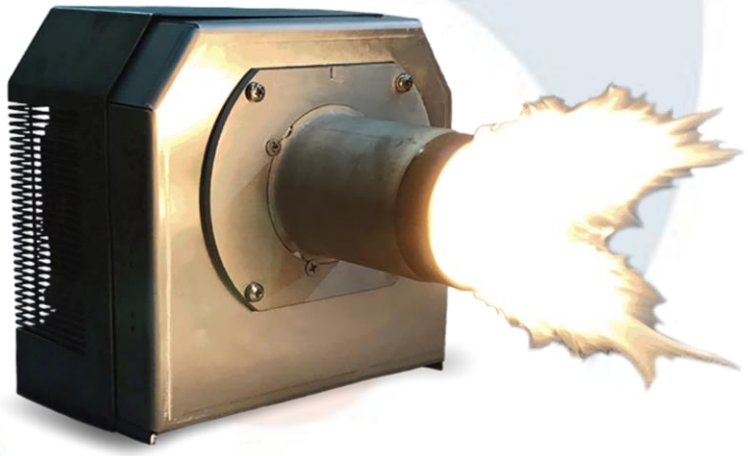
2018 NORA Technical Workshop

September 24 & 25

Babington Burner Company

Reinventing Fire



Andrew Hamer – Chief Engineer
Austin Bachmann – VP, Business Development

B100-Compatible Multi-Fuel Smart Burner (PON 2014)
Self-Modulating B50-Compatible Boiler (PON 2016)

Design – Product Development – Testing – Market Commercialization

Program Objectives: Develop an advanced multi-fuel burner that improves traditional oil-heat appliances and enables new Bio-heat® appliances using No. 2 fuel oil up to B100 – or any blend in between

Long-Term Market Goal: Demonstrate a viable and economic pathway for sustainable home heat that meets large-scale GHG emissions reduction targets and climate action goals

The Product: ***A Computer That Makes Clean Fire*** Using Any Liquid Fuel Blend of Choice

Development Approach: Combine proven low pressure air-atomizing multi-fuel burner tech with power electronics and intelligent control to enable adaptive multi-fuel heating systems

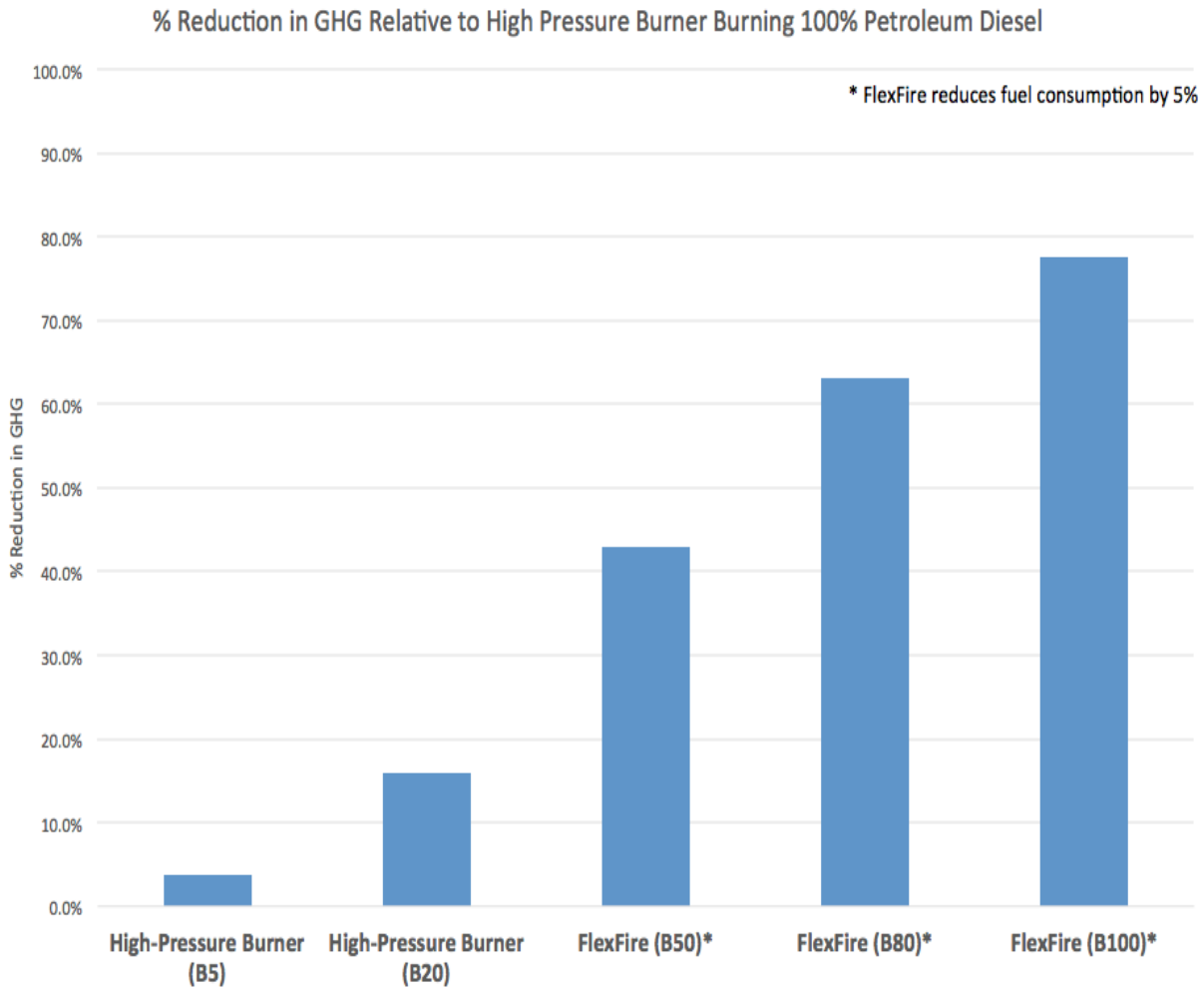
Product Specs	
High-Efficiency Performance	Ultra-clean combustion, no smoke odor or CO
Automatic Variable Firing Rate	0.38 to 0.75 GPH (phase 1)
Biodiesel and Multi-Fuel Compatibility	No. 2 oil up to B100 without parts change
Self-Tuning via Intelligent Control	Real-time fuel-air adjustments to compensate for changes in excess air level (or O2 or CO_2)
Plug and Play Replacement	Compatible with existing oil-fired appliances
Internet of Things (IoT) Enabled	Remote operation and performance monitoring w/ trend analytics enables new adaptive BioHeat® appliances

Environmental Impact
Greenhouse Gas Reductions

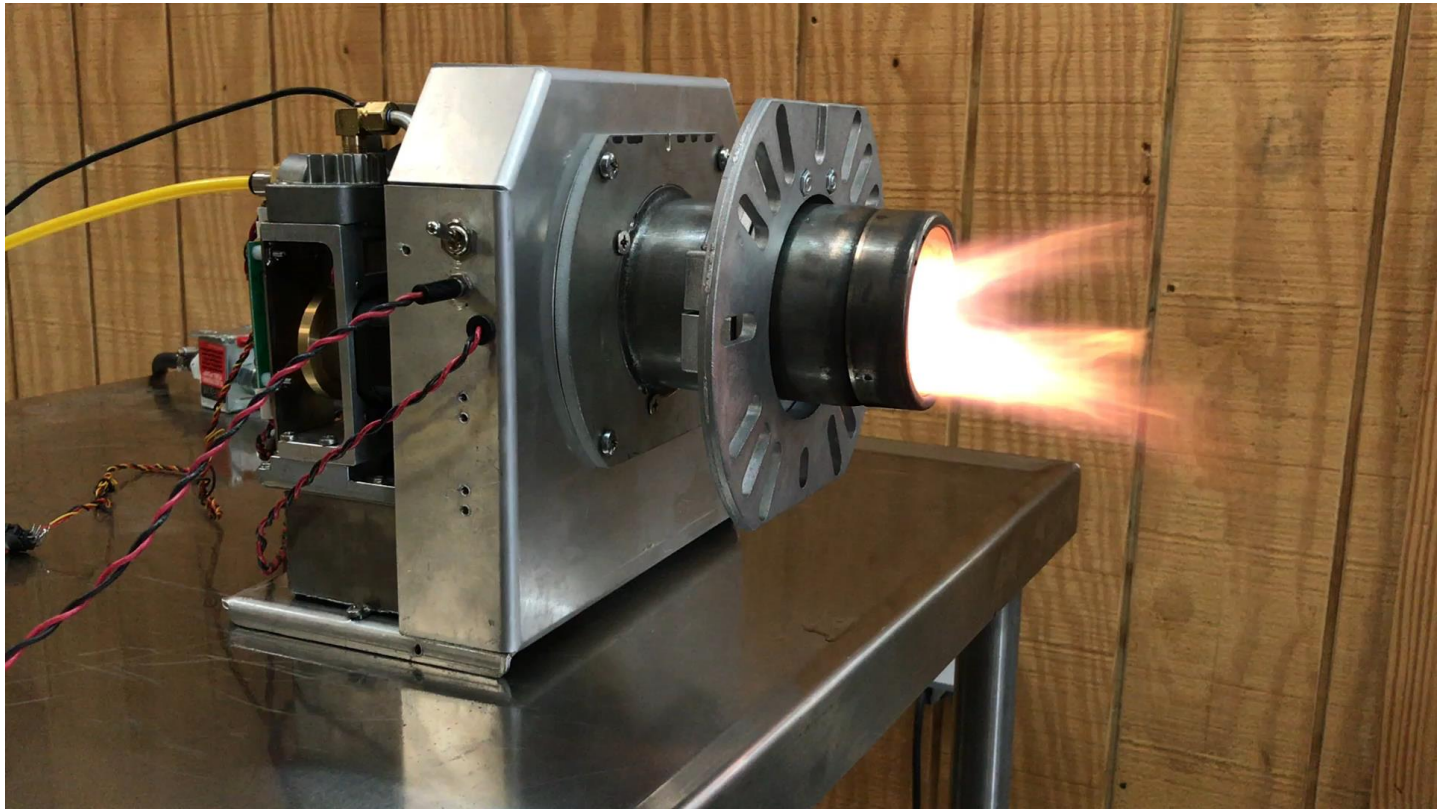
Future Impact:

Reductions in GHG emissions relative to burning 100% No.2 oil, B5 & B20

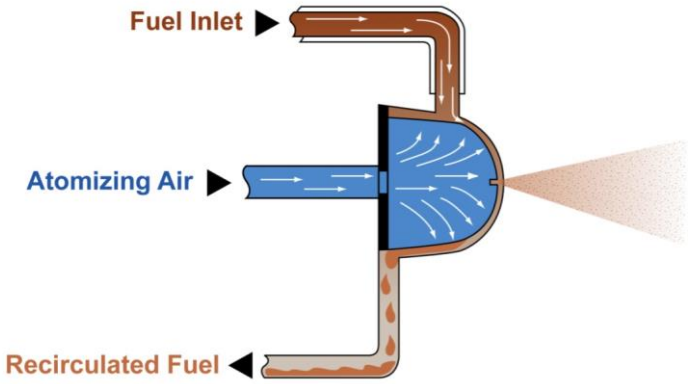
- FlexFire + B50 achieves 41-45.4% reductions in GHG emissions compared to petroleum fuel
- Use of B100 achieves 81-86% GHG reductions
- B20 blends only deliver 15% reduction in GHG emissions, falling short of NESCAUM goals



Burner Technical Performance



The Babington Method
We Turn the Nozzle Inside-Out



Low Pressure Air-Atomizing Principle

Uniformed Dispersion of Fine Liquid-Fuel Particles

Variable Firing Rate Burner

The Babington combustion process requires three fluids – fuel, atomizing air and combustion air. Each is delivered with its own DC brushless motor. With variable speed control for each of the three fluids the firing rate can be varied. Additionally, the blower speed can be adjusted to “match” the fuel speed such that the desired excess air (or oxygen, or CO2 level) can be achieved.

Under the Hood - Key Innovations
Fuel Delivery

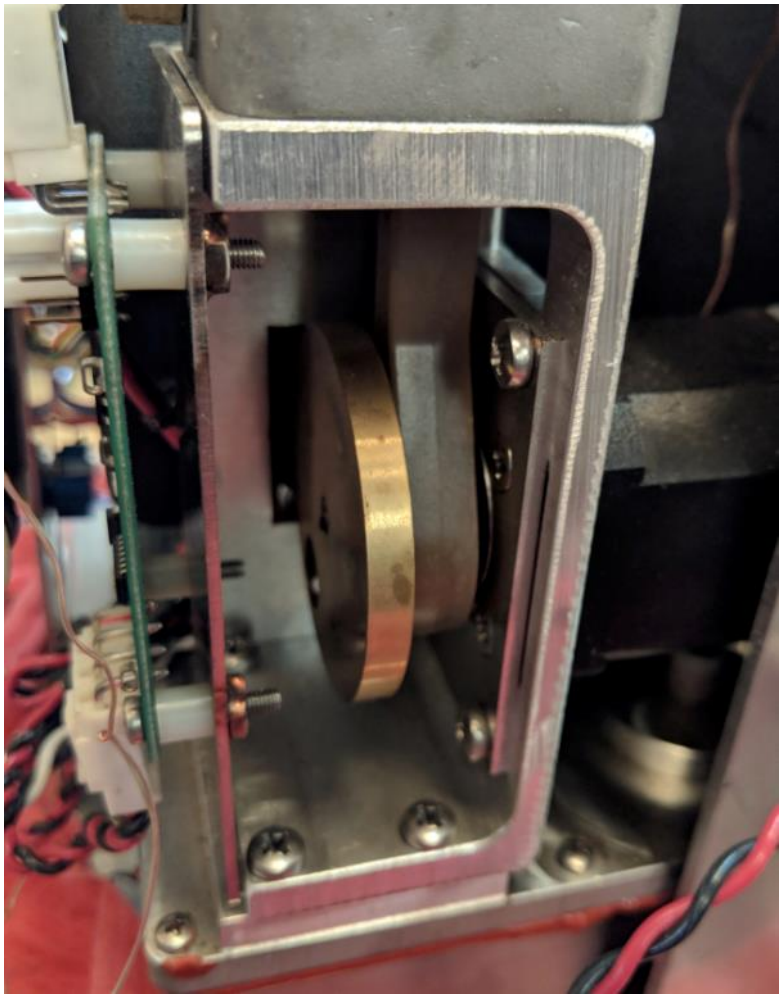
The first of the three DC brushless motors delivers fuel from the sump to the atomizing “bullets”.

The Babington principle lays a thin layer of film over a spherical bullet.

Some fuel is atomized and burned while the rest is returned to the sump.

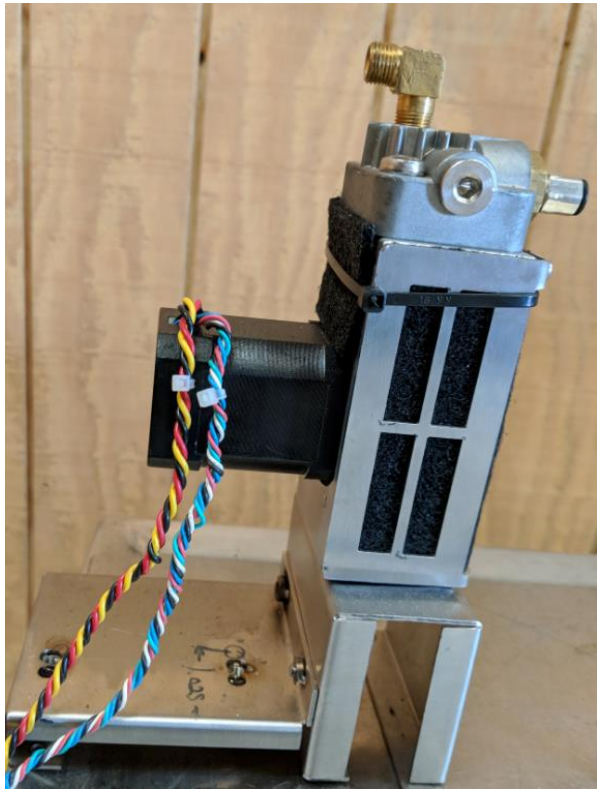
As the fuel level in the sump decreases, additional fuel is added via a separate transfer pump.

Under the Hood - Key Innovations
Atomizing Air



The second of the three DC brushless motors delivers compressed air (via a piston compressor as seen on the left) to atomize the thin layer of fuel at the bullets.

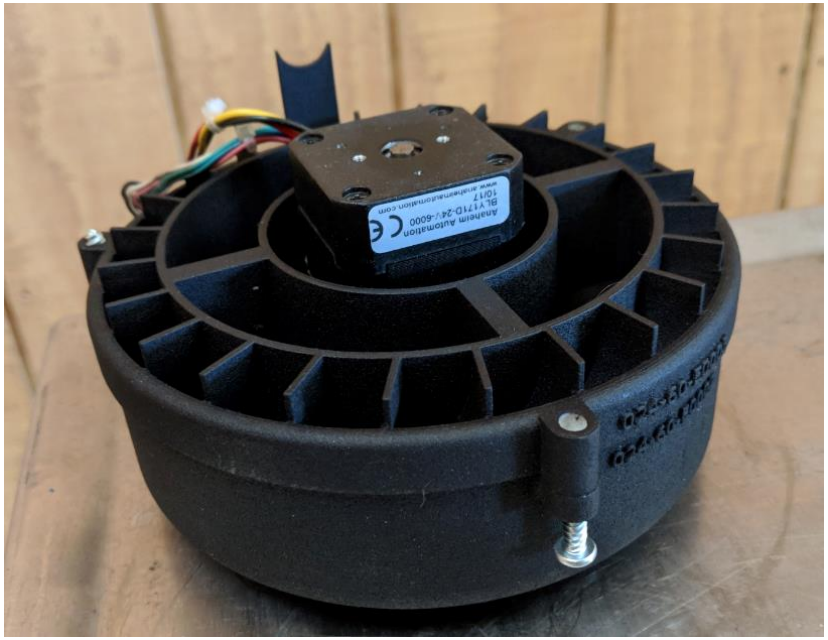
The compressor is wrapped by a filter (in black on right) and is very modular for removal and installation.



Under the Hood - Key Innovations
Blower Air

Third motor delivers combustion air via an inlet dome, a blower wheel and strut section.

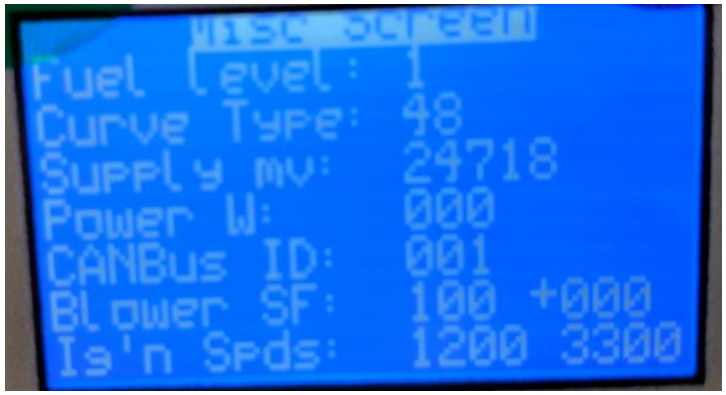
The blower speed can be programmed to be specific to ignition, shutdown, pre-purge, post-purge.



Under the Hood - Key Innovations
Intelligent Control

Fuel-Air systems are controlled by the Babington Controller, i.e. a ***computer that makes fire***. The controller determines the schedule (i.e. specific speeds and durations) for all three motors from pre-purge, ignition, operation – variable firing rate and excess air levels, shutdown and post-purge. Additionally the controller reads Proof of Flame signals and sets ignition time and duration.

Under the Hood
Key Innovations



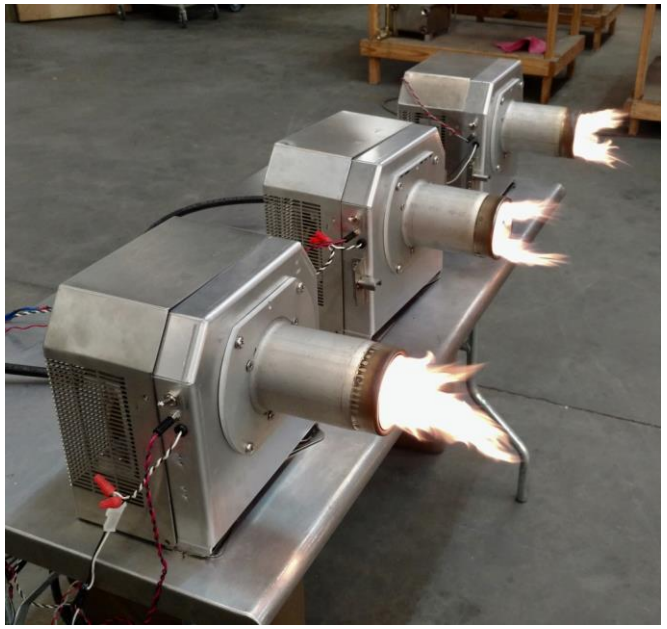
Each motor has its own information screen with operational and diagnostic information. Similar data can be communicated to computer, tablet or mobile phone.

Development of writing data to the cloud for remote diagnostics underway.

Advanced Developmental and Biodiesel Testing

Developmental testing is done in our manufacturing facility in Rocky Mount, NC. Endurance testing (cold flow and hot flow) gravimetric testing, and emissions testing can all be performed in-house.

As we have a “Computer that makes fire” it’s easy to connect burners to a computer and automatically drive the testing sequence of different operational conditions – **and** fuels!



B50-Compatible Boiler Testing Ongoing

Peerless
WBV-03-WPCL

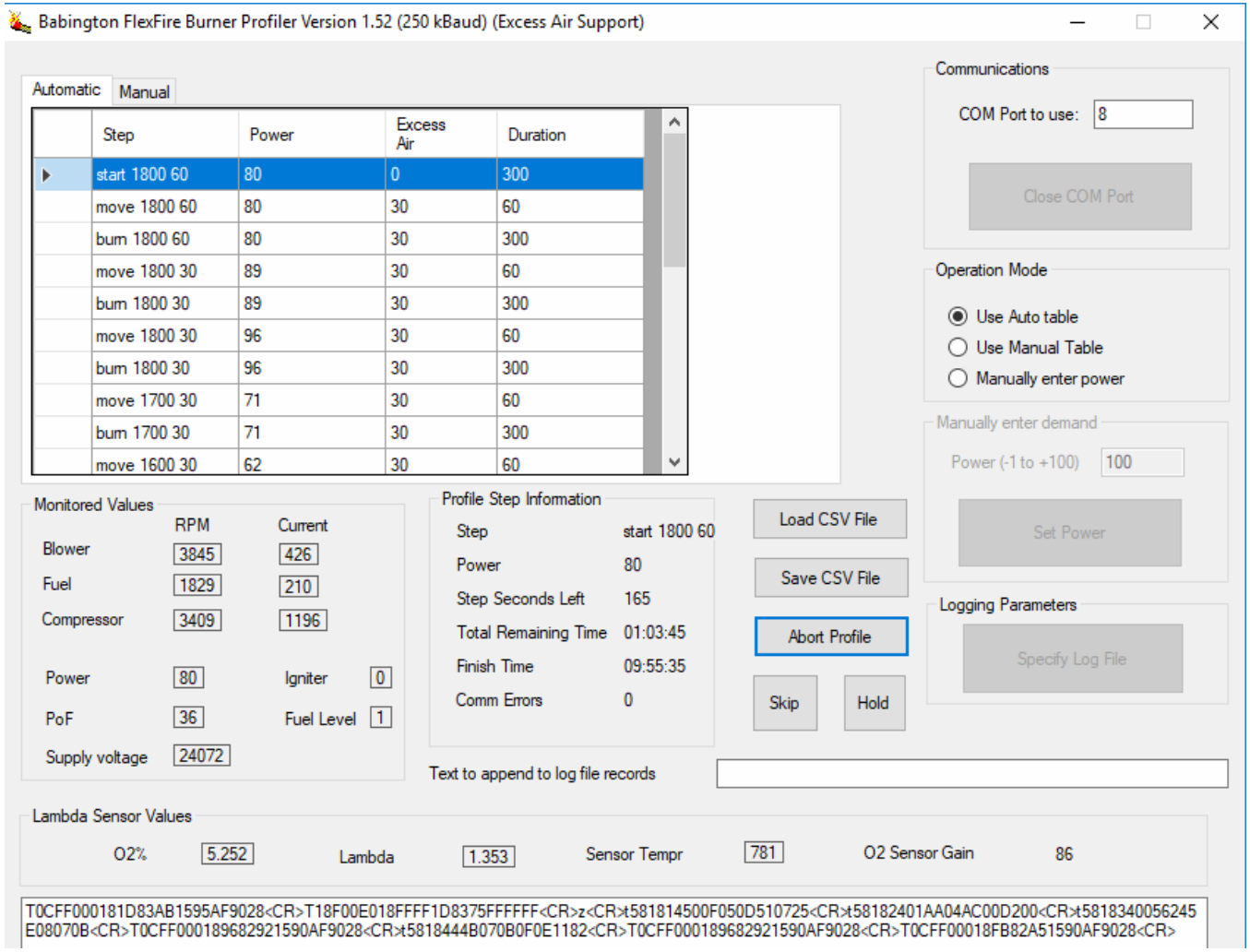
Energy Kinetics
Resolute 90+

Slantfin Intrepid
TR-20

Tyresöpannan
(German)

Currently using multiple boilers for emissions and performance testing. (Diesel to B100)

Real-Time Performance Monitoring Computer Interface



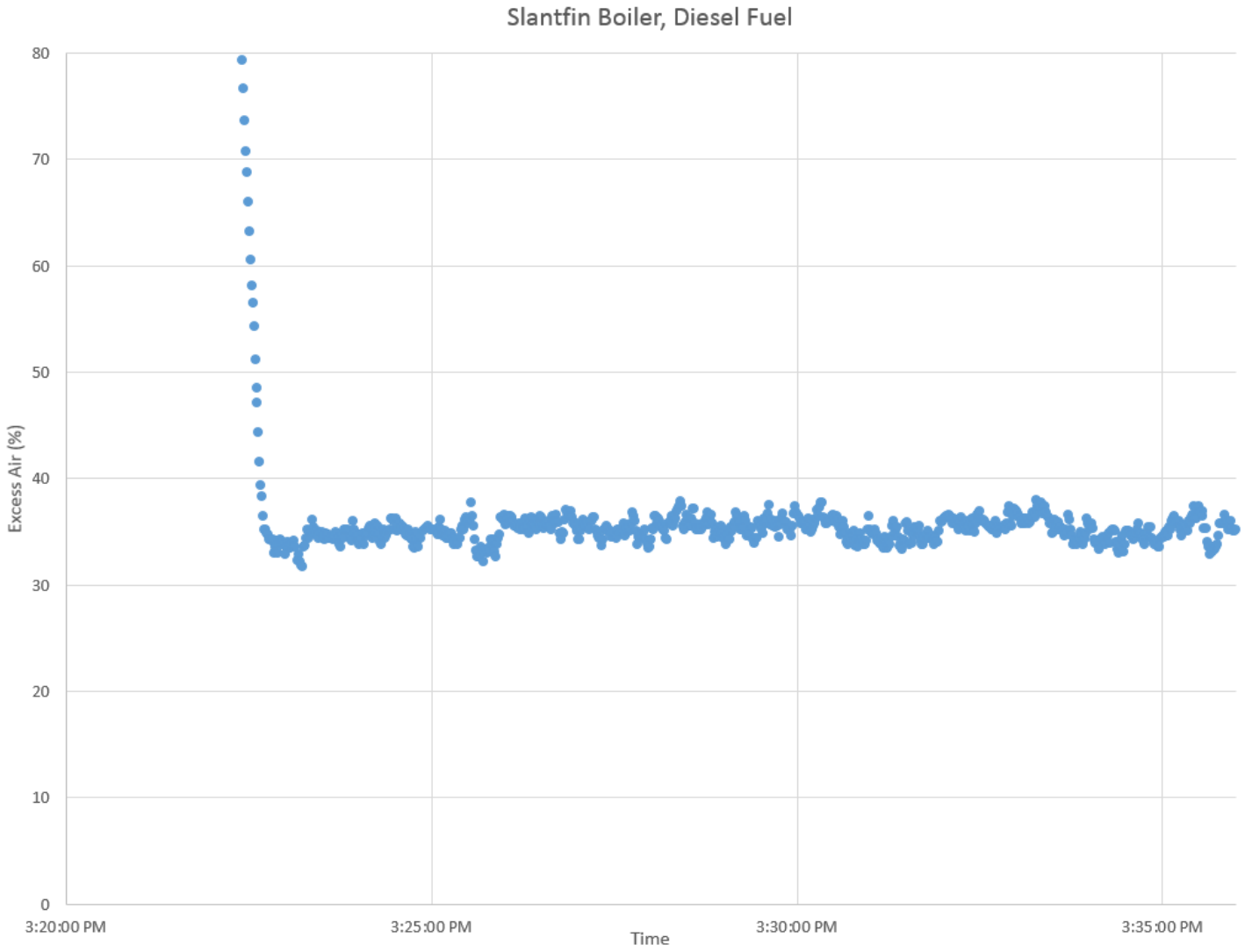
Snapshot of computer interface that controls burner operation.

Input grid is used to name the test point, set the “Power” level, or firing rate, set the “Excess Air” target and the duration of the test point.

These test sequences can be saved to file for later usage.

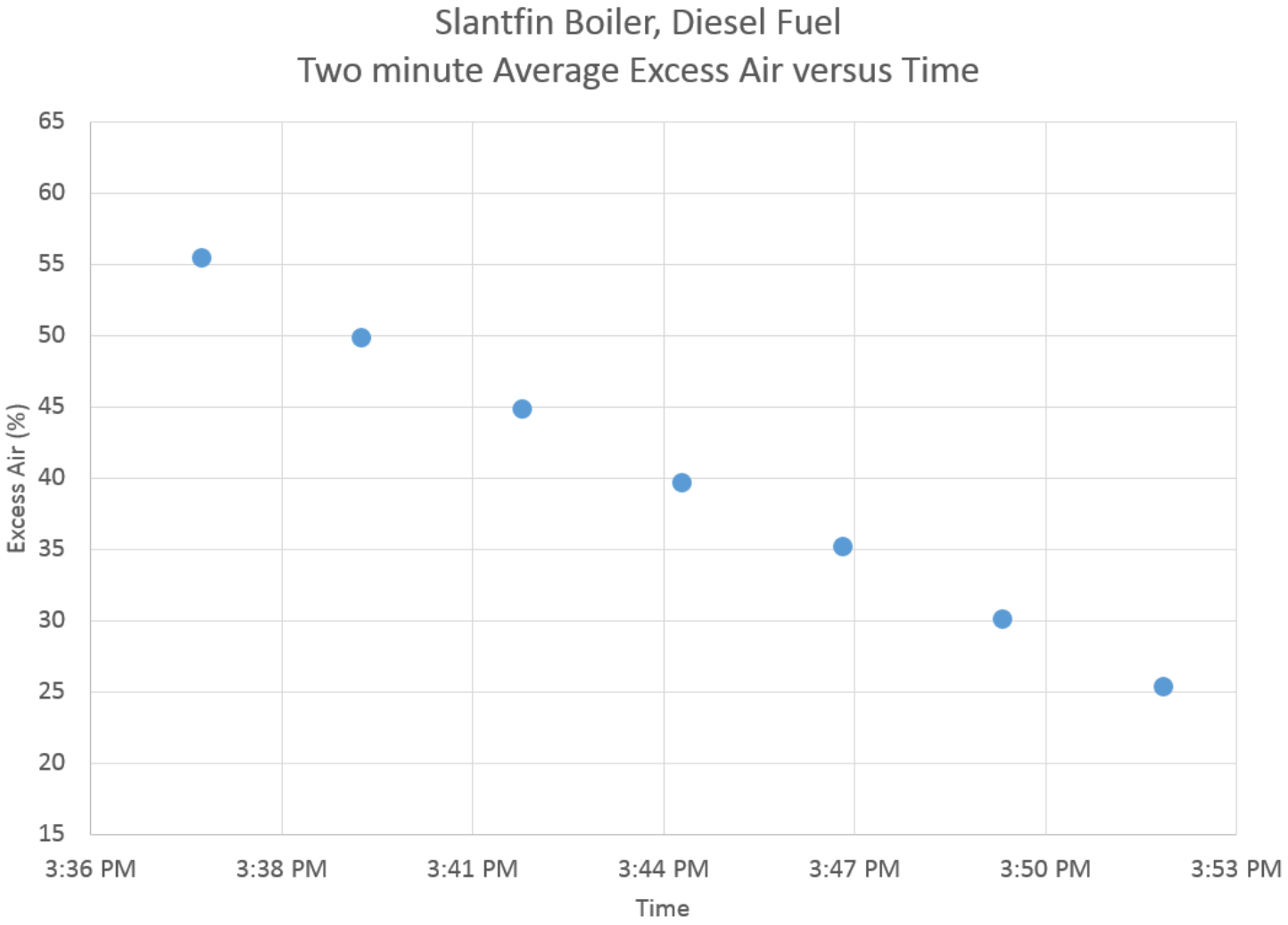
Output results are logged every second.

Startup Excess Air Target



Initial target from startup is 35% EA.

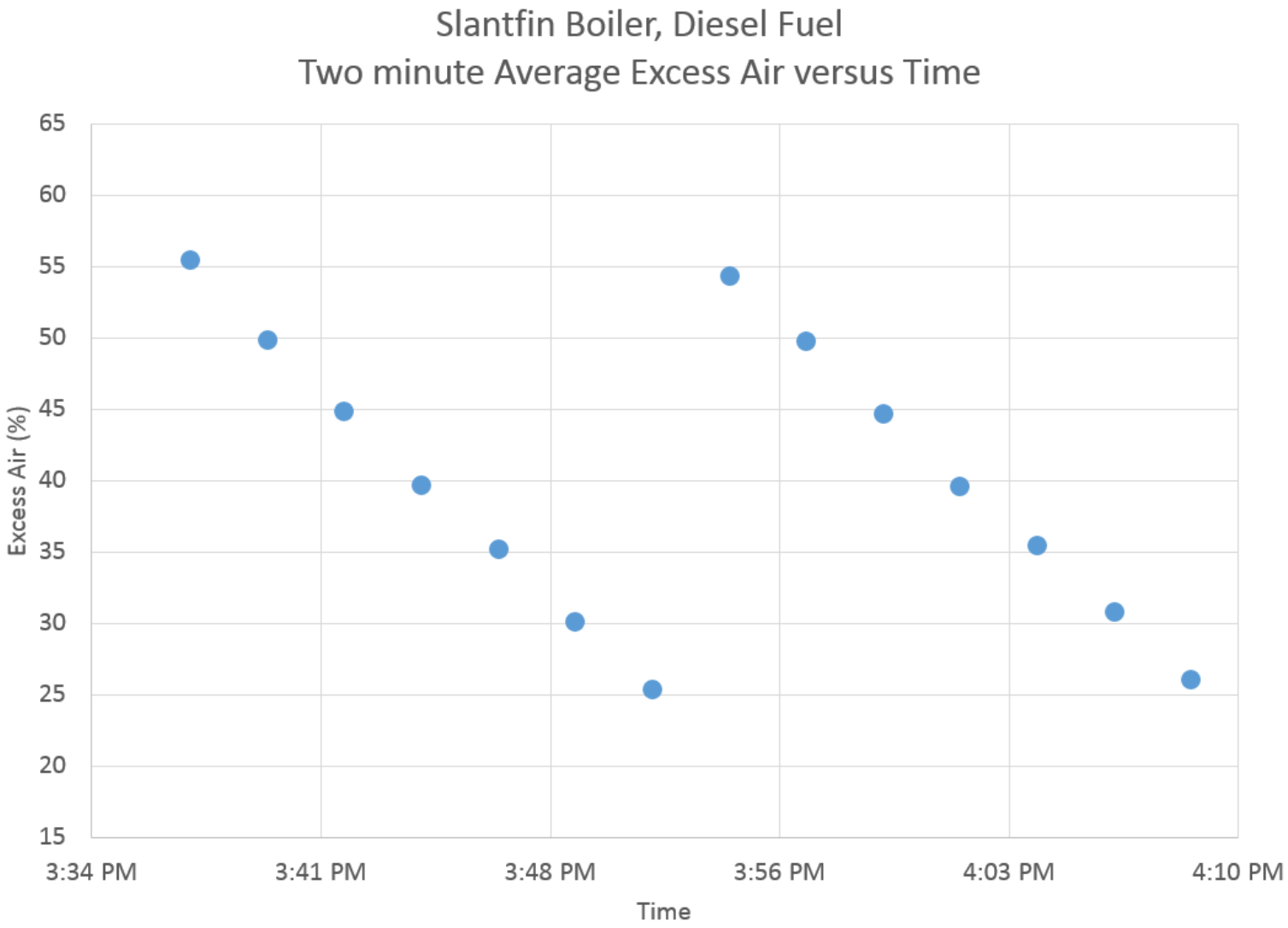
Additional Excess Air Levels



Now run 2 minute test at varying excess air levels with 25 seconds between points. Targets were 55, 50, 45, 40, 35, 30, and 25% EA.

The 2 minute average EA is graphed. (Not the target!)

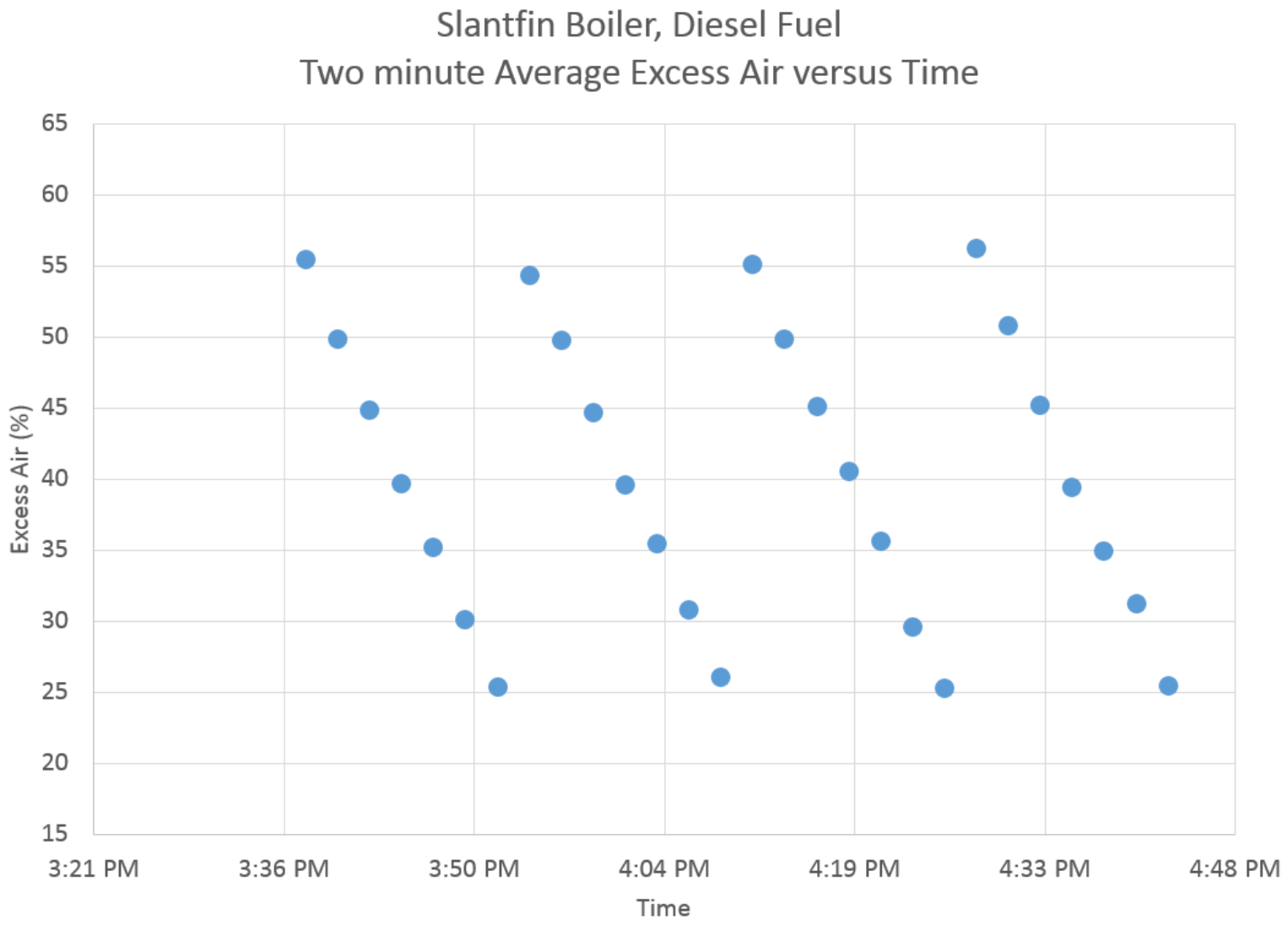
Additional Firing Rates



Same test – keep running – lower firing rate and repeat excess air targets of 55, 50, 45, 40, 35, 30, and 25% EA.

Again, the two minute average is being graphed.

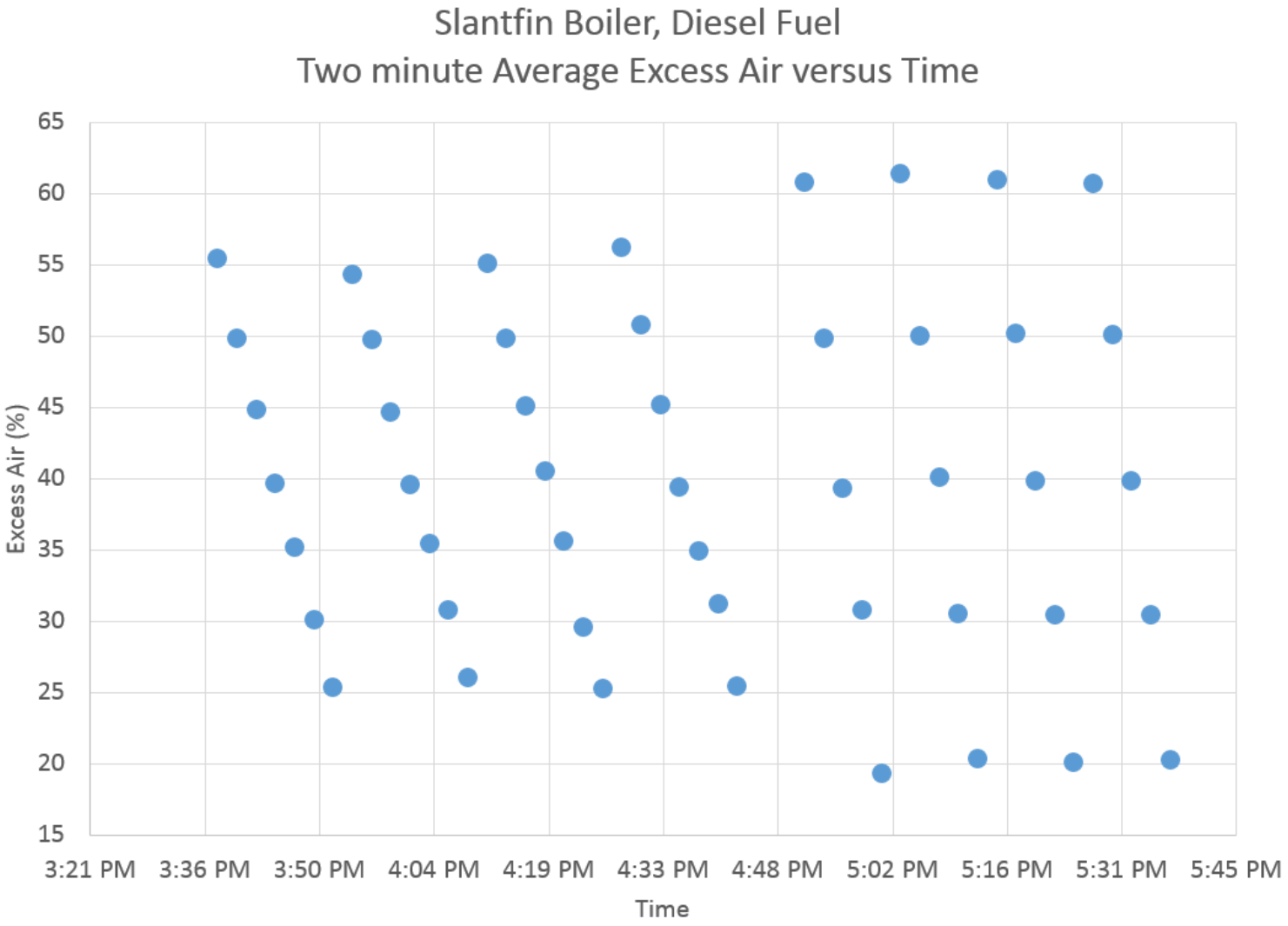
Repeat Excess Air Levels and Firing Rates



Same test – keep running – lower firing rate two more times and repeat excess air targets of 55, 50, 45, 40, 35, 30, and 25% EA.

Again, the two minute average is being graphed.

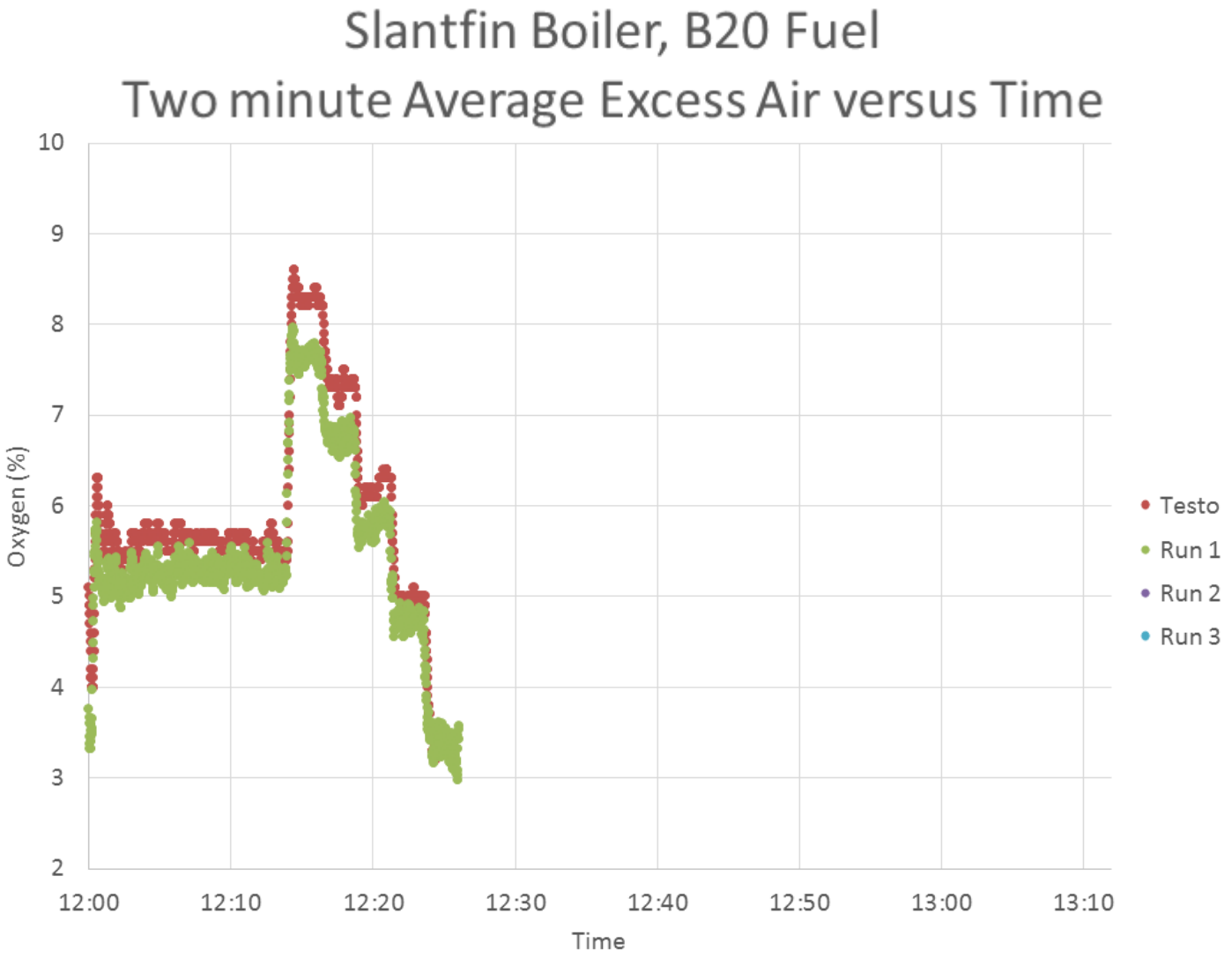
Repeat Excess Air Levels and Firing Rates



Finally, repeat previous 4 firing rates but use excess air targets of 60, 50, 40, 30, and 20% EA.

Again, the two minute average is being graphed.

B20 Testing

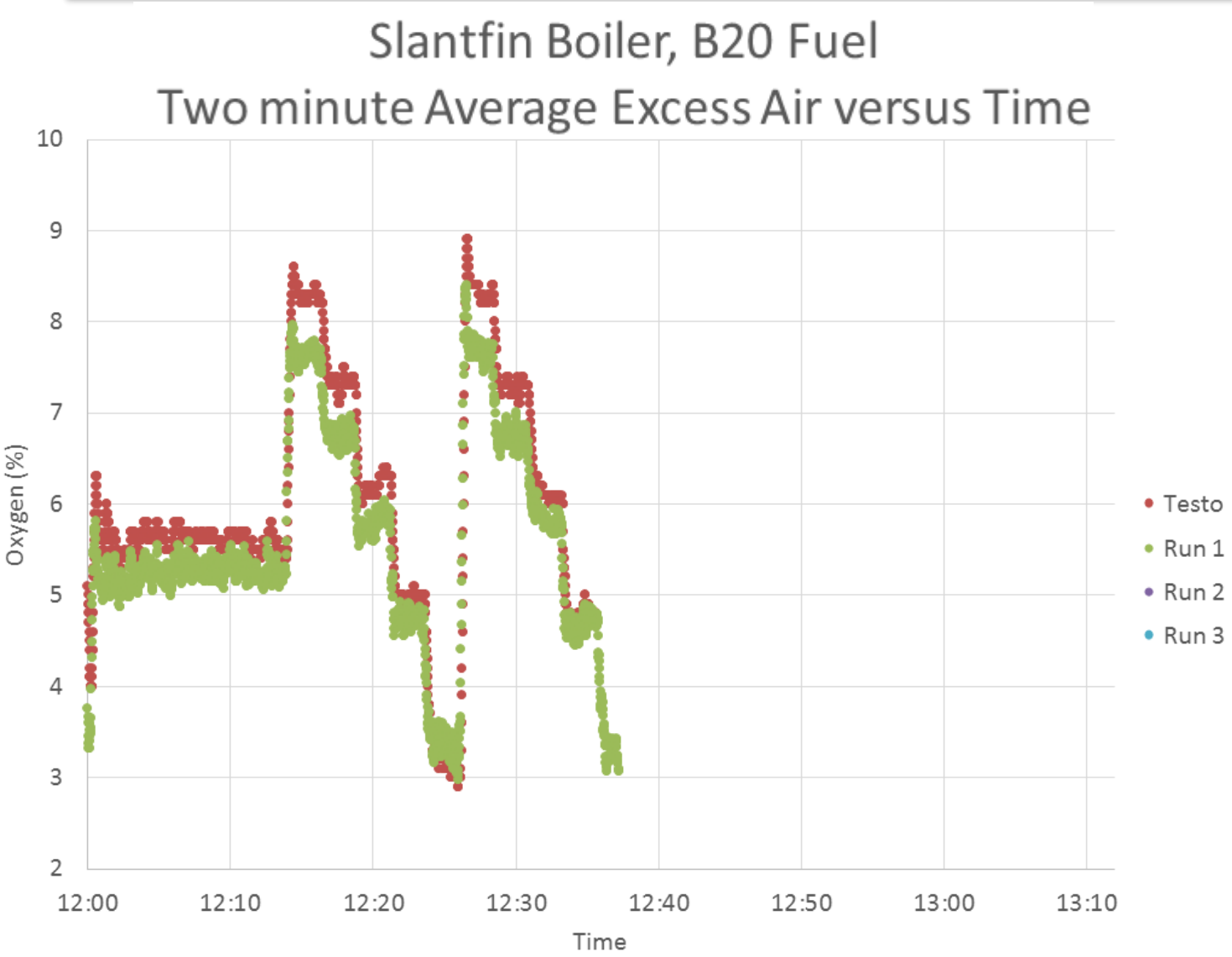


Change fuel to B20.

Compare with Testo in stack.

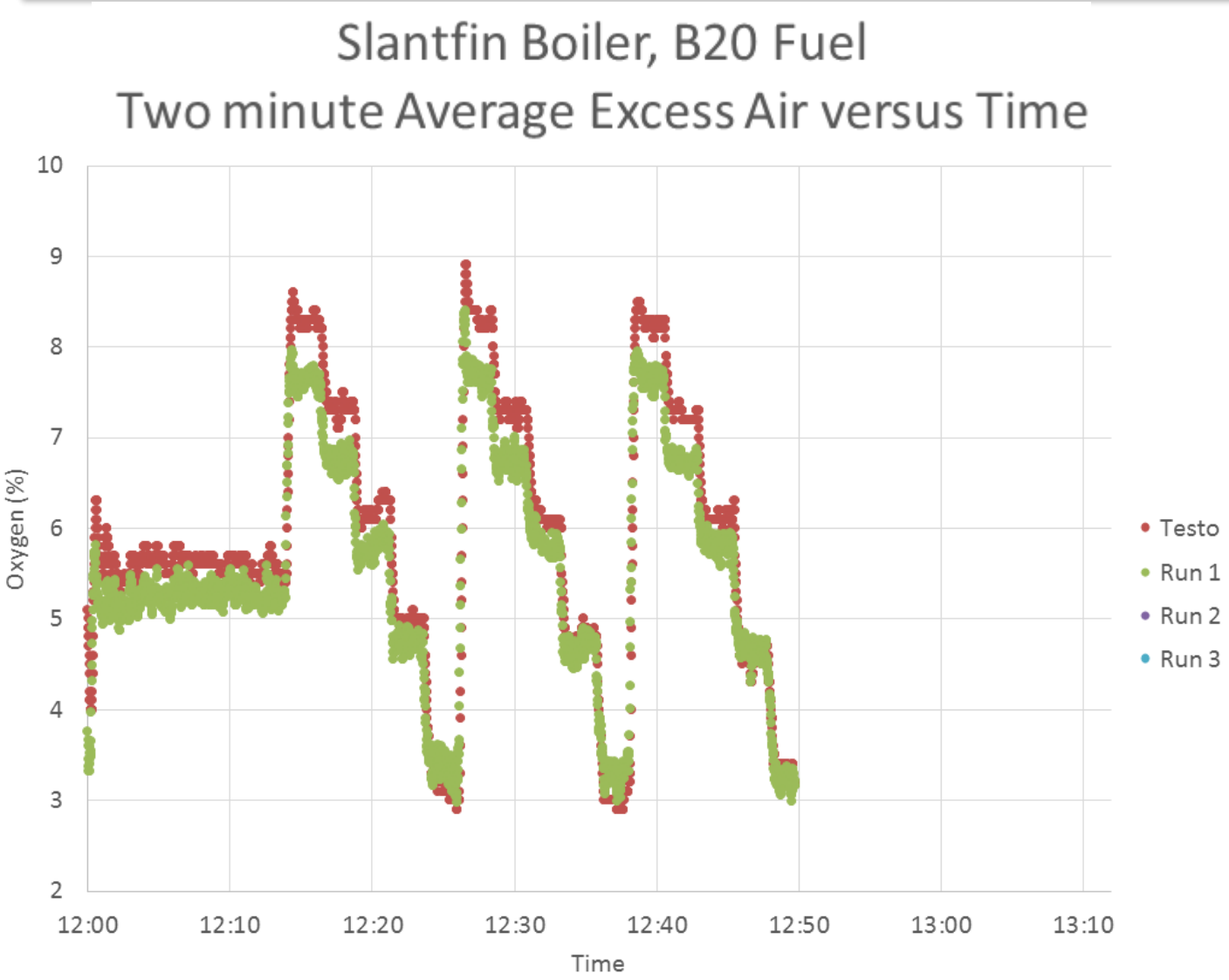
Vary excess air from 60, 50, 40, 30, 20% EA.

B20 Testing Repeat



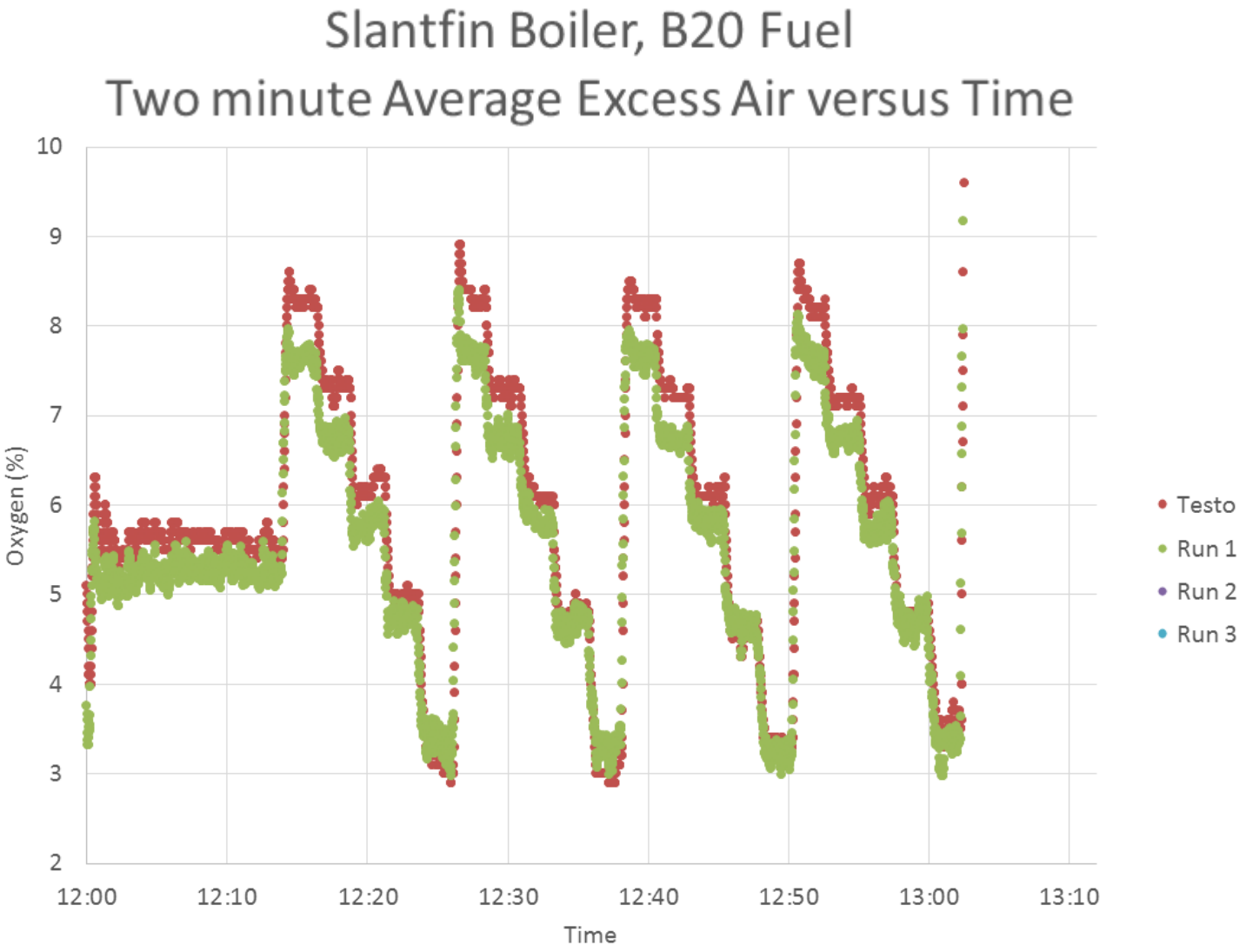
Then change firing rate and repeat EA sweep a second time.

B20 Testing Repeat



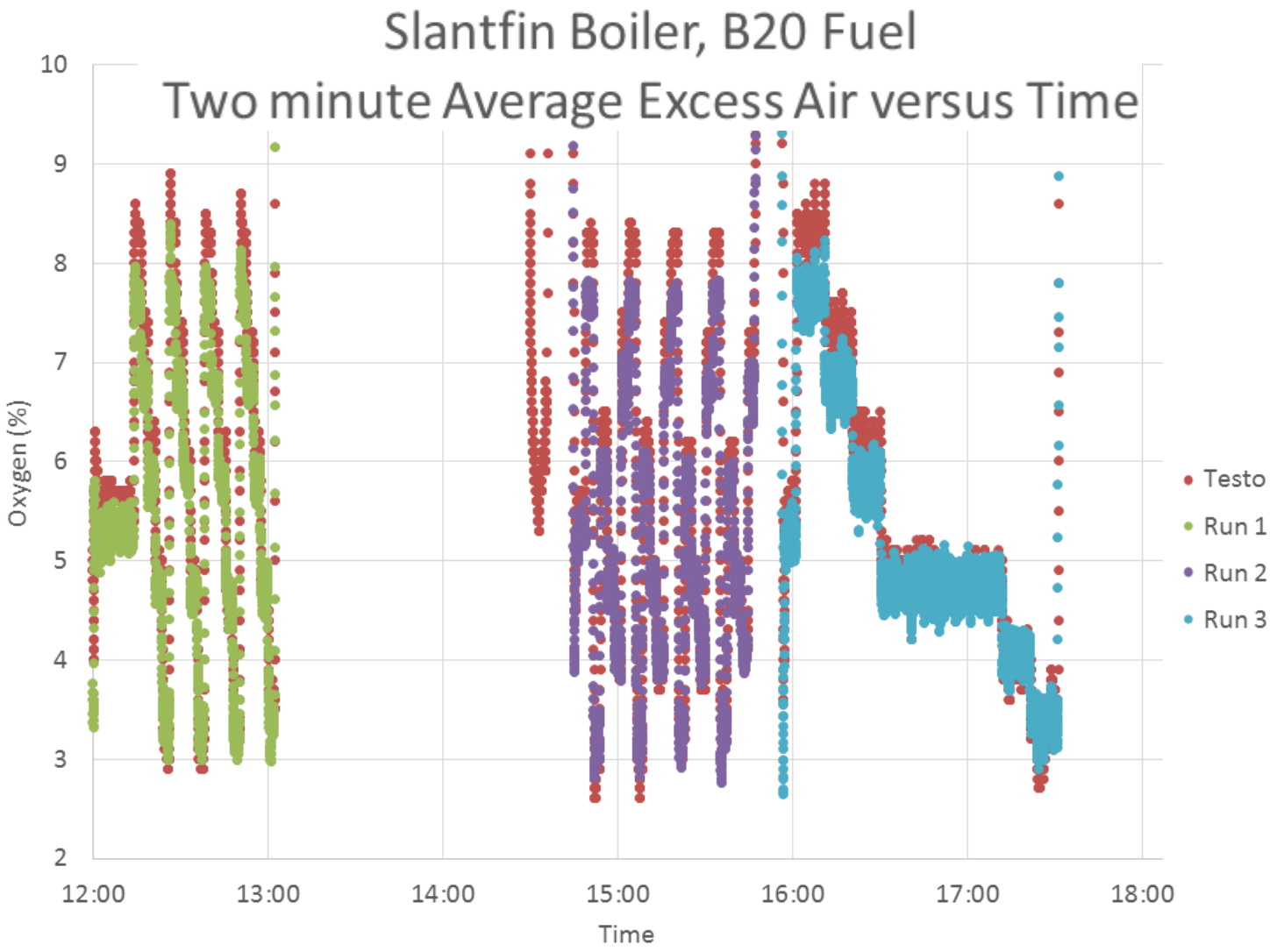
Then change firing rate and repeat EA sweep a third time.

B20 Testing Repeat



Then change firing rate and repeat EA sweep a fourth time.

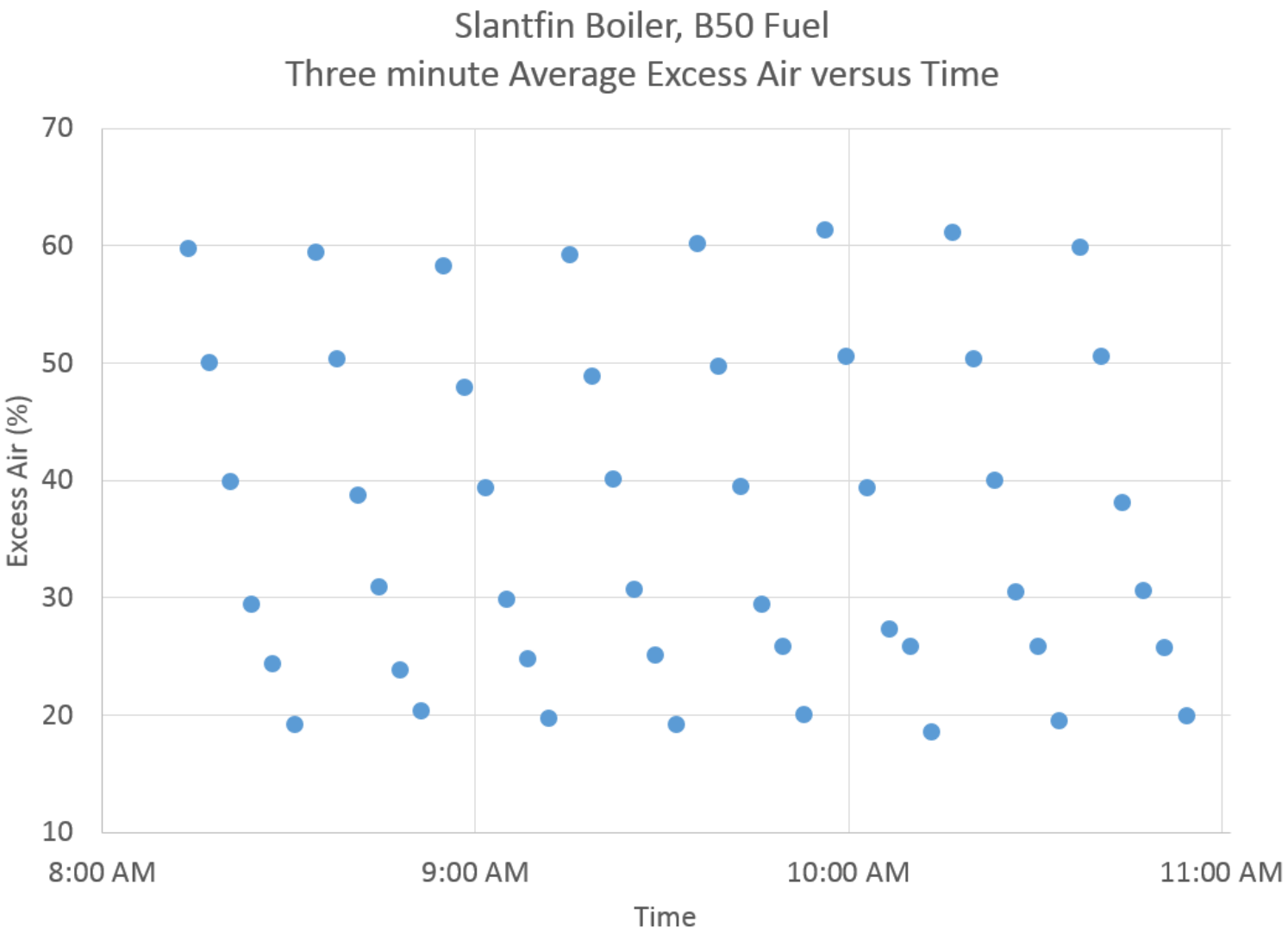
B20 Testing Repeat



Repeat Run 1 with Run 2, same conditions.

Run 3 is a similar test as 1 and 2, but with longer hold times and slightly different excess air levels.

B50 Testing



Change fuel to B50

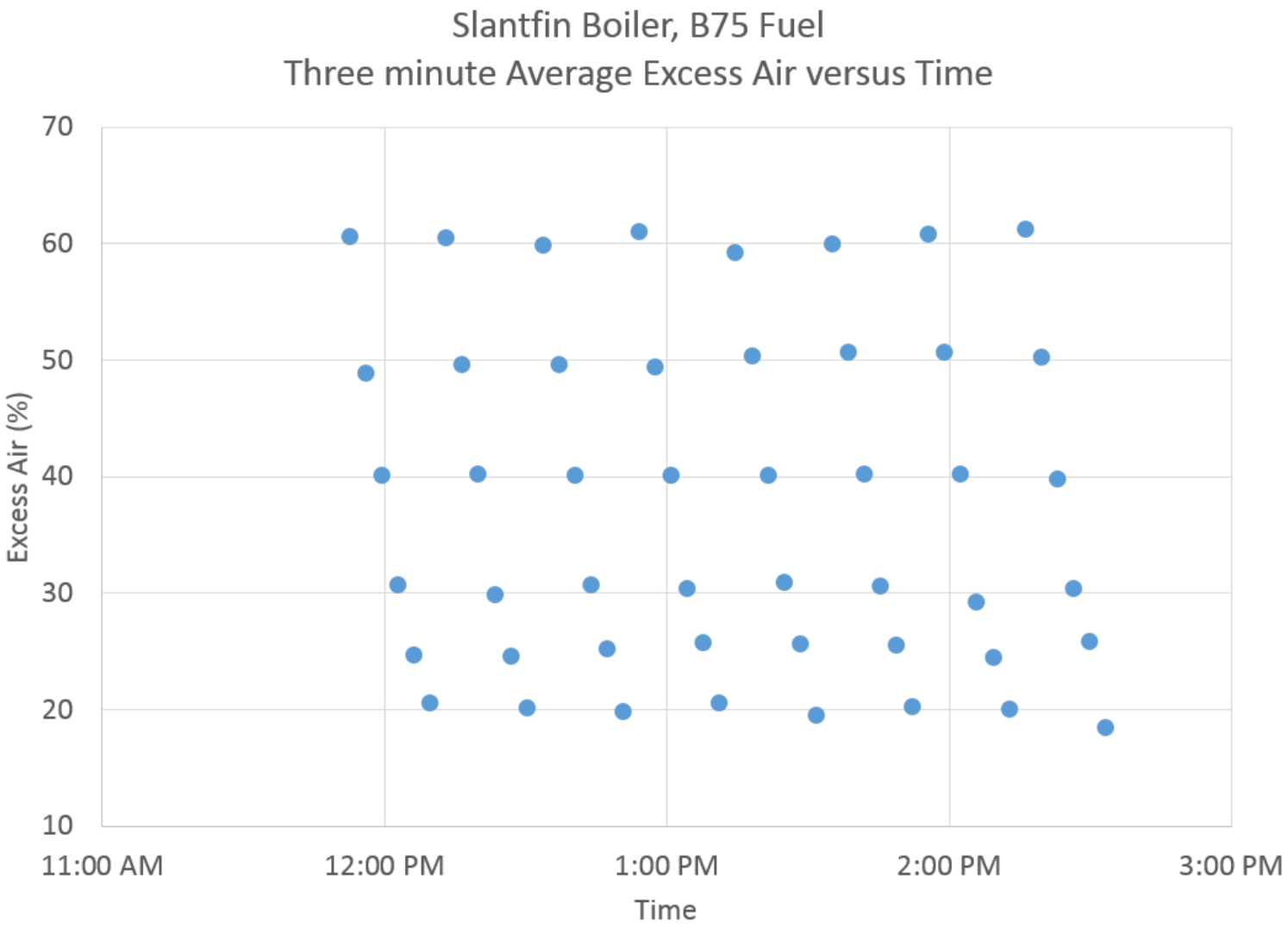
Vary excess air from 60, 50, 40, 30, 25, 20.

Vary burn rate 4 times.

Repeat 4 different burn rates.

Each data point is the average of 3 minutes after a 25 second “move”.

B75 Testing



Change fuel to B75

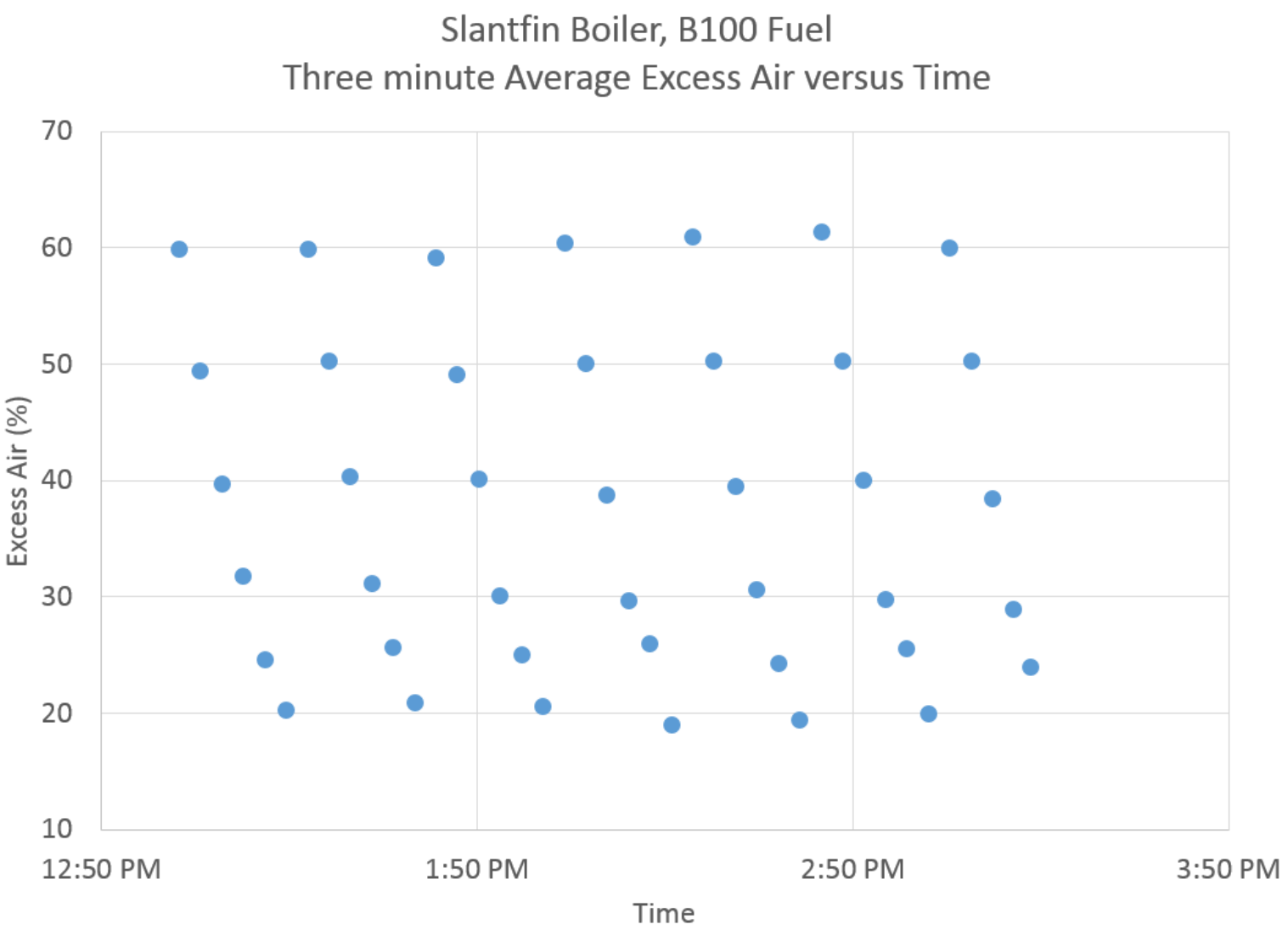
Vary excess air from 60, 50, 40, 30, 25, 20.

Vary burn rate 4 times.

Repeat 4 different burn rates.

Each data point is the average of 3 minutes after a 25 second “move”.

B100 Testinig



Change fuel to B100

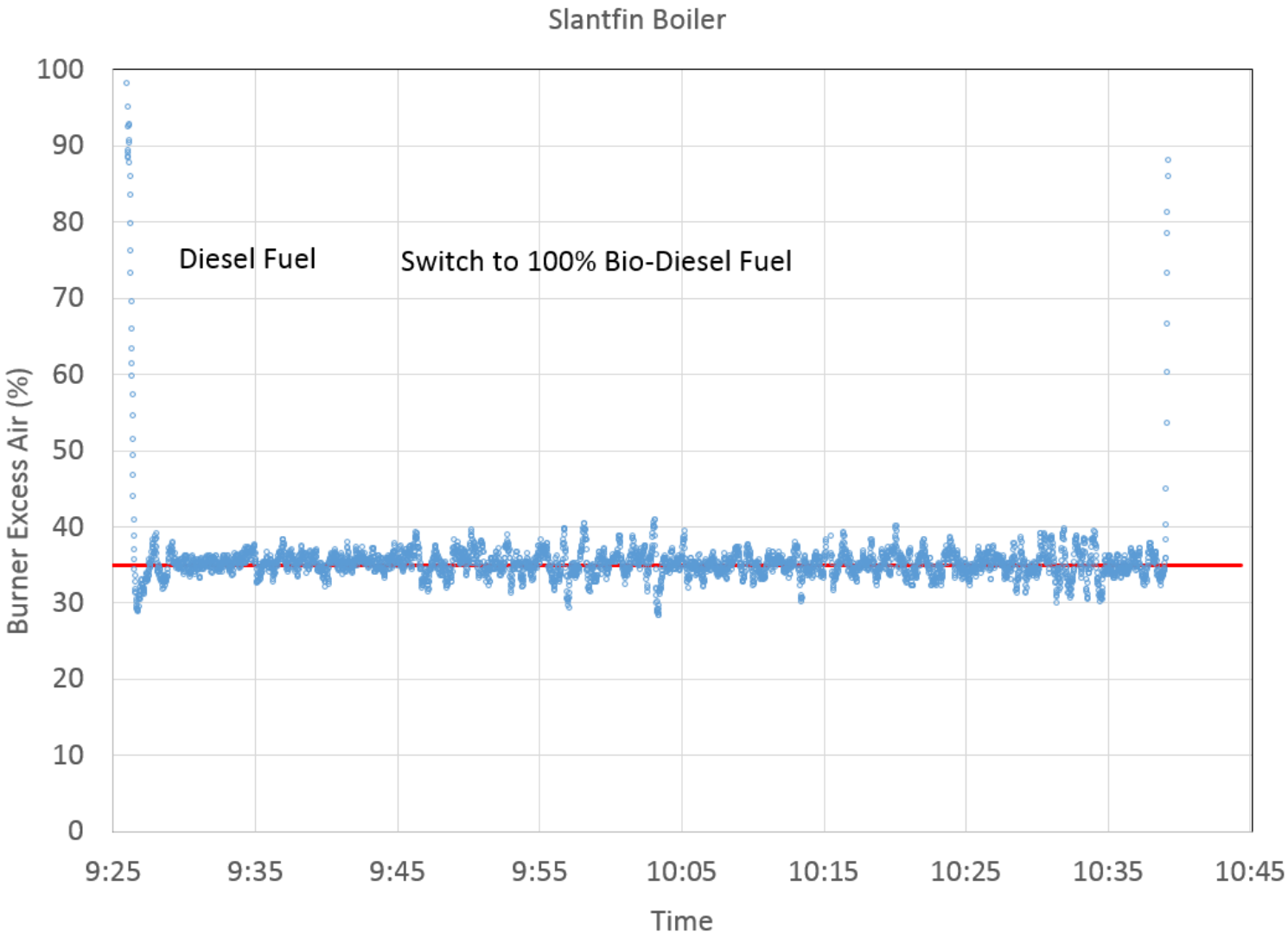
Vary excess air from 60, 50, 40, 30, 25, 20.

Vary burn rate 4 times.

Repeat 3 of the 4 different burn rates.

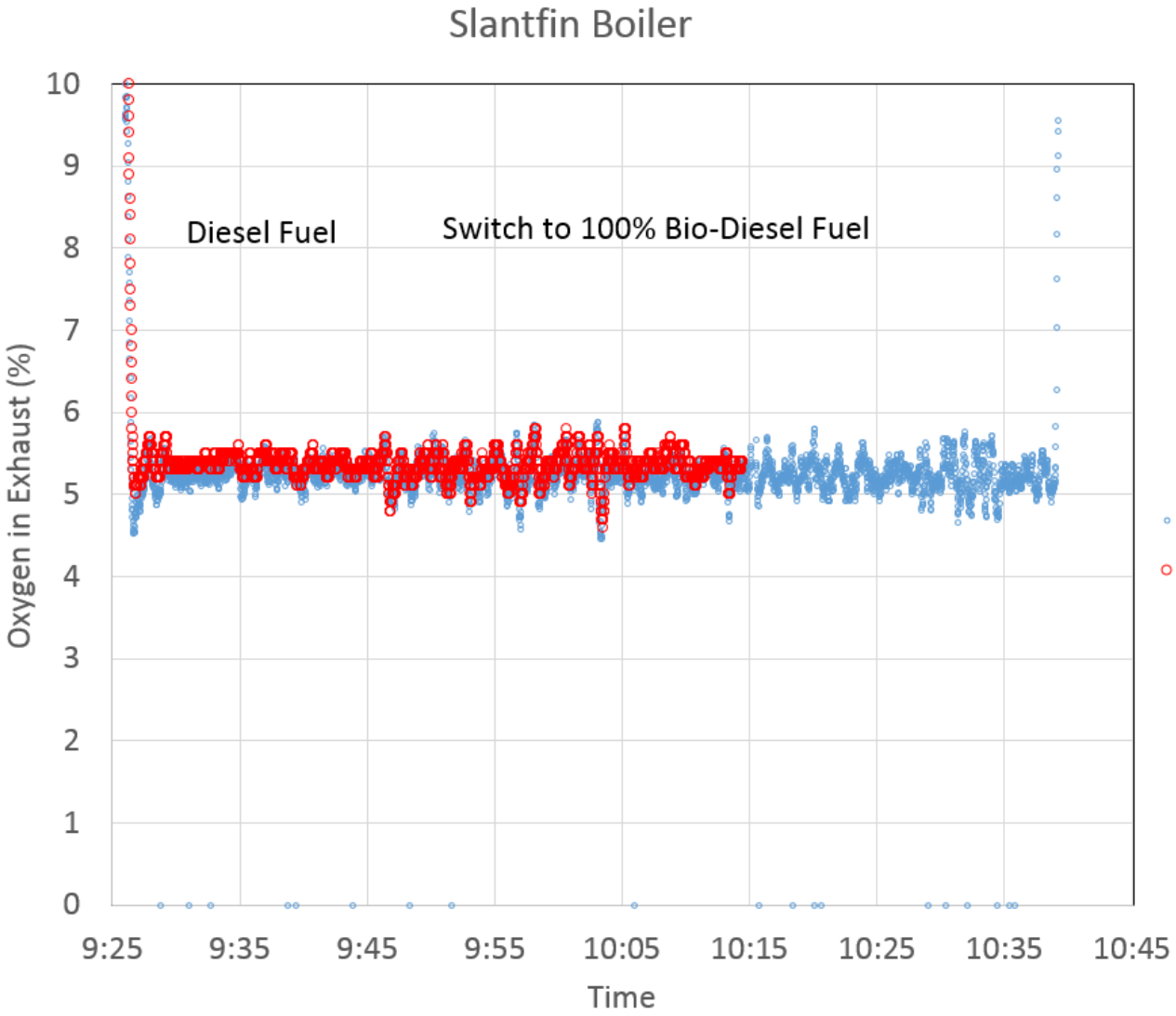
Each data point is the average of 3 minutes after a 25 second “move”.

Multi-Fuel Capability
Switching From No. 2 to B100 on the fly



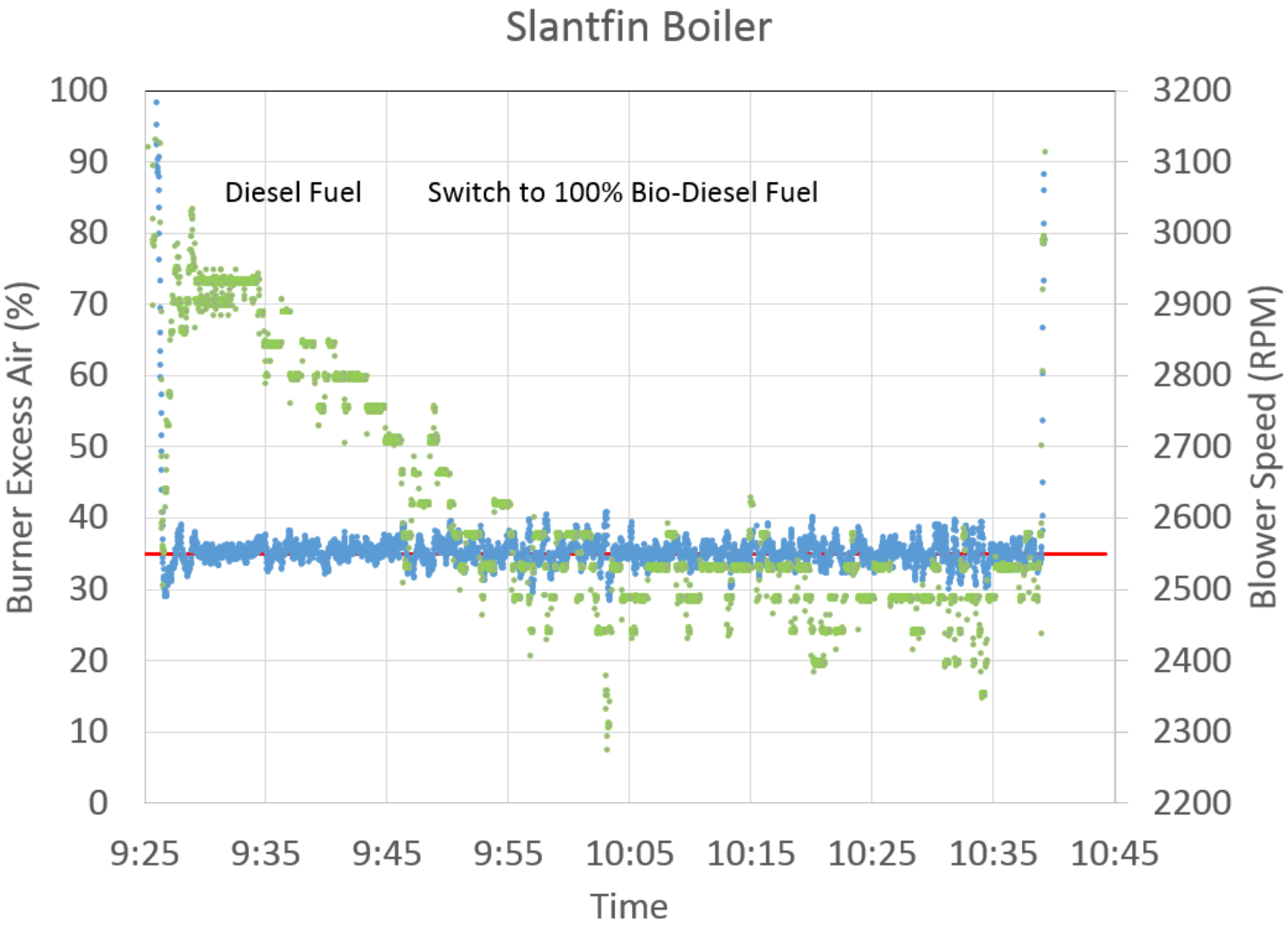
Switch fuels during operation from no. 2 fuel oil to bio-diesel

Multi-Fuel Capability
Switching From No. 2 to B100 on the fly



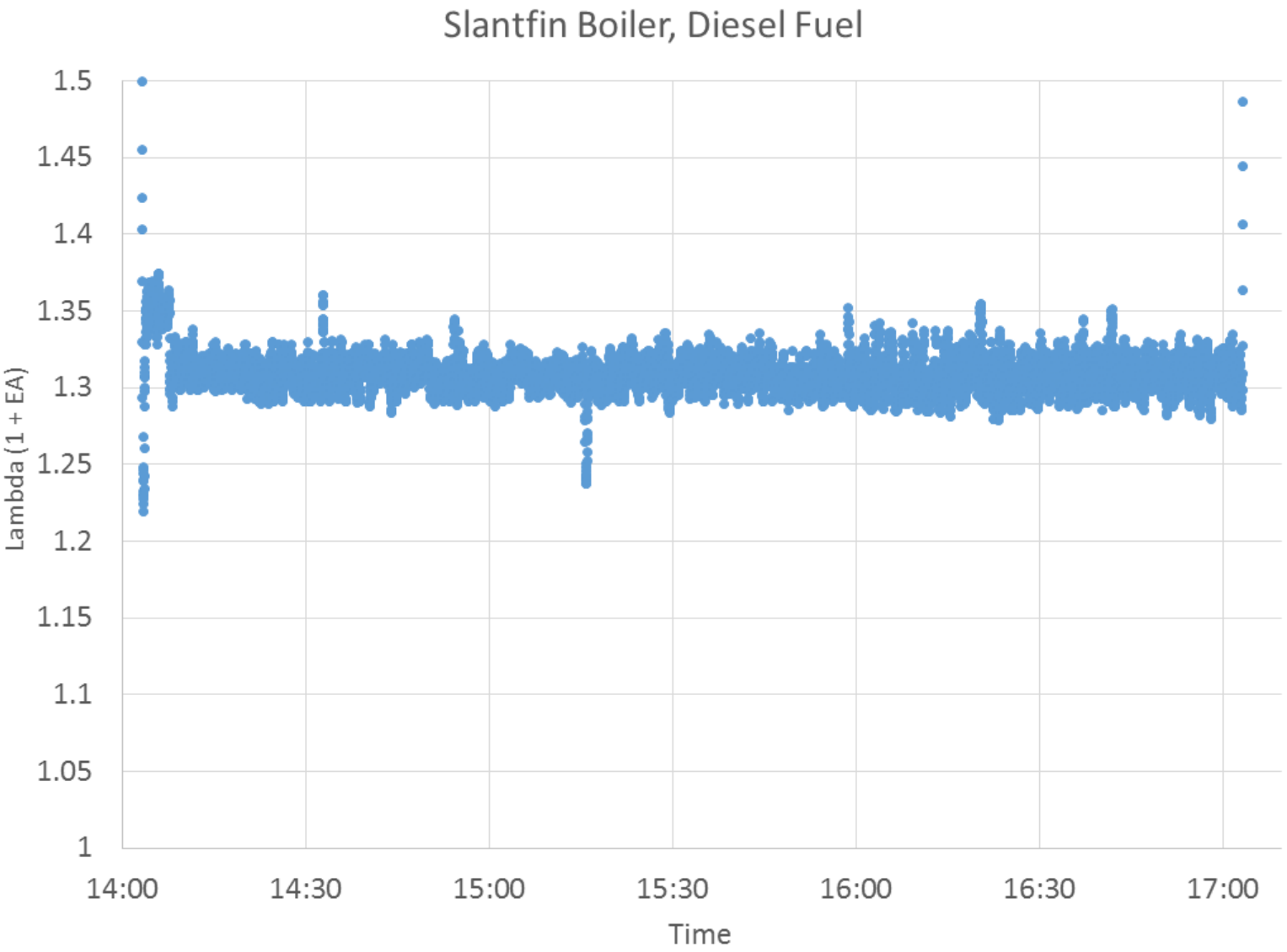
Oxygen levels are actually being measured.

Multi-Fuel Capability
Switching From No. 2 to B100 on the fly



Green data shows blower speed is actively being changed to maintain the target of 35% EA

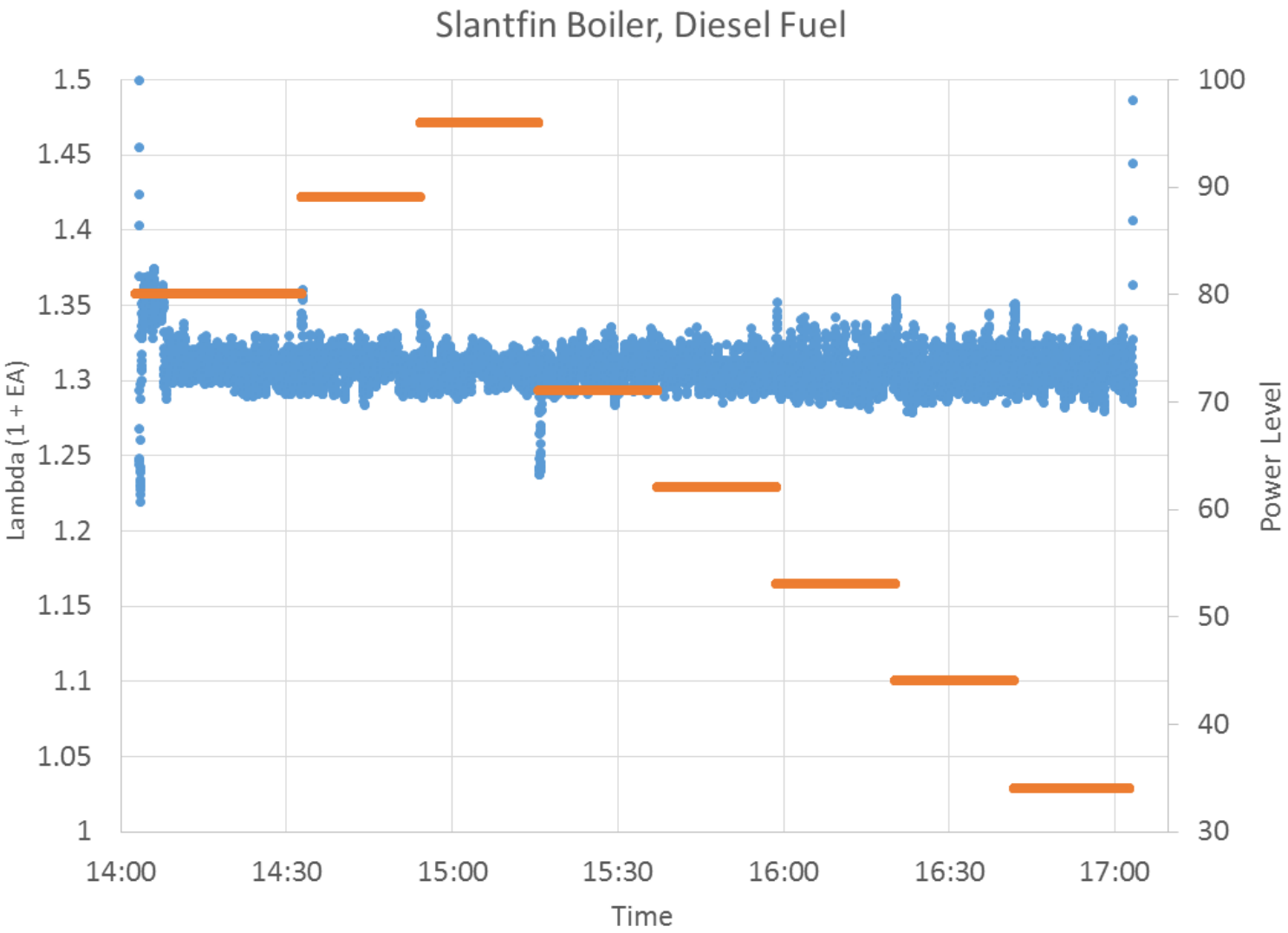
Switching firing rates on the fly



Firing rate was changed 8 times during this 3 hour run. Can you see where?

You probably can, but barely!

Switching firing rates on the fly



Horizontal lines show various power levels (i.e. firing rates) of the burner.

Next Steps:
Burner Pre-Production and Field Trials