



REPORT R-OCAS.004 Rev 1.

**SCALE DISSOLVER TESTS ON
GEOTHERMAL WELL SAMPLES**

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1. INTRODUCTION

Some basic analysis and scale dissolver tests on samples of scale and minerals recovered from Geothermal wells operated by **Client XXX** has been conducted to identify chemical solutions that may aid removal from the well tubing and formation.

Scale dissolvers HDC Mk II and Pyrosol C2 (or Pyrosol ES) have proven very effective at dissolving large fractions of the minerals, although the better performing product does differ across the samples tested.

Dissolution of between 20% and 98% of the tested samples has been achieved with a single chemical soak.

In mixtures of the scale minerals a significant improvement in scale dissolving is achieved by a two stages approach consisting of an initial soak with Pyrosol ES or Pyrosol C2, followed by a second treatment with HDC Mk II.

2. EXPERIMENTAL

A number of samples were received at the OCTL laboratory on the 23rd November 2019 and are listed in the table below.

Table 1 - Sample log

OCTL reference	Supplied description
WS 115/19	2017-03-27 PAD 406 2PH SP1
WS 116/19	MG-A 18" R/L U/S spool 3 2017-05-11
WS 117/19	2015-02-21 MGF 2PH, CUT #1 sample 3
WS 118/19	2015-02-21 MGF CUT NEAR TOP MH, sample 5
WS 119/19	MG-A 18" R/L D/S Spool #3 2017-05-11
WS 120/19	TIPF 2019-01-23 Tonganonan SS1 HP DP#3,
WS 121/19	MG-A 18" R/L D/S CUT-5, 2017-05-11 1705H
WS 123/19	MT2RD SIT PHASE2 N-G LINE FMN VESSEL 2018-10-06

Each sample was initially checked with a Geiger counter to ensure no radioactive compounds were present (LSA scale) which would have imposed handling restrictions. All samples gave counts no different from background (~0.7 cps) and hence no handling restrictions were required.

Selected samples were then photographed, sub-samples taken, ground and an FTIR scan run to characterise the basic mineralogy.

Dissolution in four different OCAS scale dissolver solutions was then evaluated as follows.

- approximately 4g, accurately weighed, of a crushed scale / mineral sample was added to a Duran bottle with 100 ml test dissolver solution
- bottles were sealed and placed in a hot roll oven at 95°C and set to roll for 18 hours.
- samples were then filtered through a Whatman filter paper and washed through with deionised water followed by acetone to remove residual water
- filtered solids were dried to constant weight in an oven at 50°C to determine % scale removal
- FTIR scans were taken on the some of the residual scales to identify any difference in the peaks and hence mineral removed by the different scale dissolvers

The quantity of scale and dissolver solution is selected such that the scale dissolver does not normally reach saturation capacity and hence as a screening exercise the maximum amount of scale that could be removed is readily compared. Later tests can be run to determine dissolving capacity (ie g/l) if required.

The four tested scale dissolver products are:

- a) HDC Mk II - a general purpose, high alkalinity, sulphate scale dissolver (Ba, Sr, Ca) with additional capability to dissolve Fe scales and carbonates and some minerals
- b) Pyrosol C2 - mild acid solution formulated to dissolve scales such as iron oxide, iron carbonate, iron sulphide and calcium carbonate
- c) Pyrosol ES - mild acid sequestrant solution with penetrating wetting agent formulated to dissolve scales such as iron oxide, iron carbonate, iron sulphide and calcium carbonate and reservoir stimulation aid
- d) SD AF4 - Organic acid complex for carbonate and sulphide scale removal

Following completion of these screening tests additional tests were run with the optimum identified dissolvers using mixtures of various scales.

3. RESULTS

3.1 Individual Scale Samples

On the basis of mineralogical descriptions supplied by Client XXX, five samples were selected as representative of different scale compositions. These are:

- WS 115/19, 2017-03-27 PAD 406 2PH SP1, described as mainly **iron oxide / hydroxide**
- WS 116/19, MG-A 18" R/L U/S spool 3 2017-05-11, described as mainly **amorphous silica, iron oxide and sulphide**
- WS 118/19, 2015-02-21 MGF CUT NEAR TOP MH, sample 5, described as **iron bearing material, magnetite / pyrrhotite**
- WS 120/19, TIPF 2019-01-23 Tonganonan SS1 HP DP#3, described as **iron bearing material, magnetite, iron oxide and iron sulphide**
- WS 123/19, MT2RD SIT PHASE2 N-G LINE FMN VESSEL 2018-10-06, described as **amorphous silica**

The individual test results are detailed below.

3.1.1 Sample appearance

Photographs of samples selected for dissolver tests are tabulated below.

Table 2 - Sample Photographs






Sample	Photograph	Description
WS 115/19, 2017-03-27 PAD 406 2PH SP1		dark brown to grey, coarse, hard mineral fragments
WS 116/19, MG-A 18" R/L U/S spool 3 2017-05-11		Porous white, grey, light brown scale sample
WS 118/19, 2015-02-21 MGF CUT NEAR TOP MH, sample 5		Flat / tabular plates of red / orange appearance

Table 2 (continued) - Sample Photographs

Sample	Photograph	Description
WS 120/19, TIFP 2019-01-23 Tonganonan SS1 HP DP#3,		Mix of scale and grains, red / brown to black with lighter grey / cream fragments
WS 123/19, MT2RD SIT PHASE2 N-G LINE FMN VESSEL 2018-10-06		Cream / white mineral fragments

3.1.2 Dissolver screening tests

Table 3 gives the dissolving results after rolling samples overnight at 95°C. The test results are presented as total % of sample dissolved rather than a final dissolving capacity, in order that the most effective dissolver can be rapidly selected.

Table 3 - Dissolution of scale at 95°C

Sample	Dissolver	% sample dissolved
Pad 406 2PH SP1	HDC Mk II	19
	Pyrosol ES	58
	Pyrosol C2	60
	SD AF4	36
MG-A 18" R/L U/S Spool 3	HDC Mk II	20
	Pyrosol ES	0.8
	Pyrosol C2	5
	SD AF4	6
Cut near TOP MH (MGF) 2015-02-21 Sample #5	HDC Mk II	28
	Pyrosol ES	62
	Pyrosol C2	63
	SD AF4	19
Tonganon SS1 HP DP#3	HDC Mk II	12
	Pyrosol ES	63
	Pyrosol C2	75
	SD AF4	34
MT2RD SIT PHASE2 N-G Line FMN Vessel	HDC Mk II	98
	Pyrosol ES	78
	Pyrosol C2	79
	SD AF4	78

The most effective products are **highlighted blue** in the above table showing HDC Mk II and Pyrosol C2 to be the optimum scale dissolvers with a variability in scale dissolved across the mineral samples. There is minimal performance difference between Pyrosol ES and Pyrosol C2.

3.1.3 Infra-red analysis

To compare dissolver effect on the samples, and whether a combination of products could be more effective than a single chemical soak, infrared scans before and after testing were conducted on:

- a) WS 115/19, 2017-03-27 PAD 406 2PH SP1, with **Pyrosol C2 and HDC Mk II**
- b) WS 116/19, MG-A 18" R/L U/S spool 3 2017-05-11, with **HDC Mk II**
- c) WS 118/19, 2015-02-21 MGF CUT NEAR TOP MH, sample 5 with **HDC Mk II and Pyrosol ES**
- d) WS 120/19, TIPF 2019-01-23 Tonganonan SS1 HP DP#3, with **Pyrosol C2**

Traces are shown below.

Fig 1 - WS 115/19, 2017-03-27 PAD 406 2PH SP1

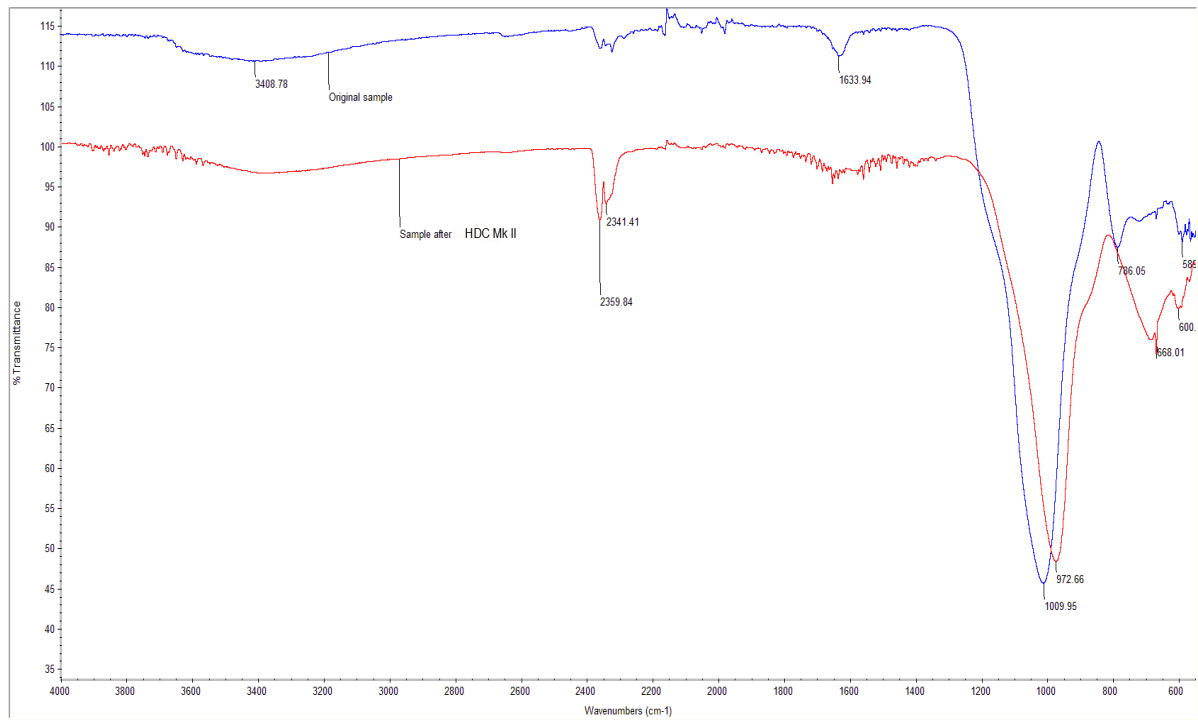
The residue traces with HDC Mk II and Pyrosol C2 differ in appearance and hence



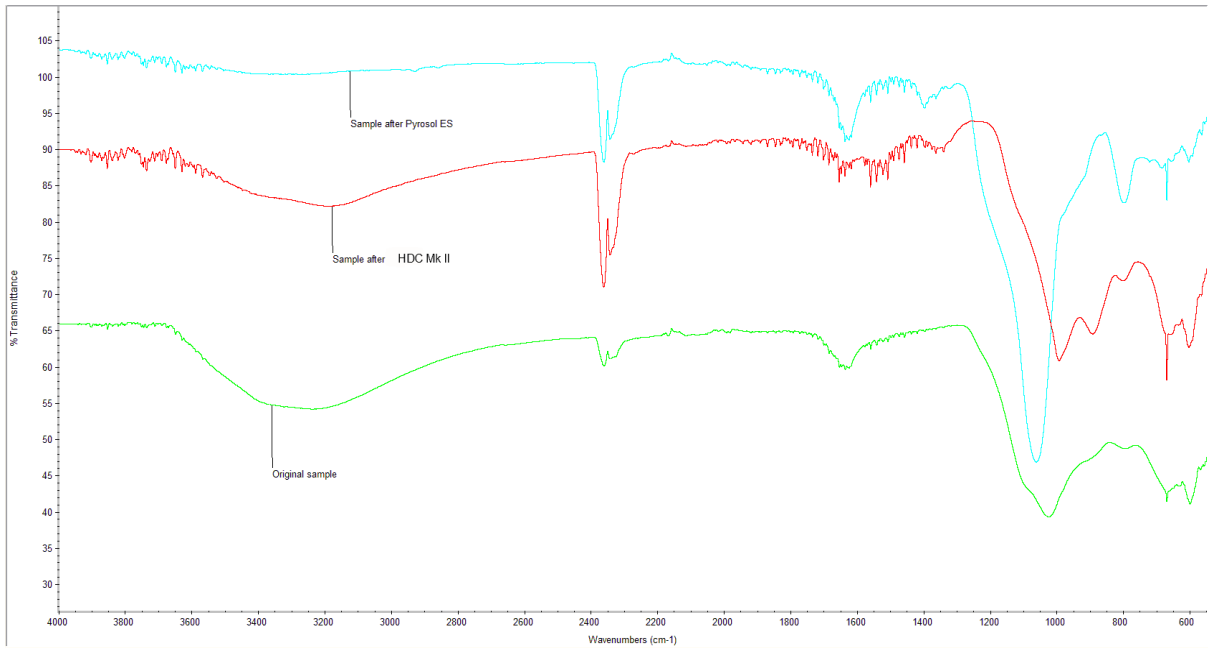
different minerals are targeted by the dissolvers. A two stage soak with HDC Mk II and Pyrosol C2 may therefore dissolve a higher total mineral content.

The trace below for WS 116/19, MG-A 18" R/L U/S spool 3 2017-05-11, only shows the result with HDC Mk II as other dissolvers were largely ineffective. The trace shows removal of peaks at 786 and 1010 cm^{-1} with underlying inert material then exposed at 973 cm^{-1} .

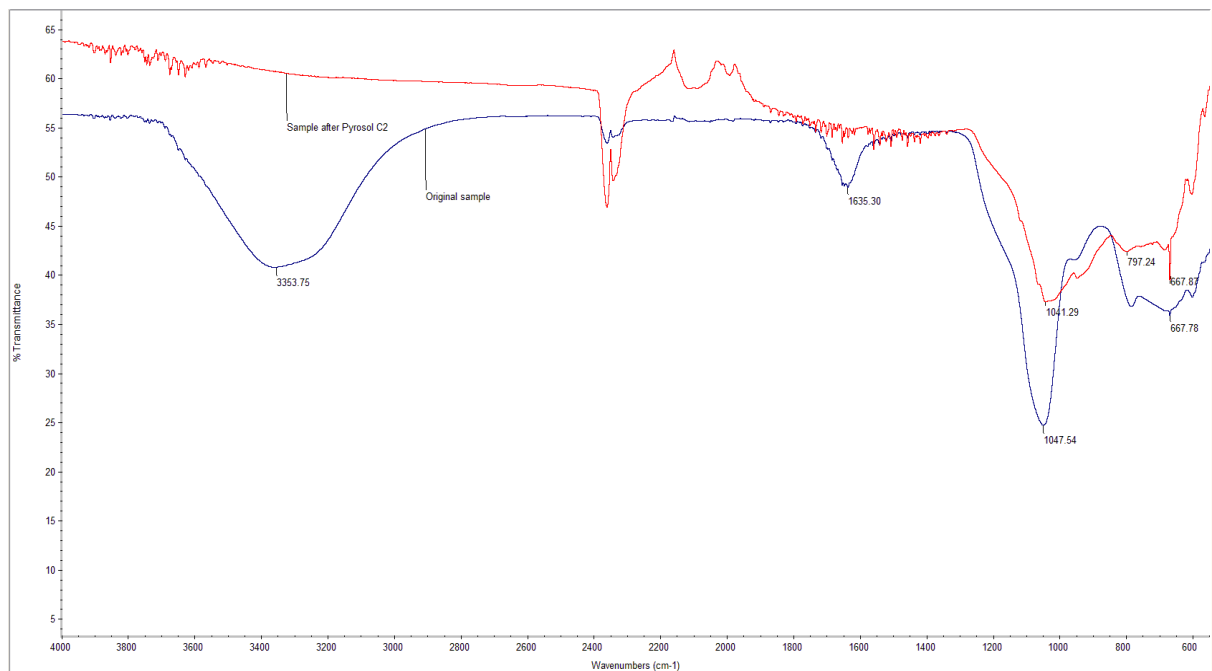
Fig 2 - WS 116/19, MG-A 18" R/L U/S spool 3 2017-05-11



Sample WS 118/19 results are shown below. Although HDC Mk II only dissolves 28% of the scale compared to 62% with Pyrosol ES, the residue traces show significant differences in the peaks across the 1060 to 800 cm^{-1} range, indicating different mineral dissolution. Although Pyrosol C2 delivered the best result (63% scale dissolved) Pyrosol ES was selected for the infrared analysis to provide a reference with this product. Again a two stage approach with the Pyrosol products followed by HDC Mk II may increase scale removal.

Fig 3 - WS 118/19, 2015-02-21 MGF CUT NEAR TOP MH, sample 5

The final result on WS 120/19, TIPF 2019-01-23 Tonganonan SS1 HP DP#3, with Pyrosol C2 is shown below. There is no specific peak targeted before and after soaking with Pyrosol C2 which appears to be a general purpose dissolver for most of the minerals comprising the sample. The residual peak at 668 cm⁻¹, normally a sulphate mineral, suggests that HDC Mk II in combination with Pyrosol C2, would increase total scale removal.

Fig 4 - WS 120/19, TIPF 2019-01-23 Tonganonan SS1 HP DP#3

3.2 Scale Mixtures

Further dissolver tests were requested using mixtures of the various well scale samples. These were produced as follows:

- a) Mix 1 General Mix - approximately 20% by weight of each of the five samples tested in the dissolver screening exercise
- b) Mix 2 - Predominantly amorphous silica - approximately 70% wt MG-A 18" R/L U/S spool 3 and 30% weight as an equal mix of the other four samples
- c) Mix 3 - Predominantly corrosion product - approximately 70% wt MGF CUT NEAR TOP MH, sample 5 and 30% weight as an equal mix of the other four samples

For ease of reference these are tabulated below.

Table 4 - Mineral mixes for dissolver tests

Mix no.	% wt in mix				
	WS 115/19, 2017-03-27 PAD 406 2PH SP1	WS 116/19, MG-A 18" R/L U/S spool 3 2017-05-11	WS 118/19, 2015-02-21 MGF CUT NEAR TOP MH, sample 5	WS 120/19, TIPF 2019-01-23 Tonganonan SS1 HP DP#3	WS 123/19, MT2RD SIT PHASE2 N-G LINE FMN VESSEL 2018-10-06
1	20	20	20	20	20
2	7.5	70	7.5	7.5	7.5
3	7.5	7.5	70	7.5	7.5
4	7.5	70*	7.5	7.5	7.5

*In mix 4 sample WS 116/19 was replaced by WS 119/19, MG-A 18" R/L D/S Spool #3 2017-05-11 due to a shortage of the original sample

Dissolver tests were run in the same fashion as the screening tests with addition of 4g of the mineral mix sample to 100 ml of dissolver solution and hot rolling overnight at 95°C. However in these tests, after recovery of remaining undissolved scale this residue was added to a 2nd and different scale dissolver (100 ml test solution) followed by further hot rolling overnight at 95°C to give a total scale removal for the two products.

Results are tabulated below.

Table 5- Mineral mix dissolver tests

Mineral mix	1 st dissolver	% scale dissolved	2 nd dissolver	% residue dissolved	% total scale dissolved
1	HDC Mk II	37.7	Pyrosol C2	60.5	76
2	HDC Mk II	27.8	Pyrosol C2	37.8	55
3	HDC Mk II	35.6	Pyrosol C2	59.0	83
1	HDC Mk II	36.3	Pyrosol ES	36.7	60
4	HDC Mk II	25.3	Pyrosol ES	28.4	46
3	HDC Mk II	25.2	Pyrosol ES	44.4	58
1	Pyrosol C2	53.4	HDC Mk II	48.7	76
2	Pyrosol C2	24.0	HDC Mk II	24.9	47
3	Pyrosol C2	59.0	HDC Mk II	66.5	86
1	Pyrosol ES	55.8	HDC Mk II	66.1	85
4	Pyrosol ES	25.2	HDC Mk II	23.7	43
3	Pyrosol ES	60.7	HDC Mk II	79.5	92

As predicted from the infrared analysis the two stage approach results in a significant increase in total scale removal with the mixed scales, compared to a single dissolver use.

Overall scale removal totals are similar with the Pyrosol C2 and HDC Mk II combinations whichever dissolver is used first in the sequence. However with Pyrosol ES better results are generally achieved if this is used first and followed by HDC Mk II.

Based upon relative costs and volumes that would be required for scale removal, the most effective well treatment would be to soak with Pyrosol ES or Pyrosol C2, displace and replace with a smaller volume of HDC Mk II.

This is because the Pyrosol compounds are most effective against the iron bearing minerals that make up a majority of the scale and HDC Mk II then dissolves residual silica and sulphate scales without spending on the removed iron scale.

4. SUMMARY

Scale solvers HDC Mk II, Pyrosol ES and Pyrosol C2 are very effective against a number of scale / mineral samples from **Client XXX** wells.

The best solver differs dependent upon the individual mineral / scale sample. Poorest results are achieved on the sample from MG-A 18" R/L U/S spool 3 2017-05-11, although 20% was dissolved with HDC Mk II. The best result was achieved with HDC Mk II and sample MT2RD SIT PHASE2 N-G LINE FMN VESSEL 2018-10-06, where almost 100% scale dissolution occurred.

In a mixture of well scale samples a two stage approach using one of the Pyrosol solvers followed by HDC Mk II gives a much higher degree of mineral scale removal than a single solver treatment and is a recommended field treatment methodology.

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