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WATER MANAGEMENT TECHNOLOGY FOR OIL PRODUCTION

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TROLL FIELD WELL 31/3-2

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TROLL FIELD

WELL 31/3-2

Results of Monitoring the Quality of Completion Fluids for the Production Test in the Oil Zone

Perforation Interval 1567 m to 1577 m

Report Prepared By
Oil Plus Limited

For Norsk Hydro

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INTRODUCTION

This reports presents the results of monitoring the quality of seawater and calcium chloride brine, circulated in well 31/3-2, in the Troll Field.

This was the clean-up procedure in preparation for the production test in the oil zone (perforation interval 1567 m to 1577 m).

The cleanliness of the completion fluid prior to perforation, and setting the gravel pack are vital to the success of the production test by reducing the skin factor of the producing zone and reducing the fines entrained within the gravel pack when placed.

The completion fluid monitoring tests were performed by Oil Plus on rig Treasure Seeker between 8th April 1984 and 17th April 1984.

SECTION 1

CONCLUSIONS AND RECOMMENDATIONS

SECTION 1. CONCLUSIONS AND RECOMMENDATIONS

These points are discussed in more detail in Section 3.

1. Two acid pill treatments, each followed by high rate seawater circulation were required to produce final seawater returns of 10 NTU turbidity. The corresponding particle size distribution was as follows:-

Particle Diameter d microns	Count per 0.05 ml of particles of diameter ≥ d microns
2	2156
3	805
5	56

Coulter Counts and turbidities were at this point levelling off towards an irreducible minimum.

The seawater circulation following the first acid pill produced seawater returns of almost as good quality after 8 hole volumes had been circulated. Six hole volumes were circulated after the second acid pill. The quality of the final seawater returns before displacing to brine corresponds closely to the best achieved for previous completions in the Troll Field.

2. Experience has shown that a realistic target for final seawater returns, which should be reached by the time ten hole volumes have been circulated, is as follows.

i). Turbidity of 10 NTU or less
ii). Particle Size Distribution

Particle Diameter d microns	Count per 0.05 ml of particles of diameter ≥ d micron
3	2,500 or less
5	1,000 or less
10	100 or less

iii). 2 or more litres passed through 0.45 u rated Millipore membrane filter in 30 mins with a pressure differential of 20 psi.

If the minimum solids level achieved for the return is significantly above this level a second acid pill treatment should be considered before displacing to brine.

3. It is often stated in procedures that the ideal finishing point for the seawater circulation is when the solids level into the well is the same as that exiting the well. This has never yet been achieved for completion in the Troll Field and is an unrealistic target.

4. During the subsequent brine circulation the target quality for the returns at the shaker box was specified in the test procedure as:-

   i). in the range of 5 NTU
   ii). 50% of particles havng a diameter of less than 2 microns

   As 50% of the particles in the brine usually have a diameter of 2 microns or less, regardless of whether the brine is relatively clean or dirty, the second part of this specification is of little use.

   Due to the gradual improvement in methods for the casing and pipe clean up, the cleanliness of brine handling and in brine filtration, in successive completions in the Troll Field, a target turbidity of 5 NTU underestimates the quality of the brine returns that can be achieved within a relatively short number of circulations. Turbidities of final brine returns of just over 1 NTU have been achieved.

5. Target brine quality, as specified in the test procedures was reached by the time three hole volumes had been circulated for the circulation prior to perforation and also for the circulation prior to setting the gravel pack. In each case, significantly better brine returns would probably have been achieved by the addition of just one or two extra circulations.

6. The production of required brine quality at the well outlet for the circulation prior to perforation was hampered by erratic filter effluent and thus, well inlet brine quality. This may be attributed to there being only two pods of Pall filters instead of the standard four pods. Thus filter changes had a more marked effect on the filter effluent. Also two pods may not have been able to maintain filter effluent quality during the highest flow rates due to the flow rate per pod exceeding the manufacturers recommendations. The standard filtration system should be employed in later completions.

7. The quality of the final brine returns prior to stopping circulation to perform perforation was as follows:-

   Turbidity 4.1 NTU

Particle Diameter d microns	Count per 0.05 ml of particles of diameter ≥ d microns
3	1906
5	403
10	44

7. Continued....

Running in hole adds to solids in the brine downhole. If an operation, such as perforation, requiring absolute cleanliness is to be performed after a trip, when conditions allow, at least one circulation should be made to ensure that the brine is still of sufficient quality after the trip.

8. Quality of final brine returns before setting gravel pack with gravel pack assembly RIH.

Turbidity 5.2 NTU

Particle Diameter d microns	Count per 0.05 ml of Particles of diameter ⩾ d microns
3	3589
5	419
10	30

9. Experience has shown that a realistic target for final brine returns representing an acceptable level of solids before perforating or setting a gravel pack is:-

i). Turbidity 2 to 3 NTU
ii). Particle Size Distribution

Particle Diameter d microns	Count per 0.05 ml of Particles of diameter ⩾ d microns
3	1,000 to 2,000
5	200 to 300
10	20 to 40

This target should be obtainable by the time five hole volumes have been circulated.

10. Brine returns of turbidity greater than 30 NTU should be dumped. Attempting to recirculate brine any dirtier than that back to the filter system will result in rapid blocking of the filters and a significant decline in the filter effluent quality to greater than 5 NTU.

With brine of less than 20 NTU at the filter inlet the recommended filter system should be able to produce a filter effluent of less than 2 NTU. As mentioned later good quality brine at the well inlet speeds up the clean up procedure.

11. Jet cleaning the casing with seawater whilst RIH with the 3½" PH-6 tubing did not speed up the clean up procedure or result in cleaner returns at the end of the seawater circulation in comparison to previous completions when this method was not used.

12. The absence of the sand pill (used in previous completions) during the abrasive treatment was not noticed in terms of the quality of the final seawater and brine returns. The scraper and the acid treatment are the most effective means of clean up when followed by maximum rate seawater circulation prior to displacing to brine.

13. Procedures of well clean up operations often state that brine circulation should continue until the solids level of the returns had reached a minimum. It is unlikely that an irreducible solids concentration would be reached because once the casing, and gravel pack string have been cleaned the filter system will still continue to remove a certain percentage of particles on each pass through the filters.

    If it proves impractical to achieve the target quality as specified above, we recommend that circulation should be continued until the clean-up rate', or reduction in particle counts (of particles of diameter greater than or equal to size which will critically block the formation, in this case considered to be 3 microns), in the returns, reduces by less than 5% in the time of one circulation.

14. To be able to achieve a target brine cleanliness for subsequent completions, as was attained for this completion, it will be important to repeat the following steps in addition to the standard scraper and acid abrasive treatments.

    i). Thoroughly clean the casing and gravel pack string before RIH. Use minimum pipe dope whilst making up the string.

    ii). Thoroughly flush and circulate seawater through the mud system, all lines to be used during the gravel pack, and the choke and kill lines, before circulating brine. The quality of the fluids flushing these lines should be carefully monitored to measure the efficiency of the clean up. It is important to recognise that seawater from the rig seawater main is a very clean fluid, even in comparison to the filtered brine, and should be used to the maximum benefit to clean up the topsides equipment and well prior to brine circulation.

    iii). Transport the brine to the rig in lined tanks on the deck of the supply boats to ensure that the brine can be filtered by the fine filters. After transportation to and filtration on the rig, brine of turbidity of less than 3 NTU should be achieved. If not investigations into the cleanliness of the brine producing and transporting system should be made. Brine of this quality is vital to the swift and successful clean up operation.

iv). Ensure lines used to transfer the brine from the supply boat to the rig are clean, and are not contaminated with diesel oil or other contaminants.

v). Always use the complete filter system, including the fine filters when filtering the brine.

vi). Thoroughly hose down the parts of the mud system to be used for the brine circulation, and circulate seawater through it so that the solids pick up in the system can be monitored prior to the introduction of the brine.

As a further assurance of brine cleanliness, thought should be given to the feasibility of bypassing the mud system altogether when circulating the seawater and brine.

vii). Use a standby system when changing filters, and ensure that enough filters are on-line to cope with the prevailing flow rate. Failure to do so will result in a deterioration of brine quality.

viii). Use a water soluble oil to lubricate the pistons of the Dowell high pressure pump unit. This prevents insoluble oil particles picked up from the pump adding to the suspended particle counts level of the brine. Water soluble oil should also be used for the pump which transfers the brine from the supply boat to the rig.

ix). Fittings should be available to provide sample points in the chicksan downstream of the Dowell high pressure pump during the brine circulation.

A sample point should also be available at the drill floor during seawater circulation, downstream of the mud pumps and the mud lines to the drill floor to distinguish between solids picked up in the mud system, and those picked up in the well.

x). The pH of the calcium chloride should be kept below 10 to ensure that the solids level in the brine is not increased by precipitates.

15. The filter skids should have sample points at the inlet and outlet. No sample point facility at the filter system inlet was available on this occasion.

SECTION 2

ANALYTICAL TECHNIQUES

SECTION 2. ANALYTICAL TECHNIQUES

This section describes the techniques used to analyse the completion fluids, in terms of particle size distribution, turbidity and the weight of suspended solids.

2.1 Seawater and Calcium Chloride Brine Quality Monitoring

2.1.1 Particle Size Analysis

The particle size analyses of the seawater and calcium chloride brine samples were conducted using a Model D Industrial Coulter Counter, counting particles of diameter between 2.0 and 15.0 microns.

This equipment measures the volume of a particle, and the particle size is expressed as the diameter of a sphere having an equal volume.

2.1.2 Turbidity

Turbidity was measured using a Hach 2100A turbidity meter. This instrument measures the amount of light scattered, at 90° to the incident light, by the suspended particles. The results are given in Nephelometric Turbidity Units (N.T.U.).

The readings are dependent on the particle size distribution and particle shape, as well as the suspended solids concentration. Thus, two waters having the same turbidity may well be quite different in terms of particle size and their distribution.

2.1.3 Membrane Filter Tests

All membrane tests were run using pre-weighed Millipore membrane filters of 47 mm diameter and 0.45 micron pore size. These tests were run in accordance with the National Association of Corrosion Engineers Standard TM-01-73. "Methods for determining water quality for sub-surface injection using membrane filters".

The method used by Oil Plus involved taking a 10 litre sample of water into a pressure cell which was then pressurised and held at 20 psig; water flowed from this cell through the Millipore filter, discharging to atmosphere.

Simultaneously, 'Slope' tests were conducted by measuring the volume passing through a Millipore membrane with time. The rate of change of the flowrate gives an indication of the water quality. The dirtier the water the more rapid the decline in flow rate.

2.1.3 Continued....

The results of the membrane filter slope tests are drawn as Barkman and Davidson Plots". The steeper the gradient of the plot the better the water quality. In essence the plots for the worst water qualities plot closest to the x-axis.

After conducting these tests the Millipores were flushed through using 0.45 micron filtered, de-ionised water to remove all traces of salt water which would otherwise crystallise on the membrane and give false results. After drying, the Millipore membranes were weighed and suspended solids calculated.

SECTION 3

RESULTS AND DISCUSSIONS

SECTION 3. RESULTS AND DISCUSSIONS

3.1 Introduction

This section presents and discusses the results of the completion fluid monitoring performed by Oil Plus in preparation for the production test in the oil zone of well 31/3-2, in the Troll field. The perforation interval was between 1567 m and 1577 m.

3.2 Results of Casing and Pipe Clean up Procedure

The clean up procedure was in preparation, initially, for perforation and the interval gravel pack which followed.

3.2.1 Seawater Circulation

Following the displacement of the old drilling mud with seawater, a 9⅝" casing scraper was RIH. A 50 bbl weighted spacer, having the same weight as the mud, was pumped ahead of the seawater.

Seawater was then circulated at a high rate, using the mud pump fed from mud pit No. 1. The string was reciprocated with the scraper at the depth of the proposed perforation interval.

Previously the parts of the mud system used for seawater circulation had been thoroughly cleaned. The seawater circulation system is illustrated in Figure 3.1.

The best possible benefit should be taken whilst circulating seawater to clean the casing and pipe. It is a clean fluid even in comparison to filtered brine and can be circulated at a higher rate. Trying to achieve the cleanest possible returns for seawater will reduce the period of brine circulation.

During the first period of seawater circulation, following the scraper run, about six hole volumes were circulated in three hours. Severe contamination of the seawater was found to have occurred between the mud pit and the standpipe manifold, the latter being the input to the well. The average turbidity of the seawater in mud pit No. 1 was about 1 NTU, whilst that at the standpipe manifold was averaging 200 NTU. The dirty lines, causing the contamination were subsequently cleaned. This produced a marked improvement in seawater quality at the well inlet for later seawater circulations, during which the inlet turbidity averaged 2.5 NTU.

This highlights the need to have sample points which help to distinguish between solids picked up in the mud system and those picked up downhole during the initial

3.2.1 Continued.....

seawater circulations, thus saving time during the seawater circulation and pin pointing sources of contamination in the mud system before the brine is introduced. The brine circulation system is illustrated in Figure 3.2.

The scraper and the 5" TAC-1 tubing was POOH. 3½" PH-6 tubing was then RIH with a perforated pump joint on the end. The 3½" PH-6 tubing was that to be used during the setting of the gravel pack and was RIH to be cleaned along with the casing during the next stages of the clean up.

After each stand of 3½" PH-6 tubing had been RIH, seawater was circulated to jet clean successive lengths of casing. The jet cleaning did not speed up the clean up procedure, in terms of the number of circulations required to reach target returns quality, when compared to previous completions when this method was not used.

Particular attention was paid to jet cleaning the proposed perforation zone.

With the 3½" PH-6 tubing RIH, a 50 bbl viscosified seawater pill, a 2000 gal 15% HCl acid pill, and a 20 bbl viscous pill were pumped downhole, in that order, by the Dowell pump unit, each separated by seawater.

Previous completions had used a sand viscous pill. Its absence on this occasion was not found to be detrimental to the rate of clean up.

Following the acid treatment the seawater was circulated at the maximum rate. The seawater returns were dumped at the shaker box. The aim was to reach an irreducible minimum of solids in the returns as measured by the Coulter Counter and the turbidity meter.

The results of the turbidity measurements and Coulter Counts at the well inlet and outlet during this seawater circulation, between 0400 hrs and 1200 hrs on 12.4.84, are illustrated in Figures 3.3 to 3.7 inclusive. The results of the membrane filter tests are illustrated in Figure 3.8. The results are tabulated in Tables 3.3, 3.7, 3.8 and 3.9.

The turbidity of the seawater returns at the shaker box, levelled off at 11 NTU after 8 hole volumes had been circulated, taking 9 hours. The average turbidity at the well inlet (standpipe manifold) was 1.6 NTU.

The Coulter Counter is more sensitive to the solids level in the seawater. Its particle counts show signs of leveling off after the results from the turbidity meter.

3.2.1 Continued....

The final Coulter counts at the well outlet were as listed below.

Particle Diameter d microns	Count per 0.05 ml particles of diameter ⩾ d microns
2	7295
3	2669
5	906
10	52
15	9

The results of the membrane filter slope tests, illustrated in Figure 3.8, indicate the improvement in the quality of the seawater returns as circulation progressed. Just over 2.5 litres was passed through the final millipore in 30 minutes.

In an attempt to produce cleaner seawater returns (of 10 NTU or less), a second acid pill was pumped downhole and seawater was again circulated at the maximum rate.

After circulating 6 hole volumes, taking 8 hours, the turbidity of the seawater returns began to level off at 10 NTU. The average turbidity at the well inlet was 3 NTU.

The final Coulter Counts at the well outlet were as follows.

Particle Diameter d micron	Count per 0.05 ml of particles of diameter ⩾ d microns
2	5321
3	2156
5	805
10	56
15	7

The results of the turbidity and Coulter Count readings during this seawater circulation, following the second acid pill, are again illustrated in Figures 3.3 to 3.7 inclusive. The results are tabulated in Tables 3.4, 3.10 and 3.11.

The main effect of the second acid pill was to reduce the counts for particles of diameter less than 5 microns, when compared to the final seawater returns after the first acid pill.

The solids level encountered in the final seawater returns was similar to that measured during previous completions in the Troll field.

3.2.1 Continued....

Experience has shown that a reasonable target for final seawater returns is:-

i). a turbidity of 10 NTU or less
ii). particle counts of 1,000 per 0.05 ml for particles of diameter greater than or equal to 5 microns.

iii). passing 2 litres or more through a 0.45 μ millipore in 30 minutes.

It is often stated in test procedures that the ideal finishing point for the seawater circulation is when the solids level into the well is the same as that exiting the well. This has never yet been achieved for completions in the Troll field and appears to be an unrealistic target.

3.2.2 Brine Circulation Prior to Perforation

At the end of the seawater circulation, the seawater was circulated out with a 20 bbl viscosified seawater pill ahead of the calcium chloride brine (SG 1.12).

The brine was circulated as shown in Figure 3.2. Water soluble oil was used to lubricate the pistons of the Dowell high pressure pump unit. This guards against insoluble oil droplets producing erroneous Coulter Counts and turbidities.

The viscosified seawater pill was dumped on return. Care should be taken not to recirculate any of the viscous pill back to the filters as this will rapidly block them.

Initital brine returns of turbidity greater than 30 NTU should be dumped. Attempting to recirculate brine any dirtier than that back to the filter system would result in rapid blocking of the filters and a significant decline in the quality of the brine at the filter outlet. As mentioned in Section 3.4 good quality brine at the well inlet is all important in achieving a clean up operation as quickly as possible. The filter system is capable of producing an effluent brine quality, averaging 2 NTU or less, when the influent quality is less than 20 NTU. The effluent quality rapidly rises to above 5 NTU when the influent quality exceeds 30 NTU. As the specification for brine quality at the well outlet was 5 NTU or less, it is obviously important to avoid recirculating brine, of turbidity greater than 30 NTU, back to the filters.

The brine circulation following the circulating out of the seawater represented the conditioning of the well with clean brine prior to tripping so that the perforation string could be RIH.

3.2.2 Continued....

The results of the turbidity and Coulter Count readings are illustrated in Figures 3.3 to 3.7 inclusive, and are tabulated in Tables 3.12, 3.13, 3.16 and 3.17. The results of the membrane filter slope tests are illustrated in Figures 3.9 and 3.10.

The target brine quality for the brine returns at the shaker box was stated in the test procedure as:-

i). in the range of 5 NTU and
ii). 50% of the particles having a diameter of less than 2 microns.

A turbidity of 5 NTU is readily achievable with the present clean up procedure and is perhaps slightly pessimistic. Turbidities of final brine returns of just over 1 NTU have been achieved in previous Troll completions without significantly longer circulation periods.

50% of particles in brine usually have a diameter of two microns or less regardless of whether the brine is relatively dirty or clean. This part of the specification is of little use.

The target quality of brine returns of less than 5 NTU was achieved after circulating approximately 3 hole volumes of filtered brine. The final brine returns averaged just over 4 NTU. Final Coulter Counts for brine returns at the various size limits were as follows:-

Particle Diameter d microns	Counts Per 0.05 ml of Particles of Diameter ≥ d microns
2	8500
3	2276
5	425
10	39
15	4

The production of good quality brine at the well outlet was hindered by erratic brine quality at the filter system outlet and thus at the well inlet. This may be attributed to there being only two pods housing Pall filters as opposed to the standard four pods. This was due to the short call out for the job. This point is highlighted in Section 3.3 which discusses filter performance and the filter system.

The indications were that better quality final brine returns could have been achieved within the space of one extra circulation.

3.2.2 Continued....

Experience has shown that a realistic target for final brine returns, representing an acceptable level of solids, before perforating or setting a gravel pack is as follows:-

Particle Diameter d microns	Counts per 0.05 ml of particles of diameter d microns
3	1,000 to 2,000
5	200 to 300
10	20 to 4
Turbidity	2 to 3 NTU

This target should be obtainable by the time 5 hole volumes have been circulated.

This could be a target to aim for in subsequent completions. If this proves impractical, brine circulation could be continued until the 'clean-up' rate, or reduction in particle counts (of particles of diameter greater than or equal to the size which will critically block the formation or gravel pack), in the returns reduces by less than 5% in the time of one circulation (assuming a fairly constant well inlet quality). The turbidity measurements are less sensitive to solids levels in the brine than the Coulter Counts and begin to level off first.

Following the conditioning of the well to filtered brine a trip was made so that the perforating string could be RIH.

Trips always add to the solids in the brine. Thus after RIH for each new operation such as perforation it would be prudent to circulate one hole volume, when possible, as a check on brine quality. With the present procedure it is not possible to check on brine quality between finishing conditioning the well to filtered brine and perforation, between which there is a trip.

3.2.3 Brine Circulation After Killed Well Following Perforation and Flow Test

The results of monitoring brine quality during this circulation between 0800 hrs and 1300 hrs on 16.4.84 are again illustrated in Figures 3.3 to 3.7 inclusive. The final brine returns averaged 6.5 NTU.

This circulation was meant to remove debris due to the perforation and flow test, prior to tripping so that the gravel pack string could be RIH.

3.2.4 Brine Circulations With Gravel Pack String RIH Just Prior to Setting Gravel Pack.

Two hole volumes were pumped in about 2 hours before the target brine quality of "in the range of 5 NTU" was achieved. Final brine returns had a turbidity of 5.2 NTU. The particle size distribution was as follows

Particle Diameter d microns	Counts per 0.05 ml of particles of diameter ⩾ d microns
2	20615
3	3589
5	419
10	30
15	11

As illustrated in Figures 3.3 to 3.7 inclusive the solids level at well outlet were still showing a marked downward trend when circulation was stopped. This helps to illustrate the pessimistic nature of the 5 NTU target quality. One more circulation would have produced significantly better quality brine at the well outlet.

3.3 Brine Filtration System and Filter Performance

The brine filtration system is illustrated in Figure 3.2. As previously mentioned this represents a deviation from the standard filtration system recommended by Oil Plus. Only two pods of Pall filters instead of the usual four were present due to the short call out for the job. It is strongly recommended that the standard filter system is used for the next completion.

With only 2 pods of Pall filters, changing the filters in one pod will have a much more marked effect on filter effluent quality than if 4 pods were available. Also 2 pods may not be able to maintain filter efficiency at the higher flow rates due to the rate per pod exceeding that recommended by the manufacturers.

The standard filtration system consists of 4 pods, each housing 18, 5 micron nominal Hytrex cartridge filters, arranged in parallel, and two pods each containing 32, 10 micron absolute Pall cartridge filters. This is the filtration system, suggested by Oil Plus, for previous completions in the Troll field. The filter details are given in Table 3.21.

Each pod containing the Hytrex filters can take a maximum flow of 5 bpm without adversely affecting filter performance. For the Pall filters the maximum recommended flow rate is 2 bpm per pod. As the maximum flow rate for the brine was approximately 6 bpm, 2 pods of Hytrex filters and 3 pods of Pall filters should be online.

3.3 Continued....

The other pods should be filled and on standby ready for when the differential pressure reaches that requiring a change of filters. The maximum allowable differential pressures for the Hytrex and Pall filters is 20 psi and 40 psi respectively.

The increase in differential pressure across the filters represents a build up of filter cake on the filter surface which improves filter efficiency. The 5 micron nominal Hytrex filters are coarse enough to let sufficient particles pass for a filter cake to build up on the Pall filters, yet still fine enough to enable a reasonable filter life for the Pall filters. The filter system is a compromise between filter efficiency and a reasonable filter life.

Filter change overs are an important aspect of filtration. The system of standby filters mentioned above should be adopted. This enables a quicker filter change to be made and also guards against the need to bypass a filter stage during filter change out.

If the coarse filtration has to be bypassed during filter changes the life of the fine filters will be dramatically reduced. If the fine filtration stage has to be bypassed during filter changes, brine of substandard quality will enter the well, lengthening the time required to reach the desired brine quality at the well outlet. Thus, efficient filter changes, adopting a standby system will lengthen filter life and save rig time during the brine circulation.

A standby system in which only one new pod of filters is introduced at one time will also help to maintain filter efficiency, again saving rig time. As mentioned above, as a filter cake builds up on filters and the differntial pressure increases, filter efficiency will also increase. If all of the filter pods are changed at once the benefit to filtration due to filter cake build up will all be lost and has to be regained gradually as the filter cakes redevelop. Changing only one pod at a time will be less detrimental to filter efficiency. In this case when only 2 pods of Pall filters were available 50% of the filters would have to be renewed at each filter change.

The results of filter system performance monitoring are tabulated in Table 3.22. No sample points were available on the filter skids at the inlet to the filter system. As a result, the filter inlet sample had to be taken from the mud pit. Care should be taken on subsequent completions that all filters skids have the facility for sample points.

Average filter efficiency for the system on Treasure Seeker for particles of diameter greater than or equal to 3 microns was 91.1%.

3.4 Brine Quality as Received on Board the Rig from the Supply Boat

Great effort was made to present the brine at the rig in as clean a condition as possible. Providing clean brine to the rig reduces the circulation required to reach the desired brine quality and also saves on the number of filters used on the rig.

To this end the brine was filtered twice onshore by 5 micron nominal Hytrex cartridge filters, and transported to the rig in lined storage tanks on the deck of the supply boat.

During some previous completions in the Troll field the brine had to be transported to the rig in the supply boats own tanks often resulting in contamination of the brine which negated the effects of onshore filtering. This meant that the brine could only be filtered by the coarse filters during transfer to the rig, and on those occasions, brine of substandard quality was placed in the rig storage tanks.

The results of monitoring the quality of the brine as it was transferred onto the rig from the supply boat are presented in Table 3.23. The brine was of sufficient quality that it could always be filtered by the complete filter system incorporating the fine Pall filters.

The absence of a sample point at the inlet to the filter system meant that the quality of the brine from the supply boat could not be monitored.

The importance of obtaining clean brine in the Dowell rig storage tanks prior to the displacement of the well to brine cannot be over emphasised. It should be possible to have brine in the storage tanks, with a turbidity of 3 NTU or less using the present filtration and transporation system. Investigation into the cleanliness of the equipment used should be made if brine of this quality is not obtained.

The quality of the brine used to perform the initial displacement of the well will greatly effect the time required to reach the target brine quality. As shown in Figure 3.2 the brine was not filtered on passing from the Dowell residence/storage tank to the Dowell pump (the brine is filtered before it enters the Dowell tank). Thus the quality of the brine when it reaches the rig is all important in saving rig time whilst performing the clean up operation.

If seawater circulations performed prior to the brine circulation have been successful, and the mud system has been thoroughly cleaned, theoretically the brine should pick up a relatively low level of solids on being circulated through the well.

3.4 Continued....

Providing the brine is clean at the well inlet the circulation and filtration will soon result in acceptable brine qualities. The importance of inlet brine quality, thorough cleaning of the system and successful seawater circulations are all crucial in achieving satisfactory completion fluid quality.

The average turbidity of the brine at the filter system outlet whilst transferring brine from the supply boat to the lined Dowell tanks on the rig was 1.1 NTU. The turbidity never exceeded 3 NTU. This indicates that brine of good quality was received on board Treasure Seeker and that the brine preparation and cleanliness was adequate.

The pH of the brine was always below 10 ensuring that the solids levels in the brine was not added to by precipitates. The stability of the counts in a filtered brine sample was periodically checked.

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SEAWATER QUALITY AT WELL INLET (STANDPIPE MANIFOLD) TABLE 3.1
5" TAC-1 TBG DRILL PIPE RIH

WELL 31/3-2

Date	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84
Time hrs	0030	0100	0130	0200	0230	0300	0330	0400	0430	0500	0530	0600
Particle dia. d microns	Number of Particles $\geq$ d µm (microns) in 0.05 ml											
2					18291	17488	17308	17352	16934	17894	17702	17013
3					17789	16698	16708	17263	14881	7946	17299	16349
5					9219	8682	9061	11410	5188	1263	10712	7246
10					362	511	645	817	268	80	671	499
15					53	62	66	40	30	14	123	73

Turbidity NTU	460	460	340	260	285	240	245	340	260	27	320	180

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SEAWATER QUALITY AT WELL INLET (STANDPIPE MANIFOLD) WHILST RIH $3\frac{1}{2}$" PH-6 PIPE TABLE 3.2

WELL 31/3-2

Date	11.4.84	11.4.84	11.4.84	11.4.84	11.4.84	11.4.84	11.4.84	11.4.84	11.4.84			
Time hrs	1125	1240	1355	1605	1750	1905	2015	2110	2135			
Particle dia. d microns	Number of Particles ≥ d μm (microns) in 0.05 ml											
2	5410	1363	1435	1494	1496	4745	5484	1923	1652			
3	1272	345	321	312	307	831	1268	330	298			
5	240	43	52	42	47	121	226	51	41			
10	14	4	5	3	6	13	17	2	8			
15	2	1	1	1	3	3	1	1	0			

Turbidity NTU	3	1.1	0.95	1.1	1.4	4.3	5.0	2.2	3.1			

OIL PLUS

TABLE 3.3

SEAWATER QUALITY AT WELL INLET (STAND PIPE MANIFOLD) AFTER FIRST ACID AND VISCOUS PILLS PUMPED DOWNHOLE
($3\frac{1}{2}$" PH-6 RIH TO TD)

WELL 31/3-2

Date	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84					
Time hrs	0315	0405	0450	0555	0800	1010	1205					
Particle dia. d microns	Number of Particles ≥ d µm (microns) in 0.05 ml											
2	1299	1499	1484	2076	1940	1134	1462					
3	363	397	392	292	355	198	292					
5	63	80	77	62	68	39	44					
10	5	4	9	5	6	9	8					
15	1	0	1	1	2	0	0					
Turbidity NTU	0.95	1.2	1.2	1.5	2.3	1.3	2.5					

TABLE 3.4

SEAWATER QUALITY AT WELL INLET (STANDPIPE MANIFOLD) AFTER SECOND ACID PILL AND VISCOUS PILL PUMPED DOWNHOLE ($3\frac{1}{2}$" PH-6 RIH TO TD)

WELL 31/3-2

Date	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84				
Time hrs	1605	1745	1925	2040	2130	2230	2330	0030				
Particle dia. d microns	Number of Particles ⩾ d µm (microns) in 0.05 ml											
2	2031	3911	1095	876	1171	698	1026	1180				
3	542	643	244	215	246	144	325	261				
5	108	67	42	10	26	15	62	45				
10	2	4	4	3	3	4	11	2				
15	0	0	2	0	1	0	6	1				
Turbidity NTU	1.1	3.6	3.7	4.6	4.5	2.2	1.9	2.8				

OIL PLUS

OIL PLUS

SEAWATER QUALITY AT WELL OUTLET (SHAKER BOX) TABLE 3.5
5" TAC 1 TBG DRILL PIPE RIH

WELL 31/3-2

Date	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84
Time hrs	0030	0100	0130	0200	0230	0300	0330	0400	0430	0500	0530	0600
Particle dia. d microns	Number of Particles ≥ d µm (microns) in 0.05 ml											
2					17364	17856	17490	17620	16792	17437	17209	17768
3					16799	17177	16485	16960	14927	16945	16500	17214
5					8224	9531	7218	8464	5202	8156	10138	11168
10					576	540	393	465	380	467	750	706
15					78	61	34	55	47	47	83	74
Turbidity NTU	290	155	410	380	210	260	180	220	120	205	230	305

OIL PLUS

SEAWATER QUALITY AT WELL OUTLET (SHAKER BOX) WHILST RIH 3½" PH-6 PIPE TABLE 3.6

WELL 31/3-2

Date	11.4.84	11.4.84	11.4.84	11.4.84	11.4.84	11.4.84	11.4.84	11.4.84	11.4.84	11.4.84	11.4.84	
Time hrs	1040	1240	1405	1450	1605	1745	1840	1940	2110	2135	2205	
Particle dia. d microns	Number of Particles ⩾ d µm (microns) in 0.05 ml											
2	11984	10517	9465	9755	10790	11610	10935	11083	12791	12310	11606	
3	4471	5869	5560	5537	6539	8146	6460	6518	7226	7391	6332	
5	2000	2262	2465	2548	2603	3952	2858	2796	2736	2592	2627	
10	473	321	267	230	150	475	267	243	243	144	246	
15	78	51	47	25	18	69	23	35	28	18	22	

Turbidity NTU	38	36	31	28	29	37	32	33	33	32	28	

OIL PLUS

SEAWATER QUALITY AT WELL OUTLET (SHAKER BOX) AFTER FIRST ACID PILL AND VISCOUS PILLS PUMPED DOWNHOLE ($3\frac{1}{2}$" PH-6 RIH to TD)

TABLE 3.7

WELL 31/3-2

Date	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84	10.4.84
Time hrs	2350	0010	0030	0245	0310	0330	0345	0425	0525	0540	0605	0625
Particle dia. d microns	Number of Particles ⩾ d µm (microns) in 0.05 ml											
2	13805	12039	12964	13040	11702	12706	13593	12246	16450	13048	10980	15624
3	8890	7061	11384	2885	2461	3297	11304	8233	5174	4824	6152	12404
5	3491	2597	6424	711	664	743	5071	3551	1300	1210	1864	4083
10	439	205	843	39	49	44	339	315	46	47	59	175
15	56	22	110	8	6	7	56	23	16	7	8	22
Turbidity NTU	41	29	67	28	25	22	45	31	11	10.2	16	29

SEAWATER QUALITY AT WELL OUTLET (SHAKER BOX) AFTER FIRST ACID PILL AND TABLE 3.8

WELL 31/3-2

Date	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	12.2.84	12.4.84	12.4.84	12.4.84	12.4.84
Time hrs	0640	0710	0725	0745	0815	0850	0915	0945	1020	1040	1105	1130
Particle dia. d microns	Number of Particles ⩾ d μm (microns) in 0.05 ml											
2	11439	10752	11112	10921	11054	10152	10947	9199	9165	9817	7639	7334
3	6593	6294	6719	6109	6323	5535	5809	4299	4260	5089	3497	3237
5	1391	2499	2869	2343	2460	1922	1926	1516	1477	1915	1236	1076
10	29	125	196	109	106	54	106	71	46	92	61	41
15	2	10	24	11	13	6	15	13	6	4	5	6
Turbidity NTU	12	18	23	20	22	18	18	16	15	16.5	12	12

SEAWATER QUALITY AT WELL OUTLET (SHAKER BOX) AFTER FIRST ACID PILL AND VISCOUS PILLS PUMPED DOWNHOLE ($3\frac{1}{2}$" PH-6 RIH TO TD)

TABLE 3.9

WELL 31/3-2

Date	12.4.84	12.4.84										
Time hrs	1220	1130										
Particle dia. d microns	Number of Particles ≥ d µm (microns) in 0.05 ml											
2	6742	7295										
3	2915	2669										
5	955	906										
10	39	52										
15	6	9										
Turbidity NTU	11	11										

OIL PLUS

SEAWATER QUALITY AT WELL OUTLET (SHAKER BOX) AFTER SECOND ACID PILL AND VISCOUS PILLS PUMPED DOWNHOLE (3½" PH-6 TO TD) TABLE 3.10

WELL 31/3-2

Date	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84		
Time hrs	1525	1550	1620	1730	1800	1830	1900	1930	2000	2030		
Particle dia. d microns	Number of Particles ⩾ d μm (microns) in 0.05 ml											
2	11106	10786	9078	14035	11256	11612	9621	8298	7201	7314		
3	6192	5507	3909	5347	5919	8645	5334	4796	3510	3808		
5	2249	1684	1404	1343	1208	4259	1952	1858	1529	1577		
10	109	90	84	34	33	360	78	90	125	123		
15	9	9	5	5	14	30	13	8	4	11		
Turbidity NTU	18	17	15	12	12	25	16	13	13	13		
Comments			Acid returns @ 1645									

TABLE 3.11

SEAWATER QUALITY AT WELL OUTLET (SHAKER BOX) AFTER SECOND ACID PILL AND VISCOUS PILLS PUMPED DOWNHOLE ($3\frac{1}{2}$" PH-6 RIH TO TD)

WELL 31/3-2

Date	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	12.4.84	13.4.84	13.4.84		
Time hrs	2100	2130	2200	2230	2300	2330	0000	0030			
Particle dia. d microns	Number of Particles ⩾ d μm (microns) in 0.05 ml										
2	6654	6454	6669	6193	5989	6633	5603	5321			
3	3465	2911	3347	2708	2625	3410	2510	2156			
5	1279	1145	1294	1033	1058	1379	927	805			
10	61	77	75	57	54	96	58	56			
15	2	6	8	7	4	7	9	7			
Turbidity NTU	12	12	12	11	10	13	9.2	9.0			

BRINE QUALITY AT WELL INLET (DOWNSTREAM DOWELL HIGH PRESSURE PUMP) PRIOR TO PERFORATION

TABLE 3.12

WELL 31/3-2

Date	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84
Time hrs	0140	1220	0245	0400	0530	0650	0750	0820	0855	0930	1030
Particle dia. d microns	Number of Particles ≥ d µm (microns) in 0.05 ml										
1.75	13194	5048	9929	20226	18782	16413	18751	20894	10642	6169	8987
2	10076	2275	5090	10090	11752	11089	13875	17360	5846	4154	4608
3	2398	828	1088	814	971	2942	3286	4343	1073	1303	1034
5	171	89	135	112	125	565	448	326	162	266	141
10	8	3	13	17	19	38	14	12	14	13	5
15	0	1	1	4	5	3	0	0	0	3	0
Turbidity NTU	2.8	1.1	2.0	2.9	5.7	6.9	3.3	4.4	2.4	1.7	9.3

OIL PLUS

BRINE QUALITY AT WELL INLET (DOWNSTREAM DOWELL HIGH PRESSURE PUMP) PRIOR TO PERFORATION

TABLE 3.13

WELL 31/3-2

Date	13.4.84	13.4.84	13.4.84								
Time hrs	1050	1110	1130								
Particle dia. d microns	Number of Particles ≥ d μm (microns) in 0.05 ml										
1.75	7114	8616	6761								
2	3686	5068	3688								
3	871	1353	693								
5	170	251	72								
10	17	7	3								
15	2	0	0								
Turbidity NTU	6.3	4.6	3.4								

BRINE QUALITY AT FILTER OUTLET WHILST CIRCULATING AFTER FLOW TEST FOLLOWING PERFORATION PROIR TO POOH

TABLE 3.14

WELL 31/3-2

Date	16.4.84	16.4.84	16.4.84	16.4.84	16.4.84	16.4.84	16.4.84	16.4.84	16.4.84	16.4.84	16.4.84
Time hrs	0830	0900	0930	1000	1030	1045	1100	1115	1130	1230	
Particle dia. d microns	Number of Particles ≥ d μm (microns) in 0.05 ml										
2	1358	4093	1639	3512							
3	425	1022	133	258							
5	75	149	23	31							
10	9	11	2	3							
15	5	9	0	0							
Turbidity NTU	1.0	1.5	0.95	1.5	9.5	8.5	6.0	2.6	1.6	3.9	

TABLE 3.15

CIRCULATION PRIOR TO GRAVEL PACK
BRINE QUALITY AT WELL INLET (DOWNSTREAM DOWELL HIGH PRESSURE PUMP)

WELL 31/3-2

Date	17.4.84	17.4.84	17.4.84	17.4.84	17.4.84	17.4.84	17.4.84	17.4.84			
Time hrs	1725	1740	1755	1810	1825	1840	1855	1910			
Particle dia. d microns	Number of Particles ⩾ d µm (microns) in 0.05 ml										
1.75	24894	25184	24036	24351	21150	19285	16467	10239			
2	22952	22474	23215	15198	12396	9838	5325	2806			
3	6050	4384	6471	1052	852	993	395	243			
5	131	70	212	96	79	130	39	26			
10	4	10	19	7	2	8	1	7			
15	0	0	2	0	0	0	0	1			
Turbidity NTU	7.2	7.5	7.1	2.6	2.3	1.6	1.4	0.95			

TABLE 3.16

BRINE QUALITY AT WELL OUTLET (SHAKER BOX)
PRIOR TO PERFORATION

WELL 31/3-2

Date	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84		
Time hrs	0320	0340	0410	0450	0530	0600	0650	0750	0820	0855		
Particle dia. d microns	Number of Particles ≥ d μm (microns) in 0.05 ml											
1.75	22745	21081	20373	19352	19061	17845	16722	13143	11083	15556		
2	20851	17620	16871	15744	15215	14698	13378	9507	7565	11989		
3	4806	5605	5521	5301	5402	5057	5227	4369	3235	3816		
5	531	578	690	609	752	743	1005	1208	1004	618		
10	44	26	66	49	66	51	58	69	117	51		
15	10	10	7	7	10	7	21	15	25	7		
Turbidity NTU	16	5.8	6.8	7.7	8.2	6.8	6.2	5.9	5.7	7.2		

OIL PLUS

OIL PLUS

BRINE QUALITY AT WELL OUTLET (SHAKER BOX)
PRIOR TO PERFORATION

TABLE 3.17

WELL 31/3-2

Date	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84	13.4.84				
Time hrs	0930	0955	1010	1030	1050	1110	1130				
Particle dia. d microns	Number of Particles ≥ d µm (microns) in 0.05 ml										
1.75	19916	19596	16675	16973	11243	9932	13658				
2	15857	14675	12569	12644	6622	5585	8500				
3	5508	4572	5043	3371	1813	1629	2276				
5	1289	1074	959	553	375	408	425				
10	80	127	71	56	43	49	39				
15	20	29	9	9	6	2	4				

Turbidity NTU	15	51	6.9	5.4	4.1	3.9	4.3				

TABLE 3.18

BRINE QUALITY AT WELL OUTLET WHILST CIRCULATING AFTER FLOW TEST FOLLOWING PERFORATION PRIOR TO POOH

WELL 31/3-2

Date	16.4.84	16.4.84	16.4.84	16.4.84	16.4.84	16.4.84	16.4.84	16.4.84	16.4.84	16.4.84	
Time hrs	0830	0900	0930	1000	1030	1045	1100	1115	1130	1215	
Particle dia. d microns	Number of Particles ≥ d μm (microns) in 0.05 ml										
2		13015	12171				16258			11994	
3		9833	7485				6633			4576	
5		4416	3493				2052			1266	
10		499	452				214			285	
15		86	81				46			88	
Turbidity NTU	64	49	36	65	75	64	20	40	67	8.5	

TABLE 3.19

BRINE QUALITY AT WELL OUTLET WHILST CIRCULATING AFTER FLOW TEST FOLLOWING PERFORATION PRIOR TO POOH

WELL 31/3-2

Date	16.4.84	16.4.84	16.4.84								
Time hrs	1230	1255	1315								
Particle dia. d microns	Number of Particles ⩾ d µm (microns) in 0.05 ml										
2	12288	13972	15797								
3	4058	4351	5077								
5	986	1027	1154								
10	187	166	193								
15	83	58	42								

Turbidity NTU	6.0	5.9	7.1								

OIL PLUS

TABLE 3.20

BRINE CIRCULATION PRIOR TO GRAVEL PACK
BRINE QUALITY AT WELL OUTLET (SHAKER BOX

WELL 31/3-2

Date	17.4.84	17.4.84	17.4.84	17.4.84	17.4.84	17.4.84	17.4.84	17.4.84			
Time hrs	1725	1740	1755	1810	1825	1840	1855	1910			
Particle dia. d microns	Number of Particles ⩾ d μm (microns) in 0.05 ml										
1.75		16286		22556	22141	23846	23811	24156			
2	15690	16246		20910	21921	22476	21940	20615			
3	15240	15627		13665	14102	12626	9738	3589			
5	9259	7519		949	814	430	365	419			
10	1030	775		61	67	27	31	30			
15	130	148		13	16	6	8	11			

Turbidity NTU	82	62	155	16	13	8.8	7.6	5.2			

TABLE 3.21

DETAILS OF FILTERS USED FOR BRINE FILTRATION

1. PECO FILTER SKIDS

2 pods per skid.	18 filters per pod.
Manufacturer:	Hytrex
Media:	Polypropylene
Length:	36⅞ inches.
Ratings of filter type used and product code:	5 microns nominal (GX 05-336C)
Recommended Flow Rate:	5 bpm per pod containing 18 filters
Recommended Δ p for change of filters:	20 psi

2. PALL FILTER SKID

2 pods per skid.	32 filters per pod.
Manufacturer:	Pall
Media:	Resin impregnated cellulose (Epocel type)
Length:	40 inches
Product Code:	AB4LC4
Rating in virgin state of AB4LC4:	10 microns absolute 99% @ 5 microns 90% @ 2 microns
Recommended Flow Rate:	2 bpm per pod containing 32 filters
Recommended Δ p for change of filters:	40 psi

FILTER PERFORMANCE

TABLE 3.22

WELL 31/3-2

Date	13.4.84			13.4.84			13.4.84			13.4.84		
Time hrs	0400			0610			0835			0915		
Sample	Filter Inlet	Filter Outlet	Eff %	Filter Inlet	Filter Outlet	Eff %	Filter Inlet	Filter Outlet	Eff %	Filter Inlet	Filter Outlet	Eff %
Particle dia. d microns	Number of Particles ⩾ d µm (microns) in 0.05 ml											
1.75	26285	23876	9.2	20256	18177	10.3	12185	2050	83.2	15072	743	95.1
2	21829	18372	15.8	16975	11179	34.1	8925	533	94.0	12077	300	97.5
3	4728	858	81.9	6067	879	85.5	4048	78	98.1	4083	54	98.7
5	797	48	94.0	691	66	90.4	1376	15	98.9	723	7	99.0
10	73	3	95.9	48	1	97.9	92	2	97.8	74	0	100
15	9	0	100	4	0	100	16	0	0	3	0	100
Pump Rate BPM	1			1			6			6		
Filters in use	5 micron nominal Hytex 10 micron absolute Pall											
Turbidity NTU	26	4.6		12.5	6.0		6.7	1.7		7.8	1.0	

OIL PLUS

TABLE 3.23

BRINE QUALITY AT FILTER SYSTEM OUTLET WHILST TRANSFERRING BRINE FROM SUPPLY BOAT TO DOWELL STORAGE TANKS ON TREASURE SEEKER

Date	Time	Turbidity at filter system outlet NTU
12.4.84	0840	2.4
	0900	0.89
	0925	0.48
	0955	0.77

SCHEMATIC OF SEAWATER CIRCULATION SYSTEM

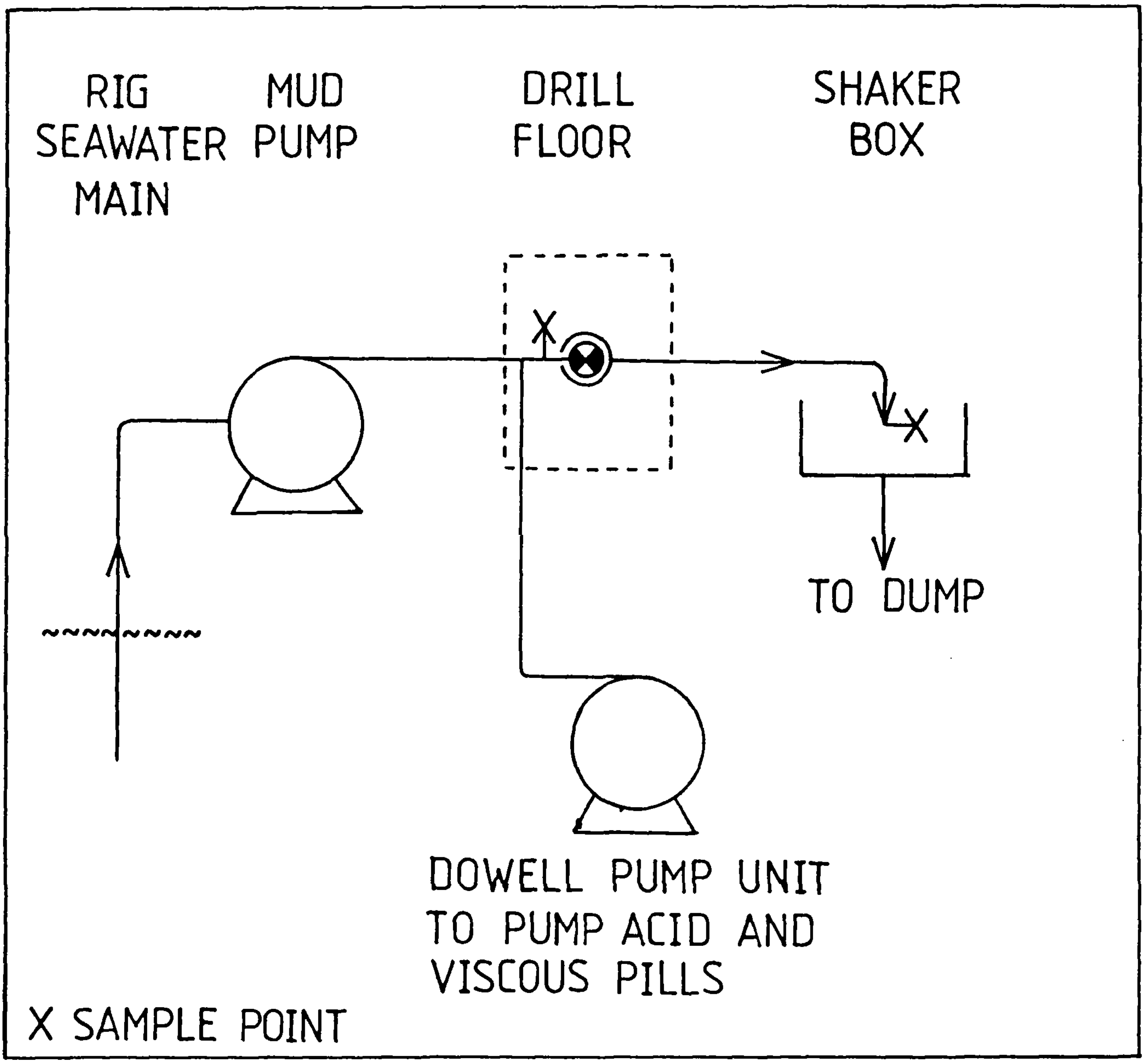


FIG 3.1.

SCHEMATIC OF $CaCl_2$ BRINE AND CIRCULATION AND FILTRATION SYSTEM

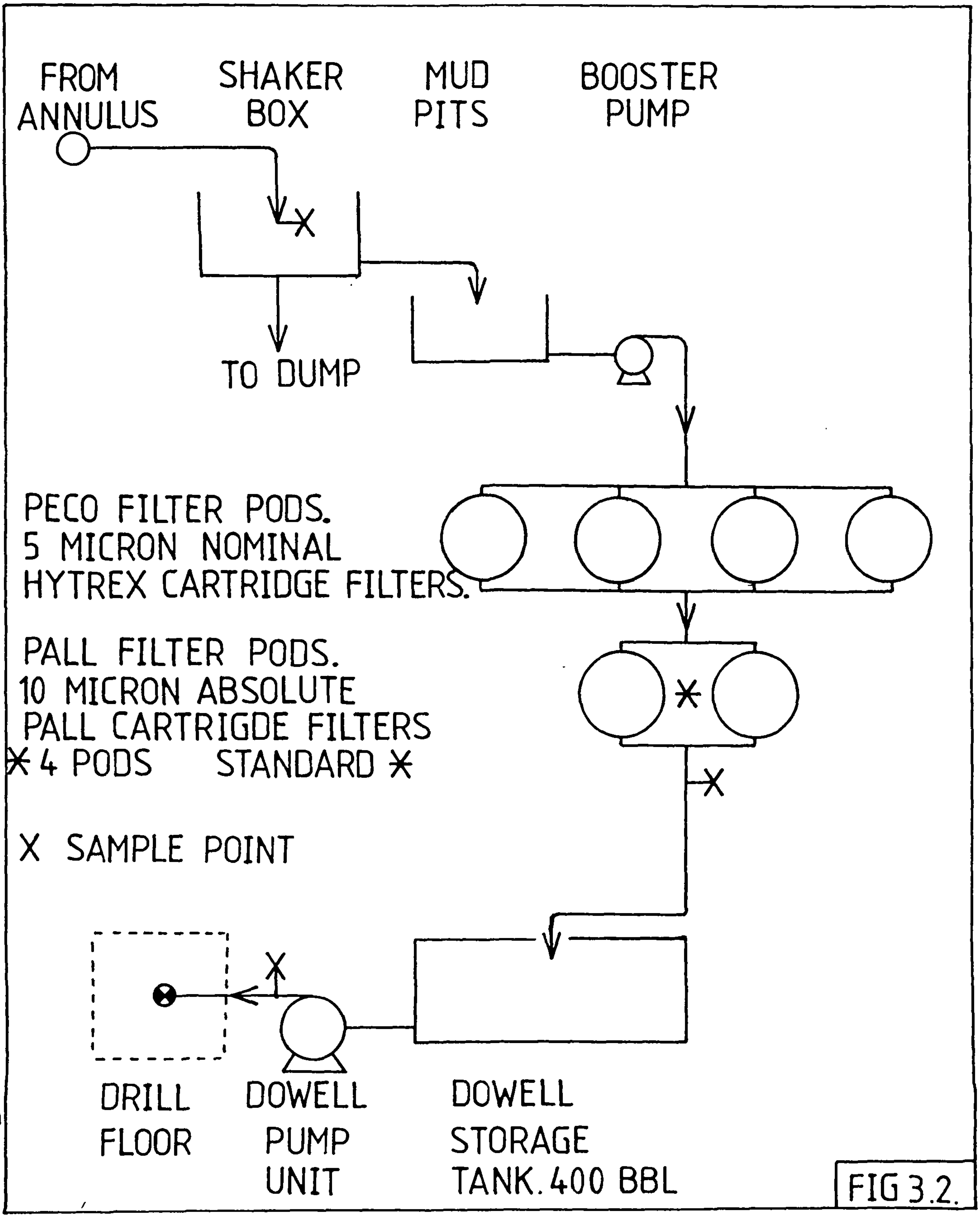


FIG 3.2.

TURBIDITY NTU.
BRINE AND SEAWATER CIRCULATION

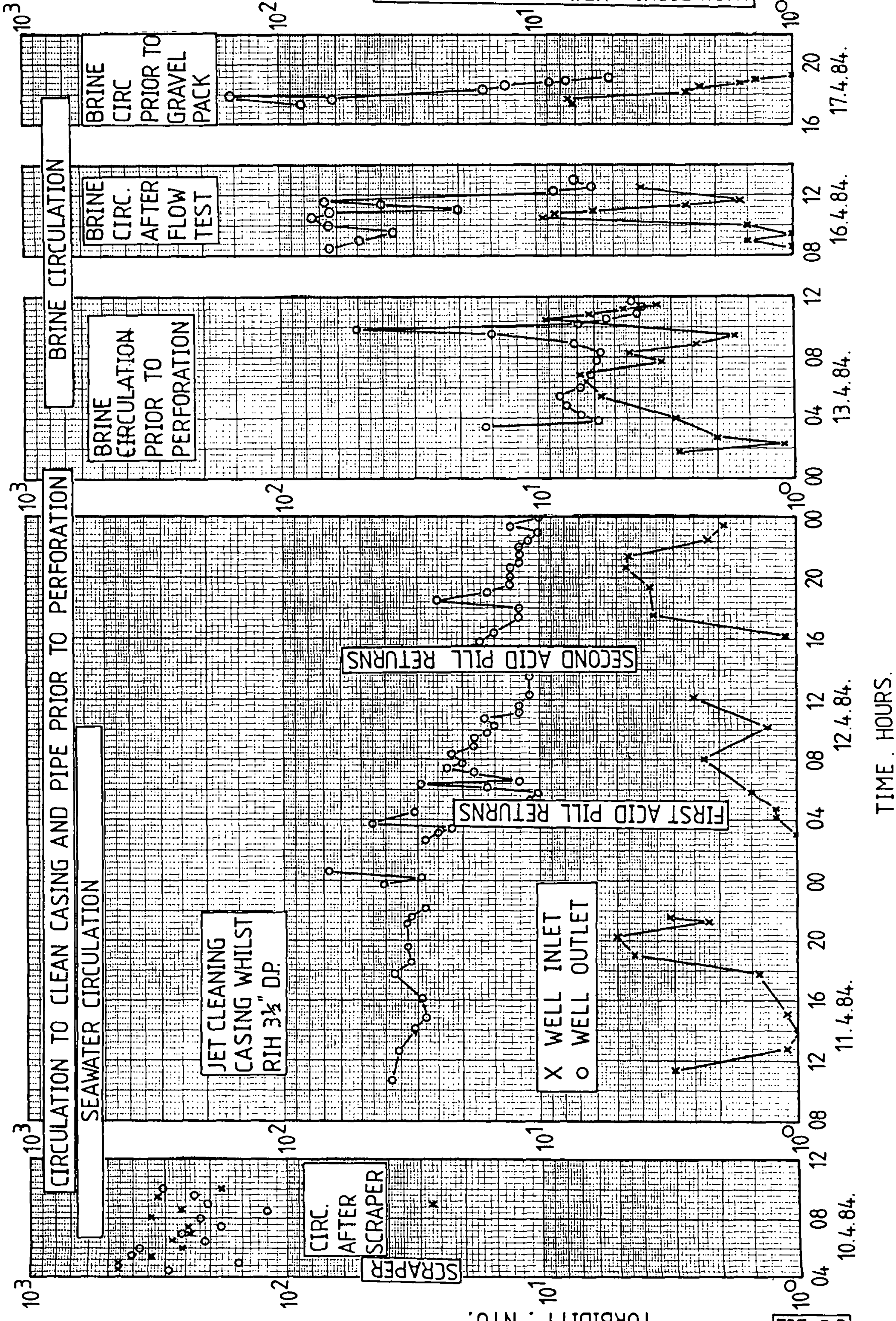
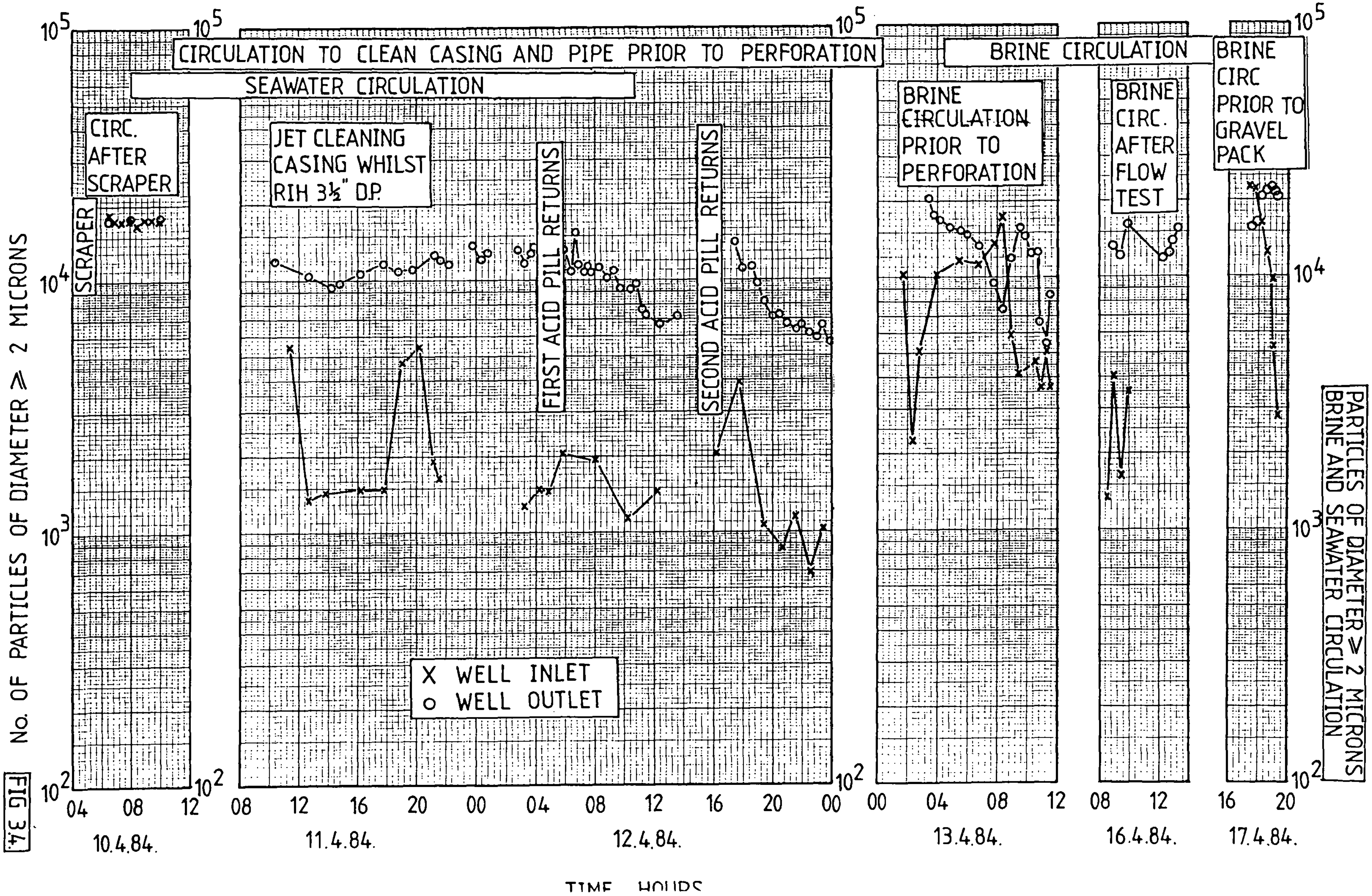


FIG 3.3.



CIRCULATION TO CLEAN CASING AND PIPE PRIOR TO PERFORATION
SEAWATER CIRCULATION
CIRC. AFTER SCRAPER
SCRAPER
JET CLEANING CASING WHILST RIH 3½" D.P.
FIRST ACID PILL RETURNS
SECOND ACID PILL RETURNS
BRINE CIRCULATION
BRINE CIRCULATION PRIOR TO PERFORATION
BRINE CIRC. AFTER FLOW TEST
BRINE CIRC PRIOR TO GRAVEL PACK
X WELL INLET
o WELL OUTLET
No. OF PARTICLES OF DIAMETER ⩾ 2 MICRONS
PARTICLES OF DIAMETER ⩾ 2 MICRONS BRINE AND SEAWATER CIRCULATION
10.4.84.
11.4.84.
12.4.84.
13.4.84.
16.4.84.
17.4.84.

FIG 3.4.

PARTICLES OF DIAMETER ≥ 3 MICRONS
BRINE AND SEAWATER CIRCULATION

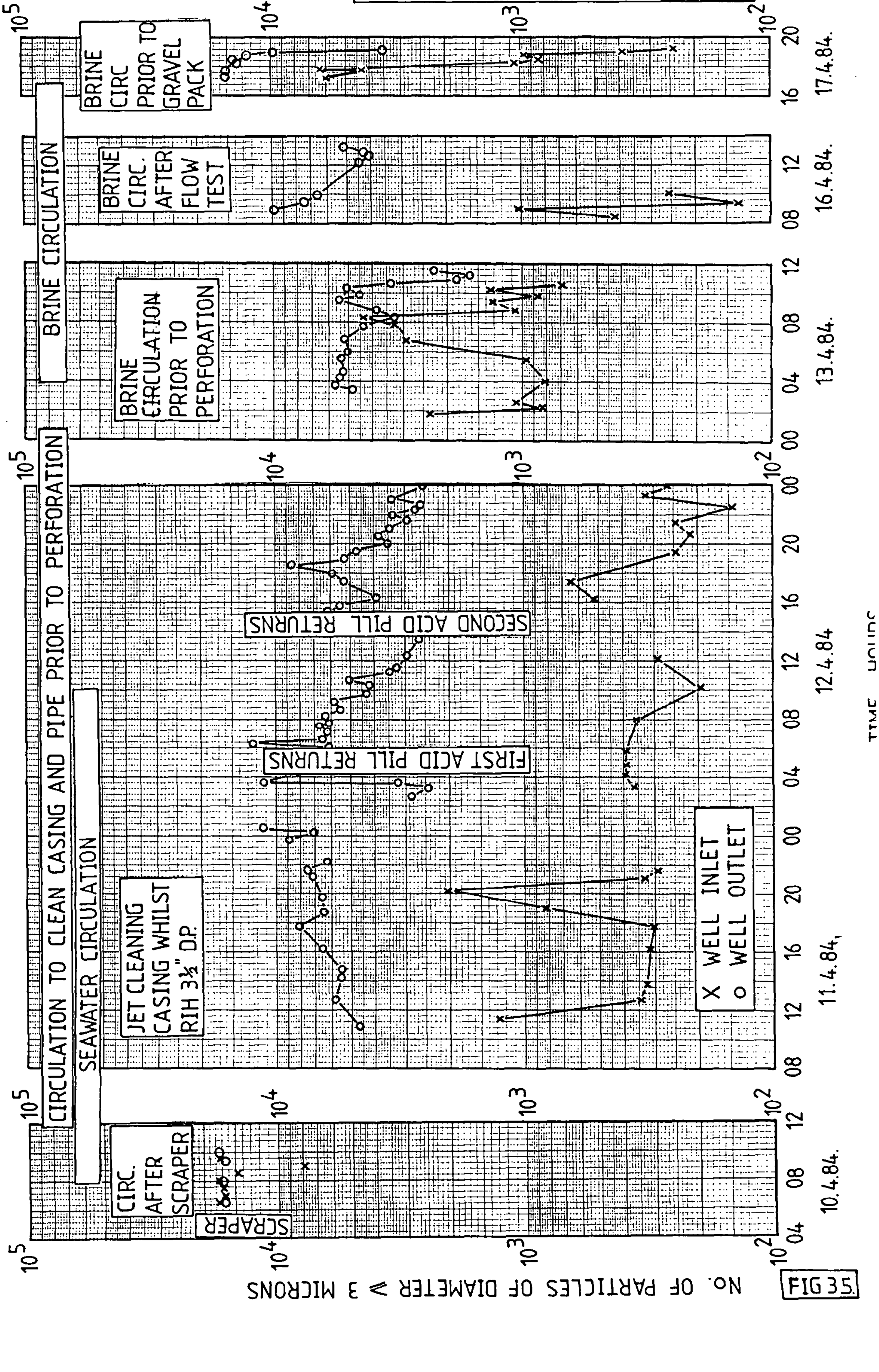
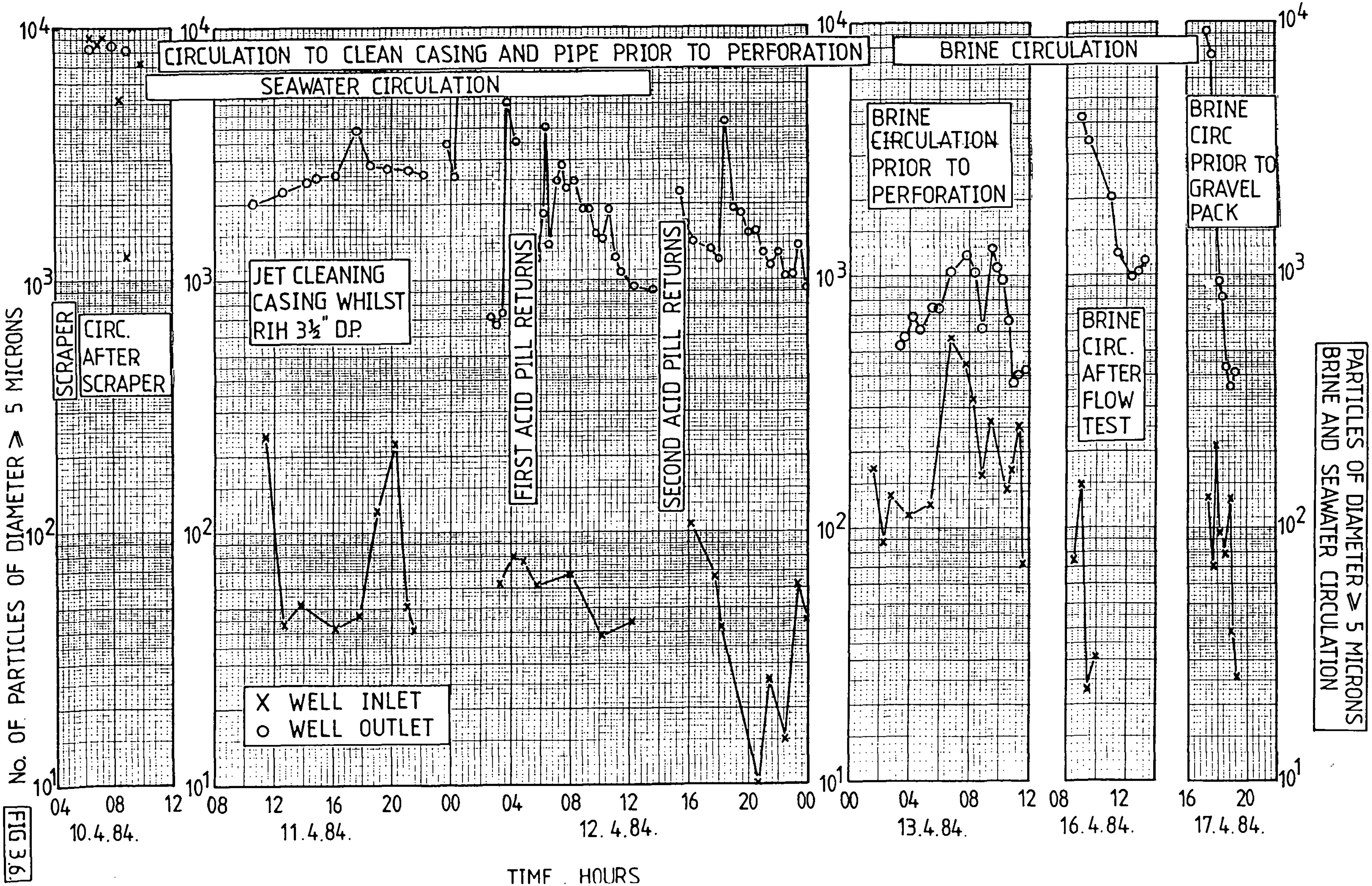
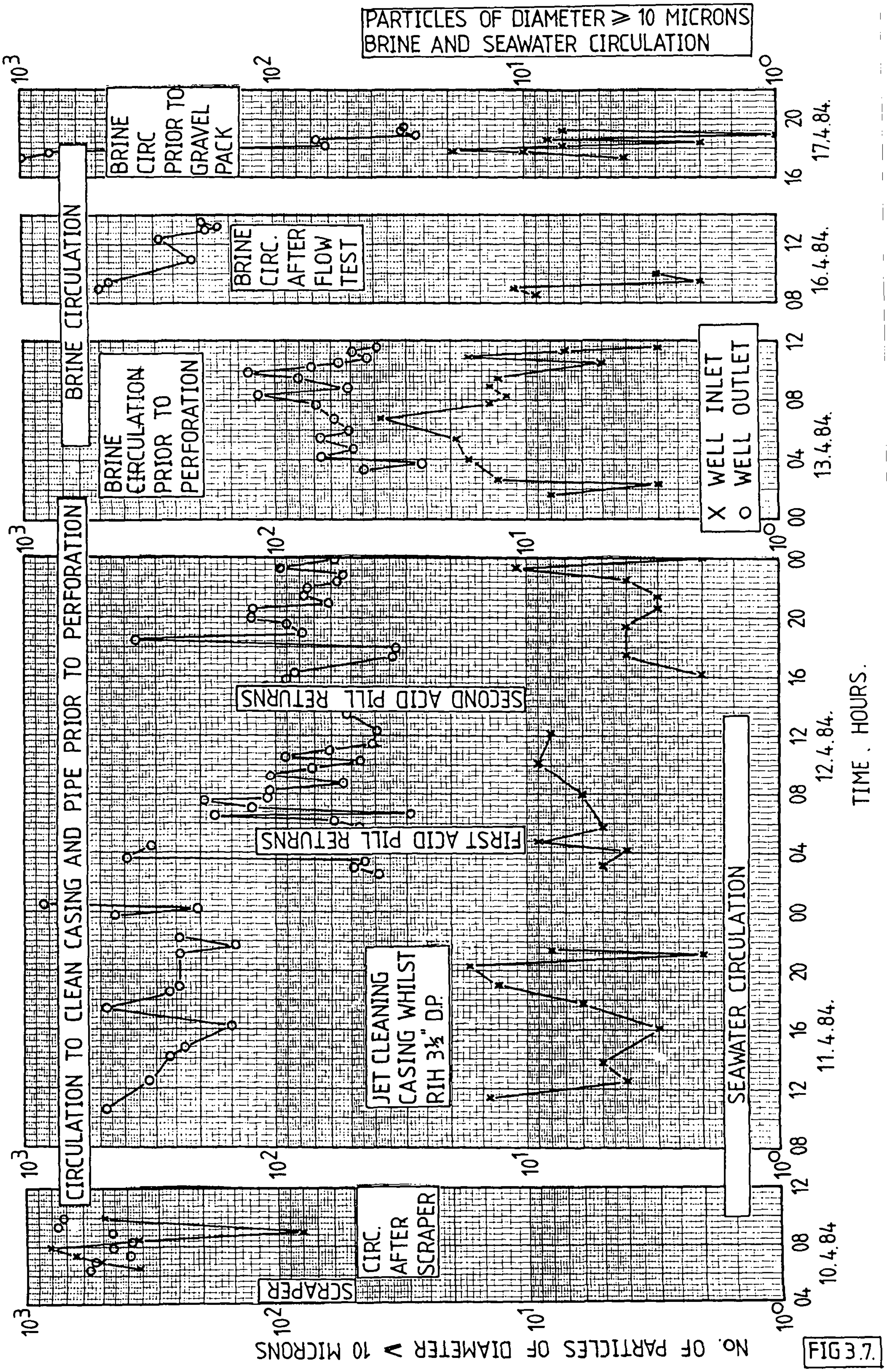


FIG 35.



PARTICLES OF DIAMETER ⩾ 5 MICRONS
BRINE AND SEAWATER CIRCULATION
CIRCULATION TO CLEAN CASING AND PIPE PRIOR TO PERFORATION
BRINE CIRCULATION
SEAWATER CIRCULATION
SCRAPER
CIRC. AFTER SCRAPER
JET CLEANING CASING WHILST RIH 3½" D.P.
FIRST ACID PILL RETURNS
SECOND ACID PILL RETURNS
BRINE CIRCULATION PRIOR TO PERFORATION
BRINE CIRC. AFTER FLOW TEST
BRINE CIRC PRIOR TO GRAVEL PACK
X WELL INLET
o WELL OUTLET
No. OF PARTICLES OF DIAMETER ⩾ 5 MICRONS
10¹ 10² 10³ 10⁴
04 08 12 10.4.84.
08 12 16 20 00 11.4.84.
04 08 12 16 20 00 12.4.84.
00 04 08 12 13.4.84.
08 12 16.4.84.
16 20 17.4.84.
TIME . HOURS

FIG 3.6.

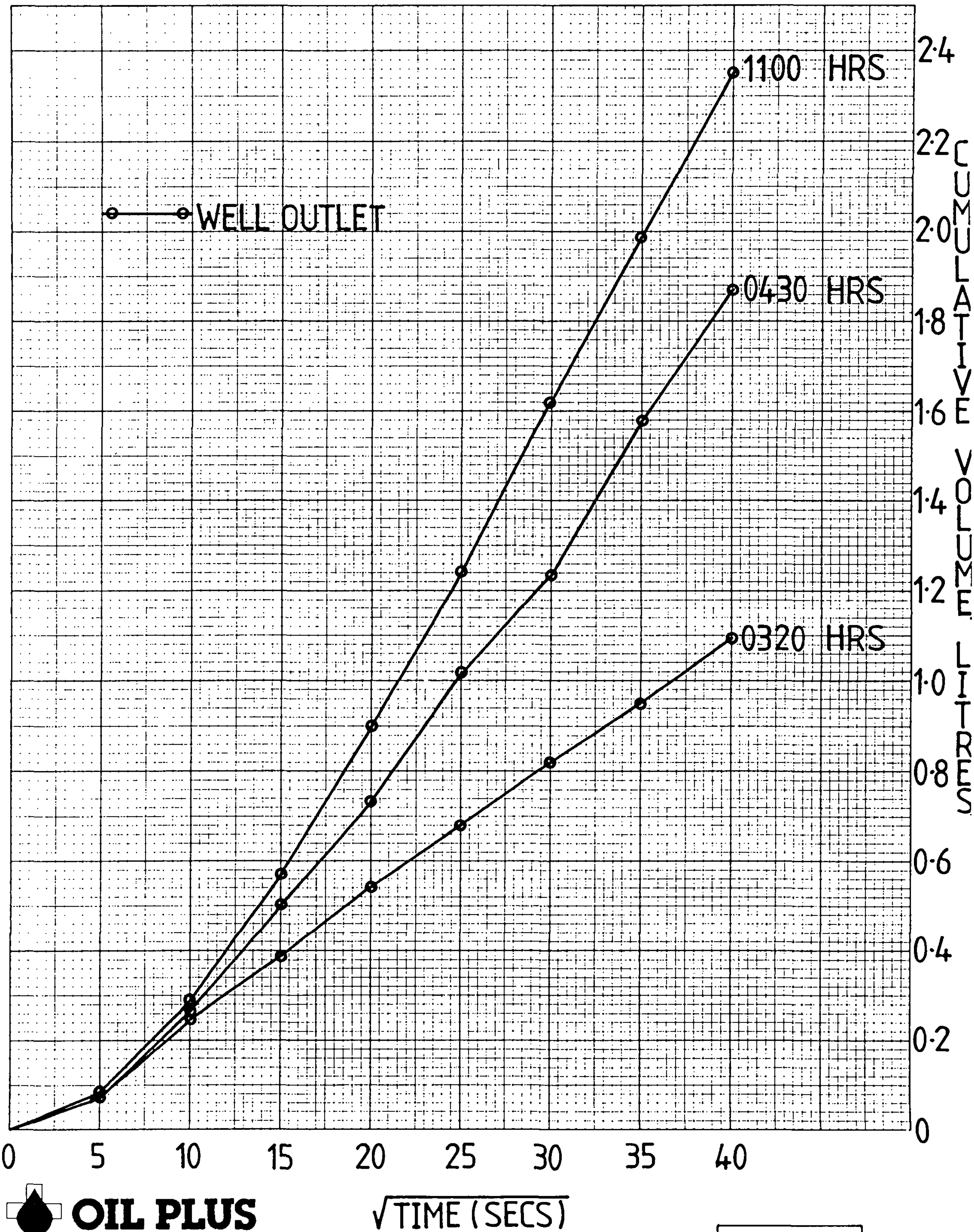


PARTICLES OF DIAMETER ≥ 10 MICRONS
BRINE AND SEAWATER CIRCULATION
BRINE CIRCULATION
CIRCULATION TO CLEAN CASING AND PIPE PRIOR TO PERFORATION
SEAWATER CIRCULATION
SCRAPER
CIRC. AFTER SCRAPER
JET CLEANING CASING WHILST RIH 3½" D.P.
FIRST ACID PILL RETURNS
SECOND ACID PILL RETURNS
BRINE CIRCULATION PRIOR TO PERFORATION
BRINE CIRC. AFTER FLOW TEST
BRINE CIRC PRIOR TO GRAVEL PACK
X WELL INLET
o WELL OUTLET
10.4.84.
11.4.84.
12.4.84.
13.4.84.
16.4.84.
17.4.84.
TIME. HOURS.
NO. OF PARTICLES OF DIAMETER ≥ 10 MICRONS

FIG 3.7.

SEAWATER CIRCULATION.
SEAWATER RETURNS.
MEMBRANE FILTER TESTS

DATE: 12.4.84.

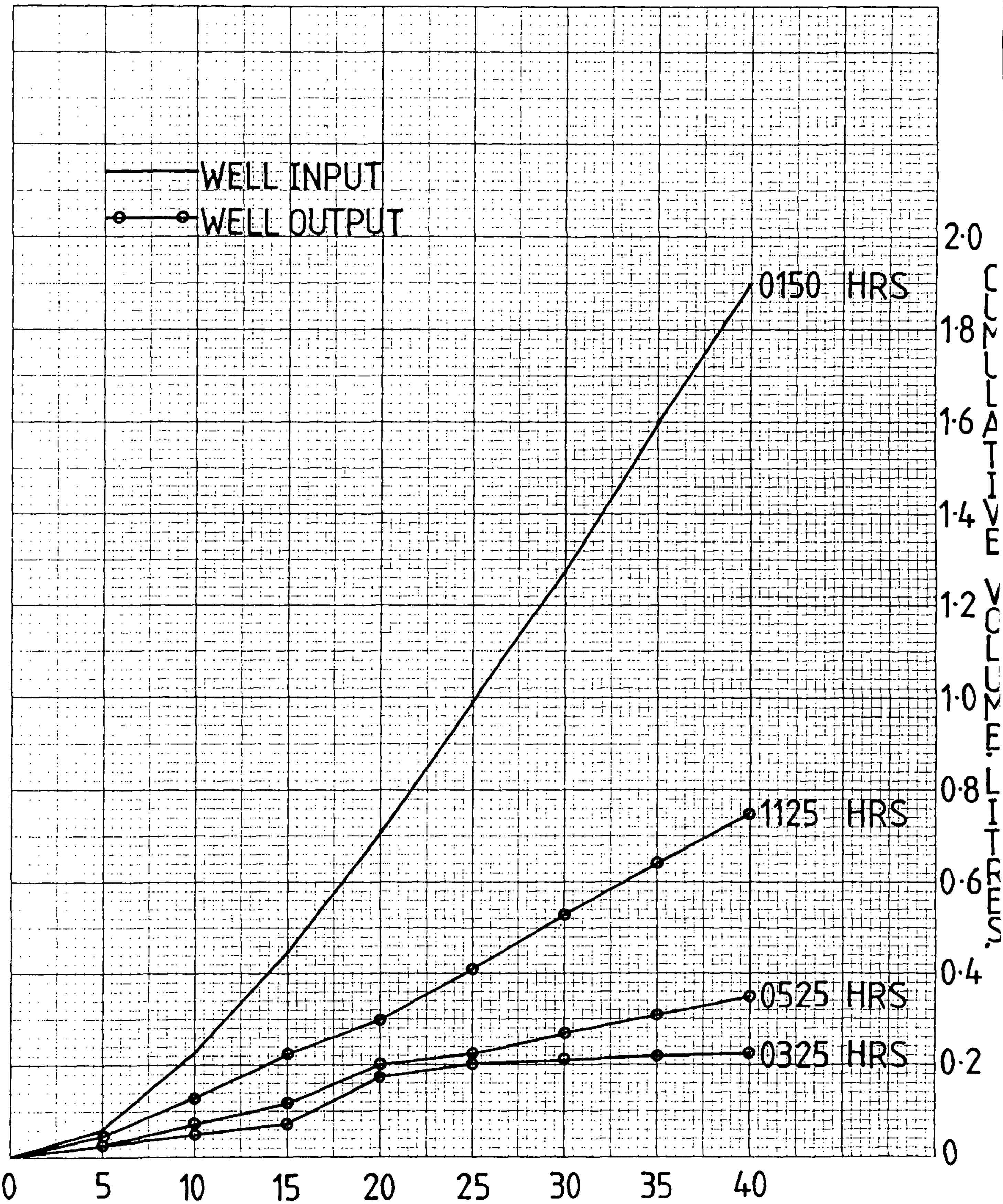


OIL PLUS

FIG 3.8.

BRINE CIRCULATION PRIOR TO PERFORATION. MEMBRANE FILTER TESTS.

DATE: 13.4.84.

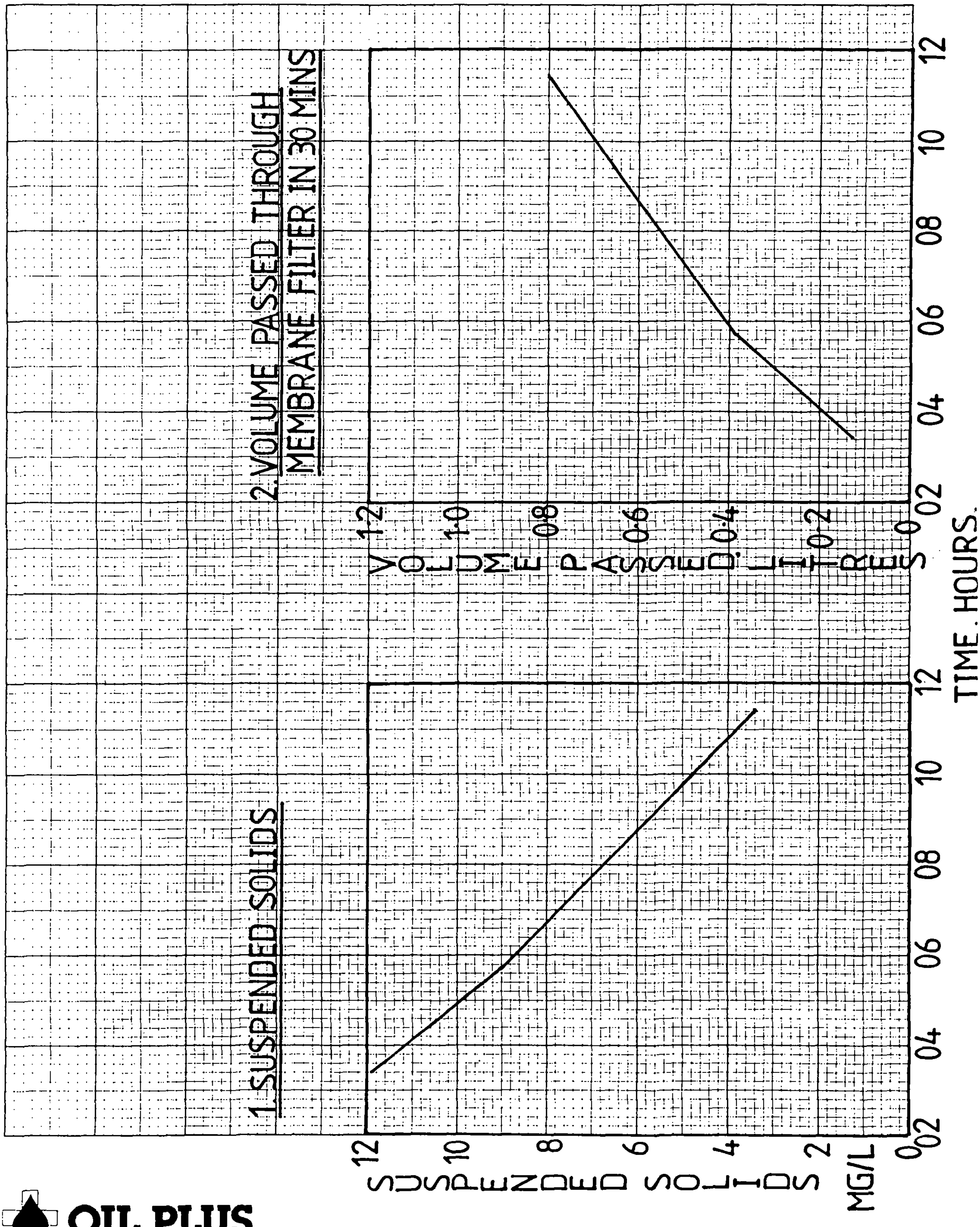


OIL PLUS

FIG 3.9.

BRINE CIRCULATION
PRIOR TO PERFORATION.
MEMBRANE FILTER TESTS.

DATE: 13.4.84.



OIL PLUS

FIG 3.10.