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TESTING OF EQUIPMENT FOR USE IN CONNECTION WITH
WORKOVERS ON FLOWING GEOTHERMAL WELLS.
SVARTSENGI, 13-18/3. ´81

Jan Egil Arneberg

JEA-81/01 Maí 1981

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1. Abstract

The intention with the test was to expose the Grant RDH and the flow restriction with cooling water, to conditions expected during workovers on the wells in Svartsengi, 15-20 bar wellhead pressure and approximately 200°C wellhead temperature.

1) Workovers in this context refers to drilling out of scale deposites in the wellbore which are to be found in the zone where 2 phase flow starts to occur.

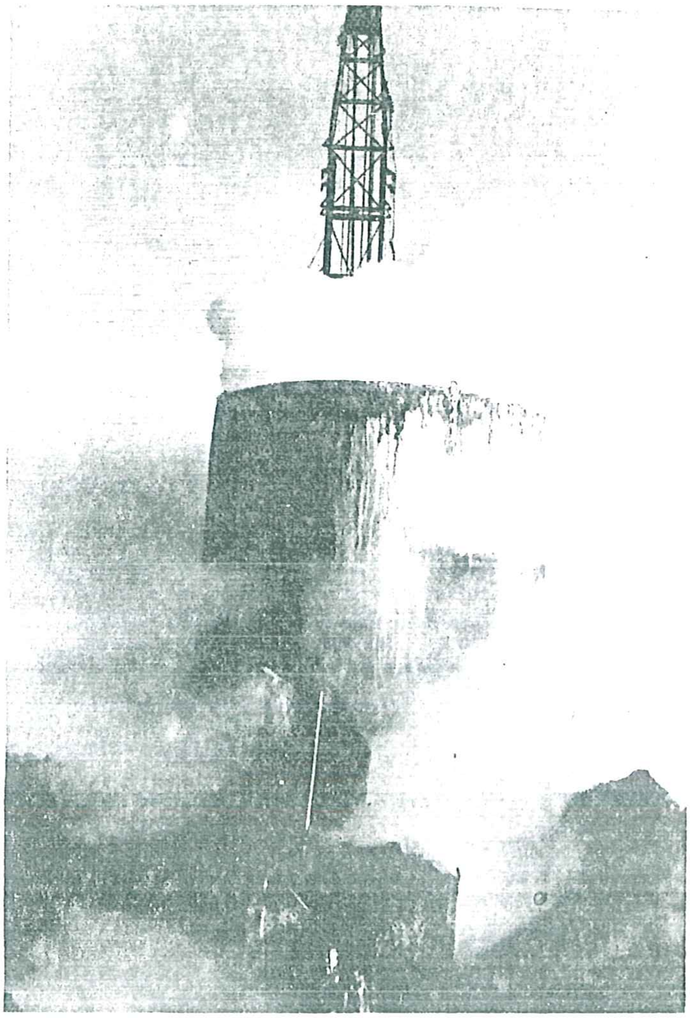
The tests were conducted on well No. 6 in Svartsengi, with a Wabco 2000 rig, a 12" Grant RDH with a 2 7/8" stripper rubber and a specially designed flow restriction, a 12" Cameron QRC BOP, 4 1/2" OD slick drill-pipe and a 4 1/2" hexagonal kelly.

The results were positive. The rate of cold water, cooling the stripper rubber, and preventing steam from reaching the rubber, seems to be the only factor which had any influence on the temperature inside the RDH. It was concluded that the cold water rate should be above 15 l/s.

The test proved beyond any doubt that the proposed work procedure and the proposed equipment worked.

Several alterations and improvements on the equipment were recommended.

LIST OF CONTENTS



2. Introduction

The workover procedure presently employed in Svartsengi requires that the wells are not flowing. The wells are therefore killed prior to start up of workovers.

This implements a rather drastic cooling of the wellbore which introduces thermal stresses on the casing and the cement sheet behind the casing.

It is believed that repeated cycles of cooling and heating can cause casing failures which might lead to loss of the well.

Workovers are carried out regularely on all wells in Svartsengi with 6 to 12 months interwalls between jobs on each well.

Casing failure is therefore expected to occur unless improved workover procedures are employed, procedures enabeling workovers to be performed on flowing wells.

A Grant, model 7068, Rotating Drilling Head (RDH) equiped with a high temperature, butyl stripper rubber, and a flow restriction which prevents steam from coming in direct contact with the stripper rubber has been considered a possible solution to the problem of performing workovers on flowing wells.

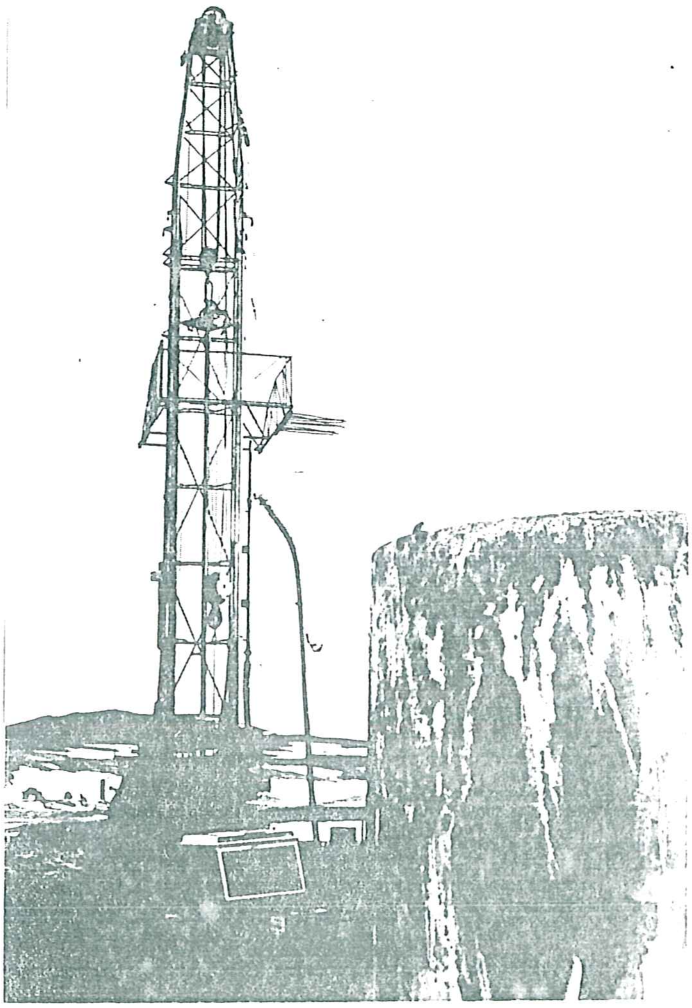
But as the Grant RDH has never, to the authors knowledge, been used under the conditions in question in Svartsengi, and as the flow restriction is a new design, it was felt necessary to perform a field test on the equipment before any decisions regarding the workover procedures were made.

3. Scope

The intention with the test was to expose the equipment to conditions expected during a workover job, for approximately the same length of time as such a job is expected to last.

The conditions were defined to be a pressure between 15 and 20 bars, and a temperature of approximately 200°C at the wellhead.

The work operations were simulated by reciprocating the kelly and the drillpipe through the stripper, and by rotating the kelly.



4. Equipment and work procedure

4.1 Necessary equipment

A medium sized drilling rig will be required. This rig must be equiped with a pull down system.

The drill string will consist of:

- a bit
- a bit sub with an outer diameter of at least 5" and with a none flow valve inside
- a short section of drillpipe, approximately 2 meters
- 4 1/2" OD slick drill collars
- 4 1/2" OD slick drillpipe
- 4 1/2" hexagonal kelly

The equipment mounted on the wellhead, shown in fig 4.1, will consist of, besides the master valve and the killine valve (which are standard equipment on all wells), a flow diverter which is connected to a silencer, a BOP with 4 1/2" piperams, a Grant RDH, model 7068, and the flowrestriction mounted inside the RDH.

In addition monitoring equipment for temperature and pressure measurements will be needed.

Cold water will be supplied by a mud pump through the sideoutlet on the RDH.

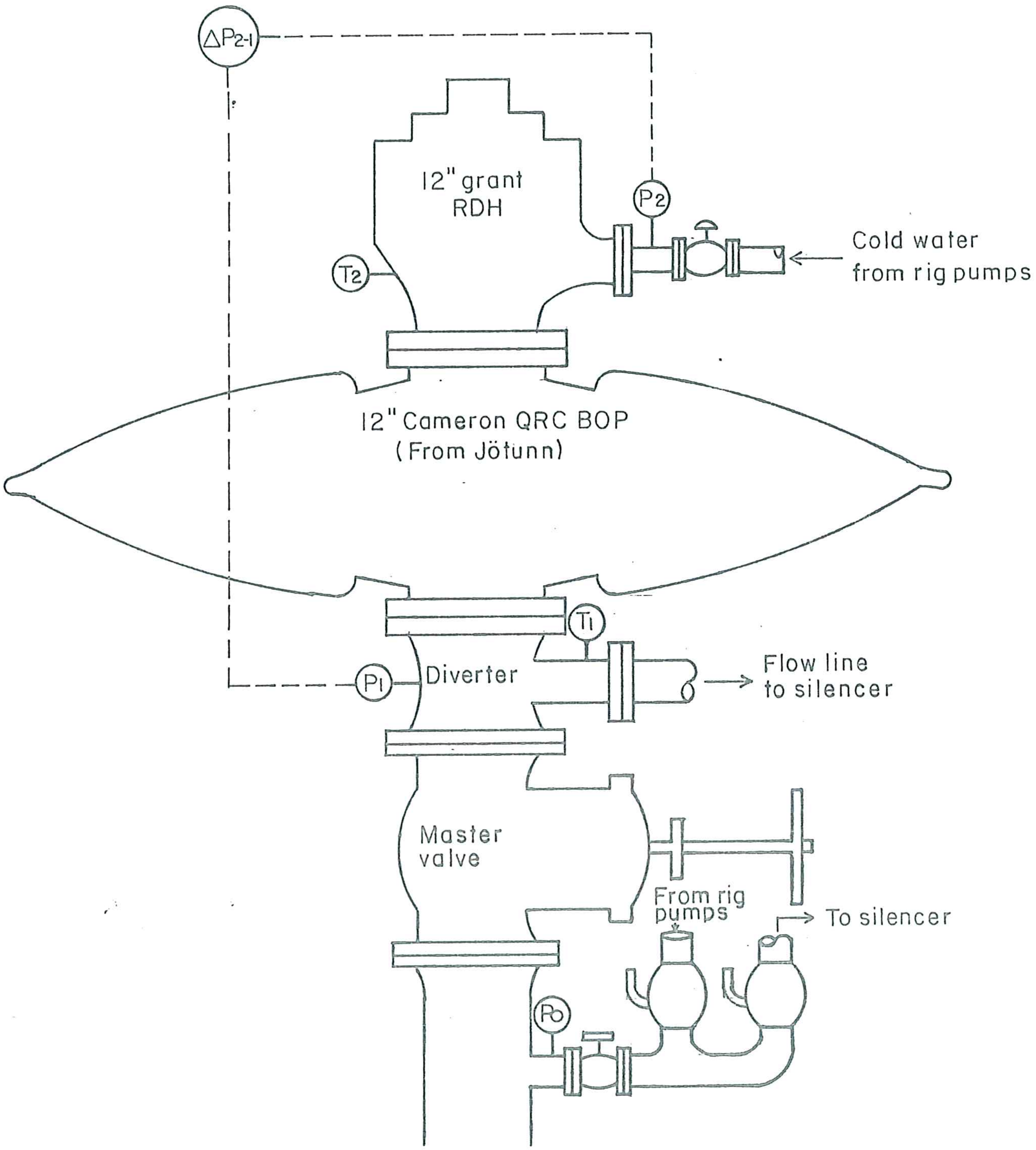
The pump is also connected to killine in case control of the well should be lost and killing of the well should be necessary. The killine outlet is also connected to the silencer, allowing a small flow of steam to pass through. This arrangement prevents the well from "dying" while the master valve is closed.

4.2 The Drilling Rig

The scale deposites are usually located at 400 to 600 meters depth in the wells. The length of the deposite zones is usually approximately 50 meters.

Set up of test equipment at well no. 6
Svartsengi

Fig. 4.1



The depth of the deposites will gradually increase as the reservoir pressure declines. A rough estimate of the pipe requirements are therefore:

- 800 meters of 4 1/2" OD slick drillpipe
- 100 meters of 4 1/2" OD slick drillcollar

Assuming 13,75 lbs/ft drillpipe and 45,8 lbs/ft drillcollar, this totals 23,4 tonns (51000 lbs). This load is well within the capabilities of the medium sized rigs in use in Iceland (Wabco 2000 or Failing 3000).

The actual load in the rig will be somewhat less, due to the effect of the flowing steam. The load is reduced by approximately 2 tonns on surface, and 8 tonns with the drillpipe at 900 meters depth (fig 4.2). The maximum load is therefore not expected to exceed 15 tonns while the well is flowing. The effect of boyancy is neglected.

The force exerted by the steam on the drillstring will exceed the force resulting from the weight of the drillstring, in the upper part of the wells (fig 4.2).

A pulldown system is therefore needed down to approximately 30 meters if 45,8 lbs/ft drillcollar is being used, or approximately 80 meters if 13,75 lbs/ft drillpipe is being used (fig 4.2).

According to fig 4.2 it is not likely that the load on the pulldown will exceed 2 tonns (4400 lbs).

It is further necessary that the rig has a minimum opening in the rotary table of 16", or that the rotary table can be removed easily.

4.3 The Grant, model 7068, Rotating Drilling head

The RDH (fig 4.3) consists of 3 vital parts. The RDH body "or bowl", the drive bushing assembly which rotates with the kelly, and the stripper rubber which is attached to the lower end of the drive bushing assembly.

The RDH has two openings the lower flange and the side flange.

Pressure on the lubrication system for the bearings is maintained by a separate tank, pressurized by air.

The RDH is designed for the petroleum industry, for use in connection with drilling under unstable conditions. Under normal operation mud, water, or air will flow in through the lower flange and out through the side flange.

The RDH is designed to withstand pressures and temperatures normally encountered during drilling operations. The RDH is therefore not expected to withstand temperatures encountered during the planned work-over in Svartsengi.

The stripper rubber is expected to deform when exposed to high temperatures. The deformation of the rubber will reduce the rubbers ability to confine pressure and leaks between the rubber and the drillstring are expected to occur within a relatively short time.

These leaks are believed to develope gradually as the deformation of the rubber progresses.

The equipment is therefore not believed to function satisfactorily for this application, unless the rubber temperature is kept at an acceptably low level.

It is therefore obvious that the side outlet cannot be used for it's original purpose.

It is further obvious that some kind of flow restriction between the stripper rubber and the steam is needed, and that cooling water is needed in order to keep the rubber temperature at an acceptable level.

4.4 The flow restriction

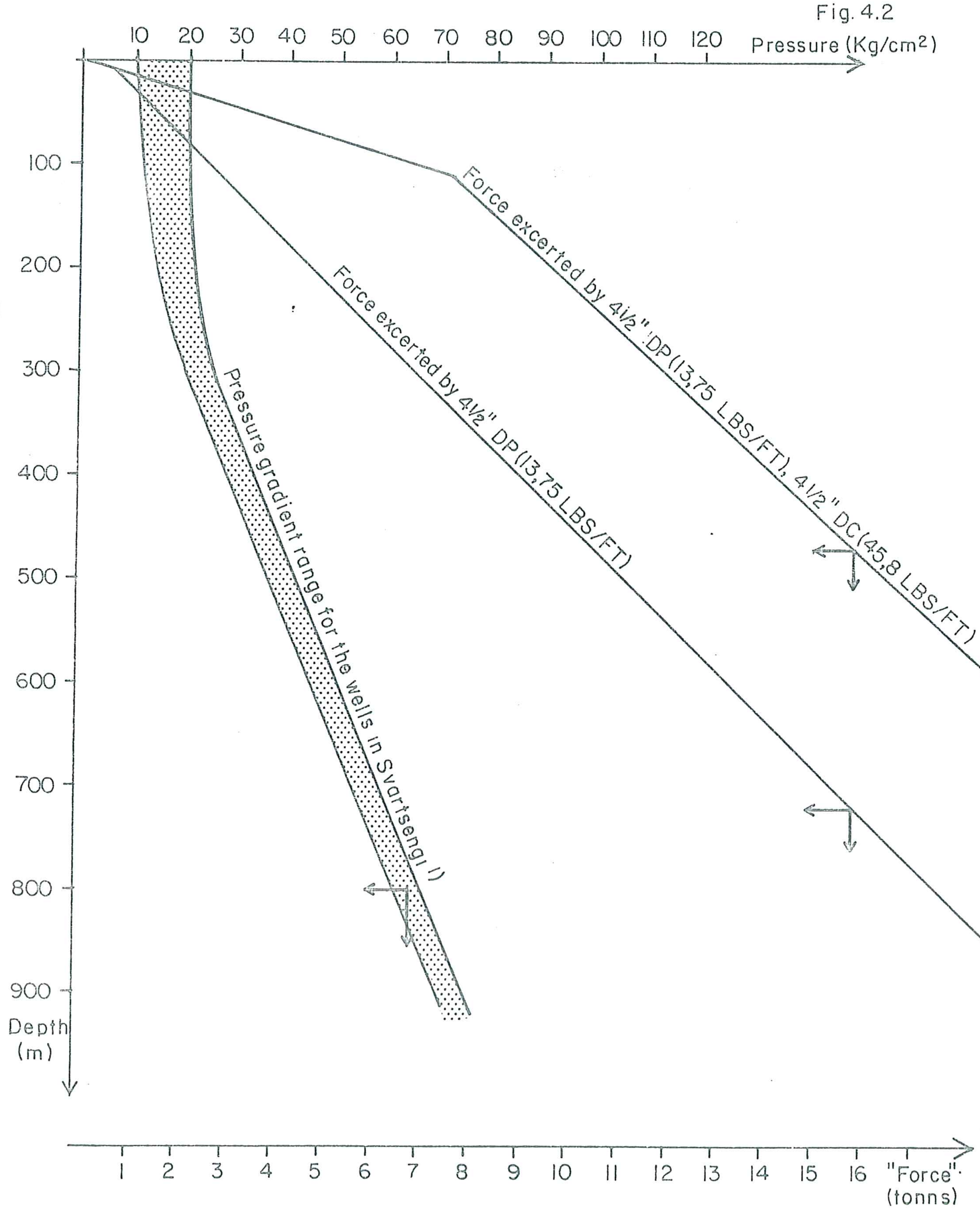
The flow restriction (fig 4.4) is a cylindrical box with a flange on top, enabling attachment to the drive bushing.

The oval holes around the cylinder (opposite the enlarged diameter section of the RDH bowl) (fig 4.5) enable cold water to reach the stripper rubber.

The lower end is partly closed by a bottom plate. In center of the bottom plate there is a piece of pipe.

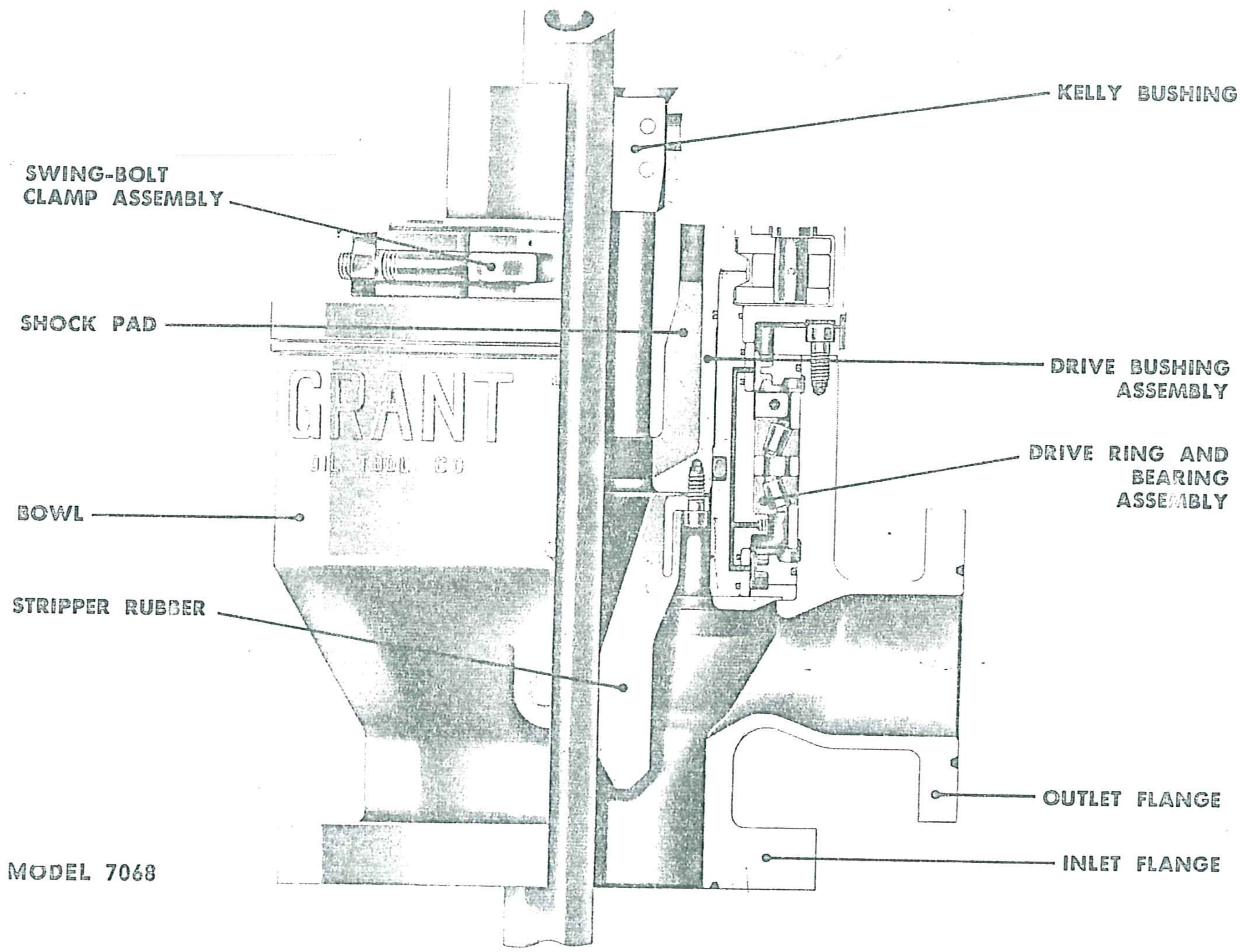
Pressure as a function of depth and "force" excerted by steam and drill string as a function of depth

Fig. 4.2



1) Based on pressure measurements as functions of depth on flowing wells in Svartsengi

The Grant Rotating Drilling head, model 7068 Fig 4.3



Ref: World Oil Composite Catalog

The flow restriction rotates with the drive bushing and the stripper rubber (fig 4.6).

The purpose of the flow restriction is to prevent steam from reaching the stripper rubber. This is achieved by pumping cold water in through the side outlet on the RDH, at a realatively high rate.

Flow restriction and cooling chamber for Grant RDH

Fig. 4.4

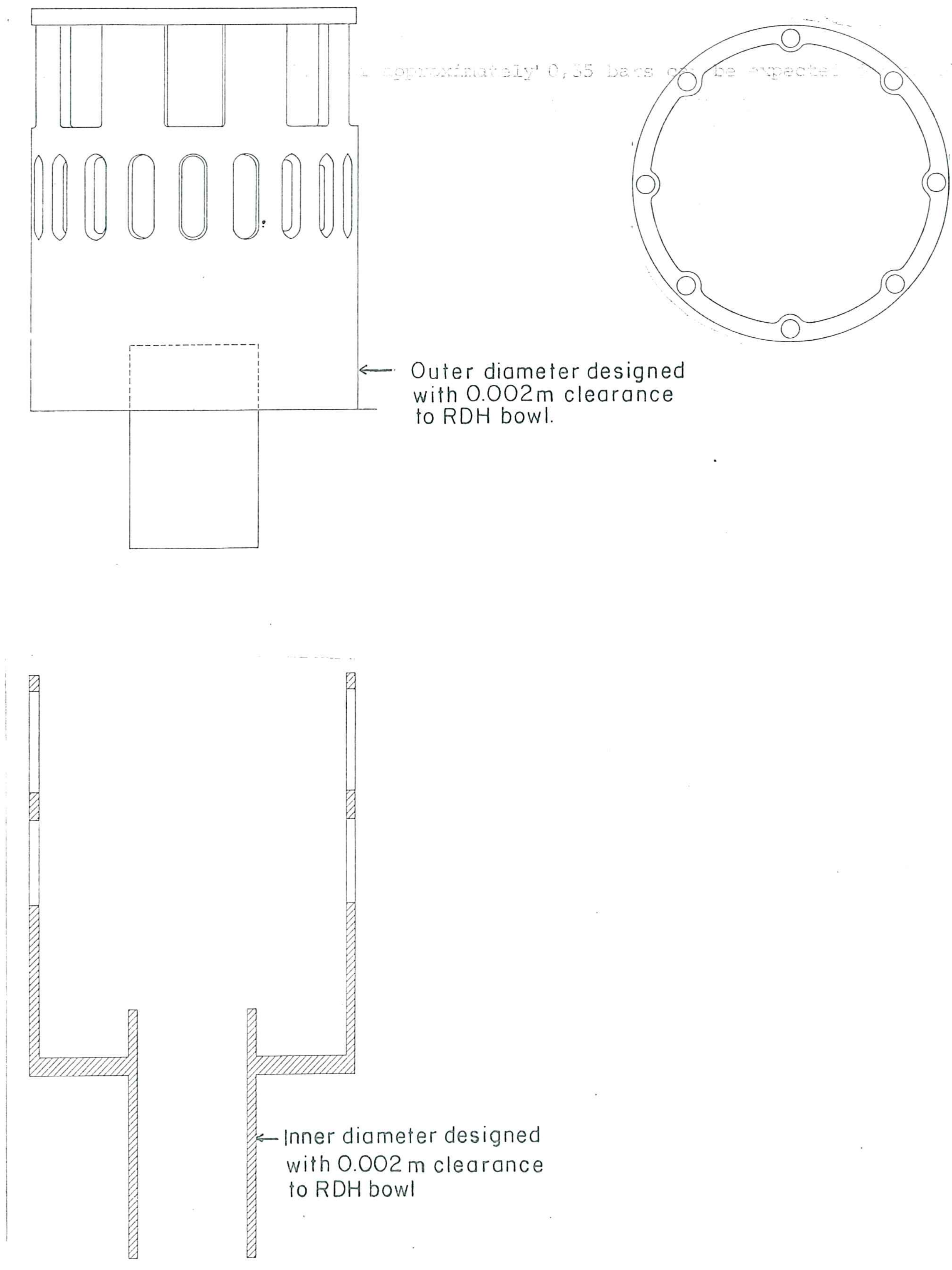
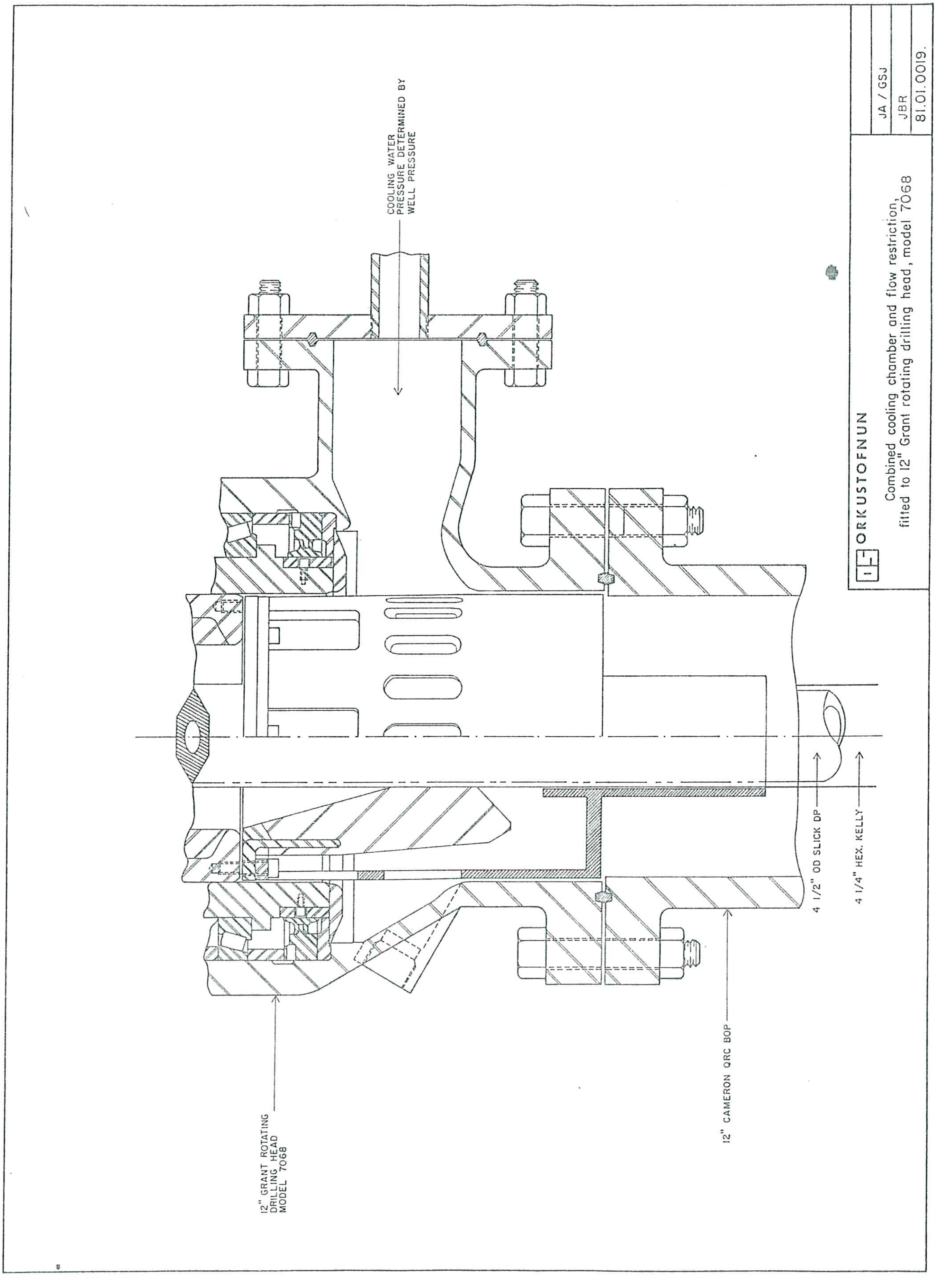


Fig. 4.5


COOLING WATER
PRESSURE DETERMINED BY
WELL PRESSURE
12" GRANT ROTATING
DRILLING HEAD
MODEL 7068
12" CAMERON QRC BOP
4 1/2" OD SLICK DP
4 1/4" HEX. KELLY
ORKUSTOFNUN
Combined cooling chamber and flow restriction,
fitted to 12" Grant rotating drilling head, model 7068
JA / GSJ
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The flow restriction is designed with a 2 mm clearance to the RDH bowl and the kelly. The original flow areas are reduced to respectively 5,5% and 5,8% for 4 1/4" drillpipe and a 4 1/4" kelly.

Calculations based on Bernoulli's equation indicates that a pressure drop of approximately 0,35 bars can be expected for a cold water rate of 20 l/s across the restriction (fig 4.7).

It is therefore believed that it is possible to prevent steam from reaching the inside of the pipe section at the bottom, and the outside of the cylinder, by maintaining a slightly higher pressure inside the RDH. This pressure is controlled by the pump rate and the pressure below the restriction.

There will be friction between the inside of the bowl and the outside of the cylinder due to excentric rotation of the drillstring, but the effect is believed to be negligible due to the flowing cold water. The rate of cold water flowing on the outside of the restriction will however be relatively low. Calculations indicate that approximately 1% of the cold water will flow on the outside.

4.5 Brief outline of the proposed work procedure

- The stripper rubber and the flow restriction are screwed on to the kelly, and lowered down in the RDH.

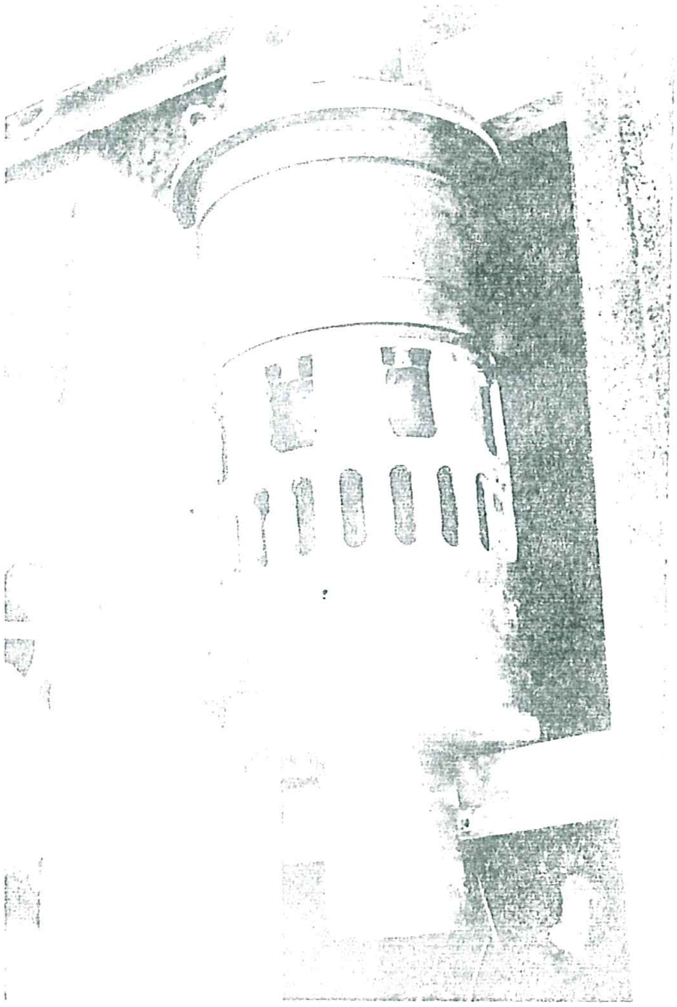
- The kelly with the short pipe section and a specially prepared penetration sub is lowered down through the stripper rubber and the flow restriction. Possibly with the help of the pulldown system.

- The kelly is then lifted up with the drive bushing assembly, the stripper rubber, and the flow restriction fastened to the kelly by the stripper rubber.

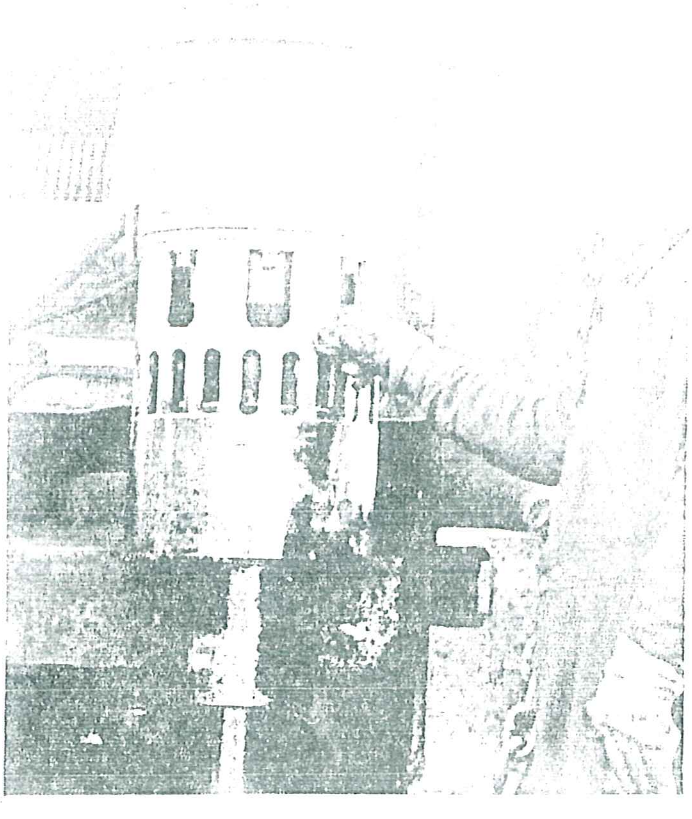
- The penetration sub is removed, and the bit and the bit sub is fastened to the pipe.

- The kelly and the rest of the equipment is lowered down in the RDH again, and the drivebushing assembly is fastened to the RDH bowl by the swing-bolt clamp.

Fig 4.6



a) Flow restriction fastened to the drive bushing with the stripper rubber inside the flow restriction



b) Drivebushing, stripper rubber and flow restriction threaded onto the kelly

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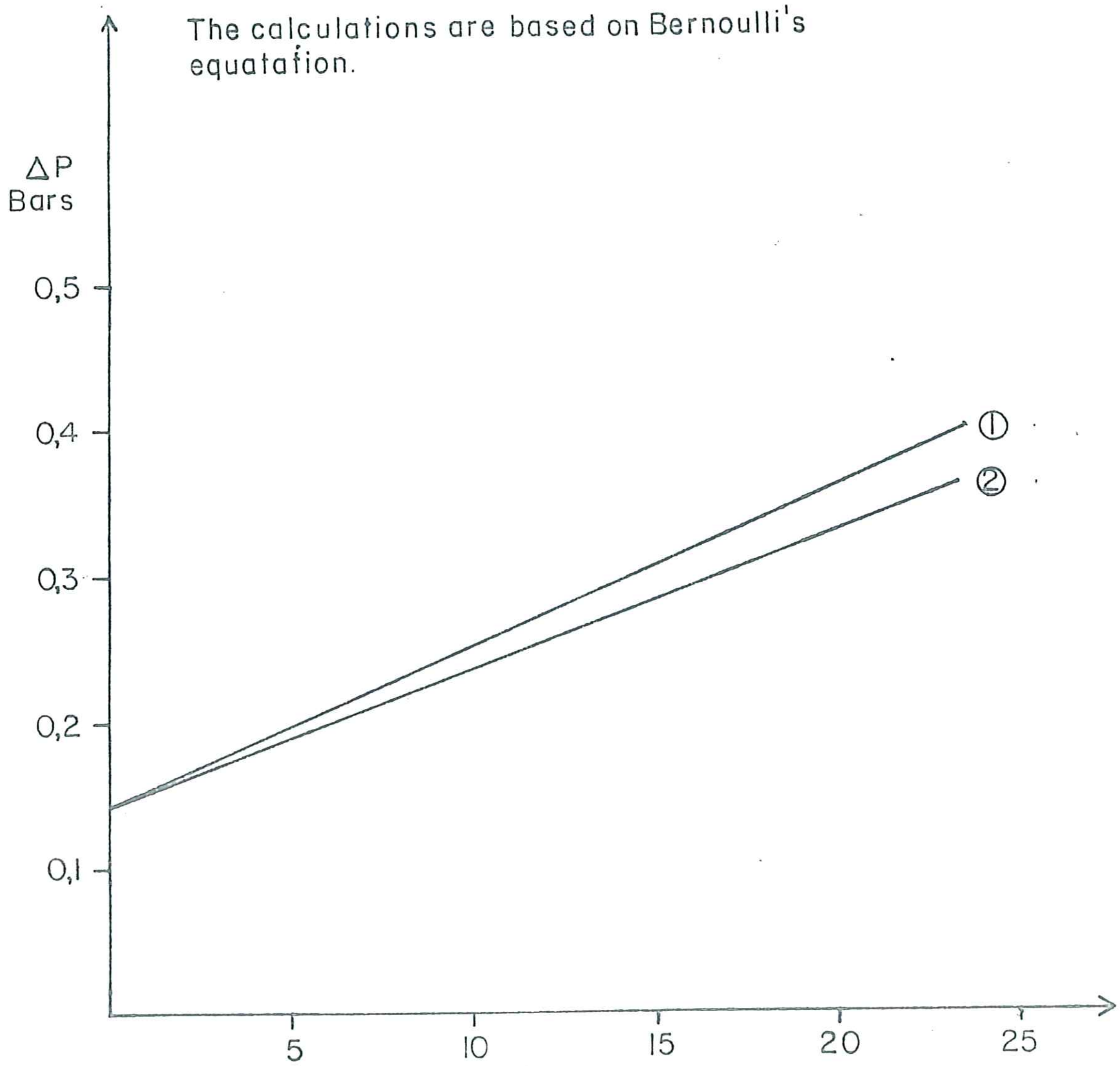
Pressure drop across the flow restriction as function of cold water flow rate

Fig. 4.7



NB! The pressure drop is calculated between the center of the cold water line and the center of the flow line in order to be comparable to the ΔP measurements made during the test

①: Ref: Drillpipe through the restriction

②: Ref: Kelly through the restriction

- The kelly is removed, and the first section of pipe or collar is fastened to the short pipe.

- Circulation of cold water through the RDH begins.

- The pipe is lowered into the hole by means of the pulldown system (the first 30 to 80 meters). The pulldown is disconnected when it is no longer needed.

- When the deposite is reached, the kelly and the kelly bushing are installed.

- The scale deposite is drilled out (6-12 hrs.). The chips/cuttings will be removed by the flowing steam. A drilling fluid is therefore not needed.

- The above mentioned stripping procedure is reversed and ended when the short pipe section sits in the rotary table.

- The mastervalve is closed.

- The swingbolt clamp is opened, and the drivebushing, stripper rubber, the flow restriction and the bit are lifted out of the RDH. This completes the workover.

4.6 The test equipment

The test equipment was more or less identical to the equipment proposed for the workover procedure (figs 4.1 and 4.8).

The RDH was a 12" with a 14" bore diameter, and the BOP a 13 5/8" Cameron QRC, with a 13 5/8" bore diameter.

The Wabco 2000 rig was used (Glaumur). 3 points for temperature and pressure measurements on the well head equipment were selected. Point 0, below master valve, point 1, at the diverter and point 2, inside the RDH (fig 4.1). Below master valve, point 0, was only the pressure measured.

At the diverter, point 1, was temperature, and pressure (indirectly) measured.

Inside the RDH, point 2, was temperature, pressure and rate of cold water measured.

In addition the pressure differential between point 2 and 1 was measured (ΔP_{2-1}) and the liquid flowrate from the silencer ($Q_{1\ liq}$).

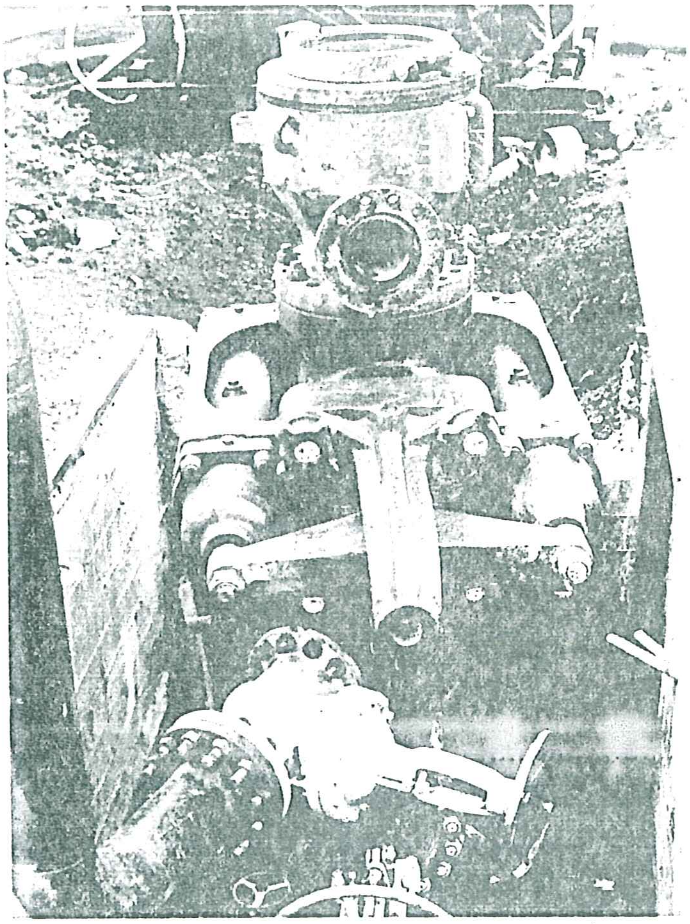


Fig 4.8

The RDH, BOP and flow diverter mounted on top of the master valve (well No. 6. Svartsengi)

P_o, P_2, ΔP_{2-1} . T_1 and T_2 were registered continously, while P_1 could be calculated from P_2 and ΔP_{2-1}, or read from a pressure gauge (both methods gave inacurate results).

$Q_{1\ liq}$ was calculated by means of a V-weir and calibration tables.
Q_2 was calculated from pump strokes and calibration tables.

5. Results and discussion

5.1 General

Because both the equipment and the workprocedure were new to this application, all steps were carried out extremely carefully.

In order to separate the various stages of the test, it can be said that there were 5 operational modes or phases.

Phase 1: Pressure testing with cold water, and with the master valve closed.

Phase 2: Gradual opening at the master valve (operating the equipment under pressures less than the desired test pressure).

Phase 3: Full pressure.

Phase 4: Full pressure and reciprocation or rotation.

Phase 5: Destructive testing of the stripper rubber and BOP seals.

The tests were carried out during 4 days, with a total of 5 test runs.

The last test run was entirely devoted to temperature testing of the stripper rubber and the BOP seals. The cold water was cut off and the temperature inside the RDH allowed to rise.

Some difficulties were experienced. The pressure meters tended to freeze in the cold weather (last 3 days). The T_1 - meter started to leak after the second day. The T_2 - meter started to leak during the destructive testing. The ΔP_{2-1} meter broke down the second day.

It was soon realized that P_o, P_2 and T_2 were the measurements of crucial importance to the test. The lack of T_1 and ΔP_{2-1} measurements did not have any significance.

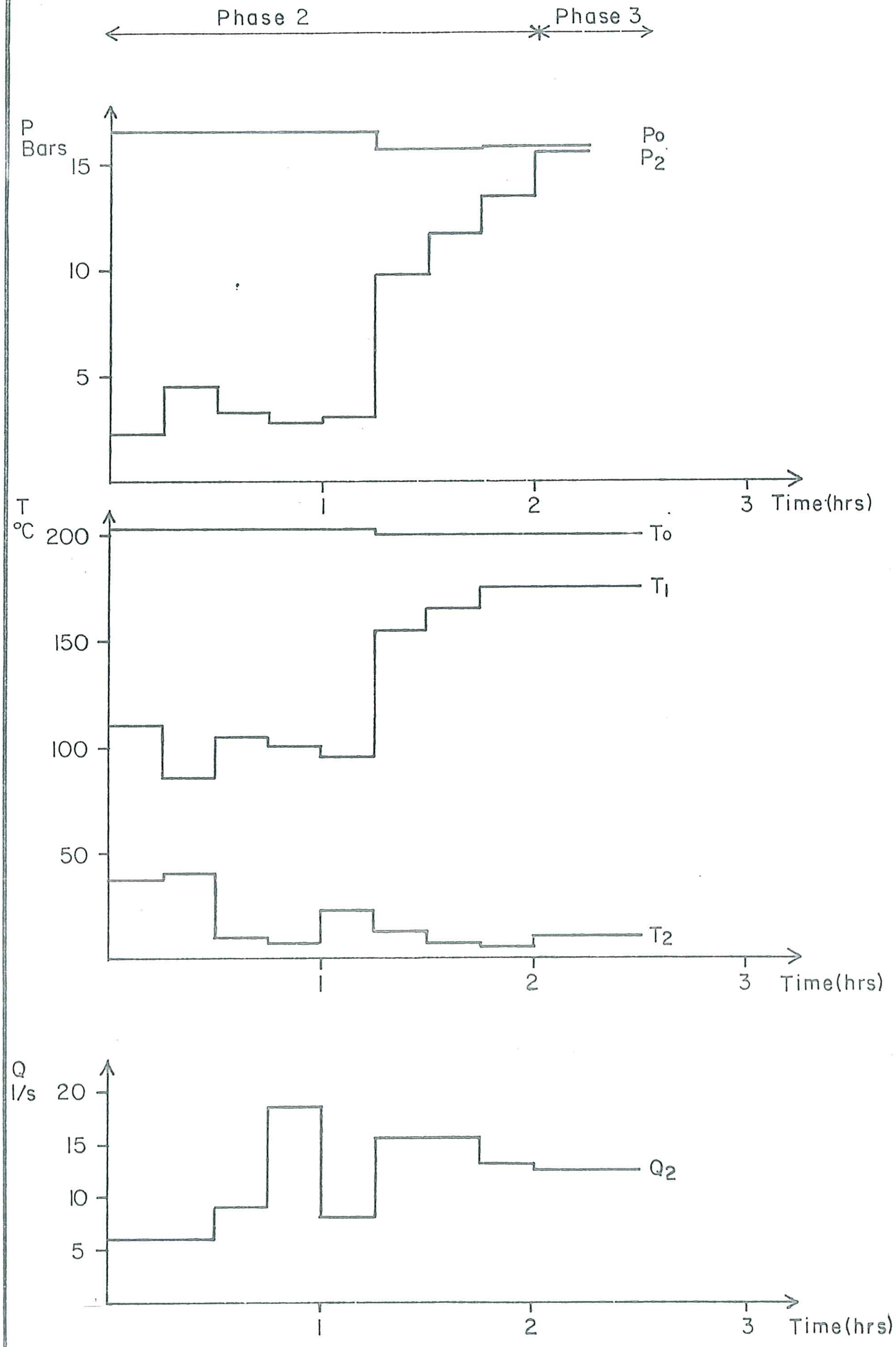
For further information on how the test progressed, see appendix 1.

5.2 Results obtained during test run No. 1, 2, 3 and 4

A somewhat simplified presentation of the results can be seen in figs 5.1, 5.2, 5.3 and 5.4.

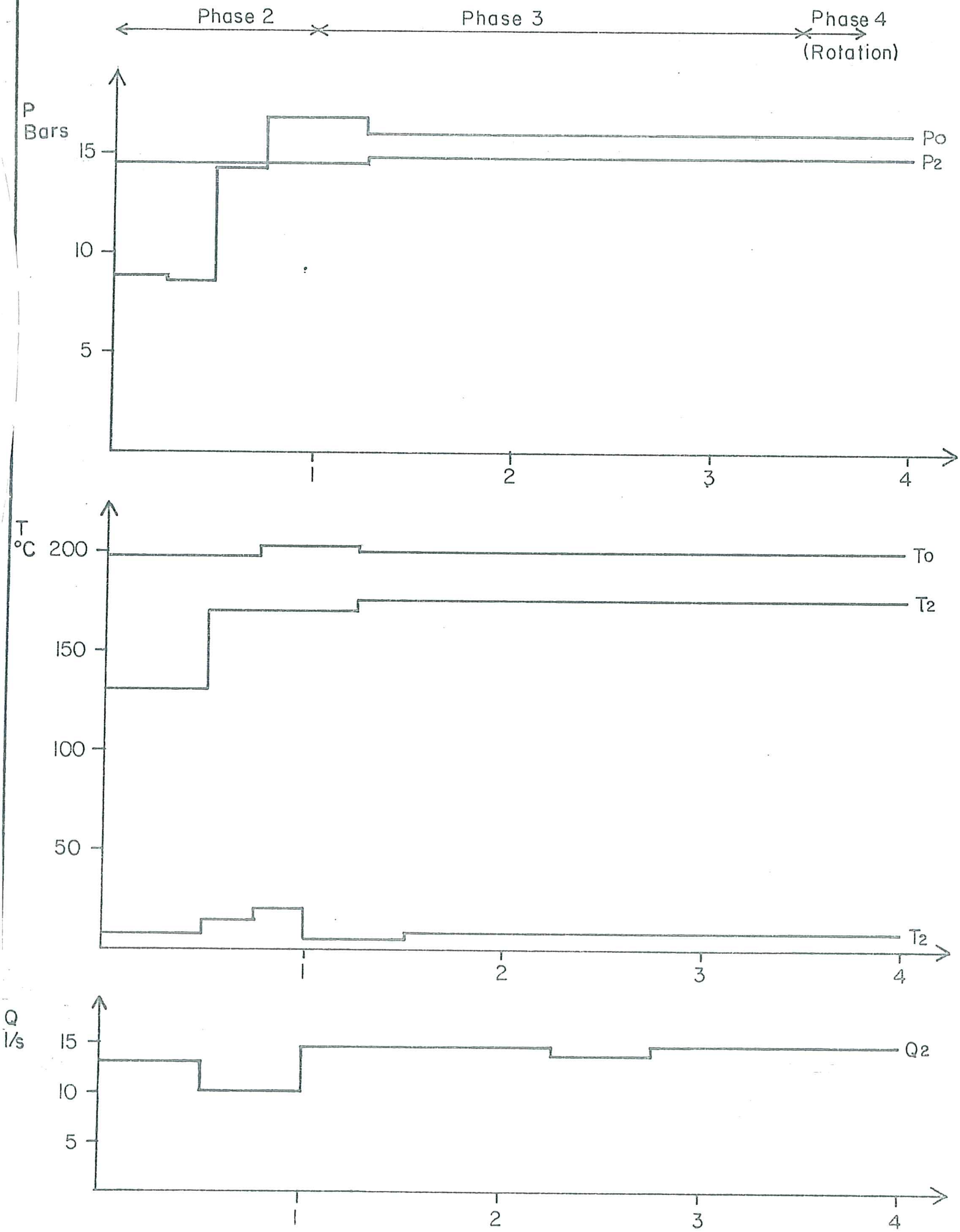
Date obtained during test run I

Fig 5.1



Date obtained during test run 2

Fig 5.2



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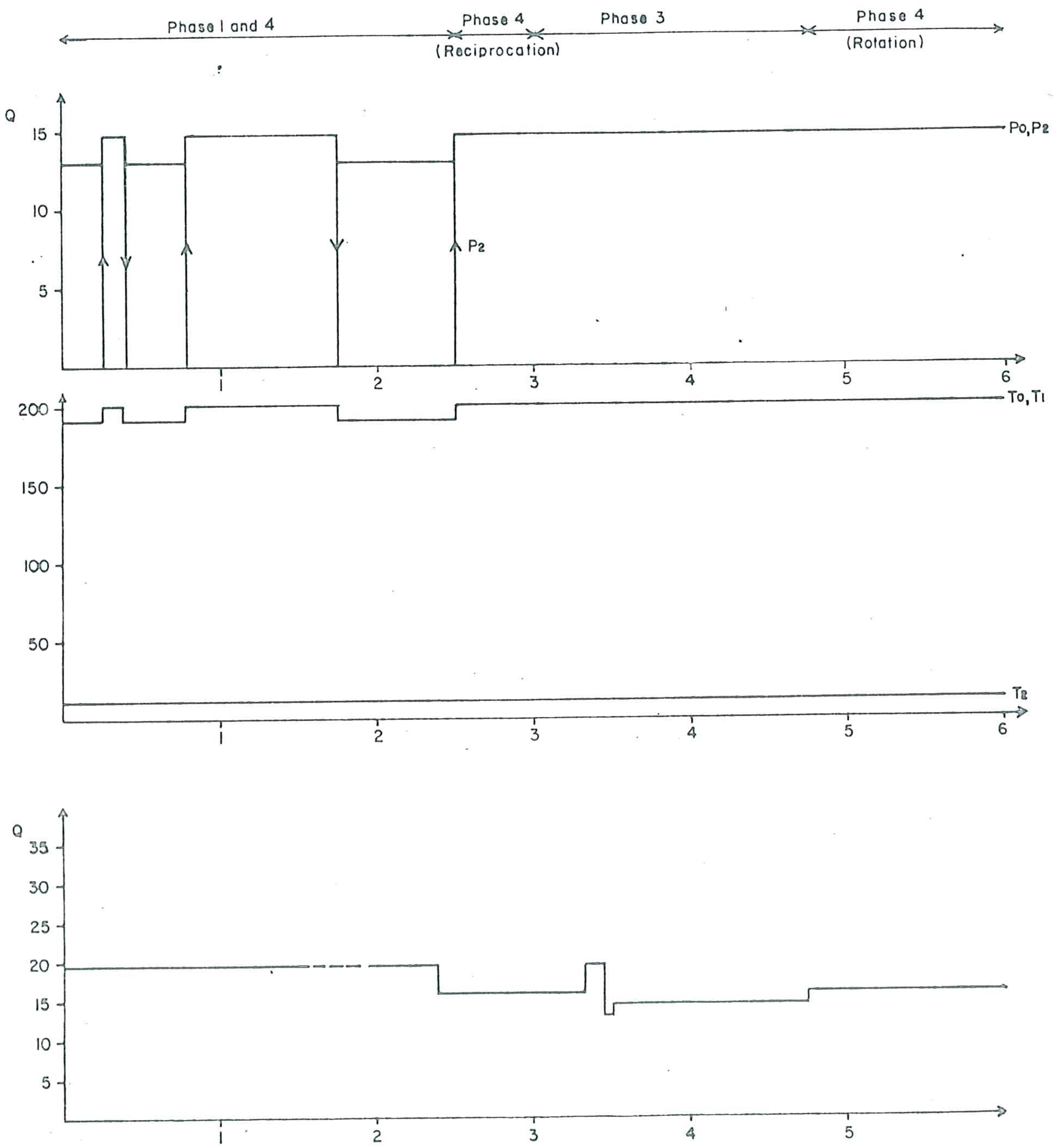
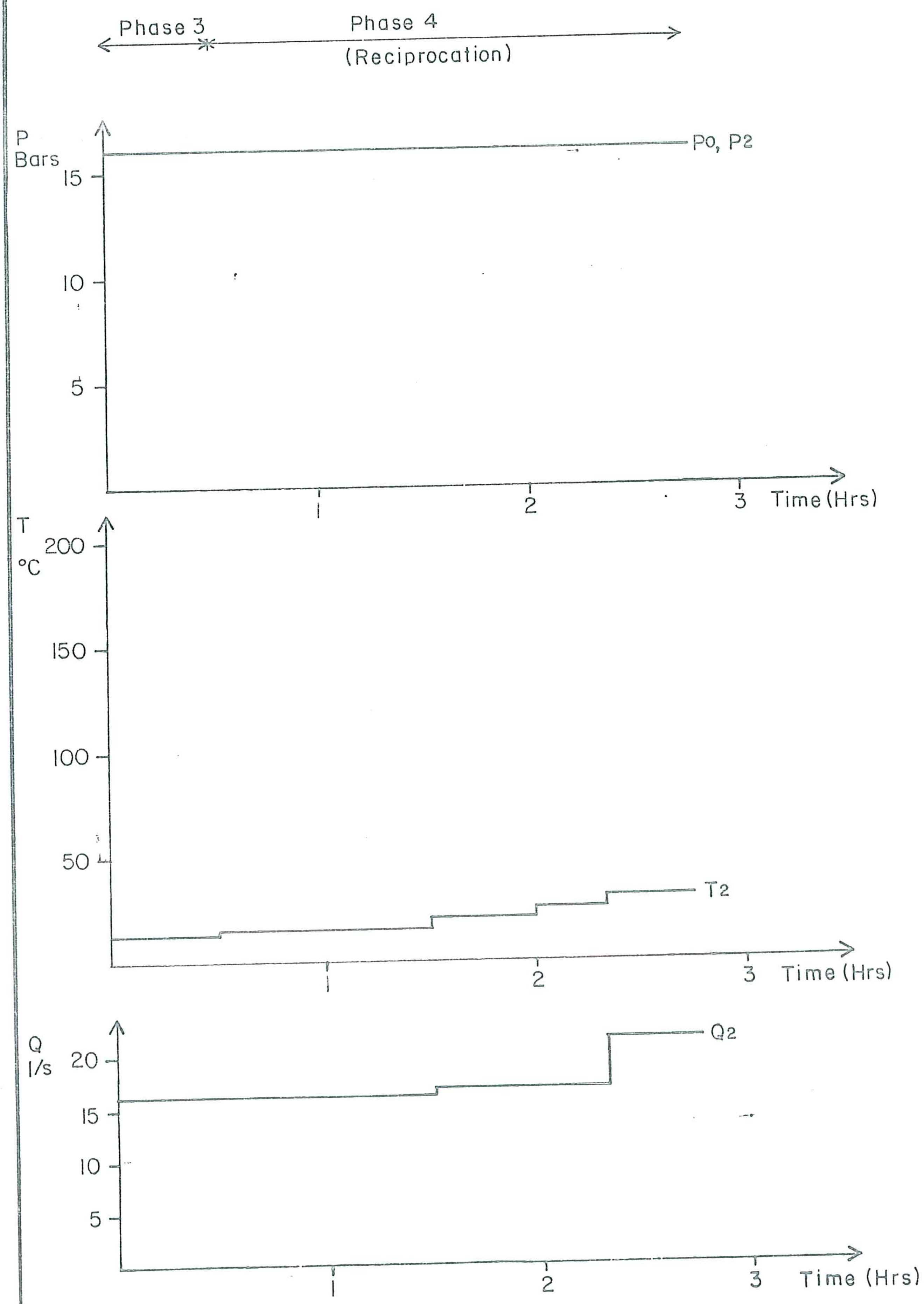
Data obtained during test run 3

Fig. 5.3



Data obtained during test run 4

Fig. 5.4



Test run No. 1 contains mainly phase 2 data. It can be seen from fig 5.1 that the temperature inside the RDH, T_2, was neither affected by the rising pressure inside the RDH, P_2, nor the rising temperature below the RDH, T_1, T_2 was however affected by the rate of cold water, Q_2.

Test run No. 2 contains mainly phase 3 data, but also some phase 2 and 4 data. The results obtained here were very similar to the ones obtained during test run No. 1. Q_2 seemed to be the only parameter affecting T_2. Rotation did not seem to have any effect on T_2.

Test run No. 3 (fig 5.3) contains mainly phase 3 data and some phase 4 data. The gradual build up of pressure (phase 2) was omitted and the master valve fully opened within a few minutes.

The results showed that it was possible to maintain stable temperature and pressure without difficulties for indefinite periods of time.

Neither reciprocation nor rotation of kelly seemed to have any effect on T_2.

Test run No. 4 (fig 5.4) contains mainly phase 4 data, and some phase 3.

The results showed that T_2 seemed to be affected by reciprocation of the pipe as the temperature tended to rise during this work operation. T_2 was not lowered when Q_2 was increased during this work operation.

The equipment was totally exposed to pressures below the wellhead pressure for 2,9 hours (phase 2), and wellhead pressure for 11,1 hours (phase 3 and 4). The kelly was rotated for 1,5 hours, and reciprocated for 0,5 hours (approximately 400 meters travelled distance). The pipe was reciprocated for 2 hours (approximately 2000 meters travelled distance).

5.3 Pressure testing (Phase 1)

The equipment was exposed to pressure up to 25 bars. No leaks were detected when all the seals were in place. Severe leakages occured at low pressures when the O-rings on the drivebushing and the RDH bowl were missing.

An attempt to establish experimental data for ΔP_{2-1}, the pressure drop across the flow restriction was made, but obviously wrong data were obtained. The ΔP_{2-1} readings were not accurate enough because of small, but disturbing fluctuations in the wellhead pressure.

5.4 Effect of cold water on T_2

Fig 5.5 contains a plot of T_2 data as a function of Q_2 for the 4 test runs.

The data obtained from the 3 first runs seem to indicate that T_2 seems to increase from the cold water temperature when Q_2 drops below 15 l/s. A rapid increase in temperature must be expected if Q_2 drops below 10 l/s.

The data obtained during test run No. 4 is not in accordance with this. This data was obtained during reciprocation of drillpipe. Steam seems to flow into the RDH on the upstroke, and the temperature seems to stabilize at increasingly higher levels, as the reciprocation continues. But it should be noted that the increase in temperature is not dramatic. 2 hours of reciprocation caused a 20°C increase in T_2.

Reciprocation of kelly did supposedly not cause any increase in T_2.

The only plausible explanation seems to be the reciprocation speed. The speed is believed to have been higher when the pipe was reciprocated, than when the kelly was reciprocated.

5.5 The flow restriction

The flow restriction seemed to work as planned.

The drawings were not followed in detail when the restriction was constructed. The bottom plate had less than 50% of the desired thickness. This plate was severely deformed by the bit sub when it hit the bottom of the restriction (presumably with a force corresponding to 2 tonns) (fig 5.6a), but this did not have any effect on the function of the flow restriction. The friction between the outside of the restriction and the RDH bowl caused some wear (fig 5.6b) on the restriction.

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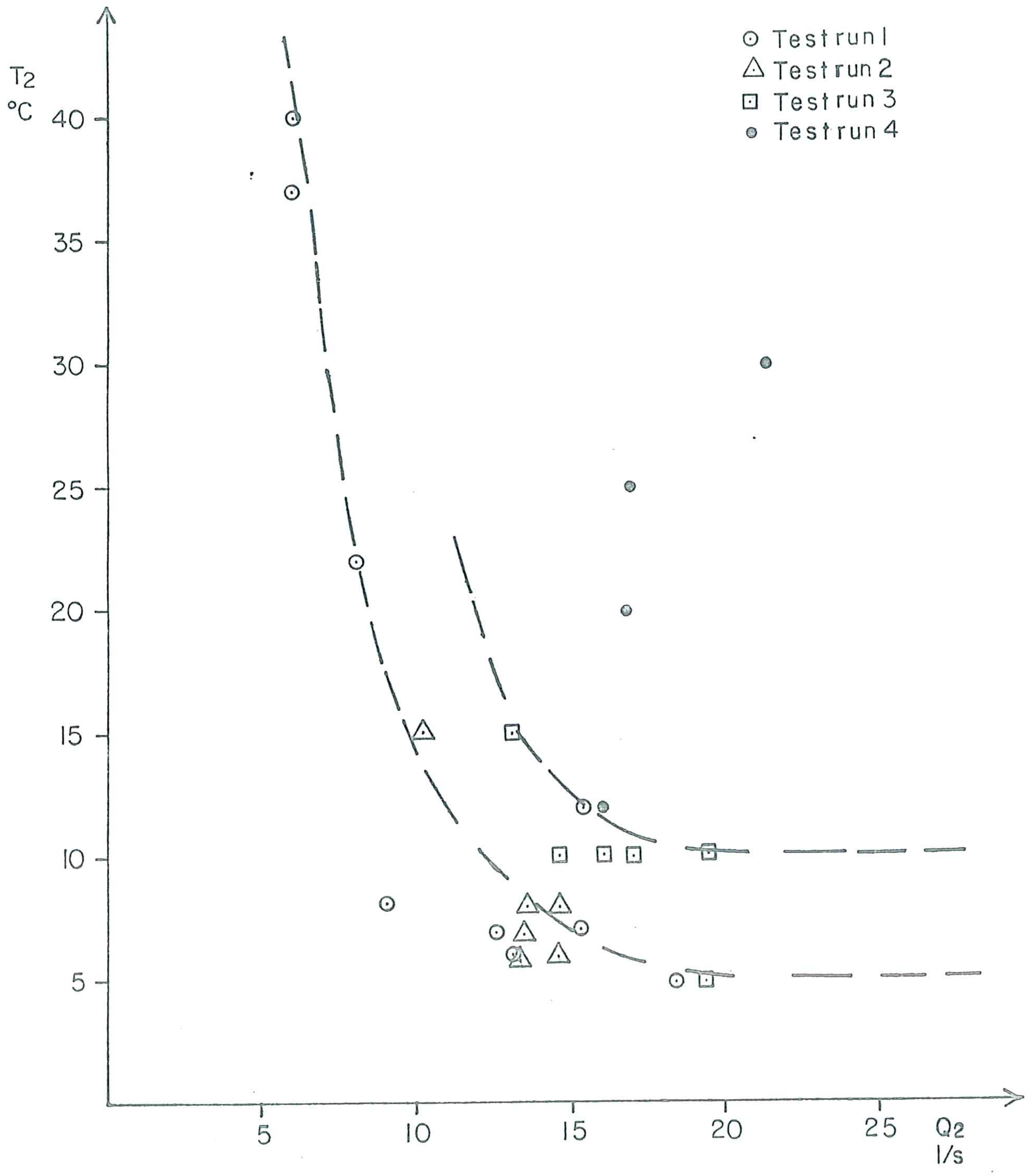
Temperativ inside the RDH as a function of cold water rate

Fig. 5.5



No cracks were detected in the top flange of the restriction (fig 5.6 c and d).

The ΔP_{2-1}, measurements had, as already mentioned, a very low accuracy. Some of the data show a fairly good concordance with the curve in fig 4.5, while some of the data indicates that the curve gives to high values.

The test showed that ΔP_{2-1} by no means is critical to the operation, it is therefore not necessary to try to stretch this data any further.

5.6 The stripper rubber

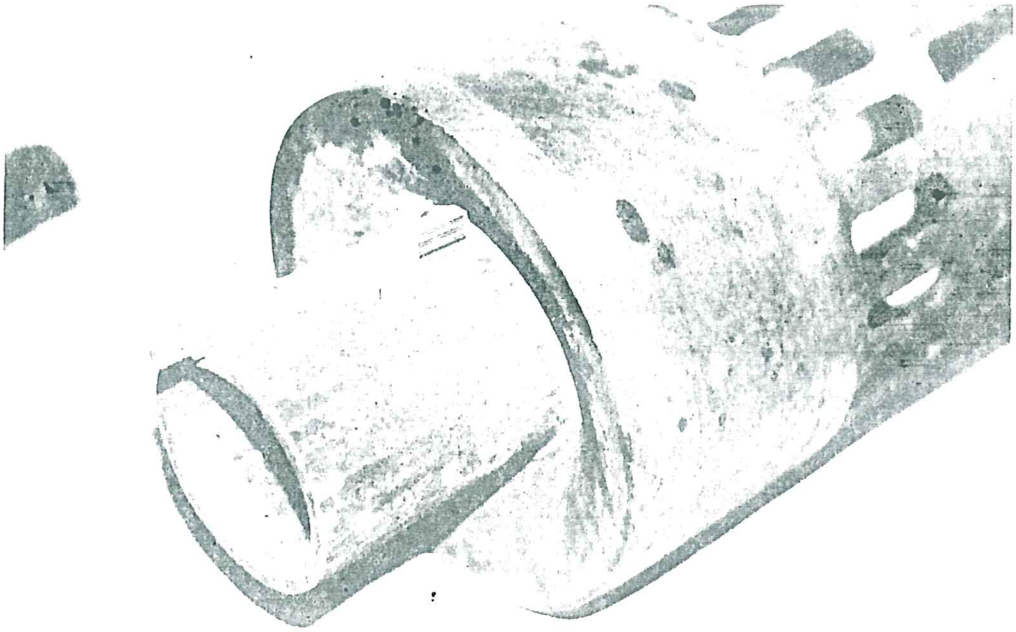
The stripper rubber was inspected twice, after test run No. 4 and after the destructive testing, test run No. 5.

Test run No. 5 lasted for one hour. The temperature inside the RDH was 195°C and the pressure 16 bars.

No leaks originating from the stripper rubber were detected during the test.

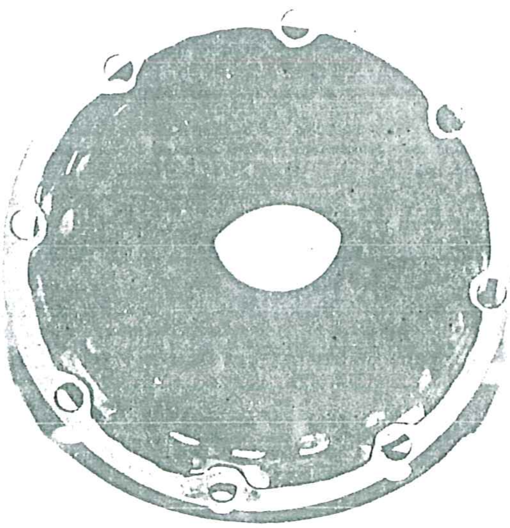
The rubber was slightly deformed after test run No. 4. The hole through the rubber was at this point approximately 3", while it originally had been 2 1/2".

Fig 5.6



a) The flow restriction deformed after being hit by bit sub

b) Wear on the flow restriction caused by friction between the restriction and the RDH bowl



c) Top flange of the restriction un-damaged after the testing

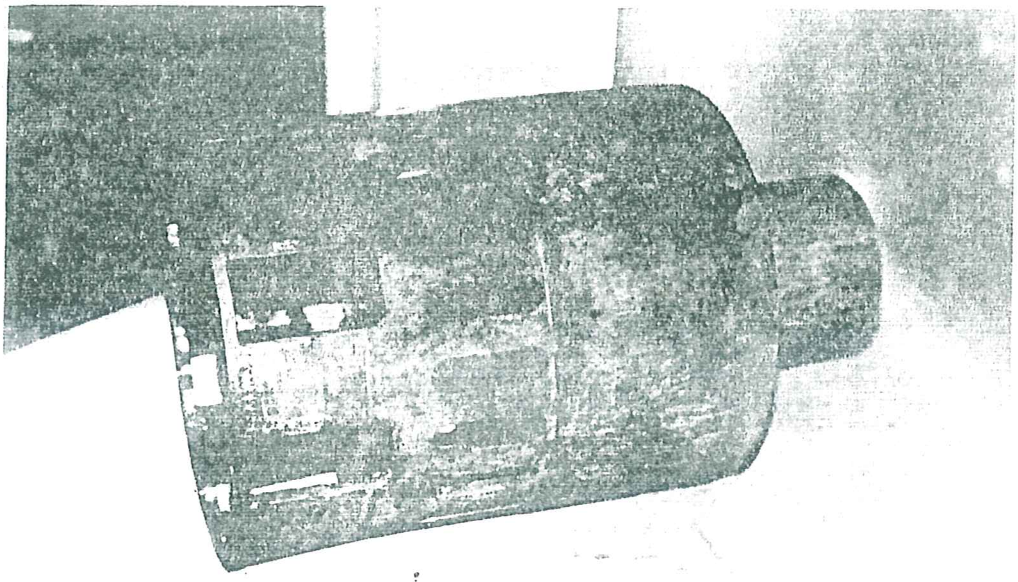


Fig. 5.6 (continued)

d). The restriction after the testing, undamaged.

Some of this can have been caused by wear, but it is most likely that deformation is the cause, because the outer diameter of the rubber was slightly increased.

The rubber was severely deformed and damaged after test run no. 5. As can be seen from fig. 5.7 , when the rubber is compared with an undamaged rubber, the hole is now drastically enlarged. The hole was measured to be 4".
The stripper rubber is no longer symmetric, and there were cracks in the rubber (fig. 5.7.c) possibly originating from gas bubbles in the rubber. This explanation is supported by the fact that the whole surface of the stripper rubber was completely covered by tiny holes.

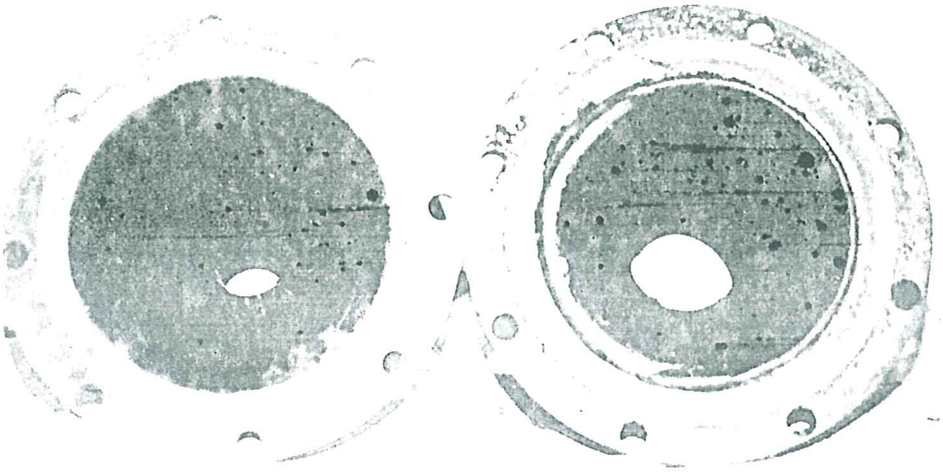
Eventhough the stripper rubber was severely damaged, it still sealed on the drillpipe.

5.7 The RDH

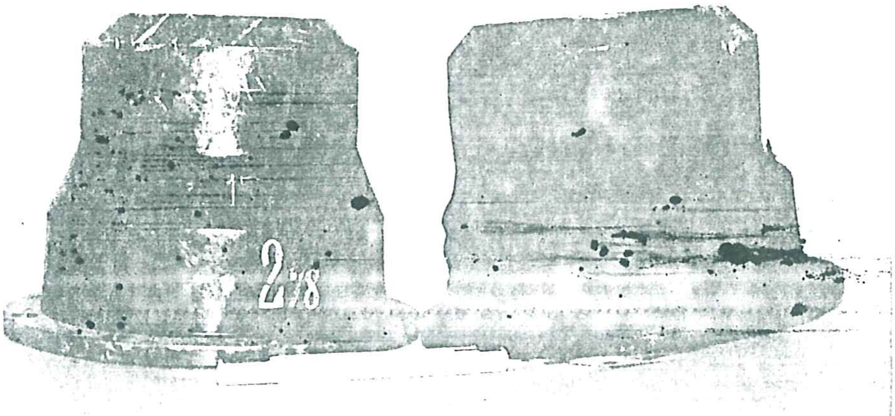
Lubrication oil from the bearings started to leak out after 30 minutes of test run no. 5. This can possibly be explained by expansion of the oil as a result of the increased temperature.

Inspection of the RDH after the test showed that it was 100% operational, eventhough one of the bearings and the seal protecting the lower end of the bearings were replaced. Grant Oil Tool Company has designed a circular plate which is intended to protect this seal. No operational difficulties with the RDH were experienced during the test.

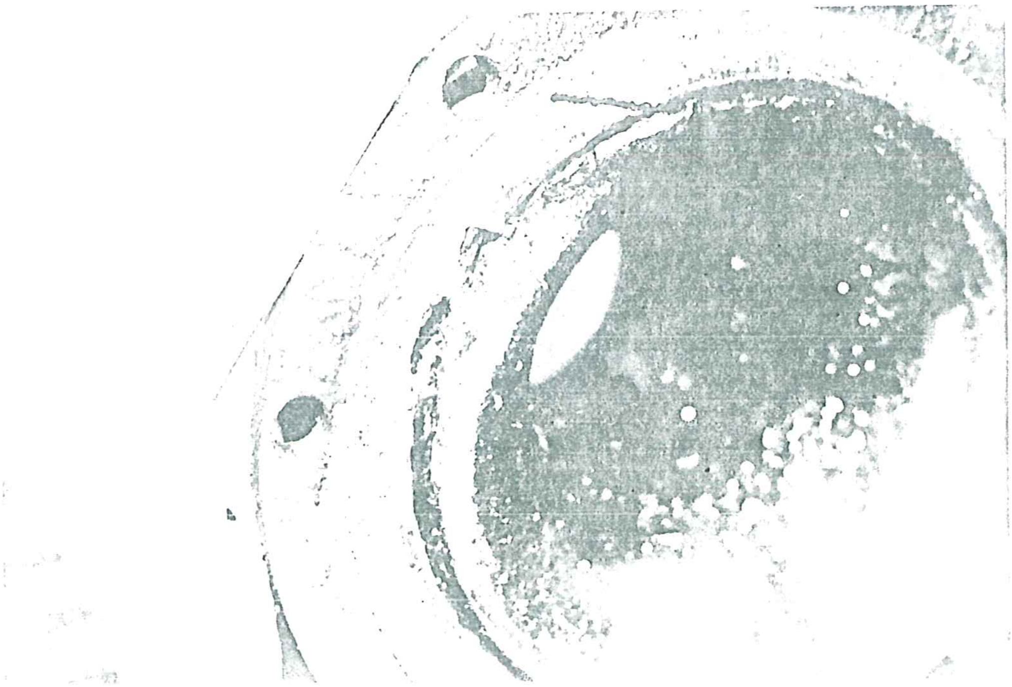
Fig. 5.7.



a) Undamaged (left) and damaged (right) stripper rubbers seen from above. Note the enlarged hole through the damaged rubber.



b) Undamaged (left) and damaged (right) stripper rubbers. Note the changes in shape.



c) Crack in stripper rubber after destructive testing.

5.8 The BOP

The BOP was operated once during the test. It was closed during test run no. 5. The BOP worked satisfactory and no steam leaked through the rams because the pressure in the RDH fell to zero immediately, and the temperature to 100°C.

Inspection of the rubber seals on the rams after the test showed that they were severely damaged (fig. 5.8).

The reason why the seals still functioned wventhough they were damaged is of course the fact that they are designed to withstand 3000 psi or 200 bars. 16 bars does therefore not put any significant strain on the seals.

Inspection of the BOP body showed that the rest of the BOP was 100% operational after the test.

5.9 The drilling rig

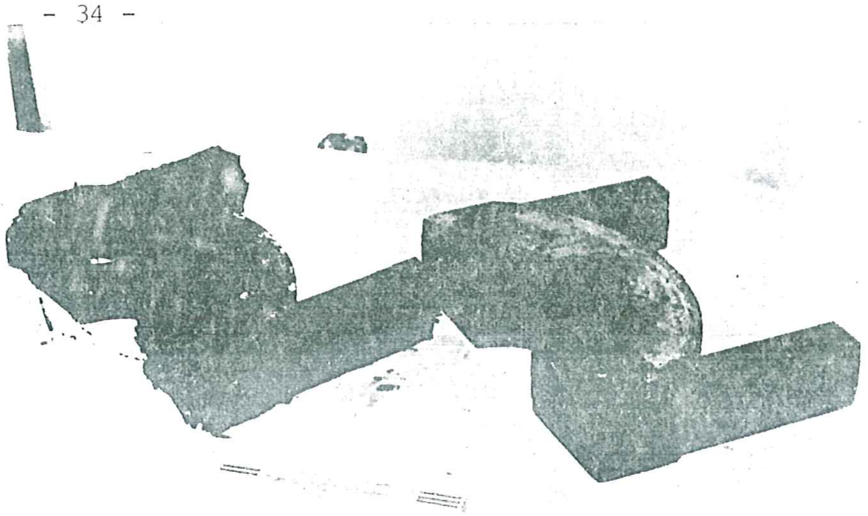
There were difficulties originating from the rig.

The distance between the top of the drive bushing on the RDH and the bottom of the rotary table was extremely small. It was necessary to burn off 5 cm of the drive bushing in order to make installation of the helly bushing bossible (fig. 5.9). The rig was jacked up to maximum hight. This problem can be solved by using a shorter BOP for instance a Schafter SL-BOP which is only half the hight, 0,45 cm vs. 0,90 m.

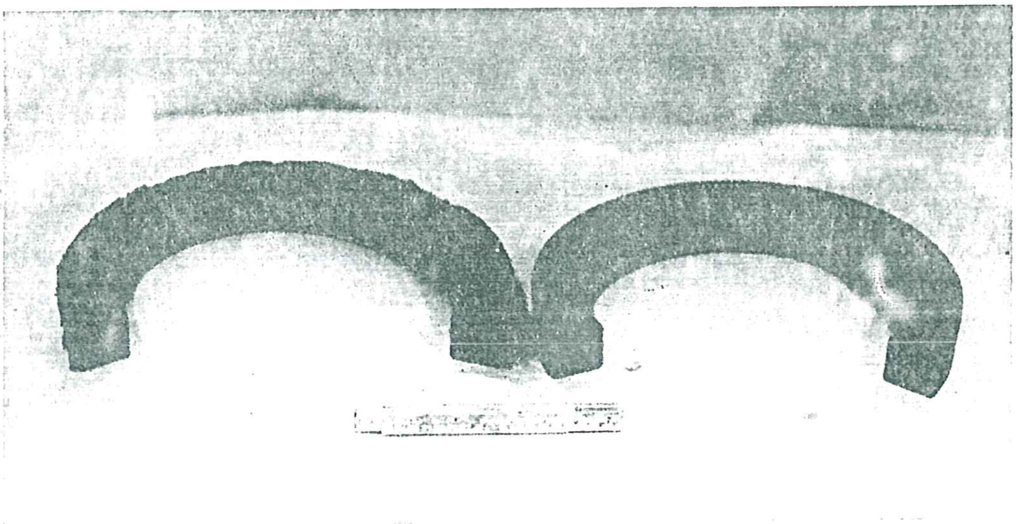
The pulldown system worked poorly, and was originally made from inferior material. The pulldown was improved several times, but still it needs to be improved.

The rotary table does not enable passage of the 16" diameter drive bushing. It was therefore necessary to remove the rotary when this piece was to be taken in and out of the hole.

Fig. 5.8.



a) Front and side seals for Cameron QRC BOP. Damaged (left) and undamaged (right). Note the worn edges.



b) Rear seals for Cameron QRC BOP Damaged (left) and undamaged (right). Note the worn edges.

It is not absolutely necessary to change the rotary, because the method being used during the test functioned, but it would ease the work.

To alligne the rig with the well proved to be difficult. The center of the rotary table was not alligned with the center of the well. This caused undersired movement of the wellhead, which strained the casing.

Except for these 4 points, the rig was functioning satisfactory.

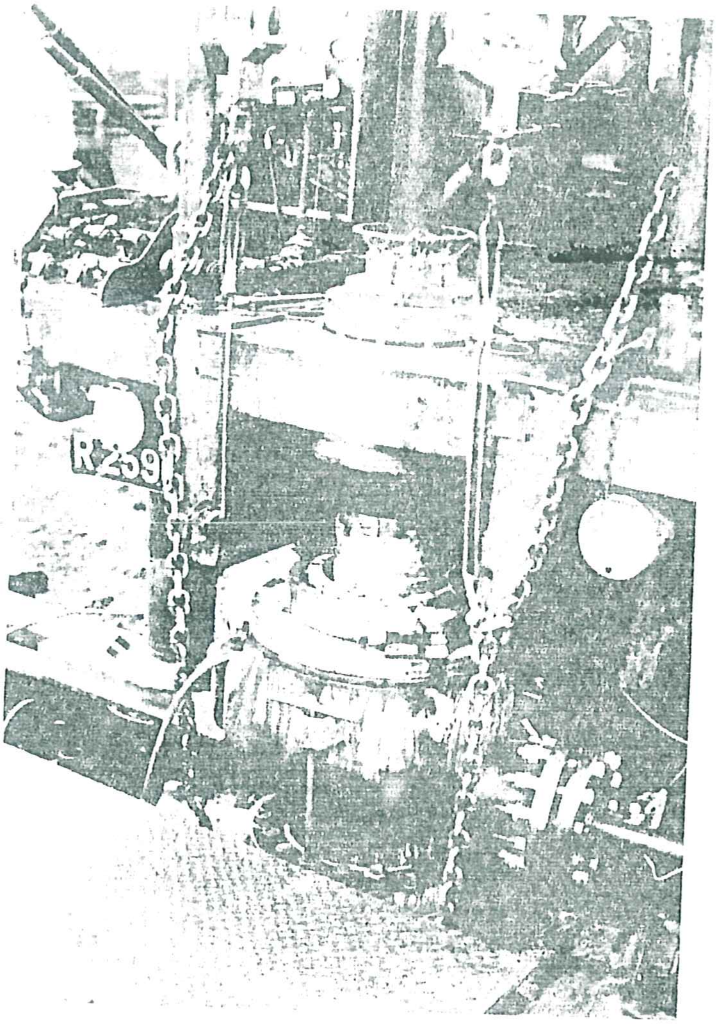


Fig. 5.9.

Rotary table and Grant RDH.
Note the extremely small clearance between the drive bushing and the rotary table.

6 CONCLUSIONS

6.1 Scope

- The test program was carried out according to its original scope.
- The test program can therefore be said to have simulated the proposed workover procedure satisfactory

6.2 The flow restriction

- The flow restriction functioned satisfactory.
- The rate of cold water should be kept above 15 l/s.
- Tripping out of the hole, or lifting of the kelly should be carried out at a moderate speed.
- The friction between the flow restriction and the RDH bowl is negligible.

6.3 The stripper rubber

- The stripper rubber functions satisfactory when operated together with the flow restriction and cold water under the conditions in Svartsengi.
- The stripper rubber deteriorates when exposed directly to the steam. The rubber will however confine the pressure for at least one hour.
- The stripper rubber is not significantly worn or deformed by normal work operations.

6.4 The RDH

- The RDH will function satisfactory for the proposed workover procedure.
- The RDH can withstand steam without being severely damaged.

6.5 The BOP

- The rubber seals on the BOP will be severely damaged during the proposed workover procedure.
- The seals will however be able to confine pressures of magnitude 15 to 20 bars, but the seals will have to be replaced after each job.

6.6 The drilling rig, Wabco 2000

- The rig functioned satisfactory, with the exception of the pulldown, and the allignment with the well.

7. RECOMMENDATIONS

7.1 The workover procedure

- There should be no need for further testing of the equipment and the proposed work procedure.

7.2 The flow restriction

- The bottom section should be made thicker (may as much as 4 cm).
- The top flange should be made without "ears" (ref. fig. 5.6.c), as there is no need for these. The "ears" are only needed for 3 1/2" and larger stripper rubbers while 2 7/8" rubbers are being used in this connection).
- The pressure drop across the restriction can be further increased by making the cylindrical section and the pipe section longer.

7.3 The stripper rubber

- The stripper rubber should be replaced after each job, as a safety precaution.

7.4 The RDH

- The circular metal plate produced by Grant Oil Tool Co. intended to protect the circular seal below the bearings should be used.

7.5 The BOP

- The rubber seals should be replaced by metal seals. This should be possible due to the relatively low pressure.

7.6 The rig

- The pulldown design should be improved.
- The space between the rotary table and the top of the RDH drive bushing should be at least 0.5 meter. This can be made possible by using a Schaffer SL BOP - or increasing the ground elevation.
- A system enabling proper alignement of the rig with the well should be developed.

7.7 Comments

This report is based on the test performed on the Grant RDH in Svartsengi. It might be possible to combine the RDH with other pieces of safety equipment other than the BOP giving the same degree of safety.

But as this potential equipment has not been tested together with the RDH, and as this report is supposed to report this particular test, such possibilities are not discussed.

A discussion of such possibilities should be carried out elsewhere.

7.8 Purchase of equipment

Some of the equipment used in connection with this test would be available for use in connection with workover in Svartsengi.
Each item is therefore discussed seperately.

RDH: There are two 12" RDH´s in Iceland, belonging to "Jötunn" and "Gufuborinn". These might be available for use, but it is probably not possible to guarantee their availability at all times.
These are equipped with 12" API 900-series flanges.
12" flanges are not standard on BOP-s any longer. If a new BOP should be purchased it is not very likely that BOPs with 12" flanges can be supplied. It is therefore recommended to select a 13 3/8" RDH which will fit in with standard BOPs.

BOP: The 12" Cameron Q C BOP from "Jötunn will not be available while "Jötunn" is drilling (4-6 months a year).
As mentioned, is this BOP rather large, approx. 90 cm height.

If it is decided to pruchase a new BOP, a 13 3/8 Schaffer SL BOP is recommended. This BOP is only 0,45 m thick.

The rig: No major changes on the rig would be necessary, unless it is decided to change the rotary Table.

The Kelly: The 4 1/4" hexagonal Kelly used in connection with the test, would be available for workover any time.

The drillpipe: There are presently 3 lengths of 4 1/2" OD slick drillpipe of rather poor quality in Iceland. Another 77 lengths (approximately) would be needed.

The drill collars: There are no 4 1/2 OD slick drill collars in Iceland. Approximately 10 lengths are needed.

The rest of the equipment such as pump, subs etc. is available.

7.9 Costs

A rough estimate of the cost of the nedded equipment, PR. 81-10-01 is

13 5/8" Grant RDH, model 7068	$ 23.000
13 5/8" Shaffer SL BOP	$ 75.000
800 meters of 4 1/2" OD slick drillpipe	~ $ 50.000
100 meters of 4 1/2" OD slick drill collars	~ $ 25.000
Misc.	$ 5.000
	$ 178.000

APPENDIX I

Test Diary

Day 1 (11/3)

The rig arrived at well no. 6 at 10.30 . It proved difficult to allign the rig with the well. The rig ended up in a small but significant angle to the cellar. It was therefore necessary to make a new support column for the right rig support.

The pump was not operating when it arrived, but it was repaired, and was, according to the rig crew,operating at the end of the day.

One of the openings on the cooling water manifold was delivered with faulty threads. These threads were sawed off and new threads were welded on.

The threads on the cooling water inlet for the RDH were also different from the specifications given. It was decided to leave these threads as they were.

Day 2 (12/3)

The fluted helly on the rig was removed, and the hexagonal helly was to be installed. It was then discovered that the sub which was intended to fit between the svivel and the kelly, was equipped with KG-20 threads instead of KG-40 threads.
It was therefore necessary to make a new sub. This sub was prepared by cutting the subs which respectively fitted the helly and the wivel and welding these together. This caused a 10 hour delay.

It was also discovered that the lower end of kelly was equipped with 3 1/2" IF-pin. The helly was originally equipped with 3 1/2" IF - box, which was the basis for the design of subs, which were to be used below the kelly. This problem was solved by using a box-box cross over rub.

An attempt to test the pump failed because the starter motor on the pump broke down. An electrician was called from Reykjavík.

The kelly was installed, and the start engine replaced at the end of the day, - 23.00 .

Day 3 (13/3)

The work platform in front of the rig was installed.
The temperature and pressure recording equipment was installed.
The equipment was pressure tested with the master valve and the flowline valve closed. A major leak occurred immediately on top of the RDH. An inspection of the drive bushing assembly and the inside of the RDH revealed that two O-rings were missing.
The thin rubber seal on the drive bushing was installed and the pressure test repeated. No leaks occurred when the pressure exceeded 4 bars.
The pressure was increased up to 25 bars, and no leaks occurred.

An attempt to investigate the relationship between flowrate and pressure drop across the box was made.

The master valve was gradually opened during a 2 1/2 hour period, the cooling water rate was adjusted accordingly. Full pressure was maintained on the box for about 20 min. The results were considered promissing.

Day 4 (16/3)

The missing seal in the RDH body was installed.
The pump was not operating satisfactory due to cement in one of the valves. The pump was running satisfactory after the cement was removed (The pump has previously been used for cementing operations).

The pressure on the equipment was gradually increased untill full pressure was reached after one hour.
Full pressure was maintained for 1 1/2 hour.
In order to install the kelly bushing for the RDH, it was necessary to remove the upper 5 cm of the drive bushing (The clearance between the rotary table and the drive bushing did not allow installation of the bushing).
The kelly was let through the stripper rubber, and to tated for approximately half an hour. Excessively high torque was experienced when the kelly was rotated. The most likely causes for this were the bit (which did not have any moving parts, and consequently caused high friction when rotated in contact with the casing) and the slightly off center location of the rotary table with regard to the well (~ 5 cm).

The kelly was pulled up, and put down again. The load on the pulldown during this operation was measured to 10.000 lbs.
The rotation was continued for another 20 min.

At this point were loads on the pull down as high as 15.000 lbs measured, this corresponded to a load of 3.4 tons on each tally. The tallies were rated for 2 tonns, and as cracks in the paint on the tallies were detected, it was decided to end the test. The tallies were obviously not safe.
It was therefore decided to replace the tallies with stronger ones, and weld on new hooks for the tallies on the rig, on each side of the rotary table.

One of the temperature probes was at this point leaking heavily, it was decided to take it back to Reykjavík for repair.

Day 5 (17/3)

The decided alterations on the pulldown were made, and the bit replaced by a closed rub.

The pressure on the equipment was increased rapidly, during a 10 min. period, up to full pressure. The temperature probe which was suposeoly repaired, started to leak immediately. The master valve was closed and the temperature probe replaced by a plug.
The meter for ΔP measurements started to give erratic values, probably due to the low ambient air temperature (-8°C). The meter was therefore shut down.

The pressure on the equipment was increased upto full pressure, during a 2 min. period. Pipe was then pulled up and down through the stripper rubber for about 15 min. This test was then ended due to brouble with the pull down.

The master valve was then closed and the pulldown inspected. It was decided to pull kelly up and down instead due to the above mentioned difficulties. The kelly was pulled up and down irregularly for approximately half an hour during a one hour period.
The test was ended when excessive wear on the pulldown wires was discovered.
The pressure probe inside the RDH started to give erratic, fluctuating values. The probe was frozen, but functioned satisfactory when thawed up.

The kelly was then rotated for 1 1/4 hour. This ended day 5. The system had then been under full pressure for 3 hours and 40 min.

Day 6 (18/3)

The wire in the pulldown system were replaced. Full pressure on the system was reached during a 4 min. period.
Pipe was then pulled up and down for 2 1/4 hours, tataling 2000 m of pipe through the rubber. The load on the pulldown was approx. 7000 lbs. The load was reduced significantly by pouring oil on top of the rubber,(down to approx. 5000 lbs) :

The stripper rubber was then inspected. The rubber was slightly deformed. The original diameter of the hole inside it of 2 1/2" was 3", and the outside diameter slightly increased.
Due to a leak on the cooling water inlet, it was necessary to weld this before the tests could continue.

The final destructive testing on the stripper rubber, was performed without cooling water.
Full pressure on the system was reached during a 20 min. period.
No major leakage of steam occurred. Small amounts of steam escaped up through the drive bushing but this was probably steam from the boiling water on top of the stripper rubber. The temperature inside the head was 195°C.
Lubrication oil from the RDH started to leak after half an hour.
The rate of leakage seemed to increase steadily with time

The temperature probe stopped functioning when the test started, probably due to a short circuit caused by a steam leakage. However, it began functioning again after 45 min., when steam started to leak through the probe.

The test was aborted after 1 hour and 5 min., when it was feared that the leakage in the lubrication system and the high temperature might ruin the RDH (and the stripper rubber).

The test was ended by closing the BOP. No leaks through the BOP were detected.