SILICA DEPOSITION TESTS AT BROADLANDS

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ABSTRACT

During 1979-1980 a series of silica deposition experiments were performed at Broadlands to determine the feasibility of reinjecting untreated geothermal water at temperatures of about 150°C. Although slight silica deposition did occur in the test pipelines the rate of deposition was very slow and this provided confirmation that reinjection of untreated geothermal hot water is a viable proposition.

INTRODUCTION

Ppproximately 12km of 300-400 NPS pipework will be required for reinjecting waste geothermal hot water at Rroadlands. Experience has indicated that silica can deposit from these waters and this made it essential to determine the feasibility of reinjecting untreated geothermal water,

D.S.I.R. chemists have studied the chemistry of silica in geothermal water and it is on their recommendation that the lowest separator pressures should be 5.5 b.a. which will produce waste water at 155°C. At this temperature the water is slightly super-saturated with respect to silica and therefore deposition can occur. The chemistry and kinetics of silica deposition is very complex and beyond the scope of this paper.

A silica deposition test plant was constructed at Broadlands BR22 to provide information on how various liquid and flow conditions affect silica deposition. In addition two full-size reinjection pipelines were constructed BR19-13 and BR35-28, to test all aspects of the reinjection of separated geothermal water,

This paper deals with the results of these tests from a practical engineering viewpoint.

TESTS

The BR22 test plant consisted of three tube bundles, two hold-up-vessels and a controlled velocity vessel.

The tube bundles were designed to simulate reinjection pipelines - i.e. to have similar friction head losses, temperature loss and residence time. Each tube bundle was made from 25 NPS mild steel steam pipe and was 457m long.

The hold-up-vessels were constructed so that hot water could be held for approximately 20 minutes before being passed into a tube bundle. Each vessel was made from a 3.5m length of 400 NPS pipe and tracer tests gave residence times varying between 5 and 60 minutes showing the flow was not uniformally distributed.

The controlled velocity vessel consisted of a sequence of 3m long pipes varying in diameter from 25 NPS to 250 NPS. The vessel was constructed to determine whether deposition was a function of velocity or turbulence.

The geothermal hot water was supplied to the test rigs from BR22. This bore is set up for experimental purpases and is producing 57 tonnes/hr with an enthalpy of 1130 kJ/kg.

The two phase bore fluid is passed into a 762mm separator operating at 10 b.g. Both the separated water and steam are discharged into a silencer. The hot water for experimental purposes was supplied from a branch line on the separated water line. This supplied hot water at 180°C. The 150°C water was produced from a 600mm separator supplied with 180°C water. The 130°C water was produced from a 150mm separator supplied with 180°C water.

The BR19-13 pipeline was constructed from 250 NPS steam pipe and was 570m long. Geothermal hot water was supplied from the BR19 separator plant and reinjected into BR13. The flow was maintained by utilising the separator pressure and the change in saturation pressure of the water associated with the temperature loss down the pipeline.

The BR35-28 pipeline was constructed from 250 NPS steam pipe and was 655m long. Geothermal hot water between 150°C-160°C was supplied from BR35 separator plant and reinjected into BR28. Initially the hot water was pumped along the pipeline by the Peerless pump - a multi-stage centrifugal pump. After several pump failures the pump was withdrawn from the operation and the flow was maintained by utilising the separator pressure.

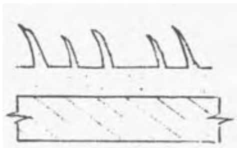
RESULTS

Each tube bundle and hold-up-vessel operated for 1 month at a time after which the tube bundles and hold-up-vessels would be inspected internally and subsequent tests proposed. The full scale reinjection tests operated continuously apart from short shut downs for measurement purposes.

After the tests had been completed the thickness of the deposition was determined by using a microscope. Generally deposit consisting of iron sulphide and silica formed on the pipe walls, The iron sulphide is the product of the corrosion reaction between the pipe and the dissolved H_2S in the water and forms a hard black deposit. Generally the deposition had a hard black appearance but when scratched the white silica deposit could be seen. In addition ridges of silica formed in the BR19-13 and BR35-28 pipeline as shown in Fig 1. The result summary of all these tests is shown in Table 1.

Fig 1. Profile of Deposition in BR19-13 & BR35-28 Pipelines.

Flow



0.3mm high ridges of pure SiO_2

0.15mm thick black deposit SiO_2 + $Fe_{1+X}S$

Pipewall

Table 1. Result Summary

Test Apparatus	Duration (months)	Sep. Press. (bars gauge)	Water Temp. (°C)	Water Flow kg/min	Hold Up Time (mins)	Deposition Rate (mm/year)	Deposition Description.
Tube Bundle 1.	2	10	184	20	11.5		Very slight deposition.
Tube Bundle 2.	6	4.1	152	18	12.8	0.25	Uniform black deposit.
Tube Bundle 3.	4.5	1.7	130	19	12.4	0.26	Uniform black deposit.
Hold-Up-Vessel A.	1	4.1	152	17	24		Massive white silica deposition throughout vessel. Approx. 3mm thick.
Subsequent Hold-Up-Vessel Tests,	1	4.1	152	17	24		Soft grey nodule type deposit approx. 1mm thick.
Controlled Velocity Vessel,	2	4.1	152	19.5	26		Slight deposit on small pipes. Nodules of silica formed on larger diameter pipes.
BR19-13	6	4.0	150	2500	8.7	0.4	Uniform black deposit + ridges of pure silica.
BR35-28	10	4.0	150	2500	10	0.24	Uniform black deposit + ridges of pure silica.

DISCUSSION

Temperature should have a direct effect on silica deposition as it alters the saturation level of silica. It was expected that a definite trend should be apparent from these tests showing a greater deposition rate at lower temperatures. The straight tube bundle tests failed to give conclusive evidence that this trend exists as the tests performed with 130% and 150°C water gave a similar type and rate of deposition,

The effect that turbulence has on silica deposition was studied by the controlled velocity vessel at BR22. In this test, water was passed through a series of different diameter pipes so that the rate of deposition could be observed over a range of Reynolds numbers varying from 8000 - 80000, There was a definite trend in that the lower the Reynolds number the greater was the rate of deposition. This deposition was of the soft grey nodule type as seen in the hold up vessels. The difference in deposition is probably due to the scouring effect that higher turbulent flows have on the pipewall. Therefore, it is likely that the deposition that occurs in low turbulence flows is only weakly mechanically bonded together whereas the deposition that occurs in high turbulence flows is more likely to be rigidly attached to the pipewalls and the particles of silica chemically bonded together. This was partly confirmed by the controlled velocity vessel because there was less silica deposition on the pipewalls in the higher turbulent flow and the deposit was very hard.

There may be a secondary effect due to turbulence that tends to promote deposition rates, As the Reynolds number increases the energy of the particles of silica in the water increases which could result in the particles of silica striking the wall at higher velocities, This explains why more silica forms on protrusions to the flow e.g. the downstream side of the branches of tees, on the upstream face of orifice plates and on the downstream sides of bends. This was clearly seen on the full scale pipelines.

In addition greater thicknesses of silica were found on the centrifugal pump impellors. Again this can be explained by the increased turbulence that occurs in a pump.

Residence time is defined as the time taken for water to pass from the separator to a point in the pipeline, All the tests showed that increased silica deposition occurred with increasing residence time. This effect was seen in the tube bundles and in the full scale pipelines.

The first hold-up-vessel test resulted in a massive white crystalline deposit throughout the vessel. However seven subsequent tests did not produce the same deposition even though all the initial operating parameters were modelled. Not being able to determine the cause of this deposition has caused considerable concern. However it appears that it was a spurious result and this type of deposition should not occur in a hold-up-vessel under normal operating conditions.

The rate of silica deposition is one of the most important parameters required for the design of reinjection pipelines. The full scale reinjection tests provided useful information on this aspect as these tests modelled the full scale reinjection system more accurately. The uniform 0.15mm thick layer of deposition that occurred right through the pipelines should be regarded as the basic iron-sulphide silica deposit that initially occurs in a pipeline and the thickness should not increase as rapidly over a longer period. However the ridges of silica that formed are more likely to be representative of the manner in which silica will deposit over a longer period. These ridges will have a significant effect on the fluid friction losses.

CONCLUSIONS

1) A slight increase in silica deposition was noticed with lower separator temperature. However no definite transition temperature was detected below which silica deposition would be a major problem. The rates of silica deposition over the range 130% - 180% were similar and should not cause problems in full size reinjection pipelines.

2) The tests suggest a design allowance for silica deposition of 0.5mm per annum.

3) Turbulence was shown to have a two fold effect on silica deposition - basically as turbulence increases the deposit decreases. However turbulence produces a secondary effect which tends to increase the rate of silica deposition as seen in the outside of bends. There is probably an optimum value of Reynolds number which will result in the lowest deposition rate.

4) Low velocities and long residence times were shown to increase the rate of silica deposition and these types of flow situations should be avoided in the reinjection scheme.