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Surplus Facilities Management Program (SFMP)
Contract No. DE-AC05-81OR20722

REPORT ON THE PERFORMANCE MONITORING SYSTEM FOR THE WASTE CONTAINMENT AT THE NIAGARA FALLS STORAGE SITE

Lewiston, New York

May 1986

Bechtel National, Inc.
Advanced Technology Division

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REPORT ON THE PERFORMANCE MONITORING SYSTEM FOR THE WASTE CONTAINMENT AT THE NIAGARA FALLS STORAGE SITE

MAY 1986

Prepared for

UNITED STATES DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS OFFICE
Under Contract No. DE-AC05-81OR20722

By

Bechtel National, Inc.
Advanced Technology Division
Oak Ridge, Tennessee

Bechtel Job No. 14501

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ABBREVIATIONS

cm	centimeter
cm/s	centimeters per second
ft	foot
in.	inch

1.0 INTRODUCTION

The Niagara Falls Storage Site (NFSS) is a U.S. Department of Energy (DOE) surplus facility located at Lewiston, New York. The waste containment structure for encapsulating low-level radioactive waste at the NFSS has been designed to minimize infiltration of rainfall, prevent pollution of groundwater, preclude formation of leachate, and prevent radon emanation. Accurately determining the performance of the main engineered elements of the containment structure will be important in establishing confidence in the ability of the structure to retain the wastes. For this purpose, a performance monitoring system has been developed for the waste containment structure to verify that these elements are functioning as intended. If the National Environmental Policy Act process results in a decision calling for final disposal of the wastes at the NFSS, the performance monitoring program described in this report will be applicable to the long-term disposal facility as well.

The performance monitoring system will be distinct from the environmental monitoring program conducted at the NFSS and will function for a shorter time. It is anticipated that the system will function for 5 years (FY 1987-91). It may, however, be maintained for a shorter or longer period depending upon the results observed. To accurately evaluate the effectiveness of the containment facility, both the data from the performance monitoring system and those from the broader environmental monitoring program must be assessed. The environmental program monitors radon concentrations in air; radium and uranium concentrations in surface water, groundwater, and sediment; and external gamma exposure.

The key objective of the performance monitoring system is the early detection of trends that could be indicative of weaknesses developing in the containment structure so that corrective action can be taken before the integrity of the structure is compromised. Consequently, subsurface as well as surface monitoring techniques will be used. After evaluating several types of subsurface instrumentation, it was determined that vibrating wire pressure transducers, in combination with surface monitoring techniques, would satisfactorily monitor the parameters of concern, such as water accumulation inside the containment facility, waste settlement, and shrinkage of the clay cover.

Surface monitoring will consist of topographic surveys based on predetermined gridlines, walkover surveys, and aerial photography to detect vegetative stress or other changes not evident at ground level.

This report details the objectives of the performance monitoring system, identifies the elements of the containment structure to be monitored, describes the monitoring system recommended, and outlines the costs associated with the monitoring system.

2.0 OBJECTIVES OF THE PERFORMANCE MONITORING SYSTEM

In December 1984 DOE requested that Bechtel National, Inc. (BNI) examine indirect means of monitoring the performance of the NFSS waste containment facility (Refs. 1 and 2). The design of the waste containment structure and the methods used to place the wastes inside the structure are intended to minimize the opportunity for contaminant migration. The design has addressed:

- Differential settlement of the wastes
- Desiccation cracking of the clay cap
- Horizontal displacement
- Surface erosion
- Animal burrowing
- Deep-rooted vegetation
- Rapid rise of the potentiometric (saturated) surface inside the containment structure

The purpose of the performance monitoring system is to detect evidence that one or more of the above conditions is occurring or has occurred so that action may be taken to remedy the situation before the integrity of the containment structure is threatened. In this way the monitoring system serves as a preventive maintenance program.

3.0 CONTAINMENT DESIGN FEATURES TO BE MONITORED

The waste containment area at the NFSS measures approximately 975 ft long by 450 ft wide and covers roughly 10 acres. A layer of gray, lacustrine clay forms the floor of the containment structure; a cutoff wall and dike keyed into the gray clay unit form the perimeter. The containment will be closed by an engineered, compacted clay cover that will extend beyond the perimeter dike.

Table 3-1 lists the main design features of the cover and the monitoring technique or instrumentation to be used in assessing their respective performances.

To predict contaminant movement in the event that the containment structure fails, numerical analysis of the potential for contaminant migration via groundwater has been conducted.

3.1 CONTAINMENT BASE AND CUTOFF WALL

The gray clay unit and the cutoff wall/dike serve as adsorption barriers to the vertical and horizontal migration of contamination from the waste containment area into groundwater. The gray clay ranges in thickness from 11 to 29 ft. It is fairly plastic with a permeability that ranges from 1×10^{-8} to 2×10^{-7} cm/s, with a median value of 8×10^{-8} cm/s (Ref. 3). Both the wall and the dike were constructed of clay; the wall was compacted to over 90 percent of maximum dry density [American Society for Testing and Materials (ASTM) D1557 test procedure] and the dike to 95 percent. The cutoff wall is keyed into the gray clay unit to a depth of at least 1.5 ft. The dike is, in turn, embedded into the clay cutoff wall. The dike is at least 8 ft thick and is constructed to a height of 5 ft above the existing ground level.

3.2 WASTE PLACEMENT

Waste has been placed and compacted within the containment structure in a manner that eliminates voids and minimizes the opportunity for differential settlement and subsidence. Contaminated soils have been compacted to 90 percent of the maximum dry density in accordance with ASTM D1557. Organic materials were separated from the waste and are not stored within the containment structure. Contaminated pipes and equipment were crushed and/or voids filled with grout. Existing drainage channels

TABLE 3-1

MONITORING TECHNIQUES AND INSTRUMENTATION FOR WASTE CONTAINMENT DESIGN FEATURES

Design Feature	Purpose	Performance Monitoring Technique/System
Clay cap	- Reduce infiltration of water	Vibrating wire pressure transducers and pneumatic pressure transducers
	- Contain radiation, prevent radon emanation	Radon monitors (environmental monitoring program)
Soil cover	- Prevent drying of clay cap	Visual inspection for cracking
	- Support growth of shallow rooted vegetation	Visual inspection
Cutoff wall/Dike	Prevent escape of contaminated water	Testing of water samples from shallow monitoring wells (environmental monitoring program)
Grouting of contaminated wastes	Prevent settlement of wastes	Grid survey, visual inspection, aerial survey
Compaction of wastes	Prevent settlement of wastes	Grid survey, visual inspection, aerial survey
Connection of cutoff wall to gray clay unit	Prevent escape of contaminated water	Testing of water samples collected from deep monitoring wells (environmental monitoring program)
Exclusion of organics from stored wastes	Prevent decay, formation of gases, and ultimate settlement of wastes	Temperature sensors in vibrating wire pressure transducers
Slope of all sections of outer soil surface	Reduce residence time of precipitation water	Grid survey, visual inspection, aerial survey

and pipes within the containment area were filled with a lean concrete mix. Buried utility pipes in the area of the cutoff wall were removed.

3.3 TOP COVER

The layers used in the cover are briefly described below (see Figure 3-1).

3.3.1 Clay Layer

The first layer of the cap consists of 3 ft of compacted clay placed immediately over the wastes. The clay layer is the principal barrier against moisture intrusion and radon emanation. The clay will be compacted to achieve a permeability equal to or less than 10^{-7} cm/s (migration rate of 30 cm/yr). Soils with values of less than 10^{-7} cm/s are considered to be virtually impermeable (Ref. 4). Compliance with both compaction density and permeability requirements during construction of the cap has been confirmed by laboratory tests. Field permeability tests are planned for fall 1985 to substantiate the laboratory results. These were done, field tests showed that the planned permeabilities were achieved during construction.

The clay layer is covered with a surface layer of loosely compacted topsoil, which forms an 18-in.-thick protective blanket to maintain moisture within the clay layer and prevent drying that could result in the formation of tension cracks.

3.3.2 Shallow-rooted Vegetal Cover

The vegetal cover will consist of selected shallow-rooted grass species to ensure that root structure will penetrate only the upper 12 in. of the topsoil. This ground cover will be mowed and maintained so that deep-rooted growth does not become established, thereby providing pathways for the infiltration of precipitation.

3.3.3 Surface Drainage

The top of the cap has been designed with a slope varying from a minimum of 5 percent to a maximum of 10 percent. The side slopes of the cover beyond the dikes will be maintained at 33 percent. These surface and side slopes will provide positive drainage, minimizing the residence time of surface water and hence infiltration.

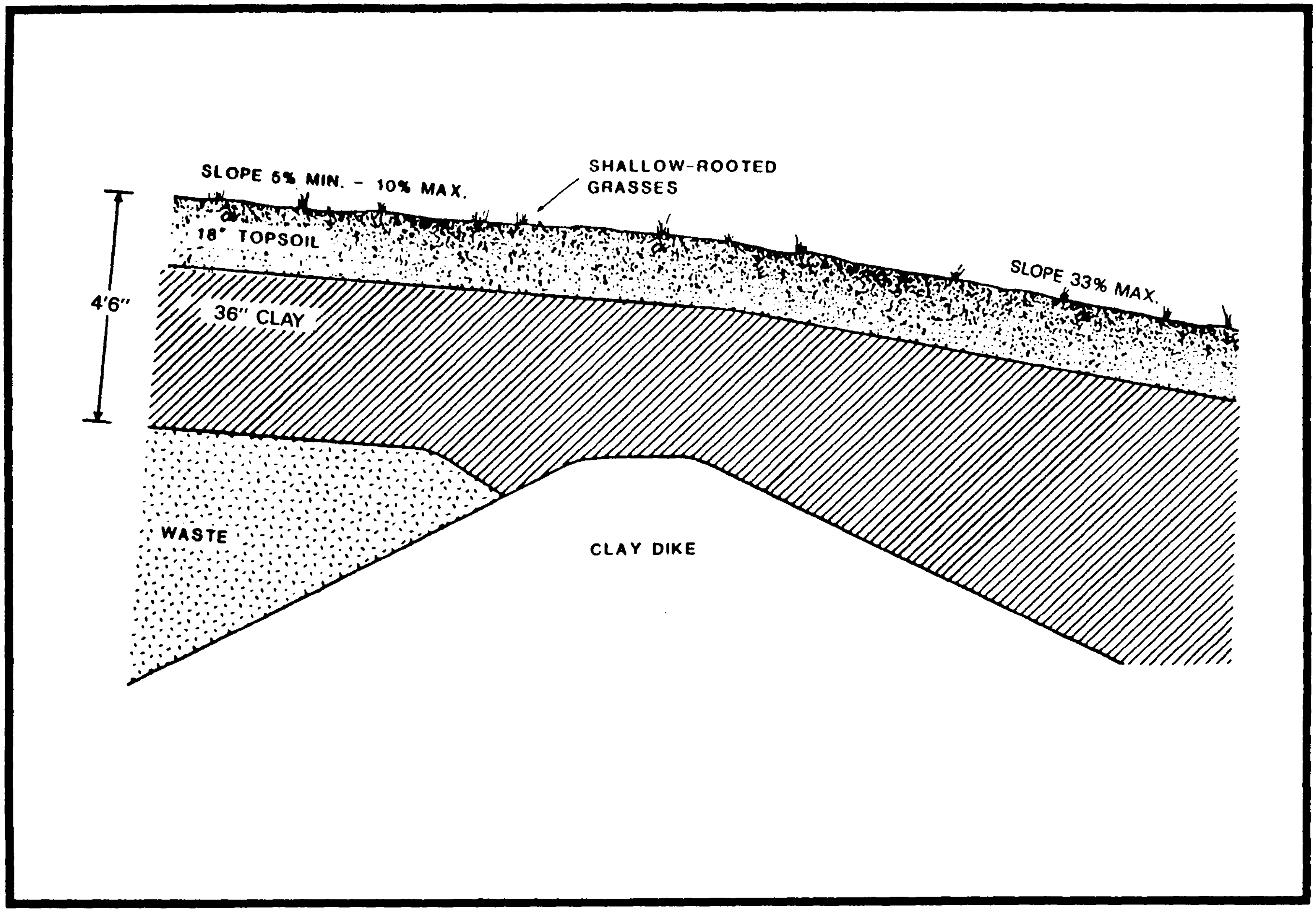

FIGURE 3-1 CONFIGURATION OF THE NFSS COVER

3.4 SEISMIC AND FLOOD PROTECTION

The above-grade dikes forming the perimeter of the containment area have been designed to withstand seismic and flood conditions calculated for the site. Stability of the side slope conditions were evaluated for static and earthquake loading; a factor of safety of at least 2 was achieved for both conditions.

4.0 RECOMMENDED MONITORING SYSTEM

Waste placement, the various layers of the containment facility cover, and surface drainage can be monitored using surface techniques. The condition of the gray clay unit and cutoff wall/dike, and the performance of the containment structure under seismic and flood conditions must be monitored by subsurface techniques. By employing both surface and subsurface methods, undesirable trends in the performance of the containment structure can be recognized early and timely action can be taken to correct weaknesses.

4.1 SURFACE MONITORING

Surface monitoring techniques to be used are topographic surveys, walkover surveys, and aerial photography. Each is described in more detail below.

4.1.1 Topographic Survey

The topography of the cap surface will be established by a land survey made on a predetermined grid. Permanent benchmarks tied to the New York State Plane Coordinate System will be the basis for this grid. The grid layout will be on 100-ft spacing in both north/south and east/west directions as shown on Figure 4-1. A 20-ft grid will be established within the 100-ft layout in areas requiring closer examination. Benchmarks will be permanent concrete monuments with brass designation markers. The grid intersections will be marked with wooden stakes driven flush with the surface of the topsoil. The wooden stakes will be no longer than 8 in. and will be reset annually or as needed. The elevation at the stakes will be measured twice a year during the first year -- once in the fall (approximately October 1) and once in late spring (approximately June 1). Subsequent topographical surveys will be made annually in the spring.

Due to the vulnerability of the wooden markers, early warning of areas of settlement will not be determined solely by means of this surveillance because the tolerance of the elevations at the stakes is estimated to be within $\pm$ 1/2 in. Elevations from the grid surveys will indicate localized areas with a trend for subsidence and will direct attention to these areas for additional surveillance.

Routine mowing of the grass cover on the waste containment area will be coordinated with the topographic surveys so that established markers can be easily located.

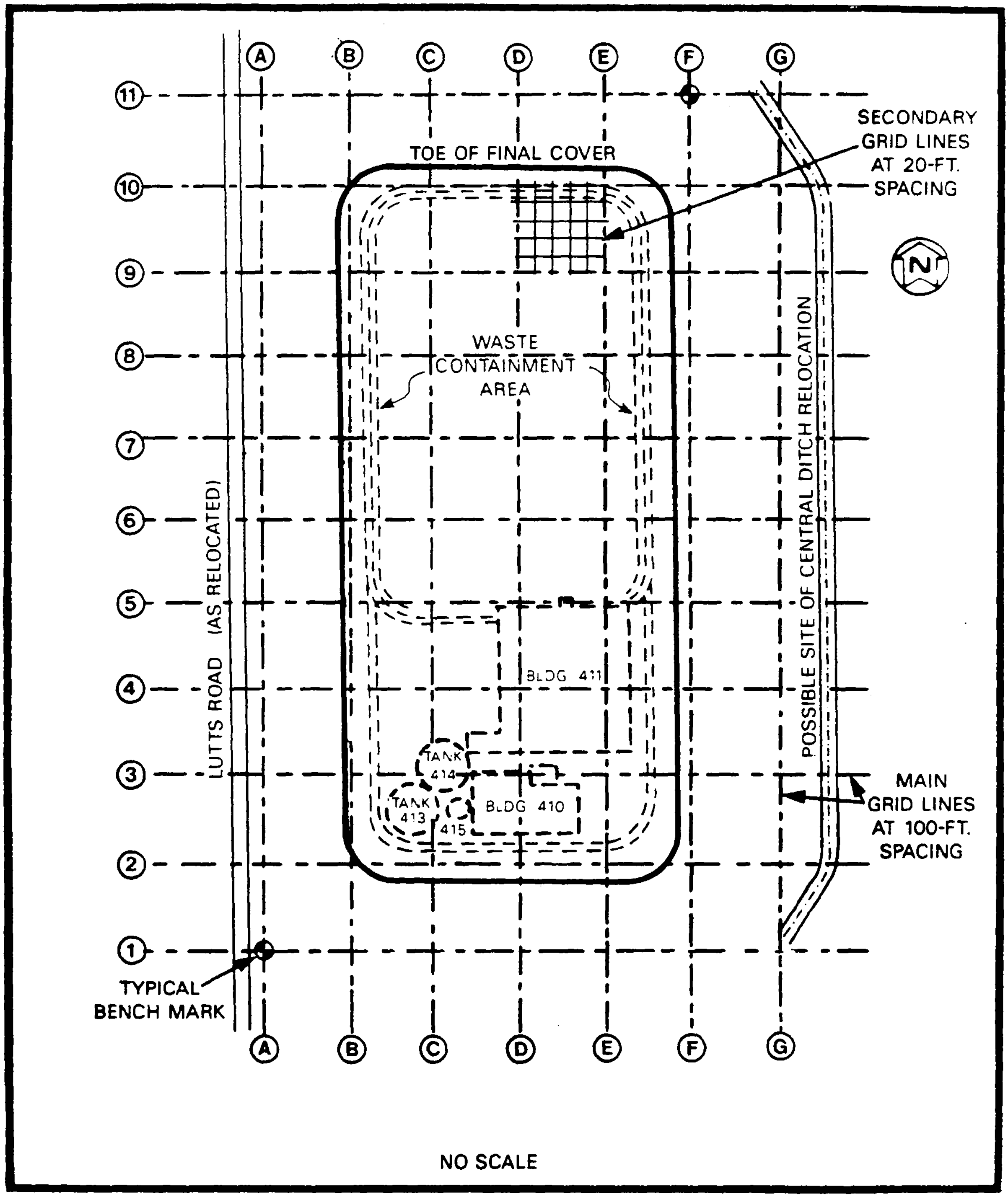

FIGURE 4-1 SURVEY GRIDS AT THE NFSS

4.1.2 Walkover Survey

During the grid survey, a walkover survey will be conducted by an assessment team of technical professionals who will evaluate the cap condition to detect settlement or movement, cracking, undesired plant growth, or other undesirable conditions. During the growing season, the condition of the cap will be visually inspected and reported each month during cover mowing operations.

4.1.3 Aerial Photography

Photogrammetric methods will be used to map the waste containment area and periodically check, redelineate, and document its dimensions and contours. Aerial mapping will provide a reference for changes in the surface contours of the waste containment structure. Infrared photography will be used to identify stressed areas of the vegetal cover. It will also be used to identify surficial moisture differentials, permitting location and delineation of saturated areas indicative of localized subsidence and ponding. This information will serve as a reference for noting trends of deviations in cap conditions.

Aerial photographs of the cap will cover an area extending a minimum of 300 ft from the toe of the side slopes. These photographs will be made in late spring (June) and fall (October) each year for the first 2 years and in the spring only for the next 3 years. The aerial surveys will be coordinated with the semiannual walkover surveys and will be flown at approximately the same time each year to optimize consistency in evaluating the mapped areas.

4.2 SUBSURFACE MONITORING

Because no penetrations through the clay cover are permitted, direct measurement methods could not be considered for detecting water accumulation inside the containment facility, measuring waste settlement, and assessing shrinkage of the clay cover. Several indirect subsurface monitoring techniques were therefore evaluated. They were assessed on the basis of their potential contribution to early detection of containment structure distress or failure, expected system reliability and lifetime, difficulty of installation and maintenance, cost per instrument, ease of data interpretation, and frequency of use. These techniques included vibrating wire pressure transducers for detecting rising potentiometric (saturated) levels inside the containment structure; multiple position extensometers to measure waste settlement; and horizontal strain meter arrays to detect horizontal movement (shrinkage) of the clay cover. It was determined that the vibrating wire pressure transducers (VWPTs), in combination with surface monitoring techniques, would satisfactorily monitor the parameters of concern (Ref. 5). A secondary system of pneumatic pressure transducers (PPTs) will provide a means of checking the operation of the VWPTs. The service life of both the VWPTs and the PPTs is estimated to be 25 years. This estimate is based on actual and continuous field operation of these instruments in dam and tunnel construction activities. A detailed description of these instruments is provided in Appendix A.

The VWPTs and PPTs will be installed in a pattern over the waste containment area as shown in Figure 4-2. A pressure increase measured by these instruments can be translated into an increase in the depth of saturation above the instrument. The rate at which the pressure changes will be indicative of the method of entry of the water causing the saturation. For example, the instruments should all stabilize within a year after closure of the containment structure. Pressure increases that occur rapidly within the first year after closure will be indicative of an opening or more permeable condition nearby, whereas a slow increase in pressure at one or more stations with steady decrease in pressure at another will indicate equalization of the water contained within the structure at closure. The differences in pressure between the instruments 4 to 5 years after closure of the containment facility will permit production of equipotential contours and sections. Each pressure measurement taken will be accompanied by a temperature measurement, taken by the temperature-sensing device incorporated into the VWPTs, which will serve to monitor potential changes in the form of the wastes.

The PPTs will be installed adjacent to three of the VWPTs. They will not be installed at all VWPT locations because the operation and reading of the PPTs require attendance by a technician while the VWPT equipment can be arranged to operate automatically with readout limited only by communication equipment availability.

In addition to the VWPTs and PPTs installed for the containment structure performance monitoring system, groundwater monitoring wells will be installed around the stored

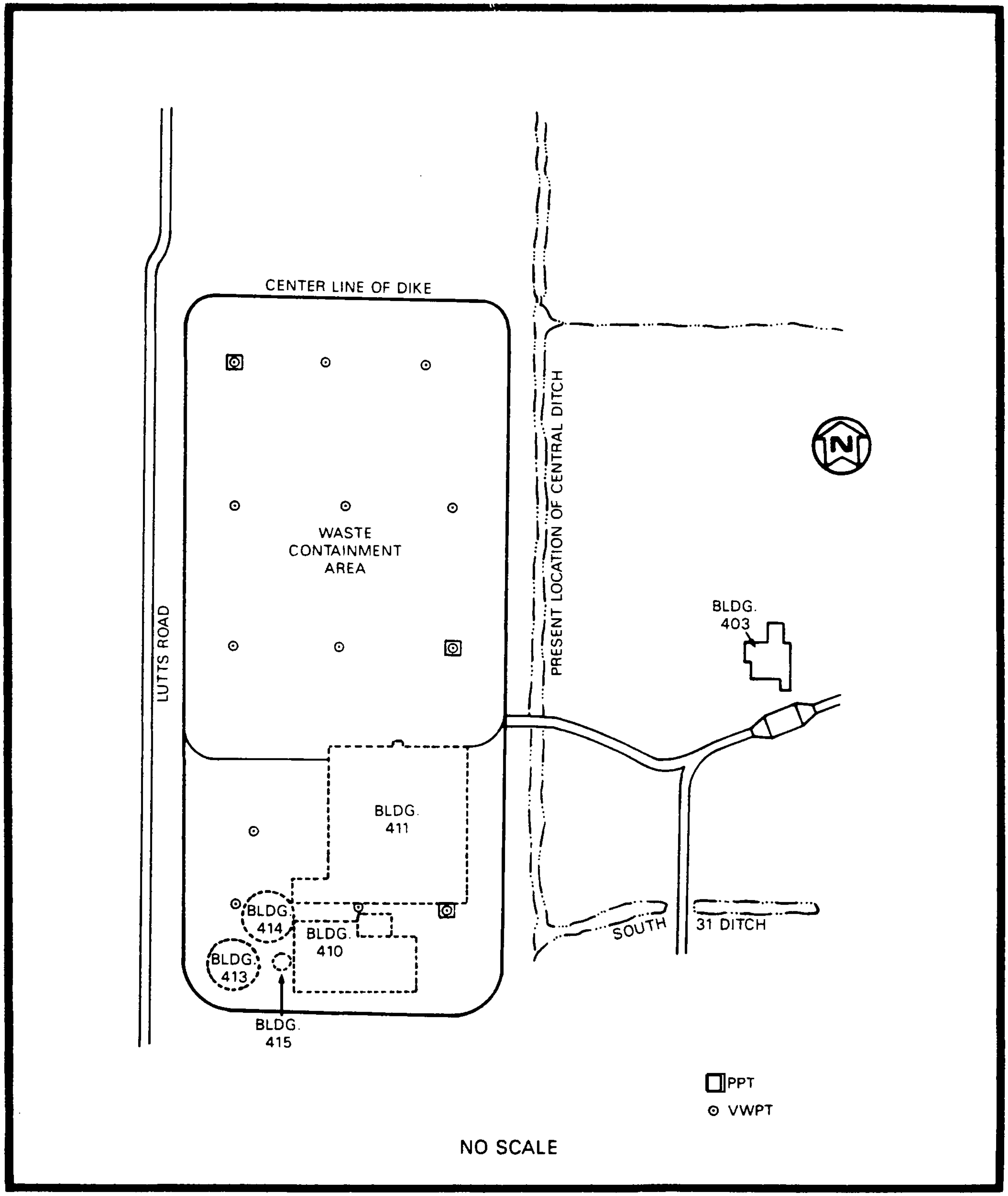

FIGURE 4-2 LOCATIONS OF VWPTs AND PPTs AT THE NFSS

wastes as part of the separately administered environmental monitoring program presently being developed. Data from these wells will provide another, albeit delayed, means of monitoring potential migration of contamination into groundwater. One well in each pair will be screened in the shallow aquifer above the gray clay layer; the other well will be screened in the aquifer below the gray clay. Analysis of samples from these wells will be described in a separate environmental monitoring report. Seven pairs of wells are scheduled for installation in FY 1986; eleven additional pairs will be installed in FY 1987. The locations of the FY 1986 wells are shown in Figure 4-3. For several years, data have been collected and analyzed from a number of wells drilled for geological investigations and environmental monitoring of the entire NFSS property. The locations of the wells in the immediate vicinity of the waste containment area are also shown on Figure 4-3.

4.2.1 Equipment Installation

The VWPT equipment will be installed in a hole, auger drilled vertically downward through the wastes to approximately 1 ft below the original ground surface. The VWPT will be placed 6 in. below original ground surface and encased by a graded sand pack that will extend above the VWPT for a distance of 2 ft. A 1-ft-thick bentonite pellet seal will be placed over the sand pack. The remainder of the drilled hole will be backfilled with cement/bentonite grout. A 2-ft-deep trench will be cut into the waste surface or clay cover to carry the readout cables from the VWPT locations to Building 403 where the data logging unit will be located (see Figure 4-2). (At the end of the 1984 construction season, the clay layer of the cap covered only the northern half of the waste containment area. VWPTs will be installed in the southern half during the 1985 construction season before the clay layer there is completed). The trench will be backfilled and hand compacted to avoid damage to the cables. Trench alignments will be designed to contain cables from as many instrument sites as practical.

For sections of the waste storage area where the clay cap is already in place, a "window" in the clay cap will be cut down to just above the cap/waste interface. The clay will be stockpiled for re-use. The hole for the instrument will be drilled through the clay "window" and the instrument installed in the manner previously described.

The PPTs will be installed in the same borehole and adjacent to each of three VWPT instruments.

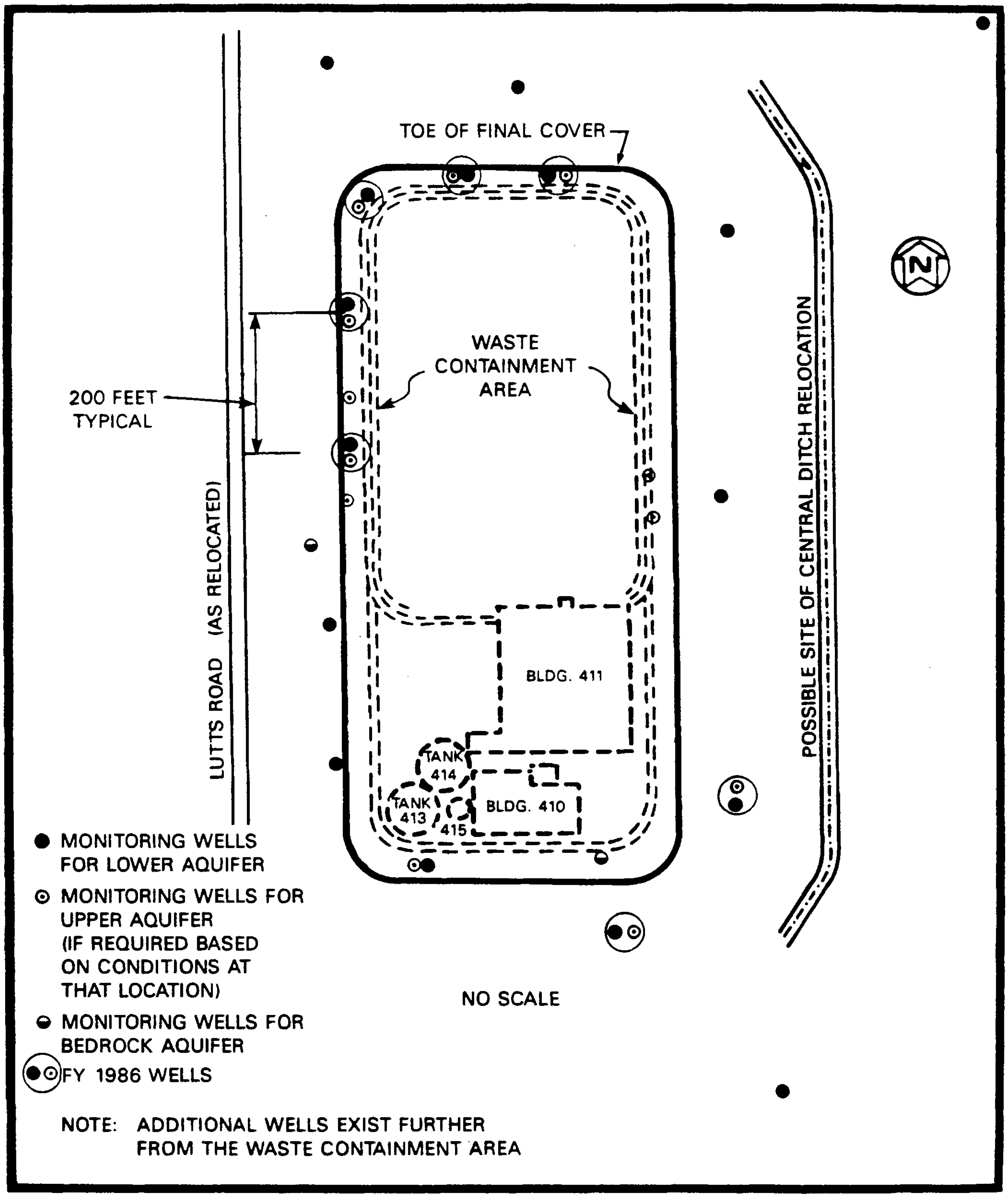

FIGURE 4-3 LOCATIONS OF EXISTING GROUNDWATER WELLS AND WELLS TO BE INSTALLED IN FY 1986 AT THE NFSS

4.2.2 Operation

The pore pressure measurement equipment, once installed and calibrated, will require a minimum of maintenance or operational activities. The VWPT equipment will be controlled by an automatic system; the PPTs must be operated by a technician in the field on a predetermined cycle to check VWPT operation.

Vibrating Wire Pressure Transducers

Monitoring of the VWPT instruments is performed by a central data logging unit. This unit should have continuous input of 120 VAC, but will automatically reset and begin operation again after a power interruption has occurred. The timing system may require adjustment after a power outage to ensure that the reading cycles occur at the designated times, but the interval between reading cycles should not be affected by a loss of power.

The readout center must be protected against extremes of temperature and humidity. High temperature and high humidity are the most serious environmental dangers to the equipment.

Pneumatic Pressure Transducers

Usual operation of the PPTs requires manual input by a technician for each reading. Gas pressure must be applied to the instrument and adjusted before a gauge reading is made. The gas supply must be available with sufficient pressure to operate each of the three four instruments installed in the waste containment area. Continuous chart records would require a continuous gas supply and a chart recorder.

4.3 MONITORING SCHEDULE

Table 4-1 summarizes the frequency of the monitoring activities now planned for implementation after closure of the NFSS waste containment area.

The walkover survey of the interim cap will be made semiannually for 5 years after closure of the containment facility and more frequently if anomalous conditions become evident. The grid survey will be performed semiannually to coincide with, or precede by

TABLE 4-1

FREQUENCY OF WASTE CONTAINMENT PERFORMANCE MONITORING

Monitoring Technique	Frequency (FY 1987-91)
Surface	
Walkover	Semiannually
Grid survey	Semiannually in first year Annually in second through fifth years
Aerial photography	Semiannually in first and second years Annually in third through fifth years
Subsurface	
VWPT	Twice daily
PPT	Weekly

a few days, the walkover survey. The 6-month interval for the grid survey will be re-examined after 5 years.

Aerial photographs will be taken of the site in late spring (June) and fall (October) each year for the first 2 years and in the spring only during the following 3 years. Evaluation of the need to continue the aerial photography will be made after 5 years.

The VWPTs will be automatically read twice daily by the data logging unit located in Building 403. The PPTs will be read weekly by a technician for the first year after closure of the containment facility. The frequency of readings will then be adjusted depending on results of the first year's operation.

5.0 PERFORMANCE MONITORING REPORTS

All surface and subsurface performance monitoring data will be evaluated immediately upon receipt. Any early warning of a breach in the waste containment structure will be documented and remedial action developed if necessary. Performance monitoring data will be reported for each calendar year. As part of this documentation, the condition of the containment structure at the start of a given year will be recorded and compared with conditions reported for the previous year. If undertaken, remedial action (such as liming and fertilizing, filling of local eroded areas, localized soil densification, herbicide or soil sterilant application, or drainage improvement) will also be documented.

6.0 COST SUMMARY

The estimate for implementing the recommended performance monitoring activities is detailed in Table 6-1. Costs are given in 1985 dollars with escalation and contingency added as bottom line adjustments.

The basis for the estimate is as follows:

1. VWPTs and PPTs will be installed during the 1986 construction season.

2. Monitoring of the cap will begin in FY 1987 and continue for 5 years through FY 1991. After the initial 5-yr period, the frequency of particular monitoring activities will be evaluated and may be modified as determined by the reported performance of the containment facility.

3. Costs cover installation of the instruments, both subsurface and surface monitoring of the containment area, and office support costs associated with these activities. No costs are included for environmental monitoring, which is a separate program, or on-site maintenance and surveillance activities.

TABLE 6-1

SURFACE AND SUBSURFACE MONITORING SYSTEM COSTS

(DOLLARS IN THOUSANDS)

Containment Monitoring Technique	Cap Monitoring (FY 1987-91)		
	Frequency	Cost ($)	
Subsurface Monitoring			
13 VWPTs and 3 PPTs			
- Installation	Initial		170
- Operation	Monthly	30	
Surface Monitoring			
- Walkover Survey	Semi-annually	35	
- Grid Survey	Semi-annually (Yr 1)	20*	
- Aerial Photography	Semi-annually (Yrs 1,2)	20**	
Management Support and Annual Report	Annually	35	
Subtotal First Year Monitoring			140
Additional Four Years' Monitoring			525
Subtotal			835
Escalation (5%/yr)			70
Contingency (10%)			90
Total Monitoring Cost			$995

*Grid survey will be performed annually during the second through fifth years at an annual cost of $15,000.

**Aerial survey will be performed annually during the third through fifth years at an annual cost of $15,000.

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2. Letter, G. D. Coxon, Bechtel National, Inc., to L. F. Campbell, U.S. Department of Energy, Oak Ridge Operations Office. "NFSS Waste Containment Performance Monitoring System," CCN 25410, February 7, 1985.

3. Acres American, Inc. Hydrologic and Geologic Characterization of the DOE-Niagara Falls Storage Site, Buffalo, NY, September 1981.

4. EG&G Idaho, Inc. Low-Level Radioactive Waste Management Handbook Series, Corrective Measures Technology for Shallow Land Burial, DOE/LLW-13Te, Idaho Falls, ID, October 1984.

5. Letter, G. D. Coxon, Bechtel National, Inc., to E. L. Keller, U.S. Department of Energy, Oak Ridge Operations Office. "Waste Containment Performance Monitoring Device," CCN 28159, June 12, 1985.

APPENDIX A

VIBRATING WIRE PRESSURE TRANSDUCER
AND PNEUMATIC PRESSURE TRANSDUCER INFORMATION

PETUR U.S.A.

INSTRUMENTS

PETUR ELECTRONIC PRESSURE TRANSDUCER -ED-100

The Petur Electronic Pressure Transducer offers a reliable yet inexpensive device for monitoring pressure. It can be used to monitor fluid levels such as ground water, weirs, resevoirs, storage tanks, etc. Its fast response makes it especially well suited for dynamic monitoring such as drawdown tests.

Each transducer is sealed against the intrusion of water and comes completely ready for submersion or direct burial. Protection is provided against overvoltage surges from external sources.

The Petur Electronic Pressure Transducer utilizes a differential silicon chip pressure gage which incorporates four strain gages into the diaphragm to form a fully active Wheatstone Bridge. One side of the diaphragm is exposed to atmospheric pressure via an open tube to the surface. The other side is exposed to the pressure to be measured. Thus, the registered pressure is guage pressure.

The Petur Electronic Pressure Transducer is available in three different grades to allow the user to determine just the right combination of economy and accuracy for his needs.

Various readout units are available for the Petur Electronic Pressure Transducer. The simplest and most economical is the ED-200 hand held readout. This battery operated unit is small enough to hold in one hand and allows the user to monitor the pressure via an LCD display. Petur Instruments also offers the inexpensive ED-210 Automatic Pressure Monitor. This battery operated device is designed to be installed at each pressure transducer location. It can be set to automatically record pressure readings at intervals from 1 minute to 24 hours. The data is stored in a 4K internal memory for retrieval later by the ED-220 Automatic Data Retrieval and Readout Unit. The ED-220 not only retrieves data from the ED-210 but can also be used as an automatic data monitor as well. It can be programmed to take readings at time intervals as small as 1 second. Alternatively, the the ED-220 can be programmed to automatically take readings at preset pressure intervals as small as 5 mm of water head (0.01 psi). The ED-220 comes with 36K of usable memory and has an RS-232 serial output for connection with an optional printer or computer.

In addition to the above readout units, the Petur Electronic Pressure Transducer may be read with the standard C-200 readout box. This box offers the flexibility to read not only electronic transducers but also pnumatic pressure transducers. This added flexibility allows users who have both pneumatic and electronic instrumentation to economically monitor all their sensors with the same unit.

Address:
19023 36th Ave West
Lynnwood, Washington 98036
USA

Telephone:
(206) 774-9191

Telex No.:
152021

* SENSOR SPECIFICATIONS *

Petur Electronic Pressure Transducer

Size: 3 inches x 0.75 inches
Range: 5, 15, 50, 100, 200 psi
Overange: 1.5 times full scale
Resolution: Infinite
Operating temperature: -40 to 120 ^{o} C
Excitation: 10 to 20 volts; 3mA current
Zero drift: $\pm$ 0.2%/6months
Output span: 0-100 mV $\pm$ 2mV
Zero offset: $\pm$ 1mV
More accurate settings of zero and span are available for applications where interchangeability is important.

Type	Lineanity	Hysteresis	Thermal Coefficient
ED-100-C	0.5%	0.15%	0.04%/^{o}C
ED-100-B	0.2%	0.10%	0.02%/^{o}C
ED-100-A	0.1%	0.05%	0.01%/^{o}C

* READOUT SPECIFICATIONS *

ED-200 Handheld Readout

Size: 4.37" x 3.25" x 1.5"
Power: Battery operated - internal 9 volt rechargeable battery.
Temperature range: 0^{o}C to 70^{o}C
Display: 3½ digit LCD
Readout units: psi
Input: 200mV (full scale)

ED-210 Automatic Pressure Monitor

Power: Battery operated- internal 12 volt rechargeable or 12 volt external battery.
Memory: 4K RAM (for expanded memory, contact factory)
Display: None
Recording interval: User selected time interval (1 minute to 24 hours)
Temperature range: 0^{o}C to 70^{o}C (wider temperature ranges are available)
Input; 100 mV (full scale)

ED-220 Automatic Data Retrieval and Readout

Power: Battery operated- internal 12 volt rechargeable or 12 volt external battery.
Memory: 36K RAM
Display: 4 digit LCD
Recording interval: user selected; time interval-1 second minimum
pressure interval-5 mm water head (0.01 psi)
Temperature range: 0^{o}C to 70^{o}C (wider temperature ranges available)
Input: 100mV (full scale)
Interface: RS -232 serial output

C-200 Combination Pneumatic /Electronic Readout

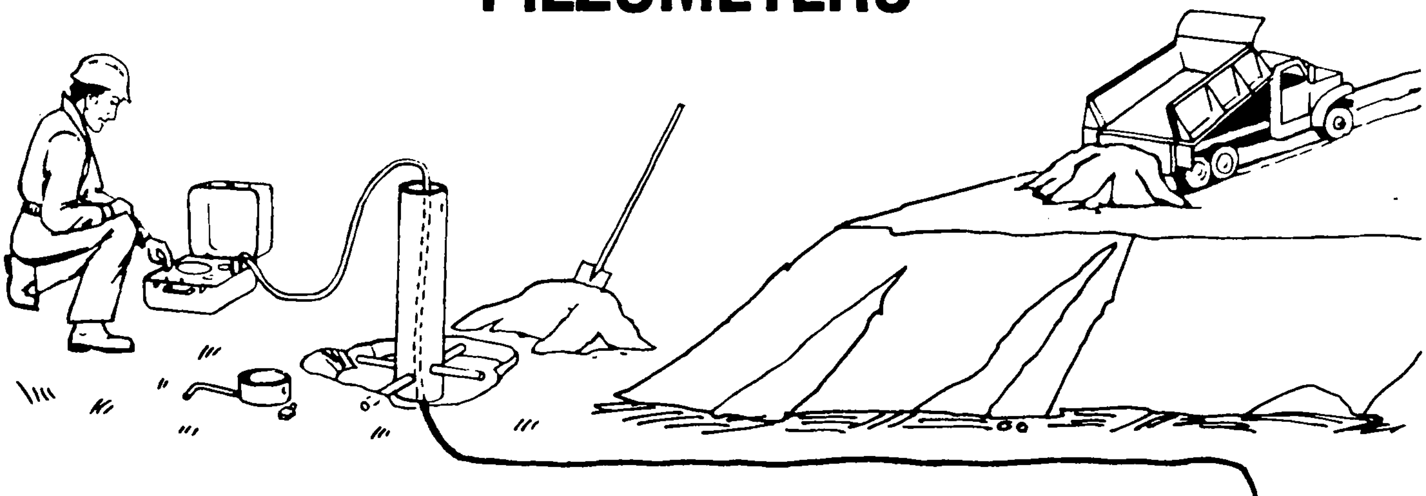
Power: Battery operated-internal 12 volt rechargeable battery.
Display: 4 digit LCD.
Temperature range: 0^{o}C to 70^{o}C (wider temperature ranges available).
Sensors: Electronic or Pneumatic.
Readout units: user selected; psi, kg/cm^2, $m-H_2O$, $ft.-H_2O$, kPa, cm-Hg.

• OPTIONS •

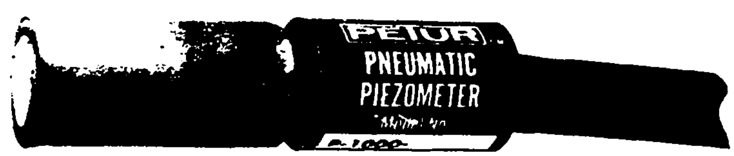
ED- 100-C	Standard Electronic Pressure Transducer
ED- 100-B	High Accuracy Electronic Pressure Transducer
ED- 100-A	Scientific Grade Electronic Pressure Transducer
ED- 200	Handheld Readout
ED- 210	Automatic Pressure Monitor
ED- 220	Automatic Data Retrieval and Readout
C- 200	Combination Pneumatic/Electronic Readout
PR- 300	Printer

PETUR® PRESSURE TRANSMITTERS

PIEZOMETERS

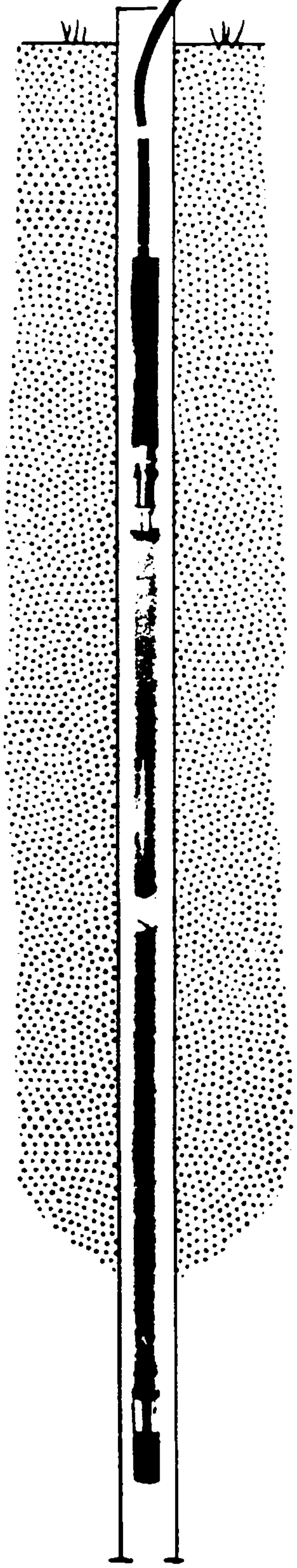


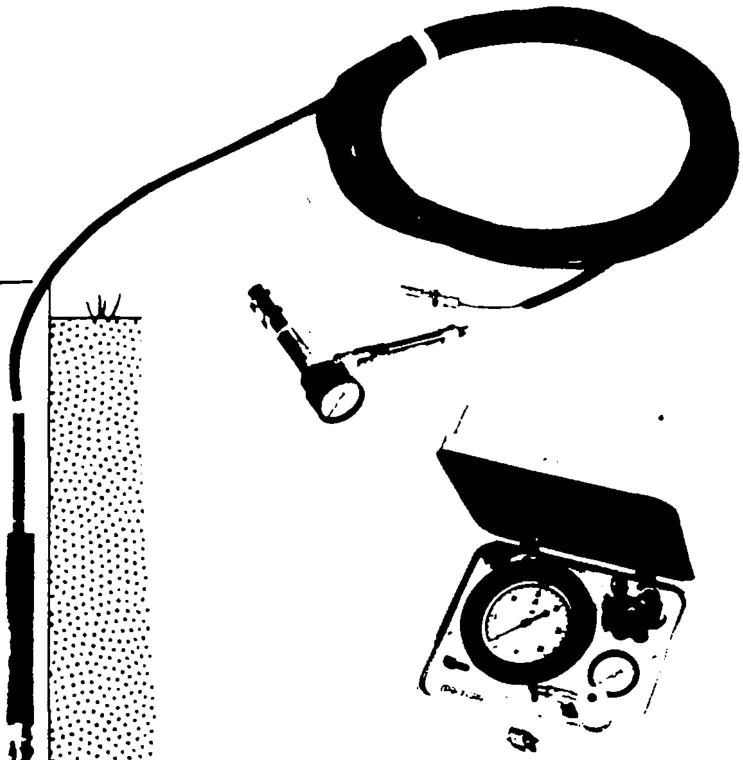
All Petur piezometer designs use the basic Petur Pneumatic Piezometer Sensor. This Patent-Pending design is based on more than 10 years of development and refinement and we believe, is the finest, most reliable pneumatic sensor available anywhere. It is non-metallic and is corrosion free, both internally and externally, and has no moving mechanical valve assemblies that will stick, jam or corrode. See specifications on back page.



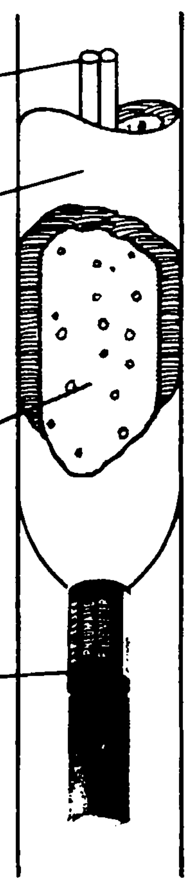
Actual Size 0.6 " diam. x 2.5 " L

PETUR INSTRUMENT COMPANY, INC.
11300 25th Ave. N.E., Seattle, WA. 98125
Telephone (206) 362-1081





PETUR MODEL P-107 EPOXY PACKER PIEZOMETER



PNEUMATIC TUBING CONNECTS SENSOR TO SURFACE READOUT

EXPANDING GLAND PROVIDES CONTINUOUS LENGTH (30") O-RING SEAL AGAINST STANDPIPE WALLS TO ISOLATE AND SEAL PIEZOMETER

HARD-SETTING EPOXY EXPANDS PACKER GLAND FOR POSITIVE PERMANENT PRESSURE SEAL

PETUR PNEUMATIC PIEZOMETER SENSOR

SPECIAL MULTIPLE IN-HOLE PACKERS AVAILABLE ON REQUEST

For rejuvenation of plugged standpipes or when standpipe or porous tip piezometers are specified on earthfill projects, consider the advantages and cost savings available by using Petur pneumatic standpipe replacement piezometers.

- Surface unit located out of construction area. No "targets" to dodge or damage.
- Installation can be performed by contractor using own crew and equipment.
- Once installed, system is maintenance free — no added riser pipes to keep pace with surchange elevation and no hand tamping.
- Lower unit cost — high reliability data system.
- No filter tip plugging — no data time lag.

For repair or rejuvenation of existing standpipes.

The Petur Epoxy Packer Piezometer is used for repair of existing standpipes which have become plugged or are marginal in operation. It is also used to eliminate the data time lag inherent with all standpipe designs. Pore pressure readings can be obtained immediately after installation.

Permanent Pressure Seal

This new design features an inflatable packer assembly or expanding gland that seals off and isolates the pneumatic sensor tip. Unlike earlier pneumatic packers, expansion of the gland and a continuous permanent pressure seal are both accomplished simultaneously by a one time automatic filling process which injects a premixed volume of hard setting liquid epoxy into the gland assembly.

Small size – fits all standpipes

Total installation time is less than one hour. Once installed it does not require any further pressure sealing apparatus or maintenance. The diameter of the packer assembly is 0.6 inches and it may be used in all standpipes. It is supplied complete and ready to install.

PETUR MODEL P-102-1 WELLPACK PIEZOMETER WITH INTEGRAL SANDPACK FILTER AND BENTONITE SEALS.

Built-In Filter and Seals

The cutaway view shows the built-in sandpack filter below the piezometer sensor and the self-actuating bentonite seal above. This unique feature ensures a proper filter installation and water seal and eliminates two critical and costly installation procedures.

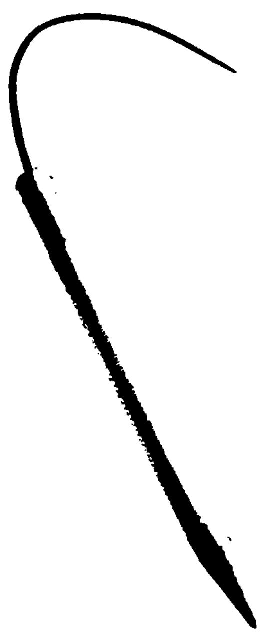
Size: 1.7" diam. by 19" long.

No Drilling Required

Foundation or Embankment Piezometers are customarily installed in a drilled borehole which usually requires expensive subcontractor services. However, in many soil conditions, costly drilling can be eliminated by the use of a driven wellpoint piezometer.

Installation by Contractor

The Petur Wellpack Piezometer may be installed by the contractor using his own equipment and personnel. In soft, graded soils of shallow to moderate depth, the wellpoint piezometer may be easily pushed or driven to the design depth using a standard drop hammer or portable air hammer.



PETUR MODEL P-102 WELLPOINT PIEZOMETER

Special Features

Optional Additional Tubing For

1. *Flushing* To remove gas pressure encountered in organic material.
2. *Operational Testing* An artificial piezometric head can be created to ensure that piezometer is functioning
3. *In-Situ Permeability Testing* A measured volume of water can be introduced from the surface. Pressurized reservoirs are available.

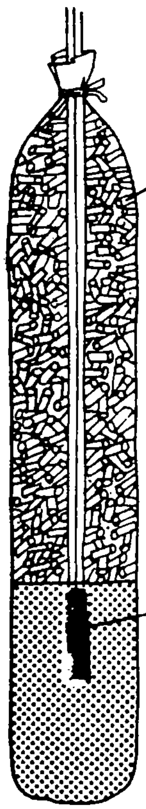
Size: 1.7" diam. by 19" long.

PETUR MODEL P-106 CANVASPACK PIEZOMETER

Where wellpoint installation is not practical and drilling is required, the Petur Canvaspack Piezometer can be installed directly by the contractor. It also features a built-in sandpack filter for the pneumatic piezometer tip and a self-activating bentonite seal.

Simplified installation with built-in filter and seals.

Installation is simply lowering the factory prepackaged canvaspack piezometer into the borehole, and backfilling. The entire procedure can be performed by the contractor without specialized equipment or highly trained personnel and at his own time schedule.



Activated bentonite pellets extrude through coarse mesh fabric to isolate and seal piezometer.

PETUR Pneumatic Piezometer sensor enclosed in sandpack filter.

Size: 2½" diam. x 30" length.

Conventional standpipe piezometers are placed within foundation boreholes or embankment material to provide data on soil conditions during and after construction. By design necessity, they must be placed within the center of the work area where their surface extension interferes with surcharging and can be easily damaged by earthmoving equipment. After the tip is installed, their height must be periodically extended to keep pace with the rising surcharge elevations and the surrounding area must be hand tamped. These limitations are unnecessarily costly to the contractor.

The widespread use of standpipes is based primarily on historic precedent and apparent lower first cost, however, the cost factor is no longer valid. The relatively recent introduction of modern design pneumatic piezometers now offers the contractor project cost savings opportunities that usually exceed the total instrumentation system cost.

Aside from cost considerations, the pneumatic piezometer is acknowledged to be technically superior since it eliminates the dual problems of filter tip plugging and "data time lag." These interdependent problems, inherent with all standpipes, result from the large volumetric change and the time required for groundwater to permeate through the soil and fill the pipe to the piezometric head. In low permeability soils the time lag can become so excessive that it is impossible to obtain any meaningful pore pressure data with a standpipe piezometer. In sharp contrast, the Petur Pneumatic Piezometer, which has a negligible volumetric change, (.001CC) provides high accuracy data immediately after installation and as no volumetric change is required, the instrument data time lag problem is completely eliminated.

Pneumatic piezometers are connected to the surface via flexible, direct burial tubing. Unlike the standpipe, which requires the readout station to be located directly above the piezometer, the readout station is typically located at the toe of the embankment with the tubing buried in a backhoe-cut ditch extending horizontally from the piezometer (or top of piezometer borehole) to the readout station.

This complete elimination of vertically extended riser tubes or pipes allows the contractor to place fill material without interfering "targets" to dodge and eliminates the necessity of hand tamping, and vertically extending the riser tubes to keep pace with the rising surcharge elevation.

SPECIFICATIONS FOR GENERAL PURPOSE PIEZOMETER — MODEL P-100

MAXIMUM OPERATING PRESSURE	DIMENSIONS	MATERIALS BODY	DIAPHRAGM	FILTER	LINEAR RANGE	SENSITIVITY*	ACCURACY	DIAPHRAGM DISPLACEMENT	MAX. TUBING LENGTH
2000 psi 138 bars	0.625" O.D. x 2.48" 1.59 cm. O.D. x 1.99 cm.	Glass filled Nylon-12	Nitrile rubber (Buna-N)	Porous (50 µ) 316 Stainless	3-2000 psi 0.2-138 bars	±0.1% at constant flow rate .0016 SCFM 28 SCCM	Equal to readout gauge	0.001 cc	5000 ft. 1500 M

*The repeatability and sensitivity of the pneumatic piezometers is extremely high and will always exceed the readout gauge accuracy.

Petur Instruments offers a complete line of Geotechnical Instrumentation including Piezometers, Readout Instruments, Total Pressure Cells, Remote Settlement Indicators, Water and Stream Samplers and Inclinometer Systems. In addition, we build specialized instruments for unique customer applications and offer engineering services, including all phases of design, installation supervision and training. Catalog and price list available upon request.

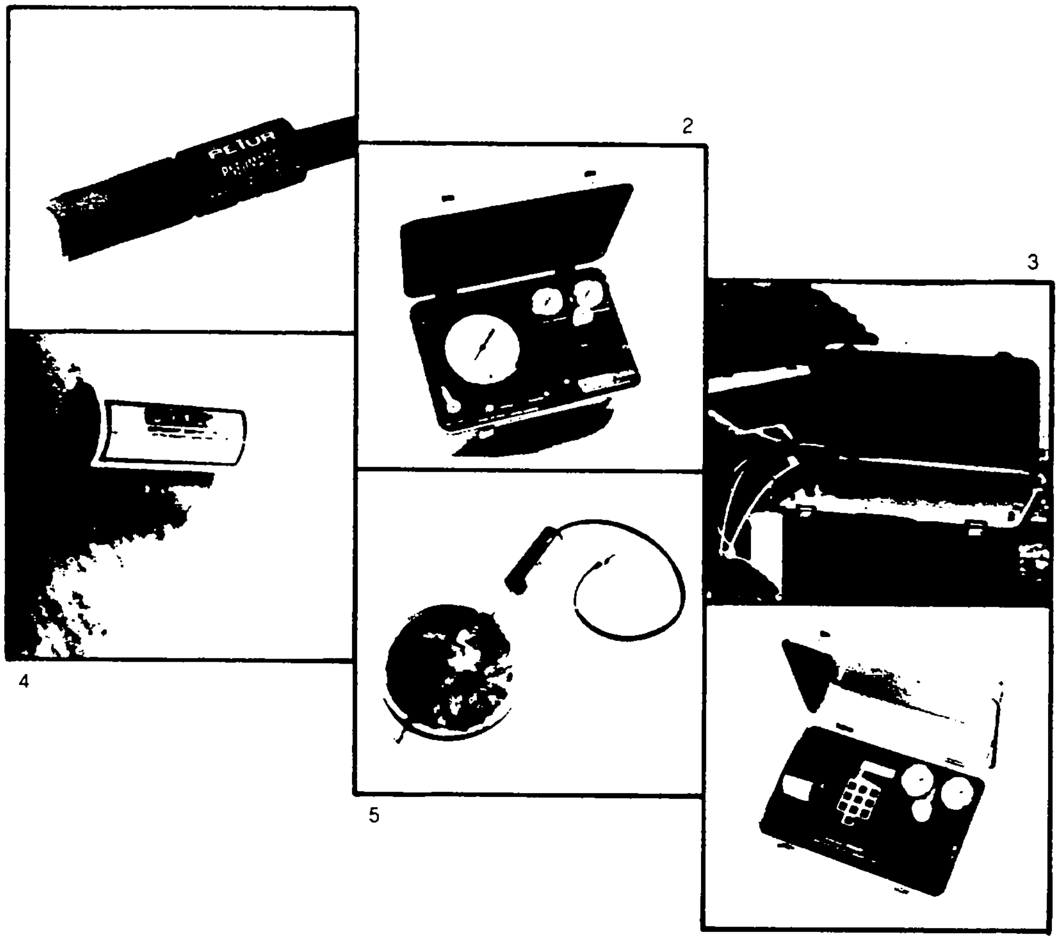
Please contact factory for further information or applications assistance.

PETUR INSTRUMENT COMPANY, INC.
11300 25th Ave. N.E., Seattle, WA. 98125
Telephone (206) 362-1081

PEIUR
INSTRUMENTS

GEOTECHNICAL INSTRUMENTATION

1 2 3



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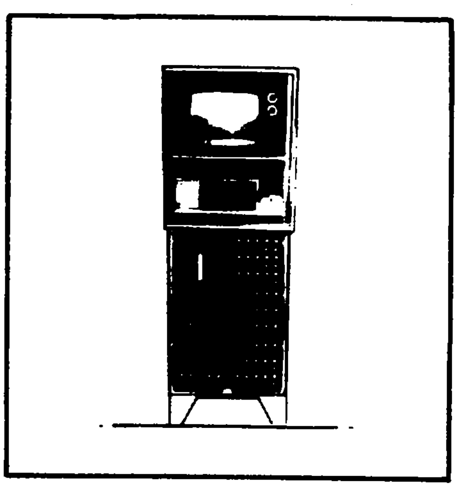
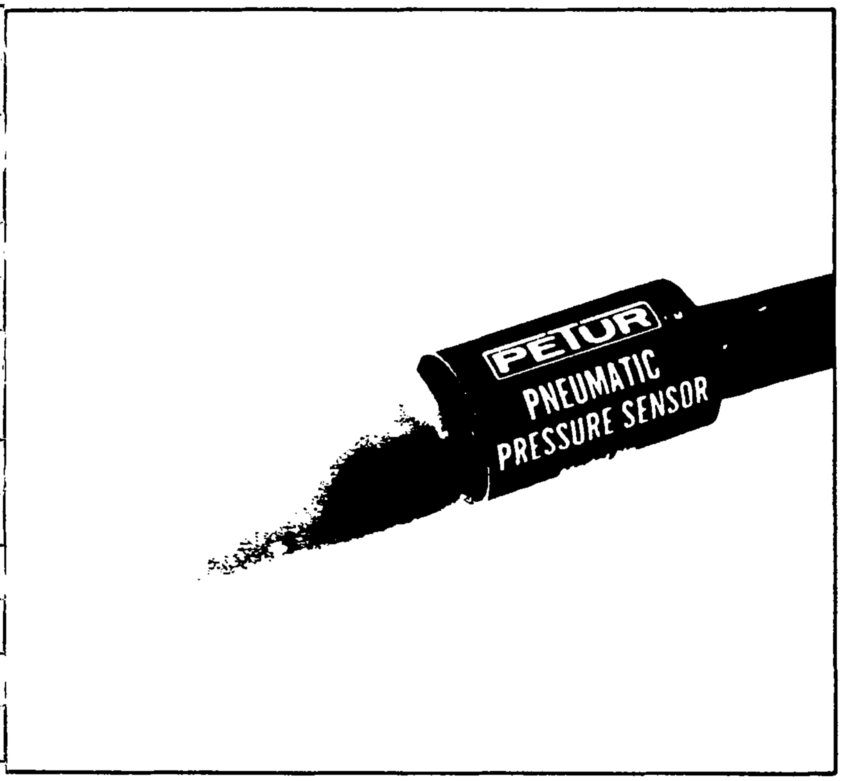


7

1. P-100 Pneumatic Piezometer
2. C-102 Pneumatic Readout Instrument
3. LS-1000P Liquid Sampler with Depth Indicator
4. SP-105 Settlement Sensor
5. TP-101 Total Pressure Cell
6. C-300 Ground Water Monitoring Instrument
7. C-400 Remote Automatic Data Acquisition System

PIEZOMETERS



MODEL P-100
GENERAL PURPOSE PIEZOMETER

The patented P-100 is an accurate and reliable pressure transducer. The small size (0.625 in. dia. x 2.5 in. length), rugged construction (glass-filled nylon body with Buna N diaphragm), and simple design (no mechanical moving parts) make the P-100 ideal for most piezometric applications.

The P-100 has an operational range of 3-2000 psi. Sensitivity and repeatability exceed currently available readout instrumentation. The P-100 needs negligible volumetric change (<0.002cc) to register a pressure, which gives it a rapid response time even in very low permeabilities.

The P-100 requires a gas flow rate of less than 35 ccm for operation. This low flow rate eliminates errors in readings due to flow turbulence and long tube lengths.

MODEL P-103
PNEUMATIC PIEZOMETER

is a 1:1 transducer with a fixed off-set pressure. The off-set can vary between 0-0.25 psi from one transducer to the next: once fixed, the off-set remains constant.

The transducer is mounted in a 1½ in. x 6 in. slotted PVC housing. The rolling diaphragm is very sensitive to small pressure changes to 10 psi, which makes the P-103 particularly suitable for monitoring low head changes. It is specifically recommended for applications where pressures range between 10 ft. of water and −1.0 atmosphere.

Flexible pneumatic tubing to surface

MODEL P-102 WELLPOINT PIEZOMETER

Pneumatic piezometer sensor

Special Features

Optional Additional Tubing For:

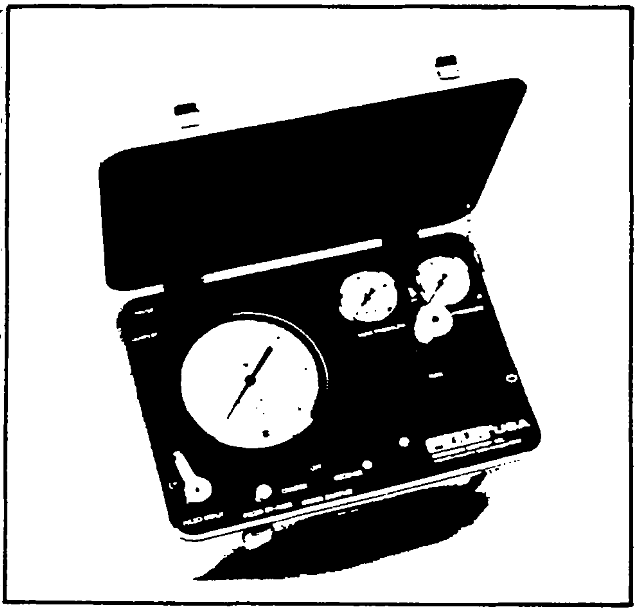
1. *Flushing* Gas pressure encountered in organic material can be removed
2. *Operational Testing* An artificial piezometric head can be created to ensure that the piezometer is functioning
3. *In-Situ Permeability Testing* A measured volume of water can be introduced from the surface. Pressurized reservoirs are available

Size 1.7 diam. by 19" long

PIEZOMETER APPLICATIONS

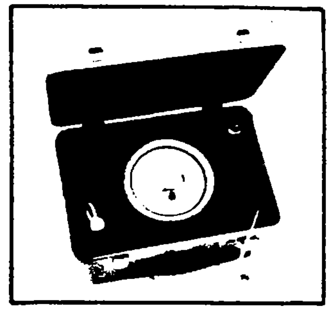
- Monitor Ground Water Levels
- Measure Excess Pore Pressure Conditions
- Safety Monitoring of Tailings and Earth Fill Dams
- Measure Uplift Pressures on Concrete Dams
- Measure Hydraulic Pressures

MONITOR AND CONTROL UNITS

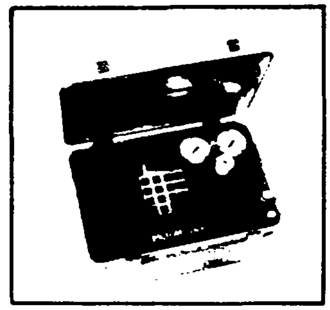


C-102 CONTROL UNIT is the standard instrument used for reading Petur pneumatic piezometers. The C-102 comes with automatic flow control provided by the patented **FC-100 FLOW CONTROLLER**. Readout is provided by a 6 in. diameter Bourdon tube gauge with full-scale accuracy of 0.25%. Full-scale accuracy of 0.1% is also available.

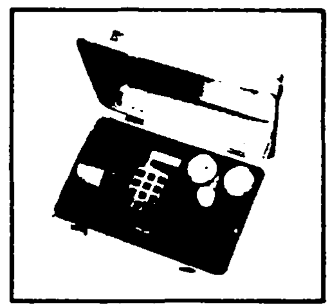
The C-102 is available in pressure ranges from 0-15 psi to 0-2000 psi. Other units of measurement are also available in the same pressure ranges. The C-102 contains an internal, 2 liter rechargeable gas supply. A filler hose is supplied with the unit. The unit operates on N_2 or CO_2.



SC-100 CONTROL UNIT incorporates a premium-quality, double-rotation 6 in. diameter guage with a scale length of 30 in. The gauge has an accuracy ±0.1 of full scale. The SC-100 is connected in series with a C-102, or similar readout unit, and is used to obtain highly accurate readings. The unit is primarily used for settlement sensor readings, or very precise piezometer readings.



C-200 CONTROL UNIT is an electro/pneumatic digital readout instrument. The readout displays 4 digits in user selectable English or Metric units (psi, kg/cm^2, m-H_2O, ft-H_2O, kPa, and cm-Hg). The C-200 is used for very accurate measurements of pneumatic and electronic sensors. The C-200 contains a rechargeable 1.2 amp hour Ni-Cad battery pack and a rechargeable, internal gas supply.



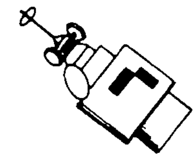
C-300 CONTROL UNIT is a pre-programmed data acquisition and memory storage system. The C-300 is designed for use as a monitoring system for drawdown pump tests. Coupled with a multiplexer, the C-300 can monitor up to 10 pneumatic channels at a selectable scanning rate. The system automatically takes a set of readings when any channel exceeds a user-determined, selectable change in pressure. Readout is an LCD display with selectable English or Metric units. An optional printer is available. The C-100 includes a rechargeable Ni-Cad battery pack, an internal gas supply and an RS-232 serial data port.

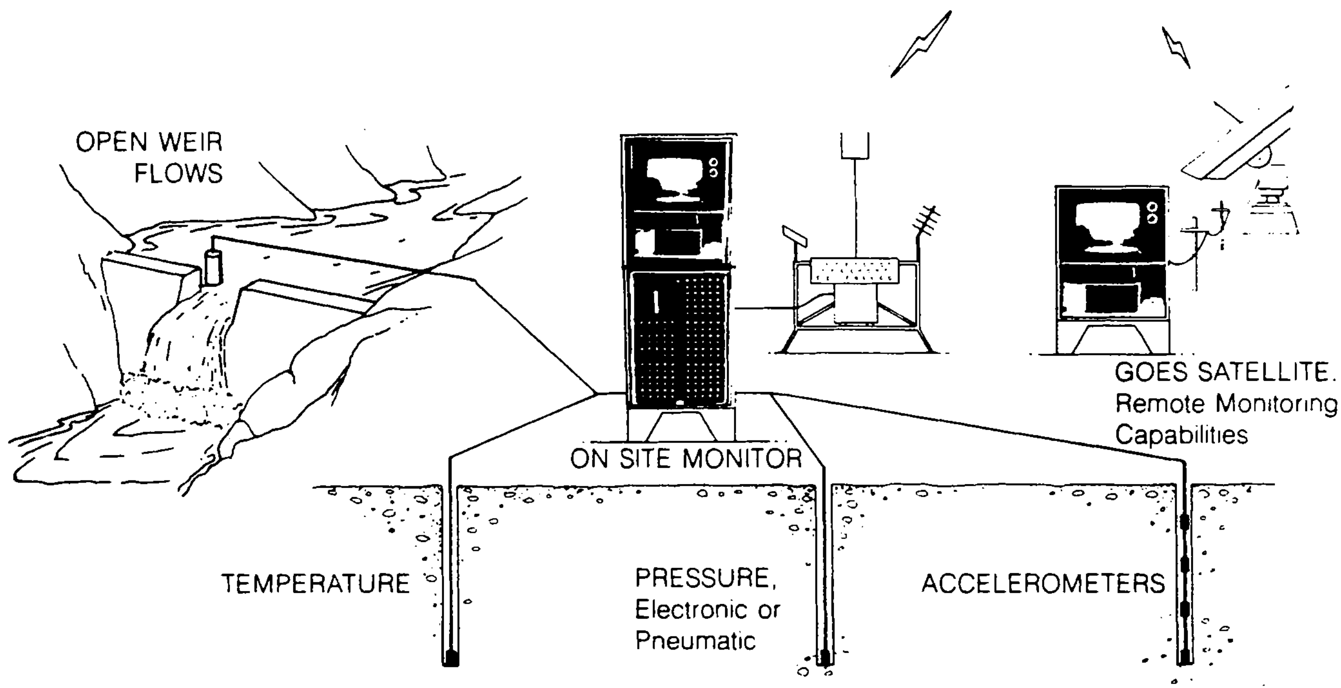
LIQUID SAMPLER with DEPTH INDICATOR collects a sample of liquid while it reads the depth at which the sample is obtained. The readout gauge records the depth directly in feet of water. The sampler operates in all types of liquids and environmental conditions. Unique construction and operation of the sampler provide large or small samples, either at a specific depth or at selected depths, and all samples at all depths are obtained without returning the sampler to the surface. The sampler is available in diameters of 0.6 in. to 3 in.

DATA ACQUISITION SYSTEMS

4096 CHANNEL
PRESSURE / PNEUMATIC
PRESSURE / HYDRAULIC
PRESSURE / ELECTRONIC
PRESSURE ACCURACY, .1%
FLOW - PNEUMATIC / ELECTRONIC

TEMPERATURE
FULLY AUTOMATED
D.C. and MILLIAMP INPUTS
E-Z-OP SOFTWARE
E-Z SET UP
OFF-SHELF COMPONENTS





Specifications

Texas Instruments Model TI-99/4A' Computer with full typewriter keyboard. TI Basic programming language.
Memory: 16K expandable to 64K. Also includes as a standard feature the Mini-Memory Command Module with 4K of RAM and 4K of ROM.

Tape Deck: For storage of user programs. Uses standard cassette tapes.
CRT Monitor: 19 inch (diagonal) color, standard.
Peripheral Expansion System: For addition of special electronic circuits or expansion of memory or accessory cards.
RS-232 Board

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INSTRUMENT COMPANY, INC.
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PETUR C-300

DATA ACQUISITION SYSTEM

SPECIFICATION SHEET

Designed for Pneumatic and Electronic Data Acquisition.

- Pre-programmed, automatic sequential readout of selected channels.
- Up to 99 channels available with multiplexer additions. C-300 comes with 2 channels.
- Programmable for English or Metric units.
- Programmable scan rate.
- Reads pressures from pneumatic (piezometer or bubbler) or electronic transducers.
- Automatic switching between high range (0-100 psi) and low range (0-10 psi).
- Accuracy is ± 0.06% of full scale.
- Sensitivity in high or low range is ± 0.01% of full scale.
- Standard pneumatic pressure range - 0 to 100 psi (231 feet of H_2O).
- Multiplexer channels can be pneumatic pressure, strain gauge or LVDT readouts.
- 32K internal memory.
- RS 232 serial data port.
- Optional strip chart printer.
- LCD data display.
- Power supply is rechargeable Ni-Cad battery and/or external 12V DC source such as a vehicle battery.

DATA SHEET

IRAD GAGE
Geotechnical Instrumentation

Vibrating Wire Piezometer (PW)

- Rugged construction.
- Small size.
- Long-term stability with high reliability.
- Remote readout capability.
- Very sensitive.

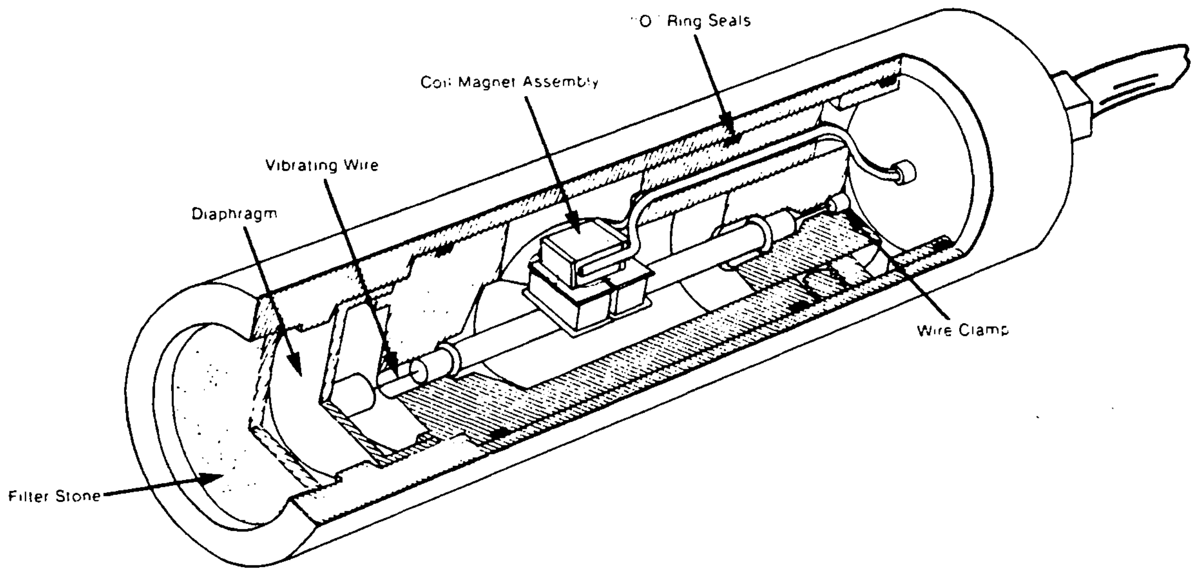
IRAD GAGE piezometers have been designed incorporating the latest vibrating wire technology to provide remote digital readouts of water pressure in fully and partially saturated natural soils, in rolled earth fills and on the interface of retaining structures. The superiority of vibrating wire diaphragm type piezometers for these kinds of measurements is well established (i.e. they exhibit [1] very small time lags, [2] an ability to measure negative pressures, [3] high sensitivity and reliability, and [4] transmission of signals as a frequency over long lead-wire lengths). The IRAD GAGE Piezometer can be buried in fill during construction, sealed in boreholes after construction, and even driven directly into loose ground from the surface (provided the appropriate head design is used). Another application to demonstrate the wide range of uses is to upgrade standpipe installations by lowering the piezometer to a fixed point and measuring head pressure directly from a remote readout station.

In use, water that enters the gage through a filter stone exerts a pressure against the face of a diaphragm. The resulting deflection changes the resonant frequency of a tensioned steel wire clamped between the diaphragm and the main body of the gage. The wire is vibrated using a coil/magnet assembly built into the gage and connected by cable to the IRAD GAGE Model MB-6 or MB-6L portable Digital Readout Box. The readout box supplies the electrical pulse to vibrate the wire and also measures the period of the resonant frequencies of these vibrations. A display of the period automatically appears by simply depressing a switch.

Calibration data are provided with each instrument to permit the calculation of water pressures. The readings can be recorded automatically on paper tape indicating time and date using the IRAD GAGE Datalogger (see data sheet).

As the signals to and from the piezometer are based on frequency rather than current or voltage there is no effect on the readings due to contact resistance, lead lengths or ground leakage. Temperature effects on the pressure readings are negligible. However, temperature measurements can be made by the inclusion of a thermistor in the gage body (an optional extra).

The basic piezometer has been designed to be versatile for many different applications. A variety of filter permeabilities can be provided to meet individual customer requirements on request. The Model PWP is designed to be pushed or driven directly into the ground on the end of an 'E' size drill rod or a one-inch water pipe. The small diameter PWS is ideally suited for upgrading existing standpipe installations, and for use in small diameter boreholes.



Specifications:

Model No.		PW	PWP	PWS
Ranges*	PSI	25, 50, 100, 500, 1000	25, 50, 100	50, 100, 500
	KPA	172, 345, 690, 3450, 6900	172, 345, 690	345, 690, 3450
Average Sensivitity		0.1% Full Scale	0.1% Full Scale	0.1% Full Scale
Length	inches (mm.)	4.9 (125)	10.0 (254)	4.6 (117)
Diameter	inches (mm.)	1.32 (33)	1.32 (33)	0.72 (18)
Filter**		30 micron	30 micron	30 micron
Electrical Cable		3 CONDUCTOR SHIELDED		

* Other ranges available on request
** Other filters available on request

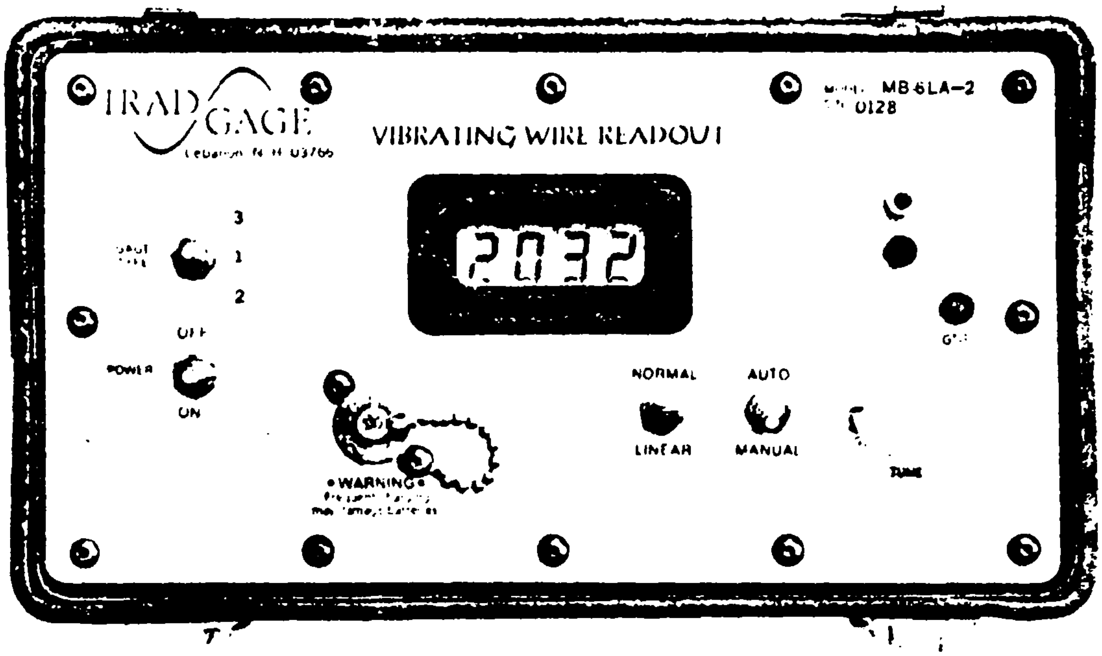
Required Accessories:
MB-6 or MB-6L Readout Box.

Available Options:
Thermistors.
Model MT-1 Thermistor Readout.
E size drill rod couplers and adaptors.

Ordering Information:

Specify:
1. Model Number.
2. Range.
3. Cable Length.
4. Size of drive pipe and required thread connections if piezometers are to be driven into the ground.
5. Add thermistor option if temperature measurements are required.
6. Contact factory for high entry value filters.

for further information write: IRAD GAGE, INC. Etna Road
Lebanon, New Hampshire 03766, USA
Telephone: (603) 448-4445



Specifications:

Model No.:	**MB-6**
Size:	6 x 6 x 10 inches (15 x 15 x 25 cm.)
Weight:	5½ lbs. (2½ kg.)
Range:	180-2000 microseconds (5.5kHz-500Hz)
Accuracy:	± 0.05 microseconds
Resolution:	Depends upon gage type (typically 1 part in 2000)
Pulse Voltage:	10V
Batteries:	Rechargeable
Connector:	Pomona 2244
Temperature Range:	Operating 20° to 110°F Storage −20° to 130°F
Display:	Liquid crystal 4 digits

Accessories:

Shoulder Strap
Charger (110 VAC)
Clip lead for gage connection

Ordering Information:

Specify:
1. Model MB-6 or MB-6L
2. Intrinsic Safety Approval
3. Charger converter (220VAC) and foreign plug adaptors
4. Audio option; internal speaker for audible check of gage operation
5. Interface for MA-5SM Datalogger

***for further information write*:**

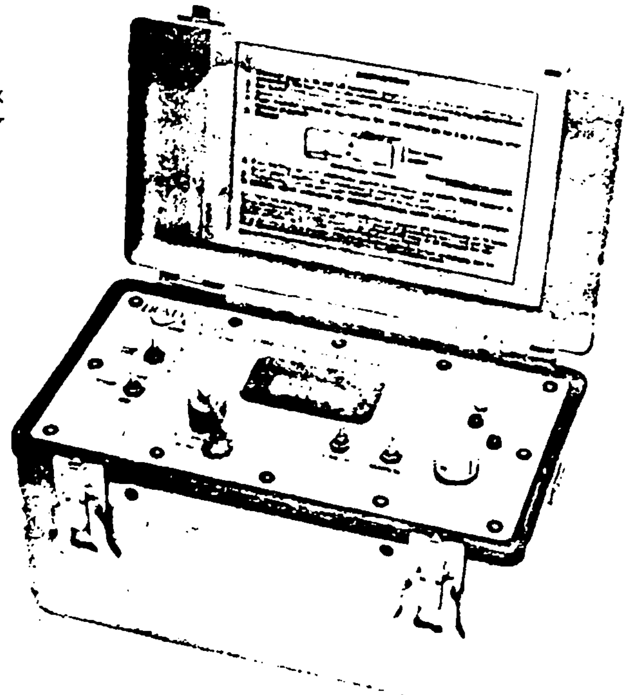
IRAD GAGE, INC. Etna Road
Lebanon, New Hampshire 03766, USA
Telephone: (603) 448-4445

DATA SHEET

IRAD GAGE
Geotechnical Instrumentation

Vibrating Wire Readout Box (MB-6, MB-6L)

The IRAD GAGE Model MB-6 Readout Box is designed to provide a digital display for IRAD GAGE Vibrating Wire Gages.



- Packaged for field use.
- Solid state printed circuitry.
- Lightweight and compact.
- Simple controls.
- Liquid crystal display.
- Approved for use in coal mines.

The IRAD GAGE Model MB-6 Vibrating Wire Readout is a lightweight, compact and simple to operate digital readout for IRAD GAGE Vibrating Wire Gages.

The readout operates by initially generating a voltage pulse containing a spectrum of frequencies spanning the natural frequency range of the wire in the gage being read. When the signal reaches the coil/magnet assembly mounted inside the gage (or probe), adjacent to the wire, it changes the magnetic field around the wire at a frequency corresponding to that of the input signal. When one of the frequencies in the input signal coincides with that of the wire, the wire vibrates and continues to vibrate after the input signal has ceased. A voltage is then generated in the coil at a frequency corresponding to that of the wire as it vibrates in the field of the coil/magnet assembly. This constant frequency signal generated by the gage is amplified by the readout meter and conditioned to eliminate electrical noise. Then, one hundred cycles of wire vibration are timed by a precise quartz clock and the time is displayed digitally.

To obtain readings, the operator: connects the gage, sets a switch to one of three positions corresponding to gage type, and depresses the 'ON' button. The reading appears in the display window and flashes on and off as the readout constantly checks the reading.

The automatic readout mode can be manually overriden to extend the range of the unit and increase the possibility of obtaining readings from damaged gages. In this mode the multiple frequency signal is replaced by a pulse containing a single frequency. The operator sets the frequency to coincide with that of the vibrating wire by turning a tuning control. Once the wire is set in motion the technique of obtaining and displaying the vibration period is the same as described above. The MB-6L reads out directly in microstrain units, eliminating the need for tables normally used with IRAD GAGE strain gages.

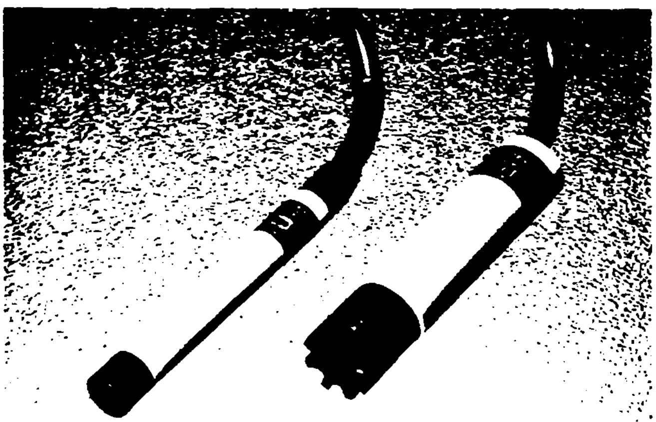
Considerable attention has been given to produce a highly reliable readout for use under adverse environmental conditions. With the lid open the metal case is splash-proof and the liquid crystal display is easily read even under bright sunlight. The solid state circuitry is mounted on printed circuit boards and the controls are sealed. The unit is powered by internally sealed rechargeable nickel-cadmium batteries (up to 15 hrs. continuous use). A low battery indicator is provided in the display.

The MB-6 readout can be adapted for use with the IRAD GAGE datalogger (MA-5SM).

The Models 514177 and 514178 are our most economical pore-pressure transducers for determining pore-water or gas pressure within embankments, foundations and slide areas. The system features high sensitivity, superior repeatability, and low diaphragm displacement. Two sizes of transducer are available; Model 514177 has a 5/8" O.D. and Model 514178 has a 1" O.D.

The transducer converts fluid pressure into pneumatic pressure which can be relayed to a remote reading station. The basic principle of operation is a hydro-pneumatic balance of forces across a flexible diaphragm.

A variety of terminal stations and portable or wall-mounted indicators provides flexibility to meet various requirements. These are coupled to the pore-pressure transducer by means of polyethylene or nylon tubing in a water-proof polyethylene jacket. This tubing is designed for direct burial and will withstand rough handling in the field. The two transducer models can both be operated with either a 2-tube or a 3-tube configuration. Accuracy is increased for longer tube lengths with a 3-tube system.



Model 514177 Model 514178

DESCRIPTION AND SPECIFICATIONS

Pore-water pressure acts upon a flexible diaphragm having negligible spring force. The force of the diaphragm due to water pressure causes a valve to close. To take a reading, when using the 3-tube arrangement, gas pressure is applied through the input tube allowing flow into the chamber and into the output tube which is connected to a high precision pressure gauge in the readout indicator. Pressure in the chamber and two tubes increases until it balances against the pore-water pressure. Excess pressure is vented to atmosphere through the opened transducer valve and third tube. The measurement may be repeated by reducing input pressure to a level just below the output pressure gauge reading at which point it will begin to decrease. The input pressure is increased again and the reading is repeated.

For the 2-tube configuration, there is no output tube. Instead, the high precision pressure gauge in the indicator measures the input pressure to the transducer. The difference between the pore pressure and the input pressure increases with longer tube lengths and higher operating pressures. However, as long as repeatable reading procedures are maintained and pore pressure changes are not extreme, high precision can be achieved.

For many applications, the flow rate may be limited by visual observation to avoid reading error. For the extremely accurate and sensitive readout pressure gauges, the flow condition is monitored with a "floating ball" flowmeter. By maintaining constant flow for each reading, the small error due to flow rate and possible operator error is eliminated. Tubing lengths for the 3-tube system may be adjusted to suit conditions with no effect to the calibration of the transducer.

Another means of operation, which also gives excellent results, is the "over pressure" method. Results are obtained by rapidly injecting gas into the input tube until gas escapes through the vent tube. When gas is detected flowing from the vent tube, the input gas is interrupted and the excess gas is slowly vented until the diaphragm valve is closed. The system pressure can then be measured in either the input tube or the gage tube. The "over pressure" method is commonly used with two-tubes, providing a more economical means of measuring pore-pressure.

This transducer does not require in-place calibration and has negligible zero shifts or changes in gauge factor. It provides a non-ambiguous measurement which is a result of the unique pneumatic-hydraulic null-balance condition. The application of this technique to measurement of pore-water pressure results in an economical, stable and sensitive transducer giving long-term repeatability for periodic measurement of fluctuating pressures. Normally, it is not necessary to refer to calibration curves at any time since the gauge factor is essentially 1.

A stainless steel disc filter is standard. Three additional types of porous filters are available. The Norton Casagrande type and the polyethylene type filters have large pore size and low air-entry pressure. The Coors filter has high air-entry pressure and permits the measurement of water pressure whenever pore-gas pressure is also present.

Fluid-pressure measurements may be continuously monitored and recorded on moving chart or digital data-logging equipment. Output signals may be compared to preset threshold values and utilized to trigger external alarms.

APPLICATION AND INSTALLATION

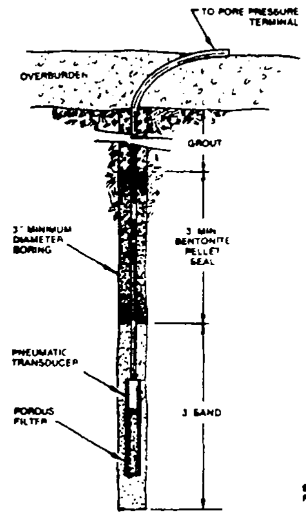
The transducer will operate in any position. It can be installed in boreholes or pressed into the soil. Well-points attached to steel pipes can be pushed into the soil and do not require drilled holes. The 5/8-inch O.D. size transducer (Model 514177) can be used in existing standpipes or placed in small size drive type well-points.

In most applications, the 1" O.D. transducer with a Norton tube filter is embedded in an open borehole and is sealed off from other water-bearing areas with Bentonite Pellets or cement grout. The tubing may be embedded directly in trenches using sand backfill to prevent rocks or other sharp objects from damaging the tubing. In cases where large lateral or vertical deformations may develop, the tubing can be protected by an outer armored conduit.

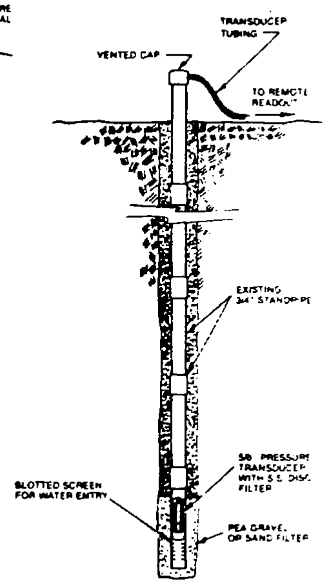
In many construction projects, it is essential to monitor pore-water pressure in both soil and rock. The transducer will provide in-situ pore-pressure data economically and reliably in support of the following objectives:

- Monitoring water-pressure changes in regard to stability of slopes.
- Control during construction of embankments and dams.
- Soil stabilization to determine seepage patterns in soil and rock.
- Surcharging of compressible foundations.
- Gauging of water table and hydrostatic pressures.
- Pumping tests to determine permeability and transmissibility coefficients.
- Measuring of pore-pressure subjected to static and dynamic transient loadings in, for example, evaluating liquefaction potential associated with earthquake accelerations.
- Stability of tailings dams and solid disposal areas.

Slope Indicator Company will be pleased to assist users with detailed installation planning.



PNEUMATIC PORE-PRESSURE TRANSDUCER INSTALLATION



PRESSURE TRANSDUCER PLACEMENT IN EXISTING WELL

Since this is a scientific instrument, measurements should be taken, recorded, and interpreted by qualified personnel. SINCO is not responsible for errors or omissions of such personnel.

TRANSDUCER SPECIFICATIONS:

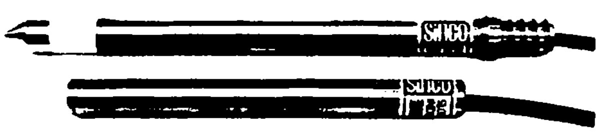
Pressure Range:	0.5-1000 psig (3.44-6894.8 kPa)
Repeatability:	± .05 psi
Accuracy:	
Calib. Zero Offset:	−.30 psi ± .05 psi (−2.0 kPa ± .35 kPa)
Sensitivity $= \frac{\text{Output}}{\text{Input}}$:	1.007 ± 0.0005
Diaphragm Displacement:	0.01 cc
Diaphragm Material:	
Standard	Buna-N Rubber
Optional:	Viton Rubber, Silicone Rubber
Body:	
Model 514177:	Nominal, ⅝" O.D. Actual, 0.625" (16 mm) O.D. ABS
Model 514178:	Nominal, 1" O.D. Actual, 1.062" (27 mm) O.D. ABS
Filters:	
Standard	S.S. Disc — 50 micron, pore size sintered stainless steel
Optional	Norton Tube — 60 micron, pore size; 1.5" (38.1 mm) O.D. x 4" (102 mm) length; .25" (6.35 mm) wall
	Polyethylene — 60 micron, pore size; 1.5" (38.1 mm) O.D. x 4" (102 mm) length; .25" (6.35 mm) wall
	Coors Tube — 1.5 to 2.2 micron, pore size; Air Entry Pressure: 18 to 28 psi (1.27 to 1.97 kg/cm²); 1.5" (38.1 mm) O.D. x 6" (152 mm) length; .25" (6.35 mm) wall

- **Vibrating Wire Frequency Signal**
- **Long leads do not affect reading**
- **Lightning protected—standard**
- **Temperature measurement—standard**
- **In-place sensitivity check—standard**

The Model 52650 pressure transducer is a reliable and accurate device for measuring liquid or gas pressures (pore-pressure) within embankments, foundations, slide areas, wells, tanks, pipelines and reservoirs.

The transducer converts fluid pressure to an electrical frequency signal which is transmitted to a remote reading station via cables. Readings can be made with a portable indicator or an automatic data logging scanner.

Materials, construction and design of the transducer make it corrosion-resistant, immersion-proof and electrically stable for long-term operation. It is designed for burial in soil or rock foundations, in earth embankments, and at the earth interface with tunnels and retaining structures. It can also be attached to pipelines and tanks or immersed in wells or reservoirs.



top: Drive-Point Piezometer with cylinder filter and EW-Rod Threads. bottom: Borehole Piezometer with Disc Filter.

Description and Specifications

The sensing element is a small diameter steel wire, restrained at both ends, which vibrates at a natural frequency determined by the tension in the wire. One end of the wire is fixed to the transducer body. The other end is fastened to a thin flexible-steel diaphragm in contact with the fluid media. Flexure of the diaphragm due to changes in fluid pressure induces a change in the natural frequency. Fundamentally, the frequency is a function of the square root of the tension stress in the wire multiplied by a constant. This frequency is a very sensitive and repeatable signal corresponding to the fluid media pressure on the diaphragm.

The integral electrical circuit drives the wire in constant oscillation at the natural frequency of the wire by means of an exiter-coil and pick-up coil in close proximity to the wire. The signal-conditioning networks in the portable indicator or scanner sustains the oscillation at a constant amplitude and squares the frequency for a digital display of the reading which is proportional to the strain in the vibrating wire. The conversion to pressure units is done by subtracting the initial reading from the current reading and dividing by the sensitivity of the transducer.

The electrical cable consists of two-conductors, shielded within a waterproof jacket. The electrical cable is bundled together with two nylon tubes within an outer polyethylene jacket. The two tubes extend into the transducer housing cavity behind the diaphragm which contains the sensing wire and the oscillator coils. The two tubes permit circulation of dry nitrogen gas in the cavity. This tube arrangement allows checking in-place sensitivity and purging moisture which may have entered the cavity. Also, when the transducer cavity is vented to the atmosphere, barometric pressure corrections of the data are eliminated. A high precision indicator, such as the Model 51411-A Pneumatic Indicator, is used to check sensitivity.

The Vibrating Wire Pressure Transducer can measure negative gage pressure (sub-atmospheric) and pressures near atmospheric with a sensitivity equal to that of the positive range.

Although temperature effects are negligible, a temperature sensor is included in the transducer's circuitry. Switching the indicator to TEMP. mode will display temperature change to permit compensation in data computations when desired. This is a standard feature in all units.

When used as a piezometer, optional filtering, such as porous disc or cylinders, is provided. Filters are available with different porosities. The larger pore sizes are most commonly used for saturated ground conditions. The smallest pore size for high-air-entry gas pressures is sometimes used in partially saturated soils. Also, as an option, a drive-point piezometer version is available with cylindrical filter and square threads at the top to couple with EW-size drill rod.

Monitoring Instruments

Readings of Vibrating Wire Pressure Transducer outputs may be made manually by means of a portable battery operated indicator, Model 52609. This indicator can read a single transducer or be connected to a multi-point terminal station by means of a jumper cable. The battery powered Model 52630 Scanner-Recorder can be set up for unattended operation providing data print-out. Automatic data logging equipment may be interfaced to have the capability of digital print-out of all data, threshold comparison, alarm triggering, and also transmission of data via telephone line to office print-out equipment.

SPECIFICATIONS

Accuracy: 0.5% Range (After sensitivity and offset correction)

Resolution: 0.05% Range

Pressure Range: (1) 150 psi (1035 kPa)
(2) 300 psi (2070 kPa)
(3) 500 psi (3450 kPa)

Sensitivity: 2.64 x 10^6 HZ^2/Range (nominal)
Calibration furnished with each transducer

Temperature Coefficient: 0.06% Range/°F (0.11% Range/°C)

Operating Temperature: 20°F to 150°F (29°C to 65°C)

Over Pressure: 100% Range
(without damage)

Diaphragm Displacement: 0.01cc/Range

Materials exposed to fluid media:

Diaphragm	Stainless Steel
Body	Stainless Steel
O-Ring	Buna-N

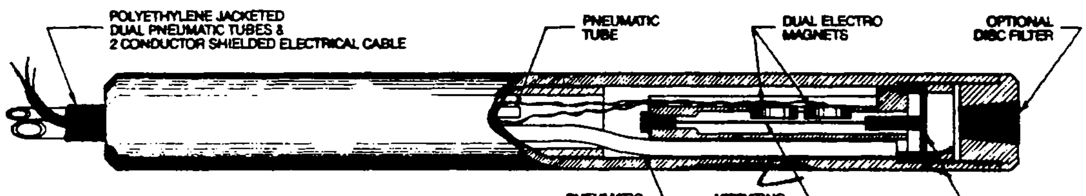
ORDERING INFORMATION

Specify by part Number as Shown Below:

52605 – □ – □ – □

Pressure Range
Body Style
Filter Style

Since this is a scientific instrument, measurements should be taken, recorded, and interpreted by qualified personnel. SINCO is not responsible for errors or omissions by such personnel.



VIBRATING WIRE PRESSURE TRANSDUCER

Body Style	Dash No.	Dimensions	Weight	Attachment Adapter
Borehole Piezometer with Disc Filter	(−1)	1.0" OD x 10.8" long (26 x 274mm)	1.3 lb (.60kg)	None
Borehole Piezometer with cylinder filter	**(−2)**	**1.0" OD x 13.0" long (26 x 330mm)**	**1.6 lb (.74kg)**	**None**
Drive-Point Piezometer with cylinder filter	(−3)	1.0" OD x 15.3" long (26 x 389mm)	2.0 lb (.91kg)	Square Threads, 3/inch for EW-Rod, 1.25" OD
	(−4)			**1" male pipe thread**
Transducer with disc filter	(−5)	1.0" OD x 10.8" long (26 x 274mm)	1.3 lb (.60kg)	⅛" female pipe thread
Transducer with no filter	**(−6)**	**1.0" OD x 10.8" long (26 x 274mm)**	**1.3 lb (.60kg)**	**⅛" female pipe thread**

Filter Style	Dash No.	Material	Dimensions	Air Entry Pressure	Pore Size
	(−1)	Norton Alundum	1" OD x 2.0" (25 x 50mm)	0	60 micron
Cylinder	**(−2)**	**Polyethylene**	**1" OD x 0.5" ID x 2.0" (25 x 12 x 50mm)**	**0**	**60 micron**
	(−3)	Coors Alumina	1" OD x 0.5" ID x 2.0" (25 x 12 x 50mm)	18 to 28 psi (124 to 193 kPa)	1.5 to 2.2
Disc	**(−4)**	**Sintered Stainless Steel**	**0.4" OD x 0.050" Thick (10 x 1 mm)**	**0**	**50 micron**

Model 52630 Vibrating Wire Scanner/Recorder

The Vibrating Wire Scanner/Recorder is a multi-channel data acquisition system that can automatically record strain data from one to ten Vibrating Wire Transducers, or up to one hundred transducers when Expansion/Junction Boxes are used. The system provides quick, accurate data for those projects requiring automatic and/or remote recording; sensitive, low drift measurements; rapid response; and very long leads between the transducer and readout point. It is a portable system that can provide telemetering from a remote location and continuous recording. It has internal rechargeable batteries or can be operated from either an external 12V DC source or AC line power. The recorder has a built-in electrosensitive printer or can be interfaced to any data terminal equipment satisfying EIA Standard RS-232C specifications for interface between data terminal equipment and data communication equipment. The system operates in a powered-down mode and can be programmed to record data at pre-set time intervals for periods up to a week or more from internal batteries, or even longer with external batteries.

The **Model 52630 Vibrating Wire Scanner/Recorder** is a portable instrument containing rechargeable batteries. It features a crystal controlled calendar and clock that can be monitored on the instrument panel, a built-in electrosensitive printer with automatic paper take-up, and a waterproof case for unattended operation even in adverse weather conditions. The Vibrating Wire Scanner/Recorder will turn on and record the date, time and output from all active channels at selected scan intervals or by remote command. It can also continuously scan and record all active channels at the maximum rate, or alternately monitor a single channel without recording. The data is displayed and recorded directly in units of microstrain and is indicated on a digital readout along with the channel number.

The Scanner/Recorder has a built-in capability for handling up to ten channels. Additional channels up to a maximum of one hundred can be recorded on the system. The **Model 52660 Vibrating Wire Expansion/Junction Box** can be connected to the system to provide additional channels. Each expander box provides ten additional channels.

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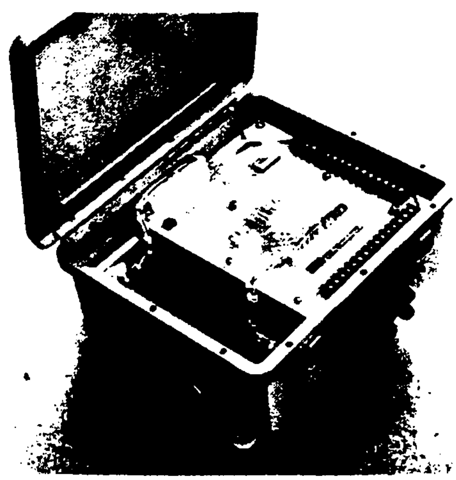
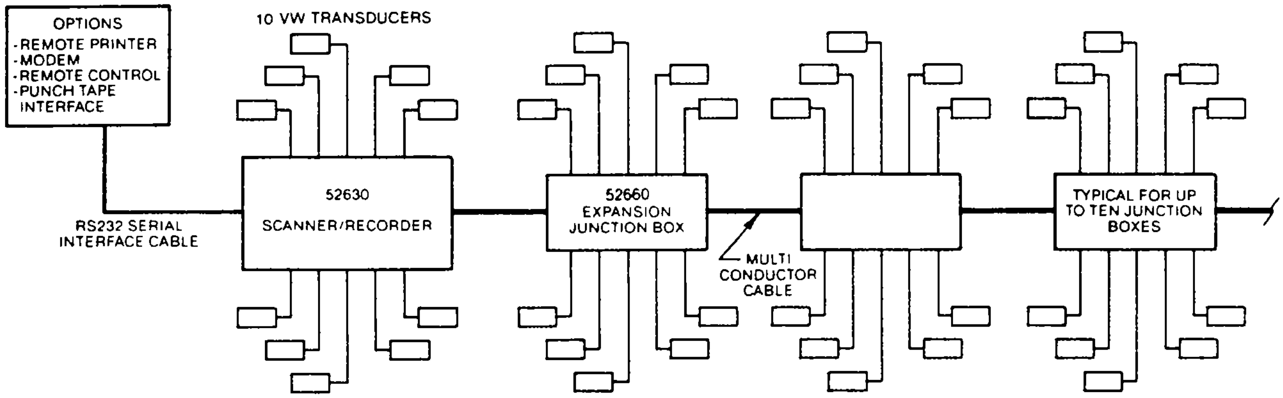


Model 52660 Vibrating Wire Expansion/Junction Box

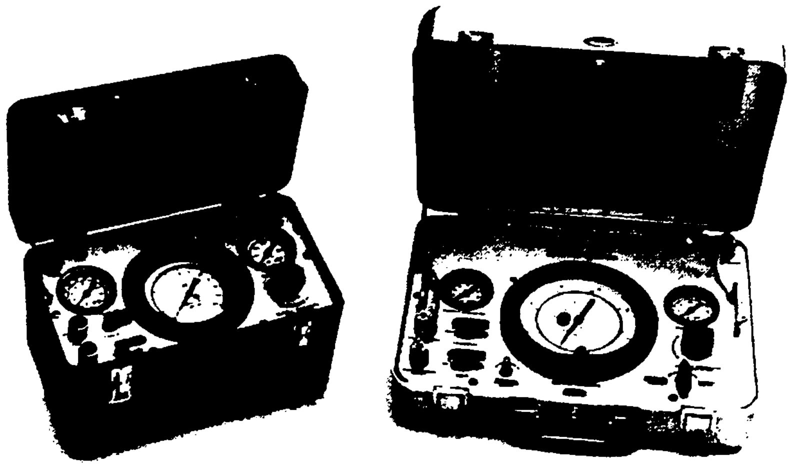


Vibrating Wire Scanner/Recorder System

SPECIFICATIONS

Model 52630 Vibrating Wire Scanner/Recorder

Channels:	10; can be expanded in multiples of 10, by using Model 52660, up to a maximum of 100
Resolution:	1 Microstrain/Digit
Temperature Coefficient:	±(.008% Reading + .3 Digits)/°F ±(.015% Reading + .5 Digits)/°C
Scan Cycle:	Continuous, minutes, hours, manual, remote
Interval:	1-99 minutes or hours
Printing Rate:	2 lines per second maximum
Scanning Rate:	30 Active Channels/Minute Minimum
Data Output:	8 bit even parity ASCII code with start/stop bits; serial by bit, serial by character
Data Interface:	EIA RS-232C Standard, others optional
Data Rate:	110, 150, 300, 1200 Baud (Bits per Second)
Operating Time:	7 days* with fully charged internal battery *(Clock Display off, 30 minute interval, 10 active channels)
Power Requirements:	
Internal Battery:	12 volt rechargeable, 13.5 A.H.
External Power:	115/230 VAC, 50-400 Hz 11-14.7 VDC, 2 amp
Operating Temperature Range:	0°F - 120°F (-18°C to 49°C)
Dimensions:	15 in. x 15 in. x 10.5 inches (38.1 cm x 38.1 cm x 26.7 cm)
Weight:	50 pounds (22.7 kg.)



Model 51421-A and 51411-A Indicators

The Slope Indicator Company's portable pneumatic indicators are quality built pressure measuring systems for operating pneumatic transducers to determine pore water, gas, or total pressure within embankments, foundations, slides, and other geotechnical study areas.

Enclosed in protective carrying cases for easy handling and operations, these indicators incorporate precision gauges, regulating valves, and a high pressure supply tank for maximum reliability and performance in field or laboratory use.

DESCRIPTION

All indicators and their components are of the highest quality. The integral tank is high grade steel, commercially inspected to meet safety standards. Industrial quality compression type tube fittings and self-locking hydraulic style panel connectors are standard to assure integrity. The indicator's panel is heavy-gauge anodized aluminum, with the internal tubing being stainless steel and nylon. The primary, or output pressure gauge is laboratory quality. A bourdon tube type design with mirror dial for increased reading repeatability and accuracy is used. Secondary gauges for supply, and tank pressure are industrial quality and are of the same bourdon tube type design, but made for continuous service and rugged application.

The indicator's controls and major components are labeled for easy identification and convenient operations. The supply tank is filled through a panel connector so that the removal of the tank is not necessary. Secondary reference gauges monitor the actual internal and external tank and input supply pressures. Visual inspection of the gas flow through use of a flowmeter mounted in the lid of the case, aids the operator in maintaining a repeatable reference that is necessary in the operating procedures of most pneumatic transducers.

The indicators are designed to operate any of Slope Indicator Company's pneumatic transducers. Operational procedure of the indicator depends upon the type of transducer. A unique transferring circuitry within the portable indicator enables the operation of different types and styles of transducers by either connecting the primary/output pressure gauge in line with the input gas supply, or by isolating it to the output return. This circuitry also enables system analysis should problems occur due to damage or mishandling.

All portable pneumatic indicators, when selected with the proper primary/output pressure gauge for overall accuracy and range, meet the requirements to give dependable and reliable information for most geotechnical investigative studies.

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SPECIFICATIONS

MODEL	51411-A	51411-A-AFC	51421-A	51421-A-AFC
Case Dimension	18 x 13 x 7 in (457 x 330 x 178 mm)		14 x 8 x 7 in (356 x 203 x 178 mm)	
Weight	28 lb (13 kg)		23 lb (10 kg)	
Gas Source	Integral Tank			
Gas Tank Volume	84 cu.in. (1.38 liters)			
Gas Type	Dry Nitrogen — Standard Grade 99.95%, Pure Grade 99.995%			
Maximum Source Pressure	2000 psi (13,800 kPa)			
Maximum Operating Pressure	500 psi (3,400 kPa)	300 psi (2,100 kPa)	500 psi (3,400 kPa)	150 psi (1,050 kPa)
Flow Meter	0.1 - 1.0 SCFH			
Flow Controller	Manual	Manual/Automatic	Manual	Manual/Automatic
Output Pressure Gauge				
Scale Length	32 in (813 mm)		9 in (229 mm)	
Accuracy	0.1% Full Range		0.25% Full Range	
Sensitivity	0.01% Full		0.05% Full	
Temperature Compensation	-25° to 125° F Automatic (-30° to 50° C Automatic)			
Zero Adjustment	Manual			
Parallex Compensation	Mirror			
Pressure Ranges				
psi — Standard	0-30, 0-60, 0-100, 0-150 psi		0-30, 0-60, 0-100, 0-160 psi	
psi — High Pressure	0-300, 0-500 psi	0-300 psi	0-300 psi	0-300 psi
kg/cm^2 — Standard	0-2, 0-5, 0-7.5, 0-10 kg/cm^2		0-4, 0-7, 0-11 kg/cm^2	
kg/cm^2 — High Pressure	0-20, 0-40 kg/cm^2	0-20 kg/cm^2	0-20 kg/cm^2	0-20 kg/cm^2
kPa — Standard	0-200, 0-500, 0-750, 0-1000 kPa		0-400, 0-700, 0-1100 kPa	
kPa — High Pressure	0-2000, 0-4000 kPa	0-2000 kPa	0-2000 kPa	0-2000 kPa
SINCO Transducers Operated by Indicators	514177, 514178, 514180, 51482, 514124		514177, 514178, 514180, 51482, 514124	
		Also 514163, 51483		Also 514163, 51483

NOTE: All indicators are shipped with nitrogen supply tank empty. Indicator tank must be empty for all air travel, unless packaging and labeling complies with Air Transport Restricted Articles Tariff No. 6-D, CAB No. 82.