

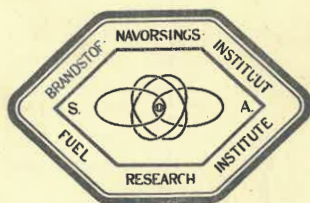
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FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

BRANDSTOF-NAVORSINGS-INSTITUUT VAN SUID-AFRIKA.

SUBJECT: THE OXYGEN ABSORPTION CHARACTERISTICS OF
ONDERWERP: SOUTH AFRICAN COALS.

DIVISION: CHEMISTRY.
AFDELING:

NAME OF OFFICER: P. G. SEVENSTER.
NAAM VAN AMPTENAAR:

THE OXYGEN ABSORPTION CHARACTERISTICS OF SOUTH AFRICAN COALS.

by: P. G. Sevenster.

All coals absorb oxygen in a physico-chemical sense and it is generally accepted that some relationship exists between the capacity of a coal to absorb oxygen and its liability to fire spontaneously. The oxygen absorption capacity, therefore, furnishes a means of studying this property. The data obtained could then be combined with other data, already existing, or to be obtained, in attempting to evaluate the relative liability of various South African coals towards spontaneous combustion.

The primary object of the present investigation was to ascertain the oxygen absorption characteristics of South African coals using a technique based on that developed by Winmill.⁽¹⁾

The apparatus consists of a glass reaction tube A, 50 cm. long having a diameter of 4.5 cm., containing a receiver B for the coal sample. The receiver is constructed of twelve aluminium cups arranged vertically on a non-corroding metal rod. The lower end of the rod is fitted with a piece of glass tubing closed at its bottom end to prevent the rod from coming in contact with the potassium hydroxide solution introduced into the tube for absorbing any carbon dioxide generated by the reaction. (See Figure 1).

The reaction/.....

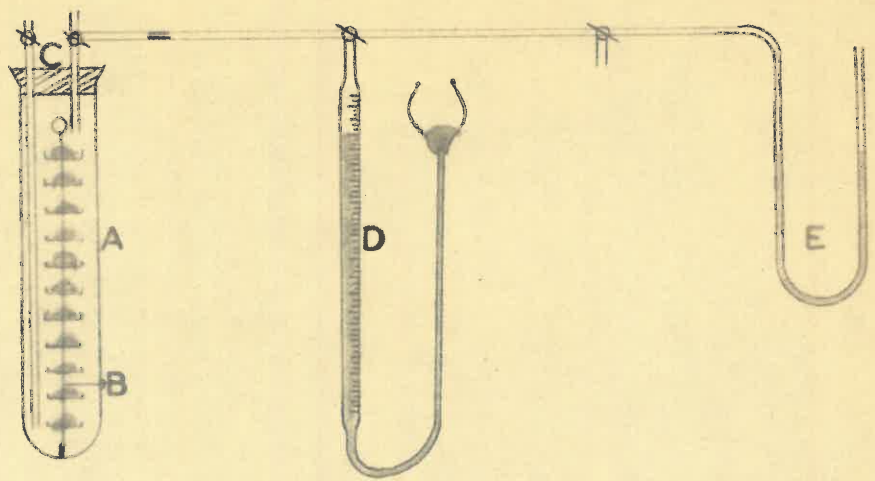


FIG. 1. OXYGEN ABSORPTION APPARATUS.

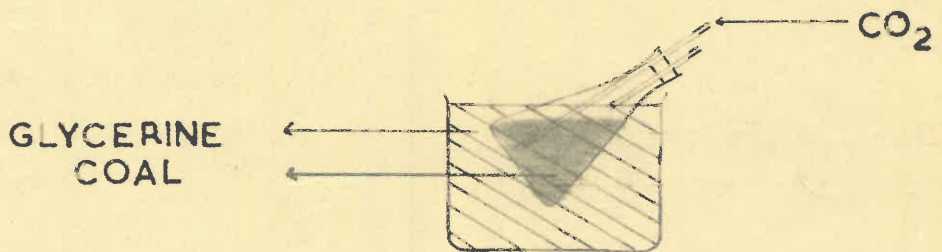


FIG. 2. DRYING COAL IN CO₂ ATMOSPHERE.

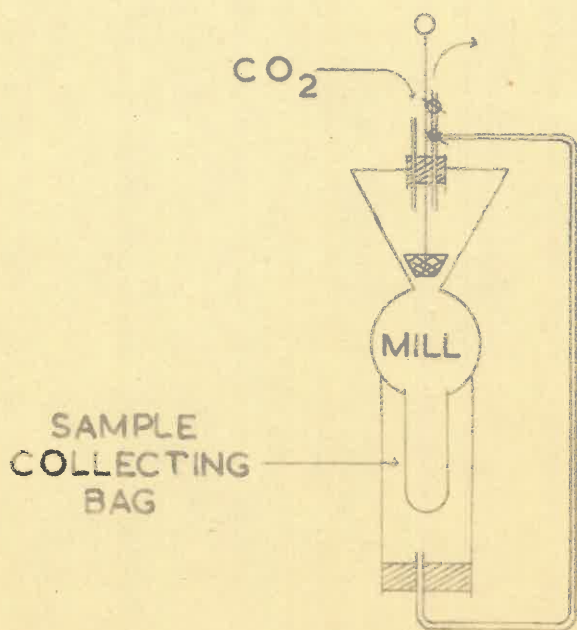


FIG. 3. CRUSHING COAL IN CO₂ ATMOSPHERE.

The reaction tube is closed by means of a rubber stopper C fitted with two glass tubes. One is used to evacuate the tube and to introduce the potassium hydroxide solution and the other tube serves to connect the reaction tube to the gas-burette D and manometer E.

The former tube extends to the bottom of the reaction tube to avoid contact of alkali with the aluminium cups.

PROCEDURE:

30 gm. of freshly ground -60 mesh coal (see : Preparation of Sample) is placed in thin layers in the cups of the receiver which is then inserted in the tube. The tube is stoppered and rendered airtight by painting with molten wax, and is then placed in a constant temperature bath.[ⓧ] (A bath was used which could accommodate six tubes.) The reaction tubes are immediately evacuated by means of a rotary oil pump for at least 48 hours to remove air, and, as far as possible, all absorbed gasses.

The gas-burette and connecting tubes are filled with oxygen from a cylinder and the exact volume at atmospheric pressure is read off. After evacuation air is let into the tube (A) and 10 ml. potassium hydroxide solution introduced.^(ⓧ)

The reaction tube and the gas-burette are then connected by means of a piece of rubber tubing.

Readings of the gas volume at atmospheric pressure, of the barometric pressure and of the room temperature at the burette are taken every time the burette requires filling or every 24 hours, whichever falls due first.

The reaction pressure is at all times maintained as near as possible to atmospheric pressure.

The total/.....

[ⓧ] Experiments are conducted at 30°C and 60°C.

(ⓧ) See recommendation on page 18.

The total volume of oxygen absorbed over a period of 96 hours is determined.

Preliminary experiments were conducted in a dry and wet atmosphere and since higher absorption figures were obtained under moist conditions and these might conform better to conditions met in practice, they were adopted as standard.

In order to ensure a controlled humidity in the reaction tubes at 30°C and 60°C the concentration of the potassium hydroxide solution used were chosen so as to exert the same vapour pressure at the two temperatures as follows:-

	<u>Temperature.</u>	
	<u>30°C.</u>	<u>60°C.</u>
Concentration of potassium hydroxide solution	20.0%	49.2%
Vapour pressure above solution	29 mm. Hg.	29 mm. Hg.
Water vapour in tube (volume per cent.)	4.5	4.5

PREPARATION OF SAMPLE:

Special precautions are necessary with samples intended for the determination of oxygen absorption characteristics. It is virtually impossible to work on an absolutely fresh sample and the only alternative is to reduce the exposure of samples to the atmosphere to a minimum.

The sample is taken at a fresh face as soon as possible after blasting, and the whole face, as normally mined, is represented. The face may be divided into two or more sections as may seem desirable from the variations noticeable in the coal, and a sample taken of each section. Samples should be taken at at least three places, suitably distributed over the working area, so as to determine any variation in the oxygen absorption characteristic of the coal sampled at the different points. The location, type of coal and thickness of section/.....

of section is described when taking the samples. Bands of shale and pyrites nodules which would normally be discarded in the preparation of the coal are measured, described and excluded from the sample.

Samples are hewn from the cleaned solid face by cutting a narrow channel with a small pick and the cuttings are immediately placed under distilled water in a 2 litre jar which is tightly closed. For convenience in the further treatment it is desirable that the volume of a sample should neither exceed 2 litres nor be appreciably less than 2 litres.

It has been estimated that even if distilled water were saturated with air the amount of oxygen dissolved in the water and available to 100 gm. of coal stored as described above would amount to only about 0.4 ml., which is much less than the experimental errors involved in the determinations. Distilled water is preferred as there is evidence that calcium salts and other soluble impurities in the water decrease, appreciably the amount of oxygen absorbed by coal.⁽²⁾

In the laboratory the sample has to be dried sufficiently in the absence of air to enable it to be pulverized. This is done by transferring it to 1 litre, wide mouth Erlenmeyer flasks. The sample is drained thoroughly by shaking the flask in an inverted position while a fine wire gauze is held over its mouth. The flask is then closed by a rubber stopper fitted with inlet and outlet tubes. (See Figure 2),

Carbon dioxide from a cylinder is now passed through the system to displace the air. And thereupon, while carbon dioxided stream is maintained the flask is submerged in a glycerine bath at 140 - 150°C for about 20 minutes or until the escape of steam at the outlet tube has apparently ceased

and the/.....

and the coal, although not quite dry, is normally dry enough for grinding. The flask is then transferred to a cold water bath for cooling in the carbon dioxide atmosphere.

The sample is crushed in a "Hush" disc pulverizer set to yield $-\frac{1}{8}$ " material which is divided into three portions in a riffle. The portions not required immediately for testing are stored under distilled water.

The portion required for immediate testing is crushed to -60 mesh in a W.B. high speed swing hammer type laboratory mill. This mill has been adapted so as to enable the sample to be kept in a carbon dioxide atmosphere throughout this final grinding.

The feeding device of the mill is replaced by a sheet metal conical container. (See Figure 3). A rubber bung fitted with a plunger and tubes closes the conical flask at the top. The plunger fits snugly in the bung but can be moved up and down. The plunger prevents coal from rushing into the mill but does not make a gas tight seal. A short length of a motor car tube is fitted tightly over the outlet of the mill, the sample collecting bag hanging inside the tube. A wooden bung, fitted with a tube to connect the upper and lower parts of the system closes the lower end of this tube.

The plunger is placed in position and coal introduced into the vessel. Carbon dioxide from a cylinder is flushed through the system replacing all air. Finally the gas outlet is closed and the carbon dioxide recirculated through

the mill, /.....

the mill, any leakage of this gas from the system being made good by applying continuously slight positive pressure from the cylinder. The mill is started, and by manipulating the plunger the coal is slowly fed to the mill.

CALCULATION OF RESULTS:

The expression for calculating the volume of gas absorbed at normal temperature and pressure is:-

$$\left\{ \frac{(a-b)273xP_1}{(t_b + 273)x29.92} \right\} + \left\{ \frac{bx273xP_1}{(t_1+273)x29.92} \right\} + \left\{ \frac{V_1x273xP_1}{(t_1+273)x29.92} \right\} - \left\{ \frac{(a-b)273xP_2}{(t_b+273)29.92} \right\} \\ - \left\{ \frac{bx273xP_2}{(t_2+273)29.92} \right\} - \left\{ \frac{V_2x273xP_2}{(t_2+273)29.92} \right\} \quad \text{which may be reduced}$$

$$\text{to } \frac{273}{29.92} \left[\frac{(a-b)(P_1-P_2)}{(t_b + 273)} + \frac{P_1(b + V_1)}{t_1 + 273} \right] - \left[\frac{P_2 (b + V_2)}{t_2 + 273} \right]$$

where

a = free volume (ml.) of gas in system (excluding burette).

b = that portion of a which is outside the thermostatic bath.

V₁ = volume of gas (ml.) in burette before absorption.

V₂ = volume of gas (ml.) in burette after absorption.

P₁ = barometric pressure (ins. Hg) when reading V₁.

P₂ = barometric pressure (ins. Hg) when reading V₂.

t₁ = temperature (°C) of burette when reading V₁.

t₂ = temperature (°C) of burette when reading V₂.

t_b = temperature (°C) of thermostatic bath.

The oxygen absorption tests are carried out on 30 gm. of moist coal in an atmosphere of air. The volume of oxygen absorbed is subsequently expressed in ml. at normal temperature and pressure absorbed by 100 grams of dry coal.

TABULATION AND DISCUSSION OF RESULTS:

For the purposes of correlation, the collieries from which the samples were taken are grouped into geographical areas.

The values/.....

The values for the volume of oxygen absorbed over a period of 96 hours calculated for 100 grams of dry coal, are expressed in ml. at normal temperature and pressure.

TABLE 1.
SAMPLES TAKEN FROM COLLIERIES IN NATAL.

Colliery.	Seam.	Sample No.	Proximate Analysis of air-dry coal.			Oxygen absorption in ml.	
			% Ash.	% H ₂ O.	% V.M.	at 30°C	at 60°C
D.N.C. No.3	Top	S443B	11.0	1.3	30.2	200	232
"	"	Bottom S446A	11.7	-	31.3	102	136
"	"	Top S449B	13.2	1.6	28.5	144	222
"	"	Bottom S443A	11.4	1.5	28.7	131	252
"	"	Bottom S444	13.0	1.3	32.0	129	177
"	"	Bottom S445	12.6	1.3	32.0	129	216
"	"	Top S446B	18.6	1.2	27.8	116	217
"	"	Bottom S448	12.8	1.3	31.8	116	222
"	"	Bottom S449A	13.8	1.5	31.3	104	219
Cambrian	Top	S450	11.5	1.2	20.6	148	251
"	Top	S451B	14.0	3.4	4.2	216	346
"	Bottom	S451A	17.4	4.1	4.1	236	330
"	Bottom	S452	14.7	1.5	26.5	175	209
"	Bottom	S453	13.6	-	26.6	171	210
Platberg	?	T183A	20.0	1.0	26.6	126	216
"	?	T183B	18.0	1.0	24.0	140	221
"	?	T184A	19.0	1.2	21.0	132	217
"	?	T184B	17.0	1.0	24.0	130	230
Alpha Anthracite	Gus	R314	9.3	1.8	10.7	214	264
Alpha Anthracite	"	R315	9.1	1.7	10.4	234	274

For most of the Natal samples tested the volume of oxygen absorbed at 30°C varies between 100 ml. and 200 ml. and at 60°C between 170 ml. and 300 ml. The moisture content of the air dried coals usually lies between 1.0% and 2.0%.

Samples Nos. S451 A and B (% V.M. 4.1) which were taken in the immediate vicinity of a dolomite dyke which intersects the coal seam, have much higher moisture contents (4.1 and 3.4%, respectively) and a greater affinity for oxygen than the other coals in this group. The anthracite samples (Nos. R314 and R 315) also show this tendency to absorb more oxygen than the other coals with the same moisture content.

TABLE 2.

SOUTHERN WITBANK AREA.

Colliery.	Seam.	Sample No.	Proximate Analysis of air-dry coal.			Oxygen absorption in ml.	
			% Ash.	% H ₂ O.	% V.M.	at 30° C	at 60° C
Alpha	No. 5	S255A	16.7	2.6	25.6	257	513
"	"	S255B	24.7	3.0	19.5	248	507
"	"	S255C	34.8	2.8	18.2	248	412
"	No. 4	S229A	14.1	-	-	270	414
"	"	S229B	22.7	-	-	223	303
"	"	S230A	14.2	-	-	271	406
"	"	S60A	16.1	3.8	25.1	319	772
"	"	S60B	29.5	3.5	20.5	194	610
"	"	S61A	15.5	3.6	26.1	306	719
"	"	S61B	27.6	3.4	22.3	230	645
"	"	R526A	15.8	3.9	25.0	240	470
"	"	R526B	30.2	4.2	19.4	210	470
W.C.C.M.Ltd.	"	S98A	15.6	3.5	26.2	275	690
"	"	S98B	22.8	3.3	24.2	242	594
"	"	S98C	20.1	3.2	26.2	192	550
South Witbank	No. 5	T102A	15.9	4.1	31.9	372	700
"	"	T102B	13.3	3.9	31.4	330	700
"	"	T102C	18.8	4.2	26.4	350	500
Acme	No. 4	S256A	11.9	5.0	28.2	332	756
"	"	S256B	20.4	4.8	24.1	318	750
"	"	S256C	21.3	4.7	23.2	352	728
"	"	S257A	11.9	2.9	28.7	399	728
"	"	S257B	20.4	3.2	22.8	382	698
"	"	S257C	21.3	2.7	26.1	437	698
New Tavistock	"	S553	18.5	3.0	24.0	441	517
"	"	S554A	13.5	3.2	26.3	552	634
"	"	S554B	17.1	3.7	20.9	414	611
"	"	S554C	17.7	3.6	26.6	340	511
"	"	S554D	21.5	3.1	24.0	267	481
"	"	S577	12.2	3.3	24.0	395	608
"	"	S578	10.4	3.7	26.5	310	689
"	No. 2	T48A	11.3	3.1	28.8	339	548
"	"	T48B	16.9	3.0	26.0	316	496
"	"	T48C	12.6	3.2	29.6	290	557

The moisture content of the samples from the Southern Witbank area varies between 2.6% and 5.0%. The volume of oxygen consumed at 30°C ranges from 190 ml. to 550 ml. and at 60°C from 303 ml. to 770 ml.

TABLE 3/.....

TABLE 3.
SOUTH EASTERN WITBANK AREA.

Colliery.	Seam.	Sample No.	Proximate Analysis of air-dry coal.			Oxygen absorption in ml.	
			% Ash.	% H ₂ O.	% V.M.	at 30°C	at 60°C
New Douglas	No. 2	S351 A	14.7	2.1	31.2	254	582
"	"	S351 B	12.9	2.2	33.3	328	526
"	"	S351 C	14.0	2.0	26.7	359	540
"	"	S351 D	15.0	2.3	22.9	274	433
"	"	S352 A	21.2	2.6	22.4	336	419
"	"	S352 B	11.9	2.6	30.3	373	435
"	"	S352 C	20.9	2.3	23.4	365	415
Tvl. Navigation	"	S156 A	15.7	2.6	26.6	226	500
"	"	S156 B	10.6	3.0	32.4	281	657
"	"	S157 A	9.5	2.9	31.6	245	596
"	"	S157 B	7.9	2.7	29.3	290	623
"	"	S158 A	12.5	2.3	26.7	223	516
"	"	S158 B	9.3	2.7	31.4	280	616

The oxygen absorbed by the samples of coal from the South Eastern Witbank area varies between 220 ml. and 370 ml. at 30°C and at 60°C between 415 ml. and 660 ml. The per cent moisture (air-dry) ranges from 2.0% to 3.0%.

TABLE 4.
WITBANK AREA.

Colliery.	Seam.	Sample No.	Proximate Analysis of air-dry coal.			Oxygen absorption in ml.	
			% Ash.	% H ₂ O.	% V.M.	at 30°C	at 60°C
Landau	No. 2	T16 A	9.0	1.6	38.9	176	315
"	"	T16 B	8.2	1.7	37.0	226	336
"	"	T16 C	9.2	1.9	29.9	159	311
"	"	T16 D	12.3	2.1	27.1	147	363
"	"	T16 E	13.5	2.3	23.8	322	333
"	"	T16 F	19.7	2.0	19.3	315	339
"	"	T17 A	9.6	1.5	39.7	276	300.
"	"	T17 B	8.6	2.0	37.4	279	314
Greenside	No. 1	T80 A	13.3	1.9	31.2	286	387
"	"	T80 B	13.9	2.0	36.9	271	347
"	No. 2	T81 A	14.9	2.1	32.0	290	310
"	"	T81 B	12.5	2.0	34.8	261	383

Regarding samples from the Witbank area, if the values for Samples Nos. T16 E and F are disregarded the volume of oxygen consumed at 30°C varies between 150 ml. and 290 ml. and at 60°C between 300 ml. and 380 ml. The air-dry moisture content varies between 1.5% and 2.3%.

The values for Samples Nos. T16 E and F are comparable with those of Samples T314 and T315 and S451 A and B. (See Table 1)

TABLE 5.

NORTHERN WITBANK AREA.

Colliery.	Seam.	Sample No.	Proximate Analysis of air-dry coal.			Oxygen absorption in ml.	
			% Ash.	% H ₂ O.	% V.M.	at 30°C	at 60°C
Coronation	No. 1	T154	9.8	2.2	26.8	173	368
"	"	T155	10.0	2.5	26.0	200	393
"	"	T138A	9.8	2.4	26.8	180	390
"	"	T138B	10.0	2.2	25.6	182	341
"	"	T138C	8.8	2.4	27.4	201	368
"	"	T139	9.2	2.1	24.0	200	324

Regarding the Northern Witbank area the oxygen absorption at 30°C varies between 170 ml. and 200 ml. and at 60°C between 324 ml. and 390 ml. The per cent moisture (air-dry) varies between 2.1% and 2.5%. The samples were taken from one colliery only.

TABLE 6.

MIDDELBURG - BELFAST AREA.

Colliery.	Seam.	Sample No.	Proximate Analysis of air-dry coal.			Oxygen absorption in ml.	
			% Ash.	% H ₂ O.	% V.M.	at 30°C	at 60°C
Palmer	?	S222	16.6	5.7	22.2	393	712
"	"	S223	13.3	6.1	22.3	437	770
"	"	S224	13.6	6.0	24.3	413	752
"	"	S225	10.3	6.6	22.3	461	956
"	"	S226	11.0	5.8	23.2	504	1062
"	"	S227	18.9	5.6	21.0	482	953
Uitkyk	?	S370A	13.3	3.2	24.5	418	655
"	"	S370B	13.7	3.6	20.1	397	614
"	"	S371A	24.6	2.9	20.9	412	487
"	"	S371B	15.9	3.5	20.1	499	631
Belfast	?	S607A	14.0	5.5	23.6	411	744
"	"	S607B	19.6	5.6	17.7	324	690
"	"	S608A	13.6	5.5	22.9	414	679
"	"	S608B	18.1	5.6	18.7	409	660

The moisture content of the samples from the Middelburg-Belfast area ranges from 2.9% to 6.6% and the oxygen absorbed at 30°C from 325 ml. to 500 ml. and at 60°C from 480 ml. to 1060 ml.

TABLE 7.

SPRINGS AREA.

Colliery.	Seam.	Sample No.	Proximate Analysis of air-dry coal.			Oxygen absorption in ml.	
			% Ash.	% H ₂ O.	% V.M.	at 30°C	at 60°C
Largo	Top	S377A	32.6	5.2	18.7	423	722
"	"	S377B	19.8	4.5	30.8	518	1091
"	"	S377C	18.0	4.8	28.4	641	1140
"	"	S378A	25.8	5.9	22.0	480	964
"	"	S378B	31.0	5.1	26.2	701	940
"	"	S378C	20.4	6.0	20.0	593	872
"	Middle	S379A	22.1	4.5	22.1	606	795
"	"	S379B	15.8	5.7	15.8	644	788
"	Bottom	S380A	23.0	3.9	27.2	612	659
"	"	S380B	13.1	4.4	26.1	627	845

The samples listed in Table 7 were taken in one colliery only. The air-dry moisture content ranges from 3.9% to 6.0% and the oxygen absorption at 30°C from 423 ml. to 700 ml. and at 60°C from 650 ml. to 1140 ml.

TABLE 8.

ORANGE FREE STATE AREA.

Colliery.	Seam.	Sample No.	Proximate Analysis of air-dry coal.			Oxygen absorption in ml.	
			% Ash.	% H ₂ O.	% V.M.	at 30°C	at 60°C
Western	?	S113A	23.2	3.7	30.2	280	676
Holdings	?	S113B	36.3	3.7	21.7	280	-
"	?	S113C	27.0	4.1	26.9	293	686
Springfield	?	T382	23.0	7.0	23.0	322	519
"	?	T383	24.5	6.8	21.0	351	555

The samples from the collieries listed in Table 8 show appreciable differences in their air-dry moisture contents, varying between 3.7% and 6.8%. The oxygen absorption values do not, however, show similar differences, the values at 30°C ranging from 280 ml. to 350 ml. and at 60°C from 520 ml. to 676 ml.

TABLE 9.

WATERBERG COALFIELD.

Colliery.	Seam.	Sample No.	Proximate Analysis of air-dry coal.			Oxygen absorption in ml.	
			% Ash.	% H ₂ O.	% V.M.	at 30°C	at 60°C
Samples taken from borehole cores.	?	T196	13.5	3.5	32.0	162	324
	?	T197	15.0	3.0	30.6	198	390
	?	T198	14.8	2.8	32.4	120	330
	?	T199	12.0	3.5	29.0	105	345

The samples from Waterberg were taken from borehole cores by the driller operating in this area. It is unfortunately not known from which seam(s) the samples were taken. The variation in the air-dry moisture content is between 2.8% and 3.5% and the oxygen absorption at 30°C varies between 35 ml. and 66 ml. and at 60°C between 108 ml. and 115 ml.

SUMMARY OF RESULTS:

The minimum and maximum values for the oxygen absorption at 30°C and at 60°C and the variation of the air-dry moisture content of the coals in each of the different areas are summarised in Table 10.

TABLE 10.

SUMMARISED RESULTS OF OXYGEN ABSORPTION DATA.

Area.	% H ₂ O.	Variation in Oxygen Absorption in ml.			
		at 30°C.		at 60°C.	
		Mini- mum.	Maxi- mum.	Mini- mum.	Maxi- mum.
Natal	1.0-1.8	100	200	136	250
Witbank	1.5-2.3	150	290	300	380
South Eastern Witbank.	2.0-3.0	220	370	415	660
Northern Wit- bank.	2.2-2.5	170	200	325	390
Southern Witbank.	2.6-5.0	190	550	303	770
Waterberg.	2.8-3.5	105	200	325	390
Middelburg- Belfast.	2.9-6.6	325	500	480	1060
Orange Free State.	3.7-6.8	280	350	520	690
Springs.	3.9-6.0	425	700	650	1140

An attempt was made to establish a relationship between the oxygen absorption characteristics of coals and their maximum inherent moisture contents. The figures given in Table 10, indicate to a certain extent, that a relationship does exist between the moisture content of the coals and the volume of oxygen consumed. The values for the moisture content given in this table were determined on air-dry coal in the conventional moisture oven. The air-dry moisture content is influenced by atmospheric conditions which may vary from day to day, and the values are therefore, subject to unpredictable variation.

It is probable that the inherent moisture content, which is an absolute property and not dependent on weather conditions, is a measure of capillary surface area, of its rank and other properties of coal such as reactivity and absorptive capacity.⁽³⁾ Consequently determinations of maximum inherent moisture content of selected samples were made.

RELATION BETWEEN OXYGEN ABSORPTION
AND MAXIMUM INHERENT MOISTURE CONTENT:

For this determination the coal sample is taken from the bed at a freshly exposed face, before it has had opportunity to dry even superficially out. It therefore contains superficial moisture as well as its maximum inherent moisture. The sample is stored under water until ready for the test.

The wet sample is crushed in a mortar to -5 + 12 mesh B.S.S. size. While on the sieve the coal is flushed with water to remove all fines. The excess water is then drained off on blotting paper and the sample subsequently transferred to a 500 ml. bottle lined with blotting paper. The drying bottle is then closed by a rubber stopper, and rotated by hand. After two minutes the paper is thoroughly wet.

The coal/.....

The coal is then transferred to another bottle lined with blotting paper by placing mouth to mouth and inverting. The treatment is repeated four times when it is found that the blotting paper remains dry, all the superficial or free moisture having been removed from the coal.

The moisture content of the coal after treatment as above is determined by the Toluene distillation method using a Starke and Deane tube to trap the distilled water. A brass distilling flask is used to prevent bumping of the coal.

The method gave results consistent to within 0.4% moisture, and these results appear in Table 11.

TABLE 11.

MAXIMUM INHERENT MOISTURE CONTENTS AND VARIOUS
OTHER PROPERTIES OF SELECTED SAMPLES.

Colliery.	Sample No.	% Max. Inh. H ₂ O.	Ml. O ₂ Absd. at 30°C.	Ml. O ₂ Absd. at 60°C.	Prox. Anal. -		Air-dry Coal.	
					% Ash.	% V.M.	% H ₂ O	Increase
D.N.C.	S446 B	1.6	116	217	18.6	27.8	1.2	0.4
D.N.C.	S443 B	2.5	200	232	11.0	28.7	1.3	1.2
D.N.C.	S446 A	2.6	102	136	11.7	31.3	2.3	0.3
D.N.C.	S443 A	2.9	131	252	11.9	30.2	1.5	1.4
Douglas.	S351 A	3.6	254	592	14.7	33.3	1.9	1.7
Douglas	S352 A	4.0	336	419	21.2	22.4	2.6	1.4
Tvl. Naviga- tion.	S157 A	4.0	244	597	9.5	31.6	2.9	1.1
West. Hold- ings.	S113 A	4.4	280	676	23.2	30.2	3.7	0.7
Tvl. Naviga- tion.	S157 B	4.5	289	620	7.9	29.3	2.7	1.8
Tvl. Naviga- tion.	S156 B	4.6	283	655	10.6	26.6	3.0	1.6
Douglas.	S351 D	4.9	274	433	15.0	22.9	2.3	2.6
West. Hold- ings.	S113 C	5.2	293	686	27.0	26.9	4.1	1.1
Alpha	S255 B	5.3	248	507	24.7	19.5	3.0	2.3
Alpha	S255 A	5.6	257	513	16.7	25.6	2.6	3.0
Uitkyk.	S371 B	5.7	499	631	15.9	20.1	3.5	2.2
Alpha	S255 C	5.8	248	412	34.8	18.2	2.8	3.0
Uitkyk.	S371 A	5.9	412	487	24.6	20.9	2.9	3.0
Alpha.	S98A	6.4	273	692	15.6	26.2	3.5	2.7
Alpha.	S60A	7.1	319	772	16.1	25.1	3.8	3.3
Palmer.	S222	7.4	393	712	16.6	22.2	5.7	2.7
Largo.	S380 A	8.0	612	659	23.0	26.1	3.9	4.1
Largo.	S377 C	8.0	641	1140	18.0	28.4	4.8	3.2
Largo.	S377 B	8.2	518	1091	19.8	30.8	4.5	3.7
Palmer	S223	8.6	437	770	13.3	22.3	6.1	2.5
Palmer	S227	8.9	482	953	18.9	18.9	5.6	3.3
Largo.	S380 B	9.0	627	845	13.2	27.2	4.4	4.6
Palmer	S226	9.0	504	1062	11.0	23.2	5.8	4.2
Largo.	S378 C	9.6	593	872	20.4	20.0	6.0	3.6
Largo.	S377 A	9.8	423	722	32.6	18.7	5.2	4.6
Largo	S379 B	10.0	644	788	15.8	30.3	5.7	4.3

In Figure 4/.....

In Figure 4 the values of the oxygen absorbed at 30°C are plotted against the maximum inherent moisture content.

Although no strict relationship can be established between the volume of oxygen absorbed and the rank of the coal (as determined by the maximum inherent moisture content), the tendency of lower rank coals to absorb more oxygen is clearly indicated.

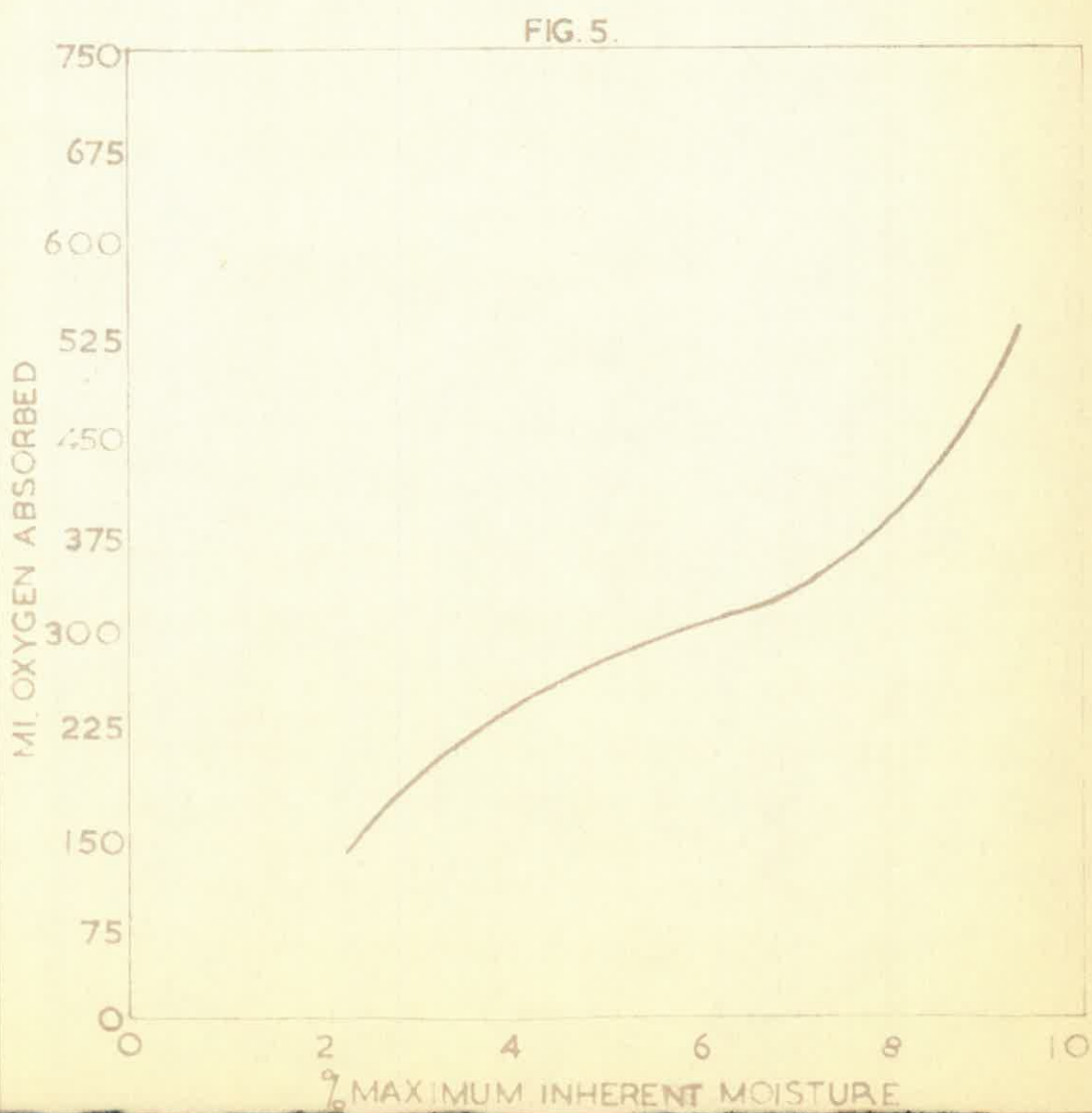
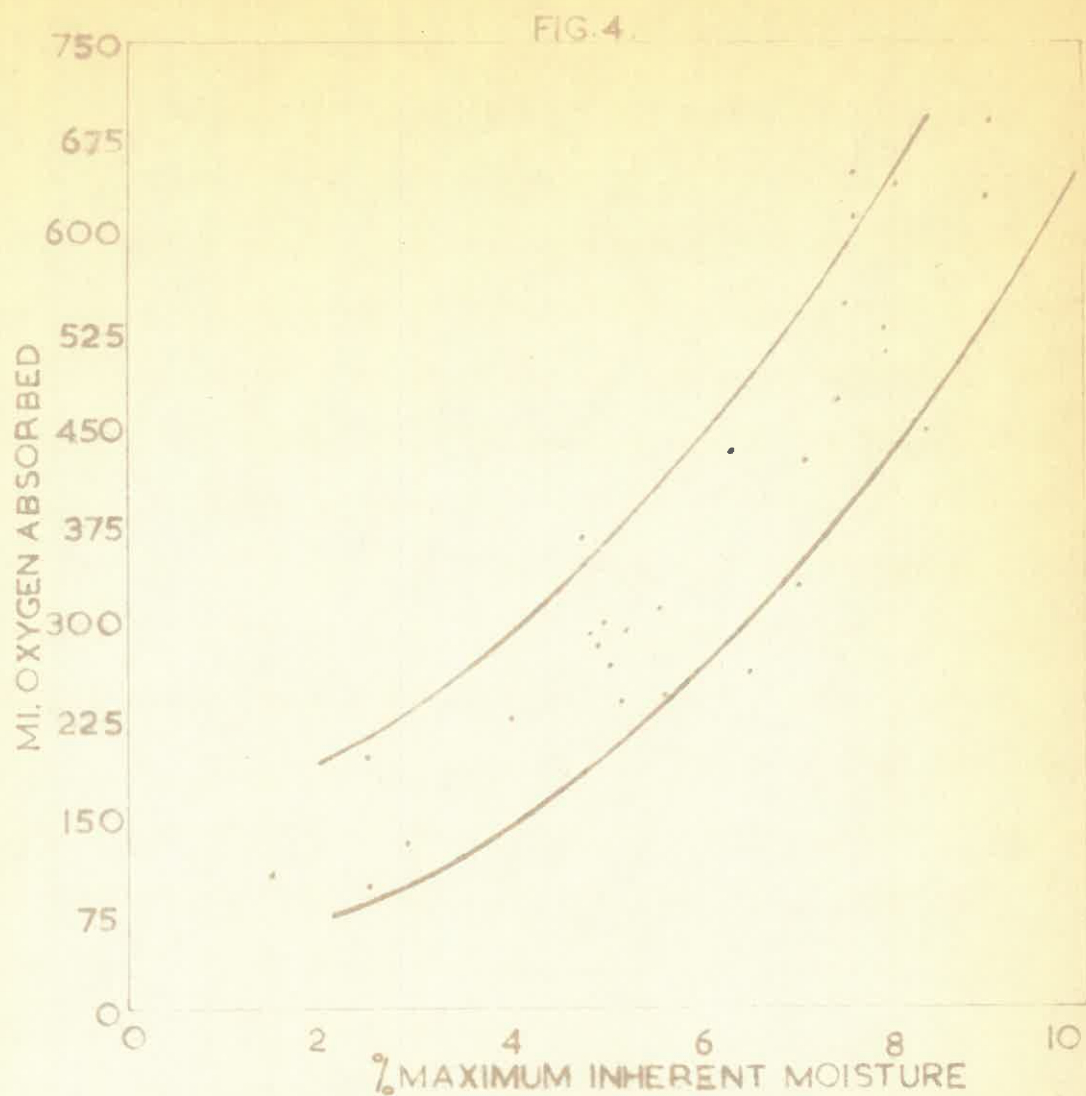
If the average values of the volume of oxygen absorbed at 30°C by coals whose maximum inherent moisture content ranges from 1.5% to 2.9%, 4.0% to 4.9%, 5.2% to 5.9%, 6.4% to 7.3%, 8.0% to 8.9% and from 9.0% to 10%, are plotted against the average values of these moisture contents for each range (see Figure 5), the resultant graph indicates more clearly that absorptive capacity increases with the maximum inherent moisture content.

The volume of oxygen consumed rises fairly steadily with increase in maximum inherent moisture content, until a moisture content of 7% is reached, thereafter the oxygen absorption increases rather more rapidly.

VARIATION OF OXYGEN CONSUMPTION WITH THE TIME OF EXPOSURE TO OXYGEN:

In order to study the variation of oxygen consumption with time the volume absorbed by 30 gm. of coal (uncorrected for ash and moisture) was plotted as abscissa, against the time of exposure to oxygen in hours as ordinate. The average value of the oxygen consumed at 30°C and 60°C respectively, for samples from the same colliery was used to plot the graph.^x Each curve, therefore, represents the average/.....

^x The maximum variation in the absorption at 30°C by the different coals from the same area is 40 ml. per 30 gm. of coal and at 60°C the variation is 70 ml. per 30 gm.



the average volume of oxygen absorbed over a period of 96 hours for coal from a particular colliery. (See Figures 6 to 14).

From these graphs it is obvious that no definite relationship can be established between the oxygen consumption and the time. It is, however, apparent that the absorption decreases appreciably after the first 72 hours of exposure. In a few cases the rate of absorption does not decrease throughout the period of exposure.

THE INFLUENCE OF PYRITES PRESENT
IN COAL ON OXYGEN ABSORBED:

Sulphur determinations were made on selected coal samples representative of the groups of collieries. Sulphate sulphur was also determined on the coal taken out of the apparatus after testing the oxygen absorption characteristics to ascertain whether any sulphate had been formed in the coal while under test.

It is evident from the data in Table 12 that the sulphate sulphur content in the samples tested did not increase to any appreciable extent during the oxygen absorption test. It is therefore concluded that any pyrites present in the coal played no appreciable part in the absorption of oxygen which confirms Lategan's findings. (5)

TABLE 12.

SULPHUR DETERMINATIONS ON SELECTED SAMPLES.

Sample No.	Before oxygen absorption.				After oxygen Absorption.		Increase in % Sulphate S. at	
	% Tot. S.	% Min. S.	% Org. S.	% Sulp. S.	at 60° % Sulp. S.	at 30° % Sulp. S.	60°	30°
S33 A	1.11	0.72	0.39	0.06	0.03	0.05	nil	nil
S60 A	1.52	1.19	0.33	0.05	0.09	0.05	0.04	nil
S61 A	1.0	0.65	0.35	0.04	0.02	0.03	nil	0.01
S113A	1.8	1.05	0.75	0.02	0.01	0.01	nil	nil
S156A	2.39	2.12	0.27	0.08	0.02	0.02	nil	nil
S157A	2.35	1.92	0.43	0.03	0.02	0.02	nil	nil
S158A	1.75	1.25	0.5	0.03	0.01	0.03	nil	nil
S222	1.1	0.74	0.36	0.01	0.01	0.02	nil	0.01
S223	0.80	0.58	0.22	0.04	0.03	0.02	nil	nil
S224	0.79	0.55	0.24	0.03	0.02	0.02	nil	nil
S225	1.01	0.59	0.42	0.06	0.03	0.02	nil	nil
S226	1.65	1.29	0.36	0.05	0.04	0.04	nil	nil
S255A	3.24	2.41	0.83	0.03	0.02	0.04	nil	0.02
S314	1.57	1.22	0.35	0.02	0.02	0.01	nil	nil

FIG. 6

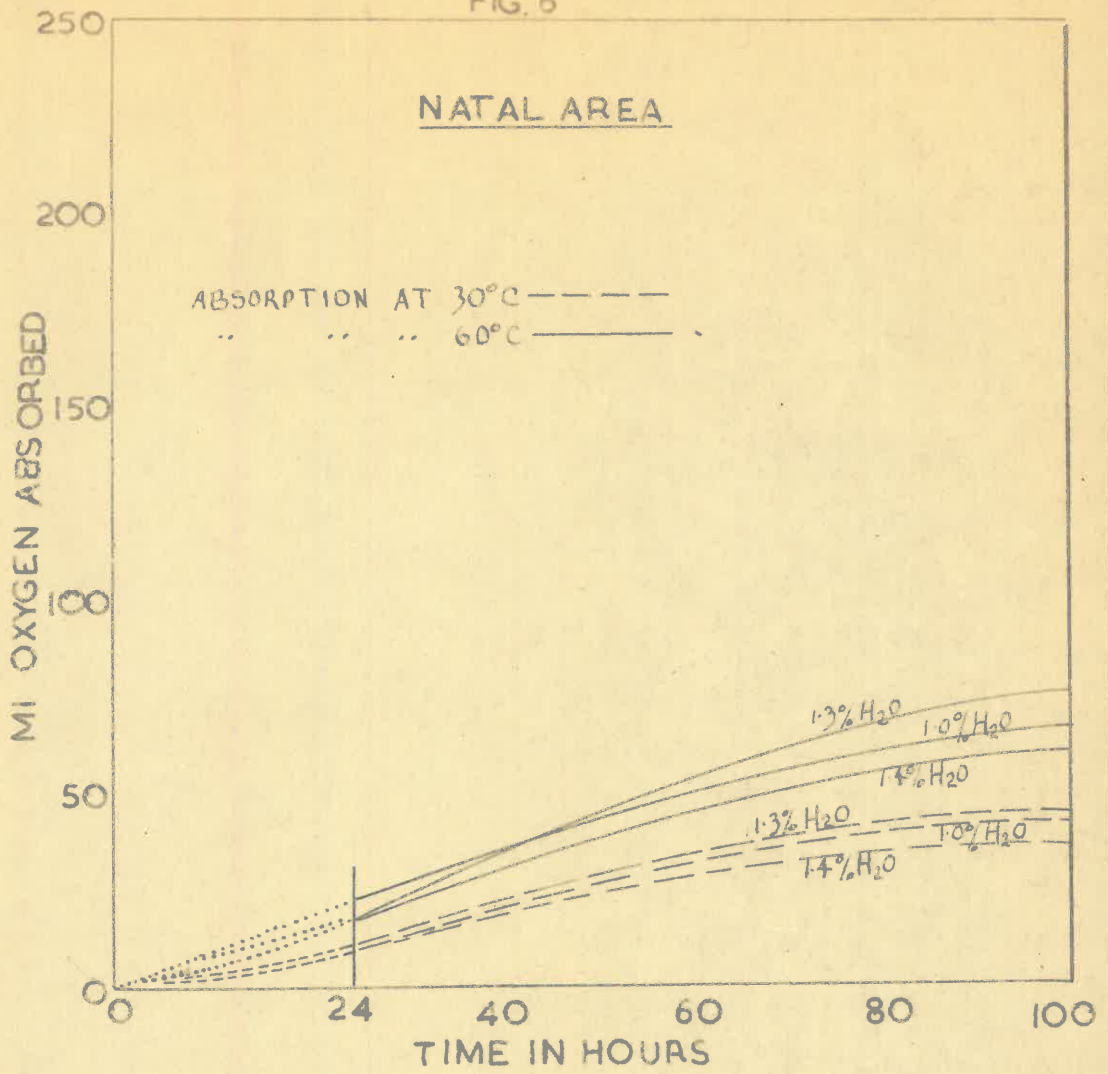


FIG. 7

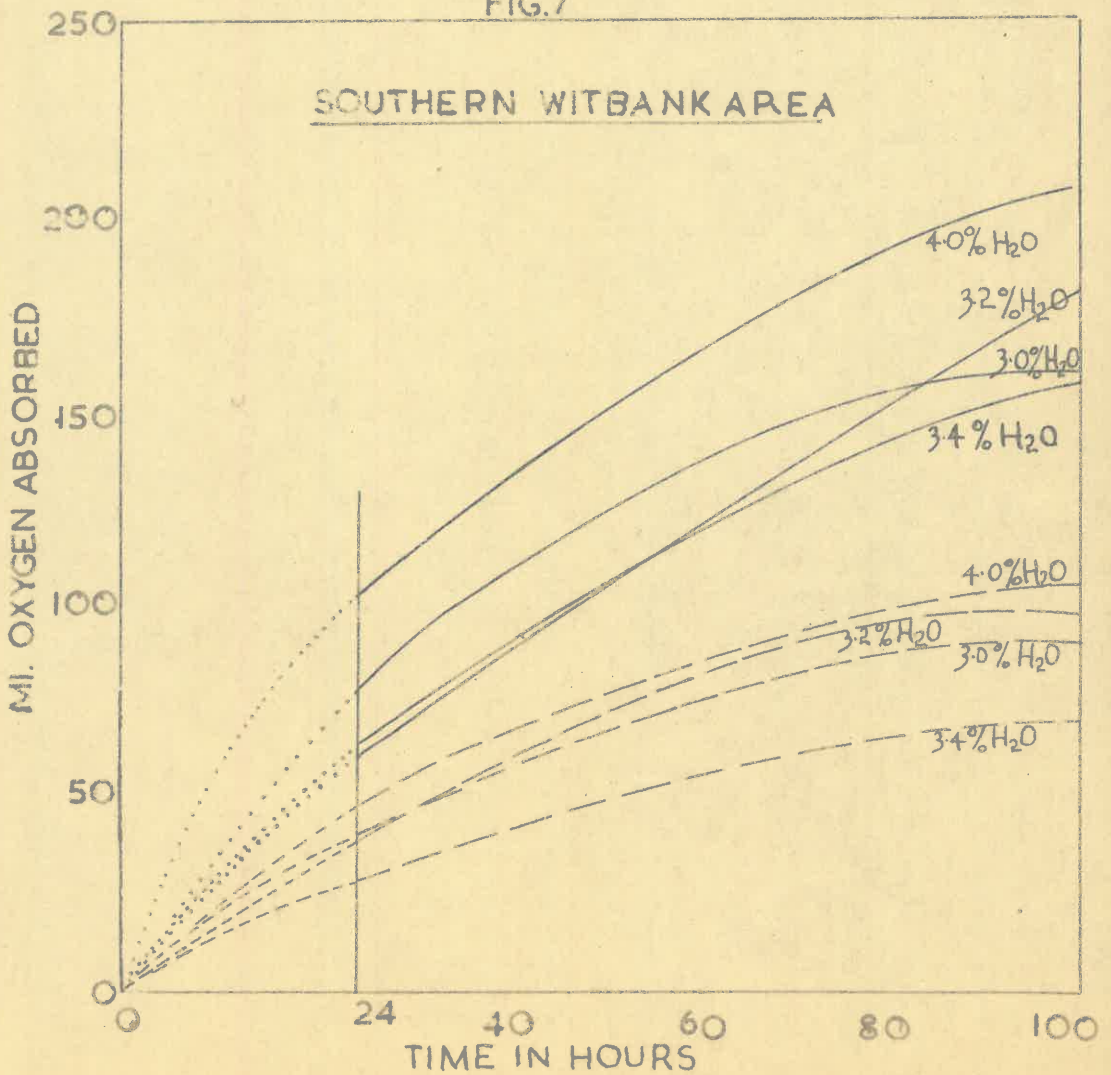


FIG. 8

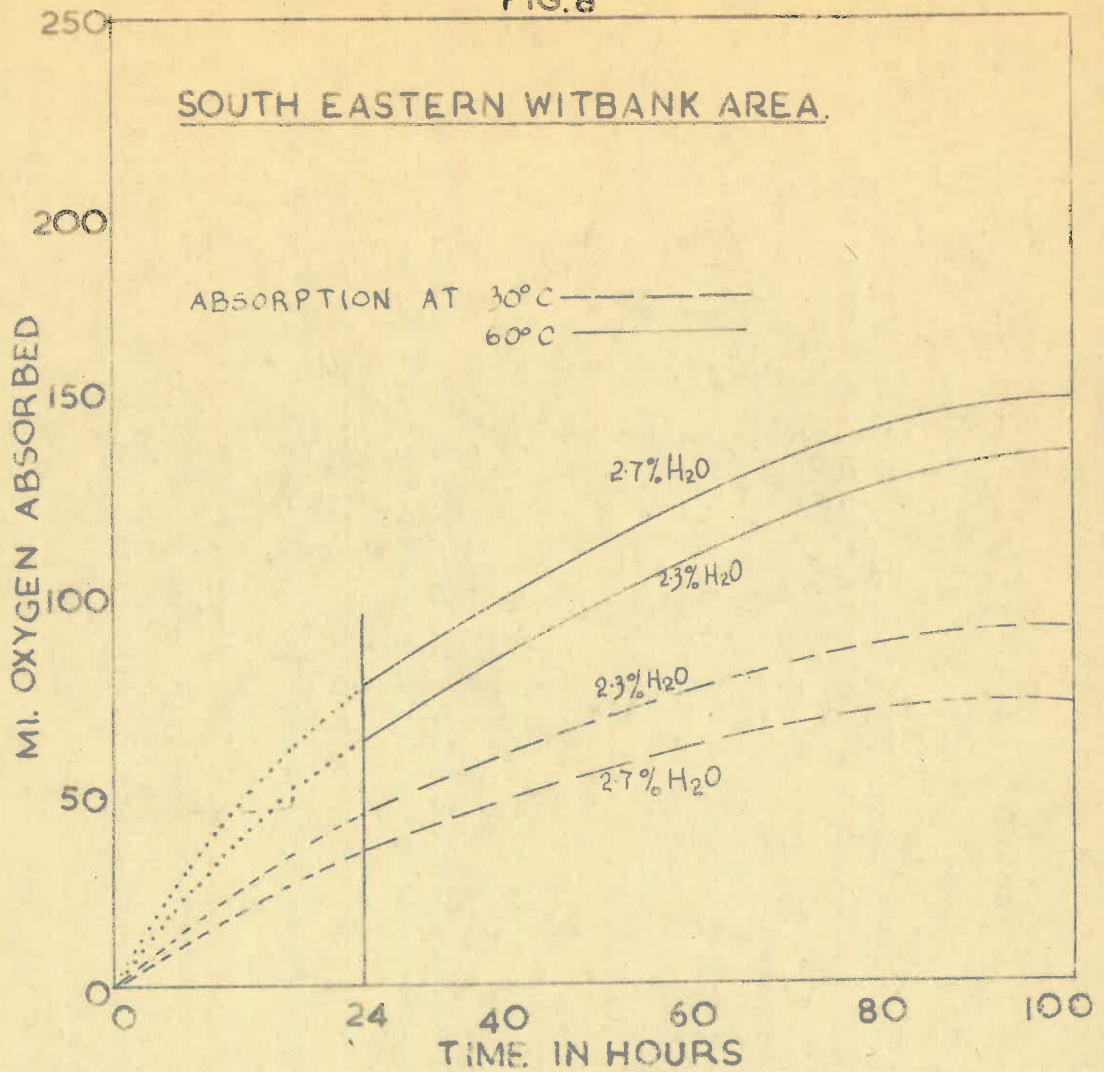


FIG. 9

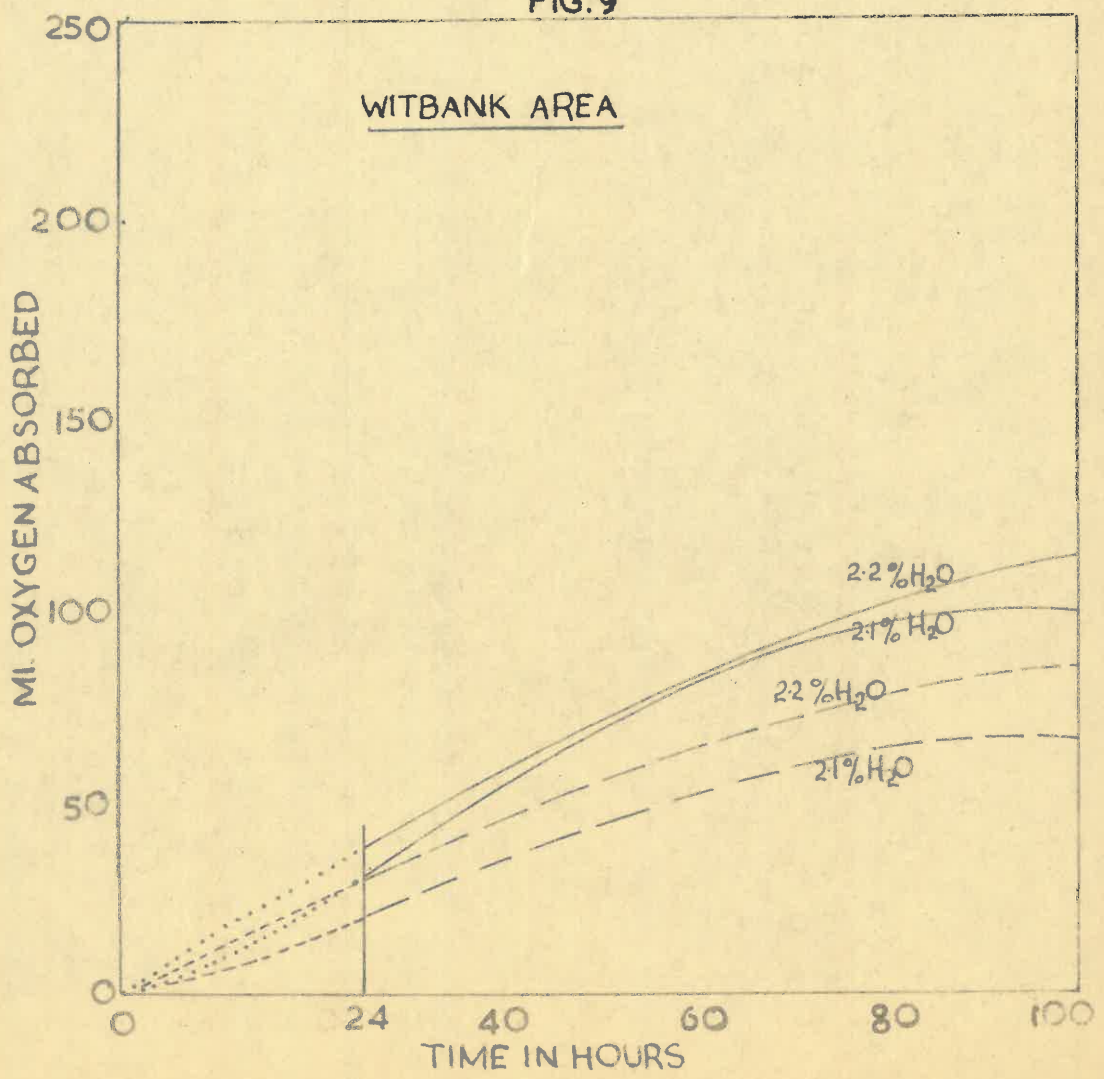


FIG. 10

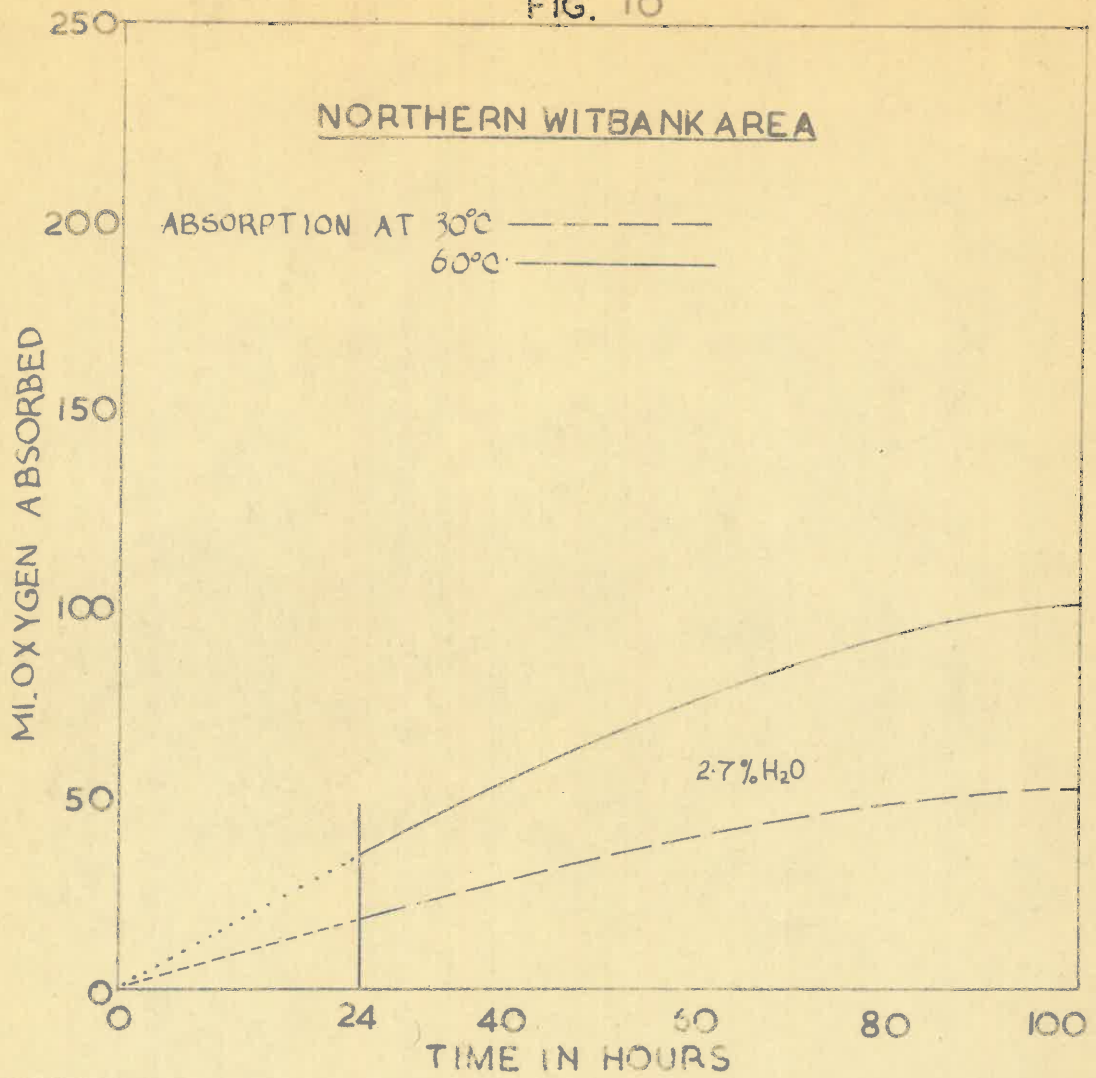
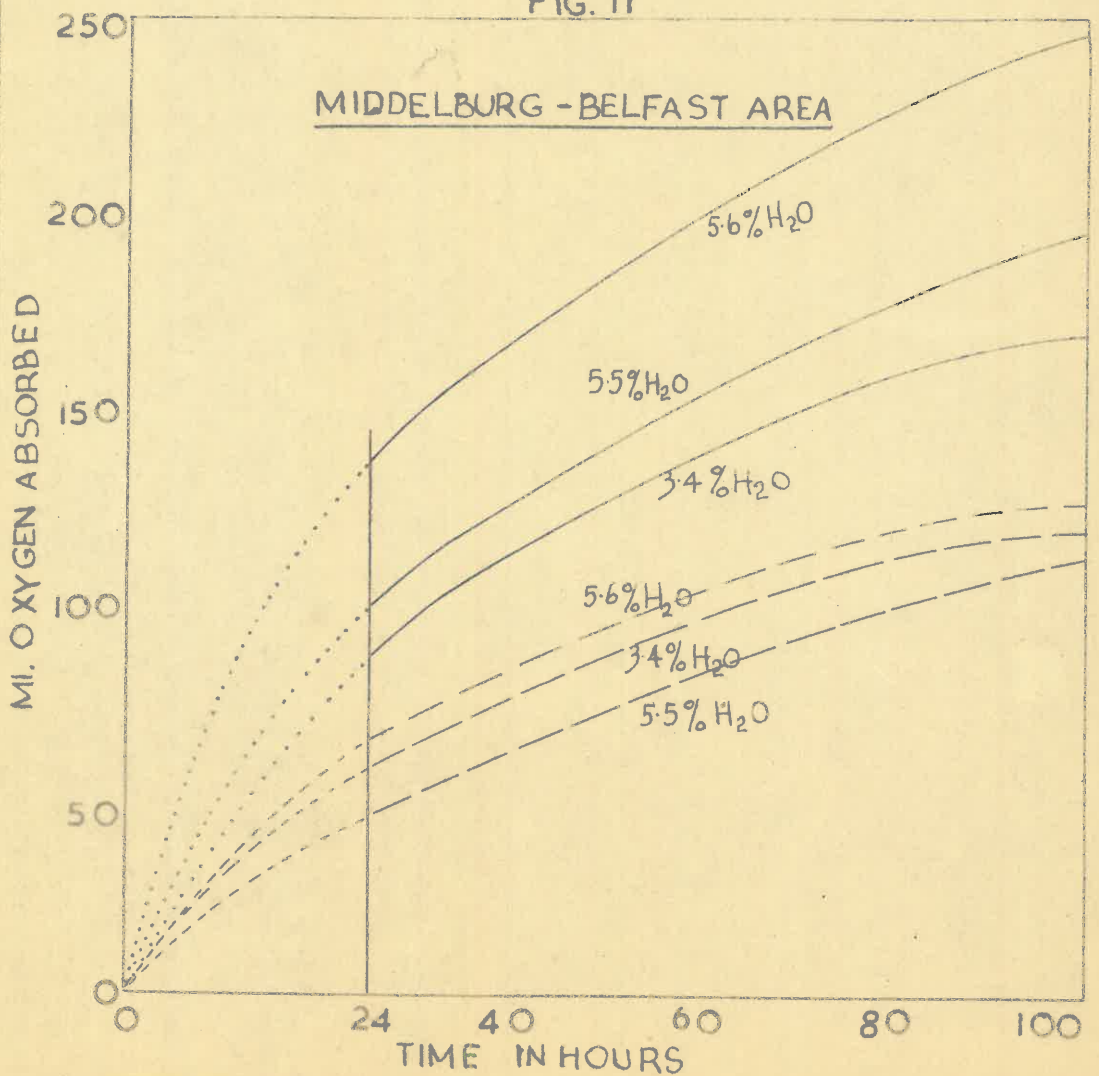


FIG. 11



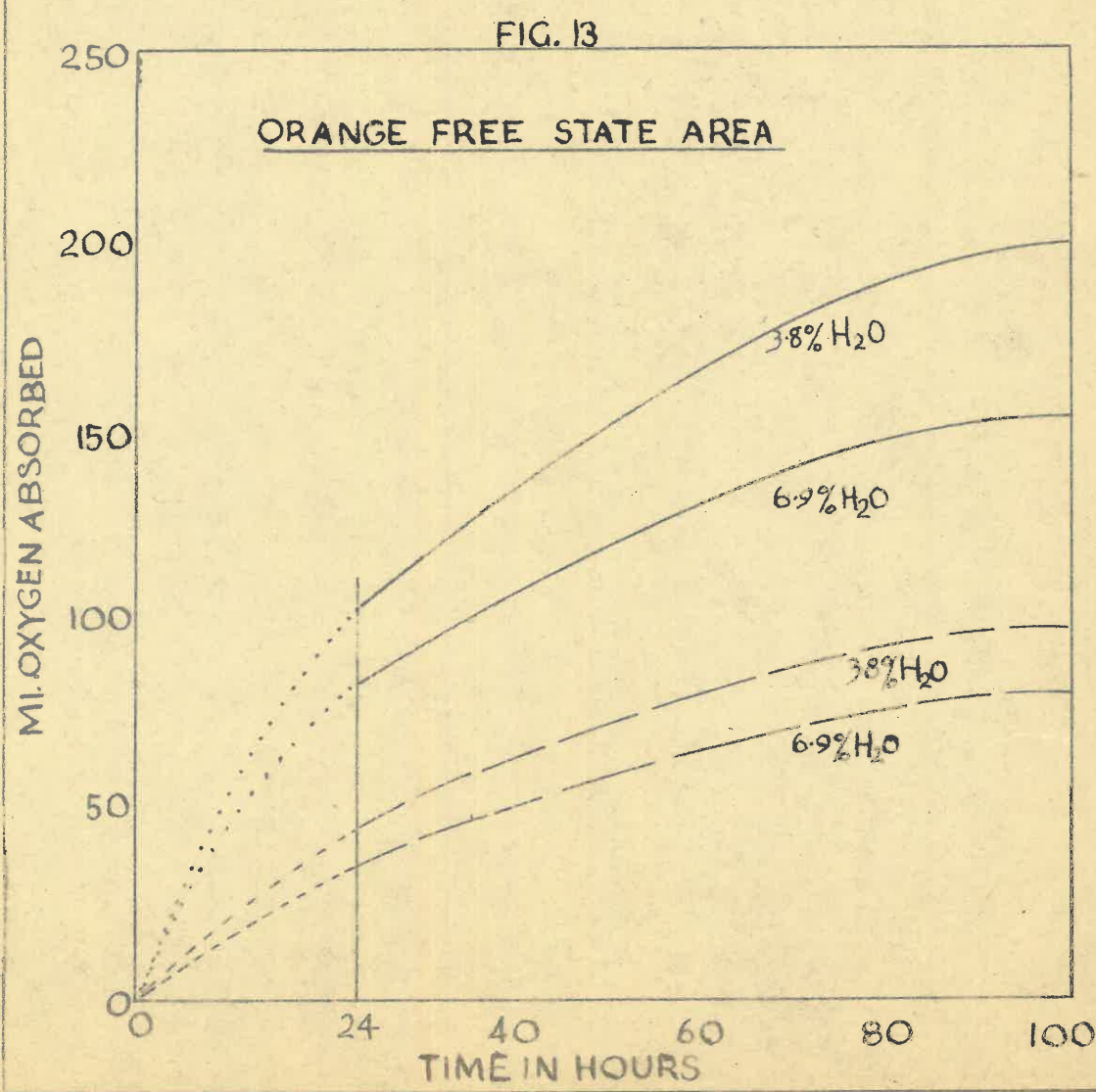
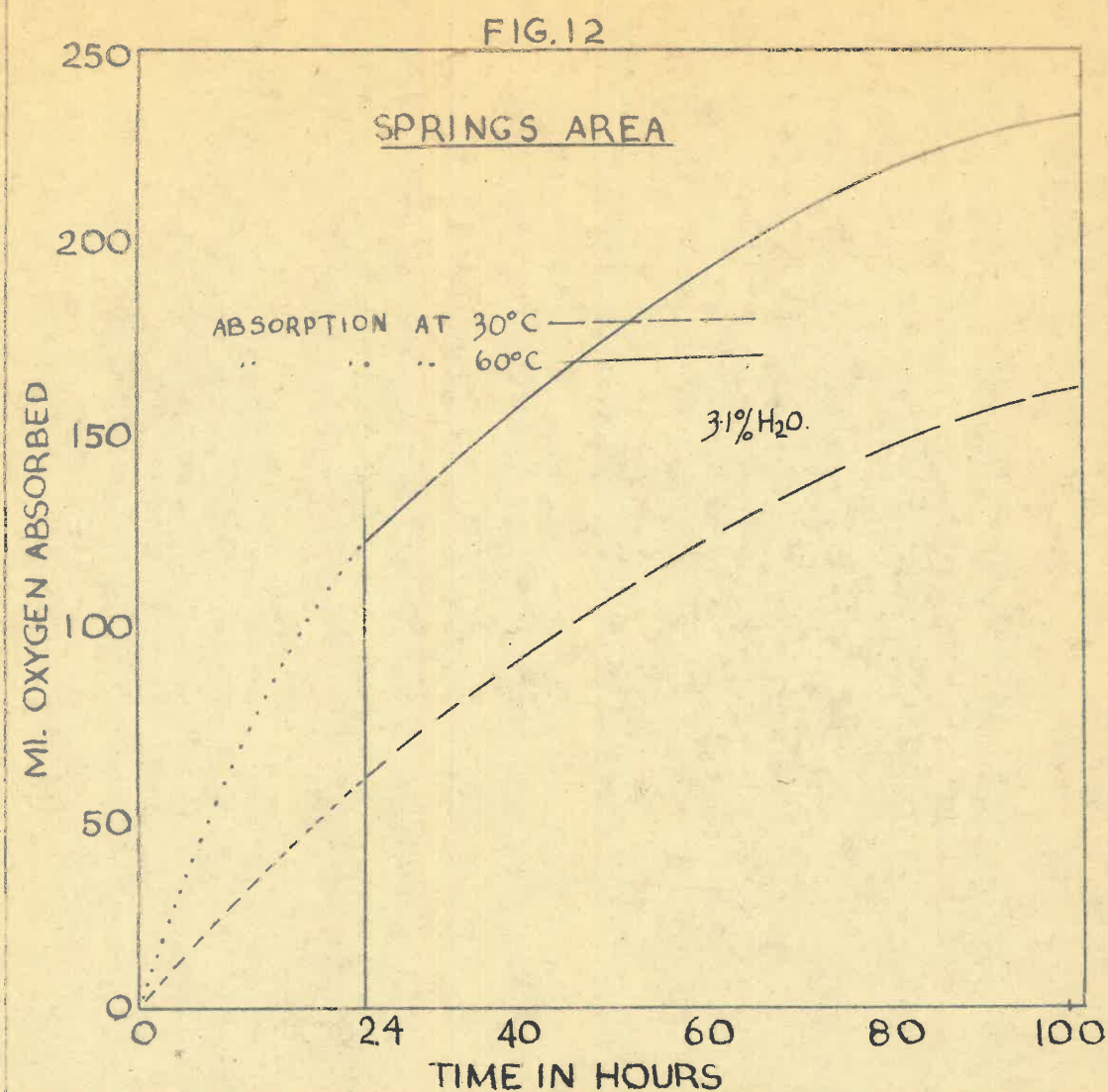
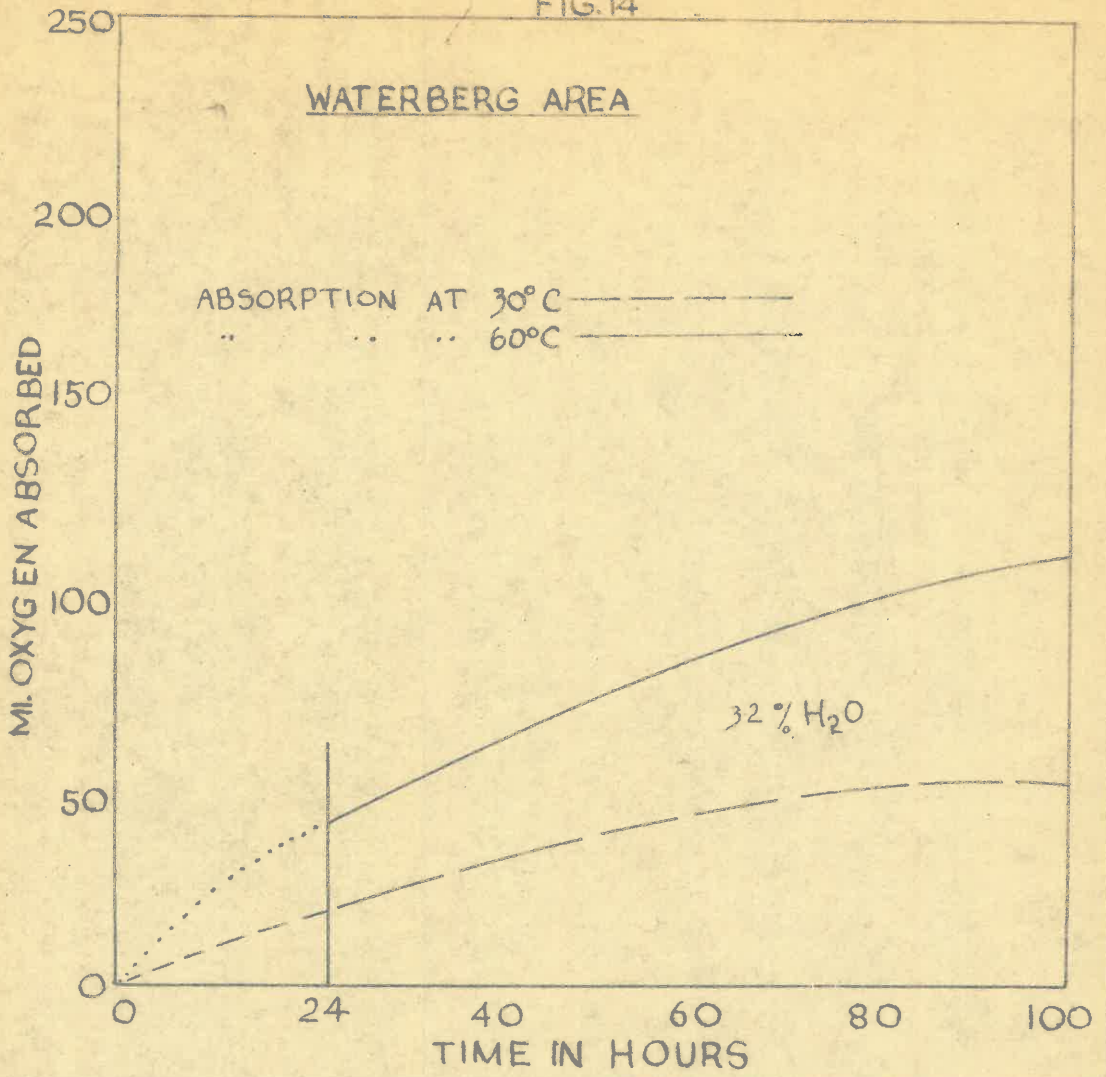


FIG. 14



THE PREVAILING ATMOSPHERIC CONDITIONS
IN THE TUBES:

Samples of the gaseous mixtures existing in the reaction tubes after absorption were taken and analysed to determine the percentage oxygen, methane, carbon dioxide and hydrogen present.

The results of these analysis appear in Table 13.*

TABLE 13.

Sample No.	Analysis of gas from tube at 30°C.			Analysis of gas from tube at 60°C.		
	% Oxygen.	% Carbon Dioxide.	% Nitrogen.	% Oxygen.	% Carbon Dioxide.	% Nitrogen.
R332	16.0	0.3	83.7	12.0	0.1	87.9
R359	20.0	0.1	79.9	16.4	0.1	83.5
R381	19.0	0.1	80.9	13.0	0.1	86.9
R444	20.0	0.2	79.8	13.0	0.2	86.8
R443	19.0	0.0	81.0	14.0	0.1	85.9
R489	17.0	0.1	82.9	12.0	0.0	88.0
R526	18.5	0.2	81.3	14.0	0.0	86.0
R591	17.6	0.0	82.4	15.2	0.0	84.8
R593	18.0	0.2	81.8	14.0	0.1	85.9
S33	19.0	0.0	81.0	13.2	0.0	86.8
S158	20.0	0.0	80.0	12.8	0.2	87.0
S379	18.0	0.0	82.0	10.0	0.0	90.0
S380	21.5	0.1	78.4	14.5	0.2	85.3
S352	21.6	0.1	78.3	11.7	0.1	88.2
T80	22.6	0.0	77.4	12.9	0.1	87.0
T81	20.6	0.2	79.2	12.5	0.0	87.5
T17	21.0	0.2	78.8	13.0	0.2	86.8
T48	18.0	0.2	81.8	12.0	0.0	88.0
T607	20.0	0.2	79.8	13.5	0.0	86.5
T608	19.4	0.0	80.6	12.5	0.0	87.5
R586	19.8	0.1	80.1	11.0	0.0	89.0
R587	20.0	0.0	80.0	14.2	0.0	85.8
R588	18.6	0.0	81.4	13.4	0.0	86.6
S222	17.8	0.2	82.0	11.6	0.0	88.4
S223	18.8	0.2	81.0	12.6	0.0	87.4
S224	18.4	0.2	81.4	13.9	0.3	85.8
S225	17.2	0.2	82.6	11.6	0.2	88.2
S226	17.6	0.6	81.8	9.8	0.2	90.0
S227	17.8	0.6	81.6	12.8	0.2	87.0
S256A	18.2	0.2	81.6	13.4	0.2	86.4
S256B	16.8	0.2	83.0	14.0	0.0	86.0
S256C	19.2	0.2	80.6	15.0	0.2	84.8
T101	22.6	0.0	77.4	12.4	0.0	87.6

* The presence of methane and other hydrocarbons and hydrogen could not be detected. From these results it is evident that the composition of the gas in the tubes kept at 30°C is very nearly that of air. There is, however, a marked oxygen deficiency in the gas in the tubes kept at 60°C. This is probably largely due to the fact that after evacuation a certain volume of air (the volume/.....

(the volume of the reaction tube is approximately 500 ml.) which is at room temperature (say 20 - 25°C) is drawn into the tubes which are closed almost immediately. (See page 2).

In the initial stage therefore, the expansion of this gas as it assumes the temperature of the bath, and the absorption of oxygen by the coal counteracts each other to some extent and virtually a larger proportion of nitrogen is present in the tubes than would be expected if air at the bath temperature had been admitted. Later on this reduction in volume is replaced by pure oxygen but it is clearly impossible to have a proportion of 80 : 20 N₂ : O₂.

The increase in the vapour pressure of the potassium hydroxide solution when introduced into the reaction tube and thus being warmed up to the temperature of the bath has a similar effect as the expansion of the gas.

The only way to counteract these effects is to preheat the air to the temperature of the bath (30°C or 60°C as the case may be) before introduction into the reaction tube. This modification in procedure is recommended. (See page 2).

VARIATION IN OXYGEN ABSORPTION OF COAL
SAMPLES TAKEN AT DIFFERENT PLACES IN THE
SAME COLLIERY:

In order to study any variations in the oxygen absorption characteristics of coals taken from the same colliery and seam but at different places distributed over the working area, the data listed in Table 14 have been compiled.

With the exception of the samples from the Durban Navigation Colliery and Belfast Colliery, the variation does not exceed 10% at any mine.

TABLE 14.

PERCENTAGE VARIATION IN OXYGEN ABSORPTION OF COAL
SAMPLES FROM THE SAME COLLIERY.*

Colliery.	Seam No.	Number of Samples taken.	Percentage Variation in Oxygen Absorption at 30°C.	Percentage Variation in Oxygen Absorption at 60°C.
Largo	Top	2	5.6	0.6
Springfield	?	2	8.3	6.5
Uitkyk	?	2	1.0	1.2
Belfast	?	2	20.0	6.6
Coronation	1	3	9.5	4.8
Landau	2	2	9.0	7.9
New Douglas	2	2	4.5	1.2
Transvaal				
Navigation	2	3	6.4	7.5
D.N.C.	Bottom	4	30.0	2.7

CONCLUDING REMARKS:

The oxygen absorbed by South African coals under certain controlled conditions vary between 100 ml. and 700 ml. (N.T.P.) at 30°C and between 170 ml. and 1200 ml. (N.T.P.) at 60°C per 100 gm. of coal.

Within certain limits the absorptive capacity of the coals tested are dependent upon their rank.

Pyrites, apparently, plays no part in the absorption of oxygen by these coals.

Unless special precautions are taken the composition of the atmospheres in the reaction tubes at 30°C and at 60°C are not the same, the per cent of oxygen in the tubes at 60°C being substantially less.

It seems that the Winmill interpretation cannot be applied strictly to South African coals as coals showing absorptions well over 300 ml. oxygen at 30°C have been successfully exported.

With a few exceptions the variation in oxygen absorption characteristics of samples of coal taken at different places in the same colliery do not exceed 10%.

LIST OF REFERENCES:/.....

* Percentage expressed as:-

$$100 \times \frac{\text{Difference between Maximum and Minimum Values}}{\text{Maximum Value.}}$$

LIST OF REFERENCES:

- (1) Illingsworth, S.R.
Analysis of Coal and its By-Products, p. 352.
London, Colliery Guardian Company Ltd. Foreword 1921.
 - (2) American Chemical Abstracts 34, 8284, 8285 (1940).
 - (3) Ultra Fine Structure of Coals and Cokes.
Publication by: B.C.U.R.A. (1944), p. 57.
 - (4) *ibid* p. 69.
 - (5) Lategan, P. N.
Non Liability to Spontaneous Combustion of First Grade
Witbank Coals. S.A. Journal of Industries, Dec. 1925.
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