Advancing Heating Oil Applications

Biodiesel Technical Workshop

October 27, 2026

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Topics

- RD/BD Field Study – 100% Renewable Fuel
- B100 Field Studies
- Burner Head Coking
- Outside Residential Tanks
- ASTM Advancement
- Biodiesel Blend Studies in France

RD/BD Field Study Overview

Goal

✓ Demonstrate the viability of a large-scale transition to a 100% renewable liquid fuel

Methodology

✓ Supply 121 sites with a blend of Renewable Diesel (RD) and Biodiesel (BD) without equipment modification or changes and monitor their performance over an 18-month period

Findings

✓ System performance met safety and operational standards while avoiding additional strain on fuel marketers and customers



Site Selection

- 121 sites representing eight fuel marketers in PA and MA selected
- Emphasis placed on obtaining a wide variety of appliances and burners to adequately represent the residential liquid fuel market
  - 84 boilers, 30 furnaces, and 7 water heaters
  - 76 Beckett, 17 Carlin, and 7 Riello burners
- Sites divided into Level 1 (28 sites) and Level 2 (93 sites) groups
- Each Level 1 site visited 5 times during the 18-month study period; 19 Level 2 sites during Visit 5
- Ongoing service data collected for all sites and compared to three-year historical service data

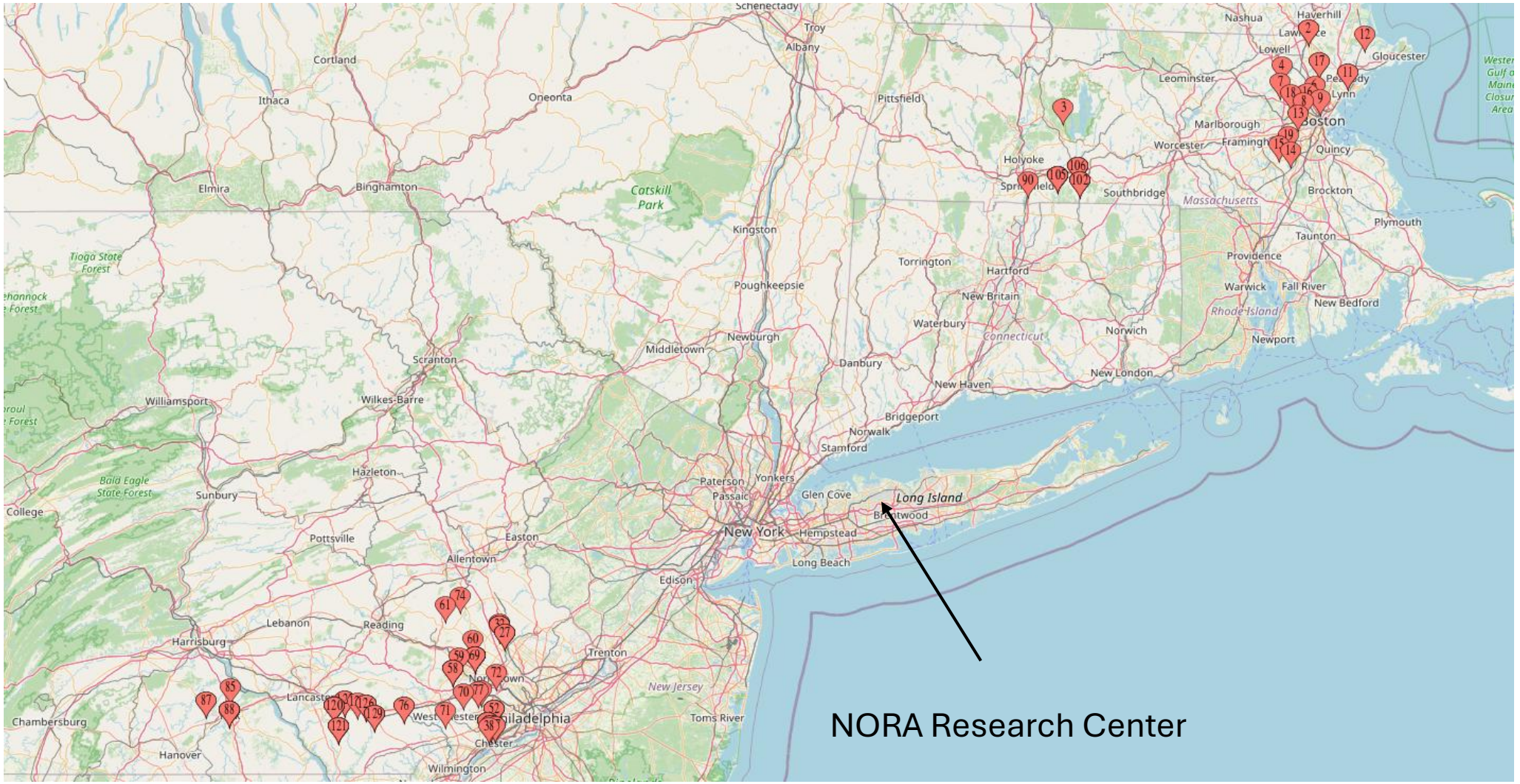
Level 1

- Visit, detailed characterization
- Sampling for changes in fuel quality
- Check combustion performance each visit
- Burner head inspection each visit
- Track service history

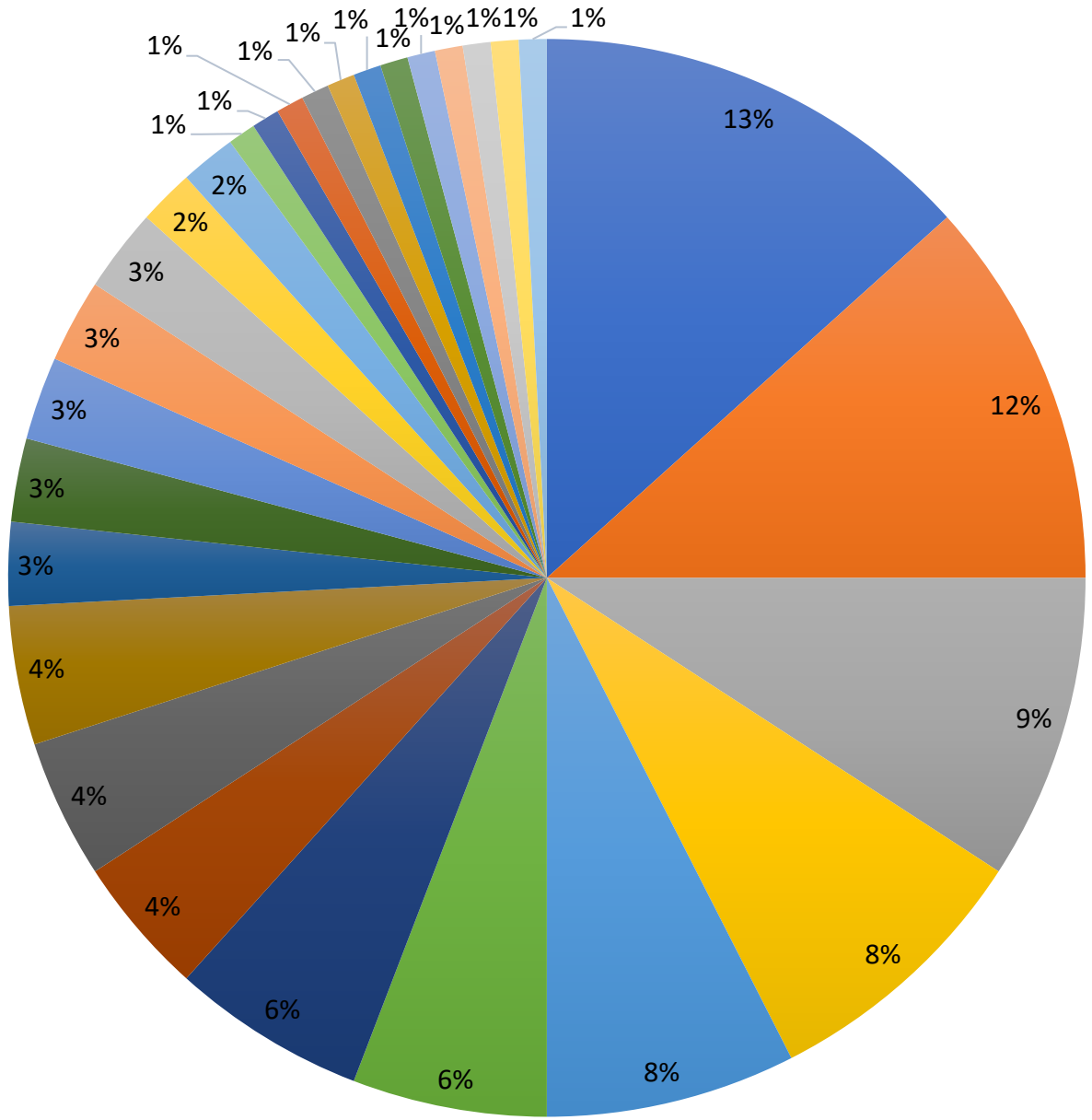
Level 2

- Check combustion performance as needed
- Track service history

Site Distribution



Equipment Distribution



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Fuel Logistics and Delivery

- Fuel provided by Chevron by rail:
  - Neat RD and BD to Broco Energy in MA for blending
  - Pre-blended RD80/B20 to Strasbourg, PA
- Fuel marketers delivered test fuel in dedicated trucks to their customers
- No reported equipment issues in the fuel supply chain
- 800 gallons average annual fuel usage among sites
- Fuel usage distribution shows several high consumption sites



Head Coking - Boilers


Site 3 - 1


Site 5 - 0

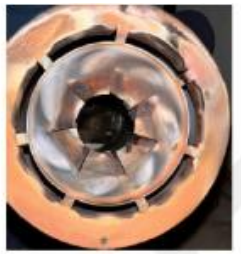

Site 7 – 3


Site 9 – 5


Site 31 - 1

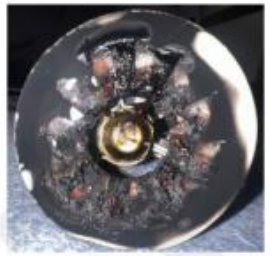

Site 44 - 3


Site 45 - 1


Site 71 - 1


Site 10 - 2


Site 15 – 2.5


Site 17 - 4


Site 18 – 1


Site 75 - 3


Site 78 - 2


Site 80 - 4


Site 85 - 1


Site 26 – 1.5


Site 27 - 2


Site 88 - 0


Site 90 - 2


Site 93 - 2


Site 107 - 2

Head Coking - Furnaces



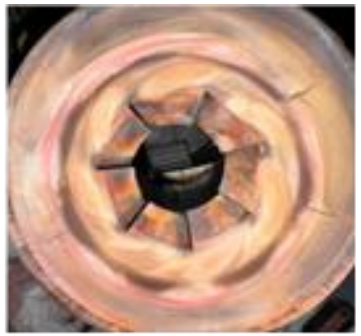
Site 8 – 0



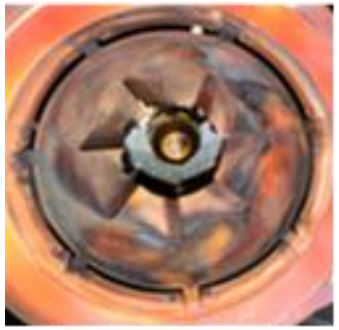
Site 11 - 0



Site 12 - 3



Site 13 – 0



Site 16 – 0



Site 19 – 0



Site 24 – 0

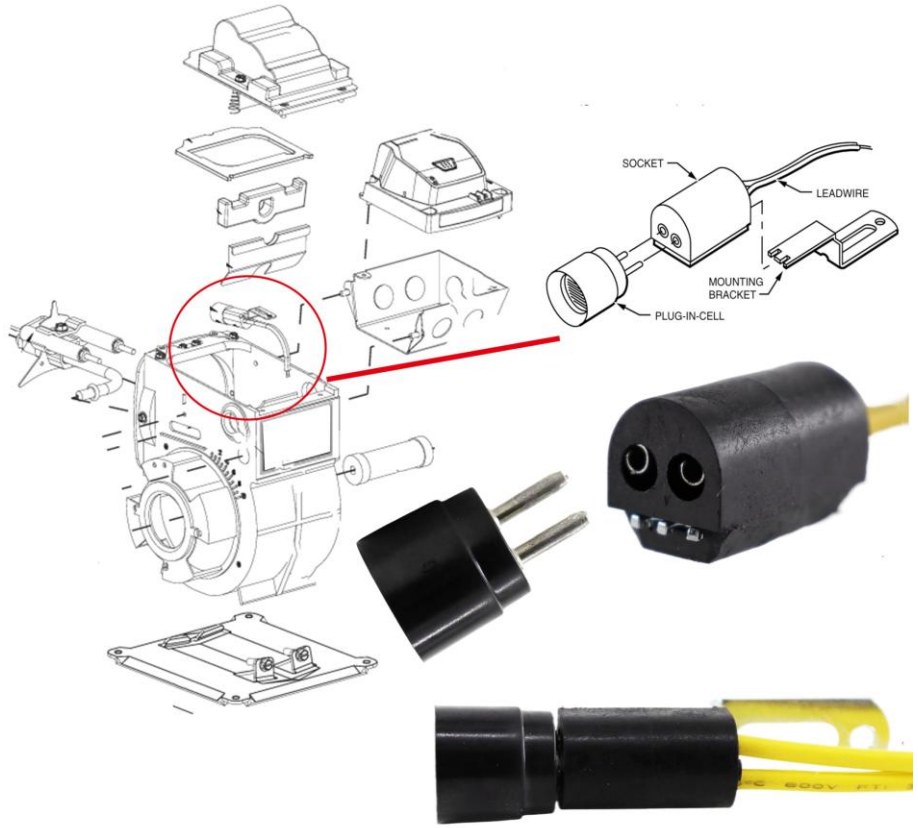


Site 28 - 0

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Operational Performance

- No systemic increase in service calls
- No leaks or failures, no material incompatibility
  - Two fuel tanks replaced during testing as a precaution
- Older generation burner control systems had some “lock-out” issues at four sites. This was corrected with a change to a modern control
- Head coking was found to be higher with some equipment, particularly on cold chamber appliances



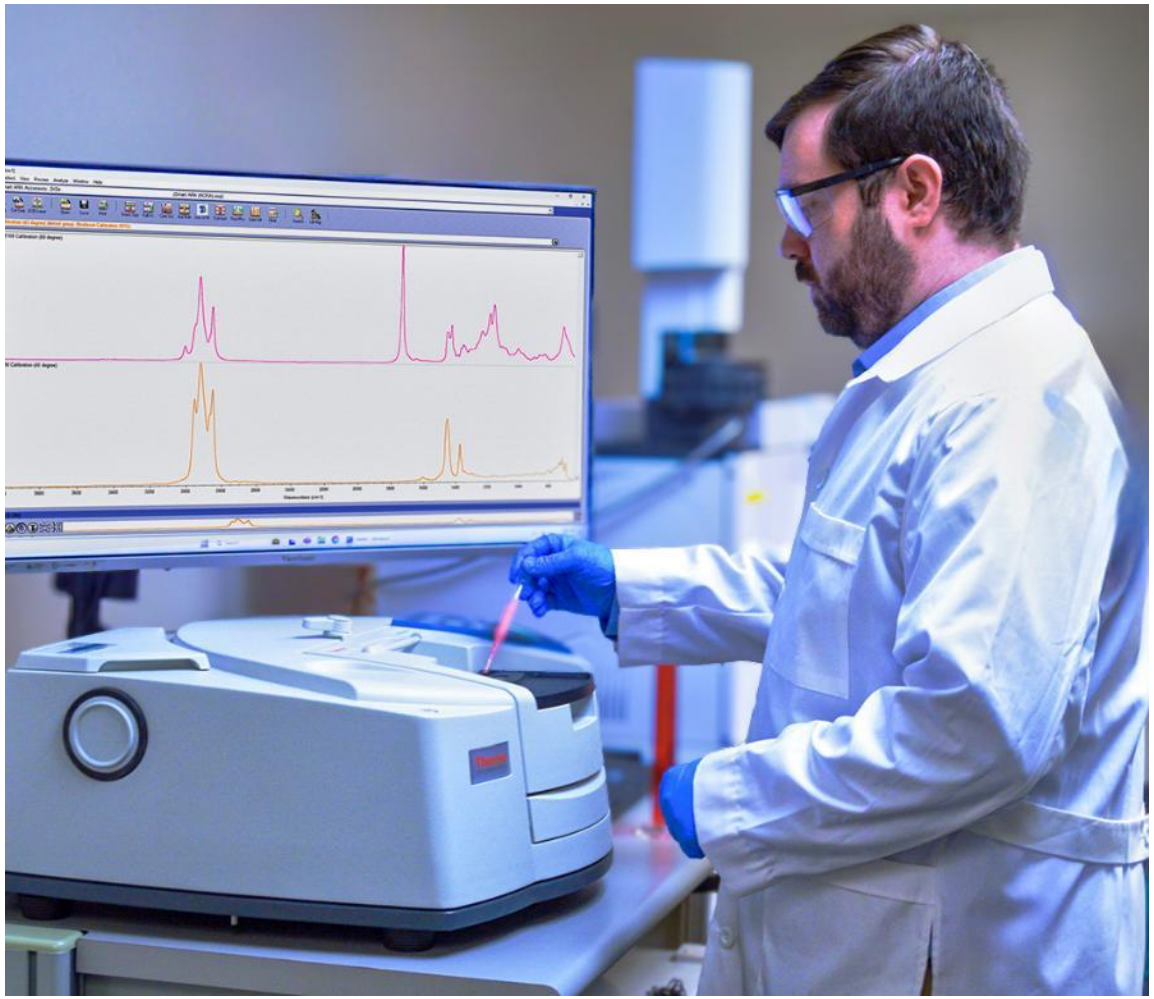
Site Visit Schedule

Visit Number	Date
1	October-November 2024 (pre-delivery of test fuels)
2	March-April 2025
3	September-October 2025
4	January 2026
5	May 2026

Level 1 Fuel Analysis

Tests Performed on Level 1 fuel samples

- Biodiesel Content
- Oxidative Reserve
- Acid Number
- Water Content
- Biological Activity
- Water and Sediment
- Viscosity
- Density



Biodiesel Content

Method: ASTM D7371

- Measure starting point of each location before introduction of renewable fuel blend
- Verify consistency of blend levels
- Most locations reach target blend of biodiesel by Visit 2
- Small number of sites received incorrect blend levels at some testing points

Biodiesel Content for RD50/B50 Sites					
	Visit 1 (% v/v)	Visit 2 (% v/v)	Visit 3 (% v/v)	Visit 4 (% v/v)	Visit 5 (% v/v)
Average	89.5	49.5	47.2	49.1	46.0
Minimum	60.9	48.8	38.9	45.2	39.2
Maximum	100.0	50.4	49.7	50.9	49.6

Biodiesel Content for RD80/B20 Sites					
	Visit 1 (% v/v)	Visit 2 (% v/v)	Visit 3 (% v/v)	Visit 4 (% v/v)	Visit 5 (% v/v)
Average	6.2	18.4	18.0	17.0	18.8
Minimum	0.0	7.8	8.3	5.1	2.9
Maximum	18.5	19.9	19.9	29.8	25.1

Oxidative Reserve

Method: EN 15751

- Oxidative reserve remained above the 6 hr minimum set by ASTM D396 for most cases
- The lowest average values were measured in Visit 3, after the summer shutdown period
  - 65% above ASTM limit after summer
  - 82% above ASTM limit by end of heating season
- Select number of sites had lower oxidative reserve measurements throughout the study

	Visit 1 (hrs)	Visit 2 (hrs)	Visit 3 (hrs)	Visit 4 (hrs)	Visit 5 (hrs)
Average	9.7	13.7	6.8	8.7	9.8
Standard Deviation	4.7	7.0	4.0	5.1	5.1
Minimum	2.5	0.6	0.6	2.5	2.2
Maximum	19.3	26.8	15.6	19.7	22.4

Visit	# of samples with oxidative reserve ≥ 6 hrs	Total Sample Count	Number of Samples in Range (%)
1	11	14	78
2	22	25	88
3	17	26	65
4	17	28	61
5	23	28	82

Total Acid Number (TAN)

Method: ASTM D664

- Majority of sites complied with ASTM D396 limit of 0.3 mg KOH/g
- Slight increase after summer (Visit 3), majority remained acceptable
- Fresh deliveries reduced acid number

	Visit 1 (mg KOH/g)	Visit 2 (mg KOH/g)	Visit 3 (mg KOH/g)	Visit 4 (mg KOH/g)	Visit 5 (mg KOH/g)
Average	0.16	0.22	0.26	0.16	0.15
Standard Deviation	0.16	0.16	0.22	0.05	0.05
Minimum	0.03	0.12	0.12	0.09	0.06
Maximum	0.68	0.96	1.3	0.31	0.27

Visit	# of samples with TAN ≤ 0.3 mg KOH/g	Total Sample Count	Number of Samples in Range (%)
1	17	21	81
2	23	25	92
3	21	26	81
4	27	28	96
5	28	28	100

Dissolved Water Content

Method: ASTM D6304

- Wide variability across sites
- Higher in summer months
- Driven by tank conditions/age

	Visit 1 (ppm)	Visit 2 (ppm)	Visit 3 (ppm)	Visit 4 (ppm)	Visit 5 (ppm)
Average	96	114	231	104	237
Standard Deviation	75	63	317	97	212
Minimum	15	9	65	23	55
Maximum	244	285	1781	438	878



Water & Sediment

Method: ASTM D2709

- Sediment levels were elevated in majority of tank levels from the start of the testing; unsurprising for a tank bottom sample
- Water present only at selected locations, same tanks repeatedly showed water
- Water occurrence was site-specific, not widespread

Site Number	Visit 1	Visit 3	Visit 4	Visit 5
1	No	No	No	No
2	No	No	No	No
3	No	No	No	Yes
4	No	No	No	No
5	Yes	Yes	Yes	Yes
6		No	No	Yes
7	No	Yes	No	No
8	No	No	No	Yes
9	No	Yes	No	No
10	Yes	Yes	Yes	Yes
11	Yes	Yes	Yes	Yes
13	Yes	Yes	Yes	Yes
14	Yes	Yes	Yes	Yes
15	No	No	No	No
16	No	No	No	No
17	No	No	No	No
18	Yes	Yes	Yes	No
19		Yes	Yes	Yes
20	Yes	No	Yes	No
21		No	No	No
22		Yes	No	No
23		No	No	No
24	No	No	Yes	No
25	No	No	Yes	No
26	No	No	No	No
27		No	No	No
28	No	No	No	No

Biological Contamination

Method: ASTM D7687

- Majority of tanks very low, well below acceptable limit of 100 pg cATP/mL
  - Median value for Visit 1 was 2.9 pg cATP/mL
  - Median value for Visit 5 was 2.8 pg cATP/mL
- High readings always associated with water
- Small number of sites had existing contamination before renewable fuel introduction

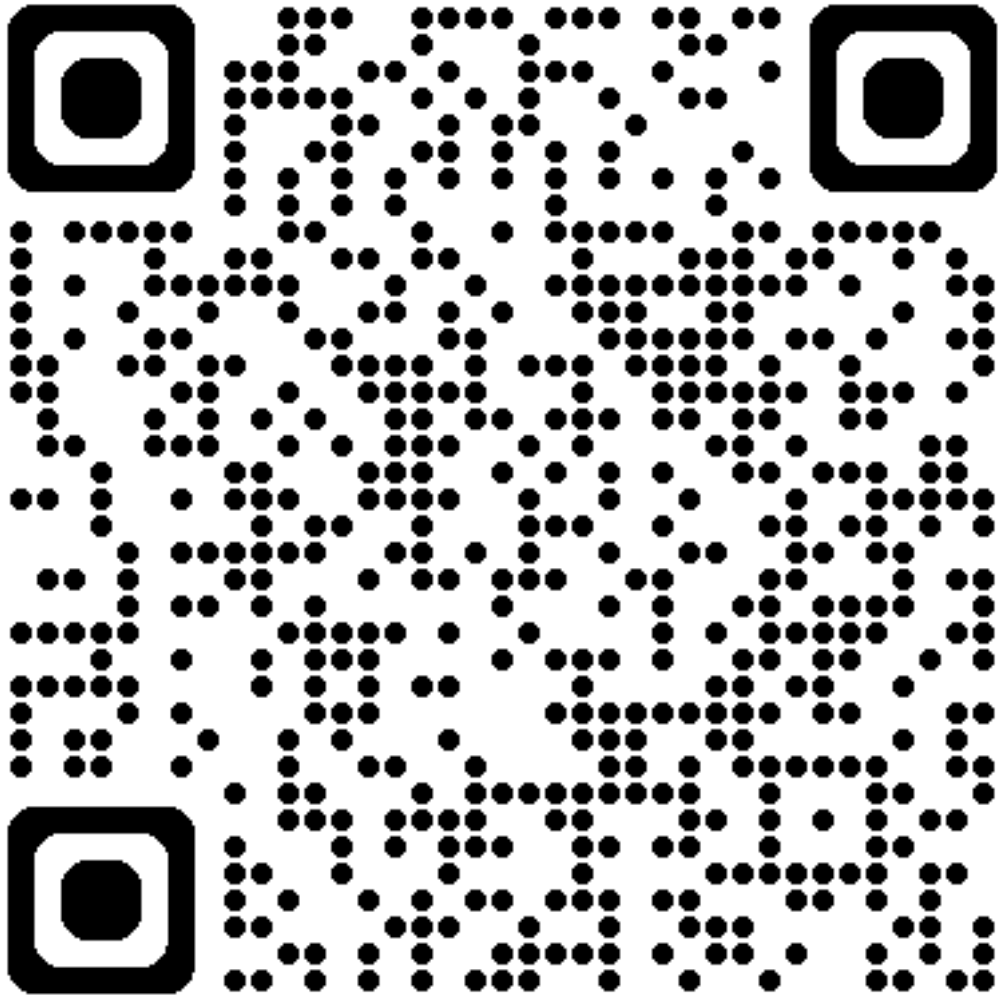
Site Number	Visit 1 (pg cATP/mL)	Visit 5 (pg cATP/mL)
1	2.9	0.8
2	2.9	0.8
3	1.92	51.2
4	1.3	1.3
5	179.9	3912.7
6	-	6.7
7	5.6	1809.0
8	3.6	1.9
9	2358.1	1.1
10	18.3	5943
11	2.6	575.6
13	0.0	4.9
14	0.0	4.9
15	1.6	0.8
16	4.9	2.1
17	2.9	0.5
18	8333.6	2.8
19	-	6.0
20	80.6	34.2
21	-	3.1
22	-	1.3
23	-	0.4
24	1.2	628.8
25	1.2	628.8
26	46.2	1.1
27	-	0.2
28	1.2	0.9

RD/BD Study Conclusions

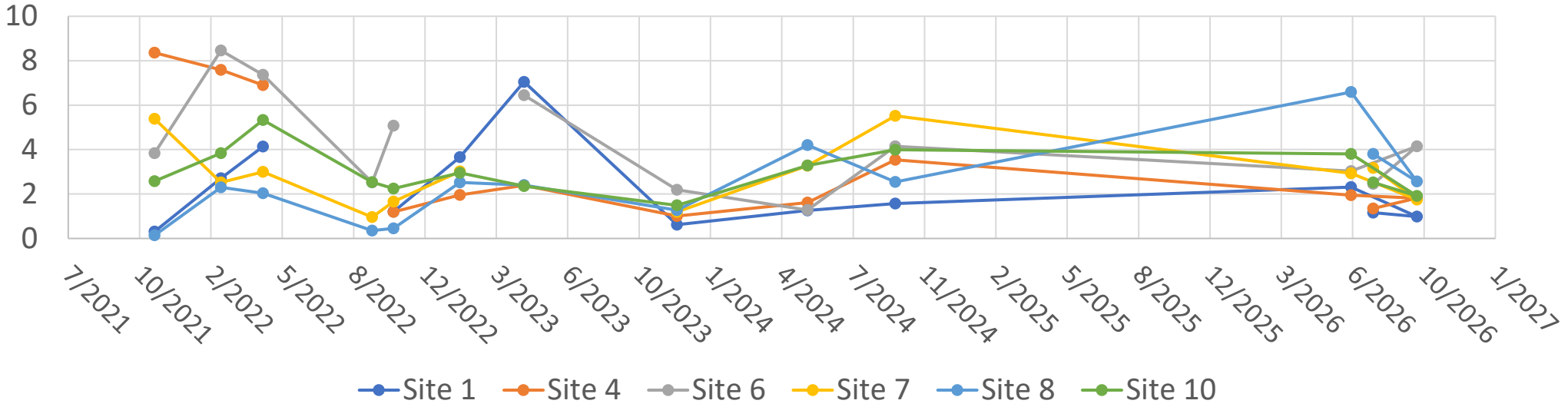
- **100% renewable** RD50/B50 and RD80/B20 blends operated **reliably in 121 existing heating systems** with no major modifications.
- Combustion performance stayed **within specifications**; **no meaningful increase** in service calls.
- Fuel quality issues were **rare, site-specific**, and tied to **pre-existing tank contamination**.
- **Storage tank condition**, rather than fuel blend, was the primary driver of long-term fuel quality.
- Burner head coking depended on **appliance design**, with no meaningful difference between the two renewable blends.



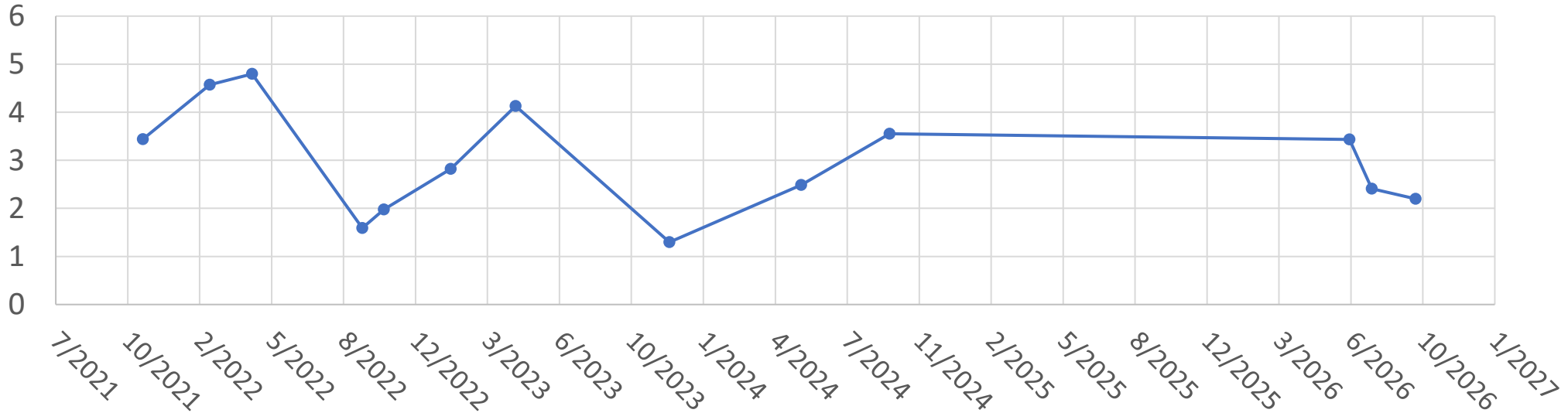
Access the full report using the following QR code



5 Years B100 Testing - Rancimat



AVERAGE



Biodiesel and Tank Corrosion

Polished steel corrosion coupon in B100 tank bottom for 5 years



Other Topics – Blue Flame Burners

Blue-Flame Burners, common in Europe, use high recirculation rates in flame tubes to reduce peak flame temperatures and NO_x.

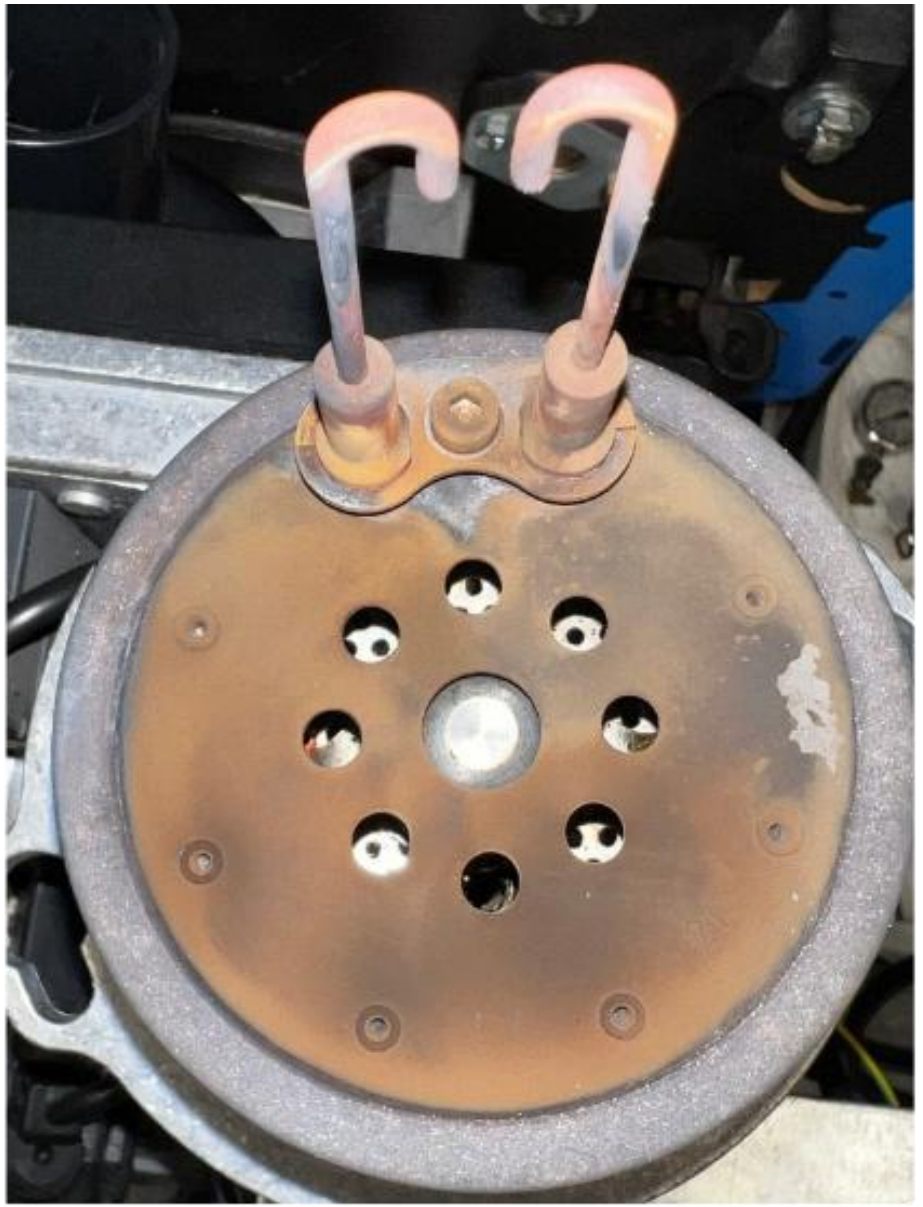


"Blue Flame" Burner Example



Long Term Head Coking Test – Blue Flame

- Fuel: B100
- Nominal Input: 0.91 gph
- Cycling Pattern: 5 mins on/5 mins off
- 14,067 cycles completed to date (~1 year of usage
- 1,149 runtime hours
- ~30 ppm NO_x, providing ~2/3 reduction compared to yellow flame burner in same application



Biofuels and the Outdoor Tank Question

- Biodiesel and Renewable Diesel can have high pour points (30-40 F)
- Blends, of course, help;
- NORA has been exploring tank heating options;
- Additives are also under consideration.



Heated Tank Enclosure

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- 3” foam board insulation R15
- 2 X 100-watt heating blankets in air space
- Thermostat control

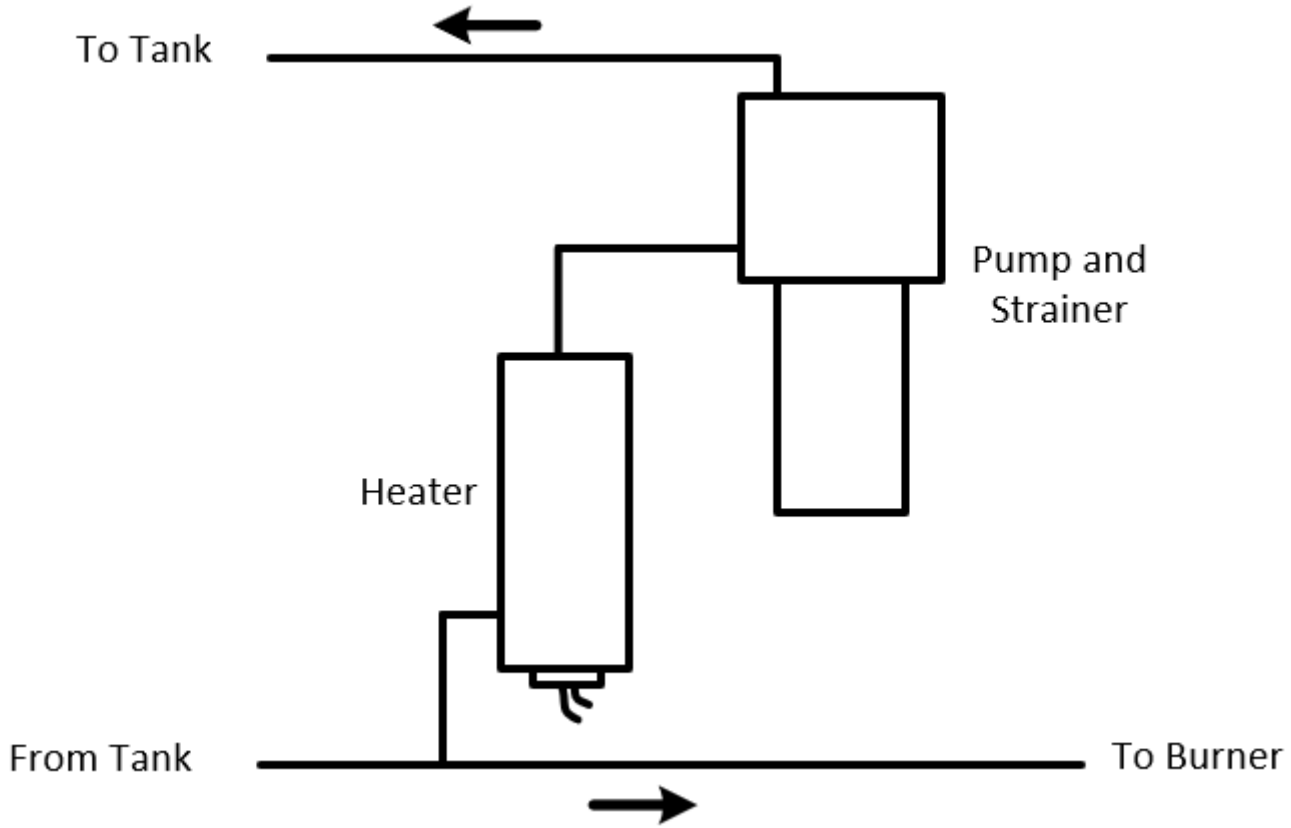




Temperatures as low as -21 °F. Very good performance. To be continued next heating season.

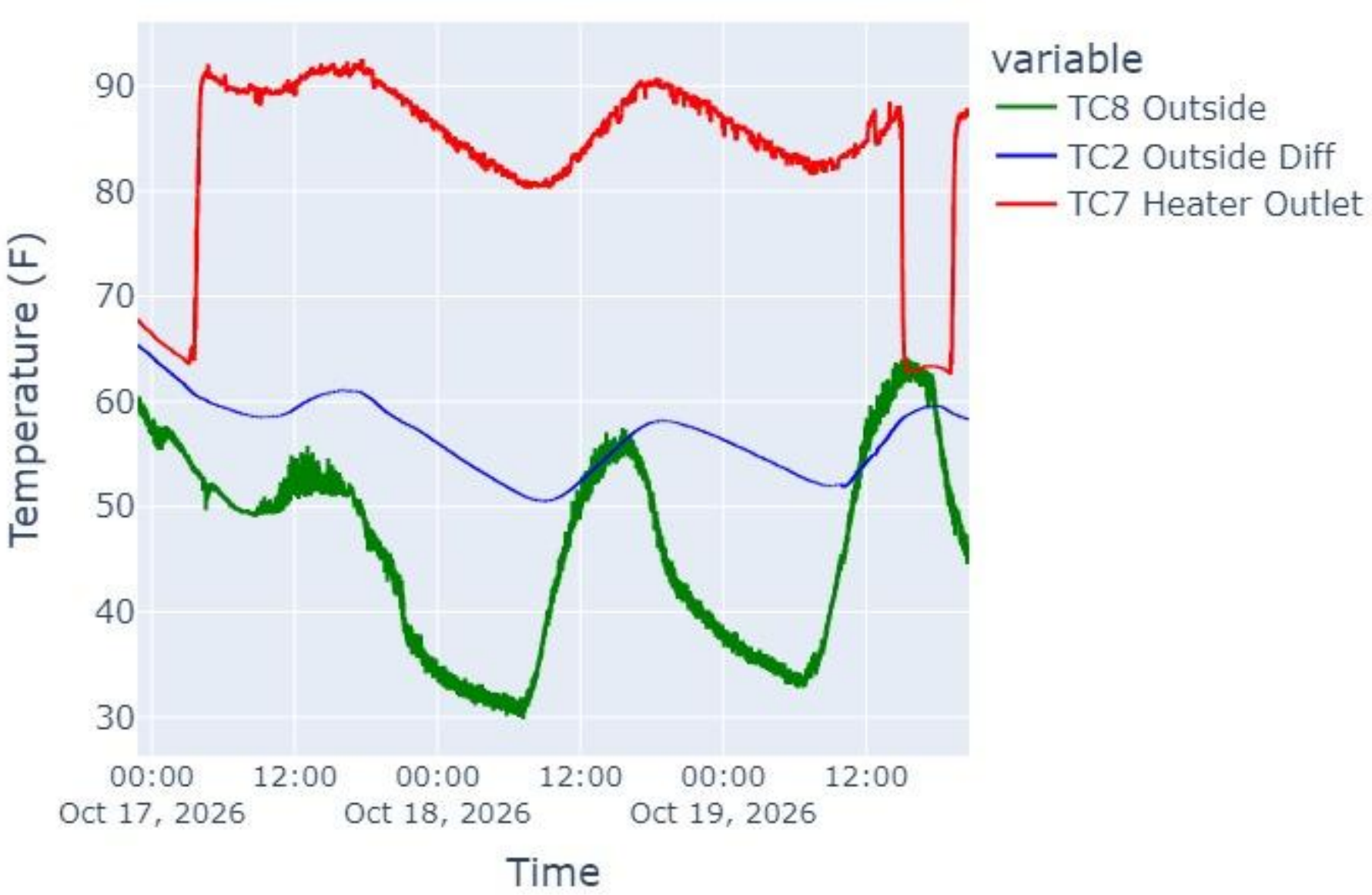


Loop Heater Concept








variable
TC8 Outside
TC2 Outside Diff
TC7 Heater Outlet
Temperature (F)
90
80
70
60
50
40
30
00:00
12:00
00:00
12:00
00:00
12:00
Oct 17, 2026
Oct 18, 2026
Oct 19, 2026
Time

New B21-B50 Grade in D396: Spring 2026 Concurrent Ballot

- B21-B50 grade next to B6-B20 grade in Table 1
- B21-B50 changes vs. B6-B20 grade:
  - B100 must meet more stringent 6 hour minimum oxidation stability reserve value prior to blending if used for blends over B20
    - Insures low acids/sediments as B50 for minimum 12 months simulated storage
      - B100 oxidation reserve is 3 hour minimum for use in blends B20 and lower
    - Final blend minimum remains unchanged at 6 hours for both B20 and B50
  - T-90 for B21-B50 increased to the B100 value of 360C
  - Acid number for B21-B50 is 0.4 max (B20 is 0.3, B100 is 0.5)
  - Significant digits on percent volume allow 50% to be added to B5

Support for ballot

Higher Blends Use – Estimated Current Status

- B20 – 500,000+ Sites
- B50 – 10,000 Site
- B100 – 200 Sites
  - New York, Vermont, Massachusetts, Maryland, Washington

TABLE 1 Detailed Requirements for Fuel Oils Conforming to Grades 1, 2, ~~or~~ B6–B20, or B21-B50[A,B]

Property	ASTM Test Method	No. 1 S15, S500, or S5000[C]	No. 2 S15, S500, or S5000[C]	B6–B20 S15, S500, or S5000[C]	B21–B50 S15, S500, or S5000[C]
Distillation Temperature, °C					
10 % volume recovered, max	D86	215	...	...	...
90 % volume recovered, min		...	282	282	282
90 % volume recovered, max		288	338	343	360
Kinematic viscosity at 40 °C, mm^2/s					
min	D445	1.3	1.9	1.3	1.3
max		2.4	4.1	4.1	4.1
Sulfur, percent by mass, max[D]					
Grade S15	D5453	0.0015	0.0015	0.0015	0.0015
Grade S500	D2622	0.05	0.05	0.05	0.05
Grade S5000	D2622	0.5	0.5	0.5	0.5
Pour Point °C, max[E]	D97	–18	–6	–6	–6
Ramsbottom carbon residue on 10 % distillation residue percent by mass, max	D524	0.15	0.35	0.35	0.35
Density at 15 °C, kg/m^3, max	D1298	850	876	876	876
Oxidation Stability, hours, min	EN 15751	...	...	6	6
Acid Number, mg KOH/g, max	D664	...	...	0.3	0.4
Biodiesel Content, percent (V/V)[F]	D7371	...	...	6–20.	21–50[I]

		Requirements for all grades	
Flash Point, °C, min	D93 – Proc. A	38	
Water and sediment, percent by volume, max	D2709	0.05	
Lubricity, HFRR @ 60 °C, micron, max	D6079/D7688	520	520[G]
Copper strip corrosion rating, max, 3 h at a minimum control temperature of 50 °C	D130	No. 3	
Conductivity (pS/m) or Conductivity Units (C.U.), min	D2624/D4308	25[H]	

French Bioheat Program – CETIAT, Lyon







- In-lab combustion tests
- B55 Field Study Just Completed
- B100 Field Study – Done 12/31/26
- In-lab long term storage tests in progress
- In-lab head coking studies being planned.

System Efficiency

- *Annual Maintenance* – clean, tune, reduce nozzle size if practical ~ 5%
- *Thermostat Setback* – 7 to 10°F reduction for eight hours per day ~ 10%. Night setback. Smart thermostats to enable real-time adjustments.
- *Zoning* – where possible reduce temperature in less used spaces.
- *Hydronic Controls* – several options e.g., outdoor reset. Focus on reducing jacket losses during low load periods ~ 5-15%.
- DHW Focus – Add an indirect to a tankless coil boiler and add controls.
- *Equipment Upgrade* – to a new boiler or furnace. Analysis of the NORA rebate program has shown furnaces ~ 10%, boilers ~ 20%. With advanced controls savings can be higher ~ 28%.
- *Hybrid hydronic systems with biofuels*

Thank you!!

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