MANUAL OF VOLUME CHANGE TEST PROCEDURES FOR UNSATURATED SOILS

by

D. G. Fredlund
Department of Civil Engineering
University of Alberta
Edmonton, Alberta

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CONTENTS

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1. INTRODUCTION

Four pieces of equipment were developed at the University of Alberta for the examination of volume change behavior in unsaturated soils. Two employed modified Anteus oedometers for one-dimensional conditions. The other two pieces of equipment allowed isotropic volume change testing conditions in modified, four-inch diameter, Wykeham Farrance triaxial cells. The details of the construction and the calibration of the equipment are presented elsewhere. [1]

The test procedures are discussed from a general standpoint while still being specific about the steps that must be taken. The enormous number of valves and the maze of tubing make it difficult for a person to successfully operate the equipment without making some mistakes. The resulting errors can be time consuming and costly. For this reason, an effort has been made to lay out the valves and tubing, and specify their manipulation in detail. The procedures described for all three types of equipment are:

i) Preparing the equipment and setting up the sample.

ii) Monitoring the diffused air volume.

iii) Changing the total, air and water pressures for a drained process.

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[1] Fredlund, D. G. "Volume Change Behavior of Unsaturated Soil," Ph.D. thesis, University of Alberta, Edmonton, Alberta.

iv) Changing the total and/or air pressures for an undrained process (Reaction tests).

v) Removal of the sample from the apparatus.

The procedures for the above categories are outlined in detail for the modified Anteus oedometers. Then important differences encountered in operating Triaxial Apparatus No.1 and No.2 are described.

2. PREPARING THE EQUIPMENT AND SETTING UP THE SAMPLE FOR THE MODIFIED ANTEUS OEDOMETERS

To the author's knowledge, the Anteus oedometers have not previously been used to independently manipulate the total, air and water pressures. Some information on the operation of the equipment when using water in the chamber, is available in the instruction manual from Testlab Corporation and in the operation manual from the Geotechnical Ocean Engineering Laboratory, Center for Marine and Environmental Studies, Lehigh University (Parker and Miller, 1973).

Let us assume that the equipment is in satisfactory working condition and we desire to perform a volume change test on an unsaturated soil. First, the volume change measuring devices are initialized and the initial pressures are set. We can now place the sample in the oedometer and proceed with the test.

Figure 1 shows a layout of the entire apparatus with the valves labelled. The letter associated with each designation

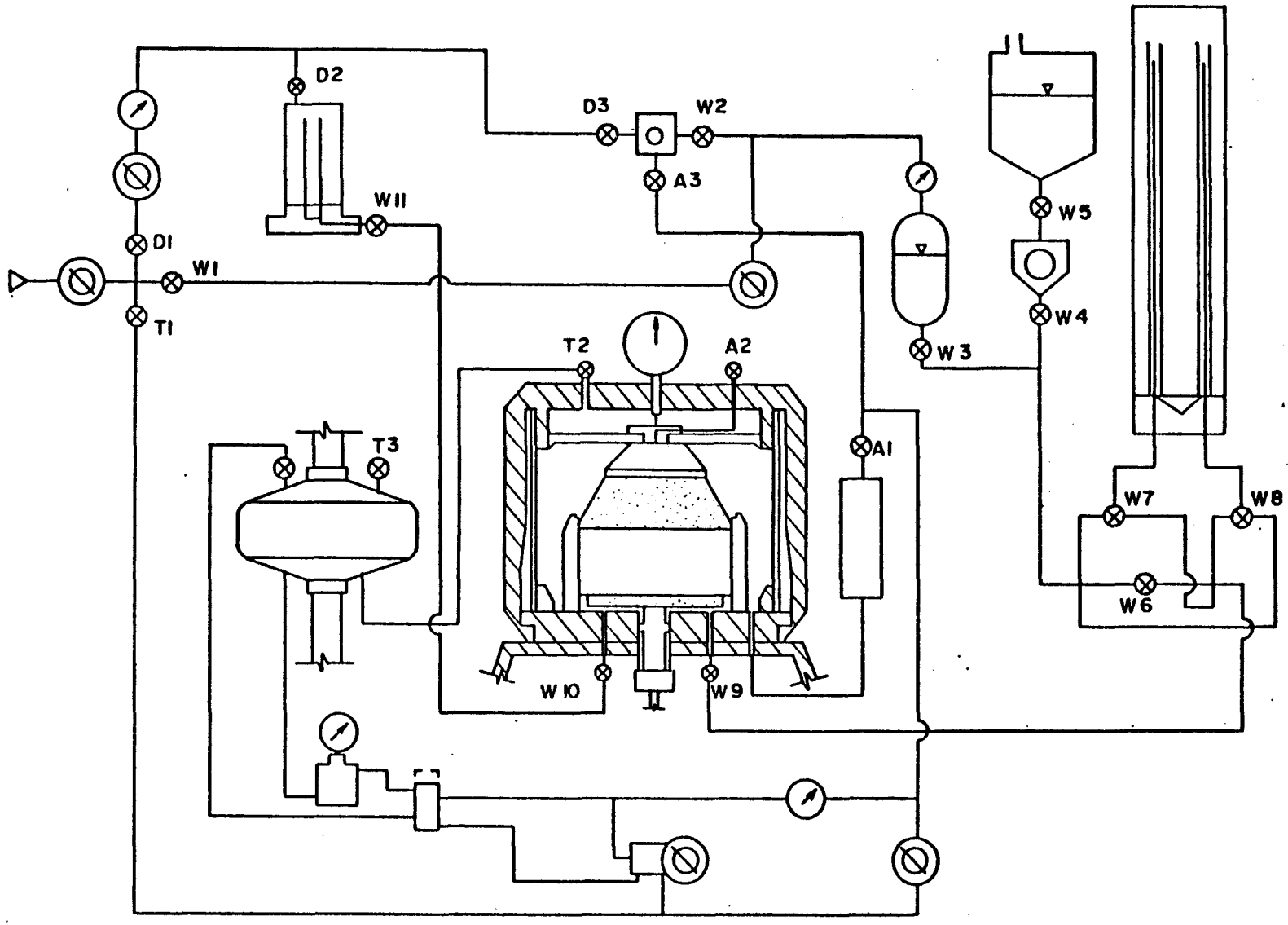

FIGURE 1 VALVE DESIGNATION ON MODIFIED ANTEUS OEDOMETER

indicates the pressure line that the valve is associated with. The code is as follows:

T - On the Total pressure line

A - On the Air pressure line

W - On the Water pressure line

D - On the Diffused Air Volume Indicator line

The names associated with each component of the equipment are given in Figures 2 and 3.

2.1 PREPARATION OF THE POROUS DISCS

The high air entry disc in the base plate is first saturated. A small amount of water is left on the surface of the disc to ensure good contact between the sample and the high air entry disc.

The low air entry upper disc should be left exposed to the atmosphere between tests to ensure that is remains dry.

2.2 SATURATION OF THE TOTAL PRESSURE LOADING CAP

The inclusion of air in the line from the sliding reservoir to the loading cap has two detrimental effects. First, the pressure response is sluggish and also inaccurate at low pressures. Second, the inclusion of air in the fluid above the loading cap makes it highly compressible. It is possible that during the manipulations of the air pressure, the total pressure may be momentarily reduced from the sample. This second effect

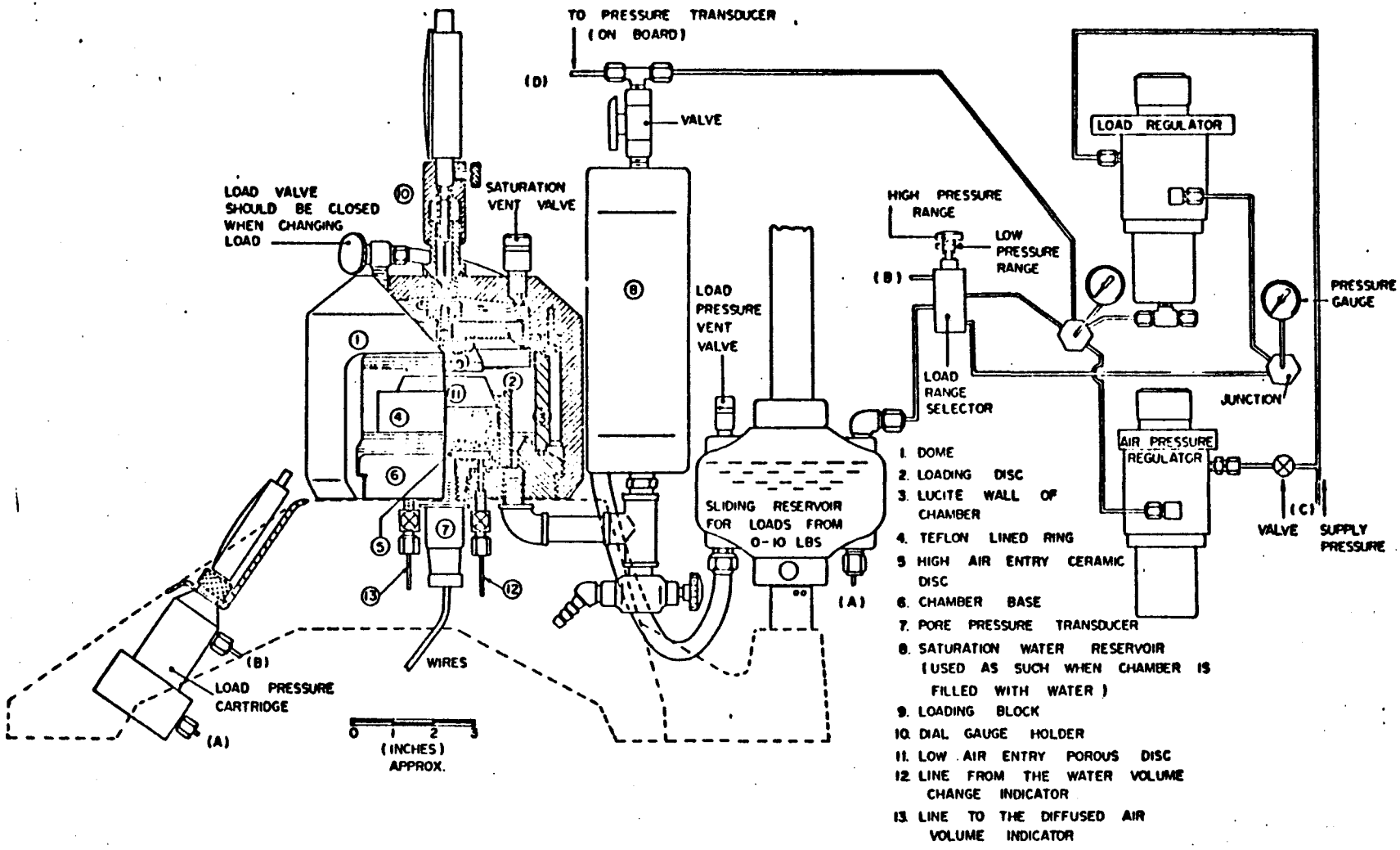

FIGURE 2 LAYOUT OF THE MODIFIED ANTEUS CONSOLIDOMETER

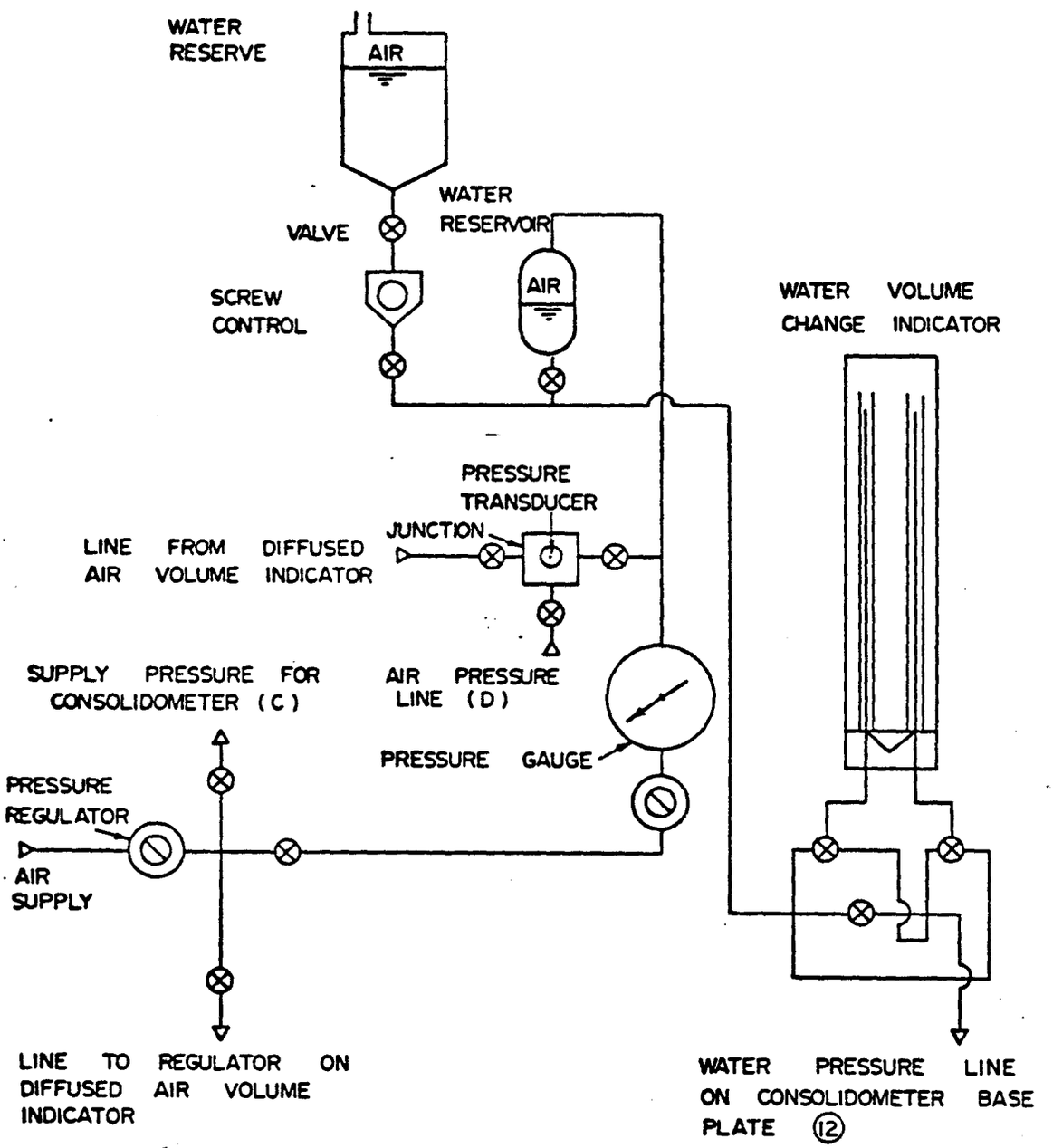

FIGURE 3 LAYOUT OF PLUMBING FOR MODIFIED ANTEUS CONSOLIDOMETERS

was particularly important during the performance of the null tests.

The zone above the loading cap is de-aired as follows:

i) Remove the dome and open the load pressure vent valve (T3).

ii) Bring the dome to an elevation below the sliding reservoir.

iii) Tilt the dome such that it orientates the connection on the dome (T2) in an upward position, pointing toward the sliding reservoir.

iv) Open the load valve (T2)

v) Allow the loading disc to move out at least 1/2 inch.

vi) Push the loading disc inward with an even squeeze.

vii) Repeat steps v) and vi) a couple times and then close the load valve (T2)

2.3 INITIALIZING THE VOLUME CHANGE MEASURING DEVICES

Three volume changes are measured during a test. These are the vertical displacement of the overall sample, the water volume change and the volume of diffused air.

a. INITIALIZING THE VERTICAL DISPLACEMENT GAUGE

The dial gauge on the dome of the oedometer can be set to a known initial value prior to the commencement of a test. This is accomplished by substituting a block of known height in

place of the sample and setting the dial gauge to its initial value.

i) The load range selector is set in the low pressure range.

ii) Open the saturation vent valve (A2) and close the valve over the saturation water reservoir (A1).

iii) Open the load pressure vent valve (T3).

iv) Raise the sliding reservoir to approximately the half way mark on the rod.

v) Open the load valve (T2).

vi) The vertical displacement dial gauge is read or set and the reading corresponds to the height of the block. The same porous discs should be in the oedometer during the calibration as will be used during the actual test. This calibration later serves as a check on the measured initial height of the soil sample.

b. INITIALIZING THE DIFFUSED AIR VOLUME INDICATOR

i) First, the line leading from the water reservoir, through the base plate to the diffused air volume indicator must be thoroughly flushed with de-aired water.

ii) Valves (W6) and (W3) are open while valves (W7) and (W8) are closed in order to by-pass the water volume change indicator during the flushing operation.

iii) The flushing pressure applied to the water reservoir should not exceed 10 psi or else damage may occur to the high air entry disc.

iv) Prior to commencing a test, the diffused air volume indicator should be almost filled with water. This can be accomplished by either of two procedures.

PROCEDURE I

- Close valve (W6)
- Open valves (W11) and (D2)
- Remove the vent at the top of the burret in the diffused air volume indicator.
- Slowly open valve (W6) until the burret is nearly full.

PROCEDURE II

- Close valve (W11) and leave valve (D2) open to the atmosphere.
- Remove the vent from the top of the burret in the diffused air volume indicator.
-Fill the burret from the top with water or "Fantastik" by means of a squeeze bottle. The "Fantastik" reduces the surface tension, allowing the air bubbles to rapidly rise in the burret.

c.) INITIALIZING THE WATER VOLUME CHANGE INDICATOR

At the start of the test, it is advisable to set the kerosene-water interface at approximately the half way mark on the burrets.

i) Valves (W9) and (W10) are closed

ii) Valve (W6) is closed and then valves (W7) and (W8) are

opened in the same direction. The kerosene-water interface level is recorded on the burret opposite to the direction that valves (W7) and (W8) point.

2.4 INITIALIZE THE TOTAL, AIR AND WATER PRESSURES

The total, air and water pressure measuring systems should be set to read their correct value for zero values prior to the start of the test. In the case of the pressure transducer on the board, (ie. air and water pressure reading) one connection at the junction block can first be removed. The transducer is then subjected to atmospheric pressure and the variable resistor is adjusted until the digital voltmeter reads zero. The zero reading on the pressure transducer at the base of the oedometer is set to zero by disconnecting the lines at valve (W9) and (W10) and adjusting the variable resistor until the digital voltmeter reads zero. Obtaining the zero reading on the total pressure measuring system is somewhat more complicated and is presented in the following a.) subsection.

The starting total, air and water pressures to be applied to the soil sample can be set prior to preparing the sample. This helps in minimizing the time from the placement of the sample on the high air entry disc, to the time the starting pressures are applied.

a.) ESTABLISHING THE ZERO READING ON THE LOAD DIAL INDICATOR

i) Check that the loading disc is near its uppermost position and close the load valve (T2).

ii) Insert an aluminum or steel block in place of a soil sample.

iii) Assemble the dome in place on the oedometer.

iv) Open the saturation vent valve (A2).

v) Close the valve over the saturation water reservoir (A1).

vi) Cpen the load pressure vent valve (T3).

vii) Put the load range selector in the lcw pressure range.

viii) Open the load valve (T2) and raise and lower the sliding reservoir noting the change in the vertical displacement dial gauge.

ix) Determine the position at which there is no tendency for a change in the dial gauge when the loading cap is free floating. The rod through the sliding reservoir should be marked to indicate the zero total pressure reading. Then the other markings may need to be shifted vertically.

x) Set the "Load Dial Indicator" at 500 which corresponds to a zero total pressure on the calibration chart.

b.) SETTING THE STARTING TOTAL PRESSURE

i) Check that the loading disc is in its uppermost position and close the load valve (T2).

ii) Put the load range selector in the desired position.

Valve (T3) is always closed unless the air pressure is to be maintained at atmospheric.

iii) Set the desired total pressure. This is really the difference between the total and air pressures since the load cartridge always registers the differential pressure with respect tc the air back pressure on the regulator. Although the load cartridge registers the differential pressure, the load applied to the top of the cap is the sum of the differential pressure and the chamber air pressure. The total pressure is immediately applied to the sample upon opening valve (T2).

c.) SETTING THE STARTING AIR PRESSURE

i) Valves (A1) and (A2) are closed.

ii) Valves (D3) and (W2) are closed while valve (A3) is opened to the board pressure transducer.

iii) Adjust the pressure regulator until the transducer reads the desired air pressure for the chamber.

iv) The chamber air pressure is applied by opening valve (A1).

d.) SETTING THE STARTING WATER PRESSURE

At the start of a test the water pressure is generally kept low while the air pressure is either high or gradually increased to measure the initial suction of the soil. It is

always desirable to subject the water to a back pressure of approximately 4 psi for two reasons. First, it provides the driving force for flushing the diffused air from the base plate. Second, the diffused air volume in the diffused air volume indicator is measured at a reduced pressure from what is was subjected to in the base plate. Therefore, the volume of air is increased in accordance with Boyle's law. The net result is that a more precise measurement of the diffused air volume is possible.

The initial water pressure is set as follows:

i) Close valves (W9) and (W10).

ii) On the water volume change indicator, close valve (W6) and set valves (W7) and (W8) in the same direction.

iii) Close valves (D3) and (A3) on the junction block and open valve (W2).

iv) Adjust the pressure regulator until the pressure transducer reads the desired value.

v) Record the burret reading in the water volume change indicator. When valve (W9) is opened, there is some compression of the water in the compartment of the base plate. This instantaneous volume change should be recorded (ie. correction applied) on the data sheet.

2.5 PREPARATION OF AN UNDISTURBED SAMPLE

The procedure described is particularly applicable to

stiff, unsaturated soil specimens.

i) Obtain the weight of the consclidation ring and a water content tare.

ii) Lightly smear the inside of the cutting ring and the consolidation ring with vacuum grease.

iii) Obtain the bulk sample from the storage room. The trimming of the sample should be ccnducted in a high relative humidity room.

iv) Place the sharp edge of the cutting ring on the sample and trim the sample to form a cylinder with a diameter slightly larger than the inside diameter of the cutting ring. Carefully push down the cutting ring while continuing the trimming process.

v) When the trimming of the sides is complete, take some of the trimmings for a water content determination.

vi) The face of the specimen at the sharp end of the cutting ring should now be trimmed smooth.

vii) The aluminum spacer is used tc push the sample back to the sleeve cn the spacer.

viii) The opposite end of the sample is now trimmed smooth.

ix) The blunt end of the cutting ring is placed on the consolidation ring and the low air entry upper disc is used to push the sample from the cutting ring into the consolidation ring. The sample should be stopped near the bottom of the consolidation ring.

x) Measure the height of the sample in at least three places by means cf a micrometer.

xi) Weight the ring and the sample. The low air entry disc is removed during the weighing. The sample is now ready for placement cnto the high air entry disc.

2.6 PLACEMENT OF THE SAMPLE IN THE OEDCMETER

The sample is placed on the high air entry disc and the consolidation ring is pushed down cver the base plate. The o-ring forms a seal between the consolidation ring and the base plate. The water pressure valve is opened and the burret reading recorded. This allows the withdrawal of water from the base plate to be measured.

The dome is placed over the sample and the air and total pressure valves opened. It is important to obtain the initial displacement readings as quickly as possible after the valves are opened. Generally only a few seconds are required from the placement of the sample on the high air entry disc to the application of the tctal and air pressures.

3. PREPARING THE EQUIPMENT AND SETTING UP THE SAMPLE FOR TRIAXIAL APPARATUS NC. 1 AND NO. 2

The preparation of the equipment and sample for Triaxial Apparatus No.1 and No.2 is similar in many respects to that of the oedometer tests. Therefore, only significant points of difference are mentioned. Figure 4 and 5 show the valve designaticns for Triaxial Apparatus No.1 and No.2, respectively.

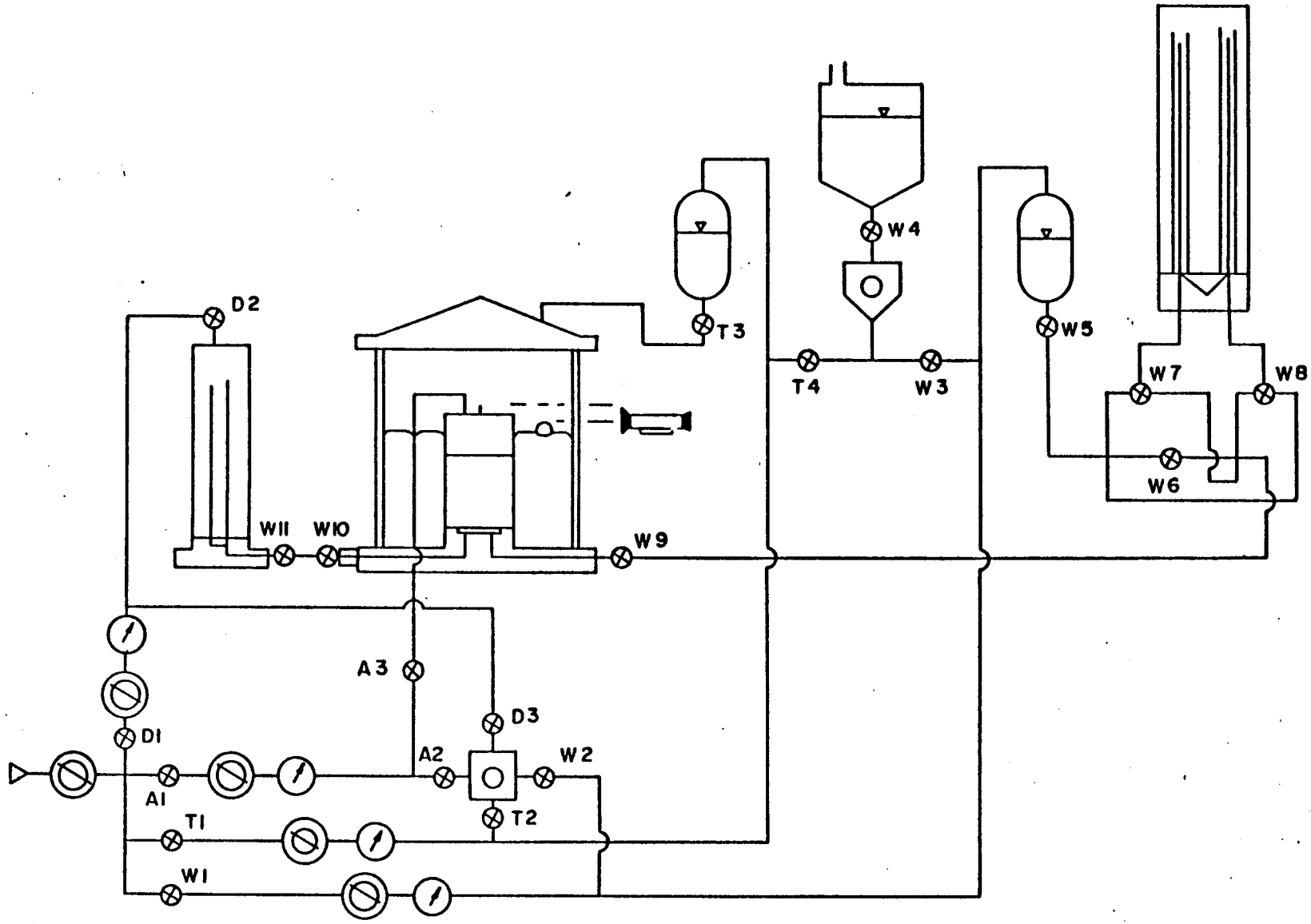

FIGURE 4 VALVE DESIGNATION ON TRIAXIAL APPARATUS NO. 1

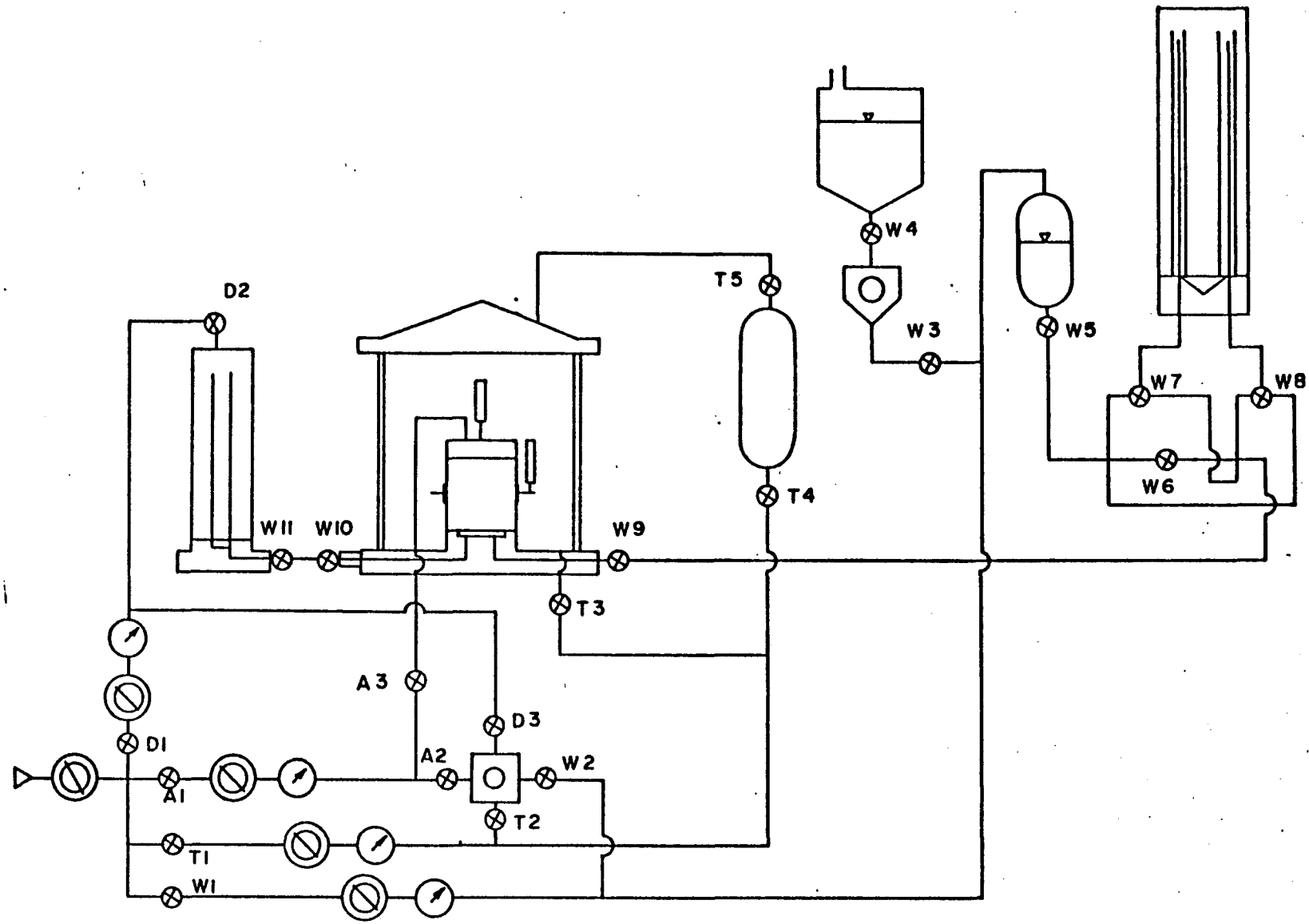

FIGURE 5 VALVE DESIGNATION ON TRIAXIAL APPARATUS NO. 2

As far as possible, an attempt was made to keep the numbering of the valves consistent with those of the oedometer apparatus.

3.1 INITIALIZING THE VOLUME CHANGE MEASURING DEVICES.

a.) INITIALIZING THE TOTAL VOLUME DISPLACEMENT DEVICES

On Triaxial Apparatus No.1, the cathetometer is made ready for the first reading prior to preparing the sample. This is the extent of the preparation. The length of time required to set up the sample is in the order of 20 minutes. Most of the time is involved in putting the membrane over the sample and filling the cell with mercury and water. During the set-up time, some water is taken into the sample and some volume change occurs. This difficulty can be essentially overcome by removing all the water from below the high air entry disc during the set-up period. The air entry value of the disc must well exceed the suction of the soil. The total and air pressures are applied when the test is ready to begin. Then the air is flushed from the base plate with de-aired water. The water volume change indicator is incorporated into the line and a record kept of the water volume changes.

A similar procedure can be used on Triaxial Apparatus No.2; however, the time required to set-up the sample is less than 10 minutes. On Triaxial Apparatus No.2, the desired locations of the vertical and lateral LVDT gauges can be established prior to setting up the sample and then quickly

installed when the sample is in place.

The operation of the diffused air volume indicator and the water volume change indicator are the same as previously outlined for the oedometer.

3.2 INITIALIZE THE TOTAL, AIR AND WATER PRESSURES

The pressure transducers should be initialized to atmospheric pressure conditions at the start of each test. Then the desired starting total, air and water pressures can be set prior to preparing the sample.

The total pressure is applied by opening valve (T3), the air pressure by opening valve (A3), and the water pressure by opening valve (W9).

3.3 PREPARATION OF THE SAMPLE

The samples used for the triaxial apparatus were either artificially compacted in a four-inch diameter compaction mold or trimmed from a four and one half inch diameter, undisturbed tube sample. A special cutting ring was machined for trimming the 4-inch diameter samples. Several lucite spacers were made to allow the length of the samples to be trimmed at 2 to 4 inches.

3.4 PLACEMENT OF THE SAMPLE INTO THE TRIAXIAL CELL

The setting up of the sample and the commencement of the test requires careful timing and a well ordered sequence of

steps. The procedure is designed to minimize the set-up time.

a.) TRIAXIAL APPARATUS NO.1

Since mercury is used around the sample, the entire assembling of the sample should be performed in a fume cabinet that can exhaust the mercury vapors.

i) Prepare the triaxial cell prior to trimming the sample. Ensure that the following things are ready.

-The high air entry disc in the base is saturated.

-The top low air entry disc is dry.

-The membranes, o-rings, membrane stretcher and load cap are ready for usage. Both the membrane and the o-rings can be placed on the membrane stretcher.

-A wrench is available to tighten the air line connection onto the cap.

-The mercury, ball bearing and water are ready to be put into the cell.

-A water content container is weighed.

ii) Trim the sample to the desired size.

-Take a water content determination from the trimmings

-Measure the height and diameter in at least three places using calipers.

-Weight the entire sample.

iii) Put the sample onto the base and place the low air entry disc and then the load cap on top of the sample.

iv) Place one membrane around the sample and put two, 1/8-inch diameter, o-rings around the pedestal and the load

cap.

v) Fasten the air pressure line onto the load cap.

vi) Place the stainless steel ball on the base of the cell.

vii) Place the inner lucite cylinder and the outer triaxial cell over the sample and tighten.

viii) Open the valve from the mercury container to fill the mercury into the cell to a height approximately 1/2 inch above the rubber membrane on the load cap.

ix) Fill the top of the cell with water.

x) Transport the triaxial cell from the fume cabinet to the laboratory and connect the cell, air and water pressure lines.

xi) Flush out the base and record the initial water volume change indicator reading. If the water was removed from the base plate during the sample setup, this step can be left until the cell and air pressures are applied (ie step xiii).

xii) Take an initial set of cathetometer readings on the cap and the ball.

xiii) Apply the pre-set cell, air and water pressures and record the displacements with time.

b) <u>TRIAXIAL APPARATUS NO.2</u>

i) Prepare the triaxial cell prior to trimming the sample.

-The high air entry disc must be saturated and the low air entry disc must be dry.

-The membranes and the aluminum foil, the membrane stretcher, the o-rings and the load cap should be ready for installation. Two 1/16-inch diameter o-rings are required for around the load cap and two 1/8-inch diameter o-rings for around the pedestal.

-A wrench is available for tightening the LVDT supports and the air line connection on the cap.

-A water content container is tared.

-Establish the location for the vertical and lateral LVDT's.

ii) Trim the sample to the desired size.

-Take a water content from the trimmings

-Measure the height and diameter in at least three places.

-Weigh the entire sample.

iii) Put the sample onto the base and place the low air entry disc and the load cap on top of the sample.

-Open valve (W9) and record the water volume change.

iv) Place one membrane around the sample. Put silicon grease on the outside of the membrane and stick the slotted aluminum foil to the membrane. Then place the second membrane over the sample. Put two, 1/8-inch diameter o-rings around the pedestal and then the two, 1/16-inch diameter o-rings around the load cap.

v) Assemble the lateral displacement gauge.

vi) Assemble the vertical displacement gauge.

vii) Connect the air pressure line onto the load cap.

viii) Place the triaxial cell over the base and tighten.

ix) Record the initial lateral and vertical displacement readings.

x) Apply the pre-set cell, air and water pressures and record the displacements with time.

4. MONITORING THE DIFFUSED AIR VOLUME

The monitoring of the diffused air volume is performed in the same manner for every apparatus. It is generally performed once a day; however, the frequency depends primarily on the magnitude of the applied air pressure. For a low air pressure, the diffused air volume can be measured less frequently. In any case, the diffused air should be measured prior to a change in the applied pressures. Since many of the tests run over a period in excess of one month, the correction for the diffused air becomes important.

The volume of diffused air can either be measured with respect tc atmospheric pressure or with respect to an elevated pressure in the diffused air volume indicator.

The procedure for recording the diffused air is as follows:

i) Take an initial set of readings which involve,

-the date and time.

-the total, air and water pressures. The water pressure in the base plate is important.

-the water volume change indicator reading.

-the vertical and horizontal displacement readings.

-the air-water interface in the diffused air volume indicator. Be sure the air pressure in the diffused air volume indicator is set at the desired value.

ii) There must be a differential pressure of from 1 to 10 psi across the base in order to cause sufficient flow to flush out the diffused air bubbles. It is desirable not to alter the back pressure on the water phase and therefore it may be necessary to elevate the air back pressure on the diffused air volume indicator. This means that the air pressure in the diffused air volume indicator can be different during the flushing operation than it was for the initial reading.

To elevate the pressures in the diffused air volume indicator, valves (D1) and (D2) are opened and the air pressure is adjusted to the desired value. If the diffused air volume is recorded with respect to the elevated backpressure, it is necessary to record this pressure on the data sheet. This is done by opening valve (D3) while the other valves to the board transducer block are closed. If the diffused air volume is recorded with respect to atmospheric pressure, it is not necessary to record the elevated diffused air volume indicator backpressure.

iii) Isolate the water volume change indicator by first closing valves (W7) and (W8) and then opening valve (W6).

There should be some means of remembering the direction of valves (W7) and (W8) prior to their being closed.

iv) Open valve (W10)

v) The differential pressure across the base should be from 1 to 10 psi. Valve (W11) is now opened and closed causing surges of water to flow through the base. The diffused air moves into the burret, displacing the water in the burret. A few seconds may be required between each surge to allow the air to rise into the burret. By using this procedure, the water pressure in the base plate only momentarily deviates from its set value.

vi) A small amount of air may be trapped within valve (W11) during the flushing process. This can be removed by tilting the diffused air volume indicator and quickly opening and closing valve (W11).

vii) Close valves (W11) and (W10)

viii) Then close valve (W6) and turn valves (W7) and (W8) to their previous directions. If this operation is performed rapidly, the water volume change indicator never changes. If it should happen to change, the new reading should be put on the next line of the data sheet as a new datum.

ix) Take the final reading in the diffused air volume indicator. It is generally desirable to allow the diffused air volume indicator to remain for approximately one minute after flushing to allow water to flow down from the walls of the burret. The final reading is taken with respect to the same pressure in the indicator as the

initial reading.

5. CHANGING THE TOTAL, AIR AND WATER PRESSURE FOR A DRAINED SYSTEM

Prior to changing any pressure, a final set of pressure and displacement readings should be taken. This includes a diffused air volume measurement. Then insert a comment card that explains the pressure change being applied.

The first card of the new pressure contains the final displacement readings (and corrections) from the previous pressure increment and refers to an elapsed time of zero minutes. These values can all be recorded prior to applying the new pressure increment. The mechanics of changing the pressure components on each apparatus are as follows:

a.) Modified Anteus Oedometer

Total Pressure Change

i) Close valve (T2)

ii) Adjust the total pressure regulator to the new value which is registered on the load pressure cartridge on the oedometer.

iii) Open valve (T2) and record the displacements.

Air pressure Change

i) Close valve (T2) and (A1)

ii) Adjust the air pressure regulator to the desired

pressure which is measured on the board transducer. Valve (A3) is open while the other valves leading to the junction are closed.

iii) The increase in air pressure is also applied to the top of the loading cap. Therefore, it is necessary to reduce the total pressure by an amount equal to the increase in the air pressure. The required reduction in the total pressure is computed from the calibration of the transducer and the load cartridge.

The difficulties associated with the above loading configuration could be overcome, however, then the apparatus would not be suitable for other types of tests. For example, it is desirable during the measurement of suction to maintain a fixed net total load applied to the soil sample. This is done automatically with the existing configuration. In actuality, there are few problems where we are interested in changing only the air pressure.

iv) The air pressure valve (A1) is opened approximately 1 to 2 seconds prior to valve (T2) and the displacements are recorded. The prior opening of valve (A1) allows time for the air in the chamber to be increased prior to opening the total pressure. If the fluid above the loading cap is saturated, very little movement of the loading cap occurs.

Water Pressure Change

i) Close valve (W9)

ii) The water volume change indicator can be either by-

passed during the change of the water pressure or left on line and the new burret reading taken as a new datum. The water pressure regulator is changed and the pressure is registered with valve (W2) open.

iii) Open valve (W9)

iv) Take a burret reading at an elapsed time of approximately two seconds. Assume that the volume change during the first two seconds is due to the compressibility of the air-water mixture in the base plate compartment. Therefore, the two second reading becomes the starting reading for the change in water volume.

b.) Triaxial Apparatus No.1

It is difficult to rapidly obtain readings using the cathetometer. In fact, it requires approximately one minute for each reading.

Total pressure Change

i) Close valve (T3)

ii) Adjust the total pressure to the desired value.

iii) Open valve (T3) and record the displacements.

Air Pressure Change

i) Close valve (A3)

ii) Adjust the air pressure regulator to the desired value.

iii) Open valve (A3)

Water Pressure Change

The procedure is the same as that used for the modified Anteus oedometer

c.) Triaxial Apparatus No.2

One of the advantages of this apparatus is that the vertical and lateral displacements can be recorded on the data acquisition system. The data acquisition system is started approximately 15 seconds prior to opening the valves for a pressure change. At an even minute, the pressure change valve is opened and the water volume change indicator is manually recorded. The data acquisition is set to record "continucusly" for the first three minutes and then changed to one minute intervals. The desired number of results are put on the data sheet.

Total Pressure Change

i) Compute the required excess pressure buildup or decrease that is required for the surge tank in order to facilitate essentially an immediate total stress response in the triaxial cell. Let the volume of the surge tank be Vs and the volume of the air in the triaxial cell be Vt. Apply Boyles law to the pressure change.

$$dUs = dUt*(Vt+Vs)/Vs$$

where dUt= the desired pressure change in the triaxial cell

dUs= the excess pressure change that must be put in the surge tank.

ii) Close valves (T5) and (T3) and leave valve (T4) open.

iii) Increase the pressure in the surge tank by an amount, dUs.

iv) Close valve (T4).

v) Adjust the pressure regulator to the cell pressure desired for after the pressure change.

vi) At the desired time, open valves (T5) and (T3) simultaneously. After approximately four seconds, close valve (T5). The displacement readings are taken at the desired intervals.

Air Pressure Change

The procedure is the same as for Triaxial Apparatus No.1.

Water Pressure Change

The procedure is the same as for the modified Anteus oedometer.

6. CHANGING THE TOTAL AND/OR AIR PRESSURES FOR AN UNDRAINED SYSTEM (REACTION TEST)

Before any reaction test, the base plate compartment should be thoroughly flushed with de-aired water. The total and/or air pressures are changed in a similar manner to those

described in the previous section. Upon a pressure application, valves (W9) and (W10) are kept closed. The pore water reaction is measured on the transducer on the base plate. It is connected to the data acquisition system and can be recorded at the desired intervals. The lateral and vertical sample displacements

7. REMOVAL OF THE SAMPLE FROM THE APPARATUS

The same general procedure is used for dismantling all pieces of equipment. The general steps are as follows:

i) Take a final set of readings of all pressures and displacements. This includes a reading of the diffused air and the water volume indicator.

ii) Close valves (W7) and (W8) and open valve (W6) on the water volume change indicator.

iii) Reduce the water pressure to zero. This is an important step since the high air-entry disc in the base can be cracked if the total and air pressures are removed prior to decreasing the water pressure.

iv) The total and air pressure are slowly reduced simultaneously until the air pressure is atmospheric. Then the total pressure is quickly reduced to zero and the cell disassembled in the reverse manner to which it was assembled.

v) Measure the height and diameter of the sample in at least three locations and obtain its total weight.

vi) Place the entire sample in the oven for several days

and then obtain its dry weight.