CO		X			X	X		X		X		X			X					
Navajo Dam	NM						X		X												

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Cososseum Mine	CA								X		X										
Stagecoach Dam	CO		X				X		X							X					
Headgate Rock Power Plant	AZ	X	X						X		X					X		X			
Promatory (Residential)	CO										X										
American Association of RR	CO							X													
Elk Creek Dam	OR		X					X	X												
Mount St. Helens Dam	WA							X													
Big Springs Mine	NV								X							X					
North Fork Dike Dam	WY								X							X					
Grizzley Gulch Dam	SD								X		X	X									
Lake Darling Dam	ND							X	X			X	X			X					
Jim Bridger Power Plant	WY		X						X		X	X				X					
Cumberland Gap Tunnel	KY							X		X	X					X					
White Pine Mine	NV								X							X					
Cottonwood Dam	NM		X																		
Davis Creek Dam	NE		X	X	X		X		X	X					X	X					
Diamond Creek Dam	WY		X		X				X						X	X					
Jordanelle Dam	UT	X	X				X	X	X					X		X					
Long Park Dam	UT				X				X												X
Mona Dam	UT								X												
Otter Creek	UT								X												
Kennecott Mine	UT	X	X						X												
Cortez Mine	NV								X												
Robinson Mine	NV								X												
Clear Lake	CA	X							X							X					
Judy Reservoir	WA						X		X											X	
East Boulder Mine	MO								X												
Still Water Mine	MO								X												

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High Savery	WY	X	X		X				X							X					
Pueblo Dam	CO								X							X					
Nixon Power Plant	CO								X												
Mason Dam	CO								X		X										
Beaver Brook	CO									X	X										
LaHara Lake	NM	X							X												
Ambrosia Lake	NM		X						X												
Twin Buttes	TX								X												
Wesley Seale	TX	X	X					X	X		X							X			
Price Freeway	AZ								X												
Fortune Reservoir	CO		X				X		X												
Rio-Salado	AZ	X							X												
Montgomery Point	AR		X						X		X										
Castle Rock	CO	X	X	X	X																
Braddock Lock and Dam	PA	X	X						X	X				X		X					
Hunting Run	VA	X					X		X											X	
Randleman	NC	X					X		X							X	X				
Pickle Jar	CO								X												
Magic Mountain	CO					X					X										
Legacy Parkway	UT	X	X	X	X				X		X			X	X						
Wolf Creek	CO	X	X	X				X	X												
Cougar Dam	OR	X							X												
Big Haynes	GA				X								X								
Elmer Thomas	OK								X							X					
Commanche	OK								X												
Tup-Pete	MO	X							X												
Barker Dam	CO	X							X												
Stewart Mountain	AZ													X							

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Jackson Lake	WY	X	X			X			X				X								
Watonburg Power Paint	CO										X								X		
McDonald Dam	MO								X												
Middle Fork	CO								X												
Hiway A16	CA		X						X												
Black Bird Mine	ID	X							X												
Numount Gold Tailings #1	NV	X																	X		
Numont Gold Tailings #2	NV	X																	X		
Ivanhoe Gold	NV																		X		
Twin Creek	NV								X												
Rabit Creek	NV								X												
New Concept	NV								X												
Sleeper Mine	NV	X																	X		
Louisville	CO										X										
Barton Mine	NV								X												
Cottonwood	NM		X																		
Big Springs	NV								X												
Coeur Rochester	NV																X				
Copperstone	AZ								X												
Colliseum	CA								X												
Hollister Mine	NV																		X		
Climax	CO								X												
Twin Lakes	CO										X										

Education:

B.A., Business Administration

A.A., Civil Engineering

Special Training:

8 Hours Annual Renewal Hazardous Waste Operations, May 1989-1998

40 Hour Hazardous Waste Operations Geotechnical Instrumentation – Federal Highway Administration, May 1988

Experience Summary

Colorado Engineering and Instrumentation, Inc. (CEI), Lakewood, Colorado, January 1986 – Present. Manager/Director – Responsible for company control and marketing. Directly responsible for instrumentation subcontracting and consulting.

Geotechnical Engineering & Mining Services, 1981 – 1986. Project Coordinator – As project coordinator, initiated all aspects of testing, drilling and instrumentation of piezometers (standpipe, pneumatic, and electronic), inclinometers, and various types of extensometers. Projects: long wall, mines, tailings dams, tunnels, airports, interstate highways, and earth embankments. Additional duties include training customer personnel.

Terrametrics, Golden, Colorado, 1978 – 1981. Senior Instrumentation Specialist – Field – level responsibilities included installing, servicing and client training in operation of geotechnical instruments. Worked with design and layout of various types of instrumentation used in monitoring pore water pressure, rock and soil movement in waterways, tunnels, earth and rock – fill dams, and railroads. Projects included Tom Big Bee Waterway, Grayrocks Dam and Power Plant and Stroncha Springs Dam. Typical instruments were inclinometers, deflectometers, load cells, flat jacks, extensometers (1 to 8 point), piezometers (stand-pipe, pneumatic, and electronic) and other Terrametrics instruments.

U.S. Bureau of Reclamation, Denver, Colorado, 1977-1978. Driller/Instrumentation Specialist – Performed rock drilling and installed piezometers, multiple borehole extensometers, rock bolt load cells, convergence meters, and tape extensometers. Also performed uniaxial flat jack test. Projects: Eisenhower Tunnel, Colorado (Colorado Department of Highways).

Colorado Signal Company, Denver, Colorado, 1976 – 1977. Utility Groundsman – Traffic-Control Systems involving design of traffic control loops and installation of overhead and underground wiring for traffic controllers and lights. Responsible for coordination with city, state, and federal personnel plus keeping track of man hours, and efficiency of records.

H. Kent Peter
Senior Project Manager

Education:

NWKAVTS, Civil Engineering, Kansas, 1970

Arapahoe Community College, Denver, 1980

Certification:

OSHA (29 CFR 1910.120) Hazardous Materials Training

MSHA (30 CFR Part 48) Safety and Health Training

Radiation Safety Training

Publications:

Geosynthetics Line Canyon Landfill, Geotechnical Fabrics report, March/April 1990

Experience Summary

Colorado Engineering & Instrumentation, Inc. (CEI), April 1999 – Present. Senior Project Manager – Management of field projects which include; site investigations, installation of geotechnical instrumentation and construction quality assurance/quality control programs. Other duties include business development, project documentation and report submittals.

Steffen Robertson and Kirsten, (U.S.), Inc., 1985 – March 1999. Division Head, Field Services – Management of preliminary site investigations, construction inspection, and quality assurance. Responsibilities include direction of field engineers and technicians, technical liaison with client and design engineers, collation of quality assurance and construction inspection documentation, and preparation of progress and license related construction reports for mining projects throughout the United States, as well as major solid waste landfill projects complying with the Resource Conservation and Recovery Act (RCRA) Subtitle D. Project components included large engineered earthen and rockfill embankments, clay liners/caps; drainage materials; concrete structures and geosynthetics/geocomposite systems.

Steffen Robertson and Kirsten, (U.S.), Inc., McLaughlin Gold Mine, Lake, Napa and Yolo Counties, California, 1983 – 1985. Field Engineer – CQA manager for the construction of all related earthen, rockfill dams, sedimentation facilities, tailings embankment, and water storage dams. The project included eight sediment dams, a large tailings dam and two water storage dams. Dealt directly with the California Division for Safety of Dams. The project also included the inspection and testing of all structural concrete placed, which included the mill foundations, etc. CQA activities also included the inspection and testing of approximately 20 miles of paved access roads. All testing for the roads was per CAL-TRAN specifications. At the peak of construction, approximately thirty inspectors were required to cover the work. Three complete mobile laboratories were staffed double-shift to comply with the strictest of specification control.

Steffen Roberson and Kirsten, (U.S.), Inc., Thompson Creek Mine, Challis, Idaho, 1981 – 1983. Staff and Field Engineer – Manager of construction inspection and quality control personnel for the construction of several sediment dams, starter embankment for the 700 – ft. high tailings dam, seepage return dam, foundation instrumentation: Piezometers, settlement sensors, and inclinometers. Supervised the installation of other instrumentation and post construction monitoring activities. Prepared daily, weekly, monthly and final reports for all related construction activities, with as-built drawings included. Acted in liaison with the owner and regulatory agencies involved with the project.

Thomas E. Summerlee & Associates, 1975 – 1981. Soil Engineering Technician and Manager – Supervision of technical personnel, subsurface investigations, laboratory testing, construction inspection, and preparation of soil and foundation reports. Major projects included soils investigations for Mt. Tolman Mine, Washington, construction inspection of earthworks for Mt. Taylor Mine, New Mexico; and construction and quality assurance testing for airstrip runways for the Canadian Artic, ADC DEWline Project.

Fox and Associates of Colorado, Inc., Wheat Ridge Colorado, 1971 – 1974. – Coordinated construction materials testing services and review subsequent test data for compliance with project plans and specifications for subdivisions, commercial developments and industrial complexes. Duties included marketing, business development, proposal and report preparation and invoicing. Responsibilities also included training, supervision and scheduling of field and laboratory technicians.

Project Experience

- **Escondida Oxide Project, Northern Chile, Andes Mountains.** Managed CQA team in the construction of a large copper head leach pad. The project components consisted of approximately 360,000 cubic meters of compacted subgrade, 1.2 million square meters of 60 mil HDPE liners, 600,000 cubic meters of protective cover and numerous solution containment ponds. Several ponds were double lined with leak detection systems. All testing of earthworks and synthetic materials was performed onsite. At the peak of construction, eight CQA monitors were required, each shift on a double shift schedule.

- **Batu Hijau Project, Sumbawa Island, Indonesia.** Project field manager during a geotechnical investigation of the infrastructure for a world class copper-gold mine being developed by Newmont/Sumitomo and Indonesian Government. The investigation included soils and rock drilling, test pitting and geophysical work. The project components consisted of the Crusher, Concentrator, Mine Maintenance Area, Overland Conveyor, Access road, Power Plant, Transmission Line and a new town to be built for the mine.

- **St. Joe State Park, Park Hill, Missouri.** Performed preliminary and final geotechnical drilling programs, borrow investigations, installation and monitoring of instrumentation for the construction of a large embankment to stabilize an existing dam. Initiated the CQA program to monitor and document the construction of the embankment.

- **Kennecott-Ridgeway Mine, Fairfield County, South Carolina.** Site selection, preliminary and final site investigations for the mine facilities, installation and sampling of monitoring wells, sampling and testing of surface waters, supervised SRK's CQA team in the construction of Phase 1, 2, 3 and 4 of the tailings facility which consists of approximately 15 million square feet of HDPE liner, 564,000 cubic yards of compacted soil liner. Assisted in design of closure plan, surface water management plan and initiated field construction of surface water control systems and waste encapsulation facilities.

- **San Luis Mine, Costilla County, Colorado.** Site selection, preliminary and final site investigations for mine facilities, prepared construction bid documents, specifications and assisted in the construction management for the project. Reviewed all CQA programs for the construction of the tailings facilities which included 160,000 cubic yards of soil liner, 1.5 million cubic yards of engineered embankments and 4.3 million square feet of VLDPE liner.

- **Puente Hills Canyon No. 9 Landfill, Los Angeles County, California.** Provided CQA management and engineering services for the County Sanitation Districts of Los Angeles County's gas-to-energy disposal facility-Los Angeles' first composite lining system, which included utilization of canyon walls. Composite materials consisted of 13.8 million square feet of HDPE geosynthetics membrane and 15,000 cubic yards of clay liner. The construction included an underdrain system, leachate collection recovery system (LCRS) and a gas delivery header piping system for power conversion.

- **Spadra Landfill, Phases 1 and 2, Los Angeles County, California.** Provided CQA management and engineering services to the County Sanitation District No.2 of Los Angeles County's Spadra Landfill composite liner system, Phase 1 and 2. Composite materials consisted of 32,000 cubic yards of clay liner with an overlay of 1,207,000 square feet of 80-mil textured high-density polyethylene geomembrane.

Canyon slopes consisted of three-tier 2.5:1 side slopes with a composite of 12-ounce geotextile, 80-mil smooth geomembrane and 10-ounce geotextile. Each layer consisted of 480,000 square feet. The construction included an underdrain piping system and a leachate collection recovery system (LCRS).

- **Quebrada Blanca, Northern Chile (Region 1) Andes Mountains.** Provided CQA management of the 1.5 million square meter leach pad for this large copper mine. Assisted in the design of the solution recovery system. Provided on site review and management of the installation of the solution recovery system. Supervised the installation of instrumentation to monitor solutions within the active heap.

- **Illinois Creek, Alaska (near Galena, Alaska) (Summer 1995).** Performed hydro geologic testing within the ore body, installed piezometers, performed pump tests and collected baseline water quality samples. Assisted in site selection and design of the proposed heap leach pad. (Spring-Summer 1996). Initiated CQA program for the construction of USMX's new gold mine. The CQA program consisted of inspection, testing and documentation of all earthworks, concrete and synthetic liners installed on the project.

- **Thunder Mountain, River of No Return Wilderness, Idaho.** Supervised the installation of eleven new ground water monitoring wells for the project. Obtained baseline quality samples for the new monitoring wells. Designed proposed dedicated monitoring well samplers for the site.

- **Grassy Mountain Cell No. 6 Tooley County, Utah.** Provided CQA for USPCI's new Hazardous Materials Landfill. Work items included 500,000 cubic yards of structural embankment fill, 90,000 cubic yards of construction reports certifying the facility.

Education:

High School Diploma,
Payson High School,
1990

Mesa Community College

University of Arizona

Arapahoe Community College

Special Training:

24 Hour Mine Safety,
April 1996

8 Hours Annual Renewal
Hazardous Waste
Operations, March 1996-1999

40 Hours Hazardous Waste
Operations, July 1995

Dam Scaling Procedures,
May 1994

Certified Forklift Operator

Experience Summary

Mr. Edwardson Has more than 10 years experience in the Geotechnical Engineering and instrumentation field supervising technical personnel, subsurface investigations, laboratory testing, construction inspection, and preparation of soil and foundation reports. He has managed the installation and inspection of various types of test equipment for monitoring the safety of mines, tunnels, roadways, and dam/reservoir projects. Mr. Edwardson is skilled in installation, calibration, operation, and the monitoring of testing equipment used to determine water pressures, temperatures, water flows, reservoir level, and slope stability. He has extensive supervising; compiling instrument data; and preparing daily, weekly, monthly, and final project reports of all related construction activities, with as-built drawings included.

Mr. Edwardson has also coordinated operations with other project managers, engineers, and prime contractors. He has operated various types of heavy equipment, including front-end loaders, excavators, dozers, compaction equipment, and forklifts. He is proficient in Windows, Work Perfect, Excel, ProComm and Managers computer software programs. Mr. Edwardson received the leadership and Outstanding Performance Award form the Spring Fire Academy.

Colorado Engineering and Instrumentation, Inc. (CEI), Lakewood, Colorado, August 1993 – Present. Project Manager/Instrumentation Specialist – Supervised the construction of all related earthen, rockfill, RCC, concrete dams, sedimentation facilities, mine tailing embankments, and storage dams. Estimates and reviews subsequent test data for compliance with project plans and specifications for various projects. Responsible for the installation of instrumentation for pre and post construction monitoring, acquiring, calibrating, installing, and monitoring various types of testing instruments at a variety of project locations throughout the United States. Mr. Edwardson schedules operations, compiles data, and prepared final construction reports for prime contractors and government agencies.

Corporate Safety Solutions, Inc., Littleton, Colorado, August 1999 – March 2000. Operations inspector – Supervised and directed the installation of new water and sewer mains for South Gate water District. Reviewed project plans and specifications to insure that the construction met all of the South Gate standards. Mr. Edwardson insured crews followed safety precautions that met the OSHA standards during construction activities.

West Metro Fire Rescue, Littleton, Colorado, March 1999 – Present. Volunteer Fire Fighter.

Education:

High School Diploma.
Lakewood High School,
1988

Civil Engineering Technician,
Red Rocks Community
College, 1995

Special Training:

8 Hour, Annual Renewal
Hazardous Waste Operations,
1990 – 1998

40 Hours, Hazardous Waste
Operations, May 1988

24 Hours, Hazardous Waste
Operations, May 1988

24 Hours Mine Safety

Nuclear Gage (Troxler),
March 1996

Experience Summary

Colorado Engineering and Instrumentation, Inc. (CEI), Lakewood, Colorado, March 1990 – Present. Geotechnical Instrumentation Specialist and field QA/QC Soils Laboratory Technician –Instrumentation responsibilities include installation of vibrating wire piezometers, stand pipe piezometers, inclinometers, thermocouples, temperature sensors, crack detection meters and settlement sensors. Also includes: pneumatic instruments and installing and servicing of different data logging equipment.

Quality control field responsibilities include the inspection of poly-liners for the mining industry landfills. Also has experience to provide on site QA/QXC testing capabilities during placement of soils and has performed these tasks on several large scale earthen embankments. Has also performed nuclear density testing at various landfills, mine sites, and highways.

Laboratory responsibilities include performance of geotechnical laboratory and field test such as grain analysis, atterberg limits, moisture content dry density, specific gravity, swell consolidation test, unconfined compression test and triaxial compression test.

Assistant Field Lab Manager at Homestake "McGlaughlin" Mine.

Liner Testing/Inspection includes: QA/QC testing, peel & shear testing with tensometer, vacuum box testing, air channel testing, checking thickness with micrometer, destructive testing and non-destructive testing.

Steffen Robertson and Kirsten, 1985 – 1990. Lab Technician – Soils testing responsibilities to include sieve analysis, atterbergs, hydrometers, proctor compaction tests and moisture content samples. Responsible for inputting all data received from associated test into computer as well as graphing all finished data such as sheer tests using shear vox on soils and poly liner used for heap leach pads and ponds at various mines.

Education:

High School Diploma.
Lakewood High School, May 1998

A.A.S., Software Engineering
Westwood College of Technology, May 2004

Special Training:

8 Hour, Annual Renewal Hazardous Waste Operations, July 1999

40 Hours, Hazardous Waste Operations, July 1998

Experience Summary

Colorado Engineering and Instrumentation, Inc. (CEI), Lakewood, Colorado, April 1994 – Present. Instrumentation Specialist/IT Manager - Duties include installation of piezometers, joint meters, strain gauges, crack meters, reservoir transducers, inclinometers, thermistors, raising of riser pipes, and installation of conduits and labeling. Also responsible for calibration of various instruments, data entry into computer, supplied reports to the approval prior to installation, compiling data from various instruments. Instrumentation data collection, data processing & presentation of various projects in Colorado for Construction and Engineering Firms. IT Manager responsibilities are primarily but not limited to install/upkeep of Local Area Network and upkeep/maintain web site.

Montgomery Point Lock & Dam Coordinator – Duties included instrumentation/drilling of inclinometers, piezometers, heave points and installation program.

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Request for Geotechnical Services Inclinometer & VW Piezometer Installation

Submitted to:

Colorado Engineering & Instrumentation
12860 West Cedar Drive
Lakewood, CO 80228

Submitted by:

ConeTec, Inc.
3589 West 500 South
Suite 3
Salt Lake City, UT 84104

CONETEC

Introduction

ConeTec, Inc. provides clients in industry and government with quality environmental and geotechnical drilling, sampling and subsurface investigation services. ConeTec, Inc. was formed in 1986 to offer state-of-the-art cone penetration testing and direct-push technologies to meet the increasing demands for quality site investigation services. ConeTec provides the finest in conventional and innovative services. We deliver today's solutions.

Our services are conveniently available from ConeTec facilities in Salt Lake City, UT, with additional offices located in West Berlin, NJ, Richmond, VA, Vancouver, BC and Edmonton, AB. We have available all necessary equipment for conventional auger, mud rotary, ODEX and direct-push drilling, sampling, cone penetration testing, and subsurface assessment. Our staff, technicians and preventative maintenance program ensure reliable effective operation. Our geologists, engineers and support personnel are highly trained, experienced professionals who understand the challenges our clients face and their needs in today's economy.

For clients in business and in government, ConeTec brings together the best in human resources and technology. Our commitment to responsive, reliable and cost-effective service mean solutions, savings and peace of mind to you and your organization.

Office Locations

Rocky Mountain:

ConeTec, Inc.
3589 W. 500 South, Ste. 3
Salt Lake City, UT 84104
Tel: (801) 973-3801
Fax: (801) 973-3802

Northeast:

ConeTec, Inc.
436 Commerce Lane, Unit C
West Berlin, NJ 08091
Tel: (856) 767-8600
Fax: (856) 767-4008

Western Canada:

ConeTec Investigations, LTD
12140 Vulcan Way
Richmond, BC V6V 1J8
Tel: (604) 273-4311
Fax: (604) 273-4066

Southeast:

ConeTec, Inc.
606 Roxbury Industrial Ct.
Charles City, VA 23030
Tel: (804) 966-5696
Fax: (804) 966-5697

Central Canada:

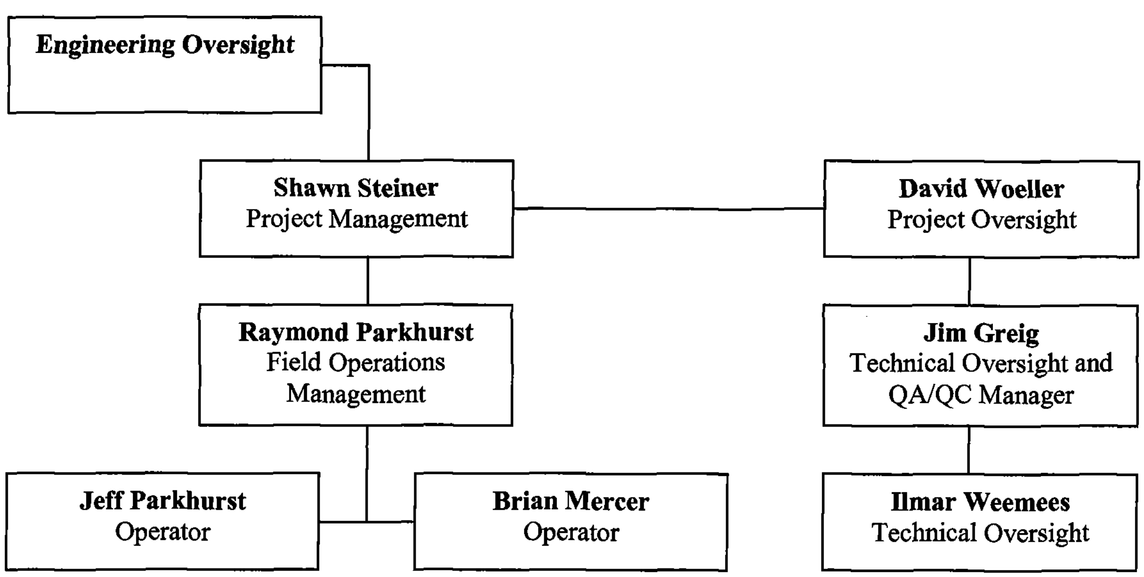
ConeTec Investigations, LTD
5603 54th Street
Edmonton, AB T6B 3G8
Tel: (780) 962-4963
Fax: (780) 960-0271

Team Organization

ConeTec specializes in performing CPT testing and other geotechnical and environmental site investigation services. All CPT testing services provided under this contract will be based from our Salt Lake City office. All field investigations are performed by specially trained geotechnical personnel and supported by experienced geotechnical engineers in order to provide high quality in situ test data. Direct supervision for all CEI projects will be provided by Mr. Shawn Steiner. Mr. Steiner has 15 years of site investigation experience and has served as ConeTec's Rocky Mountain Regional Manager for the last 9 years. Mr. Steiner can be contacted at the following:

Mr. Shawn Steiner
ConeTec, Inc.
PO Box 22082
Salt Lake City, UT 84122
Tel: (801) 973-3801
Fax: (801) 973-3802
Email: ssteiner@conetec.com

Field investigations will be performed by one of our experienced operators. Each one of our operators has at least 10 years of site investigation experience. Direct oversight and management of field activities will be performed by under the guidance of our Field Operations Manager. Project management, contracting, reporting and overall project oversight will be performed by Mr. Shawn Steiner. Overall project oversight and management will be provided by our company president, Mr. David Woeller, with quality assurance and technical assistance provide by our QA/QC manager and support team. Our project team is outlined below. Resumes for all of the key personnel are also included with this proposal



Consultant Capability

ConeTec operates a wide range of CPT equipment including, both truck mounted and track mounted CPT and auger drill rigs in our Salt Lake City office. The company is owned and operated by geotechnical engineers with diversified academic and practical backgrounds. All field investigations are performed by specially trained geotechnical personnel and supported by experienced geotechnical engineers in order to provide high quality in situ test data.

Site investigation services are typically performed as a subcontractor to the geotechnical consultant involved on the project or under direct contract with the owner of the facility.

Every investigation is performed under the direction of a project manager. The project manager is responsible for proper collection of the data and to insure that the investigation is performed in accordance with the applicable standards. Additionally, the project manager is responsible for cost control of the project, and obtaining independent review of the data prior to final submittal. Overall project quality assurance and quality control are performed by the office manager, under the direction of our president.

ConeTec has performed numerous site investigations on projects through out the world. The following table outlines some of these projects.

Project	***Purpose***	***Work Performed***
Detroit /Windsor Tunnel River Crossing	New Construction	Cone Penetration Testing
Hunts Bay Bridge - Kingston, Jamaica	Bridge/Tunnel Construction	Cone Penetration Testing
Bay Area Rapid Transit (BART) Tunnels	Seismic Retrofit	Mud Rotary Drilling , SPT Drilling, LPT Sampling, Piston Tube Sampling and Seismic Cone Penetration Testing
Webster Posey Tubes Tunnels - San Francisco, CA	Seismic Upgrade	Mud Rotary Drilling , SPT Drilling, LPT Sampling, Piston Tube Sampling and Seismic Cone Penetration Testing
Oak Street Bridge - Vancouver, BC	Seismic Upgrade	Mud Rotary Drilling & Sampling, Seismic Cone Penetration Testing
I-15 Interstate Hwy Expansion - Salt Lake City, UT	New Highway Construction	Drilling & Sampling, Seismic Cone Penetration Testing
New York City Metro Transit Authority - 2nd Avenue Subway Expansion	Underground Subway Construction	Drilling & Sampling, Seismic Cone Penetration Testing

Project	*Purpose*	*Work Performed*
Arthur Laing Bridge - Vancouver, BC	Seismic Upgrade	Mud Rotary Drilling & Sampling, Seismic Cone Penetration Testing
Legacy Highway Expansion - Salt Lake City, UT	New Highway Construction	Drilling & Sampling, Seismic Cone Penetration Testing
Port Mann Bridge - Vancouver, BC	Seismic Evaluation	Seismic Cone Penetration Testing
Nisultin River Bridge - Teslin, YT	Seismic Stability of Bridge Piers	Seismic Cone Penetration Testing
John Hart Bridge - Prince George, BC	New Bridge Construction	Seismic Cone Penetration Testing
U.S. 17 over Currituck Sound Bridge - Currituck, NC	New Bridge Construction	Cone Penetration Testing, Mud Rotary Drilling & Sampling
N.C. 12 over Oregon Inlet Bridge - Oregon Inlet, NC	New Bridge Construction	Cone Penetration Testing, Mud Rotary Drilling & Sampling
U.S. 64 over Croatan Sound Bridge - Manns Harbor, NC	New Bridge Construction	Cone Penetration Testing, Mud Rotary Drilling & Sampling
U.S. 17 over Cooper River Bridge - Charleston, SC	New Bridge Construction	Cone Penetration Testing, Mud Rotary Drilling & Sampling
USACE/SSS Railway Bridge - Aberdeen, WA	New Bridge Construction	Cone Penetration Testing
Geo Engineering - Pier 37 - Seattle, WA	New Pier Construction	Cone Penetration Testing

We do not anticipate that we will subcontract any other services in conjunction with this contract.

Equipment

ConeTec maintains a large inventory of state-of-the-art equipment to meet a wide range of environmental and geotechnical needs. Our preventative maintenance program ensures that all necessary equipment is available and operating at maximum efficiency. This commitment to quality allows us to offer the most responsive and cost-effective services. Within our Salt Lake City office we operate the following equipment:

- 25-ton Truck Mounted CPT rig
- 25-ton Track Mounted CPT rig
- Marl M-10 Truck Mounted Drill Rig
- Marl M5T Rubber Track Mounted Drill/Direct Push Rig
- Marl 2.5T Direct Push Rig
- Fraste Multi-Drill XL Rotary/ODEX Drill Rig
- Sectional drilling barges
- Portable Hydraulic Ram Set
- Portable CPT Equipment
- Various support trucks and equipment

Cone Penetration Testing Equipment

Cone penetration testing (CPT) is a process whereby subsurface soil characteristics are determined when a cone penetrometer, equipped with continuous data-logging devices is attached to a series of steel rods and driven into the subsurface using a hydraulic jack typically mounted to a truck or track based vehicle. The CPT test provides a rapid, reliable and economical means of determining soil stratigraphy, relative density, strength and hydrogeologic information. The following outlines the equipment that we anticipate would be used on this project. However additional equipment may be used depending upon the scope of the project.

- **Truck-Mounted Cone Penetration Test Rig**

  Our 25-ton truck mounted CPT rigs are capable of pushing cone penetrometers; groundwater, vapor and soil samplers; and piezometers to depths up to 300 feet, depending up subsurface conditions. This methodology rapidly provides detailed hydrogeologic profiling at an average rate of 400 to 500 feet per day. Additional ballast can be added to the rig to provide a 30-ton reaction.

  Dimensions:
  - Length: 30 feet
  - Height (driving): 13 feet
  - Height (working): 14 feet 6 inches
  - Width: 8 feet 6 inches

- **Track-Mounted Cone Penetration Test Rig**
  Our 25-ton truck mounted CPT rigs are capable of pushing cone penetrometers; groundwater, vapor and soil samplers; and piezometers to depths up to 300 feet, depending up subsurface conditions. This methodology rapidly provides detailed hydrogeologic profiling at an average rate of 400 to 500 feet per day. Additional ballast can be added to the rig to provide a 30-ton reaction.

  Dimensions:
  - Length: 25 feet
  - Height (driving): 12 feet
  - Height (working): 14 feet
  - Width: 10 feet 6 inches

- **Portable Hydraulic Ram-Set CPT Rig**
  The Ram-Set is a portable, hydraulically powered soil probe unit designed for extremely tight space conditions. The unit requires only 5 feet of vertical clearance and has a footprint of only 2 square feet. The Ram-Set can be used to obtain continuous lithologic logs with an electronic cone penetrometer. The hydraulic power unit can be stationed up to 200 feet from the Ram-set, thus eliminating exhaust from the testing area. The depth limitation of this rig in normally consolidated soil typically varies between 25 and 80 feet.

CPT testing can also be performed from a variety of other platforms and equipment. Among these options is to perform CPT testing with a drill rig. The drill rig typically has a reduced pushing capacity when compared to a dedicated CPT rig. However, the drill rigs can perform drillouts through consolidated materials to permit access to underlying softer soils.

Drilling Equipment
In addition to our CPT rigs, ConeTec, Inc. has a variety of hollow-stem auger and rotary drill rigs available from small limited-access drill rigs to large truck-mounted drill rigs. We own and operate the following equipment:

- **Marl M-10 Hollow-Stem-Auger Drill Rig**
  These truck-mounted, high-torque rigs are designed for deep soil sampling and installing monitoring wells where large augers are required.

  Dimensions:
  - Length: 29 feet
  - Height (mast down): 12 feet 6 inches
  - Height (mast up): 31 feet
  - Width: 8 feet, Weight: 30,000 pounds, Tire Pressure: 75 psi

- **Marl M5T Limited Access Hollow-Stem-Auger Drill Rig**
  These powerful hydraulic rigs are used at locations of limited access and low overhead clearance. They are mounted on rubber tracks. The M5T can obtain excellent soil, vapor and water samples using conventional hollow-stem augers or direct push technologies.

  Dimensions: - Length: 10 feet 9 inches
  - Height (mast down): 8 feet 2 inches
  - Height (mast up): 12 feet, 8 inches (need 13' 1" to mast up)
  - Width: 5 feet 1 inch to 6 feet 1 inch (depending on rig)
  - Weight: 8,500 pounds, track pressure: 6 psi

- **Fraste Multi-Drill XL Rotary/ODEX Drill Rig**
  This powerful hydraulic drill rig can drill in consolidated soils using mud rotary or ODEX drilling techniques. Additionally, the rig can perform rock coring. This rig is ideal for performing geotechnical explorations up to depths of 1,000 feet.

  Dimensions: - Length: 20 feet
  - Height (mast down): 9 feet
  - Height (mast up): 25 feet
  - Width: 7 feet
  - Weight: 15,000 pounds, track pressure: 8 psi

Testing Procedures and Reporting

All CPT testing is performed in accordance with ASTM Standard D-5778 using a 20-ton capacity cone with a tip of 15-cm^2 and a friction sleeve area of 225-cm^2. Additional size cones and modules are available depending upon the scope of the project. All cone penetrometers are calibrated on a regular basis to ANSI traceable standards.

ConeTec, Inc. provides reports in both paper and digital formats. The reports include all CPT plots, pore pressure dissipation plots, seismic CPT plots and CPT interpretations. All plots are presented in color with various colors corresponding to the particular soil classification zones. Reports can be presented in black and white if specifically requested. In addition to the hard copy of the report, the CPT plots, PPD plots and seismic CPT plots are presented digitally in PDF format. Typically, the CPT plots present the tip stress (q_t), sleeve friction (f_s), dynamic pore pressure (u_d), friction ration (R_f) and the SBT soil classification. Additional parameters can be plotted upon request. Included with the report are digital files of the CPT data, PPD data and the CPT interpretations. These files are provided in ASCII text format and Excel format. Examples of our CPT plots, pore pressure dissipation plots and CPT interpretations are appended to this proposal.

Testing Procedures and Reporting, Continued

CPT interpretations are based on published correlations. All software used in the data collection and data interpretation has been independently checked to confirm that results are consistent with published correlations. ConeTec's interpretation routines should be considered a calculator of current published CPT correlations and is subject to change to reflect the current state of practice. The interpreted values are not considered valid for all soil types. The interpretations are presented only as a guide for geotechnical use and should be carefully scrutinized for consideration in any geotechnical design. The equations for calculating certain interpretations are appended to this proposal.

Conclusion

ConeTec, Inc. provides clients in industry and government with quality environmental and geotechnical site investigation services. We have available all necessary equipment for cone penetration testing and geotechnical drilling services. All investigations are performed by specially trained geotechnical personnel and supported by experienced geotechnical engineers. Our engineers and support personnel are highly trained, experienced professionals who understand the challenges our clients face and their needs in today's economy. ConeTec brings together the best in human resources and technology. Our commitment to responsive, reliable and cost-effective service mean solutions, savings and peace of mind. In addition to offering high quality, cost effective site investigation services, ConeTec offers unparalleled customer support. Our highly trained technical staff has more than 100 years of combined experience. We can draw on this expertise to assist our clients. Our technical support team can work with your project team to select the best technologies to use to evaluate your site conditions. While having the right equipment to do the job is an important part of a project, it is even more important to know when to use a particular set of equipment to obtain the data you are looking for. The ConeTec staff can work with your project staff to assure that the right equipment is used to accomplish your project objectives.

CONETEC

DAVID J. WOELLER

President

SUMMARY OF EXPERIENCE:

David is a Geotechnical Engineer with over 26 years of practical experience. David completed special studies of in situ testing techniques in part fulfilment of the requirements for his M. Eng., degree at the University of British Columbia. He has specialized in the use of the cone penetrometer. During recent years he has been closely involved in the design and development of the seismic cone and the resistivity cone, as well as various types of SPT energy calibration. He has carried out numerous piezocone and seismic piezocone investigations, both commercial and research oriented. He has worked from coast to coast in both Canada and the United States, both on shore and off shore. Investigations have included foundation failures, frozen layers in a tailings dam, the character of spray ice islands, dredging studies, seismic wave studies, liquefaction potential analyses and standard geo-environmental site investigations. David has conducted numerous site investigations in Canada's artic, including designing and building specialized lightweight CPT systems for heli-transportable projects in permafrost environments.

Prior to starting ConeTec, David acquired considerable experience in geotechnical engineering and practical underground mining. He has organized and implemented a wide variety of site investigations for projects of all types from feasibility purposes to monitoring and failure studies. He has a solid background in foundation engineering obtained from extensive involvement in the development of heavy industrial plants, marine terminals, and bridges. His experience in the geotechnical aspects of mining includes tunnel design, tunnel dewatering, rock slope stabilization, rock bolting and shotcreting.

EDUCATION:

B. S. (Civil Engineering) Queen's University, 1978
M. S. (Soil Engineering) University of British Columbia, 1986

PROFESSIONAL AFFILIATIONS:

- Association of Professional Engineers, of British Columbia
- Canadian Geotechnical Society (CGS)
- Engineering Institute of Canada (EIC)
- Vancouver Geotechnical Society (VGS)

CONETEC

SHAWN STEINER

Western U.S. Regional Manager

SUMMARY OF EXPERIENCE:

Shawn is a Geotechnical Engineer with extensive experience in geotechnical and environmental field exploration. He has carried out numerous piezocone and seismic piezocone investigations. Shawn is currently the Western United States Regional Manager of ConeTec and is located Salt Lake City, Utah. Shawn brings five years of experience as a consulting engineer to the company. Shawn has managed numerous jobs such as foundation design and exploration, materials testing, roadway design and testing.

EDUCATION:

B. S. (Civil & Environmental Engineering) Utah State University, 1992

M. S. (Civil Engineering) Utah State University, 1996

PROFESSIONAL AFFILIATIONS:

- Registered Professional Engineer, State of Wyoming
- Licensed Water Well Driller, State of Utah
- Licensed Water Well Driller, State of Washington
- American Society of Civil Engineers (ASCE)
- National Groundwater Association
- Utah Groundwater Association

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RAYMOND PARKHURST

Field Operations Manager

SUMMARY OF EXPERIENCE:

Ray is a Geotechnical/Environmental Engineering Technician who has been performing site investigations for the over the last 14 years. His work with ConeTec has involved a variety of in situ testing throughout the Western United States. Prior to joining ConeTec, Ray performed geotechnical and environmental drilling using hollow-stem auger and continuous flight drilling techniques. Ray experiences also involve project management of numerous drilling exploration projects and management of a geo-environmental soils laboratory.

EDUCATION:

Coursework towards B.S. in Architectural Engineering, University of Wyoming

A.S. (Computer Science w/ Business Applications), West Nebraska Community College, 1989

PROFESSIONAL AFFILIATIONS and CERTIFICATIONS:

- Certified in 40-hr OSHA Hazardous Waste Clean-up Operations
- Certified ACI Concrete Field Testing Technician – Grade I
- Certified MSHA 24-hr Worker Class
- NICET Level II Technician

JIM GREIG

QA/QC Manager

SUMMARY OF EXPERIENCE:

Jim Greig is a Geotechnical Engineer with a background in In-Situ testing, instrument design and computer applications. At the University of British Columbia, Jim was involved in seismic piezocone and pressuremeter research. For his own research he studied the estimation of undrained strength from CPTU. More recently, Jim was the Manager of the UBC Civil Engineering Computing Lab where he gained experience in many aspects of computing and computer networks. He is proficient in various computer languages including C, BASIC, FORTRAN and 8086 assembler and is experienced in several operating systems such as DOS, UNIX, MTS and CPM. He has developed several graphical interactive programs and data acquisition routines for the University of British Columbia and several geotechnical consultants and contractors. Two such programs (CONEPLOT and CPT Interpretation) are used by various In Situ testing contractors and geotechnical consultants throughout the world.

Currently with ConeTec, Jim is involved in research and development of in situ testing equipment, as well as participating in various in situ testing site investigation programs.

EDUCATION:

M.A.Sc. (Geotechnical Engineering) University of British Columbia, 1985

B.A.Sc. (Geotechnical and Structural Engineering) University of British Columbia, 1981

PROFESSIONAL AFFILIATIONS:

- Association of Professional Engineers and Geoscientists of the Province of British Columbia

CONETEC

JEFFREY S. PARKHURST

Operator

SUMMARY OF EXPERIENCE:

Jeff is a Geotechnical/Environmental Engineering Technician who has been performing site investigations for the over the last 10 years. His work with ConeTec has involved a variety of CPT testing, drilling and sampling projects throughout the Western United States. Prior to joining ConeTec, Jeff performed geotechnical and environmental drilling and construction materials testing.

PROFESSIONAL AFFILIATIONS and CERTIFICATIONS:

- Licensed Water Well Operator, State of Utah
- 40-Hr HAZWOPER Training with Current 8-Hr Refresher
- 24-Hr MSHA Training with Current 8-Hr Refresher
- USDOE – Radiological Worker II Training

BRIAN MERCER

Operator

SUMMARY OF EXPERIENCE:

Brian is a Geotechnical/Environmental Engineering Technician who has been performing site investigations for the over the last 20 years. His work with ConeTec has involved a variety of drilling and sampling projects throughout the Western United States. Prior to joining ConeTec, Brian performed managed an environmental drilling company specializing in direct push drilling and sampling. Brian's experiences also include mineral exploration and well installation using a variety of rotary drilling equipment.

PROFESSIONAL AFFILIATIONS and CERTIFICATIONS:

- Licensed Well Driller, State of Utah
- 40-Hr HAZWOPER Training with Current 8-Hr Refresher
- 24-Hr MSHA Training with Current 8-Hr Refresher
- USDOE – Radiological Worker II Training

ConeTec

ILMAR WEEMEES

Software Developer and Geotechnical Engineer

SUMMARY OF EXPERIENCE:

Ilmar is a Software Developer and Geotechnical Engineer with over 15 years experience in the field of in situ testing. Ilmar completed his M.A.Sc. at the University of British Columbia with a specialization in the use of the CPT and RCPT. At ConeTec he has gained experience with CPT, RCPT, UVIF-CPT, GCPT, SCPT, Downhole and Crosshole Seismic Testing, and Surface Wave Seismic Testing (SASW.) Ilmar is currently involved with improvements to ConeTec's Windows Software, primarily focusing on seismic data acquisition and presentation. He is also responsible for the launch of ConeTec's new Controlled Source Surface Wave (CSWS) testing service.

EDUCATION:

M.A.Sc. (Soil Mechanics) University of British Columbia, 1990

B.A.Sc. (Geological Engineering, Applied Geophysics) University of British Columbia, 1987

PROFESSIONAL AFFILIATIONS:

- Registration as a Professional Engineer with the Association of Professional Engineers and Geoscientists of the Province of British Columbia
- Canadian Geotechnical Society (CGS)
- Vancouver Geotechnical Society (VGS)

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Colorado Engineering & Instrumentation, Inc.
12860 West Cedar Drive, Suite 208
Lakewood, Colorado 80228-1971
Phone: (303) 989-5159 Fax: (303) 980-6157

INCLINOMETER INSTALLATION PLAN

The drilling of the inclinometers will be performed by ConeTec with a Fraste Multi-Drill Rotary/ODEX Drill Rig. If the mud rotary or ODEX capabilities of this rig do not work, ConeTec will then use the Marl M-10 Hollow-Stem-Auger Drill Rig. Both of these rigs are described within the ConeTec Statement of Qualifications under Tab 2 of this submittal. All locations will be verified by the Contractor with the Owner along with the elevations. CEI will inspect the Owner provided casing and caps to ensure that nothing is damaged. If there are any pieces damaged, CEI will contact the Contractor and let them know. The hole will be drilled with a diameter no less than 6 inches, deviate from vertical no more than four percent, and to the elevation stated by the Owner. Once the hole is drilled to the correct elevation the drill steel may or may not be pulled from the hole, depending on subsurface conditions, and the casing will be lowered down the hole in ten foot increments. Each joint of casing will be snapped together and checked to make sure that the alignment pin is correctly in the alignment slot. Each joint will be duct taped to ensure that each joint does not come apart or rotate out of alignment. After each ten foot section is lowered but before the next section is put together CEI will verify that the groves are in the correct alignment. Once the casing has been installed to the full depth of the hole, then the groves of the casing will be checked again to make sure they are properly aligned. Grouting will then be done with a tremie pipe that will be put along side the inclinometer casing. Only the first fifteen feet will be grouted to act like an anchor. The grout to be used will be with in the specification, ninety-four pounds cement and five gallons of water. Once the anchor grout has cured then the remaining of the hole will be grouted. The grout to be used for this will be ninety-four pounds cement, thirty-nine pounds of bentonite, and seventy-five gallons of water. The grout will be tremied from the top of the anchor grout to the top of the hole with a tremie pipe as well. Once the grouting is done, then the owner provided protective casing will be placed over the inclinometer casing. Once the full installation is complete the Owner will be notified to start their initial readings.

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Holcim

Material Certification Report

Material: Hydraulic Cement, Portland Cement
Type: **I,II (ASTM C150)**

Test Period: 01-Oct-2006
To: 31-Oct-2006

Certification

Holcim cement meets the specifications of ASTM C150 for Type I-II cement.
This material meets the specifications for T-I and T-II.

General Information

Supplier:	Holcim Inc.	Source Location:	Holcim Inc.
Address:	3500 State Highway 120 Florence, CO 81226		Portland Plant
Telephone:	719-784-6325-1304	Date:	31-Oct-2006

The following information is based on average test data during the test period. The data is typical of cement shipped by Holcim; individual shipments may vary.

Tests Data on ASTM "Standard" Requirements

Chemical (C150)			Physical	Limit		
Item	Limit (%)	Result (%)	Item		C150	Result
SiO_2		20.1	Air Content (%)		12 max	7
Al_2O_3	6.0 max	4.8	Blaine Fineness (m^2/kg)		280 min	411
Fe_2O_3	6.0 max	3.3	+45 µm (No. 325) Sieve (%)		-	3.2
CaO	-	62.9	-45 µm (No. 325) Sieve (%)		-	96.8
MgO	6.0 max	1.1	Autoclave Expansion (%)		0.80 max	0.00
SO_3*	3.0 max	3.1				
Loss on Ignition	3.0 max	2.2	Compressive Strength MPa (psi):			
Insoluble Residue	0.75 max	0.65	3 Day		12.0 (1740) min	28.8 (4170)
CO_2		1.5	7 Day		19.0 (2760) min	35.7 (5180)
Limestone	5.0max	3.8				
$CaCO_3$ in Limestone	70 min	88.9				
Potential Compounds:						
C_3S	-	50				
C_2S	-	20	Initial Vicat (minutes)		45-375	118
C_3A	8 max	7	Final Vicat (minutes)		-	217
C_4AF	-	10				
			Mortar Bar Expansion (%) C1038*	0.020 max	-	0.000

Tests Data on ASTM "Optional" Requirements

Chemical (C150)			Physical	Limit		
Item	Limit (%)	Result (%)	Item	C1157	C150	Result
Equivalent Alkalies (%)	0.90	0.80				

*The mortar bar expansion is required to be leass than 0.02% at 14 days is the SO_3 is exceeded.

TECHNICAL DATA SHEET

Bentonite Based Drilling Fluid

HIGH YIELD

BENTONITE GEL

DESCRIPTION

High Yield is a Polymer Extended Sodium Bentonite that yields a minimum 200 barrel of API fluid per ton of material. It mixes rapidly for quick hydration and carries cuttings in mud with lower soil content. **High Yield** diminishes fluid loss conditions, reduces seeping into permeable formations, and helps eliminate loss circulations.

APPLICATION

High Yield is ideal for use in water well, monitoring well, mineral exploration, seismic operations, and directional drilling applications.

RECOMMENDED USAGE

Pre-treat makeup water with *Water Treat,* a pH conditioner, to pH of 8-10.

Normal Formation	:	Mix 15-20 lbs (6.8-9.1 kg) of **High Yield** per 100 gallons (379 liters) of makeup water.
Unstable Formation	:	Increase to 25-40 lbs (11.3-18.1 kg) per 100 gallons (379 liters) of makeup water.

PACKAGING

Packaged in 50 lb (22.7 kg) multi-walled paper bags.

SPECIFICATIONS

Fann @ 600 RPM	:	30.0
Filtrate	:	16.20 ml
Moisture	:	10.0 Maximum
Dry Sieve Analysis	:	75.80% (200 mesh)
Wet Sieve Analysis	:	2.3%-3.5% (200 mesh)
pH	:	7.9

TYPICAL CHEMICAL ANALYSIS

SiO_2	61.3	%
Al_2O_3	19.8	%
Fe_2O_3	3.9	%
CaO	0.6	%
MgO	1.3	%
Na_2O	2.2	%
K_20	0.4	%
Trace Elements	3.2	%
H_20 (crystal)	7.2	%

Yield >220bbl/ton

X-RAY ANALYSIS

85 %	Montmorillonite
5%	Quartz
5%	Feldspars
2%	Cristobalite
2%	Illite
1%	Calcite and Gypsum

POLYMER DRILLING SYSTEMS

P.O. Box 507 El Dorado, AR 71731 USA . Tel: (870) 863-5707 . (800) 243-7455 . Fax: (870) 863-0603

www.pdscoinc.com . e-mail: sales@pdscoinc.com

5

VW Piezometers & Pressure Transducers

Applications

For the measurement of...

- **Ground water elevations**
- **Pore water pressures**
- **Pump tests**
- **Uplift pressures in dam foundations**
- **Hydraulic pressures in tanks and pipelines**
- **Wick drain efficiency**
- **Water pressures behind tunnel linings**

• Model 4500C, 4500S, 4500H, 4500DP and 4500HD Vibrating Wire Piezometers (front to back).

Operating Principle

The transducer uses a pressure sensitive diaphragm with a vibrating wire element attached to it. The diaphragm is welded to a capsule which is evacuated and hermetically sealed. Fluid pressures acting upon the outer face of the diaphragm cause deflections of the diaphragm and changes in tension and frequency of the vibrating wire. The changing frequency is sensed and transmitted to the readout device by an electrical coil acting through the walls of the capsule.

Piezometers incorporate a porous filter stone ahead of the diaphragm, which allows the fluid to pass through but prevents soil particles from impinging directly on the diaphragm.

Advantages and Limitations

The 4500 Series Vibrating Wire Piezometers and Pressure Transducers have outstanding long-term stability and reliability, and low thermal zero shift. Cable lengths of several kilometers are no problem and the frequency output signal is not affected by changing cable resistances (caused by splicing, changes of length, terminal contact resistances, etc.), nor by penetration of moisture into the electronic circuitry.

A thermistor located in the housing permits the measurement of temperatures at the piezometer location.

All-stainless steel or titanium construction and evacuation of the capsule guarantees a high level of corrosion resistance. Integral gas discharge tubes inside the main housing protect against lightning damage.

Standard porous filters are made from sintered 316 stainless steel. High air-entry ceramic filters are available for use in applications requiring that air be prevented from passing through the filter.

Vented versions of all models are available to provide automatic compensation for barometric pressure fluctuations. Negative pressures up to 1 Bar can be measured.

Vibrating wire pressure transducers are not suitable for the measurement of rapidly changing pressures: for these purposes Model 3400 transducers should be used.

Model 4500S(H), 4500AL(V) Standard Piezometers

• *Model 4500S (front) and Model 4500AL (rear) Standard Piezometers.*

The Model 4500S Standard Piezometer is designed to measure fluid pressures such as ground water elevations and pore pressures when buried directly in embankments, fills, etc. It is also suitable for installation inside boreholes, observation wells and standard (>19 mm diameter) piezometer riser pipe.

The Model 4500SH is designed with a heavy duty housing for pressures that exceed 3 MPa.

The Model 4500AL is designed for low-pressure ranges. The vented version (Model 4500ALV) provides automatic compensation for barometric pressure changes. Thermistors are included to measure temperatures.

Model 4500DP Drive Point Piezometers

• *Model 4500DP Drive Point Piezometers.*

The Model 4500DP Drive Point Piezometer has the transducer located inside a housing with an EW drill rod thread and removable pointed nose cone. When threaded onto the end of EW drill rods, the unit can be pushed directly into soft ground with the signal cable located inside the drill rod. This model is ideally suited for use in soft clays and landfills. The piezometer may be recovered at the end of the job.

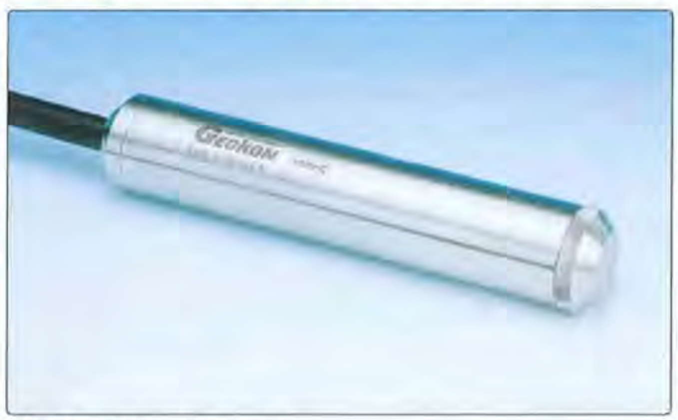
Models are also available that are similar in construction to the 4500DP but which use standard metric threads allowing for installation using cone penetrometer and other drill rods with adapters.

Model 4500B, 4500C Small Diameter Piezometers

• *Model 4500C (front) and Model 4500B (rear) Small Diameter Piezometers.*

These piezometers are designed to enable the automation of small diameter piezometer standpipes. The 4500B fits inside 19 mm pipe and the 4500C inside 12 mm pipe.

Model 4500HD Heavy Duty Piezometer



• *Model 4500HD Heavy Duty Piezometer.*

The Model 4500HD Heavy Duty Piezometer is designed for direct burial in fills and dam embankments. The 4500HD is used in conjunction with heavily armored cable to withstand earth movements during construction. Recommended for use in earth dams.

Model 4500H(H) Pressure Transducers

• *Model 4500H Pressure Transducer.*

The Model 4500H and 4500HH Pressure Transducers are supplied with a ¼ -18 NPT male or female pipe thread fitting to permit the transducer to be coupled directly into hydraulic or pneumatic pressure lines. Other pipe thread sizes are also available.

Model 4500Ti Titanium Piezometer

• *Model 4500Ti Titanium Piezometer.*

The Model 4500Ti is designed specifically for use in highly corrosive environments such as landfills and leach fields. Also used in critical areas where long term survivability is essential, for example, as in nuclear waste repositories and aggressive mine tailings. All exterior surfaces are made from titanium.

Model 4500HT High Temperature Piezometer

• *Model 4500HT High Temperature Piezometer (shown coiled for shipping (inset)).*

The Model 4500HT High Temperature Piezometer is designed for applications where the temperature may be as high as 230°C. Two versions are available, one for continuous use up to 200°C and one for up to 230°C. Teflon cables inside stainless steel tubing are normally supplied with these sensors.

Model 4580 Pressure Transducer

• *Model 4580 Pressure Transducer.*

The Model 4580 Pressure Transducers are designed for very low fluid pressure measurements, such as groundwater elevations in wells, water levels in streams, weirs, flumes, etc. Changes in water levels of as little as 0.2 mm can be measured. Non vented types can be used as a barometer to measure atmospheric pressure changes.

Technical Specifications

Model	Standard Ranges	Over Range	Resolution	Accuracy	Linearity	Temperature Range[1]	Thermal Zero Shift	Diaphragm Displacement	Length × Diameter	Mass
4500S	350, 700 kPa; 1, 2, 3 MPa	2 × rated pressure	0.025% F.S. (minimum)	±0.1% F.S.	< 0.5% F.S. (±0.1% F.S. optional)	−20°C to +80°C	< 0.05% F.S./°C	< 0.001 cm^3 at F.S.	133 × 19.1 mm	0.12 kg
4500SH	5, 7.5 MPa	2 × rated pressure	0.025% F.S. (minimum)	±0.1% F.S.	< 0.5% F.S. (±0.1% F.S. optional)	−20°C to +80°C	< 0.05% F.S./°C	< 0.001 cm^3 at F.S.	194 × 25.4 mm	0.44 kg
4500AL/ALV	70, 170 kPa	2 × rated pressure	0.025% F.S. (minimum)	±0.1% F.S.	< 0.5% F.S. (±0.1% F.S. optional)	−20°C to +80°C	< 0.05% F.S./°C	< 0.001 cm^3 at F.S.	133 × 25.4 mm	0.25 kg
4500B	350, 700 kPa; 1, 2, 3 MPa	2 × rated pressure	0.025% F.S. (minimum)	±0.1% F.S.	< 0.5% F.S. (±0.1% F.S. optional)	−20°C to +80°C	< 0.05% F.S./°C	< 0.001 cm^3 at F.S.	133 × 17.5 mm	0.10 kg
4500C	350, 700 kPa	2 × rated pressure	0.05% F.S. (minimum)	±0.1% F.S.	< 0.5% F.S.	−20°C to +80°C	< 0.05% F.S./°C	< 0.001 cm^3 at F.S.	165 × 11 mm	0.09 kg
4500DP	70, 170, 350, 700 kPa; 1, 2, 3, 5, 7.5 MPa	2 × rated pressure	0.025% F.S. (minimum)	±0.1% F.S.	< 0.5% F.S. (±0.1% F.S. optional)	−20°C to +80°C	< 0.05% F.S./°C	< 0.001 cm^3 at F.S.	187 × 33.3 mm	0.90 kg
4500HD	70, 170, 350, 700 kPa; 1, 2, 3, 5, 7.5 MPa	2 × rated pressure	0.025% F.S. (minimum)	±0.1% F.S.	< 0.5% F.S. (±0.1% F.S. optional)	−20°C to +80°C	< 0.05% F.S./°C	< 0.001 cm^3 at F.S.	203 × 38.1 mm	1.50 kg
4500H	70, 170, 350, 700 kPa; 1, 2, 3, 5 MPa	2 × rated pressure	0.025% F.S. (minimum)	±0.1% F.S.	< 0.5% F.S. (±0.1% F.S. optional)	−20°C to +80°C	< 0.05% F.S./°C	< 0.001 cm^3 at F.S.	140 × 32 mm[2] 140 × 25.4 mm	0.30 kg
4500HH	7.5, 10, 20, 35, 75, 100 MPa	2 × rated pressure	0.025% F.S. (minimum)	±0.1% F.S.	< 0.5% F.S. (±0.1% F.S. optional)	−20°C to +80°C	< 0.05% F.S./°C	< 0.001 cm^3 at F.S.	143 × 25.4 mm	0.30 kg
4500HT	700 kPa; 1, 2, 3, 5, 7.5, 10, 25, 50, 75, 100, 150 MPa	2 × rated pressure	0.025% F.S. (minimum)	±0.1% F.S.	< 0.5% F.S. (±0.1% F.S. optional)	0°C to +200°C 0°C to +230°C	< 0.05% F.S./°C	< 0.001 cm^3 at F.S.	133 × 19.1 mm	0.12 kg
4500Ti	350, 700 kPa; 1, 2, 3, 5, 7.5 MPa[1]	2 × rated pressure	0.025% F.S. (minimum)	±0.1% F.S.	< 0.5% F.S. (±0.1% F.S. optional)	−20°C to +80°C	< 0.05% F.S./°C	< 0.001 cm^3 at F.S.	125 × 25.4 mm	0.19 kg
4580-1 (Barometer)	200 Mbar[1]	2 × rated pressure	0.025% F.S.[3]	±0.1% F.S.	< 0.5% F.S. (±0.1% F.S. optional)	−20°C to +80°C	< 0.05% F.S./°C	n/a	110 × 63.5 mm	1.18 kg
4580-2/2V	17, 35 kPa	2 × rated pressure	0.025% F.S.[3]	±0.1% F.S.	< 0.5% F.S. (±0.1% F.S. optional)	−20°C to +80°C	< 0.05% F.S./°C	n/a	165 × 38 mm	0.86 kg
4580-3V	7 kPa	2 × rated pressure	0.025% F.S.[3]	±0.1% F.S.	< 0.5% F.S.	−20°C to +80°C	< 0.05% F.S./°C	n/a	165 × 63.5 mm	1.72 kg

Note: PSI = kPa × 0.14503, or MPa × 145.03
[1]Other ranges available on request.
[2]For 70 and 170 kParange only.
[3]Depends on readout system.

GEOKON

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Geokon, Incorporated
48 Spencer Street
Lebanon, NH 03766
USA

1 • 603 • 448 • 1562
1 • 603 • 448 • 3216
geokon@geokon.com
www.geokon.com

Instrumentation Cables

Applications

Geokon cables are of the highest quality materials and construction. They are designed to be matched with the appropriate instrument for a variety of geotechnical and hydrological applications. Standard and specialized cables are available for...

- **Typical applications**
- **High temperature environments**
- **Extra abrasion resistance**
- **Heavy duty use**

Geokon Model 4500HT High Temperature Piezometer depicts a Teflon cable threaded inside stainless steel tubing.

Standard Geokon cables.

Cable Design

Geokon cables are made from individual stranded copper conductors encased in an insulation material. Individual, insulated conductors are twisted into pairs, bundled inside a conductive Mylar-type shielding material and then covered by an outer jacket made from the most suitable material. In addition, cables may be water blocked, armored, or may contain steel or Kevlar cables for additional strength, or plastic tubes for circulation fluids, or for venting to atmosphere.

Cable Conductors

In general, the number of conductors in a cable is determined by the number of sensors to be connected to the cable, and the number of conductors required by each sensor.

The type of conductor normally used is stranded, 22 AWG tinned copper. Stranded conductors are more flexible than solid conductors, which makes the cable easier to handle during installation.

Cable Shielding and Insulation

Shielding provides protection from electromagnetic radiation coming from nearby electrical equipment, lightning strikes and fields surrounding power lines, transformers, etc. Geokon multi-conductor cables are individually shielded and twisted in pairs, which helps minimize common mode interference. Drain wires connected electrically to Mylar-type shields provide a simple means of connecting all the shields to a common ground. For applications with very high levels of EMI, such as in pumping wells, a special cable with a braided shield can be provided.

Plastic insulation is typically used on the individual copper conductors. Polyethylene or polypropylene insulation is used at normal temperatures and Teflon is most often used for high temperature.

Outer Jackets

Geokon cable jackets are thicker than regular commercial types, and pressure extruded, which produces cables that are rounder, firmer and easier to grip and seal at the point of entry on the sensor. A wide variety of outer jacket materials is available depending on the end use:

Neoprene: A synthetic rubber compound commonly used for outdoor applications, with good resistance to gasoline, oils etc. Ordinary rubber should never be used.

PVC: A common choice for its good electrical properties and for being waterproof. It should not be used at low temperatures where it becomes brittle.

Polyurethane: This material is very resistant to cuts and abrasions making it useful for cables that are subject to repeated rough handling. It is not as water resistant as PVC but has better low temperature capabilities.

High Density Polyethylene: An excellent material that is highly resistant to environmental attack and exhibits excellent low temperature characteristics. Unfortunately, like Teflon, the material is so slippery that splicing and potting compounds will not stick to it.

Teflon: This material is essential wherever sensors and cables are subject to high temperature. It has outstanding resistance to environmental attack and has excellent low temperature properties. However, splicing and potting compounds will not adhere to it.

Other compounds such as Kevlar or Kapton, etc. may be required where there is a need for low smoke emissions, flame retardant, or resistance to nuclear radiation.

Armor

Armored cables are most often needed for sensors installed in earth embankments or landfills where large forces are exerted on the cable by compaction equipment and earth moving vehicles, and by settlement, "weaving", and sideways spreading of the embankment as it is built. Armored cables should not be connected directly to strain gages or crackmeters because the stiffness of the cable would pull on the gage and alter the readings. Armored cable is not necessary in concrete. The armor usually takes the form of a helically laid layer of steel wire. In very severe situations, regular cable may be put inside stainless steel tubing.

Vented Cables

Special cables are available which contain plastic tubes inside of them as well as the usual conductors. These tubes can be used to transport air or other fluids. This kind of cable is required for vented piezometers, where a single vent tube allows the inside of the pressure sensor to be connected to the ambient atmosphere to provide automatic barometric compensation.

Cable Splices

Cable splicing is best done using commercially available splicing kits containing butt splice connectors and epoxy potting compounds. These help provide a waterproof and mechanically strong splice. Armored cables are difficult to splice if the mechanical strength is to be maintained; special mechanical connections need to be fabricated which will grip the armor firmly.

Technical Specifications

Model	Conductors[1]	Conductor Insulation	Cable Jacket[2]	Nominal O.D.	Temperature Range
02-187P6	4-conductor, 2 twisted pairs	10-mil high density polypropylene	blue polyurethane	0.187" (± 0.010")	−20°C to +80°C
02-187V3	4-conductor, 2 twisted pairs	10-mil high density polypropylene	red PVC	0.187" (± 0.010")	−20°C to +80°C
02-250P4	4-conductor, 2 twisted pairs	10-mil high density polypropylene	green polyurethane	0.250" (± 0.010")	−20°C to +80°C
02-250T	4-conductor, 2 twisted pairs	Teflon	white Teflon with braided silver plated copper shielding	0.250" (± 0.010")	−65°C to +200°C
02-250V6	4-conductor, 2 twisted pairs	10-mil high density polypropylene	blue PVC	0.250" (± 0.010")	−20°C to +80°C
02-312P4	4-conductor, 2 twisted pairs	10-mil high density polypropylene	green polyurethane	0.312" (± 0.015")	−20°C to +80°C
02-313P1	4-conductor, 2 twisted pairs	10-mil high density polypropylene	black polyurethane, with integral straining wire	0.313" (± 0.015")	−20°C to +80°C
02-335VT8	4-conductor, 2 twisted pairs	10-mil high density polypropylene	yellow polyurethane with integral 0.125" Ø polyethylene vent tube	0.335" (± 0.015")	−20°C to +80°C
02-500PE1	4-conductor, 2 twisted pairs	10-mil high density polypropylene	gray vinyl inside, served armor with bitumen tape filler and black polyethylene	0.500" (± 0.015")	−20°C to +80°C
04-375V9	8-conductor, 4 twisted pairs	10-mil high density polypropylene	violet PVC	0.375" (± 0.015")	−20°C to +80°C
04-500VT10	8-conductor, 4 twisted pairs	10-mil high density polypropylene	gray PVC with integral 0.125" Ø polyethylene vent tube	0.500" (± 0.015")	−20°C to +80°C
05-375V12	10-conductor, 5 twisted pairs	10-mil high density polypropylene	tan PVC	0.375" (± 0.015")	−20°C to +80°C
06-500V7	12-conductor, 6 twisted pairs	10-mil high density polypropylene	orange PVC	0.500" (± 0.015")	−20°C to +80°C
12-625V5	24-conductor, 12 twisted pairs	10-mil high density polypropylene	brown PVC	0.625" (± 0.015")	−20°C to +80°C

[1]*All conductors use 7 × 30 22 AWG wire except Model 02-250T (Teflon cable), which uses 22 gage stranded silver plated copper conductors.*
[2]*All outer cable jackets are pressure extruded. In addition, other cable jackets are available for special applications.*
Please note: *All cables use a 24 AWG stranded tinned copper drain wire, except Model 02-312P4 (braided shield).*

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Geokon, Incorporated
48 Spencer Street
Lebanon, NH 03766
USA

1 • 603 • 448 • 1562
1 • 603 • 448 • 3216
geokon@geokon.com
www.geokon.com

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Colorado Engineering & Instrumentation, Inc.
12860 West Cedar Drive, Suite 208
Lakewood, Colorado 80228-1971
Phone: (303) 989-5159 Fax: (303) 980-6157

VIBRATING WIRE PIEZOMETER INSTALLATION PLAN

All vibrating wire piezometers, Owner provided or provided by CEI, will be inspected prior to installation to ensure that all are operating properly and within the calibration tolerance. Also prior to installation, all instruments will be read and the readings will be recorded. All instruments will be installed as indicated on the plans. The location and elevation of the installation will be verified by the Contractor with the Owner prior to installation. ConeTec will be performing the CPT testing and the pushing of the piezometers. ConeTec will be using their Truck-Mounted Cone Penetration Test Rig or Track-Mounted Cone Penetration Test Rig, depending on the schedule will determine which rig is on site. Both of these rigs are described within the ConeTec Statement of Qualifications under Tab 2 of this submittal. Also a description of the CPT test is in the ConeTec Statement of Qualifications. Once the CPT testing is complete then CEI will take the initial readings on the piezometers. ConeTec will then push the piezometers to the approved elevations. After each piezometer is installed CEI will record an additional set of readings from the piezometers. The cables will be run through the Contractor provided trench to the Owner approved location of the terminal panels. All readings taken during the installation will be turned over to the Contractor.

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GEOKON The World Leader in Vibrating Wire Technology

48 Spencer Street
Lebanon, NH 03766, USA
Tel: 603•448•1562
Fax: 603•448•3216
E-mail: geokon@geokon.com
http://www.geokon.com

Instruction Manual

Model 4500

Vibrating Wire Piezometer

(Doc Rev N, 4/04)

Warranty Statement

Geokon, Inc. warrants its products to be free of defects in materials and workmanship, under normal use and service for a period of 13 months from date of purchase. If the unit should malfunction, it must be returned to the factory for evaluation, freight prepaid. Upon examination by Geokon, if the unit is found to be defective, it will be repaired or replaced at no charge. However, the WARRANTY is VOID if the unit shows evidence of having been tampered with or shows evidence of being damaged as a result of excessive corrosion or current, heat, moisture or vibration, improper specification, misapplication, misuse or other operating conditions outside of Geokon's control. Components which wear or which are damaged by misuse are not warranted. This includes fuses and batteries.

Geokon manufactures scientific instruments whose misuse is potentially dangerous. The instruments are intended to be installed and used only by qualified personnel. There are no warranties except as stated herein. There are no other warranties, expressed or implied, including but not limited to the implied warranties of merchantability and of fitness for a particular purpose. Geokon, Inc. is not responsible for any damages or losses caused to other equipment, whether direct, indirect, incidental, special or consequential which the purchaser may experience as a result of the installation or use of the product. The buyer's sole remedy for any breach of this agreement by Geokon, Inc. or any breach of any warranty by Geokon, Inc. shall not exceed the purchase price paid by the purchaser to Geokon, Inc. for the unit or units, or equipment directly affected by such breach. Under no circumstances will Geokon reimburse the claimant for loss incurred in removing and/or reinstalling equipment.

Every precaution for accuracy has been taken in the preparation of manuals and/or software, however, Geokon, Inc. neither assumes responsibility for any omissions or errors that may appear nor assumes liability for any damages or losses that result from the use of the products in accordance with the information contained in the manual or software.

TABLE of CONTENTS

LIST of FIGURES, TABLES and EQUATIONS

1. THEORY OF OPERATION

Geokon Model 4500 Vibrating Wire Piezometers are intended primarily for long-term measurements of fluid and/or pore pressures in standpipes, boreholes, embankments, pipelines and pressure vessels. Several models of the 4500 series are available (see Appendix A). Contact Geokon sales engineers for specific application information.

The instrument utilizes a sensitive stainless steel diaphragm to which a vibrating wire element is connected. See Figure 1-1. In use, changing pressures on the diaphragm cause it to deflect, and this deflection is measured as a change in tension and frequency of vibration of the vibrating wire element. The square of the vibration frequency is directly proportional to the pressure applied to the diaphragm. Two coils, one with a magnet, another with a pole piece, are located close to the wire. In use, a pulse of varying frequency (swept frequency) is applied to the coils and this causes the wire to vibrate primarily at its resonant frequency. When excitation ends the wire continues to vibrate and a sinusoidal signal, at the resonant frequency, is induced in the coils and transmitted to the readout box where it is conditioned and displayed.

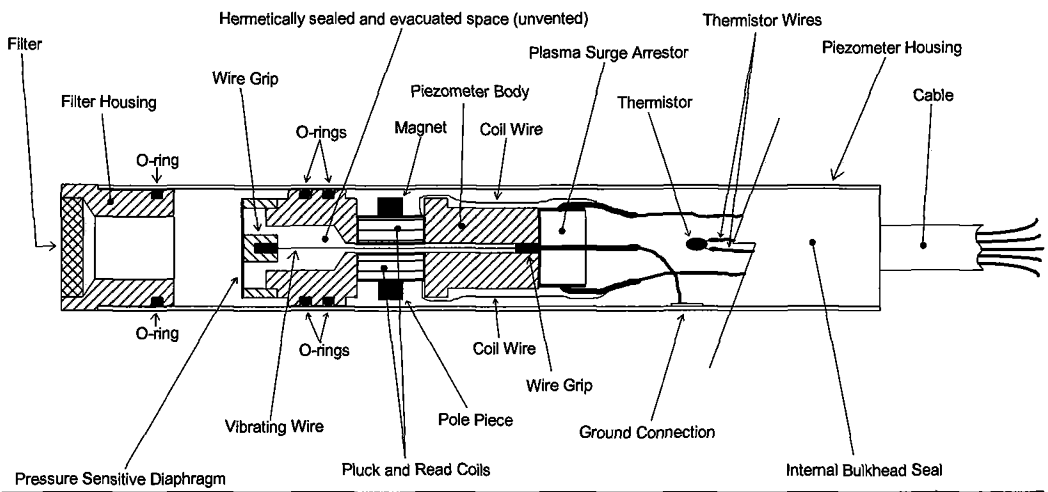


Figure 1-1 Vibrating Wire Piezometer

To prevent damage to the sensitive diaphragm a filter is used to keep out solid particles. Figure 1-1 illustrates. Standard filters are 50 micron stainless steel; high air entry value tips are available on request.

All exposed components are made of corrosion resistant stainless steel and, if proper installation techniques are used, the device should have an unlimited life. In salt water it may be necessary to use special materials for the diaphragm and housing.

Portable readout units are available to provide the excitation, signal conditioning and readout of the instrument. Datalogging systems are also available for remote unattended data collection of multiple sensors. Contact Geokon for additional information.

Calibration data are supplied with each piezometer for conversion of gage readings to engineering units such as pressure or level. See Section 4.

2. INSTALLATION

2.1 Preliminary Tests

Upon receipt of the piezometer the zero reading should be checked and noted (see Sections 3.1 to 3.3 for readout instructions). A thermistor is included inside the body of the piezometer (Figure 1-1) for the measurement of temperature (see Section 3.4 for instructions).

Calibration data are supplied with each gage and a zero reading, at a specific temperature and barometric pressure, is included. Zero readings at the site should coincide with the factory readings within 20 digits after barometric and temperature corrections are made. The factory elevation is +580 ft. Before March 21, 1995 factory barometric pressure readings were corrected to sea level; readings after this date represent absolute pressure. (Barometric pressure changes with elevation at a rate of ≈½ psi per 1,000 ft.) See Figure 2-1 for a sample calibration sheet.

GEOKON

Vibrating Wire Pressure Transducer Calibration

Model Number: 4500S-100 Pressure Range: 100 psi

Serial Number: 48056 Mfg. Number: 8-3275

Customer: Temperature: 21.1 °C

Cust. I.D. #: n/a Barometric Pressure: 998.1 mbar

Job Number: 13053 Date: Nov. 7, 1998

Cal. Std. Control #(s): 183, 468 Technician:

Pressure (psi)	Reading 1st Cycle	Pressure (psi)	Reading 2nd Cycle	Average Pressure	Average Reading	Change	Linearity (%FS)	Polynomial Fit (%FS)
0	9136	0	9141	0	9139		0.18	-0.04
20	8453	20	8456	20	8455	684	0.03	0.08
40	7772	40	7774	40	7773	682	-0.19	-0.01
60	7085	60	7083	60	7084	689	-0.19	-0.01
80	6392	80	6390	80	6391	693	-0.08	-0.03
100	5694	100	5687	100	5691	701	0.25	0.03

Linear Gage Factor (G): 0.029021 **(psi/digit)** **Regression Zero:** 9145

Polynomial Gage Factors: A: -1.40E-07 **B:** -0.026943 **C:*** 257.8826

Thermal Factor (K): -0.004326 **(psi/°C)**

Calculated Pressures:

Linear, $P = G(R_0 - R_1) + K(T_1 - T_0) - (S_1 - S_0)$**

Polynomial, $P = AR_1^2 + BR_1 + C + K(T_1 - T_0) - (S_1 - S_0)$**

***Barometric compensation is not required with vented transducers.*

Factory Zero Reading:

GK-401 Pos. B or F(R_0): 9128 Temp(T_0): 21.8 °C Baro(S_0): 1001.4 mbar Date: Jan. 27, 1997

**The user is advised to establish zero conditions in the field by recording the reading at a known temperature and barometric pressure.*

Wiring Code: Red and Black: Gage White and Green: Thermistor Bare: Shield

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

Figure 2-1 Sample Calibration Sheet

2.1.1 Establishing an Initial Zero Reading

Vibrating Wire Piezometers differ from other types of pressure sensors in that they indicate a reading at zero pressure. Therefore it is imperative that an accurate initial zero pressure reading be obtained for each piezometer as this reading will be used in all subsequent data reduction.

There are different ways of doing this but the essential element in all methods is that the piezometer be allowed to thermally stabilize in a constant temperature environment while the pressure on the piezometer is barometric only. Because of the way the piezometer is constructed it takes about 5 to 15 minutes for the temperature of all the different elements to equalize.

It will be necessary to measure the barometric pressure only if the piezometer is un-vented and if it will be installed in a location that is subject to barometric pressure changes that require correction, such as in an open well. A piezometer sealed in place at depth may be recording pressures in ground water that is not hydraulically connected to the atmosphere and for which barometric pressure compensation would be inappropriate.

The recommended way to achieve temperature stability is to hang the piezometer in the borehole at a point just above the water and wait until the piezometer reading has stopped changing. Now take the zero reading and read the temperature, indicated by the thermistor inside the piezometer.

Another way is to place the piezometer under water in a bucket and allow 5 to 15 minutes for the temperature to stabilize, then lift the piezometer out of the water and immediately take a reading. When doing this, lift the piezometer by the cable only, do not handle the piezometer housing as body heat from the hand could cause temperature transients. Use the thermistor inside the piezometer to measure the water temperature.

Another way is to simply read the piezometer while in the air while making sure that the temperature has had time to stabilized. If this method is chosen be sure that the piezometer is protected from sudden changes of temperature: Wrapping it in some insulating material is recommended.

Yet another way is to lower the piezometer to a known depth as marked out on the piezometer cable, (The diaphragm inside the piezometer is located approximately ¾ inch (15mm), from the tip. Then use a dip meter to accurately measure the depth to the water surface. Now, after temperature stabilization, read the piezometer pressure and, using the factory calibration constants and a knowledge of the pressure (height x density) of the water column above the piezometer, calculate either the equivalent zero pressure reading, if the linear regression is used, or the factor, C, if the second order polynomial is used.

A question may arise as to what to do with the filter stone while taking zero readings. If a standard stainless steel filter is being used, it will not matter if the filter stone is saturated or not. But if ceramic high air entry filter stone is in use then it must be saturated while taking the zero readings and must not be allowed to dry out to the extent that surface tension effects can affect the zero reading.

2.1.2 Checking the Calibration

The following procedure is recommended to verify the calibration factor as supplied on the calibration sheet (Figure 2-1). It should be borne in mind that the piezometer measures water pressure and that the conversion to a water level requires an accurate knowledge of the density of the water.

1. The best method is to remove the filter housing and filter stone from off the tip of the piezometer: Pulling on the knurled ring will accomplish this. Alternatively, saturate the filter stone and fill the space between it and the diaphragm with water (Section 2.6).

2. Lower the piezometer to a point near the bottom of a water-filled borehole, or below the surface of a body of water. The use of a dip meter to measure the actual depth of the water in the borehole will be very desirable.

3. Allow 15-20 minutes for the piezometer to come to thermal equilibrium. Using a readout box record the reading at that level.

4. Raise the piezometer by known depth increments. Record the pressure reading at each depth increment. Calculate the in-situ calibration factor and compare to the calibration factor on the calibration sheet. The two values should agree within ± 0.5%. Repeat test if necessary.

There are a couple of things that can affect the in-situ calibration:

- The density of the in-situ water may not be 1gm/cc if it is saline or turbid. If this is the case then the factory calibration factor, should be adjusted to take into account the actual water density.
- The water level inside the borehole may vary during the test due to the displacement of the water level as the cable is raised and lowered in the borehole. This effect will be greater where the borehole diameter is smaller. For example, a Model 4500S-50 piezometer lowered 50 feet below the water column in a 1 inch (.875 inch ID) standpipe will displace the water level by more than 4 feet! If a dip-meter is available it should be used to confirm the water levels at each depth increment.

2.2 Installation in Standpipes or Wells

A zero reading is first established (follow the procedures outlined in Section 2.1.1). The filter stone is saturated (follow the procedures in Section 2.6). The piezometer can then be lowered to the desired position in the standpipe using the cable to serve as a depth marker so that the position (elevation) of the piezometer tip is accurately known.

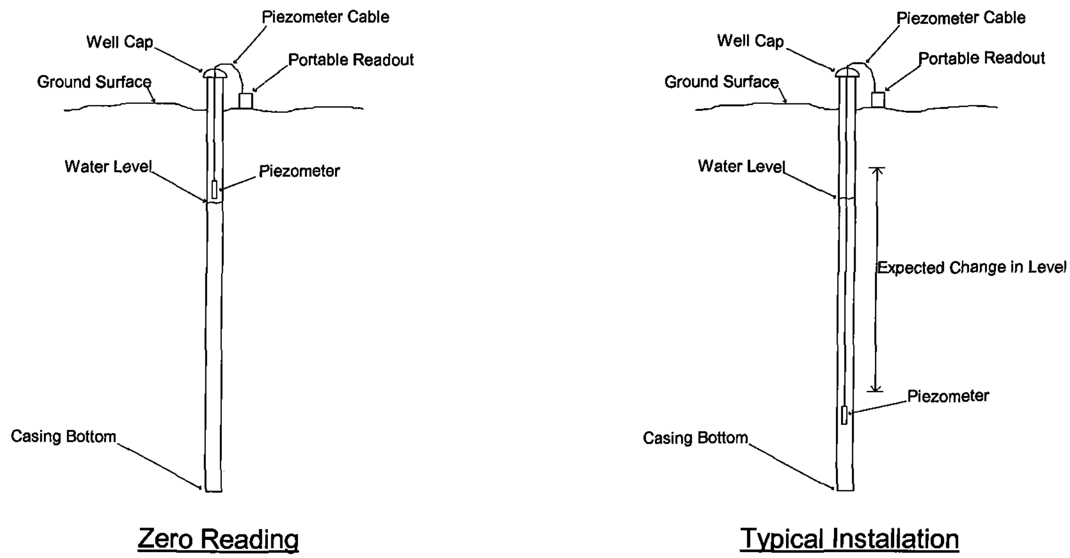


Figure 2-2 Typical Level Monitoring Installations

Be sure the cable is securely fastened at the top of the well or readings could be in error due to slippage of the piezometer into the well.

It is not recommended that piezometers be installed in wells or standpipes where an electrical pump and/or cable is present or nearby. Electrical interference from these sources can cause unstable readings.

In situations where packers are used in standpipes the same sequence as above should be noted and special care should be taken to avoid cutting the cable jacket with the packer since this could introduce a possible pressure leakage path.

2.3 Installation in Boreholes

Geokon piezometers can be installed in boreholes in either single or multiple installations per hole, in cased or uncased holes. See Figure 2-3. Careful attention must be paid to borehole sealing techniques if pore pressures in a particular zone are to be monitored.

Boreholes should be drilled either without drilling mud or with a material that degrades rapidly with time, such as Revert™. The hole should extend from 6 inches to 12 inches below the proposed piezometer location and should be washed clean of drill cuttings. The bottom of the borehole should then be backfilled with clean fine sand to a point 6 inches below the piezometer tip. The piezometer can then be lowered, as delivered, into position. Preferably, the piezometer may be encapsulated in a canvas cloth bag containing clean, saturated Ottawa sand and then lowered into position. While holding the instrument in position (a mark on the cable is helpful) clean sand should be placed around the piezometer and to a point 6 inches above it. Figure 2-3 details two methods of isolating the zone to be monitored.

Installation A

Immediately above the "collection zone" the borehole should be sealed with either alternating layers of bentonite and sand backfill tamped in place for approximately 1 foot followed by common backfill or by an impermeable bentonite-cement grout mix. If multiple piezometers are to be used in a single hole the bentonite-sand plugs should be tamped in place below and above the upper piezometers and also at intervals between the piezometer zones. When designing and using tamping tools special care should be taken to ensure that the piezometer cable jackets are not cut during installation.

Installation B

Immediately above the "collection zone" the borehole should be filled with an impermeable bentonite grout.

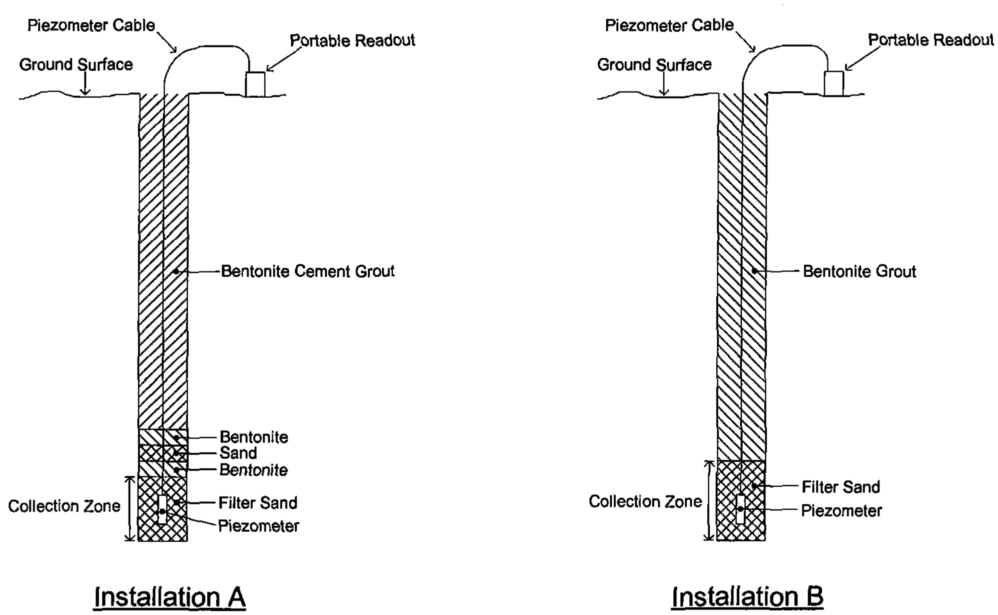


Figure 2-3 Typical Borehole Installations

It should be noted that since the vibrating wire piezometer is basically a no-flow instrument, collection zones of appreciable size are not required and the piezometer can, in fact, be placed directly in contact with most materials provided that the fines are not able to migrate through the filter.

The combination piezometer, Model 4500PN, (pneumatic and vibrating wire) is installed in the same way as above. Multiple installations of this type of piezometer can be difficult due to the size of the cable and tubing.

2.4 Installation in Fills and Embankments

Geokon piezometers are normally supplied with direct burial cable suitable for placement in fills such as highway embankments and dams, both in the core and in the surrounding materials.

In installations in non-cohesive fill materials the piezometer may be placed directly in the fill or, if large aggregate sizes are present, in a saturated sand pocket in the fill. If installed in large aggregate, additional measures may be necessary to protect the cable from damage.

In fills such as impervious dam cores where sub-atmospheric pore water pressure may need to be measured (as opposed to the pore air pressure) a ceramic tip with a high air entry value is often used which should be carefully placed in direct contact with the compacted fill material (see Installation A of Figure 2-4). In partially saturated fills if only the pore air pressure is to be measured, the standard tip is satisfactory. It should be noted that the coarse tip measures the air pressure when there is a difference between the pore air pressure and the pore water pressure, and that the difference between the two pressures is due to the capillary suction in the soil. The general consensus is that the difference is normally of no consequence to embankment stability. As a general rule the coarse (low air entry) tip is suitable for most routine measurements and, in fine cohesive soils, sand pockets should not be used around the piezometer tip (see Installation B of Figure 2-4). In high traffic areas and in material which exhibit pronounced "weaving", a heavy-duty armored cable should be used.

Cables are normally installed inside shallow trenches with the fill material consisting of smaller size aggregate. This fill is carefully hand compacted around the cable. Bentonite plugs are placed at regular intervals to prevent migration of water along the cable path.

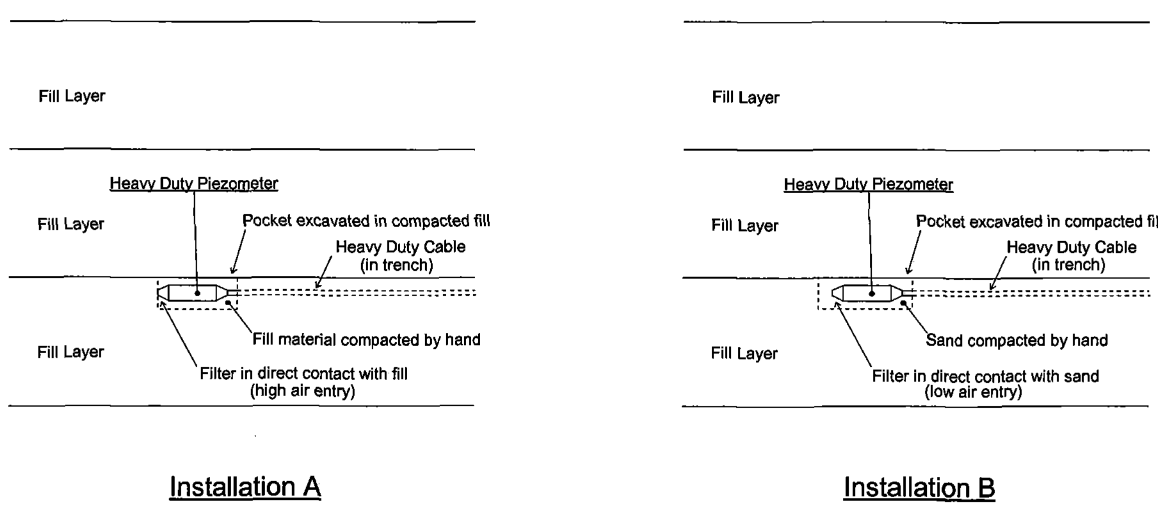


Figure 2-4 Typical Dam Installations

2.5 Installation by Pushing or Driving into Soft Soils

The Model 4500DP piezometer is designed for pushing into soft soils. See Figure 2-5. The unit is connected directly to the drill rod (AW, EW or other) and pressed into the ground either by hand or by means of the hydraulics on the rig. The units can also be driven but the possibility of a zero shift due to the driving forces exists.

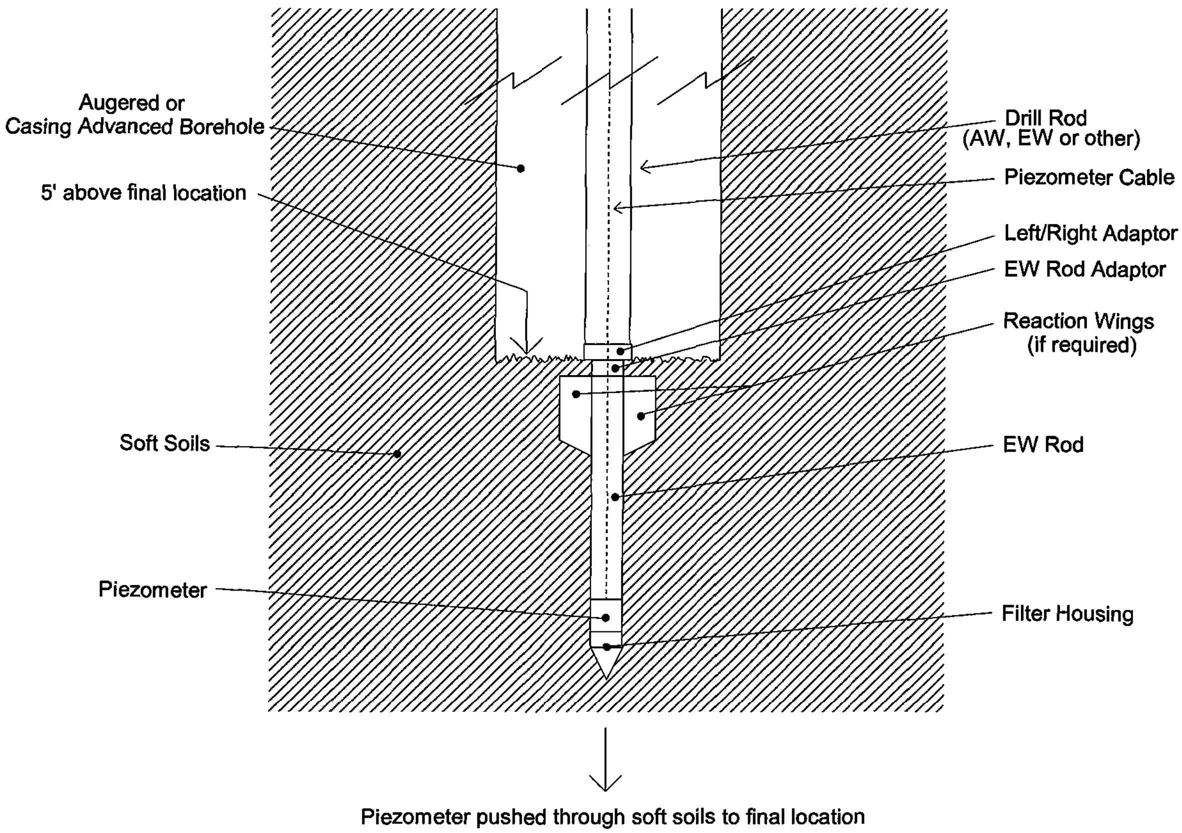


Figure 2-5 Typical Soft Soils Installation

The piezometer should be connected to the readout box and monitored during the driving process. If measurement pressures reach or exceed the calibrated range, the driving should be stopped and the pressures allowed to dissipate before continuing.

The drill rod can be left in place or it can be removed. If it is to be removed then a special 5 foot section of EW (or AW) rod with wings and a left hand thread are attached directly to the piezometer tip. This section is detached from the rest of the drill string by rotating the string clockwise. The left hand thread will then loosen. The wings prevent the special EW rod from turning. A special LH/RH adapter is available from Geokon. The adapter is retrieved along with the drill string.

2.6 De-airing Filter Tips

Most Geokon filter tips can be removed for saturating and re-assembly. The procedures are as follows:

2.6.1 Low Air Entry Filter, Model 4500S and 4500PN

For accurate results, total saturation of the filter is necessary. For the low air entry filter normally supplied, this saturation occurs as the tip is lowered into the water. Water is forced into the filter, compressing the air in the space between the filter stone and the pressure sensitive diaphragm. After a period of time, this air will dissolve into the water until the space and the filter is entirely filled with water. To speed up the saturation process, remove the filter assembly and fill the space above the diaphragm with water, then slowly replace the filter housing allowing the water to squeeze through the filter stone. With low pressure range piezometers (<10 psi) take readings with a readout box while pushing the filter housing on so as not to over-range the sensor.

To maintain saturation, the unit should be kept under water until installation.

If the 4500S piezometer is to be used in standpipes and raised and lowered many times the filter may loosen. A permanent filter assembly may be required. The removable filter may be fixed permanently by prick punching the piezometer tube approximately 1/16" to 1/8" behind the filter assembly joint.

Screens are also available for standpipe installations. Screens are less likely than standard filters to become clogged where salts in the water can be deposited if the filter is allowed to dry out completely.

2.6.2 Removable Ceramic Filter, Model 4500S

The ceramic filter on the 4500S piezometer is also removable for de-airing. Because of the high air entry characteristics, de-airing is particularly important for this filter assembly. Filters with different air entry values require different procedures.

1 Bar Filters

1. Remove the filter from the piezometer by carefully twisting and pulling on the filter housing assembly.

2. Boil the filter assembly in de-aired water.

3. Re-assemble the filter housing and piezometer under the surface of a container of de-aired water. Be sure that no air is trapped in the transducer cavity. While pushing the filter on use a readout box to monitor the diaphragm pressure. Allow over-range pressure to dissipate before pushing further.

4. To maintain saturation, the unit should remain immersed until installation.

2 Bar and Higher

The proper procedure for de-airing and saturating these filters is somewhat complex and should be done either at the factory by Geokon or by carefully following the instructions below:

1. Place the assembled piezometer, filter down, in a vacuum chamber with an inlet port at the bottom for de-aired water.

2. Close off the water inlet and evacuate the chamber. The transducer should be monitored while the chamber is being evacuated.

3. When the maximum vacuum has been achieved, allow de-aired water to enter the chamber and reach an elevation a few inches above the piezometer filter.

4. Close off the inlet port. Release the vacuum.

5. Observe the transducer output. It will take as long as 24 hours for the filter to completely saturate (5 bar) and the pressure to rise to zero.

6. After saturation the transducer should be kept in a container of de-aired water until installation. If de-aired at the factory a special cap is applied to the piezometer to maintain saturation.

2.6.3 Model 4500DP

The 4500 Drive Point is de-aired in the same way as the above models by first unscrewing the point of the piezometer assembly and then following the instruction for the 4500S.

2.7 Model 4500H Transducer

When connecting the Model 4500H transducer to external fittings, the fitting should be tightened into the ¼"-NPT thread with a wrench on the flats provided on the transducer housing. Also, avoid tightening onto a closed system since the process of tightening the fittings could over-range and permanently damage the transducer. If in doubt, attach the gage leads to the readout box and take readings while tightening. Teflon tape on the threads makes for easier and more positive connection to the transducer.

2.8 Splicing and Junction Boxes

Because the vibrating wire output signal is a frequency rather than current or voltage, variations in cable resistance have little effect on gage readings and, therefore, splicing of cables has no effect either and, in some cases, may be beneficial. For example, if multiple piezometers are installed in a borehole, and the distance from the borehole to the terminal box or datalogger is great, a splice (or junction box, see Figure 2-6) could be made to connect the individual cables to a single multi-conductor cable. This multi-conductor cable would then be run to the readout station. For such installations it is recommended that the piezometer be supplied with enough cable to reach the installation depth plus extra cable to pass through drilling equipment (rods, casing, etc.).

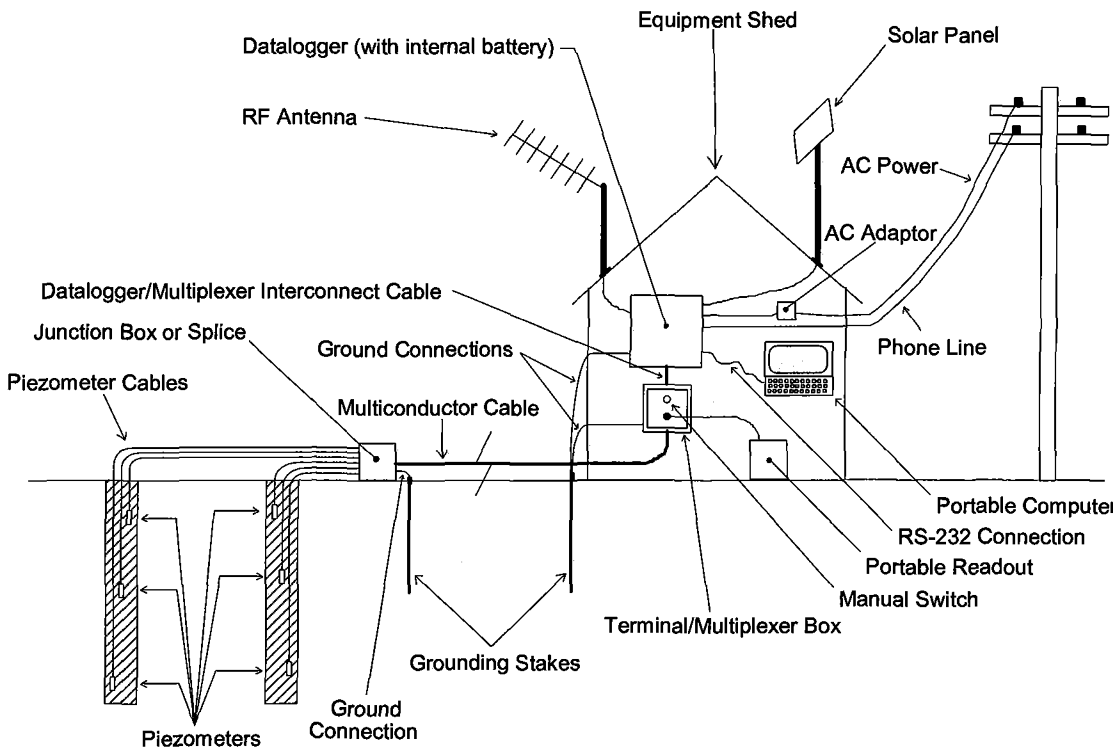


Figure 2-6 Typical Multi-Piezometer Installation

The cable used for making splices should be a high quality twisted pair type with 100% shielding (with integral shield drain wire). When splicing, it is very important that the shield drain wires be spliced together! Splice kits recommended by Geokon incorporate casts placed around the splice then filled with epoxy to waterproof the connections. When properly made, this type of splice is equal or superior to the cable itself in strength and electrical properties. Contact Geokon for splicing materials and additional cable splicing instructions.

Junction boxes and terminal boxes are available from Geokon for all types of applications. In addition, portable readout equipment and datalogging hardware are available. See Figure 2-6. Contact Geokon for specific application information.

2.9 Lightning Protection

In exposed locations it is vital that the piezometer be protected against lightning strikes.

A tripolar plasma surge arrestor (Figure 1-1) is built into the body of the piezometer and protects against voltage spikes across the input leads. Following are additional lightning protection measures available;

1. If the instruments will be read manually with a portable readout (no terminal box) a simple way to help protect against lightning damage is to connect the cable leads to a good earth ground when not in use. This will help shunt transients induced in the cable to ground thereby protecting the instrument.

2. Terminal boxes available from Geokon can be ordered with lightning protection built in. There are two levels of protection;

   - The terminal board used to make the gage connections has provision for installation of plasma surge arrestors (similar to the device inside the piezometer).

   - Lightning Arrestor Boards (LAB-3) can be incorporated into the terminal box. These units utilize surge arrestors and transzorbs to further protect the piezometer.

   In the above cases the terminal box would be connected to an earth ground.

3. Improved protection using the LAB-3 can be had by placing the board in line with the cable as close as possible to the installed piezometer (see Figure 2-7). This is the recommended method of lightning protection.

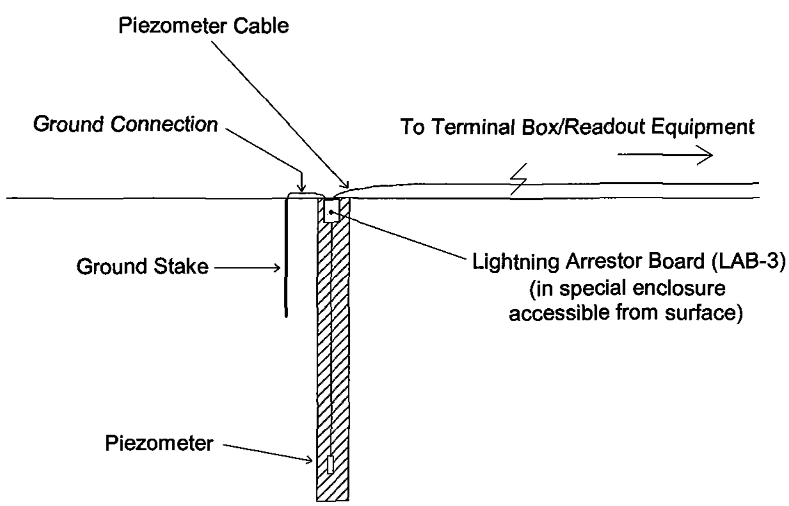


Figure 2-7 Recommended Lightning Protection Scheme

3. TAKING READINGS

3.1 Operation of the GK-401 Readout Box

The GK-401 is a basic readout for all vibrating wire gages.

Connect the Readout using the flying leads or in the case of a terminal station, with a connector. The red and black clips are for the vibrating wire gage, the green lead for the shield drain wire. The GK-401 cannot read the thermistor (see Section 3.4).

1. Turn the display selector to position "B" (or "F"). Readout is in digits (Equation 4-1).

2. Turn the unit on and a reading will appear in the front display window. The last digit may change one or two digits while reading. Record the value displayed. If zeros are displayed or the reading is unstable see section 5 for troubleshooting suggestions.

3. The unit will automatically turn itself off after approximately 4 minutes to conserve power.

3.2 Operation of the GK-402 Readout Box

The GK-402 has the added capability of storing gage readings and measuring the thermistor resistance.

Connect the Readout using the flying leads or in the case of a terminal station, with a connector. The red and black clips are for the vibrating wire gage, the white and green leads are for the thermistor. The cable shield drain wire can be connected to the black clip lead.

1. Turn on the Readout. Press any key to advance to the main menu.

2. Press "1" to advance to the reading screen. If the proper range is selected (press "2" from the reading screen, then "2" for a gage factor of 1) the gage reading in digits will appear on the display. Press "1" to store the value displayed.

3. The thermistor can be read by selecting the proper range code (at the reading screen select "2" for range, then "6" for thermistor). Look up the temperature for the measured resistance in Table B-1. Alternately the temperature could be calculated using Equation B-1.

3.3 Operation of the GK-403 Readout Box

The GK-403 can store gage readings and also apply calibration factors to convert readings to engineering units. Consult the GK-403 Instruction Manual for additional information on Mode "G" of the Readout. The following instructions will explain taking gage measurements using Modes "B" and "F" (similar to the GK-401 switch positions "B" and "F").

Connect the Readout using the flying leads or in the case of a terminal station, with a connector. The red and black clips are for the vibrating wire gage, the white and green leads are for the thermistor and the blue for the shield drain wire.

1. Turn the display selector to position "B" (or "F"). Readout is in digits (Equation 4-1).

2. Turn the unit on and a reading will appear in the front display window. The last digit may change one or two digits while reading. Press the "Store" button to record the value displayed. If the no reading displays or the reading is unstable see section 5 for troubleshooting suggestions. The thermistor will be read and output directly in degrees centigrade.

3. The unit will automatically turn itself off after approximately 2 minutes to conserve power.

3.4 Measuring Temperatures

Each vibrating wire piezometer is equipped with a thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes. Usually the white and green leads are connected to the internal thermistor. High temperature versions use a different thermistor than the standard versions.
The GK-403 readout box when used with the **standard** temperature thermistor will display the temperature in °C automatically. It will **not** do this with high temperature thermistors. The GK 401 readout box will not read temperatures directly, instead an ohmmeter must be used.

1. Connect the ohmmeter to the two thermistor leads coming from the piezometer. (Since the resistance changes with temperature are so large, the effect of cable resistance is usually insignificant. For long cables a cirrection can be applied – equal to 22 ohms per thousand feet.)

2. For standard temperature models, look up the temperature for the measured resistance in Table B-1.Page 21 Alternately the temperature could be calculated using Equation B-1. For high temperature models use Table B2 or the equation B2 given on page 22.

4. DATA REDUCTION

4.1 Pressure Calculation

The digits displayed by the Geokon Models GK-401 or GK-403 Readout Boxes on channel B are based on the equation

$$\text{Digits} = \left(\frac{1}{\text{Period}}\right)^2 \times 10^{-3} \quad \text{or} \quad \text{Digits} = \frac{\text{Hz}^2}{1000}$$

Equation 4-1 Digits Calculation

For example, a piezometer reading 8000 digits corresponds to a period of 354μs and a frequency of 2828 Hz. Note that in the above equation, the period is in seconds: the readout boxes display microseconds.
Since digits are directly proportional to the applied pressure,

Pressure = (Initial Reading - Current Reading) × Calibration Factor

or

$$\mathbf{P = (R_0 - R_1) \times G}$$

Equation 4-2 Convert Digits to Pressure

Since the linearity of most sensors is within □ 0.2% FS the errors associated with non-linearity are of minor consequence. However, for those situations requiring the highest accuracy it may be desirable to use a second order polynomial to get a better fit of the data points. The use of a second order polynomial is explained in Appendix D.

The calibration sheet, a typical example of which is shown in figure 2.1 on page 4, shows the data from which the linear gage factor and the second order polynomial coefficients are derived. Columns on the right show the size of the error incurred by assuming a linear coefficient and the improvement which can be expected by going to a second order polynomial . In many cases the difference is minor. The calibration sheets gives the pressure in certain engineering units. These can be converted to other engineering units using the multiplication factors shown in Table 4-1 below.

From → To ↓	psi	"H_2O	'H_2O	mm H_20	m H_20	"HG	mm HG	atm	mbar	bar	kPa	MPa
psi	1	.036127	.43275	.0014223	1.4223	.49116	.019337	14.696	.014503	14.5039	.14503	145.03
"H_2O	27.730	1	12	.039372	39.372	13.596	.53525	406.78	.40147	401.47	4.0147	4016.1
'H_2O	2.3108	.08333	1	.003281	3.281	1.133	.044604	33.8983	.033456	33.4558	.3346	334.6
mm H_20	704.32	25.399	304.788	1	1000	345.32	13.595	10332	10.197	10197	101.97	101970
m H_20	.70432	.025399	.304788	.001	1	.34532	.013595	10.332	.010197	10.197	.10197	101.97
"HG	2.036	.073552	.882624	.0028959	2.8959	1	.03937	29.920	.029529	29.529	.2953	295.3
mm HG	51.706	1.8683	22.4196	.073558	73.558	25.4	1	760	.75008	750.08	7.5008	7500.8
atm	.06805	.0024583	.0294996	.0000968	.0968	.03342	.0013158	1	.0009869	.98692	.009869	9.869
mbar	68.947	2.4908	29.8896	.098068	98.068	33.863	1.3332	1013.2	1	1000	10	10000
bar	.068947	.0024908	.0298896	.0000981	.098068	.033863	.001333	1.0132	.001	1	.01	10
kPa	6.8947	.24908	2.98896	.0098068	9.8068	3.3863	.13332	101.320	.1	100	1	1000
MPa	.006895	.000249	.002988	.00000981	.009807	.003386	.000133	.101320	.0001	.1	.001	1

Table 4-1 Engineering Units Multiplication Factors

Note: Due to changes in specific gravity with temperature the factors for mercury and water in the above table are approximations!

4.2 Temperature Correction

Careful selection of materials is made in constructing the vibrating wire piezometer to minimize thermal effects, however, most units still have a slight temperature coefficient. Consult the supplied calibration sheet to obtain the coefficient for a given piezometer.

Since piezometers are normally installed in a tranquil and constant temperature environment, corrections are not normally required. If however, that is not the case for a selected installation, corrections can be made using the internal thermistor (Figure 1-1) for temperature measurement. See Section 3.4 for instructions regarding obtaining the piezometer temperature.

Temperature correction equation is as follows;

Temperature Correction = (Current Temperature - Initial Temperature) × Thermal Factor

or

$$P_T = (T_1 - T_0) \times K$$

Equation 4-3 Temperature Correction

The calculated correction would then be **added** to the Pressure calculated using Equation 4-2. If the engineering units were converted remember to apply the same conversion to the calculated temperature correction!

For example, assume the initial temperature was 22° C, the current temperature is 15° C, and the thermal coefficient is –.01879 PSI per °C rise (Figure 2-1). The temperature correction is .13 PSI. Adding this to the calculated pressure in the example of Section 4.1 results in a temperature corrected pressure of 19.98 PSI.

4.3 Barometric Correction (required only on non-vented transducers)

Since the standard piezometer is hermetically sealed and unvented, it responds to changes in atmospheric pressure. That being the case, corrections may be necessary, particularly for the sensitive, low pressure models. For example, a barometric pressure change from 29 to 31 inches of mercury would result in ≈1 PSI of error (or ≈2.3 feet if monitoring water level in a well!). Thus it is advisable to read and record the barometric pressure every time the piezometer is read. A separate pressure transducer (piezometer), kept out of the water, may be used for this purpose.
Barometric correction equation is as follows;

Barometric Correction = (Current Barometer - Initial Barometer) × Conversion Factor

or

$$P_B = (S_1 - S_0) \times F$$

Equation 4-4 Barometric Correction

Since barometric pressure is usually recorded in inches of mercury a Conversion Factor is necessary to convert to PSI. The Conversion Factor for inches of mercury to PSI is .491. Table 4-1 lists other common Conversion Factors.

The calculated correction is usually **subtracted** from the Pressure calculated using Equation 4-2. If the engineering units were converted remember to apply the same conversion to the calculated barometric correction!

The user should be cautioned that this correction scheme assumes ideal conditions. In reality, conditions are not always ideal. For example, if the well is sealed, barometric effects at the piezometer level may be minimal or attenuated from the actual changes at the surface.Thus errors may result when applying a correction which is not required.

An alternative to making barometric correction is to use piezometers that are vented to the atmosphere. Note section 4.3.1.

Equation 4-5 describes the pressure calculation with temperature and barometric correction applied.

$$P_{corrected} = ((R_0 - R_1)\times G) + ((T_1-T_0) \text{ x } K) - ((S_1-S_0) \text{ x } F)$$

Equation 4-5 Corrected Pressure Calculation

4.3.1 Vented Piezometers

Vented piezometers are designed to eliminate barometric effects. The space inside the transducer is not hermetically sealed and evacuated (see Figure 1-1), but is connected via a tube (integral with the cable) to the atmosphere. A chamber containing desiccant capsules is attached to the end of the tube to prevent moisture from entered the transducer cavity. Vented piezometers require more maintenance then non-vented types, and there is always a danger that water can find its way into the inside of the transducer and ruin it.

As supplied, the outer end of the desiccant chamber is closed by means of a seal screw to keep the desiccant fresh during storage and transportation. **THE SEAL SCREW MUST BE REMOVED BEFORE THE PIEZOMETER IS PUT INTO SERVICE!** The desiccant capsules are blue when fresh, they will gradually turn pink as they absorb moisture. When they have turned light pink in color they should be replaced. Contact Geokon for replacement capsules.

4.4 Environmental Factors

Since the purpose of the piezometer installation is to monitor site conditions, factors which may affect these conditions should always be observed and recorded. Seemingly minor effects may have a real influence on the behavior of the structure being monitored and may give an early indication of potential problems. Some of the factors include, but are not limited to; blasting, rainfall, tidal levels, excavation and fill levels and sequences, traffic, temperature and barometric changes (and other weather conditions), changes in personnel, nearby construction activities, seasonal changes, etc.

5. TROUBLESHOOTING

Maintenance and troubleshooting of vibrating wire piezometers is confined to periodic checks of cable connections and maintenance of terminals. The transducers themselves are sealed and not user serviceable. Following are typical problems and suggested remedial action.

- **Piezometer fails to give a reading**

1. Check the resistance of the coils by connecting an ohmmeter across the gage terminals. Nominal resistance is 180Ω (±5%), plus cable resistance at approximately 15Ω per 1000' of 22 AWG wire. If the resistance is very high or infinite the cable is probably broken or cut. If the resistance is very low the gage conductors may be shorted. If a cut or a short is located in the cable, splice according to instructions in Section 2.8.
2. Check the readout with another gage.
3. The Piezometer may have been over-ranged or shocked. Inspect the diaphragm and housing for damage. Contact the factory.

- **Piezometer reading unstable**

1. Connect the shield drain wire to the readout using the green (GK-401) or the blue (GK-403) clip.
2. Isolate the readout from the ground by placing it on a piece of wood or similar non-conductive material.
3. Check for sources of nearby noise such as motors, generators, antennas or electrical cables. Move the piezometer cables if possible. Contact the factory for filtering and shielding equipment available.
4. The Piezometer may have been damaged by over-ranging or shock.
5. The body of the Piezometer may be shorted to the shield. Check the resistance between the shield drain wire and the Piezometer housing.

- **Thermistor resistance is too high**

1. Likely there is an open circuit. Check all connections, terminals and plugs. If a cut is located in the cable, splice according to instructions in Section 2.8.

- **Thermistor resistance is too low**

1. Likely there is a short. Check all connections, terminals and plugs. If a short is located in the cable, splice according to instructions in Section 2.8.
2. Water may have penetrated the interior of the piezometer. There is no remedial action.

APPENDIX A - SPECIFICATIONS

Model	4500S	4500AL[1]	4500B	4500C	4580[2]
Available Ranges (psi)	0-50 0-100 0-150 0-250 0-500 0-750 0-1000 0-1500 0-3000 0-5000 0-10000 0-15000	0-5 0-10 0-25	0-50 0-100 0-250	0-50 0-100 0-250	0-1 0-5
Resolution	0.025% FS	0.025% FS	0.025% FS	0.05% FS	0.01% FS
Linearity	0.5% FS[3]	0.5% FS[3]	0.5% FS[3]	0.5% FS[3]	0.5% FS[3]
Accuracy	0.1% FS[4]	0.1% FS[4]	0.1% FS[4]	0.1% FS[4]	0.1% FS
Over-Range	2 × FS	2 × FS	2 × FS	2 × FS	2 × FS
Thermal Coefficient	<0.025% FS/°C	<0.05% FS/°C	<0.025% FS/°C	<0.05% FS/°C	<0.025% FS/°C
OD	.75" 19.05 mm	1" 25.40 mm	.687" 17.45 mm	.437" 11.10 mm	1.5" 38.10 mm
Length	5.25" 133.35 mm	5.25" 133.35 mm	5.25" 133.35 mm	6.5" 165.10 mm	6.5" 165.10 mm

Table A-1 Vibrating Wire Piezometer Specifications

Accuracy of Geokon test apparatus: 0.1%

Contact Geokon for specific application information.

Notes:

[1] Accuracy of test apparatus: 0.05%

[2] Other ranges available upon request.

[3] 0.1% FS linearity available upon request.

[4] Derived using 2nd order polynomial.

APPENDIX B – **STANDARD TEMPERATURE** THERMISTOR TEMPERATURE DERIVATION

Thermistor Type: YSI 44005, Dale #1C3001-B3, Alpha #13A3001-B3

Resistance to Temperature Equation B1:

$$T = \frac{1}{A + B(\mathrm{LnR}) + C(\mathrm{LnR})^3} - 273.2$$

Where; T = Temperature in °C.
LnR = Natural Log of Thermistor Resistance
$A = 1.4051 \times 10^{-3}$ (coefficients calculated over the –50 to +150° C. span)
$B = 2.369 \times 10^{-4}$
$C = 1.019 \times 10^{-7}$

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	+30	525.4	+70	153.2	+110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	+1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.66K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-34	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	292.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	5692	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.0	53	250.9	93	83.6	133
41.56K	-26	4939	14	929.6	54	243.4	94	81.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	**3000**	**25**	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

Table B-1 **STANDARD TEMPERATURE** Thermistor Resistance versus Temperature

High Temperature Thermistor Linearization using SteinHart-Hart Log Equation

Thermistor Type: Thermometrics BR55KA822J

Basic Equation B2:

$$T = \frac{1}{A + B(\text{LnR}) + C(\text{LnR})^3} - 273.2$$

Where: T = Temperature in °C.
LnR = Natural Log of Thermistor Resistance
$A = 1.02569 \times 10^{-3}$
$B = 2.478265 \times 10^{-4}$
$C = 1.289498 \times 10^{-7}$

Note: Coefficients calculated over -30° to +260° C. span.

Table B2

Temp	R (ohms)	LnR	LnR^3	Calculated Temp	Diff	FS Error	Temp	R (ohms)	LnR	LnR^3	Calculated Temp	Diff
-30	113898	11.643	1578.342	-30.17	0.17	0.06	120	407.62	6.010	217.118	120.00	0.00
-25	86182	11.364	1467.637	-25.14	0.14	0.05	125	360.8	5.888	204.162	125.00	0.00
-20	65805	11.094	1365.581	-20.12	0.12	0.04	130	320.21	5.769	191.998	130.00	0.00
-15	50684.2	10.833	1271.425	-15.10	0.10	0.03	135	284.95	5.652	180.584	135.00	0.00
-10	39360	10.581	1184.457	-10.08	0.08	0.03	140	254.2	5.538	169.859	140.01	-0.01
-5	30807.4	10.336	1104.068	-5.07	0.07	0.02	145	227.3	5.426	159.773	145.02	-0.02
0	24288.4	10.098	1029.614	-0.05	0.05	0.02	150	203.77	5.317	150.314	150.03	-0.03
5	19294.6	9.868	960.798	4.96	0.04	0.01	155	183.11	5.210	141.428	155.04	-0.04
10	15424.2	9.644	896.871	9.98	0.02	0.01	160	164.9	5.105	133.068	160.06	-0.06
15	12423	9.427	837.843	14.98	0.02	0.01	165	148.83	5.003	125.210	165.08	-0.08
20	10061.4	9.216	782.875	19.99	0.01	0.00	170	134.64	4.903	117.837	170.09	-0.09
25	8200	9.012	731.893	25.00	0.00	0.00	175	122.1	4.805	110.927	175.08	-0.08
30	6721.54	8.813	684.514	30.01	-0.01	0.00	180	110.95	4.709	104.426	180.07	-0.07
35	5540.74	8.620	640.478	35.01	-0.01	0.00	185	100.94	4.615	98.261	185.10	-0.10
40	4592	8.432	599.519	40.02	-0.02	-0.01	190	92.086	4.523	92.512	190.09	-0.09
45	3825.3	8.249	561.392	45.02	-0.02	-0.01	195	84.214	4.433	87.136	195.05	-0.05
50	3202.92	8.072	525.913	50.01	-0.01	-0.01	200	77.088	4.345	82.026	200.05	-0.05
55	2693.7	7.899	492.790	55.02	-0.02	-0.01	205	70.717	4.259	77.237	205.02	-0.02
60	2276.32	7.730	461.946	60.02	-0.02	-0.01	210	64.985	4.174	72.729	210.00	0.00
65	1931.92	7.566	433.157	65.02	-0.02	-0.01	215	59.819	4.091	68.484	214.97	0.03
70	1646.56	7.406	406.283	70.02	-0.02	-0.01	220	55.161	4.010	64.494	219.93	0.07
75	1409.58	7.251	381.243	75.01	-0.01	0.00	225	50.955	3.931	60.742	224.88	0.12
80	1211.14	7.099	357.808	80.00	0.00	0.00	230	47.142	3.853	57.207	229.82	0.18
85	1044.68	6.951	335.915	85.00	0.00	0.00	235	43.673	3.777	53.870	234.77	0.23
90	903.64	6.806	315.325	90.02	-0.02	-0.01	240	40.533	3.702	50.740	239.69	0.31
95	785.15	6.666	296.191	95.01	-0.01	0.00	245	37.671	3.629	47.788	244.62	0.38
100	684.37	6.528	278.253	100.00	0.00	0.00	250	35.055	3.557	45.001	249.54	0.46
105	598.44	6.394	261.447	105.00	0.00	0.00	255	32.677	3.487	42.387	254.44	0.56
110	524.96	6.263	245.705	110.00	0.00	0.00	260	30.496	3.418	39.917	259.34	0.66
115	461.91	6.135	230.952	115.00	0.00	0.00						

Table B2 High Temperature. Temperature v Thermistor Resistance

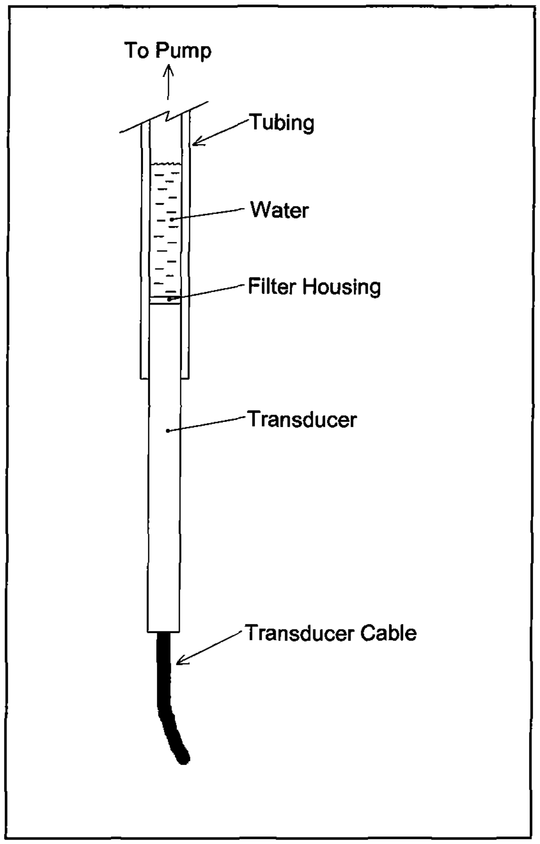
APPENDIX C - NOTES REGARDING THE MODEL 4500C

Installation

The construction of this very slender vibrating wire transducer, requires a miniaturization of the internal parts and consequently they are somewhat delicate. Despite every precaution it is possible for the zero to shift during shipment due to rough handling. However, tests have shown that the zero may shift but the calibration factors do not change. Therefor it is doubly important that the initial no load zero reading be taken prior to installation. **And it is also important to handle the transducer gently during the installation procedure.**

If the pressures to be measured are less than 5 psi the filter stone in the filter housing must be saturated. ***However, the filter stone and housing are not removable in the 4500C. Any attempt to remove the filter stone or the housing will destroy the transducer!***

To saturate the filter a hand vacuum pump and short length of tubing (½" surgical tubing) is required. Attach the tube to the transducer as shown in the figure. Fill the tubing with approximately 2" (5 cm) of water. Hold the transducer so that the water rests on the filter. Attach the other end of the tube to the hand vacuum pump. While holding the transducer so that the water rests on the filter (and doesn't enter the pump!), squeeze the hand pump to initiate vacuum in the tubing. This will draw the air out of the filter and the space behind it. The water will replace it. A vacuum of 20-25" Hg. (50-65 cm Hg.) is sufficient for proper evacuation.



A hand pump that has been used successfully is the mityvacII® by Neward Enterprises, Inc. of Cucamonga, CA, USA. Hand pumps and tubing are available from the factory.

Data Reduction

Data reduction follows the same procedures as outlined in Section 4 of this manual.. Use Table 4-1 to convert psi to other engineering units.

APPENDIX D- NON LINEARITY AND THE USE OF A SECOND ORDER POLYNOMIAL TO IMPROVE THE ACCURACY OF THE CALCULATED PRESSURE

Most vibrating wire pressure transducers are sufficiently linear (± 0.2 % FS) that use of the linear calibration factor satisfies normal requirements. However, it should be noted that the accuracy of the calibration data, which is dictated by the accuracy of the calibration apparatus, is always ± 0.1 % FS.

This level of accuracy can be recaptured, even where the transducer is non-linear, by the use of a second order polynomial expression which gives a better fit to the data then does a straight line.

The polynomial expression has the form:

$$\text{pressure} = AR^2 + BR + C$$

where R is the reading (digits channel B) and A,B,C, are coefficients. The figure on page 24 shows a calibration sheet of a transducer which has a comparatively high non-linearity. The figure under the "Linearity (%FS)" column is

$$\frac{\text{Calculated pressure- True pressure}}{\text{Full-scale Pressure}} \times 100\%$$

$$= \frac{G(R_0 - R_1) - P}{\text{F.S.}} \times 100\%$$

For example when P= 40 psi, G (R_0 - R_1) gives a calculated pressure of 39.642 psi.The error is 0.357 psi or as much as 9.9 inches of water!

Whereas the polynomial expression gives a calculated pressure of A $(7773)^2$ + B (7773) + C = 39.996 psi and the actual error is only 0.004 psi or 0.1 inch of water.

Note. If the polynomial equation is used it is important that the value of C, in the polynomial equation, be taken in the field, following the procedures described in section 2.1.1. The field value of C is calculated by inserting the initial zero reading into the polynomial equation with the pressure, P, set to zero.

It should be noted that where changes of water levels are being monitored it makes little difference whether the linear coefficient or the polynomial expression is used.

GEOKON

Vibrating Wire Pressure Transducer Calibration

Model Number: 4500S-100 Pressure Range: 100 psi

Serial Number: 48056 Mfg. Number: 8-3275

Customer: Temperature: 21.1 °C

Cust. I.D. #: n/a Barometric Pressure: 998.1 mbar

Job Number: 13053 Date: Nov. 7, 1998

Cal. Std. Control #(s): 183, 468 Technician:

Pressure (psi)	Reading 1st Cycle	Pressure (psi)	Reading 2nd Cycle	Average Pressure	Average Reading	Change	Linearity (%FS)	Polynomial Fit (%FS)
0	9136	0	9141	0	9139		0.18	-0.04
20	8453	20	8456	20	8455	684	0.03	0.08
40	7772	40	7774	40	7773	682	-0.19	-0.01
60	7085	60	7083	60	7084	689	-0.19	-0.01
80	6392	80	6390	80	6391	693	-0.08	-0.03
100	5694	100	5687	100	5691	701	0.25	0.03

Linear Gage Factor (G): 0.029021 (psi/digit) **Regression Zero: 9145**

Polynomial Gage Factors: A: -1.40E-07 B: -0.026943 C:* 257.8826

Thermal Factor (K): -0.004326 (psi/°C)

Calculated Pressures: **Linear, $P = G(R_0 - R_1) + K(T_1 - T_0) - (S_1 - S_0)$****

Polynomial, $P = AR_1^2 + BR_1 + C + K(T_1 - T_0) - (S_1 - S_0)$**

***Barometric compensation is not required with vented transducers.*

Factory Zero Reading:

GK-401 Pos. B or F(R_0): 9128 Temp(T_0): 21.8 °C Baro(S_0): 1001.4 mbar Date: Jan. 27, 1997

**The user is advised to establish zero conditions in the field by recording the reading at a known temperature and barometric pressure.*

Wiring Code: Red and Black: Gage White and Green: Thermistor Bare: Shield

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

Vibrating Wire Pressure Transducer Calibration Sheet

APPENDIX E

Installation Instructions Multilevel Piezometer

1. Preliminary Tests

Upon Receipt of the instrument it should be checked for proper operation per the Model 4500 Vibrating Wire Piezometer Manual.

Check the general appearance of the device to be sure that all of the components are undamaged and are firmly held together and that the springs are properly connected to the platens.

2. Saturating the Filter Stone

The filter section is saturated by by disconnecting the Swagelok union at the transducer and immersing the transducer upside down in a bucket of water. A vacuum is then applied to the filter line with the large syringe supplied with the system, removing entrapped air. The transducer itself can purged of air by injecting water into the fitting with a small diameter tube attached to the syringe. The tube is then reconnected to the filter platens and the assembly should be held in its installed orientation, underwater, until lowered into the borehole.

3. Loading and Releasing the Spring Mechanism

There are three different ways in which the spring loaded filter housing can be compressed so it can be pushed down the borehole and released so that the filter presses against the walls of the borehole. The user is requested to refer to the method currently in use.

3.1. The Pneumatic Cutter Method

The system is designed to be installed around one inch flush-coupled grout pipe although other grouting arrangements may be used. The assembly is held together, for installation, by nylon tywraps, which are installed through the eyebolts in the platens and through the holes in the cutting tool. Orient the tool such that it will be above the assembly when lowered into the borehole, and that the tube is between the platens, and then tywrap. *See photo 1.* Do not over tighten the tywraps; the assembly must remain free to slide around the grout pipe.

When lowering the assembly down the borehole (over and around the grout pipe) the instrument electrical cable and the inflation line must be kept at the same length and tension, more or less, to prevent tangling. To prevent the assembly from hanging up inside the borehole it may be necessary to add a weight.

When the proposed elevation is reached the tool is activated, cutting the tywraps and forcing the platens against the borehole walls. When using the small C02 cartridges, always use a fresh cartridge for each piezometer. If installed in drill casing, the sensor is lowered to the proposed elevation and the casing is pulled just above this elevation before the assembly is released. The tool is then removed from the drillhole and the next assembly prepared for installation. When lowering the next and subsequent piezometers down the hole, feed the cables from the lower piezometers through the middle of the assembled piezometer rather than around the outside. This will prevent the cables from interfering with the filter and preventing close contact with the borehole wall.

When all the assemblies are installed the hole can be grouted from the bottom up using a bentonite cement grout. The grout pipe can be either removed from the hole or left in place.

More details of the Installation and the Assembly are shown on the next page.

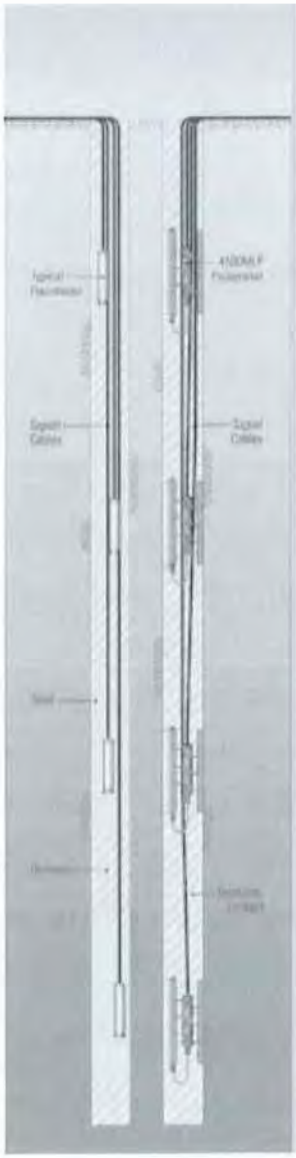


Figure showing the conventional method of installtion versus the MLP method

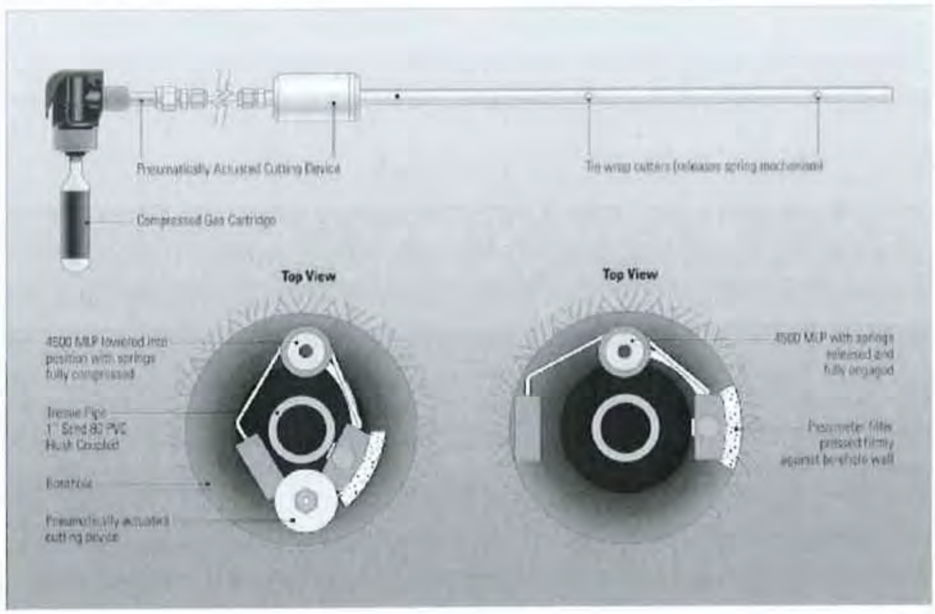


Figure showing installation details

3.2 The Pull-Pin Method

In this method the piezometer assembly is held in its closed position by means of a pull-pin, which, after the two platens are squeezed together, passes through both sets of three eyebolts mounted on the two platens.

If the **grout pipe** is going to be **removed** from the borehole, the piezometer assembly must be lowered over and around the grout pipe to the proposed elevation. If the piezometer assembly has a tendency to hang up in the borehole, a small weight can be added to it.
While holding the piezometer in position by the electrical cable, the pull-pin cable should be pulled gently until all the slack is taken out, and then pulled with a sudden strong jerk, which will release the platens without changing the position of the piezometer relative to the borehole. Piezometers should be installed sequentially from the bottom up.

If the **grout pipe** is going to be **left in** the borehole the piezometer assemblies can be attached to it in a manner that does not restrict the movement of the platens. The grout pipe can be assembled, length by length, and the piezometer assemblies attached to it by taping the electrical cable to the grout tube close to the piezometer. The grout pipe and piezometer assemblies can then be lowered down the hole as a unit. When the final position is reached the pullpins can then be pulled, activating the platens.
A bit of practice pulling the pins before the actual installation will give some "feeling" and confidence as to how the system works.

3.3 The Perforated Grout Pipe Method

In this method each piezometer assembly is held to the grout pipe by means of a single nylon tyrap that passes diametrally through two holes on opposite sides of the grout pipe. The tyrap also holds the piezometer assembly in its closed position. As the grout pipe is assembled and pushed into the borehole the assemblies are added and the electrical cables fed into the hole. When the assembly is completed and the grout tube has reached its final position, a special weight, provided with the equipment, is tied to a length of aircraft cable and is then allowed to fall freely down the inside of the grout pipe. As the weight hits each of the tyraps stretching across the pipe the tyrap is snapped, allowing the piezometer to expand against the walls of the borehole.
. The tying sequence is as follows: Pass the tyrap through the grout pipe, then through the spaces between the leaf springs, then around the two platens and then to itself and tighten it around the grout pipe. Keep the lower cables inside the tyrapand piezometer assembly. The tyrap should pass just beow the center leaf spring such that the bottom of the platen assemblies will be biased in an inward direction.

8

Vibrating Wire Settlement Systems

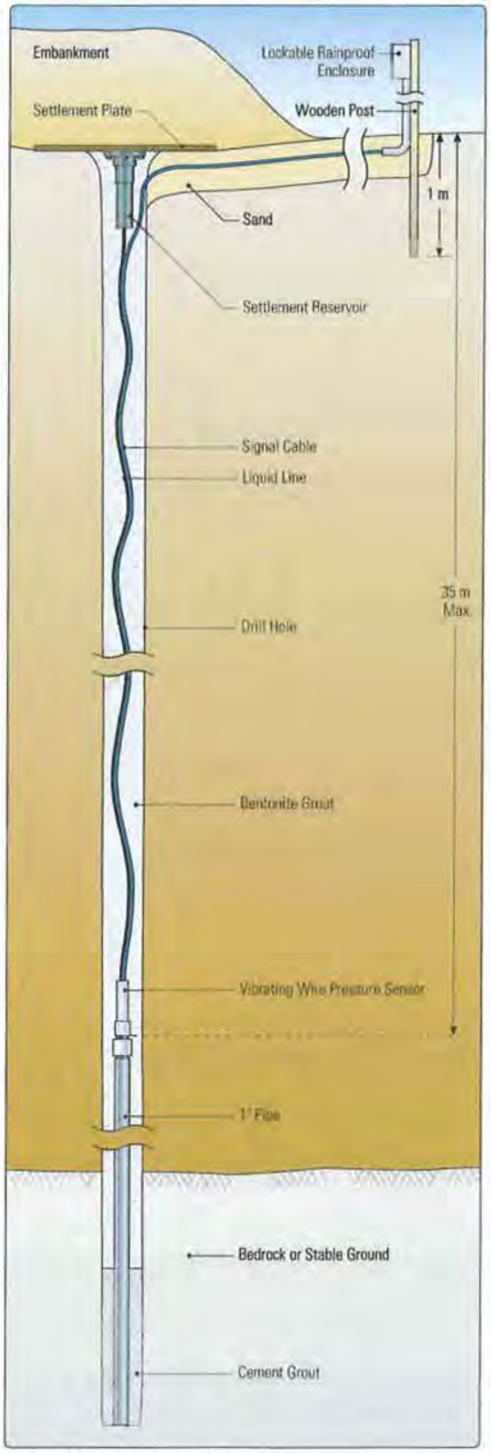
Applications

The 4600 Series Settlement Systems are designed to measure the settlement of surface or subsurface points in or under...

- **Dams**
- **Fills and embankments**
- **Foundations**
- **Roadways**
- **Storage tanks**
- **Surcharges**

Model 4600 Vibrating Wire Settlement System.

Model 4600 Settlement System



Typical Model 4600 installation.

Operating Principle

The Model 4600 is designed for use where there is bedrock or stable ground, accessible by drilling a borehole, which can be used as a stable benchmark immediately beneath the point of settlement. A vibrating wire pressure sensor, anchored on a pipe grouted into solid ground or bedrock at the bottom of the borehole, is connected by a liquid-filled tube to a reservoir attached to a settlement plate located at the ground surface. As the fill is placed, the reservoir settles and the liquid pressure on the sensor diminishes. An electrical cable runs from the sensor to a remote readout location.

Where it is important to know in which subsurface zone settlement is occurring, a special version, the Model 4600M, can be used. It comprises of several 4600 systems, installed one above the other, in a single borehole. Intermediate combinations of reservoir and sensor are held in place in the borehole by leaf spring or hydraulic anchors.

Typical applications for the Model 4600 are: the measurement of sea-floor settlement beneath the construction of a sand-island, and the measurement of settlement beneath a surcharge in a swampy area.

Advantages and Limitations

A closed loop vent line between transducer and reservoir prevents temperature and barometric pressure fluctuations from affecting the readings. The use of long horizontal liquid-filled tubes, which could be susceptible to air bubble formation, is not required. However, the proximity of stable ground beneath the settlement point and the drilling of a borehole are required. Systems are supplied fully sealed and assembled, ready for installation.

Technical Specifications

Standard Ranges[1]	7, 17, 35 m
Resolution	0.025% F.S.
System Accuracy[2]	±4, ±6, ±12 mm
Temperature Range[1]	−20°C to +80°C
Length × Diameter	*(Reservoir)* 305 x 60 mm *(Sensor)* 191 x 35 mm

[1]Other ranges available on request.
[2]System accuracy is the equal to the precision with which changes of the pressure can be measured.

Model 4650 Settlement System

◦ *Model 4650 Settlement System.*

Applications

The Model 4650 is designed for remote measurement of the settlement of a point in or below fills, surcharges, embankments, etc. Systems with tube lengths of up to 300 m have been used successfully to measure settlements in earth dam embankments.

Operating Principle

A vibrating wire pressure sensor is attached to a settlement plate located at the point of settlement. The sensor is connected via two liquid-filled tubes, extending laterally, to a reservoir located on stable ground. The sensor measures the hydraulic head of liquid between the sensor and reservoir locations.

Advantages and Limitations

A vented cable runs from the sensor to the remote readout location and connects to the reservoir so that barometric pressure fluctuations do not affect the readings.

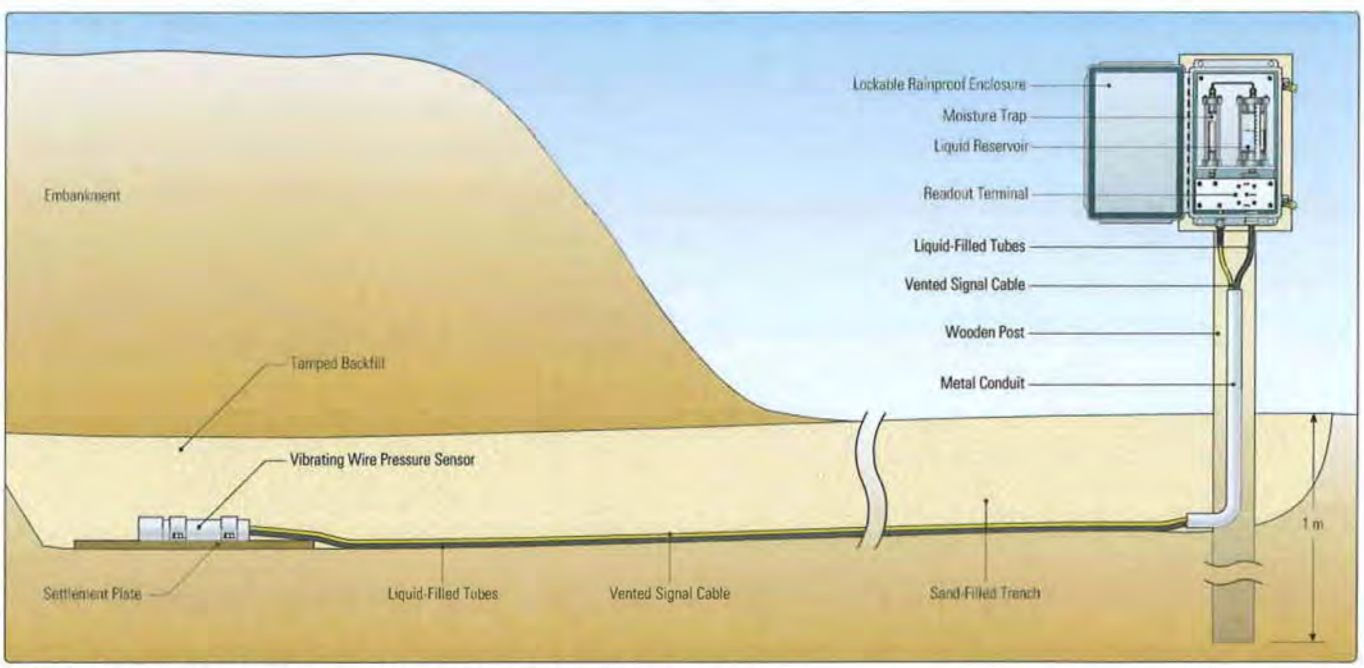
The liquid-filled tubes can be flushed to remove any air bubbles that might form.

It is possible to perform in-situ checks at any time on both the calibration and zero stability.

Technical Specifications

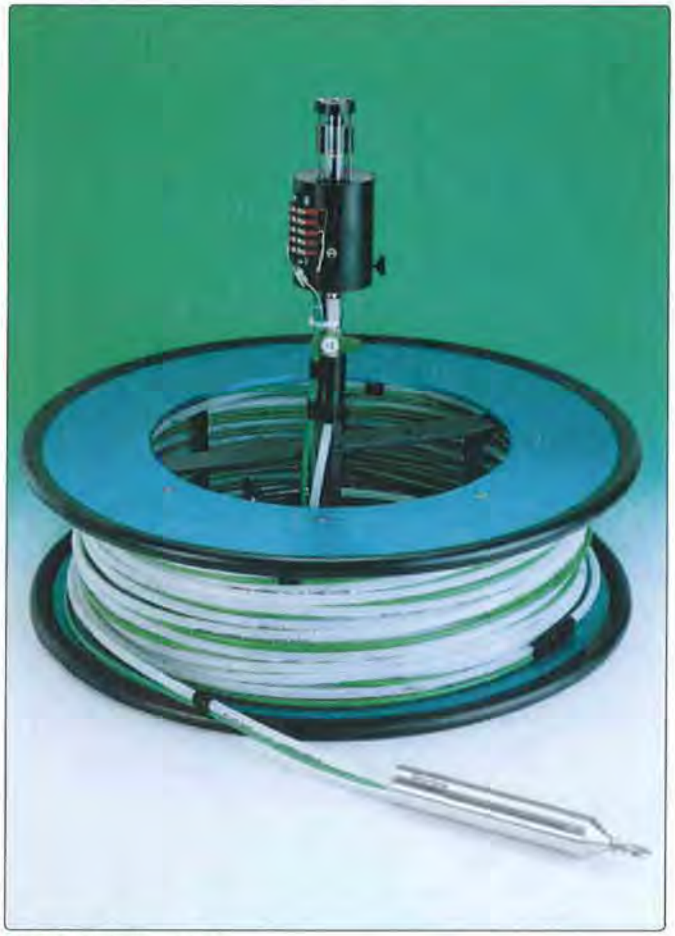
Standard Ranges[1]	7, 17 m
Resolution	2, 4 mm
System Accuracy[2]	±4 to ±6 mm
Temperature Range[1]	−20°C to +80°C

[1]Other ranges available on request.
[2]System accuracy is the equal to the precision with which changes of the pressure can be measured.



◦ *Model 4650 installation for the remote measurement of subsurface settlement beneath a large embankment.*

Model 4651 Settlement Profiler



Model 4651 Settlement Profiler.

Applications

The Model 4651 Settlement Profiler is a portable device designed to measure profiles of heave and settlement beneath fills, embankments, roadways, storage tanks, structures, etc. It can be used to measure differential settlements at discrete points on structures such as building columns, etc., and also to monitor surface settlement above tunneling activities.

Operating Principle

A sensitive Vibrating Wire Pressure Sensor is located inside a torpedo that can be pulled through a buried pipe, or carried from point to point. The Sensor is connected, via a liquid-filled tube, to a reservoir located on stable ground. The tubing is stored on a reel, which is mounted horizontally at the reservoir location, and is free to turn as the torpedo is pulled into the hole, or, is positioned at different locations. The sensor measures the hydraulic head between the reservoir and the sensor locations.

Advantages and Limitations

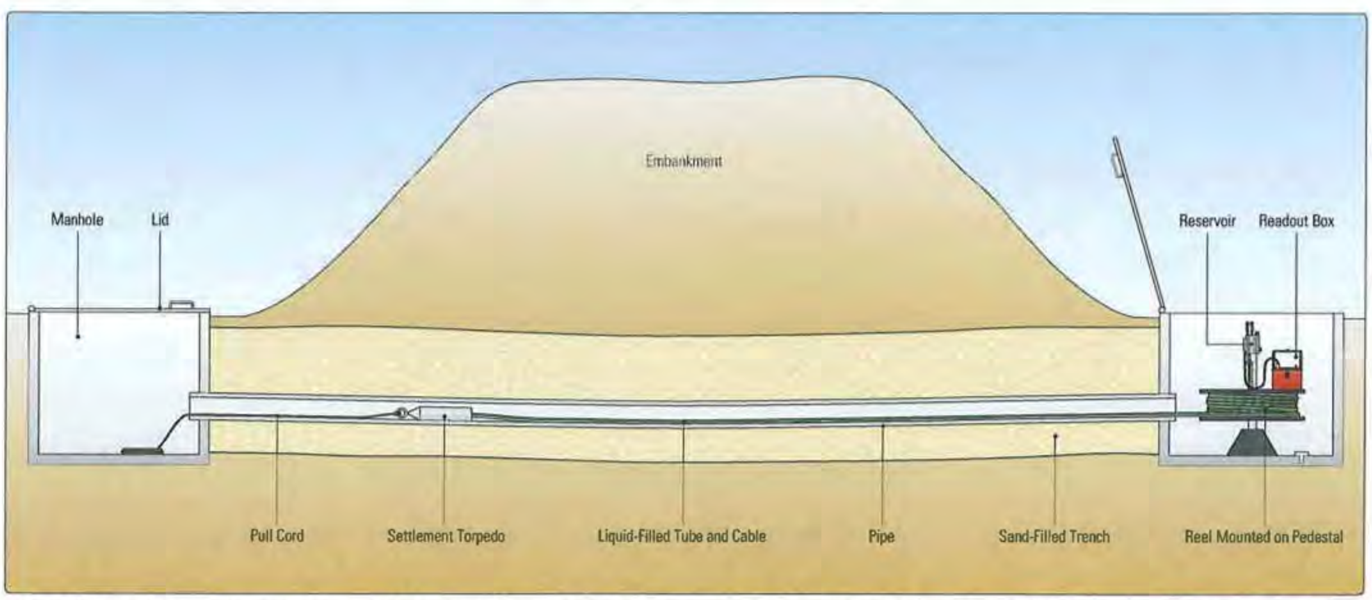
Independent measurements of settlement can be made at closely spaced intervals providing a detailed profile of differential settlements over a wide area.

The Sensor is vented so that barometric pressure fluctuations have no effect on the readings.

Technical Specifications

Standard Range[1]	7 m
Resolution	±2 mm
System Accuracy[2]	±4 mm
Temperature Range[1]	−20°C to +80°C

[1]Other ranges available on request.
[2]System accuracy is the equal to the precision with which changes of the pressure can be measured.



Model 4651 installation used to measure and monitor embankment settlement. As an alternative installation, the empty manhole (shown above at left) and open-ended pipe may be replaced by a capped pipe with a pulley and return cable to pull and position the torpedo from the reel end of the pipe (shown above at right).

Model 4675 High Sensitivity Settlement System

Model 4675 High Sensitivity Settlement System.

Applications

The Model 4675 is designed to detect and measure very small changes of elevation at discrete locations. It has been used to measure differential settlements along tunnels, deflections of bridges and bridge piers, the settlement of building columns and floor slabs, etc. (i.e. situations in which high sensitivity is essential).

Operating Principle

A series of vessels are interconnected by a liquid-filled tube. One reference vessel is located on stable ground and the other vessels are located at the points of settlement. Each vessel contains a cylindrical weight suspended from a vibrating wire transducer. The common liquid level inside each vessel partially submerges the hanging weights; settlement of a vessel causes an apparent rise of the water level in that vessel leading to a greater buoyancy force on the weight and a reduction in the tension and frequency of the vibrating wire.

Advantages and Limitations

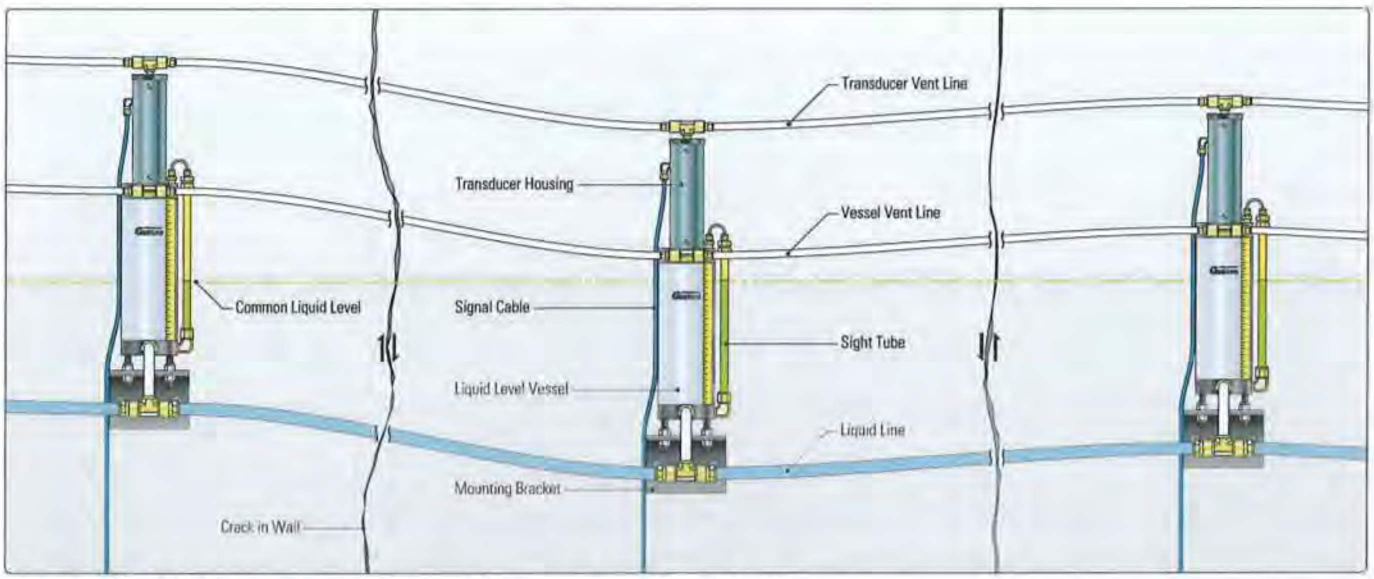
Very high resolution, of the order of 0.07 mm, can be attained. A vent line connected to each of the ves-sels prevents the readings from being affected by ambient air currents and barometric fluctuations. The readings are not significantly affected by temperature changes.

The vessels must be installed at the same elevation and the connecting liquid-filled tubing must remain below the vessels at all points.

Technical Specifications

Standard Ranges[1]	150, 300, 600 mm
Resolution	0.07, 0.07, 0.15 mm
System Accuracy[2]	±0.1 to ±0.4 mm
Temperature Range[1]	−20°C to +80°C (using antifreeze solutions)

[1]Other ranges available on request.
[2]System accuracy is the equal to the precision with which changes of the pressure can be measured.



Installation of the Model 4675 on a concrete wall with exaggerated settlement to illustrate change in elevation.

GEOKON

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Geokon, Incorporated
48 Spencer Street
Lebanon, NH 03766
USA

1 • 603 • 448 • 1562
1 • 603 • 448 • 3216
geokon@geokon.com
www.geokon.com

Instrumentation Cables

Applications

Geokon cables are of the highest quality materials and construction. They are designed to be matched with the appropriate instrument for a variety of geotechnical and hydrological applications. Standard and specialized cables are available for...

- **Typical applications**
- **High temperature environments**
- **Extra abrasion resistance**
- **Heavy duty use**

Geokon Model 4500HT High Temperature Piezometer depicts a Teflon cable threaded inside stainless steel tubing.

Standard Geokon cables.

Cable Design

Geokon cables are made from individual stranded copper conductors encased in an insulation material. Individual, insulated conductors are twisted into pairs, bundled inside a conductive Mylar-type shielding material and then covered by an outer jacket made from the most suitable material. In addition, cables may be water blocked, armored, or may contain steel or Kevlar cables for additional strength, or plastic tubes for circulation fluids, or for venting to atmosphere.

Cable Conductors

In general, the number of conductors in a cable is determined by the number of sensors to be connected to the cable, and the number of conductors required by each sensor.

The type of conductor normally used is stranded, 22 AWG tinned copper. Stranded conductors are more flexible than solid conductors, which makes the cable easier to handle during installation.

Cable Shielding and Insulation

Shielding provides protection from electromagnetic radiation coming from nearby electrical equipment, lightning strikes and fields surrounding power lines, transformers, etc. Geokon multi-conductor cables are individually shielded and twisted in pairs, which helps minimize common mode interference. Drain wires connected electrically to Mylar-type shields provide a simple means of connecting all the shields to a common ground. For applications with very high levels of EMI, such as in pumping wells, a special cable with a braided shield can be provided.

Plastic insulation is typically used on the individual copper conductors. Polyethylene or polypropylene insulation is used at normal temperatures and Teflon is most often used for high temperature.

Outer Jackets

Geokon cable jackets are thicker than regular commercial types, and pressure extruded, which produces cables that are rounder, firmer and easier to grip and seal at the point of entry on the sensor. A wide variety of outer jacket materials is available depending on the end use:

Neoprene: A synthetic rubber compound commonly used for outdoor applications, with good resistance to gasoline, oils etc. Ordinary rubber should never be used.

PVC: A common choice for its good electrical properties and for being waterproof. It should not be used at low temperatures where it becomes brittle.

Polyurethane: This material is very resistant to cuts and abrasions making it useful for cables that are subject to repeated rough handling. It is not as water resistant as PVC but has better low temperature capabilities.

High Density Polyethylene: An excellent material that is highly resistant to environmental attack and exhibits excellent low temperature characteristics. Unfortunately, like Teflon, the material is so slippery that splicing and potting compounds will not stick to it.

Teflon: This material is essential wherever sensors and cables are subject to high temperature. It has outstanding resistance to environmental attack and has excellent low temperature properties. However, splicing and potting compounds will not adhere to it.

Other compounds such as Kevlar or Kapton, etc. may be required where there is a need for low smoke emissions, flame retardant; or resistance to nuclear radiation.

Armor

Armored cables are most often needed for sensors installed in earth embankments or landfills where large forces are exerted on the cable by compaction equipment and earth moving vehicles, and by settlement, "weaving", and sideways spreading of the embankment as it is built. Armored cables should not be connected directly to strain gages or crackmeters because the stiffness of the cable would pull on the gage and alter the readings. Armored cable is not necessary in concrete. The armor usually takes the form of a helically laid layer of steel wire. In very severe situations, regular cable may be put inside stainless steel tubing.

Vented Cables

Special cables are available which contain plastic tubes inside of them as well as the usual conductors. These tubes can be used to transport air or other fluids. This kind of cable is required for vented piezometers, where a single vent tube allows the inside of the pressure sensor to be connected to the ambient atmosphere to provide automatic barometric compensation.

Cable Splices

Cable splicing is best done using commercially available splicing kits containing butt splice connectors and epoxy potting compounds. These help provide a waterproof and mechanically strong splice. Armored cables are difficult to splice if the mechanical strength is to be maintained; special mechanical connections need to be fabricated which will grip the armor firmly.

Technical Specifications

Model	Conductors	Conductor Insulation	Cable Jacket[2]	Nominal O.D.	Temperature Range
02-187P6	4-conductor, 2 twisted pairs	10-mil high density polypropylene	blue polyurethane	0.187" (± 0.010")	−20°C to +80°C
02-187V3	4-conductor, 2 twisted pairs	10-mil high density polypropylene	red PVC	0.187" (± 0.010")	−20°C to +80°C
02-250P4	4-conductor, 2 twisted pairs	10-mil high density polypropylene	green polyurethane	0.250" (± 0.010")	−20°C to +80°C
02-250T	4-conductor, 2 twisted pairs	Teflon	white Teflon with braided silver plated copper shielding	0.250" (± 0.010")	−65°C to +200°C
02-250V6	4-conductor, 2 twisted pairs	10-mil high density polypropylene	blue PVC	0.250" (± 0.010")	−20°C to +80°C
02-312P4	4-conductor, 2 twisted pairs	10-mil high density polypropylene	green polyurethane	0.312" (± 0.015")	−20°C to +80°C
02-313PI	4-conductor, 2 twisted pairs	10-mil high density polypropylene	black polyurethane, with integral straining wire	0.313" (± 0.015")	−20°C to +80°C
02-335VT8	4-conductor, 2 twisted pairs	10-mil high density polypropylene	yellow polyurethane with integral 0.125" ∅ polyethylene vent tube	0.335" (± 0.015")	−20°C to +80°C
02-500PE1	4-conductor, 2 twisted pairs	10-mil high density polypropylene	gray vinyl inside, served armor with bitumen tape filler and black polyethylene	0.500" (± 0.015")	−20°C to +80°C
04-375V9	8-conductor, 4 twisted pairs	10-mil high density polypropylene	violet PVC	0.375" (± 0.015")	−20°C to +80°C
04-500VT10	8-conductor, 4 twisted pairs	10-mil high density polypropylene	gray PVC with integral 0.125" ∅ polyethylene vent tube	0.500" (± 0.015")	−20°C to +80°C
05-375V12	10-conductor, 5 twisted pairs	10-mil high density polypropylene	tan PVC	0.375" (± 0.015")	−20°C to +80°C
06-500V7	12-conductor, 6 twisted pairs	10-mil high density polypropylene	orange PVC	0.500" (± 0.015")	−20°C to +80°C
12-625V5	24-conductor, 12 twisted pairs	10-mil high density polypropylene	brown PVC	0.625" (± 0.015")	−20°C to +80°C

[1]All conductors use 7 × 30 22 AWG wire except Model 02-250T (Teflon cable), which uses 22 gage stranded silver plated copper conductors.
[2]All outer cable jackets are pressure extruded. In addition, other cable jackets are available for special applications.
***Please note:** All cables use a 24 AWG stranded tinned copper drain wire, except Model 02-312P4 (braided shield).*

GEOKON

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Geokon, Incorporated
48 Spencer Street
Lebanon, NH 03766
USA

1·603·448·1562
1·603·448·3216
geokon@geokon.com
www.geokon.com

Geokon, Inc

TWIN NYLON TUBING WITH POLYETHYLENE JACKET
(PART NO. TUB-100, MODEL 4650-10)

Technical Specifications:

- Nylon 11 tubing 0.250" O.D. x 0.050" wall thickness, burst pressure 2500 psi, (1) tube natural, (1) black.
- Pressure extruded yellow polyethylene jacket, 0.070" thickness
- Nominal dimensions: 0.640" + 0.025" wide x 0.340" + 0.020" thick
- Weight: approximately 7.8 lbs/cft.

3M

82-A Series Power Cable Splice Kit

Instructions

LISTED 98U1
Wire connector system for use with underground conductors.

1.0 Applications:

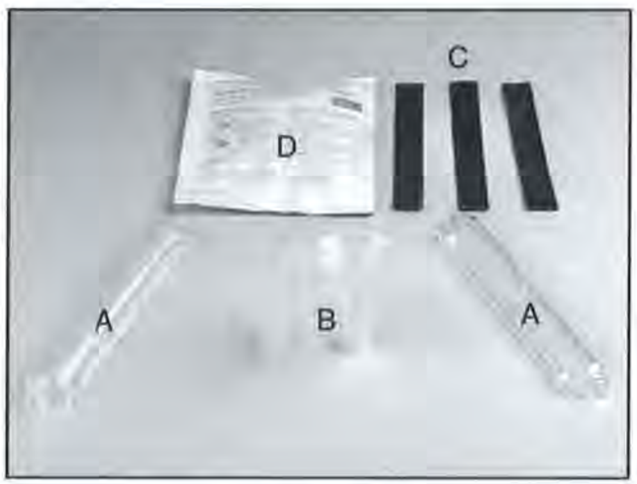
Designed for use in weather-exposed or direct-burial locations. For making inline (straight) splices on unshielded, synthetic insulated cables rated up to a maximum of 5kV and for multiple conductor cables rated up to a maximum of 1kV. UL Listed for direct burial and submerged applications up to 600 volts and 90°C. For use with UL Listed connectors only. These kits will accommodate the following connectors and conductor sizes:

Table A

Kit No.	Conductor Size	Connector O.D.	Cable O.D.	Sheath Opening (L)	(A)	(B)
82-A1	#2 AWG (max.)	13/32" (maximum)	5/8" (maximum)	4 1/2" (maximum)	1/2 connector length	1/4"
82-A2	#2 AWG (min.) #3/0 (max.)	5/8" (maximum)	1" (maximum)	6" (maximum)	1/2 connector length	1/2"
82-A3	#3/0 (min.) 400 kcmil (max.)	1" (maximum)	1 9/16" (maximum)	9" (maximum)	1/2 connector length	1/2"

2.0 Kit Contents:

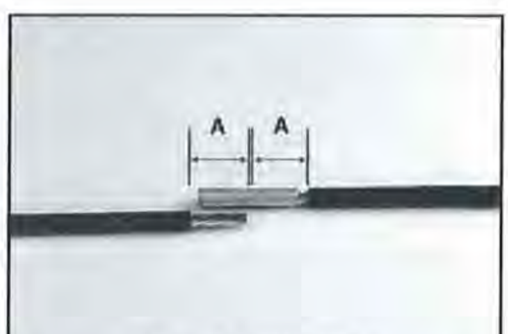
Mold Body..A
Pouring Spouts..B
Scotch™ 23 Electrical Tape C
3M™ Scotchcast™ No. 4 Resin..................D



3.0 Prepare Cable:

3.1 **For 1000 volt:** Thoroughly scrape all wax and dirt 5" back from each cable end. Prepare cable ends exactly as shown. See Table A for proper sizing and dimensions.

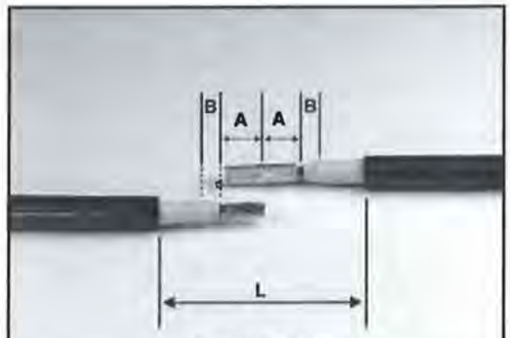
Sheath Cutback ....A



1000 Volt maximum

3.2 **For 5 kV maximum:** Thoroughly scrape all wax and dirt 5" back from each cable end. Prepare cable ends exactly as shown. Do not cut insulation while removing outer sheath. See Table A for proper sizing and dimensions.

Bare Conductor ....A
Insulation Pencil ....B
Maximum Sheath Opening L



5 kV maximum

4.0 Connection

4.1 Make connections according to instructions for connector being used. The mold will accept: a) Crimped type connectors and b) Split solder sleeve connectors.

4.2 **Multi-conductor Cables.** Stagger individual connectors (provide lateral spacing of 1/2" between ends of connectors) and insulate connector with Scotch™ 23 Electrical Tape. Sheath opening should not exceed dimension "L" in Table A.

Note: Connectors not provided with kit.

4.3 **Tape Over Connector Area.** Apply one layer, half-lapped, Scotch 23 Electrical Tape over connector area only. Do not wrap tape onto the pencilled area.

5.0 Install Mold Body

5.1 Trim mold ends with knife to fit cable slightly loose. Hold mold halves in place, centered over splice. Snap mold halves together firmly. Check to see that both seams are carefully snapped together. Tape ends of mold body around cable to seal. Use supplied Scotch 23 Electrical Tape.

IMPORTANT: Stretch tape to 3/4 original width.

0 Pour Splice

1 Put pouring spouts in holes.

2 Position splice level. Mix resin thoroughly per instructions on resin package. Pour resin immediately after mixing. Fill only through one spout until both spouts are completely filled. When resin has solidified and cooled, splice may be put into service. Clip off spouts, if desired.

IMPORTANT NOTICE

Before using this product, you must evaluate it and determine if it is suitable for your intended application. You assume all risks and liability associated with such use.

Warranty; Limited Remedy;Limited Liability. This product will be free from defects in material and manufacture as of the date of purchase. **3M MAKES NO OTHER WARRANTIES INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.** If this product is defective within the warranty period stated above, your exclusive remedy shall be, at 3M's option, to replace or repair the 3M product or refund the purchase price of the 3M product. **Except where prohibited by law, 3M will not be liable for any loss or damage arising from this 3M product, whether direct, indirect, special, incidental or consequential regardless of the legal theory asserted.**

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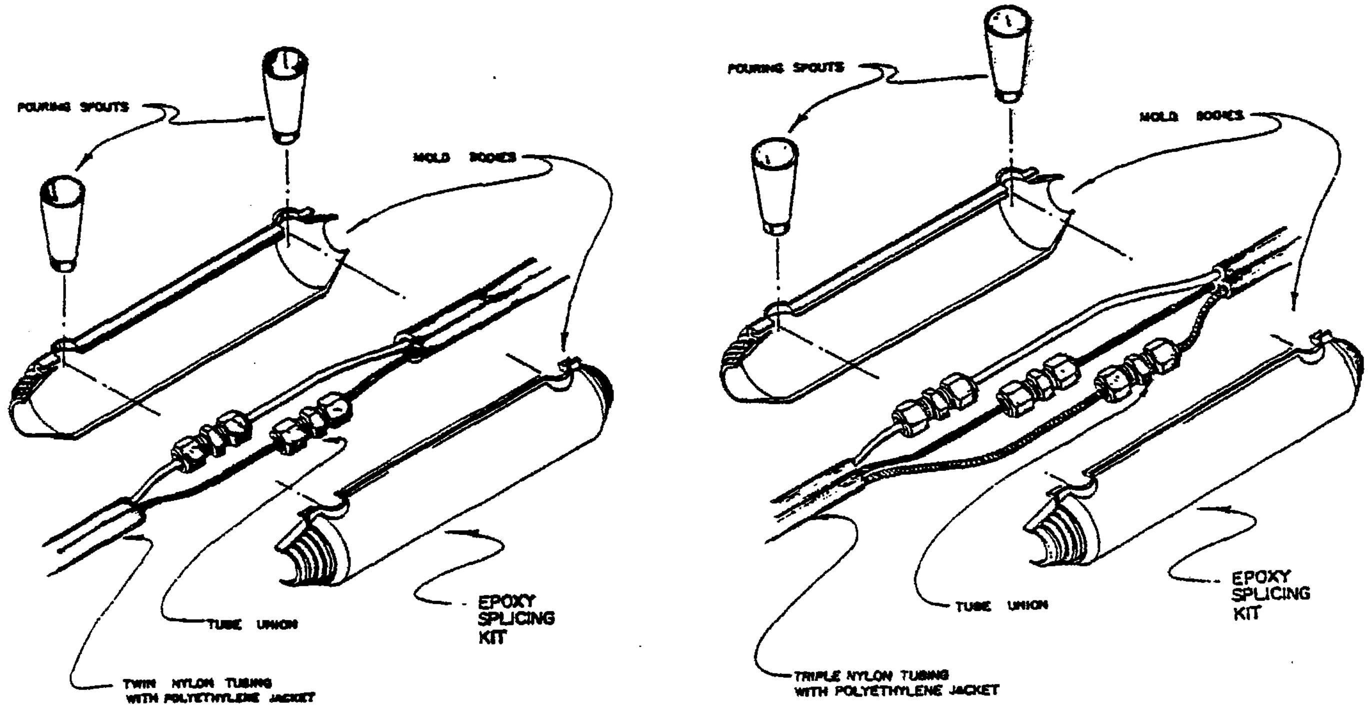
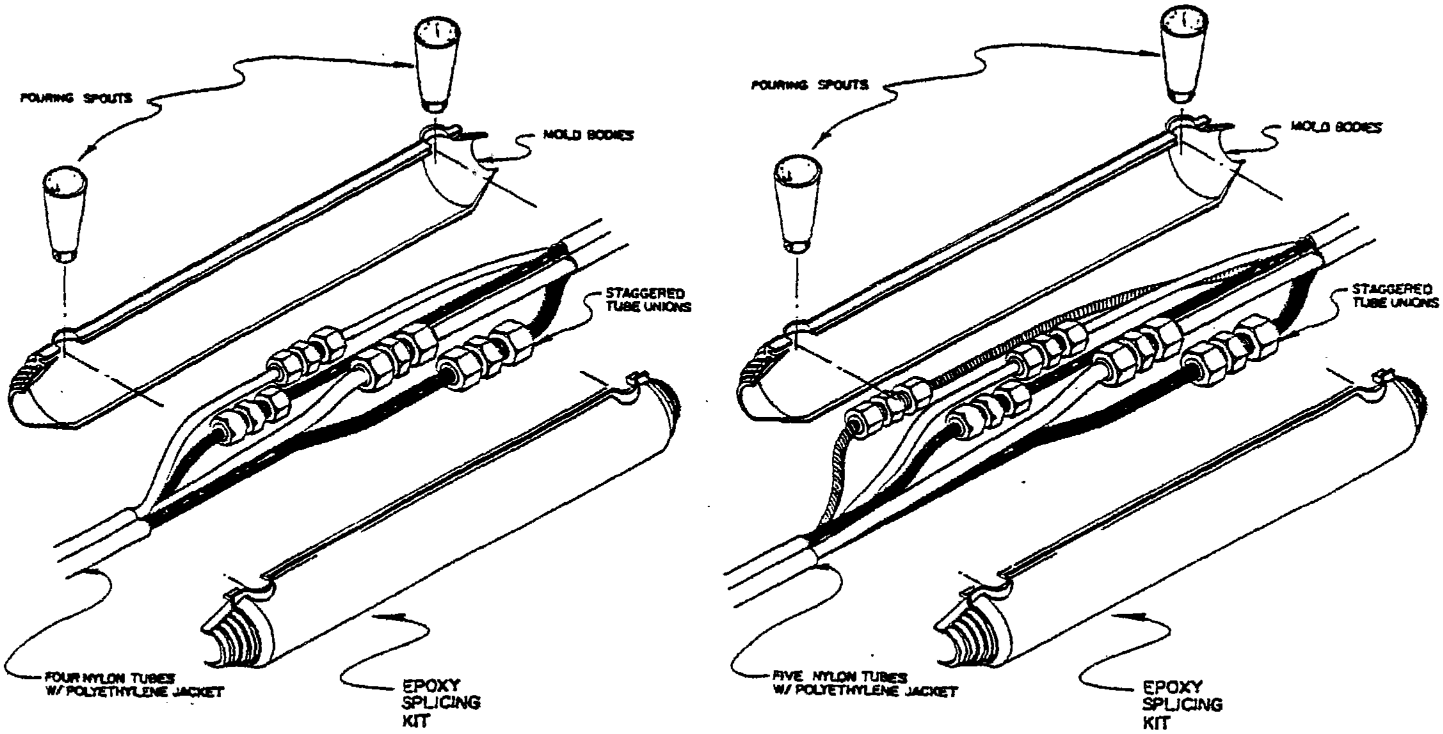


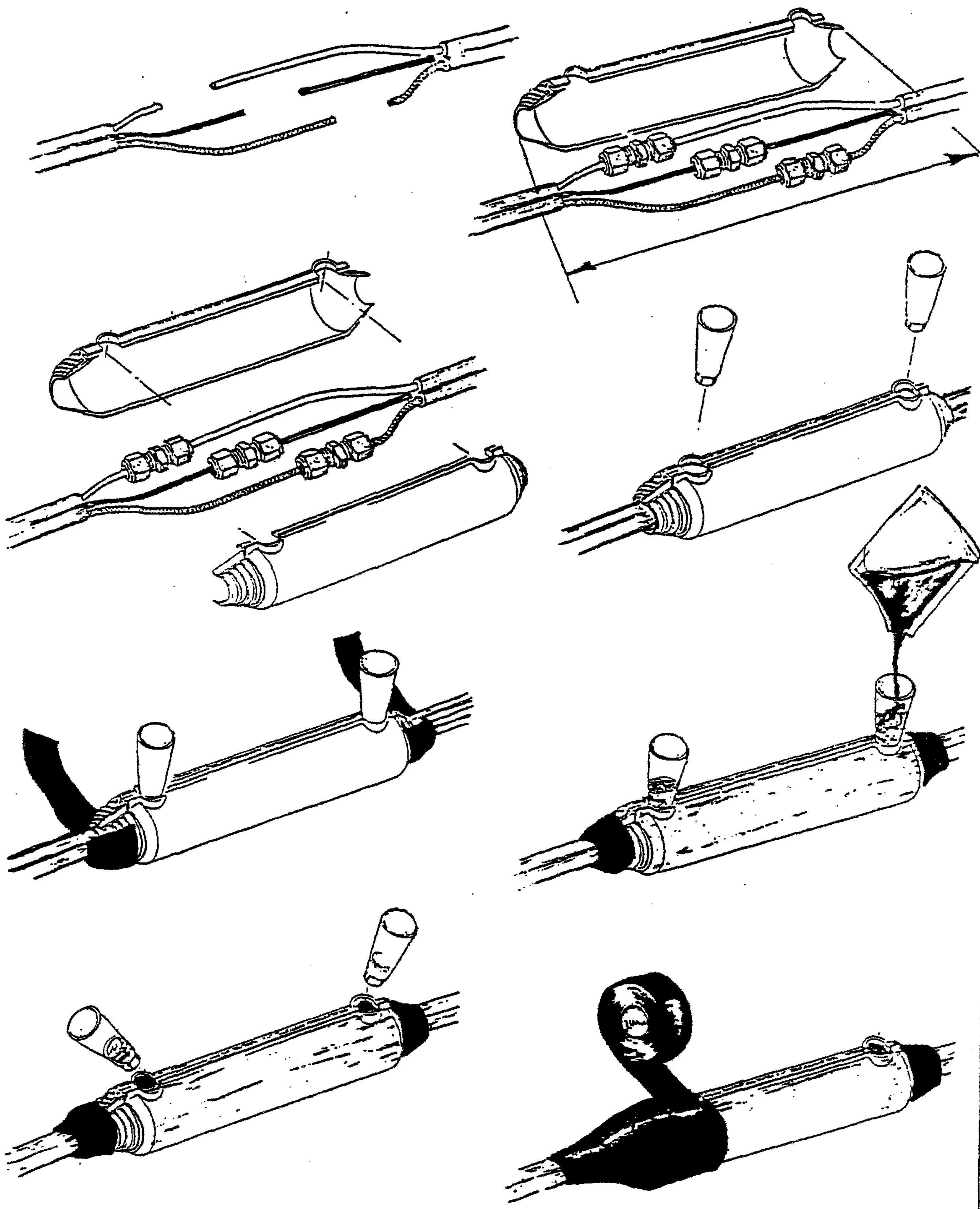
Note: Stagger couplings as needed to fit splicing kit which will vary with the number of tubes used.



Tubing Splicing Detail

Printed in USA (1-80)

Fig.5



Swagelok

MEET THE CHALLENGE℠

12/5/2006 4:08:29 PM

www.swagelok.com ®

Tube Fittings - Straights

Ordering #: B-400-6

Description: Brass Swagelok Tube Fitting, Union, 1/4 in. Tube OD

Specification Summary

General	
Body Material	Brass
Body Type	Union /Reducing union
Series	Swagelok tube and adapter fittings
End Connections	
End Connection 1 Size	1/4 in
End Connection 1 Type	Swagelok® tube
End Connection 2 Size	1/4 in
End Connection 2 Type	Swagelok® tube
Options	
Cleaning	Swagelok SC-10

REVIEW PRODUCT CATALOG FOR COMPLETE SPECIFICATIONS INCLUDING WARNINGS AND CAUTIONS.

Safe Product Selection: When selecting a product, the total system design must be considered to ensure safe, trouble-free performance. Function, material compatibility, adequate ratings, proper installation, operation, and maintenance are the responsibilities of the system designer and user.

Caution: Do not mix or interchange valve components with those of other manufacturers.

Colorado Engineering & Instrumentation, Inc.
12800 West Cedar Drive, Suite 208
Lakewood, Colorado 80228-1971
Phone: (303) 989-5159 Fax: (303) 980-6157

VIBRATING WIRE SETTLEMENT SYSTEMS INSTALLATION PLAN

All vibrating wire settlement systems, Owner provided or provided by CEI, will be inspected prior to installation to ensure that all are operating properly and within the calibration tolerance. Also prior to installation, all instruments will be read and the readings will be recorded. All instruments will be installed as indicated on the plans. The location and elevation of the installation will be verified by the Contractor with the Owner prior to installation. Once the elevation and the location have been verified CEI will install the instrument and run the cable/tubing to the location of the terminal panel approved by the Owner in the Contractor provided trench. Once the instrument is in place there will be a survey done on the instrument to retain the x, y, and z coordinates. Also a survey will be done on the terminal panel which houses the fluid reservoir. All readings taken during the installation will be turned over to the Contractor.

10

GEOKON — The World Leader in Vibrating Wire Technology

48 Spencer Street
Lebanon, NH 03766, USA
Tel: 603•448•1562
Fax: 603•448•3216
E-mail: geokon@geokon.com
http://www.geokon.com

Instruction Manual

Model 4650

VW Settlement Sensor

(Doc Rev G, 04/06)

Warranty Statement

Geokon, Inc. warrants its products to be free of defects in materials and workmanship, under normal use and service for a period of 13 months from date of purchase. If the unit should malfunction, it must be returned to the factory for evaluation, freight prepaid. Upon examination by Geokon, if the unit is found to be defective, it will be repaired or replaced at no charge. However, the WARRANTY is VOID if the unit shows evidence of having been tampered with or shows evidence of being damaged as a result of excessive corrosion or current, heat, moisture or vibration, improper specification, misapplication, misuse or other operating conditions outside of Geokon's control. Components which wear or which are damaged by misuse are not warranted. This includes fuses and batteries.

Geokon manufactures scientific instruments whose misuse is potentially dangerous. The instruments are intended to be installed and used only by qualified personnel. There are no warranties except as stated herein. There are no other warranties, expressed or implied, including but not limited to the implied warranties of merchantability and of fitness for a particular purpose. Geokon, Inc. is not responsible for any damages or losses caused to other equipment, whether direct, indirect, incidental, special or consequential which the purchaser may experience as a result of the installation or use of the product. The buyer's sole remedy for any breach of this agreement by Geokon, Inc. or any breach of any warranty by Geokon, Inc. shall not exceed the purchase price paid by the purchaser to Geokon, Inc. for the unit or units, or equipment directly affected by such breach. Under no circumstances will Geokon reimburse the claimant for loss incurred in removing and/or reinstalling equipment.

Every precaution for accuracy has been taken in the preparation of manuals and/or software, however, Geokon, Inc. neither assumes responsibility for any omissions or errors that may appear nor assumes liability for any damages or losses that result from the use of the products in accordance with the information contained in the manual or software.

Contents

1. General Description

The 4650 Settlement System is designed to measure the differential settlement between two points. A reservoir is located at a stable reference point and is connected to a sensor located at the settlement point by two liquid-filled tubes. The sensor senses the pressure of liquid within the tube and this provides a measure of the height of the liquid column and hence a measure of the elevation difference between the reservoir and the sensor.

Figure 1 shows a typical installation used to measure the settlement inside an embankment. The sensor is read by means of an electrical cable extending to the readout location. Readout may be by GK-401, GK-403, GK-404 or the Micro-10 Datalogger. The sensor contains a thermistor for measurement of temperature and also has gas discharge tubes for protection against lightning damage. The cable also contains a vent tube that connects the air inside the sensor to the space above the reservoir. This ensures that the sensor readings are unaffected by any changes in barometric pressure. A desiccant chamber located at the reservoir end of the vent line prevents moisture from migrating into the line.

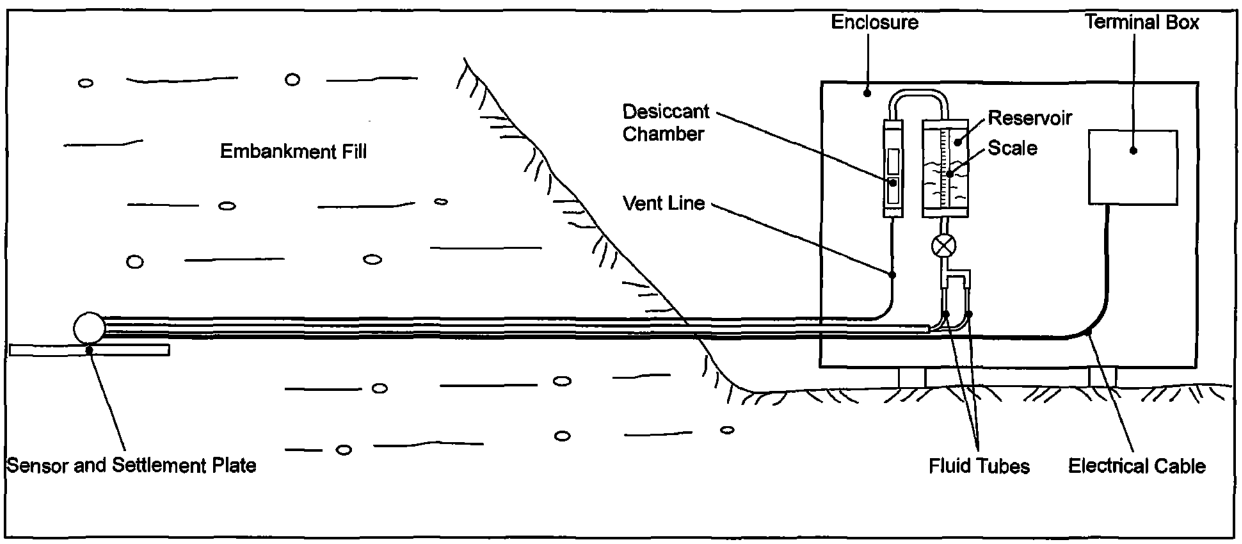


Figure 1. Typical installation of Vibrating Wire Settlement System.

Figure 2 shows details of the sensor.

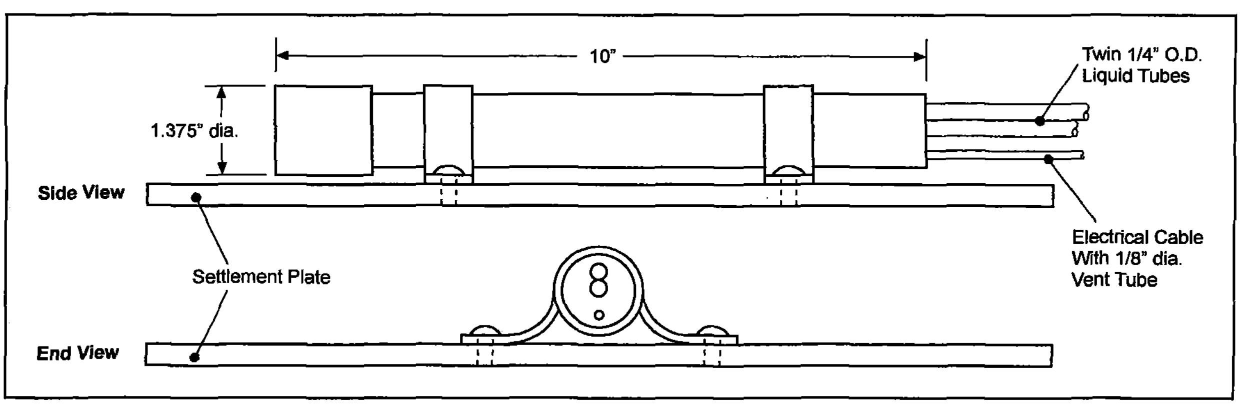


Figure 2. Sensor details.

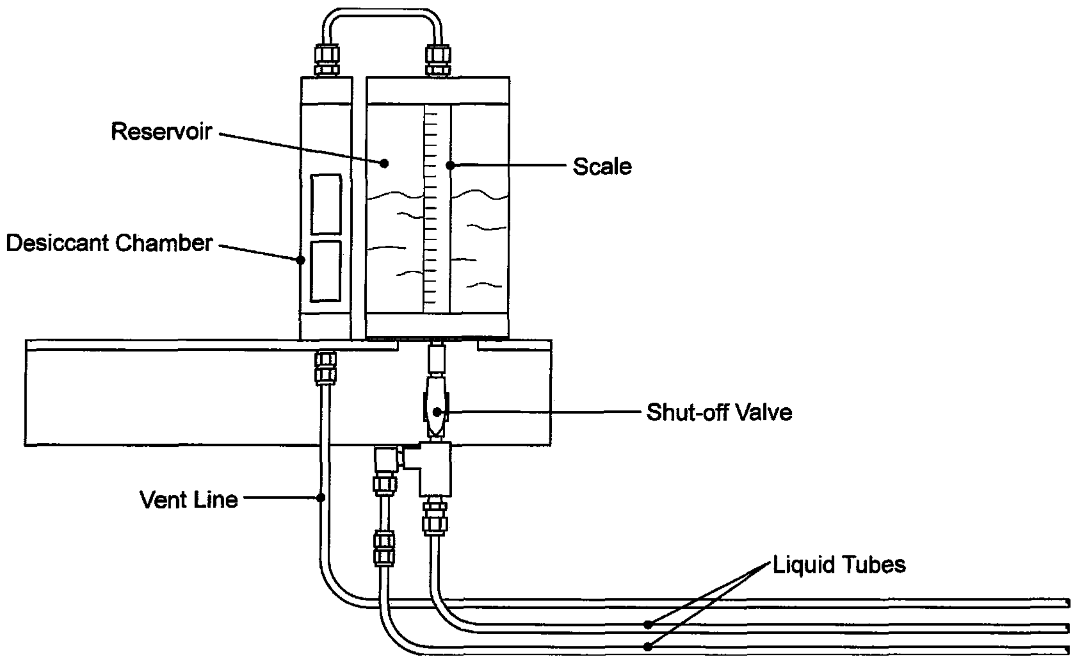


Figure 3. Reservoir Details.

than one sensor can be connected to a single reservoir. The use of two liquid-filled tubes permits the tubing to be flushed periodically to remove any accumulation of air bubbles. The liquid used is typically a de-aired antifreeze mixture, which resists the growth of algae and is not susceptible to freezing.

2. Installation Procedures

Most installations are in fills and embankments where the sensor and cables are buried. Elsewhere the cables and sensors may be attached directly to structures undergoing settlement of heave. The reservoir location must always be at a higher elevation then the sensor and higher than any part of the liquid-filled connecting tube.

Pre-filled systems are usually delivered with de-aired antifreeze solution already in the liquid lines; an extra length of small diameter tubing is connected to the outer ends of the liquid lines to allow the system to breath during transportation while simultaneously protecting the sensor from being over-ranged by temperature or pressure fluctuations and preventing the entry of air-bubbles into the main liquid lines.

Alternatively, systems may be provided with the tubing empty for filling in the field.

2.1 Installing the Sensor

The sensor is usually attached to a settlement plate using the bracket(s) provided.

The settlement plate might be attached directly to a structure, using bolts; in the case of installation in fills a smooth, flat-bottomed excavation should be made about 300 to 600mm deep. The sensor plate is placed on this flat surface and covered with fine material, similar to the fill, with all particles removed over 10mm size. This material should be tamped down around the cell until the excavation is filled back to the original ground surface.

The elevation of the settlement plate should be measured at the time of the installation using conventional level survey techniques. Check also that the sensor is still functioning after tamping.

2.2 Installing the Cables and Liquid-Filled Tubes

Cables and tubing need to be placed in a trench approximately 300 to 600 mm deep. The trench should not undulate and individual cables and tubes should be laid side by side without touching or crossing each other. In no place should the tubing be higher than the reservoir location. Before back-filling the trench examine the tubing for signs of air-bubbles: If any are noted the tubing will need to be flushed before initial readings are taken.

Compact the material in the trench around the cables. Do not allow large angular pieces of rock to rest directly on the cable. To prevent migration of water along the trench, bentonite plugs can be constructed at intervals.

Trenches in earth dam embankments should never penetrate entirely through the clay core. Compaction of the fill above the cables can proceed in a normal manner when the cover exceeds 600mm depth. Where cables are not buried they should be adequately supported along their length to prevent undulations. They should also be protected from direct sunlight and insulated from rapid temperature fluctuations by encasing them in styrofoam or urethane foam, etc.

2.3 Installing the Reservoir

The reservoir should be installed on stable ground or at a location that can be level surveyed. The terminal housing should be affixed to stakes grouted firmly into the ground or preferably into a concrete pad poured at a location. The elevation of the reservoir pad should be surveyed and recorded at the time of installation. Remove the top fitting from the sight tube and fill the reservoir with de-aired antifreeze solution until it is half full as shown by the sight tube. The reservoir should never be located where it is exposed to direct sunlight.

When connecting the tubes from the sensor to the reservoir do not allow air to be trapped inside the tubing. Make sure that the vent line to the sensor is not blocked. This can be checked using an aspirator bulb to draw a vacuum on the vent line while observing the sensor reading on the GK-401, GK-403 or GK-404 readout box. Attach the vent line to the vent line manifold and add fresh desiccant to the desiccant chamber (or the vent line manifold)

A few drops of light oil added through the top of the reservoir will prevent evaporation from the liquid surface. Make sure that the connecting tubing between the vent line manifold (or desiccant chamber) and the reservoir is not blocked.

Connect the sensor cable to the terminal panel, if one exists: Black and Red wires are connected to the gage position; Green and White wires are connected to the thermistor (temperature) position. Manual switch panels can be used in conjunction with GK-401 or GK-403 readout boxes. Terminal strips are used in conjunction with dataloggers.

2.4 Taking Initial Readings

Initial readings must be taken with great care; they are the base line readings to which all subsequent readings are compared. It is important that the liquid-filled tubes be at a constant temperature. If the tubes are not completely buried the readings should be taken at a time when the temperature is relatively constant; certainly the readings should never be taken when the tubes are exposed to direct sunlight. Also, there should be no air bubbles in the liquid tubes. If air bubbles are detected the tubes should be flushed before the initial readings are taken. If there is any doubt, take readings, flush the tubing and again take readings. Repeat if necessary until the readings are stable.

Take careful measurement of the elevation of the liquid level inside the reservoir sight tube. Make a mark on the tube opposite the liquid level. This will serve as a quick visual check on any fluctuations and enable a quick means of measuring the magnitude of the change for correction of subsequent calculations of settlement (see section 12) Reservoir level fluctuations may be due to temperature or pressure fluctuations or due to leakage. Record the ambient temperature.

3. Flushing Procedures

Periodic flushing of the liquid-filled tubes may be required to remove air bubbles. Tubes should always be filled with de-aired liquid. The best way to de-air a liquid is to use a Nold Deaerator (ask Geokon for more details). De-aired liquid is also available from Geokon in 2 gallon or 5-gallon pressure tanks specially designed to prevent air from reaching the fluid. The liquid should also resist the growth of algae and should not be liable to freeze in cold climates. The growth of algae can be prevented by dissolving a crystal of copper sulfate in the liquid or by using commercial grade ethylene glycol solutions, which also prevent freezing. The use of distilled water, rather than tap water, is recommended. Figure 4 shows the apparatus recommended for flushing the tubes.

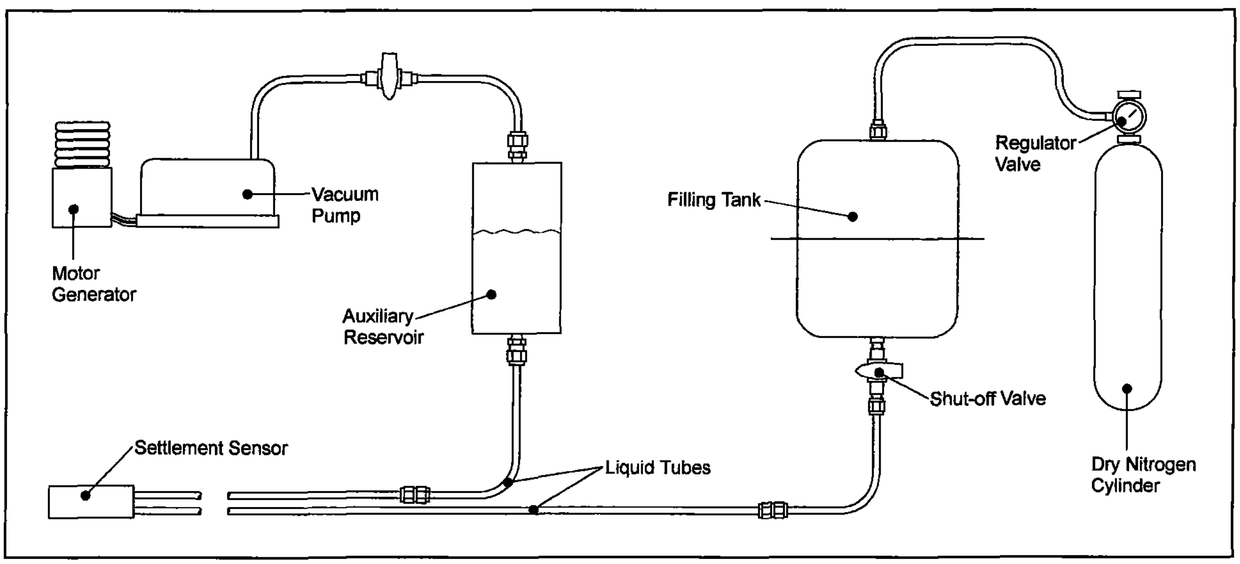


Figure 4. Flushing Apparatus

The shut off valve at the base of the reservoir is closed; one of the tubes is disconnected and then reconnected to the base of the filling tank filled with de-aired liquid. The second tube is disconnected and attached to the base of an auxiliary reservoir. To speed up the flushing process (for tubes longer than 200m) it is recommended that a vacuum pump be attached to the top of the auxiliary reservoir. A nitrogen cylinder with regulator is connected to the top of the filling tank. Start the vacuum pump running then open the valve at the bottom of the pressure tank. Adjust the nitrogen pressure until the settlement sensor reads at its maximum range value on either a GK-401 or GK-403 Readout Box. Be careful not to over range the sensor by more than 20%. Do not allow the nitrogen pressure to exceed the pressure rating marked on the outside of the filling tank (usually 100 psi (700kPa). ***Failure to observe this precaution could result in injury.*** As flushing proceeds, the auxiliary reservoir may need to be emptied periodically. Store the flushed liquid in a container for later disposal. Do not allow any liquid to enter the vacuum pump as this could ruin it. Continue flushing until all the old liquid has been removed. Dye, added to the new flushing fluid, can be used to indicate when the flushing is complete. A 300-meter length of tubing requires 2.5 liters (0.67 gallons) of liquid. When flushing is complete reconnect the fluid lines to the base of the reservoir being careful not to introduce air-bubbles during the process.

4. Purging the Vent Lines

The vent line must remain open at all times connecting the inside of the sensor to the space above the reservoir. Any blockage of the vent line due to pinching, dirt, or moisture will cause false readings that fluctuate and/or are sensitive to temperatures.

Blockages due to pinched tubes can be confirmed by applying a vacuum to the vent line and observing the reading on the sensor. If the sensor does not respond the tube is blocked by dirt or pinched, and this might be correctable if the blockage is accessible. Blockages due to moisture and condensation can be purged using a vacuum pump to evacuate the vent line. As the vacuum is applied watch for signs of water in the vent line. When the vacuum has stabilized stop the pump, disconnect the vent line and quickly re-attach either a desiccant chamber containing fresh desiccant, or a cylinder of dry nitrogen. This ensures that the gas drawn back into the vent line is dry. Check that the vent line connection is open between the desiccant chamber (or vent line manifold) and the top of the reservoir.

5. In-Situ Calibration

A valuable feature of the Model 4650 settlement system is the ability to perform in-situ calibrations. This is done by connecting an auxiliary reservoir to one of the fluid lines as shown in figure 5.

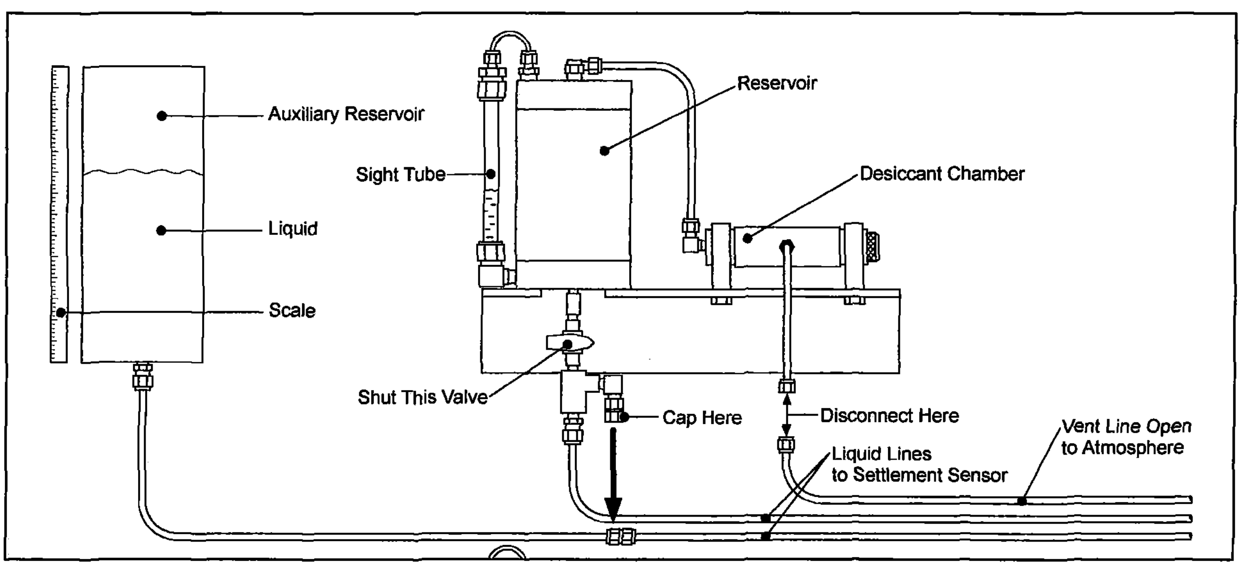


Figure 5. In-Situ Calibration Apparatus.

First close off the valve at the bottom of the reservoir, half-fill the auxiliary reservoir with the same liquid used in the reservoir and connect it via a short length of tubing to one of the fluid lines, being careful not to introduce air into the lines. Cap off the open fitting on the reservoir connection and disconnect the vent line from the vent manifold. Raise and lower the auxiliary reservoir by measured amounts using a scale to measure the elevation of the water level. Read the sensor using a GK-401, GK-403 or GK-404 readout box. Record the readings after allowing sufficient time for the readings to stabilize (usually requires around 1 to 5 minutes although it will be noted that the sensor responds instantaneously to change of water elevation even where the liquid tubes are very long.) Record the sensor readings at five or more different elevations, then, from the data calculate the calibration factor and compare it with the factory-generated value on the calibration sheet. Remove the auxiliary reservoir and reconnect the fluid line to the base of the reservoir and the vent line to the desiccant chamber or vent line manifold. Re-open the valve at the base of the reservoir.

6. In-Situ Zero Check

This procedure is not recommended as a regular procedure but only one to be undertaken if there is some serious doubt as to the zero stability of the sensor or to confirm a sudden or critical change in the amount of settlement which is causing concern.

Disconnect the vent line from the desiccant chamber Close the valve at the bottom of the reservoir. Disconnect the liquid lines from the bottom of the reservoir connect one of them to a nitrogen cylinder. Turn on the nitrogen and adjust the pressure so that the sensor reading is at its maximum value. (Do not exceed 20% above this maximum range.) The other tube can be left open (with long lengths of tubing (> 200m) the process can be speed up by attaching a vacuum pump to the end of the other fluid line.) When all the liquid has been purged from the lines allow the nitrogen to flow for another 30 minutes. This will tend to dry out the inside of the tubing. Turn off the nitrogen and disconnect the ends of the tubing so that they are both open to atmosphere along with the open vent line. Wait until the sensor reading stabilizes and then record this zero reading. Compare this reading with the factory zero reading shown on the calibration chart.

Refill the liquid lines following the flushing procedures described in section 3 with the following difference:
If a vacuum pump is used allow the vacuum pump to run for 30 minutes or until the sensor reading has stabilized before opening the valve at the bottom of the filling tank to allow liquid to enter the lines. This will greatly reduce the chances of air being trapped inside the tubing and sensor cavities.

7. Special Tools & Apparatus Required for Test Procedures

- GK-401 or GK-403 Readout Box
- Assorted wrenches
- Nitrogen supply cylinder with regulator valve
- Pressure tanks filled with de-aired liquid (50% anti-freeze solution made with distilled water and containing dye)
- Vacuum pump and rubber connecting hoses with pinch clamps
- Motor generator (Gasoline powered)
- Auxiliary reservoir
- Miscellaneous connecting tubes & fitting

8.Maintenance

Every 3 months

- Conduct a visual examination of the reservoir terminal housing. Check for leaks by observing the water level in the reservoir sight tube. Add additional fluid as necessary by removing the top connector of the Tygon sight tube. Alternatively, if the water level in the reservoir begins to rise this may be due to squeezing of the tubing by ground pressures. It is important not to let the fluid overflow from the reservoir into the vent line; this could adversely affect the readings. So drain off any excess fluid before it reaches the top of the reservoir. If regular maintenance is not possible then it is advisable to disconnect the tubing connecting the top of the reservoir to the desiccant chamber and leave them both open to the atmosphere.

- Replace the desiccant capsules in the vent line manifold or desiccant chamber. Desiccant capsules are dark blue when active and pink when inactive.

Every 12 months

- Flush the liquid tubes with fresh de-aired liquid.

- Check the in-situ calibration as described in section 5.

9. Trouble Shooting

Faulty readings may show up as unstable, fluctuating readings, sudden large changes of readings or readings of 9999 on dataloggers, unrelated to physical phenomena. The first task should be to see if the fault lies with the readout device. If a datalogger is in use, try reading the sensors with a portable GK-401 or GK-403 Readout box.

9.1 Unstable Readings

Unstable readings with dataloggers may be caused by electrical noise from nearby power lines or electrical equipment. Remove such equipment, if possible, or read the sensors when the power is switched off.

Fluctuating readings may also be the result of air-bubbles in the liquid lines or of plugged vent lines. Follow the procedures outlined in Section 3 & 4.

9.2 Reading of 9999

These will show up on dataloggers if the reading is over-range. This can happen if the electrical leads are shorted or open. Check the resistance between the black and red conductors. The resistance should be 180 ohms ±10 ohms plus 5 ohms for every 100 meters of lead wire. If the resistance is substantially different from these values check for loose connections in the terminal box and for visible signs of cable damage.

9.3 Sudden or Large Changes in Readings

May be caused by leakage of liquid from the liquid lines. Check the reservoir sight tube. If leakage is detected and there are more than one sensor connected to the reservoir turn off each sensor valve at the base of the reservoir one by one till the leaking sensor is found. If preferred this sensor can be left isolated from the system so as not to disrupt the others.

10. Specifications

Refer to the product literature sheets for specifications of the vibrating wire sensor transducer.

- Electrical cable – Model 02-335VT8, 2 shielded pairs 22 Ga. W/ ground wire and integral 1/8" diameter polyethylene vent tube. 0.375 inch diameter polyurethane jacket. Resistance 16 ohms/1000 ft. (5.25 ohm/100m)
- Liquid tubes- Twin type 11 nylon tubes ¼" O.D. covered with 1mm polyethylene jacket.
- Liquid- A 50% solution of commercial grade ethylene glycol mixed with distilled water and de-aired, specific gravity 1.065. Freezing point –40°C.
- Desiccant Capsules- Geokon Model 4500-8

11. Taking Readings

Initial readings are taken as described in Section 2.4. Follow the instructions of either the Datalogger or portable readout box in use. The sensor is connected to the black and red leads the thermistor to the green and white leads. (Read the sensors on channel B)

When taking sensor readings record also the height of the fill above the sensor, the temperature and any other physical phenomena or construction activity that might affect the readings.

Temperature at the sensor location will be read automatically by a datalogger and by a GK-403 or GK 404 readout box. If a GK-401 is in use the sensor thermistor can be read using an ohmmeter to measure the resistance. Appendix 1 gives a reference table for converting resistance to temperature. Be sure to allow for the resistance of the sensor cable (5.25 ohms per 100m).

12. Data Reduction

12.1 Calculation of Sensor Elevation

Readings can be used to calculate the elevation of the sensor and to plot them on a graph versus time. The graph should also show the elevation of the fill above the sensor at the time of each reading. A plot of temperature can also be included. For the standard 4650 settlement system using type 4500 SV or 4500 ALV transducers the readings will get smaller as the sensors settle relative to the reservoir.

For these sensors the elevation, E, of the sensor is given by:

$$\mathbf{E = E_0 - ((R_0 - R_1)\ G - \Delta E_{RES})\ Meters}$$

Where $\mathbf{E_0}$ is the sensor elevation at installation.

$\mathbf{\Delta E_{RES}}$ is any change of the fluid level inside the reservoir sight glass. If the fluid level falls, ΔE_{RES} is negative. If the fluid level rises, ΔE_{RES} is positive.

$\mathbf{R_0}$ is the initial sensor reading

$\mathbf{R_1}$ is the subsequent sensor reading

G is the calibration factor supplied with the sensor

A typical calibration sheet as, supplied by the factory, is shown in figure 6 (on page 11).

Example:

$\mathbf{E_0}$ = 541.623 meters

$\mathbf{R_0}$ = 9030

$\mathbf{R_1}$ = 8800

G = 0.00140meters/digit

$\mathbf{\Delta E_{RES}}$ = –10mm (i.e. the level of water in the reservoir sight tube is 10mm lower than the level measure at the time of the initial reading).

So the new sensor elevation is

$$E = 541.623 - ((9030\text{-}8800)\ 0.00140 - (-0.010))$$

$$E = 541.291 \text{ meters}$$

Or, in other words, there has been a settlement of 332mm.

12.2 Calculation of Settlement

The amount of settlement, S, of the sensor is given by the equation

$$\mathbf{S = (R_0 - R_1)\ G - \Delta E_{RES.}\ Meters}$$

So in the last example, S = (9030-8800) 0.00140 - (–0.010) = 0.261meters = 332mm

12.3 Correction for Settlement or Heave of the Reservoir Terminal

Periodic level surveys should be made of the elevation of the concrete pad on which the reservoir terminal is located. Any settlement should be subtracted from the calculated sensor elevations.

12.4 Corrections for Temperature

Temperature effects on liquid volume (liquid density) and on the expansion and contraction of the liquid confines can be quite complex and in some ways self canceling. Liquid lines in fills are generally well insulated so that temperature effects tend to be insignificant. Systems exposed to the atmosphere and to sunlight may suffer from rapidly changing temperatures at different parts of the system causing significant fluctuation of the readings. In such cases precautions may be necessary to obtain readings at times of maximum temperature stability.

Temperature effects on the sensor can be corrected for but are usually quite insignificant especially if the sensor is buried.

The temperature correction to the elevation, $\mathbf{E_T}$, is given by:

$$\mathbf{E_T = +(T_1 - T_0)\ C}$$

Where $\mathbf{T_0}$ is the initial temperature, $\mathbf{T_1}$ is the current temperature and **C** is the temperature correction factor included on the calibration sheet.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Settlement System Calibration Report

Model Number: 4650-1-7.01 m

Date: August 04, 1999

Serial Number: 50695

Transducer Size: 10 psi (vented)

Transducer Number: 9-146

Cal. Std. Control #(s): 377, 405, 213

Customer I.D. #: B1

Temperature: 23.9 °C

Customer:

Tubing: 331m

Job Number: 13809

Cable: 331m

Technician: [signature]

*tubing filled and gage calibrated with 1:1 mix water/anti-freeze - specific gravity 1.065

Elevation m	Reading GK 403 Pos. B	Difference
0.6096	9769.5	
0.9144	9551.5	218.0
1.2192	9334.5	217.0
1.5240	9117.0	217.5
1.8288	8899.5	217.5
2.1336	8681.0	218.5
2.4384	8463.0	218.0

Calibration Factor G = 0.00140 m/Digit

Thermal Factor K = -0.00349 m/°C

DO NOT EXCEED 7 m (23 Feet) BETWEEN RESERVOIR & TRANSDUCER

Wiring Code: Red and Black: Gage White and Green: Thermistor

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

APPENDIX A – **STANDARD TEMPERATURE** THERMISTOR TEMPERATURE DERIVATION

Thermistor Type: YSI 44005, Dale #1C3001-B3, Alpha #13A3001-B3

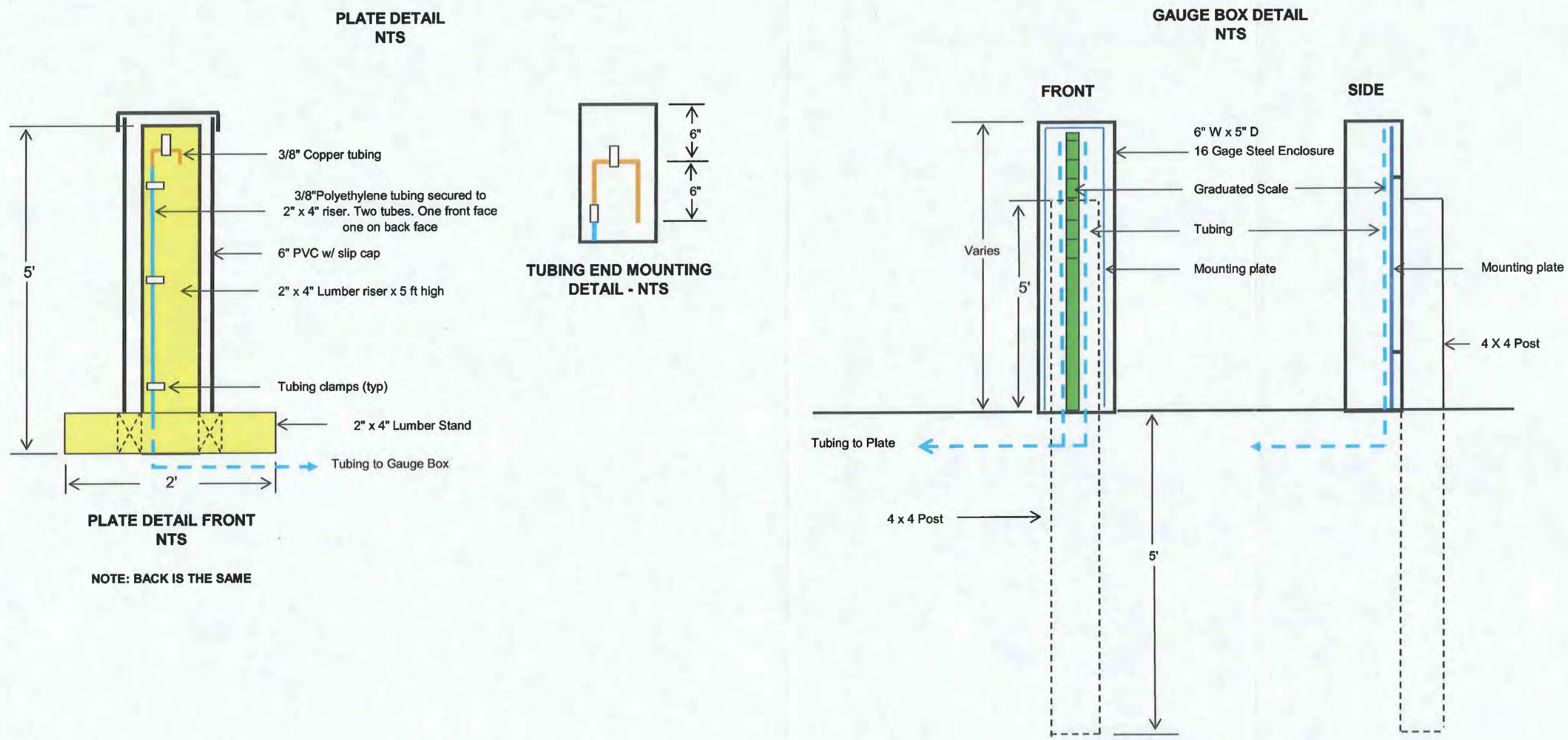
Resistance to Temperature Equation B1:

$$T = \frac{1}{A + B(LnR) + C(LnR)^3} - 273.2$$

Where; T = Temperature in °C.
LnR = Natural Log of Thermistor Resistance
A = 1.4051 × 10^{-3} (coefficients calculated over the –50 to +150° C. span)
B = 2.369 × 10^{-4}
C = 1.019 × 10^{-7}

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	+30	525.4	+70	153.2	+110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	+1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.66K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-34	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	292.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	5692	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.0	53	250.9	93	83.6	133
41.56K	-26	4939	14	929.6	54	243.4	94	81.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	**3000**	**25**	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

11



SETTLEMENT PLATFORM DETAIL

CEI FIGURE NO.1

ASTM Specification > Copper Tube Size > Maximum Pressure Range, psi

Tubing

This product matches all of your selections.

Part Number: 8967K5

Type	General Purpose Copper Tubing
Material	General Purpose Copper (Alloy 122)
Shape	Single Line
Copper Tube Size	3/8"
Copper Tube Size Note	Tube size is the accepted designation for wrot copper tube fittings, not an actual size.
Outside Dia.	1/2" (.5")
Outside Dia. Tolerance	±.002"
Inside Dia.	.436"
Wall Thickness	.032"
Maximum Pressure	720 psi @ 70° F
Operating Temperature Range	-425° to +400° F
Metal Bendability	Not Bendable
Temper	Hard
Tensile Strength	High
Metal Construction	Seamless
Metal Flareability	Not Flareable
Sterilize With	Steam (autoclave)
Shipped As	Straight Length
Specifications Met	American Society for Testing and Materials (ASTM)
ASTM Specification	ASTM B75
Compatible Fittings	Compression and Wrot Copper
Length	6'

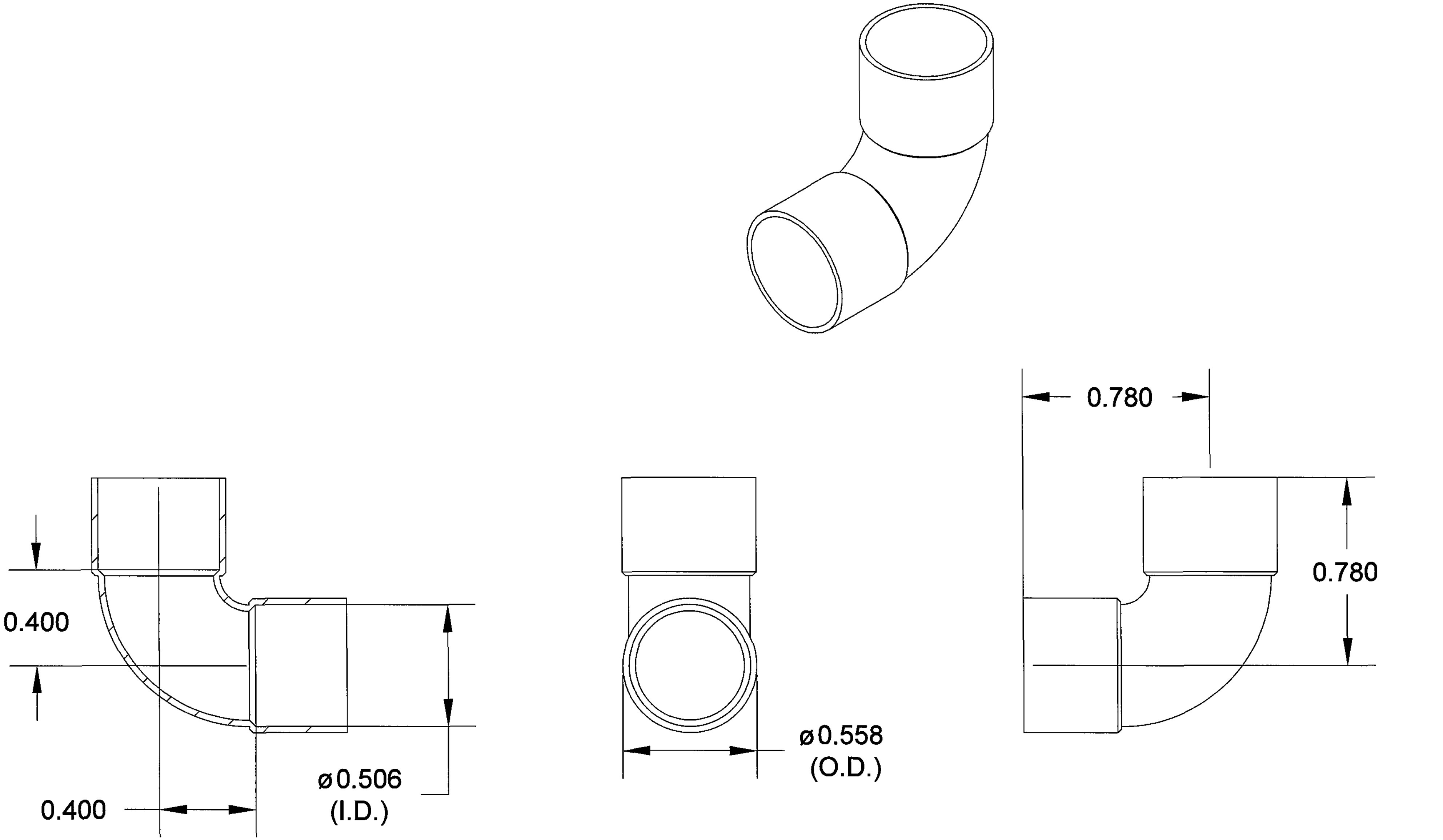
Inside Dia. > Translucent

Tubing

This product matches all of your selections.

Part Number: 5384K566

Type	Semirigid Polyethylene Tubing
Material	LDPE (Low-Density Polyethylene)
Shape	Single Line
Outside Dia.	1/2" (.5")
Inside Dia.	3/8" (.375")
Wall Thickness	1/16" (.0625")
Reinforcement	Unreinforced
Color	Translucent White
Maximum Pressure	123 psi @ 75º F
Operating Temperature Range	-40º to +150º F
Performance Characteristics	Vacuum Rated
Vacuum Rating	28" Hg at 75º F
Bend Radius	2-1/2" (2.5")
Durometer	94A (Rigid)
Tensile Strength	4,298 psi
Elongation	395%
Sterilize With	Not Rated
Specifications Met	United States Food and Drug Administration (FDA)
FDA Specification	FDA Compliant
Compatible Fittings	Instant and Compression
Standard Lengths, ft.	25, 50, 100
Chemical Compatibility Link	5384KAC
WARNING	Tubing will crack if subjected to continual flexing.



McMASTER-CARR SUPPLY COMPANY	PART NUMBER 5520K78
DATE SEPT 2001 / PAGE 1 OF 1	Wrot-Copper Soldered-Joint Tube Fitting 90° Elbow, 3/8" Tube Size
SCALE 0.0 0.5 1.0	
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES	http://www.mcmaster.com (c) 2001 McMaster-Carr Supply Company

GRAINGER. FOR THE ONES WHO GET IT DONE

Print *printed* December 5, 2006

Strap,Conduit,Pk100

Conduit Strap, Conduit Size 3/8 Inch, Steel/Zinc Plated One Hole Pipe, 3/4 x 1 47/64 Inches, Package 100

Grainger Item #	3KF71
Price (pk.)	**$32.55**
Brand	THOMAS & BETTS
Mfr. Model #	HS 100 SC
Ship Qty.	1
Sell Qty. (Will-Call)	1
Ship Weight (lbs.)	2.35
Usually Ships	Today
Catalog Page No.	541

Price shown may not reflect your price. Log in or register.

Additional Info

Conduit Straps

Tech Specs

Item: One Hole Pipe Strap
EMT Size (In.): 3/8
Finish: Zinc
Material of Construction: Steel
Package Quantity: 100

Notes & Restrictions

There are currently no notes or restrictions for this item.

MSDS

This item does not require a **Material Safety Data Sheet (MSDS).**

Required Accessories

There are currently no required accessories for this item.

Optional Accessories

Anchor,Plug,Pk 100

Item #: 4AL67
Brand: RED HEAD
Usually Ships: Today
Price (ea): $15.14

Alternate Products

There are currently no alternate products for this item.

Repair Parts

There is currently no Repair Parts information for this item.

Colorado Engineering & Instrumentation, Inc.
12860 West Cedar Drive, Suite 208
Lakewood, Colorado 80228-1971
Phone: (303) 989-5159 Fax: (303) 980-6157

MANOMETER SETTLEMENT PLATFORMS INSTALLATION PLAN

All instruments will be installed where indicated on the plans. The location and elevation of the installation will be verified by the Contractor with the Owner prior to installation. Once the elevation and the location have been verified and surveyed CEI will install the instrument and run the tubing from the platform to the gauge box, location to be approved by the Owner in the Contractor provided trench. The location will be a minimum of fifteen outside of the planned embankment limits. The trench will be a minimum of twelve inches deep. The bottom six inches will be placed with sand. Once the first level of sand is placed then the tubing will be placed in the trench. All tubing will be checked for levelness. Once the tubing is placed and the tubing is secured to the platform and gauge box CEI will fill the tubes with a mixture of fifty percent antifreeze and fifty percent water. Before any backfilling of the trench, CEI will have the Owner verify that the instrument is installed correctly. Once the Owner confirms that the instrument is installed correctly then the Contractor will backfill the next level of the trench with sand, a minimum of six inches. Once the instrument installation is completed there will be a survey done on the platform to retain the x, y, and z coordinates. Also a survey will be done on the gauge box. All readings taken during the installation will be turned over to the Contractor.