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Flow Assurance

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Evaluation of Clearwell Technology On Carbonate Brine Scaling Using Tube Blocking Method

Final Report

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1.0 INTRODUCTION

Westport Technology Center has been asked to perform a laboratory study evaluating the effectiveness of the Clearwell instrument in reducing scale deposition and plugging. Previous industry studies have been performed and give guidance to test methods and the parameters that influence scaling rates in a pipe. Several of these parameters are listed below;

- Scale frequently appears due to a pH change in the fluid as well as an increase in the saturation index of carbonate minerals,
- shear force effects scaling rates as fluid velocity increases,
- and, effect of scale inhibitors.

Westport has the capability to perform scaling studies for scale inhibitor evaluation using the tube blocking method.

2.0 EXPERIMENTAL PROCEDURE

Tube Blocking Method for Scale Rates

A well-developed method for determining scaling rates is the tube blocking method. This test method is appropriate for evaluating the effectiveness of the Clearwell product in the reduction or elimination of scale deposition and plugging.

The method uses two fluids; one having anionic scaling ions (e.g. HCO_3), and the other containing cationic scaling ions (e.g. Ca^{2+}). Equal amounts of NaCl are added to the test fluids to give them a known salinity. Both fluids are pumped at a constant rate through heated 1/8" OD tube coils inside an oven, which then commingle in a test coil of known length and inside diameter. Pressure drops are recorded on the inlet and outlet of the test coil. A backpressure regulator is used on the outlet of the system to maintain a constant pressure during the test. The duration of the test is based on the amount of time it takes for the test coil to become plugged (not to exceed 24 hours). Our current scale plugging test apparatus can encompass temperatures up to 500°F and pressures up to 7500 psig.

In published literature, it has been shown that a higher flow velocity can shear scale crystals from the tubing walls and slow down or eliminate scale plugging. Multiple flow rates can be run to determine the effect of flow velocity on scale plugging.

Pressure drop data can be used to determine the thickness of the scale layer coating the inside of the tube, if it is assumed that surface coating is uniform.

The concentration of scale forming ions as well as the change in the pH of the produced test solution can be monitored throughout the duration of the test if desired, but would require additional apparatus.

3.0 MATERIALS

Tubing Materials

1/8" Stainless Steel tubing with a 0.060 ID.

Brines

Brine A and B compositions listed to produce a calcite scale:

<u>Brine A</u>	<u>g/kg</u>
CaCl ₂ ·2H ₂ O	36.87
NaCl	138.9
<u>Brine B</u>	<u>g/kg</u>
NaHCO ₃	1.5

4.0 TEST PROCEDURES

Calcite Scaling Brine 1/8" OD Coils

Testing was performed in 1/8" OD stainless steel coils with and without using the Clearwell instrument. These tests were performed at approximately 125°F and 180 psig.

A 0.5 ml/min rate of injection of the calcite scaling brines through the 1/8" OD (0.060" ID) preheating coils produced a 1.0 ml/min injection rate through the test coil. The pressure limit on the injection pump was set at 5000 psig.

Pressure differential was measured across the test coil using a Heise PM1 digital pressure gauge with a pressure limit of 7500 psig.

Once flow had been initiated through the coils, the test was allowed to run until the test coil plugged or a maximum time of twenty four hours was reached.

Upon completion of the initial scaling test without the Clearwell instrument, all coils were thoroughly cleaned with 10% HCl to remove any calcite scale that had precipitated. The system was then setup to run the tube plugging test using the Clearwell instrument.

5.0 RESULTS

Calcite Scaling Brine 1/8" OD Tubing without Clearwell Instrument (Test #1)

Complete plugging of the tubing material never took place. However, a significant amount of scale being deposited in the test coil was apparent by the steady increase in differential pressure up to 3000 psig. The test was stopped and the system flushed with 10% HCl overnight to ensure the removal of the carbonate scale.

Results of the initial scale plugging test using calcium scaling brines, conducted without the Clearwell instrument, are presented in Figure 1.

Calcite Scaling Brine 1/8" OD Tubing with Clearwell Instrument (Test #2)

A second test was performed using the Clearwell instrument to determine the effect it had on scale deposition and plugging. Modifications of the test apparatus were needed to ensure that the stainless steel tubes were not in contact with each other or any grounding source that would inhibit the signal transfer of the instrument.

There was a pressure buildup (2000psig) and release after about 10 hours followed by a large pressure buildup to 5000psig, which caused the injections pumps to shut down. However upon disassembly, it was found that the plugging was in the 1/8" stainless steel cross (mixing head) used to connect the two preheating coils to the test coil. This plugging was theorized to be from the static section of the fitting to which the pressure transducer was connected to (there is no flow through the pressure transducer line or the sensor itself).

NOTE: This technology does not stop scale production, but rather causes the scale particles to stay suspended in the flowing media and not adhere to pipe surfaces.

The 1/8" OD stainless steel tube was flushed with fresh water using a small pump with a low pressure limit (200 psig) and was found to contain only small crystals that were not significant enough to have caused plugging in the tubing. Modifications of the test rig's plumbing were made to ensure there were no "dead areas" in the flowing system and a second screening of the Clearwell instrument was performed in Test 3.

Results of the initial scale plugging test conducted with the Clearwell instrument using calcium scaling brines is presented in Figure 2.

Calcite Scaling Brine 1/8" OD Tubing with Clearwell Instrument (Test #3)

Pressure response data from the second screening test using the Clearwell instrument indicated only one rapid increase in pressure differential (800 psig) at approximately 600 minutes. This pressure "spike" could have been from scale crystals becoming trapped in a tight bend of the 1/8" OD tubing or at a small orifice at the outlet of the mixing coil. The pressure increase lasted for approximately 30 minutes before releasing. Once the scale crystals had cleared the tube the pressure differential decreased sharply to 1.78 psig where it remained until the conclusion of the test, 24 hours.

Results of the second scale plugging test conducted with the Clearwell instrument using calcium scaling brines is presented in Figure 3.

Calcite Scaling Brine 1/8" OD Tubing without Clearwell Instrument (Test #4)

An additional test was performed without the Clearwell instrument to ensure plugging of the 1/8" OD coil would occur with the modifications that were made to the test rig after Test #2. Pressure response data from this test indicated an onset of plugging at approximately the same time duration as the initial test without the Clearwell instrument.

Results of the second scale plugging test conducted without the Clearwell instrument are presented in Figure 4.

6.0 CONCLUSIONS AND RECOMMENDATIONS

This initial screening of the Clearwell Technology was performed to rapidly gain information on the ability of the apparatus to prevent scale buildup. The tube plugging test is a very critical test for determination of scaling potential from the commingling of two brines (i.e. injection water and formation brine). Basically, if two brines are incompatible and precipitate scale particles the small ID of the coil will cause a pressure increase and possible total blockage. Total blockage or pressure buildup will occur from a "bridging" of particles or by a true scale buildup on the inside surface.

It was decided that this test procedure would be a quick and effective method to evaluate the effectiveness of the Clearwell technology without elaborate large flow loop testing. The results from these initial tests indicate that the Clearwell technology does in fact have an effect on precipitated scale and its unimpeded flow through a capillary, or pipe. Although some bridging may have taken place it did break and displace from the system. In larger pipe diameter this would not be a factor of concern. The test results are very promising and warrant further investigation of the Clearwell technology for its application and financial impact in the oil industry.

It is Westport's recommendation that further study be initiated to fully investigate, but not limited to, the following:

- It is understood that the Clearwell technology does not mitigate scale production, but causes the scale particles to stay suspended in the flowing media and thus not deposit on the pipe wall; larger flow loop tests need to be performed to determine pipe wall scale buildup rates (no possibility of particle bridging) without Clearwell and then with Clearwell
- Other predominate scale species need to be screened, i.e. irons, sulfates, carbonates
- The ability to "clean up" previously deposited scales on internal flow line surfaces
- The ability to function in commingled production (predominate hydrocarbon phase)
- Effectiveness as a corrosion inhibiting process
- Effectiveness of inhibiting other solids inherently present in produced fluids (possibly asphaltenes or hydrates) as flow assurance problems
- Effectiveness as a bacteria inhibiting process

Ultimately field trails will be desired to understand the effectiveness of the technology as it transmits through torturous paths and over long distances. Some opinions (internal Westport) were expressed about the ability to transmit without loss of signal through great water depths or through very saline formations typical of the GoM (brines being very conductive and "stealing" the signal).

Figure 1
Calcite Scaling Test #1
(without Clearwell Instrument)

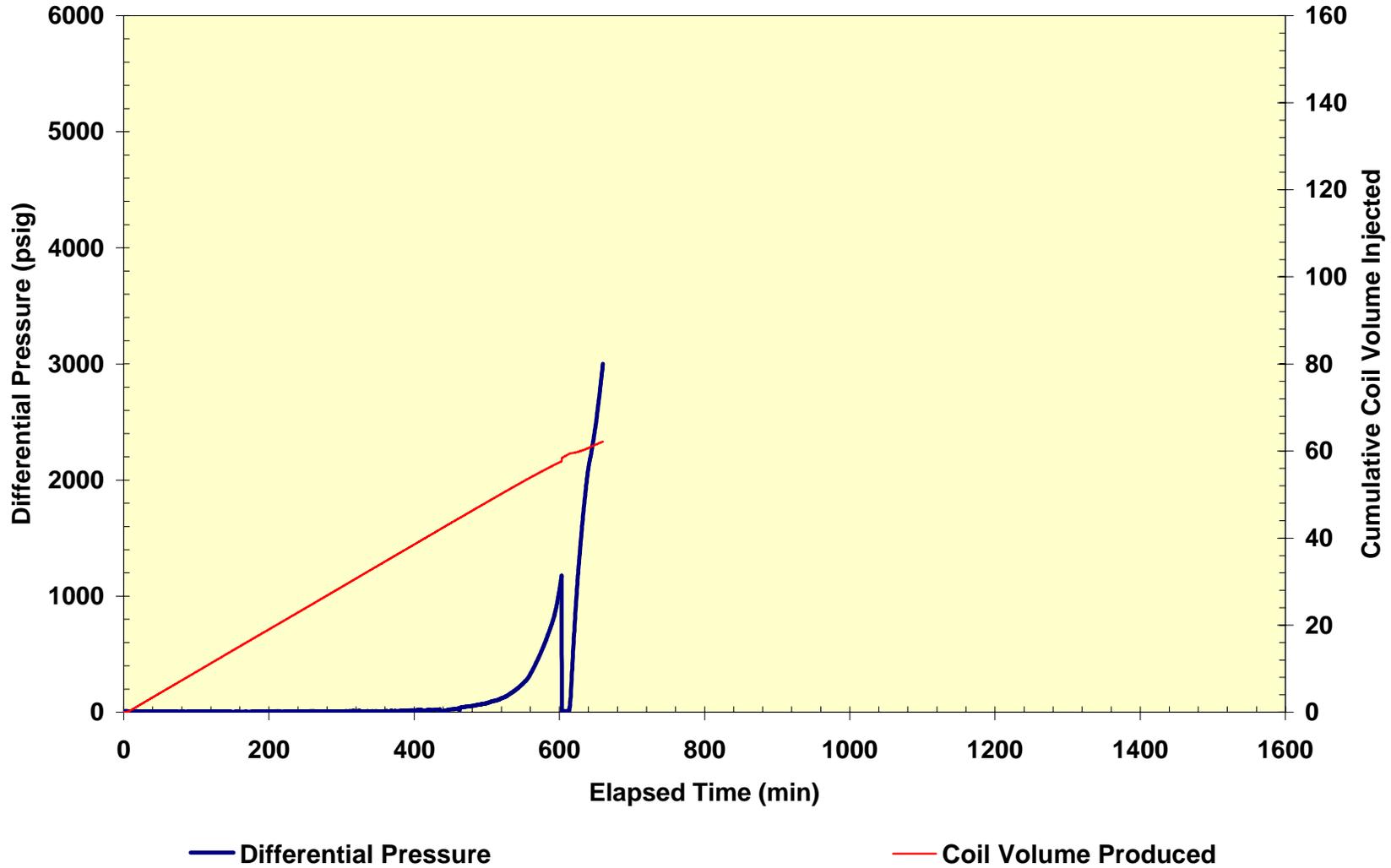


Figure 2
Calcite Scaling Test #2
(with Clearwell Instrument)

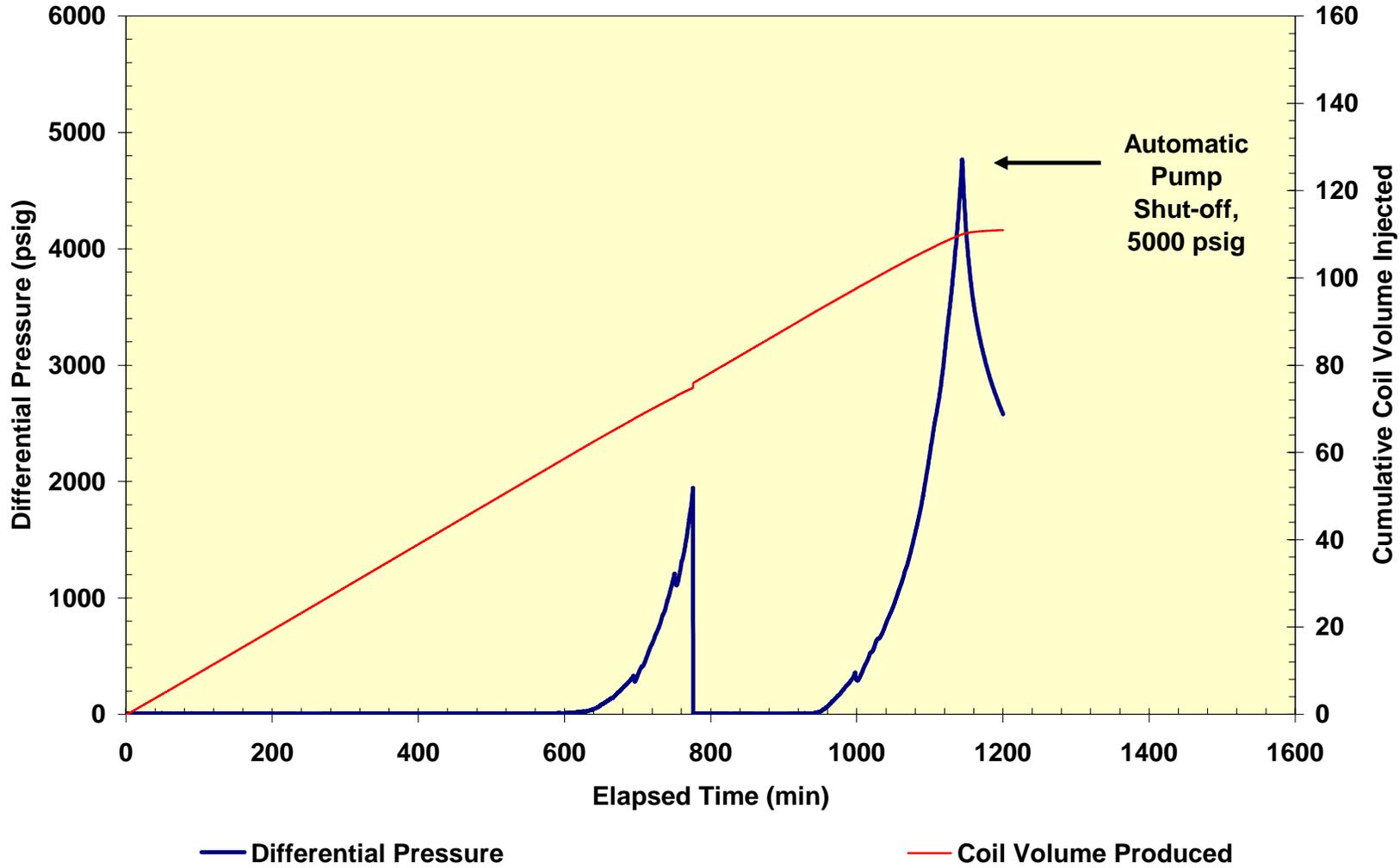


Figure 3
Calcite Scaling Test #3
(with Clearwell Instrument)

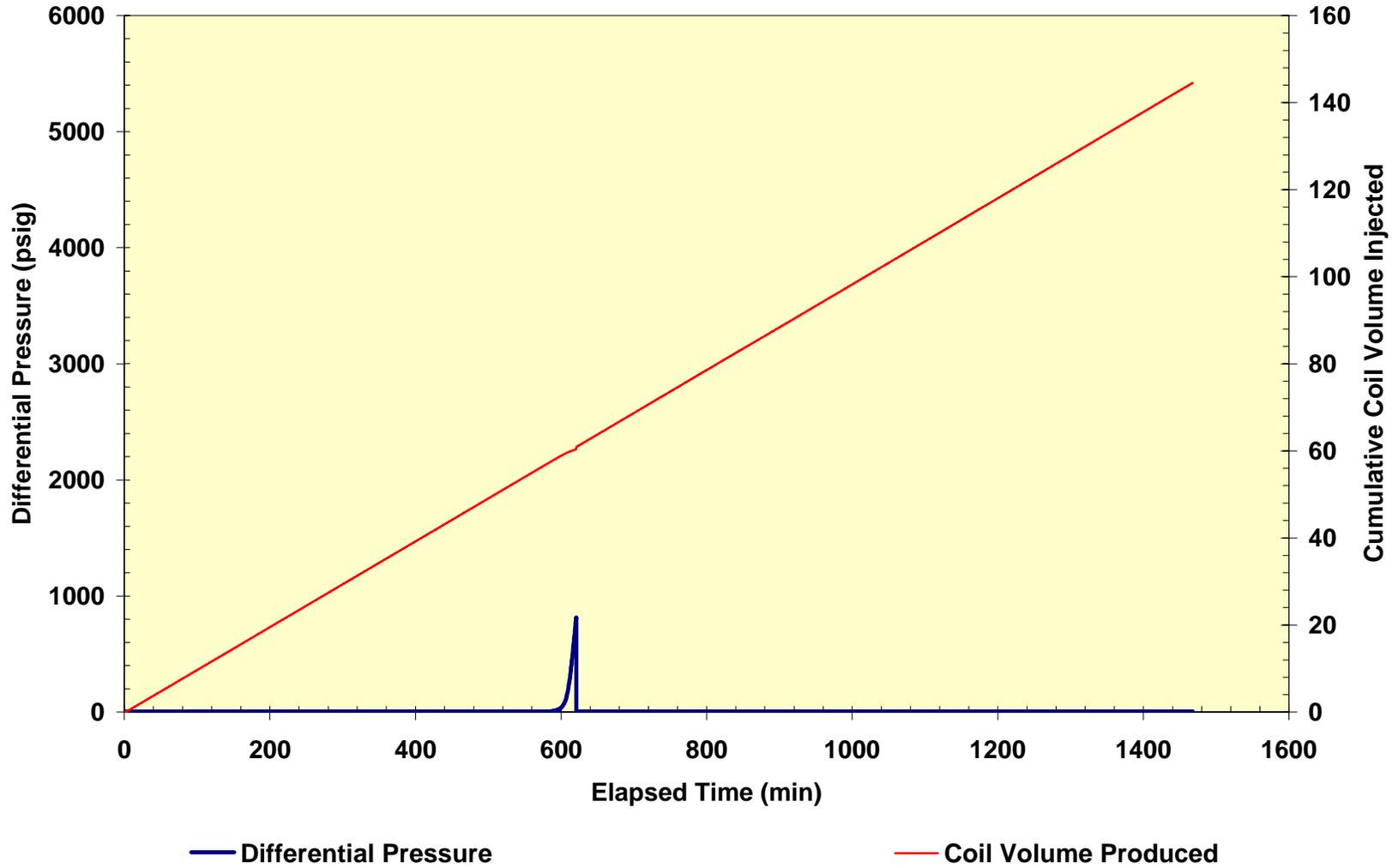
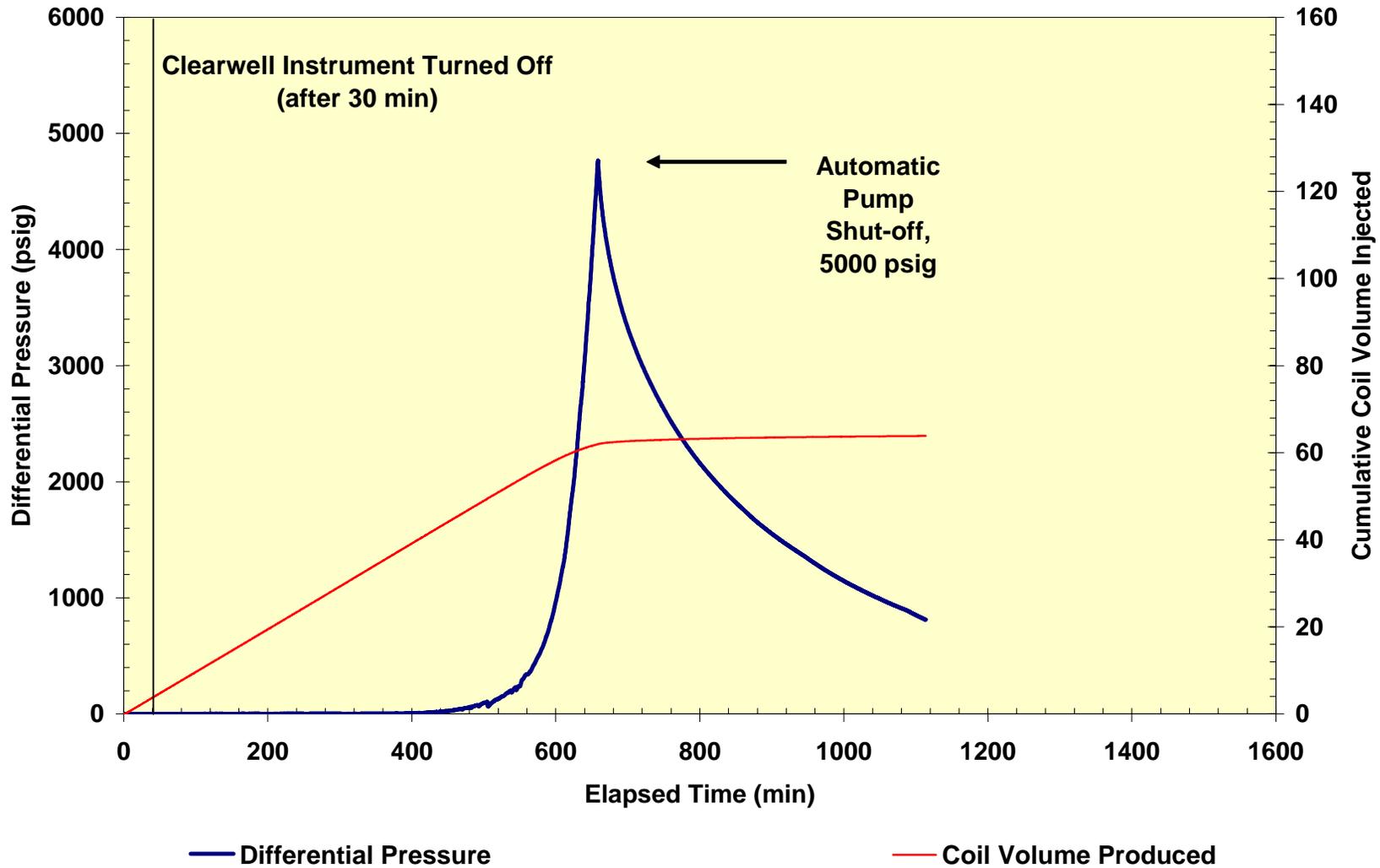


Figure 4
Calcite Scaling Test #4
(without Clearwell Instrument)



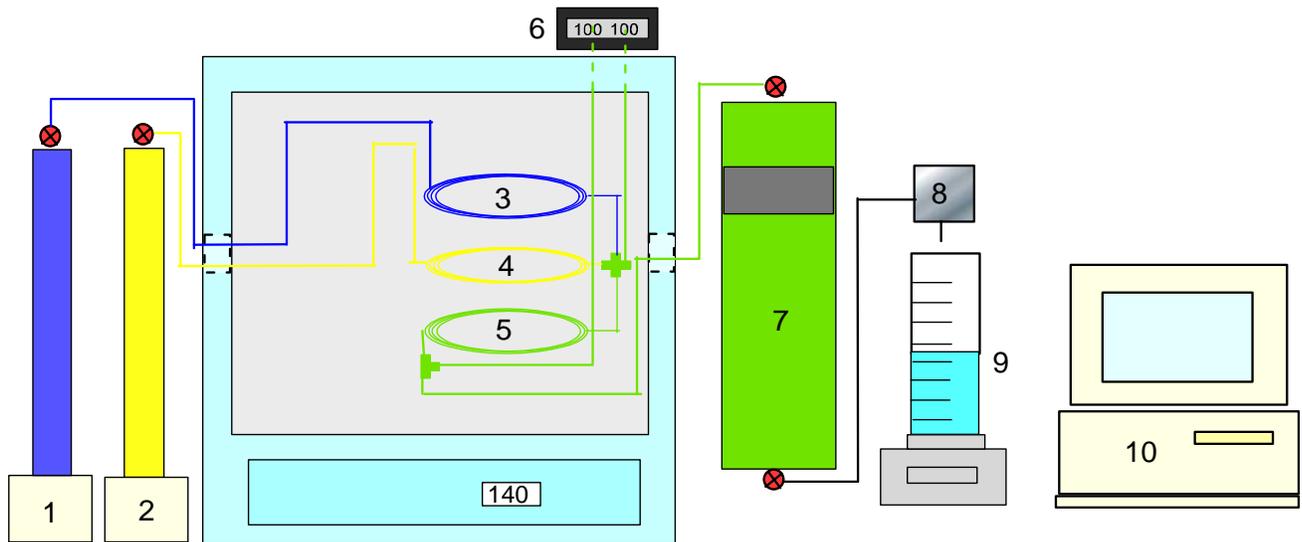
APPENDIX

Diagram of Tube Blocking Apparatus

Westport Technology - Scale Tube Blocking Method Setup

Date: 11-14-04

Drw by: Jeremy Rohan



- 1) Brine 1 Pump
- 2) Brine 2 Pump
- 3) Brine 1 pre-mixing coil
- 4) Brine 2 pre-mixing coil
- 5) Test coil
- 6) Heise PM1 Digital Pressure Gauge Test Coil Inlet & Test Coil Outlet
- 7) Produced fluid accumulator
- 8) Back pressure regulator
- 9) Scale and graduated cylinder
- 10) Data acquisition system