Cousland No. 1 Well

Drilling Completed	;	2.12.38.
Abandoned	:	12.7.51.
Re-drilling completed	:	12.11.56.
Casing depths	:	11$\frac{3}{4}$" to 268' 8$\frac{3}{4}$" to 2057'
Wellhead pressure before abandonment	:	400 p.s.i.g.

Note for Record

Cousland No. 1 Well Abandonment

11/11/74	Plant and equipment to site.
12/11/74	Unload and position gear, connect pump attempt kill well, water went away (4000 g).
13/11/74	(Water late - pump broken down). Pressure Casing 400 tubes 370. Dismantle hut and fittings part off lines etc.
14/11/74	Press Tubes 370 casing 400 pump 4 x 1000 g. slugs of water whilst bleeding off gas press 0 Rig hoist, lift bonnet, fit cementing head.
15/11/74	Press Casing 200 tubes 20 pump 2000 gls water whilst bleeding off gas - all quiet - fit BOP. Remove tubes - break off anchor joint - fit bar collar run tunes to TD c 1629' set tubes to 1620'.
16/11/74	Pressure tubes 0 casing 50 - produced 1000 gl water to cellar connect pump circulate 1 hour still producing gas with return mix and pump 2000 gals water with 1 ton salt 1.0356 circulate all day losing 200 g/hr. to formation.
17/11/74	Pressure nil (vacuum on casing and tubes) establish circulation with 1500 gls plain water circulate 1 hour (losses 150 g) Mix and pump 72 bags Class "B" cement and 1.8 SG followed by 16 cu.ft. water leaving cement at 1380' pull tubes to 1304' and back circulate clean. Started aqueeze at 400 psi building up to 1200 psi. after 30 cu.ft. pressure started falling. Shut in.
18/11/74	Opened casing and tubing, flow from tubes. until columns equalized. Locate cement at 1492' set tubes to 1480'. Swab down to about 950' flag line (Echo not working).
19/11/74	Press 0, level same, mix and pump 408 bags class "B" placing cement at 160' pull tubes to 61' circulate dig out cellar bottom gas test - 0 - $11\frac{3}{4}$ casing not located.
20/11/74	Locate cement at 152' mix and pump 2 tons Portand cement to top up - gas test - cut off wellhead 7' down de-rig hoist.
21/11/74	Hand mix bagged cement top up cellar and casing. Load gear move off.

Abandonment completed.

D. L. Martin

DLM/JK

4248

16th November, 1966.

Bolton's Superheater & Pipe Works Ltd.,
Adswood,
Stockport,
Cheshire.

Attention Mr. Braddock.

Dear Sir,

You very kindly sent to the Scottish Gas Board a copy of your drawing for the 3", 4000 p.s.i.g. gate valve installed on Cousland No. 1 Well.

As requested we are now returning the drawing. We took the liberty of obtaining a print of the drawing for our records, and I have enclosed an additional print which may be of use to you.

Yours faithfully,
for BP PETROLEUM DEVELOPMENT LIMITED.

K. S. Collinson.

cc: Mr. M. E. McColm.

KSC/DVL.

4249

16th November, 1966.

Scottish Gas Board,
Distribution Department,
29 Waterloo Place,
Edinburgh 1.

Attention Mr. Strang.

Dear Mr. Strang,

Cousland Natural Gas Well

Further to my letter of the 8th November, I am now forwarding a copy of the manufacturers drawing of the 3" M.V. on Cousland No. 1 Well.

As mentioned previously, we would be pleased to know the results of your work on repacking the valve in question.

Yours faithfully,
for BP PETROLEUM DEVELOPMENT LIMITED.

K. S. Collinson.

cc: Mr. M. E. McColm.

KSC/DVL.

5. East Camus Road,
Fairmilehead,
Edinburgh, 10.
9/11/66.

Dear Mr Collinson,

Thank you for your letter and cheque of yesterdays date.

I'm pleased to know the valve can be packed under pressure, and will be happy to assist Mr Strang anytime he should require my services.

Yours faithfully,
J. M. Gibson.

4205

8th November, 1966.

Mr. Gibson,
5 East Camus Road,
Fairmile Head,
Edinburgh 10.

Dear Mr. Gibson,

Many thanks for your letter of 1st November. I appreciate your able assistance in the matter of the 3" Master Valve at Cousland No. 1 well.

I have been in contact with the valve manufacturers, and they confirm that the valve can be re-packed under pressure. They suggest closing the valve tightly and then opening the bleed plug at the base of the valve to relieve any trapped pressure in the valve body. The valve can then be repacked, but it may be expedient, if possible, to remove old packing and insert new packing by slackening off gland nuts and raising the gland without entirely removing the gland.

I have been in contact with Mr. Strang of the Scottish Gas Board, (copy of letter enclosed), and he is going to arrange for the valve to be repacked. Mr. Strang expressed a wish that you would assist them in this operation, and he will probably be contacting you.

We enclose a cheque for £5.5.0. as a fee for your services to date, and should you be called upon again by the Gas Board we would be only too pleased to recognise your services in a similar manner.

Again many thanks,

Yours faithfully,
for BP PETROLEUM DEVELOPMENT LIMITED.

K. S. Collinson.

cc: Manager.
Mr. Adcock.
Mr. McColm.

KSC/DVL.

4906

8th November, 1966.

Scottish Gas Board,
Distribution Department,
29 Waterloo Place,
Edinburgh 1.

Attention: Mr. Strang.

Dear Mr. Strang,

Cousland Natural Gas Well

With reference to our recent telephone conversation, I am writing to confirm the position regarding the repacking of the 3" M.V. on Cousland No. 1 well.

Mr. Braddock of Bolton's Superheater and Pipe Works Ltd. (i.e. the valve manufacturers) affirms that the valve in question can be repacked under pressure. He stated that the closed in pressure should be below 1000 p.s.i.g; the valve should be tightly closed and then 'trapped pressure' in the valve body be slowly bled down through the drain plug in the base of the valve. The packing (1⅛ - 1¼ graphited asbestos) can then be replaced.

I have written to Mr. J. Gibson concerning the proposed work, and I feel sure he will be willing to assist in any way possible if you contact him. I enclose a copy (apologies for the rather poor reproduction) of the manufacturers drawing of the valve, and I will forward to you another copy when those are to hand.

Please let us know at your convenience, the results of work on the valve, and do not hesitate to contact us if you require further assistance.

Yours faithfully,
for BP PETROLEUM DEVELOPMENT LIMITED.

K. S. Collinson.

cc: Manager.
Mr. Adcock.
Mr. McColm.
Mr. J. Gibson.
Mr. H. Jones (BP Grangemouth).

KSC/IVL.

BP REFINERY (GRANGEMOUTH) LIMITED

TELEPHONES
GRANGEMOUTH 2601

TELEGRAMS
"BEEPEE" GRANGEMOUTH
"BEPEBUNKER" GRANGEMOUTH

K.F Cairns
Group Dist

Waverly
2533

Mr Strang

Mr Braddock
Bolton Valves

YOUR REF

OUR REF HJ/JB

GRANGEMOUTH
Stirlingshire

3rd November, 1966.

Bolton Valves
Stockport
tel 3604

BP Exploration Co. Ltd.,
Eakring,
P.O. Box 1,
Southwell,
NOTTS.

Attention: Mr. Colinson

Dear Mr. Colinson,

Cousland Natural Gas Well

With reference to our recent conversation by telephone, we have just received a print of the main valve fitted at Cousland, and we are sending it to you for your information as requested.

It would appear that if the well can be allowed to "blow-down", then repacking could be done with the valve in situ. Under these circumstances, we would be pleased if you would return the drawing for our records.

We shall be pleased to receive your recommendation in due course.

Yours faithfully,
for BP REFINERY (GRANGEMOUTH) LIMITED

H. Jones

H. Jones

Klinger can supply packing. 1⅛" - 1¼" GRAPHITED ASBESTOS
5lbs minimum 2 weeks delivery.

District approval Mr Strang, Scottish Gas Board, 29 Waterloo Place Edinburgh 1

Encls.

Dear Mr Collinson. 1/11/66.

As requested, I visited Cousland No1 yesterday and inspected the wellhead. At present the well is closed in and shows a pressure of 460" P.S.I.

The 3" Main Valve is a Bolton 4000 P.S.I. test and is of the screwed bonnet type. The leak is at the stuffing box, which has been taken up all the way. With the valve closed the leak is not noticeable, but when opened it is a small leak which I expect through time will get worse. The 2" Bolton production valve is also leaking slightly, but still has movement on the stuffing box which could be taken up. However when repacking the 3" M.V. it would possibly be as well to repack the 2" P.V. as the well has been installed for production nearly ten years.

All the valves from the M.V. upwards are Bolton screwed bonnet type, and the two valves which are below the M.V. and fitted to the annular space are 2" Newman - McEvoy.

If the valves can be repacked under pressure it will be a simple job, but if not it will be rather a major job to kill the well. This would require a pump capable of at least pumping at 650 P.S.I. and storage tanks to hold at least 1000 cubic feet of water.

It would also require a compressor of higher pressure than normal, say up to 300 P.S.I. to bring the well back in again. It may even require to be swabbed if it cannot be brought in by the compressor.

I hope Mr Collinson you dont think I am being rather forward with my suggestions. I really am only trying to be helpful and having had experience with this well before I know it can be stubborn. If you speak to Mr Adcock he will also say the same.

The Gas Board official who visits the well is a Mr Buchanan who can be reached by ringing Waverley 2533. Extension 16.

The sketch I have made of the wellhead is rather rough, but will give you all the information you require.

The tubing in the well is either 2½" ext upset or 2" plain - I cannot quite remember. It is set somewhere around 1550' suspended from the 8" flange.

Regarding expenses, I believe the company have a rate for this type of job. My car mileage was around 25 miles. This was composed of a journey to Musselburgh from Edinburgh and then to Cousland and return to Edinburgh.

If at any time I can be of assistance to you I'll be pleased to help in whatever way I can.

Regards.

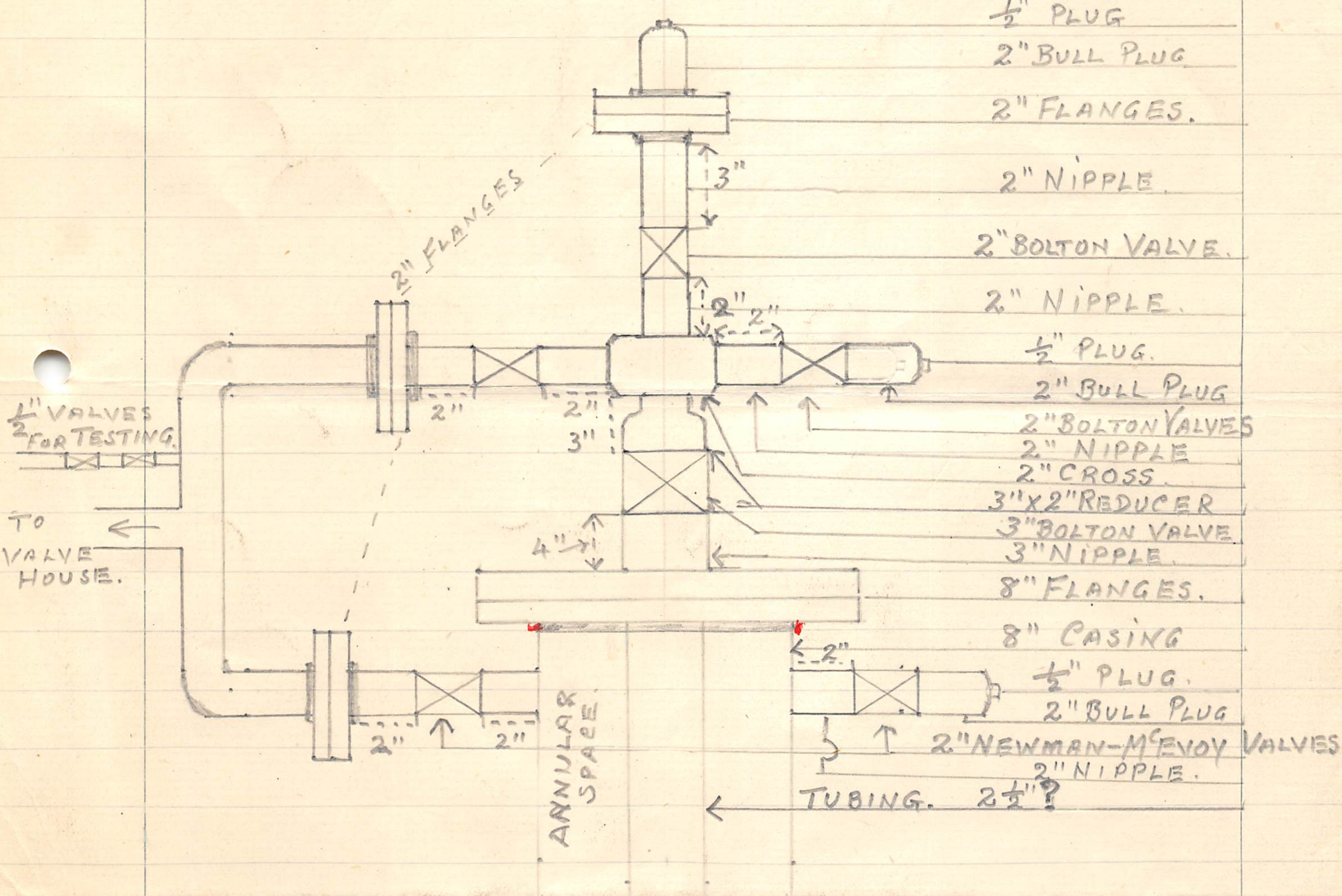
Yours faithfully,

J. M. Gibson.

5. East Camus Road,
Fairmilehead,
Edinburgh. 10

COUSLAND No 1.

TIE RODS ARE FITTED ON UPPER & LOWER VALVES.



H.120 C.1.40

Mr. Watson TDW

Copy

From BP EXPLORATION CO. LTD.,
EAKRING.

To CHIEF DEVELOPMENT ENGINEER
(MR. TOMBS)
ENGINEERING DEVELOPMENT BRANCH
REFINERIES DIVISION.

Our Ref. EXP/1/3874 **Your Ref.**

Date 16th January 1957

Subject PRODUCTION SCHEME FOR COUSLAND NO. 1 WELL

I am sending you herewith for your information a copy of the Scottish Gas Board's letter dated 10th January 1957.

You will note that they confirm requiring us to install the plant which we are purchasing on their behalf. If Messrs. Scottish Oils Ltd. are manufacturing the separator it would be most convenient if they could also undertake the installation of the wellhead equipment.

The Scottish Gas Board have also asked us to supply the 4" diameter blow-off valve in addition to the 2" diameter blow-off valve. Both these valves will be presumably of similar design.

C.M. Adcock

C.M. Adcock

c.c. Manager,
Reservoir Engineering,
Drilling Fluids and Production Branch.

CMA/EMH

COPY

THE SCOTTISH GAS BOARD
26 Drumsheugh Gardens,
Edinburgh, 3.

Your ref:
RPO/1

10th January 1957.

C.M. Adcock, Esq.,
BP Exploration Company Limited,
Britannic House,
Finsbury Circus,
London E.C.2.

Dear Mr. Adcock,

Natural Gas at Cousland

I have now received your letter of 4th January, 1957 enclosing a copy of your report of the production tests carried out at Cousland on 11th and 12th November, 1956 after Number 1 Well was brought back into production. This is, of course, of great interest to us and I shall circulate it as necessary.

I have noted from your letter that your engineering branch are now planning the wellhead equipment on our behalf. I confirm that we will require you to assemble the equipment which you are purchasing for us, and it will therefore be in order if you complete the production scheme up to the point where our 4-inch diameter pipe line will commence.

I should point out at this stage that the 4-inch diameter equipment to be fitted by us includes a blow off valve of similar design to the blow off valve in the 2-inch diameter section to be installed by you. We are presuming that you will be arranging to provide the 4-inch diameter blow off valve as well as the 2-inch diameter blow off valve, but we shall arrange to fit the former along with our governor and other equipment.

We now look forward to receiving your working drawing showing the general arrangement of the equipment, together with the dimensions of the flanges, and other details.

Yours sincerely,

(Sgd.) T.S. Ricketts.

DCE/AH

CHIEF ENGINEER.

Mr. Watson

Copy

From BP EXPLORATION CO.LTD.,
EAKRING.

To VIA EXPLORATION RECORDS.
Manager, Reservoir Engineering
Drilling Fluids & Production
Branch.

Our Ref. PRO/1

Your Ref.

Date 4th January 1957.

Subject PRODUCTION SCHEME FOR COUSLAND NO. 1 WELL.

As requested we are forwarding to you two copies of the completion report on the bringing in of Cousland No. 1 well, and the carrying out of production tests on 11th and 12th November 1956.

We have forwarded a third copy to the Scottish Gas Board at Edingburgh, for their information and retention.

C. M. Adcock

C. M. ADCOCK.

CMA/EEK.

Mr. Watson
CEW

PRO/1.

4th January 1957.

T. S. Ricketts, Esq.,
The Scottish Gas Board,
26 Drumsheugh Gardens,
Edinburgh, 3.

Dear Mr. Rickets,

PRODUCTION SCHEME FOR COUSLAND NO.1 WELL.

Thank you for your letter dated 28th December which crossed with my letter to you dated 27th December. Yesterday I visited our Engineering Development Branch at Beaufort House, London, to discuss the details of the production scheme for No. 1 well.

Our Engineering Branch are now planning the scheme on the assumption that all the production plant will be located about 100' away from the wellhead. We presume that you will require us to assemble the equipment which we will be purchasing on your behalf: in which case we will complete the production scheme to the commencement of your 4" pipe line. Details of the flanges, etc. will be shown on the general arrangement drawing which we will be sending you in due course.

I am forwarding to you a copy of the report giving the details of the production tests we carried out on 11th and 12th November 1956 after bringing in the well.

Yours sincerely,

C. M. Adcock

C. M. ADCOCK.

CMA/EEK.

C.11.46

Mr. Watson

TW

Copy

From BP EXPLORATION CO.LTD. E A KRING.

To CHIEF DEVELOPMENT ENGINEER (Mr.Tombs) ENGINEERING DEPT. BRANCH, REFINERIES DIVISION.

Our Ref. PRO/1 **Your Ref.** **Date** 4th January 1957.

Subject PRODUCTION SCHEME FOR COUSLAND No.1 WELL.

Further to our discussion at Beaufort House yesterday, we confirm that we have not got in stock the required flanges for the 11.3/4" casing.

We agree therefore with your suggestion that the water separator should be fabricated from 12" line pipe. It would also be most convenient if Messrs. Scottish Oils Ltd. will undertake to make this separator.

As requested, we are forwarding to you a copy of the Scottish Gas Board's letter dated 28th December 1956. We are taking up the matter of the assembly of the wellhead plant at Cousland with the Scottish Gas Board; but we presume that we shall be required to connect in the equipment up to the Gas Board's 4" pipe line.

C. M. Adcock

C. M. ADCOCK.

c.c. Manager,
Reservoir Engineering,
Drilling Fluids & Production Branch.

CMA/EEK.

C.11.46

Mr. Watson

Copy

From BP EXPLORATION CO.LTD., EAKRING.

To ENGINEERING DEVELOPMENT BRANCH. REFINERIES DIVISION. (ATTENTION: MR. R.G.GRANT.)

Our Ref. PRO/1. **Your Ref.**

Date 28th December 1956.

Subject PRODUCTION SCHEME FOR COUSLAND NO. 1 WELL.

At Mr. Dickie's request we are sending you our estimate for the cost of fabricating the high pressure mist extractor and water separator. It will be noted that we have only an approximate cost for the flanges for the 11.3/4" casing. At an average cost of circa £20 each these flanges are the most expensive part of the separator.

It is proposed to use slip-on flanges for welding to the casing, and blank matching flanges. The top section of the separator should be flanged at each end to give access to the impact baffle plate and to the agglomerator plate. One end of the bottom section of the separator should also be flanged for cleaning purposes.

There is thus little scope for saving on the flanged ends of the separator. The details of the cost estimate for the complete separator are as follows:-

Quantity.	Description.	Unit Cost.	Total Cost.
24'	11.3/4" casing	21/9d.per ft.	£26
8	4 slip-on & 4 blank flanges for 11.3/4" casing	circa £20	£160
2	H.P.drain cocks. Suggest Klinger type AB-22 - 3/8" bore F/S (forged steel)	£5.10.0.	£11
1	Forged steel Reflex gauge. Suggest Klinger type K Model VII	£10	£10
2	Connecting tubes for Reflex gauge	£1	£2
1 pair	Klinger cocks type AB-18 KD forged steel for 600 p.s.i. working pressure	£21	£21
1	Drain cock for Reflex gauge	£3	£3
	Cost of fabrication of separator	-	£27
	TOTAL COST.		£260

It will be noted that thisprice does not include the concrete supports for the separator; nor does it include the 2" inlet and outlet valves, and the separator bye-pass.

It is suggested that in your general arrangements drawing you indicate that the separator and pressure control equipment be sited 100' away from the wellhead. This will allow space for workover operations, such as running Otis equipment etc. It is believed that the Scottish Gas Board is planning to locate all the pressure control equipment in a small building, which can be gas heated if necessary to avoid freezing conditions affecting the operation of the instruments in use.

C. M. Adcock

C. M. ADCOCK.

c.c. Manager,
Reservoir Engineering,
Drilling Fluids & Production Branch.

CMA/EEK.

Mr: Watson

COUSLAND NO. 1 WELL

PROGRAMME TO PUT WELL ON PRODUCTION

ORIGINAL ROTARY TABLE ELEVATION 565'

WELL DATA

	Depth below R.T.
1. May 1945	
Top of cellar wall	6'
Cellar floor	12'
Perforations in upper sand (a)	1,582' - 1,613'
(b)	1,623' - 1,630'
Perforations in lower sand	1,720' - 1,735'
Top of cement plug in 8.3/4" casing	1,740'
11.3/4" casing shoe at	268'
8.3/4" casing shoe at	2,057'
Top of fish at	2,086'
2. July 1951	
Plugged back with cement to	1,465'
Anti-corrosive mud to	50'
Cement plug to cellar floor	12'
Wellhead burned off at cellar floor level	12'

WORKOVER PROGRAMME

1. Prepare wellhead for cleaning out operations

   i) Locate top of well at cellar floor level.
   ii) Weld joining plate between 11.3/4" and 8.3/4" casing.
   iii) Weld 8.5/8" casing collar to 8.3/4" casing.
   iv) Screw in flanged casing nipple with 2" side connections to bring wellhead up to ground level.
   v) Fit Shaffer gate for use during cleaning out operations.

2. Cleaning out operations

   i) Clean out top cement plug, anti-corrosive mud, and bottom cement plug to 1660', i.e. to circa 30' below the 1582'-1630' sand.
   ii) Change over to clean water. Capacity of 8.3/4" No.5 I.J. casing 2.154 gallons per foot; i.e. capacity of casing 3600 gallons to 1660'. Hence minimum surface storage capacity required 6000 gallons.
   iii) Run gamma-ray log to locate the position of the sand interval below the new wellhead.
   iv) Remove Shaffer gate.

3. Perforation programme

The original gas/water level in the 1582' - 1630' sand is put at - 1110' sub-sea, i.e. 1675' below original R.T. At this stage it is not proposed to perforate opposite the thin sand lens from 1623' - 1630'. Thus there is scope for the coning up of reservoir water up to 1613', the bottom of the main sand body, before water is produced with the gas production. It will be noted that this represents a rise of 62', so that there should be a reasonable chance of maintaining dry gas production.

The following is the shaped charges casing perforation programme:-

i) Fire five guns as follows:-

	Depths	
	Below original R.T.	Below cellar wall
Gun 1	1582' - 1588'	1576' - 1582'
Gun 2	1588' - 1594'	1582' - 1588'
Gun 3	1594' - 1600'	1588' - 1594'
Gun 4	1600' - 1606'	1594' - 1600'
Gun 5	1606' - 1612'	1600' - 1606'

The final depth corrections to be made after taking gamma-ray log.

ii) Keep the well full of water during perforation operations. Keep a record of all water lost to the formation.

4. Well completion after perforation

A. Run in 2" plain tubing string

i) Bottom two joints of tubing to be plain, with the end of the bottom joint plugged.
ii) Tubing joint opposite sand to be perforated with circa 40 holes each 1/2" diameter.
iii) Fit special coupling with aluminium bursting disc above perforated tubing joint.
iv) Run in plain tubing and screw into special matching flange.

B. Make up wellhead Christmas tree

i) Make up 3" (or 2") master valve above tubing flange.
ii) Make up 2" cross with 2" side valves and 2" top valve.
iii) Complete wellhead with a pair of flanges with 2" bull plug fitted with a 1/2" plug for a pressure gauge connection.

PROCEDURE FOR BRINGING THE WELL IN

i) Connect in the 3" burning line (as used at Fordon, complete with pressure connections) from 2" side valve on cross to burning point. By-pass the low pressure water separator used at Fordon.

ii) Open up fully side valve to burning line.

iii) Open up control valve above cross; drop go-devil; shut control valve immediately. After the aluminium disc has burst, produce at maximum flowing rate into the burning line until all water has been recovered from the casing.

iv) Keep annular space closed-in; and record annular space pressures.

v) After reproducing water in well close side valve on cross.

vi) Record annular space and tubing pressures until equilibrium pressure has been obtained. Check pressure by means of a dead-weight tester.

Notes

a) Suppose bursting disc is placed at 1500'. Internal volume of 2" tubing 0.136 gallons per foot. Hence volume of 1500' tubing 204 gallons.

b) Suppose the water is aerated by the gas so that the tubing fills to surface. Annular space volume 1.96 gallons per foot. Hence maximum initial drop in A.S. level 104'.

c) Indicated reservoir pressure at 1582' circa 640 p.s.i.g. Hence free water level 640/.434 or 1475' above 1582'; i.e. 107' from surface. Hence, the breaking of the bursting disc should just about bring the well in.

OPERATIONAL NOTES

i) The main production line to be one side line to the cross. The second side line to the cross to be used for bringing in the well, and specific productivity tests.

ii) One side line to the annular space to be retained as an alternative production line for use in emergency if production through the tubing is shut-in. The second annular space valve to be used for recording annular space pressures; and for pumping water to the well to kill it if required.

iii) The isolating valve above the cross is to permit the running of instruments into the well, such as floats, dippers, and pressure recorders.

C. M. Adcock

Eakring
18.10.56
CMA/EMH

1st January 1957.

Mr. Wauman

COUSLAND NO. 1 WELL.

REPORT ON PUTTING THE WELL BACK TO PRODUCTION FROM THE 1582 - 1632 GAS SAND.

11th - 12th November 1956.

C. M. ADCOCK.

CONTENTS.

APPENDIX.

LIST OF GRAPHS.

COUSLAND NO. 1 WELL.

REPORT ON PUTTING THE WELL BACK TO PRODUCTION FROM THE 1582'-1632' GAS SAND.

11th - 12th November 1956.

I **WELL DATA.** Rotary Table Elevation 565'.

Depths below R.T.

1. May 1945.

Top of cellar wall	6'
Cellar floor	12'

Casing perforation with 3/8" bullets. (in 1939)

(a) Upper gas sand - top member 131 bullets 1582' - 1613'
lower member 33 bullets 1623' - 1630'
(b) Lower gas sand - top member 61 bullets 1720' - 1735'
lower member 186 bullets 1760' - 1806'

Top of cement plug in 8.3/4" casing	1740'
11.3/4" casing shoe at	268'
8.3/4" casing shoe at	2057'
Top of fish at	2086'

2. July 1951.

Plugged back with cement to	1465'
Anti-corrosive mud to	50'
Cement plug to cellar floor	12'
Wellhead burned off at cellar floor	12'

3. November 1956.

Anti-corrosive mud and cement in casing cleaned out to 1663'
Upper gas sand from gamma ray log - top member 1582' - 1602'
lower member 1614' - 1630'
Casing perforated with shaped charges
Upper gas sand - top member 120 shaped charges 1575' - 1605'

II **CUMULATIVE GAS PRODUCTION FROM WELL.**

Million cubic feet.

1. Gas from 1760' - 1806' sand to tests ending 15th May 1939 — 35.9

2. Gas from 1582' - 1632' and 1720' - 1735' sands to tests ending 19th May 1945 — 30.65

3. Gas from 1582' - 1602' interval during tests from 10th - 12th Nov. 1956
(a) To bring in the well 580,000 cubic feet
(b) During production tests 734,000 cubic feet — 1.314

HENCE CUMULATIVE TOTAL FROM WELL — 67.864.

III OBJECTIVE IN PRODUCING SOLELY FROM THE TOP MEMBER OF THE 1582' - 1632' GAS SAND.

1. During the production tests in November 1939, with the casing perforated opposite the 1582' - 1632' and 1720' - 1735' sands, the water level built up in the well. It was not definitely known whether the water produced was reservoir water or shooting water; but it was certain that it was coming from the 1720' - 1735' sand. Hence, with the 1720' - 1735' sand now below the cement plug at 1663', the possibility of water production from this horizon has been excluded.

2. The sand member from 1582' - 1613' constitutes the main section of the upper gas sand. Correlating reservoir pressures in wells 1 and 5, the indicated gas/water level is put at 1110' sub-sea, equivalent to a depth of 1675' in well 1. These considerations put the gas/water level 70' below the perforated interval in well 1. Hence, at low production rates, and a minimum of water coning, the well should produce dry gas for a considerable period of time.

3. On present considerations the 1582' - 1632' sand is the most important gas sand, and contains the bulk of the Cousland gas reserves. Most of the gas supply to be obtained in the neighbourhood of well 1 will be derived from this sand. Gas reserves in the lower sands in well 1 must be discounted since they occur not far off edge-water level.

IV FURTHER POSSIBILITIES AT COUSLAND.

Further possibilities of increasing the gas supply from the Cousland anticline are conditioned by the consideration as to whether additional drilling is economically justifiable. In general terms the following are the main prospects:-

1. The 1720' - 1806' sand group of well 1.

   The indicated gas/water level in this sand group is put at 1280' sub-sea (see Report on Cousland 5) equivalent to a depth of 1845' in well 1. However, an earlier assessment placed the gas/water level at 1802' in well 1.

   There may be a 90' structural rise from well 1 to the crest of the Cousland anticline (Report GL-RGWB-5) in which case most of the gas reserves in the 1720' - 1806' sand group could be drawn from a crestal well. The 90' structural rise would also be sufficient to ensure water free gas production at moderate rates. If this sand can be put on production the value of the Cousland gas reserves would be much enhanced.

2. The 2094' - 2122' sand group of well 1.

   This gas sand is mentioned as a further possibility as it is liable to be overlooked. During a formation test in well 1 water-free gas was produced at a rate of 150,000 cubic feet per day. This may not be a particularly promising production rate from the economic standpoint; but the geological opinion is that sand conditions improve towards the inferred crestal area (Report GL-RGWB-5).

The 2094' - 2122' sand may therefore have developed into as prolific a gas sand in the crestal area of the anticline as any of the other Cousland gas sands: and in an area of good sand development there is also the possibility of discovering other gas sands.

V RESULTS OF CASING PERFORATION WITH SHAPED CHARGES.

1. Improved penetration of shaped charges.

When bullets were used in 1939 the casing cannot have been particularly effectively perforated: when the well was bailed, bullets were recovered in the bailer. During the cleaning out operations in 1956 the drilling bit was badly scored with bullet marks, indicating that there were bullets still protruding from the casing.

2. Improved well performance by perforating only the upper gas sand.

During the flowing tests in 1939 wellhead pressures declined excessively due to the build-up of the water level in the casing. After the flowing tests had been completed it took about a week for the water level to fall back to somewhere near the 1720' - 1735' sand. There was then a further very slow rise in the closed-in wellhead pressure.

After perforating the 1582' - 1602' sand member in 1956 no reservoir water production was obtained during the short production tests. At the conclusion of the production tests the closed-in pressure built-up to within 20 p.s.i. of the equilibrium pressure in 10 minutes; and to the final equilibrium pressure within about one hour.

3. Improved gas production capacity.

During the original formation test in 1938 gas was produced from the 1582' - 1632' sand at a rate of 3 million cubic feet per day. Before carrying out the 1956 production tests 2.1/2" tubing had been run in the well. The maximum production rate obtained was 3.56 million cubic feet per day through the tubing. The pressure loss due to friction in the tubing was 279 p.s.i. In consequence, the working pressure at the sand face at this production rate was still as high as 376 p.s.i.a. The open flow potential of the well has been calculated using the method recommended by the Railroad Commission of Texas. From the graph it is seen that the maximum open flow well capacity is of the order of 4.5 million cubic feet per day.

4. Initial wellhead pressure recorded after bringing in well.

Before opening up the well again in 1956 the previously recorded closed-in wellhead pressure was 621.4 p.s.i.g. on 4th June 1947. After bringing in the well and reproducing the shooting water, the measured closed-in wellhead pressure was 620.4 p.s.i.g. For the purposes of calculation the datum pressure has been taken as 621 p.s.i.g. at the wellhead.

From the earlier production tests it would appear that the reservoir pressure drop per million cubic feet gas production was 1.6 p.s.i. approximately. If the well is now produced at a rate of circa 100,000 cubic feet per day, there will be no measurable bottom hole differential pressure. Thus, and so long as there is no water production, any drop in the formation pressure will be immediately apparent by a similar fall in the wellhead pressure. Hence, a continuous record of reservoir pressure decline rates will be obtained.

VI COMMENTS ON PRODUCTION TESTS.

1. Reservoir Pressure decline with production.

The gas produced during the production tests on 11th and 12th November 1956 was 734,000 cubic feet. This was too small a production to determine the reservoir pressure decline with production.

It will be noted that there was no detectable decline in the closed-in wellhead pressure of 621 p.s.i.g. before and after the production tests. Possibly the true decline rate is less than 1.6 p.s.i. per million cubic feet production (see memo D.C./359 dated 31st Jan.1942). It will be a simple matter to study pressure decline rates when the well is produced steadily into the gas main.

The static reservoir pressure at 1582', the top of the gas sand, has been calculated to be 660 p.s.i.a. This is the shut-in pressure which has been used to calculate the open flow potential of the well from back-pressure tests using the Railroad Commission of Texas method.

2. Production Test Results.

By producing the well through tubing the working pressure at the sand face can be calculated for each stabilised production rate from the pressure in the annulus between the tubing and casing. A burning line of 3" nominal bore and 530' long was used for the determination of production rates by measuring the fall in pressure between an upstream and a downstream connecting point. TheMolesworth flow formula was used for calculating small production rates; and the Weymouth flow formula for all other production rates.

Using the data obtained during these tests the following graphs have been constructed:-

Graph 1. - Annular Space Pressures, Tubing Pressures and Pressure loss due to friction in tubing versus gas production rates.

Graph 2. - Square of pressure loss in tubing versus gas production rates. This gives a straight line graph from which the pressure loss at any given production rate can be calculated.

Graph 3. - Gas production rates versus Bottom hole differential pressures. The B.H.D.P. is the difference between the shut-in reservoir pressure and the working pressure at the sand face.

Graph 4.- Back pressure curve to determine the open flow potential of the well. A straight line graph is obtained by plotting the difference in the square of the formation shut-in pressure and the square of the working pressure at the sand face.

3. Cooling effect due to gas expansion.

As no bottom hole choke has been run in the tubing, the cooling effect due to gas expansion will take place at the wellhead. It is only at the higher production rates that there is sufficient pressure loss in the tubing for the bulk of the cooling effect to take place in the tubing. This is illustrated by the following graph:-

Graph 5.- Upstream line temperatures (i.e. near gas expansion point) and Tubing pressures plotted against gas production rates.

It will be noted that a minimum temperature of 17°F has been recorded at a production rate of about 750,000 cubic feet per day with a tubing pressure of just under 600 p.s.i.g. The upstream line temperature does not rise above freezing point until the production rate reaches 2.75 million cubic feet per day, with a tubing pressure of circa 340 p.s.i.g.

It willalso be noted that at a production rate of around 100,000 cubic feet per day the cooling effect will be largely offset by a gain in temperature from the atmosphere. Hence freezing conditions should only occur at particularly low atmospheric temperatures.

4. Build-up of closed-in wellhead pressure.

The first closed-in wellhead pressure build-up was recorded after bringing the well in on 10th November. The second closed-in wellhead pressure build-up was recorded after the completion of the production tests on 12th November. Both tubing and annular space pressures were recorded.

Graph 6.- Annular space closed-in wellhead pressures plotted against time in minutes, recorded after the production tests on 12th November.

Tubing pressures, andthe pressures recorded on 10th November have not been plotted since very similar curves are obtained in each case. It will be noted that the closed-in equilibrium pressure is obtained within about one hour.

5. Reservoir water production.

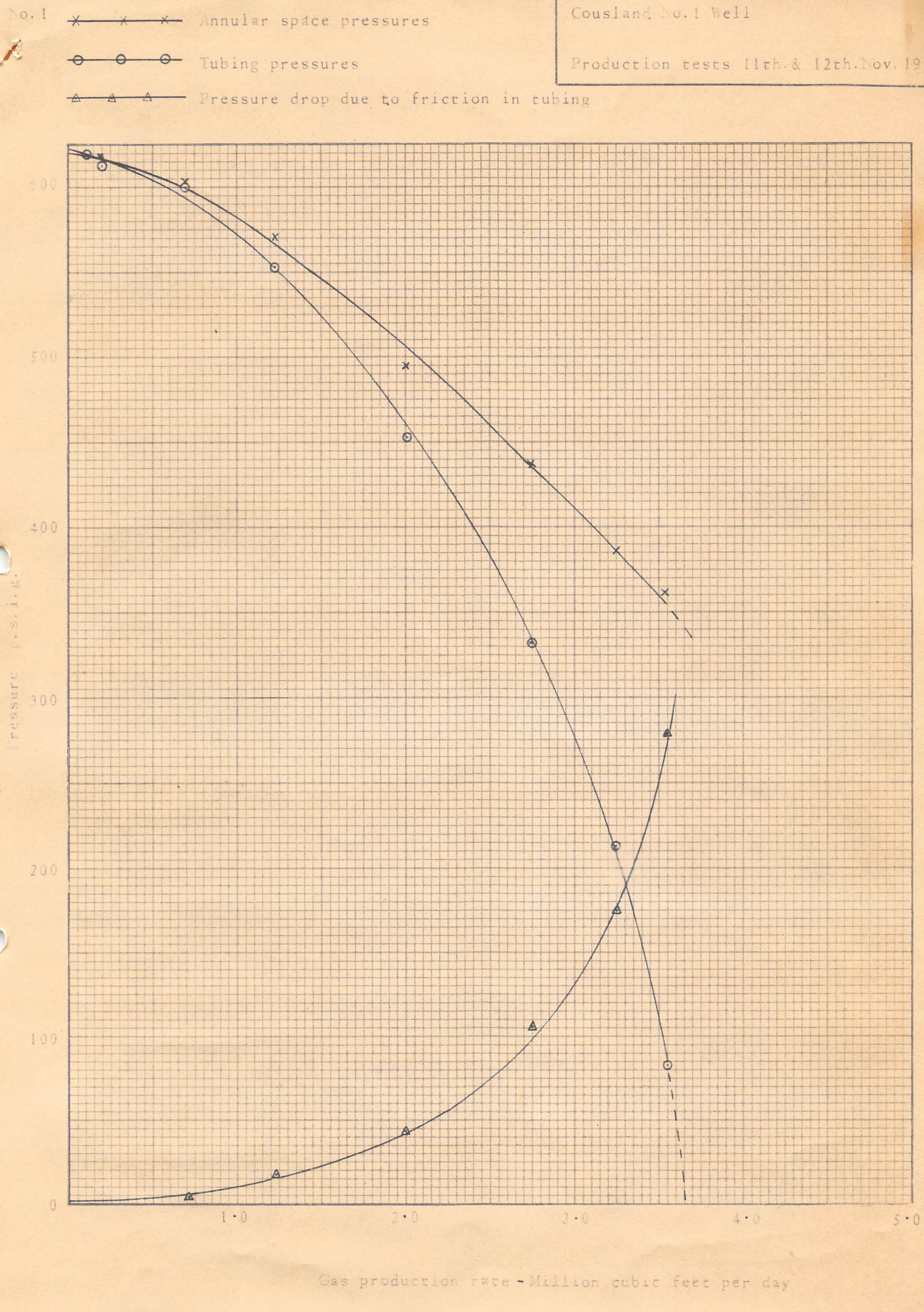
There was no pressure evidence at all for the production of formation water during the gas production tests. On 11th November a dipper was run into the tubing as far as the bursting disc, but no water was recovered.

C. M. Alcock

Graph No. 1

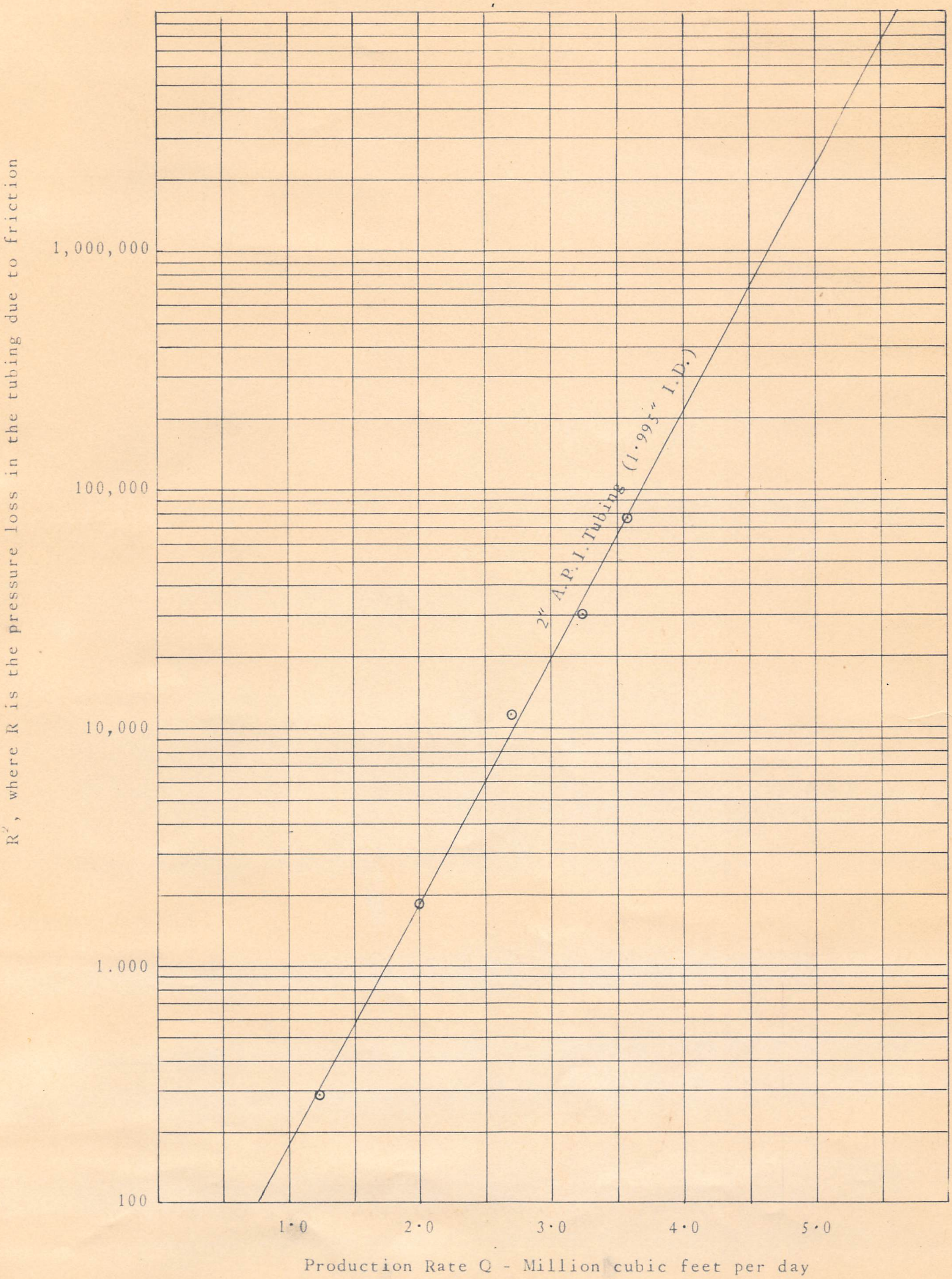
Cousland No. 1 Well

Production tests 11th. & 12th. Nov. 1956



Friction pressure loss in tubing during production tests

(Tubing to top of perforations 1565′)

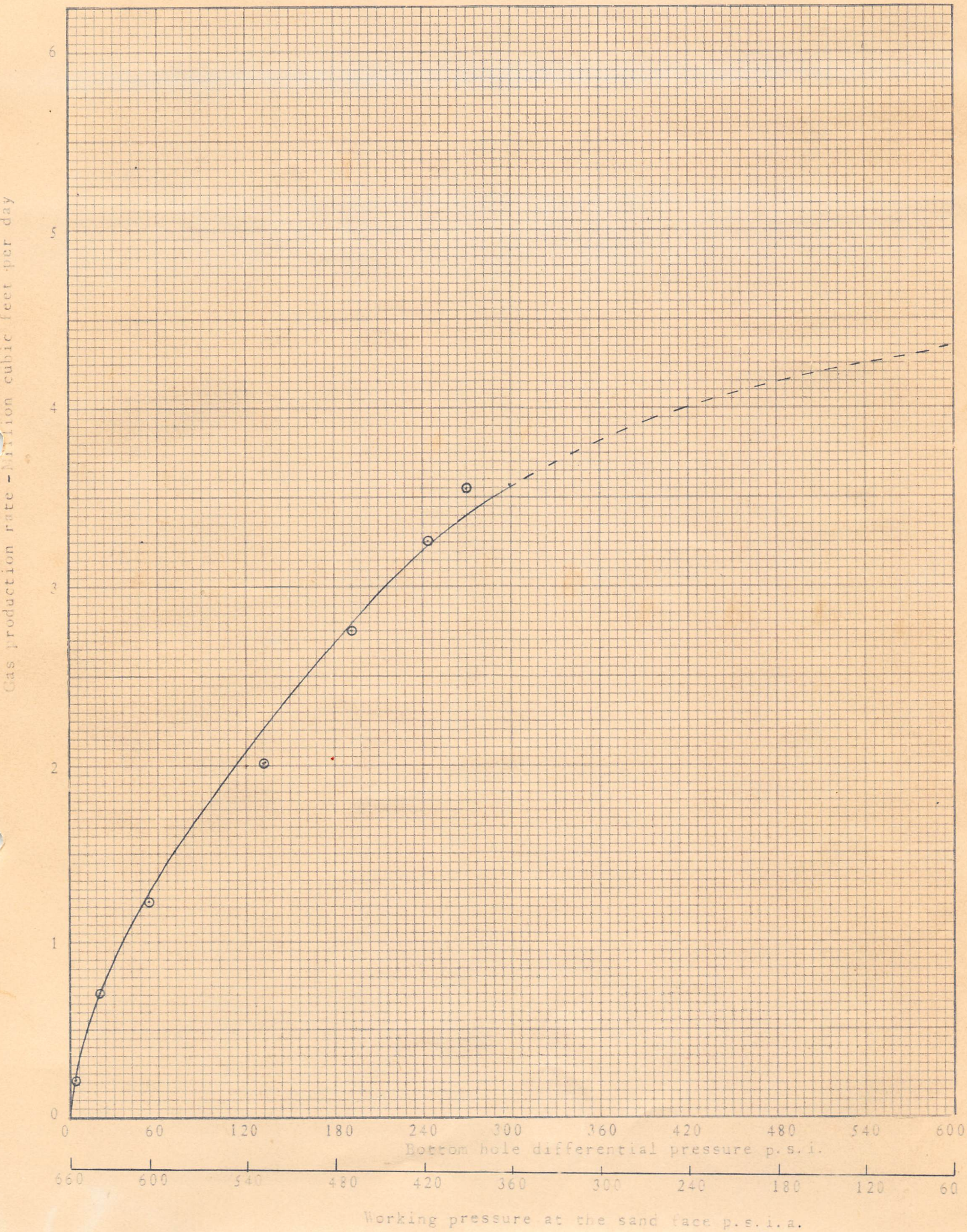


Graph No. 3

Cousland No. 1 Well

Production tests 11th. & 12th. Nov. 1956

Production rates v Bottom hole differential pressures



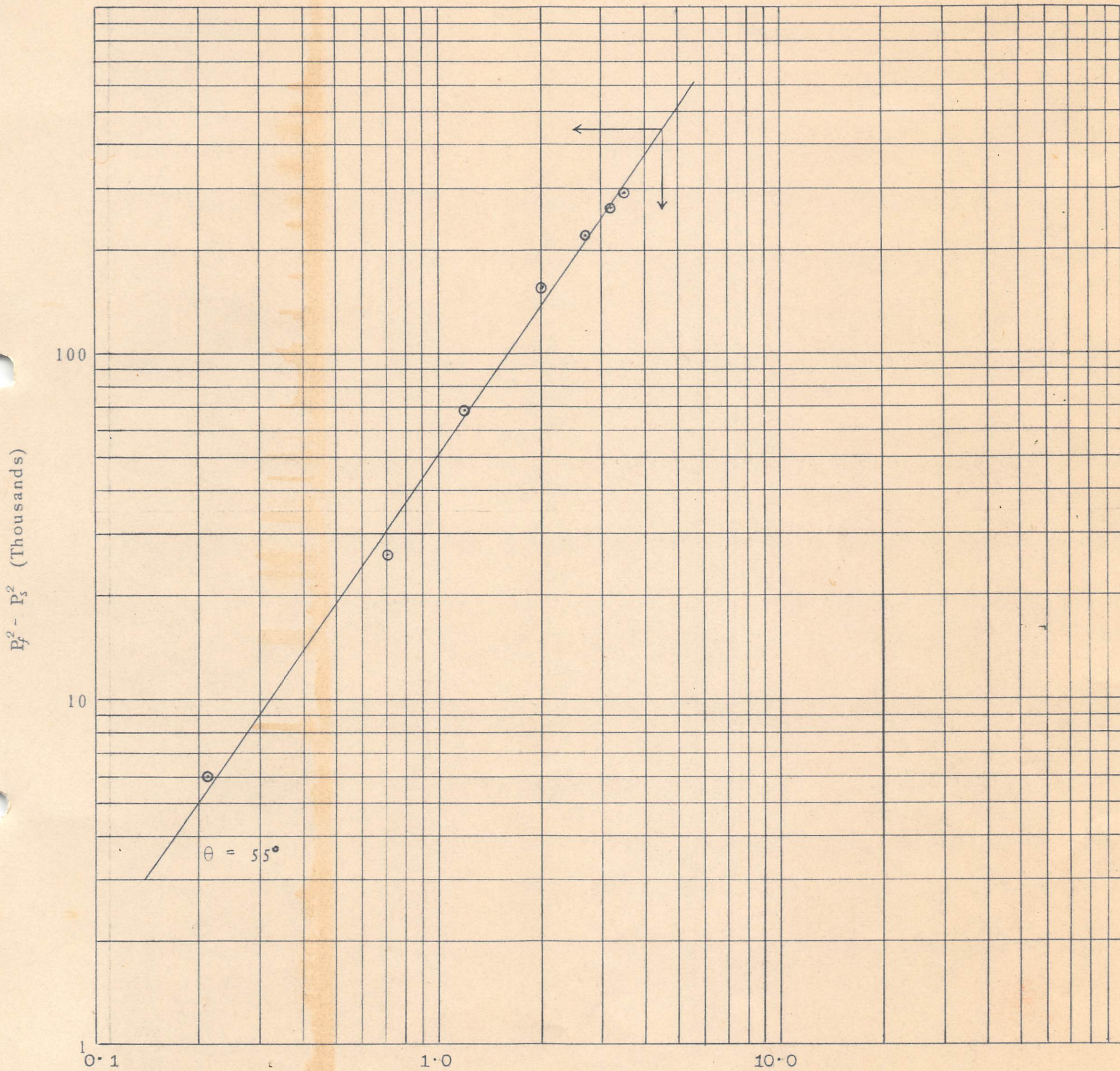
Graph No. 4.

Cousland No. 1 W

Railroad Commission of Texas Method

Back pressure curve. Exponent n = ·7002

Open flow potential 4½ million cubic feet per day

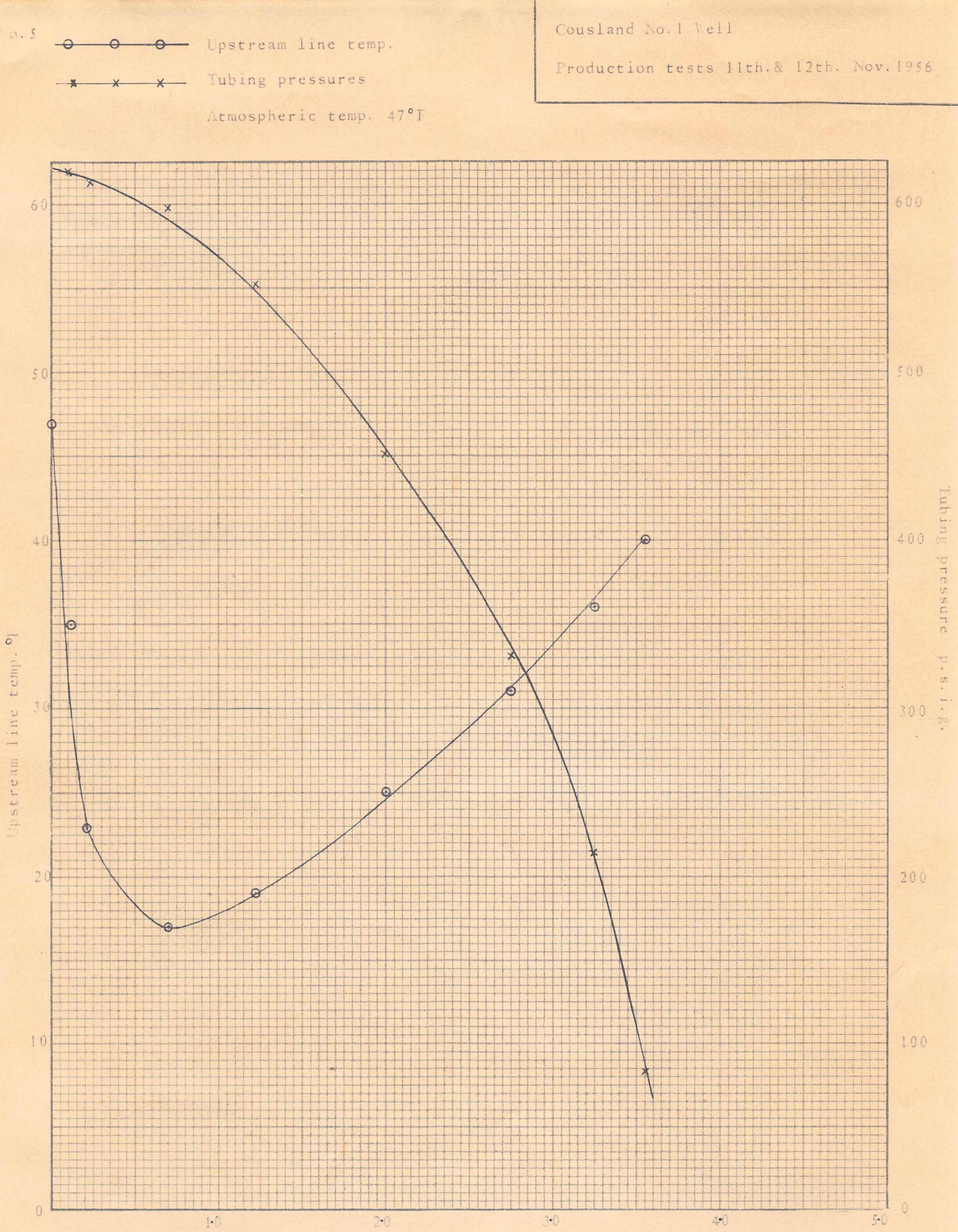


$Q = C\,(P_f^2 - P_s^2)^n$

P_f = Shut in formation pressure p.s

P_s = Working pressure at sand face

Graph No. 5

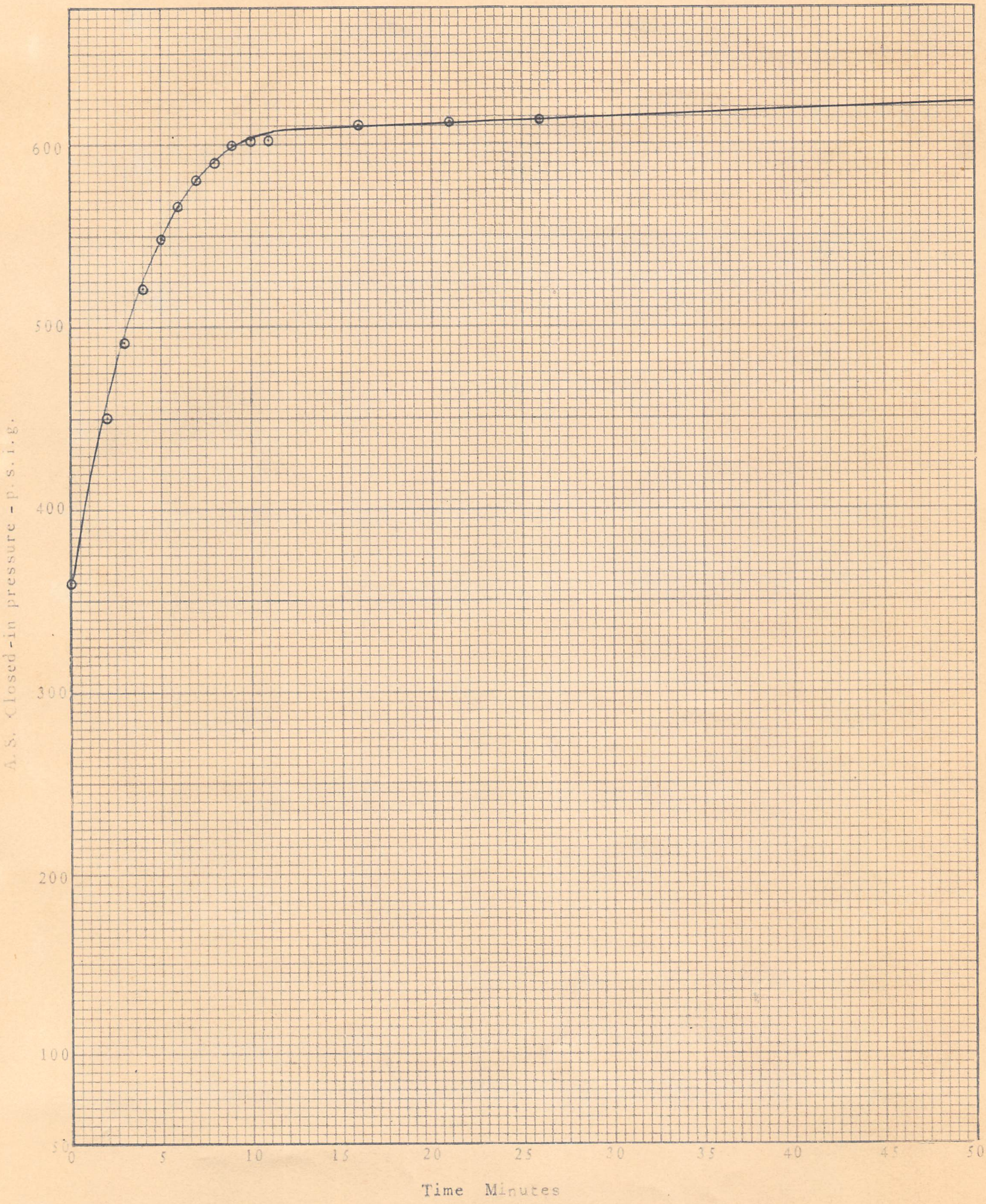

Upstream line temp.
Tubing pressures
Atmospheric temp. 47°F
Cousland No.1 Well
Production tests 11th.& 12th. Nov.1956
60
50
40
30
20
10
0
600
500
400
300
200
100
0
1·0
2·0
3·0
4·0
5·0
Upstream line temp. °F
Tubing pressure p.s.i.g.
Gas production rate - Million cubic feet per day

Graph No. 6

Cousland No. 1 Well

Pressure build up curve after production tests on 12th November

Annular space closed-in wellhead pressure build up curve



APPENDIX.

COUSLAND NO. 1 WELL.

I WELLHEAD PRESSURE BUILD-UP DATA.

Gauge pressures corrected by dead weight tester

Date 10th November 1956.

After bringing in well and reproducing water in the casing.

9.50 p.m. Closed-in tubing.

Time.	Minutes.	P.S.I.G. Tubing	P.S.I.G. Annular Space	Remarks.
9.52 p.m.	2	400	415	Pressure before closing-in.
9.55 p.m.	5	502	520	Tubing 78 A.S.355.
10.00 p.m.	10	602	610	
10.04 p.m.	14	606	620	
10.10 p.m.	20	612	622	
11.00 p.m.	70	612	622	
Midnight	130	622	-	A.S.gauge out of order.
11th November.				
1.00 a.m.	190	622	-	
2.00 a.m.	250	622	-	
10.00 a.m.	-	622	622	Checked A.S.pressure with tubing gauge.
10.40 a.m.	-	622	622	Tubing pressure by D.W.T. 620;4

Date 12th November 1956.

After completion of production tests; and producing 580,000 cubic feet gas.

6.31 p.m. Closed-in tubing.

Time.	Minutes.	p.s.i.g. Tubing.	p.s.i.g. Annular Space.	Remarks.
6.33 p.m.	2	450	450	Pressure before closing-in.
6.34 p.m.	3	495	492	Tubing 138 A.S.360
6.35 p.m.	4	525	522	
6.36 p.m.	5	545	549	Gauge pressures corrected by dead-weight tester.
6.37 p.m.	6	567	567	
6.38 p.m.	7	580	582	
6.39 p.m.	8	593	592	
6.40 p.m.	9	600	600	
6.41 p.m.	10	605	602	
6.42 p.m.	11	607	603	
6.47 p.m.	16	613	610	
6.52 p.m.	21	614	612	
6.57 p.m.	26	615	614	
13th November.				
9.30 a.m.	-	620	622	

II TABULATION OF PRODUCTION TEST RESULTS.

1. By Molesworth flow formula.
   (for very small pressure differences).

2. By Weymouth flow formula.

1. Molesworth Flow Formula.

$$Q = 41{,}500 \times \left(\frac{d^5h}{GL}\right)^{\frac{1}{2}} \times \left(\frac{520}{T}\right)^{\frac{1}{2}}$$

where,

Q = Standard cubic feet per day of gas.
d = Inside diameter of pipe in inches.
    For 3" nominal bore pipe $D^5 = 243$.
h = Pressure difference - inches of water.
G = Specific gravity of gas relative to air.
L = Length of burning line section in feet. (530')
T = Absolute temperature of the gas °R.

For Cousland gas.

G = 0.6

Hence $Q = 36{,}300 \times h^{\frac{1}{2}} \times \left(\frac{520}{T}\right)^{\frac{1}{2}}$

Date 11th November 1956.

Barometric pressure - 29.34"Hg = 14.4 p.s.i.a.

1. By Molesworth Flow Formula.

(for very small pressure differences).

Closed-in Wellhead pressures (corrected gauge) Tubing 620 p.s.i.g.
Annular Space 622 p.s.i.g.

Flow Test No.	1		2		3	
Duration	hours	mins.	hours	mins.	hours	mins.
	2	20	0	17	1	45
Average wellhead pressures - p.s.i.g. corrected gauge.	T	A.S.	T	A.S.	T	A.S.
T = Tubing A.S.= Annular Space.	620	622	618	622	613	617
Average burning line pressures. P_1=Upstream pressure. P_2= Downstream pressure.	P_1	P_2	P_1	P_2	P_1	P_2
Inches mercury	-	-	0.77	-	2.55	-
Inches water	11.2	0.8	10.5	0.8	34.7	4.3
$h = P_1 - P_2$ (inches water)	10.4		9.7		30.4	
$h^{\frac{1}{2}}$	3.22		3.12		5.52	
Average burning line temperatures °F. T_1= Upstream temperature T_2= Downstream temperature.	T_1	T_2	T_1	T_2	T_1	T_2
	39	47	32	45	23	42
(a) T mean °F	43		39		33	
(b) T mean °R	503		499		493	
(c) 520/T mean R	1.034		1.043		1.055	
(d) (520/T mean R)$^{\frac{1}{2}}$	1.018		1.022		1.028	
Average production rates - cubic feet per day. $Q = 36,300 \times h^{\frac{1}{2}} \times \left(\frac{520}{T}\right)^{\frac{1}{2}}$	119,000		116,000		206,000	
Cubic feet per hour	4,960		4,840		8,600	

2. Weymouth's Flow Formula.

$$Q = 886.22 \times d^{2.667} \times \left(\frac{P_1^2 - P_2^2}{L}\right)^{\frac{1}{2}} \times \left(\frac{0.6}{G}\right)^{\frac{1}{2}} \times \left(\frac{520}{T}\right)^{\frac{1}{2}} \times \left(\frac{1}{Z}\right)^{\frac{1}{2}}$$

where,

Q = Standard cubic feet per day of 0.6 gravity gas at 60°F and 14.40 p.s.i.a. base pressure.
d = Diameter inside of pipe in inches.
For 3" nominal bore pipe (3.07"i.d.) $d^{2.667}$ = 19.8
P_1 = Upstream end pressure in the burning line - p.s.i.a.
P_2 = Downstream end pressure in the burning line - p.s.i.a.
T = Absolute temperature of the gas - °R
Z = Compressibility factor
G = Specific gravity of the gas relative to air flowing through the line.
L = Length of the burning line section in miles.
Length = 530' = 0.1004 miles.

For Cousland gas.

G = 0.6
Z = 1 (under conditions of measurement)

Hence $Q = 55{,}400 \times (P_1^2 - P_2^2)^{\frac{1}{2}} \times \left(\frac{520}{T}\right)^{\frac{1}{2}}$ cubic feet per day.

Barometric pressure 29.6" Hg = 14.5 p.s.i.a.

Mean atmospheric Temperature 47°F.

Date 12th November 1956.

2. By Weymouth Flow Formula.

Closed-in Wellhead pressures (corrected gauge) Tubing 620 p.s.i.g.
Annular Space 622 p.s.i.g.

Flow Test No.	4	5	6	7	8	9
Duration	hours 1, minutes 58	hours 2, minutes 15	hours 1, minutes 45	hours 1, minutes 15	hours 1, minutes 15	hours 0, minutes 30
Average wellhead pressures - p.s.i.g. corrected gauge. T = Tubing. A.S. = Annular Space.	T 599 / A.S. 602	T 553 / A.S. 570	T 452 / A.S. 495	T 331 / A.S. 437	T 213 / A.S. 387	T 83 / A.S. 362
Average Burning Line pressures. P_1 = Upstream pressure, P_2 = Downstream pressure.	P_1 / P_2	P_1 / P_2	P_1 / P_2	P_1 / P_2	P_1 / P_2	P_1 / P_2
(a) Inches water	– / 18.3	– / –	– / –	– / –	– / –	– / –
(b) Inches mercury	10.3 / –	– / 4.0	– / 9.0	– / 12.1	– / 14.6	– / –
(c) p.s.i.g.	5.04 / 0.65	12.67 / 1.96	25.4 / 4.41	37.8 / 5.94	46.6 / 7.17	53.5 / 11.5
(d) p.s.i.a.	19.54 / 15.15	27.17 / 16.46	39.9 / 18.91	52.3 / 20.44	61.1 / 21.61	68.0 / 26.0
(e) $(p.s.i.a.)^2$	382 / 229	735 / 271	1590 / 358	2730 / 418	3730 / 467	4630 / 676
(f) $P_1^2 - P_2^2$	153	464	1232	2312	3263	3954
(g) $(P_1^2 - P_2^2)^{\frac{1}{2}}$	12.37	21.55	35.15	48.1	57.1	62.8
Note: Gauge pressures have been corrected by D.W.T.						
Average Burning line temperatures °F. T_1 = Upstream temperature. T_2 = Downstream temperature.	T_1 17 / T_2 46	T_1 19 / T_2 39	T_1 25 / T_2 29	T_1 31 / T_2 30	T_1 36 / T_2 32	T_1 40 / T_2 33
(a) T mean °F	31	29	27	30	34	37
(b) T mean °R	491	489	487	490	494	497
(c) 520/T mean °R	1.059	1.064	1.067	1.062	1.054	1.047
(d) $(520/T°R)^{\frac{1}{2}}$	1.03	1.033	1.034	1.032	1.028	1.023
Average production rates - Cubic feet per day. $Q = 55,400 \times (P_1^2 - P_2^2)^{\frac{1}{2}} \times \left(\frac{520}{T}\right)^{\frac{1}{2}}$	705,000	1,230,000	2,020,000	2,750,000	3,250,000	3,560,000
Cubic feet per hour.	29,300	51,200	84,000	115,000	135,000	148,000

CUMULATIVE GAS PRODUCTION FROM COUSLAND NO.1 WELL.

A. From 1582 - 1632 and 1720 - 1735 gas sands.

1. Cumulative gas produced to tests ending 24th June 1943. 30,618,000 cu.ft.

2. Approx. gas produced whilst running tubing ending 19th May 1945.
Circa 32,000 cubic feet. Cumulative 30,650,000 cu.ft.

3. Approx. gas produced whilst bringing well in 10th November 1956.

(a) Circa 4 p.m. to 6 p.m. @ 80,000 ft. 3/hr: 160,000 cu.ft.

(b) 6 p.m. to 9.50 p.m. @ 110,000 ft. 3/hr: 420,000 cu.ft.

580,000 cu.ft.

Cumulative - 31,230,000 cu.ft.

4. Gas produced during tests on 11th and 12th November 1956.

Test No.	Prodn. rate.Cu. ft./hr.	Duration of test. Hours.	Prodn. during test. Cu.ft.	Total prodn. since commencement of tests. Cu.ft.	Remarks.
1	4,960	2.33	11,500	11,500	Production tests on 11th November using Molesworth Flow Formula. Production tests on 12th November using Weymouth Flow Formula.
2	4,840	0.28	1,400	12,900	
3	8,600	1.75	15,000	27,900	
4	29,300	1.97	57,600	85,500	
5	51,200	2.25	115,000	200,500	
6	84,000	1.75	147,000	347,500	
7	115,000	1.25	143,500	491,000	
8	135,000	1.25	169,000	660,000	
9	148,000	0.50	74,000	734,000	

Hence cumulative production from well to end 1956:-
31,964,000 cubic feet.

B. From 1760 - 1806 gas sand.

Cumulative gas produced to tests ending 15th May 1939. 35,900,000 cu.ft.

HENCE TOTAL CUMULATIVE PRODUCTION FROM WELL - 67,864,000 cu.ft.

III BOTTOM HOLE PRESSURE DATA AND OPEN FLOW POTENTIAL OF WELL.

Note: On 4th June 1947 the closed-in surface pressure recorded by deadweight tester was 621.4 p.s.i.g. This compares with 620.4 p.s.i.g. recorded on 11th November 1956 after bringing on production the 1582-1613 sand member. (gamma log 1580'-1602').

Reservoir Temperature - 68°F at 1582'.
Assume average static well temperature 60°F.

1. Determination of pressure at sand face from surface closed in pressure.

Pressure formula.

$$\text{Log}_{10} P_2 = \text{Log}_{10} P_1 + \frac{qsl}{144 \times 2.3026 \times A \times Z}$$

where P_2 = pressure at sand face at 1580' - p.s.i.a.
P_1 = closed-in pressure at top of column - p.s.i.a.
q = density of air at atmospheric pressure and average temperature of gas column (60°F)
= 0.07634 lbs. per cubic foot.
s = specific gravity of gas relative to air = 0.6
l = length of gas column = 1580'
A = Atmospheric pressure = 14.7 p.s.i.
Z = compressibility factor = 0.915 at 660 p.s.i.a. & 60°F.

$$\text{Hence, Log}_{10} P_2 = \text{Log}_{10} P_1 + \frac{0.07634 \times 0.6 \times 1580}{144 \times 2.3026 \times 14.7 \times 0.915}$$

Hence $\text{Log}_{10} P_2 = \text{Log}_{10} P_1 + 0.0162$.

2. Calculation of Gas Pressure gradient from gas analysis.

Gas analysis of gas sample from 1582 - 1632 sand.
Sunbury Report reference A.P.S.51.

1	2	3	4	5	6	7	8
Component	Mole Fraction n	Molecular weight of Component M	n M	Critical Temperature of component. T c	nTc	Critical Pressure of Component P c	nPc
N_2	0.015	28	0.42	227	3.4	492	7.4
C_1	0.959	16	15.35	344	330.0	673	645.0
C_2	0.026	30	0.78	550	14.3	709	18.4
	1.000	-	16.55	-	347.7	-	670.8

Base on reservoir temperature at 1582' - 68°F - 528°R
Base on reservoir pressure at 1582' - 660.3 p.s.i.a.

(a) Pseudo-reduced temperature $\frac{528}{347.7} = 1.52$

(b) Pseudo-reduced pressure $\frac{660.3}{670.8} = 0.985$

(c) Compressibility factor (from graph) = 0.910 (Z)

(d) Average molecular weight of gas = 16.55

(e) Density $= \frac{1}{V} = \frac{PM}{ZRT} = \frac{660 \times 16.55}{0.910 \times 10.73 \times 528}$

Hence Density = 2.12 lbs. per cubic foot.

(d) Gas Gradient $= \frac{2.12}{144} = 0.0147$ p.s.i. per foot.

3. Check on Reservoir Pressure at 1582'.

Wellhead closed-in pressure - 636 p.s.i.a.
Pressure of 1582' column of gas - 23.3 p.s.i.
Hence Reservoir Pressure at 1582'-659.3 p.s.i.a.

4. Gas production rates at bottom hole pressure and temperature.

(a) Volume of reservoir space containing 1 cubic foot of gas at S.T.P.

$$B = \frac{14.7\ Z}{P} \times \frac{T}{520} = 0.02827\ \frac{TZ}{P}$$

Where P = Reservoir Pressure - p.s.i.a.
T = Reservoir Temperature °R
Z = Compressibility factor.
B = Volume of reservoir space containing 1 cubic foot gas.

$$S = \frac{1}{B} = \frac{P}{0.02827\ TZ}$$

Where S = gas saturation, or cubic feet of gas at STP in 1 cubic foot reservoir space.

Base on T = 528°R

$$\text{Hence } S = \frac{P}{14.92 \times Z}$$

5. Open flow potential of well from back-pressure tests.

Method used as detailed by the Railroad Commission of Texas in their publication "Back-pressure test for Natural Gas Wells."

Basis.

When the rate of flow is plotted against the corresponding value for the difference in the square of the shut-in pressure in the formation and the square of the working pressure at the sand face on logarithmic co-ordinate paper, the points delineate a straight line which is expressed by the formula:-

$$Q = C\ (P_f^2 - P_s^2)^n$$

Where:- Q = Rate of flow in cubic feet per 24 hours.
C = A numerical co-efficient, characteristic of the well.
P_f = Shut-in formation pressure - p.s.i.a.
P_s = Working pressure at the sand face - p.s.i.a.
n = Numerical exponent characteristic of the well. The value of "n" is equal to the reciprocal of the slope of the back-pressure curve.

(a) Check on pressure calculations.

$$BHP = Psi + \frac{14,268 \times Psi \times G \times L}{759,931 \times Tsi.}$$

Where:- BHP = Bottom Hole Pressure - p.s.i.a.
Psi = Wellhead Pressure under shut-in conditions.
G = Specific gravity of the gas in the flow-string (air = 1).
L = Length of the flow-string - feet.
Tsi = Average temperature of flow-string °F.

$$\therefore \text{BHP} = 636 + \frac{14.268 \times 636 \times 0.6 \times 1580}{759,931 \times 520}$$

$$= 636 + 21.9 = \underline{657.9 \text{ p.s.i.a.}}$$

Hence $P_{av} = \frac{636 + 657.9}{2} = 646.9$ p.s.i.a.

Hence $P_z = \frac{646.9}{670.8} = 0.964.$

Hence $T_z = \frac{520}{347.7} = 1.497.$

Where P_z = Pseudo-reduced critical pressure
and T_z = Pseudo-reduced critical temperature.

Hence Fpv (Supercompressibility factor) = 1.053

Now $Fpv = \left(\frac{1}{Z}\right)^{\frac{1}{2}}$

$S = (Fpv)^2 = \frac{1}{Z} = 1.108.$

Now $Pf = Psi \times e^{KS}$

And $Ksi = \frac{GL}{53.34 \times Tsi}$

Where Pf = Formation Pressure - p.s.i.a.
Psi = Shut-in wellhead pressure - p.s.i.a.
e^{KS} = Factor for evaluating the pressure drop due to the weight of the gas column to the sand face.
53.34 = Gas constant for air.
Tsi = Shut-in well Temperature °R.

Hence $Ksi = \frac{0.6 \times 1580}{53.34 \times 528} = 0.0337.$

Hence KS = 0.0337 x 1.108 = 0.0373.

$e^{KS} = (2.718)^{0.0373}$

$\log e^{KS} = 0.0373 \times \log 2.718$
$= 0.0373 \times 0.4343 = 0.0162.$

And $e^{KS} = 1.038.$

Hence Pf = 636 x 1.038 = <u>660.0 p.s.i.a.</u>

This is in good agreement with the figure of 660.3 p.s.i.a. as initially calculated. Hence the calculations already made for P_s the working pressures at the sand face have been accepted.

The values of $(P_f^2 - P_s^2)$ have been plotted versus the corresponding rates of flow on logarithmic co-ordinate paper. The straight line through these points has been extended until it intersects the horizontal line representing $Pf^2 = 436,000$. At the point of intersection a vertical line is dropped to the abscina to determine the open flow potential of the well; and from the graph this is seen to be 4½ million cubic feet per day.

The exponent "n" of the flow equation is the cotangent of the angle θ, and is the slope of the back-pressure curve. By measurement $\theta = 55°$, and n = .7002.

6. <u>Pressure loss due to friction in tubing during production tests.</u>

It will be noted from the graph that the square of the pressure loss in the tubing due to friction gives a straight line relationship when plotted against production rates.

The friction pressure drop R has been taken as the difference between the wellhead Annular Space and Tubing pressures. By adopting this procedure no corrections have to be made for changes in temperature and variations in the density of the gas column.

From the graph it will be noted that at a production rate of 4 million cubic feet per day $R^2 = 230,000$; and hence R = 480 p.s.i. But from the back pressure production curve it will be noted that at 4 million cubic feet per day $(P_f^2 - P_s^2) = 365,000$. Hence $P_s^2 = 71,000$, which gives a pressure at the sand face of 266 p.s.i.a. Hence the well could not be produced at 4 million cubic feet per day through 2" tubing.

BOTTOM HOLE PRESSURE - PRODUCTION DATA.

Test No:	Closed-in pressure.	3	4	5	6	7	8	9
A.S. Wellhead pressure - p.s.i.g.	621	617	602	570	495	437	387	362
p.s.i.a.	636	632	617	585	510	452	402	377
$\text{Log}_{10} P_1$	2.8035	2.8007	2.7903	2.7672	2.7076	2.6551	2.6042	2.5763
$\text{Log}_{10} P_1 + 0.0162$	2.8197	2.8169	2.8065	2.7834	2.7238	2.6713	2.6204	2.5925
∴ P_2 - p.s.i.a.	660.3	656.0	640.4	607.3	529.4	469.1	417.3	391.3
p.s.i.g.	645	641	626	592	515	454	402	376
Bottom Hole differential pressure - p.s.i.	-	4.3	19.9	53.0	130.9	191.2	243.0	269.0
Gas production rates at S.T.P. - cubic feet per day.	-	206,000	705,000	1,230,000	2,020,000	2,750,000	3,250,000	3,560,000
Production rates at bottom hole pressure and temperature.								
pseudo-reduced temperature	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52
pseudo-reduced pressure $P_2/670.8$	0.985	0.979	0.956	0.906	0.789	0.700	0.623	0.584
Compressibility Z (from graph)	0.910	0.910	0.911	0.912	0.922	0.932	0.940	0.944
$S = \frac{P}{14.92 \times Z}$ (a) $14.92 \times Z$	13.56	13.56	13.58	13.60	13.74	13.90	14.02	14.07
(b) S	48.7	48.4	47.2	44.7	38.5	33.7	29.8	27.8
Hence gas rates at bottom hole temperature and pressure: Cu.ft./day.	-	4,260	14,950	27,500	52,500	81,600	109,000	128,000
Open flow potential of well.								
P_f^2 (Shut-in formation pressure)	436,000	.	.	.	.	.	.	.
P_s^2 (working pressure at the sand face)	-	430,000	410,000	368,000	280,000	220,000	174,000	152,000
$P_f^2 - P_s^2$		6,000	26,000	68,000	156,000	216,000	262,000	284,000
Friction Pressure loss in tubing.								
Tubing wellhead pressure - p.s.i.g.	-	613	599	553	452	331	213	83
Hence pressure loss due to friction R - p.s.i.	-	4	3	17	43	106	174	279
Hence R^2	-	16	9	289	1,850	11,240	30,280	77,840

IV DIARY OF WORK CARRIED OUT TO BRING IN THE WELL.

NOVEMBER 1956.

Note: In July 1951 the well had been plugged back with cement to 1465'. Anti-corrosive mud had been run into the casing to 50', with a cement plug tosurface. During the current workover operation the top cement plug and the anti-corrosive mud were cleaned out. The bottom cement plug was drilled out to 1663'. The lower sand from 1720' to the top of the original cement plug at 1735' were therefore still plugged off with cement. The procedure was therefore to put the 1582' - 1632' sand on production only in order to avoid bringing in reservoir water. The details relating to the bringing in of the well are as follows:-

Thursday 8th Nov.	11.00 a.m.	Well standing full of water with cement plug drilled out to 1663'.
	11.30 a.m.	Arrival of Schlumberger truck. Running gamma ray survey to locate shooting interval. The gamma ray log indicated that the top sand member occurred over the interval 1580' - 1602'; and the lower sand member over the interval 1614' - 1630'.
	1.45 p.m.	Preparing to shoot the top sand member over the interval 1575' - 1605', the Schlumberger depths being measured from the Cardwell rotary table.
	2.40 p.m.	Fired four guns, thus perforating the casing with 96 shaped charges over the interval 1581' - 1605'. The fifth gun failed to fire, there being a hole in one cap which caused the gun to become water-logged.
	3.40 p.m.	Re-loaded and fired fifth gun over the interval 1575' - 1581' with 24 shaped charges. Hence casing perforated with a total of 120 shaped charges. During shooting, the casing was kept full of water; and it was found that the well would not take any water at all.
	3.45 p.m.	Running in 2" plain A.P.I. tubing (i.d. 1.995") with the end of the bottom joint plugged; and the perforated joint covering the interval 1565' - 1589'. The bursting disc holder, complete with aluminium bursting disc was run immediately above the perforated joint.
	5.30 p.m.	Completed running in tubing. The top joint was screwed into a flange to match up with the casing flange.
	6.00 p.m.	Preparing to remove Cardwell rotary table, sleepers, etc; and to make up the production wellhead.
Friday. 9th Nov.	9.00 a.m.	Wellhead made up complete with 3" main valve, and 2" side valves on tubing and casing annulus. No water had been lost to the well overnight, there being no annular space pressure.
	9.15 a.m.	Opened up 2" tubing valves to burning line.
	9.40 a.m.	Dropped first 'go-devil'. Bursting disc did not break.
	10.15 a.m.	Dropped second 'go-devil'. Bursting disc did not break.
	10.45 a.m.	Dropped third 'go-devil'. Bursting disc was fractured. Indications were that the 'go-devils' dropped into the tail pipe. Air was sucked into the annular space indicating that the water levels in casing and tubing were being equalised.

Friday. 9th Nov. (contd.)	11.00 a.m.	The fluid levels had become equalised; but no gas production was obtained through the tubing.
	12.05 p.m.	Obtained a supply of compressed air from the quarry which was connected in to the casing annulus. Pressure circa 100 p.s.i.g.
	12.10 p.m.	Opened up compressed air to the casing annulus.
	12.13 p.m.	Well producing water through the tubing into the cellar.
	12.35 p.m.	No further water produced by air supply, which was disconnected. Casing annulus pressure 65 p.s.i.g. Shut-in tubing.
	12.50 p.m.	Annular space 66 p.s.i.g. Tubing 40 p.s.i.g.
	1.57 p.m.	Annular space 57 p.s.i.g. Tubing 60 p.s.i.g.
	2.00 p.m.	Blew down tubing pressure. Gas and a little water produced.
	2.05 p.m.	Shut-in tubing.
	2.50 p.m.	Annular space 51 p.s.i.g. Tubing 52 p.s.i.g. Blew down tubing pressure. Gas and a little water produced. Shut-in tubing.
	3.28 p.m.	Annular space 46 p.s.i.g. Tubing 50 p.s.i.g. Blew down tubing pressure. Gas and a little water produced. Shut-in tubing.
	4.19 p.m.	Annular space 37 p.s.i.g. Tubing 45 p.s.i.g. Blew down tubing pressure. Shut-in tubing. Keeping well shut-in overnight. Awaiting 2" swab from Eakring.
Saturday. 10th Nov.	9.15 a.m.	Annular space 35 p.s.i.g. Tubing 40 p.s.i.g. Well standing shut-in, awaiting 2" swab.
	12.00 p.m.	Re-connected compressed air from quarry to casing annulus, and pressure built up to 75 p.s.i.g. Received 2"swab. Running swab into tubing and recovering water.
	12.10 p.m.	Shut off compressed air to repair pipe line leaks.
	12.15 p.m.	Swab rubbers badly cut after 3 runs to about 70'. No spare rubbers available. Hence swabbing ceased.
	12.30 p.m.	Air pressure 75 p.s.i.g. Flowing water through tubing. Shut compressor down to repair air leaks.
	12.50 p.m.	Opened up air line after repairing leak. Water flowing out of tubing.
	1.05 p.m.	Air pressure 93 p.s.i.g. Shut-in tubing after water ceased to flow.
	1.10 p.m.	Opened up tubing to vacuum tanker. Annular space 90 p.s.i.g. Tubing 22" vacuum.
	1.35 p.m.	Disconnected vacuum tanker, and closed-in tubing. Water recovery to date during test:- Nov.9th - 400 gallons, Nov.10th - 500 gallons. Total 900 gallons.
	2.45 p.m.	Annular space 93 p.s.i.g. Tubing 20 p.s.i.g. Opened up tubing to atmosphere. Blew down annular space pressure fast to rock well.
	2.48 p.m.	Shut-in annular space and tubing valves. Re-connected air supply to casing annulus. Building up pressure.
	3.00 p.m.	Annular space 90 p.s.i.g. Tubing 35 p.s.i.g. Blew down tubing pressure; and well started flowing water slightly through tubing into cellar.
	3.05 p.m.	Water and gas production increasing. Pumping water from cellar into vacuum tanker.
	3.17 p.m.	Closed-in tubing. Preparing to flow well to burning line. Water recovered circa 500 gallons, i.e. cumulative since start of tests in all 1400 gallons.
	3.20 p.m.	Annular space 120 p.s.i.g. Tubing 110 p.s.i.g. Shut off compressed air supply from quarry.

Saturday. 10th Nov.	3.25 p.m.	Annular space 170 p.s.i.g. Tubing 210 p.s.i.g. Opened up well to burning line through tubing. Well surging gas and water.
	4.00 p.m.	Estimated water production rate 6 gallons per minute.
	4.25 p.m.	Surging ceased, and obtained a continuous gas flow. Water estimated produced 400 gallons, i.e. cumulative 1800 gallons.
	4.35 p.m.	Lit gas flare. Dribble of water being produced from end of burning line.
	5.30 p.m.	Slight water dribble from end of burning line.
	8.30 p.m.	Flame observation indicated the production of dry gas. Hence all water in casing presumed reproduced.
	9.50 p.m.	Shut-in well. Annular space 355 p.s.i.g. Tubing 78 p.s.i.g.
	10.00 p.m.	Annular space 610 p.s.i.g. Tubing 600 p.s.i.g.
	10.10.p.m.	Annular space 622 p.s.i.g. Tubing 610 p.s.i.g.
Sunday. 11th Nov.	10.00 a.m.	Annular space 622 p.s.i.g. Tubing 620 p.s.i.g. (calibrated gauge).
	10.40 a.m.	Tubing closed-in pressure - 620.4 p.s.i.g. checked by deadweight tester.
	12.00.p.m.	Ran dipper to 1559' below R.T., i.e. above 'go-devil' level.
	12.15 p.m.	Pulled out dipper. No fluid obtained. Hence no detectable water in well.
	12.43 p.m.	Commenced flowing well at rate of 119,000 cubic feet gas per day.
	3.03 p.m.	Flowing rate decreased to 116,000 cubic feet gas per day.
	3.15 p.m.	Increased production to an average of 206,000 cubic feet gas per day.
	5.00 p.m.	Shut off burning line, completing low rate production tests.
	5.05 p.m.	Closed-in tubing for the night.
Monday. 12th Nov.	9.20 a.m.	Annular space 622 p.s.i.g. Tubing 620 p.s.i.g. (corrected gauge).
	9.32 a.m.	Opened up well to burning line. Average production rate 705,000 cubic feet gas per day.
	11.30 a.m.	Increased production rate to an average of 1,230,000 cubic feet per day.
	1.45 p.m.	Increased production rate to an average of 2,020,000 cubic feet per day.
	3.30 p.m.	Increased production rate to an average of 2,750,000 cubic feet per day.
	4.45 p.m.	Increased production rate to an average of 3,250,000 cubic feet per day.
	6.00 p.m.	Increased production rate to an average of 3,560,000 cubic feet per day.
	6.30 p.m.	Completed production tests. Shut in burning line.
	6.31 p.m.	Closed-in tubing.
	6.57 p.m.	Annular space 612 p.s.i.g. Tubing 615 p.s.i.g.
Tuesday. 13th Nov.	9.30 a.m.	Annular space 620 p.s.i.g. Tubing 618 p.s.i.g. (corrected gauge).

Copy

Mr. Watson
RW

From BP EXPLORATION CO. LTD., EAKRING.

To ENGINEERING DEVELOPMENT BRANCH, REFINERIES DIVISION. (ATTENTION OF MR. R.C. GRANT)

Our Ref. PRO/1/3770 **Your Ref.**

Date 27th December 1956

Subject PRODUCTION SCHEME FOR COUSLAND NO. 1 WELL

Further to our telephone conversation this morning we are sending you a copy of our drawing No. BM 655 A showing the safety precautions which the Scottish Gas Board decided should be taken to protect their 4" pipeline from the 600 p.s.i. wellhead pressure.

A covering note discussing these points is attached to the drawing. We are also sending you herewith one of Messrs. I.V. Controllers Ltd. catalogues, for you to decide whether you consider that the pressure regulators suggested are the most suitable type for the work required of them.

C. M. Adcock

C.M. Adcock.

c.c. Manager, Reservoir Engineering
Drilling Fluids and Production Branch.

CMA/EMH

3771

27th December 1956

T.S. Ricketts Esq.,
The Scottish Gas Board,
26 Drumsheugh Gardens,
Edinburgh 3.

Dear Mr. Ricketts,

Production Scheme for Cousland No.1 Well

Further to our meeting in Edinburgh last week, I have now had drawing No. BM 655 amended to show the safety precautions, which, it was decided should be taken to protect the 4" main pipeline from the 600 p.s.i. well-head pressure.

I am sending you a copy of our amended drawing No. BM 655 A herewith together with a covering note on the points discussed. I have sent this information on to our Engineering Branch in London for them to prepare the working drawing, and to cost the complete production scheme to your 4" main pipe line.

Yours sincerely,

C.M. Adcock

CMA/EMH

COUSLAND NO. 1 WELL.

GAS PRODUCTION SCHEME.

Revision of scheme as a result of a meeting with the Scottish Gas Board on 20th December 1956.

The diagrammatic sketch BM 655 A shows the amended arrangement for the proposed gas production scheme. This proposal was arrived at after a discussion with Messrs. Ricketts, Cox, Elgin and Cairns at the Scottish Gas Board's Office in Edinburgh on 20th December 1956.

The discussion centred around the safety precautions to be taken to prevent the possibility of the full wellhead pressure of 600 p.s.i. being transmitted to the 50 p.s.i. cast iron main pipe line to Musselburgh.

The following points were agreed:-

(1) Fit a by-pass line across the high pressure water separator.

(2) Install the Flow Bean on the high pressure side of the pressure controller. The throughput of the flow bean would then be circa 2000 cubic feet per day at the wellhead pressure instead of 100,000 cubic feet per day at atmospheric pressure.

(3) Fit two high pressure regulators instead of only one. It is thought that two of the type H5 controllers made by Messrs. I.V. Pressure Controllers Ltd. would be suitable for this work. The regulators to be connected in series; and the first controller to reduce the pressure from 600 p.s.i. to 100 p.s.i., and the second controller to reduce the pressure from 100 p.s.i. to 25 p.s.i.

(4) The Gas Board's governor is connected into the 4" pipeline, and will be set to reduce the pressure from 25 p.s.i. to 10 p.s.i. It is required to fit a shut-off valve controlled by the pressure on the downstream side of the Gas Board's governor. If the pressure in the 4" line rises to 30 p.s.i. then the cut off valve will close.

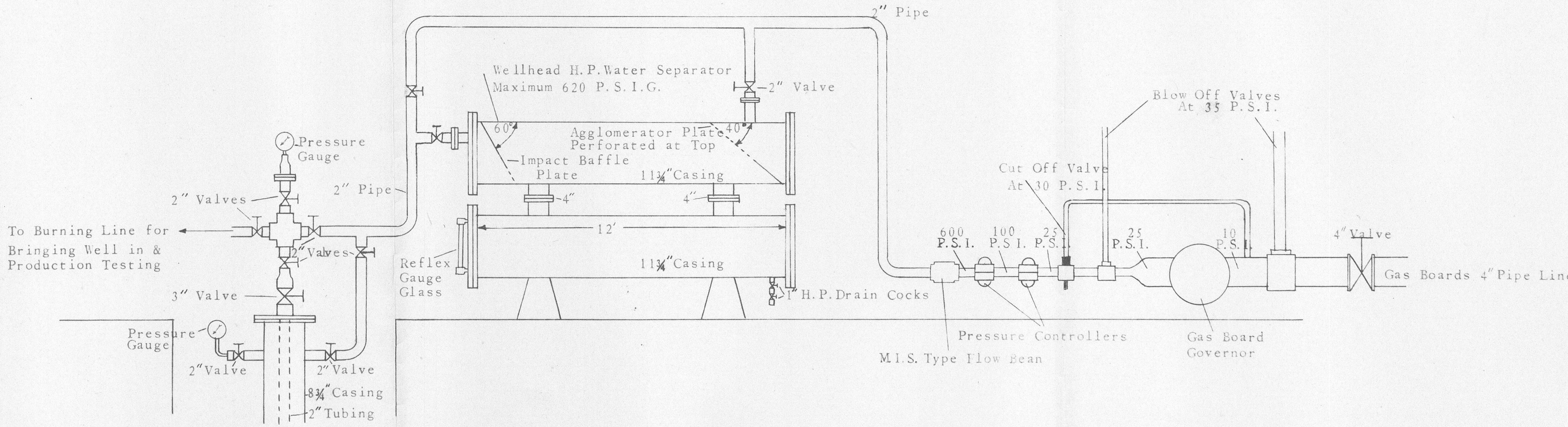
(5) In addition to the shut-off valve, a safety release valve is required between the shut-off valve and the Gas Board's governor. This is to be set to blow off at 35 p.s.i. In consequence, it will only come into operation after failure of the other control mechanisms.

(6) The Gas Board will supply all instruments and fittings for the 4" pipe line. It will be noted that it is proposed to install a second safety release valve after the Gas Board's governor. Again this would blow off at 35 p.s.i., and would only come into operation after the failure of all the other pressure controllers.

It is pointed out that it is planned for the pipeline to be completed by May 1957; and all equipment should be available for installation by this date.

...ing
...56
...H

C. M. Adcock



BP EXPLORATION CO. LTD., EAKRING NOTTS.

COUSLAND NO. 1 WELL

DIAGRAMMATIC ARRGT. OF WELLHEAD PLANT FOR GAS OFFTAKE TO GAS BOARDS' PIPE LINE

Scale : Diagrammatic Date : 22.11.56	BM. 655/a

COUSLAND NO. 1 WELL.

Mr: Kirby

GAS PRODUCTION SCHEME.

Wellhead Plant required to connect the Gas Supply into the Gas Board's Pipe Line.

The diagrammatic sketch BM.655 shows the proposed arrangement for the production scheme. The layout has been arranged to keep capital expenditure down to a minimum. The proposals are based on the recent production tests carried out on 11th and 12th November. Details of the production scheme are as follows:-

1. Gas Offtake.

The planned gas offtake from the well is an initial 100,000 cubic feet per day delivered at 50 p.s.i. pressure into the Gas Board's pipe line to Musselburgh gasworks. The offtake is to be increased at a later date if the well is found to stand up satisfactorily to this production rate.

2. Essential Plant Requirements.

The gas production is to be drawn through 2" tubing in the well; and only exceptionally from the casing annulus. An initial wellhead pressure of 620 p.s.i.g. has been recorded after bringing in the well. The following are the main plant requirements:-

A. High pressure mist extractor and water separator.
B. Pressure regulator to reduce the gas pressure to 50 p.s.i.g.
C. Flow bean for rough production control.

A. High pressure mist extractor and water separator.

With the specific view of avoiding water production, only the top member of the 1582' - 1632' sand has been exposed by perforating the casing with shaped charges over the interval 1575' - 1605'. The gamma ray log indicated that the top sand member occurred over the interval 1580' - 1602'; and the lower sand member over the interval 1614' - 1630'. The1720' - 1806' sand has been left shut off by a cement plug inside the casing, as it was from this sand that water was produced when the casing was perforated to 1735'.

There is thus every chance that the well will produce dry gas for a considerable period of time, particularly at low production rates when no water coning will take place. The indicated gas/water level from pressure data (see report on Cousland Well 5) is put at 1675', or 70' below the bottom of the present perforated interval.

However, it is proposed to incorporate in the production plant a simple mist extractor and water separator as a safeguard against water production contingencies. The suggested high pressure water separator is based on the following considerations:-

(i) High pressure v. low pressure separators.

A high pressure separator operating at the wellhead pressure is to be preferred to a low pressure sepatator. At 600 p.s.i.g. the dew-point gas will contain 3 lbs. water per 100,000 cubic feet gas; but at 50 p.s.i.g. the water content of the dew-point gas will be trebled.

The centrifugal force type separator is not suitable for water separation at high pressure as the required tangential velocity of around 100 feet per second cannot be obtained with small gas production rates. For instance, 0.1 cubic feet of gas per second at 30 atmospheres is equivalent to 260,000 cubic feet of gas per day at atmospheric pressure.

(ii) Momentum type separator.

However, a simple momentum type separator should be quite satisfactory. This is preferably of horizontal design for ease of access, etc; and it is proposed to use two lengths of 11.3/4" casing approximately 12' long, and joined together by two flanged 4" pipe connections as shown on the attached sketch. The top section of casing is the mist extractor and water separator; and the bottom section of casing is a collecting chamber for the separated water. The gas inlet is at the top of the water separator section. The gas production impinges on an impact baffle plate which serves as a coalescing medium for water globules. The bottom of the baffle plate is perforated to allow the gas to pass into the separator chamber, and the water to flow into the collecting chamber.

The gas outlet from the separator is at the top on the far side from the gas inlet. The gas is made to pass through a plate with small perforations before it reaches the gas outlet. This plate is essentially a water agglomerator to trap and coalesce any water particles still carried in the gas. The base of the plate near the water outlet would not be perforated. It will be noted that the water drain-off is at the base of the water collecting chamber. Two high pressure 1" drain cocks are provided. When these two drain cocks are open the gas pressure will force the water out of the collecting chamber. It will be noted that the fitting of a reflex gauge glass is also recommended so that the water level in the collecting chamber can be observed.

B. Pressure regulator to reduce the gas pressure to 50 p.s.i.g.

The gas production tests indicated that at a production rate of 100,000 cubic feet per day there was no detectable wellhead pressure drop. In consequence, the full pressure drop from 620 p.s.i.g. to 50 p.s.i.g. will occur at the pressure regulator. The gas cooling, due to expansion, (Joule-Thomson effect) will therefore occur at the pressure regulator. Duringthe production test at 100,000 cubic feet per day the temperature of the gas was lowered to freezing point. Freezing conditions became more severe up to production rates of around 1 million cubic feet per day; and became less severe thereafter due to the gas expansion taking place in the tubing itself. Freezing conditions result not only in the formation of ice, but also in the formation of gas hydrates, resulting in plugging conditions.

Natural gas hydrates form in the neighbourhood of 50°F with pressures of about 500 p.s.i. Hydrates form at the dew-point, and are most likely to collect at points in the system cooled by gas expansion. Hydrate control is by heating the gas to above the dew-point, or by various dehydration processes, or by the addition of anti-freeze compounds: this latter is the simplest method, and is the one indicated for small production rates. Methanol (Methyl alcohol) is a recognised anti-freeze compound. For pressures of 600 p.s.i. and a temperature of 40°F. the concentration of methanol in the vapour phase required to prevent the formation of hydrates is 27 lbs. Methanol per million cubic feet of gas. However smaller quantities, say 10 lbs. per million cubic feet, may be effective. If the Methanol is introduced into the gas stream as a vapour, the latent heat of vapourization (512 B.Th.U's per lb), and the heat of solution (112 B.Th.U's per lb) wouldbe available to help keep up the temperature of the gas. However, for small production rates of 100,000 cubic feet per day it is not considered necessary to make provision for Methanol injection.

At low production rates the gas will no doubt take up from the atmosphere the bulk of the heat loss on gas expansion. At higher production rates it will be necessary to install either some form of surface heating equipment, or a bottom hole choke in the tubing string. The simplest scheme for surface heating is a thermo-siphon system, gas heated, using water circulation through a simple heat exchanger. However, a better arrangement to overcome surface cooling is undoubtedly to incorporate in the tubing a bottom hole choke pressure regulator. The gas expansion will then take place at the bottom hole choke; and the bulk of the heat loss will be recovered from the reservoir, and so surface freezing conditions will be avoided. The required equipment will be expensive. However, details of cost are being obtained; and if it is found eventually that the well can be produced satisfactorily at substantially increased production rates, then the cost of this equipment will no doubt be justified.

For the present it is considered that the only equipment which must be installed is a reliable pressure regulator to reduce the pressure from 620 p.s.i.g. to 50 p.s.i.g. Consider using the type H 5 Controller made by Messrs.I.V. Pressure Controllers Ltd. (Technical Leaflet T.L.101). This controller has an 8" diaphragm, and 2" B.S.P.pipe connections. It is suitable for inlet pressures from 30-4000 p.s.i.g., and outlet pressures from 5-1500 p.s.i.g. With a 3/8" orifice valve size, 600 p.s.i. wellhead pressure, and 550 lbs. differential pressure across the regulator, the rated throughput capacity is 864,000 cubic feet per day. At 200 p.s.i. wellhead pressure and 150 p.s.i. differential pressure, the rated capacity is 288,000 cubic feet per day. Similarly, with a 1/2" orifice, 600 p.s.i. wellhead pressure and 550 lbs. differential pressure, the rated capacity is 1,440,000 cubic feet per day. At 200 p.s.i. wellhead pressure and 150 p.s.i. differential the rated capacity is 500,000 cubic feet per day. It is recommended that the regulator be fitted in the first instance with the 3/8" orifice.

C. Flow bean for rough production control.

It is proposed that the approximate rate of production only should be controlled at the wellhead. It will be noted that the pressure controller does this to some extent; and in point of fact the N.I.S. type flow bean shown on drawing BM.655 could be omitted from the production scheme if desired. However, this is a simple and inexpensive type of flow bean. Its main function is to restrict to a greater extent than can be obtained with the pressure regulator the quantity of gas flowing into the Gas Board's 4" pipe line. Hence the installation ofthe flow bean c an be regarded as a safety precaution to keep the gas flow into the pipe line below a certain maximum agreed limit.

It will be noted that a 4" valve has been shown at the entry to the Gas Board's pipe line. No provision has been shown for metering the gas. It is presumed that the metering to conform with statutory requirements will be carried out at Musselburgh; and that any metering that may be undertaken at the wellhead will be for checking purposes only.

3. Discharge of Accumulated Water in the Well.

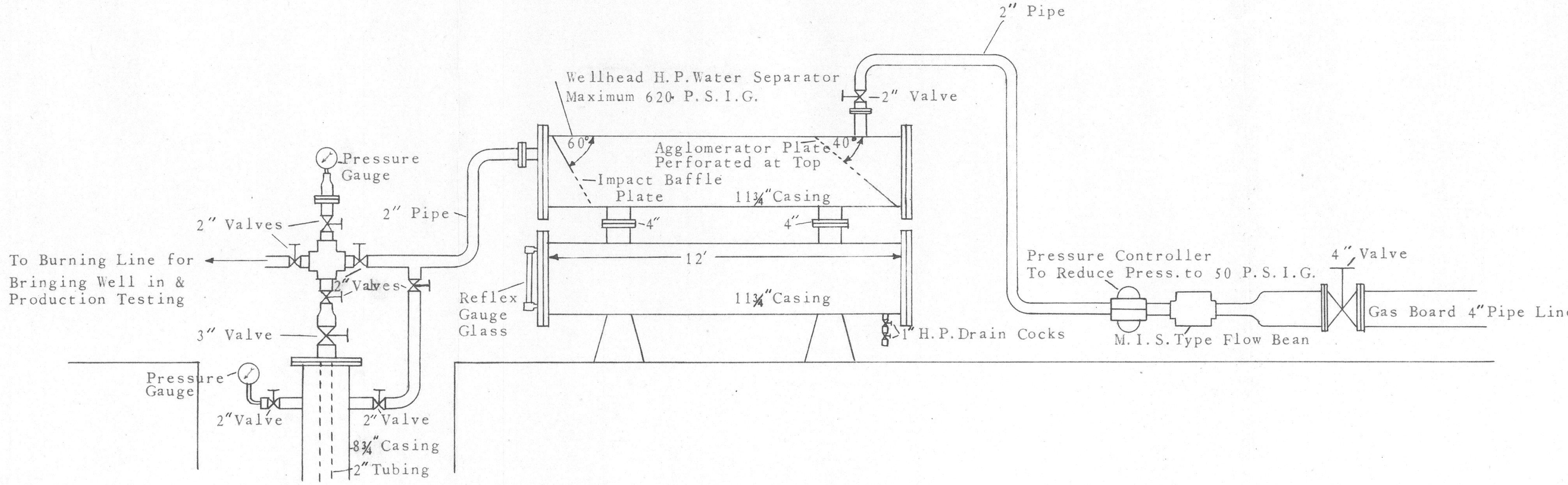
Should the well start producing water in any quantity it may accumulate in the casing. This will be indicated by an abnormal casinghead pressure drop; and also to a lesser extent by an excessive fall in the tubing pressure. Should this eventuality occur the gas production to the separator would be switched from the tubing to the casing annulus. The well would then be flowed at a fast rate through the tubing to the burning line until the accumulated water in the casing has been discharged at surface. The burning line valve would then be closed; and the gas production switched back from the casing annulus to the tubing. Wellhead pressures should return to the values recorded before the water began to accumulate. It is pointed out that if a bottom hole choke has been run the gas expansion will take place at the bottom of the tubing; and it will require less gas to discharge the accumulated water at surface.

No reservoir water has so far been obtained from the 1582'-1623' sand in No. 1 well. A geological correlation with No. 5 well (See P.E. completion report for No.5 well) shows the equivalent sand in Well 5 separated into three lenses, viz: 1693'-1700', 1712'-1720' and 1730' - 1760'. Samples of nearly uncontaminated reservoir water were obtained from the last two sands with specific gravities of 1.01 and 1.008 respectively. Both these edgewaters are of the chloride type; and it is anticipated that any water production from No. 1 well will be likewise a very weak brine.

C. M. Adcock

C. M. ADCOCK.

EAKRING.
26.11.56.
CMA/MEK.



BP EXPLORATION CO.LTD., EAKRING NOTTS.	
COUSLAND NO.1 WELL DIAGRAMMATIC ARRGT. OF WELLHEAD PLANT FOR GAS OFFTAKE TO GAS BOARDS' PIPE LINE	
Scale : Diagrammatic Date : 22.11.56	BM. 655
[signature]	[signature]

H. 121—C. 3.43

Mr. Cousins
Mr. Waters

RECEIVED
-4 JUL 47

UK/COUS/1/T2

Memorandum

From D'ARCY EXPLORATION CO.LTD.
EAKRING.

To FIELDS BRANCH,
BRITANNIC HOUSE.

Our Ref. C.G.-10 **Your Ref.** **Date** 3rd July, 1947.

Subject COUSLAND NO. 1 WELL - COLLATION OF CLOSED-IN-PRESSURE RECORDS

We are sending you herewith the usual two copies of a report giving the collation of Cousland No. 1 closed-in-pressures since the flowing tests carried out in 1939.

C. L. Adcock

CMA/REE

ENCLOSURES

Reference C.G. - 10

24th June 1947

Cousland No. 1 Well

Record of closed-in-pressures measured since the flowing tests carried out in 1939

Closed in pressures, with one exception, have been measured by dead weight tester at the 10562' elevation. The penultimate measurement was made in May 1945 before carrying out the work required to put the well on production. The last measurement was made in June 1947, and shows that the pressure is still rising, although at a very slow rate. The recorded measurements are as follows:-

Date	p.s.i.g.	
11. 12. 39	589.9	
23. 7. 40	614.2	
22. 6. 43	615	(tested gauge)
3. 5. 45	618.3	
4. 6. 47	621.4	

The 1000 lbs Dewrance dead weight tester was used for all the measurements. The wellhead gauge pressures recorded at the same time as the D.W.T. pressure on 4th June 1947 was 657 lbs.

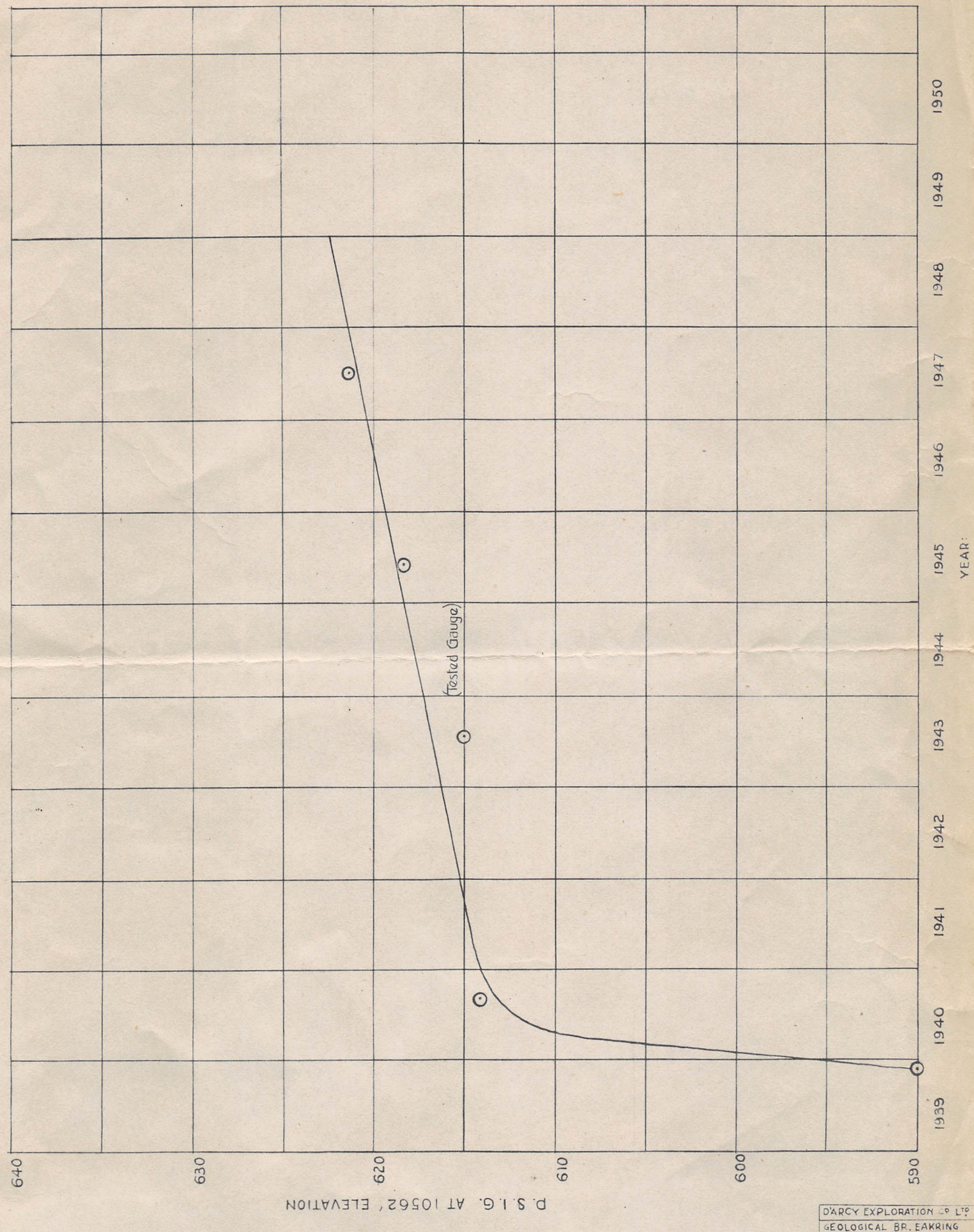
The corrected gauge pressures have been plotted on the graph attached herewith, from which it will be seen that there is no evidence as yet of the true equilibrium pressure being in sight of attainment.

C. M. Adcock

Eakring
26th June 1947
CMA/CP

COUSLAND N°1 WELL

RECORD OF CLOSED IN PRESSURES. MEASURED BY D.W.T. SINCE THE FLOWING TEST CARRIED OUT IN 1939.



D'ARCY EXPLORATION CO LTD
GEOLOGICAL BR. EAKRING
AREA: COUSLAND.
REF: CG-10
27·6·47

TELEPHONE
CENTRAL 7422.

"BP"

BRITANNIC HOUSE,
FINSBURY CIRCUS,
LONDON, E.C.2.

29th August, 1946.

Dear Taitt,

This is to confirm my telephone conversation with you in which I told you of the mistake which I had made in my letter of yesterday's date on the subject of Cousland gas reserves. I had taken from Mr. Strong's memo. of 10th May his figures for the volume of gas at 40 atmospheres pressure and overlooked the fact that he had intended this to mean the volume of gas at atmospheric pressure. The figures are, therefore, substantially less than I quoted in my letter, and, in fact, the reserves figures more nearly approach Mr. Comins's estimate than I had expected.

Yours sincerely,

A. H. Taitt, Esq.,
EAKRING.

Reference C.G. - 9 20th June, 1945

Cousland No. 1. Well
Rotary Table elevation 565'
Tests carried out whilst preparing to put well on production

SUMMARY

Before carrying out any work on the well the closed in pressure was measured by dead weight tester and found to be 618.3 p.s.i. This compares with the last pressure measured by D.W.T. of 614.2 p.s.i. on 23rd July 1940 (Report ref: C.G.-7 dated 23rd August 1940). The free water level was also determined and found to be 1722' below the R.T., the previous observation having been made on 8th December 1939 after completion of the production tests, when a level of 1708' (which was then still falling) was recorded (Report ref: C G-5 dated 11th Dec. 1939). This therefore shows that the lower gas sand (1720'-35') remained covered by water during the whole period.

Before running the float the gate of the 8" top valve had to be freed, and whilst doing this a white solid accumulation was found on top of the gate, which evidently consisted of gas hydrates, as a sample was found to burn, leaving a residue of water. The method of killing the well preparatory to running tubing by pumping a plug to approximately 1480' was not successful, as the plug had apparently acquired sufficient momentum to keep on going after pumping had ceased. The plug therefore went beyond the top gas sand (1582'-1630') and it was subsequently pushed to 1738'.

The VE holiday then intervened, and the well was afterwards killed by blowing down the pressure and pumping water to it. The hole was kept full by circulating over the wellhead. On the first occasion that the tubing was run a bursting disc was placed at 980', but this was so thick that although it became fractured, it did not break up after a particularly heavy go-devil had been dropped. The well had therefore to be killed a second time, the tubing pulled, and the bursting disc removed. The tubing was then run back to 1732'. In the tubing a ⅛" gas lift hole drilled in a tubing coupling was run to a 1000' and another one was run to 1200' so that the well could be brought in if the water level in the casing stood up at too high a level. However, the water ran away very freely into the formation (50% faster after killing the well the second time), and no difficulty was experienced in bringing the well in.

The nett quantity of water lost during the present tests was approximately 15,000 gallons, which together with the quantity of water originally lost to the formation estimated at 20,000 gallons, makes a total loss of approximately 35,000 gallons.

The present production programme is to produce the well through the annular space, thus allowing water to accumulate in the casing. This water would be blown out through the tubing at time intervals determined by its rate of accumulation. It is suggested that it might be preferable from an operating point of view to produce the well through the tubing, which would remove the water as fast as it collected in the hole. It is anticipated that the water would only come into the hole relatively slowly, and that the water separating facilities to be provided, would be able to handle the water produced. Trouble might be experienced from freezing of valves etc., but as a heater is being installed in any case, it is probably worth while testing out whether the

well could be produced satisfactorily through the tubing, for the difficulties which it would be expected would occur through freezing may not be appreciably greather than when the well is produced through the annular space.

DETAILED REPORT

(1) Water lost to the formation

		Cu. ft. (actual)	Cu. ft. (cumulative)
7th May - Water lost whilst pumping plug to 1380'	-	450	
Water pumped to reduce pressure to 75 lbs.	-	430	880
12th May Water pumped to well to kill it.	-	600	
Water lost whilst circulating over wellhead	-	200	1680
16th May Water pumped to well to kill it.	-	650	
Water lost whilst cirulating over wellhead.	-	300	2630

Hence total water lost was approximately 16,400 gallons
Water recovered through tubing etc: approximately 1,400 "

Hence nett loss 15,000 gallons
Estimated earlier loss 20,000 "

Hence total quantity of water lost to the formation 35,000 gallons

(2) Pressure build - up record as "killing" water ran away into the formation and the well came in.

(a) 12th-14th May after running tubing for the first time.

12th May	2.00 p.m.	-	0 hrs.	-	Nil pressure	
	10.30 p.m.	-	5.5 hrs	-	45	p.s.i.
13th May	1.00 p.m.	-	23	"	210	"
	6.15 p.m.	-	28¼	"	260	"
14th May	8.30 a.m.	-	42½	"	400	"
	10.36 a.m.	-	44½	"	418	"

(b) 16th-17th May after running tubing for the second time

16th May	7.00 p.m.	-	0 hrs	-	Nil pressure	
	10.30 p.m.	-	3½ "	-	20	p.s.i.
	11.00 p.m.	-	4 "	-	40	"
	12.00 p.m.	-	5 "	-	45	"
17th May	1.00 a.m.	-	6 "	-	60	"
	2.00 a.m.	-	7 "	-	70	"
	3.00 a.m.	-	8 "	-	90	"
	4.00 a.m.	-	9 "	-	100	"
	5.00 a.m.	-	10 "	-	125	"
	6.00 a.m.	-	11 "	-	150	"
	7.00 a.m.	-	12 "	-	165	"
	8.00 a.m.	-	13 "	-	180	"
	9.00 a.m.	-	14 "	-	200	"
	10.00 a.m.	-	15 "	-	220	"

	11.00 a.m.	-	16	hrs	-	230	pressure
	12.00 p.m.	-	17	"	-	245	"
	1.00 p.m.	-	18	"	-	265	"
	2.00 p.m.	-	19	"	-	275	"
	3.00 p.m.	-	20	"	-	280	"
	4.00 p.m.	-	21	"	-	300	"
	5.00 p.m.	-	22	"	-	320	"
	6.00 p.m.	-	23	"	-	340	"
	7.00 p.m.	-	24	"	-	350	"
	8.00 p.m.	-	25	"	-	360	"
	9.00 p.m.	-	26	"	-	380	"
	10.00 p.m.	-	27	"	-	400	"
	12.00 a.m.	-	29	"	-	400	"
18th May -	1.00 p.m.	-	30	"	-	412	"
	2.00 a.m.	-	31	"	-	425	"
	3.00 a.m.	-	32	"	-	435	"
	4.00 a.m.	-	33	"	-	445	"
	5.00 a.m.	-	34	"	-	465	"
	6.00 a.m.	-	35	"	-	480	"
	7.00 a.m.	-	36	"	-	495	"
	8.00 a.m.	-	37	"	-	500	"

Well and tubing data

8¼" No. 5. I.J. casing	-	2.1540 gallons per foot
2" tubing - external volume	-	0.1938 " " "
Hence annular space volume	-	1.9602 gallons per foot

2" tubing external volume	-	0.1938 gallons per foot
2" tubing internal volume	-	0.1354 " " "
Hence volume of steel	-	0.0584 gallons per foot

980 + 1354 / 1339 / 1.96

Position of Bursting disc

Suppose the bursting disc is run to a depth of ~~x~~ feet, 980' and that the bursting of it would lower the level in the annular space by h feet, then :-

$$0.1354 (x-h) = 1.9602 h$$

Hence $x = 15.49 h$ But $x = 980'$

Hence $h = 980/15.49 = 63'$

1.9602 / 1354 / 9.0956

Thus breaking the bursting disc would lower the A.S. level by 63'.

Position of free water level.

2.0956 / 1354

The F.W.L. in No. 1. well is not known. However the free water level in No. 2. well was 262' above M.S.L. on 23rd June 1943 (Report Ref: C.G.-8). If the same level is applicable to No. 1. well then this would correspond to a distance of 303' below the Rotary Table.

However, basing on the bottom hole pressure at 1582', and assuming this to be approx: 20 lbs in excess of the closed in pressure, then the free water level becomes :-

F.W.L. = 638/.435 = 1466' above 1582 or 116' down.

Water level in hole to fill tubing to F.W.L. supposing the F.W.L. is at 200'

Tubing capacity to 200' = (1732'-200) x .1354 = 207 gallons
Now the hole capacity (less steel) per foot = 2.154 -0.0584 = 2.0965 g.p.ft.

Hence water can fill tubing to F.W.L. when 207/2.0965 = 99' of water in the hole.

Thus the water level would be at 1732 - 99 = 1633'.

Calculated annular space closed in pressures from water levels h' above the top of the sand at 1582'.

Basing on the A.S.C.P = 600 - .435 h

h.	F.W.L.	A.S.C.P.
82'	1500'	564 p.s.i.
182'	1400'	522 "
282'	1300'	479 "
382'	1200'	436 "
482'	1100'	393 "
582'	1000'	349 "
682'	900'	306 "
782'	800'	262 "
882'	700'	219 "
982'	600'	175 "
1082'	500'	132 "

Bringing well in

1st attempt on 14th May after dropping go-devils

The closed in pressure was 420 lbs making the F.W.L. at approx: 1160'. However, the bursting disc only fractured and did not burst so that only a very small gas production was obtained and no water was reproduced.

2nd attempt on 17th-18th May without running bursting disc

By calculation the well would not come in until the A.S.C.P. had risen to over 350 p.s.i. thus reducing the F.W.L. below 1000' and exposing the first gas lift hole. Attempts were carried out on the 17th to produce the well through the tubing as the A.S.C.P was building up, but up to a pressure of 300 p.s.i. confirmation was obtained that the well would not come in.

By 8.00 a.m. on 18th May the A.S.C.P. had built up to 500 p.s.i. thus making the F.W.L. in the hole at approximately 1350', and exposing both gas lift holes. Thus the quantity of water to be reproduced in the hole was approx: 800 gallons (1732-1350) x 2.0965.

Whilst the 800 gallons water were being reproduced the annular space pressure built up from 500 p.s.i. to 611 p.s.i. Thereafter a little water started to come back from the formation, and as the tubing emptied of water the gas production increased considerably, and eventually practically all gas and only a negligible quantity of water were being produced.

It is a little difficult to estimate the quantity of gas required to reproduce the water when there is a substantial quantity in the hole, as this must depend largely on operating conditions. Initially the production appeared to consist entirely of water, but the gas production rate must have been of the order of 100,000 to 200,000 cubic feet per day or say 4000 to 8000 cubic feet per hour; and as the water was being reproduced at the rate of about 100 cubic feet per hour, the resulting gas/water ratio would be of the order of 40-80/1 or say 7 to 14 cubic feet of gas are required to reproduce 1 gallon of water from the hole.

The following table summarises the results of bringing in the well :-

Time	Interval mins:	A.S.pressure p.s.i.	Water reproduced During interval	Water reproduced Cumulative	Remarks
9.25 a.m.	-	523	-	-	Opened slightly side valve from tubing.
9.30 a.m.	5	510	-	-	Reproduction of water commenced.
9.35 a.m.	5	510	52	52	Production appeared to consist mostly of water.
9.40 a.m.	5	515	65	117	
9.45 a.m.	5	520	52	169	
9.50 a.m.	5	525	52	221	
9.55 a.m.	5	535	65	286	
10.00 a.m.	5	540	52	338	
10.05 a.m.	5	550	52	390	
10.10 a.m.	5	560	65	455	
10.15 a.m.	5	570	65	520	
10.20 a.m.	5	580	52	572	
10.25 a.m.	5	590	40	612	
10.30 a.m.	5	595	52	664	
10.35 a.m.	5	600	52	716	
10.40 a.m.	5	608	40	756	Pumping water away
10.42 a.m.	2	-	20	776	Stopped pumping water away.
10.47 a.m.	5	611	40	816	Hole now empty of its water content
10.52 a.m.	5	610	40	856	Clearing tubing and reproducing water from for[illegible]
10.57 a.m.	5	610	40	896	
11.07 a.m.	10	610	80	976	
11.17 a.m.	10	610	65	1041	
11.27 a.m.	10	595	65	1106	Gas prdn: rate now over ½ million cu. ft/day.
(11.37 a.m.	10	585	52	1158	Closed in side valve from tubing slightly.
(11.38 a.m.	-	-	-	-	Pumping water away.
(11.40 a.m.	3	590	30	1188	Closed in side valve from tubing slightly
11.50 a.m.	10	610	36	1214	
12.00 p.m.	10	610	-	1214	Water as a mist now being reproduced.
12.20 p.m.	10	612	-	1214	
1.00 p.m.	40	614	13	1227	Well closed in.

It is thus seen that the total quantity of water recovered whilst bringing the well in was approximately 1230 gallons. This has been rounded off and called 1400 gallons as some water was blown back whilst killing the well, which could not be measured.

After this test confirmation was obtained that the water level was right down by running the dipper and float (this was difficult to run owing to the waxy tubing) and at 5.00 p.m. the F.W.L. was determined to be at 1723'.

On the following morning 19th May the C.I.P. was 630 lbs (618 lbs by D.W.T.), and the hole was clear of water to 1711'. The well was produced for ½ hour at the rate of approximately ½ million cubic feet gas per day but no water production was obtained.

Diary of work carried out

3rd May - 10.40 a.m. - Closed in pressure 615 p.s.i.gauge equivalent to 618.3 p.s.i. gauge by D.W.T. Free water level found by float at 1722' below R.T. Bottom found by dipper at 1740' below R.T. Specific gravity of water from dipper 1.0034 @ 60°F (Salinity 156 parts per 100,000 Cl)
Gas hydrates - (a white solid which burnt leaving a residue of water) - found in 8" valve before stripping it off the wellhead.

7th May - 8.00 a.m. onwards. - Pumped plug (3'-6" long) to 1380'. Stopped pump and followed plug with Halliburton weight. Plug kept going on slowly. Depth reached by plug before starting pump 1600'. Pressure on wellhead 90 p.s.i. rising to 150 p.s.i. Pumped water to well pushing plug to 1738' and pressure dropped to 75 p.s.i.

4.45 p.m. - Closed in well for VE holiday.

10th May - 8.00 a.m. onwards. - Wellhead pressure 580 p.s.i. rising gradually. Tried to pump water to well but unsuccessful.

11th May - 8.00 a.m. onwards. - Stripped 1st assembly fittings for pumping plug, and made up and tested tubing head assembly.

12th May - 9.00 a.m. - Started to kill well by blowing down pressure (618 p.s.i.) and pumping water to it.

11.30 a.m. - Completed killing well, and kept well dead by circulating water over wellhead.

11.45 a.m. - Started running tubing with bursting disc.

2.00 p.m. - Finished running tubing.

10.30 p.m. - Wellhead pressure 45 p.s.i.

13th May - 6.15 p.m. - Wellhead pressure 260 p.s.i.

14th May - 10.41 a.m. - Wellhead pressure 420 p.s.i. - Dropped first go-devil.

10.46 a.m. - Opening tubing side valve to drilling tank.

11.17 a.m. - Well singing but no water production obtained.

12.50 p.m. - Tried to run float which would not go below 40' owing to waxy tubing.

1.45 p.m. - Ran weight which held up at 980', the position of the bursting disc.

1.48 p.m. - Closed in tubing side valve.

1.54 p.m. - Wellhead pressure 442 p.s.i. - Dropped second and much heavier go-devil.

1.58 p.m. - Opening tubing side valve - some gas blowing.

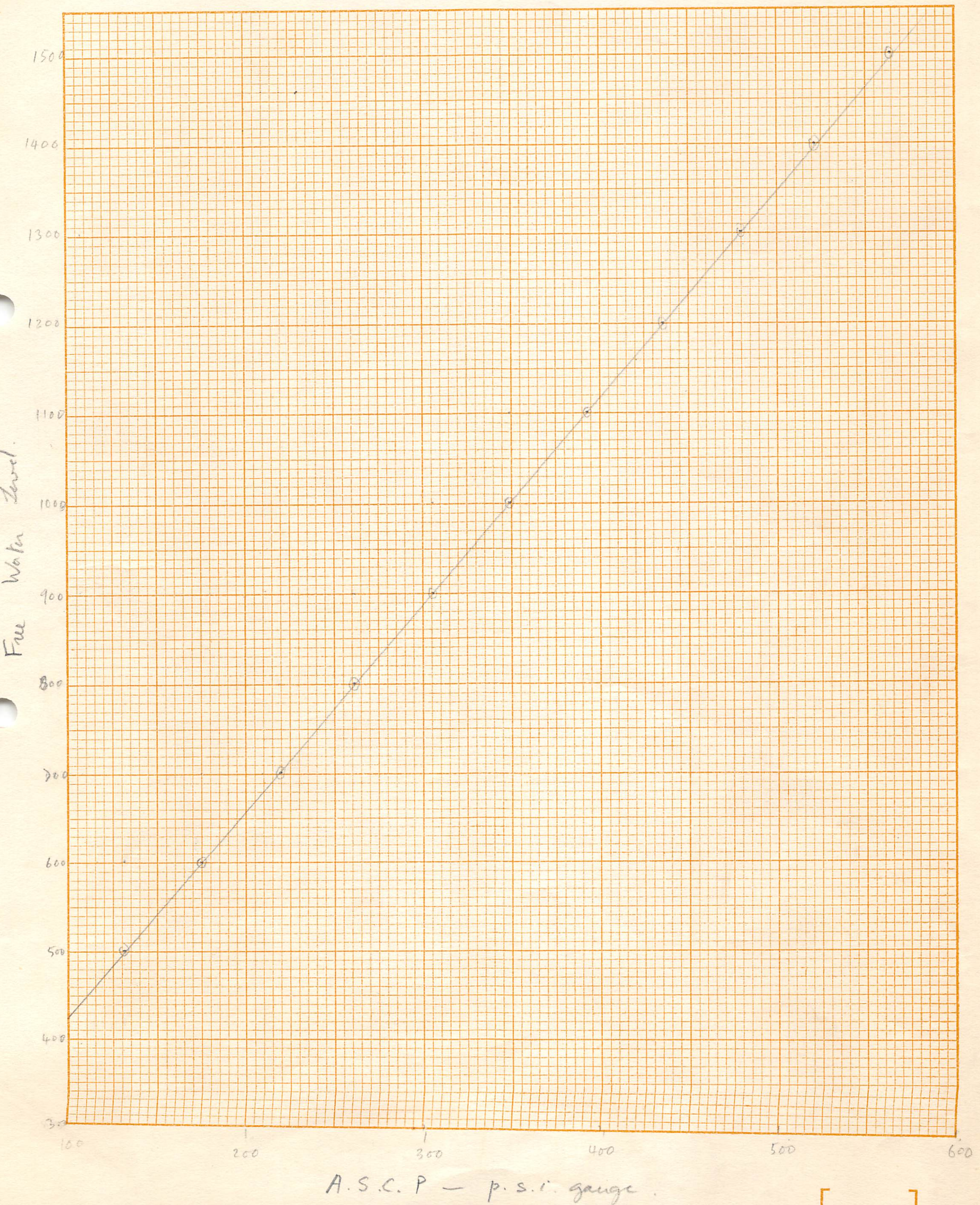
2.26 p.m. - Wellhead pressure 439 p.s.i. - Blew out a little water.

14th May -	4.00 p.m. -	Gas production rate on open end orifice meter 50,000 cubic feet per day.
	4.12 p.m. -	Closed well in.
	4.40 p.m. -	Wellhead pressure 450 p.s.i.
15th May -	9.40 a.m. -	Wellhead pressure 610 p.s.i.
	10.10 a.m. -	Could not get float below 600' owing to waxy tubing.
	~~10.40 a.m. -~~	~~Ran weight~~ which held up at 978'.
	10.55 a.m. -	Opening tubing side valve to drilling tank.
	10.58 a.m. -	Well producing a slug of water.
	11.15 a.m. -	Gas production rate on open end orifice meter 70,000 cubic feet per day.
	11.20 a.m. -	Shut well in.
	3.40 p.m. -	Wellhead pressure 630 p.s.i.
	3.50 p.m. -	Ran dipper to 976', but obtained no water.
16th May -	2.00 p.m. -	Started to kill well by blowing down pressure and pumping in water.
	4.30 p.m. -	Well killed - started to pull tubing to bursting disc.
	7.00 p.m. -	Removed bursting disc (which was broken in three pieces but held in place by the 2" plug) - Ran back tubing to 1732' and closed in well.
	11.00 p.m. -	Wellhead pressure 40 p.s.i.
17th May -	9.50 a.m. -	Wellhead pressure 210 p.s.i.
	9.55 a.m. -	Opened up tubing. No gas lift. Closed in tubing.
	4.00 p.m. -	Wellhead pressure 300 p.s.i. Well would not produce through tubing.
18th May -	9.20 a.m. -	Wellhead pressure 523 p.s.i. Producing through tubing to drilling tank.
	9.30 a.m. -	Well started producing water.
	11.17 a.m. -	Wellhead pressure 610 p.s.i. Water reproduction rate diminishing rapidly.
	11.40 a.m. -	Water reproduction practically ceased.
	1.01 p.m. -	Closed well in.
	1.20 p.m. -	Wellhead pressure 630 p.s.i. Ran dipper to 1630' below R.T. No water.
	1.45 p.m. -	Ran dipper to 1727' below R.T. - Obtained sample of water.
	2.30 p.m. -	Wellhead pressure 630 p.s.i. equivalent to 617.7 p.s.i. by D.W.T.
	3.30 p.m. -	Weighted float with water.
	5.00 p.m. -	Free water level found by float 1723' below R.T. (difficult owing to waxy tubing)
19th May -	8.00 a.m. -	Cleaned container and float of wax.
	9.30 a.m. -	Could not run float, tubing too waxy.
	10.00 a.m. -	Ran dipper 1711' below R.T. - No water obtained.
	10.30 a.m. -	Started to flow well through tubing.
	11.00 a.m. -	No water reproduction, so closed in well

CMA/IBR

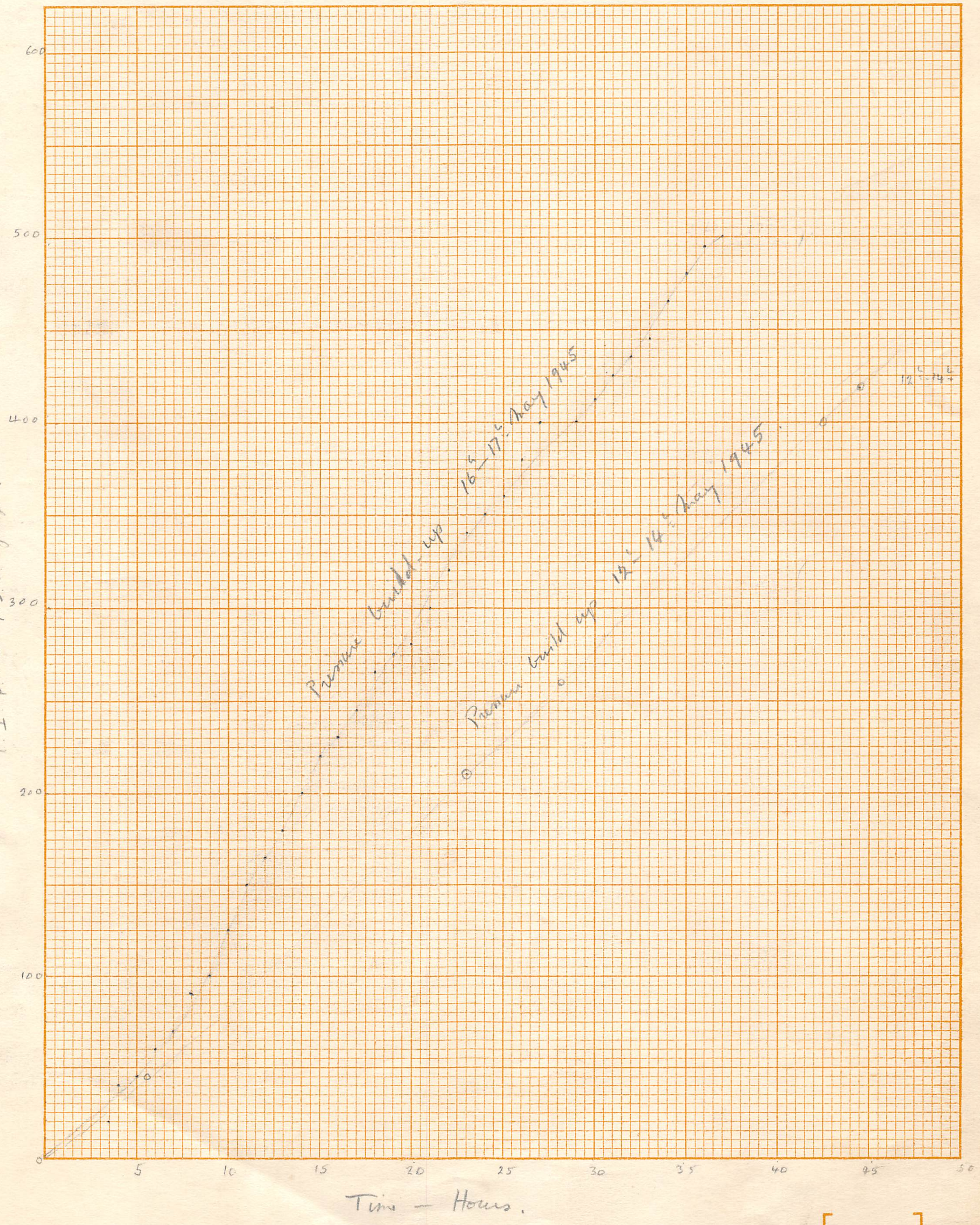
Cousland No. 1 Well.

F.W.L. determined from A.S.C.P.



Cousland No. 1 Well.

Pressure build up as water ran back into formation.



122.—C. (12.41)

Gte.

Copy

a.G.D.

From :- Mr. D. Comins. **To** :- Mr. Adcock.

Our Ref. **Your Ref.** **Date** :- 10th May, 1945

Subject Cousland Testing : Programme when and after reproducing water.

Reminders re action :-

(a) Collect sample of killing water.

(b) Collect samples reproduced water at appropriate intervals watching out for any change - in any case retain final sample.

(c) Measure cumulative volume of water reproduced in diary form and at any significant stages of programme.

(d) At discretion shut down reproduction for short time at appropriate intervals to determine rate of draw down by float.

(e) At any convenient time when G.W.L. still above 1500 feet shut down for 2 hours and then attempt water reproduction through tubing by natural flow without swabbing. Objective to prove whether the ⅛" gas lift holes are fulfilling their purpose as without gas lift water could not be reproduced with G.W.L. at this level.

(f) After either well dry or say 25% more water reproduced than lost in present job and the last one (when loss estimated at 20,000 galls) shut in, check G.W.L by float, leave say overnight; check G.W.L; flow out all water by natural flow in minimum time measuring water and if possible, gas.
Objective to determine how long will be required, when well is on routine production, to lower G.W.L. so many feet and the gas wastage involved.

These reminders are for guidance confirming verbal arrangements. In practice action may be varied at your discretion bearing in mind the objectives aimed at. In addition to those specifically mentioned an important objective is to arrive at some conclusion as to whether the well makes formation water in addition to reproduction of lost killing water.

(Sgd) D. COMINS

Copies to :- Works' Manager, Eakring.
Fields Branch (Mr. C.A.P. Southwell)

DC/IBR

24.4.45.

Cous.

O.E.B.

MR. BREMNER
" WATERHOUSE
" GIBSON
" DONALD
" MASON
" ADCOCK
" COMINS
FILE

COUSLAND NO.1 WELL

Programme to put well on production

WELL DATA

	Depth	Elevation
Original Rotary Table Elevation	0	10,565'
Top of cellar wall	6'	10,559'
Cellar floor	12'	10,553'
Perforations in upper sand	1582'/1630'	8983'/8935'
Perforations in lower sand	1720'/35'	8845'/8830'
Top of cement plug in 8¼" casing	1740'	8825'

The object of this programme is to put the well in a suitable condition for continuous gas production. As there may be a water show with the gas, two inch tubing is to be run to bottom, suitably perforated, so that accumulations of water can be blown from the hole when necessary.

1. As soon as the well head has been uncovered a message is to be sent to Eakring. Arrangements will be made forthwith to send someone to Cousland with the necessary apparatus to measure an accurate well head pressure by D.W.T., determine the water level in the hole, and check the top of the cement plug by Halliburton weight.

2. Strip off the top valve and connections down to the 10" main valve. A bushing is provided, screwed externally 10" I.J. and internally 8¼" I.J. at one end and externally 8¼" I.J. at the other end. Into the female 8¼" thread is to be screwed a short 8¼" nipple which will just clear the 10" main valve gate when the bushing is screwed into the valve. On top is an 8¼" reconditioning collar, an 8¼" double male nipple, at least 2' O.B., a second reconditioning collar followed by a water bushing and sub from 8¼" to 3" and a 3" H.P. valve. A cementing plug is to be inserted in the bushing on top of the 10" main valve before putting on the wider bushing.

3. Open the 10" main valve and pump the plug down with water. The pumping pressure should gradually decrease as the column of water builds up above the plug. When the plug reaches about 1480' the water should about balance the gas pressure and the well should be "dead". The position of the plug can be followed by Halliburton weight.

4. Strip off the connections to the top of the 10" main valve and screw in special bushing, screwed externally 10" I.J. and internally 8¼". Into this screw the special tubing head ex Eskdale. Test above main valve to 1000 p.s.i.

5. The 2" upset tubing should be already measured and sufficient 2" plain pony joints added to the bottom to leave the bottom of the tubing when landed between 1730' and 1735'. The bottom pony will be perforated with 40 ⅝" holes. Run the 2" tubing into the well and put couplings perforated with a ⅛" hole (painted red) in such positions that they will be landed at ~~1200~~ 1000' and ~~1400~~ 1200'. In the next coupling above the upper

/continued

perforated coupling put a C.I. bursting disc. When the tubing reaches the top of the plug it should force the plug down, but when this stage is reached provision should be made to land the tubing at any time in the tubing head, in case water losses to the formation become excessive. Should this occur it will be necessary to fill the well with mud. However, this expedient is considered unlikely as, even if it proves impossible to keep the casing full of water, it should be easily possible to keep the well from coming in. Run the tubing to the landing depth, land in the tubing head, and make up the permanent tubing connections. The tubing and tubing head connections should be made up as shown on the drawing attached.

All water pumped to the well should be measured.

6. When the tubing and tubing head connections have been made up and the tubing connected to a 2" line to a measuring tank, drop the go-devil and break the C.I. disc. This may cause the well to flow water through the tubing and clear the hole but it is more likely that it will be necessary to swab. All water flowed and swabbed should be measured before running away.

COUSLAND NO.1

List of Material:

1. 1700' 2" upset tubing.

2. 2 lens. 2" U. tubing with perforated collars.

3. 5' length 2" plain tubing perforated with 40 ⅜" holes.
   (collars painted red - ex Workshops, ordered)

4. One 10', two 4' and one 2' plain 2" tubing ponies

4a. Two 2" upset and 2" plain tubing nipples.

** 5. C.I. bursting disc.

6. Bushing 10" I.J. male to 8¾" male

** 7. Short 8¾" guide nipple to screw into (6)

8. 2 reconditioning collars 8¾" I.J.

** ? 9. 8¾" double male nipple long enough with the other fittings to accommodate 3'6" long plug.

10. Water bushing 8¾" I.J. to 4½" F.H. box and sub 4½" F.H. pin to 3" B.S.

* 11. 3 3" short nipples H.P. (Eskdale)

12. 1 3" Tee H.P.

13. 2 3" H.P. valves (ex Wells E6 and KH28)

** 14. Spread bushing 10" I.J. male x 8¾" I.J. female (Workshops)

* 15. Tubing head, landing collar and clamps (ex Eskdale)
   (it should be checked that landing collar suits 2" upset tubing)

* 16. 3" H.P. valve (ex Eskdale)

* 17. 3" x 2" H.P. nipple (do.)

* 18. 2" H.P. cross (Eskdale)

* 19. 6 - 2" H.P. nipples (do.)

* 20. 5 - 2" H.P. valves (do.)

* 21. 1 - 2" series 60 flange (do.)

22. 3'6" long plug to run in 8¾" casing (Stores)

23. Go-devil

24. 2" swab complete with sinker, rope sockets (⅝" & ½") and 12 spare rubbers (Stores)

25. Swabbing line (⅝" or ½")

26. 3" and 2" containers for running weights, etc. (McLeod)

27. 2" swabbing container ?

* 28. B.O.P. and accumulator and fittings (ex Eskdale)

29. H.P. Test Pump ex Eakring

* To come from Eskdale No.2

** To be made in Workshops, not yet ordered

Mr Dickie.

H. 121. (C. 5.44)

Memorandum

A.H.B

From FIELDS BRANCH,
BRITANNIC HOUSE.

To WORKS MANAGER,
EAKRING.

Our Ref. S/DRG/164 **Your Ref.**

Date 19th April, 1945.

Subject COUSLAND GAS SCHEME.

With reference to Mr. Bremner's telephone message of to-day, we enclose copy of a draft of the programme which was prepared when this matter was first raised in 1942.

We are not certain that this was the final plan, but we can find no other similar scheme on our files.

For the surface equipment, memorandum No. DC/622 of May 24th 1944, a copy of which we enclose, states that the production hook-up will be similar to that shown on drawing BM.175 of 6.6.45.

[signature]

Enclosures.

MCS/CEP

H.120.—C.6.39.

Copy

From MR. COMINS **To** MR. SOUTHWELL

Our Ref. DC/622 **Your Ref.** **Date** 24th May, 1944.

Subject COUSLAND PRODUCTION SCHEME.

The proposed production hook up is the same as in the line drawing B.M.175 dated 6.6.43 for Eskdale No.2 except that:-

1. None of the plant shown in red will be required. (This was for acid treatment, bringing in well when dead, etc.)

2. In addition it will be necessary to provide an H.P. vertical water separator, line pressure regulator; line safety valve and positive displacement integrating meter on the annular space production line as shown in line drawing B.M.136 dated 31.7.42 for Cousland 1. (In the Eskdale scheme R. & T. were taking over the gas immediately down stream of the annular space line beans.) Throughputs and line pressures will be 125,000 cu.ft./day and 30/40# gauge with provision for handling 250,000 cu. ft. day at 50/60# line pressure at a later stage.

Mr. Johnson will:-

1. Prepare drawings on these lines.
2. Check up with Eakring Management that all the necessary plant ordered against B.M.175 is still available, where it is and its cost by items.
3. Estimate cost of remaining plant to be ordered.
4. Estimate installation cost of all plant.

c.c. Mr. Johnson

DC/CEP

Cousland No.1 & No.2 locations.

No.2 Well.

Determination of free water level on 23rd. June.

Since no Halliburton equipment was available, the water level was determined by means of a length of string and a 100 foot steel tape measure. The water mark on the string was readily determined as the water left a pronounced black stain on the string as well as wetting, the string above the water level being clean and dry.

The water level was found to be 159' from the wellhead flange, or 169' from the rotary table (See report C G - 7 dated 3rd August 1940). This represents a rise of 9' in nearly 3 years; the previous level having been recorded on 22nd July 1940.

No.1 Well.

Determination of Closed in pressure on 22nd. June.

No dead weight tester was available to measure the pressure, so that the pressure measured by the wellhead gauge (Budenberg No. 6216176) was recorded, and a second measurement was made on another gauge (Wm: Bramall No.454428) which was calibrated subsequently at Eakring by D.W.T. The results obtained were as follows:-

Date	Wellhead gauge. Budenberg	Test Gauge Wm: Bramall	D.W.T. pressure	Hence Wellhead gauge correction
11.00 a.m. 22nd June	627 lbs/sq.in.	640 lbs/sq.in.	615 lbs/sq.in.	-12 lbs/sq.in.

The last pressure measured on the well was recorded by D.W.T on 23rd July, 1940 and was found to be 614.2 lbs/sq.in., so that the pressure now recorded does not necessarily mean that there has been a rise in pressure, although the rise could have been as much as 2 lbs/sq.in.. In view of the rise of the water level at No.2 well, it is considered probable that some rise in the pressure at No.1 well has taken place.

Gas Samples collected for Sunbury whilst the well was flowing (a) at 650,000 (b) at 500,000 cubic feet per day.

June 22nd	11.00 a.m.	Closed in pressure 627 lbs/sq.in. gauge reading
	12.10 p.m.	Started flowing well at 650,000 cubic feet per day.
	4.10 p.m.	Shut well in.
	4.15 p.m.	Closed in pressure 625 lbs/sq.in. gauge reading
June 23rd	9.35 a.m.	Closed in pressure 626 lbs/sq.in. gauge reading
	9.45 a.m.	Started flowing well at 650,000 cubic feet per day.
	12.00 p.m.	Collected gas sample No.G1 (cylinder No.2/4)
	12.05 p.m.	Adjusted rate of flow to 500,000 cubic feet per day.
	2.15 p.m.	Collected gas sample No.G2 (cylinder No.2/5)
	3.15 p.m.	Shut well in.
	4.00 p.m.	Closed in pressure 625 lbs/sq.in. gauge reading

P.T.O.

June 24th	10.05 a.m.	Started flowing well at 650,000 cubic feet per day.
	1.10 p.m.	Filled first of Sunbury cylinders.
	2.38 p.m.	Filled second of Sunbury cylinders.
	3.28 p.m.	Shut well in.
	4.30 p.m.	Closed in pressure 625 lbs/sq.in. gauge reading.

Notes on flowing tests.

A check on the length of the burning line was carried out. It was confirmed that this was 324 feet (0.0614 miles) as given in the report C G - 1 dated 13th November 1939. The well was then connected from the 3" side valve to the burning line by means of a short length of 1" hose. This hose had been replaced by a newer length in good condition, but nevertheless it was not considered satisfactory to produce the well through this hose.

The 3" side valve and burning line were in too confined a position to enable them to be connected together readily and quickly by means of 3" fittings. It was therefore decided to connect them together by means of ½" fittings, the rate of production being controlled through a ½" H.P. needle valve. This "hook-up" has been left connected to the well.

It was found that the ½" valve could handle the 650,000 cubic feet per day production, but frequent adjustment of the valve "setting" was found to be necessary. This was essentially due to the cold generated by the gas expansion, but whether the valve became slowly blocked by "ice" or "hydrates" is not known. If it had not been for this blocking the ½" valve would have probably been capable of handling a production of about 1,000,000 cubic feet per day; but for continuous production the ½" "hook-up" would probably not be able to handle more than about 500,000 cubic feet per day.

Connected into the burning line was a 3" valve, but the effect of this has been neglected in calculating production rates. A stand pipe had been connected to the end of the burning line on a previous occasion to deliver the gas well up into the atmosphere, and so it was not necessary to burn it. This means that continuous production tests could be carried out if required, without having to shut the well in during 'Black-out' hours.

All the cylinders were filled through a ¼" connection taken below "B" and "N" valves. No cylinder was filled until the well had been flowing for two hours beforehand on the day in question; and when the production rate was changed, the well was flowed for a further two hours before collecting the sample. For the sake of comparison, production rates have been calculated from (a) the A.I.O.C. (b) the Weymouth (c) the Oliphant formulae

Barometric pressures were recorded by means of a pocket aneroid barometer, which had previously been calibrated at Eakring against a mercury barometer.

The following table enumerates the results obtained:-

COUSLAND NO. 1 WELL -, RECORD OF PRODUCTION DATA OVER PERIOD 22ND - 24TH JUNE INC. 1943.

DATE.	Time well flowing. From	To	Hrs.	cum. hours.	Atmosphere. Temp. °F.	Pressure Ins. Hg.	Pressure lbs. / sq. ins.	Well Flowing press. lbs/in² Gauge	Corr. Gauge	Line Temps. °F. Intl. end	Terminal end	av.	Line Pressures Initial end (gauge) Ins. Hg.	lbs./sq.in. abs.	Terminal end (gauge) Ins. Hg.	lbs./sq.in. abs.	Production Rates cubic feet / 24 hours. A.I.O.C.	Weymouth	Oliphant	Av. Prod. rate cu. ft. per 24 hrs.	Pro du pe cu.
22nd June.	12.10 pm.	4.10pm.	4	4	-	29.2	14.28	611	599	31	47	39	7.0	3.43	0.9	0.44	676,000	660,000	690,000	675,000	112,
23rd June	9.45 am.	12.05pm.	2.33	6.33	61	29.14	14.31	610	598	30	54	42	7.3	3.58	1.20	0.59	677,000	659,000	688,000	675,000	65,
	12.05 pm.	3.05pm.	3	9.33	61	29.16	14.32	615	603	36	56	46	4.7	2.31	0.8	0.39	528,000	514,000	535,000	526,000	65,7
24th June	10.05 am.	3.25 pm.	5.33	14.66	64	29.39	14.43	610	598	29	49	39	7.0	3.43	0.9	0.44	678,000	660,000	690,000	676,000	150,

* The Cumulative gas production from the well has been recorded since the beginning of the production test on 3rd November, 1939

359 for lower sand

CMA/MWH

COUSLAND NO. 1 WELL -, RECORD OF PRODUCTION DATA OVER PERIOD 22ND - 24TH JUNE INC. 1943.

ell flowing. To	Hrs.	cum. hours.	Atmosphere. Temp. °F.	Atmosphere. Pressure Ins. Hg.	Atmosphere. Pressure lbs. / sq. ins.	Well Flowing press. lbs/in² Gauge	Corr. Gauge	Line Temps. °F. Intl. end	Line Temps. °F. Terminal end	Line Temps. °F. av.	Line Pressures Initial end (gauge) Ins. Hg.	Line Pressures Initial end lbs./sq.in. abs.	Line Pressures Terminal end (gauge) Ins. Hg.	Line Pressures Terminal end lbs./sq.in. abs.	Production Rates cubic feet / 24 hours. A.I.O.C.	Production Rates cubic feet / 24 hours. Weymouth	Production Rates cubic feet / 24 hours. Oliphant	Av.Prod. rate cu. ft. per 24 hrs.	Prod. during period cu. feet.	Cumulative Prod. cubic feet. during test.	Cumulative Prod. cubic feet. From well.*
.0pm.	4	4	-	29.2	14.28	611	599	31	47	39	7.0	3.43	0.9	0.44	676,000	660,000	690,000	675,000	112,500	112,500	30,336,500
5pm.	2.33	6.33	61	29.14	14.31	610	598	30	54	42	7.3	3.58	1.29	0.59	677,000	659,000	688,000	675,000	65,500	178,000	30,402,000
5pm.	3	9.33	61	29.16	14.32	615	603	36	56	46	4.7	2.31	0.8	0.39	528,000	514,000	535,000	526,000	65,700	243,700	30,467,700
25 pm.	5.33	14.66	64	29.39	14.43	610	598	29	49	39	7.0	3.43	0.9	0.44	678,000	660,000	690,000	676,000	150,300	394,000	30,618,000

*...mulative gas production from the well has been recorded since the beginning of the production test on 3rd November, 1939.

359. [illegible] lower sand

Notes on the cylinders filled.

The D.E.C. cylinders consisted of two 2 litre cylinders which were filled at a pressure of 600 lbs/sq.in. Each cylinder was blown down 10 times to remove any traces of air before the final sample was taken. Cylinder No.2/4 was filled when the well was flowing at a rate of 675,000 cubic feet per day, and cylinder No.2/5 when the well was flowing at a rate of 526,000 cubic feet per day.

Mr. Duck arrived from Sunbury on 24th June (the third day of flow) to collect further samples. He had two cylinders each having a capacity of one cubic foot to fill, of the oxygen type, with only one outlet. The cylinders had been evacuated at Sunbury, but they did not appear to have retained their vacuum on arrival at Cousland. Mr. Duck had been given no guidance as to the rates at which the well should be flowed when each cylinder was filled, but be explained that he wished to fill both cylinders under similar conditions so that both samples should be as nearly as possible identical; and so it was decided to fill them both when the well was flowing at a rate determined to be 676,000 cubic feet per day. He filled and emptied each cylinder four times before taking the final sample, the filling pressures being 540 lbs/sq.in. and 580 lbs/sq.in. respectively. All four cylinders were forwarded to Sunbury by goods train, this having been their instructions for the dispatch of their own cylinders.

Reference numbers allocated to earlier reports.

CG-1	Dated	13th	November	1939
CG-2	"	20th	"	1939
CG-3	"	27th	"	1939
CG-4	"	4th	December	1939
CG-5	"	11th	"	1939
CG-6	Not Dated	?12th	"	1939
CG-7	Dated	3rd	August	1940

C. M. Adcock

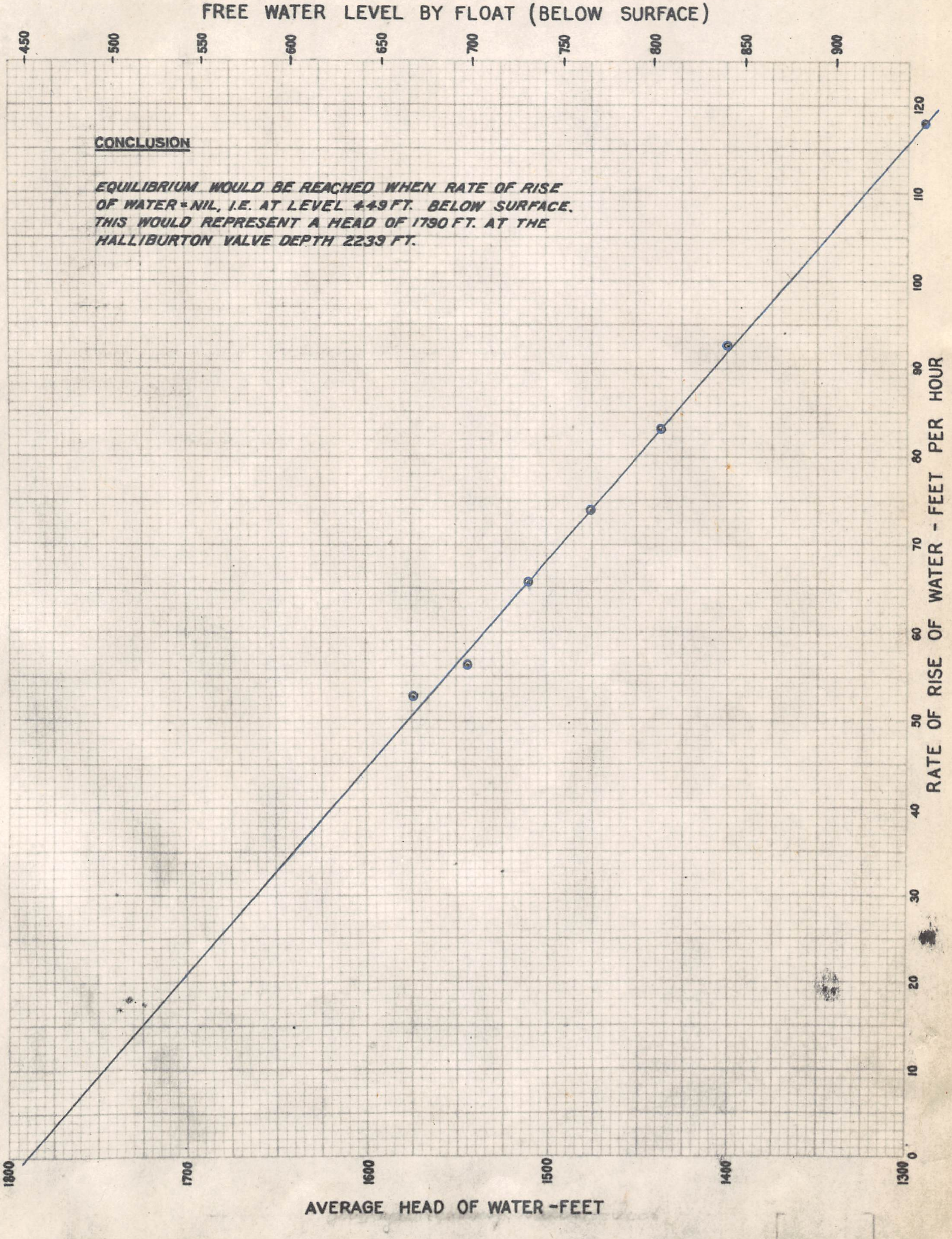
CMA/JMJ

GRAPH 2

COUSLAND Nº1

ESTIMATION OF LEVEL TO WHICH WATER FROM 1731' SAND WOULD EVENTUALLY RISE.

⊙ BASED ON FLOAT MEASUREMENTS OF FWL AGAINST TIME, SEE GRAPH 1

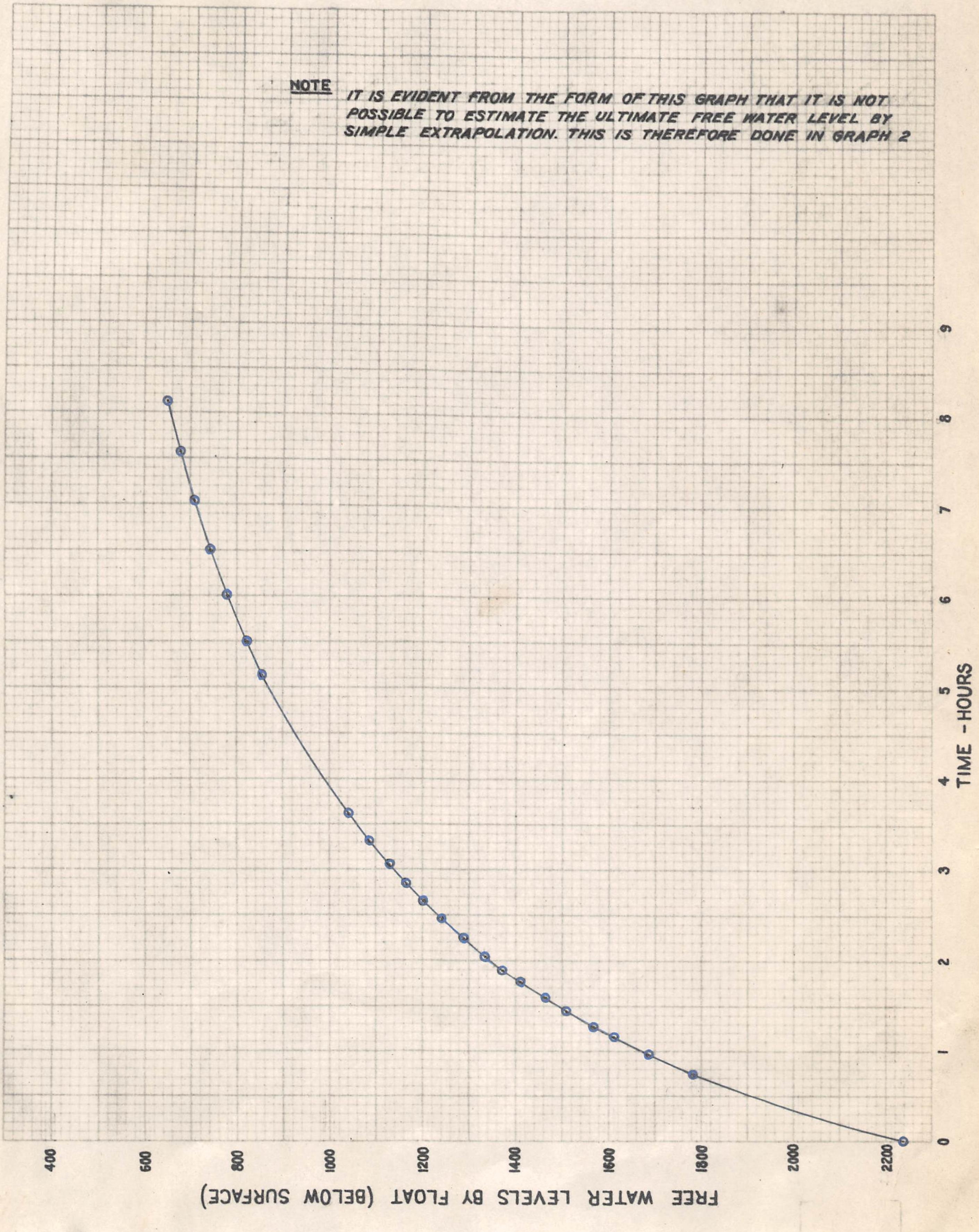


GRAPH I

COUSLAND N° I

RISE OF LEVEL OF WATER FROM 1731' SAND

⊙ ACTUAL FREE WATER LEVEL BY FLOAT
DEPTH OF PACKER 2243'
" " HALLIBURTON VALVE 2239'

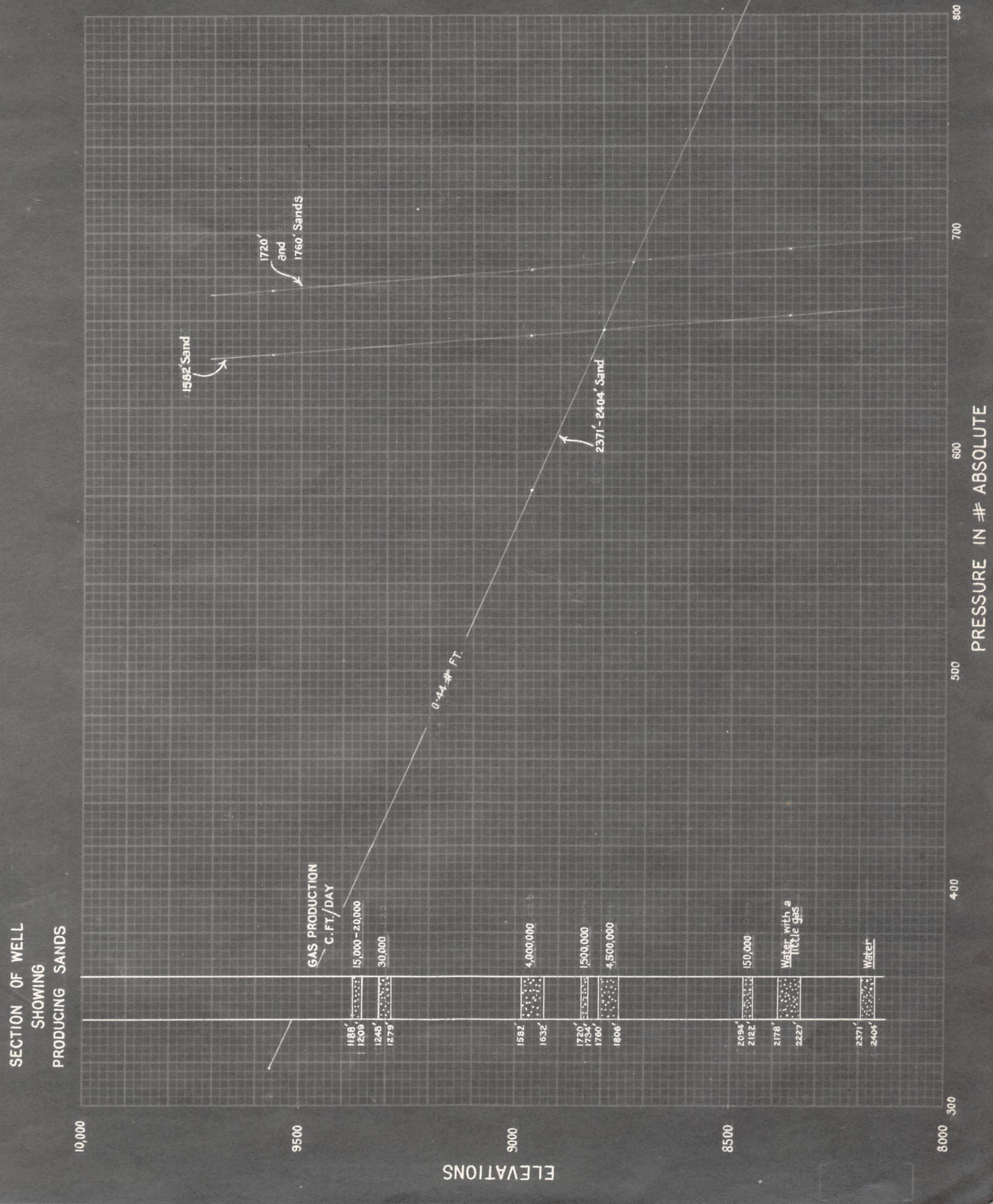


YELLOW GAS PRESSURE

BLUE WATER PRESSURE

COUSLAND No I WELL

GAS AND WATER RESERVOIR PRESSURES AT VARYING ELEVATIONS



H.119. C.1.40

Grantham 1.25.
Edinburgh 8.20.

Memorandum

From MR. COMINS **To** MR. ADCOCK

Our Ref. DC/545 **Your Ref.** **Date** 18th June, 1943.

Subject COUSLAND NO.1.

Confirming discussion the main purpose of your visit is to obtain representative samples for Sunbury of the gas with the well flowing at rates of (a) 500,000 c.ft./day, (b) 650,000 c.ft./day. Sunbury chemists may in addition take their own samples, but for comparison and in order to satisfy them as to the reliability of our routine method of sampling you should provide them in any case with one 2 litre sample for each rate of production, at say 500# pressure. (Sunbury should be requested to let us know the pressure on the containers when opened by them.)

Samples will be collected on the second day of flow - the well not being flowed at night; and you should telephone or telegraph Mr. R. C. Thomson, Britannic House, in time for him to make arrangements for Sunbury Chemists to attend on the second day of flow. I have advised him that this will probably be on Tuesday or Wednesday next. It is desirable that the well shall have been flowed steadily for at least 2 hours at the production rate desired before the samples are collected and if time is short the 500,000 c.ft./day test and sampling may be omitted.

From the results of previous tests it is estimated that at 650,000 c.ft./day the wellhead flowing pressure will be about 15# below the closed in pressure and at 500,000 c.ft./day about 10# below the closed in pressure.

The closed in pressure before the well is flowed should be noted on the well gauge (Budenberg 1000# Gauge No.6216176) and also on a gauge to be taken up by you and brought back to Eakring for D.W.T. Correction. On leaving site the well gauge should be replaced but left shut off.

If practicable the opportunity should be taken to get a dip of the free water level in No.2 well. (This was only 178 feet when last dipped 11.7.40.)

P.T.O.

Arrangements

Please let me know the date, time and station at which you will be arriving Edinburgh and I will telephone Scottish Oils asking them to book you a room. On arrival telephone them, Mr. Crichton or Mr. Burnett(?), Broxburn 34 or 35 day or Philpston 5 out of office hours to ask where room booked. Scottish Oils will also advise you where to hire a car and may be able to help you with a fitter and pipe fittings as necessary. The 1½" flexible hose at present connecting one 3" side valve to the 3" burning line should in any case be replaced as it is probably perished. If Scottish Oils are unable to help you, Anglo-American have kindly offered to do so. Telephone Ellis, Dalkeith 3288. Mr. Whittingdale also suggests that you might be able to get a room at the Stair Arms, Pathead, (near the well) and to hire a car from Dix's Garage, Dalkeith.

DC/CEP

Billsthorpe 55
Farnsfield 281
Brittanic House. London - Central 7422.
Burgage Southwell 3261
3262
3164
Anglican
Telese
London.

Mr. Rowley
Broxburn
34
Crighton
Crighton
2 p.m.
Hotel
Harrow
Dalkeith
3274
Croall & Son.
taxis

Mr. Adcock

DC/546

18th June, 1943.

Messrs. Scottish Oils Ltd.,
Middleton Hall,
Uphall,
Westlothian.

For the attention of Mr. Crichton

Dear Sirs,

We confirm our telephone conversation with your Mr. Burnett (?- the line was bad) advising you that, at the request of Mr. R. C. Thomson, we shall be flowing Cousland No.1 for a couple of days next week and asking whether you could kindly help our Mr. Adcock who will be doing the job:-

1. By booking a room for him if possible in Edinburgh but if not in any town near Cousland. Mr. Adcock will telephone you on arrival either at Broxburn 35 or Philpston 5 if out of office hours. Could you leave a message for him at these numbers?

2. By advising him where best to hire a car during his stay.

3. By if practicable lending him a fitter and supplying a few pipe fittings (probably 3") to our debit.

At present it is expected that Mr. Adcock will travel up on Sunday, arriving in the evening, but we will telephone you confirming this tomorrow morning. Needless to say we shall be most grateful for any assistance you may be able to give him.

Yours faithfully,

For D'ARCY EXPLORATION COMPANY LTD.

c.c. Mr. Adcock

DC/CEP

(Sgd.) D. COMINS

DRAFT

PROGRAMME WITH TIME AND COSTS FOR "BRINGING IN" COUSLAND NO.1 AS A GAS-WELL.

It will be necessary to insert a string of tubing, in this case 2", into the well to ensure that as water accumulates it can be discharged from the well by the flow of gas.

The scheme recommended is to pump in a cementing-plug by following the plug with water until it is just above the first perforation in the 8¾" casing. When this point is reached and the well is full of water, the well will be "dead" and there should be no difficulty in inserting the 2" tubing. The 2" tubing can then be run to a point just above the cementing-plug.

The well-head should then be fitted with a special landing-head and a blowout preventer, after which the cementing-plug can be forced down by the 2" tubing, assisted if necessary by pumping water in the annular space. A special landing-collar must be fitted in the 2" tubing string at such a position as will enable the tubing to be hung at the correct place.

The 2" tubing will be perforated where necessary and a bursting-disc fitted above the perforations. After the tubing is landed it will be suspended in the head by the landing-collar, the blowout will be removed, 2 valves and a short container fitted to the 2" tubing, and a go-devil dropped in to break the bursting-disc.

Material required (Main items)

Cardwell hoist and gear.

A.E.C. engine and Wilson-Snyder slush pump.

ft. 2" tubing, perforated, with bursting-disc.

Special well-head and landing-collar threaded 2" pipe thread.

Blowout preventer, accumulator and fittings.

2" swab and running tools.

Containers for go-devil and swabbing.

2" valves, small tools, pressure gauges, packing, bolts.

Go-devil, tubing handling gear, tongs, etc.

A plentiful supply of water must be available.

Fuel Oil.

Time and Costs.

	Time	Cost
(1) Transport outfit from Eakring and erect		
(2) Prepare well-head, pump in plug and insert 1st section of tubing.		
(3) Put on special head and blowout preventer, run balance of tubing.		
(4) Set tubing in well-head, take off B.O.P., attach valves and break bursting disc.		
(5) Swab well "in" if necessary.		

Mr Bremner — This is a copy. You will note that we did not rely on the bursting disc to bring the well in but on swabbing. The disc was mainly there as safety measure to avoid any risk of gas blow through tubing whilst running in; gas blow through A.S. being taken care of by running through B.O.P.

20/4/45

55

PROGRAMME WITH TIME AND COSTS FOR " BRINGING IN"

COUSLAND NO.1 AS A GAS-WELL

It will be necessary to insert a string of tubing, in this case 2", into the well to ensure that as water accumulates it can be discharged from the well by the flow of gas.

The scheme recommended is to pump in a cementing-plug by following the plug with water until it is just above the first perforation in the 8.3/4" casing. When this point is reached and the well is full of water, the well will be "dead" and there should be no difficulty in inserting the 2" tubing. The 2" tubing can then be run to a point just above the cementing-plug.

The well-head should then be fitted with a special landing-head and a blowout preventer, after which the cementing-plug can be forced down by the 2" tubing, assisted if necessary by pumping water in the annular space. A special landing-collar must be fitted in the 2" tubing string at such a position as will enable the tubing to be hung at the correct place.

The 2" tubing will be perforated where necessary and a bursting-disc fitted above the perforations. After the tubing is landed it will be suspended in the head by the landing-collar, the blowout preventer will be removed, 2 valves and a short container fitted to the 2" tubing, and a go-devil dropped in to break the bursting-disc.

MATERIAL REQUIRED (Main items)

Cardwell hoist and gear.
A.E.C. engine and Wilson-Snyder slush pump.
1750 ft. 2" tubing, slotted, with bursting- disc.
Special well-head, and landing-collar threaded 2" pipe thread.
Blowout preventer, accumulator and fittings.
2" swab and running tools.
Containers for go-devil and swabbing.
2" valves, small tools, pressure gauges, packing, bolts.
Go-devil, tubing handling gear, tongs, etc.
A plentiful supply of water must be available.
Fuel oil.

TIME AND COSTS

	Time	Cost
(1) Transport outfit from Eakring and erect	3 days	£ 80
(2) Prepare well-head, pump in plug and insert 1st section of tubing	3 days	15
(3) Put on special head and blowout preventer, run balance of tubing.	2 days	10
(4) Set tubing in well-head, take off B.O.P., attach valves and break bursting-disc	2 days	10
(5) Swab well "in" if necessary	3 days	15
(6) Fuel for 14 days.		15
(7) Dismantle and return men and gear	3 days	80
(8) Subsistence allowances		15
	16	240
Add cost of material remaining on well or made specially for the job, and consumable stores, travelling, etc.		360
		600
Add 10% for contingencies		60
		660

7th Feb. 1942. MCS/CEP

A249/6931. C.11.38

COPY

Memorandum

From MR. COMINS, SOUTHWELL.

To Mr. HARTLEY, SUNBURY.

Our Ref. DC/358 **Your Ref.**

Date 31st January, 1942.

Subject COUSLAND: GAS PRODUCTION SCHEME.

A diagrammatic sketch outlining the revised scheme as agreed with you is attached, also a recapitulation of considerations taken into account in order that these may be borne in mind when reviewing the scheme as a whole or modifying it in detail.

Our understanding of the position is that, subject to your confirmation of the general scheme, you will now have it followed up in sufficient detail

(a) to forestall delay on account of plant design and enquiries for suitable equipment should we be asked to go ahead at short notice.

(b) to enable a time estimate to be made. The 15" casing can be supplied ex our stock in lengths varying from 24 to 28 feet.

The only points now in abeyance appear to be

(a) Whether a Tracy Purifier shall be used instead of 15" casing for the Mist Extractor.

(b) Whether some form of safety valve should be installed down stream from the master valve on the A.S. of the type which would close automatically in case of major damage, e.g. demolition of the system beyond that point, and prevent the well blowing wild. There would be not need for such a safety valve beyond the tubing master valve as production from the tubing would be intermittent. This point was not discussed with you.

(Sgd.) D.COMINS.

Enclosures - 2

DC/CEP

DC/359 31st January, 1942.

COUSLAND : GAS PRODUCTION SCHEME.

I. Recapitulation of Considerations taken into account.

1. Maximum requirements from Field 1.0 m.c.ft./day at 30# abs. delivery pressure. Maximum delivery pressure to pipe line at site therefore 80# abs. Supply is to be regarded as partly or wholly standby. Provision therefore necessary for controlling lower delivery pressures at site over range 80# abs. to say 40# abs.

2. Sharing offtake with Anglo-American our normal proportion (maximum) would be 0.5 m.c.ft./day; but, in view of possibility of considerable delay before they are in a position to produce their proportion, and also as a precaution against increased demands from the Field, production scheme designed to handle 1.0 m.c.ft. maximum.

3. Initial flowing pressure of well at 0.5 m.c.ft./day estimated to be approximately 600# abs. and at 1.0 m.c.ft./day approximately 580# abs., declining at rate of 1.63# /m.c.ft. gas produced. Thus, at 0.5 m.c.ft./day offtake estimated decline about 25# /month and at 1.0 m.c.ft./day about 50# /month. Velocities and dimensions are calculated on basis of an eventual flowing pressure at 1.0 m.c.ft./day of 200#, but, as estimated closed in pressure of well now is of order of 630/640# abs., high pressure piping and vessels provided to withstand this pressure with factor of safety of 3.

4. Water was rising in the hole during the production test. It was not proved whether this was edge water or only returning drilling water. If edge water, it would continue to rise and reduce production capacity at any given flowing pressure to below the estimates quoted and eventually kill production entirely. There would also be a progressive increase in mist production.

As an insurance against this - the cost being negligible compared with that of the pipe line and of the issues involved - provision is made:-

(a) for running tubing to allow the water to be evacuated intermittently by gas lift, and

(b) for water separation and for mist extraction at the highest pressures available.

Routine production would be from the annular space with no free water and little if any mist - the separators then merely acting as first stage mist extractors.

With complete mist extraction at 600# and assuming a flowing temperature of 70^{o}F, the water vapour going forward in 1 m.c.ft. gas per day should not exceed the equivalent of about 3 gallons of water per day, and there would have to be about 30^{o}F of frost in the (unburied I understand) pipe line before any of this could condense in it. For 200# mist extraction the comparable figures are about 8 gallons per day and 10^{o}F of frost. (Even if the water now in the hole is returning drilling water and can be entirely evacuated, the gas would still carry water vapour, being in equilibrium with edge water in the reservoir.)

Although a very small amount of condensation is possible inthe pipe line, it would be advisable to allow for drips as a precaution against accumulation at low points which, through freezing, might lead to complete blockage of the line.

5. Owing to the varied conditions of pressure, production and water content which the production system must handle over a period, provision is made for as much flexible as possible, including a positive integrating gas meter rather than an orifice meter, which will also save a good deal of work in operation.

II. Notes on Sundry Details.

The diagrammatic sketch is mainly self explanatory, but it is as well to record the reasons for certain details of arrangement. Working from the well:-

The water blow off line is provided in order that the initial gush of water when evacuating water through tubing may be disposed of and any mud or sand debris ejected before connecting in to the l.h. separator.

Valves and piping around wellhead are arranged so that flow from either tubing or annular space can be diverted to either or both separators. It may be necessary to maintain production from the annular space, simultaneously with gas lifting water through the tubing. The valves on the A.S. and on the tubing nearest the well should be considered as master valves - i.e. not for routine use.

Liquid Level Regulators on Separators and Mist Extractor. These have been shown as agreed with you instead of the drain traps originally proposed by us. It should be borne in mind however that, on routine production from A.S., it is probable that very little water if any will be produced, although water production when flowing through the tubing may be considerable.

The Safety Valves on the Separators and Mist Extractor. would only appear necessary to comply with Board of Trade Regulations. It can be guaranteed that under no circumstances could the pressure exceed about 700≠ even with the separators shut in and isolated in hot weather.

Emergency waste water and gas line. This is for use when first admitting tubing production to the l.h. separator for testing whether separation is effective and for temporary use if there is considerable water carry over with the gas in the initial stages of water reproduction. If the carry over is only slight it would not be used and the tubing production be passed through both separators.

Pressure Regulator. Upstream pressures may vary from 600≠ to 200≠ abs. dropping during production life of well. Downstream pressures may vary from 80≠ abs. (assuming 1.0 m.c.ft. maximum demand from Field) down to say 40≠ abs. at low temporary demand.

Provision is made for warming the regulator or any other point where freezing up may occur with steam hose from the small gas fired boiler. It is a question as to whether some continuous heating arrangements should be provided at the pressure regulator.

The Variable Flow-bean Box and fine adjustment valve on bypass.
This is where accurate control of delivery pressure to meet production requirements will be effected. (The flow beans shown at entry to separators are merely for purposes of preliminary beaning down of production near the wellhead to a figure at separator back pressure slightly in excess of the offtake required, in order to avoid use and cutting out of valves.) We will supply drawings of these bean boxes which are very cheap.

Gas Meter. Positive integrating meter provided in order to save work on changing orifice plates to meet fluctuating demand and in computing charts. (The staff position may be difficult.) Although specified in diagram to work at 80# abs. the actual workign pressure may be as low as say 40# abs.

Water Meters. No provision is made for water meters, only for connections, as we shall have no idea of capacities required until the sheme is in operation, when preliminary tests can be made into say a 400 gallon tank.

Water Disposal. The water is nearly fresh and there should be no difficulty in disposal. If necessary it can be returned to No.2 well.

(Sgd.) D.COMINS.

DC/CEP

File Cousland General.

August 3rd 1940.

Capt. Cowans
Manager
& Burgage

Cousland No.1 and No.2 Locations.

No.2 Well. Tests carried out on July 22nd.

Water Level.

2.00 p.m. By running the float the level was found to be 178' from the R.T. The R.T. elevation is 431.5' and hence the elevation of the water level is 10253.5'. N.B. the flange from which measurements are made is 10' below the R.T. On December 1st 1939 the water level was found to be 195' from the R.T. Hence the rise in water level over this period is 17'.

Water Pressure.

3.20 p.m. The Amerada gauge was run into the well, the top of the gauge being at 2016' and hence the bottom at 2018' from the R.T. A check pressure was obtained first of all at 1500' from the R.T. The 12 hours clock was used when running the Amerada, and the gauge was left for ½ hour at each depth. A maximum thermometer was run as well, but the minimum temperature which it would register was 60°F, and no record was obtained at this temperature. The calibrating temperature was 58°F, and hence no corrections have been applied to the measured pressure. The Amerada gauge was calibrated at pressures of 795 and 800 lbs/sq:in:, and the water pressure at the depth of 2016' from the R.T. was hence determined to be 796 lbs/in:^{2} gauge.

N.B. The max: thermometer was checked up against a lab: thermometer by immersing in a beaker of warm water, & it was found to be registering correctly.

Estimated temperature at 2016 ft = 73°F based on a temperature of 70.3°F 246 ft higher in No 1 well — 1770 ft & to get gradient assuming a surface temp of 50°F

actual pressure, allowing for temp. calibration

No.1 Well. Tests carried out on July 23rd.

Closed in pressure.

10.00 a.m. The C.I.P. was measured by D.W.T. and was found to be 614.2 lbs/in:^{2} gauge at 64°F. The elevation of the R.T. is 565'-2", and the distance from the R.T. to the cellar floor is 12'. The position of measurement was 3'-2" above the top of the cellar wall (the depth of the cellar being 6'), and hence the elevation of the pressure measurement is 10562'-4". The pressures recorded in previous reports were all determined at the above elevation. The last pressure was obtained on December 11th 1939 and was found to be 589.9 lbs/sq:in:, and hence the rise of pressure was 24.3 lbs/sq:in:

Wellhead gas for Sunbury Research Station.

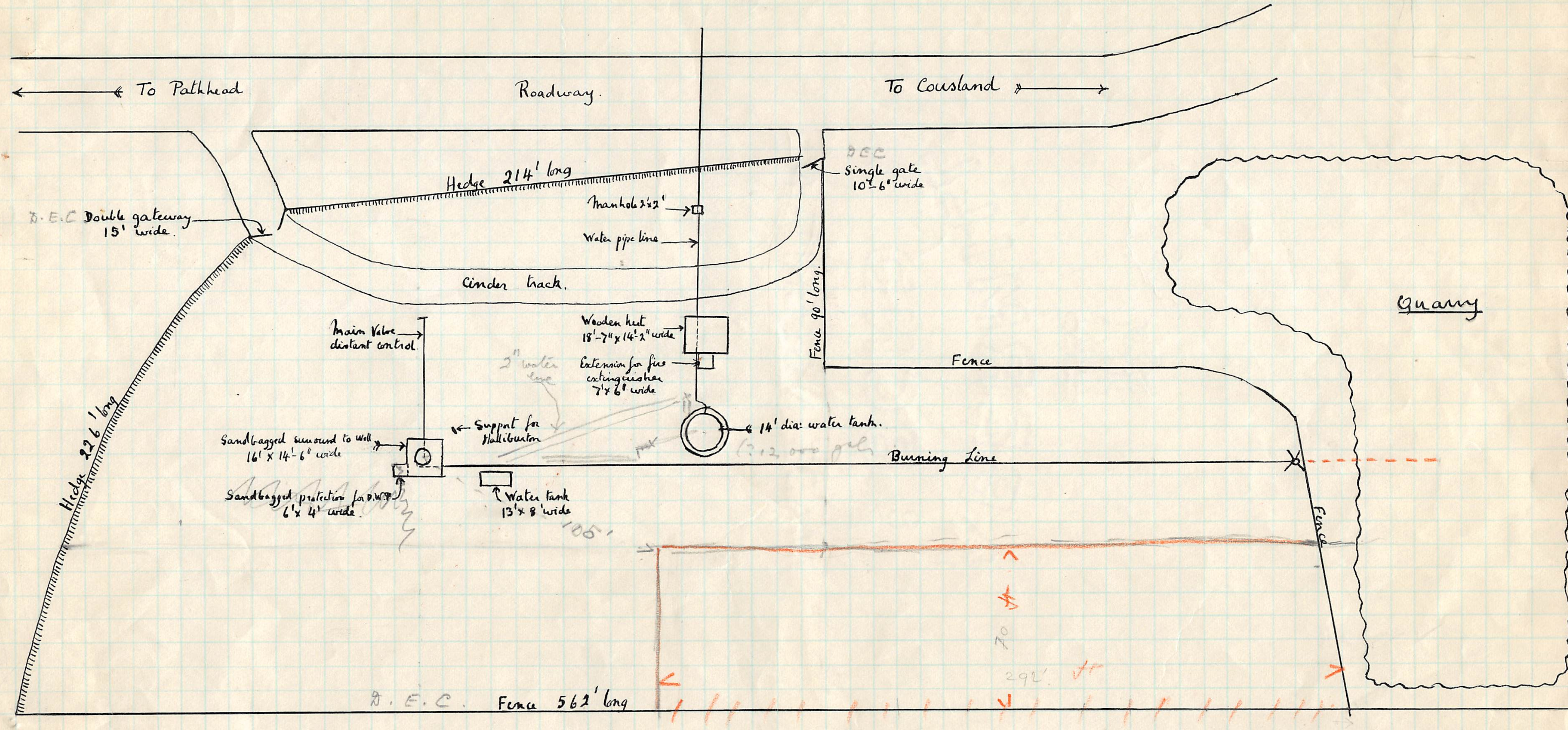
Three O.W.E. cylinders were filled with gas at a pressure of 600 lbs/in:^{2} gauge, and were despatched to Sunbury by passenger train, the filling temperature being 65-70°F.

Layout of Nos. 1 & 2 Locations.

Two plans are attached herewith showing the position of all equipment at Nos. 1 and 2 locations, and the present boundaries to the land. At No.2 location the earth mound made for the bund is still in existence, and no doubt this earth would be used for filling up the cellar when the surrounding concrete walls etc are demolished. There is a good cinder track at No.1 location which could be used by light lorries, but there is no made-up track or roadway at No.2 well.

C. M. Adcock

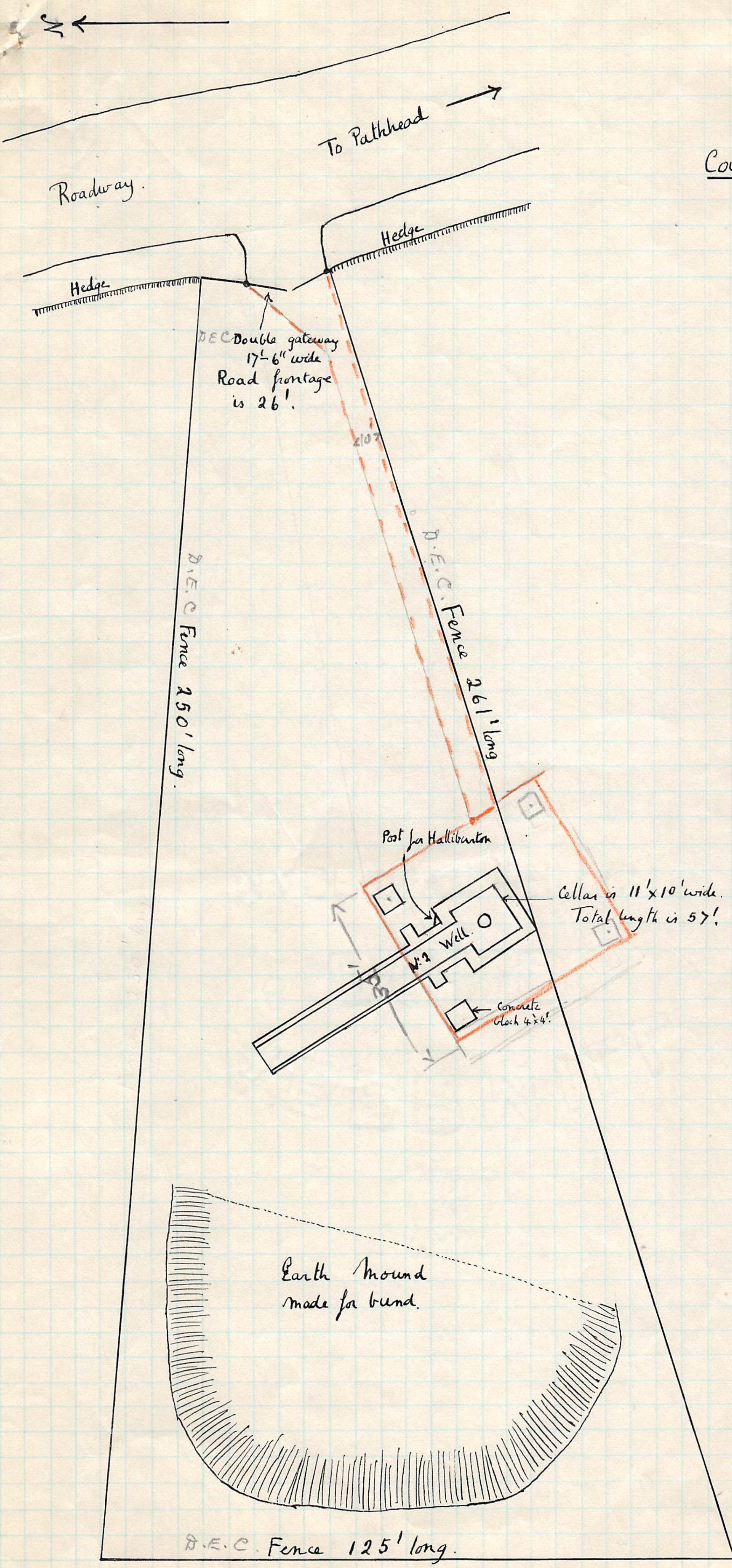
Cousland No. 1 Well



Scale:- 1 square = 10'

C.M.A.
Aug: 2nd 19'

Cousland No. 2 Well



Scale:– 2 squares = 10'

C. M. A.

Aug: 2nd 1940.

CG-6

Cousland No.1. Location.

Completion of Production Test Report. December 11th 1939.

After December 9th the fall in the fluid level was no longer observed, as running the float entailed the loss of a small quantity of gas, and as it was desired to obtain a value for the maximum closed in pressure. The pressures obtained, using the D.W.T., are tabulated below, and it will be seen that on December 10th and 11th no observed rise in the pressure took place, so that it seems probable that the maximum closed in pressure is 590 lbs/sq:in. No further pressure readings were taken after December 11th.

Date.	Time.	Pressure.
December 9th.	9.00 a.m.	588.1 lbs/sq:in:
	2.30 p.m.	588.9 " .
December 10th.		
	10.30 a.m.	589.9 " .
	3.30 p.m.	590.0 " .
December 11th.	9.00 a.m.	589.9 " .
	3.30 p.m.	589.9 " .

H 119—C1.39.

Memorandum

From D'Arcy Exploration Co. Ltd., Cousland.

To Mr. A. F. Bremner, D'Arcy Exploration Co. Ltd., Eakring.

Our Ref. **Your Ref.** **Date** 11th December, 1939.

Subject COMPLETION REPORTS.

COUSLAND NO.1.

Plugging back to 1740'.

When the production test of the 1760'/1806' Sandstone was completed on the 12th August, preparations were made to plug the hole with cement, from the 8.3/4" Float Collar at 2051' to 1740', i.e., 20 feet above the top of the perforations.

The necessary equipment, including one Slush Pump, A.E.C. Engine and Dual Control were transferred and installed at No.1 Location. The Cardwell Hoist was then placed in position at the Wellhead. The Well was opened to the 3" Flow Line and Gas pressure slowly reduced until pressure showed less than 100 lbs. per square inch. The Well was killed and water rose to surface after pumping 1600 cubic feet, but water level fell rapidly to 400 feet from surface where the drop in level was much slower. By pumping 300 cubic feet of water every 4 hours we found we could keep the Well under control. 2050 feet of 3" Tubing was run in the hole with a 4.1/2" Non Return Valve fitted at 1740 feet, and 106.9 cubic feet of 1.8 S.G. Slurry was pumped to Tubing followed by 72 cubic feet of water. When the Cement was placed the Tubing was pulled up to 1740 feet and the hole circulated to remove surplus cement. 24 Hours later the Cement level /

Cement level was found to be at 1782 feet, and a further 14.5 cubic feet of Cement was pumped to Well. This brought the level up to 1736 feet and the surplus cement was bailed out with a 6" Bailer until it picked up at 1740 feet. This was checked with the Halliburton Measuring Device. The cementation was successfully tested by bailing the hole dry.

Gun Perforating - 1720'/1735'.

Before commencing Gun Perforating on 21st August, the hole was again filled to surface with water. The Schlumberger Outfit was then placed in position and 60 shot holes, spaced 3" apart, were made with 3/8" dia. Bullets from 1720' to 1735'. This operation was completed on the 22nd August. The water was bailed with a 6" Bailer through an 8.3/4" dia. Container, 31 feet long, with 2 feet Polished Rod. The short Container being used in view of the restricted height of the Cardwell Hoist. When the water was bailed down to 500 feet, the gas pressure rose to 60 lbs. per square inch and eventually increased to 400 lbs. per square inch when the hole was bailed dry to 1739 feet, and a thick oil emulsion was found at this depth when the Halliburton dipper was run 48 hours later. The Well was closed in from the 22nd August to the 10th September when it was opened up for a short production test of the 1720'/1735' Sandstone; the highest closed in pressure recorded was 586.9 lbs. per square inch. The result of the test showed a Gas production of approximately 800,000 cubic feet of gas per day, flowhead pressure 5.5 lbs. per square inch /

5.5 lbs. per square inch. No water was produced and when the Halliburton dipper was run the hole was found to be dry.

Gun Perforating - 1630'/1582'.

On the 16th October, preparations were made to carry out Gun Perforating operations. The pressure of 586.4 lbs. per square inch was successfully killed by flowing the Gas through the flow-line until the pressure was practically nil, and water was then pumped and hole filled to surface. As the formation was inclined to take water, the hole was kept full from the Water Reserve Tank by regulating the valve.

Gun Perforating from 1582 feet to 1613 feet, and from 1623 feet to 1630 feet was commenced on the 17th October and completed on the 20th October. 164 Bullets, 3/8" diameter, were fired spaced 3" apart. For details see separate report sent 21/10/39.

The Well was closed in from the 21st October to 3rd November when it was opened up and produced through the burning line, the rate of flow being approximately 1,000,000 cubic feet gas per day.

For details of Production Tests carried out, attached please find copies of reports of the Petroleum Engineer.

The Well was again closed in on the 2nd December to observe closed-in-pressures. The Wellhead is protected with bags of sand with free access to the Cellar for observing pressure on the Gauge. /

the Gauge. The Well is controlled by Remote Control from Main Valve. The Site has now been cleaned up, the sleeper track uplifted and sleepers transferred to Eakring. There is now only one Building left on Site, the Blacksmith's Shop, this accomodates the Fire Appliances which include -

1 - 34 Gall. Foamite 'DM' Engine complete.

6 - Spare Foamite Charges for above, 34 gall.

2 - 2-Gall. Phomene Fire Extinguishers.

2 - 2-Gall. Conquest Fire Extinguishers.

It has been arranged for two men on each of the three shifts per day to be present while the Well is closed in.

--------oOo-------

COUSLAND NO.2 LOCATION.

All the ground has now been restored to its original contour,where excavations have been filled in the loose earth has been left one foot above ground level to allow for subsidence. The only foundations left are the four main derrick blocks and the cellar which have been cleaned up and white washed. The Wellhead has also been painted with grey paint. Work is now being carried out removing the drilling mud from the bund to the quarry at No.1 Location, and this should be completed about the 16th December. Two Watchmen, working 12 hours shifts, will look after Location when finally evacuated.

COUSLAND NO.3 LOCATION.

This Location was cleaned up, the land surface restored to its original condition, except for the four derrick blocks, and the cellar. All surplus mud was removed from the bund to the quarry at No.1 Location. The loose earth, which makes up the bund, has been left to be used for filling in when cellar concrete has been removed. All work was completed on the 14th November 1939, and the site left in excellent condition. We were then given to understand that Agreement concerning the Land would be taken over by the Military Authorities.

H.120 42539/9301 WWN

EAKRING

Cousland

Copy

From FIELDS BRANCH, SOUTHWELL.

To FIELDS BRANCH, SUNBURY.

Our Ref.

Your Ref.

Date 29th November, 1939.

a.J.B.

Subject COUSLAND NO. 1 PROGRAMME

Cousland No. 1 is now due for shut down to obtain the reduction in reservoir gas pressure caused by production. Approximately 27,000,000 cubic feet have been produced since November 3rd and it is clear that the upper sand (1582/1632) may be quite useful, the flowing pressure at 1.0 m. c.ft/day having only fallen 25 # during the period - from 580 # to 555 #.

Based upon the closed-in pressure after a 26 hour shut down 17th/18th November the reserves of the two sands now exposed in the well work out at 325,000,000 cu.ft. on the assumption that there has been no water encroachment. There is no evidence, however, that the pressure had really reached equilibrium and the figure for reserves to be calculated from the next shut down may prove to be much bigger. Of the 325,000,000 cu.ft. referred to above, 25,000,000 may be allocated to the middle sand (1720/1735 ft.), this estimate being based on data obtained when that sand only was exposed. The present position regarding the reserves estimates in this well is, therefore as follows:-

	Million cu.ft.
Bottom Sand 1760 - 1806	175
Middle Sand 1720 - 1735	25
This was in connection with the bottom sand during the tests of the latter, the connection being behind the casing. This channel has now been cemented off and the middle sand is no longer in connection with the bottom sand, but is in direct connection with the upper (1582/1632) sand as the casing opposite both sands is now perforated.	
Top Sand 1582 - 1632	300 (preliminary figure)
This is a minimum figure assuming no water encroachment and may be far too low. The final estimate awaits the result of the shut down now due.	Total: 500 (minimum)

No water has been produced in the course of the present production test, but some water has entered the hole, and when the well is flowing is now at 1628 ft. from surface, i.e. just above the bottom of the upper sand. This is probably merely water returning from the formation as some 20,000 gallons were lost, mainly to the middle sand, during gun perforation, and even should it prove to be edge water the behaviou of the well indicates that it is not coming from the upper sand. (The comparatively unimportant middle sand could, if necessary, be plugged back).

It is, however, essential to clear up the source of this water - little can be done from analysis alone at the present stage as in any case the return of some perforating water is inevitable. It is, therefore, recommended that, on conclusion of the closed-in pressure, test water should be produced from the well until either:

(a) 20,000 gallons have been recovered with water still coming in, or

(b) until conclusive evidence is obtained from analyses, whichever of these may be the shorter.

We wish to carry out the closed-in pressure test referred to above before this water production owing to the difficulty of estimating gas production accurately when accompanied by water, but a confirmatory closed-in pressure test should again be made on conclusion of the water production.

The method of producing the water may be either:

(a) by flowing the well through casing at a much higher rate than at present. It is probable that 3 or 4 days' production at the rate of 5 to 10 million cu.ft. of gas a day would suffice, but a firm estimate is not possible. This is the only method at present practicable owing to the absence of equipment;

(b) by running tubing to near bottom and using the gas from the upper sand to gas-lift the water to surface. This has the advantage that the gas production required to produce the water would be much less than under (a), but would involve considerable delay both in obtaining the information and in the evacuation of the area - the necessary equipment not being on site.

A decision at your early convenience is requested as to which of these two methods of producing the water should be adopted - the point being as to whether there is any commercial or political objection to the extra gas production involved by (a). We shall also be glad of your confirmation by telegram that we may shut down the well forthwith for closed-in pressure test as per programme.

This memorandum has been prepared in discussion and agreement with Messrs. Seamark and Dickie.

(Sgd.) D. COMINS.

Copies to:-

Mr. Adcock, Cousland
D.E.C., Eakring.

DC/RW

Spare Copy - without R.K.D's note on flowing test, and graphs.

15th May, 1939.

E File

MR. SOUTHWELL.

COUSLAND : RESERVES AND EDGE WATER CONDITIONS.

Data and deductions to be drawn from the recent pressure and production tests in Cousland No.1 (1760/1806) and 2 (2016/2120) are given in detail in the attached memo. and appendices, mainly as a record of facts and methods of estimation.

The main point is however:-

(a) That gas:water level of the 1760/1806 ft. sand is at about the bottom of this sand in No.1 well.

(b) That the edge water appears to be "dead", i.e. its pressure is reduced by production by the same extent as the gas pressure.

(c) That the estimated reserve of gas which can be drained from the 1760/1806 ft. sand by No.1 well alone is of the order of only 200 to 250 million cubic ft. This may or may not represent the whole reserves of this sand throughout the area. Dr.Lees has pointed out that the sand may not be continuous. It may be lenticular or alternatively sections of the sand may be cut off by faults from effective communication from the remainder of the sand. In either case the total gas reserves of the 1760/1806 sand would be many times the estimate of the amount recoverable in No.1 well, but on the other hand a number of production wells would be required to produce them.

Further evidence on this point will be available when it has been determined whether No.2's pressure in the 2016/2120 sand has been reduced by the production from No.1.

(Sgd.) D. COMINS.

COUSLAND.

RESERVES ESTIMATES AND DATA OF THE 1760/1806 SAND IN NO.1 WELL.

15th May, 1939.

12th May, 1939.

COUSLAND : ESTIMATE OF GAS RESERVES WHICH COULD BE DRAINED FROM THE 1760/1806 SAND IN COUSLAND NO.1.

1. Graph A attached shows the estimated gas reserves which could be drained in No.1 well corresponding to any value for the final closed in pressure after the production test 17th - 24th April.

The calculation of this graph is given in Appendix I. The calculation assumes that gas:water level in the sand has not yet risen as a result of production, the water production being merely due to coning up whilst on flow. This assumption is supported by the following facts:-

(a) By pressure correlation between the closed in pressure of Cousland 1 before the main production test, and the water pressure in Cousland 2 in the equivalent sand (2016/2120), it was estimated that gas:water level was at about 1800 ft. in No.1 (See Mr. Dickie's report dated 20th April, 1939).

(b) Water was produced within a very short time of the start of the production test indicating the close proximity of gas:water level.

(c) At the end of the closed in pressure test following the production test gas:water level was found to be below the lowest perforations - 1806 ft.

It would appear therefore that the edge water is not in sufficiently good connection with any permanent water table, to give the effect of a water drive over a short period

2. Final equilibrium of closed in gas pressure of No.1 was not in fact reached before the well was again put on to production tests. The last pressure measured was 552.1 #, the corresponding figure for gas reserves being 200 million cubic ft.

3. Extrapolation of the curve of pressure rise (Graph B) and an estimate of the final closed in pressure has however been made

(a) By plotting the rate of entry of gas (measured at bottom hole pressure and temperature) into the well against the corresponding back pressure on the reservoir at any time (Graph C derived from Graph D). This relation proving to be practically linear, the final back pressure can be estimated (corresponding to a nil value for rate of entry of gas), the corresponding closed in pressure being obtained from Graph E. The result obtained was 561 # gauge.

(b) By a method suggested by Dr.Rankine, in which the expression for the rise of pressure is assumed to be exponential (See Appendix II). This also yields results of the same order - 565 #.

In view of the correspondence of results obtained by these two methods it would appear safe to assume that the final closed in pressure will not exceed say 570 # and that gas reserves recoverable in No.1 well from the 1760/1806 sand are therefore of the order of only 250 million cubic feet.

4. Details of the production test are given in Mr.Dickie's report (Appendix III).

(Sgd.) D. COMINS.

APPENDIX I.

COUSLAND NO.1 : CONSTRUCTION OF GRAPH FOR ESTIMATION OF GAS RESERVES OF THE 1760/1806 SAND FROM THE PRODUCTION TEST DATA.

Let:-

Initial poresface in sand be	V m.c.ft.
Gas production during test be	G m.c.ft. (at N.T.P.)
Water production	W m.c.ft.
Reservoir Temperature	$T^{o}F$ abs.
Initial Reservoir Pressure at 1770'	P_1# abs.
Final " " " "	P_2# abs.
Deviation factor at P_1 and T	D_1
" " " P_2 " T	D_2

and Initial Gas Reserves at Atm.Pressure and 60°F(regd.) R m.c.ft.

Then

$$R = V \times \frac{P_1}{14.7 D_1} \times \frac{520}{T} \longrightarrow (1)$$

and assuming water produced is replaced in the reservoir by gas and not by encroaching edge water:-

$$R - G = (V + W) \times \frac{P_2}{14.7 D_2} \times \frac{520}{T} \longrightarrow (2)$$

Substituting for V in (2) :-

$$R - G = \left(\frac{14.7\, D_1\, T R}{520\, P_1} + W \right) \frac{520\, P_2}{14.7\, D_2 T}$$

and simplifying :-

$$R = \frac{G + \frac{35.4}{T} \frac{P_2}{D_2} W}{1 - \frac{P_2 D_1}{P_1 D_2}} \longrightarrow (3)$$

<u>Now</u>

P_1 is known = 688 # gauge = 702.7 # abs.

T = 70.3°F = 530.3°F abs.

D_1 at 70.3°F = 0.892

G is calculated by R.K.D. to be = 35.4 m.c.ft.

W " " " " 75,700 gals = .0122 m.c.ft.

$$\therefore \text{R (minimum)} = \frac{35.4 + \frac{35.4}{530.3} \times 0.0122 \frac{P_2}{D_2}}{1 - \frac{0.892\,P_2}{702.7\,D_2}}$$

$$= \frac{35.4 + 0.000814 \frac{P_2}{D_2}}{1 - 0.001269 \frac{P_2}{D_2}} \longrightarrow (4)$$

$$\text{and } V = R \times \frac{14.7\,D_1 T}{520\,P_1}$$

$$= R \times \frac{14.7 \times 0.892 \times 530.3}{520 \times 702.7}$$

$$= 0.01905\,R \longrightarrow (5)$$

Let S acres be area of sand corresponding to V. Then assuming 20% average porosity and 46' average thickness of sand.

$$S = V \times \frac{5}{46} \times \frac{10^6}{9} \quad \text{sq.yds.}$$

$$= 12080 \text{ V sq.yds.} = \frac{12080}{4840} \text{ V acres}$$

$$= 2.498 \text{ V acres} \longrightarrow (6)$$

and if Z yds. be diam. of circle of this area

$$.7854Z^2 = 12080 \text{ V}$$

$$\therefore Z = 124\sqrt{V} \text{ yards} \longrightarrow (7)$$

Substituting varying values of P_2 (with corresponding values of D_2) in these formulae we get:

P_2 gauge	P_2 abs.	D_2	R m.c.ft. from (4)	V m.c.ft. from (5)	S Acres From (6)	Z Diam. of sand circle yards From (7)	Closed In Pressure (gauge) Corresponding to P_2 (From Graph 2)
477.	491.7	0.925	109.5	2.09	5.22	179.	457
558	572.7	0.913	176	3.35	8.36	227	534
600	614.7	0.906	258.5	4.92	12.28	275	575
640	654.7	0.900	500	9.52	23.75	382	613
660	674.7	0.897	800	15.24	38.00	484	632
670	684.7	.895	1200	22.86	57.00	592	642
680	694.7	.8935	2570	49.00	122.2	868	651

Addendum. The value of W has since been corrected to 73,500 but as this correction would make a negligible difference to results these have not been recalculated.

APPENDIX II

COUSLAND No.1

CLOSED IN PRESSURE TEST 24/4/39 TO 9/5/39.

ESTIMATION OF ULTIMATE CLOSED IN PRESSURE

The following rough method of predicting the probable ultimate closed in pressure is due to Dr. Rankine. It is, however, pointed out by him that pressure differences should be expressed in terms of the squares of the pressures and that, therefore, the following method, though giving a reasonably accurate approximation as regards the result, is not altogether sound as regards argument.

The experimental pressure build-up curve suggests the form -

$$p - p_o = A\left(1 - e^{-\lambda t}\right)$$

where p = pressure at any given time t

and λ = constant.

When $t = o$, $p = p_o$,

when $t = \infty$, $p_f - p_o = A$

and $\therefore\ p - p_o = (p_f - p_o)\left(1 - e^{-\lambda t}\right)$ ⟶

This may be expressed as

$$\lambda t = \log(p_f - p_o) - \log(p_f - p).$$

Whence, if t be plotted against $\log(p_f - p)$, taking different values for p_f, the correct value of p_f will result in a straight line.

The application of the method resulted in the attached graphs, from which it will be seen that a value of p_f = 565 # is nearest to a straight line.

JMW.

COUSLAND No.1

CLOSED IN PRESSURE TEST 24/4/39.

PREDICTION OF FINAL CLOSED IN PRESSURE

In the graphical method already set out, Dr. Rankine had treated the experimental curve as though it were exponential, whereas an examination of the problem from first principles led him to the conclusion that this was not so.

Regarding p_1 as the pressure in the reservoir tending to force the gas into the well with an exit pressure p, then by Meyers formula -

$$dV = K \frac{(p_1^2 - p^2)}{p} dt$$

where dV is an elementary volume of gas emerging at pressure p.

$$\text{Now } dm = \rho\, dV$$

where dm is an elementary mass of the gas emerging.

$$\therefore \frac{p}{\rho} . dm = K (p_1^2 - p^2)\, dt$$

If temperature is constant and gas emerges into a fixed volume, $\frac{p}{\rho}$ is constant and $dm \propto dp$.

$$\text{Hence, } \frac{dp}{dt} = a (p_1^2 - p^2) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (a)$$

and, if at zero time t_o, pressure is p_o

$$\frac{(dp)}{(dt)_o} = a (p_{1_o}^2 - p_o^2)$$

$$\text{Choosing } \frac{dp}{dt} = \frac{1}{2} \frac{(dp)}{(dt)_o}$$

$$p_{1_o}^2 - p_o^2 = 2 (p_1^2 - p^2)$$

If p_1 be regarded as constant, and therefore equal to p_f, then

$$p_f^2 = 2 p^2 - p_o^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (b)$$

Now, from equation (a)

$$\frac{dp}{p^2 - p_f^2} = - a.dt$$

$$\frac{dp}{2 p_f^2} \left(\frac{1}{p - p_f} - \frac{1}{p + p_f} \right) = - a . dt$$

$$d \left(\log \frac{p - p_f}{p + p_f} \right) = - 2 a . p_f^2\, dt = \lambda\, dt.$$

$$\log \frac{(p_f - p)}{(p_f - p_o)} \cdot \frac{(p_f + p_o)}{(p_f + p)} = - \lambda t$$

$$\log \frac{(p_f - p_o)}{(p_f - p)} \cdot \frac{(p_f + p)}{(p_f + p_o)} = \lambda t$$

$$\log (p_f - p_o) + \log (p_f + p) - \log (p_f - p) - \log (p_f + p) = \lambda t$$

from which λ may be determined.

It is then possible to predict p at any given time t, or, alternatively, to find at what time t the pressure will have any given value p.

APPLICATION OF METHOD

Select any point p_0 on curve reasonably far from the commencement of the test on the time scale (Dr. Rankine is of the opinion that, in the early stages, other sources may have contributed to the pressure build-up which do not affect the solution of the present problem). Now find the point p on the curve such that the slope of the tangent is half that of the slope at p_0. (This is for convenience and direct application to the foregoing equation only. Any two known slopes may be used with the appropriate modification of the equation.).

Substituting the values of p and p_0 in equation (b), the value of p_f is found, in this case, to be 605.5 # abs. R.P. at depth 1,770', equivalent to 565 # gauge at surface. This is the exact value obtained independently by the logarithmic method.

As a check, if p_0 and p have been accurately chosen, the horizontal distances x_0 and x respectively between points p_0 and p and the intersection of their respective tangents with the line drawn at pressure p_f will be equal.

J.W.

Miss Marrable   ak/Cousland 1/T.2
File
Mr B R [illegible]

A249/6931—C.7.37

Memorandum

From D'ARCY EXPLORATION CO.LTD.
LONDON.

To MR.SEAMARK.

Our Ref.   **Your Ref.**   **Date** 29th March,1939.

Subject COUSLAND. THE 1248'-1279' SAND OF NO.1.

In Cousland No.1 the 1248' (U.G.C. 93.17) sand produced gas at the rate of 30,000 cu.ft. per day and several gallons of oil.

In Cousland No.2 the representative of this sand was encountered at 1490' (8941) and was found to contain salt water which had a C.I.P. of approximately 15 lbs/sq. ins.

At the D'Arcy end of the D'Arcy-Cousland structure the 1248 ft sand is correlated with the 1735' (90 36) oil sand of Midlothian No.1 and the c.a. 2100' (8521) or possibly 2001' (8620) sand of Midlothian No.2. This sand produces oil, c.a. 6 bbls/day and water in No.1 and water in No.2. The fact that water only is produced in No.1 if the well is pumped hard for some days but if left standing oil accumulates seems to indicate that the well has entered the sand near oil/water level and that edge water is being coned up.

The evidence taken as a whole therefore indicates that oil water level is at approximately the 9000 contour. As ground elevation on the Cousland structure only rises slightly above 600 ft. A.S.L. the depth to oil water level at any part of the structure is at most only just over 1600 ft.

In view of the comparatively shallow depths to the oil sand over most of the structure would it not be possible to develop this sand with the heavier Failing Outfit? I would suggest drilling a 7.3/4" hole to the top of the sand, running and cementing 6" casing to this point, and drilling in using oil circulation.

A. [illegible]

I consider it would be very risky to attempt to run 1600 ft of 6" casing with the Failing outfit. A better scheme would be to drill for 6" casing but insert 4". This would obviate the risk of mud ringing to a large extent. The well could be finished at 3 7/8" dia and this would enable a deep well pump to be used. [signature] 6/4/39.

A249/6931—C.7.38.

Memorandum

From D'ARCY EXPLORATION CO.LTD. LONDON.

To D'ARCY EXPLORATION CO.LTD. ESKDALE.

Our Ref.

Your Ref.

Date 11th August,1939.

Subject COUSLAND NO.1 PROGRAMME.

We confirm our telephone conversation of today in which we agreed to your revised programme sent to us under cover of your memo UK/COUS/1.

The only comments we have to make are:-

(1) The difficulty of running drill pipe instead of tubing, owing to the lengths, which must be handled under the Cardwell mast.

(2) If bailing is to be done under pressure conditions by the use of a container, you may have to have a shorter bailer made up, again owing to the height of the Cardwell mast.

(3) In landing the cement it should be appreciated that you will have no gear available by which excess cement can be drilled out; the height to which the cement is landed should therefore be watched very carefully.

M Seaman

H.120.—C.1.39

F

Copy

From D'ARCY EXPLORATION CO. LTD., ESKDALE. **To** D'ARCY EXPLORATION CO. LTD., LONDON.

Our Ref. UK/COUS/1 **Your Ref.** UK/A.31 **Date** 10th August, 1939.

Subject COUSLAND No.1 PROGRAMME

Attached is the revised programme for Cousland No.1 Test Well, compiled with Mr. R.K.Dickie, and in line with your memorandum of the 11th May, 1939.

We estimate that approximately ten days will be required to carry out this programme up to item 7.

We should be glad to have your confirmation of this programme.

(Sgd.) S. Roger.

cc - Petroleum Engineer,
Cousland.

SR/VEB

COUSLAND NO.1 TEST WELL: PROGRAMME

1. Blow down to zero.

2. Pump in water to fill well. If well takes water uncomfortably fast, switch to mud around 1.2 S.G. until intake reduced to reasonable quantity.

3. Run drill pipe to bottom, circulate mud, and fill with cement to 1740 ft. After cement in hole circulate at 1740 ft. to wash out any surplus.

4. Allow cement to set and bail hole to 1740 ft. as check on cement job.

5. Fill hole with water.

6. Gun perforate 1720/1735 ft. with 60 shot-holes, $\frac{3}{8}$" diameter bullets.

7. Bail out water under pressure using container, producing as little gas as possible.

8. Obtain bottom hole static pressure.

9. Carry out gas production test, starting at low rate of flow, increasing by stages to ascertain if water is coming up.

---

cc - Petroleum Engineer, Cousland.

SR/VEB

H.120.—C.1.39

Copy

From D'ARCY EXPLORATION CO.LTD LONDON. **To** D'ARCY EXPLORATION CO.LTD. ESKDALE.

Our Ref. **Your Ref.** **Date** 11th MAY 1939.

Subject TESTS ON COUSLAND NO.1.

a J b

We confirm our telephone discussion of this morning during which we gave you the programme for the above tests. The programme will be as follows :-

(1) Run 2" tubing to top of present cement plug and circulate out any mud or settlings on bottom.

(2) Switch over to cement and fill hole to 1780 ft. raising 2" pipe as cement is pumped in.

(3) If possible bail hole dry and obtain bottom hole closed-in pressure.

(4) Carry out gas production test, starting at low rate of flow (200,000 cubic ft.) and increasing by stages to ascertain whether water is still coming up.

(5) Plug to 1740 ft. using same method as for (1) and (2).

(6) Bail fluid out of the well to test for effectiveness of the cement plug to 1740 ft.

(7) Fill hole with fluid.

(8) Gun perforate 1720/1735 ft. zone with 60 shot holes.

(9) Bail water out using container method. The reason for this bailing is to remove the fluid without having to produce gas at the high rate necessary to remove the fluid by the gas flow. It will also enable a more accurate figure to be obtained for initial reservoir pressure.

(10) Close in and get bottom hole static pressure.

(11) Carry out production test, as in (4)

We appreciate that you have only the small derrick erection winch with which to carry out this programme and we shall be glad if you will satisfy yourself before attempting it that this has sufficient capacity for the work proposed.

(Sgd.) M.C.SEAMARK.

ON ADMIRALTY LIST.

MINERAL BORERS & PROSPECTORS.
ARTESIAN WELL & GENERAL ENGINEERS.

DIAMOND DRILLING MACHINERY, DIAMOND MERCHANTS.

Borings made from 2" to 30" and any depth.
Vertical up and Angular Diamond Borings a Speciality.

CONTRACTS TAKEN FOR HOME AND ABROAD.

Fl.

Andrew Kyle, Limited,
Airyknowe,
Galston,
AYRSHIRE.

NATIONAL SCHEME FOR DISABLED MEN

Telegraphic Address.
"KYLE, AIRYKNOWE, GALSTON."

PHONE No. 338 GALSTON.

31st August, 1938.

Replied stating that as one of our own outfits will become available we shall do the work ourselves. MS 17/10/38

Messrs. D'Arcy Exploration Co., Ltd.,
Cousland,
DALKEITH.

Dear Sirs,

Further to yours of the 27th inst., and the very pleasant Meeting our Mr. Andrew Kyle, Jnr. had with you yesterday; we have now pleasure in herewith enclosing our Tender for your proposed Borings, and trust it meets with your approval.

We understand your proposed borings would be in the Windygates district of Fifeshire. We know this district pretty well, and carried through a Bore ($18\frac{1}{2}$" Diam.) for water at Cameronbridge Distillery in the Spring of 1938. This Bore went to a depth of 84 fms. 2ft. 2- ins. The Bore commenced in the Base of the Upper Coal Measures, and was in the Millstone Grit practically throughout.

We estimate that it would take from 3- to 4- months to complete a Boring to a depth of 100- fms., and about 8- weeks to complete one to a depth of 50- fms.

Should you require any further information, we shall be pleased to supply same on hearing from you.

Yours faithfully,

FOR ANDREW KYLE LIMITED,

Andrew Kyle Director

P.S.
We could reduce the above time by working double-shift.

ALL ORDERS AND CONTRACTS ARE SUBJECT TO THE USUAL CLAUSES RELATING TO STRIKES. ACCIDENTS. AND OTHER DELAYS BEYOND OUR CONTROL.

Specification
Tender

Andrew Kyle, Limited.

Mineral Borers, Prospectors & Engineers.

Airyknowe,
Galston,
AYRSHIRE.

Telegraphic Address.
"KYLE, AIRYKNOWE, GALSTON."

31st August, 1938.

To Messrs. D'Arcy Exploration Co., Ltd.,
Cousland,
D A L K E I T H.

Dear Sirs,

We shall be pleased to undertake to carry through your proposed shallow test borings by our power driven diamond drill, which gives a core of the strata passed through, at the following rates and conditions:-

- to	100- fms.	@	12/-	per foot.
100- to	200- fms.	@	14/-	per foot.

These rates cut all rocks hard or soft, provide all the necessary boring material, diamonds, labour, stores, upkeep, and insurances of all kinds.

We would go through the alluvium large enough to allow us to commence boring in the strata with a 4" Diamond Crown, which gives a core of approximately 3"., and this size we would keep up as far as practicable. Thereafter, we would continue the boring with a 3.1/4" Diamond Crown, which gives a core of approximately 2".

We would supply and insert the necessary tubes free of charge. The tubes remain our property, but if left in the boring at your instructions, then you to pay for same at Invoice price.

You/

Messrs. D'Arcy Exploration Co., Ltd., 31/8/38.

What is the cost of this?

You to pay carriage and cartage on Plant from Galston to the site and back - or equal distance.

You to have a water supply of approximately 8- G.P.M. convenient to the site of the Bores.

I prefer to pay lump sum for dismantling & removing

You to allow us men's time at the rate of 40/- per shift of 8- hours *x* for withdrawing tubes, dismantling, and removing plant between each boring.

Agree.

Should the boring require cementing on completion, you to provide cement on the site, and allow us men's time at the rate of 7/- per hour. This rate includes the use of our Plant.

Is a 90% payment not too high before completion?

Cash to account monthly, less 10% to be retained until completion of contract.

Yours faithfully,

FOR ANDREW KYLE LIMITED,

Andrew Kyle Director

x. The value of the tubes might not justify the cost of recovering them, in which case the cost would have to be added to the cost per foot.
N.S.

25th May, 1938.

COUSLAND : RESERVOIR EQUILIBRIUM CALCULATIONS.

I. BASIC DATA.

(a) Calculation of Reservoir Pressures and pressure/ft. of reservoir gas in the 1580 foot gas sand and the 1720 foot gas sand.

Data - C.P. at 1632' test was 680 # gauge = 695 # Abs.
C.P. at 1734' " " 580 # " = 595 # Abs.

Pressure #/ft. (at assumed Temp. 90°F)

For 695 # $= \dfrac{.072 \times .58 \times 695}{144 \times 14.7 \times D}$

$D = 1 - \dfrac{.18 \times 695}{1470} = 1 - .085 = .915$

∴ Pressure #/ft. = .015 # →

∴ R.P. at 1580' = 695 + 1580 x .015
= 695 + 24 = 719 # Abs. →

For 595 # $= \dfrac{.072 \times .58 \times 595}{144 \times 14.7 \times D}$

$D = 1 - \dfrac{.18 \times 595}{1470} = 1 - .0728 = .927$

∴ Pressure #/ft. = .0127 # = .013 (say) →

∴ Pressure at 1720' = 595 + 1720 x .013
= 595 + 22 = 617 # Abs. →

(b) Water - Assume pressure/ft. between limits of 0.45 and 0.50 #

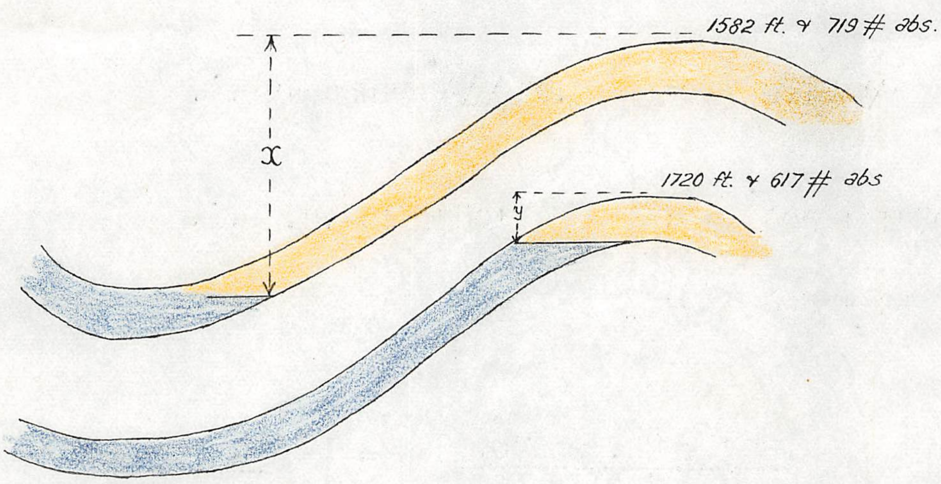
Reservoir Crude (if any) Assume pressure/ft. 0.35 #

II. Now assuming a common water table in the two sands the lower pressure in the lower one may be accounted for by either:-

(a) a longer column of gas in the upper sand than in the lower one.

(b) a longer column of oil in the lower sand than in the upper one.

III. Calculation of (a)



Let x be depth of gas column in upper sand below 1582 ft.

" y " " " " " " lower " " 1720 ft.

Consider equilibrium at gas : water level in the lower sand.

(a) On basis of water 0.45 #/ft.

Pressure calculated from upper sand data :-

$= 719 + .015x - 0.45\ (x - y - (1720 - 1582)$

$= 719 + .015x - 0.45x + 0.45y + 0.45 \times 138$

$= 781 - 0.435x + 0.45y \longrightarrow (1)$

and from lower sand data

$= 617 + .013y \longrightarrow (2)$

$\therefore 617 + .013y = 781 - 0.435x + 0.45y$

$\therefore .435x - .437y = 164$

i.e. roughly $x - y = \frac{164}{.435}$ = roughly 380 ft.

and if $y = 0$ this is precise

(b) <u>Repeating on basis of water 0.5#/ft.</u>

$617 + .013y = 719 + .015x - 0.5x + 0.5y + 0.5 \times 138$

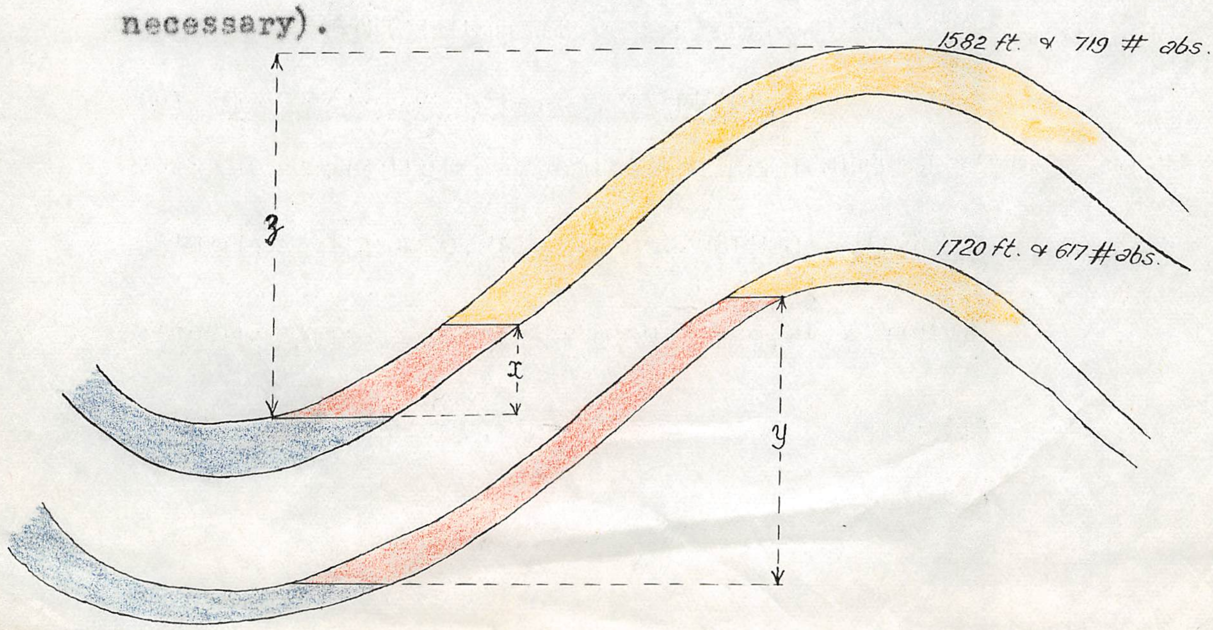
$\therefore .485x - .487y = 171$

i.e. roughly $x - y = \frac{171}{.485}$ = roughly 350 ft.

and if $y = 0$ this is precise.

IV. Calculation of (b).

For the calculation it is necessary to assume that oil : water level is at closure in each sand - a reasonable assumption. (No assumption regarding the depth of closure is however necessary).



Consider equilibrium at oil : water level in the lower sand.

1. <u>On basis of water pressure 0.45 #/ft.</u>

Pressure from upper sand data

$= 719 + .015(z - x) + .35x + 0.45\ (1720 - 1582)$

$= 719 + .015\,z + .335x + 62$

$= 781 + .015\,z + .335x$

and from lower sand data

$= 617 + .013(z - y) + .35y$

$= 617 + .013\,z + .337\,y$

$\therefore$

$\therefore\ 617 + .013z + .337y = 781 + .015z + .335x$

$\therefore\ .337y - .335x = 164 + .002z$

$\therefore$ roughly $y - x = \dfrac{164}{.337} + \dfrac{.002z}{.337}$

= roughly 490 ft. + .006z

Now .006z is so small that it may be ignored (even if z was 100[0] ft as compared with about 400 ft. geologically expected .006z woul[d] only be 6 ft.)

If x = o y = 490 ft. say, 500 ft.

2. <u>On basis of water pressure 0.5 #/ft.</u>

Then $719 + .015\,z + .335x + 0.5\ (1720 - 1582)$

$= 617 + .013\,z + .337\,y$

$\therefore\ .337y - .335x = 171 + .002z$

and roughly $y - x = \dfrac{171}{.337} + \dfrac{.002}{.337}\,z$ = roughly 510 ft.

if x = o y = 510 ft. say 500 ft.

D. COMINS.