Confined Burn Facility (CBF) Pilot-Scale Testing

2000 Global Demil Symposium

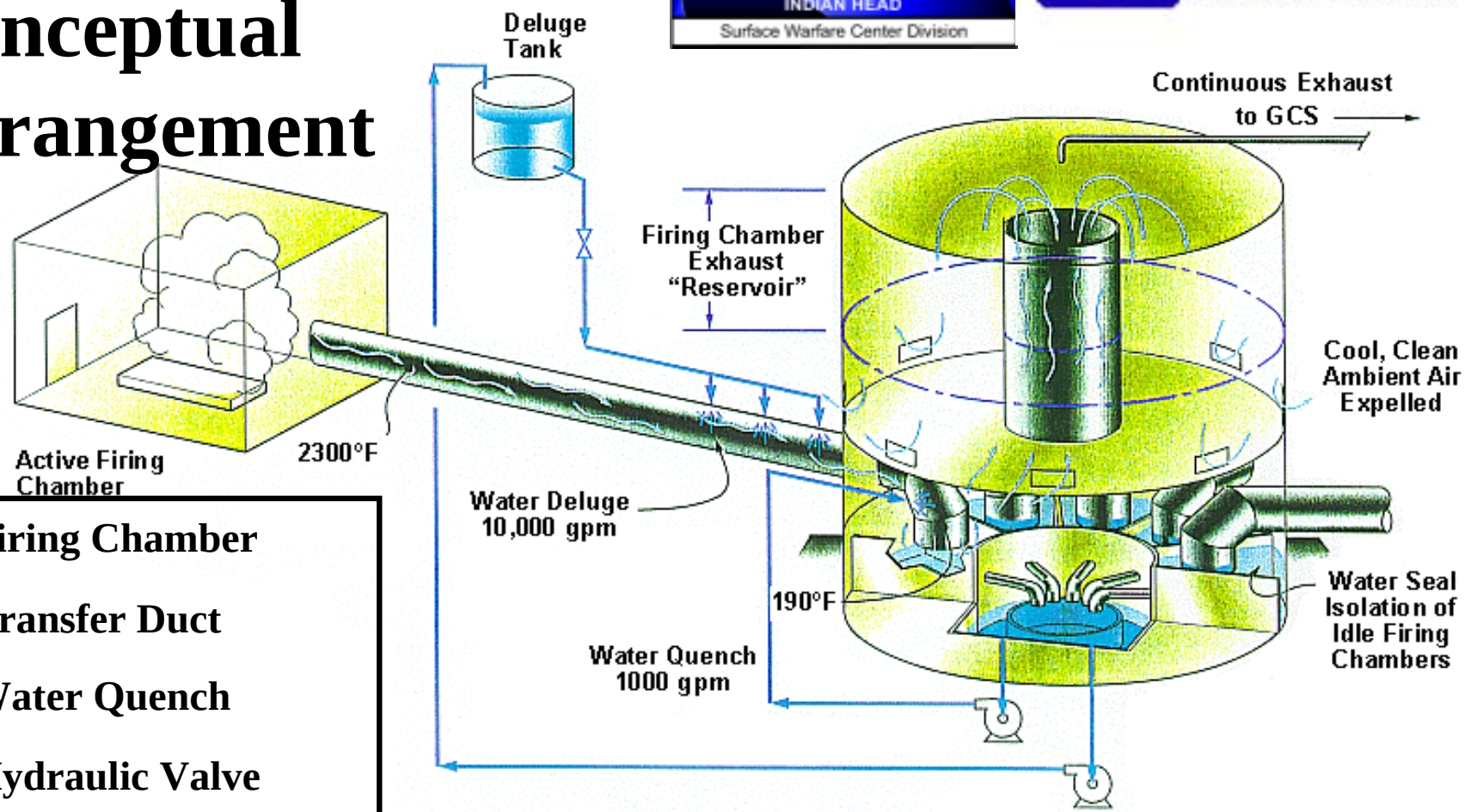
Timothy Brennan - IHDIV NSWC, Indian Head, MD

Jeff Fleming - IT Corporation, Knoxville, TN

Russell Kominski - IHDIV NSWC, Indian Head, MD

May-2000

CBF Subsystems and Conceptual Arrangement



- Firing Chamber
- Transfer Duct
- Water Quench
- Hydraulic Valve
- Surge Containment Chamber
- Gas Cleaning System

UTTS Surge Containment System

U.S. Patent Numbers
5,791,266 and 5,881,654

CBF Project Structure

- **Phase 1 - Concept Development**
  - Scope and Industry Search
  - Feasibility Study
  - Conceptual Design
  - Preliminary Hazard Analysis
- **Phase 2 - Small-Scale R&D**
  - 0.5 - lb Bench-Scale CBF (BCBF) Design
  - Testing/Report
- **Phase 3- Scale Up Development**
  - 10-lb Pilot-Scale CBF (PCBF) Design
- **Phase 4 - 10 lb PCBF Testing**
  - Described Herein
- **Phase 5 - 80 lb Demonstration Scale CBF (DCBF) System Design**

CBF Project Structure

- Phase 6 - DCBF Testing, Treatability Study, Pre-Test Burns
- Phase 7 - Full-Scale Unique Designs and Military Handbook - CBF Design Guide

- Sponsors
  - Andy Del Collo - NAVFAC 15R
  - Dr. Frank Stone - OPNAV N-45G R&D Coordinator

PCBF

Firing Chamber/Door/Exhaust Exit

Surge Tank/Firing Chamber

Firing Chamber/Surge Tank/Support Equip.

Carbon Adsorber/Surge Tank/Firing Chamber

PCBF PEP Sample Selection

- 9 Types of PEP in 28 Test Firings
  - HEN-12 Sheetstock - Doublebase (DB) - High Surface - Capacity Tests
  - ARP Chunks - DB - Compare to BCBF tests
  - ABL 917 Casting Powder - DB - High Surface/High NC - Capacity Tests
  - CAP Cast DB - Aluminized DB - Capacity Tests
  - NOSIH BC-10 - High Al, AP Composite - Compare to BCBF Tests
  - NOSIH-EC - High AP Composite - Compare to BCBF Tests
  - N-60 - High Smoke Composite - Low Ox Tests vs. Firing Chamber Vol.
  - Explosive Slum - Cast. Solvent/Diluting Solvent/Sawdust w/Fuel Oil
  - TNT/Excelsior - Low Ox Class 1.1 Test

PCBF Test Charge Breakdown

- 18 Planned and 9 Field Determined Tests Conducted
  - 8 Planned DB Tests - Step Up to Capacity
    - HEN-12 and ARP
  - 7 Field DB Tests - Aluminized and Casting Powder Capacity
    - ARP, CAP and ABL -917
  - 7 Planned Composite Tests - Step Up to Capacity
    - NOSIH BC-10 and N-60
  - 3 Planned Slum Tests - Slow Burn Waste Response
    - NG Casting Solvent/Diluting Solvent Absorbed in Sawdust, and Burned Over a Fuel Oil Pool Fire
  - 1 Field TNT/Excelsior Test - Low Ox Response
  - 1 Field Composite - Low Ox/High Ox/High Charge Weight Response
    - 21.765lb (N-60 - High Smoke/NOSIH EC - High AP)

PCBF

HEN-12 DB Propellant Sheetstock with Velostat® Strips

May-2000

PCBF

ARP Cast DB Propellant Chunks

PCBF

CAP Cast DB Propellant Chunks

PCBF

ABL 917 Casting Powder in Velostat® Bags

May-2000

PCBF

NOSIH BC-10 High AL (18%) Composite Propellant

May-2000

PCBF

NOSIH EC High AP (85%) Composite Propellant

May-2000

PCBF

May-2000

N-60 (Smokey Sam) Composite Chunks

PCBF

Explosives Slum (NG Casting Solvent, Diluting Solvent, and Saw Dust in Velostat® Bags Over Fuel Oil)

May-2000

PCBF

TNT Shards in a Bed of Excelsior

PCBF Emissions Monitoring and Sampling

- **Surge Tank Top Gas Monitored (CEM) - All Runs**
  - **Carbon Monoxide (CO)**
  - **Carbon Dioxide (CO_2)**
  - **Nitrogen Oxides (NOx)**
  - **Oxygen (O_2)**
  - **Total Hydrocarbons (THC)**
- **Withdrawal Gas Sampled for Particulate - All Runs**
- **Withdrawal Gas Sampled for Acid/Metals - Select Runs**
  - **Chlorine (Cl_2)**
  - **Hydrochloric Acid (HCl)**
  - **Hydrogen Cyanide (HCN)**
  - **Multi Metals (40 CFR 264 Appendix IX metals)**

PCBF CEM Results

- Nitrogen Oxides - NOx
  - Avg. Conc. (ppm) Lower Than Bench CBF
    - PCBF: 3.89 to 240.37 - 825 Max.
    - BCBF: 5.2 to 1384.1 - >10,000 Max.
    - Avg. Diff. - Greater Withdrawal Flow in PCBF
    - Max. Diff. - Less Opportunity for Air Mixing in BCBF
  - Generation Rate (lb/100lb PEP) Consistent
    - PCBF: 0.0678 to 3.0428 - 1.233 Avg.
    - BCBF: 0.0378 to 5.5574 - 1.294 Avg.
  - Higher NOx for DB and Slum vs. Composite in Both Units
    - Nitrogen Content in DB and NG in Slum Converts to NOx

PCBF CEM Results

- Carbon Monoxide - CO
  - Avg. Conc. (ppm) Lower Than Bench CBF
  - Generation Rate (lb/100lb PEP) Higher Than BCBF
    - PCBF: 0.187 to 12.22 - 3.312 Avg.
    - BCBF: 0 to 10.94 - 1.81 Avg.
    - Surprising - Air Vol./Charge Wt. Less in BCBF
    - PCBF Low Temps Could Freeze Out CO
    - Or BCBF Retained CO in Firing Chamber - Not Counted

PCBF CEM Results

- **Total Hydrocarbons - THC**
  - **Conc. (ppm) Much Lower Than Bench CBF**
  - **Generation Rate (lb/100lb PEP) Much Lower Than BCBF**
    - **PCBF: 0.0019 to 0.2246 - 0.517 Avg.**
    - **BCBF: 0 to 5.3597 - 2.5787 Avg.**
    - **Not Consistent w/Results for CO**
    - **Should Vary Proportionally**

PCBF CEM Results

- **Carbon Dioxide - CO_2**
  - **Conc. (ppm) Higher Than Bench CBF**
  - **Generation Rate (lb/100 lb PEP) Higher Than BCBF**
    - **PCBF: 49.8 to 170.1 - 106.7 Avg.**
    - **BCBF: 0 to 27.8 - 7.1 Avg.**
    - **PCBF Closely Matches Predictions of POLU Computer Model**
    - **Most Measured Values on High Side of Predictions**

PCBF Analytical Results

- Multi-Metals (40 CFR 264 Appendix IX)
  - Lead
    - Expected Levels for DB
    - Several Non-Leaded PEP Charges Showed Lead
      - Test P-9 (NOSIH BC-10) - >1.47 lb/100 hr
      - Levels Lessened Steadily
      - Previous 2 Charges - ABL-917 Cast Powder - Highest Lead Content
      - Quench Drained, Rinsed, and Refilled Before P-9
      - Lead Particulate Retained in Firing Chamber
      - F.C. Lining Rough/Hard to Remove Particulate
      - Subsequent Burns Slowly Swept Lead Out of F.C.
  - Chromium, Manganese, Mercury and Nickel Detected
    - Sporadic, Low Level - No Pattern or Source Identified

PCBF Analytical Results

- Chlorine/Chloride
  - Expected Non-Detect for DB
  - Expected Significant Levels for Most Composite (AP)
    - Chlorine: 0.1326 to 3.1454 lb/100 hr
    - Chloride: ND to 0.8213 lb/100 hr
  - Chlorine Detected in Subsequent Slum Burns
    - Probable Source - Quench Water
    - Chlorine Treatment Indicated - Water and Gas Streams
- Particulate
  - PEP Dependant - Highest for N-60 (Smokey Sam)
  - Some Exceed RCRA Subpart O Standards
    - Removal Indicated - Most <10 microns, 60-90% <2 microns
    - Large Particles Retained/Removed by F.C./Quench Spray
    - No Relationship Discernable

PCBF Analytical Results

- TCLP - Solid and Liquid Residues
  - Complete TCLP List Analyses Performed
  - Particulate
    - Firing Chamber - ND or Low for All, Except Pb
    - DB Composited Sample - 5490 mg/l Pb
    - Other PEP Composited Sample - 6.3 mg/l Pb
    - Firing Chamber Pb Retention again
  - Quench Waters, Rinse Waters, Decontamination Waters
    - Low or ND Levels
    - Highest for Pb - DB Quench Rinse Water
    - Indicates Leachable Sludge Formation - Removed by Rinse
    - Low Pb in Subsequent Waters - Rinsing Effective Removal

PCBF System Capacity

- PEP Charge Capacity
  - Design- 10 lb Charges
  - Successfully Operated
    - All PEP Types at Least 12.5 lb Charges
    - Some PEP Types up to 17.5 lb Charges
    - Actual Capacity 25 to 75% Larger Than Designed
- Firing Chamber Capacity Limitations
  - Available Oxygen Limit - Keep Exhaust Gas LEL < 25%
  - Thermal Limit - Liner Material Thermal Stability
  - Controlling Limit
    - Thermal as Charge Size Increases
    - LEL as PEP Fuel Content Increases

PCBF System Capacity

- **Transfer Duct**
  - **Most Accurately Sized Component**
  - **Limited Excess Capacity for Most PEP Types**
  - **Limiting Factor - Flow - Back Pressure >Door Rating**
- **Surge Tank**
  - **Limit Only Approached for PEP/Fuel Mixtures (Slum)**
  - **No CO or LEL Detected at Vents for Pure PEP**
  - **Actual Capacity Probably 90% Larger Than Designed**

PCBF Conclusions

- Surge Tank Wind Screen Prevented Wind Induced Fugitive Emissions
  - Need to Prevent Quench Water Loss Through Vent Holes
- Transfer Duct Most Limiting Subsystem
  - Need to Allow Decent Low Pressure Flow Over Wider Range of Charge Weights
- Quench Flow Appeared Excessive for Pure PEP Burns
  - Excess Flow May Be Responsible for Excellent Surge Tank Performance - Retain Comparable Quench Flow Capability in Future Systems
- Surge Tank Allowed Fugitive Emissions (1 ppm CO) for Very Slow Burning PEP
  - Slow Burning PEP - Low Flow Rate - By-Pass Surge Tank for These Items - Not Needed
- Sweep Air Short Circuited to Transfer Duct - Inhibited Clean Air Purge Ability
  - Close Proximity of Sweep and Duct - Increase the Flow Path Length - Enhance the Sweep

PCBF Conclusions

- Surge Tank Stratification Inhibited by "Over Quench"
  - Design Concept - Surge Tank Works by Buoyancy - Works Better by Plug Flow/Reduced Volume - Spray Quench Needs High Turn-Down Capability - Take Advantage of Both
- High AP Composite Produced Liquid HCl on Floors and Walls F.C.
  - Examine Alternative Refractory - Pre-heat F.C. Walls Above Acid Sat. Temp
- Little Temp. Increase Beyond Surface of Refractory
  - Refractory May be as Thin as Practical for Construction
- Firing Chamber Charge Capacity Limits
  - Oxygen Depletion in F.C. - Design for Sufficient Total System Oxygen - Must Characterize Waste Stream for Oxygen Content Before Design
  - Thermal Limits of F.C. Lining Materials - Derive Radiant Heat Transfer Parameters for Design - Also Must Characterize PEP Stream
- Flow From Firing Chamber Reversed After Flame Extinguishment
  - Due to Rapid Temp. Decrease - Heat Transfer to Walls
  - Helped Prevent Fugitive Emissions From Surge Tank - Increased Vent Influx

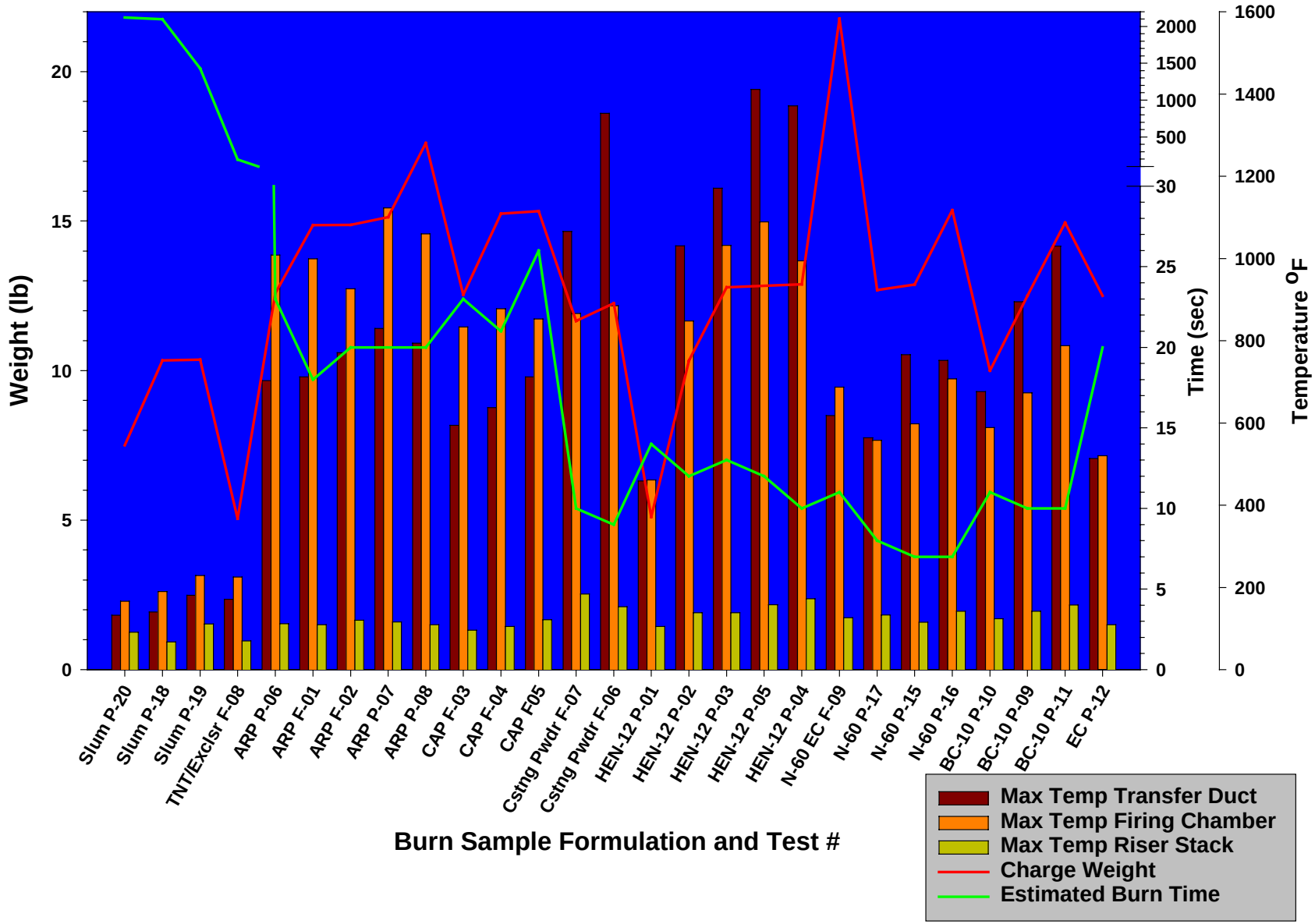
PCBF Conclusions

- **Overall PCBF Capacity Estimate : Oxygen Depletion**
  - **HEN-12 Doublebase Propellant - 15.13 Pounds**
  - **CAP Al Doublebase Propellant - 14.49 Pounds**
  - **NOSIH BC-10 AL Composite Propellant - 20.18 Pounds**
  - **Based on 10% Air Expulsion Without Reaction**
  - **PCBF Did Not Approach Any Thermal Limit**
- **HEN-12 Design Charge Exhibited Large Variation in Results**
  - **CAP - Similar Burn Rates - Good Repeatability - Replace HEN-12**
  - **Add NOSIH BC-10 - 2nd Design Basis (Composite)**
- **Fondag Refractory Liner Unsatisfactory**
  - **Gunite Application - Rough Surfaces - Holds Particulate/Acid**
  - **Acid Appeared to Attack Fondag - Problem w/Gunite Application?**
  - **Need to Identify Alternative Liner - Smooth/Acid Resistance**
- **Broad Applicability Across Known PEP Types Reinforced**

Appendix

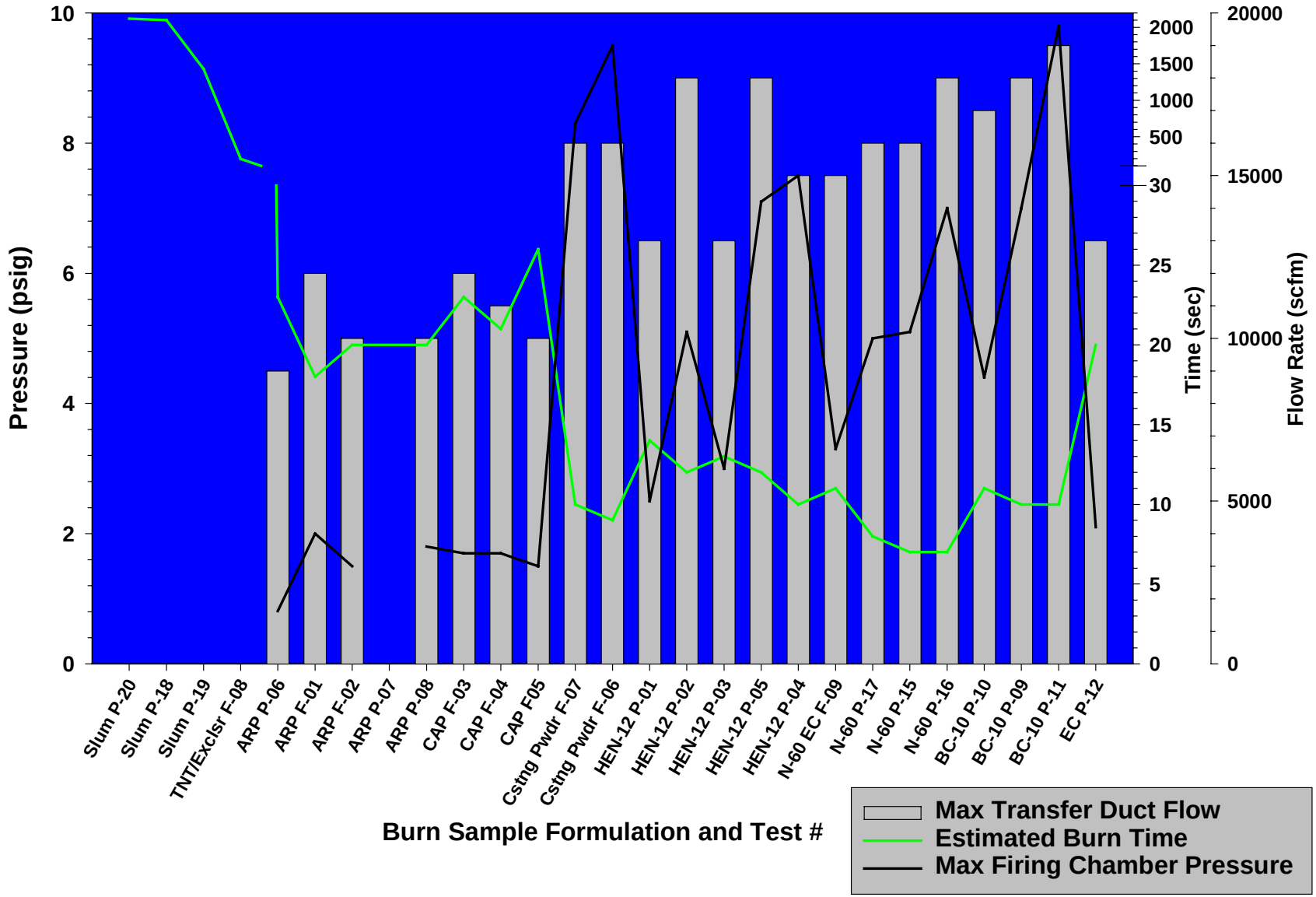
Additional
Charts, Tables, and Pictures
For
Further Understanding
of the
PCBF

PCBF Summary of Test Results - Weight, Burn Time, Temperature, Pressure



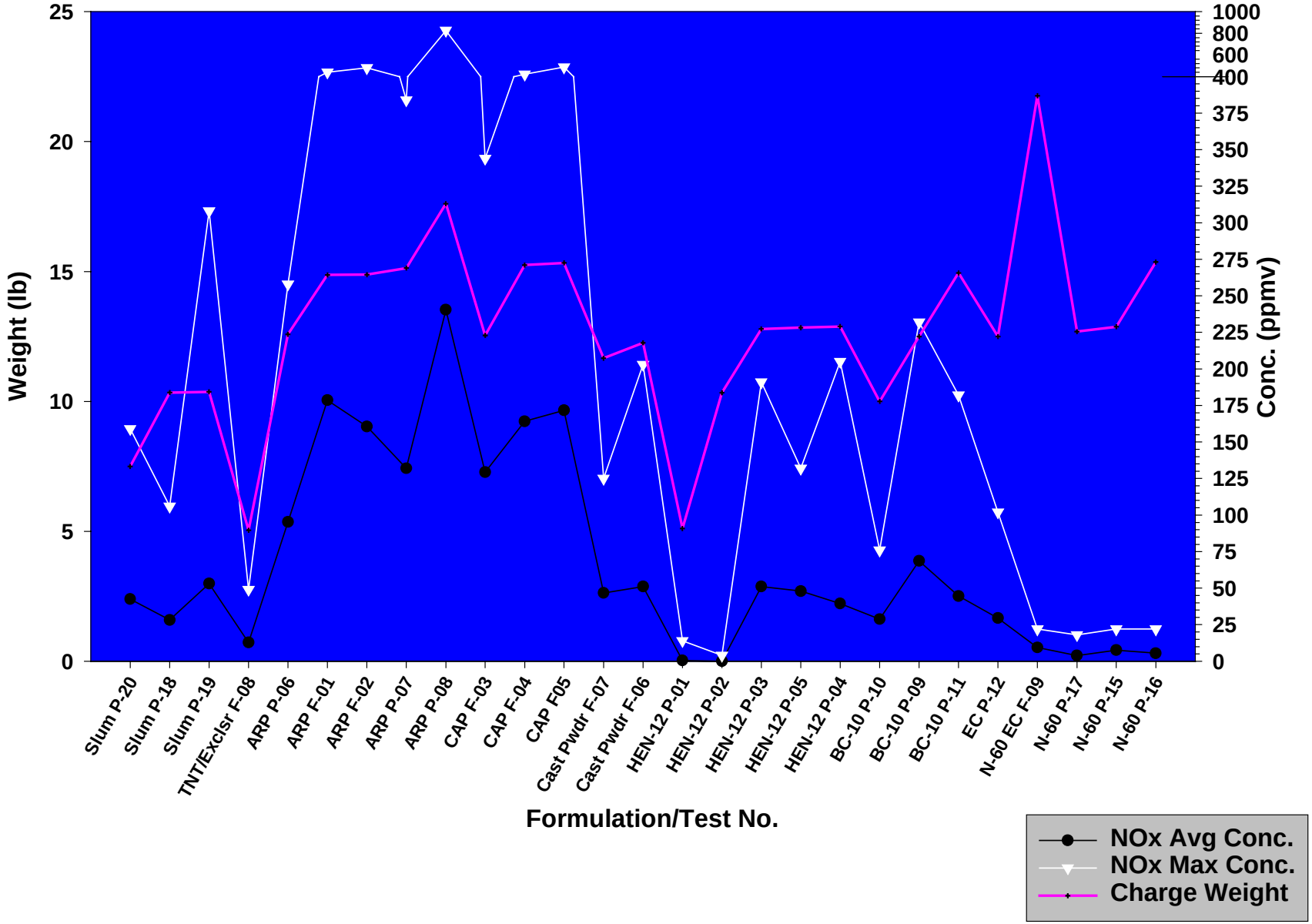
May-2000

PCBF Summary of Test Results



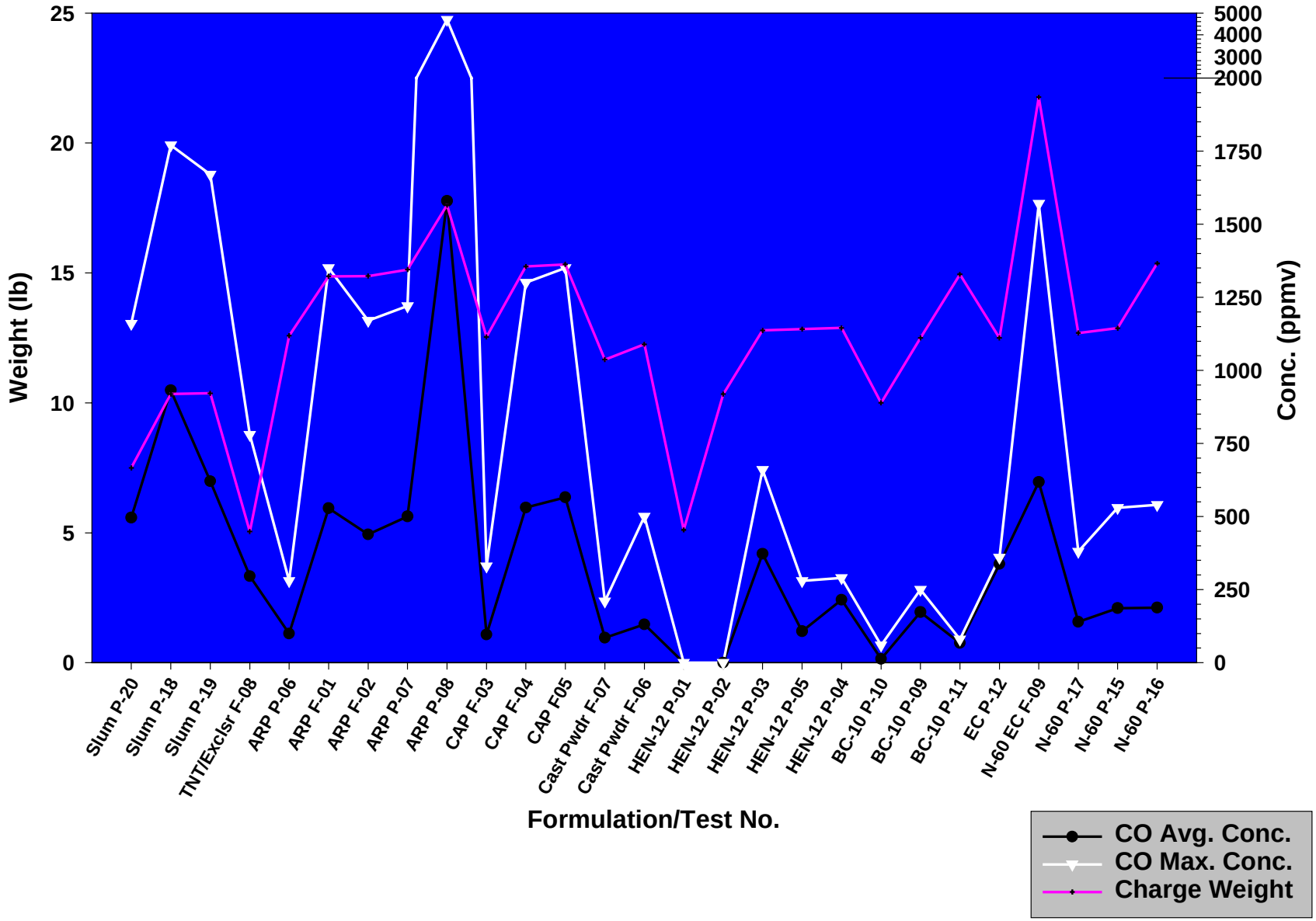
May-2000

PCBF CEM for NO_X

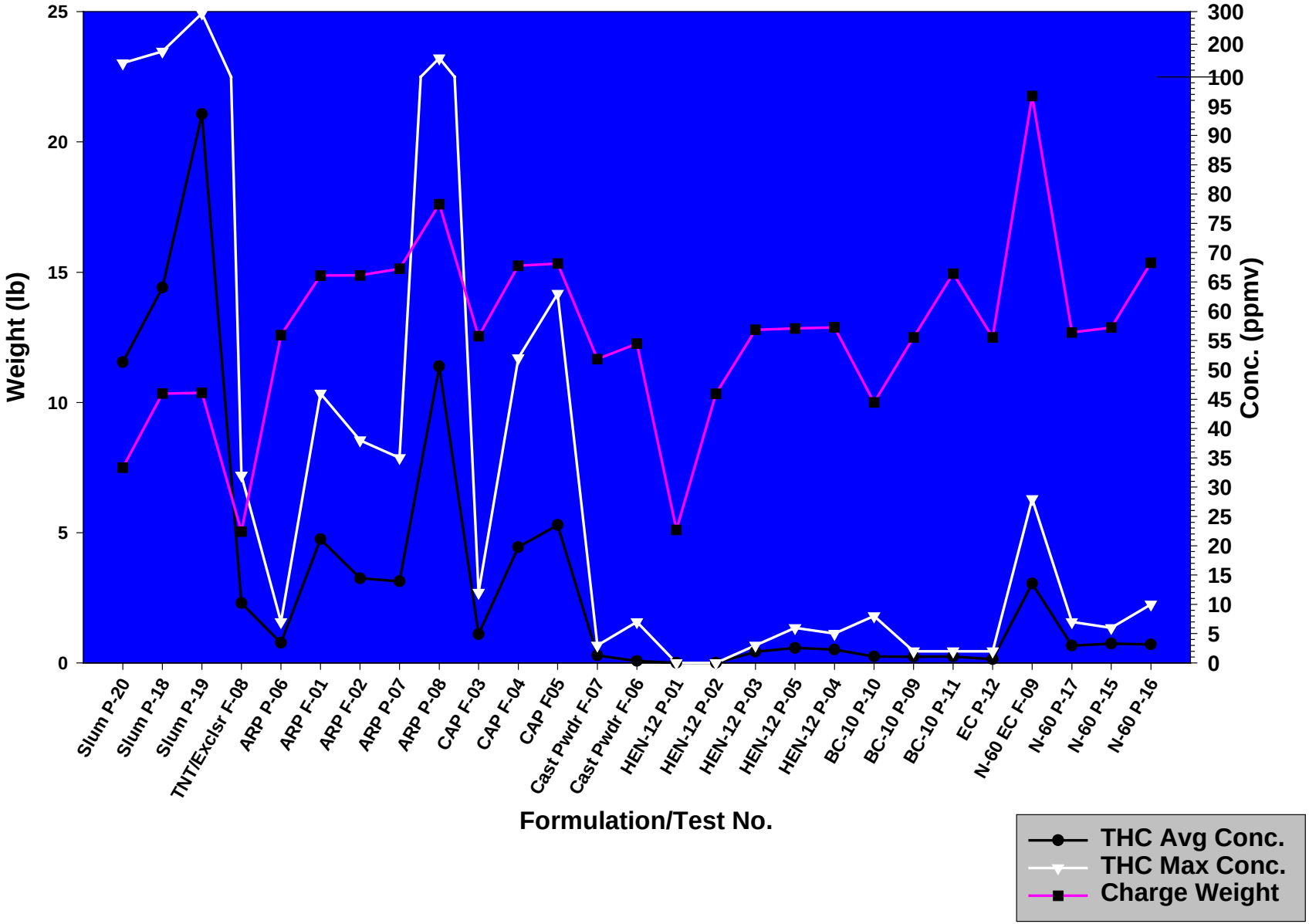


May-2000

PCBF CEM for CO

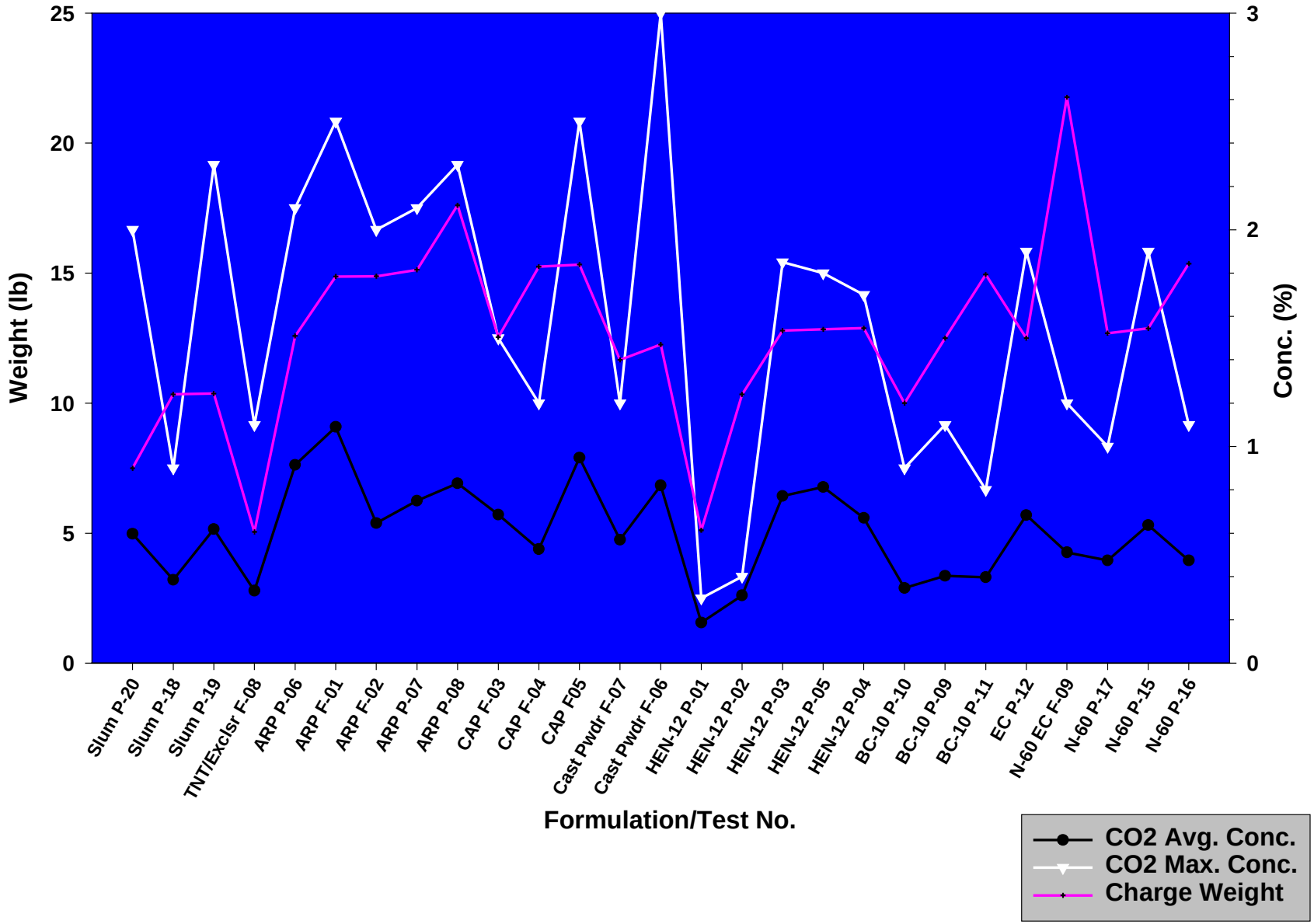


PCBF CEM for THC



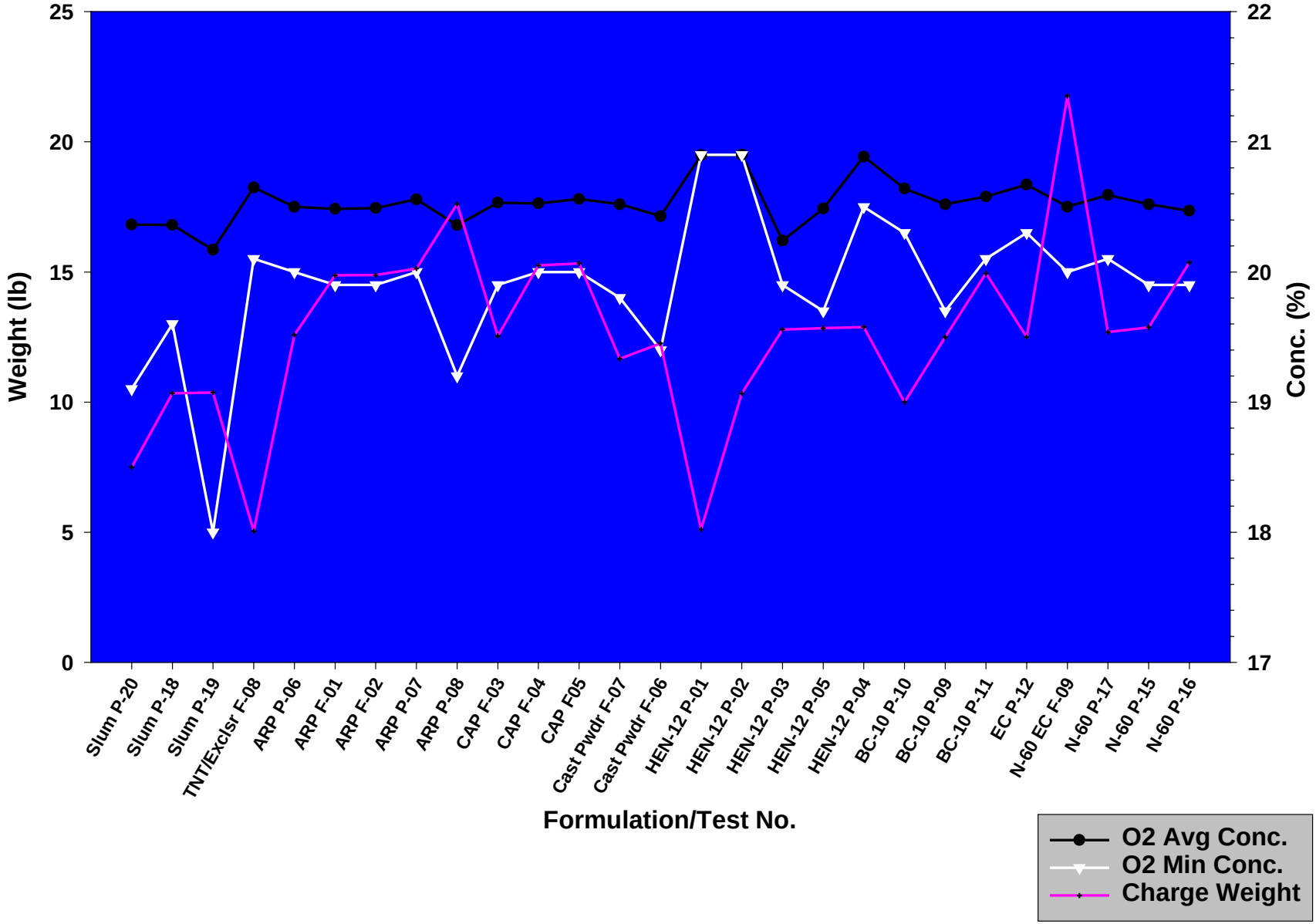
May-2000

PCBF CEM for CO_2



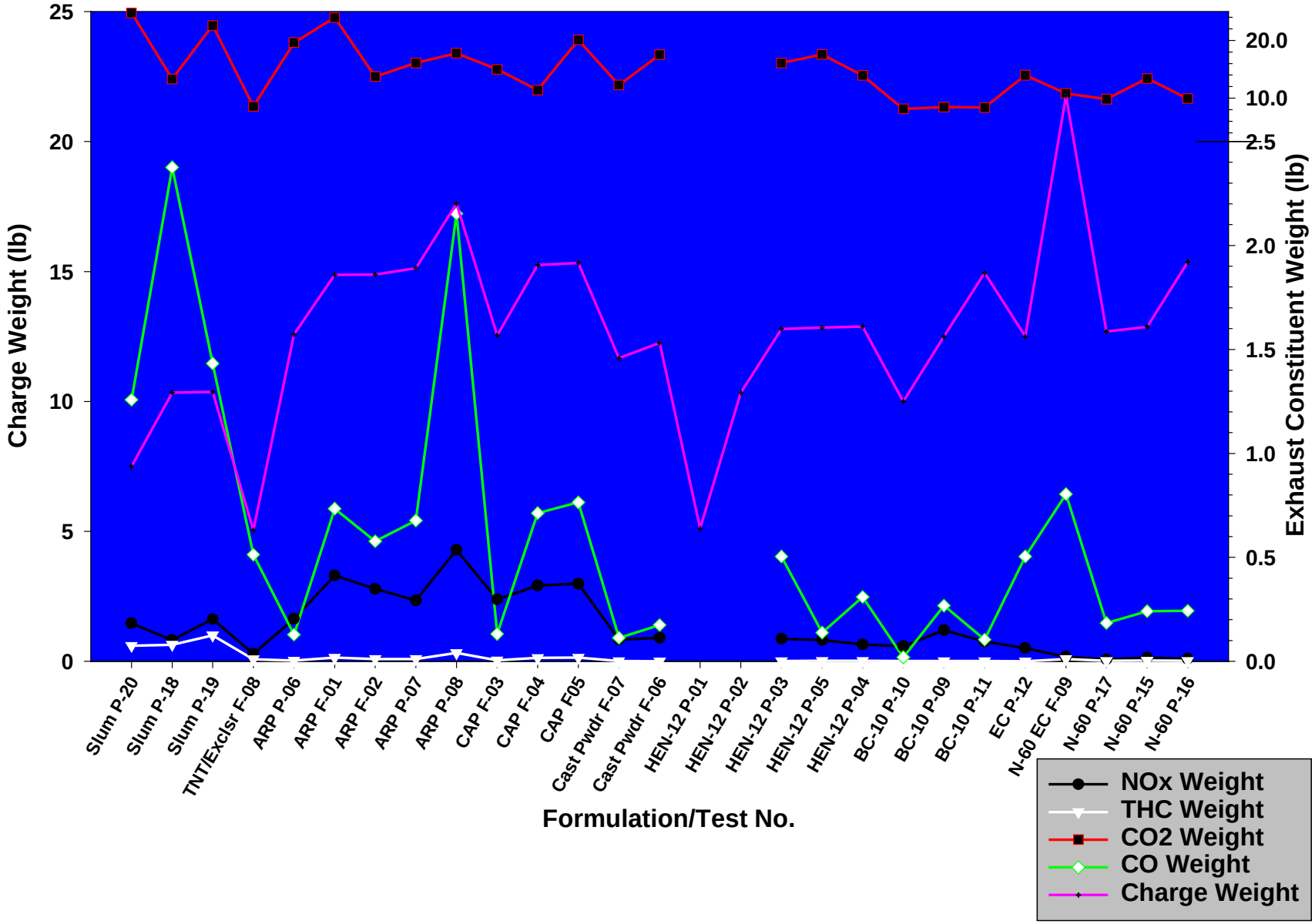
May-2000

PCBF CEM for O_2



May-2000

PCBF Total Weight NO_X, THC, CO_2, and CO by CEM



May-2000

PCBF Analytical Result

	TEST NUMBER								
TEST PARAMETER	P-1	P-2	P-3	P-4	P-5	P-6	P-7	P-8	P-9
Particulate Concentration (gr/dscf)	0.0138	0.0470	0.0431	0.0591	0.0307	0.0560	0.0660	0.0764	0.0534
Particulate Mass Rate (lbs/hr)	0.025	0.083	0.077	0.103	0.056	0.099	0.116	0.138	0.097
Gas Stream Moisture (% by Vol.)	1.79	1.92	1.32	2.82	1.12	1.80	2.61	1.25	1.15
Gas Flow Rate (scfm)	211	210	211	210	214	211	210	214	215
Gas Flow Rate (dscfm)	207	206	208	204	212	207	205	211	213
HCN Mass Rate (lbs/100hr)		ND		ND	ND	0.0170	0.0618		0.0031
Chlorine Mass Rate (lbs/100hr)		ND		ND	ND	ND	ND		0.4536
Chloride Mass Rate (lbs/100hr)		ND		ND	ND	ND	ND		0.1919
Metals Mass Rate (lbs/100hr)									
Arsenic		ND		ND	ND	ND			ND
Antimony		ND		ND	ND	ND			ND
Barium		ND		ND	ND	ND			ND
Beryllium		ND		ND	ND	ND			ND
Cadmium		ND		ND	ND	ND			ND
Chromium		0.0001		ND	ND	ND			0.0001
Lead		0.3818		1.8112	0.3360	0.5436			1.4752
Manganese		0.0010		ND	0.0007	0.0002			0.0008
Mercury		ND		ND	ND	ND			ND
Nickel		0.0003		ND	0.0004	ND			0.0005
Selenium		ND		ND	ND	ND			ND
Silver		ND		ND	ND	ND			ND
Thallium		ND		ND	ND	ND			ND

PCBF Analytical Result

	TEST NUMBER								
TEST PARAMETER	P-10	P-11	P-12	P-15	P-16	P-17	P-18	P-19	P-20
Particulate Concentration (gr/dscf)	0.0945	0.0678	0.0190	0.1564	0.1946	0.0945	0.0070	0.0498	0.0076
Particulate Mass Rate (lbs/hr)	0.167	0.118	0.035	0.280	0.335	0.163	0.012	0.116	0.018
Gas Stream Moisture (% by Vol.)	2.01	3.59	0.97	1.96	3.56	3.03	2.89	1.82	1.26
Gas Flow Rate (scfm)	210	210	215	213	208	208	213	276	273
Gas Flow Rate (dscfm)	206	202	213	209	201	202	207	271	270
HCN Mass Rate (lbs/100hr)	ND	0.0012	ND	0.0553	0.0961	0.0786	0.0055	0.0210	
Chlorine Mass Rate (lbs/100hr)	0.1452	0.1329	0.7997	1.6665	3.1454	1.5884	0.1670	0.1326	
Chloride Mass Rate (lbs/100hr)	ND	0.0532	0.3110	0.4298	0.8213	0.4853	ND	ND	
Metals Mass Rate (lbs/100hr)									
Arsenic			ND	ND			ND		
Antimony			ND	ND			ND		
Barium			ND	ND			ND		
Beryllium			ND	ND			ND		
Cadmium			ND	ND			ND		
Chromium			0.0001	ND			0.0000		
Lead			0.3801	0.0406			0.0312		
Manganese			0.0069	0.0019			0.0002		
Mercury			ND	ND			0.0001		
Nickel			0.0007	ND			ND		
Selenium			ND	ND			ND		
Silver			ND	ND			ND		
Thallium			ND	ND			ND		

PCBF TCLP Results

	H-5912	H-5913	H-5918		H-5923		H-5910		H-5911		H-5928		H-5933	
	Firing Chamber		Quench Water		Quench Rinse		Quench Water		Quench Rinse		Firing Chamber		Surge Tank	
	Comp. Part.	DB Particulate	Composite		Composite		Double Base		Double Base		Decon Water		Decon Water	
			Navy	Contrctr	Navy	Contrctr	Navy	Contrctr	Navy	Contrctr	Navy	Contrctr	Navy	Contrctr
Analyte	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
VOC's														
Methyl Ethyl Ketone	ND	0.021(J)	NA	0.16(J,B)	NA	0.13(J,B)	NA	ND	NA	ND	NA	0.13(J,B)	NA	0.13(J,B)
Vinyl Chloride	ND	ND	NA	0.0026(J,B)	NA	0.0025(J,B)	NA	ND	NA	0.045(J)	NA	0.0025(J,B)	NA	0.0025(J,B)
Semivolatile's														
o-Cresol	ND	ND	NA	ND	NA	0.033(J)	NA	ND	NA	ND	NA	ND	NA	ND
m-Cresol & p-Cresol	ND	ND	NA	ND	NA	0.074(J)	NA	ND	NA	ND	NA	ND	NA	0.0094(J)
2,4-Dinitrotoluene	ND	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	0.0056(J)	NA	ND
Pyridine	0.016(J)	0.18	NA	ND	NA	0.014(J)	NA	0.025(J)	NA	ND	NA	0.020(J)	NA	ND
Herbicides														
2,4-D	ND	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	0.006	NA	ND
Pesticides														
Heptachlor	ND	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	0.00023(J)	NA	ND
Metals														
Barium	1.7(J)	0.34(J)	0.0182	0.14(J)	0.245	0.16(J)	0.0554	0.31(J)	<0.0013	0.22(J)	0.175	0.42(J)	0.0979	0.37(J)
Cadmium	0.028(J)	0.024(J)	<0.0037	ND	<0.0037	ND	<0.0037	ND	<0.0037	ND	<0.0037	0.0070(J)	<0.0037	ND
Chromium	ND	0.12(J)	<0.014	ND	<0.014	ND	<0.014	ND	<0.014	ND	<0.014	0.0086(J)	<0.014	ND
Lead	6.3	5490	<0.11	ND	<0.11	ND	<0.11	0.12(J)	1.12	0.44(J)	<0.11	ND	<0.11	ND
Selenium	ND	ND	<0.14	ND	<0.14	ND	<0.14	ND	<0.14	ND	<0.14	ND	<0.14	ND
Mercury	ND	0.00050(J)	ND	ND	ND	ND	ND	0.00013(J)	ND	0.000098(J)	ND	ND	ND	ND

Notes:

ND = Not Detected

NA = Not Analyzed

(J) = Compound was detected at a concentration below the reporting limit, therefore the value is estimated.

(B) = The associated Method Blank contained the target analyte at a reportable level.

May-2000

PCBF

Transfer Duct/Sweep Blower

Transfer Duct/Vent Holes in Surge Tank

Quench Water Sump in Surge Tank

May-2000

PCBF

Control/Data Acquisition/Video Systems

Data Acquisition System

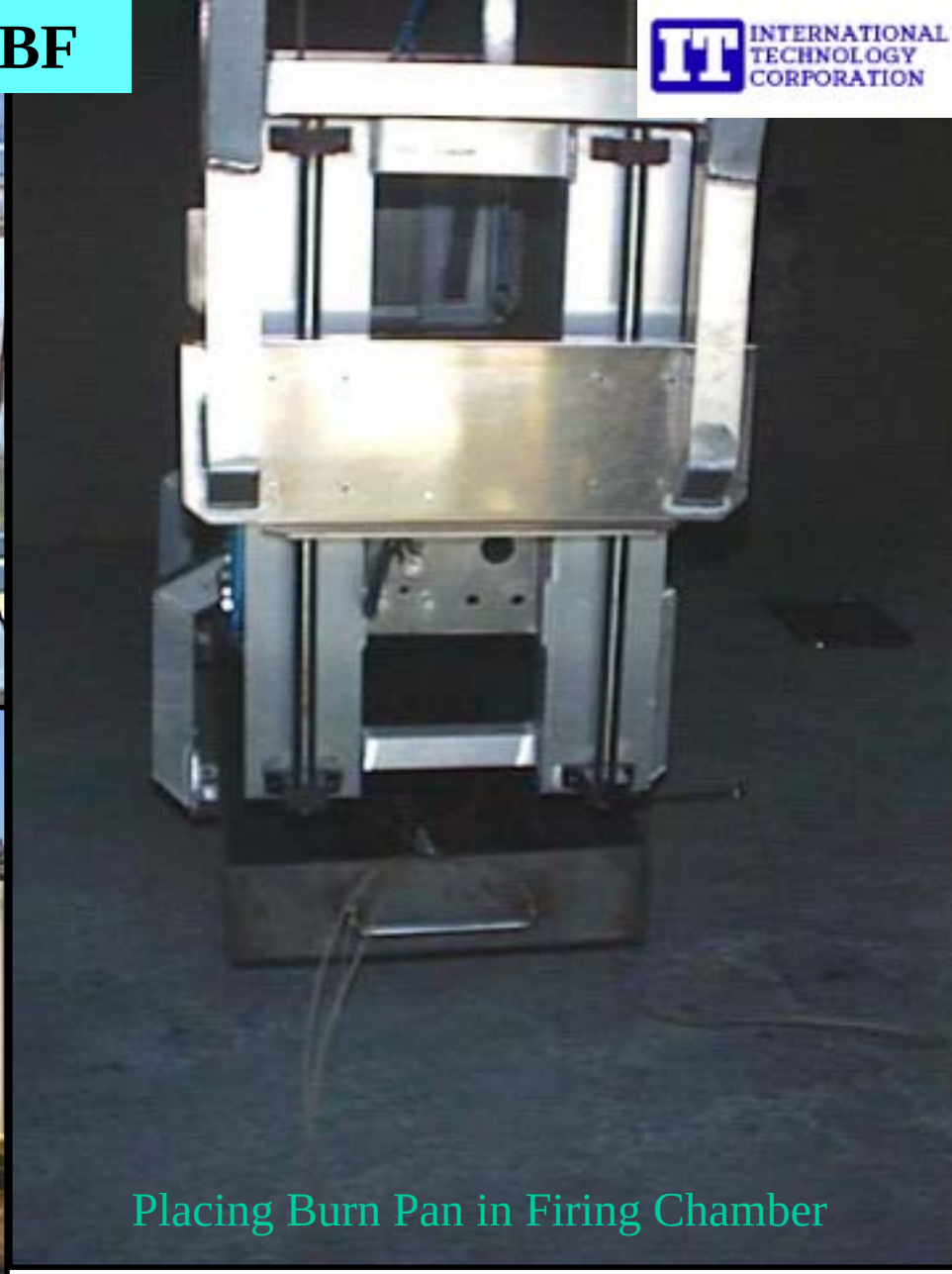
IT Corp. CEM Systems Van/Control Building

Air Sample Pumping and Control Equipment

PCBF

Burn Pan in the Pan Placement System's Jaws

PPS Allowed Stand Off Loading



Placing Burn Pan in Firing Chamber