Development of Title 24's New Drain Water Heat Recovery Savings Algorithm

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Outline

- Background
- Goals and Methods
- Laboratory Testing
- Data Analysis Methods
- Algorithm Development
- Validation and Results

Background – Title 24

- California’s building energy efficiency code
- Three ways to add new technologies
  - Mandatory: Must be in all buildings
  - Prescriptive Path: List of building characteristic that meet code. Baseline for the performance path
  - Performance Path: Builders create own building design. Use simulation to show lower energy use than baseline. Compliance options represent possible choices

Background – Title 24 Draw Profile

- Title 24 has a new hot water draw profile
- Based on measured data
- Use patterns are a function of number of bedrooms in the house
- Not currently available, but should be
  - Allow third parties to validate work
  - Very useful tool for simulation inputs, and research studies
- I'd be happy to find a way to make them publicly available
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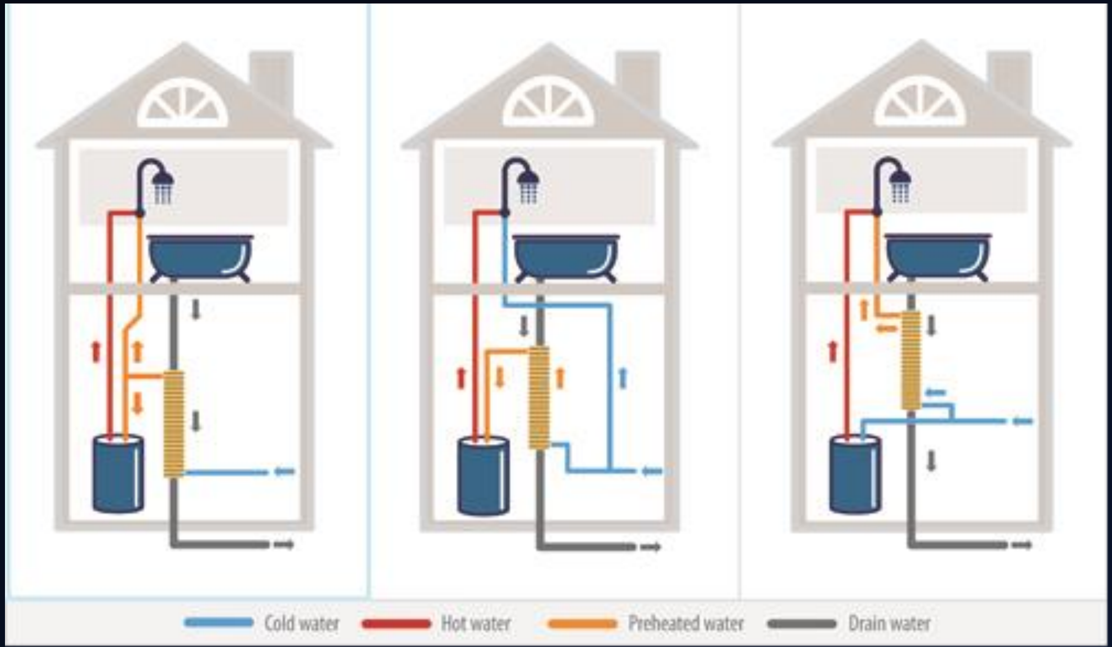
Vertical DWHR

- Tube-in-tube heat exchanger
- Transfers heat from hot shower drain flow to cold potable water flow
- Can be installed three ways
- Equal Flow, Unequal – Water Heater, Unequal - Shower



Project Goals

- Create algorithm for vertical DWHR
- Situation:
  - Location in the state changes (Inlet water temperature)
  - Installation configuration (Water flow rates)
  - Number of bedrooms in the house (Impacts Title 24 draw profile)
  - CSA rating (Effectiveness at 2.51 gal/min) as user-defined input

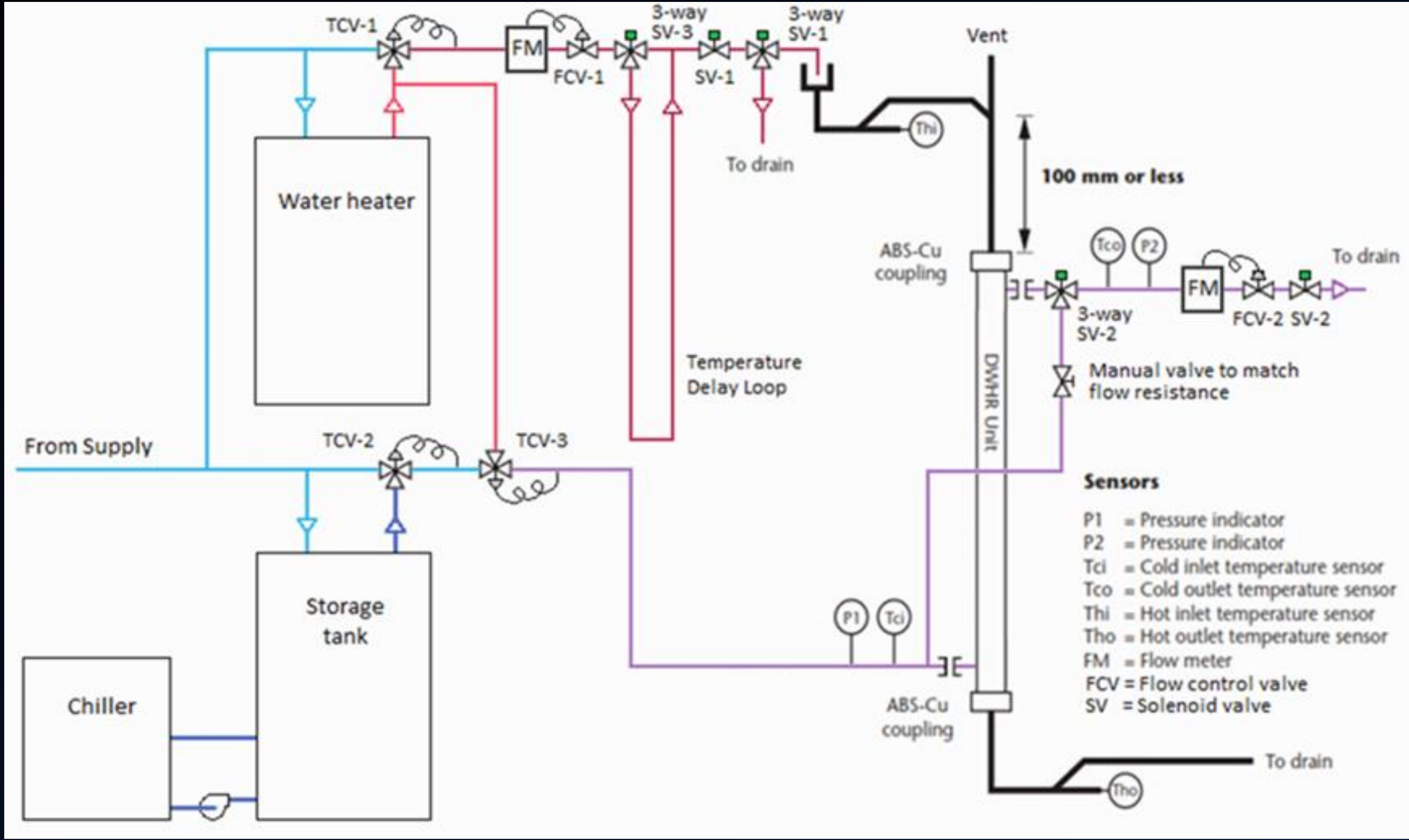
Algorithm Development Plan

- Create correction factors as a function of:
  - Potable and Drain water temperature
  - Potable and drain flow rate
  - Duration of shower
- $\varepsilon_{Shower} = \varepsilon_{CSA} * (Correction\ factors)$
- Identify energy savings using available energy and effectiveness
- Test four units to compare performance, and create a generic model

Data Requirements

- We need…
  - Steady state effectiveness data
  - Transient effectiveness data
  - In a LOT of temperature/flow scenarios

Schematic of the test lab



Uncertainty

Measurement	Uncertainty
Temperature (deg C)	0.5
Drain-Side Flow (%)	1.57
Potable-Side Flow (%)	4.16

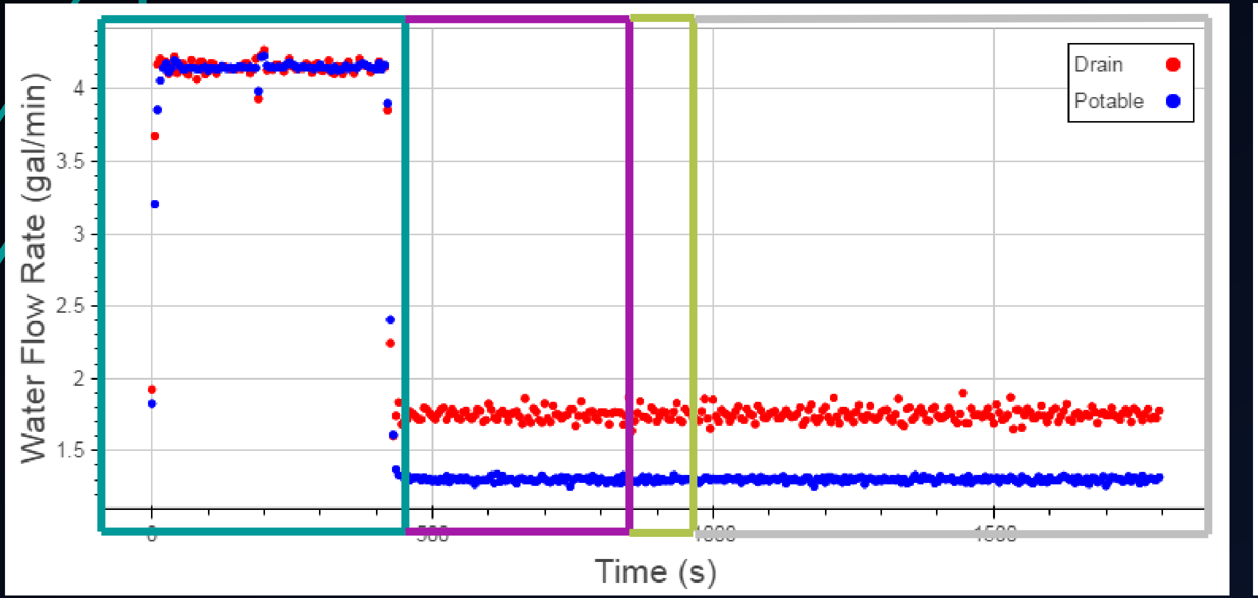
- Uncertainty in flow higher than desired
  - Testing at lower flows than anticipated, uncertainty increased at lower limit of flow meter
- Uncertainty in calculated effectiveness varies from test to test
  - Typically around 5 percentage points

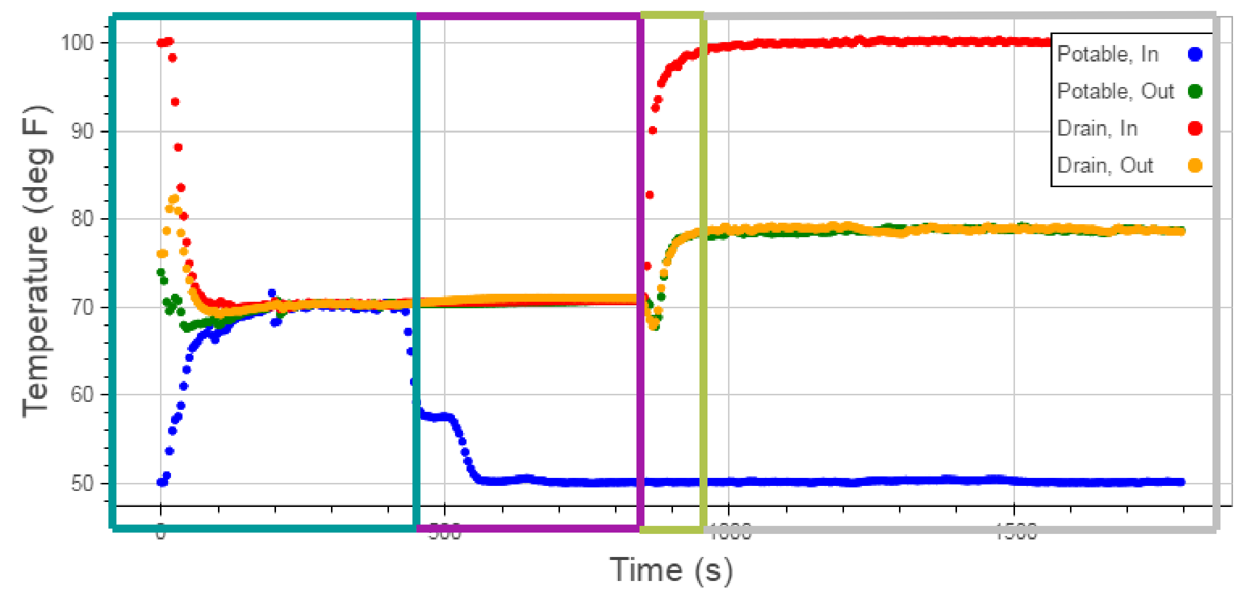
Control and Automation

- Uses LabView controls
- All control is automated
- Can input time, temperature, flow requirements and let the lab perform days worth of tests unobserved
- Dramatically reduces labor time and cost for projects

Process of a test

1. Pre-test purge
2. Conditioning
3. Warm-up
4. Steady state

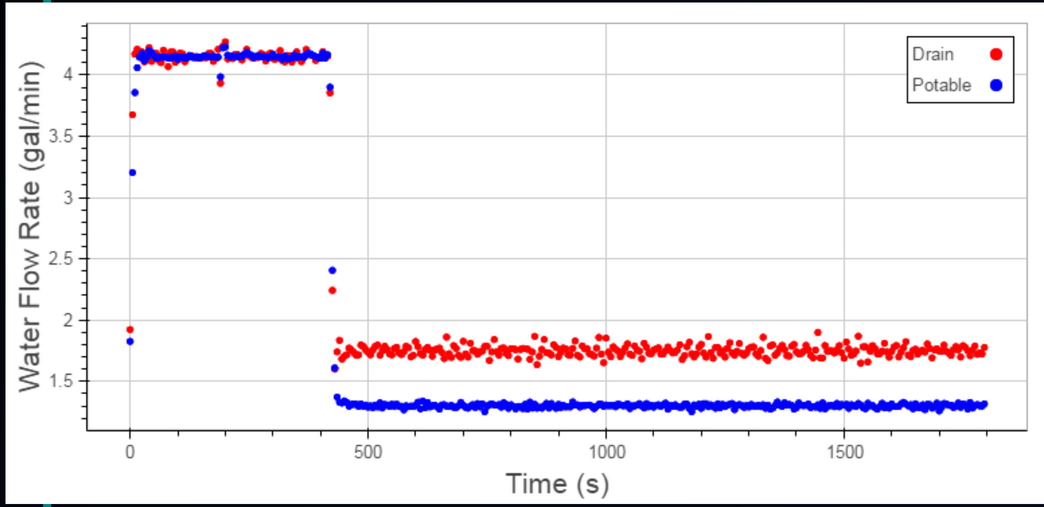


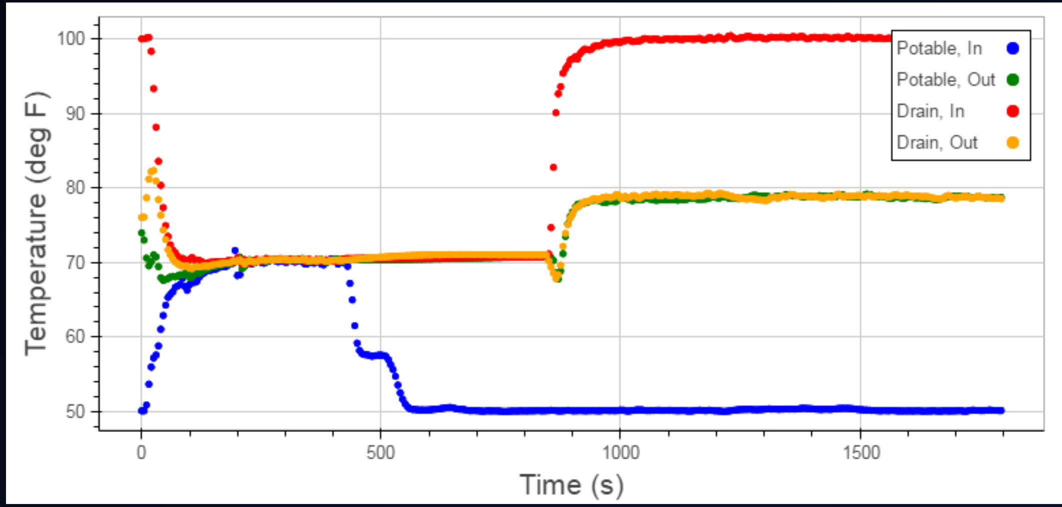


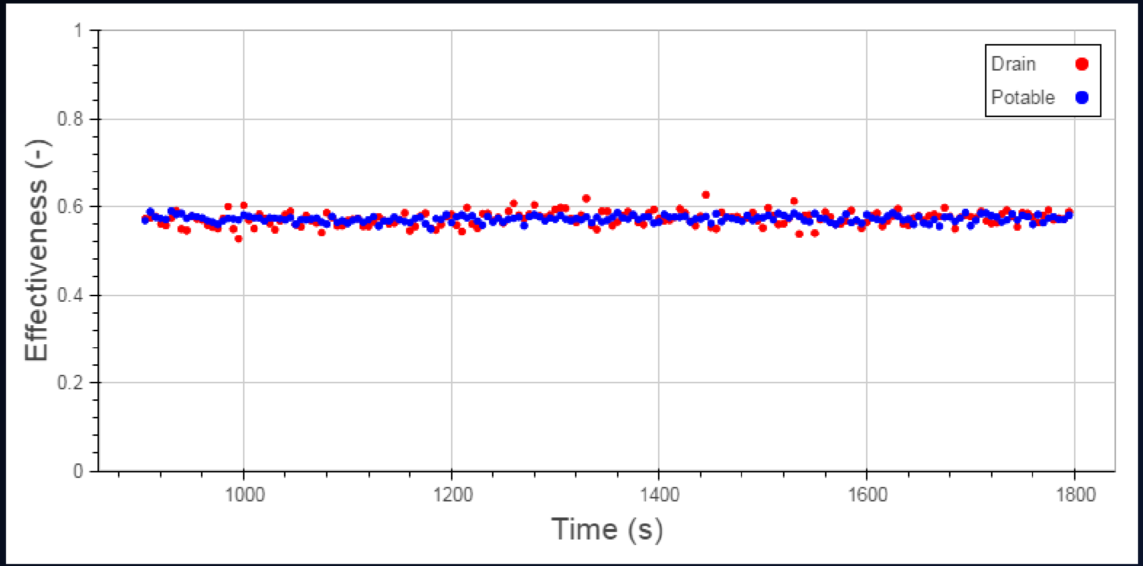
Data Analysis

- Automated python script
  - Minimizes labor time
  - Creates plots describing tests
  - Automatically identifies effectiveness, and stores it for algorithm development
  - Creates 1-d and 2-d curve fits for each of the correction factors

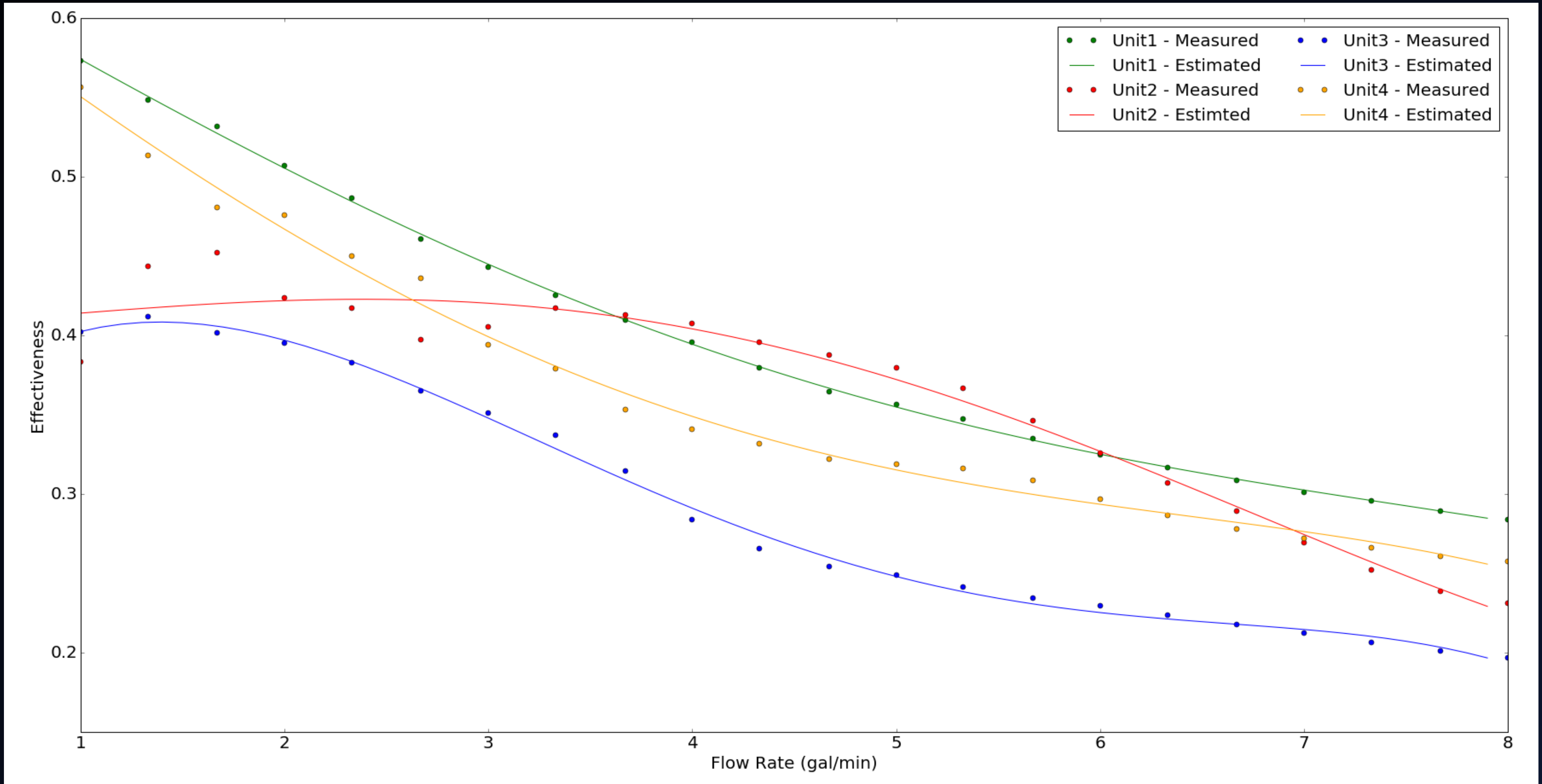
What does the data from each test look like?



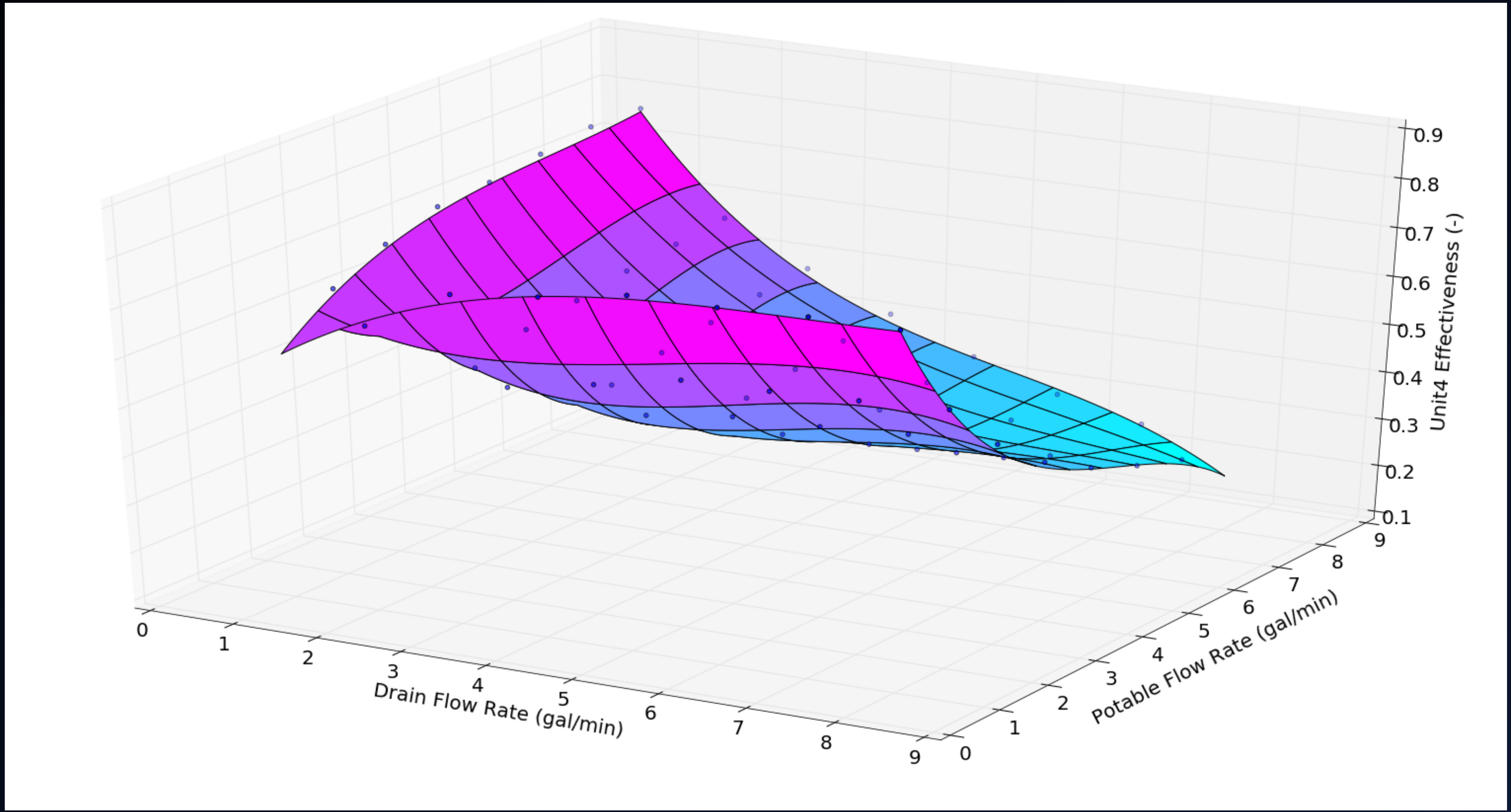




What do the Equal Flow regressions look like?

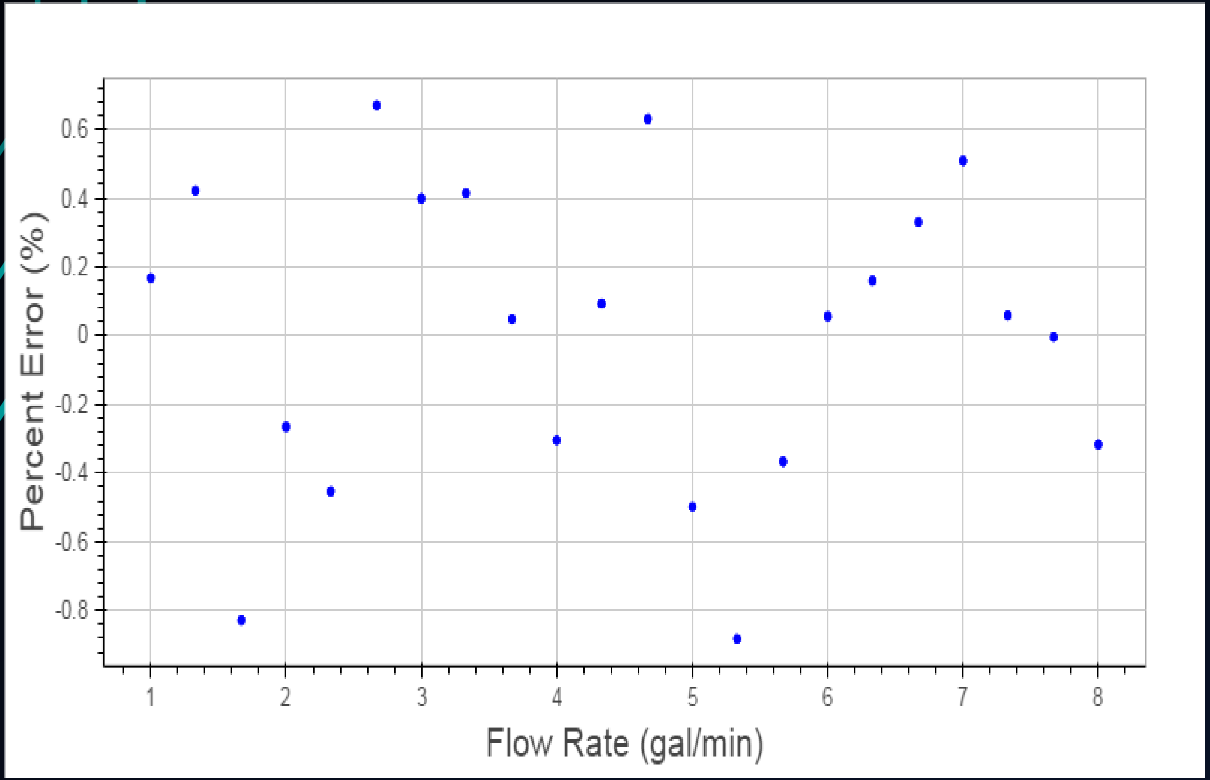


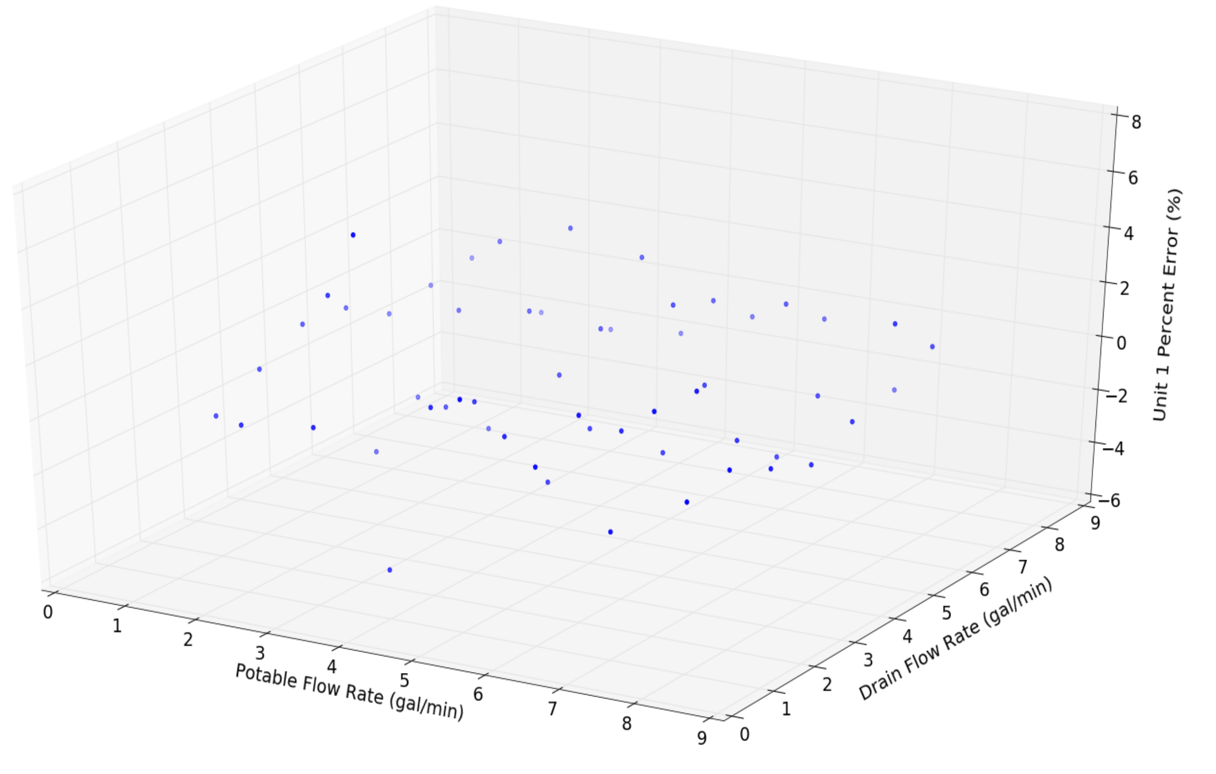
What does an Unequal Flow regression look like?



How accurate are the individual model regressions?

- Hard to provide details in a presentation
  - Generally less than 5% error in a prediction
    - Less than measurement uncertainty

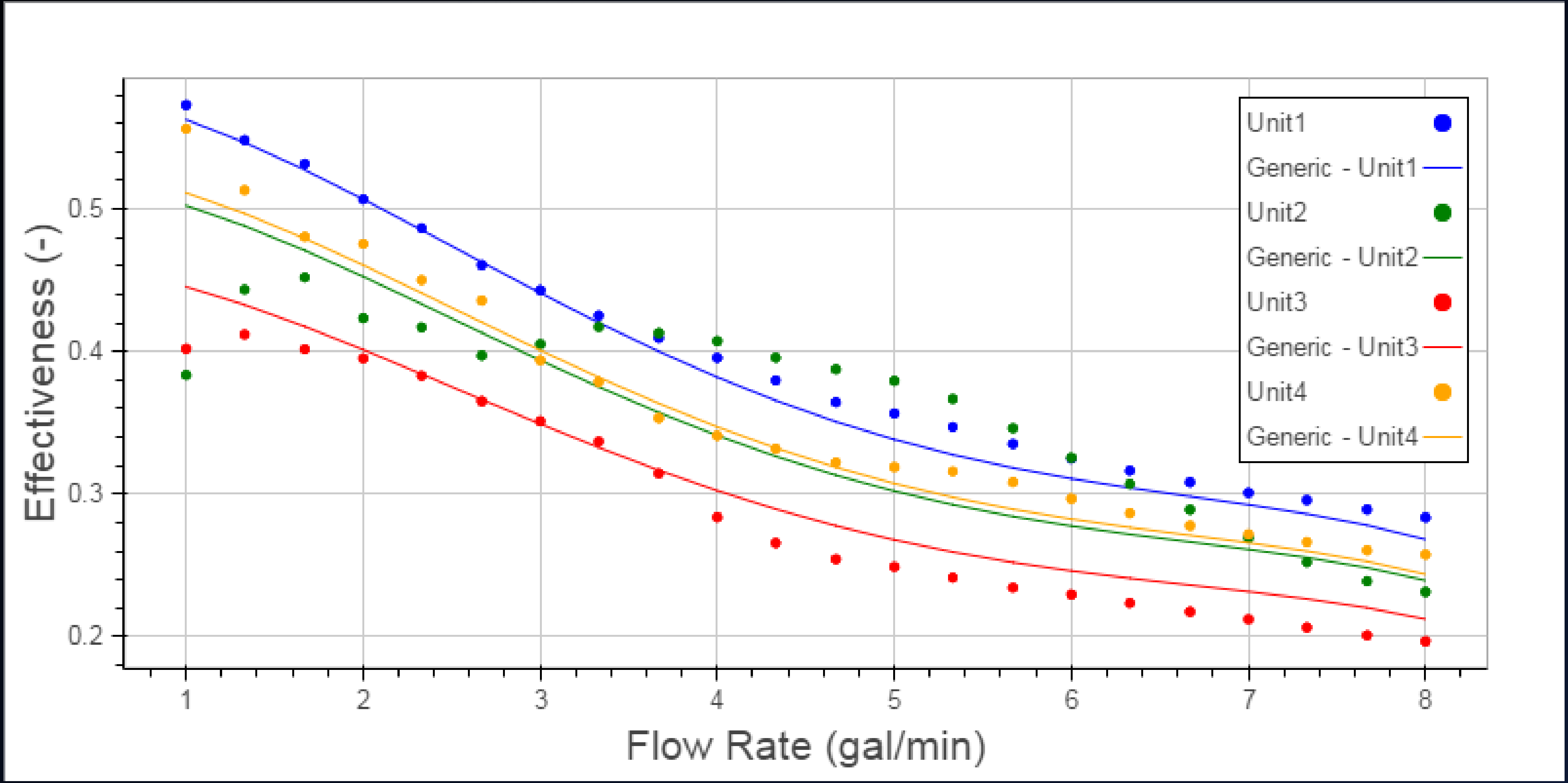




How was the generic algorithm created?

- The effectiveness results were divided by CSA ratings to create correction factors
- The correction factors were averaged across three units to create correction factors for the generic model
- The resulting algorithm is
  - $\varepsilon_{Shower} = \varepsilon_{CSA} * (Generic\ correction\ factors)$
  - More specifically…
    - $\varepsilon_{Shower}(\dot{V}, T) = \varepsilon_{CSA} * Average(\frac{\varepsilon_1(\dot{V},T)}{\varepsilon_{CSA_1}} + \frac{\varepsilon_3(\dot{V},T)}{\varepsilon_{CSA_3}} + \frac{\varepsilon_4(V,\dot{T})}{\varepsilon_{CSA_4}})$

How well did the generic model work (Equal Flow)?



How well did the generic model work (Annual Predictions)?

- Compared generic model to individual models:
  - 1-5 bedroom houses
  - San Diego, San Francisco, Sacramento
- Unit 1 (<2% error)
- Unit 3 (4-10% error)
  - Weakness: Unequal flow, potable <1.5 gal/min

Where do we go from here?

- Use Benefit/Cost calculations to decide how vertical DWHR will be added to Title 24
  - Bo will discuss this next
- Incorporate algorithm into California Building Energy Compliance Calculator (CBECC)
  - Slated to be included in the 2019 version of Title 24
- New project performing similar work on horizontal DWHR
- What do you want to do?
  - "We have the tools, and we have the talent!" – Winston Zeddemore, Ghostbuster

Conclusions & Contact

- Created an automated laboratory and data analysis tools
- Performed testing to identify performance of vertical DWHR in many situations
- Created a generic algorithm capable of predicting performance of DWHR units with minimal data inputs
- Have the Title 24 draw profile, and want to find a way to make it public
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