ST05- P5.10_C
34/10-1 Relief

WELL 34/10-1

BRENT FORMATION
RELIEF WELL
PROGRAM

statoil

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RELIEF WELL PROGRAM FOR WELL 34/10-1, BRENT FORMATION

1. General

This program presents plans for drilling two relief wells, one shallow and one deep, and some trial calculations for the killing operations. The following main assumptions have been made:

1. - any uncontrolled production will be from the sand below 1780 m RKB and will be oil with some gas. The GOR is assumed to be approx. 500 STCF/STB.

2. - rock properties will be comparable with those encountered in the Statfjord field.

3. - the further drilling of the well is performed according to program.

4. - two relief wells can be drilled. The first rig on location will drill to a point above the 9 5/8" casing shoe, and the second will drill to the lower part of the producing zone .

5. - two alternative kill operations can be visualized:

   a) the primary kill will probably be performed through the shallow relief well. The deep well must be completed to permanently remove the problem, but the pressure for speed is released if the shallow operation is successful. It is however,, very possible that equal time will be spent for the two wells.

   b) the possibility of having a primary kill through the deep relief well will always exist.

Kill calculations have been made for both situations.

6. - relief well casings can be set at depths according to the experience from drilling the uncontrolled well.

7. - curved and deviated sections in the relief holes will be made as short as possible.

8. - 500m is an acceptable approximation of a safe surface distance offshore. For the case of a shallow relief well a shorter distance must, however, be accepted to avoid too severe dog-legs and hole angles.

2. The Relief Well Geometry.

2.1 General comments

1) The object of a relief well is to establish communication with the uncontrolled well at a predetermined interval. This is done by drilling a deviated hole from a safe surface location.

2) We will consider a minimum safety distance to the blowing well to be about 500m (experienced at previous operations offshore). The distance will, however, be less for the shallow relief well.

3) The hole must be straight until the 20 inch casing is set. The dog-leg in the 17½ inch hole should not exceed 2 degrees per 100 feet to avoid excessive stresses in the 13 3/8 inch casing.

4) Hole deviation should not exceed 40 degrees to avoid drilling problems and to minimize the time consumption.

5) The 12 1/4 inch hole allows dog-legging up to 2.5 degrees per 100 feet. The 8½ inch hole can have even worse dog-legs from the mechanical stress point of view, but that is considered impractical while drilling the hole.

2.2 The Shallow Relief Well Geometry

2.2.1 The target.

A comprimise between the time aspect, the geometrical limitations and the killing capacity requirements (ref. next section), yields 1600 m as target for the shallow well. There should not be any difficulties in reaching this target in a safe manner with the present drilling technology, and the target is also acceptable from a killing standpoint (the kill operation requires increasing pumping capacity as the point of communications is moved upwards).

2.2.2 Well geometry and spud location.

Alternative geometries have been evaluated, and the one chosen is described below. The theory is presented in Appendix 1.

a) The kick-off point will be at 500 m with the 20 inch casing set at 488 m.

b) The build-up curve has a dog-leg of 2 degrees per 100 feet. The length of the build-up curve is 609 m. At this point the hole deviation is 40 degrees.

c) The 40 degrees deviated hole is continued over a distance (measured) of 117 m down to a true vertical depth of 1151m (RKB). The horizontal distance to the blowing well at this point is 163 m. The 13 3/8 inch casing is set in the deviated hole at a true vertical depth at 1450 m.

d) At 1151 m the hole is kicked off downwards (towards the vertical), with a dog-leg of 2.5 degrees per 100 feet. The length of the build-down curve is 488 m, and the hole should now be vertical and at the target depth of 1600 m.

e) The first log attempting to locate the blowing well should be performed when the distance between the wells based on directional surveys, is about 50 m.

f) The spud location should be selected on a radius of 443 m from the 34/10-1 well.

2.3 The Deep Relief Well Geometry.

2.3.1 The target.

The main objective of this well is to establish communication with the blowing well at reservoir depth to assure complete stabilisation. The target is therefore to obtain physical contact between the wells at the lower part of the producing formation, assumed to be 2100 m in 34/10-1.

2.3.2 Well geometry and spud location.

Different alternatives have been evaluated and the one selected is described below.

a) The kick-off point will be at 550 m true vertical depth (RKB).

b) The build-up curve will have a dog-leg of 1 degree per 100 feet.

c) At 1424 m t.v.d. the hole deviation is 30^{o}, and the hole is continued at this angle untill a t.v.d. of 1750 m is reached.

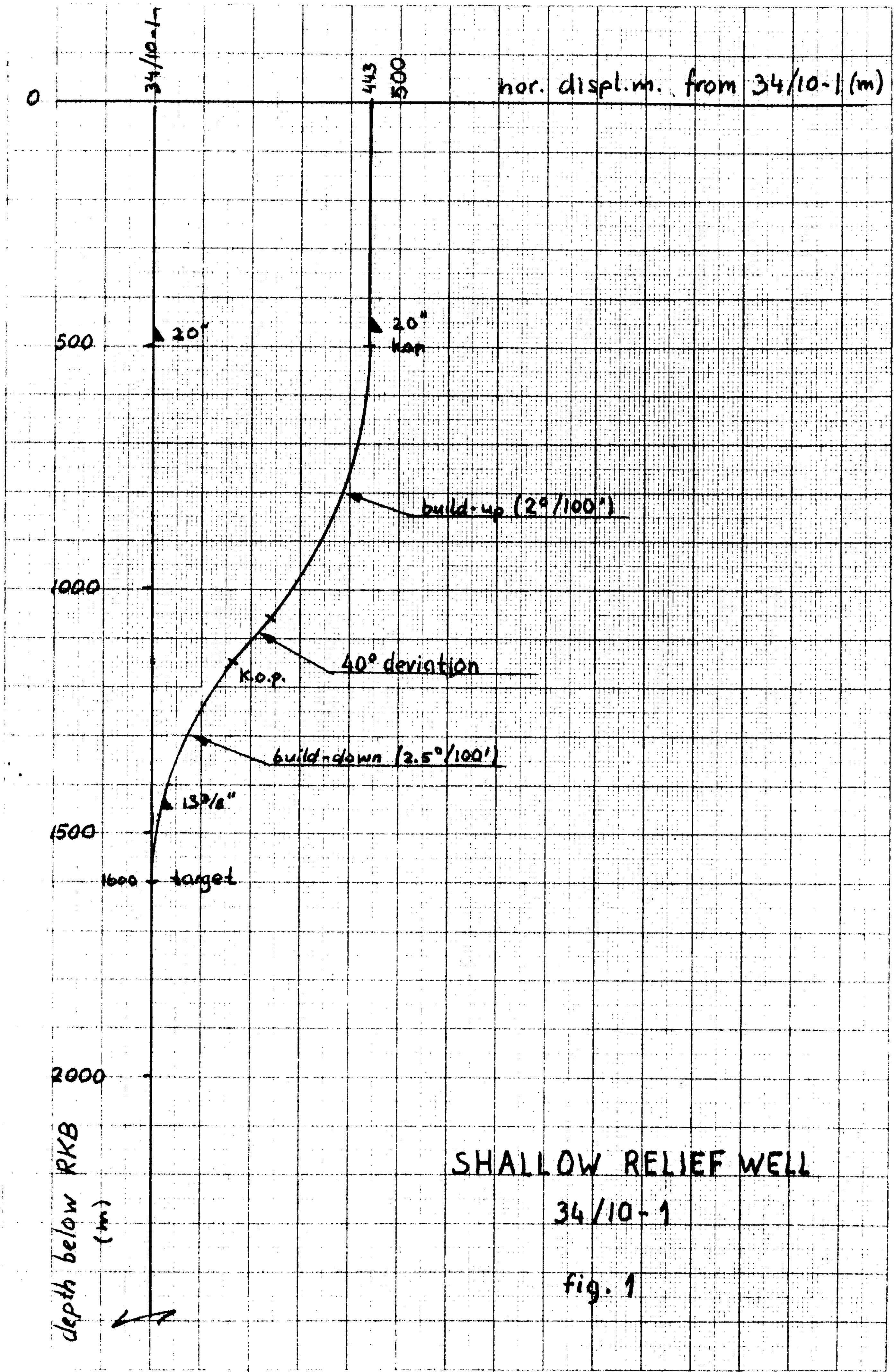
d) The 9 5/8" csg. is set at 1450m and the 13 3/8" csg is set at 1740 m.

e) From 1750m the hole angle is built down with a dog-leg of 2.5 degrees per 100 feet.

f) The two wells will be parallell at 2100 m.

g) Logging can be performed to try and locate the blowing well when the calculated separation is about 50 m if there is any kind of steel left in the blowing hole at these depths.

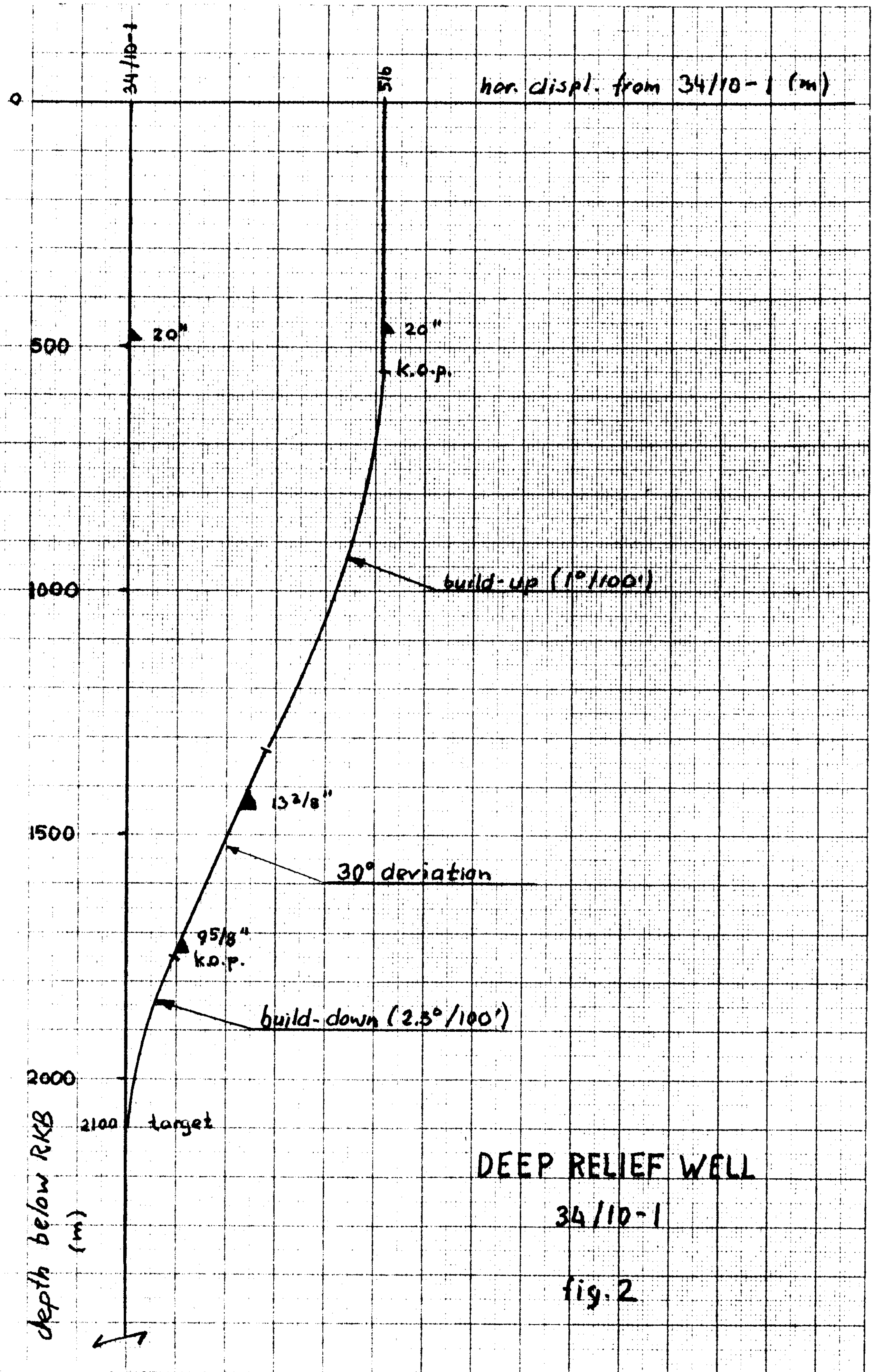
h) The spud location will be on a 516 m radius from the 34/10-1 location. There should be a 180 degree displacement between the shallow and the deep relief well locations to avoid cross-anchoring.



SHALLOW RELIEF WELL

34/10-1

fig. 1

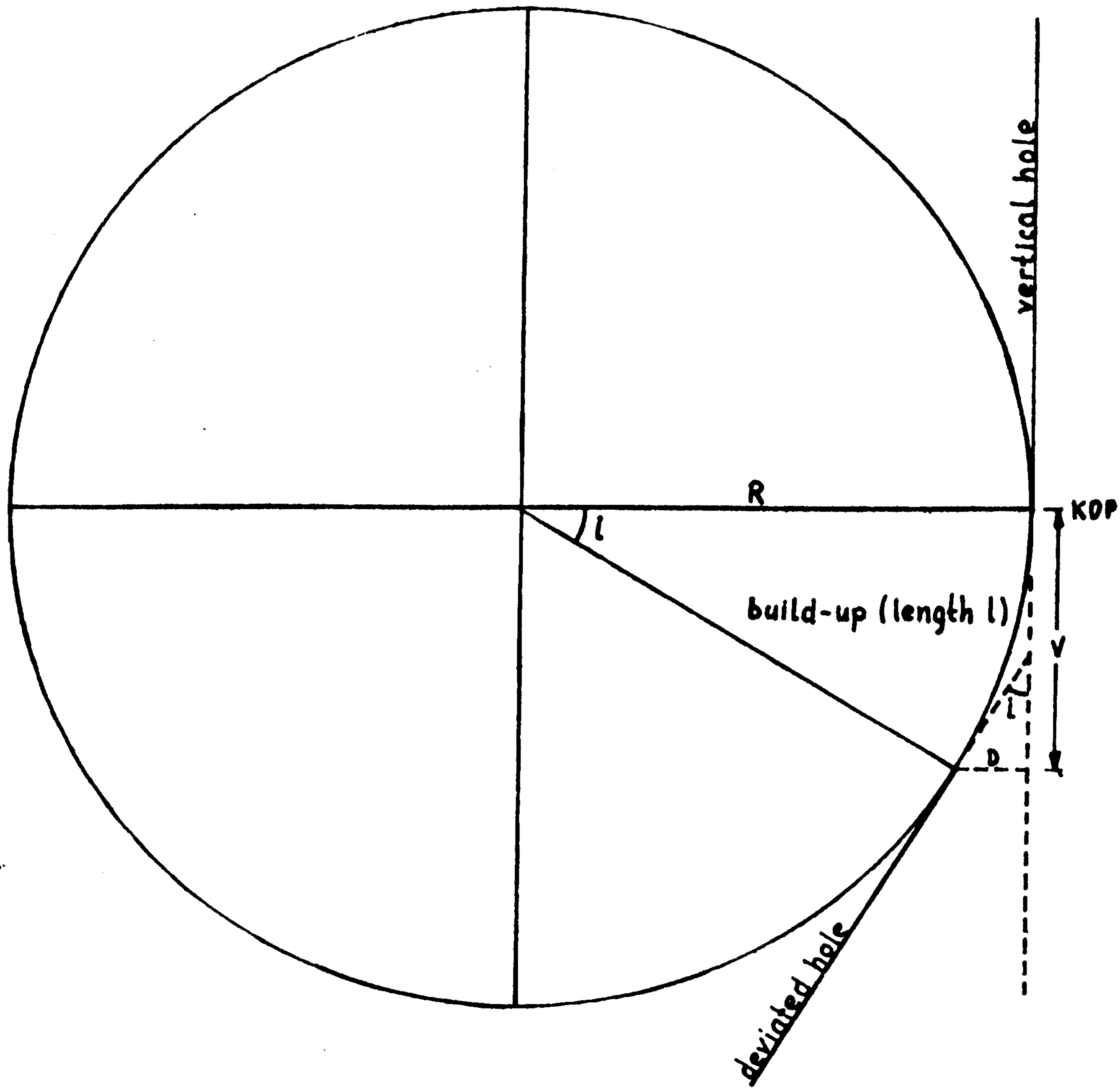


DEEP RELIEF WELL

34/10-1

fig. 2

Build-up/down curvature calculations.



The dog-leg is defined as change in indination per drilled length (s degrees over a distance l). The correlation between s, l and the radius R is then:

$R = \frac{180\ l}{\pi\ s}$ and further we have:

$V = R \sin i$ (i is the deviated hole inclination)

$D = R - R \cos i$

$M = \pi Ri/180$

fig.3

Lengths, depths and displacements of selected build-up curves.

i \ dog leg / R	1 1747	1.5 1164	2.0 873	2.5 699	
10°	303	202	157	121	V
	26.5	17.7	31.1	10.7	D
	305	203	152.4	122	M
20°	597	398	299	239	V
	105.5	70.1	52.7	42.0	D
	610	406	305	244	M
25°	738	492	369	295	V
	164	109	81.7	65.5	D
	762	508	381	305	M
30°	874	582	437	350	V
	234	156	117	93.6	D
	915	609	457	366	M
35°	1002	668	501	401	V
	316	211	158	127	D
	1067	711	533	427	M
40°	1123	748	561	449	V
	409	272	204	163	D
	1220	813	609	488	M

The dog-leg is given as degrees per 100 feet, R, V, D and M are in meters.

fig.4

3. The kill operation

3.1 Cases to be studied

The kill operation has been calculated for the deep relief well case and the shallow relief well case.

In both cases the well is assumed to blow through a 8.5 inch hole without restrictions.

3.2 Considerations

- The produced fluid has a GOR of 500 STCF/STB in average and uncontrolled production is assumed to behave like a fluid flow in a major part of the wellbore.

- It is noticed from calculations that the blowout potential is only to minor extent affected by the reservoir productivity index. The flowing well capacity is the main restriction to productivity.

  Based on the following data the blowout potential has been calculated to 148000 barrels/day at reservoir conditions.

  - average fluid density : = 7 ppg
  - average fluid viscosity : = 5 cp
  - static res. pressure : = 4700 psi
  - reservoir depth : = 6890 feet
  - productivity index : = 0.008 psi/(B/D)

3.3 Pump effect and pressure calculations

The pump effect and pressure has been calculated for both the deep and the shallow relief well for alternative pump-rates.

3.3.1 Shallow relief well pump capacities.

A 5½" drillpipe will be used for injection in this case. The required pump performance has been calculated for a 16.25 and a 19.5 lbs/ft. string. The calculations have been based on a 20 ppg, 70 cp kill mud.

The results are presented in fig. 5. It is assumed that only mud pumps with big liners will be used for this case to obtain a maximum injection rate. The pump effect required (from fig. 5), or the injection rate will determine the number of pumps required for the job.

3.3.2 Deep relief well pump capacities.

A 5 inch drillpipe (4.24 inch i.d.) will be used as injection string for this case. The killmud will be 20 ppg, 70 cp. Like in the case above, the required effect or the injection rate will determine the number of pumps. The results of the calculations are presented in fig. 6.

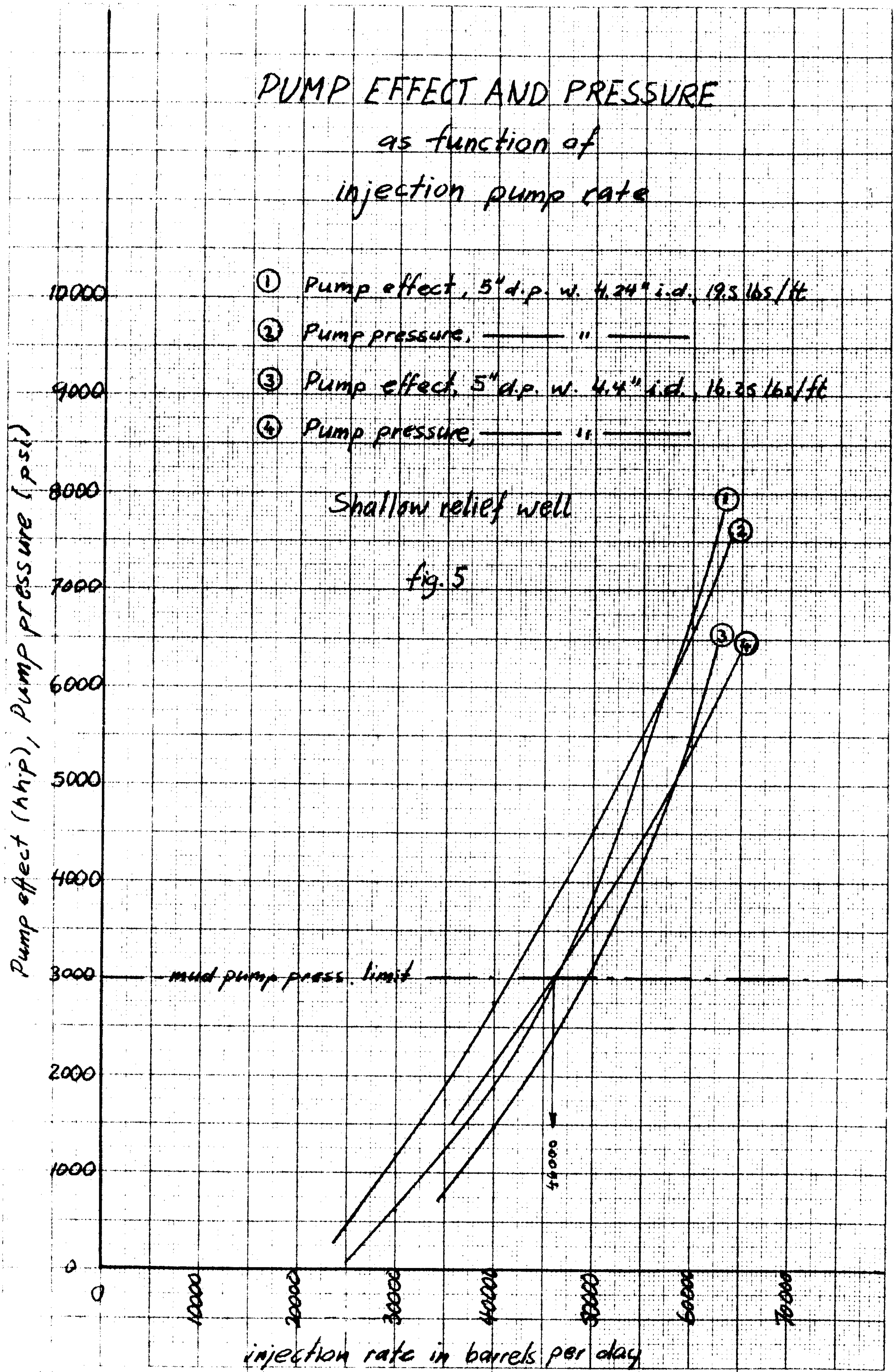
3.4 Killmud volume calculations

3.4.1 Shallow relief well killmud volume.

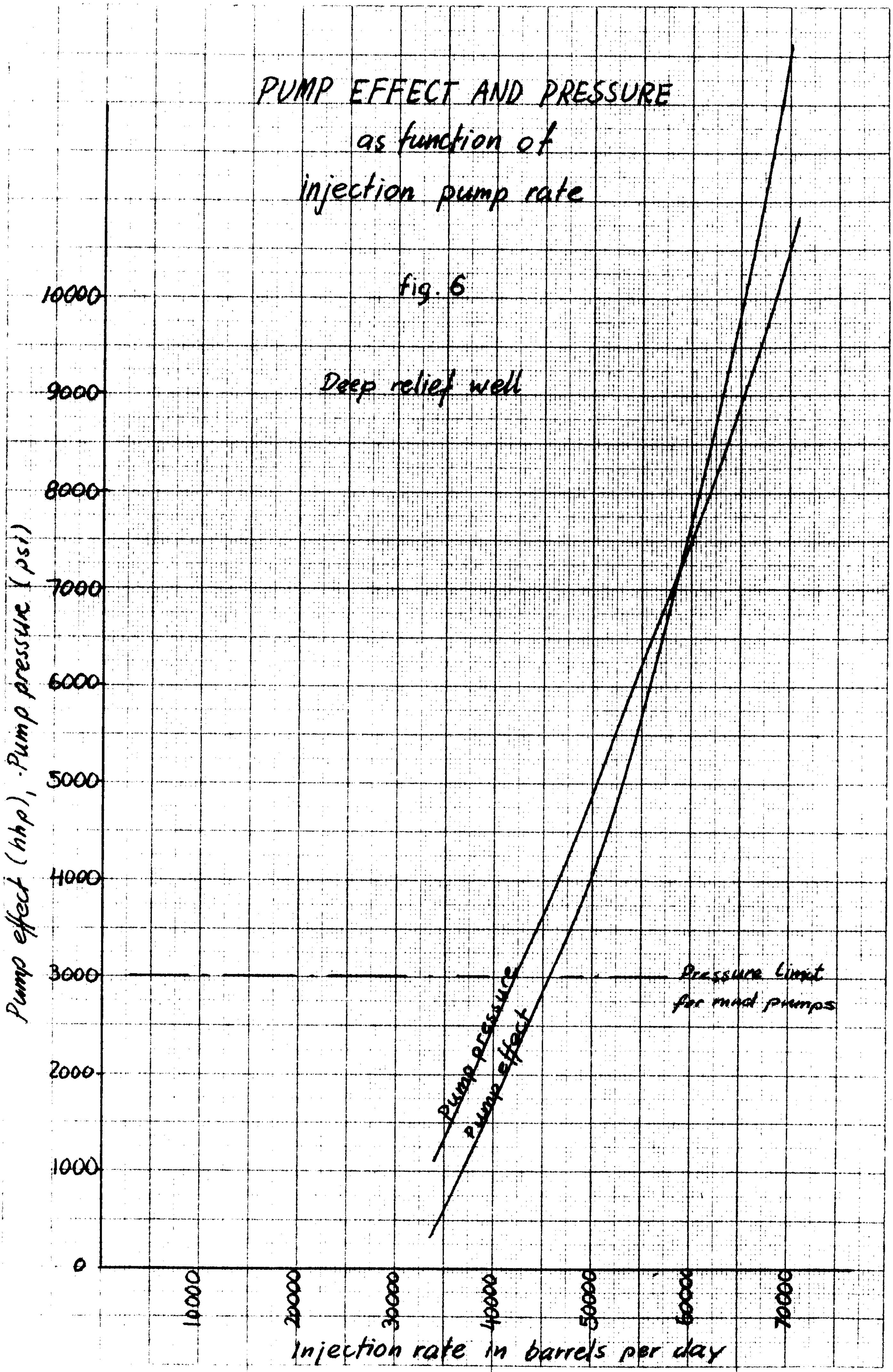
The calculations have been made for a killmud of 20 ppg, 70 cp. Different killrates between 40000 B/D and 70000 B/D have been calculated as shows in fig. 7. The required killfluid volume varies from an unknown high number to 280 bbls.

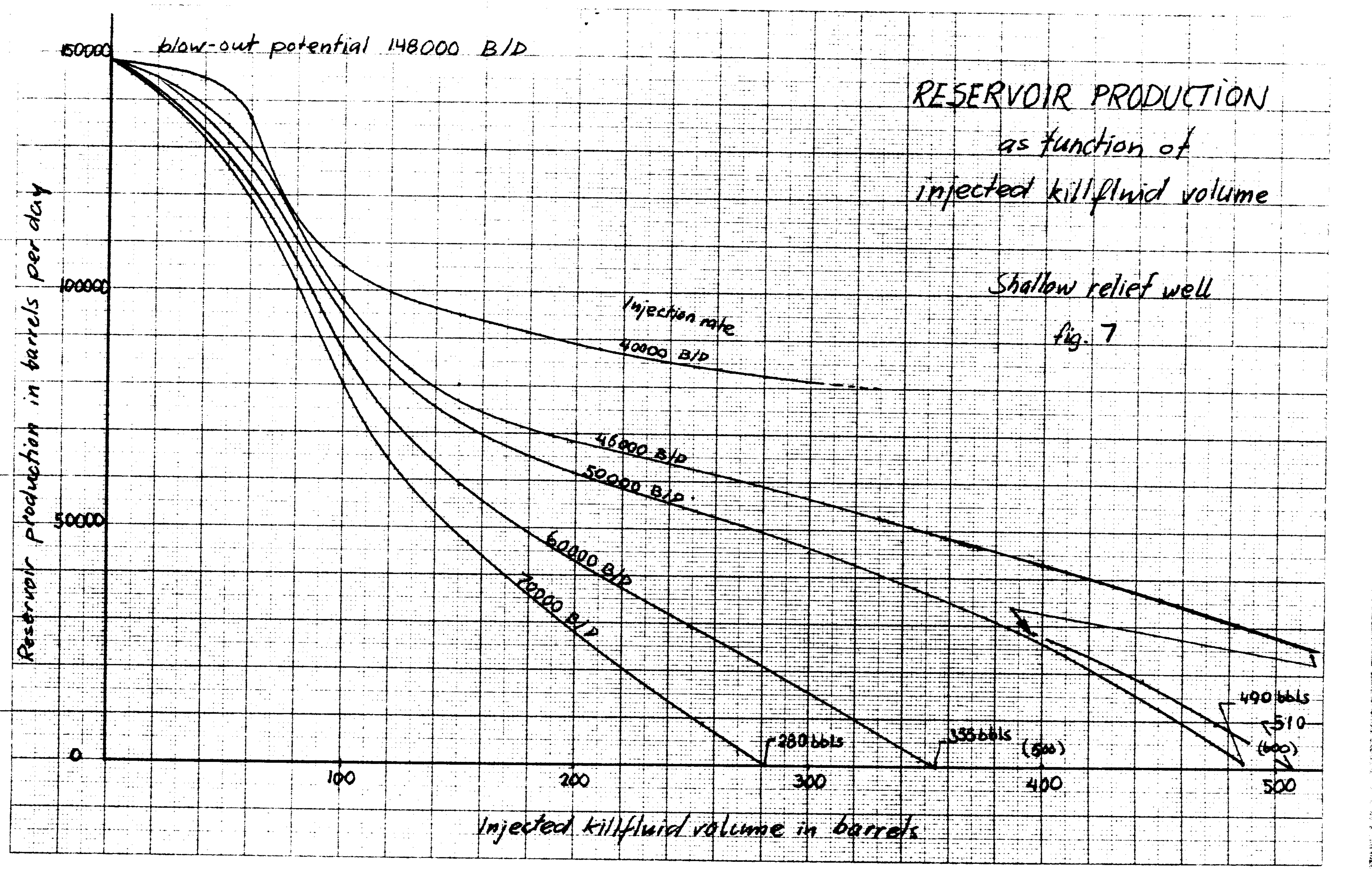
3.4.2 Deep relief well killmud volume.

The calculations have been made for a 20 ppg, 70 cp kill-mud and two killrates, 40- and 60000 B/D. The required killmud volume varies from 205 to 219 bbls which means that the killrate has a minor influence in this case. (fig.8)

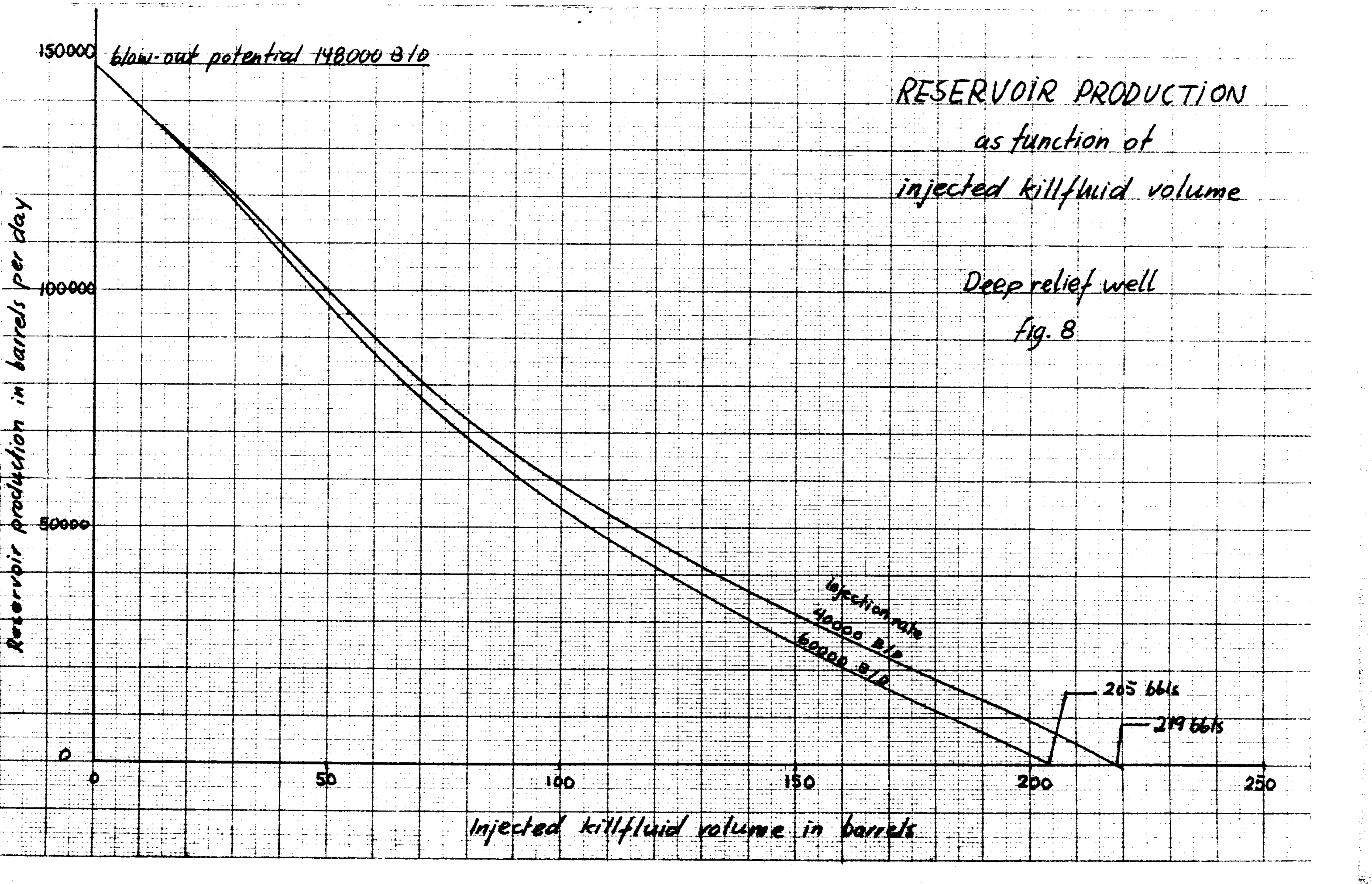


PUMP EFFECT AND PRESSURE
as function of
injection pump rate
① Pump effect, 5" d.p. w. 4.24" i.d. 19.5 lbs/ft
② Pump pressure, ——— " ———
③ Pump effect, 5" d.p. w. 4.4" i.d. 16.25 lbs/ft
④ Pump pressure, ——— " ———
Shallow relief well
fig. 5
Pump effect (hhp), Pump pressure (psi)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
mud pump press. limit
46000
0
10000
20000
30000
40000
50000
60000
70000
injection rate in barrels per day


PUMP EFFECT AND PRESSURE
as function of
injection pump rate
fig. 6
Deep relief well
Pump effect (hhp), Pump pressure (psi)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
10000
20000
30000
40000
50000
60000
70000
Injection rate in barrels per day
Pressure limit for mud pumps
Pump pressure
Pump effect



RESERVOIR PRODUCTION
as function of
injected killfluid volume
Shallow relief well
fig. 7
blow-out potential 148000 B/D
Reservoir production in barrels per day
150000
100000
50000
0
Injection rate
40000 B/D
46000 B/D
50000 B/D
60000 B/D
70000 B/D
280 bbls
355 bbls
(500)
490 bbls
510
(600)
100
200
300
400
500
Injected killfluid volume in barrels



150000
blow-out potential 148000 B/D
RESERVOIR PRODUCTION
as function of
injected killfluid volume
Deep relief well
fig. 8
100000
50000
0
Reservoir production in barrels per day
injection rate
40000 B/D
60000 B/D
205 bbls
219 bbls
0
50
100
150
200
250
Injected killfluid volume in barrels

4. CONCLUSIONS

4.1 Pump performance data

For the biggest slush pumps, we can in average use the following performance data when using the biggest liners:

Hydraulic output effect	:	1500 hhp.
Displacement rate	:	870 gpm (30000 B/D)
Pressure capacity	:	3000 psi

The cement pumps will have the following performance:

Hydraulic output effect	:	550
Displacement rate	:	147 gpm (5000 B/D)

at a discharge pressure of 6000 psi. The displacement rate will increase if the discharge pressure is allowed to decrease.

4.2 Conclusion on the killing operations

4.2.1 Killing through a shallow relief well.
From fig. 5 it can be seen that 46000 B/D is the maximum possible injection rate as long as slush pumps are to be used. If the 16.25 lbs/ft, 5" drillpipe is used, an injection rate of 46000 B/D will be selected. This will require two slush pumps. The number of pumps should, however, be doubled to have sufficient back-up. The required pump effect will be 2400 hhp at this rate and this is within the capacity of two pumps. The operation will theoretically comsume 510 barrels of killmud.

4.2.2 Killing through a deep relief well.
In this case it will be very questionabel how much pressure will be required for establishing communication. From fig. 8 it can be noticed that the mud consumption is little influenced by the injection rate. It will therefore be natural to use a low injection rate. This will allow mud pumps with a high volume output to be used.

If a rate of 40000 B/D is used, the pump pressure will be 2500 psi and the effect will be 1600 hhp. This allows two slush pumps to do the job. The cementing unit can be used for back-up. The theoretical consumption of killmud will be 205 barrels.