CSIR REPORT
EMA-H 8903

Issued by:

EMA (Pretoria)
CSIR
P O Box 395
PRETORIA
0001

INSTRUCTION MANUAL FOR THE USE OF CSIR TRIAXIAL ROCK STRESS MEASURING EQUIPMENT

April 1989

INSTRUCTION MANUAL FOR THE USE OF CSIR TRIAXIAL ROCK STRESS MEASURING EQUIPMENT

SYNOPSIS

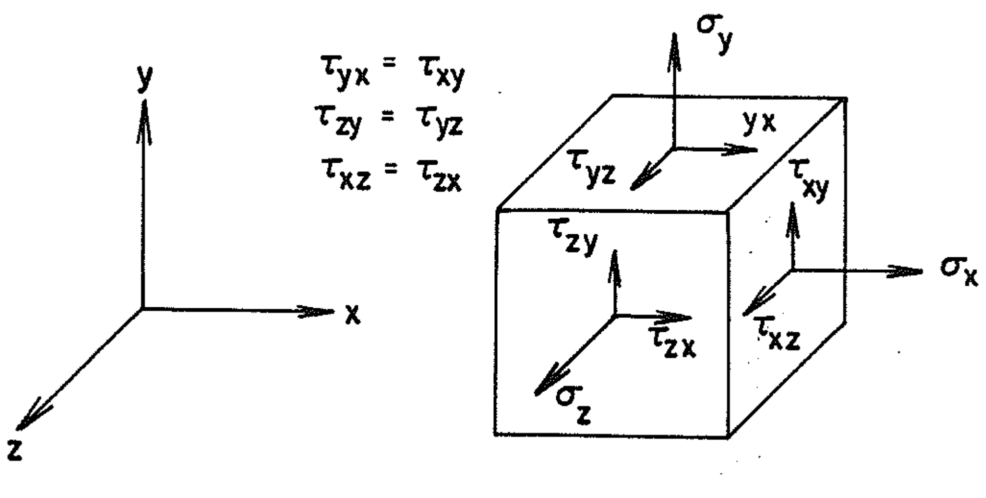
This is an updated version of CSIR Report No ME 1763 entitled "Instruction manual for the use of the CSIR triaxial rock stress measuring equipment" by F A Vreede. The Manual contains a detailed description of CSIR Triaxial Rock Stress Measuring Equipment and instructions for its use.

The overcoring technique employed for the determination of the absolute stress in rock is described.

1. INTRODUCTION

This manual is intended as a guide for users of CSIR triaxial rock stress measuring equipment, whose main component, the strain cell, is designed to measure the state of stress at any one point in a rock mass by means of an overcoring technique in a single borehole. The state of stress is described by a symmetric tensor with six components.

The manual contains a detailed description of the components of the equipment and complete instructions on the in situ technique. Statistical methods to check and evaluate the reliability of each test are presented, and laboratory tests are described to determine the modulus of elasticity and Poisson's ratio on core samples obtained during the measurements.



THE STATE OF STRESS PRESENT AT ANY POINT IN A ROCK MASS (NEGATIVE DIRECTIONS SHOWN)

2. SHORT DESCRIPTION OF THE MEASURING PRINCIPLE

The strain cell makes use of three strain gauge rosettes, using the principle of electric wire resistance, which are glued onto the wall of a borehole. Overcoring the portion of the hole where the rosettes are placed relieves the stresses in the ring-shaped piece of rock between the borehole and the overcoring cut, and the strains induced thereby are measured. These strains are functions of the state of stress at the point of measurement and when the elastic modulus and Poisson's ratio of the rock are known all six tensor components can be calculated.

The positions of the three strain gauge rosettes relative to a right-handed system of orthogonal coordinates (w, y, z) are shown in Fig 1. The positive z-direction points outwards along the axis of the measurement borehole. The x-direction is horizontal and the y-direction is vertical or horizontal depending on whether the borehole is drilled in a horizontal or vertical direction.

The four individual strain gauges of each strain gauge rosette are orientated as is shown in Fig 2 when viewed from the axis of the borehole. Gauge B is parallel to the borehole axis. Gauges A and B are normal to one another and so are gauges C and D, lying at 45° to both A and B. The strains measured by these gauges are referred to as e_A, e_B, e_C and e_D respectively. They are not independent of one another and it is easy to prove that an expression called the residue of the measurements

$$r = e_A + e_B - e_C - e_D$$

has an expected value of zero.

In each test a total number of twelve readings is taken, numbered as is shown in Table I below.

Table I: Numbering of Strain Gauge Readings

	e_A	e_B	e_C	e_D
Rosette 1	e_1	e_2	e_3	e_4
Rosette 2	e_5	e_6	e_7	e_8
Rosette 3	e_9	e_{10}	e_{11}	e_{12}

The numbers correspond to the switch positions on the central panel which will be described later.

A computer program for use in an IBM compatible PC is available and is described in a separate manual. The program has been designed to extract all the necessary information from the data of a series of tests and full instructions are provided on input preparation. The residue values are used to check the reliability of the strain readings and the validity of the assumptions on which the calculations are based. The output is self-explanatory and can be included in the report of an investigation without editing.

The original technique was published by Leeman.[1] Details on formulae and test reliability can be found in research reports.[2,3,4]

3. COMPONENTS OF THE TRIAXIAL EQUIPMENT

A detailed description of each component and its function is given below. It is recommended that the operator familiarize himself, in the laboratory, with the function and operation of each control feature and component before proceeding to the test site. The equipment comprises the following main components which are shown in the photographs in Figs 3 and 4.

1. Strain indicator, control switching panel and compressed air control panel which are built into the wooden carrying case. These items are marked A, B and C respectively in Fig 3.
2. Strain cell (D in Fig 4).
3. Installing tool (E in Fig 4).
4. Installing tool holder (F in Fig 4).
5. Installing rods (G in Fig 4).
6. EX borehole spraying tool (H in Fig 4).
7. EX borehole plug (I in Fig 4).
8. Centering device for drilling EX hole (J in Fig 4).

The sizes of the boreholes are given in Table II.

Table II: Diameters of diamond-drilled holes

Type or Size	External Diameter (mm)	Internal Diameter (mm)
X.R.T.	29,60	18,80
EX and EXM	37,50	21,50
EX Casing shoe	47,80	38,10
AX and AXM	47,80	30,10
BX and BXM	59,70	42,00
BX Casing bit	75,40	56,20
BX Casing show	75,40	60,30
NX and NXM	75,40	54,00
NXU	76,00	60,00
NX Casing bit	91,90	68,40
NX Casing shoe	92,00	76,00
NXC	92,00	68,50
NXCU	92,00	73,00

3.1 Strain indicator and control panels (see Fig 3)

The strain indicator is not supplied with the equipment and a standard sensitive instrument (such as a Huggenberger TI) must be obtained locally and fitted into the wooden carrying-case. Most models operate on dry batteries and their voltage should be checked before a test is started.

As can be seen in Fig 3 the control switching panel has two plug connections. They are clearly marked "input" in one case and "output" in the other. The strain cell cable should be connected to the input and the strain indicator to the output by means of the short cable supplied.

In the centre of the panel is a selector switch by means of which any one of the gauges in the strain cell can be connected to the strain indicator. If the switch is in position 1, strain gauge No 1 is connected to the bridge in the strain indicator. Switching to position 2 connects gauge No 2 and so on.

The orientation device in the installing tool functions only in horizontal or near horizontal boreholes and with the switch marked "orienting" turned on. First the installing tool is rotated freely until the red lamp lights up. Thereafter the tool is rotated slowly in a clockwise direction until the green lamp lights up. The gauges will then be correctly orientated for cementing into position.

Another switch and an indicator lamp (blue) marked "pressure" will be noted on the left-hand side of the panel. These two items are only used when another instrument, the CSIR "doorstopper" strain cell, is used with the control panel.

The various controls on the compressed air control panel are clearly marked. The hose for the supply of the compressed air (690 kPA = 100 lb/ins^2) should be connected to the inlet. The connection for the supply to the installing equipment is also clearly indicated. The air supply to the panel is turned on by putting the topmost valve (resembling a toggle switch) to the "on" position.

The supply from the panel to the installing tool is turned on by operating the valve marked "installing tool". The regulator in the centre of the panel should be adjusted until the pressure gauge shows a reading of 410 to 480 kPa (60 - 70 lb/ins^2).

A filter and watertrap are also incorporated in the compressor air line. The valve marked "filter drain" is opened to drain accumulated water from the watertrap. While the equipment is in use, this valve should be opened at least once a day until no water comes out of the drain pipe at the back of the wooden carrying case.

The compressed air supply should contain no oil because most glues will not adhere to an oil-covered surface. Bottled air or gas is recommended.

3.2 Triaxial strain cell (see D in Fig 4)

The strain cell is supplied as a single unit so that the user only has to glue a 6 mm thick disc (EX size) of rock to the dummy gauge to make a strain cell ready for use. The disc of rock must be of the same type as that in which measurements will be carried out. Strain gauge glues must be chosen with setting times appropriate to the conditions of use.

An enlargement of the strain cell is shown in Fig 5. Strain cells are not re-usable.

3.3 Strain cell installing tool (see E in Fig 4)

The installing tool is used to install a strain cell in the borehole. It fits into the installing tool holder (F in Fig 4) which acts as a guide for the tool and strain cell in the NXCU section of the borehole. A photograph of the installing tool fitted in the tool holder is given in Fig 7.

The strain cell is plugged into the plug at the front end of the tool as shown in Fig 7. The rosette plugs in the strain cell are forced out of the strain cell body by means of the actuator which is a pneumatically actuated rod protruding from the front end of the installing tool.

A mercury switch is incorporated in the installing tool and is adjusted so that the orienting lamps on the switch panel light up when the rosette gauges are in the correct position according to Fig 1 (see Section 3.1 for more details). If, for any reason, the orientation system requires adjustment, use the following procedure:

1. Take a strain cell and, after loosening the Allen screws, pull off the two cylindrical covers and pull out rosette No 1.
2. Plug the cell into the installing tool and loosen the four Allen screws at the front end which hold the plug in position.
3. Connect the installing tool with the control unit by means of the extension cable and switch on the orientation system.
4. Put the installing tool on two vee blocks which are placed on a perfectly flat and level surface.
5. Put a small square on the flat surface with the vertical leg tight against the flat area of rosette No 1.
6. With one hand hold the square in position so that the cell and plug remain stationary, and with the other hand rotate the installing tool anti-clockwise until both orientation lights are off.
7. Slowly rotate the tool in a clockwise direction until the red light lights up.
8. Slowly rotate a few degrees further until the green light lights up. Correct orientation should now have been obtained. The red light may be on or off.
9. Hold the tool in that position while an assistant fastens one of the Allen screws. Thereafter fasten all four Allen screws, but finger tight only.

10. Check if the position of rosette No 1 is now correct when the green light lights up. If not, loosen all four Allen screws and repeat the procedure from step 4 until the accuracy is satisfactory.
11. When the adjustment is satisfactory, tighten all four Allen screws and reassemble the strain cell.

3.4 Installing tool holder (coupling unit) (see F in Fig 4)

The installing tool holder is designed to accommodate the installing tool (see E in Fig 4), the spray unit (see H in Fig 4) and the EX borehole plug (see I in Fig 4). These components all fit into the front end of the tool holder and are held in position by means of two Allen screws. The installing rods (see G in Fig 4) screw onto the back end of the tool holder.

3.5 Installing rods (see G in Fig 4)

The installing rods are designed so that they screw into each other and, when screwed home, lock the joint. They are easily released by unscrewing the locking nut.

It is important to keep the joints clean and free of grit particularly under the relatively dirty conditions encountered on site. Occasional light lubrication of the joints is advisable.

3.6 Borehole spray unit (see H in Fig 4)

The borehole spray unit is used to spray the portion of the EX borehole where the triaxial strain cell is to be installed with a primer suited to the glue to be used. After drilling, the borehole is flushed out with water, blown out with compressed air and then sprayed with the primer.

To use the unit it is filled with the primer as is shown in Fig 6 and connected to the compressed airline. It is then fitted into the tool holder as is shown in Fig 7.

The unit is pushed into the EX borehole (see Fig 8) and the compressed air control on the air panel opened. This causes the primer to be sprayed onto the side walls of the EX borehole. The unit should be moved backwards and forwards in the EX hole while the air outlet is open.

3.7 EX Borehole plug (see I in Fig 4)

The EX borehole plug is used to prevent cooling water entering the EX borehole during the overcoring operation. To install the plug it is fitted in the tool holder and pushed into the mouth of the EX hole by means of the installing rods. A small force is maintained on the rods while they are turned in a clockwise direction. This causes the rubber bushes in the plug to expand and make contact with the sidewalls of the borehole. It can be judged, from the resistance to turning the rods, when the plug is sufficiently secured, then the rods are pulled out leaving the plug behind in the mouth of the EX borehole.

It is very important to note that the expansion of the rubber bushes in the plug results in a radial stress being applied to the inside of the EX borehole. If this radial stress is too great the core may crack near the mouth of the EX hole on overcoring. The plug should therefore never be over-tightened. The correct technique is soon mastered with a bit of practice.

3.8 Borehole centering device (see J in Fig 4)

This device is designed to ensure accurate concentric collaring of the EX hole in the flat end of the NXCU borehole (see Fig 8). To use it the three extension rods are pushed right in so that the EX drill bit only protrudes about 60 mm from the short NXCU spacer ring. It can then be attached to the drill rods and pushed into the hole for drilling the EX hole.

4. THE IN SITU TECHNIQUE

To measure the strain relief in situ an overcoring technique is used. The technique is described below.

4.1 Drilling and preparation of the borehole

1. A drilling machine, with sufficient power to drill an NXCU borehole smoothly and without vibrations into the rock, is required.

2. A standard NXCU borehole (NX casing - thin wall for overcoring) is drilled to the depth at which it is desired to determine the stress as is illustrated in Fig 8a. The borehole can be drilled in any convenient direction, provided the direction is accurately known.A case where the direction of the borehole is the z-direction of the coordinate system is shown in Fig 1. However, since the

orientation device in the equipment only functions in horizontal or near horizontal boreholes, it is advantageous to drill the borehole in a direction close to the horizontal.

It must be remembered that a lot of trouble can be avoided later on if the borehole is drilled one or two degrees upwards from the horizontal so that cooling water will drain out of the hole.

If the strain cell is used in a vertical borehole another orientation method (like making marks on the installing rods) must be used.

In general the boreholes must not contain any water. Although the strain cell can be glued to a wet rock surface, it will definitely not function under water.

3. The end of the borehole is ground flat with a suitable flat-faced NXC diamond bit to ensure accurate collaring of the EX hole which is then drilled into the end of and concentric with the NXCU borehole for a distance of 45 cm, as is shown in Fig 8b.

4. The 45 cm of EX core obtained should now be examined for cracks and discontinuities. If this core is broken or any cracks are present the NXCU borehole should be drilled deeper until a position is found where a crack-free piece of

EX core can be obtained. When this is achieved, the piece of EX core should be marked for future identification.

5. The EX portion of the borehole is next flushed with water and blown out with compressed air. The borehole spray unit is then filled with primer and the primer is sprayed onto the sidewalls of the EX portion of the borehole. On removal from the borehole the spray unit should immediately be washed in water to remove all traces of the primer.

4.2 Preparation and installation of the strain cell

1. The installing tool is fitted to the tool holder, the electrical cable and air tubing is connected to it and a strain cell is plugged into the tool. The gauges in the strain cell are tested one by one by operating the approriate switch on the control switching panel while noting the reading on the strain indicator. All readings should be steady and the indicator should balance at a reading between 12 000 and 18 000 micro strain (i.e. near the middle of the scale). The operation of the orientation device should also be tested at this stage.

2. If all gauges are in working condition the strain cell can be prepared for installation. Each of the three rosettes is rubbed with smooth sandpaper to remove the shiny appearance of the gauge and each gauge wiped with a piece of cotton wool moistened with alcohol. The installing tool, with the strain cell plugged into it is then placed in a position

from where it can quickly be pushed into the hole. This is particularly important if a quick-setting glue is used.

3. The glue is mixed and a 1 to 2 mm thick layer applied to each rosette. Immediately after this the assembly is pushed into the borehole until the strain cell is in position in the EX section of the hole. (It must be pushed in as far as it will go.) (See Fig 8c.) The strain cell is then orientated by turning the rods clockwise until the green lamp on the control box just lights up. The air valve is opened to operate the actuator. It is left open for at least 30 s to allow the glue to set and then closed again.

4. Once the glue has set, initial strain readings are taken from each of the gauges in the strain cell. Readings should be repeated at five minute intervals and plotted until the results become stable. Should there be no sign of stabilisation of the readings it is almost certain that the gauges are not properly bonded to the rock.

5. When the strain readings are stable, the installing tool is removed from the borehole leaving the strain cell in the EX portion of the hole. The mouth of the EX hole is then plugged with the borehole plug and the strain cell is overcored by extending the length of the NXCU borehole until it has reached a position past the end of the EX hole as is shown in Fig 8d.

6. The cylindrical core containing the strain cell is removed from the borehole by using a core spring immediately behind the drill bit (see Fig 8c), the borehole plug is taken out of the core and the installing tool is pushed into the EX hole so as to connect the strain cell to the control box again. Final strain readings are then taken from the strain gauges in the strain cell. Once again readings should be taken at five minute intervals until they remain stable.

4.3 Checking of test results on site

Even when all operating instructions have been followed carefully, unforeseen circumstances can cause malfunction of the equipment. If faulty results can be spotted before the investigating team has left the site it is easy to repeat them. The following technique works well if the strain data of at least 10 tests are avaialble and it is explained by means of an example.

In Table III the strain readings from 13 tests have been listed under e_1 to e_{12}. For each rosette the residue is calculated with formula 5.1 and recorded under r_1 to r_3. Finally, the sum of the absolute values $| r_1 | + | r_2 | + | r_3 |$ is recorded. These sums are then arranged according to magnitude from the highest value downwards and a value 0 is added at the bottom, giving 14 values in all as is shown in Fig 9 left. The order numbers are converted to a percentage so as to make the last equal to 50%. This is accomplished by multiplying by 50/14.

Table III

Test No	Strain relief recorded on overcoring (mm/mm)												$r = e_A + e_B - e_C - e_D$			
	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}	e_{11}	e_{12}	r_1	r_2	r_3	sum (r)
1	136	109	260	169	351	100	85	69	344	107	144	12	-184	297	295	776
2	204	55	276	-1	102	49	52	253	35	131	-18	148	-16	-154	36	206
3	171	111	434	-27	176	90	40	225	46	122	12	147	-125	1	9	135
4	185	125	10	290	50	120	145	35	185	45	175	45	10	-10	10	30
5	175	125	0	275	55	95	-35	20	190	170	230	135	25	165	-5	195
6	696	220	678	291	-91	206	300	-149	321	250	-57	621	-53	-36	7	96
7	416	11	82	340	-46	80	74	-68	536	35	321	218	5	28	82	65
8	865	315	450	630	140	230	335	240	520	-65	190	400	100	-205	-135	440
9	965	405	330	1090	-185	360	235	-25	990	425	990	345	-50	-35	80	165
10	310	5	278	-45	120	50	-80	175	-5	55	55	35	82	75	-40	197
11	205	35	265	-15	205	15	-30	225	110	40	60	65	-10	25	25	60
12	260	300	330	15	205	155	40	330	170	150	105	35	215	-10	180	405
13	235	20	110	120	560	115	330	325	-60	100	-15	40	25	20	15	60

Each value is now plotted on an arithmetical probability graph sheet and a wavy line is obtained. It can be seen that the highest ordinate deviates considerably more than 25% from an average straight line, indicating that this test is faulty and must be discarded. The exercise is repeated after this value is eliminated from the list as is shown in Fig 9 right. All values are now inside the 25% lines and can therefore be accepted.

5. STATISTICAL CHECKING OF TEST RESULTS

More sophisticated checks can be conducted on the test results. An example of such a check list is given in Table IV.

The R set provdes a check on operation conditions.

The D set provides a check on virgin stress homogeneity.

None of the checks provide absolute certainty as to the worth of a test, but based on common sense, the following evaluation guide-lines can be given:

(i) The standard of acceptability depends on the requirements of the virgin stress measuring programme.

(ii) Tests which are obviously at fault should be discarded.

(iii) Any test which cannot be fully accepted should be marked dubious.

5.1 The R check

Reliable results can only be obtained when the equipment functions correctly. Strain cell tests are carried out under uncontrolled conditions, so the chances of malfunction cannot be ruled out. Four-gauge rosettes allow a check to be made which can point out most of the failures. It is easy to prove that for each rosette a certain quantity, called the residue, depends only on the errors of measurement:

$$r = (e_A + e_B) - (e_C + e_D) \quad (5.1)$$

The measurements e have been identified in Table I.

Under favourable conditions the frequency distribution of R is normal with an average of zero. The check list contains the standardised residue deviation of the three rosettes for each test:

$$R_i = \text{abs}\ (r_i - r)\ /\ \text{std}\ (r) \quad (5.2)$$

i = 1, 2, 3

r = average of all residues

std (r) = standard deviation of all residues

The standard deviation of the residues is printed at the head of the check list. It has been proved[4] that its value is twice the standard deviation of the strain reading errors themselves.

Rosettes with excessively high R values are faulty. Since adverse site conditions tend to affect all three rosettes of a test, a faulty test can also show up through the average residue deviation of all three rosettes:

$$RAV = \sqrt{(R_1^2 + R_2^2 + R_3^2)/3} \qquad (5.3)$$

which is also given in the check list.

The properties of the normal distribution provide a criterion for excessive values of R and RAV. A list of the expected highest value among a total number of N values is given in the right-hand column of Table IV. For R the number N is equal to three times the number of tests and for RAV the number N is equal to the number of tests. In the example in Table V where the calculated R and RAV values are shown for a number of tests it can be seen that RAV for Test No 1 is not acceptable so that this test must be discarded.

Table IV: Statistical Expectations for Check Values

Number of values	Highest expected values of	
	D1	R, RAV, D2
10	1,45	1,64
20	1,66	1,96
40	1,84	2,24
100	2,06	2,58
200	2,21	2,81
500		3,04

Table V: Example of tabulated check results

Test No	R1	R2	R3	RAV	D1	D2
1	1,88	2,61	2,59	2,38	1,39	1,82
2	0,32	1,60	0,17	0,95	0,68	0,69
3	1,33	0,16	0,08	0,78	0,57	1,07
4	0,07	0,26	0,07	0,16	0,86	0,30
5	0,07	1,37	0,21	0,80	1,27	1,79
6	0,66	0,50	0,10	0,48	0,46	1,20
7	0,12	0,10	0,13	0,12	0,68	0,10
8	0,77	2,08	1,43	1,52	3,46	2,25
9	0,63	0,49	0,58	0,57	0,53	1,11
10	0,60	0,53	0,54	0,56	0,87	0,67
11	0,26	0,07	0,07	0,16	0,31	0,15
12	1,84	0,26	1,51	1,38	1,52	0,72
13	0,07	0,02	0,03	0,04	1,04	0,46

5.2 The D check

The calculations are based on the assumption that the virgin state of stress does not vary appreciably over distances of the order of magnitude of the borehole diameter. This assumption is reasonable but not always true. Strong stress gradients may occur in the neighbourhood of cracks or joints. Because the measurements are done at three separated points, a check can be made on the local homogeneity of the stress field.

For each test the check list contains two check values D_1 and D_2, which depend not only on the errors of measurement but also on the gradients of the virgin stress across the borehole.

The value of D_1 which measures the bending effect is given by:

$$D_1 = [\epsilon_z\ (max) - \epsilon_z\ (min)] / [\sqrt{0,75}\ std\ (r)] \qquad (5.4)$$

The value of D_2 which measures the torsion effect is given by:

$$D_2 = [\gamma_1 + \gamma_2 + \gamma_3]/[\sqrt{1,5}\ \text{std}\ (r)] \qquad (5.5)$$

If there are no gradients the highest values of D_1 and D_2 are expected to conform to Table IV. The number N is equal to the number of tests.

If the greatest value of D_1 or D_2 for a test is excessive, strong virgin stress gradients occur at that point. It is to be expected that excessive values for D_1 and D_2 occur together. In the example shown in Table V it is clear that the D values of Test No 8 are too high so that the value of the test is dubious. The stress calculations are unreliable and in any case the stress tensor is not representative of the general virgin stress field.

6. LABORATORY TESTS

1. The modulus of elasticity and the Poisson's ratio of the rock at each measurement station should be determined in the laboratory. For this purpose one or more rock specimens should be cut from the piece of EX core obtained during each measurement.

   These specimens should be instrumented with strain gauges and subjected to standard uniaxial compression tests in the laboratory.

2. It is recommended that the test described below be carried out in the laboratory to ensure that all the strain gauges were bonded

satisfactorily to the rock during the in situ test.

The cylindrical core containing the strain cell should be cut into a hollow cylindrical specimen of about 150 mm in length. Wires should then be connected to the pins on the strain cell and these wires should in turn be connected to a suitable switching box. (The switching panel on the control box will do.)

After this, the hollow specimen containing the strain cell should be placed between the loading plates of a compression testing machine. The load should be increased in increments and at each increment the reading from all strain gauges should be taken. This should be continued until the load is such that the specimen is subjected to a compressive stress of about 50% of the compressive strength of the specimen. Unloading in increments (again taking all readings at each increment) should then be carried out.

By plotting load against strain for each strain gauge it is a simple matter to detect a strain gauge which is not bonded to the rock. If such a gauge (or gauges) is found then obviously the result of that measurement should be treated as dubious.

7. REFERENCES

1. LEEMAN, E.R. and HAYES, D.J. A technique for determining the complete state of stress in rock using a single borehole. Proc. 1st Congr. I.S.R.M. Lisbon 1966.

2. VAN HEERDEN, W.L. The influence of various factors on the triaxial strain cell results. CSIR Report No ME 1178, February 1973.

3. VREEDE, F.A. Critical study of the method of calculating virgin rock stress from measurement results of the CSIR triaxial strain cell. CSIR Report No ME 1679, May 1981.

4. VREEDE, F.A. Instruction manual for the use of the CSIR triaxial rock stress measurement equipment. CSIR Report No ME 1763, June 1982.

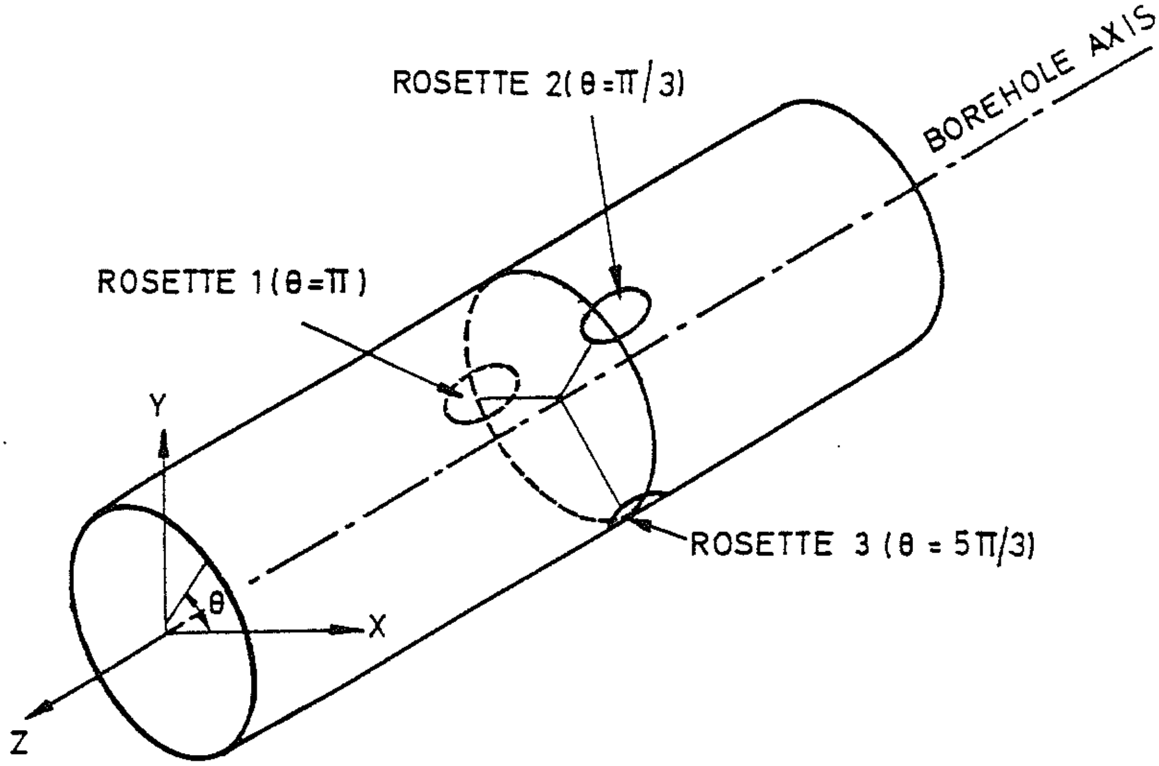


FIGURE 1: THE POSITION OF THE THREE ROSETTE GAUGES AS WELL AS CO-ORDINATE SYSTEM USED IN CONJUNCTION WITH THE STRAIN CELL.

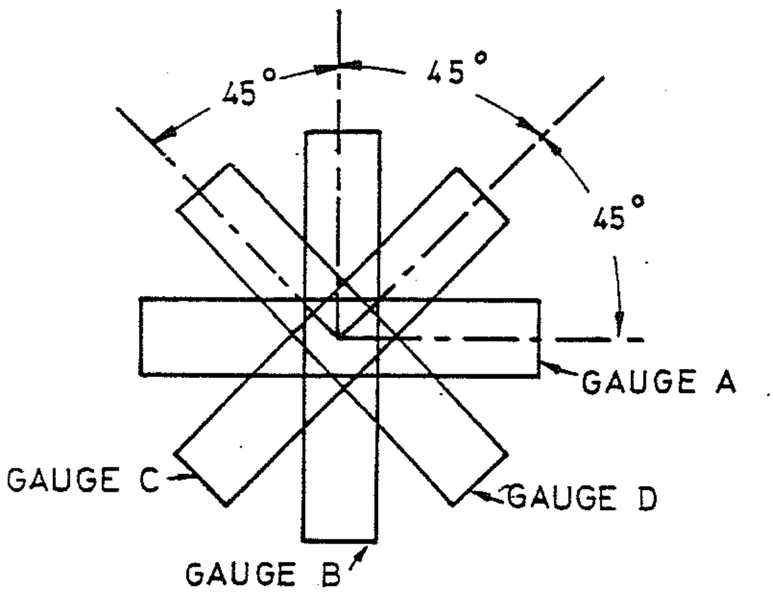


FIGURE 2: STRAIN GAUGE CONFIGURATION FOR EACH ROSETTE VIEWED FROM AXIS OF BOREHOLE (GAUGE B IS ALWAYS ORIENTED TO MEASURE IN THE Z-DIRECTION)

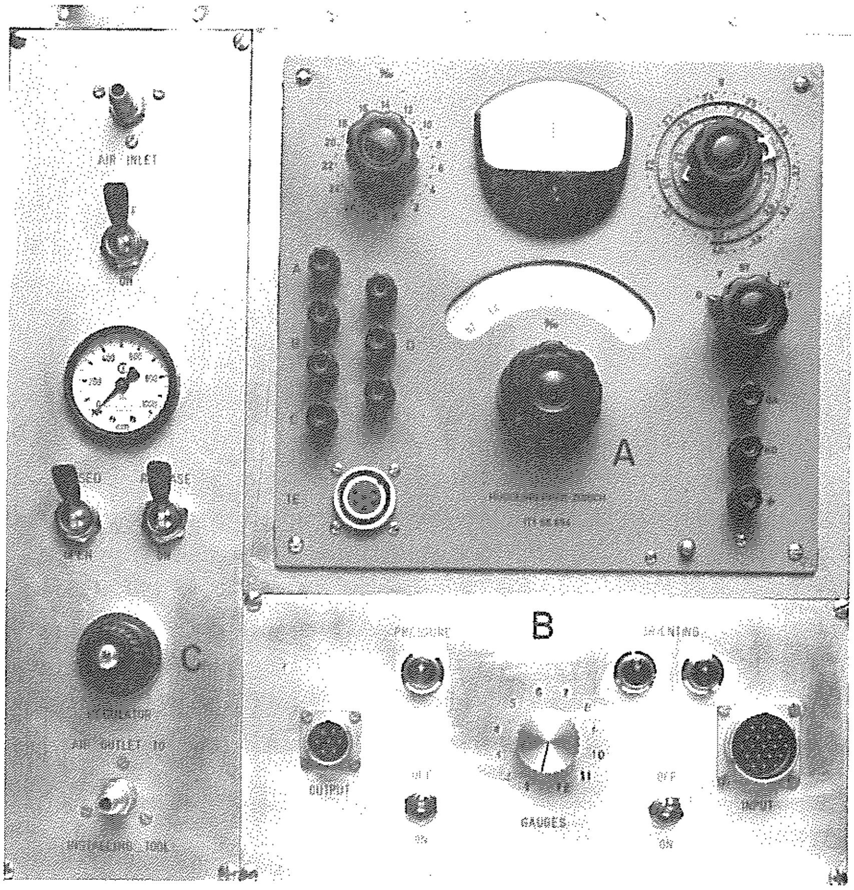


FIGURE 3

The strain indicator and control panels

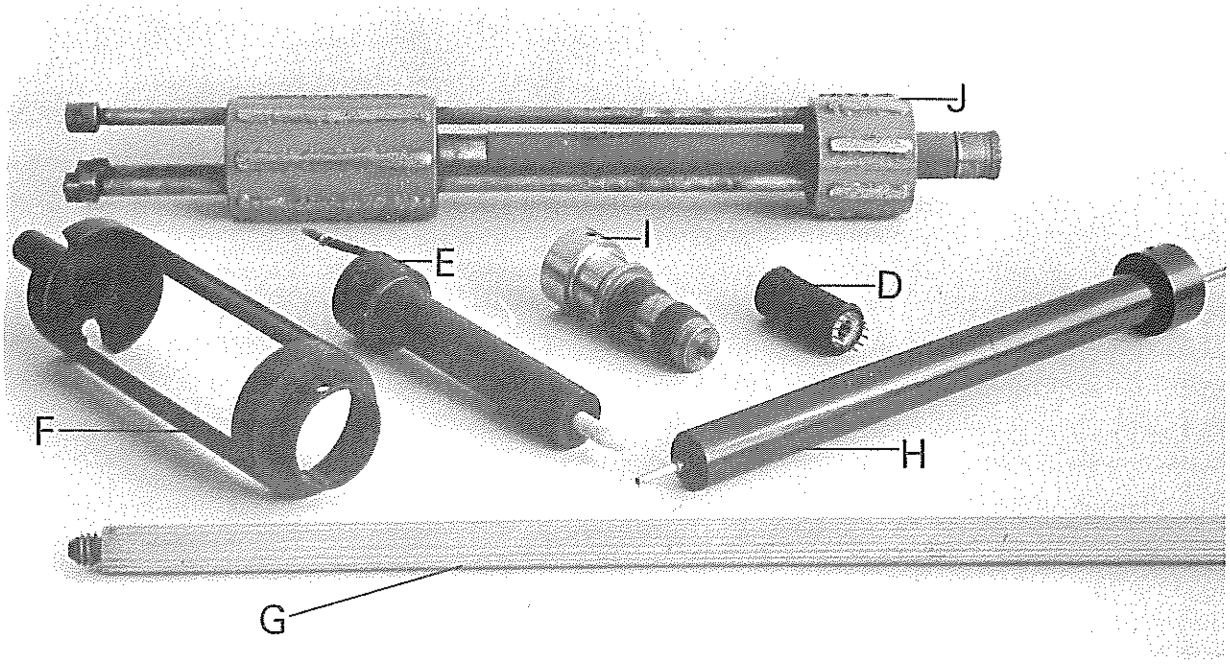


FIGURE 4

Components of the triaxial rock stress measuring equipment

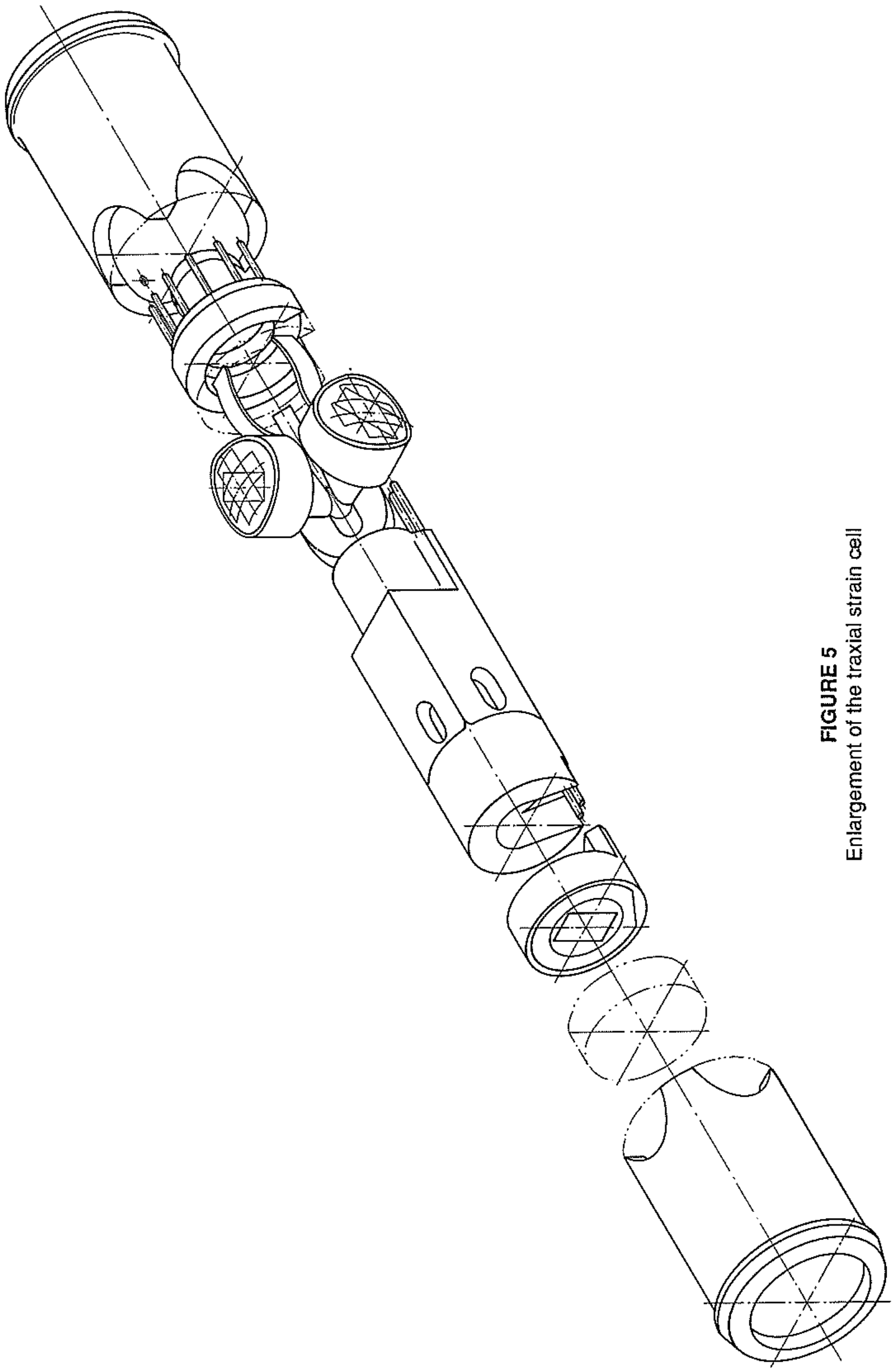


FIGURE 5
Enlargement of the traxial strain cell

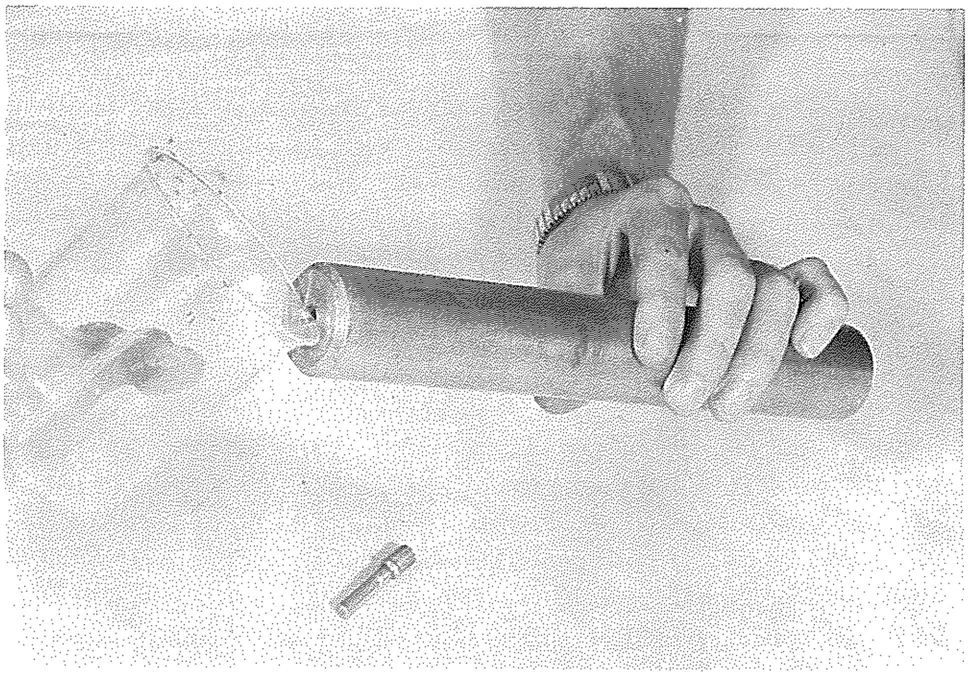


FIGURE 6

Filling the acetone syringe

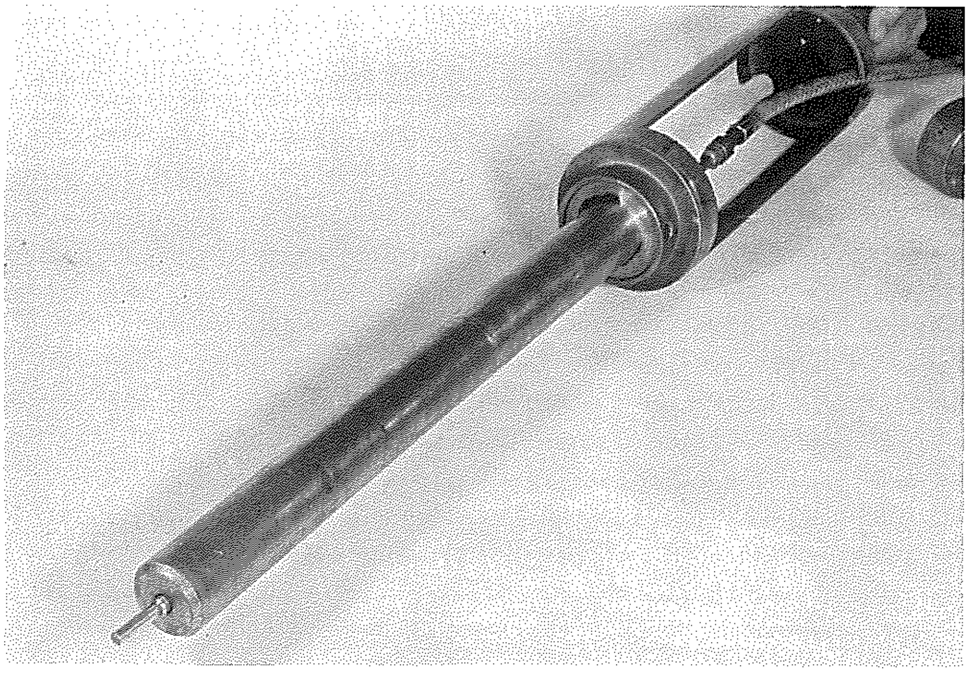
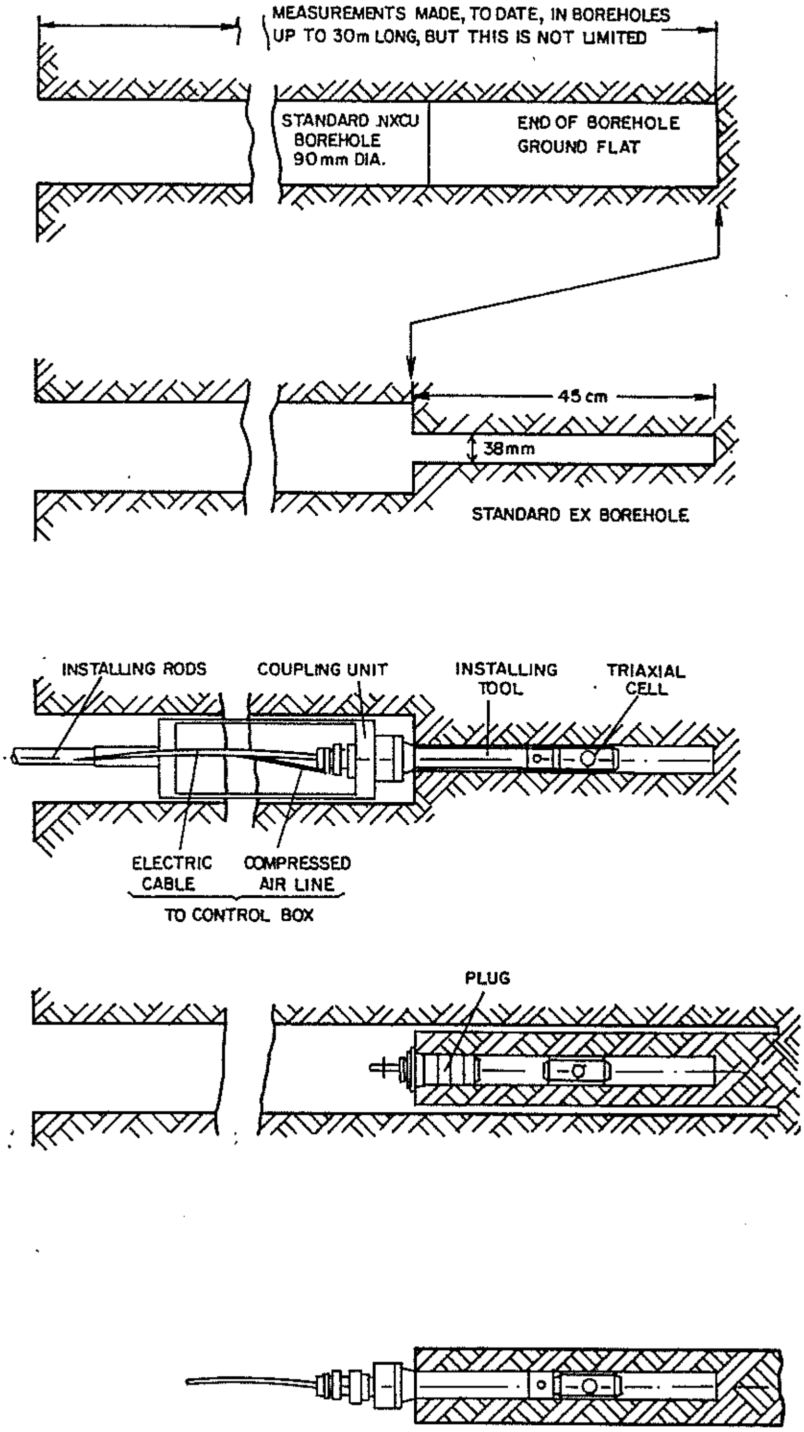


FIGURE 7

The syringe fitted into the coupling unit



(a) The borehole is drilled into the rock mass to the point where the stress in the rock is to be measured.

(b) A pilot hole 45 cm long is drilled into the end of and concentric with the main borehole.

(c) After ensuring that the pilot hole is clean and dry (by sprying with a water repellant, if necessary) the triaxial cell, plugged into the installing tool, is inserted in the pilot hole and oriented as indicated by the lamp on the control box. Compressed air is introduced by opening the valves in the control box and the three strain gauge rosettes are forced out against the sidewalls of the pilot hole and glued in position.

(d) When the glue has set, the strain readings are taken, the installing tool is removed and the pilot hole plugged. The triaxial cell is overcored using the NXCU coring crown used to drill the main borehole. This relieves the stresses in the rock to which the strain gauge rosettes are glued.

(e) The cylindrical core is broken off the end of the borehole, the plug removed and the installing tool plugged into the triaxial cell and the stress relieved strain readings taken.

FIGURE 8: DESCRIPTION OF THE USE OF THE TRIAXIAL STRAIN CELL

SUM	NO	%
776	1	3,57
440	2	7,14
405	3	10,7
206	4	14,3
197	5	17,9
195	6	21,4
165	7	25,0
135	8	28,6
96	9	32,1
65	10	35,7
60	11	39,3
60	12	42,9
30	13	46,4
0	14	50
50/14 - 3,5714		

SUM	NO	%
DISCARDED		
440	1	3,85
405	2	7,69
206	3	11,5
197	4	15,4
195	5	19,2
165	6	23,1
135	7	26,9
96	8	30,8
65	9	34,6
60	10	38,5
60	11	42,3
30	12	46,2
0	13	50
50/13 - 3,8462		

FIGURE 9: SITE CHECK FOR FAULTY TESTS