PUBLIC POWER CORPORATION

ATHENS, GREECE

MILOS GEOTHERMAL DEVELOPMENT

Consultant's Field Report

December 1988

ORKUSTOFNUN
NATIONAL ENERGY AUTHORITY

VIRKIR CONSULTING GROUP LTD.

REYKJAVÍK, ICELAND

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1. INTRODUCTION

At the request of Public Power Corporation two consultants from Virkir/NEA, Mr. Sverrir Thorhallsson and Dr. Einar Tjörvi Elíasson, traveled to Greece, December 13-22, to inspect the turbine and surface equipment of the 2 MW geothermal power plant on Milos.

The turbine rotor was removed for inspection to determine the effectiveness of "turbine washing" to remove deposits, and to see whether it had caused any erosion damage. The steam separators and parts of the reinjection system were also opened for inspection.

During their stay on Milos, the Consultants took part in several meetings between Mitsubishi and the Public Power Corporation. Minutes were taken by PPC at these meetings, and two Field Reports were submitted to PPC during their stay. Before departing from Athens, the Consultants also had a meeting with Mr. A. Ghinis. This report provides a more detailed description of the findings. A copy of the Field Reports is included in the Appendix.

Since the December visit, Virkir/NEA has replied to requests from PPC and provided addresses of firms supplying equipment for the control of hydrogen sulfide emissions. On March 3, Virkir/NEA received from PPC a report by Mitsubishi (MHI) describing the Companies "final improvements". Both of these subjects are addressed in this report.

2. FIELD INSPECTION OF CRITICAL EQUIPMENT

The following chapter outlines the main findings of the field inspection of the 2MW Geothermal Power Plant in Milos, carried out at the invitation of PPC. The inspection took place on December 18 and 19, 1988 and concentrated on the parts of the system given below as titles to sub-chapters.

2.1 The 2 MW Turbine Rotor and Casing

The turbine casing had been opened prior to the inspection and the turbine rotor placed upon blocks, but the lower half of the diaphragms were stuck in the casing and had therefore not been removed.

The following main observations were made:

(a) There was a great deal of oxygen corrosion noticed on the diaphragms, the rotor shaft, the high pressure side labyrinth seals and on the turbine blades and blade bands.
(b) The black particulate dust evident in the demister and the moisture separator, was also observed within the casing.
(c) The rotor and stator blades of the turbine were heavily pit-corroded and there was clear evidence of erosion of the first and second stage stator blades.

(d) On the last stage rotor blades, 26 stellite wear strips were missing. Closer inspection showed that the silver solder used had been eroded away, probably by the condensate being shed by the blades. All these wear strips had been shed prior to an earlier inspection and the stripped last stage rotor blades did not show visible wear, in spite of the two washing trials carried out in the interval.

(e) Turbine washing had been carried out for about two (2) days prior to this plant shut-down, and the washing had only been partially successful in removing the scale, especially in the first two stage stator and rotor nozzles, where some scale was still present at the top and bottom of the nozzles.

(f) The labyrinth seals were quite heavily clogged up by dirt and some of the seals in the casing need replacing.

There is very little doubt that dust particles are carried with the steam into the turbine, causing the observed erosion and some of the clogging seen around the diaphragm nozzles and labyrinth glands. In all probability most of these particles, which are black in colour, originate in the production well.

This dust problem can only be cured by improved steam cleaning, which is contingent upon properly de-superheating the steam after the high pressure separator and before it enters the steam cleaning part of the steam supply system, i.e. the low pressure separator, the demister and the moisture separator.

2.2 Moisture Separator

The moisture separator consists of a horizontal cylinder, which is fitted with a bank of corrugated stainless steel plates for separating out any moisture in the steam, and some baffle plates to guide the steam flow. The plate bank is inclined at about 15° to 20° to the vertical and leans into the direction of flow. The separator was also fitted with two spray nozzles one facing into the steam inlet pipe and the other into the outlet pipe. The latter, it was learned, had initially faced towards the plate bank, i.e. also facing into the flow. Their function was understood to be to de-superheat the steam and wash the plates. Neither of the nozzles is currently in function.

The moisture separator had been opened prior to the inspection by removing the end cover giving good access to the separator internals. The first impressions gained were as follows:

(a) The interior of the moisture separator was heavily contaminated with black dust particles.

(b) The corrugated stainless steel plates showed a clear evidence of cracking, probably corrosion cracking.

It is the opinion of Virkir/NEA, that these dust particles have their origin in the geothermal well, though some may be due to corrosion products from the piping and separator system being swept along with the steam flow.

The cracking observed in the bank of corrugated stainless steel plates is in the view of Virkir/NEA, corrosion cracking due to a combination of high chloride (Cl^-) and H_2S content.

2.3 Low Pressure Steam Separator and Demister

The low pressure steam separator operating at 8 bars was opened for inspection to check for signs of scaling and especially to check the condition of the wire mesh demister mats. The demister was installed by MHI in the upper part of the separator earlier in the year, to improve the separation efficiency.

The inside of the separator was relatively clean of deposits, as could be expected, but the face of the demister mat was partly plugged by foreign material. The plugging has caused sufficiently high pressure differential to deform the mats in places, but they were still in place.

The mats were removed for inspection and tests showed that the black deposit could be removed relatively easily by high pressure water washing. The stainless steel screen holding the mats was cracked, indicating stress corrosion cracking of the wire. Washing nozzles were initially installed above the mats, but washing had not been applied.

A sample of the black powdery deposit was collected and scanned with XRF and XRD X-ray equipment. The major constituents observed were iron (Fe), zink (Zn) and calcium (Ca). Surprisingly practically no sulfur was detected. Some NaCl and KCl was also found. This powdery black deposit was found in most equipment down stream of the low pressure separator, and is suspected to contribute to turbine scaling.

2.4 High Pressure Separator

The high pressure steam separator (25 bar) and hot water collecting tank (HWCT) were both opened for inspection. The inside of the separator was totally covered by a scale deposit, except at the very top where steam alone is present. By carefully noting the position and thickness of deposits, much can be learned about the performance of the separator, for example, the height of dynamic water level, height of creeping water on vortex pipe, spray carry-over. The high pressure separator shows signs, that on the inner walls of the cylinder the dynamic water level has reached the height of the vortex pipe, and to the top of the vortex pipe itself. The thickness of the deposit below the water level was roughly 6 mm, and the same thickness and type of scaling was observed inside the hot water collecting tank. The deposit is hard, but breaks relatively easily off upon impact.

2.5 Wellhead and Orifice Valve

The 6" orifice valve between the wellhead and the high pressure separator was removed for inspection. The high pressure side was clean of deposits, but a very hard deposit was found down-stream. Massive build-up of scale was not found inside the pipe, as was found by the thermometer well on the 3" pipe, during the inspection in the spring of 1988. The pipe has since been enlarged in size by MHI from 3" to 6", as was suggested by Virkir/NEA at the time. These improvements have eliminated this problem, but the temporary by-pass pipes that had previously been added to solve the problem of flow restriction from the well to the separator, have yet to be removed.

2.6 Reinjection Pipeline

Scaling inside the pipeline was inspected at four locations. The reinjection pumps, however, could not be opened for visual inspection, due to lack of spare parts and also because the pumps had only recently been cleaned.

The flow control valve was inspected and found to be in working order, in spite of the six weeks of operation since being cleaned last. The design of the valve internals (valve plug and carbon rings plus guide sleeve) cause the valve to stick due to scaling. Based on past experience, the valve has to be removed for servicing every three weeks for removing the deposits and to open the pressure equalization port on the plug.

The pipeline was inspected at SP-1, some twenty meters down stream of the control valve, where the orifice meter is installed. Severe scaling was found in the bypass pipe, and deposits cause the shut-off valves to leak. The orifice plate and the pressure taps of the flowmeter require frequent cleaning due to deposition.

The first few hundred meters of the pipeline were replaced last summer by MHI and its diameter increased in size to allow more room for scale accumulation. Inspection at the first expansion loop of the new pipe showed uniform scale of approximately 4 mm thickness.

In general it can be stated that the brine handling equipment on the power plant site shows a <u>scaling rate of approximately 1 mm per month.</u>

The reinjection pipeline was inspected close to the reinjection well. The pipeline was inspected at the orifice meter beside well M-1. The observed scaling was small, only some 1 mm thick. The orifice plate itself was clean for all practical purposes.

3. TURBINE WASHING

Turbine washing is a procedure used to clean steam turbine blading of solids' deposition using wet steam or heated condensate. The cleaning process is carried out without opening up the turbine, either with the machine non-operating or still in operation. This technique has been successfully used in conventional steam turbine plants for a number of years, but is generally not recommended for frequent use, due to the inherent danger of water droplet erosion and thermal shock effects. Turbine wet steam washing must for the above reasons always be carried out with great care and under carefully controlled conditions.

The condensate washing action functions principally in two ways, i.e.:

(a) it dissolves soluble solids contained in the deposited scale and so weakens the matrix of the scale.
(b) the weakened scale matrix, consisting largely of silica and its compounds, is then mechanically washed away by droplet impingement action and the liquid flow, which always attaches itself to the solid boundaries of the fluid passageways.

It is generally recommended that the steam entering the first stage nozzles of the turbine stator during washing have a dryness ranging between 90% to 95% (by weight) and that all casing and labyrinth seal drains be kept open. To minimize thermal shock and improve the homogeneity of the wet steam entering the turbine, it is also strongly advised that the temperature of the condensate injected into the steam flow be at least 100°C. The wet steam washing should be started very gently, and the steam wetness controlled by measuring pressure and temperature after the main control valve and plotting the values obtained on a Mollier Diagram. The liquid injection quantity should be gradually increased until the values obtained indicate that the inlet steam is within the above dryness range.

It is recommended that the progress of the washing be initially gauged by chemical analysis of the condensate from the turbine casing drains. When concentrations measured in the condensate have reached normal values, the washing can stop.

It is further recommended that the cleaning be carried out at an approximately constant load, somewhere in the mid-load range. This improves the ability to accurately control the wetness of the inlet steam and reduces possible erosion effects while keeping steam velocities through the passages at a reasonable level for efficient scale removal.

4. STEAM PURITY

It is of paramount importance not to loose sight of the relevance of the steam purity to the successful operation of the Milos 2MW Geothermal Power Plant. The higher the economically attainable steam purity, the less frequently it becomes necessary to clean the turbine by wet steam washing, the more stable the plant operation and the greater the turbine longevity. All these parameters improve the economics and security of plant operation.

5. REINJECTION WELL PERFORMANCE

Temperature and pressure profiles have been measured three times in the reinjection well M-1 since the last review of the data, which was up to March 1, 1988. The development of the data indicates a fairly stable pressure and temperature conditions in the well during injection. Indications are that temperature at the bottom of the well is rising slightly, which is consistent with earlier measurements and could mean that a reduced portion of the injected brine is absorbed by the bottom fracture zone. The pressure response shows a tendency for gradual decrease. This could indicate that the injection capacity of the well has been improving, or that the injection rate has decreased and is on the average less than the estimated value of 6.67 kg/s (24 ton/hr). This could be checked by measuring the injection rate. For that purpose the brine flow meter should be transferred close to the reinjection well, where scaling is less severe, as was recommended earlier by Virkir/NEA.

In VIRKIR/NEA's last report, a simple analytical model with propagating thermal front into a porous media was used to match the injection pressure data. The problem of a propagating thermal front is highly non-linear, and the simple analytical model can therefore not handle long periods of zero injection. To examine this, a numerical simulation of the problem would be required.

The analytical model was nevertheless checked against the additional data using the same parameters as earlier. An adequate match is obtained between measured (smoothed) and calculated pressure values until June 1988. At that date, the reinjection was interrupted for nearly two months. After injection was restarted in late July, the model predicts higher pressure increase in well M-1 than is actually measured. Possible reasons could be, that the model fails as stated earlier, the reinjection rate is less after July than it was before, or the injectivity of well M-1 has improved from earlier conditions during this last period. Further data and possibly numerical simulation is required to distinguish between these possibilities.

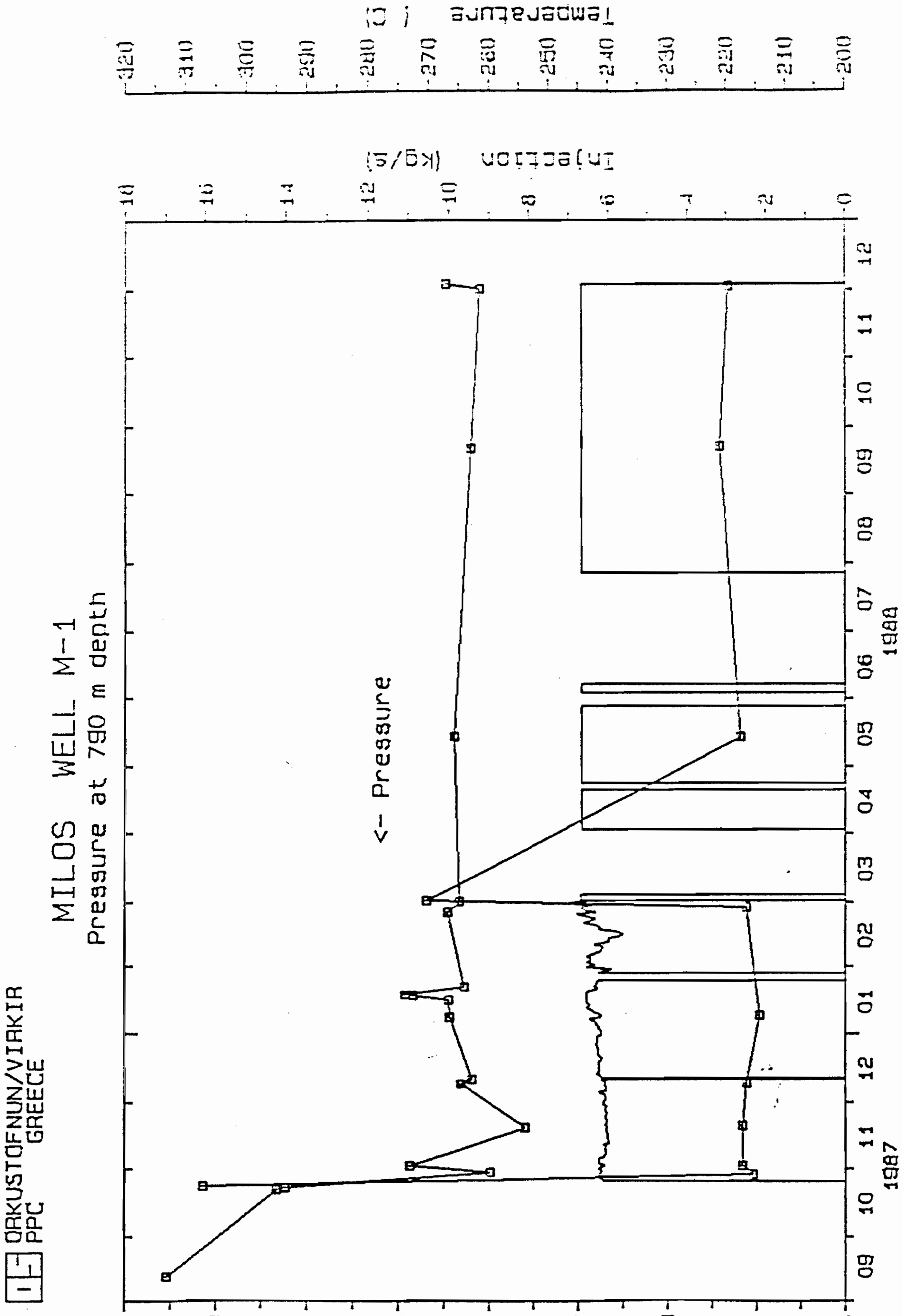

Fig. 1. Pressure at 790 m depth

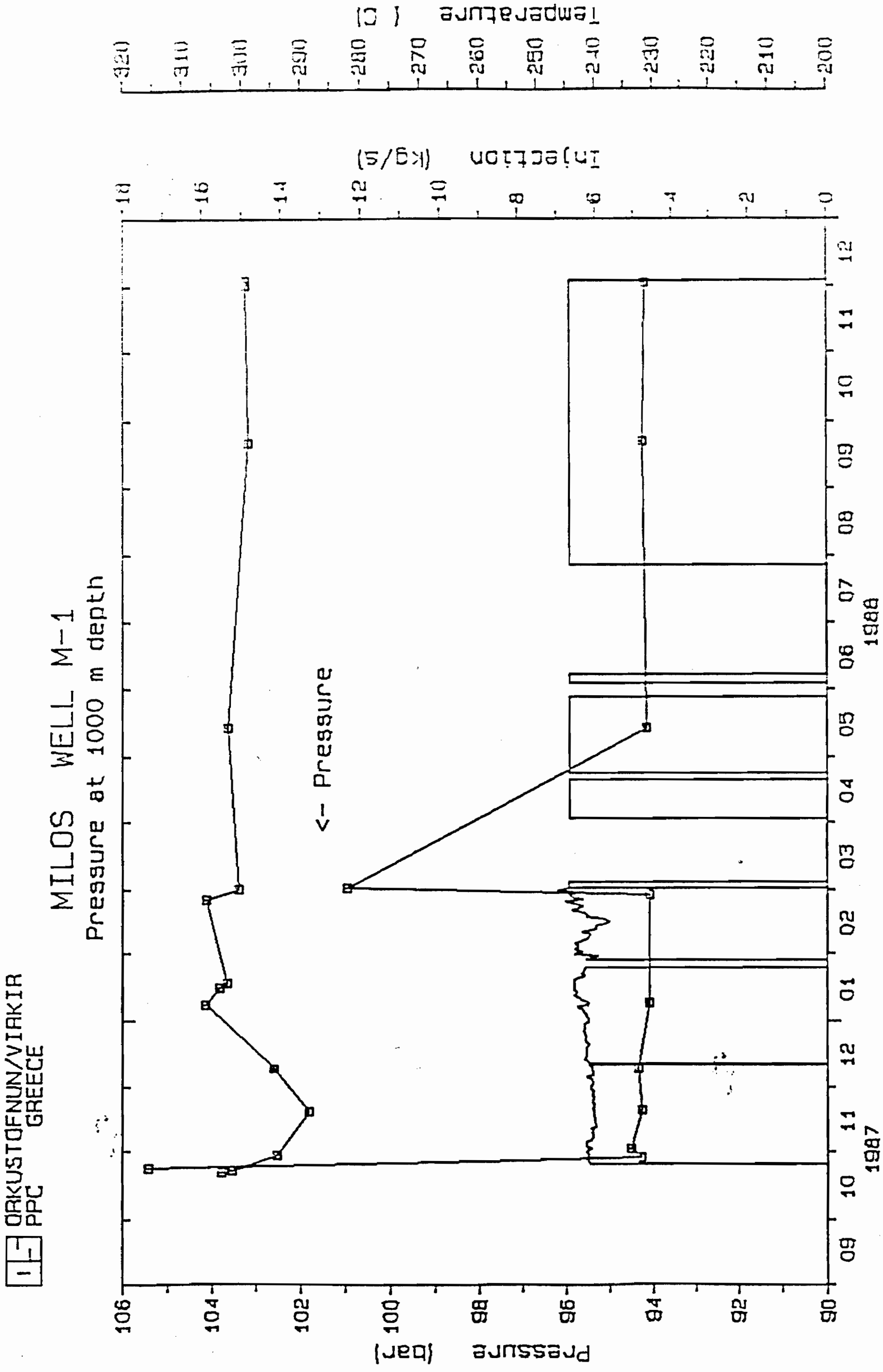

Fig. 2. Pressure at 1000 m depth

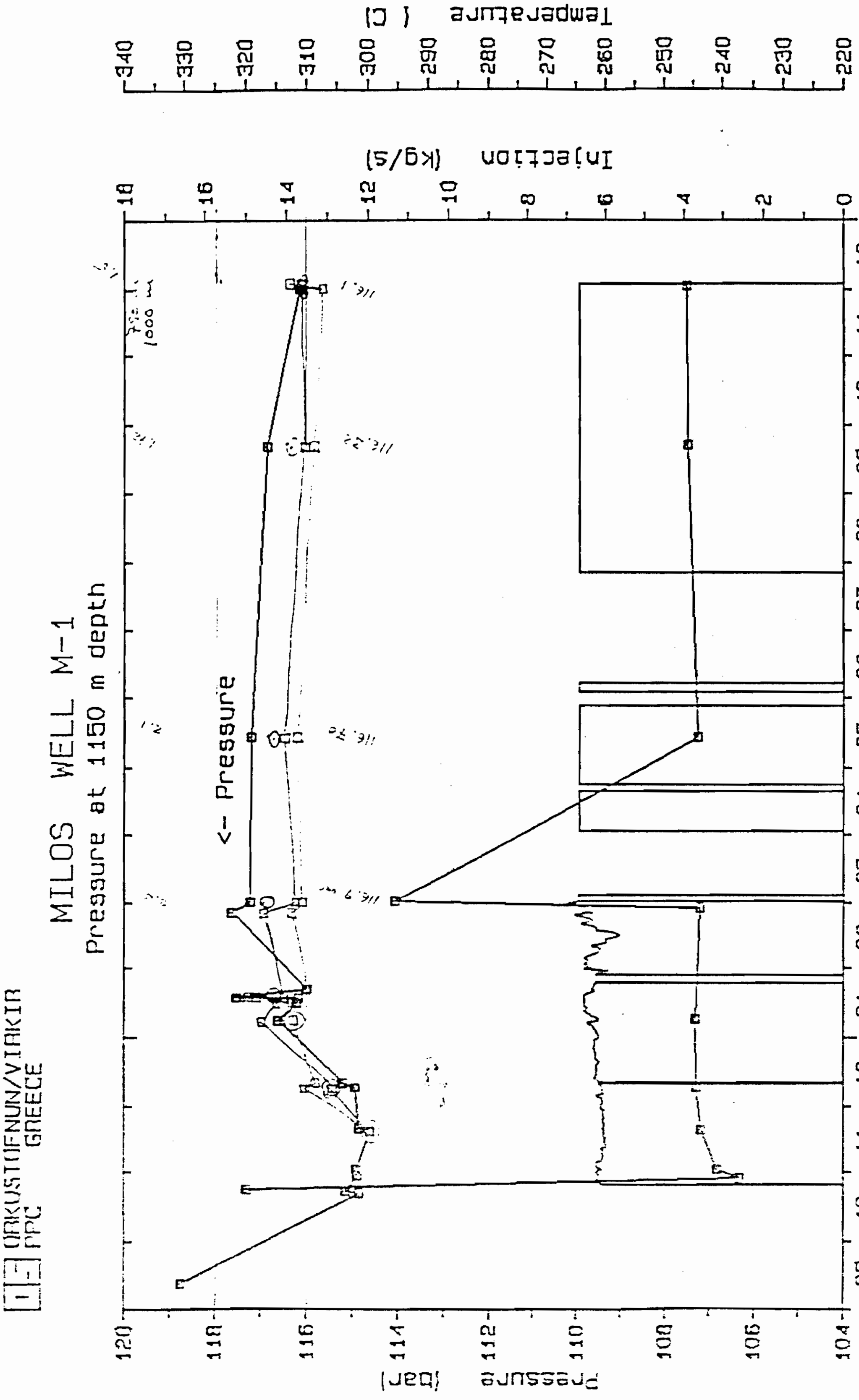

Fig. 3. Pressure at 1150 m depth

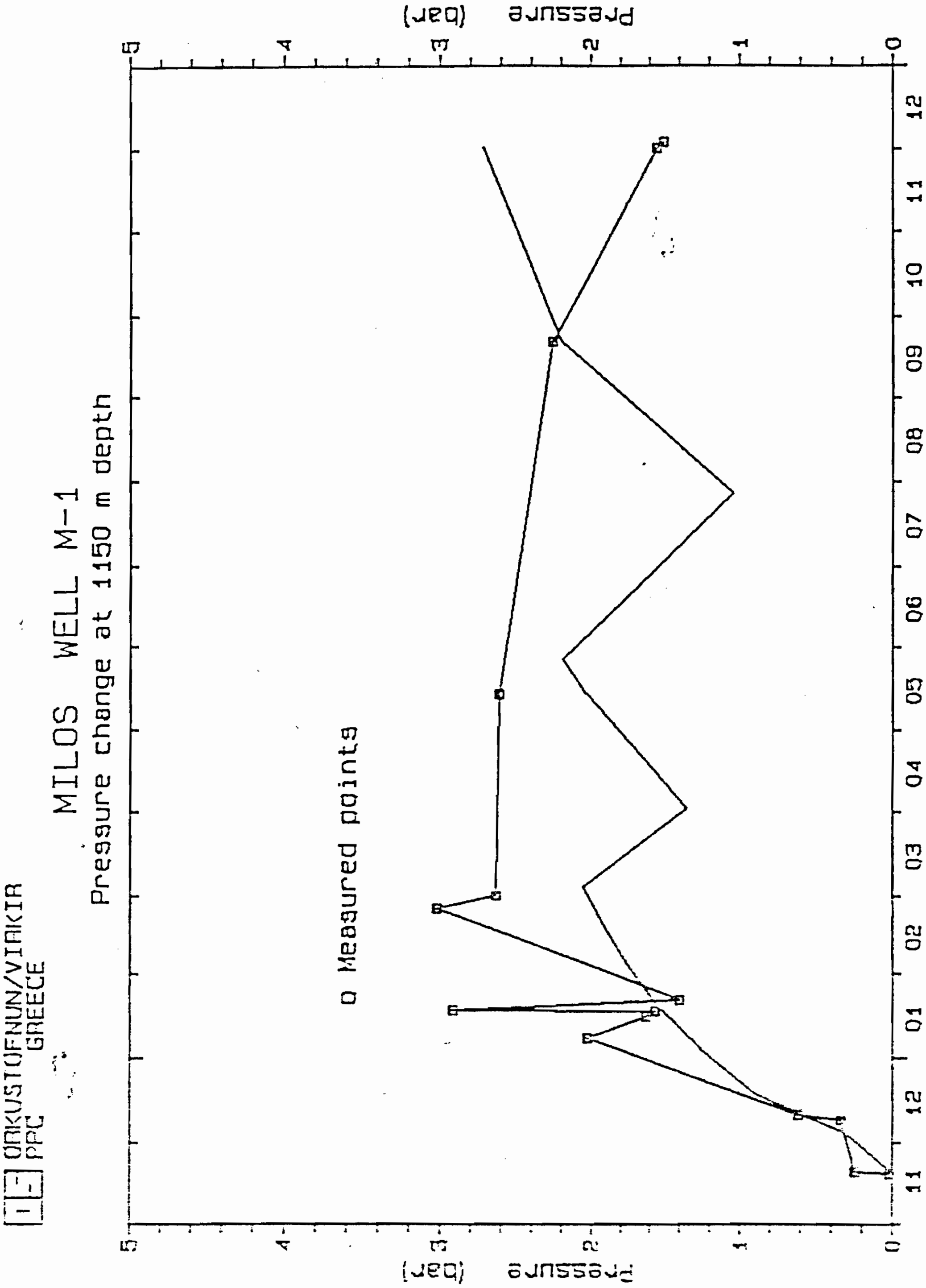

Fig. 4. Pressure change at 1150 m depht

6. DISPOSAL OF SILICA SLUDGE FROM PONDS

The problem of disposing of the silica sludge in the concrete ponds at both well sites, was brought to the Consultant's attention. The same matter was discussed during meetings with MHI early in the project. MHI has not supplied equipment or recommendations for cleaning the ponds, and thus it is up to PPC to decide on the method for removing the silica deposits. The silica sludge is only accumulated during periods when the reinjection well is not receiving effluent. During unhindered operation of the reinjection well, this will not pose a problem. Since operation of the 2 MW plant started silica sludge has accumulated in both ponds, and the ponds are currently approx. 1/3 full of sludge. Two methods should be considered for cleaning the ponds, viz:

(a) Connect a sludge pump to the bottom outlet of the pond, and pump the slurry to a dewatering plant. Water jetting will have to be applied to the silica sediment to produce a slurry thin enough for pumping. Susequent dewatering can be accomplished by filtration in a semi-automatic plate and frame filter press, which will discharge a relatively dry filter cake. The filter cake can then be loaded on to trucks and taken to a disposal site.

(b) The other alternative is to pump the slurry directly to a disposal site, for example an abandoned mining site. Dewatering would take place by evaporation and the seepage of excess water into the ground. The silica sludge is expected to be relatively clean of arsenic and other harmful constituents. A XRF-scan of a sample of silica sludge collected from the pond at well M-1, showed for example no presence of arsenic.

Before either of these methods can be applied in Milos, further studies have to be undertaken with respect to the environmental impact of the disposal site, and also to collect pertinent design information on the dewatering plant.

7. H_2S ABATEMENT

In a telex no. 36.21.210, dated Dec. 23, 1988, Mrs Rea Tassiou, Director of Alternative Energy Forms, asked Virkir/NEA to advise on specialist companies in the field of H_2S-abatement.

There are two recognized techniques in H_2S-abatement, which have been successfully adopted in the geothermal electric power industry, viz the Stretford Process and the Dow RT-2 H_2S-removal system. The former eliminates more than 90% of the gas present in the steam and converts it into solid sulphur. The latter is a more recent development, which it is claimed will remove all the H_2S from the steam and convert it into soluble sulphur compounds suitable for reinjection.

In a telex to PPC dated Jan. 5, 1989, Virkir/NEA forwarded the names of two companies and contact persons. The two companies recommended are highly experienced in the geothermal application of these techniques having gained their experience in designing and constructing systems of this type for the Geysers Field in California.

The recommended companies were:

1) Stretford H_2S control system

Peabody Process Systems Division,
201-Merritt-7,
Norwalk, CT 06852,
USA.
Telex: 965870
Telefax: (203) 846-8368
Telephone: (203) 846-1600

Contact person: Dr. Carl van Cini

2) Dow RT-2 H_2S removal system:

Dow Chemical
B1605 Building,
Freeport, TX 77541,
USA.
Telex: 762101
Telefax: (409) 238-5183
Telephone: (409) 238-7721

Contact person: Mr. Larry H. Kirby

There is still another solution commonly used, which is much less expensive both as regards capital expenditure and operating costs, and may very well be sufficient, if local weather conditions permit. This solution was mentioned at the meeting in the PPC offices on Dec. 21, 1988. It simply consists of collecting all non-condensible gas at a common point, and feeding the collected gas in below the cooling tower fans. This ensures a very good mixing of the H_2S gas with atmospheric air and thus keeps the H_2S level well below that, which is safe.

8. COMMENTS ON MITSUBISHI'S "FINAL IMPROVEMENTS"

In a letter to Mrs. L. Tassiou, dated February 23, 1989 (ref. MHI-ML 145), Mitsubishi describes the improvements that the Company proposes to make prior to PPC's acceptance. Many of theses improvements were discussed during the December meetings, and MHI has now made specific recommendations which are to be "the final improvements". They are briefly outlined in the following, with a comment from Virkir/NEA on each item:

1. Turbine washing operation:

Mitsubishi recommends that turbine washing be tested at accelerated rates during the two plus two (2+2) month commercial operation. Detailed procedures are given for turbine operation and for monitoring of turbine wear and corrosion.

Virkir/NEA recommends that PPC approve the programme, but postpone approval until the results of the inspections are known.

2. Gas extraction system:

MHI proposes to use one steam ejector for the non-condensible gas removal, as the mechanical extractor system has failed.

Virkir/NEA recommends that PPC approve the change, as it will make the plant more reliable.

3. Replacement of RIP flushing pump:

MHI proposes to install double non-return valves.

Virkir/NEA recommends that PPC approve this minor improvement.

4. Isolation valve for sample pipe no.3:

MHI recommends, replacing the isolation valves with a through conduit type of a valve.

Virkir/NEA recommends that PPC approve this change, and further that the bypass, spoolpiece and orifice flow meter at SP-1 be removed, as scaling at that point is too high.

5. Reinjection pump:

MHI recommends only to heat the mechanical seal flushing water from 30°C to 80-90°C. Further MHI deems one month operation time between overhauls to be "quite normal", considering the brine quality in Milos.

Virkir/NEA is of the opinion, that this modification will only improve the pump operation insignificantly. The only improvement that the Conslultant can propose for improving the operational reliability is to have new reinjection pumps installed. The new pumps should be larger in size, have larger internal clearances and an oversized motor.

6. Two phase flow line:

MHI proposes to remove pipes that are not required after the bottleneck removal at the M-2 wellhead.

Virkir/NEA initially recommended this modification.

7. Main oil pump:

MHI proposes to substitute the shaft material with a more corrosion resistant stainless steel.

Virkir/NEA recommends that this modification be made.

8. High pressure separator:

MHI proposes to install a guide plate in the separator inlet to increase the inlet velocity, and also to install a water scoop at the outlet to the HWCT to lower the water level.

Virkir/NEA has had no experience with such measures, and operation experience will thus have to decide the effectiveness of this modification. The Consultant had pointed out at the December meetings, that increasing the vortex pipe height would be likely to slightly improve the steam separator efficiency.

9. Scale catch pot for M-1 well side:

MHI proposes to increase the scale catch pot from 6" to 8" diameter.

This modification is in line with the Virkir/NEA suggestion.

10. Turbine vibration:

MHI proposes to improve the balancing facility of the turbine, and to bring in own specialists to fine balance the unit.

Virkir/NEA finds these measures highly acceptable. This opportunity should also be used to train PPC personnel in field balancing, and to make sure that proper equipment is available to them.

11. Steam spray water (before 8 bar separator):

MHI has already made this modification.

Virkir/NEA recommends this change, but would additionally like to see better instrumentation installed for checking that the proper flow rate is used. The plant operators have to be trained to monitor the condensate injection at this position, which is vitally important in ensuring adequate steam purity.

12.Brine level control:

MHI proposes to supply PPC with a spare control valve identical to the present one.

This valve has been found to be unacceptable by operational experience in Milos, due to frequent sticking and high spare parts consumption. Virkir/NEA recommends that a wafer type butterfly valve with an oversize stem and actuator be installed instead.

13. Moisture separator:

MHI proposes to install chevron type plates, as per Virkir/NEA's recommendation.

The use of stainless steel instead of mild steel, can lead to corrosion cracking of the plates due to oxygen ingress during stops.

14. Stellite strips on the 5th stage blades:

MHI intends to remove the remaining stellite wear strips, as the Companies erosion index calculations show that they are not required.

Virkir/NEA recommends that this change be made, but points out that only actual operating experience can show the effect of all the factors unique to Milos.

9. CONSULTANT'S GENERAL COMMENTS

The 2MW Geothermal Power Plant in Milos operates on a geothermal brine of a very complex and difficult chemical composition as regards scaling.

The modifications featured in this report are not likely to materially improve the performance of the plant, but rather alleviate the problems that have caused some of the most serious disruptions to the continuous operation of the plant. It is the considered opinion of Virkir/NEA, that many of the problems experienced in operating the Milos plant are directly caused by these prolonged disruptions. It will therefore be essential in future to keep the plant running as continuously as is expedient and take care to keep atmospheric oxygen away from all steam passageways as much as possible. Virkir/NEA also like to point out the importance of draining away from these passages, at the start of each stop, all moisture thoroughly and expeditiously.

The two most serious problem areas, viz steam purity and effluent reinjection, have to a certain extent been addressed by the modifications featured in this report and only operating the plant over a prolonged period can show the degree of success attributable to this endeavour. More modifications, based on the operating experience of the problems specific to the Milos brine and load conditions, are envisaged as having to continue, however, after PPC has taken over the plant and before economical acceptability has been achieved for the plant.

Before taking over the plant it will be essential for the PPC to ensure that all emergency systems are working properly. Also that both spares lists and recommended spares for maintenance heavy key items are available and up to date.

In the view of Virkir/NEA, the PPC has with this pioneering project in Milos, managed to solve the problem of operating a geothermal flash/reinjection power plant using brine extremely rich in dissolved solids as well as can be expected in light of the current status of the technology. Virkir/NEA therefore restate the opinion, that it would be of great interest to PPC as well as any others, who might contemplate adopting similar methods for utilizing difficult brines for generating electricity, to have the Milos experience and methodology written up and presented at a Science Review type meeting. This would also be a most fitting end to the very worthwhile development project, that the Milos Plant has proved to be.

APPENDIX

FIELD REPORT 1 AND 2

Virkir/NEA

Mrs. Rea Tassiou, Director
Direction of Alternative Energy Forms
Public Power Corporation
10, Navarinou Street
ATHENS 106 80
GREECE

Athens 1988.12.21

Re: Field report of Mr. Sverrir Thorhallsson and Mr. Einar T. Eliasson, December 15-22, 1988

At the request of PPC Mr. Sverrir Thorhallsson and Mr. Einar T. Eliasson of Virkir/NEA travelled to Milos to take part in inspection of the 2 MW geothermal power plant and technical discussions. During our three day stay on Milos we took part in three meetings with personnel of your department and of the Direcion of Exploitation and Production. Two of the meetings were with Mitsubishi's site representative Mr. Sakanashi for technical discusions on the findings, and possible remedies. Please find enclosed two field reports that were given to Mr. Koutroupis on Milos, one relating to the turbine and steam purity, and the other to the reinjection system.

Minutes of the two meetings with Mitsubishi were taken by Mrs. Delliou and Mr. Cristanis of your department, but they have not been distributed due to the tight time schedule of our stay. Virkir/NEA has for the same reason not had time to prepare a field report, but our main findings and recommendations will be outlined to Mr. A. Ginnis Tassos at your Athens office to-day.

Due to the Christmas and New Year's holidays the preparation of our report will take about three weeks, and we expect to be able to send it to PPC after the middle of January 1989.

Sincerely yours,

Sverrir Thorhallsson, proj. mgr.

Encl.
1. Field report nr. 1
2. Field report nr. 2

Virkir/NEA
1988.12.18

FIELD REPORT NR. 1

VISUAL INSPECTION OF THE 2 MW GEOTHERMAL POWER PLANT ON MILOS DECMBER 18, 1988 YIELDED THE FOLOWING PRELIMINARY OBSERVATIONS

TURBINE UNT:

1. Three day washing of the turbine last week seems to have been as effective as can be expected, under the prevailing conditions. Rotor and stator blades were nearly clean, but the diaphram walls and the shroud band area had deposits and corrosion products remaining. This type of cleaning is ineffective for the labyrinth glands.

2. There is no evidence to suggest that the washing contributes significantly to blade erosion.

3. There is no evidence linking turbine washing with the loss of the 29 pieces of stellite erosion shields (out of a total of 52) on the last stage.

4. The turbine internals are not considered sufficiently clean to be put into service without prior cleaning.

STEAM PURITY:

5. The LP separator wire mesh demister is extensively plugged by depoits, and has been deformed to such an extent that it is not considered safe for continued operation. Differential pressure gauge for the demister is missing.

6. Demister corrugated plates are cracked, corroded and partly plugged. The demister bank can not be recommended for further use as is.

7. The de-superheater and wash nozzles, five in all, are fed by the same cooling coil. This makes good balancing very inefficient.

8. It was reported that the main steam pressure indicator is unreliable. This may lead to improper de-superheating with the consequent decrease in steam purity.

PRELIMINARY RECOMMENDATIONS:

TURBINE:

- Sand or hydroblast turbine internals
- Restellite last stage rotor blades
- Clean all loose matter from separators, moisture separator, steam mains (after the separator), exhaust conduit, condenser.
- Clean and replace defective labyrinth seals
- Clean turbine casing drains
- Clean regulating valve,and main stop valve
- Put strainer on steam main before turb. shut-off valve
- Put drain pots on steam main before strainer

SEPARATORS:

- Repace mist elimator plates with chevrons made of materials resistant to corrosion and corrosion cracking
- Blank off chevron scrubbing nozzles
- Relace (or remove) LP mist eliminator matts
- Install separate heat exhangers for:
  a) de-superheater nozzles
  b) turbine wash water

  and fit with appropriate controls.
- Clean LP separator and de-mister
- Calibrate P and T sensors on the steam main

SUGGESTONS FOR IMPROVED TURBINE WASHING OPERATION:

1. Keep temperature of wash water close to the prevailing saturation temperature
2. Carry out turbine washing at steady 50% load
3. Keep turbine drains fully open during washing process
4. Install P and T sensors for monitoring steam chest

S. Thorhallsson
E.T. Eliasson

Virkir/NEA
1988.12.20

FIELD REPORT NR. 2

VISUAL INSPECTION OF THE STEAM COLLECTION AND REINJECTION SYSTEM FOR THE 2 MW GEOTHERMAL POWER PLANT ON MILOS DECEMBER 18 AND 19, 1988 YIELDED THE FOLOWING PRELIMINARY OBSERVATIONS

SEPARATORS:

1. No scaling was observed upstream of the orifice valve. This implies that the well is not scaling, and thus the function of the wellhead valves not impaired.

2. Scaling down-stream of the orifice control valve was found to be appr. 3-4 mm. Pieces of logging cable were found lodged in the valve.

3. Significant scaling was observed on the inside of the HP separator body, extending to a hight approximately level with the mouth of the vortex pipe. This indicates a hight of dynamic water level which is likely to cause an unacceptable amount of carry-over. The outside of the vortex pipe was also found to be totally covered by scale indicating that water has crept up the walls of the vortex pipe. The thickness of scaling at the separator bottom was appr. 5-6 mm and tapered in thickness up the walls of the separator.

4. The scaling in the HWCT (hot water collecting tank) was observed to be 3-4 mm thick, and even thicker in the emergency overflow pipe.

5. The reinjection pumps had recently been cleaned, and it was therefore not found necessary to open a reinjection pump for inspection.

6. The brine flow-control valve shows scaling after 30 days of use, but the valve stem was found to be free. Normally the valve has to be removed for cleaning and replacement of carbon sealing rings every 20-30 days.

7. At the first elbow on the 8" rinjection pipeline the scaling thickness was found to be 3-4 mm after four (4) months of operation, indicating an effective scaling rate of appr. 1 mm per month.

8. The loop bypassing the SP-1 and orifice meter is heavily scaled, and the isolating vales leaky due to scaling.

9. The SP-3 spoolpiece at the M-1 well was inspected and found to have a 1 mm thick scale and some loose scale deposits on the bottom of the pipe. The orifice plate was found to be practicaly clean of scale.

10. The dirt trap at well M-1 was found to be full of loose scale and debris carried by the fluid.

PRELIMINARY RECOMMENDATIONS

- The implementation of the Virkir/NEA recommendation, made in a letter to Mr. Koutroupis dated 1988.03.03 (see Febr. trip report), to increase the HP separator inlet pipe size from 3" to 5" seems to have been effective in reducing the scaling problem. This modification has moreover eliminated the need for the multiple pipes previously used to feed the separator.

- It is recommended the vortex pipe of the HP separator be extended some 20-30 cm to help reduce the risk of carry-over. The actual length of extention needed should to be studied.

- The present inspection supports the previously discussed solution to install a rentention tank before the reinjection pumps. This will possibly reduce the high initial rate of scale deposition in the reinjection pipe and pumps.

- It is recommended that an in-place cleaning of the reinjection pumps, using inhibited acid, be investigated further. This technique has been successfully used for a similar duty in Iceland (see Febr.trip report).

- The possibility should be considered to substitute the current level control valve by one or more of the following:
a) the installation of a frequency control (thyristor) for the reinjecion pumps and thus control flowrate and pressure by varying the pump speed
b) the installation of a control valve better suited for operation in a scaling environment, e.g. butterfly or ball type valves. This is in line with MHI suggestions made in their Nov. 25 letter to the PPC.
c) Locate the control valve more than 300 m down-stream from the HWCT where the scaling rate is slower

- Remove orifice meter and SP-1 and extend the 8"diameter reinjection pipe to the reinjection pumps.

- It is proposed that the dirt traps in the reinjection pipeline be increased in size.

- To make cleaning and maintenance of valves, pipes, traps, separators etc. quicker and easier we recommend that the following equipment be procured:

a) a portable hydro- or sandblasting equipment such as the Danish KEW hydroblast equipment or the Italian SAPI air-blasting one. Both of these have given excellent service in Iceland.

b) air-powered impact wrenches in the size ranges required for the plant

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