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UTILIZATION OF DIFFERENTIAL PRESSURE TRANSDUCERS TO MEASURE VOLUME CHANGE OF SOIL SPECIMENS DURING TRIAXIAL SHEAR TESTING

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Abel A. Benavidez

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16. ABSTRACT

This report presents a method for accurately measuring volume change of soil specimens during triaxial shear tests utilizing a commercially available differential pressure transducer interfaced with a computer.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS-- / soil/ differential transducer/ triaxial shear/ volume change/ differential pressure transducer/ float volume/ measurement device/ capacitance probe/ triaxial shear/ LVDT (linear variable differential transformer)

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by

Abel A. Benavidez

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Geotechnical Branch
Division of Research and Laboratory Services
Engineering and Research Center
Denver, Colorado

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UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

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INTRODUCTION

Soil specimen volume change during saturation, consolidation, and axial loading is one of several parameters measured during triaxial shear testing. The soil specimen volume change is measured by determining the amount of water entering or leaving the triaxial confining pressure cell. While there are several methods used for measuring soil specimen volume change during triaxial shear testing [1],[1] most methods require complex and expensive equipment.

The objective of this investigation was to determine the suitability of a differential pressure transducer for measuring soil specimen volume change during a triaxial shear test.

Past experience in the Geotechnical Branch, Division of Research and Laboratory Services, E&R Center, has been limited to three types of volume change measurement devices. They were:

1. A measurement device utilizing a large bore LVDT (linear variable differential transformer) with its core attached to a float (fig. 1).–This device worked well; however, extensive modifications were required to the volume tube and mounting brackets to adapt them to existing triaxial shear chambers. This prompted a search for a less complicated and more economical method of volume change measurement.

2. A capacitance probe device furnished to the Geotechnical Branch by the Power and Instrumentation Branch (fig. 2).–This device worked fairly well; however, it required considerable maintenance and was difficult to calibrate.

3. A commercially manufactured capacitance probe.–This device worked well under atmospheric pressure. However, when additional lateral pressure was applied to the system, the water level sensor readings became erratic.

The inaccuracies and problems encountered using these devices for the measurement of specimen volume changes during triaxial shear tests prevented totally automated data acquisition of the triaxial shear test.

Based on these needs, a list of requirements was developed for a more suitable water level measurement device. These requirements included:

1. Ease of installation.–The device should be easily installed on an existing triaxial shear machine without extensive modifications to the unit.

2. Accuracy of at least ± 0.25 percent of full range.–Based on standard cylindrical triaxial shear specimen with dimensions of 2-in (50-mm) diameter by 5-in (127-mm) height, volume change readings should be accurate to within ± 0.05 percent.

3. Capability of measuring differential pressures up to 30 inches (762 mm) of water [1.08 lb/in² (7.45 kPa)].

4. Capability of operating under pressures up to 200 lb/in² (1380 kPa).

5. Manufactured from state-of-the-art electronic components.

6. Calibration and adjustment possible without use of special electronic equipment.

7. Must interface with the existing Hewlett-Packard 9845B computer (–0 to 5 volts d-c signal output).

8. Cost.–Not more than $500 per unit.

9. A standard, off-the-shelf item (not custom made).–Special electronic or mechanical knowledge not required for installation and calibration.

The model P-3061 differential pressure transducer manufactured by the Schaevitz Engineering Company was selected for further evaluation.

DESCRIPTION

The differential pressure transducer selected for this evaluation uses a pressure capsule coupled to an LVDT core which in turn passes through the center of the LVDT body (fig. 3).

When equal pressure is applied to ports 1 and 2, no movement occurs in the capsule; therefore, the LVDT core will not move and no voltage change is registered. However, if a load such as from a water column is added to port 1, the transducer will register a change in voltage corresponding to the change in pressure.

Note: Fluids should not be introduced in port 2 since this side of the transducer is very difficult to de-air.

When a soil specimen changes volume during testing, the water level in the volume tube rises or falls

[1] Numbers in brackets refer to entries in bibliography.

(see fig. 4). When this happens, the capsule deflects, thereby causing the LVDT core to move and produce an electrical output proportional to its displacement.

Peripheral equipment to the differential pressure transducer on the triaxial shear machines includes:

1. A d-c power supply with an output variable between 0 to 30 volts d-c;

2. A digital voltmeter used for calibration;

3. A transparent head tank; and

4. Miscellaneous valves and standard pipe fittings (see appendix for a detailed list of fittings and valves needed for this installation).

The only modification required to the standard differential pressure transducer would include drilling and tapping a 1/8-inch NPT (American National Standard Pipe Thread) hole in the transducer bottom cap. The purpose of this modification is to allow the system to be flushed through the head tank (figs. 3 and 4) to remove any air in the system. When measuring volume changes during triaxial shear tests, de-aired water must be used and all air must be removed from the system by using a vacuum. If all the air is not removed, the volume change values obtained will be inaccurate.

TEST RESULTS

Initial testing of the differential pressure transducer was performed using a standard triaxial shear machine interfaced to an existing Hewlett-Packard 9845B data acquisition computer system. Under atmospheric pressure, the difference between the visual and electronic readings is negligible; however, when lateral pressure is applied to the specimen, the differential pressure transducer indicates a higher volume change than the visual readings.

This difference appears to be caused by deformation of the transducer case when pressure is applied. Since the difference is proportional to the lateral pressure applied to the differential transducer and is approximately linear, a plot of the difference between visual and electronic readings versus lateral pressure is generated and the slope of the line can be determined. The slope of the line is used in the computer program to correct for this difference.

Note: this correction should be determined for each differential transducer when it is put into use.

Figure 5 is a typical plot showing the difference between the visual and electronic readings due to applied lateral pressure.

The preliminary tests were performed on UU (unconsolidated-undrained) triaxial shear specimens. Since that time, 70 to 90 CD (consolidated-drained) and CU (consolidated-undrained) test specimens have been successfully tested. Figure 6 shows a comparison of visual and electronic volume change readings. Tables 1, 2, and 3 show the data comparing the visual readings versus the electronic readings for tests at three different lateral pressures. Figures 7, 8, and 9 show visual readings plotted versus electronic readings. The difference is negligible.

Table 1.—*Computer vs visual volume tube reading, spec 1 ($\sigma3$=50 lb/in^2)*

Lateral pressure (lb/in^2)	Computer readings (inches)	Visual reading (inches)	Difference in inches
0.0	10.01	10.01	0.00
10.0	11.01	11.00	+.01
15.0	11.39	11.38	+.01
20.0	11.74	11.74	.00
29.9	12.49	12.51	–.02
40.0	13.35	13.38	–.03
49.8	14.64	14.70	–.06
49.8	14.85	14.85	.00
49.8	15.01	15.00	+.01
49.8	15.03	15.02	+.01
49.8	15.09	15.10	–.01
49.8	15.77	15.78	–.01
49.8	16.42	16.42	.00
49.8	17.11	17.12	–.01
49.8	17.73	17.72	+.01
49.7	18.08	18.08	.00
49.7	18.37	18.38	–.01
49.7	18.63	18.64	–.01
49.7	18.85	18.86	–.01
49.7	18.98	19.00	–.02
49.6	19.13	19.14	–.01
49.6	19.26	19.27	–.01
49.6	19.37	19.38	–.01
49.6	19.45	19.45	.00
49.6	19.50	19.50	.00
49.6	19.53	19.54	–.01
49.6	19.53	19.54	–.01
49.6	19.53	19.54	–.01
49.6	19.48	19.49	–.01
0.0	0.25	0.25	.00

Table 2.—*Computer vs visual volume tube reading, spec 2 (σ3=100 lb/in²)*

Lateral pressure (lb/in²)	Computer readings (inches)	Visual reading (inches)	Difference in inches
0.0	10.01	10.01	0.00
10.9	11.02	11.03	−.01
19.7	11.57	11.58	−.01
29.9	12.41	12.43	−.02
40.2	13.41	13.43	−.02
50.2	14.41	14.42	−.01
60.0	15.53	15.54	−.01
70.4	16.76	16.80	−.04
81.2	18.04	18.05	−.01
90.8	18.82	18.82	.00
99.8	19.87	19.88	−.01
99.8	20.03	20.03	.00
99.8	20.09	20.10	−.01
99.7	20.12	20.12	.00
99.7	20.05	20.08	−.03
99.8	20.06	20.06	.00
99.8	20.52	20.52	.00
99.7	21.57	21.59	−.02
99.7	22.13	22.15	−.02
99.7	22.59	22.61	−.02
99.7	22.78	22.80	−.02
99.6	22.89	22.91	−.02
99.7	22.93	22.95	−.02
99.6	22.94	22.96	−.02
99.6	22.92	22.95	−.03
99.6	22.89	22.90	−.01
99.6	22.83	22.85	−.02
99.6	22.76	22.78	−.02
99.6	22.66	22.67	−.01
99.6	22.53	22.55	−.02
99.6	22.41	22.45	−.04
99.5	22.27	22.30	−.03
99.5	22.14	22.10	+.04
0.0	19.70	19.70	.00

Table 3.—*Computer vs visual volume tube reading, spec 3 (σ3=200 lb/in²)*

Lateral pressure (lb/in²)	Computer readings (inches)	Visual reading (inches)	Difference in inches
0.0	5.00	5.00	0.00
10.9	6.35	6.31	+.04
19.9	7.07	7.04	+.03
29.5	8.08	7.88	+.05
39.8	9.28	9.22	+.06
49.9	10.34	10.28	+.06
59.8	11.42	11.46	−.04
69.8	12.58	12.64	−.06
80.0	13.45	13.48	−.03
89.7	14.31	14.31	.00
99.7	15.16	15.22	−.06
109.6	15.86	15.84	+.02
120.4	16.41	16.39	+.02
129.7	16.99	16.98	+.01
139.6	17.49	17.48	+.01
149.9	17.96	17.94	+.02
159.8	18.40	18.38	+.02
169.7	18.68	18.68	.00
177.3	18.91	18.89	+.02
189.6	19.21	19.20	+.01
199.7	19.54	19.50	+.04
199.8	19.62	19.62	.00
199.7	19.64	19.64	.00
199.6	19.65	19.65	.00
199.6	19.67	19.67	.00
199.5	19.73	19.73	.00
199.5	19.59	19.58	+.01
199.4	19.70	19.70	.00
199.5	19.93	19.92	+.01
199.5	20.04	20.02	+.02
199.4	20.05	20.05	.00
199.3	20.00	20.00	.00
199.4	19.95	19.94	+.01
199.4	19.90	19.89	+.01
199.3	19.83	19.82	+.01
199.4	19.75	19.74	+.01
199.3	19.67	19.67	.00
199.3	19.58	19.58	.00
199.3	19.44	19.43	+.01
199.2	19.32	19.32	.00
199.1	19.23	19.22	+.01
199.4	19.13	19.14	−.01
199.2	19.05	19.03	+.02
199.0	19.95	19.93	+.02
199.1	18.94	18.94	.00
0.0	16.75	16.76	−.01

CONCLUSIONS

After evaluating the differential pressure transducer measurement of volume change of soil specimens during triaxial shear testing with lateral pressures ranging from 0 lb/in² (0 kPa) to 200 lb/in² (1380 kPa) and differential water column heights of 0 to 30 in (762 mm), the following conclusions were made:

1. The Schaevitz model P-3061 series differential pressure transducer when used in conjunction with a Hewlett-Packard 9845B data acquisition computer system can produce accurate and reliable volume change readings for an extended period of time.

2. Differential pressure transducers are relatively inexpensive (less than $300 each). If a reasonable amount of care is exercised when pressure or

vacuum is applied, there is very little risk of rupturing the capsule inside of the differential transducer (fig. 3).

3. Accuracy of these transducers exceeds that specified by the manufacturer (0.25 percent over full range), in most cases.

4. The differential transducers have been in use on 12 triaxial shear machines for 1 year and have performed in a very satisfactory manner.

5. The differential transducers have other applications in the Geotechnical Branch Soil Testing laboratory including measuring volume change and changes in head on back pressure permeability tests.

BIBLIOGRAPHY

[1] Alva-Hurtado, J. E., and E. T. Selig, "Survey of Laboratory Devices for Measuring Soil Volume Change," *ASTM Geotechnical Testing Journal*, vol. 4, pp. 11-18, March 1981.

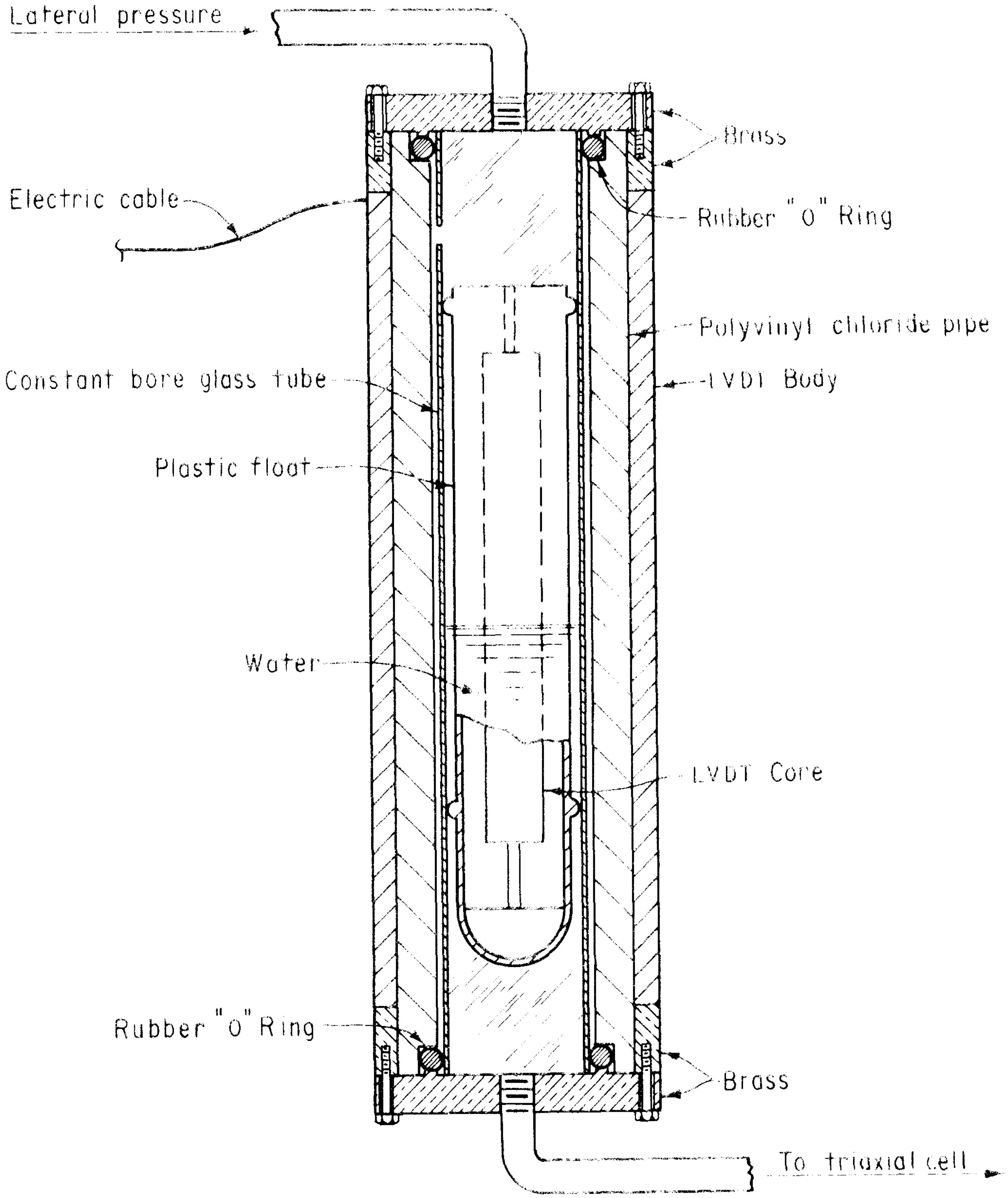

Figure 1.-Schematic of a float measurement device.

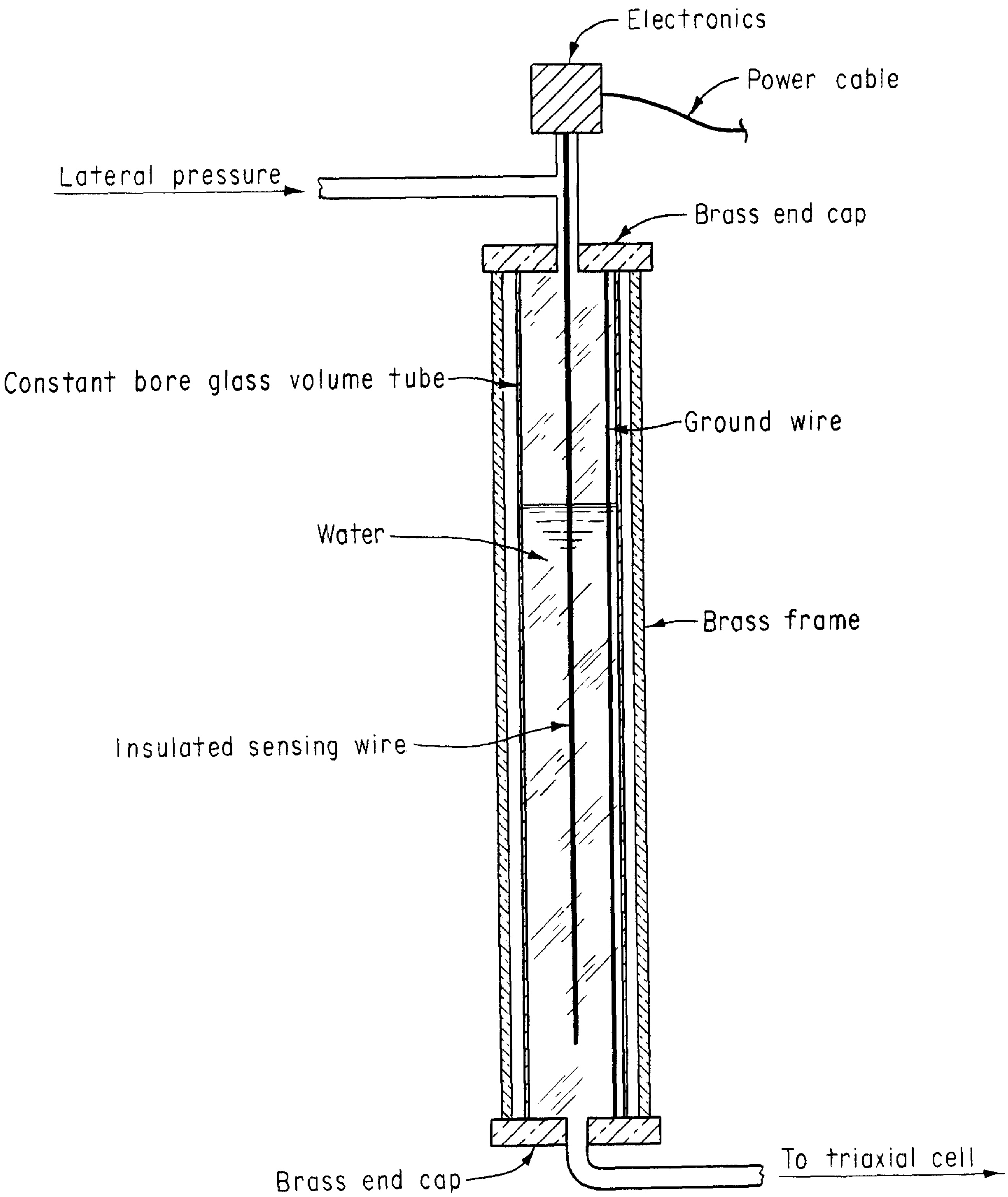

Figure 2.–Schematic of a typical capacitance measurement system.

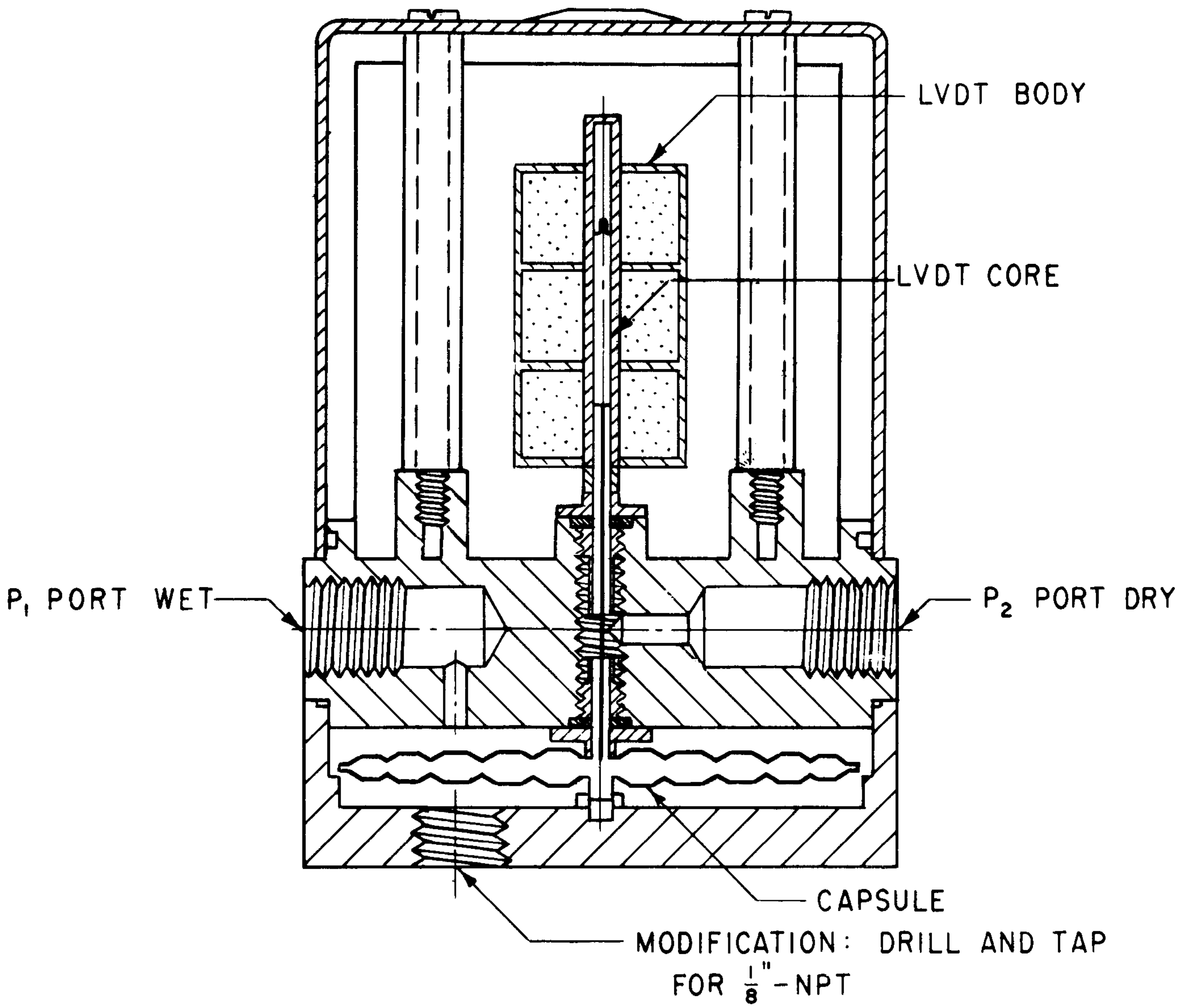

Figure 3.–Cutaway view of the differential transducer.

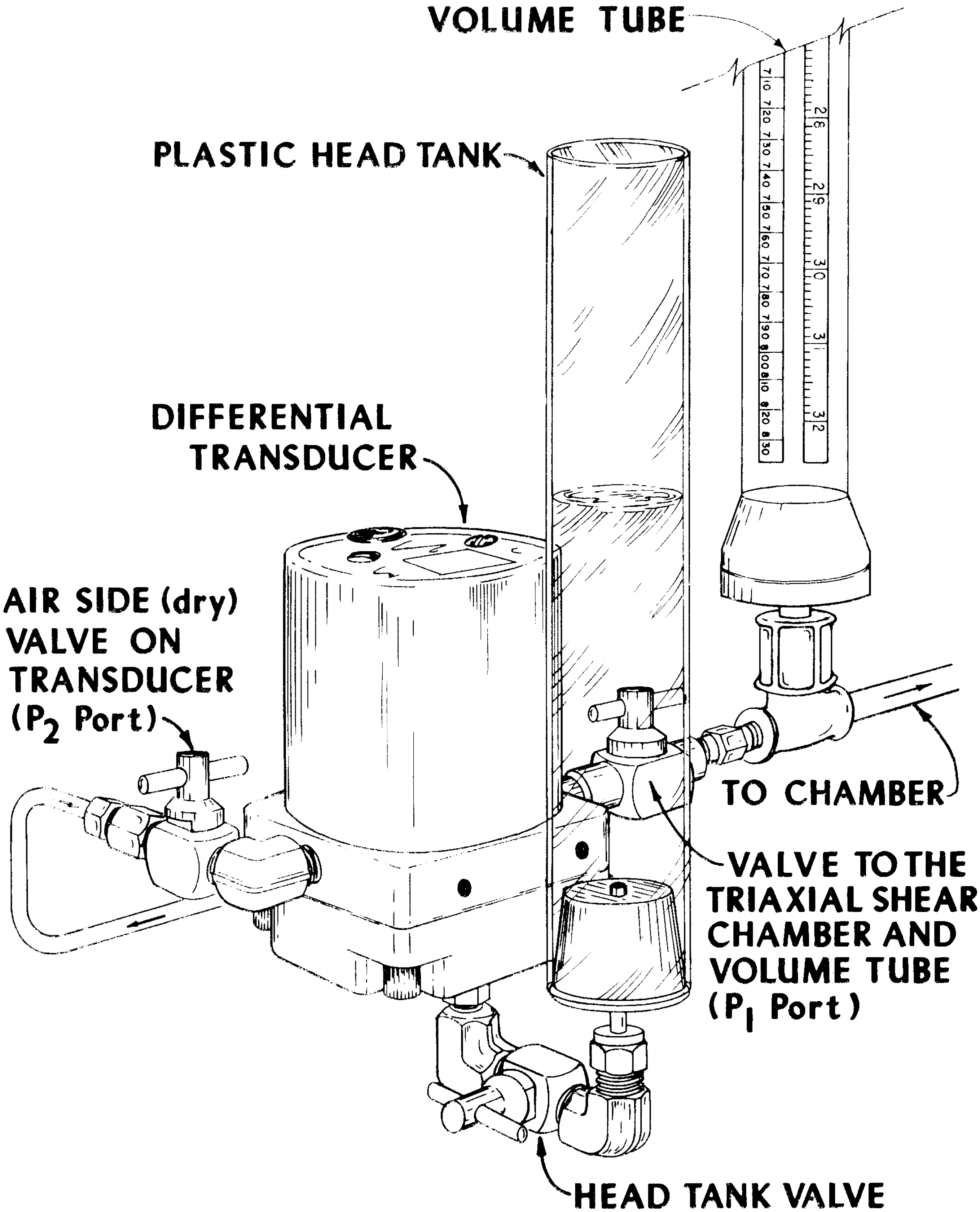

Figure 4.–Typical installation of the differential pressure transducer

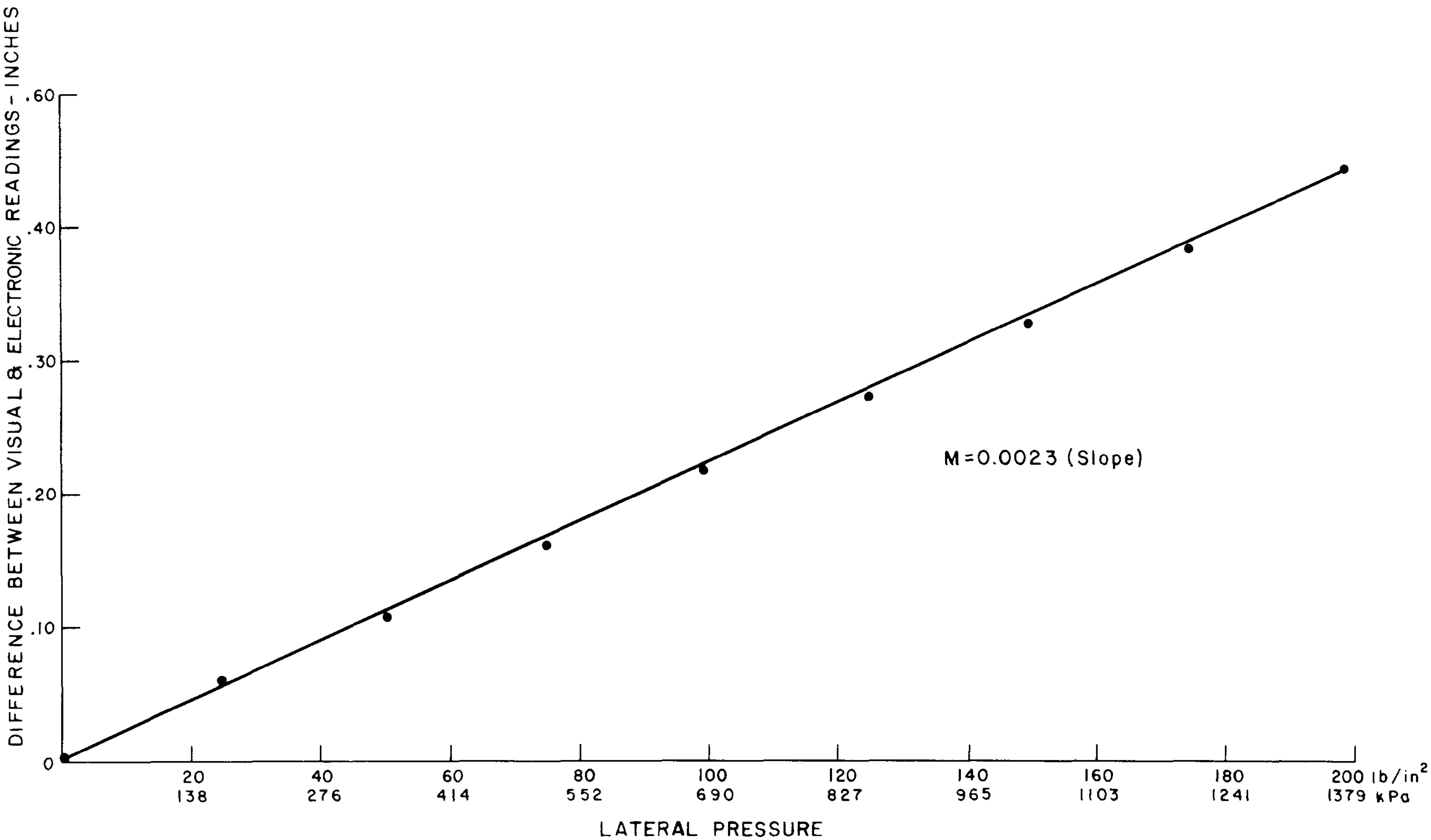

Figure 5.–Typical plot of the difference between visual and computer readings due to applied lateral pressure.

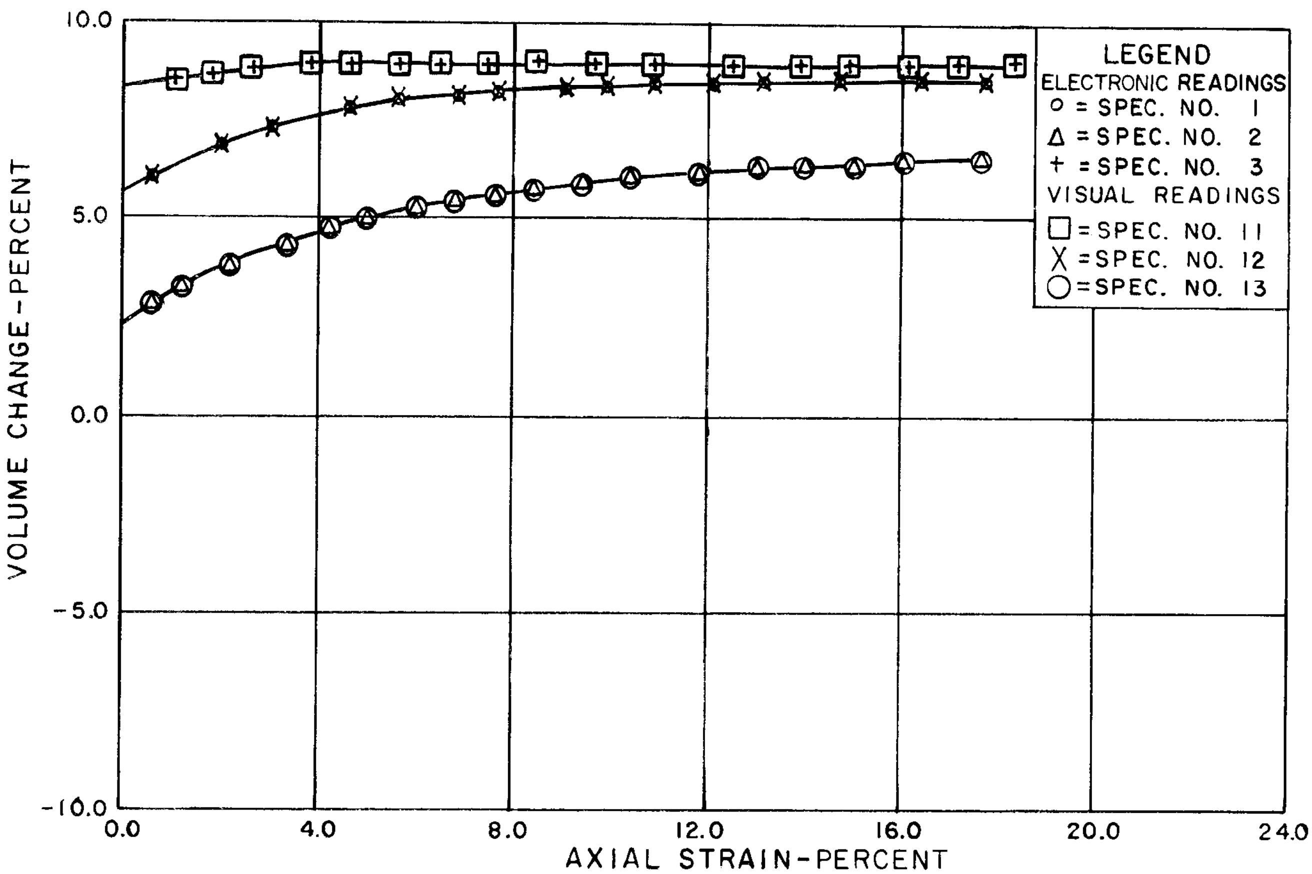

Figure 6.–Volume change versus axial strain.

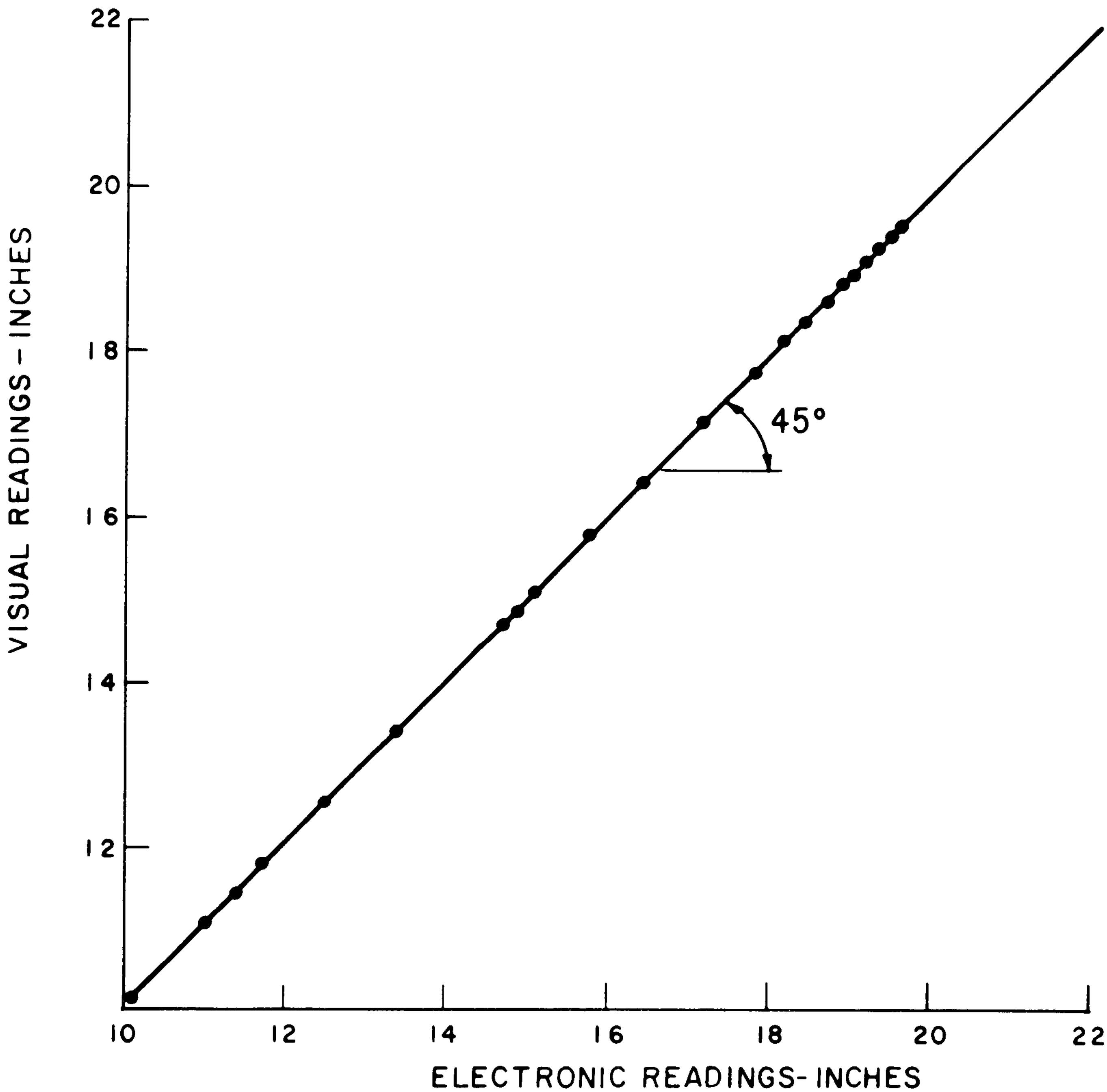

Figure 7.–Visual versus computer readings, spec 1 ($\sigma 3 = 50$ lb/in^2)

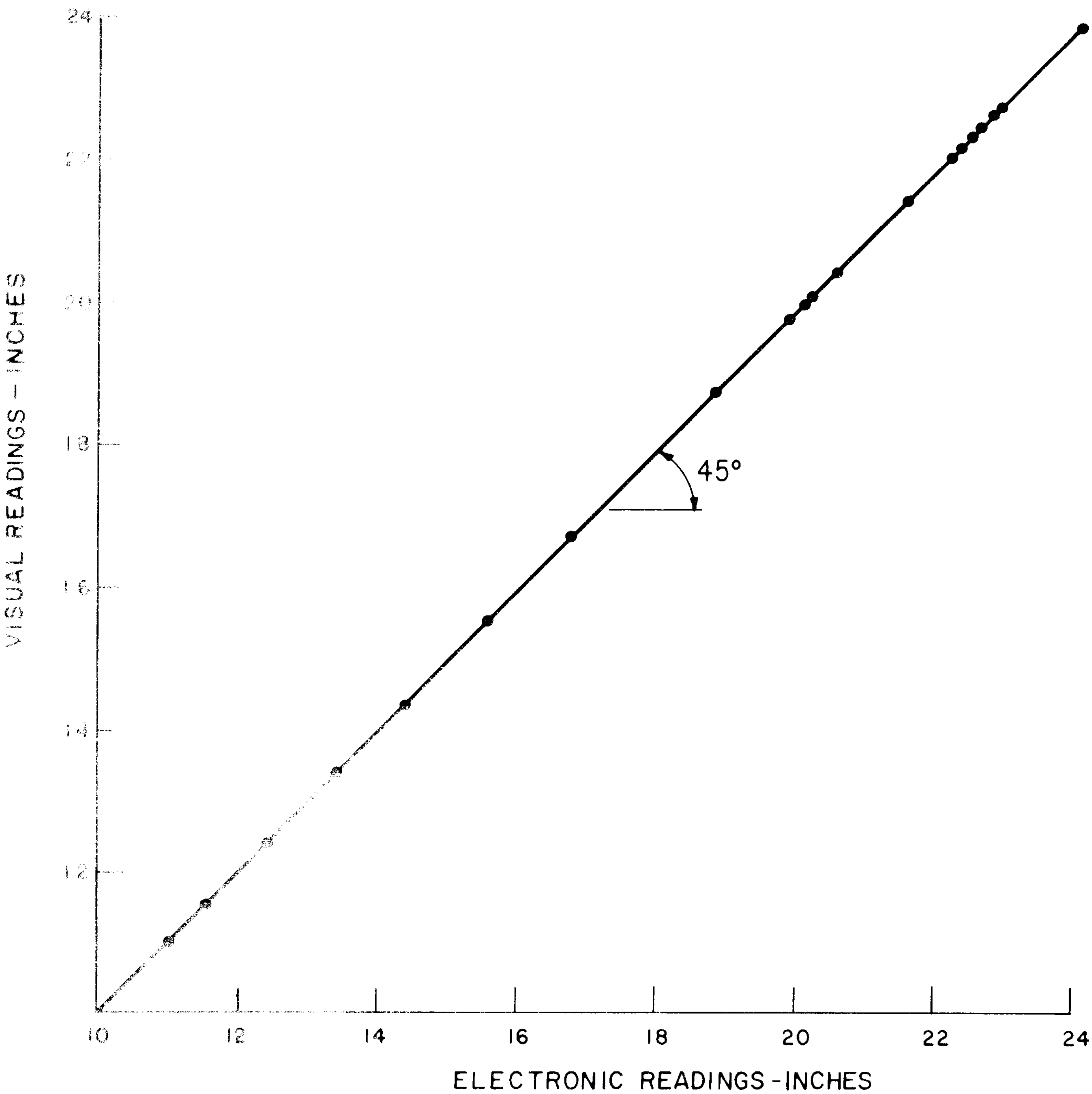

Figure 8 -Visual versus computer readings, spec 2 ($\sigma 3 = 100$ lb/in²)

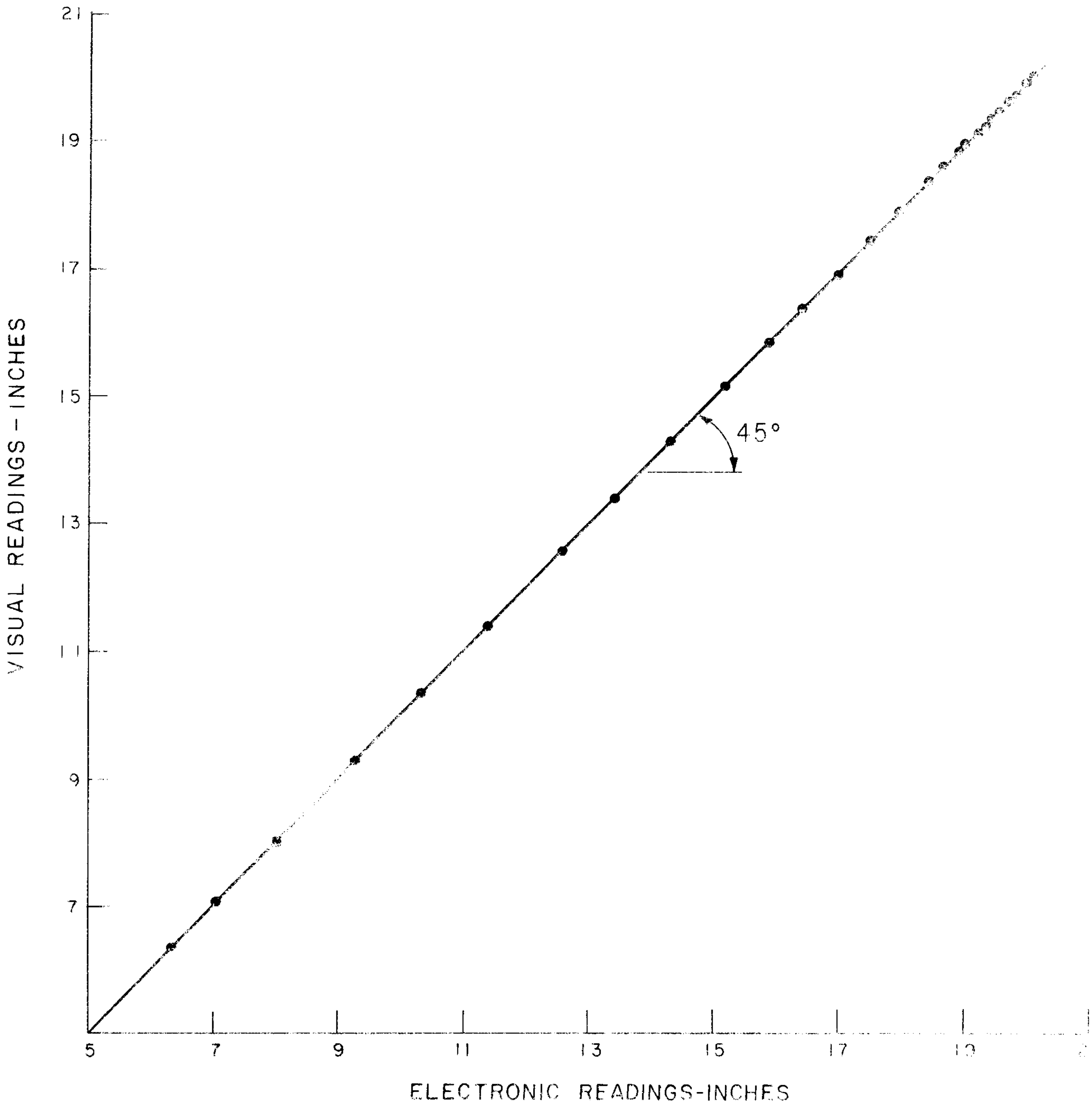

Figure 9 –Visual versus computer readings, spec 3 ($\sigma 3 = 200$ lb/in^2)

APPENDIX

INSTALLATION OF THE TRANSDUCER ON THE TRIAXIAL SHEAR CHAMBER

Figures A-1 and A-2 show the triaxial shear equipment used for triaxial shear testing in the Geotechnical Branch, E&R Center, without and with the differential pressure transducer installed, respectively. A schematic diagram of the testing apparatus is shown in figure A-3.

All pressure connections can be made with standard brass fittings available in most laboratory shops.

Plumbing Material Required for Installation

Item	Number required
1. Brass male elbow, 1/4-inch tube by 1/8-inch NPT	1
2. Brass female elbow, 1/4-inch tube by 1/8-inch NPT	1
3. Brass hex nipples, 1/8-inch NPT	5
4. Brass street elbows, 1/8-inch NPT	2
5. Brass elbows, 1/8-inch NPT	1
6. Brass female connector, 1/4-inch tube by 1/8-inch NPT	1
7. Brass male valve, 1/8-inch NPT	1
8. Brass female valve, 1/8-inch NPT	2
9. A 12-inch piece of 1/4-inch-o.d. flexible seamless copper	1
10. Clear plastic acrylic tubing, 1 inch i.d. by 1.25 inch o.d. and 9 inches in length	1
11. No. 5-1/2 rubber stopper	1
12. A 2-inch piece of 1/4-inch-o.d. flexible seamless copper refrigeration tubing	1

Electrical connections should be made in accordance with the manufacturer's bulletin, which are as follows:

1. Red--power + (+ excitation) from the power supply 20 V d-c.

2. Black--power -- (- excitation) from the power supply 20 V d-c.

3. Green-output + (+ signal) to computer.

4. White-output -- (- signal) to computer.

5. Shield--transducer case.

Note: It is extremely important [illegible] wires be tied together [illegible] be attached to the triaxial chamber [illegible] complete the grounding of the [illegible]

Calibration

The following is based on the assumption that the transducer is being powered by 20 volts d-c, that the transducer is interfaced with a computer such as the Hewlett-Packard 9845B, and that the computer has been programmed to convert the output of the differential transducer into the correct readings.

1. Apparatus

   a. A digital voltmeter which can accurately read to 1 millivolt;
   b. A supply of de-aired water [illegible]
   c. A handheld vacuum/pressure pump

2. Calibration of water column height versus differential pressure transducer voltage output

   a. Fill the unit and volume tube to at least the 10-inch (254-mm) level with de-aired water.

   Note: The bottom plate on the differential transducer should be removed by unscrewing the four cap head screws which hold it to the body of the transducer and filled with de-aired water. Open the valve to the plastic head tank and allow some water to drain over the exposed capsule. Next, place the bottom plate back on the differential transducer, being careful not to entrap air. Leave the valve to the plastic head tank open slightly to relieve any pressure which results from tightening the cap screws.

   b. Flush the unit thoroughly, utilizing the hand held vacuum/pressure pump by forcing the water from the plastic head tank located on the transducer through the volume tube and back into the head tank.

c. Extreme caution must be used when flushing the system since an overpressure greater than about 10 lb/in^2 (70 kPa) can damage the measuring capsule inside the differential pressure transducer. Symptoms of overpressuring may include the following:

(1) Transducer instability (voltage readings), or
(2) Inability to adjust the transducer to zero.

d. Connect a cable with double banana plugs on both ends from the voltmeter to the power output jack located on the triaxial shear apparatus or a test stand.

e. Activate the meter and select a range capable of measuring at least 5 volts d-c.

f. Disconnect the lateral pressure air hose from the control panel and open the valve at the top of the volume tube.

Note: If the lateral pressure hose is not disconnected from the control panel, the regulator often allows a small amount of air to leak through it, and the differential transducer will function erratically. The transducer output will not stabilize because the applied pressure is unsteady.

g. Open the valve to the plastic tube located on the differential transducer, and slowly drain the water in the volume tube to the 30-inch (762-mm) mark at the rate of approximately 30 in/min.

h. Read the voltmeter. It should register 1.000 $\pm$ 0.004 volt. If it does not, adjust the zero screw on the differential transducer until the correct reading is obtained.

Note: The zero screw zeroes the gain on the amplifier.

i. Fill the volume tube to the 0.0-inch mark on the scale and read the voltage. It should be 4.000 $\pm$ 0.004 volts. If it is not, adjust the span screw.

Note: It may be necessary to repeat steps 2.g., h., and i. several times until the correct readings are obtained.

j. If more than five trials are necessary to obtain the correct readings, the unit should be examined for leaks or trapped air.

3. When the zero and span have been properly adjusted, press the key marked CAL on the Hewlett-Packard 9845 computer keyboard. The symbols used in the computer program are Y = Yes; N = No; CAL = Calibration; and NO = Number. The program will in turn request an answer to the following questions:

a. "System No. for Calibration." Enter the triaxial shear apparatus system number and press the continue key.

Note: Each triaxial shear machine has a system number assigned to it in the memory of the computer.

b. "Channel No." Enter the appropriate channel number and press the continue key.

Note: Channel 4 is normally assigned as the volume tube reading channel.

c. "Value." Enter the first volume tube reading and press the continue key.

Note: Normally, the first volume tube reading is 0.0.

d. "Another value (Y or N)." Press the Y key and then the continue key. Drain the water to the 10-inch level in the volume tube, enter 10 on the computer keyboard, and press the continue key.

e. "Another value (Y or N)." Press the Y key and then the continue key. Drain the water to the 20-inch level in the volume tube, enter 20 on the computer keyboard, and press the continue key.

f. "Another value (Y or N)." Press the Y key and then the continue key. Drain the water to the 30-inch level in the volume tube, enter 30 on the computer keyboard, and press the continue key.

g. "Another value (Y or N)." Since you have drained the water to the bottom of the volume tube, press the N key and the continue key. When you depressed the N key, you have in essence told the computer that this sequence is completed except for recording and plotting.

h. "Record CAL factors (Y or N)."

Note: If this calibration is to be used as a permanent record, press the Y key and the continue key. If not, press the N key and the continue key.

i. "Plot CAL factors (Y or N)." If you wish to graphically observe the calibration data, press the Y key and the continue key. If not, press the N key and the continue key.

Note: The operator is not restricted to using volume tube measurements of 0, 10, 20, and 30 inches. Any level or number of levels between 0 and 30 inches can be used. However, a 0-, 10-, 20-, and 30-inch sequence is recommended for standardization.

4. Frequency of Calibration

The calibration procedure should be performed when a transducer is put into service and prior to performing each triaxial shear test. Special attention should be paid to the output voltage of the transducer at the different water levels. They should read as follows:

0-inch volume tube, voltage
= 4.000 $\pm$ 0.004 V d-c.

30-inch volume tube, voltage
= 1.000 $\pm$ 0.004 V d-c.

5. Calibration of the difference between visual and electronic readings due to applied air pressure is accomplished in the following manner:

a. De-air and flush the volume tube and differential pressure transducer;

b. Set the water level in the volume tube at 10 inches;

c. Connect the air pressure supply line to the triaxial shear chamber;

d. Disconnect the lateral pressure air hose from the control panel;

Note: If the lateral pressure hose is not disconnected from the control panel, the regulator often allows a small amount of air to leak through it, and the differential transducer will function erratically. The transducer output will not stabilize because the applied pressure is unsteady.

e. If this transducer channel has been calibrated before, change the Cf (correction factor) to zero to obtain a valid calibration curve in this way:

(1) Press and hold the shift button on the computer, then press the Cf button and release the shift button.

(2) The computer displays "System No. for Cf."

(3) Enter the triaxial shear apparatus system number and press the continue button.

(4) The computer displays "Value."

(5) Enter the slope of the line, which in this case is 0.0, and press the continue button.

(6) Computer answers "Cf is stored."

(7) When the correction factor "Cf" is stored in the computer memory, the program will automatically correct the volume tube readings for any value of lateral pressure.

f. Obtain a water-level reading utilizing the computer in the following manner: Press system number key on computer "System No." (enter the system number at this time). Press continue key.

(1) Press the read key on the computer. It will display all channel readings.

(2) Compare the visual reading on the volume tube versus the electronic reading by the computer and record.

(3) At this time, read and record the volume tube and electronic readings.

Note: Also record the serial number of the transducer, the date, and the unit on which the transducer is mounted.

(4) Check the pressure gage reading; it should register zero.

(5) Connect one end of the lateral pressure hose to the triaxial unit and the other end to the control panel. Turn the valve located on top of the volume tube to the off position.

(6) Raise the lateral pressure in 25-lb/in^2 (172-kPa) increments to 200 lb/in^2 (1380 kPa) at a rate of approximately

10 lb/in² (70 kPa) per minute. Read and record both volume tube and electronic readings at 25-lb/in² (172-kPa) increments.

Note: A 5-minute interval between readings is sufficient time to allow expansion of the system to stabilize.

(7) Compute the difference between the volume tube and the electronic readings.

(8) Plot the lateral pressure readings versus the difference between the volume tube and electronic reading (fig. 8).

(9) Draw or compute a best-fit line from the origin through the data points.

(10) Compute the slope of the line (fig. 8).

g. Enter the value of the slope into the memory of the computer in the following sequence:

(1) Press and hold the shift button on the computer, then press the Cf button and release the shift button.

(2) The computer displays "System No. for Cf."

(3) Enter the system number and press the continue button.

(4) The computer displays "Value."

(5) Enter the slope of the line and press the continue button. Computer answers "Cf is stored."

h. When the correction factor "Cf" is stored in the computer memory, the program will automatically correct the volume tube readings for any value of lateral pressure; and

i. The difference between visual and electronic readings by the computer due to applied lateral pressure should be checked when a transducer is put into service.

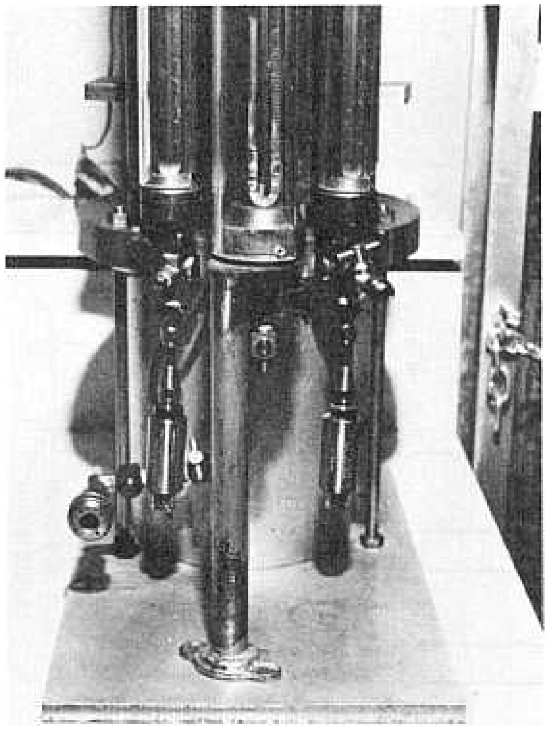

Figure A-1.–Triaxial shear machine prior to installation of the differential pressure transducer. P801-D-80636

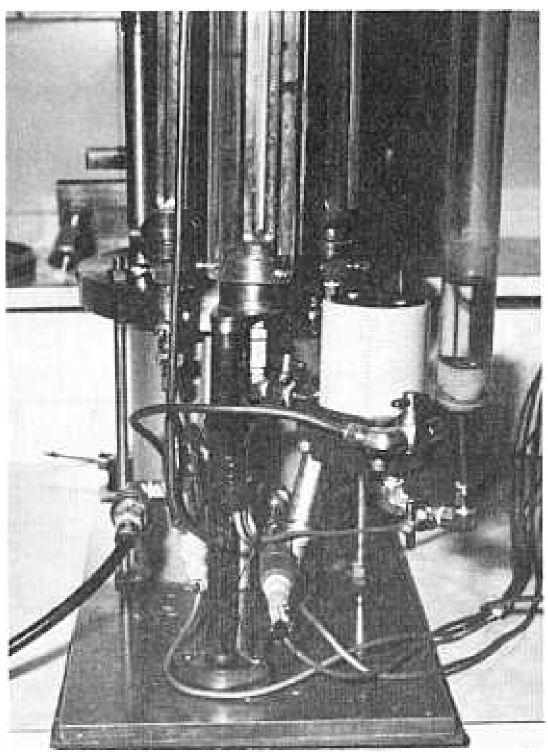

Figure A-2.–Triaxial shear machine after installation of the differential pressure transducer. P801-D-80637

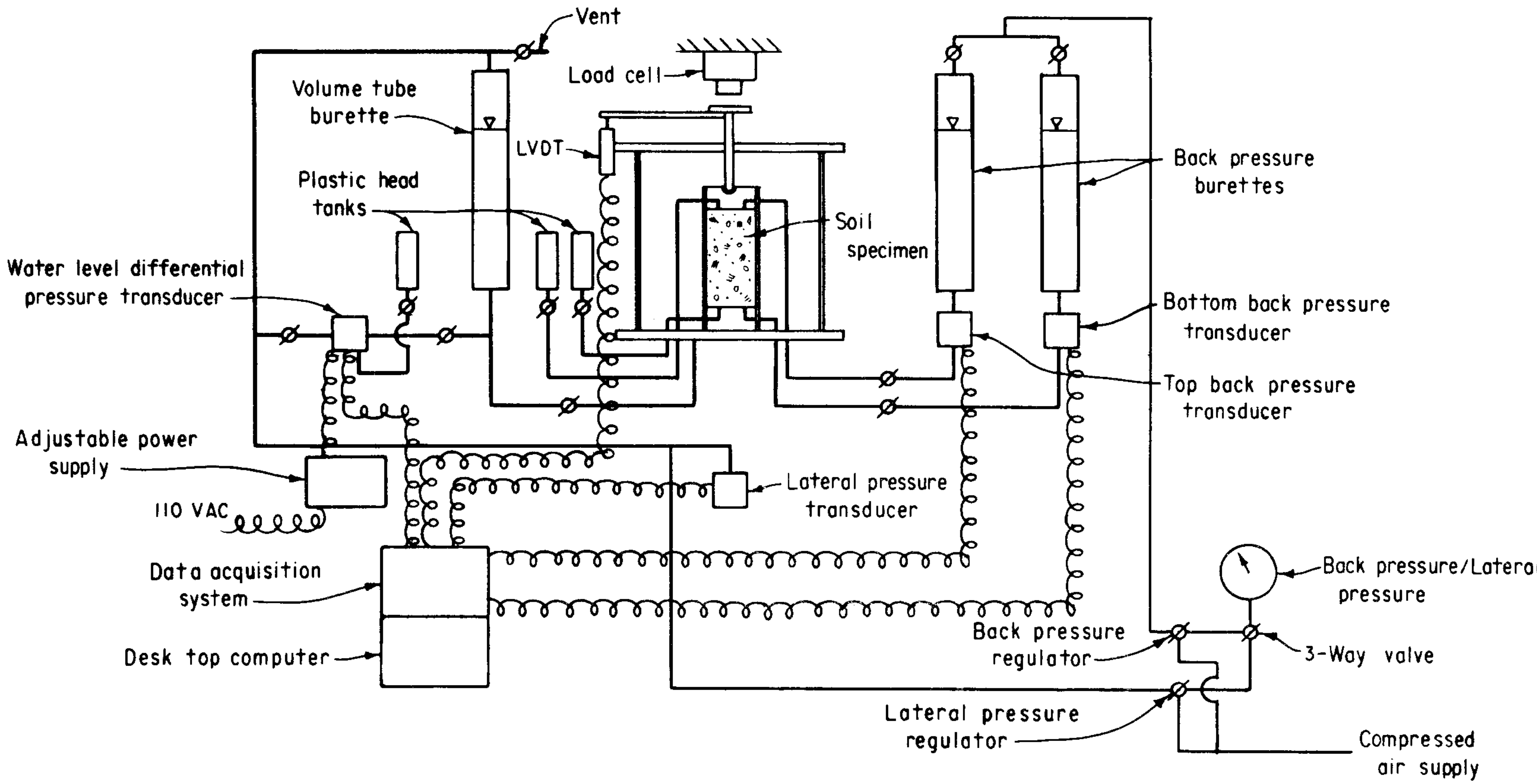

Figure A-3.–Schematic diagram of triaxial shear testing apparatus with differential transducer installed.

GPO 843-431

Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.

A free pamphlet is available from the Bureau entitled "Publications for Sale." It describes some of the technical publications currently available, their cost, and how to order them. The pamphlet can be obtained upon request from the Bureau of Reclamation, Attn D-922, P O Box 25007, Denver Federal Center, Denver CO 80225-0007.