

# FNSB Air Pollution Control Commission

## July 21, 2020 Meeting

### Retrofit Control Device Testing Results

#### Staff Report by:



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ADEC Air Quality Division



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# How did we get here?

Ord. 2017-63  
Provisions for ESPs  
9/28/2017

APCC not supportive of Ord. 2017-63  
12/12/2017

Citizen Science ESP Study North Pole Feb. 2018

Wood Stove Design Challenge in D.C. – ESP Testing Nov. 2018



Protocol development begins Nov. 2017  
Ongoing through Dec. 2019

Ord. 2017-63 defeated  
2/22/2018

Ord. 2018-26  
Ord. 2018-20-1G  
Standards for RCDs & Funding for Testing  
9/13/2018



# How did we get here (continued)?

Prop 4 passes. ESP standards removed from FNSB Code Dec. 2018

Release of RFP for lab and retrofits May 2019

Lab and RCDs selected Aug. 2019

FNSB Testing Conducted Jan – March 2020

Stakeholders Group Final Report Recommends ESP Testing Dec. 2018

Ord. 2018-20-2J to lapse FNSB funding for testing defeated. 6/27/2019

GVEA / Smoke-busters Pilot Project Winter 19/20

ADEC Testing Conducted Feb. – March 2020



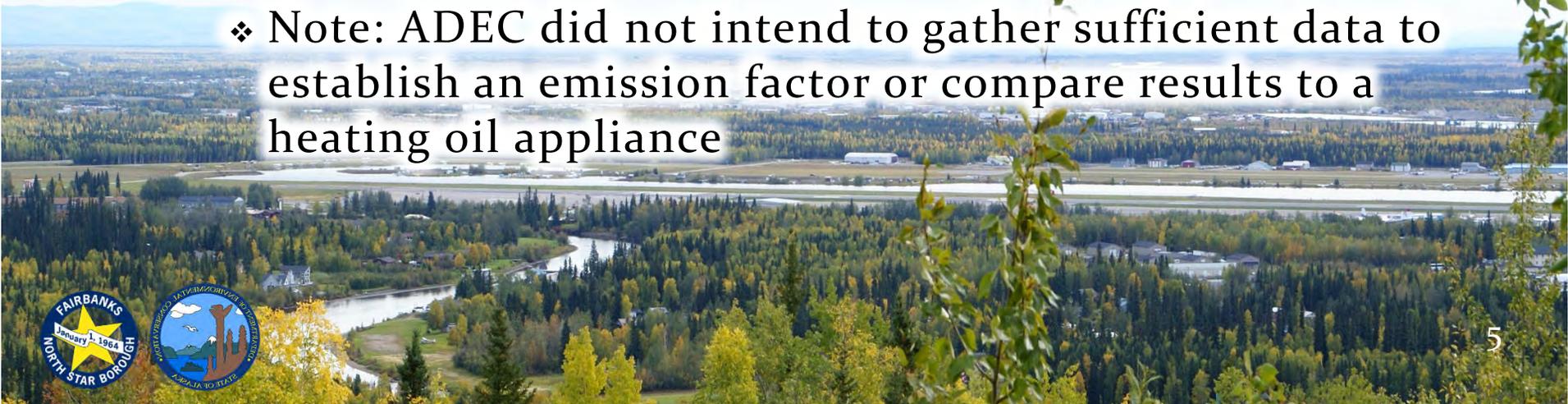
# Why did FNSB conduct testing?

- Purpose of FNSB testing had three main components regarding the performance of Retrofit Control Devices (RCDs):
  1. Obtain sufficient data to create an emission factor for RCDs on certain appliance categories for use in the SIP
  2. Compare to fuel oil heating appliance for curtailment exemption
  3. Evaluate the efficacy of RCDs for use in the FNSB



# Why did ADEC conduct testing?

- Purpose of ADEC testing was to provide additional information in support of the FNSB study with the primary goals of:
  1. Provide initial information on ESP performance with cordwood stoves
  2. Aid the FNSB in study efforts by providing insight on whether a broader more robust testing program is warranted
- ❖ Note: ADEC did not intend to gather sufficient data to establish an emission factor or compare results to a heating oil appliance



# Which RCDs were tested?

- FNSB tested two RCDs:
  1. Grace Fire StoveCAT retrofit catalytic system
  2. OekoTube Electrostatic Precipitator (ESP)
  
- ADEC tested one RCD:
  1. OekoTube ESP



# Appliance Types

- Residential wood heaters contain several types of appliances
  - Needed to narrow down the field
  - With the goal of fuel oil equivalency started with the cleanest appliances – EPA Step 2 Certified
- Proposed testing defined three appliance categories:
  - EPA Step 2 Certified Pellet Appliance
  - EPA Step 2 Certified Catalytic Cordwood Appliance
  - EPA Step 2 Certified Non-Catalytic Cordwood Appliance



# Appliance Types (continued)

## FNSB Testing

- EPA Step 2 Certified Pellet Appliance
  - Easier to test (relative to cordwood)
  - Relative steady state (compared to cordwood operation)
    - ❖ Auger fed
    - ❖ Controlled air supply
    - ❖ Homogenous fuel supply

## ADEC Testing

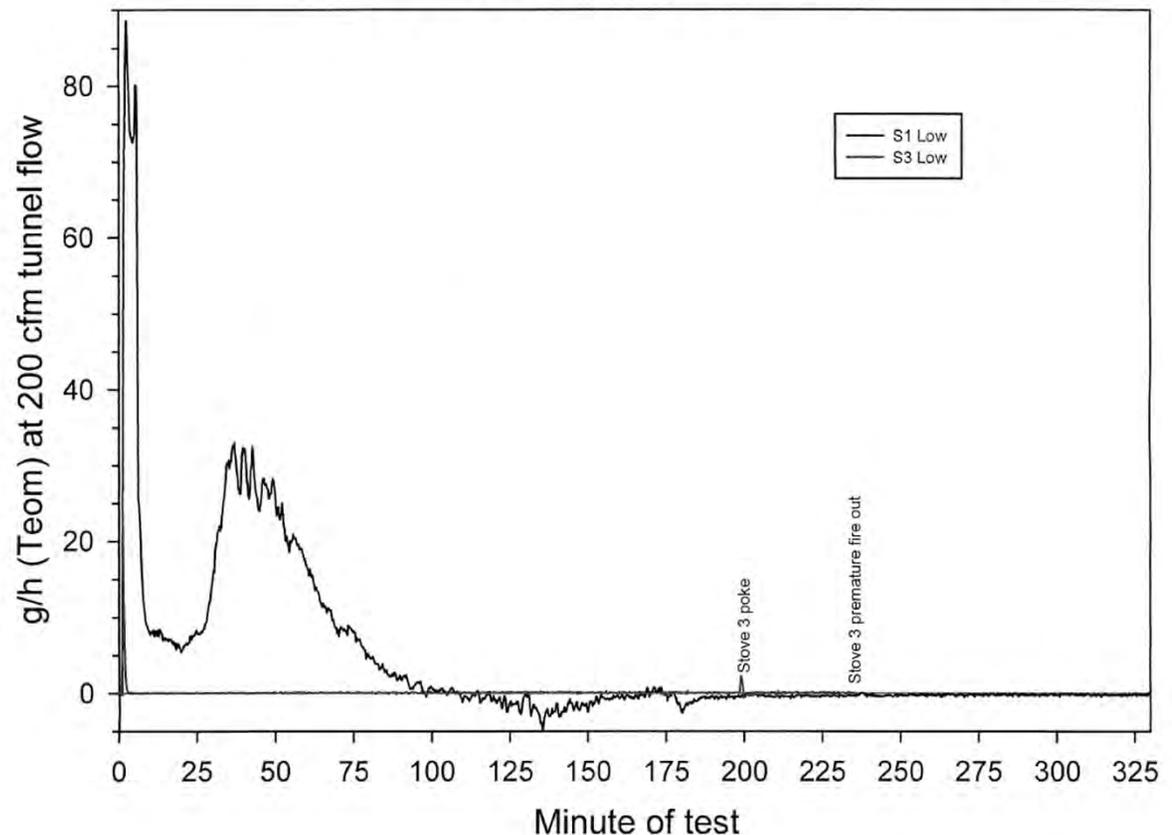
- EPA Step 2 Catalytic Cordwood
- EPA Step 2 Non-Catalytic Cordwood
  - ❖ Higher number of appliances in FNSB



# Testing Protocol - General

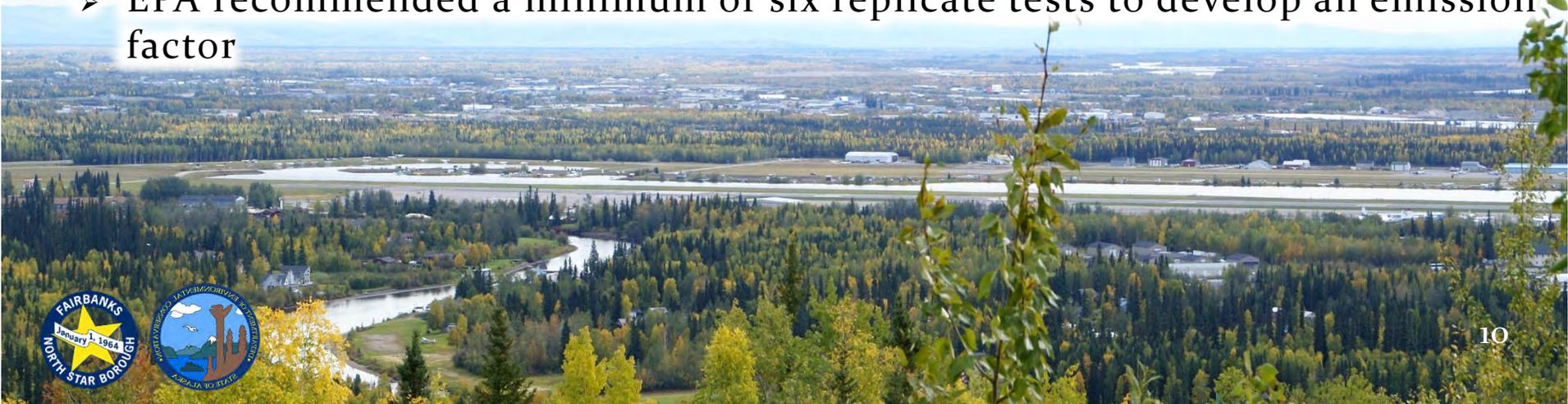
- Importance of burn phases and test duration
  - Cordwood appliances are not steady state
    - ❖ i.e. if a stove is certified at 2.0 g/h it does not emit at a constant 2.0 g/hr during operation
    - ❖ Challenging to reduce a dynamic system that changes with time to a single value
- Each burn phase (e.g. low, high, etc.) has different characteristics

M28 Low Fire, Teom g/h, October 2017 HLS



# Testing Protocol - General

- Particulate measurement method
  - Stack gas has to be diluted with ambient air prior to measurement
    - ❖ Dilution tunnel – EPA Certification method
    - ❖ Dekati e-Dilutor – Not recognized as federal method
  - Two measurement methods
    - ❖ Filter – EPA Certification method, provides one number for entire burn phase or test
    - ❖ TEOM – Not recognized as a federal method, provides time resolved emission data
  - Testing pre and post RCD
    - ❖ Baseline without control compared to separate test with control
    - ❖ Simultaneous sampling
- Replicate testing (i.e. repeated testing)
  - EPA recommended a minimum of six replicate tests to develop an emission factor



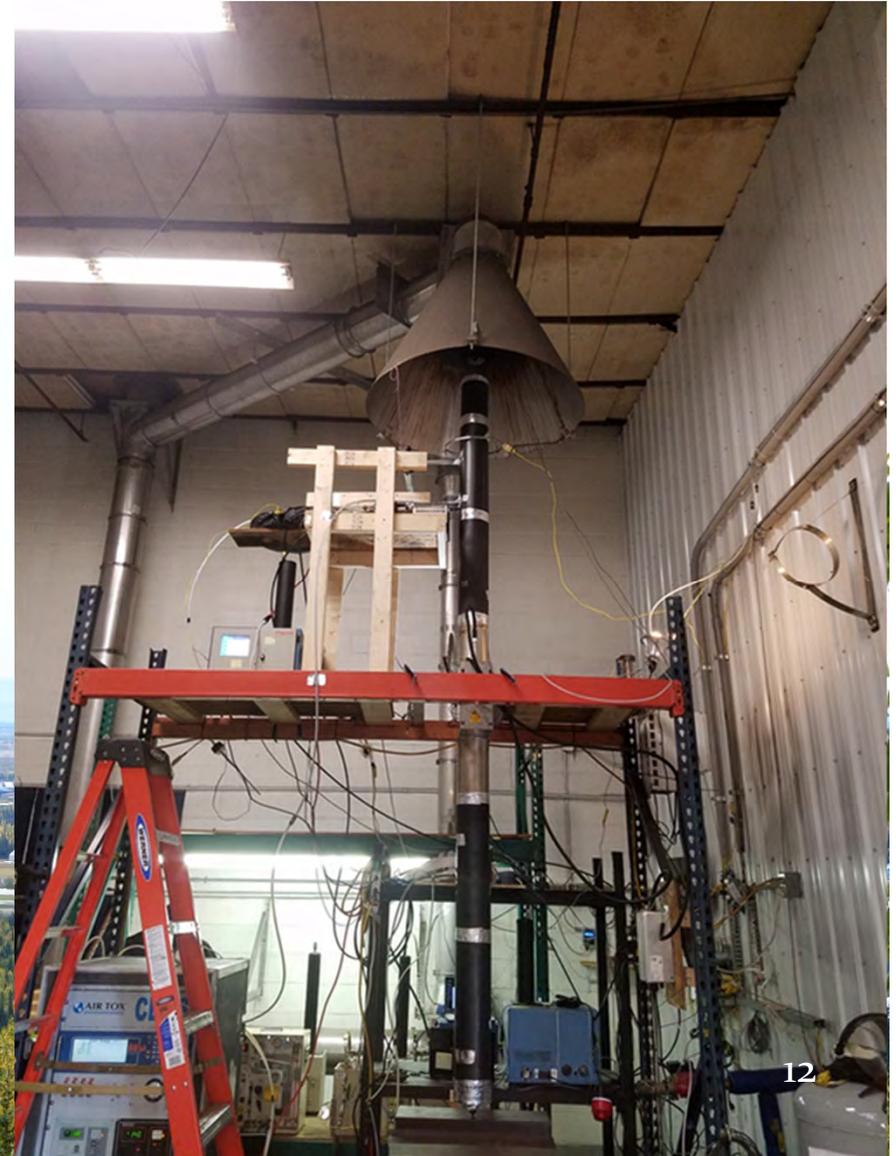
# FNSB Testing Protocol (pellet appliance)

- Over 18 months worked with EPA and multiple test laboratories
  - Operation and burn phases the same as EPA certification
    - ❖ Start-up, high, medium, low
  - Dilution method – Dekati e-Dilutor
  - Two separate PM measurement methods
    - ❖ TEOM
    - ❖ Filter
  - Simultaneous sampling with ESP
  - Baseline without control compared to separate test with control for StoveCAT
  - Six replicate tests with ESP
  - StoveCAT replicates reduced (more information in results)



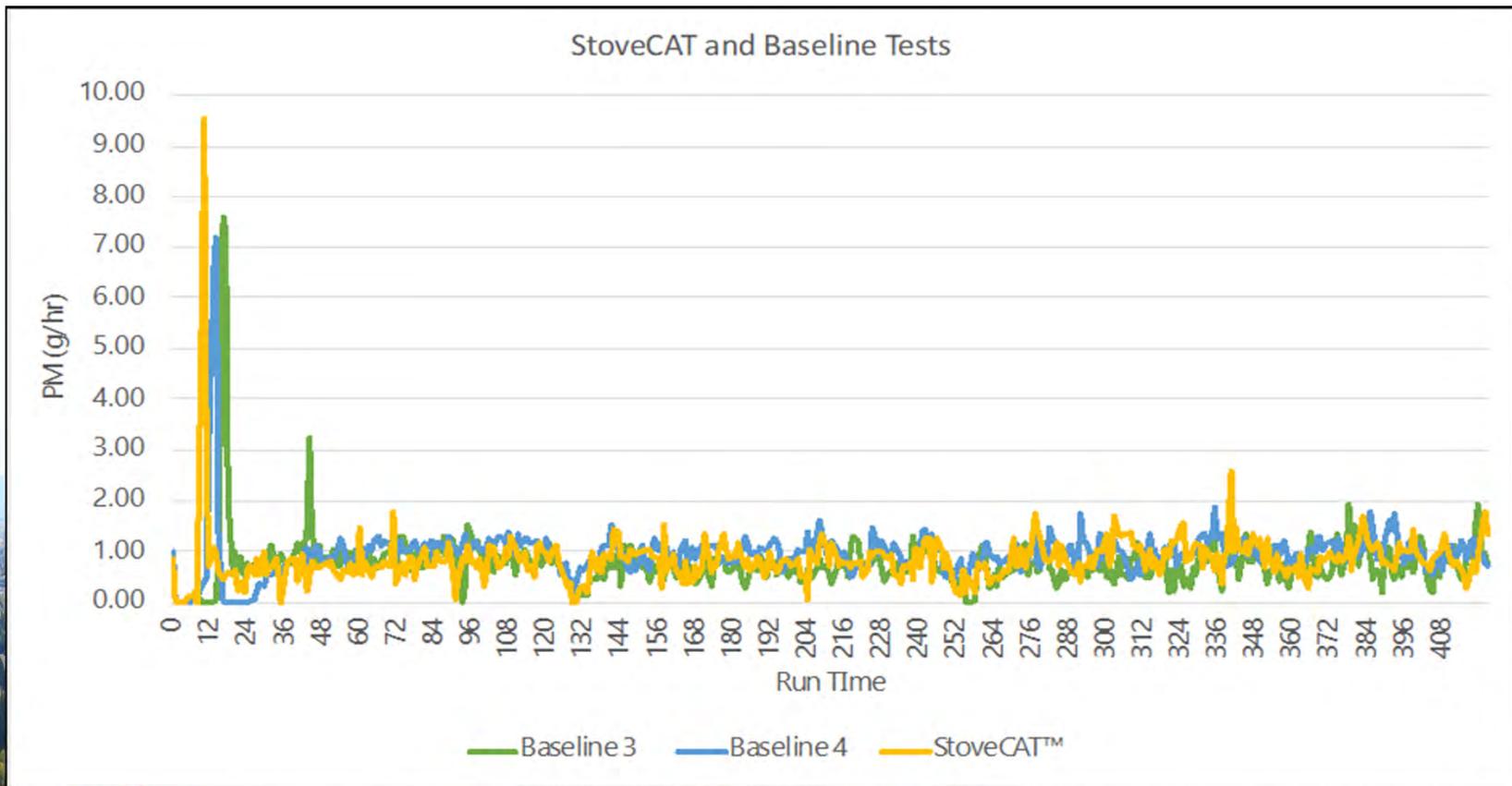
# ADEC Testing Protocol (cordwood appliances)

- Operation and burn phases
  - Integrated Duty Cycle (IDC)
    - ❖ Not recognized as Federal Method
- Dilution Tunnel
- PM measurement
  - TEOM
  - Select tests with filter
- Baseline w/o control compared to separate test with ESP
- Three replicate tests



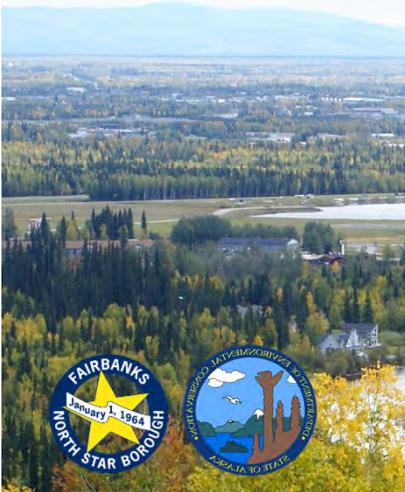
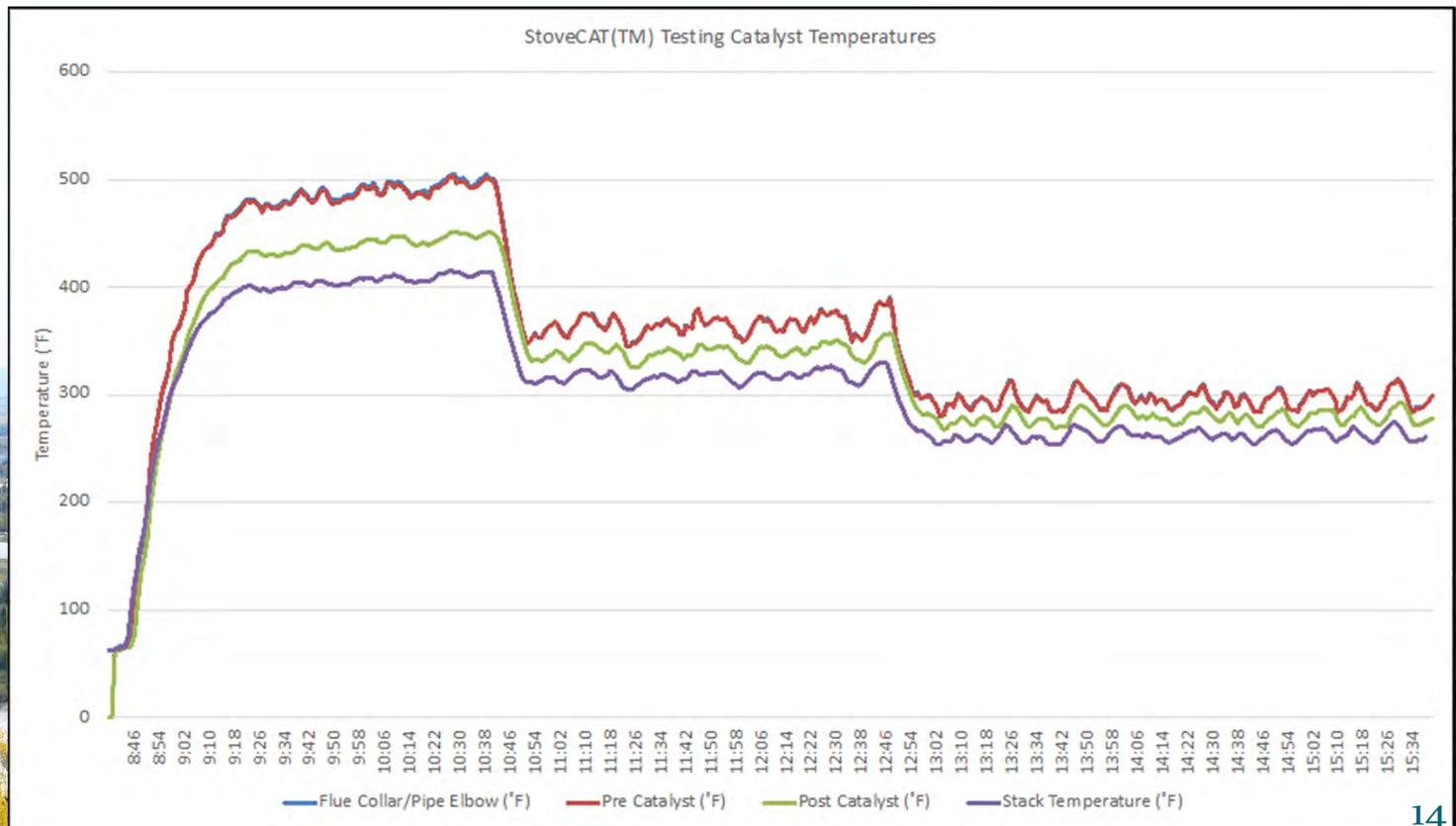
# Test Results – FNSB Testing - StoveCAT

- EPA Step 2 Certified Pellet Appliance
- Non-simultaneous testing
- No discernable difference between baseline tests and tests with StoveCAT



# Test Results – FNSB Testing - StoveCAT

- Catalyst needs:
  - Fuel (hydrocarbons)
  - Oxygen
  - Temperature
- Pellet appliance does not have temp. or fuel to support catalytic reaction



# Test Results – FNSB Testing - StoveCAT

- Key Takeaways

- Catalyst never activated and had no effect on PM emissions as evidenced by catalyst temperature data
- StoveCAT not designed for the operating conditions of a pellet stove
- Without emission reductions there is no need to develop an emission factor
- Baseline and replicates reduced to conserve budget



# Test Results – FNSB Testing - ESP

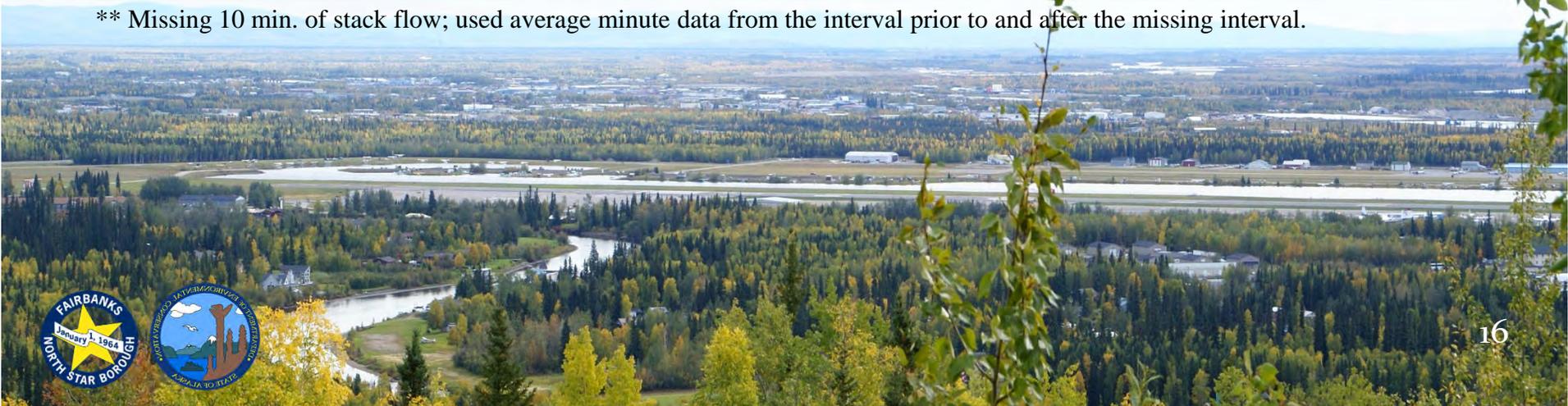
EPA Step 2 Certified Pellet Appliance w/ ESP

Simultaneous testing

Average control efficiency over 6 tests by PM Measurement Method

<b>ESP PM Control Efficiency (% reduction)</b>							
Test Run	ESP 2**	ESP 3	ESP 7	ESP 8	ESP 9	ESP 10	Average
Filter	90	38	51	70	94	86	72
TEOM	69	60	37	49	41	24	47

\*\* Missing 10 min. of stack flow; used average minute data from the interval prior to and after the missing interval.



# Test Results – FNSB Testing - ESP

## EPA Step 2 Certified Pellet Appliance w/ ESP TEOM Test Results By Burn Phase

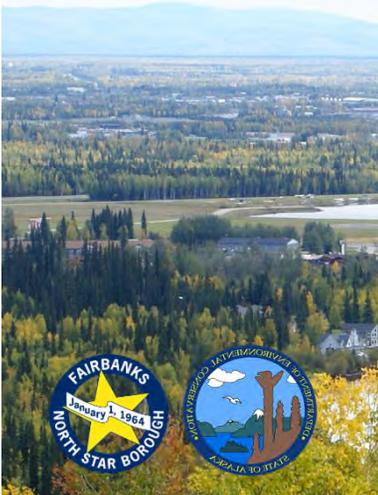
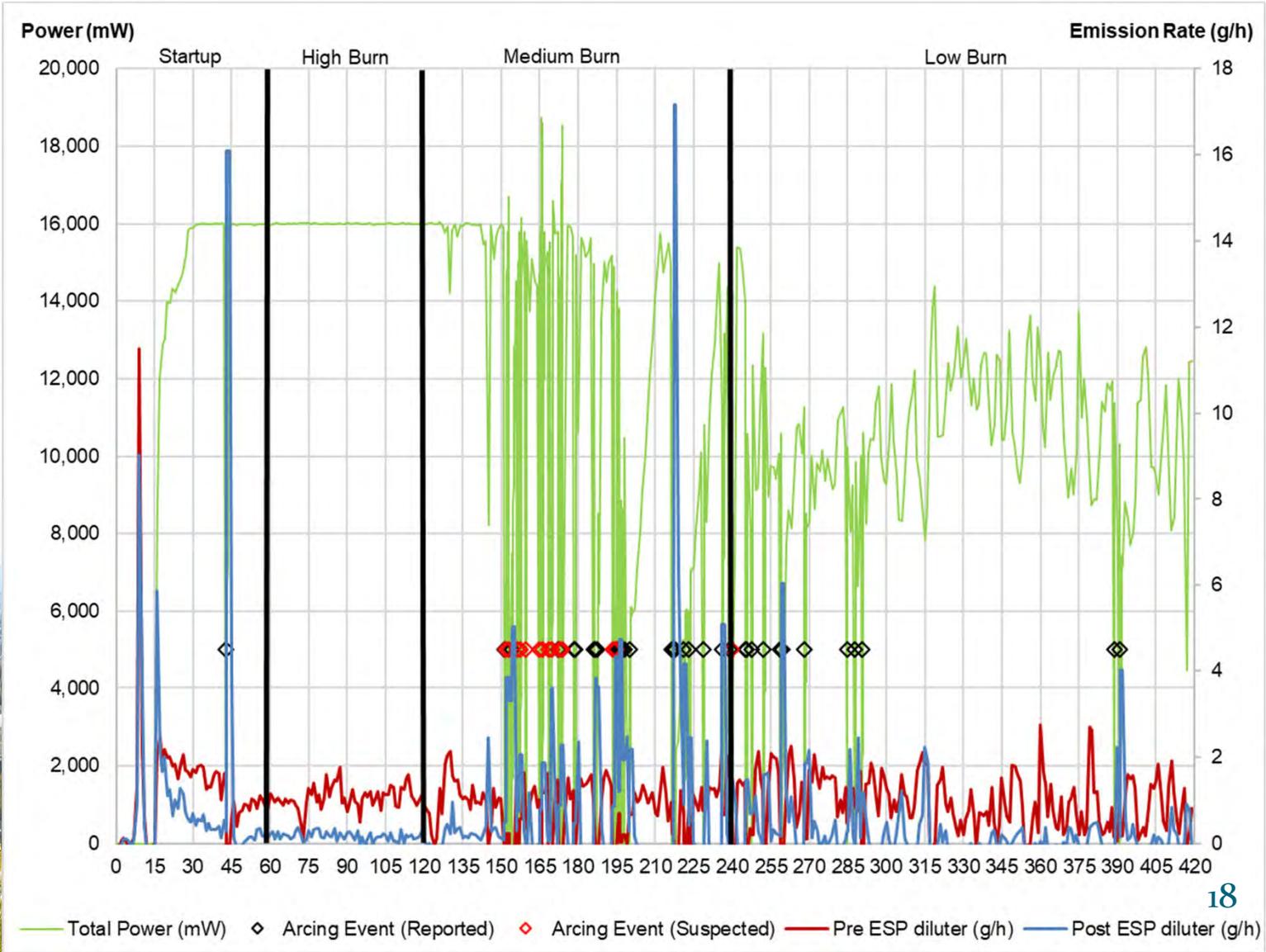
<b>Average TEOM Measurements</b>					
	Entire Cycle	Startup	High Burn	Medium Burn	Low Burn
Average Emissions (g/hr)					
Pre ESP	1.0	1.3	1.1	0.8	0.9
Post ESP	0.5	0.9	0.3	0.6	0.4
Average Efficiency (% reduction)					
Mean Value	47	30	74	25	55
Std. Deviation	16	24	12	36	15



# Test Results – FNSB Testing - ESP

## EPA Step 2 Certified Pellet Appliance w/ ESP

### TEOM Test Results By Burn Phase



# Test Results – FNSB Testing - ESP

EPA Step 2 Certified Pellet Appliance w/ ESP Simultaneous testing

<b>Comparison of Pellet Stove Emission Factors to Other Residential Heating Sources</b>		
	<b>PM<sub>2.5</sub> Emission Factor (lb/MMBtu)</b>	<b>Source</b>
<b>Pellet Stove (EPA Certified)</b>		
No Control	0.090	ClearStak
with ESP Control (TEOM removal efficiency)	0.047	ClearStak
With ESP Control (Filter removal efficiency)	0.031	ClearStak
<b>Other Residential Heating Sources</b>		
#1 / #2 Fuel Oil Furnace (weighted 31.8% #1, 68.2%, #2)	0.0034	OMNI run #17
Natural Gas Furnace	0.0000488	Brookhaven Report



# Test Results – FNSB Testing - ESP

## EPA Step 2 Certified Pellet Appliance w/ ESP

### Key Takeaways

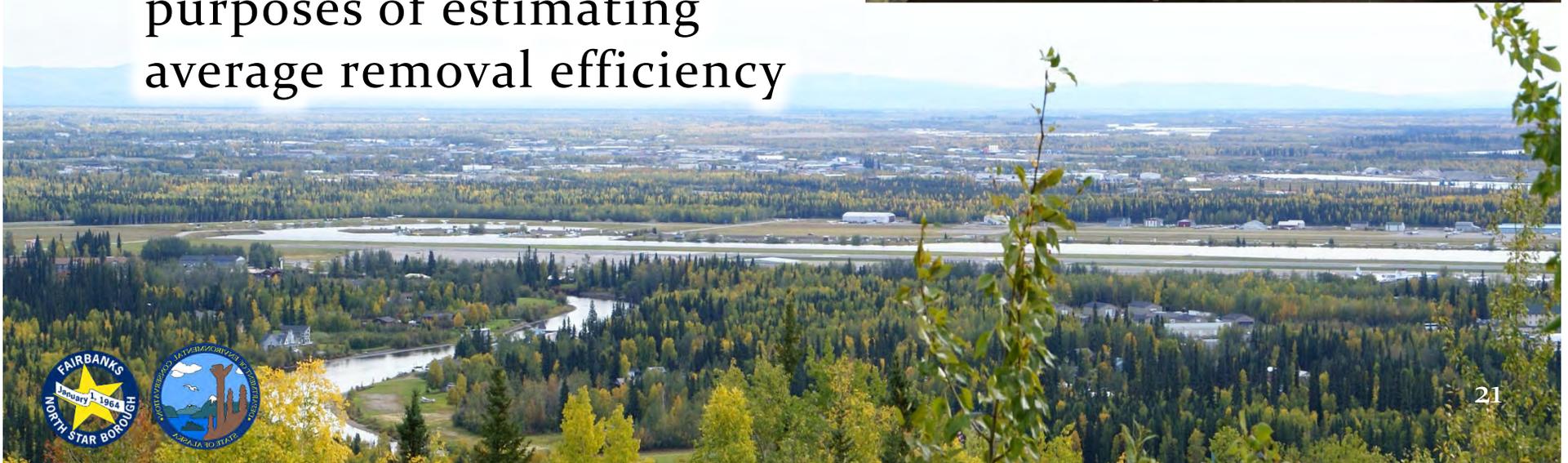
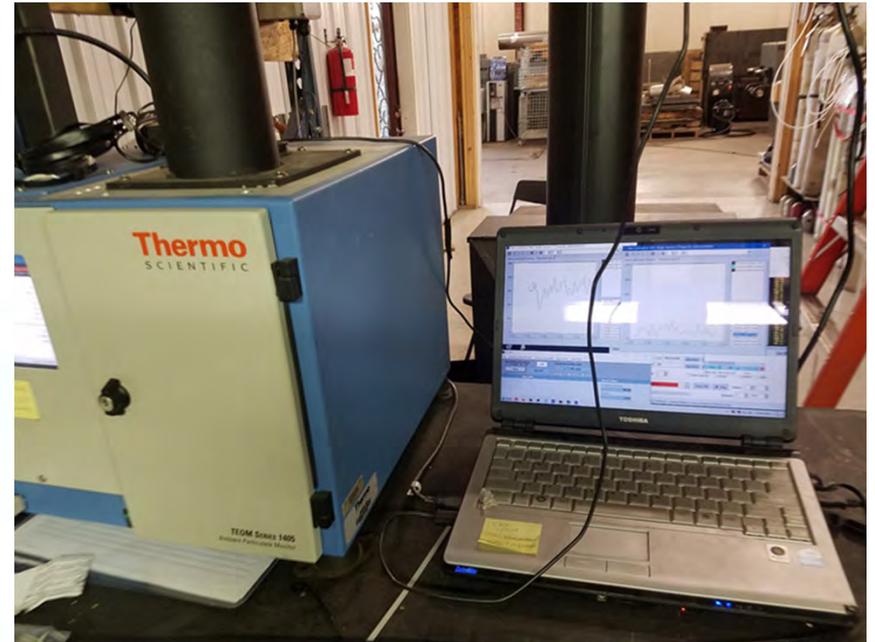
- Test results approx. 10 times greater than fuel oil
  - Does not support a Stage 2 exemption
- Sufficient testing completed on pellet appliance to support development of an ESP emission factor
- ESP-equipped pellet stove could provide a quantifiable emission benefit if:
  - Durability, maintenance, cleaning, and monitoring are addressed



# Test Results – ADEC Testing - ESP

EPA Step 2 Certified Non-Catalytic Cordwood Appliance

- 5 baseline tests conducted, 2 invalidated due to test method deviations
- 4 ESP tests conducted, 1 considered an anomaly for purposes of estimating average removal efficiency



# Test Results – ADEC Testing - ESP

## EPA Step 2 Certified Non-Catalytic Cordwood Appliance

<b>Non-Catalytic Cordwood Stove</b>				
<b>Non-Simultaneous PM Test Measurements and Average Efficiency by Test Method</b>				
<b>(g/hr)</b>				
<b>TEOM</b>				
<b>Test Type</b>	<b>ESP 1</b>	<b>ESP 2</b>	<b>ESP 4</b>	<b>Average</b>
Average Baseline				24.87
ESP	5.59	7.11	7.22	6.64
<b>Control Efficiency</b>				73.3%
<b>Filter</b>				
<b>Test Type</b>	<b>ESP 1</b>	<b>ESP 2</b>	<b>ESP 4</b>	<b>Average</b>
Average Baseline				29.76
ESP	8.21	11.25	10.63	10.03
<b>Control Efficiency</b>				66.3%



# Test Results – ADEC Testing - ESP

## EPA Step 2 Certified Non-Catalytic Cordwood Appliance

<b>Non-Catalyst Cordwood Stove</b> <b>TEOM Test Measurements and Control Efficiency by IDC Test Phase</b> <b>(g/hr)</b>							
Test Phase	Average Baseline	ESP				Average ESP*	Control Efficiency
		#1	#2	#3	#4		
Startup	6.53	4.31	3.83	112.03	4.91	4.35	33.4%
High	22.37	5.18	6.30	20.22	9.14	6.87	69.3%
Maintenance	44.05	1.77	5.66	16.58	2.65	3.36	92.4%
Overnight	17.83	9.00	8.70	9.53	9.54	9.08	48.8%

\*Does not include ESP #3, where ESP was not functioning.



# Test Results – ADEC Testing - ESP

## EPA Step 2 Certified Non-Catalytic Cordwood Appliance

- Note on ESP conditioning and cleaning:
  - ESP was conditioned for a period of 24 hours prior to pellet testing
  - ESP was cleaned then tested on a pellet appliance with 105 hours of run time
  - ESP was not cleaned after pellet testing then installed for cordwood testing



# Test Results – ADEC Testing - ESP

## EPA Step 2 Certified Non-Catalytic Cordwood Appliance

Dust accumulation after 105 hours of operation on a pellet appliance



Creosote buildup after 34 hours of operation (after Run 3) on a non-catalytic cordwood appliance with dry fuel in a controlled environment



# Test Results – ADEC Testing - ESP

## EPA Step 2 Certified Non-Catalytic Cordwood Appliance

- Photograph showing material removed from ESP
  - Creosote buildup occurred after 34 hours of operation with dry fuel in a controlled environment
  - Due to excessive creosote build-up ESPs may present a safety concern to homeowners when installed on a cordwood appliance



# Test Results – ADEC Testing - ESP

## EPA Step 2 Certified Non-Catalytic Cordwood Appliance

### Key Takeaways

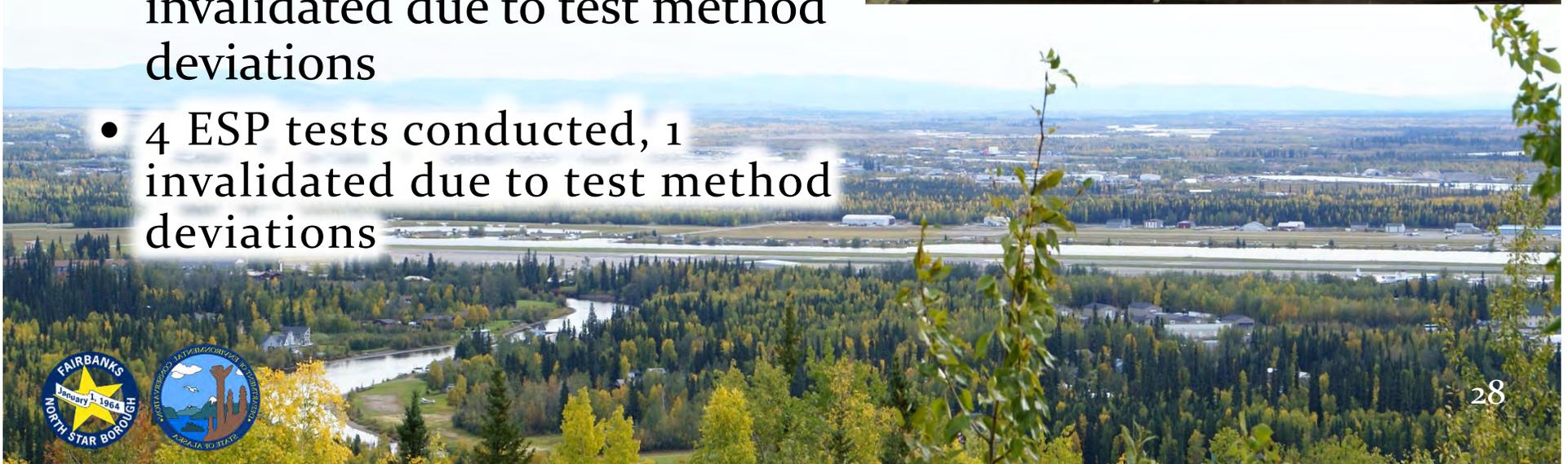
- The ESP failed on one run due to excessive creosote build-up after 34 hours of operation with dry fuel in a controlled environment
- Recommend manufacturer revisit/update design and conduct testing to address creosote build-up and associated safety concerns
- Ignoring creosote impacted measurements significant emission reduction potential exists
  - ESP control efficiency was 66% (filter) and 73% (TEOM)



# Test Results – ADEC Testing - ESP

## EPA Step 2 Certified Catalytic Cordwood Appliance

- Non-simultaneous testing
  - Baseline w/o ESP
  - Separate runs with ESP
- PM measurement by TEOM only, no filter measurements
- 3 baseline tests conducted, 1 invalidated due to test method deviations
- 4 ESP tests conducted, 1 invalidated due to test method deviations



# Test Results – ADEC Testing - ESP

## EPA Step 2 Certified Catalytic Cordwood Appliance

**Catalytic Cordwood Stove  
TEOM Test Measurements and Control Efficiency  
(g/hr)**

Baseline		ESP			Average Baseline	Average ESP	Control Efficiency
#2	#3	#2	#3	#4			
2.38	4.17	1.86	3.57	4.29	3.28	3.24	1.13%

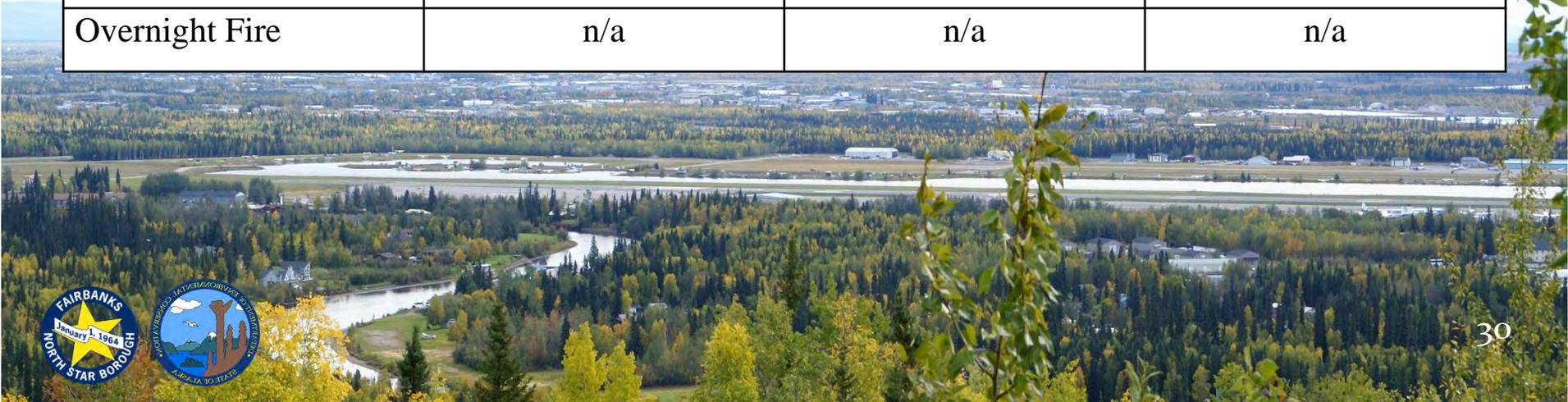


# Test Results – ADEC Testing - ESP

## EPA Step 2 Certified Catalytic Cordwood Appliance

**Catalytic Cordwood Stove  
TEOM Test Measurements and Control Efficiency by IDC Test Phase  
(g/hr)**

<b>Test Phase</b>	<b>Baseline</b>	<b>ESP</b>	<b>Control Efficiency</b>
Startup	19.21	17.5	8.9%
High Fire	0.32	0.14	56.1%
Maintenance Fire	2.02	0.80	60.4%
Overnight Fire	n/a	n/a	n/a



# Test Results – ADEC Testing - ESP

## EPA Step 2 Certified Catalytic Cordwood Appliance

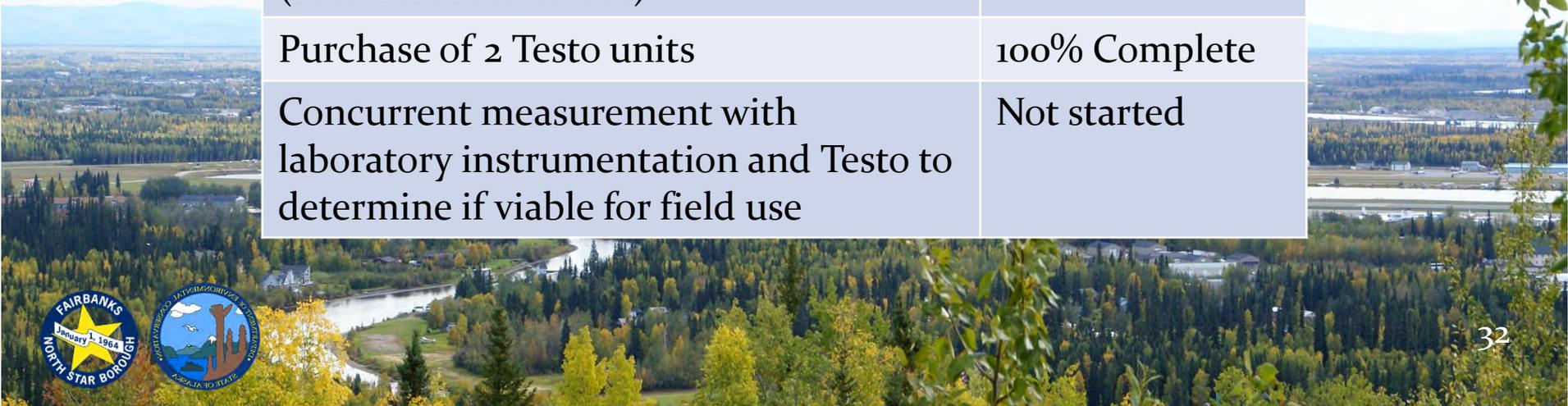
### Key Takeaways

- Test results indicate an overall removal efficiency of 1%
- Low removal efficiency attributed to:
  - Initial emission spike accounts for most of the emissions over the period of the test
  - Delay in ESP start-up until after the initial emissions spike



# How much FNSB testing is left to do?

Original Testing Program Included	Complete?
Development of protocols for pellet, non-catalytic cordwood, and catalytic cordwood appliances	75% Complete
Pellet appliance testing	100% Complete
Catalytic cordwood appliance testing	25% Complete
Non-catalytic cordwood appliance testing	25% Complete
Development of protocol and Quality Assurance Project Plan (QAPP) for Testo (suitable for field use)	Not started
Purchase of 2 Testo units	100% Complete
Concurrent measurement with laboratory instrumentation and Testo to determine if viable for field use	Not started



# How much is remaining in the project budget?

Thank you to entities that contributed to the project:

- ADEC for funding preliminary cordwood appliance testing
- NESCAUM for providing all appliances for the testing
- Superior Pellets for providing local Fairbanks pellets

These contributions helped keep project costs down.

Original appropriation = \$458,000

Project balance = Approximately \$315,000

The project scope has changed sufficiently such that to continue testing it will require the FNSB Assembly to re-appropriate funds prior to proceeding.

**Primary goal for APCC meeting is to provide recommendation on if/how to proceed with the testing program**



# Additional Considerations for the ESP

- Safety concerns need to be addressed
- What is the implementation strategy? i.e. What is the incentive for a homeowner to purchase an ESP?
- Durability in Alaska's harsh winter environment needs to be assessed
- Longevity over the expected life of the equipment needs to be assessed
- Maintenance requirements, cleaning frequency, and monitoring protocols need to be developed
- Shows potential for emission reductions



# FNSB Staff Recommendation – Pellet Appliance Testing

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- StoveCAT retrofit on pellet appliance
  - Testing results do not show emissions benefit for pellet appliances, did not complete six replicates
  - Staff does not recommend any additional testing
- ESP on pellet appliance
  - Testing results do show emissions benefit for pellet appliance
  - Testing complete, no further testing recommended



# FNSB Staff Recommendation – Catalytic Cordwood Appliance Testing

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- StoveCAT retrofit on catalytic cordwood appliance
  - No testing has been completed
  - Second catalyst would lack temperature, oxygen, and fuel required to sustain catalytic reaction
  - Staff does not recommend pursuing testing
- ESP on catalytic cordwood appliance
  - Testing results show limited benefit due to emission spike and delay in ESP start-up
  - Staff does not recommend pursuing testing



# FNSB Staff Recommendation – Non-Catalytic Cordwood Appliance Testing

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- StoveCAT retrofit on non-catalytic cordwood appliance
  - No testing has been completed
  - Testing is technically difficult and resource intensive, focus on the device with more potential and don't dilute resources
  - Staff does not recommend pursuing testing
- ESP on non-catalytic cordwood appliance
  - Testing results show emission benefit along with safety concerns from creosote build-up
  - Staff recommends additional testing, only after safety concerns have been rectified



# FNSB Staff Recommendation – Testo Unit

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- Two hand held Testo units have been purchased
- Development of protocol and lab verification was postponed due to difficulties in testing program
- Testo units with a portable protocol could be useful for field studies in Fairbanks
- Staff recommendation is to proceed with development of protocols, QAPP, and lab verification of Testo unit



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Questions?

