Operation Manual for Modified Geotest Back Pressured Consolidometers A and B

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Introduction

This manual provides a clear, concise set of instructions for the calibration, use and maintenence of the Atlantic Geoscience Centre consolidation/permeability test system. Included are all diagrams, notes for sample preparation and descriptions of the equipment that the operator might wish to have at hand. Units are given in SI throughout and the operator is only expected to be reasonably experienced in consolidation testing in order to successfully produce the high quality results that this system is capable of.

A back pressured consolidometer is a variation of the standard Casagrande-type lever-arm oedometer commonly found in geotechnical labs in private industry as well as universities; its major advantages being that it maintains the sample in a fully saturated state and greatly symplifies permeability testing. Consolidation stresses are applied hydraulically via a sliding bellofram-piston arrangement. Loads up to 512 kPa are accurately applied using a small hydraulic chamber; higher loads to 11 MPa are applied through a larger chamber. Back pressure is maintained at a constant value and is connected to the feedback side of the load regulator; thus flucuations in line pressure to the system do not cause changes in the stress applied to the sample. Sample height change is measured with a strain-gaged displacement transducer wired into a data acquisition system consisting of a mass storage datalogger serial linked to a Compaq XT microcomputer.

The system is designed to apply loads in the traditional incremental manner, each load increment given sufficient time for the sample to fully dissipate the excess pore water pressure created by application of the load. The software that collects incoming data and stores it in files also has the capability of displaying the sample height versus the square root of time on the monitor during the test, thus allowing the opertor to monitor the progress of consolidation. This feature facilitates rapid testing whereby loads are added as soon as 100 percent primary compression has been achieved. As many as two tests can be run simultaneously.

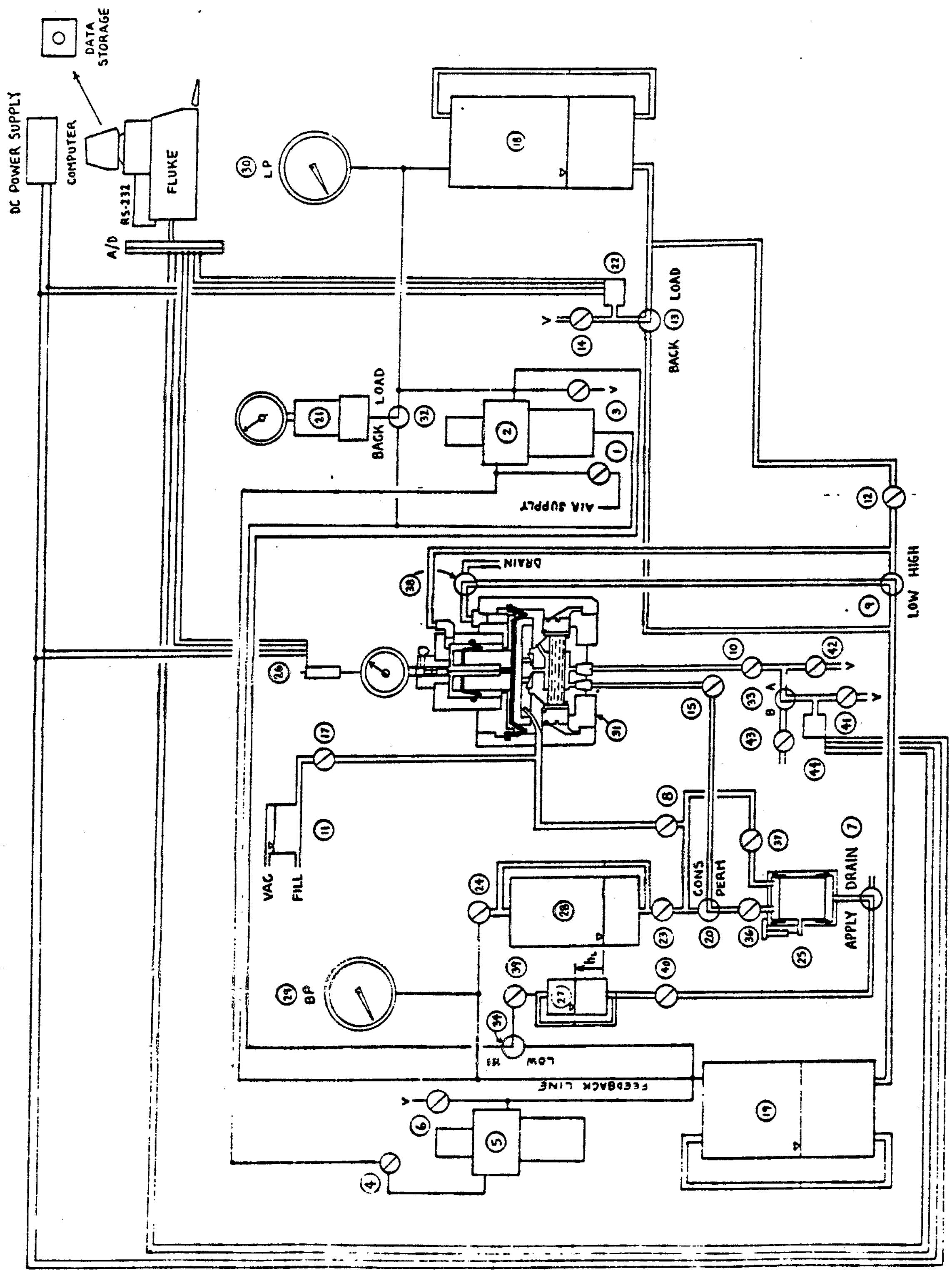
Additional programs are available to assist the operator in plotting the data files, creating the void ratio versus log effective stress curve, calculating the coefficient of permeability, and producing data summary sheets detailing the test results. The actual software programs are not given herein as they are subject to continual upgrading and are device-specific, and are therefore quickly outdated.

System Operation

1. List of Components:

(1) Load Pressure Supply Valve
(2) Load Pressure Regulator
(3) Load Pressure Vent Valve
(4) Back Pressure Supply Valve
(5) Back Pressure Regulator
(6) Back Pressure Vent Valve
(7) Permeability Transducer Deair Valve
(8) Top Saturation Equalizer Valve
(9) Load Range Selector Valve
(10) Bottom Saturation Valve
(11) Nold Deaireator
(12) Terminal Valve
(13) Pressure Transducer Selector Valve
(14) Pressure Transducer Deair Valve
(15) Bottom Saturation Equalizer Valve
(17) Top Saturation Valve
(18) High Load Pressure Reservoir
(19) Low Load Pressure Reservoir
(20) Permeability
(21) Load pressure Cartridge and Dial Indicator
(22) Pressure Transducer
(23) Bottom Saturation Reservoir Valve
(24) Top Saturation Reservoir Valve
(25) Permeability Transducer
(26) DCDT and Strain Indicator Dial Assembly
(27) Permeability Head Reservoir
(28) Saturation Water Reservoir
(29) Back Pressure Test Gauge
(30) Load Pressure Test Gauge
(31) Loading Dome
(32) Pressure Cartridge Selector Valve
(33) Pore Pressure Transducer Selector Valve
(34) Permeability Gradient Selector Valve
(36) Permeability Transducer Control Valve
(37) Permeability Transducer Bypass Valve
(38) Low Load Terminal Valve
(39) Top Permeability Reservoir Valve
(40) Bottom Permeability Reservoir Valve
(41) Pore Pressure Transducer Deair Valve
(42) Pore Pressure Deair Valve for System A
(43) Pore Pressure Deair Valve for System B
(44) Pore Pressure Transducer

System diagram illustrating overall layout:



AFTER GEOTEST INSTRUMENT CORP.

SCALE NONE
DATE 2.23.89
DRAWN BY MAC
REVISED MAC

~ MODEL S3200 ~

BACK PRESSURE CONSOLIDOMETER

DRAWING NUMBER 89-1

2. Filling Load Pressure Circuit with Fluid:

1. Connect a length of tubing from deairaetor to Valve 14.

2. Turn valve 13 to **LOAD.**

3. Turn valve 9 to **HIGH.**

4. Turn valve 12 to **OPEN.** Valve (38) is closed.

5. Open valve 3.

6. Open valve 14.

Water flows into the High Load Reservoir (18). Turn 14 off when reservoir is half full. Deair the pressure transducer (22) by turning (13) to midway position, open (14) and tilt control panel to remove trapped air. Close (14) and return (13) to **LOAD.** Application of a small load pressure is now needed to fill the loading chambers in the loading dome (31).

7. Close valve (4).

8. Close valve (1).

9. Close valve (3).

10. Turn valve (32) to **LOAD.**

11. Set Load Regulator (2) to minimum output (fully out).

12. Turn on air pressure supply on wall to maximum output.

13. Close valve (12).

14. Open valve (1).

15. Set Load Regulator (2) to 5 psi.

16. Open valves (12),(13) slowly until loading piston comes to a stop against stop inside the loading dome. Close (12) and (38).

17. Reduce Load Regulator (2) output to minimum.

18. Close valve (1) open valve (3).

19. Open valves (12) and (38).

20. Push loading piston into dome on stand until there is no movement. Close valves (12) and (38).

21. If more water is needed in the system (if the Load Reservoir (18) is less than half full), begin at No. 2 and redo entire sequence until both load chambers are fully deaired.

Water can be traded between the High and Low Load Reservoir if necessary. This can inadvertantly occur during the actual test, depending on the maximum stress applied and the number of unloading stresses. At the start of each test, ensure that the levels in the reservoirs (18) and (19) are about equal and they are half full. Valve (12) must be closed as water is forced into loading dome and then allowed to fill the reservoirs to the appropriate levels.

22. Turn (13) to **BACK**.

23. Turn (9) to **LOW**.

24. Open (14) until Back Pressure Reservoir (19) is half full.

25. Close (14). Now apply a small pressure to deair valve (9).

26. Close valve (6).

27. Set Back Pressure Regulator (5) to minimum.

28. Open valve (1).

29. Open valve (4).

30. Set Back Pressure Regulator output to 5 psi. Reduce to minimum.

31. Close valve (4).

32. Open valve (6).

Add water if necessary (repeat Nos. 22 to 25) until Back Pressure Reservoir (19) is half full. You will now need to deair the small loading chamber; leave Back Pressure on Large Load Chamber; but at minimum. The following sequence must be followed to deair the tubing and the chambers inside the loading dome.

33. Close (6).

34. Open (4).

35. Set Load Regulator (2) to 5 psi.

36. Open valves (12) and (38).

37. Reduce Load Regulator (2) output to minimum (2 psi).

38. Open valve (3).

39. Push loading piston into dome while on stand.

40. Close valves (12) and (38).

41. Close valve (1).

42. Open valve (6).

The loading chambers are now deaired and you are ready to proceed.

3. Sample Preparation and Installation:

Make sure you have the following equipment nearby:

1. 2 filter papers cut slightly smaller (Whatman No. 50).
2. Stainless steel ring with teflon insert.
3. Aluminum trimming spacer block for 3/4 in. high sample.
4. Stainless steel centering adapter ring.
5. Top saturation nylon pedestal.
6. Nylon extrusion piston.
7. Two black part-spherical spacers.
8. Spray silicon and silicon grease.
9. Wire saw.
10. Kem-wipes.
11. Penknife or something to remove wax from sample.
12. Deaired bronze stones.
13. Data entry sheets.
14. Tared water content tins (one per sample).
15. Specimen.
16. Small spatulas for removing caps from core samples.

Be sure not to confuse either the big steel rings or the top pedestal blocks between Systems A and B; they are slightly different sizes.

1. Check that the loading piston is fully retracted within the dome.

2. Place porous stone into base receptacle.

3. Top porous stone should be mounted in top nylon pedestal and kept immersed in water once it is deaired.

4. Grease base; cover aluminum outer base and stainless steel base with O-ring to prevent corrosion.

5. Grease the teflon liner in the oedometer ring. Place onto base pedestal. Insert stainless steel centering adapter ring into receptacle in top of oedometer ring.

6. Record initial sample information on data sheet (tin no., tare wt., ring diameter).

Table 1. Ring inside diameters (sample diameters).

System	A	B	Liner
I.D.	6.250 cm	6.240 cm	Teflon
I.D.	6.200 cm	6.215 cm	Steel

7. On System A, turn valve (16) to **OPEN**; on System B, open valve (16).

8. Deair a quantity of tap water in the deairaetor. Ensure that the Deairaetor Vent and Supply valves are both closed and the aspirator pump is creating a good vacuum.

9. Remove the wax from around the sample. Open the sample.

10. Spray the top and bottom of the aluminum spacer block. Push the short shoulder on the aluminum trimming spacer block into the worst face of the sample in the thin-walled ring so that the sample is extruded and can be trimmed off with a wire saw. Save the trimmings for index property testing. Cover cut face of sample with a filter paper.

11. Remove the trimming block with a twisting action to break the cohesion. Spray the other side of the block with silicon and push it into the sample from the freshly cut side. Extrude enough sample for a water content determination. Record the weight on the data sheet. Extrude the rest and trim off the excess. Cover the cut face with the other filter paper. The sample is now trimmed to be approximately 3/4 inch high.

12. Remove the push block and weigh the sample; record the weight in the space on the data sheet for **"sample + ring wt."**

13. Make sure valve (16) is open. Take the large nylon push block with a hole through the centre and place it into the thin-walled ring against the sample. Place the ring into the centering adapter ring on top of the oedometer ring. Push the push block and the sample down into the oedometer ring until it stops. Close valve 16. Remove the centering adapter ring. Place nylon top pedestal block on top of sample. Place two black part-sperical spacers into recess on top of nylon pedestal. Ensure that the piston is fully retracted inside the loading dome and valves (12) and (38) are closed. Turn valve (35) to **DRAIN** to allow air to escape while the dome is attached. Place the loading dome onto the base, then rotate it to engage the bayonet locks.

4. Application of Contact Load:

1. Ensure that valve (35) is still on **DRAIN**. Turn valve (9) to **LOW**. Open valve (1) several turns. Load Regulator (2) is at minimum output. For System A, open Load Vent Valve (3) to prevent pressure buildup. This is not necessary for System B.

2. Open valve (3). Open valves (12) and (38) to allow loading piston inside dome to move. Increase Load Regulator (2) output until the axial strain dial gauge (26) on top of the loading dome shows a lowering of the piston. As the dial gauge reading approaches the contact point for a 3/4 inch high specimen, reduce the Load Regulator output. Suck air out of the loading dome from the free end of the tubing attached to valve (35) until the axial dial gauge stops moving. Hold the vacuum until you can shut valves (12) and (38). The sample is now

seated by the piston and saturation can begin. Close valves (1) and (3).

Table 2. Contact dial guage readings.

System	A	B
Dial Guage Reading at Contact	998	703

5. Saturation and Back Pressuring:

1. The sample will not be allowed to swell as it is saturated and back pressured since the valves which permit the load piston to move (12, 38) are closed. Determination of swelling pressure is optional and is covered in a later section. If the sample is prevented from swelling, it will swell under the first few load increments until its swell pressure has been reached.

2. System B only: Filling the permeability burette.

    1. Open valves (6), (15), (16), and (17). Open valve (33), turn (34) to **ON**, and fill the burette to the bottom of the graduations. Close valve (33) and turn (34) to **OFF**.

3. Check the position of the following valves:

    1. (3),(6),(12),(15),(16),(17), and (38) are closed.

    2. (9) is on **LOW**, (15) is open, turn (35) to **FILL**.

    3. System A (20) is on CONS, (37) is closed; System B (33) is closed, (34) is **OFF**.

    4. Turn (9) to **HIGH** for application of back pressure throughout the system.

    5. Deair some water in the deairaetor. The water level should be 1/2 inch down from the top of the steel rods inside the deairaetor for proper deairing. Vent deairaetor to atmosperic pressure; open deairaetor **DRAIN** valve.

4. Introduce water into cell:

   1. Ensure valves (8) and (23) are open on System A; valve (8) on System B is open.

   2. Open valves (6) and (17). Water will first fill the cell chamber, then the back pressure reservoir (19). When level reaches the halfway point in (19) (System A); the 2/3 level (System B), close valve (17). The dial gauge (26) will move somewhat as the dome tightens on the base. The piston remains in contact with the sample, however.

   3. Open valves (1) and (4). (3) and (6) remain closed from now on. Increase the Back Pressure Regulator (5) output to about 2 psi. Turn (13) to **BACK**. Monitor the Back Pressure on the Fluke datalogger {**MONITOR C11**} gives System A and {**MONITOR C12**} shows System B.

   4. Open valve (16) and catch the water in a beaker until air bubbles stop; close valve (16). Turn Pore Pressure Selector valve (33) to **System A** to deair the pressure transducer. Briefly open valve (42) to deair the tubing, then close. Follow a similar procedure for valve (43) if System B is to used.

5. Back Pressure the sample:

   1. Open valve (39) on System A.

   2. Increase the Back Pressure Regulator output (5) until the desired back pressure is achieved. Allow sufficient time between increases for the back pressure to become effective throughout the sample (5 minutes for each 25 kPa). The final back pressure should be left on for 72 hours before proceeding unless you are sure that the sample is fully saturated.

   3. Once the final back pressure is reached, turn valve (13) to **LOAD** in preparation for loading the sample.

6. Determination of Swell Pressure:

1. Turn valve (9) to **LOW** and valve (32) to **LOAD**. Turn valve (13) to **LOAD** and monitor Load Pressure on CH 11 (System A) or CH 12 (System B).

2. Open valve (12) slightly and note the direction of dial gauge movement. If the axial dial gauge pointer (26) moves in a counter-clockwise direction, then the sample is compressing; conversely if the pointer moves clockwise, then the sample is swelling.

3. To prevent the sample from swelling, increase the Load Pressure Regulator (2) output until the axial dial gauge pointer stops increasing. Ideally, this should be done so as to prevent any change in sample height from the initial value established after back pressuring.

4. Continue opening valve (12) and increasing the Load Pressure until the sample has maintained the same dial gauge reading for 30 minutes. Further application of load pressure then causes the sample to begin to consolidate. Close valve (12) and record the Load Pressure by monitoring CH 11 (System A) or CH 12 (System B). To determine the swell pressure in kPa, refer to the equation given in Appendix B, Section 1.

7. Incremental Loading:

1. Use **Low** Load Range for 0 <= SIGMAV' ON SAMPLE <= 500 kPa and **High** Load Range for SIGMAV' > 500 kPa. Before turning valve (9) to **HIGH** at any time, be sure to reduce the Load Regulator (2) output to the new value according to the loading schedule to avoid sudden shock to the sample.

2. Close valves (12) and (38) and select appropriate load range with valve (9), observing the preceeding caution. Use the loading schedule below to select the Load Pressure for the desired SIGMAV' on the sample. Add the back pressure to that Load Pressure to get the total Load Pressure and set the Load Regulator (2) to that total Load Pressure.

3. Make sure that the Fluke datalogger is not scanning or monitoring and that the ABC Swithbox is set to **A - FLUKE**.

Initiate the program called "FLUKECOM" on the computer as follows:

```
CONSOLID> flukecom
```

Select the number of test systems in use. Enter the two digit code number for each system (tests are numbered consecutively from 1 to 99). This code number is used as the basis for defining file names within the software. If this is a new test (ie. this is the first load increment), enter the initial setup data. It is critical that certain data be entered for the first load increment:

> Dial Gauge Reading at Start (div.) = ? (usually about 998 div. for System A and 703 div. for System B).

Note that due to sample preparation variability and dome expansion during back pressuring, the Dial Guage Reading may differ from that during sample installation.

> Initial DCDT Output (mm) = ? **{MONITOR C17}** for System A or **{MONITOR C18}** on System B).
>
> Stress Increment (kPa) = ? (necessary for proper creation of filenames).

4. Monitor Load Pressure on the Fluke (valve 13 must be on LOAD) ie. **{MONITOR C11}** or **{MONITOR C12}**. Set the Load Pressure with the Load Pressure Regulator (2) according to the loading schedule given in Appendix A. When the desired Load Pressure has been set, turn off Monitor ie. **{MONITOR}** on the Fluke (if you don't do this, the program will crash when it sets up communications with the Fluke).

   Note: If you running an unload increment, you will need to tell the program so at the appropriate time.

5. Follow the instructions on the screen. Press **{SCAN}** on Fluke when requested, wait for **END OF SCAN** message, turn valves (12) and (38) on simultaneously on System A (and B if you are running two samples). Wait for one or two scans, then request a graph to see if the computer program is aquiring data from the Fluke. If no data shows on the plot, end the increment by pressing **{e}** on the keyboard of the computer, turn off **{SCAN}** on the Fluke,

and close valves (12) and (38). Rerun the increment from scratch as before.

6. To end a load increment, press **{e}** on the computer and turn off **{SCAN}** on the Fluke. Close valves (12) and (38) on System A (and B if it was in use).

7. For another load increment, begin again at (1) and follow the same routine.

8. Permeability Measurement:

Permeability testing can be performed only if the sample is fully saturated and has been consolidated to some known stress level. The sample height is obtained from the compression data and involves a simple calculation, knowing the initial sample height after back pressuring.

$$H = H_i - dH$$

This allows the void ratio to be determined prior to the end of the consolidation test; however, it requires that the operator perform the calculations outlined on the data sheet which are normally performed by the program called PARAM.BAS.

It is necessary to determine the sample height accurately for Constant Head Permeability testing since the flow velocity data are plotted against the applied hydraulic gradients; a linear correlation passing through the origin confirms the existence of laminar flow by Darcy's Law and ensures that an accurate measurement of permeability has been made. Thus it can be seen that it takes a minimum of three series of flow measurements at different hydraulic gradients to achieve this correlation. The magnitude of the head difference applied across the sample is at the discretion of the operator. Naturally there is a trade-off between the size of the head diference applied and the time required to generate a measureable flow.

Measurements made a low hydraulic gradients can be very time-consuming in the case of clays and it is advisable in those cases to apply gradients in excess of 10 to ensure that environmental temperature flucuations do not seriously affect the flow data. In the case of impermeable smectitic clays, gradients as high as several hundred may have to be employed to initiate flow. However, flow at high gradients can be unstable since clay particles may be induced to move through the pore spaces out of the sample and will eventually clog the porous stones at the sample boundaries. For this reason, Whatman No. 54 filter papers should always be employed to minimize piping of fines in long-duration tests. The filter papers have a negligable impeding effect on the flow velocity since they are many orders of magnitude more permeable then the sample itself.

1. Close valves (12) and (38) for the permeability test to ensure that all volume changes are halted. Open valve (15) if it closed. Allow 1 hour for delayed consolidation to come to an end. Ensure that valve (40) is open.

2. Check the Back Pressure on the Fluke. Head differences applied to the sample must take the back pressure into account. Turn valve (13) to **LOAD**.

3. Note the sample height (H) on CH 17 (System A) or CH 18 (System B). Use this value to calculate the present void ratio according to the following formulae:

$$e = e_i - \frac{(H_i - H)}{H_s}$$

4. Compute the head difference (h_l) required for the desired hydraulic gradient (i) according to:

$$h_w = (H)(i)$$

5. For head differences in excess of 120 cm, proceed directly to step 6. Raise the Permeability Load Reservoir (27) to deliver the calcualated head difference which is equivalent to an equal column of water of height h_l. Ensure that the Permeability Gradient Valve (34) is on **LOW**.

6. This procedure is for use when H_l exceeds 120 cm. Turn valve (34) to **HIGH**. Set the Load Regulator output (2) to the required pressure determined from the following equation:

$$h_p = (h_l/100\ \text{cm/m})(9.81\ \text{kN/m}^3) + \text{Back Pressure}$$

Set the meniscus in the Permeability Head Reservoir (27) to the same height as that in the Saturation Reservoir (28).

7. Turn Selector Valve (20) to **PERM.** Ensure that valves (39) and (40) are open; (8) and (23) should be open. Valve (37) is closed. Valve (7) is on **APPLY.**

8. Open valve (36) to apply the head difference to the sample. After several minutes, begin recording readings of elasped time and volume change in the Volume Change Transducer (25). It is useful to set the time interval on the Fluke and enable **SCAN GROUP 1** on the Fluke; **SCAN GROUP 0** should be disabled for the duration of the permeability test. The **OUTPUT DEVICE MENU** should be reprogrammed to turn off ouput to **PORT B** and send it instead to the **PRINTER.** When **{SCAN}** is pressed, the Fluke will automatically record the required transducer readings and elapsed time on the printer tape.

9. Plot the volume change **versus total** elapsed time. If the rate of volume change has become stable, press **{SCAN} to turn off the Fluke;** valve (36) can be closed and you can proceed to apply a different hydraulic gradient. If no more gradients are required and you wish to perform another consolidation stage, follow the instructions in step 10.

10. Close valve (36) and turn valve (20) to **CONS.** Disable **SCAN GROUP 1** and enable **SCAN GROUP 0** on the Fluke; also be sure to reprogram the **OUTPUT DEVICE MENU** to enable **PORT B** and disable the **PRINTER.** Check the the ABC switch is set to **FLUKE.**

Correction of the coefficient of permeability to account for variation between the in situ permeant viscosity and that existing in the laboratory is commonly applied after all data has been reduced to final permeability form. Individual corrections should be made therefore for each flow measurement, but only to the permeability value itself. This speeds the process considerably as the operator only needs to establish that laminar flow exists within the sample before an average permeability can be calculated for a given hydraulic gradient.

Values of the coefficient of permeability determined in this manner will hardly ever agree with those calculated from the time-compression data since one-dimensional consolidation theory makes some rather gross assumptions regarding the nature of k during any given strain increment; namely Terzaghi theory assumes that *k* does not vary with the degree of consolidation. The difference is normally an order of magnitude.

9. Dismantling of Sample:

1. Close valves (12) and (38). Monitor CH 11 or CH 12 and check that valve (13) is on **LOAD**. Open valves (12) and (38). Reduce the Load Pressure (2) output until the axial dial gauge pointer (26) has completed one full revolution. Close (12) and (38). This procedure removes all vertical stress from the sample and allows the operator to take the cell apart. Reduce the Load Regulator output (2) to minimum.

2. Turn valve (13) to **BACK**. Monitor the Back Pressure on CH 11 or CH 12. Reduce the Back Pressure Regulator (5) output to 150 kPa.

3. Place a 1 litre beaker under the drainage tubing connected to valve (38). Turn valve (38) to **DRAIN** until all of the water has been forced from the system. Turn valve (38) to **APPLY**. Place the beaker under the outlet from valve (42 - SYS A; 43 - SYS B) and open it until water is purged from the base of the cell. Close valve (42 or 43).

4. Reduce Back Pressure to minimum. Close valves (1) and open valves (3) and (6) to vent the air pressure from the system. Leave (3) and (6) open while the equipment is not being used to prevent pressure buildup.

5. Turn valve (38) to **DRAIN** to vent dome. Close valve (42 or 43). Rotate the dome free of the bayonet locks. Using two large screwdrivers inserted into the groove in the stainless steel oedometer ring, pry up on the dome to break the seal on the O-ring inside. The dome can be removed and placed on its pedestal.

6. Dab up excess water and note the color of the water. If it is very cloudy or if there is much sediment extruded from around the top of the sample, note that on the data sheet. (The final dry weight of the sample will then be underestimated; therefore the calculated dry weight should be used in place of the measured value to back-calculate the initial void ratio.) Remove the black part-spherical spacers but leave the top block inside the ring. Open valve (42 or 43) to vent the bottom of the sample and remove the ring with the sample from the base pedestal.

7. Use the top block to push the sample out of the ring and place it in a tared tin. Weigh it and record the data on the data sheet under the "Final Water Content" area. Dry the sample in the oven and record the oven-dried weight.

8. Push the loading platen into the dome as outlined in Section 2, taking care that the final water levels in the High and Low Load Reservoirs are about the same (see the Note in Section 2 about trading water between reservoirs).

9. Clean all surfaces and apply a light coat of silicon grease to prevent salt deposits. Clean porous stones and place top blocks under water. Do not mix up the stones between System A and B since their thicknesses are individually calibrated and are referenced to when determining the initial sample height.

10. Calibration Procedures:

It is generally not required to calibrate the load chambers as the stresses on the sample are determined from the effective bellofram seal area. It is important to note that the two Systems may with continued use suffer deterioration of the rolling bellofram. A useful check on the condition of the bellofram is to check how much load pressure is required to overcome the rolling friction in the bellofram. This offset must be subtracted from the effective load pressure in order to obtain the actual effective load pressure acting over the seal area. This is illustrated in Appendix B.

Also, from time to time, it will be necessary to replace the teflon liners in the stainless steel oedometer rings due to wear. Their diameters are recorded in the software as 6.25 and 6.24 cm for System A and System B, respectively.

Periodically, the axial displacement transducers (DCDTs) should be recalibrated to ensure that they have not drifted. After this has been done, the new calibration factor must be entered into the signal conditioning software on the Fluke (see CH 17 and 18). Similarly, the pressure transducers require periodic recalibration; their calibration factors are found under CH 11 and 12.

The permeability transducer should be recalibrated by causing a volume change to occur with the Shape DCDT in place. Its calibration factor is found on CH 16.

11. Analysis of Results:

Software has been written to facilitate the reduction of the raw time-compression datafiles stored in the **\CONS** directory. Programs are available to plot the datafiles, to calculate all test variables, to create the void ratio versus effective stress files, to plot the e-log P' curve along with the coefficients of consolidation and secondary compression versus effective stress, and finally to produce a summary table of the consolidation test results. They are described in this section. No software has been written to automatically determine the sample heights at the end of primary consolidation; this is left to the judgement of the operator.

1. Aquisition of time-compression data:

The program which collects the raw transducer readings, displays a real-time graph of sample height versus the square root of time on the screen, and also creates the time-compression datafiles is invoked by checking that the computer is connected to the ABC switch box via an RS232C cable (no null modem) and that the ABC switch is turned to **FLUKE**. The operator then types the following commands on the keyboard:

```
>CD\CONS
CONS>FLUKECOM
```

The program asks how many systems are to be operated (System A or B or both). Next, the operator is prompted for the test I.D. number (1 to 99). This I.D. is used to create a datafile for this stress increment of the form **ID.DAT**. Sample heights are stored in this file. The program automatically adds a letter **A** or **B** after the test I.D. to differentiate between datafiles for Systems A and B.

Then the operator is prompted for some key information. If this is the first in a series of stress increments for a given sample, some initial information is required before the program asks for the stress, date, loading range, load pressure, and whether this is a swell increment and whether the root time axis on the screen should be expanded (for very overconsolidated or impermeable clays).

Before the operator starts a scan on the Fluke and opens valves (12) and (38) on the control panel, they must set the load pressure in the system to the new level. This is explained in more detail in the section on incremental loading; suffice it to say that the load pressure set must always include the back pressure (if any) and **MONITOR** must be turned off before a scan can be initiated. As indicated on the screen, the procedure is to set the load pressure, turn off **MONITOR**, press **{SCAN}** and quickly open valves (12) and (38) to apply the load. This will ensure that the computer receives an initial sample height before the load is applied to the sample and that the time counter is set to zero at the time of the load application.

The operator should wait for one further scan to be completed before a real-time graph is requested. This is done by pressing [G] on the keyboard. If two systems are running simultaneously, the computer asks the operator for which one. Generally, since the Fluke scans every 15 seconds, a graph can only be produced once per scan. Also, since the computer does not record every scan, there will be intervals for which no new data appears on the graph. Once the stress increment is deemed to have reached a satisfactory end-point (usually t_{100}), the operator ends the increment by pressing [E] on the keyboard, turns off **{SCAN}** on the Fluke, and closes valves (12) and (38) on the systems A and\or B in preparation for the next stress increment.

To run another increment, the operator must again run the program from the start as explained above.

2. Plotting time-compression curves:

Each **.DAT** datafile contains the information needed to define the entire load-deformation response for a given increment. This data is best displayed in graph form in two formats: root time and logarithm time versus sample height. To invoke these programs, turn the ABC switch to **PLOTTER**, turn the plotter on, load the paper, and type

CONS>**SQPLOT** for root time plots

or type

CONS>**LOGPLOT** for log time plots.

The computer will then ask for a filename, you enter:

Enter Test I.D. : **IDSYSSTRESS** ie. "**99A1024**"

The computer determines the endpoints of the graph axes and gives you the option of changing them. The graph will then be plotted.

3. Analysis of time-compression graphs:

Talyor's root time curve-fitting technique is used generally to define the end-of-primary sample heights; however the user can substitute those determined from the Schmerttman log time method if they desire.

The operator determines the following parameters for each graph:

H_{100} (mm) the sample height after 100 % consolidation

t_{90} (min) time at 90 % consolidation (root time graphs only)

t_{50} (min) time at 50 % consolidation (log time only)

C_{α} (%) coefficient of secondary compression (log time only)

4. Creation of test variable datafiles:

A program called PARAM allows the user to create a datafile which is accessed later by other programs; this datafile contains key information such as initial sample parameters, sample information, etc. It is invoked by typing

```
CONS>PARAM
```

The program will not be discussed in detail here as it is fairly self-explanatory.

5. Creation of void ratio - effective stress datafiles:

The sample heights, consolidation and creep parameters are now entered into a datafile with the help of a program called VOID. Simply type

```
CONS>VOID
```

enter the test I.D., and input the information as requested. The output files created by this program will be used later when plotting the e-log P' curve and creating the summary tables.

6. Entry of measured permeability data:

The program called PERM allows the user to input measured permeability data into a file that will be accessed later on when the final summary report is created. Simply type

```
CONS>PERM
```

and enter the test I.D. when prompted, followed by the actual permeability data.

7. Printing the summary table:

A program called VOIDPRNT creates a table of the stresses applied, the void ratios, the C_v data, calculated as well as any measured permeabilities, and C_α. This report supplements the summary of the index information created earlier. Simply type

```
CONS>VOIDPRNT
```

and enter the test I.D.

8. Plotting the void ratio - effective stress curve:

There is a very useful program called VOIDPLOT that plots all of the consolidation test data in a report-quality final form on the plotter. Again, the plotter must be connected (ABC switch on **PLOTTER**). Then type

```
CONS>VOIDPLOT
```

The computer will ask for the test I.D., after which it will automatically set the axis endpoints and give you the option to change them. You will be prompted to input the exponent at which you would like to see the coefficient of consolidation (C_v) data plotted at; this feature allows you to change the scale of the C_v data so that it fills its plot area. Generally the data covers one to two orders of magnitude, with the initial one or two values being very much larger. This data can be windowed out by selecting the appropriate axis range.

The program then asks you if you would like to revise the axis endpoints, then allows you to add some summary stress history data in the upper right-hand corner of the graph (this is usually ignored except for the final version of the graph). You will then see a beautiful plot of you well-executed test results plotted before your eyes.

Appendix A

Summary of Loading Pressures

Stress on Sample in Oedometer Ring (kPa)	System A Eff. Load Pressure (kPa)	System B Eff. Load Pressure (kPa)	Loading Range
4	13.7	23.7	Low
6	17.0	27.0	Low
8	20.3	30.4	Low
12	27.0	37.1	Low
16	33.7	43.8	Low
24	47.0	57.2	Low
32	60.4	70.6	Low
48	87.0	97.4	Low
64	113.7	124.3	Low
96	167.1	177.9	Low
128	220.5	231.5	Low
192	327.2	338.8	Low
256	434.0	446.1	Low
384	647.5	660.7	Low
512	93.7	95.2	High
768	139.8	141.5	High
1024	185.9	187.8	High
1536	278.1	280.5	High
2048	370.3	373.2	High
3072	554.8	558.5	High
4096	739.2	743.9	High
6144	1108.0	1114.6	High
8192	1476.9	1485.2	High

Important:

1. Stress on sample above includes actual diameter of steel rings for System A and B.
2. The above schedule is meant to serve as a guideline in selecting a load schedule. Other loads are possible.

Appendix B

Calibration Characteristics

1. Load Schedules:

The loading schedule given in Appendix A is derived from the seal area of the rolling bellofram, the pressure offset caused by rolling friction in the belloframs, and the actual sample diameter. A summary of the fundamental data is given below:

$A_{low\ range} = 18.1\ cm^2$
$A_{high\ range} = 167.6\ cm^2$
$A_{sample\ (A)} = 30.17\ cm^2$ (Diameter = 6.200 cm)
$A_{sample\ (B)} = 30.32\ cm^2$ (Diameter = 6.215 cm)
$LP_{0\ low\ A} = 7.0\ kPa$
$LP_{0\ high\ A} = 1.5\ kPa$
$LP_{0\ low\ B} = 17.0\ kPa$
$LP_{0\ high\ B} = 2.5\ kPa$

The formula used to determine the effective load pressure for the Low Load Range in kPa is as follows:

$$\text{Eff. } LP_{low} = \frac{A_{sample}}{A_{low}} \cdot \text{Stress} + LP_{0\ low}$$

Similarly, the formula for the High Load Range is:

$$\text{Eff. } LP_{high} = \frac{A_{sample}}{A_{high}} \cdot \text{Stress} + LP_{0\ high}$$

2. Axial displacement transducers:

The DCDTs are calibrated using the DCDT micrometer with them powered on. The present calibration factors are given below.

System A: Serial No.: 3394-25

CH 17 = 0.3768 x CH 17 [mm]

System B: Serial No.: 3358-25

CH 18 = 0.3746 x CH 18 [mm]

3. Volume change transducer:

A Shape volume change transducer has not yet been installed on System B, therefore permeability volume changes on that system must use the burette system. For System A the calibration is as follows:

System A: Serial No.: 3121-25

CH 16 = CH 16 x 0.69529

4. Pressure transducers:

The Sensotec pressure transducers used in this apparatus have a maximum capacity of 1379 kPa. They have been calibrated and the characteristics are as follows:

System A - Load/Back Press.: Serial No.: 133309

CH 11 = -45.666 x CH 11 - 92.7 [mm]

System B - Load/Back Press.: Serial No.: 133299

CH 12 = 46.064 X CH 12 - 98.0 [mm]

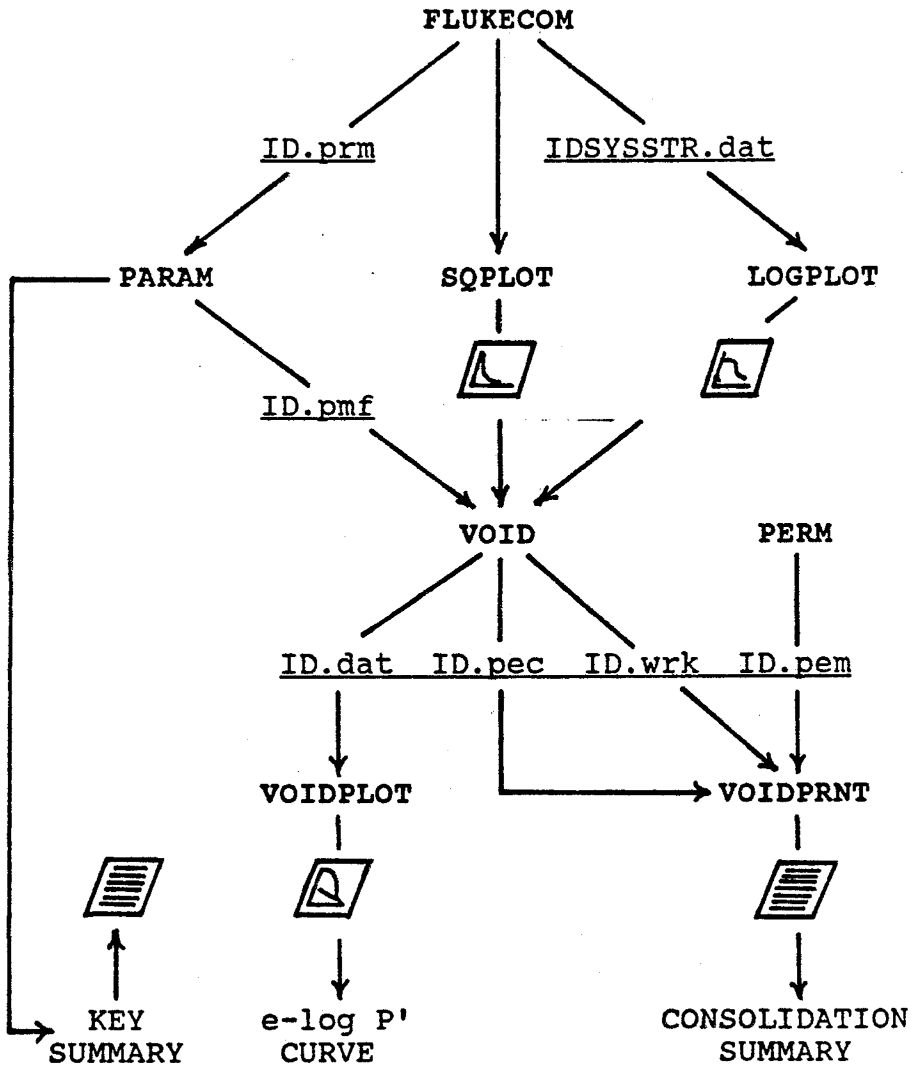
System A/B - Pore Pressure: Serial No.: 135497

CH 13 = 46.361 x CH 13 - 110.1 [mm]

Appendix C

Software Documentation

A flow chart of the various programs is given below along with their respective input and output files. Programs are indicated by boldface type.



Appendix D

Examples of Typical Test Data

```
              Consolidation Test Summary
              --------------------------
                   Test No.     49


Date (DD/MM/YYYY)        : 8/30/1988
Program/Cruise I.D.      : ODP LEG 110
Site and Core I.D.       : SITE 671 B
Depth Below Seabed (m) : 135.52
Sample Description       : Fissured stiff brown Clay ooze.
Sample Condition         : Fissured
Drainage Condition       : DOUBLE
Machine and Sample No. : A - 49
Back Pressure (kPa)      : 300


Water Content (%)              Initial         Final
                             (Trimmings)       Sample
-----------------            -----------       ------

Wt. of Can + Wet Soil (g)  :  52.912          84.237
Wt. of Can + Dry Soil (g)  :  33.764          59.327
Wt. of Can (g)             :  1.516           1.522
Wt. of Water (g)           :  19.148          24.91
Wt. of Dry Solids (g)      :  32.248          57.805
Water Content, no Salt (%) :  59.37733        43.09316
Fluids Content, w. Salt (%):  62.88519        45.36517


Initial Void Ratio Calculation - Sample Data
--------------------------------------------

Specific Gravity          :  2.84      Ring Diameter (cm)     :  6.25
Wt. Ring + Sample (g)     :  130.667   Height of Sample (cm) :  19.4146
Wt. Thin Walled Ring (g):  36.745    Area of Sample (cm2)   :  30.67962
Wet Wt. Cons. Sample (g):  93.922    Vol. of Sample (cm3)   :  59.56325
Dry Wt. Cons. Sample (g):  57.805    Bulk Density (g/cm3)   :  1.576845
Water Cont. no Salt (%) :  62.48076 Sat. Unit Wt. (kn/m3) :  15.46412
Water Cont. w. Salt (%) :  66.24818 Eff. Unit Wt. (kn/m3) :  5.371117

Computed Dry Wt. of Solids, no salt (g)       :  56.49506
Meas. Dry Weight of Solids, with salt (g)    :  57.805
Computed Height of Solids (cm)                :  .6301251
Initial Height of Voids (cm)                  :  1.311335
Initial Degree of Saturation (%)              :  91.68372
Void Ratio at start of test (ei)              :  2.081071
In Situ Void Ratio (eo)                       :  2.052107
Final Void Ratio (ef)                         :  1.405234
```

Consolidation Test Summary

Test No. 49

Load Increment Ratio	1.0	Dial Guage Constant (mm/div)	0.01
Init. Dial Reading (div)	1023	Zero Dial Reading (div)	1238
Init. DCDT Output (mm)	17.3540	Init. Sample Height (mm)	19.4146

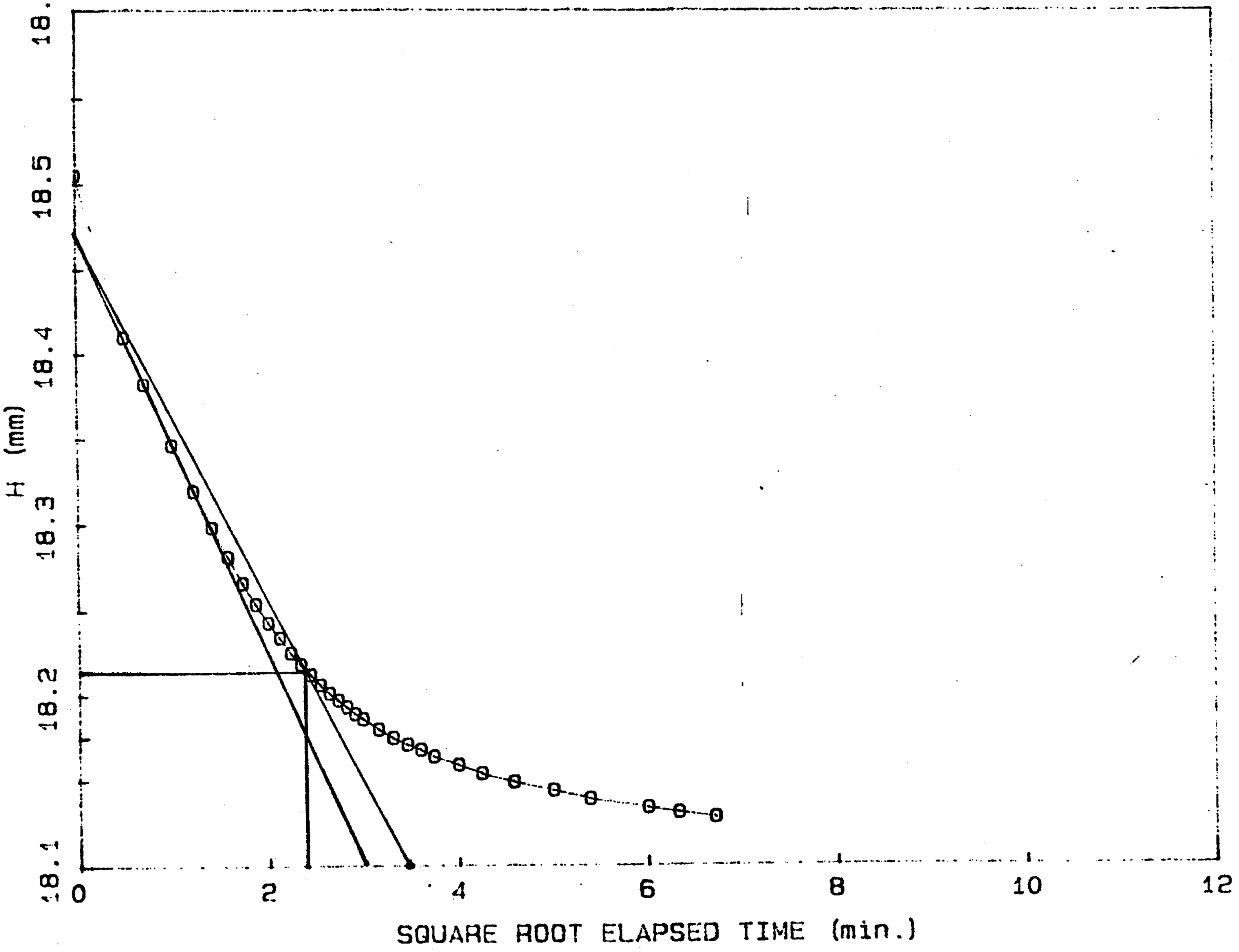
Consol Stress (kPa)	Sample Height (mm)	Void Ratio Change	Void Ratio	Average Height (mm)	t50 (min)	t90 (min)	Log Cv (cm2/s.)	Root Cv (cm2/s.)	Calpha (%)
0	19.4146	0.0000	2.0811	0.0000	0.000	0.000	0.000E+00	0.000E+00	0.00
4	19.3846	0.0048	2.0763	19.3996	0.000	0.462	0.000E+00	0.288E-01	0.00
8	19.2747	0.0222	2.0589	19.3297	0.000	0.689	0.000E+00	0.192E-01	0.00
16	18.8695	0.0865	1.9946	19.0721	0.616	2.335	0.485E-02	0.550E-02	0.71
32	18.6086	0.1279	1.9532	18.7390	0.708	1.082	0.407E-02	0.115E-01	0.70
64	18.1750	0.1967	1.8843	18.3918	1.496	5.760	0.186E-02	0.207E-02	1.03
128	17.6522	0.2797	1.8014	17.9136	1.578	7.182	0.167E-02	0.158E-02	1.44
256	16.9610	0.3894	1.6917	17.3066	1.758	5.760	0.140E-02	0.184E-02	1.97
512	15.9778	0.5454	1.5357	16.4694	1.496	4.666	0.149E-02	0.205E-02	3.32
1024	14.8393	0.7261	1.3550	15.4086	1.640	5.760	0.119E-02	0.146E-02	2.41
2048	13.7294	0.9022	1.1788	14.2843	1.496	4.113	0.112E-02	0.175E-02	3.27
4096	12.2962	1.1297	0.9514	13.0128	1.380	5.125	0.101E-02	0.117E-02	2.90
512	12.6984	1.0659	1.0152	12.4973	0.000	0.000	0.000E+00	0.000E+00	0.00
128	13.2320	0.9812	1.0999	12.9652	0.000	0.000	0.000E+00	0.000E+00	0.00
32	13.7360	0.9012	1.1799	13.4840	0.000	0.000	0.000E+00	0.000E+00	0.00
8	14.4625	0.7859	1.2952	14.0992	0.000	0.000	0.000E+00	0.000E+00	0.00

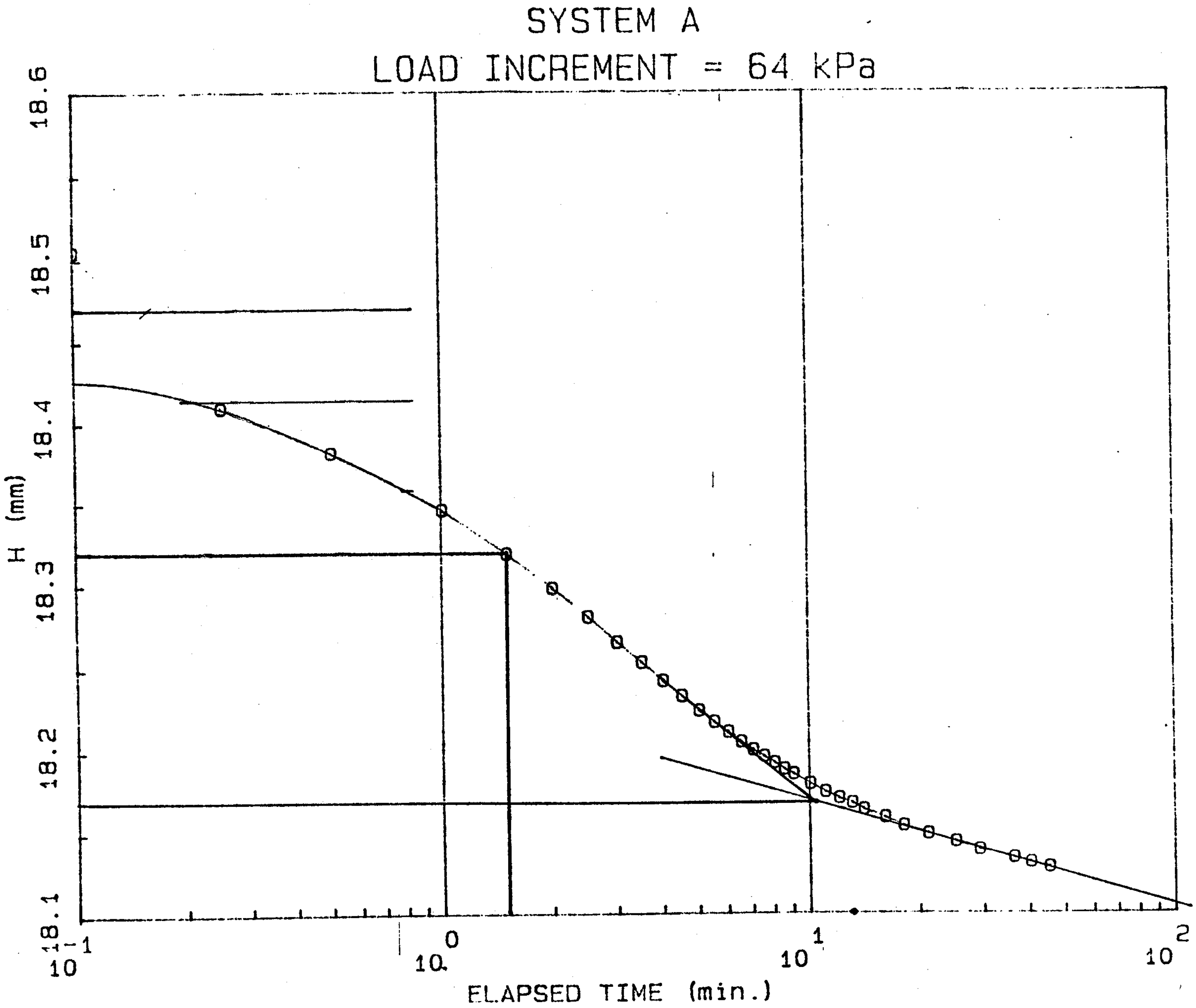
Stress (kPa)	Void Ratio	mv (m2/kN)	Log k (cm/s)	Root k (cm/s)	Work (kJ/m3)
4	2.0763	0.000E+00	0.000E+00	0.000E+00	0.00
8	2.0589	0.141E-02	0.000E+00	0.183E-05	0.04
16	1.9946	0.261E-02	0.853E-06	0.967E-06	0.29
32	1.9532	0.840E-03	0.230E-06	0.651E-06	0.62
64	1.8843	0.699E-03	0.876E-07	0.975E-07	1.69
128	1.8014	0.420E-03	0.473E-07	0.448E-07	4.27
256	1.6917	0.278E-03	0.263E-07	0.345E-07	11.11
512	1.5357	0.198E-03	0.199E-07	0.273E-07	30.56
1024	1.3550	0.115E-03	0.919E-08	0.113E-07	75.59
2048	1.1788	0.558E-04	0.422E-08	0.659E-08	163.40
4096	0.9514	0.360E-04	0.245E-08	0.284E-08	390.16
512	1.0152	0.578E-05	0.000E+00	0.000E+00	342.45
128	1.0999	0.716E-04	0.000E+00	0.000E+00	333.66
32	1.1799	0.270E-03	0.000E+00	0.000E+00	331.58
8	1.2952	0.150E-02	0.000E+00	0.000E+00	370.23

Summary of Measured Permeabilities

VOID RATIO	k (cm/s.)
1.6580	0.552E-07
1.6580	0.425E-07
1.6580	0.404E-07
1.5060	0.162E-07
1.5060	0.179E-07
1.5060	0.228E-07
1.3150	0.633E-08
1.3150	0.838E-08
1.3150	0.964E-08

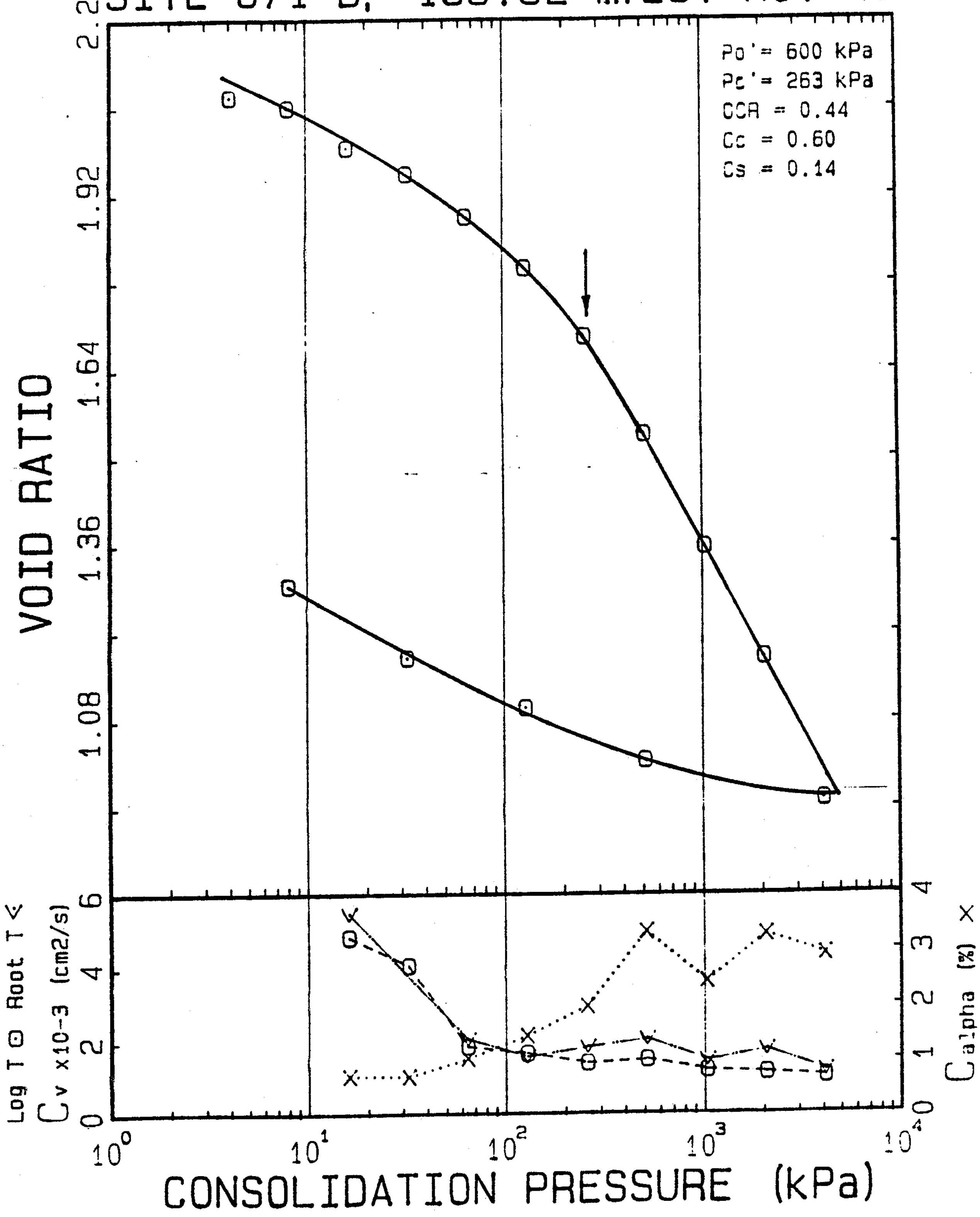
SYSTEM A
LOAD INCREMENT = 64 kPa

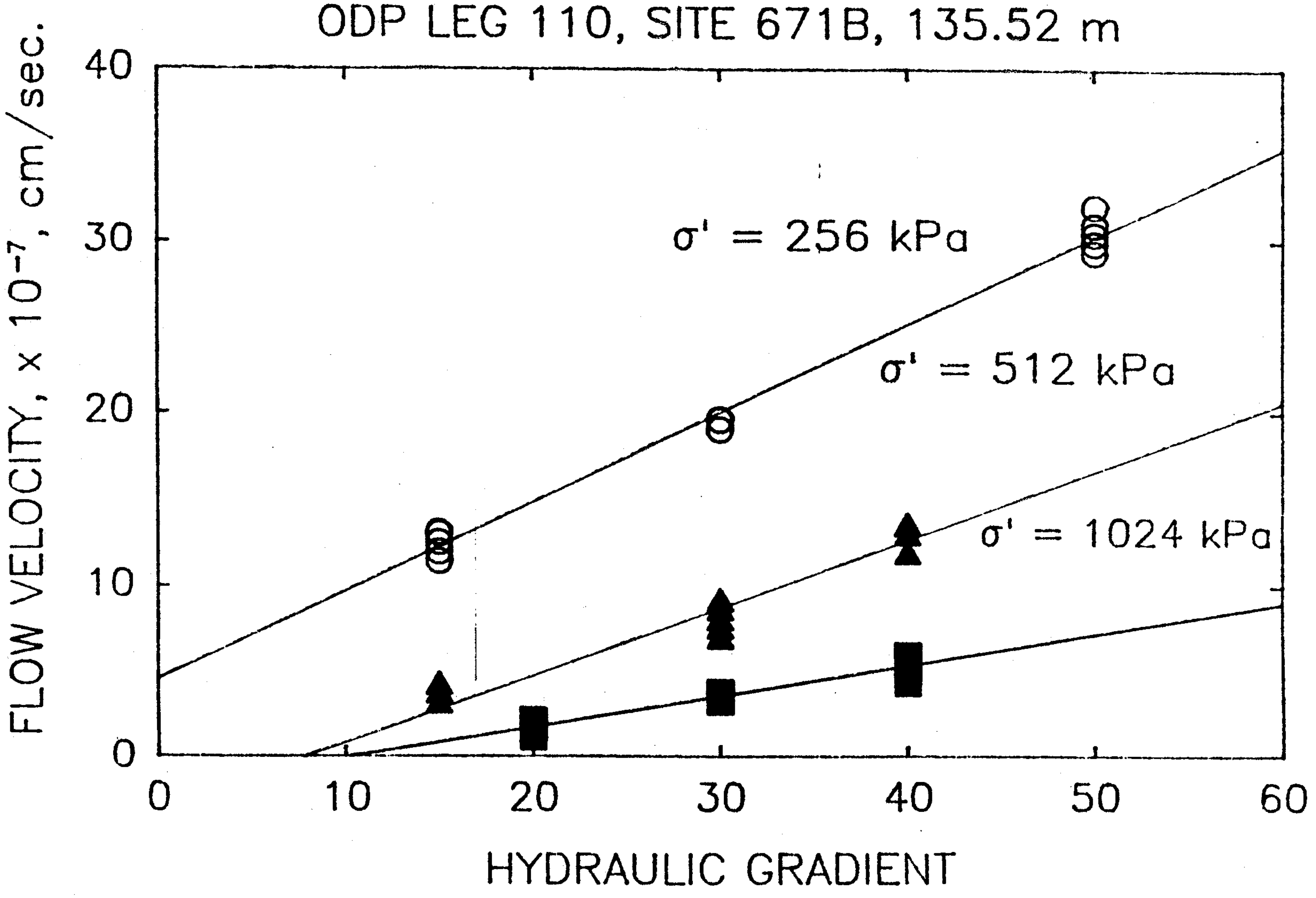


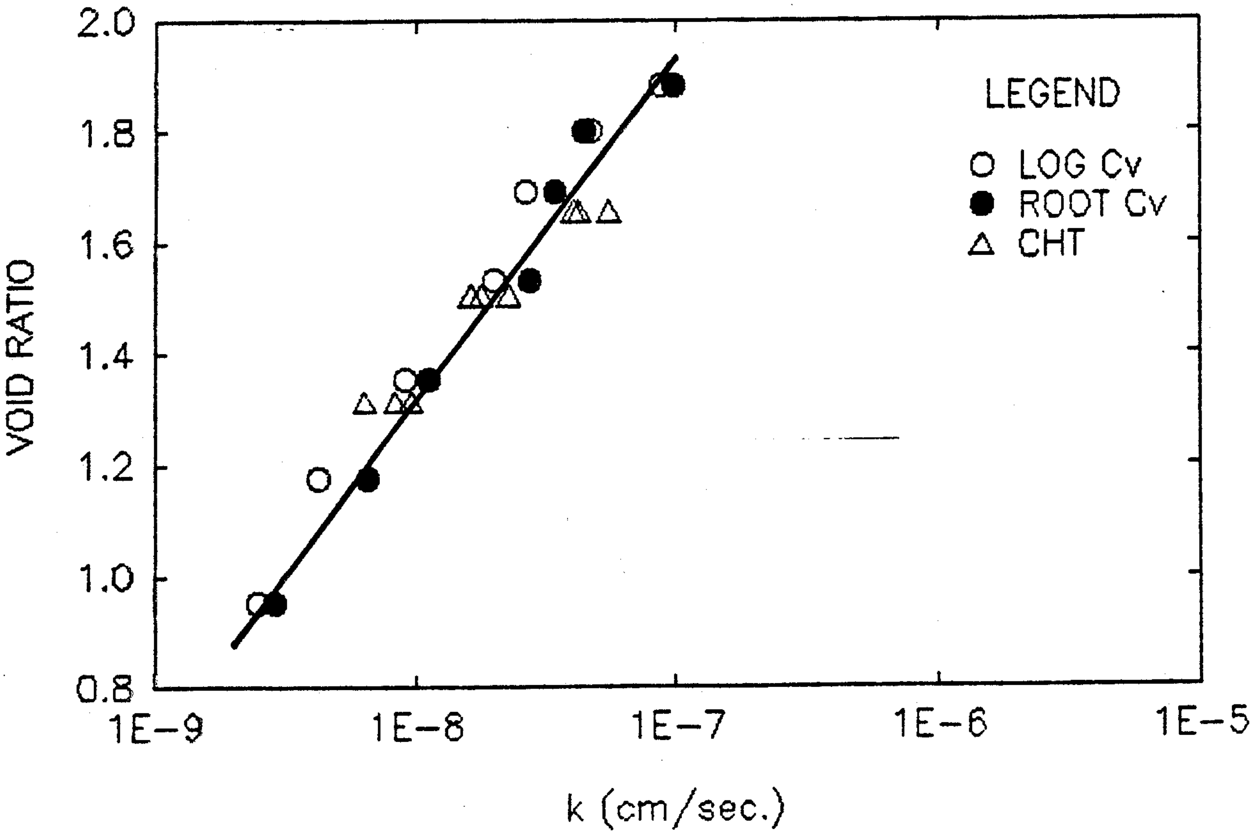

SYSTEM A
LOAD INCREMENT = 64 kPa
H (mm)
18.6
18.5
18.4
18.3
18.2
18.1
10^{-1}
10^{0}
10^{1}
10^{2}
ELAPSED TIME (min.)

ODP LEG 110

SITE 671 B, 135.52 mTEST NO. 49




ODP LEG 110, SITE 671B, 135.52 m
FLOW VELOCITY, x 10^{-7}, cm/sec.
HYDRAULIC GRADIENT
σ' = 256 kPa
σ' = 512 kPa
σ' = 1024 kPa
0
10
20
30
40
0
10
20
30
40
50
60



2.0
1.8
1.6
1.4
1.2
1.0
0.8
VOID RATIO
1E-9
1E-8
1E-7
1E-6
1E-5
k (cm/sec.)
LEGEND
○ LOG Cv
● ROOT Cv
△ CHT

Appendix E

Schematic of Pressure Regulator

(after Geotest manual)

References

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