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Presentation title:
Real-Time Sensors for Multi-Phase measurement of pipe flows in steam and gathering lines.
Laboratory and field trial results

Prefer poster or oral presentation.

Real-Time Sensors for Multi-Phase measurement of pipe flows in steam and gathering lines.
Laboratory and field trial results

Laboratory and field trial results of testing of two new sensor techniques for measuring parameters of two-phase or multi-phase flows are presented. The sensor techniques are specifically developed for ease of deployment in geothermal piping, with the intent of providing affordable sensor technology that could be deployed on a per-well basis throughout a production steamfield.

Laboratory results suggest that the use of both sensors working together may be able to determine multi-phase information about oil/gas flows in gathering lines.

The sensor techniques are introduced, as well as results of laboratory and field trial data gathering.

Real-Time Flow Sensors
for Geothermal Steamfields, and Possibly Oil/Gas Lines

Presenter:
John Sisler
Steamfield Sensors

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- Advantages of Knowing Flow Information Real-Time
- The Two Sensor Methods: Quick Technical Review
- Field Trials: First Look at Raw Data
- Field Trials: Data Analysis
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Advantages of Knowing Flow Information Real-Time

- Geothermal energy producers need to know their well performance, and current monitoring techniques cannot provide data continuously.
- Well response is measured quarterly, or in extreme cases monthly, which is still no more than one data point per month.
- With such data, there is no way to effectively track effects of one well on another.
- Much time passes before you can know the effects of a change made to a well, whether done to improve day-day operations or develop long-term plans for the reservoir, and the opportunity for improvement is delayed.
- Real-time sensors allow managers to develop effective plans **before the opportunity is lost.**

The Two Sensor Methods: Quick Technical Review

- LC Sensor: Measures pipe content by evaluation of Weight.
- RF Sensor: Measures pipe content by evaluation of Internal Pipe Impedance.

- Both measure water content inside the pipe.
- Both offer data in real-time (per minute) intervals with +/- 2% accuracy.

- The two sensors use very different means to measure the pipe content, but can use similar software for data analysis.

- LC Sensor installs at pipe supports, with no contact to geothermal fluid.
- RC Sensor Installs through standard pipe tap ports, and is not affected by pipe stresses or environmental effects.

The LC Sensor

< Geothermal piping on sliding supports

LC Sensor installed on sliding pipe shoe >

The RF Sensor

< Installed through TFT injection port

Installed through TFT sample port >

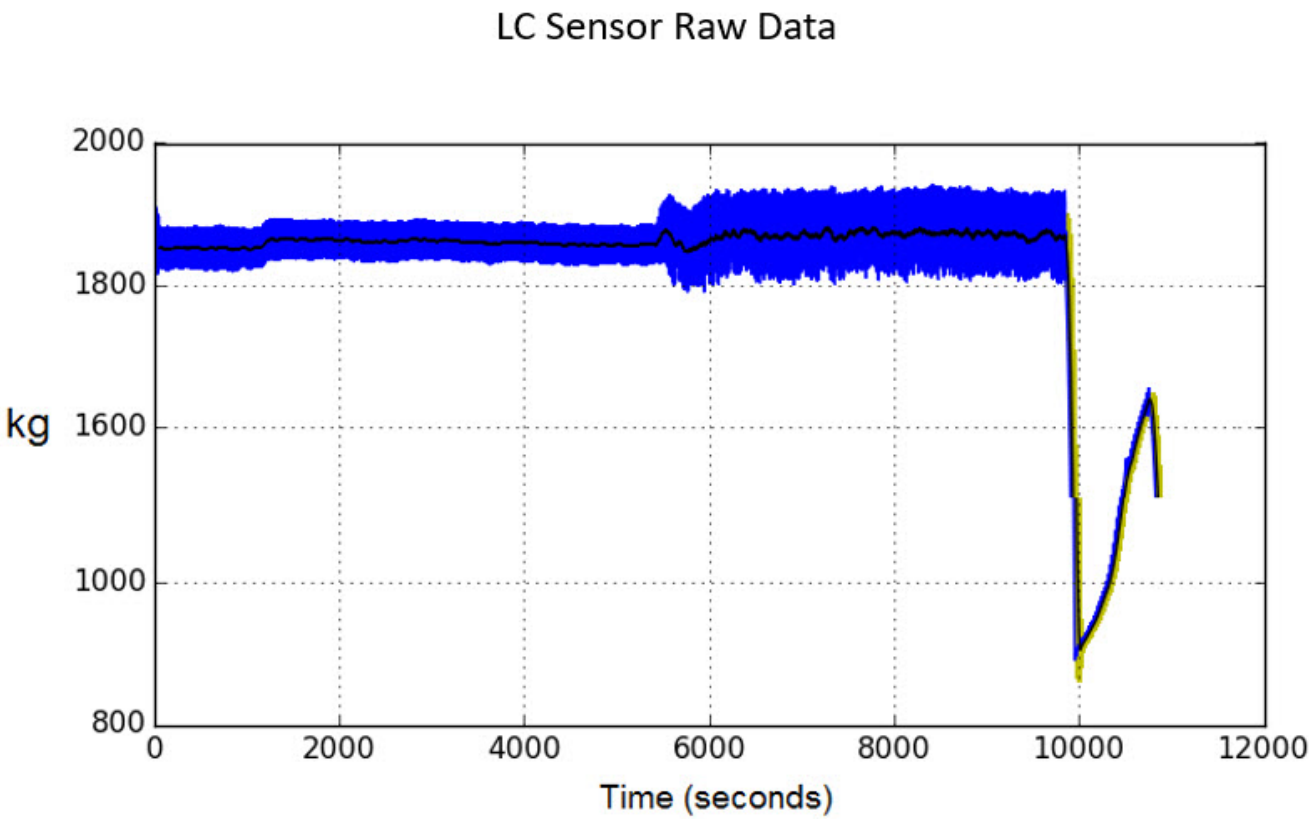
LC and RF Sensor Data Analysis

- Sensors take measurements multiple times per second.
- Sensors include a control computer, which allows for full connection to wired data networks, wireless networks, or stand alone data logging.
- Data is analyzed by various mathematical operations.
- Accuracy is +/- 2% at 1-minute intervals.
- Analyzed results are used for:

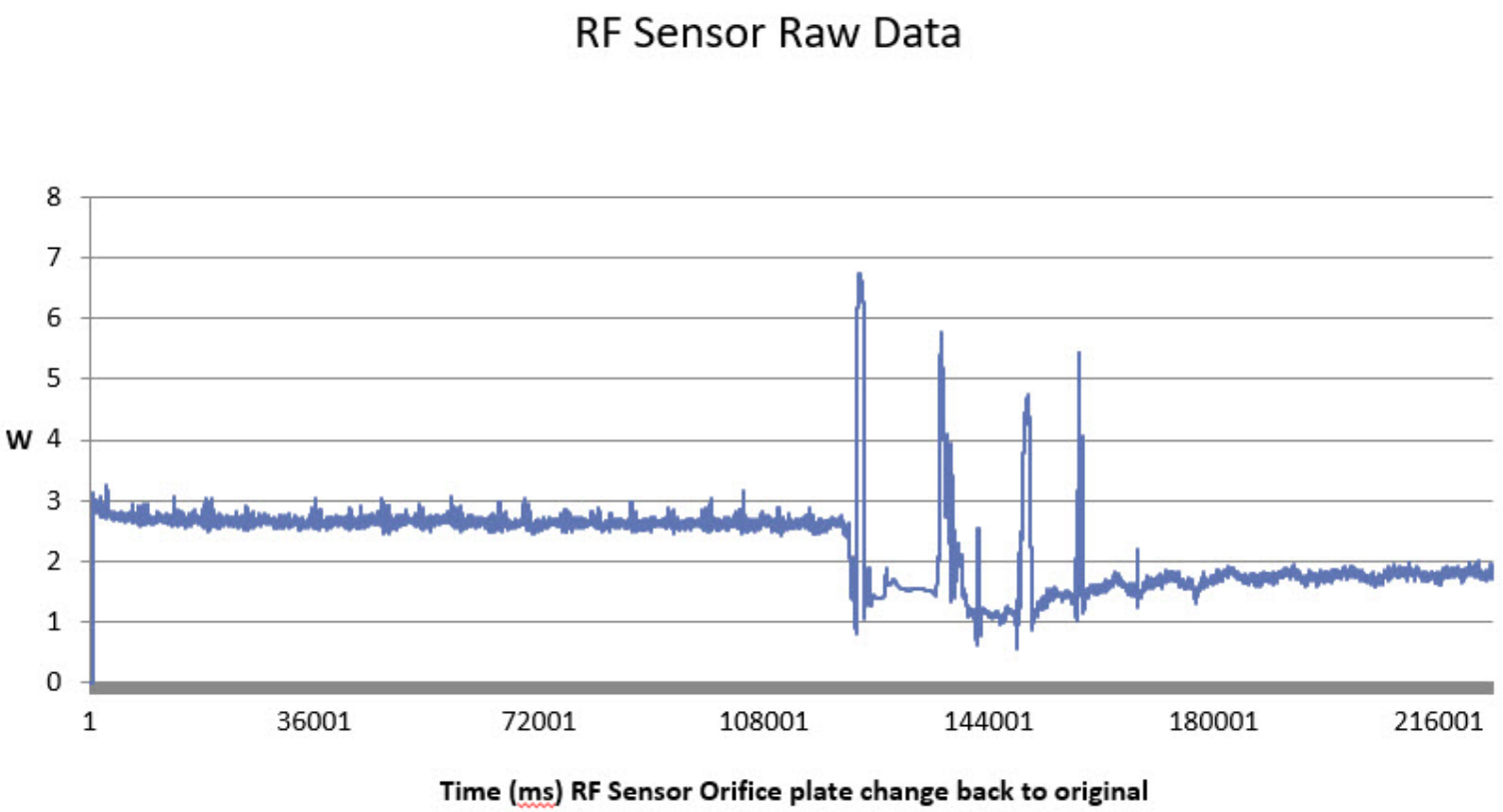
  Tracking of well performance - Tracking of water flow rates - Water build-up

  Changes in flow regime - Monitoring of unsafe conditions - Well interactions

Field Trials: First Look at Raw Data

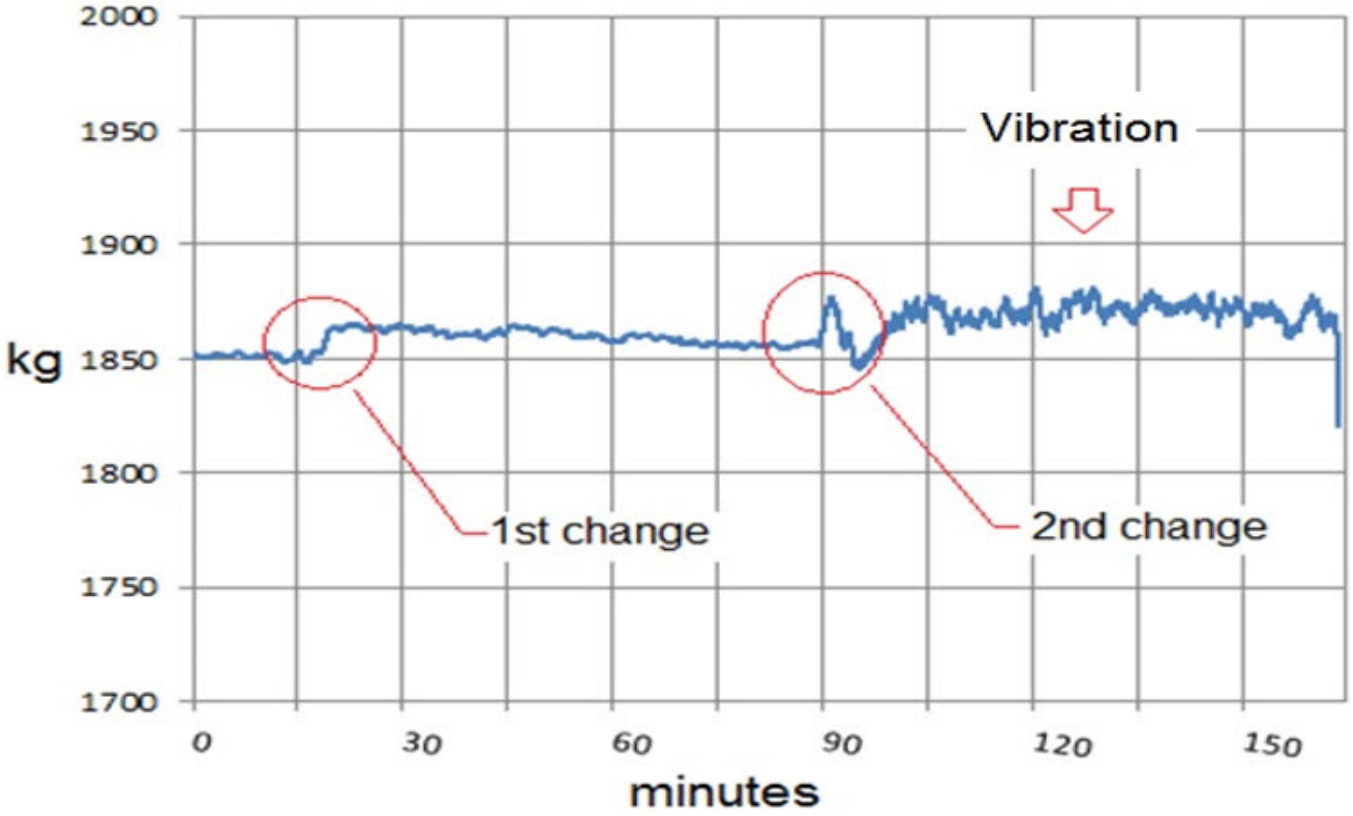


Field Trials: First Look at Raw Data



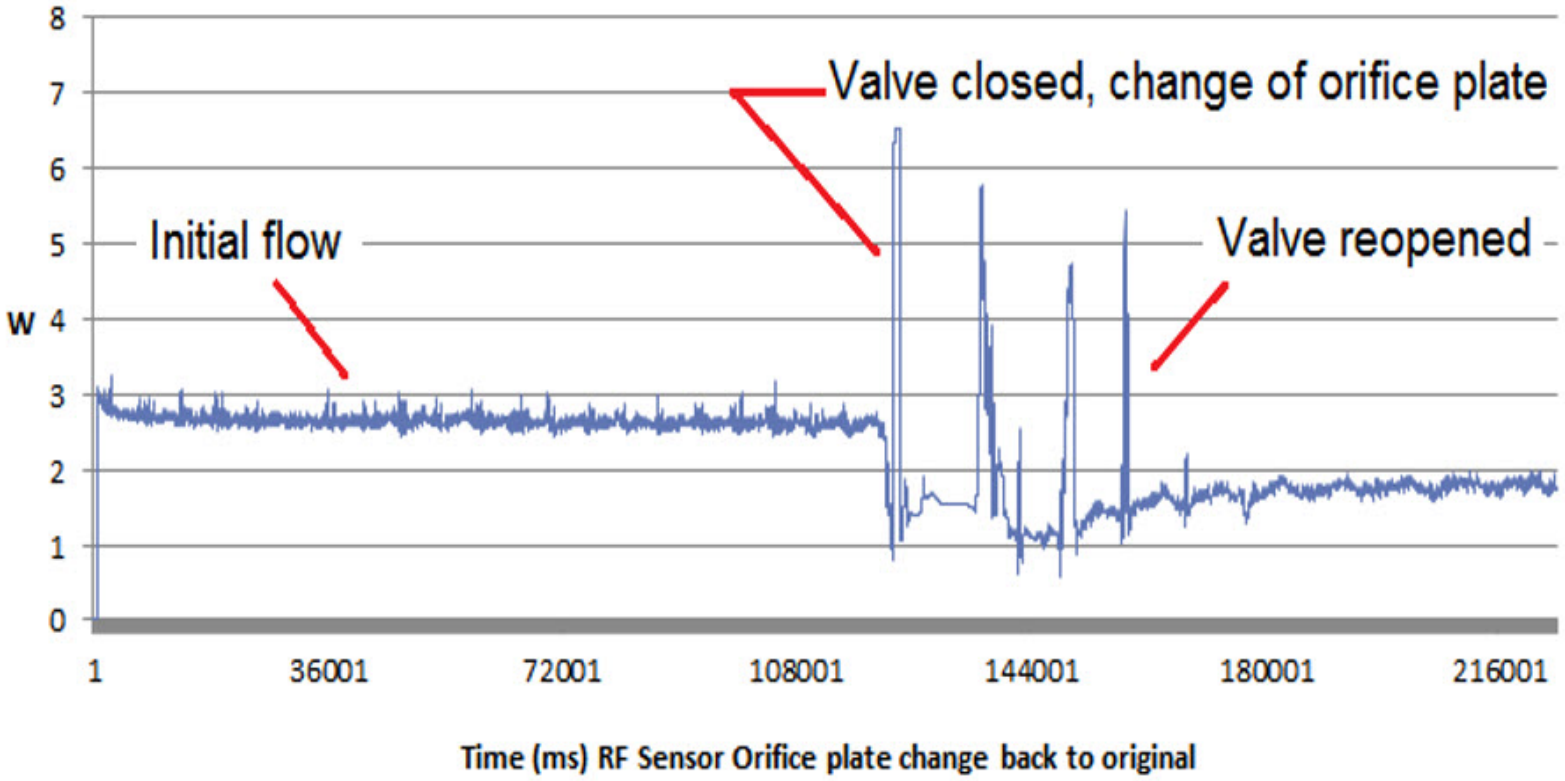
Field Trials: Data Analysis

LC Sensor: Averaged



Field Trials: Data Analysis

RF Sensor, event notations

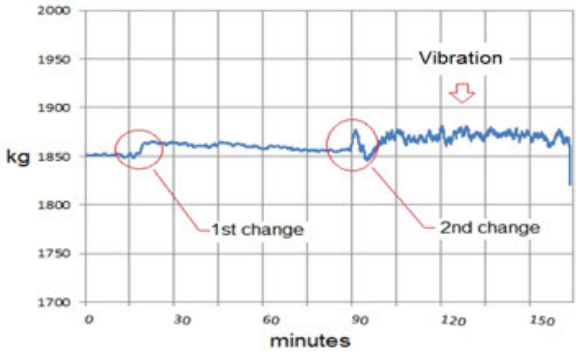


Field Trials: Data Analysis

- Sensors measure water content.
- Computer uses pipe ID and distance between supports to calculate void fraction.
- Trends are found in the data by:
  - Statistical evaluation such as Standard deviation
  - Frequency analysis with Fourier transform
  - Pattern recognition and time correlation
- Historical analysis can also be performed, to provide comparison of current performance to past trends.

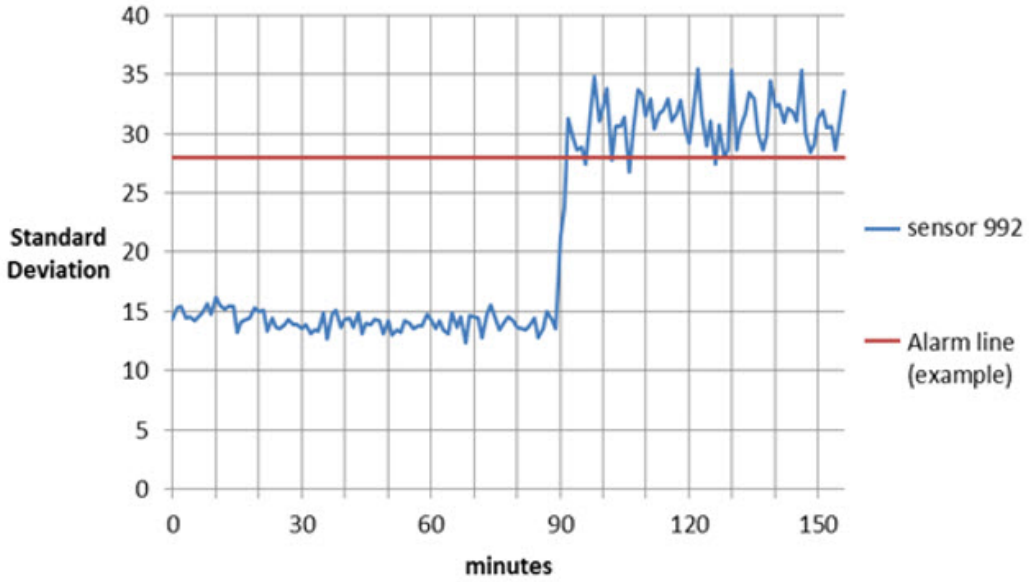
Field Trials: Data Analysis

Standard Deviation



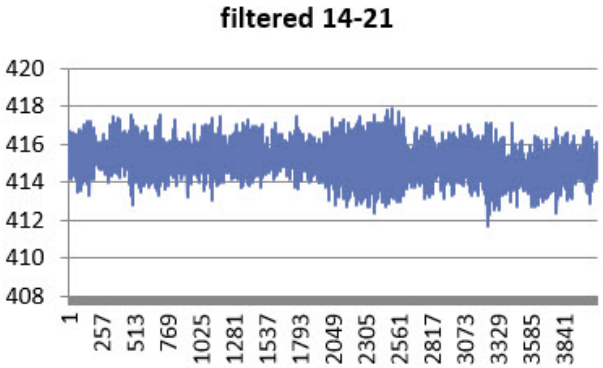
< Averaged data

Standard Deviation >



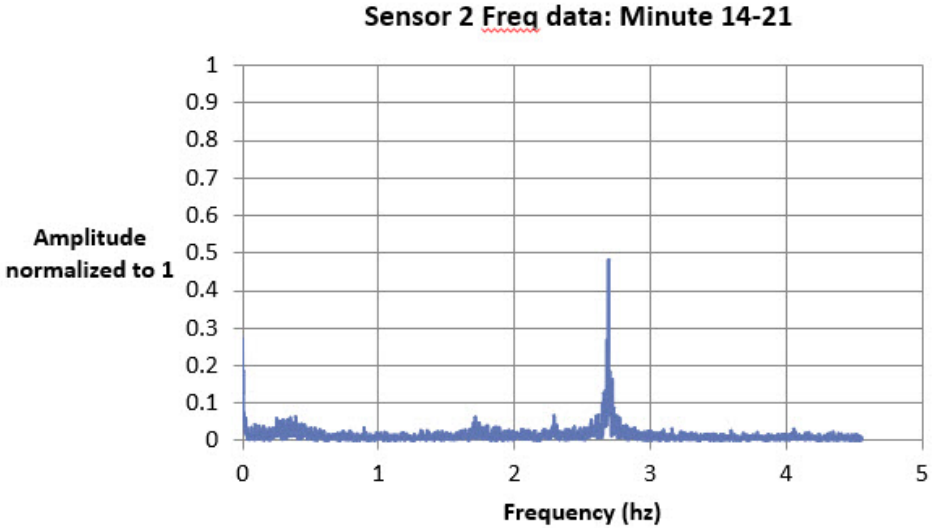
Field Trials: Data Analysis

Frequency Analysis

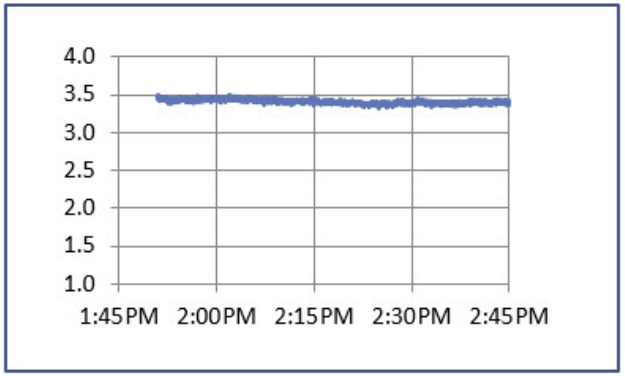


< Raw Data

Data viewed in Frequency Domain >



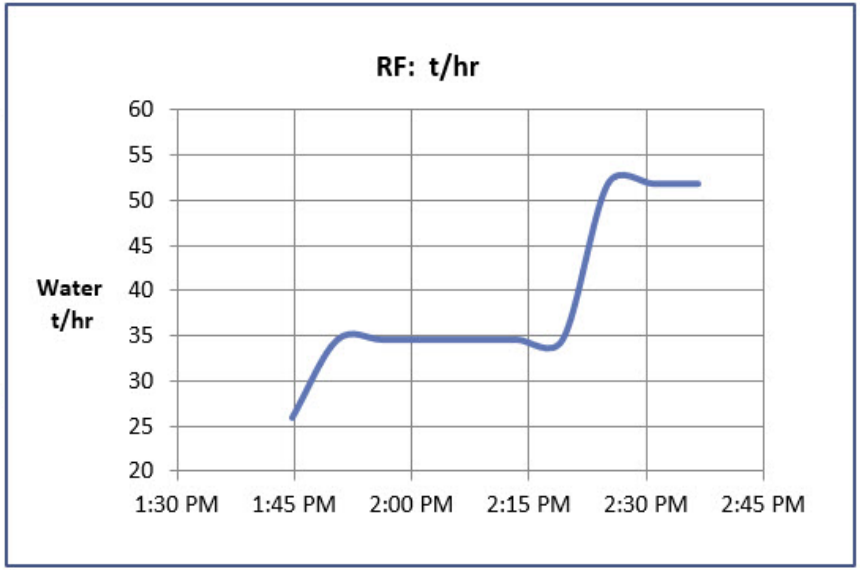
Field Trials: Data Analysis



Raw Data, Sensor 1

Raw Data, Sensor 2

Time Correlation



Water Mass Flow Rate

Future Testing

- Geothermal Field trial: May/June 2018. Includes multi-well testing for evaluation of well interaction.
- The sensors measure water content, and should be able to do so in gas lines similar to what has been seen in steam (geothermal) pipelines.
- It may be possible to measure more parameters such as gas/water/oil, with both sensors working in tandem.
- Steamfield Sensors is actively pursing more opportunities for field trials, to gather more datasets from real world wells. This will be extremely useful for software development.

Please contact:
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Conclusion

- Two new sensor techniques have been tested in field trials.
- The sensors provide real-time data on geothermal flows with +/- 2% accuracy.
- Trends in the flow can be seen immediately. The data is analyzed to calculate void fraction.
- When two sensors are used, trends in the data can be used to determine water flow rates.
- Further analysis of the data can provide safety alarms for changes in flow regime, build-up of water, and vibrations in pipes or valves.
- The sensor can act stand alone for data logging, or connect to wired or wireless networks.

Thank You

Questions ?

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Current sensor methods

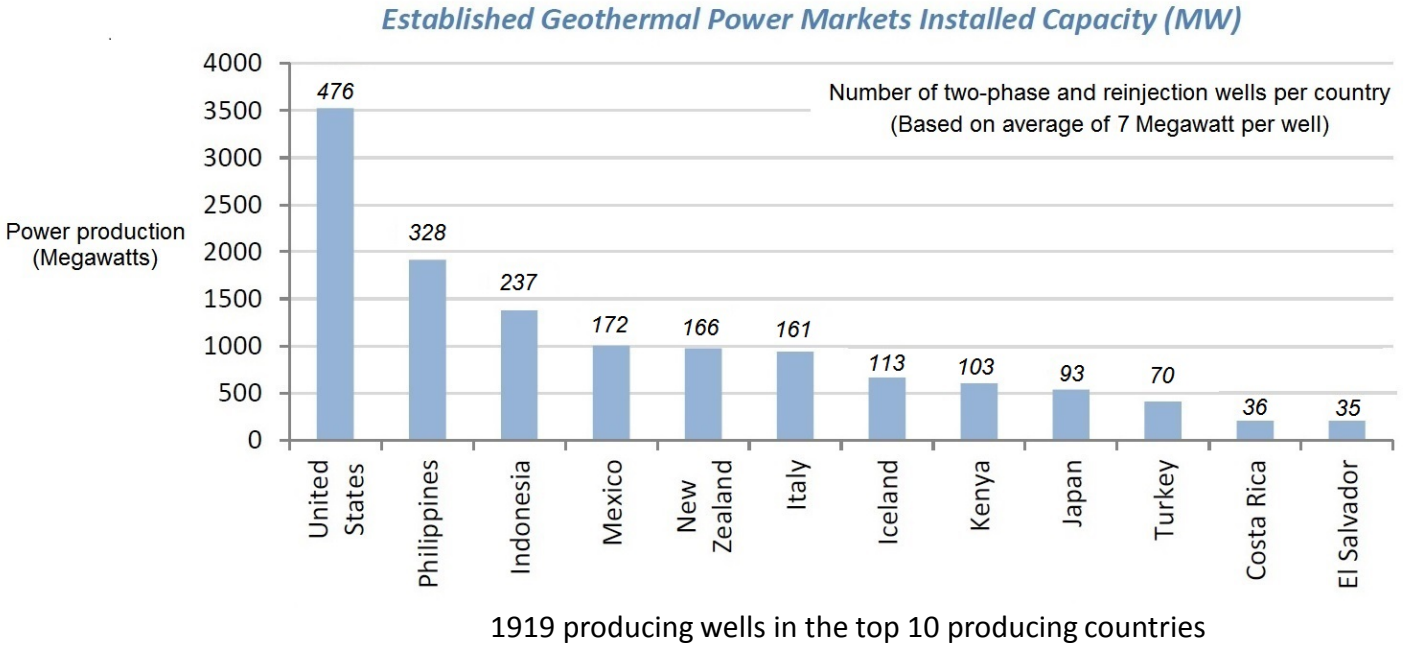
- **Common non-real-time sensor methods used in the fields today:**
- Horizontal discharge: +/- 6% accuracy. Noise/pollution issues. Well must be offline.
  Steamfield Sensors: +/- 2% accuracy. No noise/pollution issue. Well remains online.
- Tracer flow test: +/- 6% accuracy. Chemical analysis. Results not available on-site.
  Steamfield Sensors: +/- 2% accuracy. Results available immediately.

- **Other real-time sensor methods:**
- Acoustic: Special Installation. In-pipe maintenance. Unpredictable response.
- Capacitive: Special installation. In-pipe maintenance. Initial expense.
- Dual-tap orifice plate: Special installation. In-pipe maintenance. Pressure drop.

Steamfield Sensors sensor methods do not require special installation, can be maintained from outside the pipe, and have no effect on pipe flow.

Worldwide market and worldwide deployment

- Geothermal Energy producers are worldwide. Producers with two-phase flows (mixed water and steam) have the largest need for these sensors.



1919 producing wells in the top 10 producing countries

From: Geothermal Energy Association: 2015 Annual U.S. & Global Geothermal Power Production Report and Petrowiki: Geothermal drilling and completion

RF Sensor Field Tests

LC Sensor Field Tests