EPA
United States
Environmental Protection
Agency

Methods evaluation testing at Wright-Patterson Air Force Base—preliminary results

John Kinsey, U. S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, Research Triangle Park, NC

EPA United States Environmental Protection Agency

Test participants

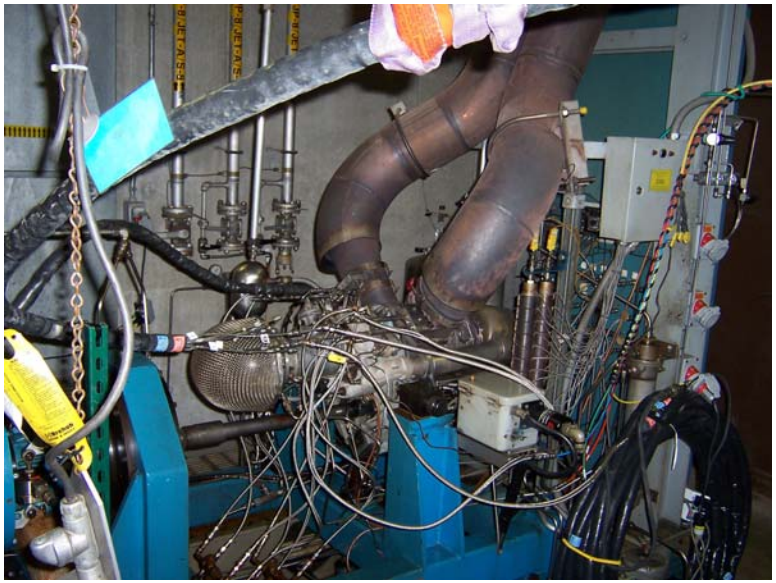
- Air Force Research Laboratory (AFRL):
  - Edwin Corporan
  - Chris Klingshirn
  - Joe Mantz
  - David Anneken
  - Matt DeWitt
  - Matt Wagner
  - Dean Brigalli
- U. S. Environmental Protection Agency, Office of Transportation and Air Quality (EPA-OTAQ):
  - Bob Giannelli
  - Solveig Irvine
  - James Sanchez
- U. S. Environmental Protection Agency, Office of Research and Development (EPA-ORD):
  - John Kinsey
- Artium Technologies, Inc.:
  - Will Bachalo
- Sensors, Inc.:
  - Carl Ensfield

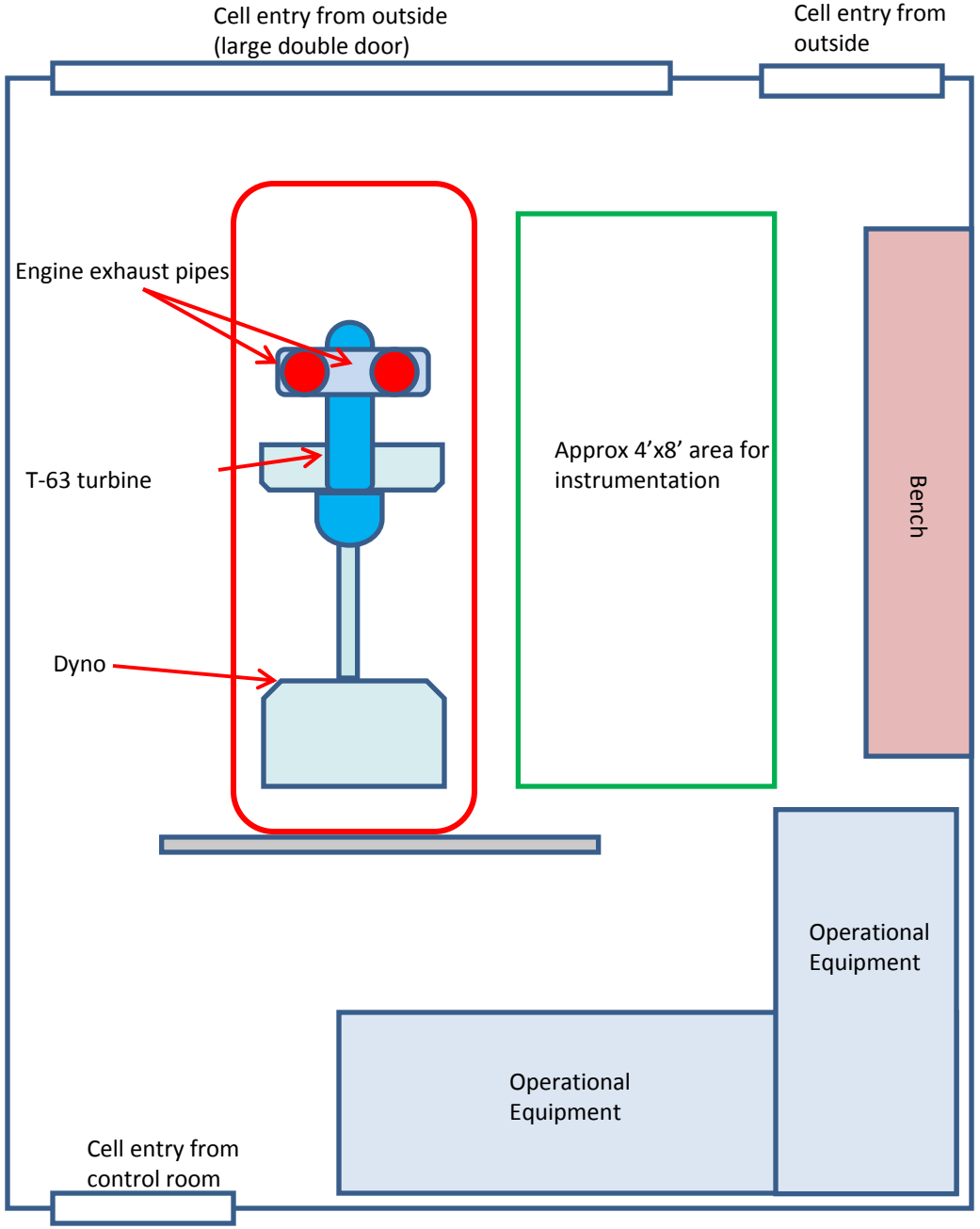
EPA United States Environmental Protection Agency

Measurement activities

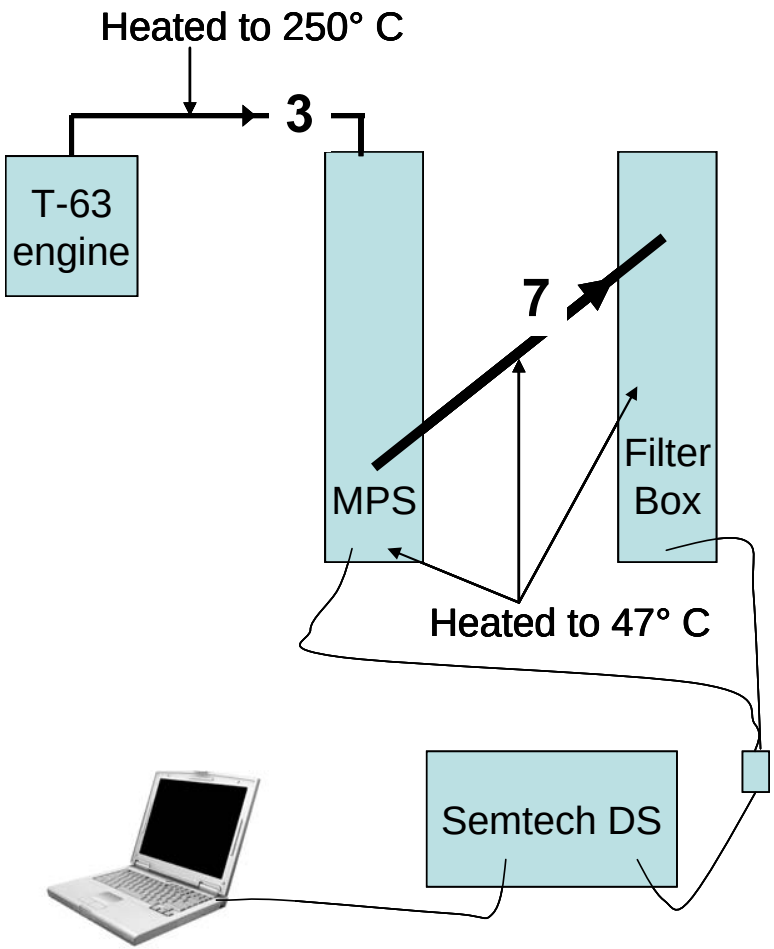
- AFRL:
  - Operation of T63 helicopter engine on JP-8 and Fischer-Tropsch (F-T) fuels
  - Raw combustion gases including smoke number and LECO filters in smoke meter for elemental carbon
  - Diluted sample streams with Thermo 5012 Multi-Angle Aerosol Photometer (MAAP) for black carbon (BC) and TSI 3936 Scanning Mobility Particle Sizer (SMPS) for particle number and size distribution
- EPA-OTAQ:
  - Triplicate filter sampling for total particulate matter (PM) using 40 CFR Part 86.1065 apparatus
  - AVL 483 Microsoot Sensor (MSS) photoacoustic analyzer for BC on undiluted probe
- EPA-ORD:
  - NIOSH Method 5040 quartz filter sampling for elemental carbon/organic carbon (EC/OC) on diluted line
  - MAAP for BC on same diluted line
- Artium:
  - LII 300 laser induced incandescence analyzer (BC) on undiluted line

AFRL engine test cell layout





EPA Part 1065 sampling system



Filter Box

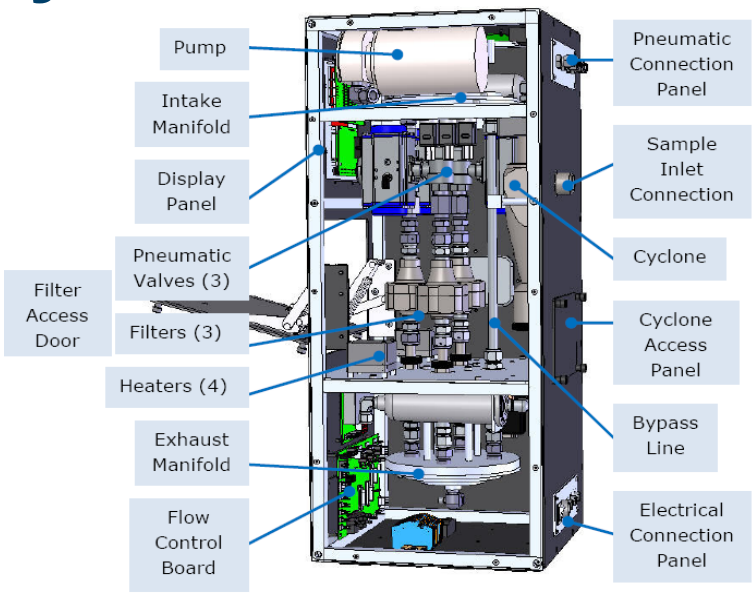
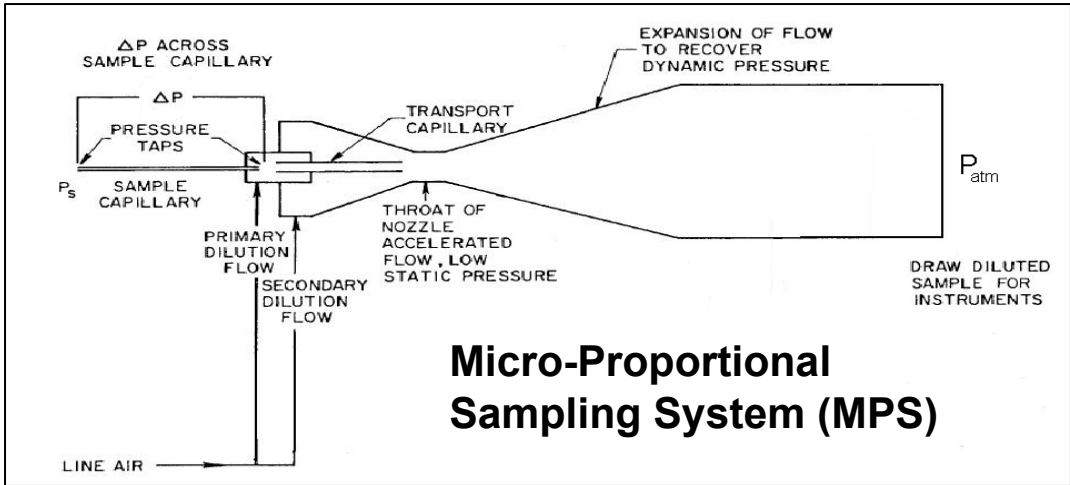


Figure 2.1 Filter System Cabinet Interior

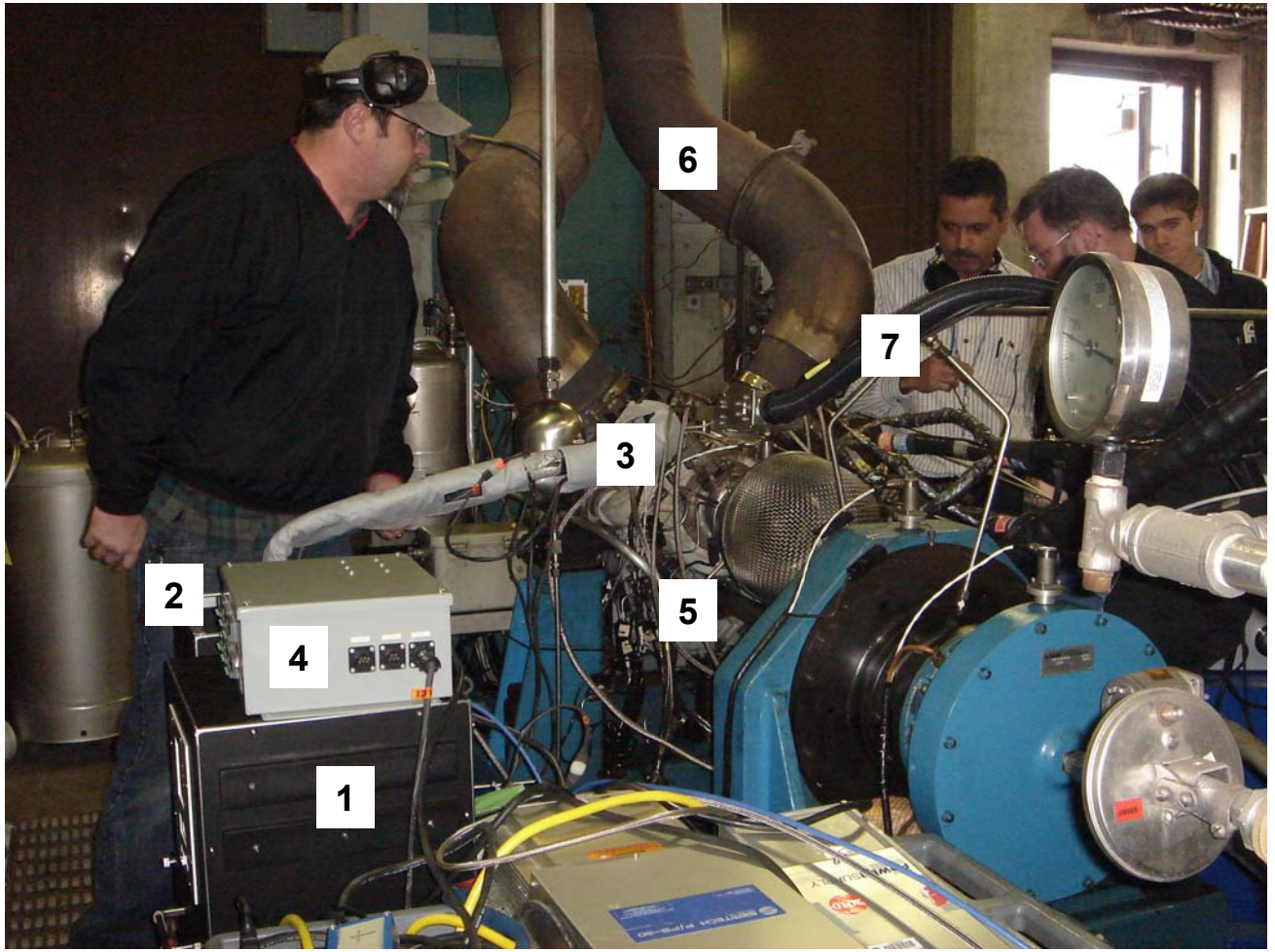


Micro-Proportional Sampling System (MPS)

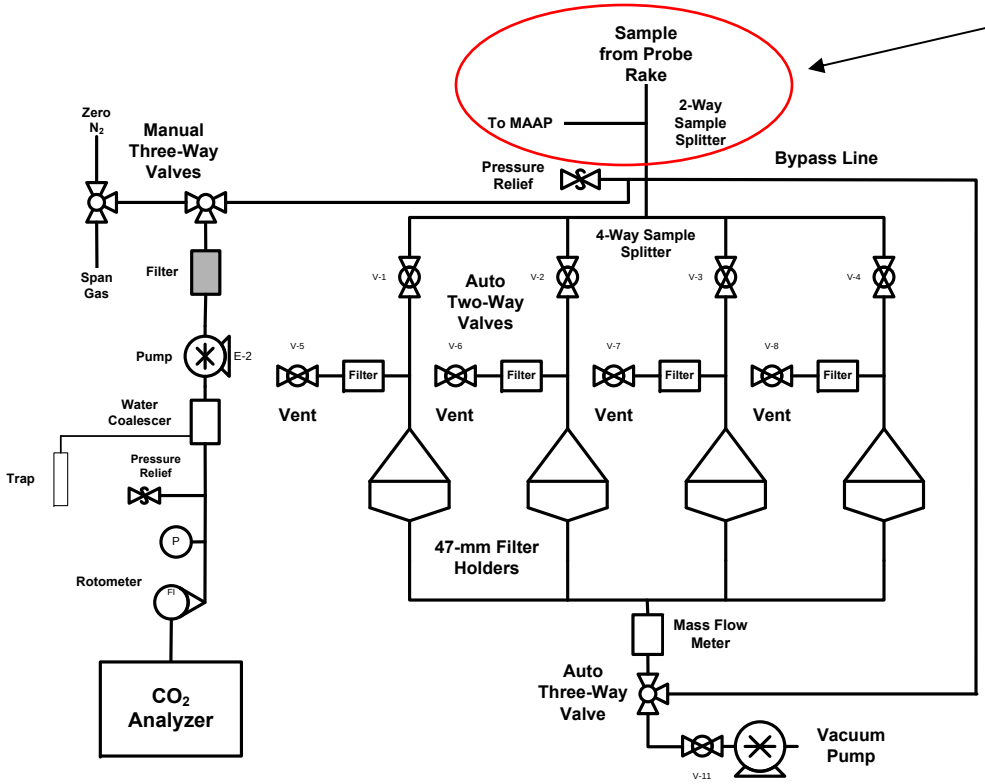
Photo of engine test cell and equipment

Key:

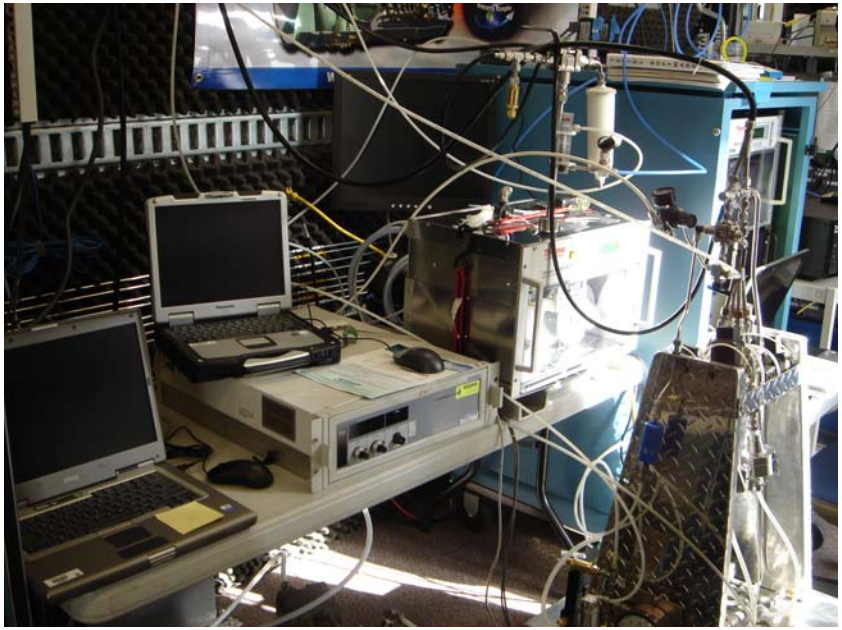
1. Filter box
2. MPS diluter
3. Short heated line
4. Line temperature controller
5. T63 engine
6. Engine exhaust
7. Short heated line to AVL MSS photoacoustic analyzer



EPA-ORD sampling system

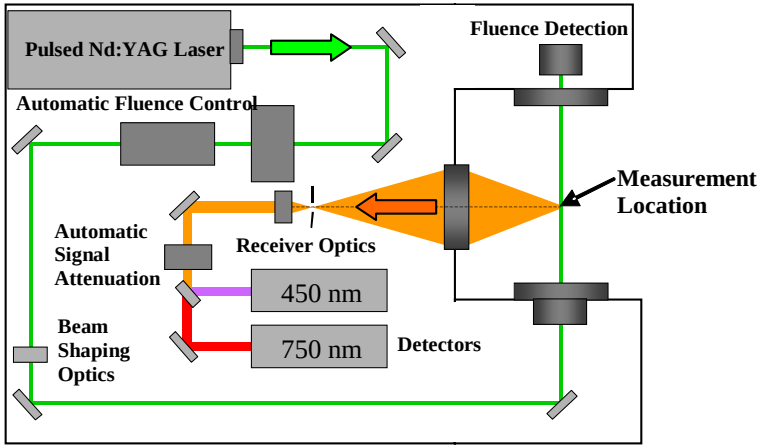


Note split sample to filters and MAAP



EPA
United States
Environmental Protection
Agency

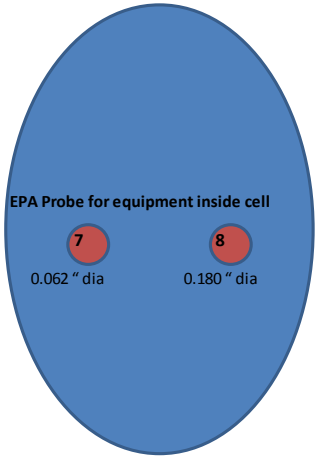
Artium Model LII 300 in use at WPAFB



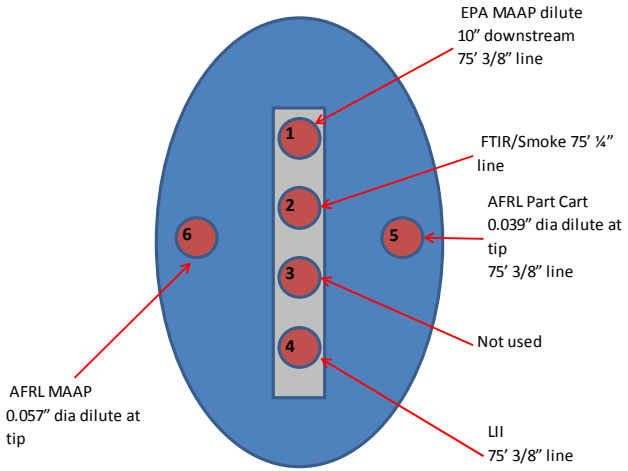
Schematic of LII instrument optics layout, showing path of laser beam and detected particle incandescence from Section A.8.2.1 of SAE Aerospace Information Report 6037

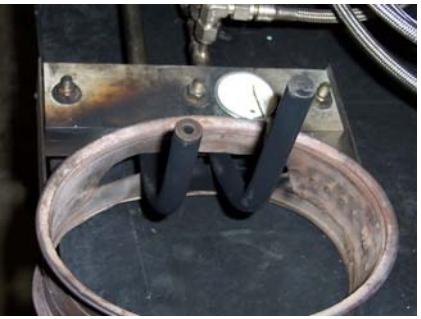
Probe configuration

East Side Exhaust Outlet



West Side Exhaust Outlet



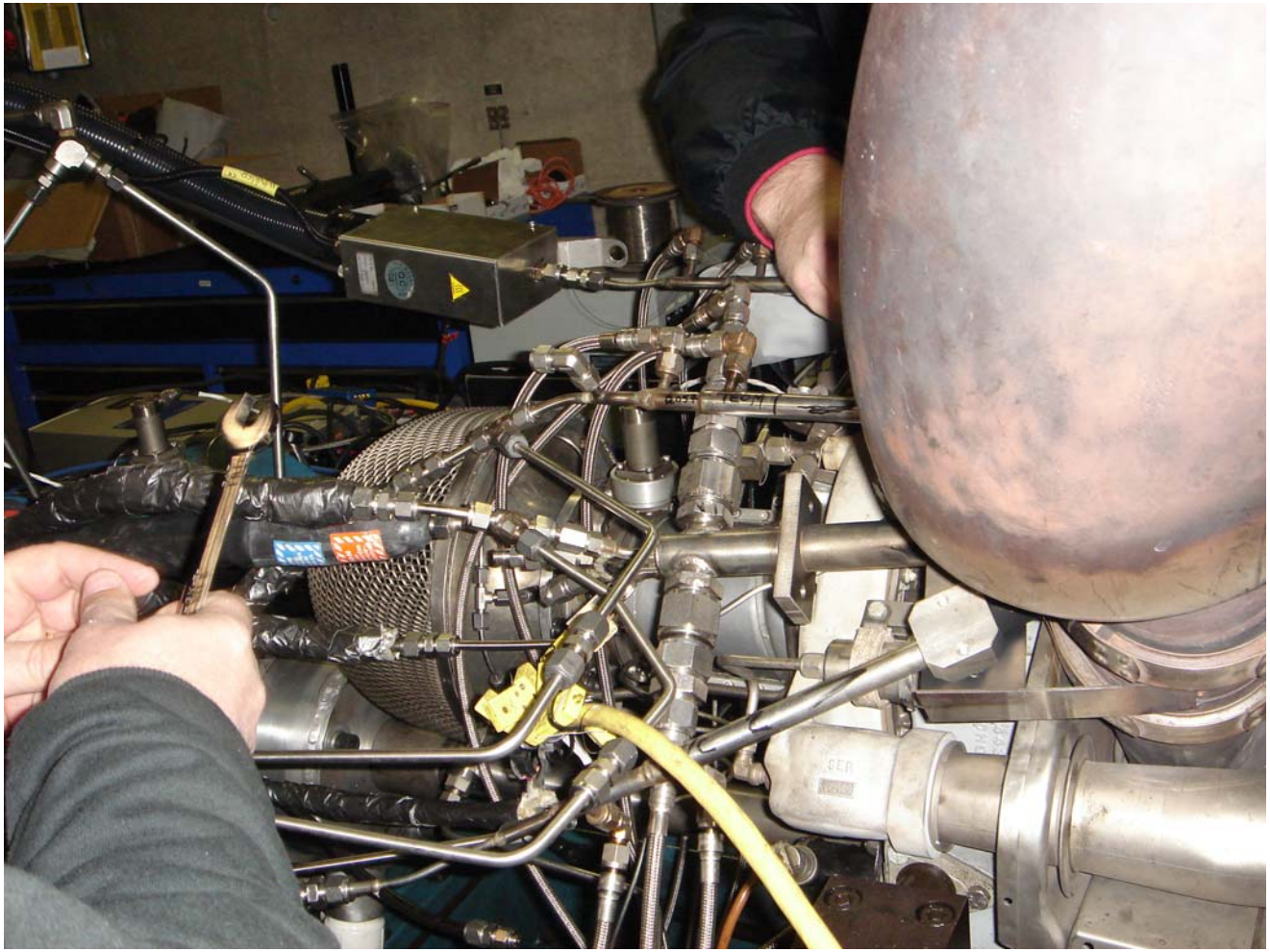


Probes 7 and 8

Organization	Instrument	Probe	Test No.	Engine Power	Average Dilution Ratio
AFRL	LECO	2	All	All	0
	MAAP	6	1,2,4	4	5 to 43
			1,2,4	30	10 to 48
			1,3,4	85	12 to 36
			1,3,4	100	100 to110
	MAAP	4	3	4	5 to 43
			2,3	30	10 to 48
			2	85	12 to 36
			2	100	100 to110
		6 (FT Fuel)	5	4	5 to 43
			5	30	10 to 48
			5	85	12 to 36
EPA-ORD	NIOSH 5040	1	All	4	19
			All	30	26
			All	85	44
			All	100	47
	MAAP	1	All	4	19
			All	30	26
			All	85	44
			All	100	47
EPA-OTAQ	AVL Microsoot Sensor	7		All	2
	Part 1065 Filters +	8		4	11
	MPS			30	11
				85	11
				100	11
Artium	LII	4	1,2,4	4	0
			1,2,4	30	0
			1,3,4	85	0
			1,3,4	100	0
	LII	6	3	4	0
			2,3	30	0
			2	85	0
			2	100	0
		4 (FT Fuel)	5	4	0
			5	30	0
			5	85	0

EPA
United States
Environmental Protection
Agency

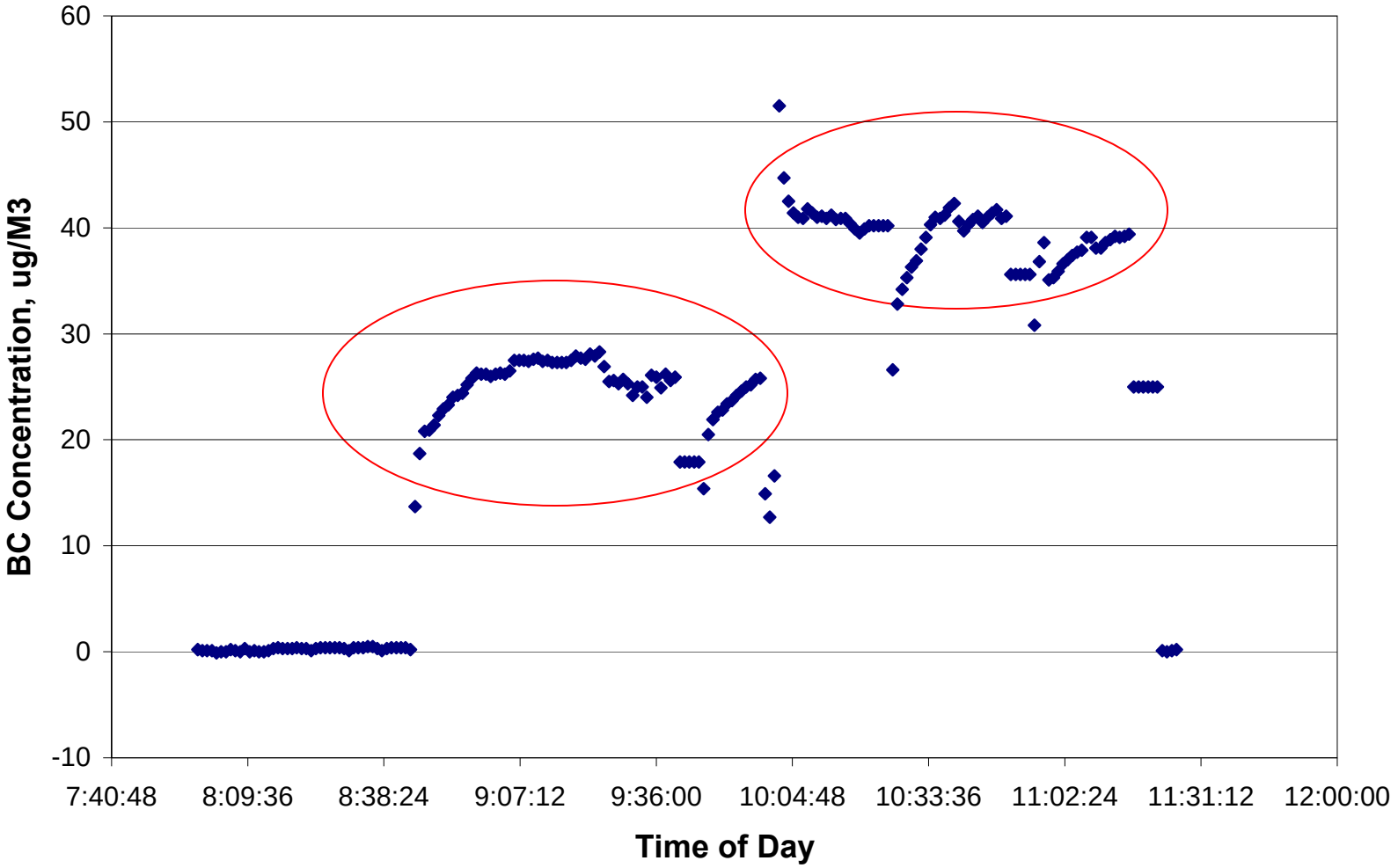
Photo of probes and sampling lines in engine exhaust



United States Environmental Protection Agency

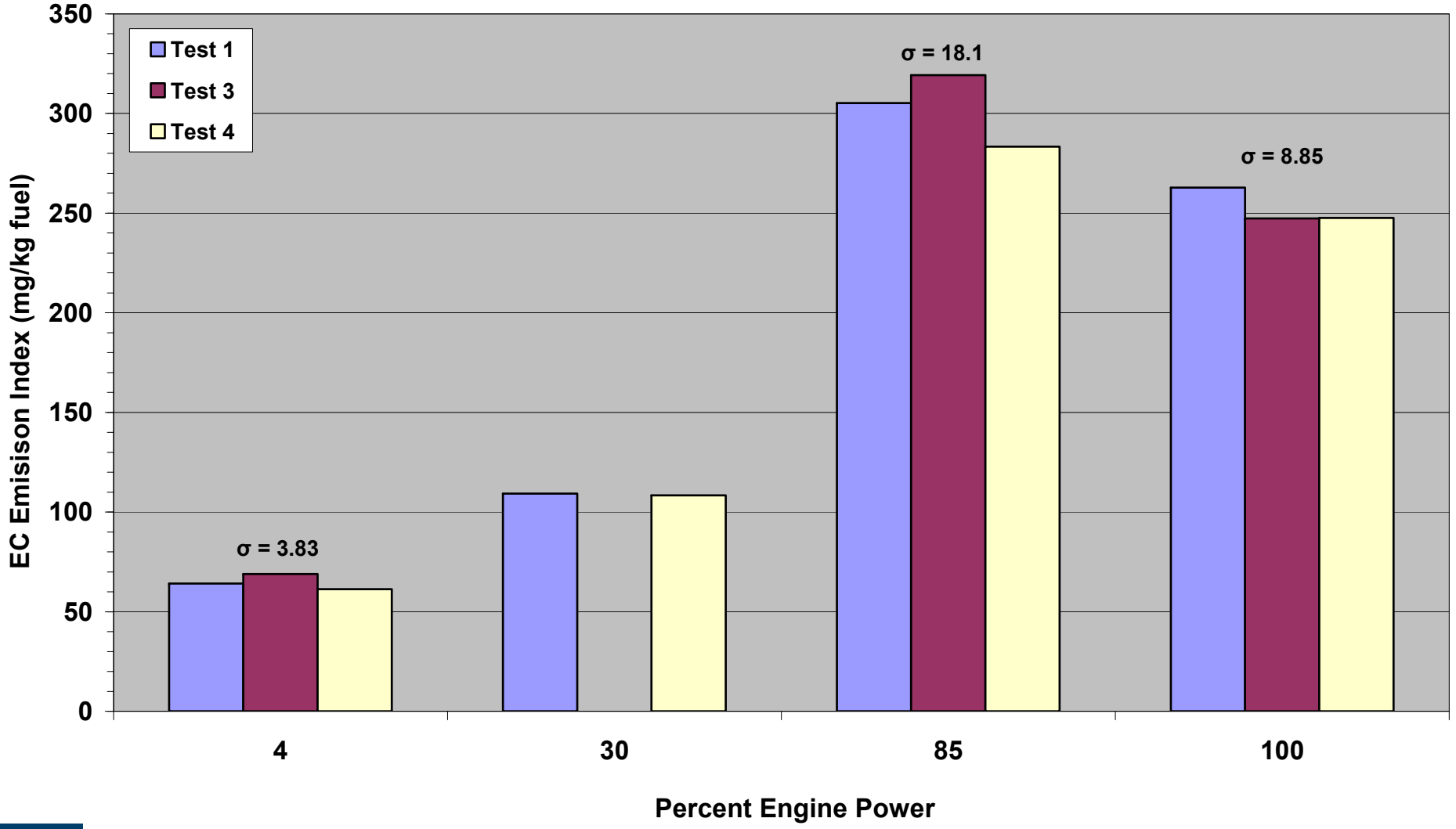
EPA-ORD data comparisons

Direct output from MAAP (1-minute data)



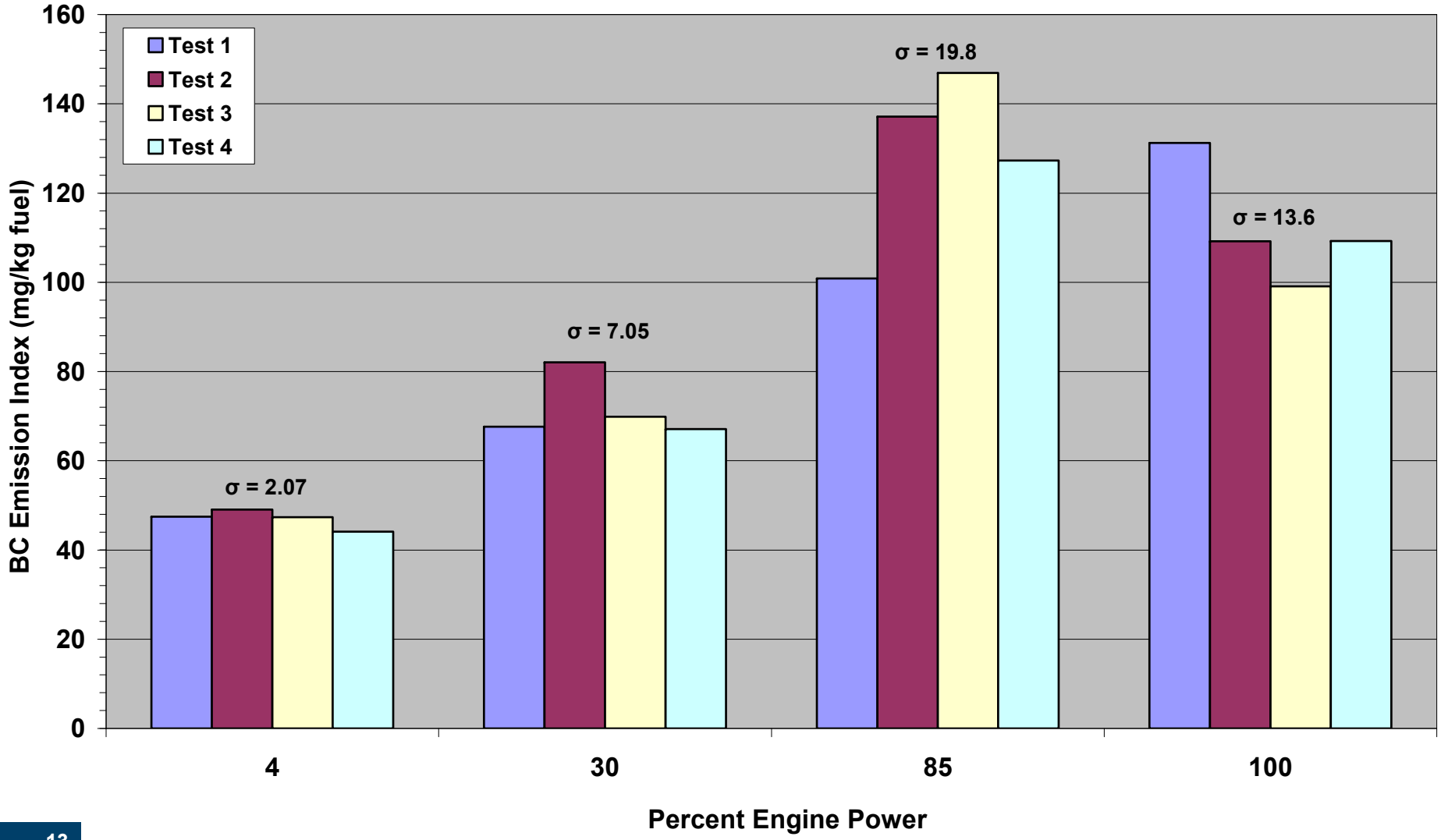
EPA United States Environmental Protection Agency

NIOSH 5040 Elemental Carbon Emission Indices (JP-8 Only)



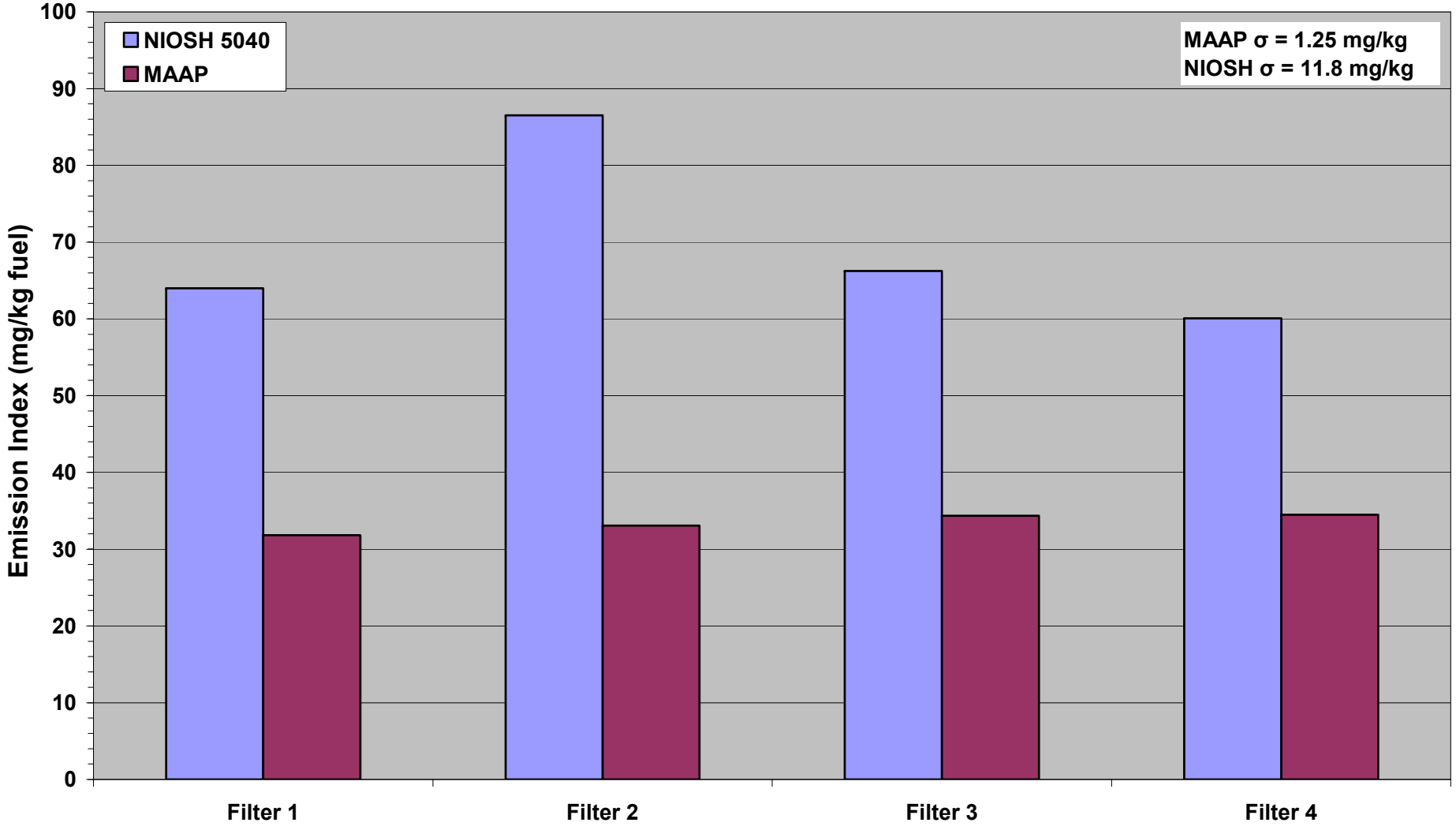
United States Environmental Protection Agency

EPA MAAP Black Carbon Emission Indices for JP-8



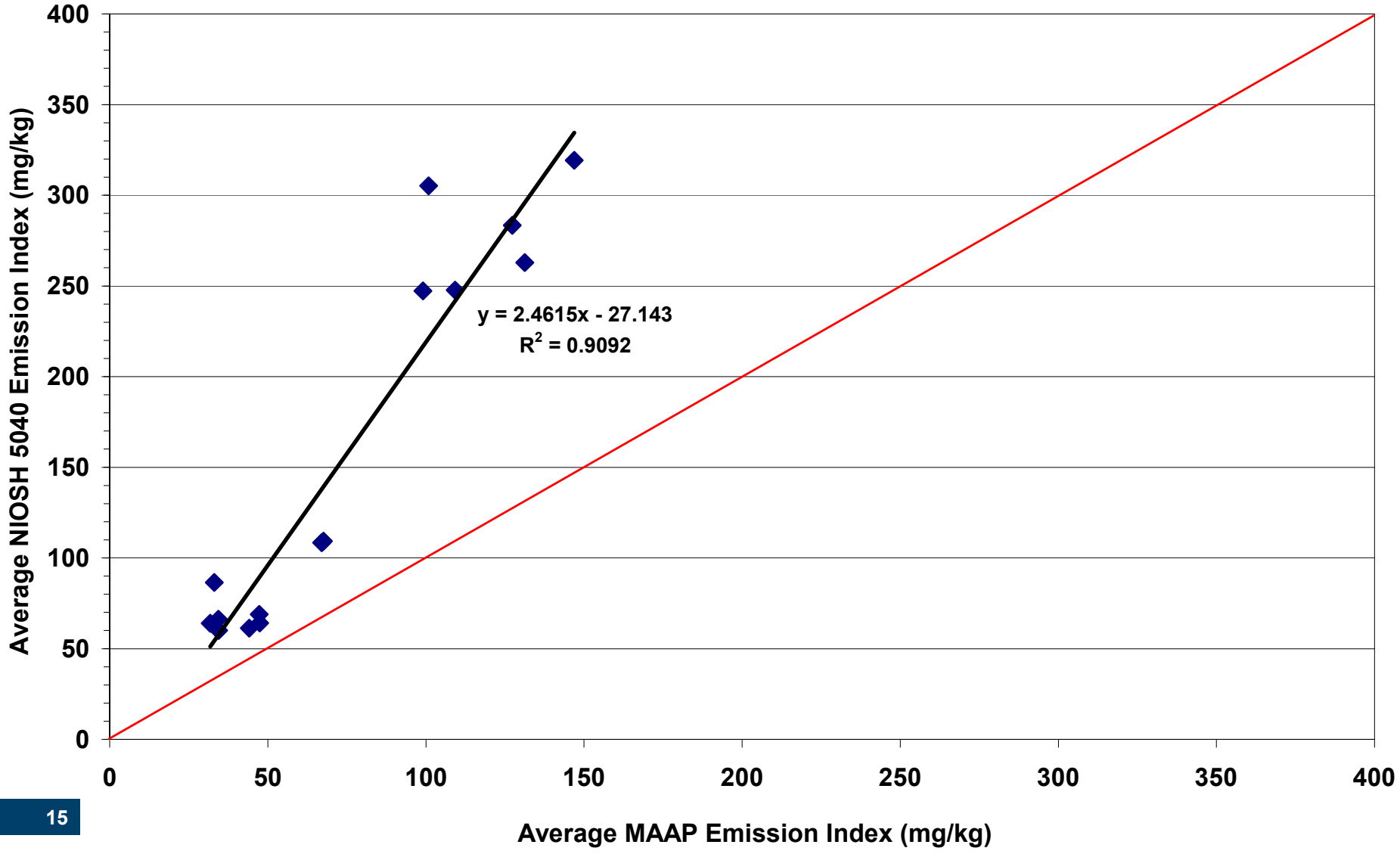
United States Environmental Protection Agency

EPA MAAP Black Carbon vs. NIOSH 5040 Elemental Carbon for F-T Fuel (85% Power--Test 5)



United States Environmental Protection Agency

MAAP Black Carbon vs NIOSH 5040 Elemental Carbon (All EPA Data)

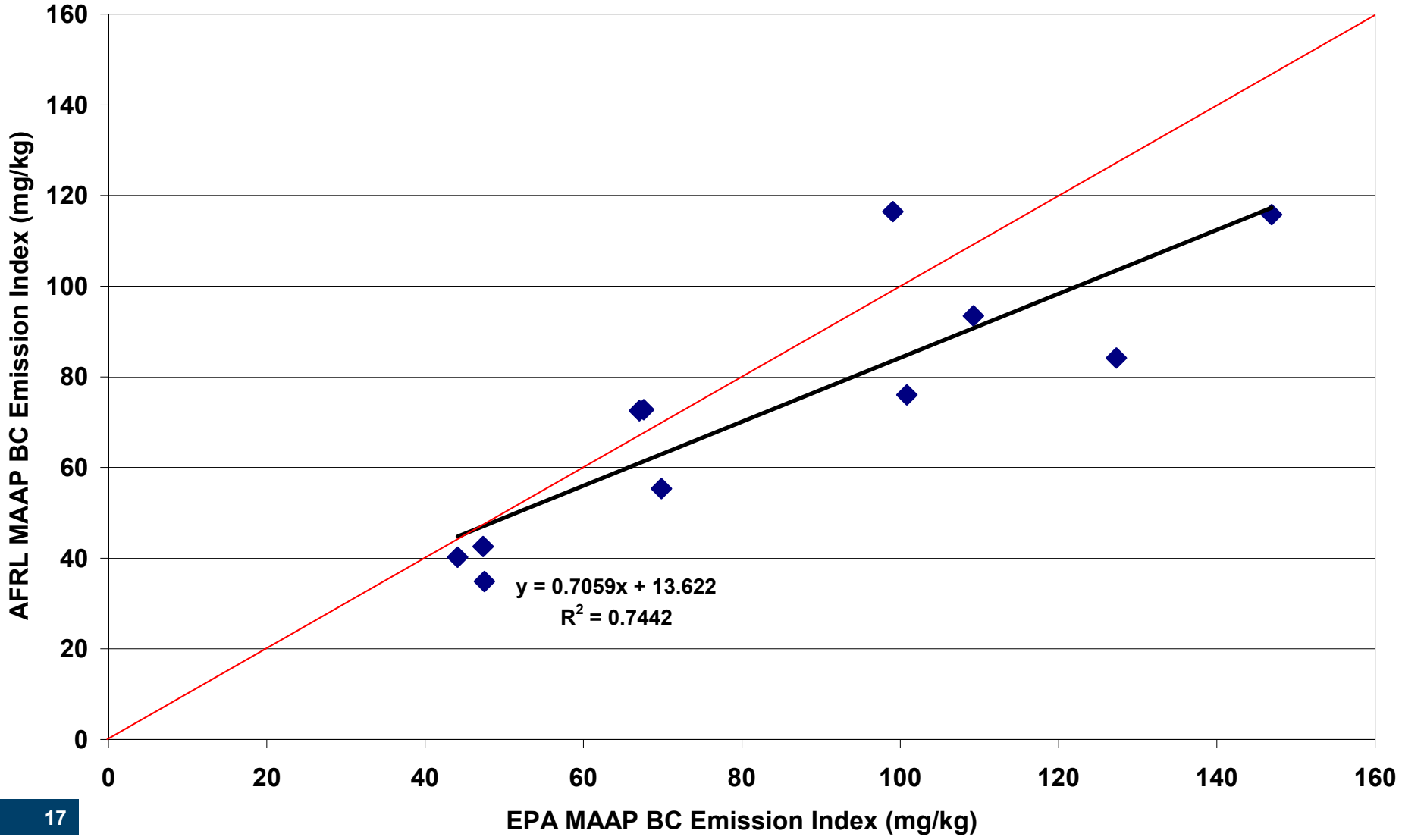


United States Environmental Protection Agency

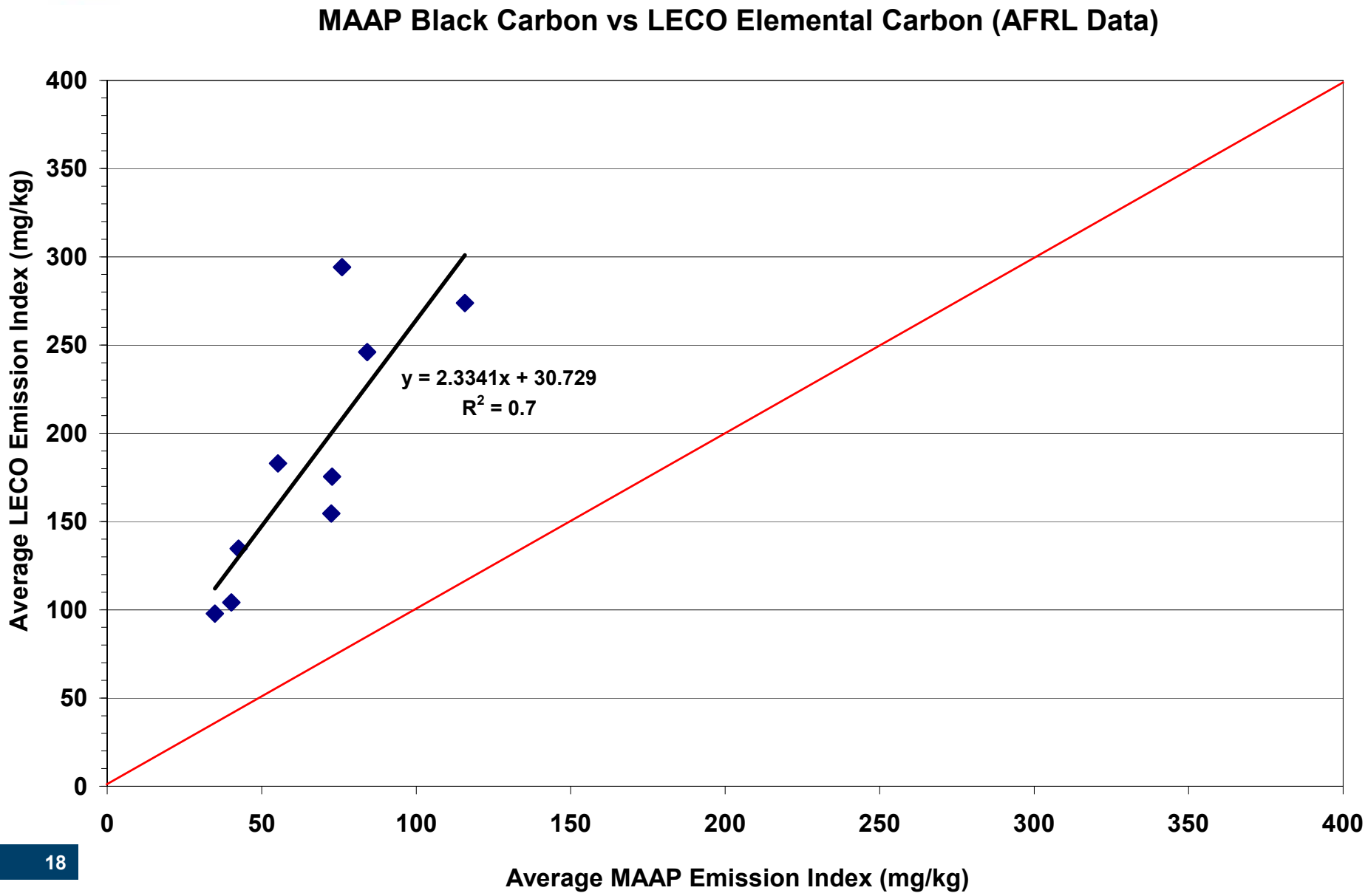
EPA-ORD vs. AFRL data comparisons

United States Environmental Protection Agency

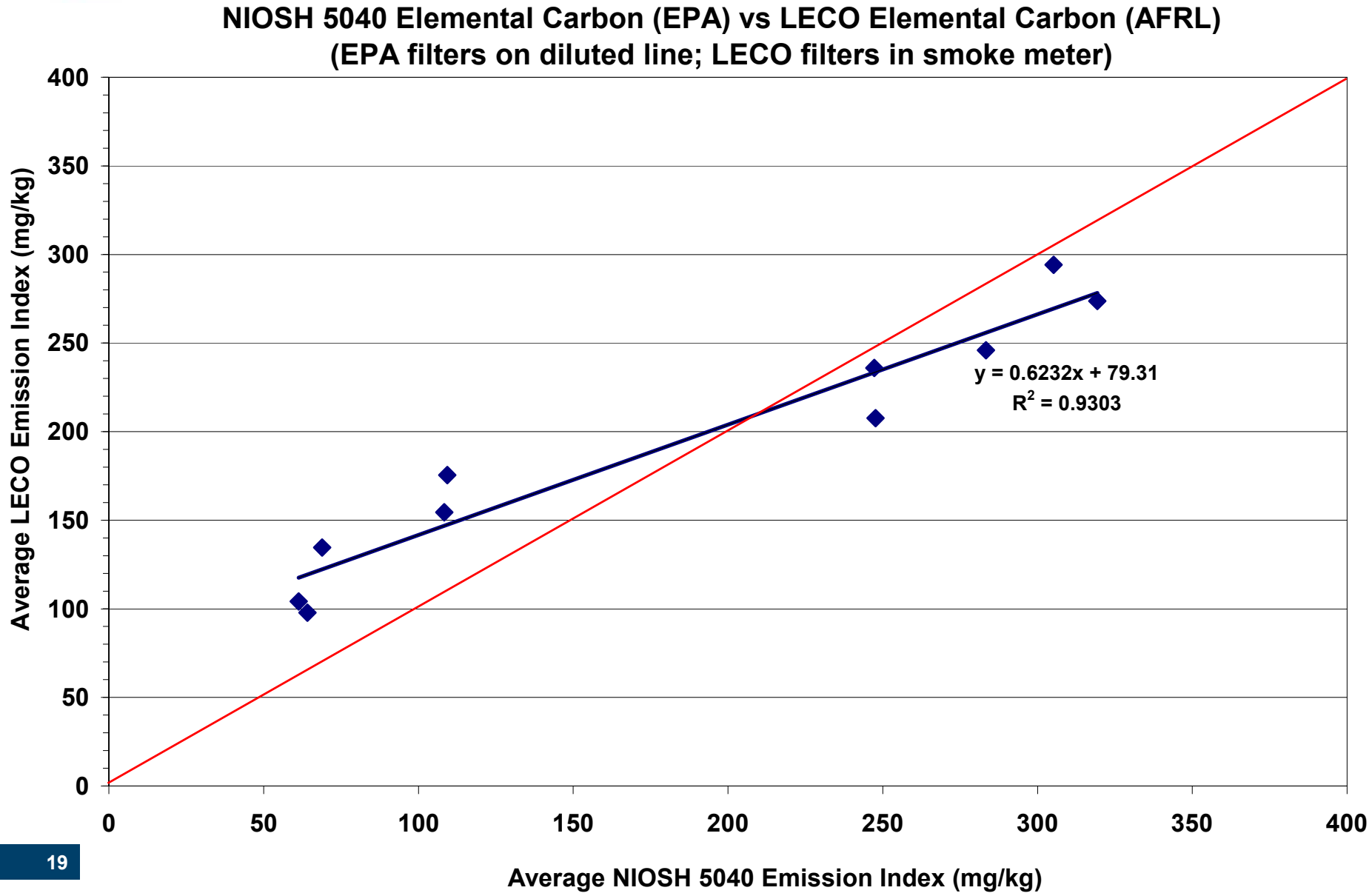
Comparison of EPA MAAP vs. AFRL MAAP Black Carbon (BC)



United States Environmental Protection Agency

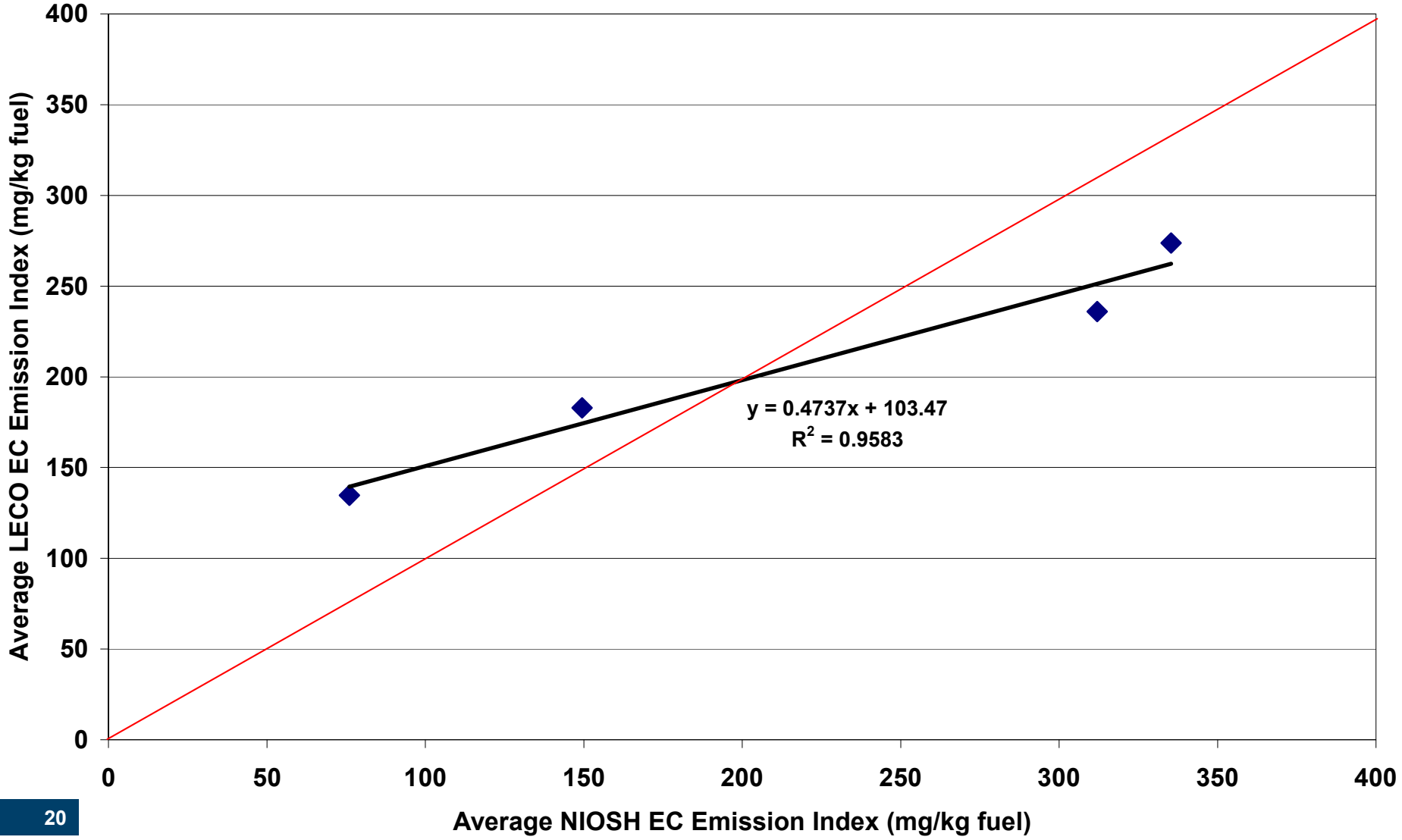


United States Environmental Protection Agency



United States Environmental Protection Agency

NIOSH 5040 Filters vs. LECO Filters (both filter sets in smoke meter)

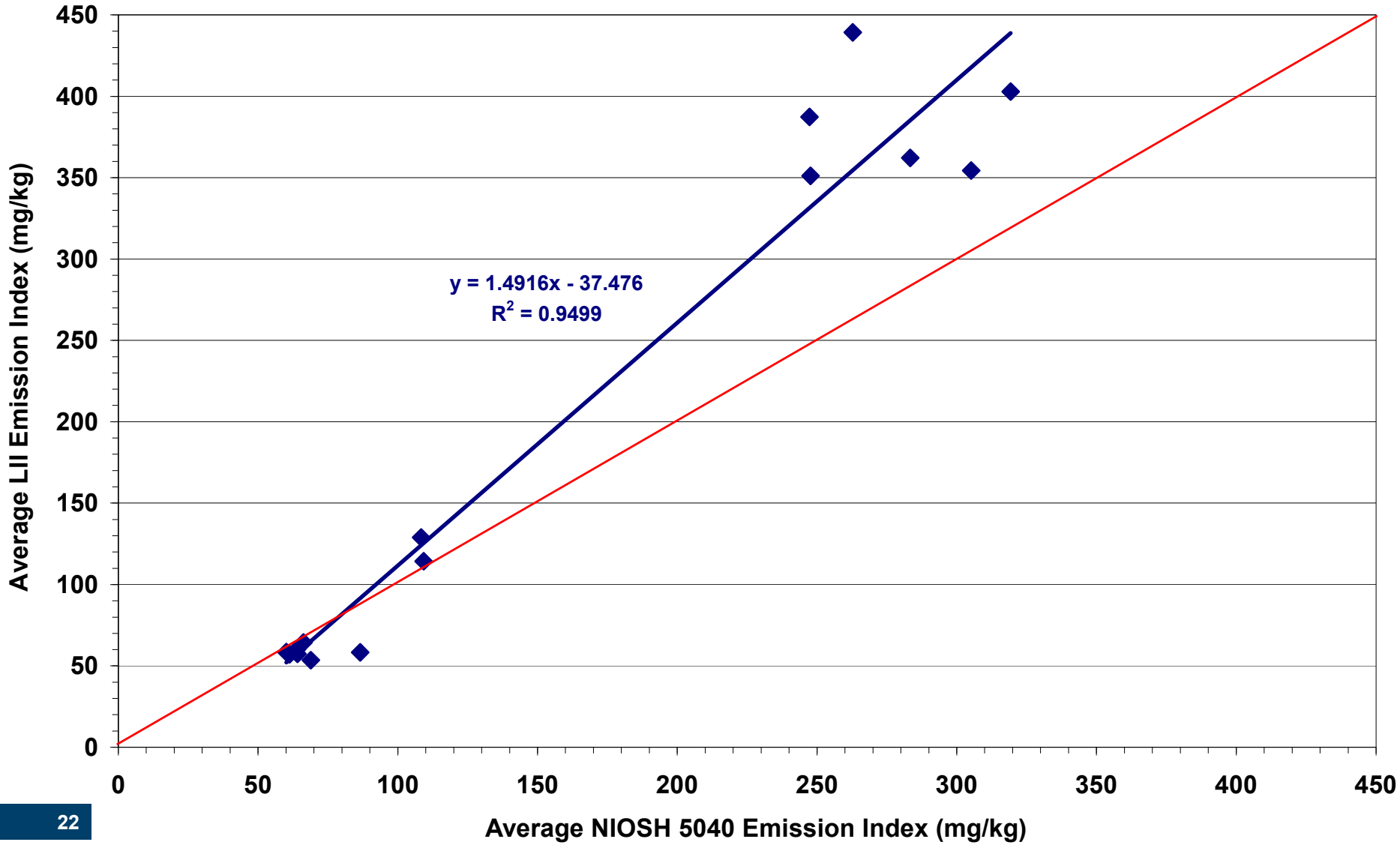


United States Environmental Protection Agency

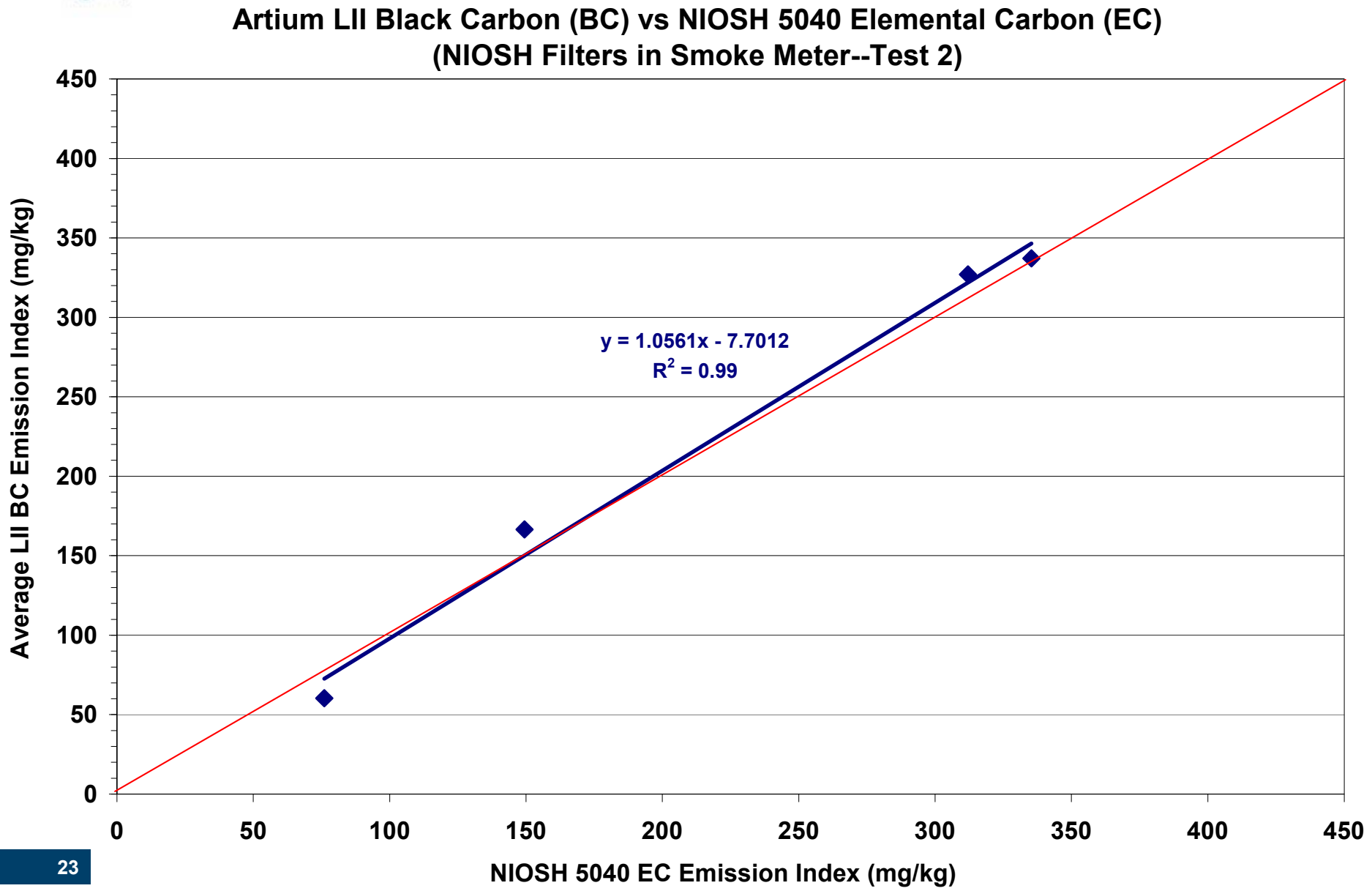
Artium LII vs. EPA-ORD data comparisons

United States Environmental Protection Agency

Artium LII Black Carbon vs EPA NIOSH 5040 Elemental Carbon (All Data)

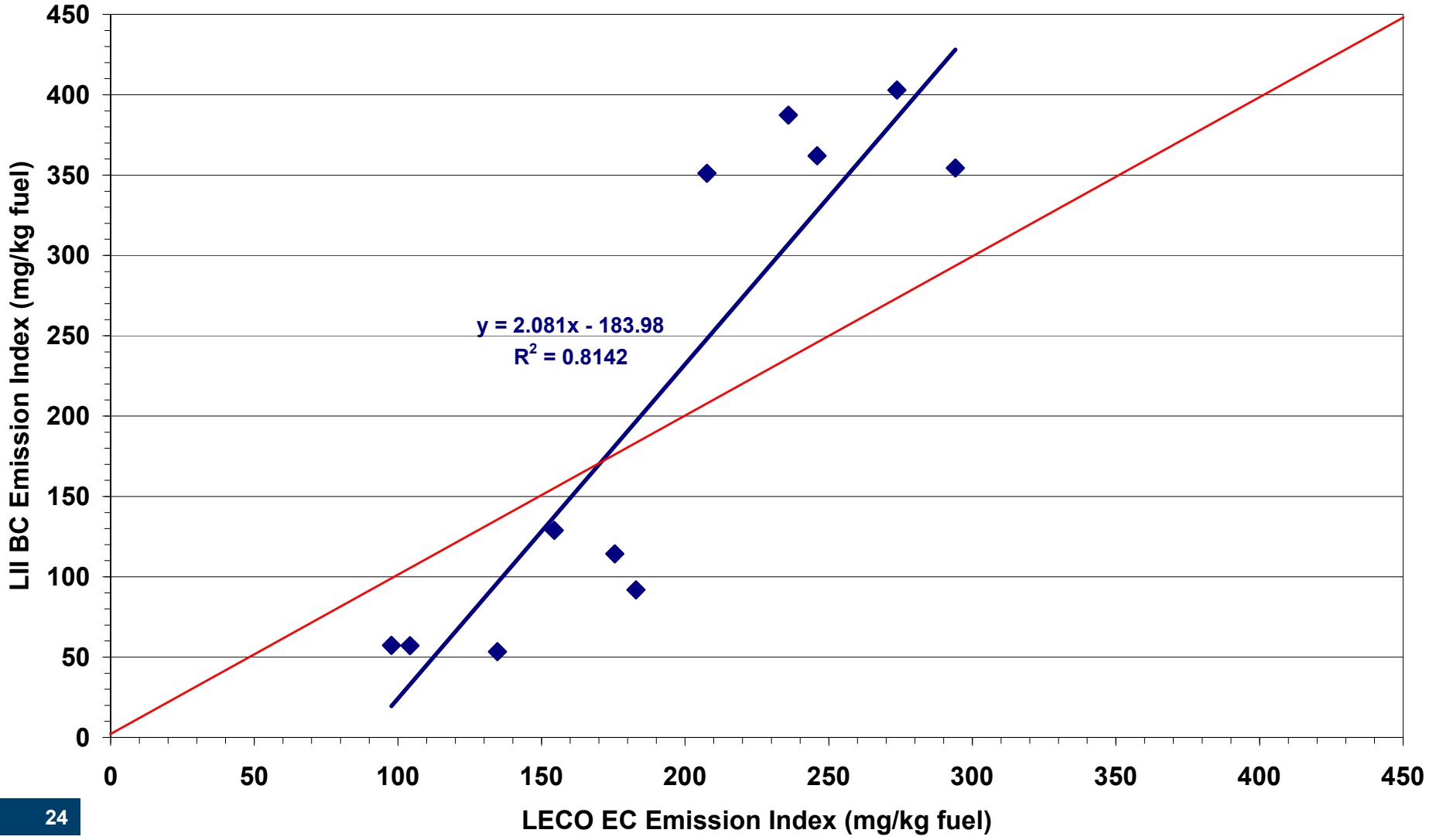


United States Environmental Protection Agency



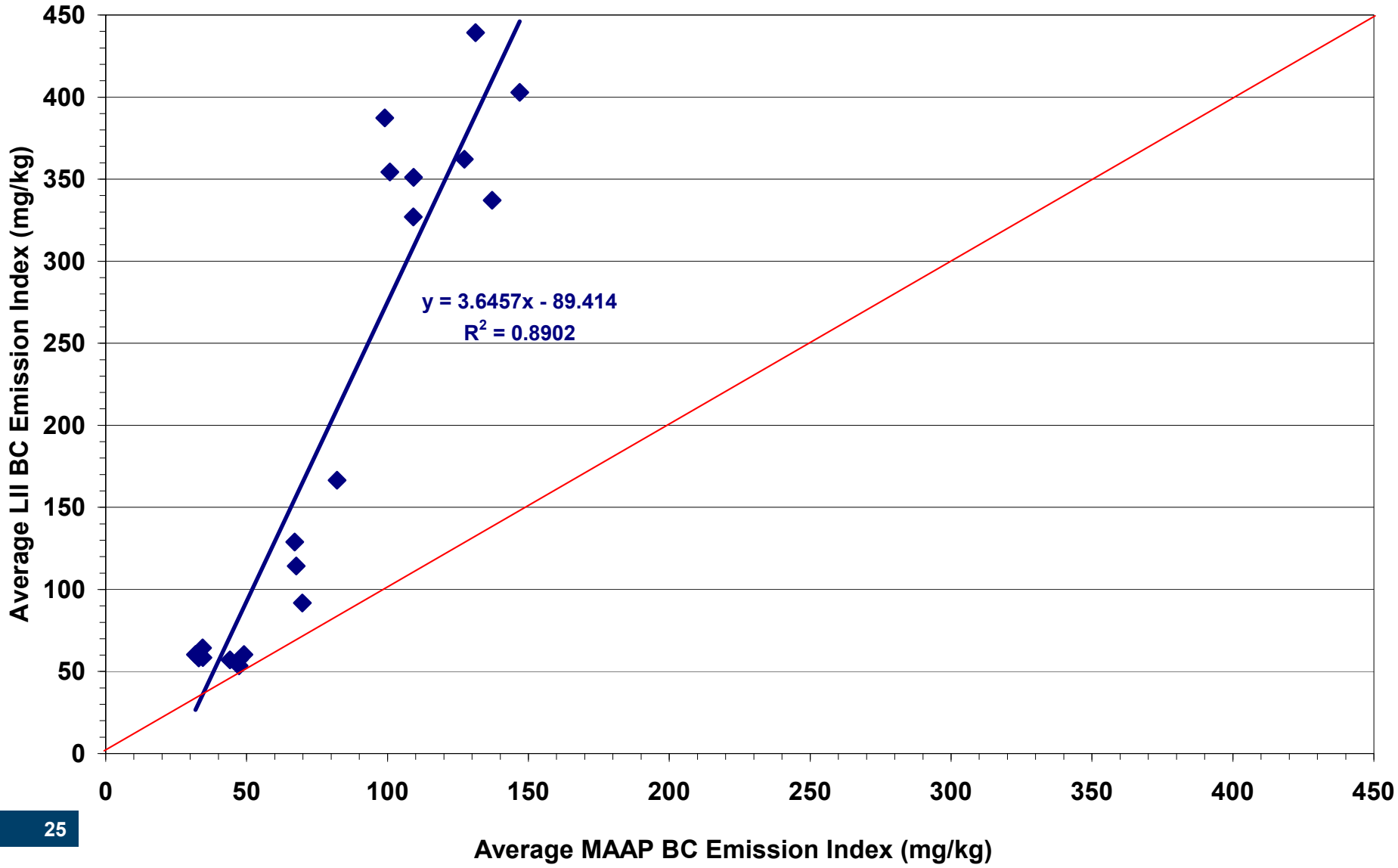
United States Environmental Protection Agency

Artium LII vs. AFRL LECO Emission Indices (JP-8)
(LECO filters in smoke meter)



United States Environmental Protection Agency

Artium LII Black Carbon vs. EPA MAAP Black Carbon (All Data)

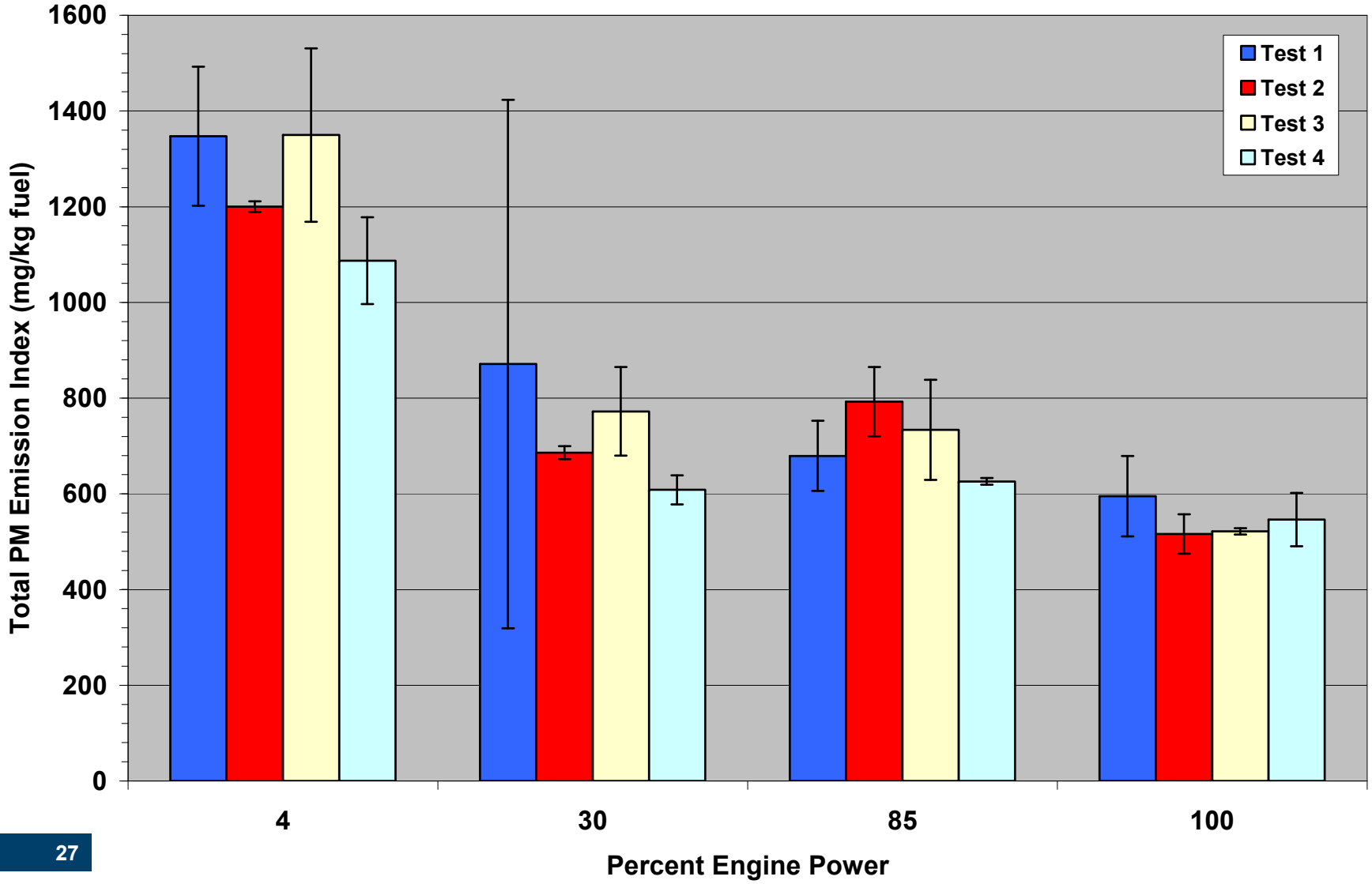


United States Environmental Protection Agency

EPA-OTAQ data comparisons

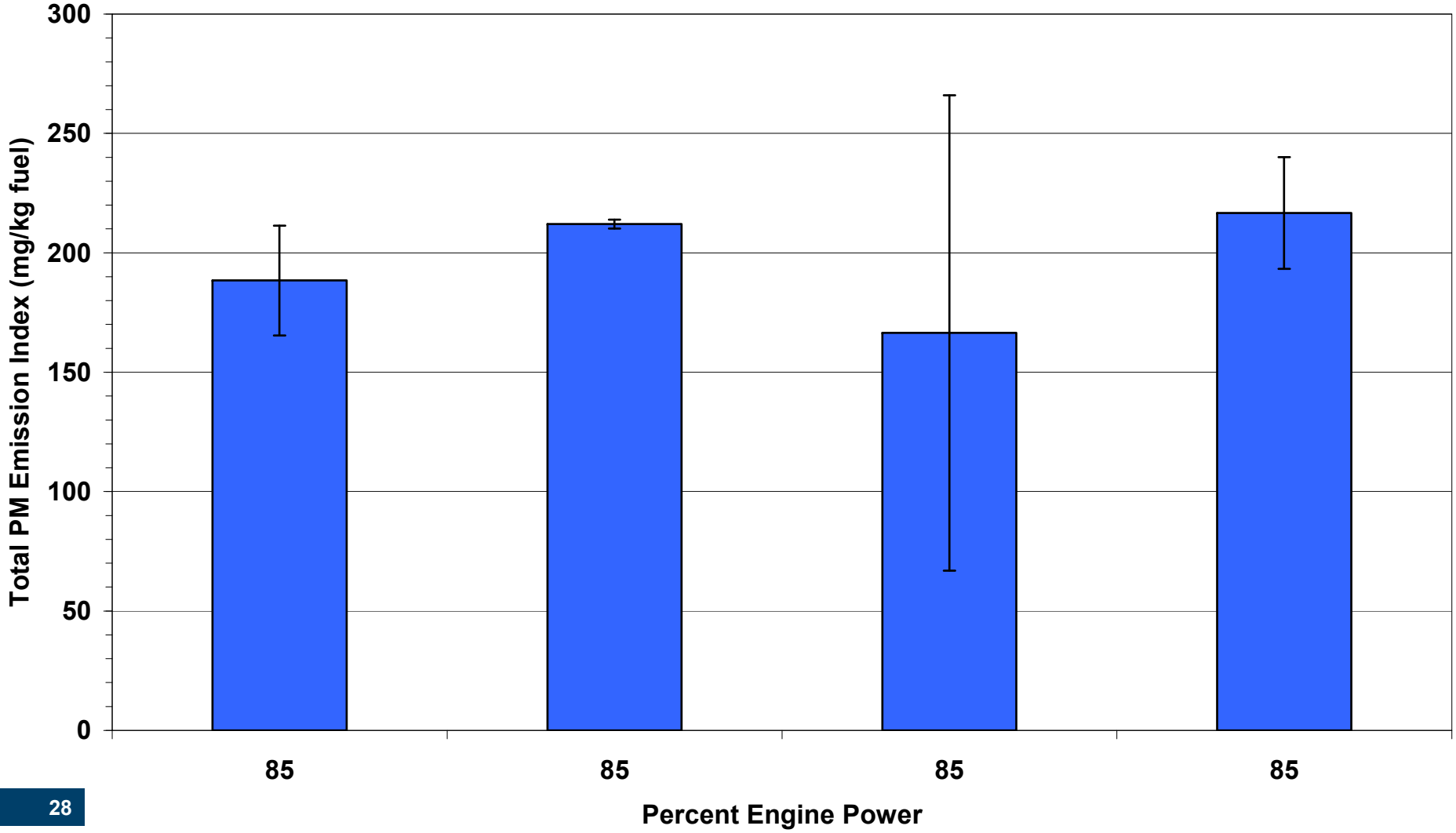
EPA United States Environmental Protection Agency

Total PM Emission Indices from Part 1065 Teflon Filter Samples (JP-8)
(3 filter samples/test condition)



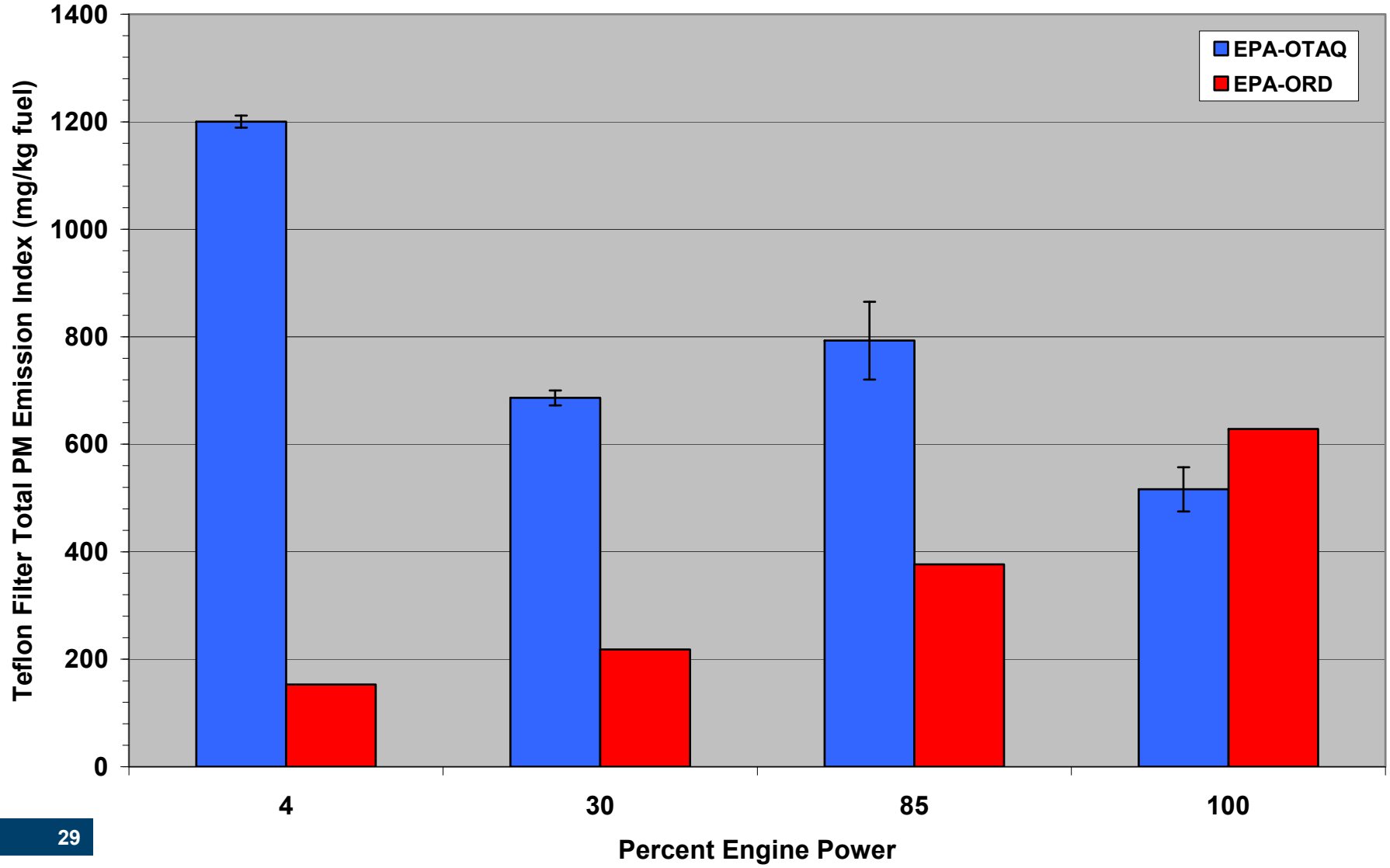
United States Environmental Protection Agency

Total PM Emission Indices for Part 1065 Teflon Filters (FT Fuel)
(3 filter samples for each power condition)



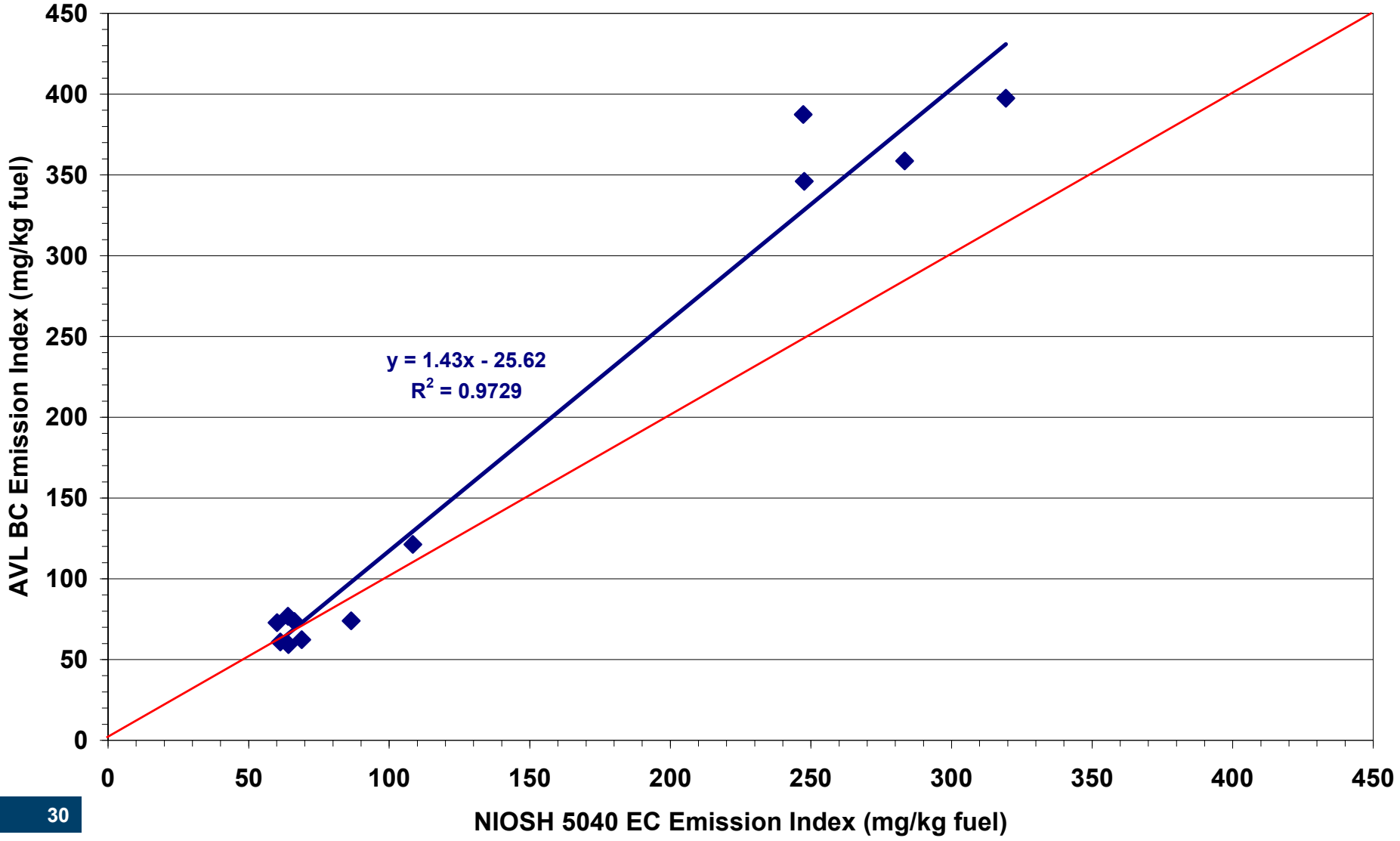
United States Environmental Protection Agency

EPA-OTAQ vs. EPA-ORD Total PM Emission Indices (Test 2)



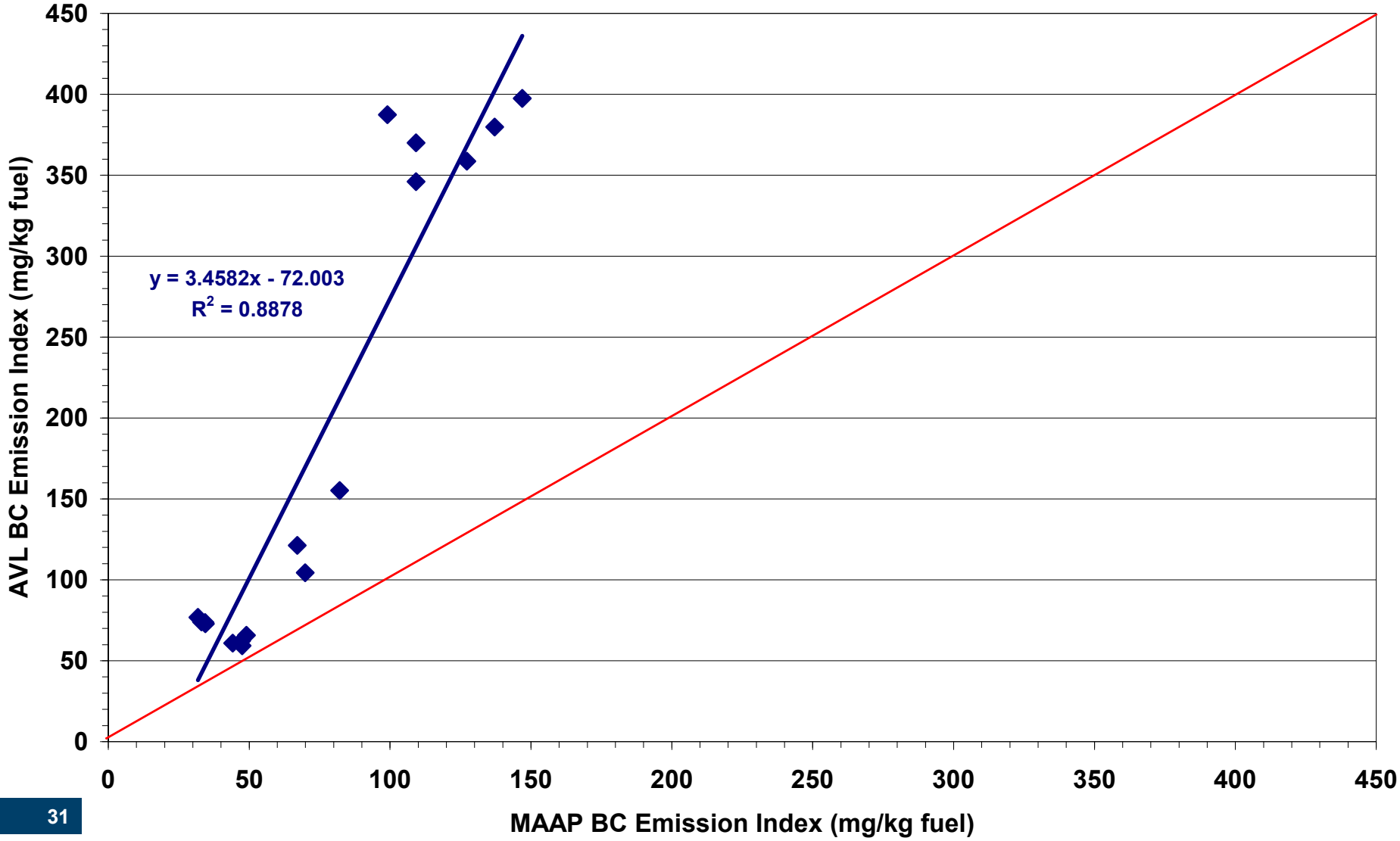
United States Environmental Protection Agency

AVL Photoacoustic Black Carbon vs. NIOSH 5040 Elemental Carbon



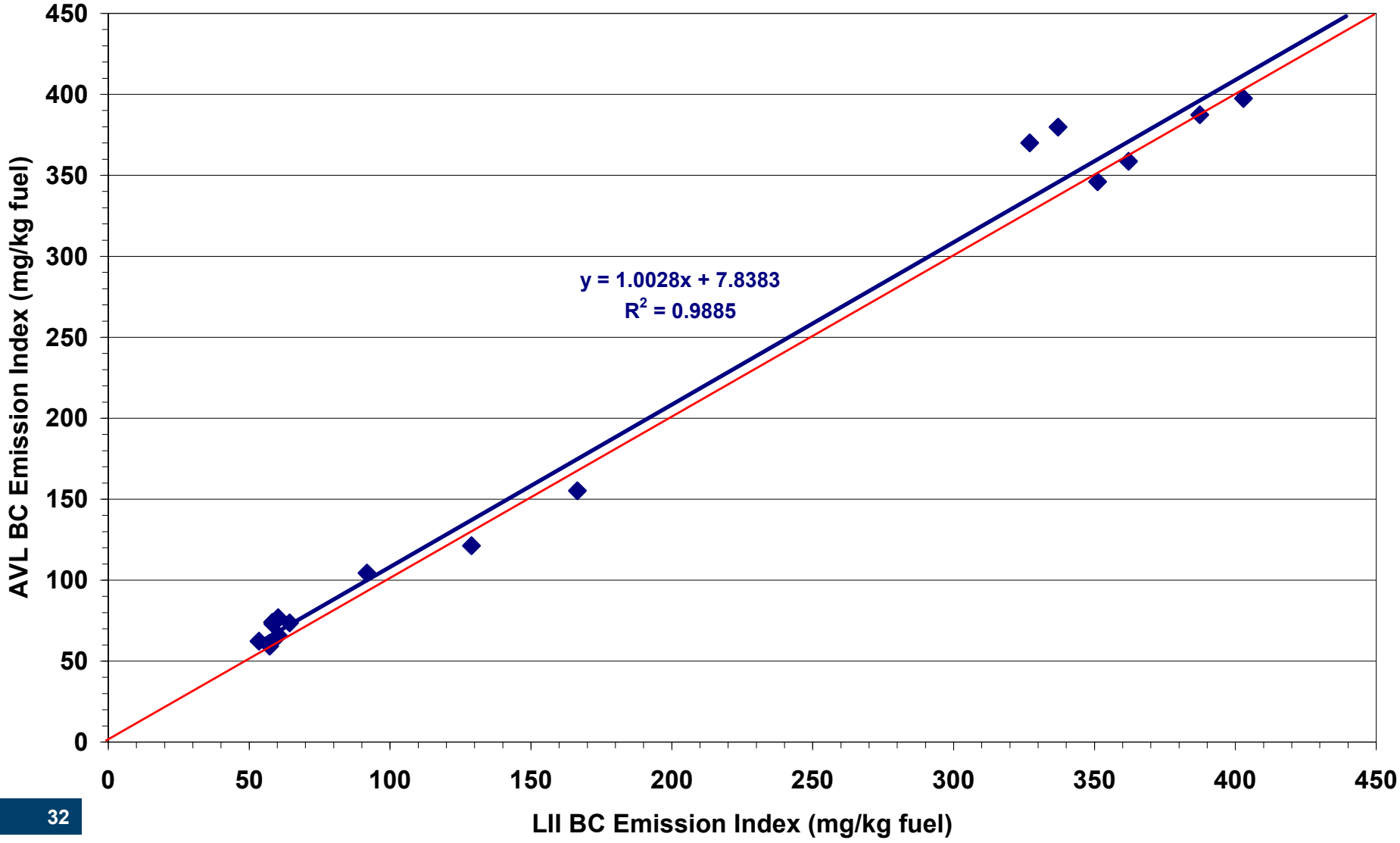
United States Environmental Protection Agency

AVL Photoacoustic Black Carbon (BC) vs. EPA MAAP BC Emission Indices



United States Environmental Protection Agency

AVL Photoacoustic Black Carbon (BC) vs. Artium LII BC Emission Indices



United States Environmental Protection Agency

Conclusions (1)

- Good precision was observed for both NIOSH 5040 and EPA MAAP for low power conditions but at higher power, the EIs were not as precise
- The EIs derived from both the EPA and AFRL MAAP instruments are well correlated (r^2 = 0.91 to 0.93) with those determined by NIOSH Method 5040
- Comparisons between the EPA and AFRL MAAP instruments were not as good as seen in prior studies, probably due to different operating configurations as well as the use of the 1-min data off the instrument instead of post-processed results.
- The EIs generated from the LECO smoke meter filters were poorly correlated (r^2 = 0.7) to the AFRL MAAP results but were well correlated (r^2 = 0.96) to NIOSH 5040
- The EIs determined by the LII are highly correlated (r^2 = 0.95) to those derived from NIOSH 5040. This is especially true (r^2 = 0.99) for the NIOSH filters used in the smoke meter for Test 2.

United States Environmental Protection Agency

Conclusions (2)

- The EIs derived from the LII data are only moderately correlated (r^2 = 0.81) with the LECO results but show better agreement (r^2 = 0.89) with the EPA MAAP instrument
- Significant variation was found in the Part 1065 filter sampling from test to test for the same engine power condition. The cause of this variation is still under investigation.
- Generally poor agreement was observed between the Part 1065 Teflon filter sampling conducted by EPA-OTAQ in the test cell as compared to that performed by EPA-ORD at the end of a 75-ft sampling line. Significant differences in probe design and dilution ratio could explain at least some of these variations.
- Good correlation (r^2 = 0.97) was found between the AVL photoacoustic analyzer and NIOSH 5040 but a slightly lower agreement (r^2 = 0.89) was found between the AVL and the EPA MAAP.
- Excellent agreement (r^2 = 0.99) was observed between the AVL photoacoustic instrument and the Artium LII analyzer.