of the apparatus is shown in DIAGRAM 1. Later the water bath and the fittings listed in this paragraph, plus the Jalabo VC1 circulator, were duplicated. A further six bombs were also made, bringing the number of bombs up to twelve.

3.1.3 Gas Supply

Methane supply is from an A1 cylinder of 98,0% pure thane initially supplied at 17 MPa (Item 12). A Harris 87-2500A regulator for inflammable gas with a bottle pressure (Item 13) and outlet pressure (Item 14) gauges is coupled to it via a left hand thread. A 2m Parker SSOH-4 SAE 100 R high pressure flexible hose leads from the regulator to an inlet Whitey needle valve. The same system is used for helium supply. The helium is 99,5% pure and the coupling to the regulator is via a right hand thread (PLATE 6).

The inlet valves are connected to 0,25", 1 mm thick stainless steel tubing. There is a T piece leading to a 1000 cc Whitey HDF-1000-304 sampling cylinder (Item 8) rated to 12,4 MPa working pressure. Three further T pieces lead to the three gauges, a 0 to 16 MPa (Item 5) and a 0 to 1600 kPa (Item 4) pressure guage and a 0 to -100 kPa vacuum gauge (Item 3). Finally Swagelok SS-4HO-6-S4 flexible metal hose leads via Swagelok quick-connections and Whitey valves to the bombs.

3.1.4 Test Sample Container (Bomb)

For each sorption apparatus there are 6 bombs. Each bomb comprises of three parts as shown in DIAGRAMS 2 AND 3 and PLATE 3. The top stainless steel grade 316 section, (Item 5), has a Duran sintered disc filter of

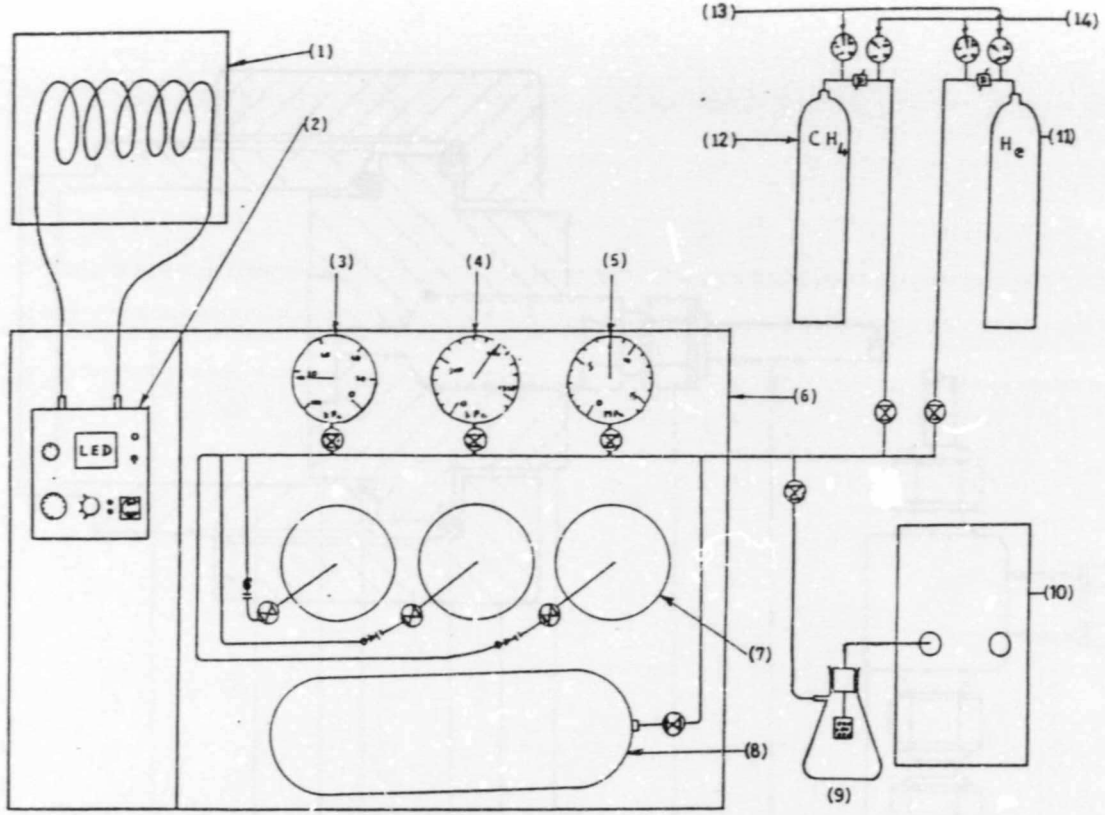

DIAGRAM 1

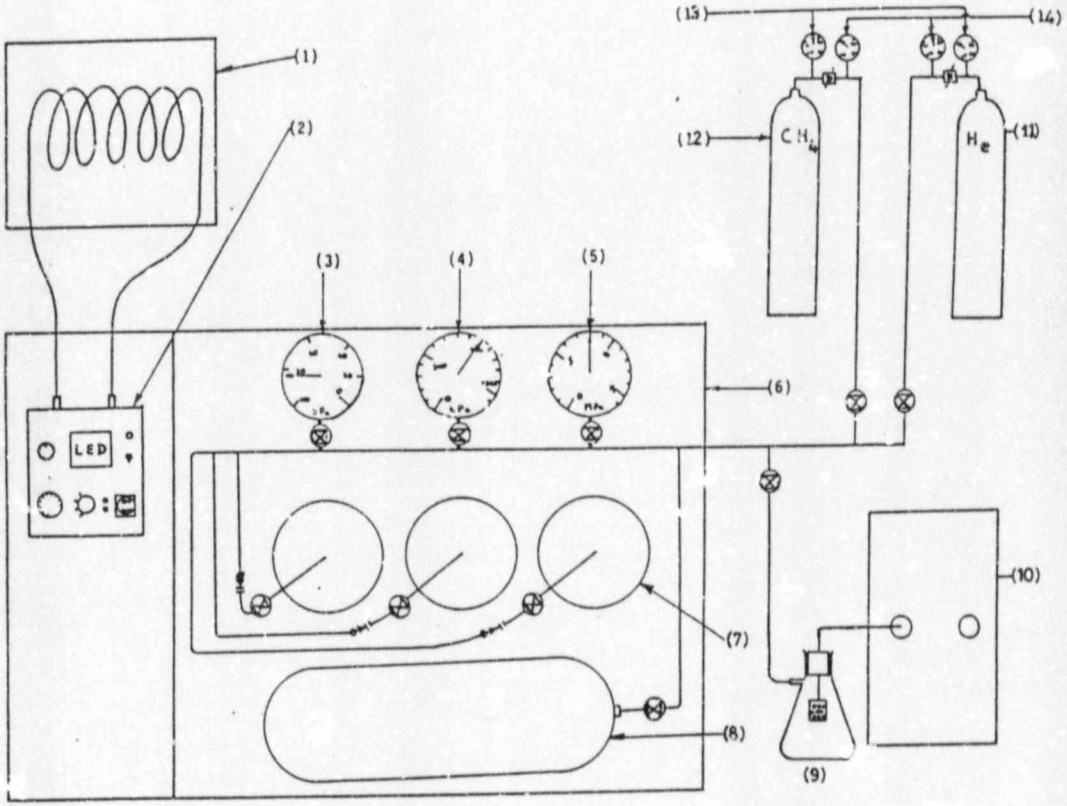

DIAGRAM 1

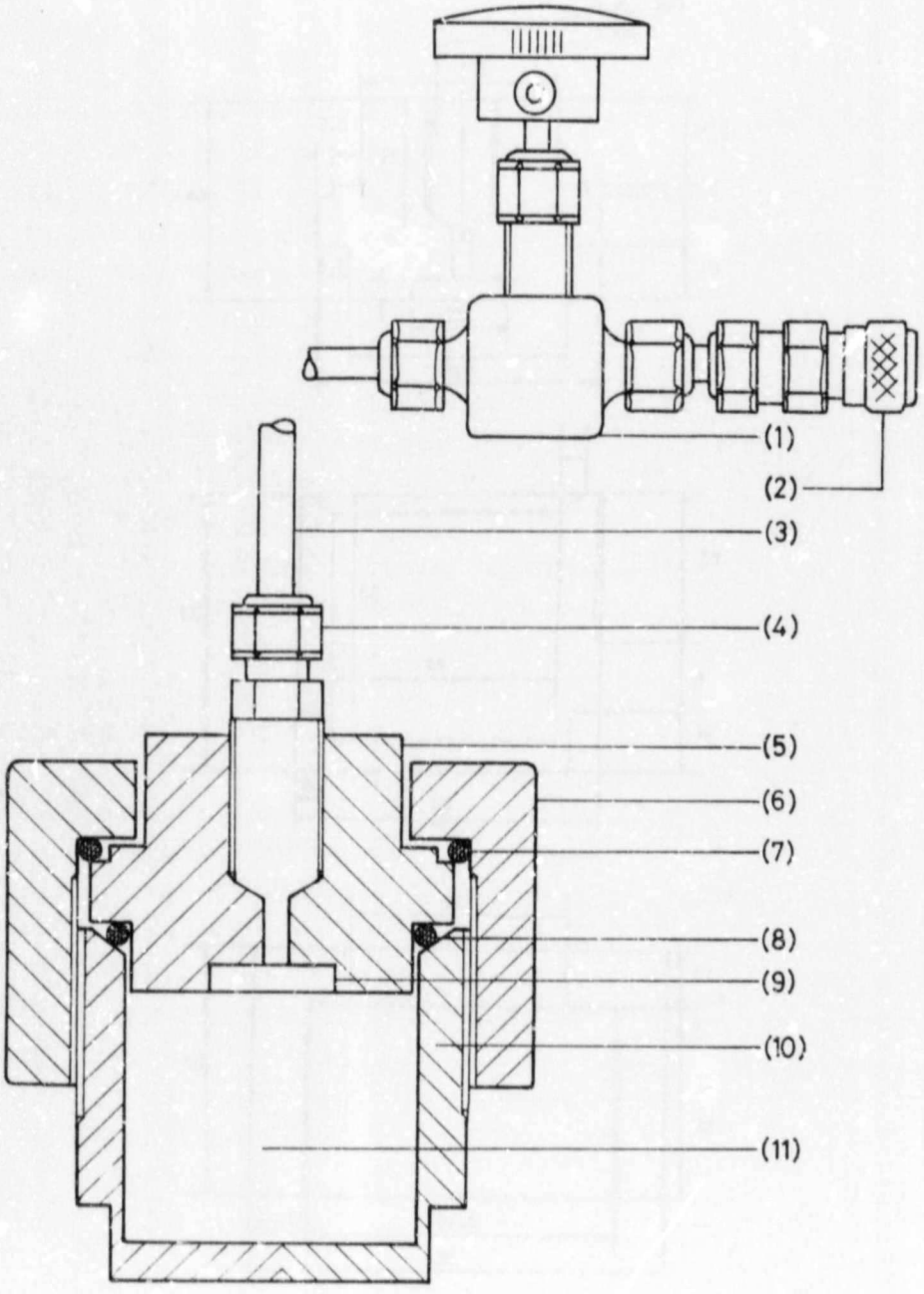

DIAGRAM 2

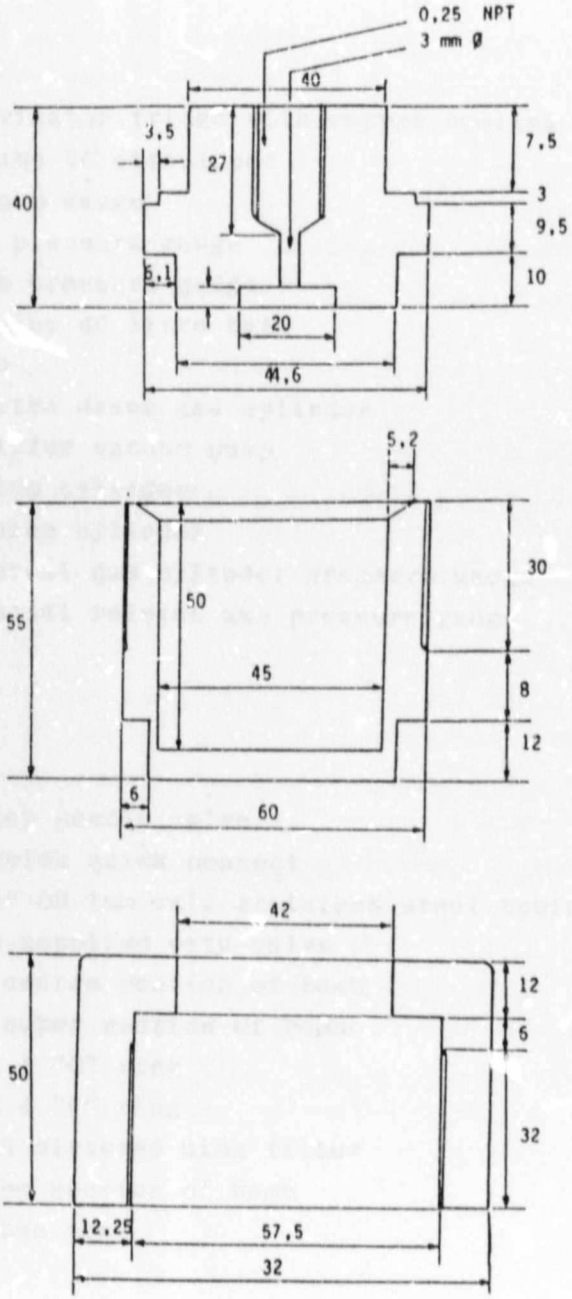
0,25 NPT
3 mm ø
40
3,5
27
7,5
3
9,5
10
40
5,1
20
41,6
5,2
30
50
55
45
8
12
6
60
42
12
6
50
32
12,25
57,5
32

DIAGRAM 3

Diagram 1

1) Kelvinator fridge with copper cooling coil
2) Julabo VC circulator
3) Vacuum gauge
4) Low pressure gauge
5) High pressure gauge
6) Labotec 40 litre bath
7) Bomb
8) 1 litre drawn gas cylinder
9) Pfeiffer vacuum pump
10) Helium cylinder
11) Methane cylinder
12) Internal gas cylinder pressure gauge
13) External release gas pressure gauge

Diagram 2

1) Whitey needle valve
2) Swagelok quick connect
3) 0,25" OD 1mm wall stainless steel tubing
4) Nuts supplied with valve
5) Top centre section of bomb
6) Top outer section of bomb
7) 42 x 4 "O" ring
8) 60 x 4 "O" ring
9) Duran sintered disc filter
10) Bottom section of bomb
11) Crushed coal

Diagram 3

Exploded view of the components of the bomb, showing dimensions.

porosity 2 at the bottom, (Item 9), to prevent fine coal powder from being blown out during desorption or being sucked out during evacuation (not shown in PLATE 3 as this was taken before this modification was made). This top section is threaded on top for coupling to the stainless steel tube which leads to the Whitey needle valve and Swagelok quick-connect body.

The outer section, (Item 6), was initially also made of stainless steel (PLATE 3) but it was found that even with Dows Corning 7 thread lubricant, the threads could bind. These outer sections were consequently remade using brass. Holes were drilled in the body to accept a special spanner for tightening and loosening it.

The bottom section, (item 10), is also made of stainless steel with two flats at the bottom for being fitted in a vice. It can comfortably accept 35,0 g of powdered coal and a special tamping piece was made to compress the powdered coal in an attempt to load the cylinder with a 50 g charge. The mass of powdered coal was measured using a laboratory Mettler balance (PLATE 15) with a range of 0-1100 g and accuracy of 0,1 g. Filling of the cylinder reduces the amount of free gas desorbed and increases the amount of adsorbed methane. The free gas forms the bulk of the gas released and results in tedious, time consuming work. The additional adsorbed methane makes the results more accurate.

3.1.5. Vacuum Pump and Water Trap

The Whitey pressure release needle valve can be coupled up to a reinforced PVC pipe after the excess gas at high pressure has been bled off. This PVC pipe leads to a side port on the thick wall 2 litre vacuum flask. Inside the flask is a perforated brass cylinder with a

ping pong ball inside. If water is sucked into the flask it will act like a child's snorkel tube and block the outlet to the vacuum pump before water can be sucked into it as had once happened prior to fitting the in line water trap. This ruins the very expensive vacuum pump oil and can cause damage to the pump if it is not switched off immediately. The layout of this apparatus is illustrated in DIAGRAM 1 and PLATE 10.

The Pleiffer DUO 004A two stage vacuum pump, (Item 10), is capable of better than 2 x 10^{-2} kPa without ballast, but it was always operated with gas ballast to prevent any vapour in the gas from condensating in the vacuum pump oil. In ballast mode it is also capable of 2 x 10^{-2} kPa vacuum pressure. The pumping rate is 4,2 m^3/h (= 70 l/min).

3.1.6 Coolers

Initially a domestic refrigerator was used. The Kelvinator R816 fridge had holes drilled through the back where PVC flexible hosing is lead through to a copper coil imersed in water in the fridge's vegetable tray. The 149W motor was found to be sufficient to keep the water temperature in the Labotec bath down to 20° C even in summer but cannot reach down to 10° C even in winter.

For this reason the Labotec 432 flow through cooler was purchased. It has a circulation pump which is rated at 10 l/min which matches the Jalabo VC head. It has its own thermostat and the compressor will only switch in if extra cooling is required. This can be set by the black knob in the centre of the dial. The cooling arrangements are shown in Item 1 in DIAGRAM 1 and PLATES 7 and 8.

3.1.7. Didgi-quartz Barometer

This extremely accurate unit is shown in PLATE 9 and is capable of discerning pressure difference if moved up or down by less than 30 centimetres. However the readout is a L.E.D. number related to pressure and a L.C.D. number in kilo Ohms, related to the internal resistance of the circuitry, which is sensitive to temperature. There are ten calibration factors which have been determined for the calibration of this unit. The L.C.D. and L.E.D. numbers are entered into a program and the readout gives barometric pressure in kilo Pascals. The calibration factors and program are given in Appendix A.

3.1.8. Desorbed Volume Measuring Apparatus

This apparatus is illustrated in DIAGRAM 4 and PLATE 11. After the valves on the bomb have been closed and the excess pressure bled off, the quick-connects on the bombs are disconnected and the bombs taken out of the bath.

Then the bombs are connected to the quick-connect nipple on the tubing and this is led under a 1000 cc laboratory measuring cylinder which has been filled with water before being inverted. As the valve is carefully opened the gas is released and so lowers the water level until finally all the gas has been desorbed. The bottom miniscus is read against the 10 cc intervals in the cylinder graduation.

Water temperature is measured using a 310 mm Labotec 0-50°C mercury thermometer, graduated in 0,10°C intervals.

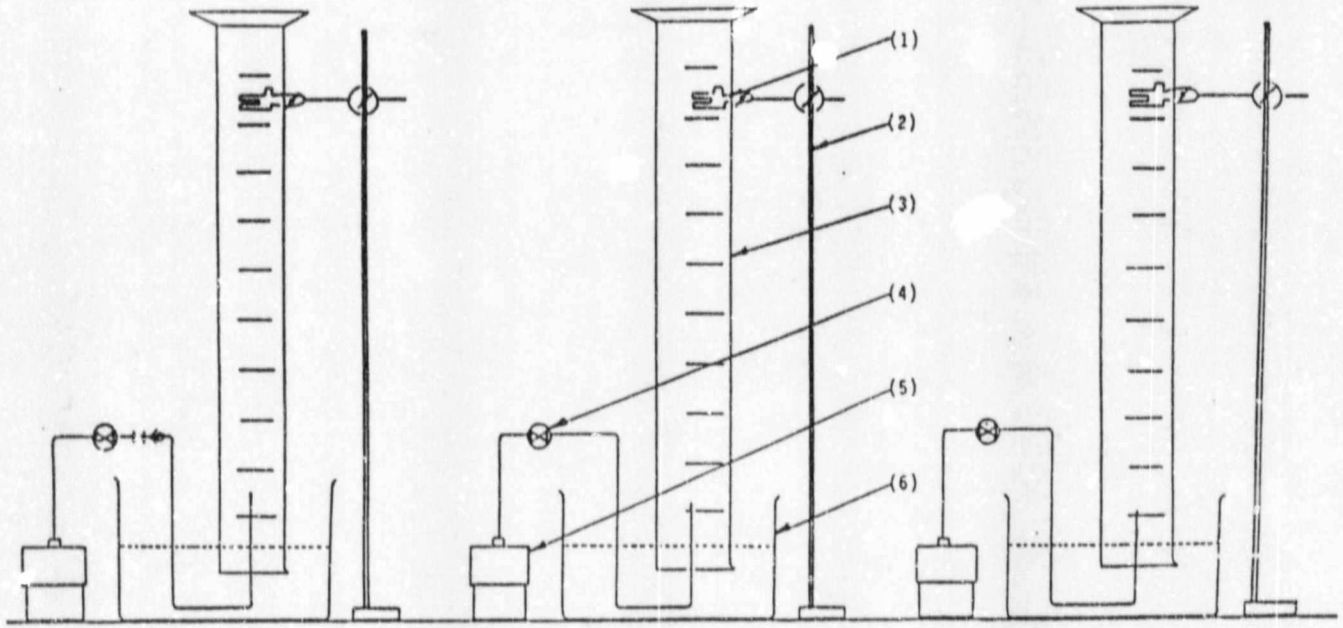

DIAGRAM 4

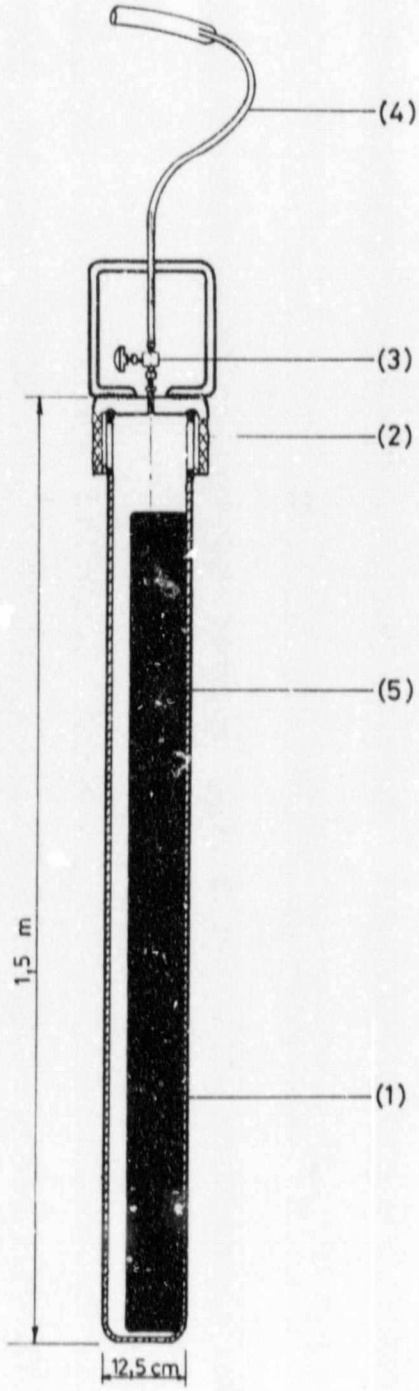

DIAGRAM 5

Diagram 4

1) Clamp
2) Retort stand
3) 1000cc measuring cylinder
4) Discharge coupling
5) Bomb
6) Plastic basin

Diagram 5

1) Stainless steel cylinder
2) Removable stainless steel cap
3) Whitey needle valve
4) 0.25" OD, 1 mm thick wall stainless steel tubing with plastic end tube
5) Coal core

3.2 Methane Sorption Test Apparatus - Direct Method

A large stainless steel cylinder was made to insert coal cores (DIAGRAM 5) (PLATE 12). The top section was threaded onto the bottom section and had a rubber "O" ring to form an airtight seal. This top section had a handle and a Whitey needle valve fitted. The stainless steel tubing had a plastic tube fitted to the end of it and this could be inserted under the measuring cylinder.

3.3 Permeability Test Apparatus

3.3.1 Coring Apparatus and Dessication Vessel

Permeability testing involves the use of cores rather than crushed material. The coring apparatus can be used to drill cores at any angle into a block of coal (PLATE 16). This enables the production of cores parallel and perpendicular to the bedding plane or any other orientation deemed necessary. The coring unit is a Matheys OPT 11 and the diamond saw used to cut the cores to length is a Diamond Boart DB 20 (PLATE 17). An in-house built lapping machine (PLATE 18) then ensures the ends of the cores are smooth, perpendicular and parallel to each other.

As the coring process is very time consuming it is normal to produce batches of cores from the same block. Only one core can be tested at one time so the rest have to be stored in an environment in which they will not deteriorate prior to being tested. A normal dessication vessel with silica gel crystals inside, had its lid modified to have an inlet and outlet port. In this way the air can be purged out with nitrogen supplied by an A1 sized cylinder (PLATE 23).

3.3.2 Clockhouse Triaxial Stress Loading Rig

After designing a frame and apparatus to apply triaxial loading, it was found that an existing piece of apparatus could be modified. It is a more accurate unit, purpose built for axial tension or compression, and for radial loads too. This apparatus is shown in DIAGRAM 6.

The Clockhouse A 13 axial loading test machine, (Item 1), (PLATE 19) is driven by a highly geared electric motor. It has fast up or down travel for positioning the base, which can move through 63,4 cm. If this range of travel is not enough the crosshead can be unbolted and moved to a new position.

The loading is then done using the slow down position for compression. Also a slow up for tension or a constant rate of tension or compression could be preset using the dial on the panel, (Item 2), which could be set between 6,35 mm/min - 0,005 mm/min. However neither the tension aspect nor the constant load rate facilities are used for this work.

The Clockhouse D 35 constant pressure apparatus (PLATE 22) provides the confining pressure using hydraulic oil pumped by a pressure pump driven by a three phase electric motor. This oil is fed to a piston in a precision bored cylinder. Weights are mounted on the shaft of this piston which must balance the upward force of the viscous oil flowing between the piston and the cylinder walls. The confining pressure is determined by the amount of weight applied to the shaft of the piston and is accurate to within 2%. This pressure is read off using the guage on the front panel of the D 35.

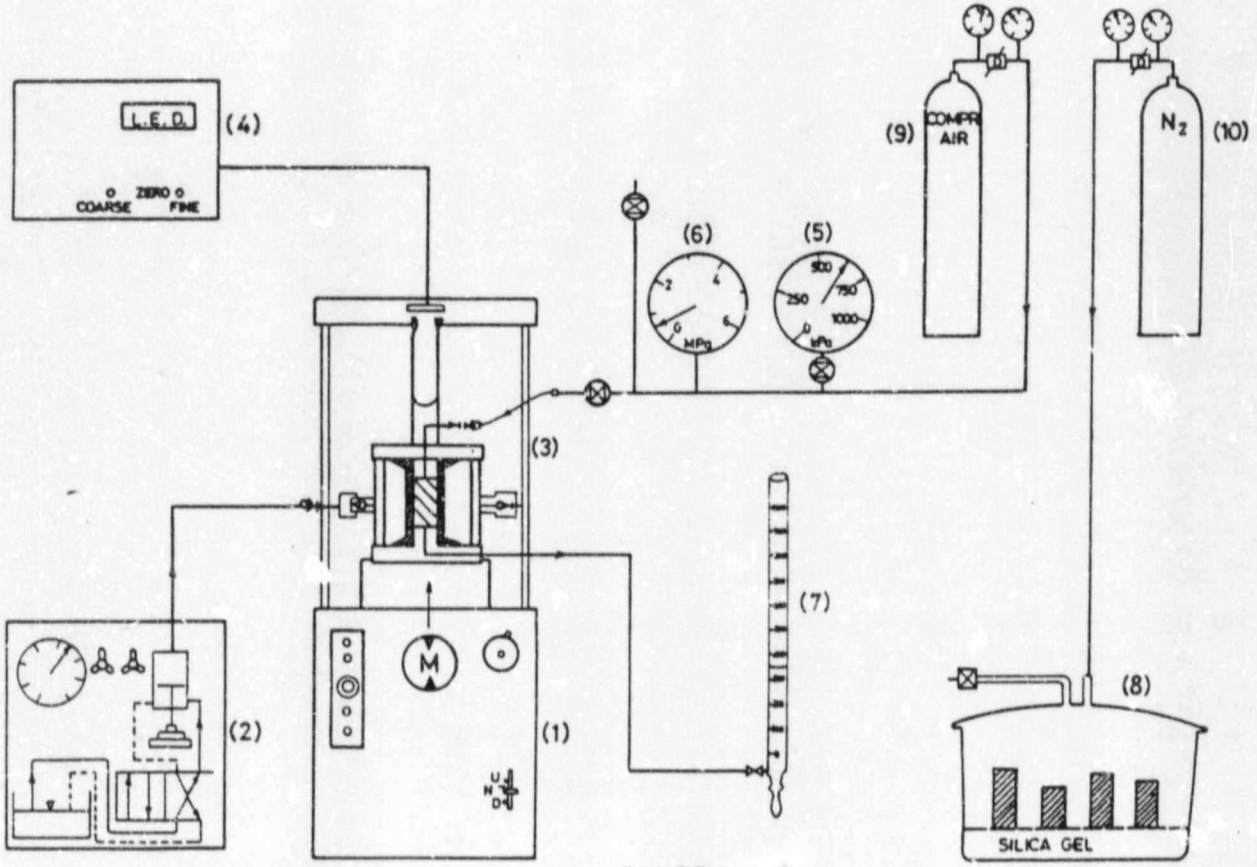
L.E.D.
(4)
ZERO
COARSE
FINE
(9)
COMPR AIR
N2
(10)
(6)
(5)
MPa
(3)
(7)
(2)
M
(1)
(8)
SILICA GEL

DIAGRAM 6

The oil for confining pressure is led by a high pressure hydraulic hose and Parker Hannifin quick connect coupling to the Hooke cell.

3.3.3 Hooke Cells

We have four Hooke cells (DIAGRAM 7) for AX,BX,NX, and TNX size cores. Usually only the smallest cores are used. It comprises of a base, (Item 4), which has been remade to have a platten at the bottom and a gas outlet pipe. The top sliding piece, (Item 1), has also been remade to have a similar platten, with a gas inlet, and an articulating ball joint to ensure the load is applied axially.

The top screw on cap, (Item 2), cylindrical body, (Item 3), and rubber inner sleeve, (Item 5), as well as the male screw on coupling, (Item 6), are standard. All inner parts of the cell must be very thoroughly cleaned as any fine dirt can allow the oil past the rubber inner sleeve and contaminate the core. This inner rubber sleeve is compressed against the core by the hydraulic oil fed into it to simulate radial confinement.

3.3.4 Pressure Transducer

The transducer, as shown in PLATE 19 and DIAGRAM 6, is called a Calculus System Projects ES 2000 loadcell indicating controller. The display can be either 3 1/2 didgit LCD with 12,7 mm character height or 4 1/2 didgit LCD with 8 mm character height, with selectable decimal point. It is accurate to within 0,05% of a division of indicated value, and is temperature stable within 0,05% per 10° C. It also has many other

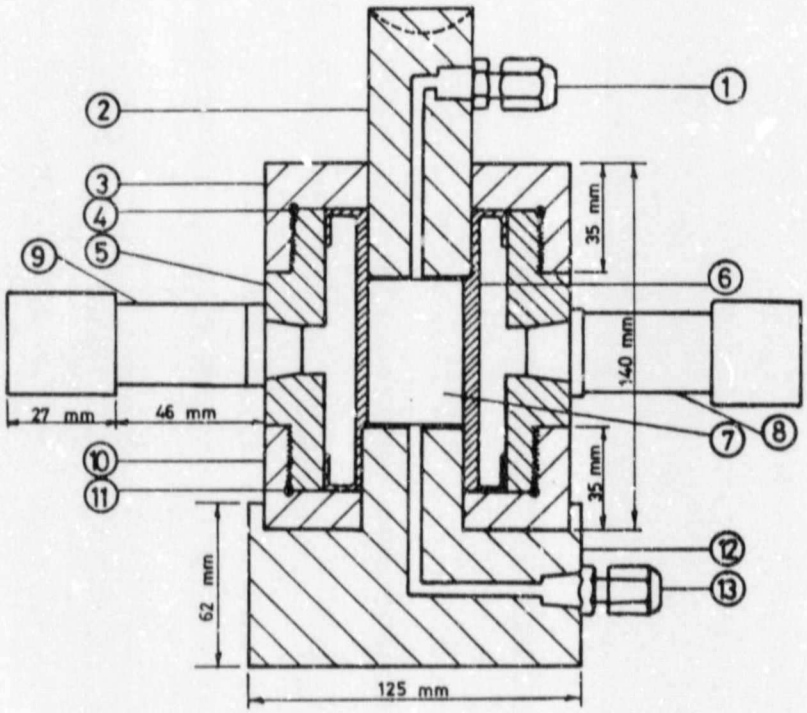

DIAGRAM 7

Diagram 6

1) Axial load Clockhouse A13 rig
2) Radial load Clockhouse pump
3) Hooke cell
4) Calculus System Projects ES 2000 pressure transducer
5) Low pressure guage
6) High pressure guage
7) Gas flow rate measuring pipette
8) Dessication vessel
9) Compressed air A1 cylinder
10) Nitrogen A1 cylinder

Diagram 7

1) Gas inlet
2) Top platten
3) Top outer section
4) "O" ring
5) Middle section
6) Rubber sleeve
7) Core
8) Oil inlet
9) Oil outlet
10) Bottom outer section
11) "O" ring
12) Base section including bottom platten
13) Gas outlet

features not used for our setup.

3.3.5. Compressed Air Supply

It was decided to pass compressed air through the core, rather than methane as this is far cheaper. A slight correction can be made for the different viscosities of the two gasses.

The compressed air is normal non-dried air supplied in an A1 cylinder at 17 MPa. This is coupled via a left hand thread to a OGM 10 regulator rated up to 1 MPa. The Harris 87-2500A regulator from the methane cylinder used in sorption tests can be coupled up instead of this unit, for high pressure gas output to verify the Klinkenberg effect (PLATE 20).

The pressure of the gas coming in is regulated by the regulator mounted on the compressed air cylinder and the in-line CPI needle valve. This pressure feed is measured by one of two Wika master pressure guages, one for high pressure 0-6000 kPa and one 0-1000 kPa in the same manner as for the sorption apparatus. There is also a bleed off valve for releasing gas pressure before disconnecting the Hooke cell when testing is complete.

This compressed air is led to the Hooke cell's top platten. The compressed air then passes through the coal core to the bottom platten from where it is led to the flow rate measuring apparatus.

3.3.6 Flow Rate Measuring Apparatus

A PVC pipe from the bottom platten is connected to an inlet port at the bottom side of the modified pipette (DIAGRAM 6 and PLATE 21) where a flow thumb screw would normally be. What is normally the bottom outlet of the pipette, has a rubber end similar to one used on a bottle for eye drops. This contains a soapy solution and when it is squeezed this makes a soap bubble above the incoming gas. The rate that this bubble rises up the pipette is measured with a stop watch. Thus the amount of gas and the time it takes to escape, can be measured.

4. EXPERIMENTAL PROCEDURE AND DATA PROCESSING

4.1 Methane Sorption Testing - Indirect Method

4.1.1 Sampling Procedure

In order to obtain reasonably reliable data from a programme of manageable size, it was decided to take three samples from each mine. The three sites were chosen to give the best spread of geographical location and depth, and include a sample from methane problem area if there was one.

Three lumps, each about fist size, are chipped out from the seam using a geological hammer, one near the top of the working seam, one near the middle and one near the bottom. Also if it could be seen that there were some bright bands, a piece roughly in proportion to the amount of bright band was taken. Fairly large lumps are taken to minimise the effect of oxidation which reduces the adsorbative capacity of the coal.

Simultaneously the dry bulb temperature was taken or it was obtained from recent measurements taken by the mine ventilation officer. The mine section, heading number and date is labelled on the plastic sampling bag. The seam name, surface elevation, overburden and coal seam thickness and any other relevant details were obtained from the survey and mine ventilation departments.

4.1.2 Sample Preparation

Pieces were chipped off the lumps roughly in proportion to the relative lump sizes. These chips were then placed in the crucible, which, in turn was then placed in the Seibtechnik disc mill and run for two minutes.

The 200-300 g of finely crushed coal was placed in a labelled plastic bag which was rolled to remove as much air as possible, as it was not known how fast the oxidation of the fine coal takes place.

The crushed coal was measured into two 35,0 g samples on a Mettler laboratory balance which was accurate to 0,1 g (see Plate 2). These samples were then placed in three bombs after these bombs had been cleaned out with alcohol and the threads and rubber "O" rings lightly lubricated with Dows Corning 7 compound. This means that while three of the bombs are desorbing, the other three will be adsorbing methane, so doubling the output of results.

The remainder of the sample lumps were sent to Maclachlan and Lazaar assaying laboratories for proximate and HGI analyses.

4.1.3 Adsorption Process

The bombs were evacuated to remove any air. Then three bombs and the Whitey sampling cylinder were pressurised to 10,0 MPa with methane.

After about 5 minutes the pressure readings on the pressure gauges stabilised and excess gas is bled off or gas was let in if there was a shortfall. The Jalabo VC head was used to keep the water at the set temperature ($10^{o}C$, $20^{o}C$ or $30^{o}C$). The adsorption process was run for at least 3 hours giving more than sufficient time for the methane to be adsorbed to a point of equilibrium.

4.1.4 Desorption Process

The valves for the three bombs and the sampling cylinder were closed and the pressure in the tubing bled off. The bombs were then disconnected and reconnected to a section of tubing.

The water in the basin was set as closely as possible to the bath temperature. Boiling water was added to bring the temperature up or ice cubes from the refrigerator ice tray used to reduce the temperature. This was done to minimise any error arising from the gas either expanding or compressing slightly as it passes through the water.

Water from the basins was used to fill the measuring cylinders which were then inverted in the basin. The tubing from the bomb was led under the cylinder and the valve on the bomb was opened to release the gas.

At pressures over 1,0 MPa, more than 1000cc of gas was typically released. Thus the gas was allowed to desorb until the 1000cc mark was reached when the valve was closed. The temperature of the water was taken and then the measuring cylinder refilled and the process repeated until all the free gas was desorbed. The barometric pressure was also taken. Program 1 in Appendix A was used to obtain the barometric pressure from the readout of the didgi-quartz barometer.

For methane the last part of the desorption process was slow and was allowed to continue until 3 hours had elapsed from starting desorption. Finally all the temperatures taken during the process were used to obtain a weighted value of mean temperature.

(eg for say 3,0 MPa test at 30° C then for 1000cc at 31,91°C and 1000cc at 31,23°C + 652cc at 24,35°C, T = 30°C + [(1000 x 1,91)+(1000 x 1,23)-(652 x 5,65)]/2652 = 29,8°C).

4.1.5 Dead Space Determination

Between 70 and 80% of the methane released during the desorption process was not adsorbed methane but methane compressed in the voids between the powdered coal particles and the void above the coal and in the tubing. To ascertain the volume of this "dead space" helium was used since it is inert and has been shown (64) that it is not adsorbed by coal.

The same process as described in 4.1.3 and 4.1.4 was repeated but only 20 minutes for pressurisation and 20 minutes for desorption is necessary. The difference in compressibility between helium and methane was compensated for by using a relative compressibility factor. Program 2 is given in Appendix B. The slight difference between the barometric pressure when the methane was desorbed to when the helium was desorbed was also compensated for in Program 2 although this effect is very minor.

4.1.6 Sorption Data Processing

The raw data was entered onto a P.C. and Program 3 listed in Appendix C was written to tabulate the results and perform all calculations. Boyle's law was used to take basin temperature T_w and barometric pressure B.P. into account.

4.1.7 Methane Sorption Testing - Direct Method

The direct test cylinders were delivered to the laboratory as soon as possible. However more than 24 hours had elapsed from intersecting the coal seam to commencing desorbing. TABLE 11 lists all the pertinent data supplied by Messrs A.M. Sanford and R.D. Saunderson of Anglovaal Ltd. TABLE 12 lists the test results.

The graphical method was used to determine the lost gas Q_1. Examples of graphs of the gassiest of the samples tested, namely the two cylinders, Gus/top and Gus/bottom of core K200 are given in FIGURES 67 and 68.

From FIGURE 67 for Gus/top, Q_1 is 165 cc and Q_2 is 2490 cc. Thus $Q_1 + Q_2$ is 2655 cc. Similarly from FIGURE 68 for Gus/bottom Q_1 is 145 cc and Q_2 is 2875 cc. Therefore for the Gus seam in total (Gus/top + Gus/bottom) $Q_1 + Q_2$ combined equals 5510 cc. The mass of coal in the 2 cylinders is 1.64 (relative density) x 1.39 (seam thickness of Gus/top + Gus/bottom combined) x $/4 \times (75)^2$ = 10071 g.

Borehole number	K200		K207		K208		K217		K218		K201	
Collar elevation (m)	1454.5		1418.5		1560.9		1492.0		1413.7		1462.3	
Drilling history (m)	air drilled		water drilled		water drilled		air drilled		air drilled		air drilled	
(a) Percussed to	155.15		-		-		-		-		-	-
(b) 75 mm air flushed cored to	182.48		-		-		-		-		-	-
(c) 47.5 mm TNW diamond to	-		163.26		302.45		199.86		165.12		-	-
(d) 63 mm NQ diamond to	-		170.53		309.39		206.66		172.30		-	-
Coal seam	Alfred	Gus	Alfred	Gus	Alfred	Gus	Alfred	Gus	Alfred	Gus	Alfred	Gus
Depth to top of seam	163.01	177.98	150.92	165.73	287.36	304.76	-	201.98	151.42	166.74	-	176.27
Depth to base of seam	163.97	179.37	152.18	167.12	289.09	306.22	-	203.32	152.26	168.34	-	177.57
Seam thickness	0.96	1.39	1.26	1.39	1.73	1.46	-	1.34	0.84	1.60	-	1.30
Sampling date (1986)	18-19 April	19 April	07 May	07 May	13 May	13 May	16 June	16 June	17 June	17 June	-	-
Time intersection of coal	23h21	06h[illegible]	11h39	14h32	09h25	12h58	-	13h35	09h26	13h06	-	-
Time pulling of rods	23h48	07h10	12h18	15h35	09h48	14h57	-	-	-	-	-	-
Time at surface	00h14	07h37	12h20	15h55	09h55	15h38	-	-	-	-	-	-
Time out of core barrel	00h17	07h42	12h23	16h00	10h01	15h46	-	-	-	-	-	-
		07h56	12h37	14h53	10h13	-	-	14h34	-	13h56	-	-
		08h04	12h33	16h10	10h16	16h06	-	14h32	10h20	13h52	-	-
Temperature of seam (C)	-	-	21.3	21.7	23.1	23.4	-	-	-	-	-	21.5
Sleeve inflation pressure (MPa)	-	-	-	-	-	-	-	-	-	-	-	2.0
Measured seam pressure (MPa)	-	-	-	-	-	-	-	-	-	-	-	1.22

Table 11

		GUS (top)				GUS (bottom)			
Date	Test time t	Elapsed time t (min)	Cumulative time t (min)	t (min)$^{\frac{1}{2}}$	Cumulative gas desorbed (cc)	Elapsed time (t) (min)	Cumulative time t (min)	t (min)$^{\frac{1}{2}}$	Cumulative gas desorbed (cc)
19/4/86		76				68			
21/4/86	15h00		3372	58.1	500		3364	58	500
22/4/86	08h00		4392	66.3	925		4384	66.3	1280
	09h15		4467	66.8	925		4459	66.8	1290
	09h40		4492	67.0	935		4484	67.0	1305
	10h15		4527	67.3	960		4519	67.2	1320
	16h30		4902	70.0	1090		4894	70.0	1450
23/4/86	06h00		5712	75.6	1200		5706	75.5	1590
24/4/86	08h00		7272	85.3	1370		7264	85.2	1790
	16h00		7752	88.0	1470		7744	88.0	1855
28/4/86	08h00		13032	114.2	1850		13024	114.1	2155
	11h00		13212	114.9	1870		13204	114.9	2165
29/4/86	08h00		14472	120.4	1910		14464	120.3	2255
01/5/86	10h00		17472	132.2	2070		17464	132.2	2465
02/5/86	11h00		18972	137.7	2210		18964	137.7	2585
	19h00		19452	139.5	2260		19444	139.4	2635
05/5/86	06h30		23022	151.7	2280		23014	151.7	2795
	12h00		23352	152.8	2320		23344	152.8	2815
	15h20		23552	153.5	2480		23544	153.4	2835
06/5/86	10h30		24702	157.2	2490		24694	157.1	2865
	11h45		24807	157.5	2490		24799	157.5	2875

Table 12. Direct Test Klipspruit core K200 Gus Seam

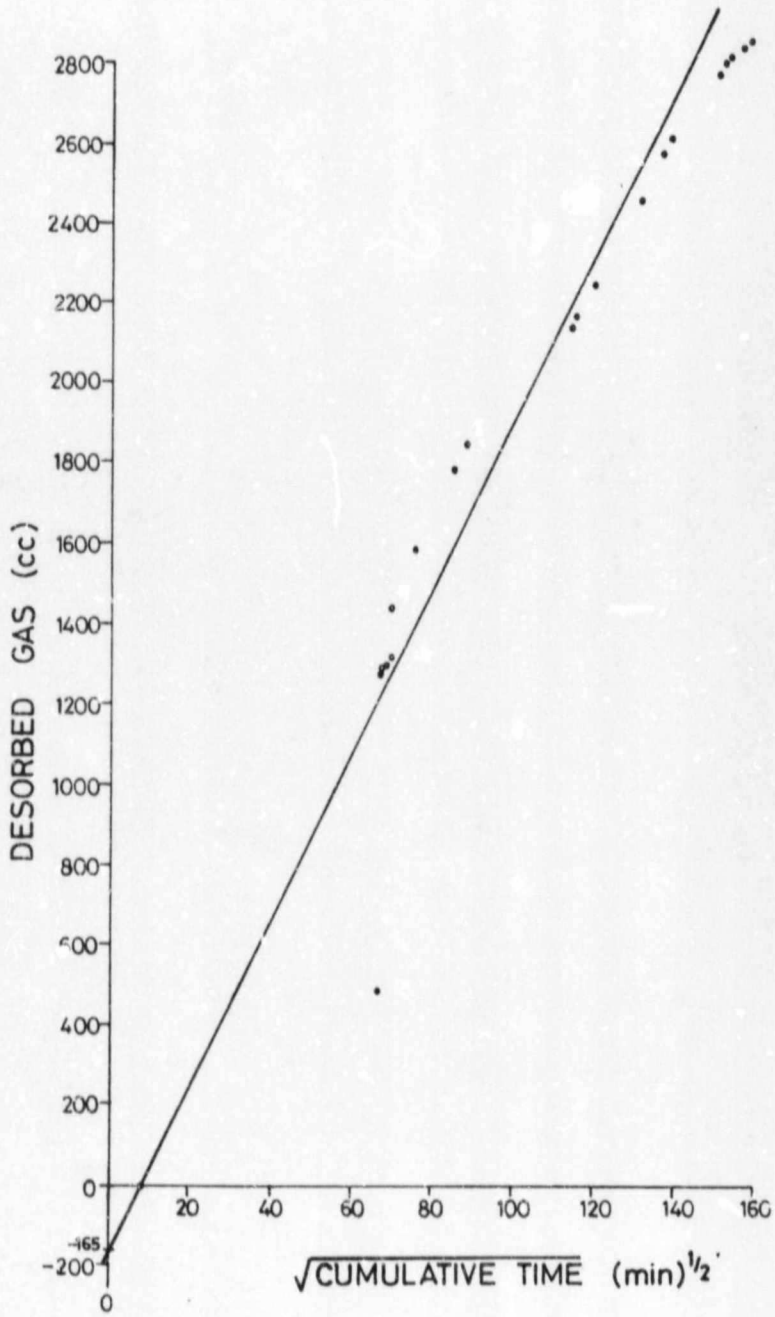
DESORBED GAS (cc)
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
-165
-200
0
20
40
60
80
100
120
140
160
√CUMULATIVE TIME (min)^1/2

FIGURE 67

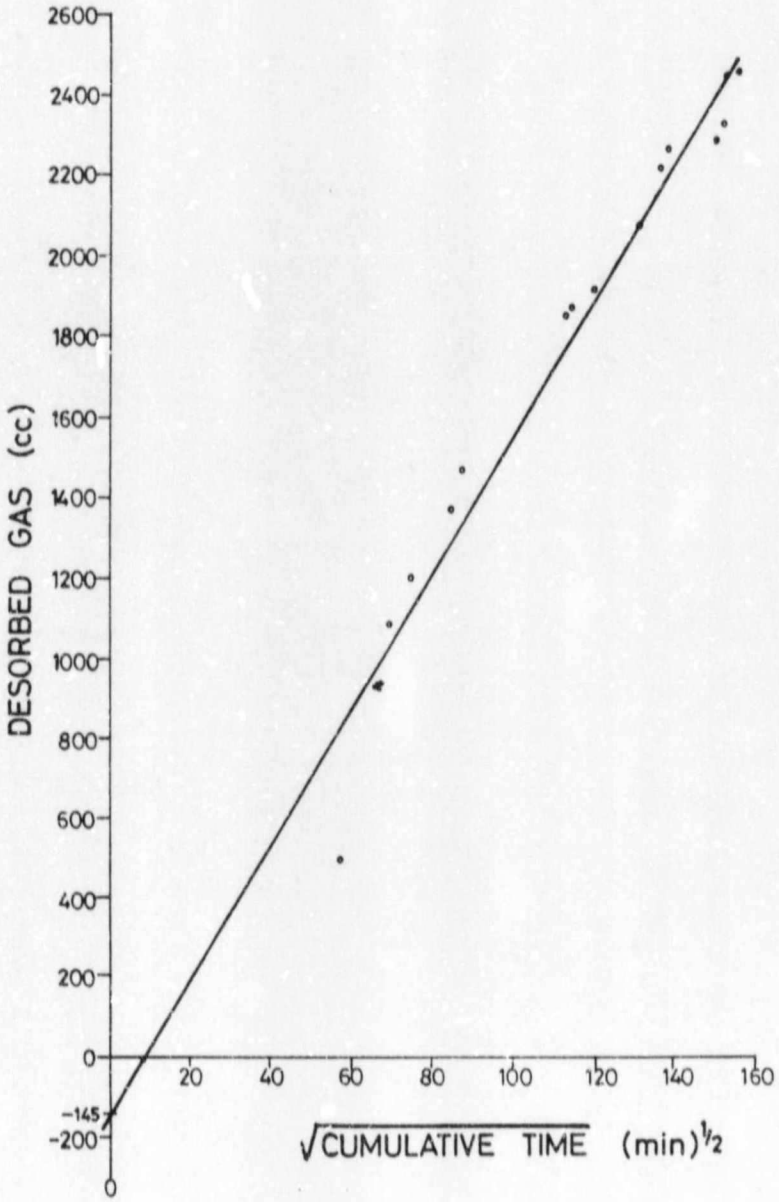
DESORBED GAS (cc)
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
-145
-200
0
20
40
60
80
100
120
140
160
√CUMULATIVE TIME (min)^1/2

FIGURE 68

5. RESULTS AND DISCUSSION

5.1 Presentation of Sorption Results - Indirect Method

The data, after being processed by Program 3, is written out under headings and the 10°C, 20°C and 30°C isotherms are drawn on one plot. The same process is repeated at 10°C, 20°C and 30°C for results converted to a dry ash free, standard temperature and pressure basis. An example of a printout of the tests which have been processed by Program 3, together with the Langmuir isotherm plots, is presented in the following pages of this dissertation. TABLE 13 lists the Langmuir constants for the tests run.

5.2 Accuracy of Reported Sorption Data

The inherent accuracy of this test method is considered to be approximately 20%. Every effort has been made to minimise any errors which may arise from:-

i) Pressure measurement

The earlier Wika gauges were replaced with larger more accurate (+- 0,3%) master gauges. Both the methane and helium pressure readings were checked to ensure that any error should err on the same side of the true pressure. Thus if both were say + 0,3% their effect should almost cancel out as the volume of helium is subtracted from the volume of methane during the calculations. Nonetheless there is probably some small error inherent in these readings.

TABLE 13 LANGMUIR CONSTANTS (E G BILLENKAMP)

Colliery	Sample Number	Test Temperature 10°C				20°C				30°C			
		k_1 (m^3/t)	k_2 (MPa^{-1})	$k_1(dS)$ (m^3/t)	$k_2(dS)$ (MPa^{-1})	k_1 (m^3/t)	k_2 (MPa^{-1})	$k_1(dS)$ (m^3/t)	$k_2(dS)$ (MPa^{-1})	k_1 (m^3/t)	k_2 (MPa^{-1})	$k_1(dS)$ (m^3/t)	$k_2(dS)$ (MPa^{-1})
Ermelo	1												
	23	16.216	0.769	21.332	0.778	14.827	0.686	19.621	0.683	24.768	0.197	32.473	0.200
	24	10.759	0.771	14.033	0.781	9.313	0.874	12.222	0.869	13.559	0.316	17.672	0.320
	25	9.830	0.868	13.194	0.879	8.770	0.921	11.842	0.915	10.324	0.538	13.871	0.543
Majuba	2					6.473	1.128	10.196	1.128	7.588	0.438	11.952	0.438
	3					15.188	0.470	25.634	0.470	13.253	0.340	22.368	0.340
Hlobane	4					8.320	1.608	11.390	1.608	8.442	0.743	11.557	0.746
	5					11.587	0.402	15.536	0.402	11.455	0.373	15.359	0.373
	6					8.995	1.241	12.468	1.241	11.119	0.617	15.412	0.617
Bosjesspruit	7					10.216	0.927	14.395	0.927	6.945	0.807	9.786	0.807
	8					12.369	0.894	17.539	0.895	7.206	0.971	10.218	0.971
	9					10.544	0.927	17.635	0.927	5.775	1.291	9.659	1.291
Springfield	10	22.171	0.247	34.827	0.248	3.878	1.473	6.126	1.473	4.065	-8.086	6.412	-8.358
	11	13.087	0.621	21.234	0.625	5.550	0.781	9.037	0.781	6.279	1.455	10.199	1.481
	12	20.717	0.506	29.433	0.508	7.638	0.975	10.886	0.975	8.809	1.234	14.195	1.257
Phoenix	13	14.813	0.595	20.789	0.590	11.262	0.813	15.705	0.805	6.962	1.455	9.724	1.446
	14	14.419	0.546	20.089	0.542	11.533	0.823	15.966	0.816	4.378	9.536	6.073	9.167
	15	14.991	0.644	20.649	0.638	11.984	0.753	16.407	0.746	9.139	1.572	12.539	1.558
Umgala	16	15.834	1.023	21.184	1.035	20.725	0.534	28.067	0.531	18.535	0.556	25.006	0.559
	17	10.759	0.972	15.019	0.982	20.260	0.319	28.642	0.316	13.534	0.613	19.068	0.616
Utrecht	18	18.444	0.916	23.572	0.926	22.025	0.629	28.489	0.625	24.129	0.413	31.075	0.416
Klipspruit	19	16.091	0.670	21.299	0.666	9.899	0.554	12.960	0.562	10.074	0.794	13.274	0.795
	20	10.244	0.844	17.253	0.839	11.634	0.863	19.407	0.877	13.350	0.360	22.349	0.361
	21	8.148	1.014	12.086	1.015	8.465	1.032	12.631	1.040	13.080	0.559	19.483	0.563
	22	6.142	1.164	8.030	1.567	10.732	0.366	14.001	0.369	7.765	0.780	10.128	0.785
Piet Retief	26	19.037	0.795	27.031	0.775	20.837	0.585	29.463	0.578				
	27	19.302	0.868	27.717	0.846	19.606	0.833	28.024	0.823				
	28	18.213	0.861	26.422	0.839	20.802	0.544	30.087	0.537				
Blinkpan	29	11.783	0.658	16.384	0.665	14.504	0.402	20.369	0.398	16.316	0.283	22.770	0.282
	30	12.675	0.708	16.242	0.715	14.857	0.428	19.223	0.424	13.869	0.400	17.840	0.396
Douglas	31	12.313	1.132	16.352	1.147	20.052	0.233	26.934	0.231	13.646	0.524	18.161	0.520

PHOENIX COLLIERY

COMPUTER REFERENCE:	PHOEN13
SAMPLE NO.:	13
SAMPLING DATE:	27/02/86
SECTION REFERENCE:	404
AREA:	Beath shaft
COAL SEAM:	Phoenix No.1
SURFACE ELEVATION:	1531.00 m
OVERBURDEN:	47.10 m
MINING HEIGHT:	2.10 m

SAMPLE ANALYSES

RANK:	Bituminous
H.G.I.:	42.00
FIXED CARBON:	50.10 %
VOLATILES:	29.80 %
ASH:	17.90 %
MOISTURE:	2.20 %
APPROXIMATE GAS PRESSURE:	0.32 MPa
APPROXIMATE GAS TEMPERATURE:	0
DRY BULB TEMPERATURE:	16.50 C

TEST DETAILS

TEST NUMBER: 34 TEST DATE: 01/04/86
TEST TEMPERATURE: 10 C SAMPLE MASS: 35.00 g

TEST PRESSURE	BAROMETRIC PRESSURE		VOLUME METHANE	WATER TEMP.	VOLUME HELIUM	WATER TEMP.
	METH	He				
(MPa)	(KPa)	(KPa)	(cc)	(C)	(cc)	(C)
0.50	82.57	82.37	440	17.40	291	15.00
1.00	82.52	82.52	813	17.90	588	17.30
2.00	82.34	82.32	1349	15.00	1048	15.80
3.00	82.71	82.60	2045	13.30	1587	12.10
4.00	82.77	82.61	2678	10.80	2077	13.70
6.00	82.55	82.49	4090	13.50	3205	16.10
8.00	82.78	82.50	5399	14.80	4142	15.40
10.00	82.89	82.32	7172	13.90	5289	15.00

TEST RESULTS

MEASURE METHANE CONTENT	CALC. METHANE CONTENT	DIFF	ERROR	MEASURE METHANE CONTENT daf STP	CALC. METHANE CONTENT daf STP	DIFF	ERROR
(m /t)	(m /t)	(m /t)	(%)	(m /t)	(m /t)	(m /t)	(%)
3.98	3.40	0.6	17	5.56	4.74	0.8	14
5.76	5.53	0.2	4	8.05	7.72	0.3	4
6.91	8.05	-1.1	14	9.63	11.26	-1.6	20
9.07	9.50	-0.4	5	12.69	13.29	-0.6	6
11.23	10.43	0.8	8	15.73	14.60	1.1	11
10.43	11.57	-1.1	10	14.58	16.21	-1.6	14
9.27	12.24	-3.0	24	12.98	17.16	-4.2	34
12.54	12.68	-0.1	1	17.60	17.78	-0.2	1

Langmuir constant K1 = 14.813320
Langmuir constant K2 = 0.595387
Correlation coefficient= 0.960152

Langmuir constant K1dS = 20.788930
Langmuir constant K2dS = 0.590288
Correlation coefficient= 0.958691

TEST DETAILS

TEST NUMBER: 37 TEST DATE: 10/03/86
TEST TEMPERATURE: 20 C SAMPLE MASS: 35.00 g

TEST PRESSURE	BAROMETRIC PRESSURE METH	BAROMETRIC PRESSURE He	VOLUME METHANE	WATER TEMP.	VOLUME HELIUM	WATER TEMP.
(MPa)	(KPa)	(KPa)	(cc)	(C)	(cc)	(C)
0.50	82.04	82.24	437	22.30	298	20.80
1.00	81.95	81.86	770	21.10	577	20.60
2.00	82.08	81.89	1403	19.70	1106	20.80
3.00	82.08	81.98	1980	20.00	1629	19.00
4.00	82.33	81.98	2657	20.20	2112	20.00
6.00	82.41	82.14	3978	19.80	3190	20.80
8.00	82.49	82.12	5263	19.70	4112	21.30
10.00	82.95	82.00	6712	20.70	5479	21.30

TEST RESULTS

MEASURE METHANE CONTENT	CALC. METHANE CONTENT	DIFF	ERROR	MEASURE METHANE CONTENT daf STP	CALC. METHANE CONTENT daf STP	DIFF	ERROR
(m /t)	(m /t)	(m /t)	(%)	(m /t)	(m /t)	(m /t)	(%)
3.76	3.25	0.5	16	5.22	4.51	0.7	22
5.07	5.05	0.0	0	7.03	7.01	0.0	0
7.13	6.97	0.2	2	9.90	9.69	0.2	3
6.48	7.99	-1.5	19	9.01	11.11	-2.1	26
9.88	8.61	1.3	15	13.76	11.98	1.8	21
9.72	9.35	0.4	4	13.55	13.01	0.5	6
11.00	9.76	1.2	13	15.36	13.59	1.8	18
-0.53	10.03	-10.6	105	-0.75	13.97	-14.7	147

Langmuir constant K1 = 11.261760
Langmuir constant K2 = 0.812581
Correlation coefficient= 0.920961

Langmuir constant K1dS = 15.704680
Langmuir constant K2dS = 0.805471
Correlation coefficient= 0.919552

TEST DETAILS

TEST NUMBER: 40 TEST DATE: 03/03/86
TEST TEMPERATURE: 30 C SAMPLE MASS: 35.00 g

TEST PRESSURE	BAROMETRIC PRESSURE METH	BAROMETRIC PRESSURE He	VOLUME METHANE	WATER TEMP.	VOLUME HELIUM	WATER TEMP.
(MPa)	(KPa)	(KPa)	(cc)	(C)	(cc)	(C)
0.50	82.43	82.36	415	29.40	303	32.00
1.00	82.52	82.40	730	28.60	606	33.70
2.00	82.20	82.06	1401	30.30	1149	31.20
3.00	82.11	82.04	2005	29.70	1695	29.00
4.00	82.65	82.52	2480	28.90	2109	30.30
6.00	82.67	82.65	3772	30.00	3144	31.00
8.00	82.73	82.40	5070	29.00	4214	31.60
9.50	82.23	82.45	6167	33.60	4974	29.80

TEST RESULTS

MEASURE METHANE CONTENT	CALC. METHANE CONTENT	DIFF	ERROR	MEASURE METHANE CONTENT daf STP	CALC. METHANE CONTENT daf STP	DIFF	ERROR
(m /t)	(m /t)	(m /t)	(%)	(m /t)	(m /t)	(m /t)	(%)
3.18	2.93	0.3	9	4.44	4.08	0.4	12
3.48	4.13	-0.6	16	4.86	5.75	-0.9	22
5.90	5.18	0.7	14	8.21	7.23	1.0	19
5.60	5.66	-0.1	1	7.78	7.90	-0.1	2
5.86	5.94	-0.1	1	8.20	8.29	-0.1	2
6.76	6.25	0.5	8	9.46	8.72	0.7	12
5.45	6.41	-1.0	15	7.63	8.95	-1.3	21
1.11	6.49	-5.4	83	1.55	9.06	-7.5	116

Langmuir constant K1 = 6.962179
Langmuir constant K2 = 1.455196
Correlation coefficient= 0.986792

Langmuir constant K1dS = 9.723879
Langmuir constant K2dS = 1.445944
Correlation coefficient= 0.987098

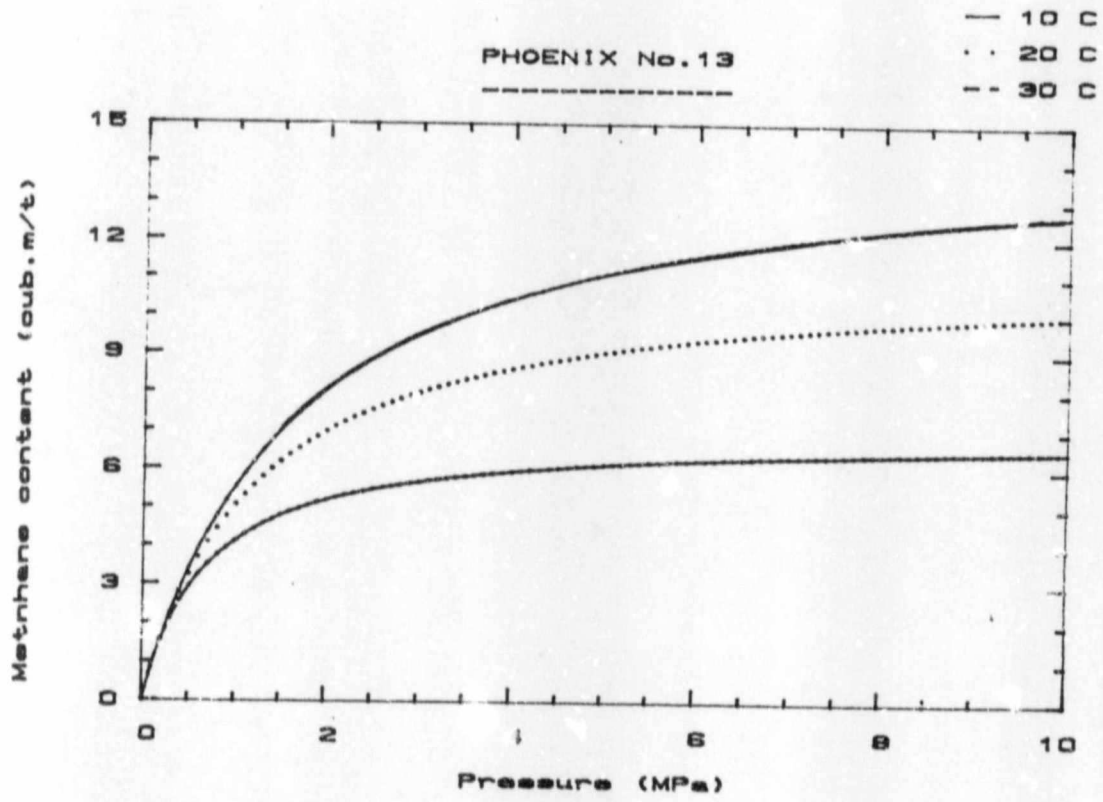
PHOENIX No.13
10 C
20 C
30 C
Methane content (cub.m/t)
15
12
9
6
3
0
0
2
4
6
8
10
Pressure (MPa)

FIGURE 69

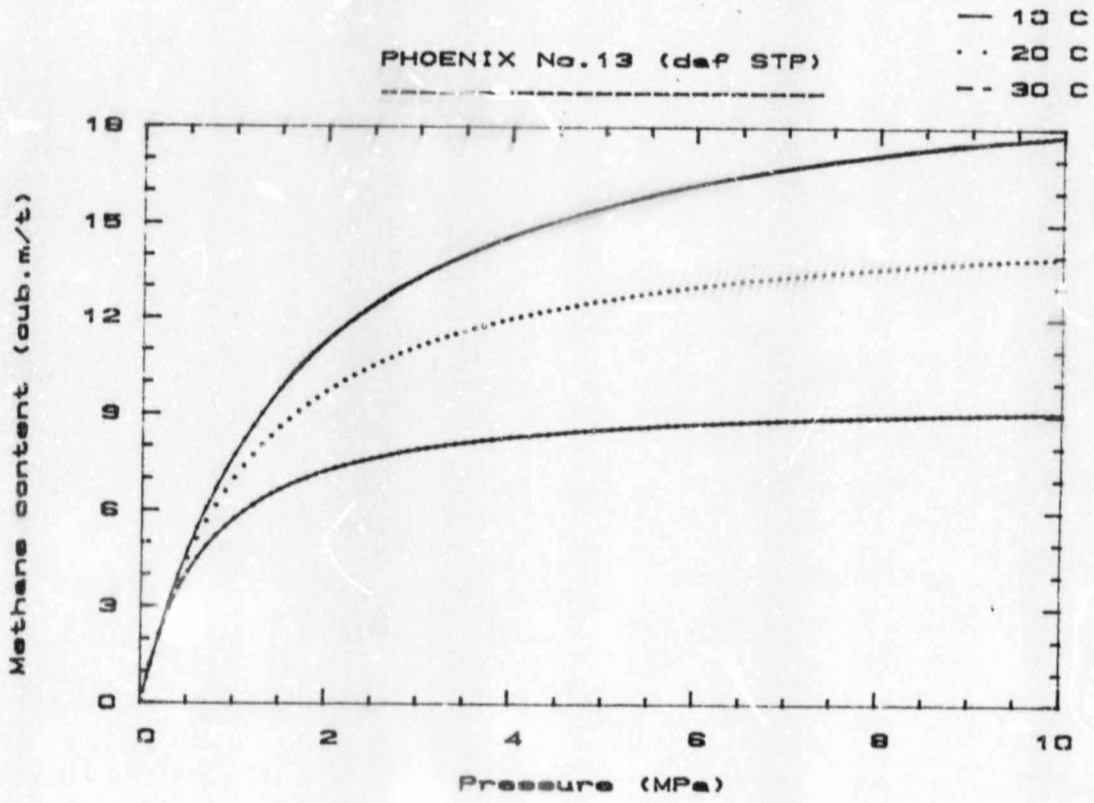
PHOENIX No.13 (daf STP)
10 C
20 C
30 C
Methane content (cub.m/t)
0
3
6
9
12
15
18
0
2
4
6
8
10
Pressure (MPa)

FIGURE 70

ii) Volumetric measurement

Replication of experiments showed that for each 1000 cc measured the reading could be out by at most 3 cc. Let us assume that for a pressure of 10,0 MPa, the average methane reading is overestimated by +2 cc/1000 cc and the helium reading is underestimated by the same amount i.e. an extreme case V (CH_4) would be over by about 14 cc and V (He) under by about 11 cc, causing V (He) equiv to be under by 14 cc. Thus the error in methane content TDM is 28 cc/35,0 g = 0,8 m^3/t. This error is then as much as 4-8% of the total.

iii) The assumption that the gas reaches the same temperature as the basin water

During desorption the initial 1000 cc volumes are bled off quite quickly and only the final volume of methane is allowed to take a long time to bleed off.

It has not been established whether the final temperature of the gas in the cylinder is the same as that of the water bath. The gas probably has not quite reached the same temperature of the water for the 1000 cc volumes. However the error this causes is quite small.

iv) Test gas impurities

The compressibility factors obtained from the two references (9, 19) relate to pure methane and helium. The methane and helium used in these tests is C,5% and 0,1% impure respectively. Any inaccuracies which could have been caused by this

has been compensated for by using the compressibility factor for air. Thus the methane compressibility and helium compressibility factors are a weighted combination of gas and air.

The final figure is a relative compressibility factor. This is the ratio of methane to helium compressibility factors. How this figure has been derived is given in a worked example for 3,0 MPa in Appendix B. It is no longer possible that any measurable inaccuracy could arise from gas impurities.

These four factors above do not account for why there are such large variations in the test results. However this phenomena can be seen in the published results of other research workers (118). Reference (118) quoted that the tests should be run at least three times, and a mean value used. Unfortunately this would cause each series of tests to take an unacceptably long time period (6-8 weeks). As a result, the mining department has elected to purchase a gravimetric test apparatus which is far less time consuming.

5.3 Regression Analyses of Langmuir constants versus Fixed Carbon and Volatiles

The regression aspect of the Statgraphics software package was used to compare the percentage fixed carbon and volatiles to K_1 and K_2. The K_1 and K_2 values used were those for dry, ash free coal.

The results confirm those from other researchers in that methane sorption capability of South African coals is proportional to rank and thus inversly proportional

to percentage volatiles. Plots of this regression is given in Appendix E.

5.4 Presentation of Sorption Results - Direct Method

The quantity of gas that would enter the mine during mining is $Q_1 + Q_2$. The remnant gas Q_3 that still remains in the coal in the test cylinders would also remain in the coal which is being transported to surface.

Thus for the gassiest sample tested, K200 Gus seam, $Q_1 + Q_2$ = 5510 cc and the mass of coal = 10071 g. Thus this direct test indicates a methane make of 5510/10071 = 0.55 m^3/t.

The depth of the bottom of the Gus seam is 179.37 m and top of the seam is 177.98 m. Using A.G. Kim's (41) method, the expected gas pressure is 0.63 x 1000 x 9.81 x [(177.98+179.37)/2] = 1.1 MPa. Comparing this with the indirect test 20°C isotherm (FIGURE 71) at 1.1 MPa, the expected gas make is 3.7 m^3/t. Even using the lower limit of 0.26 instead of 0.63 x hydrostatic head gives an expected gas pressure of 0.46 MPa and an expected gas make of 1.9 m^3/t.

It can be seen that the direct and indirect tests for the same sample do not agree by a factor of 6.7. This is an unacceptably large discrepancy. Usually the two methods agree to within 20% and sometimes only to within 30% but not 670%. For this reason the results were considered suspect. After the Klipspruit tests were complete, no further direct tests were done.

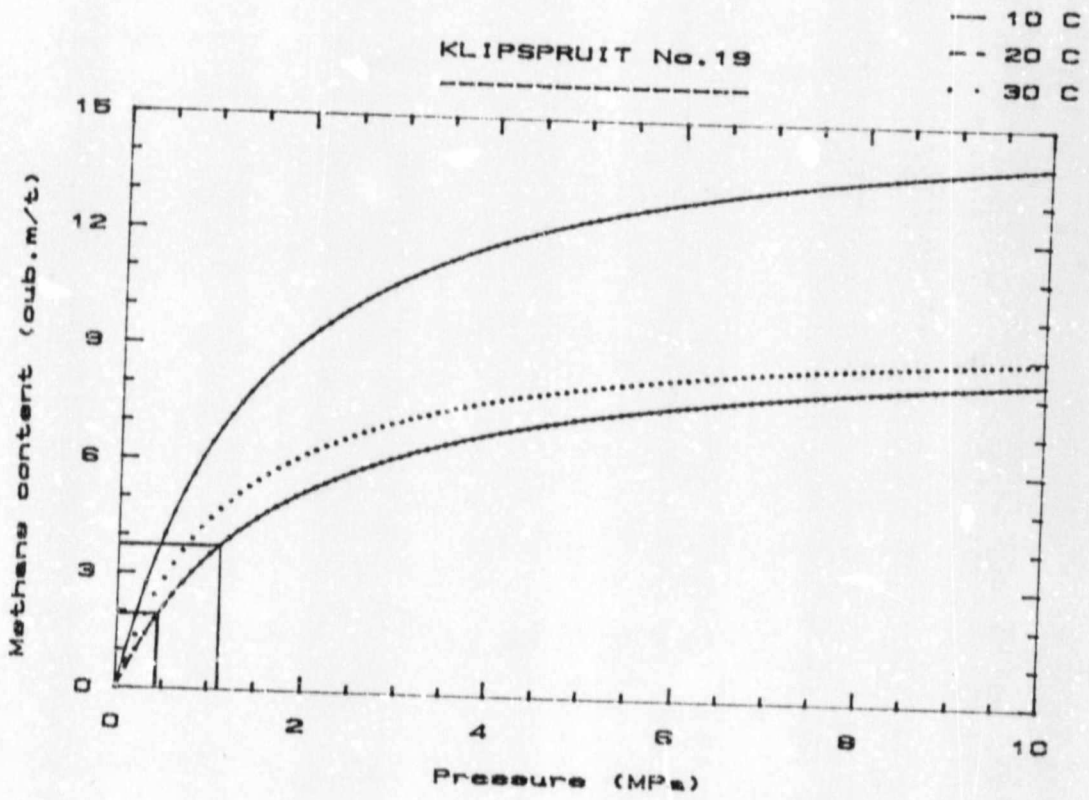

FIGURE 71 Klipspruit core K 200 Gus seam

5.5 Permeability and Gas Pressure Work

The permeability test apparatus had only been tested and commissioned when the sorption testing was completed. This work is now ongoing. The borehole gas pressure probes have also been commissioned and tests have just begun. No results were ready for this report.

5.6 Discussion

The only underground seam temperature and gas pressure readings were done by Anglovaal on a borehole for their Klipspruit project. The results are listed in TABLE 11.

The depth at which this core was excavated is of the order of the depth of many of the mines sampled. The seam temperature shown here would lead us to assume that other seam temperatures are around 20°C.

The seam gas pressure data may or not be accurate as it is possible that some of the full pressure build up may not have occurred as gas may have bypassed the seals via the permeable strata.

The ratio of overburden depth has been determined by research at the USBM in America by A.G. Kim (41).

Seam gas pressure $P = 0,63 \times$ hydrostatic head

$= 0,63 \times \rho_{water} \times gh$

where ρ_{water} = density of water = $1,0 \times 10^3$ kg/m^3

$g = 9,81$ m s^{-2}

h = depth of overburden + 1/2 (seam thickness)

The hydrostatic head is taken as the upper limit for gas pressures which may be encountered. The lower limit is the same margin (1,0 - 0,63 = 0,37) below the value determined by Kim's method. Thus the expected gas pressure is between 0,26 to 1,0 times the hydrostatic head, with the most likely value being 0,63. The range of seam temperatures measured in S.A. are between 18°C and 23,4°C. The ranges for pressure and temperature lead to a large degree of uncertainty of what the in-seam methane content is. This problem will be overcome when pressure and temperature measurements have been taken as part of work which is now in progress.

This is not the full picture of expected methane release. Surrounding strata contributes a significant amount of the gas make. Sandstone and carbonaceous shale have about 10% of the gas of the nearest coal seams. Non carbonaceous shale has only 1% of the gas content of nearby seams. An average of 4% was found to be the best fit in Germany. For longwall mining up to 100 m of the roof starata and 50 m of the strata in the floor contribute to gas make. The percentage of this contribution is related to the distance from the working seam (FIGURES 35-39).

The total desorbable methane content (TDM) does not take the free gas accumulated in the pores and fissures in coal. This accounts for about another 10% of desorbable methane underground. However not all of the total desorbable methane content is desorbed underground. Only 50-80% is desorbed underground and the remaining 20-50% leaves the mine as risidual gas in the coal transported out of the mine. In France this is taken as being the TDM less 2 m^3/t. For lack of any research done in South Africa, the methane make from the worked seam and surrounding strata can be taken as:

Expected methane make
= 0,1 x TDM + TDM - 2,0 m^3/t + surrounding strata
= 1,1 x TDM - 2,0 m^3/t + (4% of TDM x sliding scale for roof and floor strata)

The area in the roof can be assumed to be up to 100 m in the roof and 50 m in the floor for longwall mining but far less for board and pillar workings. More research into this is required.

Peaks in methane make must also be considered. For calculating ventilation requirements to dilute the methane to within mining standards a peak factor of 2,0 is usually used.

The permeability aspect really falls outside the initial scope of this work but it has been designed and commissioned for future work. Thus any discussion is relegated to recommendations in the next chapter.