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Next Generation Injection Manifold for Controlled Delivery of Liquid Amendments for Enhanced Distribution and Contact

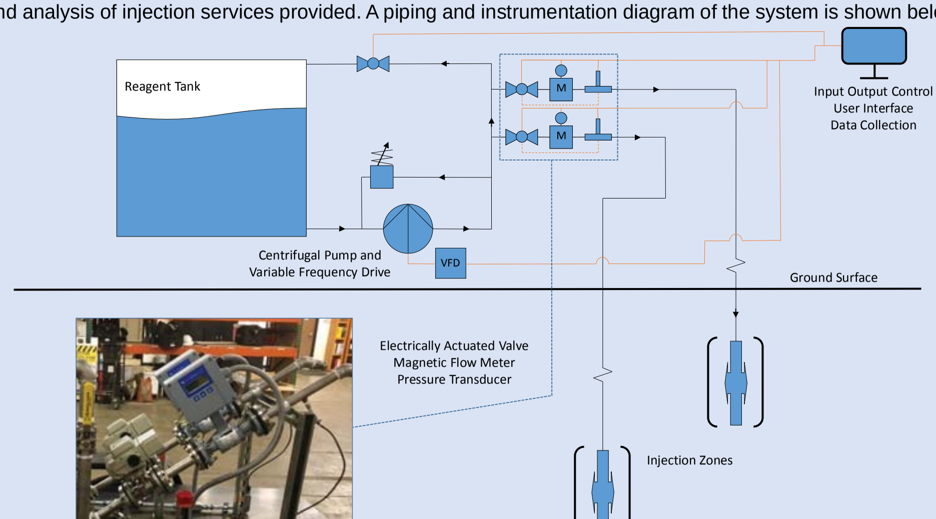
Daniel Caputo, Site Characterization Manager – Western Region; Eliot Cooper, Director of Remediation

Objective

During the course of hundreds of injection projects, Cascade has observed that a great deal of effort and expense goes into the site characterization, amendment selection, and design, but the enabling injections systems rely on human controlled equipment (pumps and valves) for injection control. Most projects require careful control of liquid amendments, such as those where fracture pressure is likely low. Current manually controlled injection systems do not meet the control requirements needed to achieve the best possible distribution. Furthermore, current injection logging does not document data on a time scale that provides adequate documentation to allow remediation professionals to understand/verify that an injection was conducted to design specifications. Therefore, to improve overall injection performance, Cascade developed a prototype injection system that aims to both provide precise control of injection operating parameters and document primary and calculated system parameters on a time scale that is relevant to the sophistication and expense of the remediation being conducted.

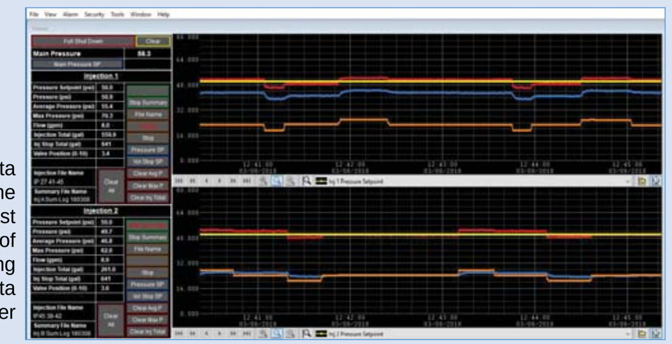
Design

Cascade's Automated Injection Manifold (AIM) system is a two point injection manifold that automatically controls injection pressure based on a user defined setpoint, typically less than the calculated fracture pressure. Simultaneously, the AIM system incorporates a data collection component that logs both primary and calculated system parameters at a rate of 1 hertz. This data can be provided to remediation professionals for documentation and analysis of injection services provided. A piping and instrumentation diagram of the system is shown below.



The software interface was designed to allow for real-time monitoring and control of injection pressure, while optimizing flow rates, at each individual port on the manifold. Field staff can observe the following injection parameters on a real-time graph during the injection:

- Injection Pressure Setpoint
- Injection Pressure
- Injection Flow
- Valve Position



Additional calculated parameters are shown numerically:

- Average Pressure
- Maximum Pressure
- Total Volume Injected
- Target Injection Volume

Details regarding the file names that data is being logged to are also shown. The software also allows for viewing past data, adjustment of scaling, importing of other data streams, and redefining control based on site specific data streams (well water level, groundwater temp, water quality parameters, etc.).

Testing

A test of the AIM system was conducted on at a site in Southern California during ongoing bio substrate injection operations. In the area where the test was conducted, the design called for 2 injections of 641 gallons of 1 wt.% emulsified soy bean oil diluted with water at each of 6 injection intervals. The objectives of testing included:

- Confirm operational basics – pump, electrical communications, plumbing, etc.
- Define how well system controls pressure and flow using 1 injection port.
- Define how well system controls pressure and flow using 2 injection ports.
- Define the limits of the system.
- Workout any software bugs.

During testing, the AIM system injected into 6 different injection intervals at two injection locations. A portion of the intervals were conducted simultaneously. The data in the next section has been selected from the data collected during testing. The last injection conducted only injected a partial volume so that the tanks could be emptied. The data from this injection is presented in Chart 2.

Data Analysis

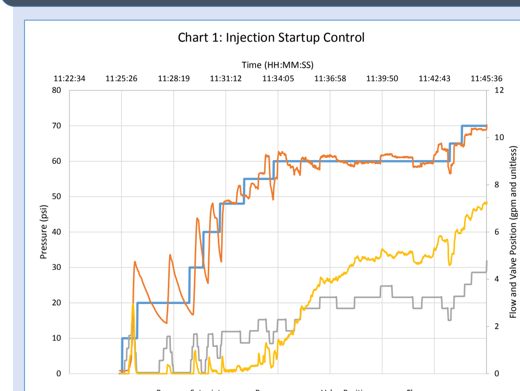


Chart 1 shows the ramp up of pressure to achieve flow during injection startup. The pressure setpoint is increased in roughly 10 psi increments. As shown on the graph, upon opening the valve (grey), there is a brief period of flow which is due to the injection piping/hose filling. Correspondingly, actual pressure increases to 30 psi then slowly dissipates. As the operator increases the pressure setpoint and the actual pressure dissipates to below the setpoint the valve opens, and in turn, increases the pressure again. This process is repeated until constant flow is achieved, but is less than desirable as it may lead to exceeding fracture pressures. However, in this case, the oscillation in pressure leads to gradual increase in flow, which is positive. Once flow is achieved, the pressure/valve loop takes good control for the duration of the injection.

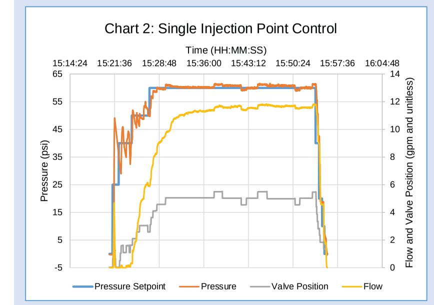
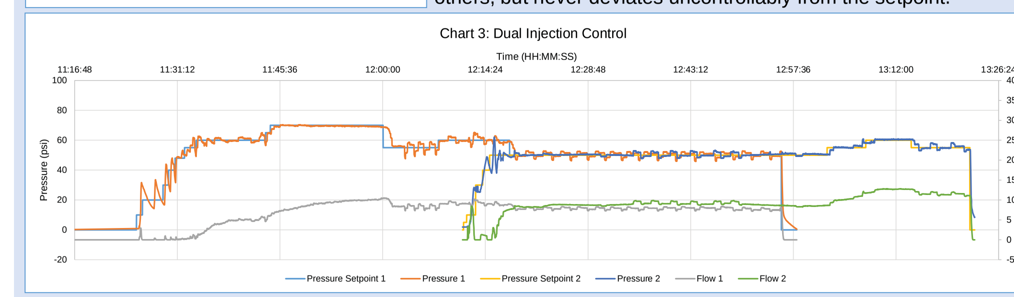


Chart 2 shows an injection 320 gallons of 1 wt.% emulsified soy bean oil in water. This injection shows a smooth ramp up in flow, but similar pressure oscillation on startup observed in Chart 1. During this injection pressure was optimized to achieve maximum flow. What is notable in this chart is the excellent control of pressure during the injection.

Chart 3 shows pressure setpoint, pressure, and flow for both ports of the AIM system. Initially only port 1 is injecting, at approximately 12:11 port 2 begins injecting. At approximately 12:18 both port's setpoints are set to 50 psi. At 12:56 the port 1 injection is ceased. The system shows better control during some time periods then others, but never deviates uncontrollably from the setpoint.



Next Steps

The goal of the AIM system was to design and build a better injection system for liquid amendments. A system that would remove the human error from the control aspect of today's injection manifolds and to develop a data logging system that provides information on a time scale that indicates whether or not injections have been performed according to specifications. With some exceptions, and room for improvement, the system has met these goals during initial tests. The data logging system works as designed, and provides useable comma-delimited data that can easily be transferred to an Excel document or to a database. Pressure control works well when flow is achieved but managing start up pressure can be a challenge. Based on the test conducted, the following improvements have been identified as next steps:

- Develop a startup mode that allows precise control of startup conditions. This will likely involve controlling valve position electronically so that pressure can be carefully increased until flow is achieved, at which point, the system would automatically control pressure.
- Increase the size of the pump to give the system a greater pressure and flow range to support expanding the system to a 10-point manifold for full-scale projects.
- Incorporate programming to control pressure or flow rates based on other design parameters including groundwater elevation in monitoring wells, subsurface or groundwater temperature, groundwater quality data, or subsurface pressure data.
- Incorporate programing to support simultaneous feeding of additional inline feed streams, e.g. oxidant activators.
- Develop offsite control to support field operators.
- Although the system is currently designed to optimize low pressure liquid injection, the same control system and logic could be used for high pressure jetting of liquids.