HEALTH EFFECTS OF SUBCHRONIC INHALATION OF SIMULATED DOWNWIND COAL COMBUSTION EMISSIONS

Driving Issues

Strategy

Technical Approach

Schedule

Progress to Date

Joe Mauderly and Jake McDonald

NATIONAL ENVIRONMENTAL RESPIRATORY CENTER

Because You Never Breathe Only One Pollutant !

Lovelace Respiratory Research Institute

Albuquerque, NM

FUNDAMENTAL ISSUE DRIVING THESE PROJECTS:

Which air contaminants drive which health effects?

We have "multi-pollutant" questions …..

Which air contaminants are causally related to which health effects, and which are the most toxic ?

To what extent can we lump pollutants for regulatory purposes ?

What are the contributions and relative importances of different sources ?

Are there combinations of air contaminants that have health significance ?

What plausible changes in air quality would yield the greatest, most cost-effective, health benefit ?

Are emissions regulations reducing health risks ?

….. but we largely have single-pollutant answers

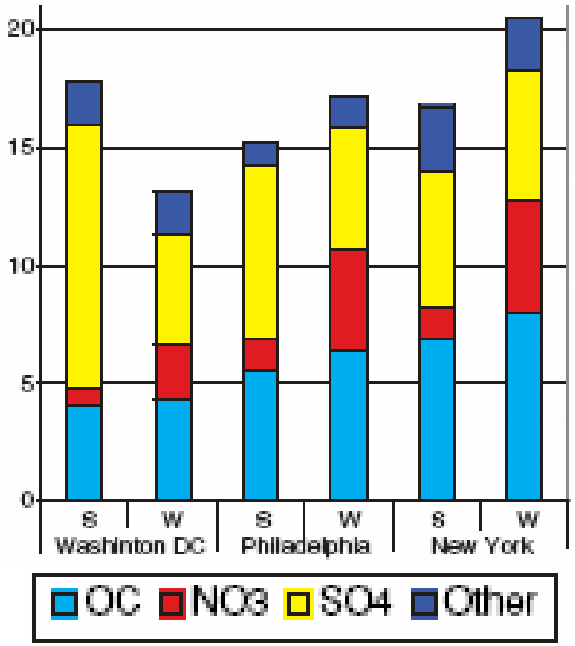
Tend to regulate ⇒ debate ⇒ study pollutants and sources one-at-a-time

- **Focus on a few air contaminants and sources**
- **Limited ability to deal with complex mixtures**
- **Few direct comparisons among pollutants and sources**

WE ARE STRUGGLING TO UNDERSTAND THE RELATIVE CONTRIBUTIONS OF DIFFERENT SOURCES

Example: Contribution of sulfate to health effects of fine PM

- Sulfate constitutes a substantial portion of fine PM mass in the eastern U.S.
- Mass-based standards presume that sulfate contributes a proportional share of health impact
- Because most sulfate is formed from SO_2, this health burden is charged to SO_2 sources, the largest of which is coal combustion



However:

Information to date indicates that most sulfate has very low toxicity (e.g., Grahame & Schlesinger, *Inhal. Toxicol.* 17:15, 2004)

Much less attention has been given to the organic fraction

On the other hand, SO_2-derived H_2SO_4 contributes to secondary organic aerosol through acid catalysis

EPA/OAQPS PM STAFF PAPER – 2nd DRAFT

Key Uncertainties and Research Recommendations

1. **Thoracic coarse PM:**
   - Spatial variability of concentration
   - Composition and health impacts of different components
   - Whether certain components (e.g., crustal) are less toxic
2. **Fine PM:**
   - Components, properties, and sources linked to health effects
3. Shape of concentration-response functions, including thresholds
4. Relationship between PM and other pollutants in causing effects
5. Refinement of exposure modeling strategies to take into account time-varying factors
6. Exposure time periods linked to effects (e.g., hourly)
7. Characterization of hourly and daily background for PM

HOW CAN WE IDENTFY CAUSAL POLLUTANTS ?

1. **Study every pollutant individually**

   We don't even know them all (and don't have the $$)

   Combinations may have different effects

2. **Predict effects using structure-function models**

   We don't have structure-response or exposure-response data for many classes, and almost none for combinations

3. **Study combinations of selected species to test for interactions**

   More than 3 become intractable (A, B, C, A+B, A+C, B+C, control)

4. **Focus research on a "menu" of selected combinations of pollutants**

   You have to define the "right" menu

   Source emissions and CAPs are examples of this strategy

   Can use "biodirected fractionation" to identify putative causal agents

5. **Study effects of ambient air directly (using humans or animals)**

   Can't control or predict exposures & rarely measure everything

   Can't create concentrations above ambient

6. **Apply multivariate analysis to a database produced by identical studies of mixtures that vary in composition and toxicity**

   A plausible approach - if you have such a database

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EXAMPLE OF A MULTIVARIATE APPROACH:

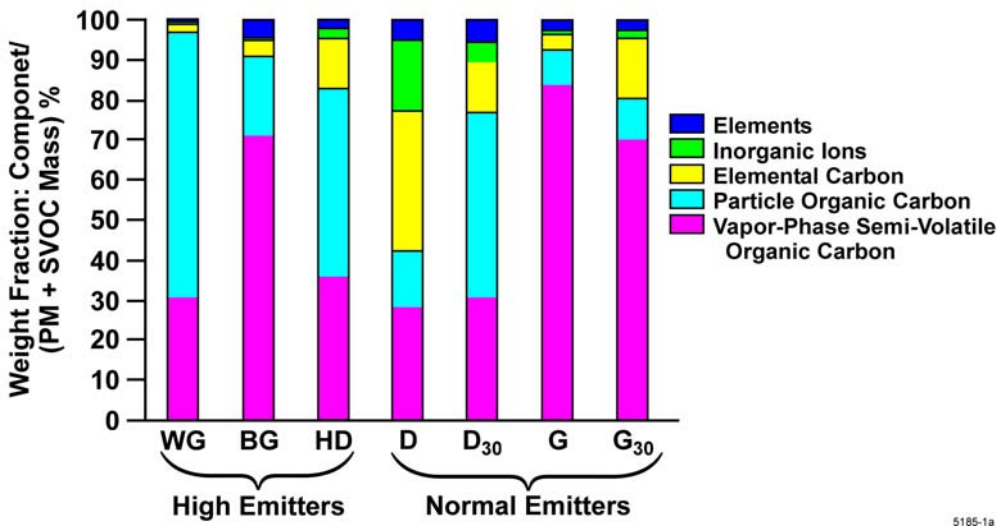
DOE Study of Toxicity of Engine Emission Samples

1. Collected emissions from in-use vehicles “as received”
2. PM and vapor-phase SVOCs collected during urban driving cycle
3. Analyzed composition in detail
4. Re-combined the 2 fractions in their original ratio
5. Inflammation after instillation into rat lungs

Samples

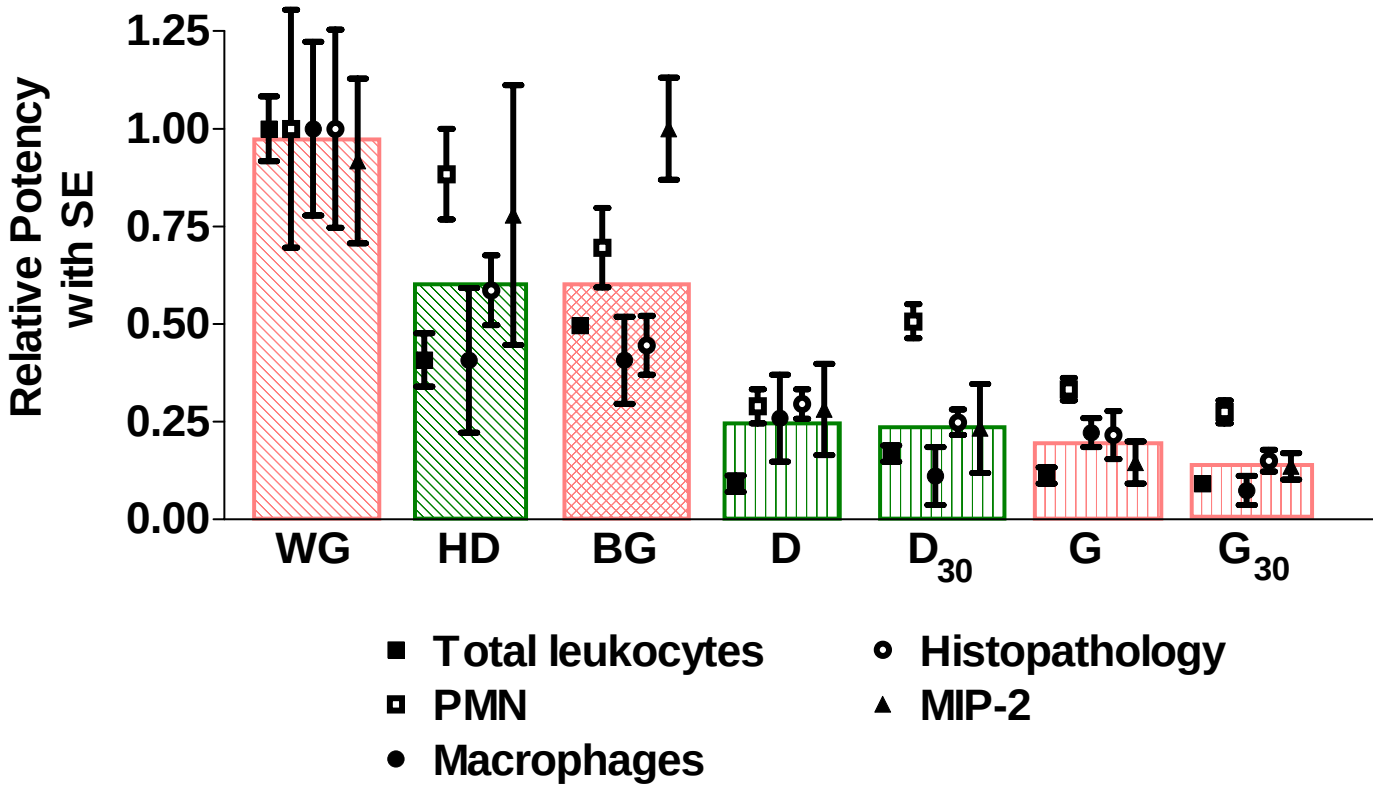
Gasoline (5)	G
Gasoline 30º	G_{30}
White smoker gas.	WG
Black smoker gas.	BG
Diesel (3)	D
Diesel 30º	D_{30}
High-emitter diesel	HD

Composition



THE SAMPLES HAD A 5-FOLD RANGE OF LUNG TOXICITY PER UNIT OF MASS

Example: Lung inflammation at equal mass doses



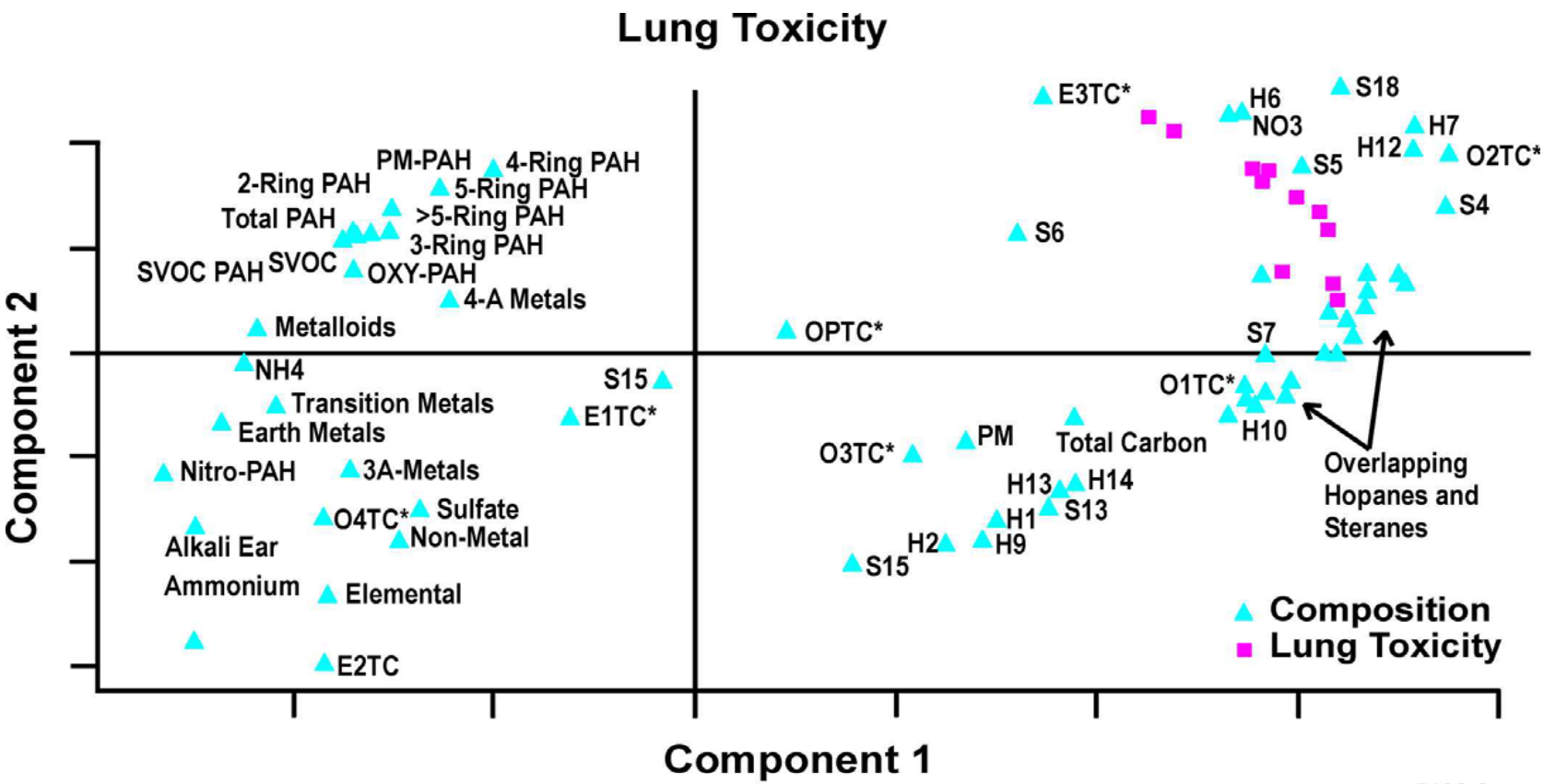
At equal mass doses:

1. <u>High-emitters</u> produced <u>more toxic</u> emissions per unit mass
2. Normal-emitter diesel and gasoline had similar toxicity

PCA/PLS REVEALED THE PHYSICAL-CHEMICAL COMPONENTS THAT CO-VARIED WITH TOXICITY

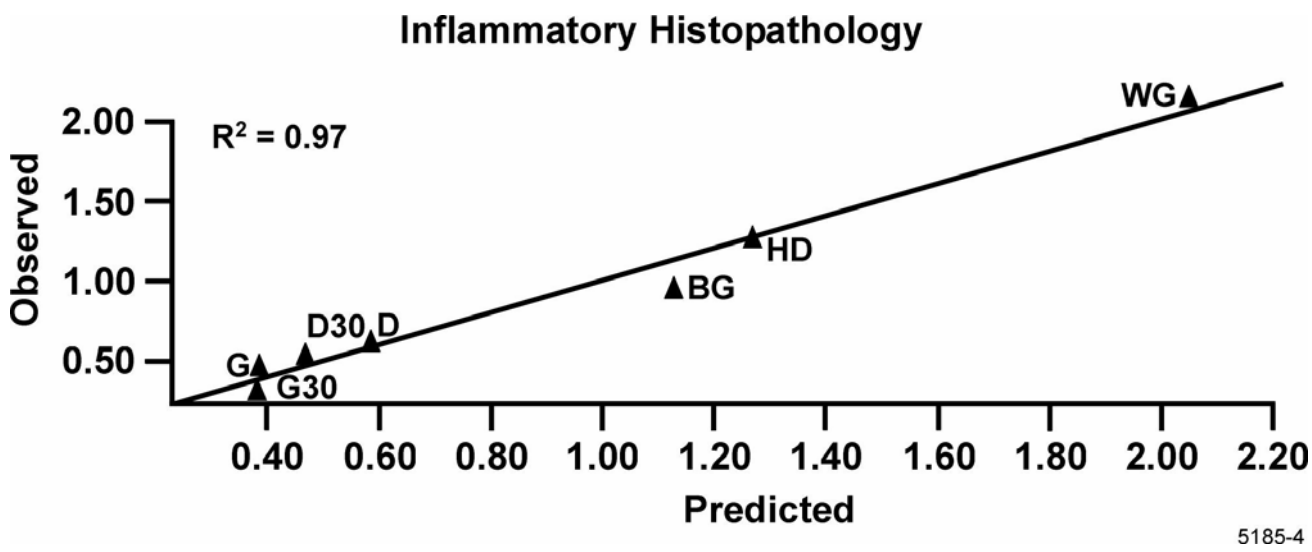
PCA = Principal Component Analysis
PLS = Partial Least Squares Regression

2-Component Loading Plot Showing Co-Variance with Toxicity



*Carbon Analysis Fractions

PCA/PLS PRODUCED GOOD MODELS FOR PREDICTING DIFFERENCES IN TOXICITY FROM COMPOSITION



PM-associated organic carbon, particularly hopanes and stearanes (markers of crankcase oil), co-varied most closely with toxicity in this set of samples

The strategy was validated by identifying certain nitro-aromatic compounds as responsible for bacterial mutagenicity

[McDonald et al., *Env. Health Perspect. 112: 1527-1538, 2004*]

NATIONAL ENVIRONMENTAL RESPIRATORY CENTER

A laboratory research program to determine the contributions of different air contaminants and their sources to the respiratory and cardiovascular health impacts of complex air pollution mixtures

Strategy: Create and analyze a composition-concentration-response data matrix developed by identical laboratory studies of different source-based complex atmospheres

Involve stakeholders in planning and support of research

Vest approval authority in independent advisory body

Base experimental design on expert consensus

Make unique resources available to other investigators

[www.nercenter.org]

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Dan Costa, PhD, Environmental Protection Agency
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Sverre Vedal, MD, University of Washington
Ron White, MST, Johns Hopkins University
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	California Trucking. Assn.	*Hearth, Patio, & Barbecue Assn.*
	Detroit Diesel	*Phillips Petroleum*
		Salt River Project

RESEARCH TEAM

Management

Joe Mauderly, DVM	Principal Investigator
Jake McDonald, PhD	Principal Co-Investigator
Nancy Crowley, PhD	Database Manager
Lynn Fondren, CIH, MS	*Director of E S &H*
Steven Gaa, MBA	QA Auditor
Stephanie Taulbee, MSPH	*Director of Quality*
Roger Van Andel, DVM, PhD, DACLAM	*Director of Laboratory Animal Care*

Investigators

Ted Barrett, PhD	Respiratory immune responses
Steven Belinsky, PhD	DNA methylation injury
Matt Campen, PhD	Cardiovascular responses
Andrew Gigliotti, DVM, PhD, DACVP	Necropsy and histopathology
Jake McDonald, PhD	Exposure operations and characterization
Matt Reed, PhD, DABT	Study Director, general toxicology, resistance to infection
JeanClare Seagrave, PhD	Bronchoalveolar lavage
Steve Seilkop, MS (SKS Consultants)	Univariate data analysis
Jim Swenberg, PhD (Univ. N. Carolina)	DNA oxidative injury
Richard White, BS	Daily exposure supervisor
Barry Wise, PhD (Eigenvector Res.)	Multivariate data analysis

Chemical Analysis Contractors

Judy Chow, ScD (Desert Research Institute)	Analysis of ions
Eric Grosjean, PhD (DGA, Inc.)	Analysis of carbonyls & organic acids
Jamie Schauer, PhD (Univ. Wisconsin)	Analysis of elements
Barbara Zielinska, PhD (Desert Research Institute)	Analysis of organic compounds

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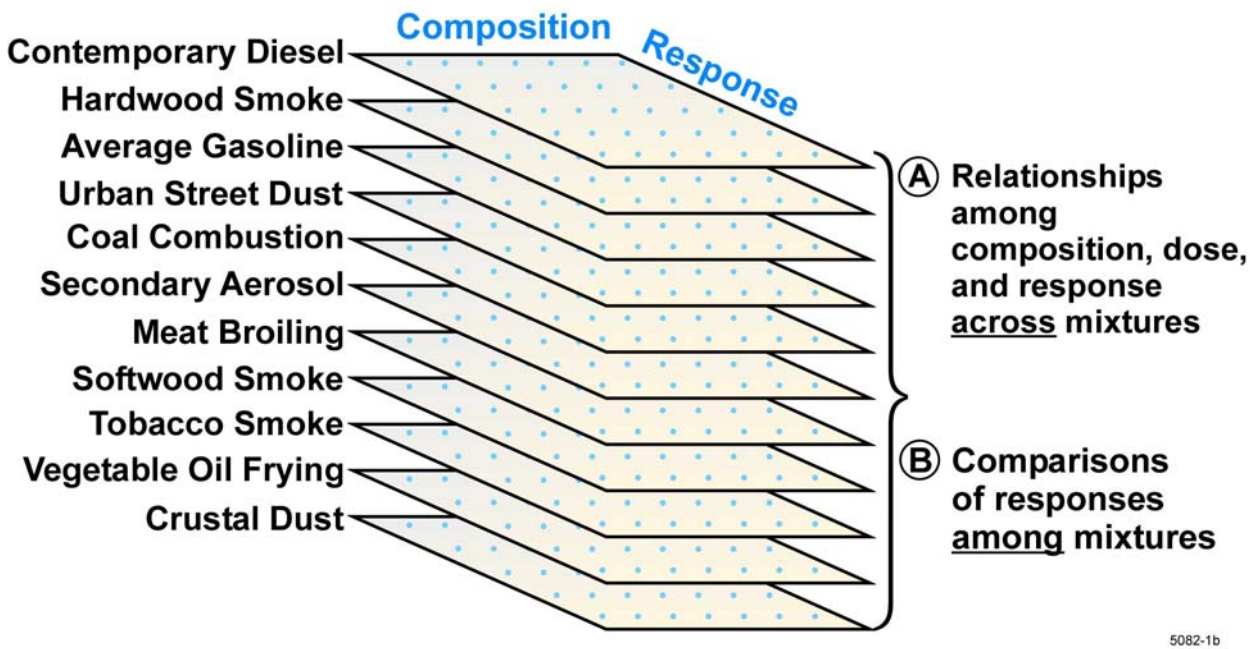
WE ARE BUILDING THE COMPOSITION-CONCENTRATION-RESPONSE DATABASE



- Dose-response studies (4 treatment groups + control)
- Expose 7 d/wk for up to 6 mo
- Characterize exposure at highest practical level of detail (>500 analytes)
- Measure health outcomes in 5 general categories (>200 parameters)

EXPOSURES ARE CHARACTERIZED IN DETAIL

Particles:

- Mass concentration
- Size distribution
- Number counts
- Morphology
- Size-specific chemistry
- Extractable fraction
- Mutagenicity of extracts

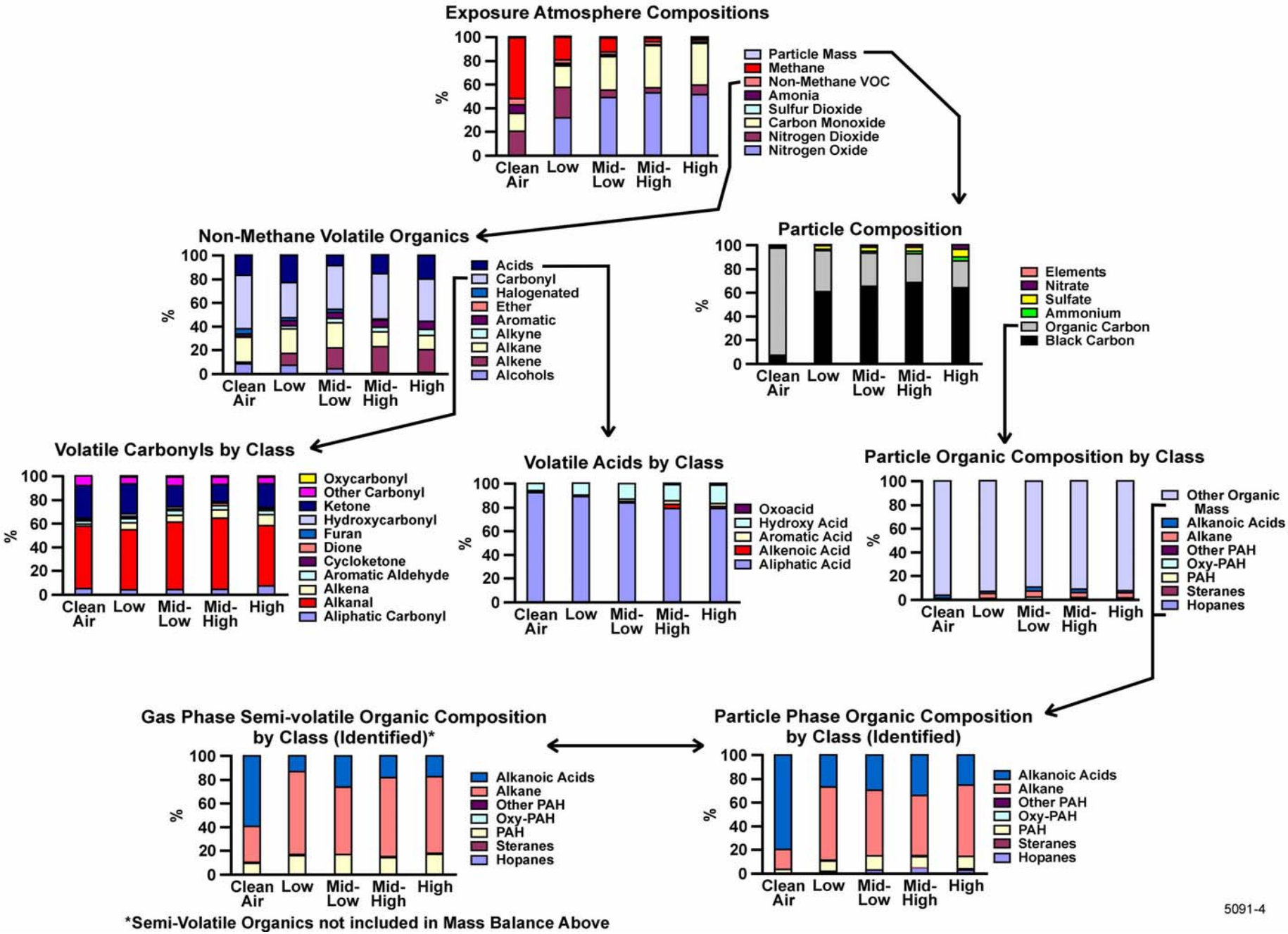
Gases:

- CO
- CO_2
- NO_x
- SO_2
- HC
- NH_3

Particle extract and SVOC:

Ammonium	n-alkanes, cycloalkanes	organic acids
Sulfate	alkenes	alkaloids
Nitrate	Branched alkanes, alkenes	nitrosamines
Elements	Furans, benzofurans	PAHs (+ oxy, nitro)
	Terpenes	Hopanes
	Volatile aromatics	Steranes
	Phenols (+methoxy)	Aliphatic alcohols
	Carbonyls	Carbohydrates

BREAK-DOWN OF EXPOSURE COMPOSITION



*Semi-Volatile Organics not included in Mass Balance Above

[McDonald et al., *Env. Sci. Technol*. 38: 2513, 2004]

MANY HEALTH EFFECTS ARE MEASURED

General toxicity in F344/CrlBR rats and A/J mice

- Body & organ weights of F344 rats and A/J mice
- Hematology, clinical chemistry, coagulation of F344 rats
- Bronchoalveolar lavage of F344 rats
- Histopathology of all major organs of F344 rats

Pulmonary immune responses in BALB/C mice:

- Development of allergic responses
- Exacerbation of allergic responses

Resistance to respiratory infection in C57/BL6 mice

- Instilled *Pseudomonas aeruginosa* (test at 18 hrs)
- Instilled Respiratory Syncytial Virus (test at 4 days)

Cardiac effects in SHR/Crl rats

- Heart rate and variability
- ECG Waveform abnormalities
- Heart and vessel histopathology

Carcinogenic potential in F344 rats and A/J mice:

- DNA Methylation in F344 rats and A/J mice
- Oxidative DNA damage in F344 rats and A/J mice
- Micronuclei in A/J mice

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PROGRESS ON BUILDING THE DATABASE

Diesel Emissions

Exposures completed

Nearly all data completed

Several papers published

Hardwood Smoke

Exposures completed

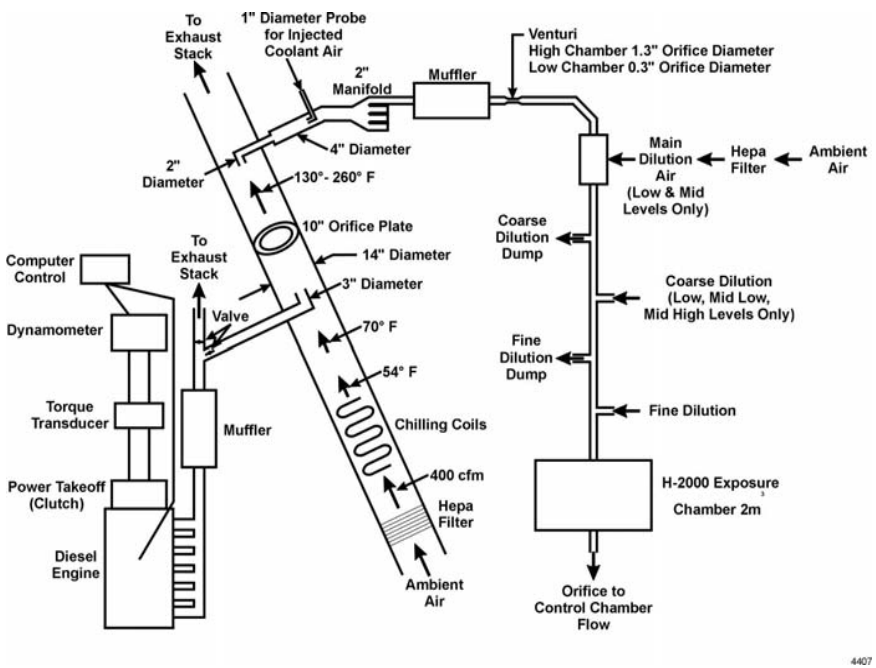
Working up data and papers

Gasoline Emissions

Exposures underway

“CONTEMPORARY” DIESEL EMISSIONS

(Now a “Baseline” for “Clean Diesel”)



<u>2000</u> Cummins 5.9L ISB 6 cyl. Turbo

D-2 Cert. Fuel (370 ppm S, 29% aromatics)

Shell Rotella-T® 15W-40 crankcase oil

Stock exhaust system with muffler

Repeated heavy-duty certification cycle

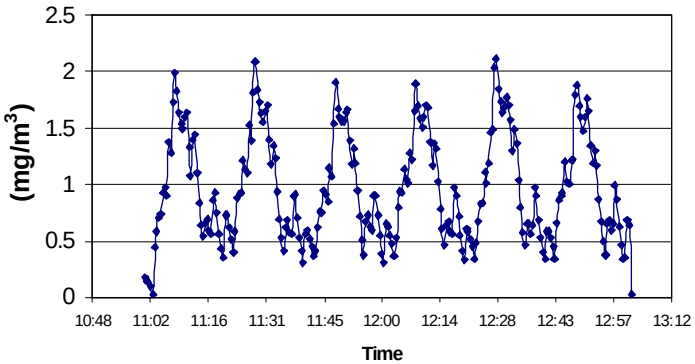
Cold start excluded

Emissions diluted with carbon- and HEPA-filtered air

Expose at 1000, 300, 100, 30, 0 µg PM/m³

(dilutions ≈ 1:10 to 1:300)

PM Concentration in High Level Chamber During Multiple Cycles



HARDWOOD SMOKE

Uncertified heating stove (Pineridge, 2 ft^2)

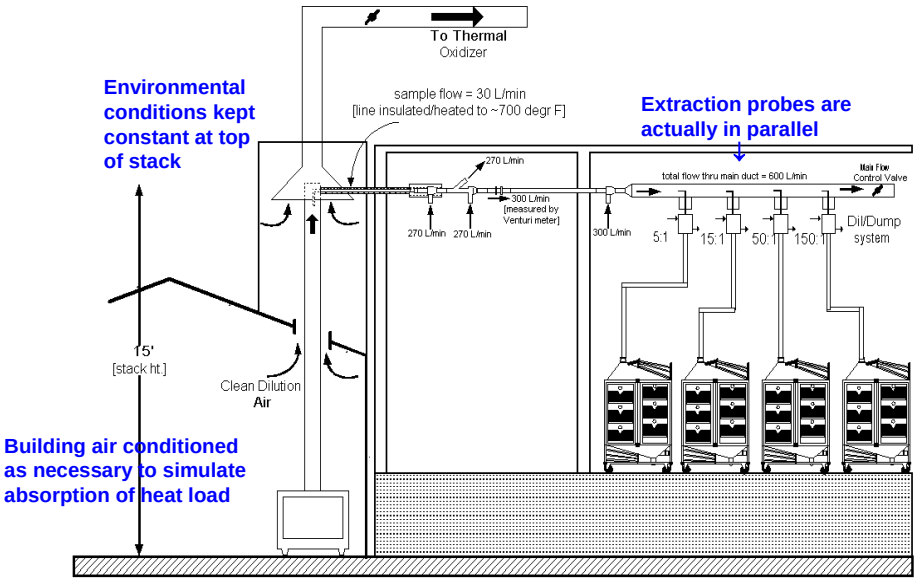
Scaled room air conditioned to absorb heat load

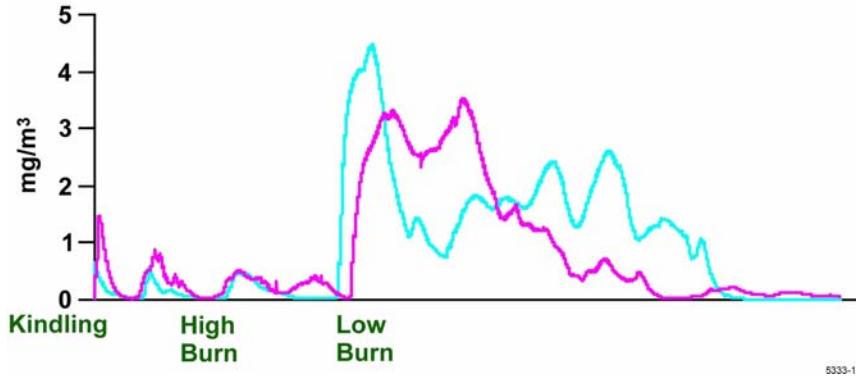
Oak from Missouri at 20% moisture

15 ft (4.6 m) stack with constant draft conditions

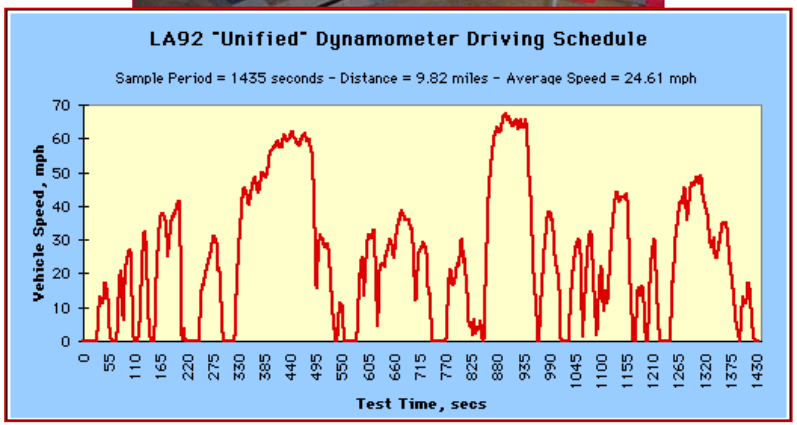
3-phase burn cycle

Exposed at same PM mass concentration as diesel (dilutions ≈ 1:300 to 1:9000)





GASOLINE EMISSIONS



Exposures began on October 18

1996 4.3 L General Motors V-6 engines

- 3 in-use Chevrolet S-10 pickup trucks
- Mid-range mileage (40-70k miles)
- Normal emissions

(California) Unified Driving Cycle

- 3-phase cycle mapped from chassis dynamometer and modified for continuous use on engine stand
- Use 2 engines for 2 cold starts/day

Gasoline blended to 2002 U.S. national average regular unleaded

- No added oxygenates
- Reid vapor pressure =10.3 psia
- 275 ppm sulfur, 30% aromatics

Pennzoil® multi-grade oil

AC Delco Duraguard® filters

Exposures at dilutions of ~12:1 (including filtered atmosphere at this dilution), 20:1, and 110:1

- PM ≈ 60, 30 & 7 μg/m^3
- NOx ≈ 19, 12 & 2 ppm

PAVED ROAD DUST

$PM_{2.5}$ fraction of re-suspended dust collected from road surfaces

Collecting dust for pilot study

- **Determine range of composition and acute toxicity**
- **Determine strategy for main study material**

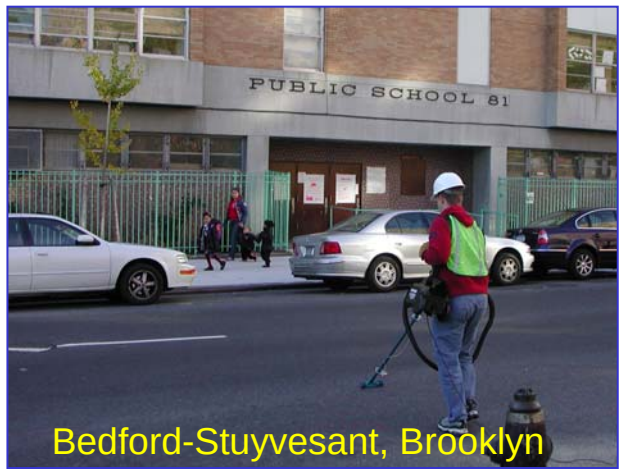
Main study to begin in late 2005

Mid-town Manhattan

46 Expressway, Totowa NJ

Residential near refinery, El Paso

Suburban Paramus NJ



Bedford-Stuyvesant, Brooklyn

Albuquerque Truck Stop

COAL COMBUSTION EMISSIONS

Obviously an important source type to study

- Different composition from other "mixtures"
- Considerable controversy in absence of much data
- Selecting exposure scenario is challenging

We first conducted a literature review (commissioned by NETL)

"*Feasibility of Approaches for Generating Inhalation Exposures to Coal Combustion Emissions for Toxicological Studies to Simulate Exposures of Populations*" (August 2003)

Only 2 studies plausibly relevant to the issue:

Kirchner et al. (1980)

- Fluidized bed emissions at 15,000 and 25,000 µg ash/m^3
- Exposed mice up to 1000 hrs
- Some health effects, but never published in detail

Chen et al. (1990)

- Drop-tube furnace emissions at 6,000 µg PM/m^3
- Exposed guinea pigs for 2 hrs
- Reported slight changes in respiratory function

Grant DE-FC26-05NT42304

- 3-year project period: 2/3/05 – 1/31/08
- Signed on 2/15/05
- Project has two phases (budget periods):

Phase 1: 2/3/05 – 5 31/06		$510,280 (50% of costs)
Phase 2: 6/1/06 – 1/31/08		$449,756 (20% of costs)
	Total	$960,036 (29.4% of costs)

Actual project costs are estimated at $3,269,342

Phase 1

Task 1: Assemble drop-tube furnace and emissions modification system

Task 2: Conduct iterative generation/modification trials using PRB coal

Task 3: Conduct generation trials using low-sulfur Appalachian coal

Task 4: Summarize experience and propose strategy for animal exposures

Phase 2

Task 1: Set up and test multi-level inhalation exposure system

Task 2: Conduct animal exposures

Task 3: Conduct health measurements and analyze data

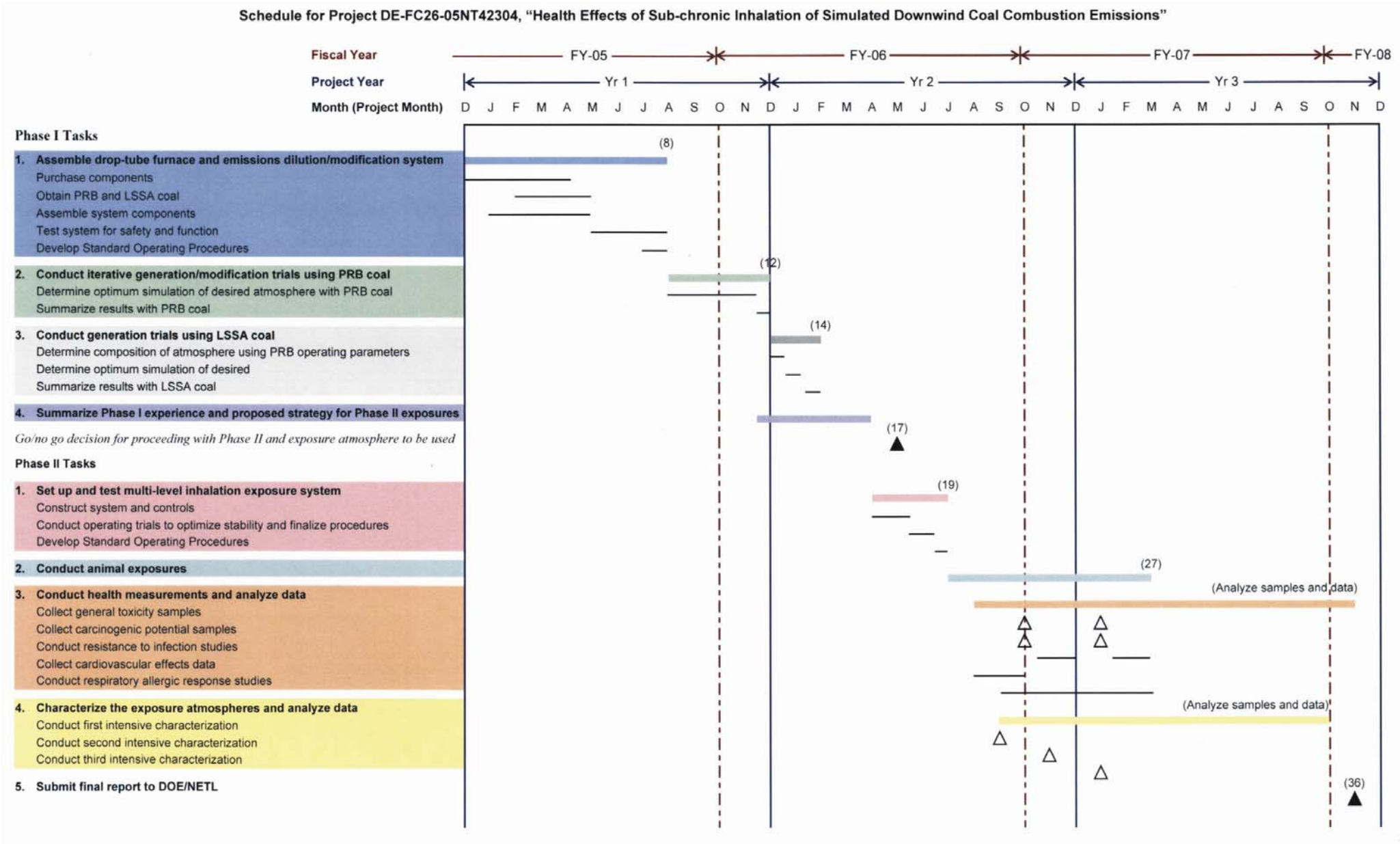
Task 4: Characterize exposure atmospheres and analyze data

Task 5: Submit final report to NETL

SUMMARY SCHEDULE

11/04 – 1/05	Visit EERC and EPA, finalize design and order components
2/04 – 8/05	Assemble & test generation/modification system
8/05 – 12/05	Generation trials with PRB coal
12/05 – 2/06	Generation trials with low-sulfur Appalachian coal
3/06	Summarize results & propose approach for subchronic study
5/06	Decision on approach for subchronic study
4/06 – 7/06	Develop & test subchronic exposure system
7/06 – 3/07	Conduct subchronic exposures
11/07	Complete analysis of results

DETAILED SCHEDULE



WE CONSULTED WITH SEVERAL GROUPS TO DEVELOP A "STRAW MAN" STRATEGY

- **Adel Sarofim (U. Utah): Visited LRRI**
- **We visited:**

  EPA/ORD coal combustion group (Linak/Miller)

  U. Utah coal combustion group (Lighty/Sarofim)

  Reaction Engineering Intl. (Davis)

  New York University (Chen)

  UND/EERC (Benson et al.)
- **We had discussions with:**

  Yost Wendt, U. Arizona

  Larry Monroe and John Jansen, Southern Co.

  Constance Sioutas, Univ. Southern Calif.

WE PROPOSED USING MODIFIED EMISSIONS FROM COMBUSTING PRB COAL IN A DROP-TUBE FURNACE

Coal type

- Wanted to use coal among the lower sulfur types
- Powder River Basin (PRB) coals have large and growing market share

Alternative approaches to generating exposure atmosphere

1. Start by resuspending collected ash (e.g. Wendt et al)
   - Collect from large pilot or full scale combustor
   - Lose gas phase and PM size characteristics
2. Start by burning coal in a lab-scale combustor (e.g. Chen et al, 1990)
   - Retain gas phase and PM characteristics (size)
   - May not adequately represent chemical speciation in full scale combustor

Regardless of initial approach, the final exposure atmosphere will have to be modified from starting material

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WE CONDUCTED A PEER WORKSHOP TO EXPLORE APPROACHES FOR THE EXPOSURES

Feb. 27-28, 2003

Bill Aljoe	DOE/National Energy Technology Laboratory
Steve Benson	EERC, University of North Dakota
Lung-Chi Chen	New York University
Paul Chu	Electric Power Research Institute
Tom Grahame	DOE/Fossil Energy HQ
John Jansen	Southern Co.
JoAnn Lighty	University of Utah
Bill Linak	EPA
Jim Meagher	NOAA Aerometry Laboratory
Bruce Miller	Pennsylvania State University
Larry Monroe	Southern Co.
Niki Nicholas	Tennessee Valley Authority
Annette Rohr	Electric Power Research Institute
Roger Tanner	Tennessee Valley Authority
John Watson	Desert Research Institute

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WORKSHOP CONSENSUS RECOMMENDATIONS

1. **Recommended simulating "mid-distant" downwind exposure to emissions from coal-fired power plant, and key reaction products**

   Avoid fresh "top of stack" exposure

   Can not simulate all atmospheric reactions; focus on key components

2. **Provided Consensus "recipe" of key composition targets:**

   Sulfate to ash PM ratio

   SO_2:SO_4 molar ratio

   Total S:NO_y molar ratio

   Cut PM size to respirable range

   Carbon content of ash

   Ratios of N species (NO_y)

   Don't bother with "secondary" products

   Measure, but don't manipulate, Hg

3. **Recommended exploring utility of two coal types**

   Coals employed in high-volume for power generation

   - Powder River Basin subbituminous
   - Low-sulfur Central Appalachian bituminous

4. **Did not come to consensus on starting point for exposure atmosphere**

   Nearly equally split between resuspending ash and burning coal

   All agreed that a useful study could be done either way

NERC ESAC unanimously advised starting by burning coal

COMPOSITION TARGETS FOR EXPOSURE

1. **Use same PM mass concentrations as in first two exposures**

   1000, 300, 100, 30, and 0 $\mu g/m^3$

2. **Resulting target mass concentrations):**

   Sulfate to ash PM ratio ≈ 100:1

   990 $\mu g/m^3$: 9.9 $\mu g/m^3$

   Carbon content of ash ≈ 5-10%

   1 $\mu g/m^3$

   SO_2:SO_4 molar ratio ≈ 1:1

   660 $\mu g/m^3$ (0.2 ppm) : 990 $\mu g/m^3$

   N species (NO_y): 20% NO, 55% NO_2, 15% HNO_3, 10% PAN

   Total S:NO_y molar ratio ≈ 2:1

   NO=1155 $\mu g/m^3$ (0.6ppm), NO_2=420 $\mu g/m^3$ (0.3 ppm),

   HNO_3=315 $\mu g/m^3$(0.1 ppm), PAN=21 $\mu g/m^3$(0.004 ppm)

   Don't bother with O_3 or other "secondary" reaction products

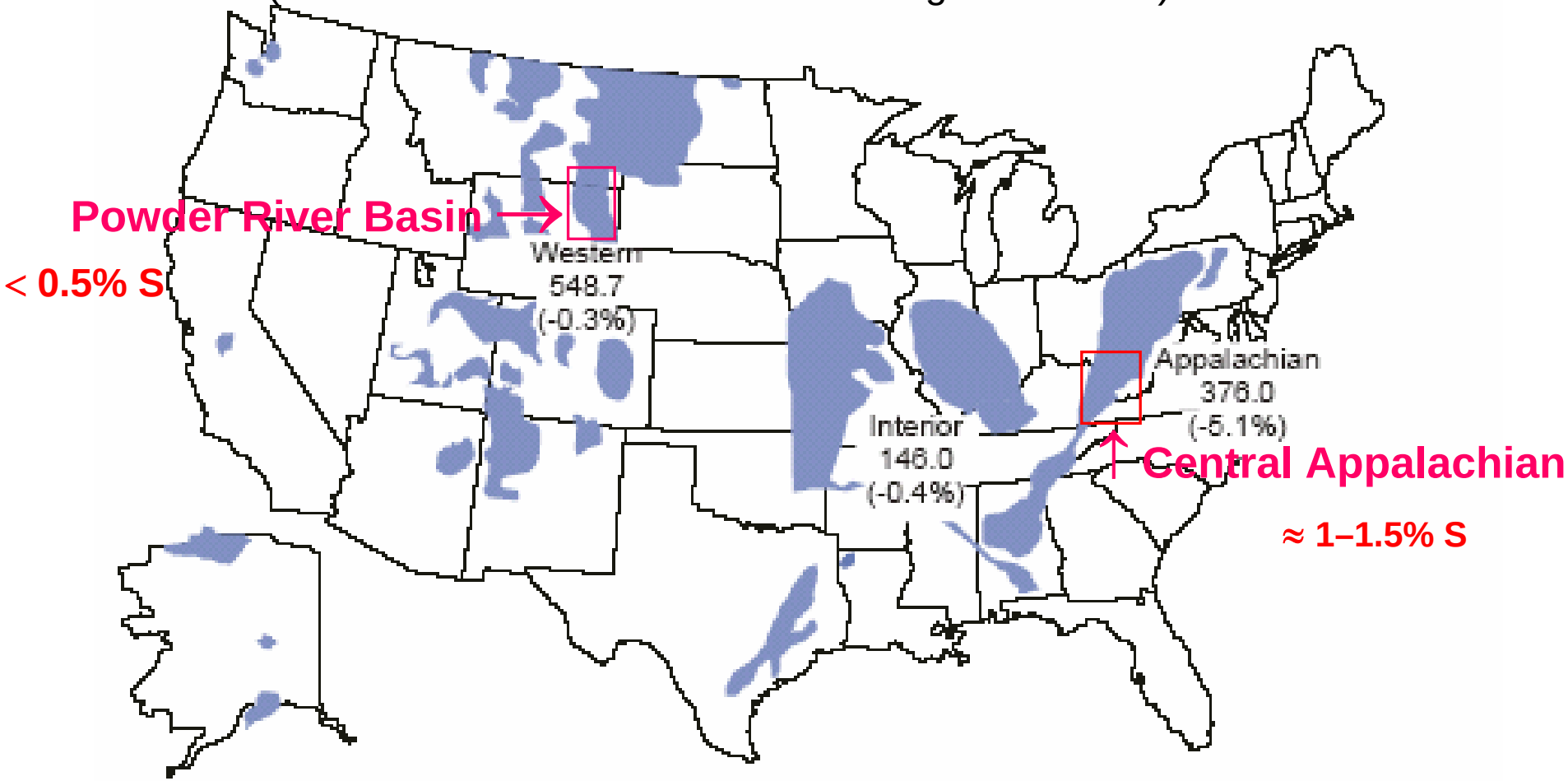
   Delete PAN

   Cut PM size to range respirable by rodents

   ≈ $PM_{2.5}$

SELECTION OF COAL TYPES: REGION

Coal Production by Region, 2003
(Million Short Tons and Percent Change from 2002)



Source: Energy Information Administration, "Annual Coal Report 2003", Table 1; DOE/EIA-0584(2003) (Washington, D.C., September 2004).

Percent of 2003 U.S. production:

Wyoming = 35%

Central Appalachia (eastern KY, southern WVA) = 18%

SELECTION OF COAL TYPES: COAL BED

Table 5. Coal Production and Coalbed Thickness by Major Coalbeds [a]

Coalbed ID Number[1]	Coalbed Name	Production (thousand short tons) Underground	Surface	Total
1699	Wyodak	-	320,551	320,551
0036	Pittsburgh	74,417	2,994	77,411
0489	No. 9	31,387	10,404	41,791
1569	Beulah-Zap	-	28,838	28,838
1697	Canyon	-	27,861	27,861
0111	Hazard No. 5-A	6,333	19,908	26,241
0151	Upper Elkhorn No. 3	16,660	4,483	21,143
0484	Herrin (Illinois No. 6)	15,192	4,337	19,529
0103	Stockton-Lewiston	5,919	12,754	18,673
0084	Lower Kittanning	8,335	9,897	18,232
1808	Rosebud	-	16,978	16,978
0135	Hazard No. 4	9,262	5,797	15,059
1787	Roland	-	14,948	14,948
1696	Anderson-Dietz 1-Dietz 2	-	14,316	14,316
0176	Eagle	12,398	1,392	13,790
0168	Pond Creek	11,073	1,128	12,201
0344	Pocahontas No. 3	9,857	-	9,857
1755	D	9,540	-	9,540
0142	Williamson (Amburgy)	7,137	2,340	9,477
1750	Wadge	8,029	1,253	9,282
0071	Upper Freeport	5,858	3,264	9,121
0480	No. 7	3,421	5,612	9,033
1753	Somerset B	8,928	-	8,928
1488	Fruitland No. 8	5,890	2,911	8,802
0483	Hymera (Indiana No. VI)	-	8,547	8,547
Major Coalbeds Total		**249,634**	**520,514**	**770,149**
Other Coalbeds		**102,942**	**196,881**	**299,823**
Unknown[3]		**209**	**475**	**1,781**
U.S. Total		**352,785**	**717,870**	**1,071,753**

PRB

Eastern Kentucky

Southern West Virginia

Now identifying bed and seam having most appropriate characteristics

From: Annual Coal Report, DOE/EIA 0584 (2003)

SELECTION OF COAL TYPES: COUNTY

Thousand Short Tons, 2003

Central Appalachian

Eastern Kentucky

Pike	27,547
Perry	12,405
Harlan	10,548
Knott	10,201

Southwest West Virginia

Boone	30,308
Kanahwa	16,613
Mingo	13,976
Logan	10,537

Powder River Basin

Wyoming

Campbell	333,827
Converse	29,533

Given acceptable characteristics, we want counties and mines representing highest volumes

From: Annual Coal Report, DOE/EIA 0584 (2003)

Lovelace

SELECTION OF COAL TYPES: MINE

Example: Powder River Basin

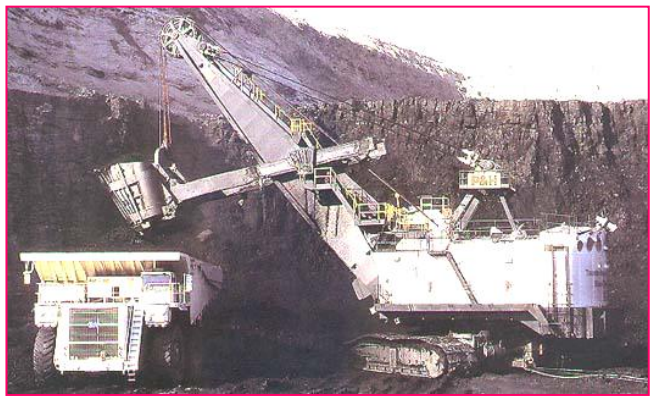
Black Thunder Mine, Wright, Campbell County, WY

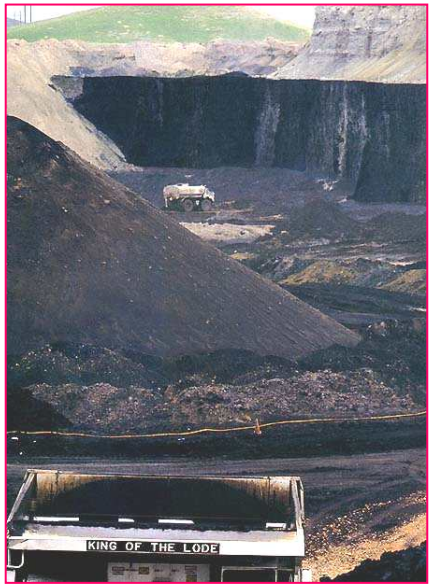
"Typical PRB combustion characteristics" (EERC)

Second largest producing mine in basin

General characteristics:

- 0.3% sulfur
- 27% moisture
- 33% volatiles
- 35% fixed carbon
- 5% ash





(There will probably be sensitivities to naming specific mines in publications)

COAL PROCUREMENT AND PROCESSING

1. **Obtain new lot of coal at mine or delivery point in condition delivered for use in power plants**

   Currently working with EERC and Southern Co. on this

2. **Ship coal to EERC, where it will be pulverized as in their studies**

   They have agreed to do this

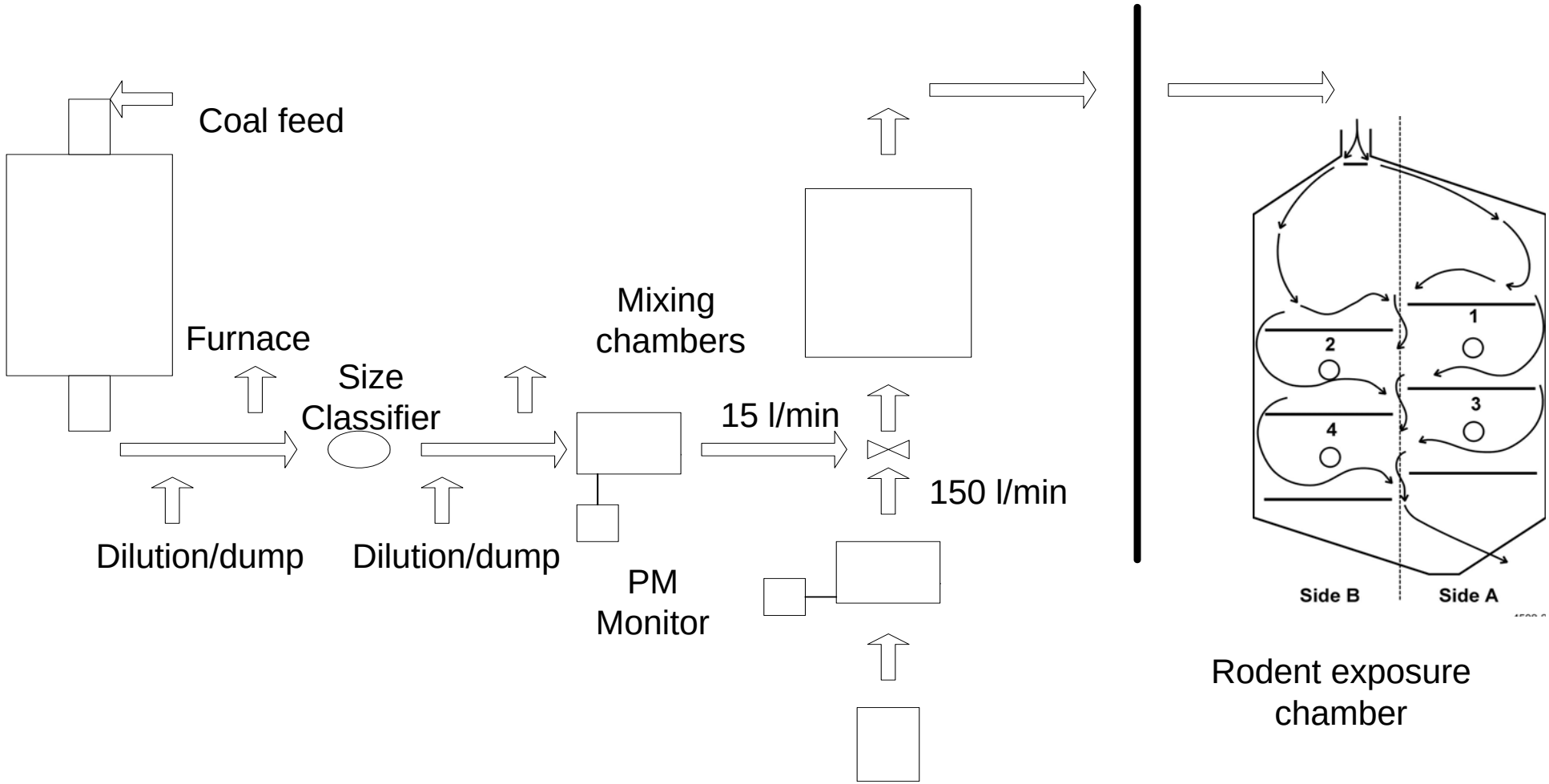
3. **Pulverized coal will be shipped to LRRI, where it will be stored under nitrogen**

   We will obtain and store the coals in amounts that will allow options for additional studies, eg.:

   - 6-month exposures to emissions from both coals
   - Short follow-on studies of specific responses
   - Sharing with other labs for bridging studies

Lovelace

CREATING THE EXPOSURE ATMOSPHERE



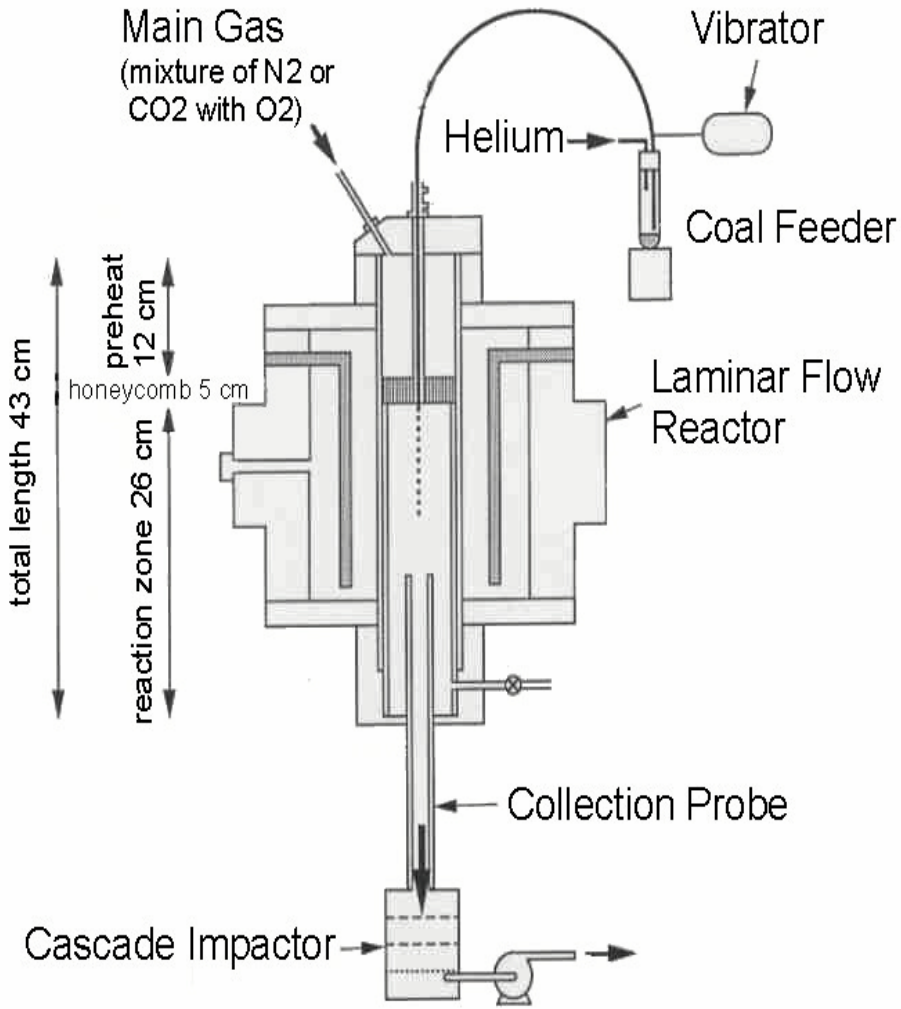
Ash diluted to 300 µg/m^3

Sulfate diluted to 3000 µg/m^3

Combined at 10:1 flow ratio

Gases metered in on separate lines

DROP-TUBE FURNACE DESIGN: MIT APPROACH

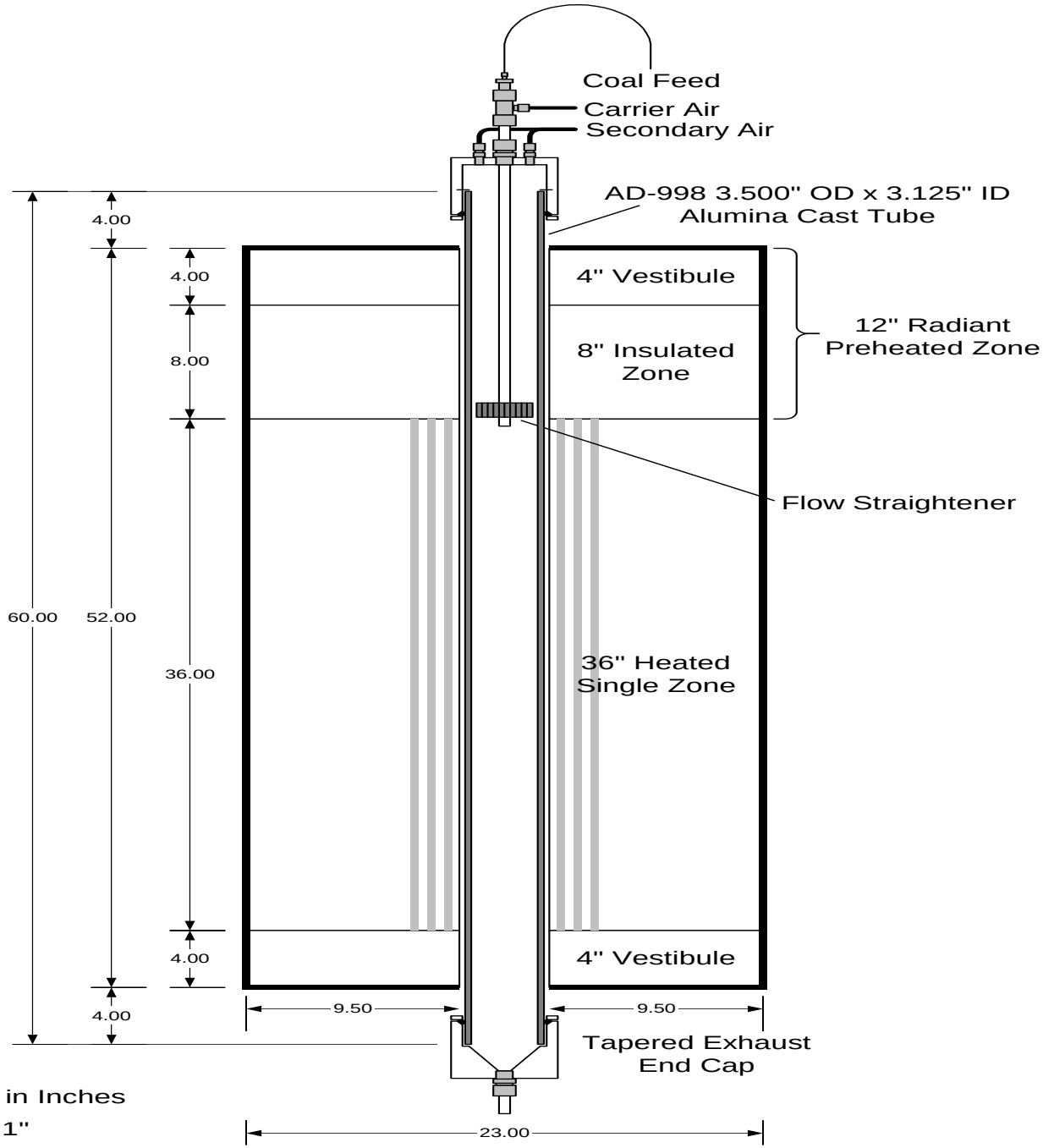


- **Fully assembled ≈ 9 ft. tall**
- **Dilute streams of coal are fed via a hypodermic needle.**
- **Particles are entrained by preheated gas and passed through the reaction zone.**
- **The feed rate of coal is approx. 0.05 gm/min**
- **The reaction zone is heated by a graphite element furnace.**
- **Temperature can range from 373 K to 1750 Kelvin.**

EPA APPROACH

Made improvements to coal feed system

LRRI DESIGN

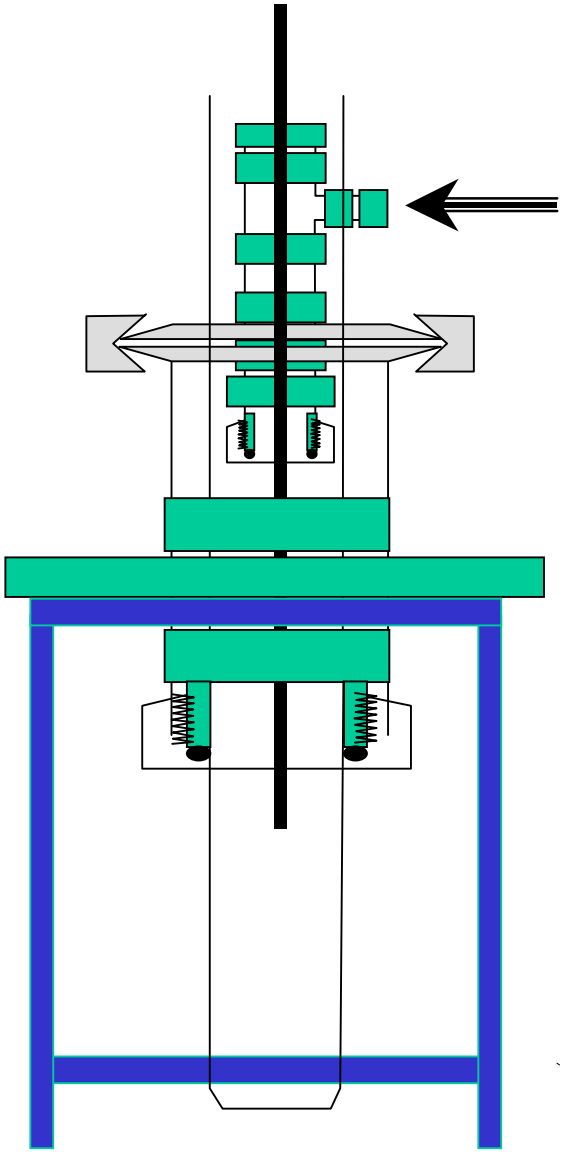


Dimensions in Inches

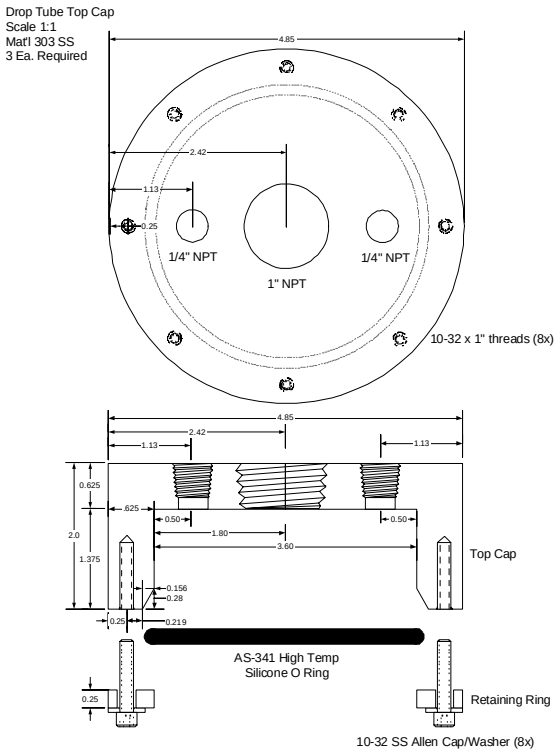
Scale 1/8" : 1"

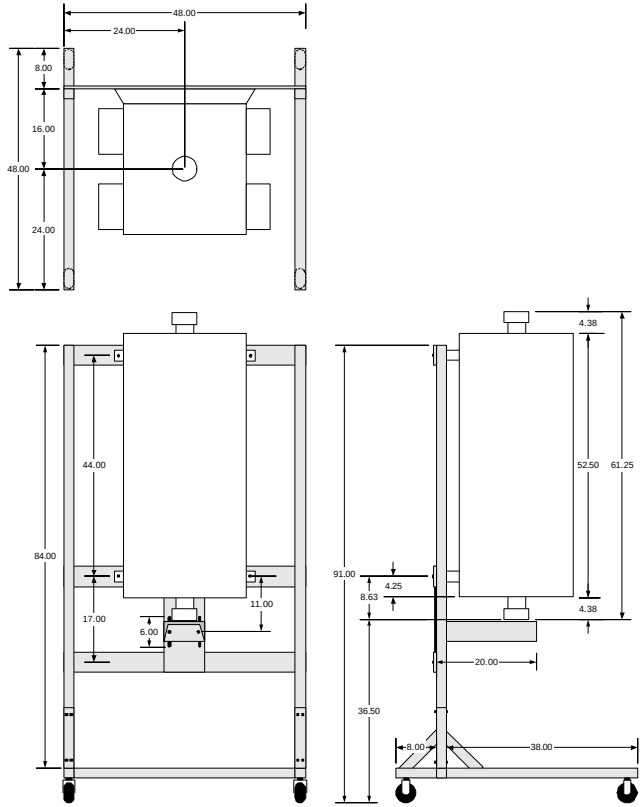
DETAILS OF COMPONENTS

Coal feed



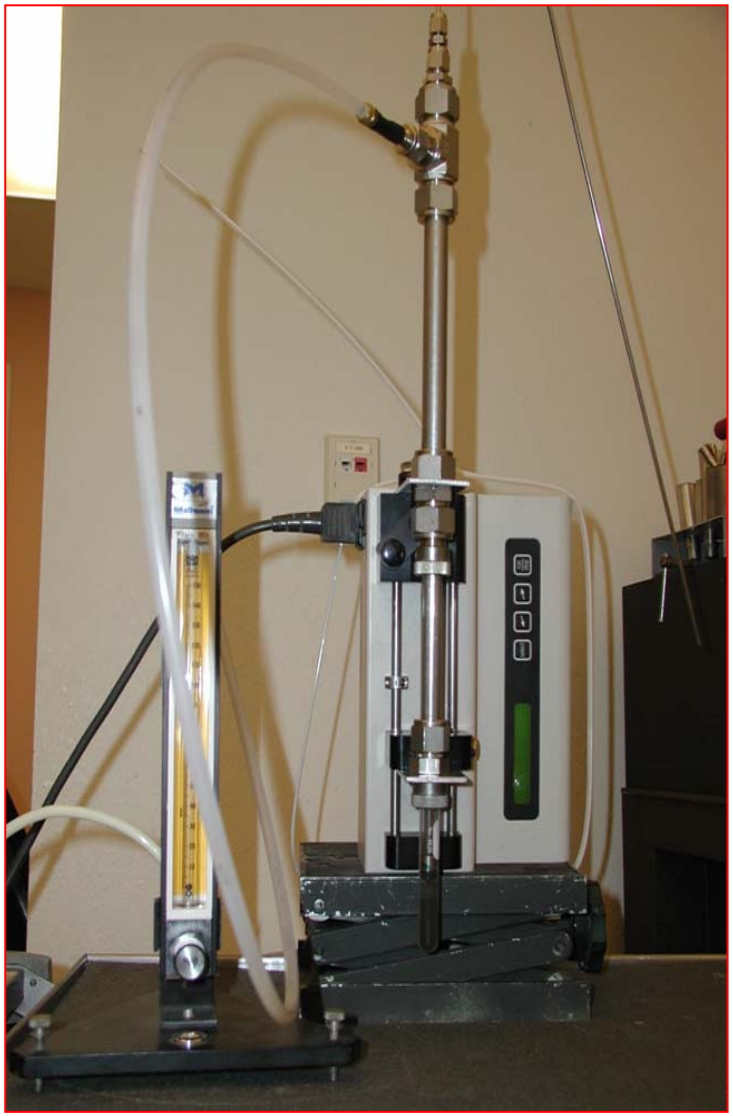
End Caps





Furnace Support

TESTING AND ASSEMBLY IS UNDERWAY



Coal feed being tested and refined

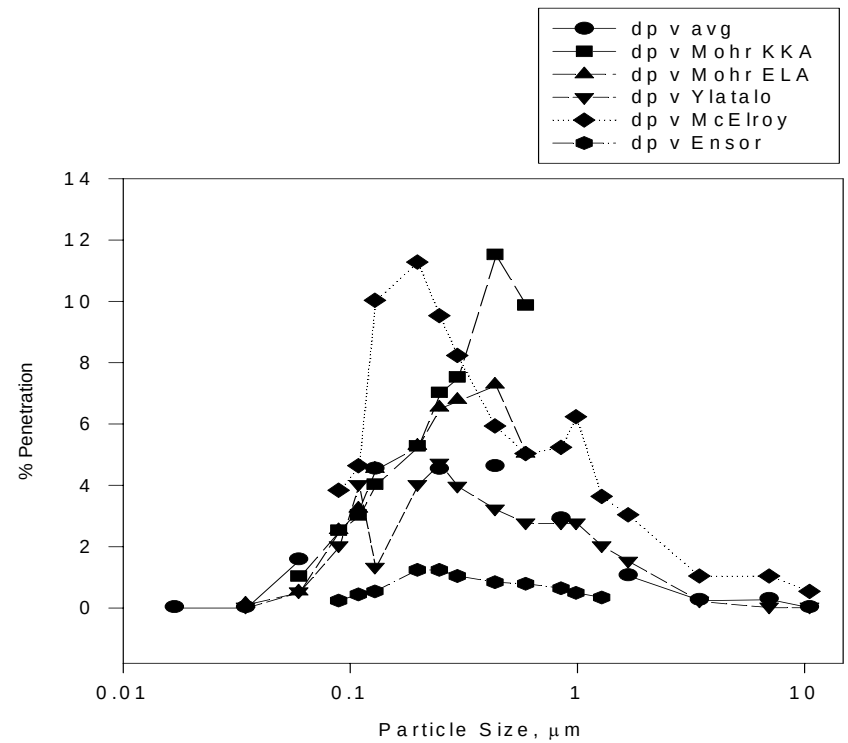
Furnace being mounted to support

MANIPULATION OF FURNACE EMISSIONS

- **Emissions will be chilled immediately using a heat exchanger to quench reactions**
- **The coarse particle fraction will be removed using an impactor (this fraction is efficiently removed by ESP in a full-scale unit)**

ESP Penetration for selected full-scale units

(Helble)



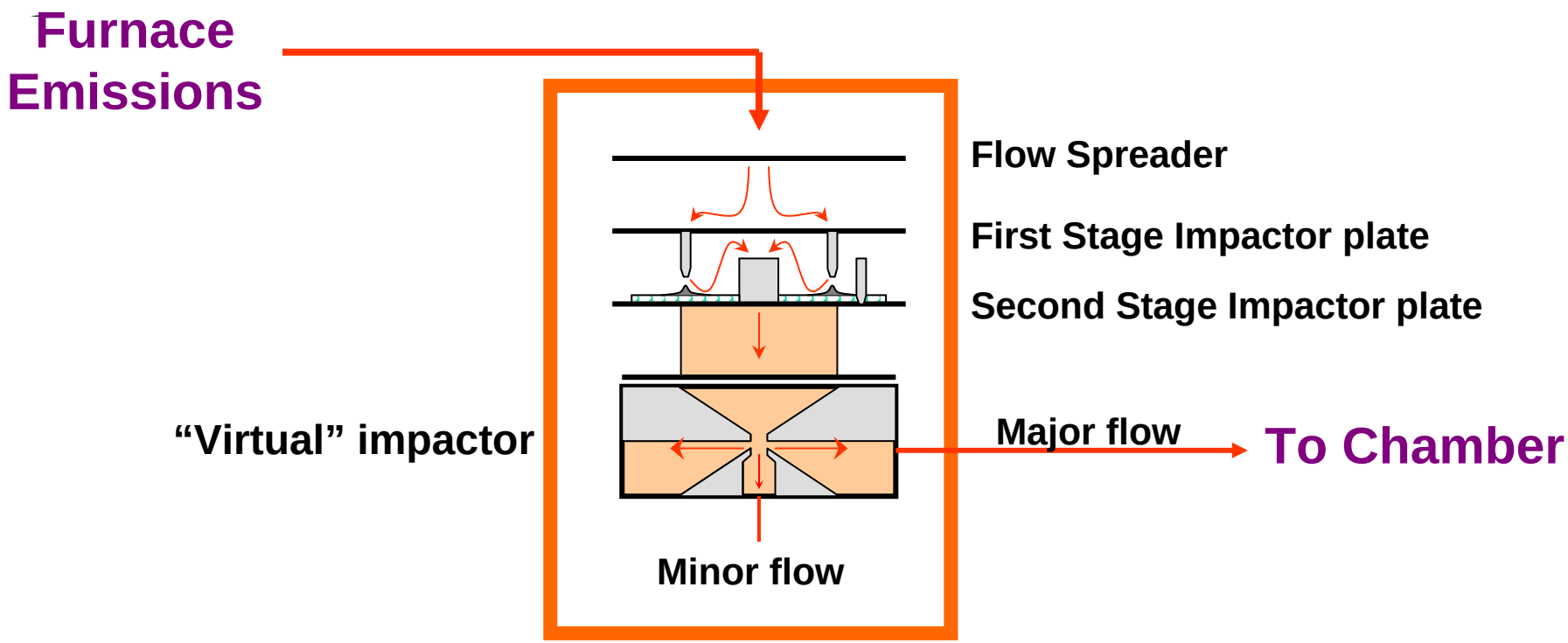
MODIFYING PM SIZE DISTRIBUTION

Option 1. Pilot scale ESP

Option 2. Pilot scale filter/bag house

PM removal by either option 1 or 2 may be too efficient on our small scale, depending on target concentrations.

Option 3. Impactor or other size selector



OTHER COMPONENTS

Sulfate and Ammonia

- Produce sulfate aerosol using Lemar-Sinclair generator
  - Particle size will be engineered to be biomodal.
- Animals will produce NH_3 in chambers
  - ~100-200 µg/m^3 (0.1-0.3 ppm)
- NH_4SO_4 will be formed
  - Workshop recommended having some neutralized sulfate, but keeping atmosphere acidic (~50 %). This can be accomplished without adding NH_3

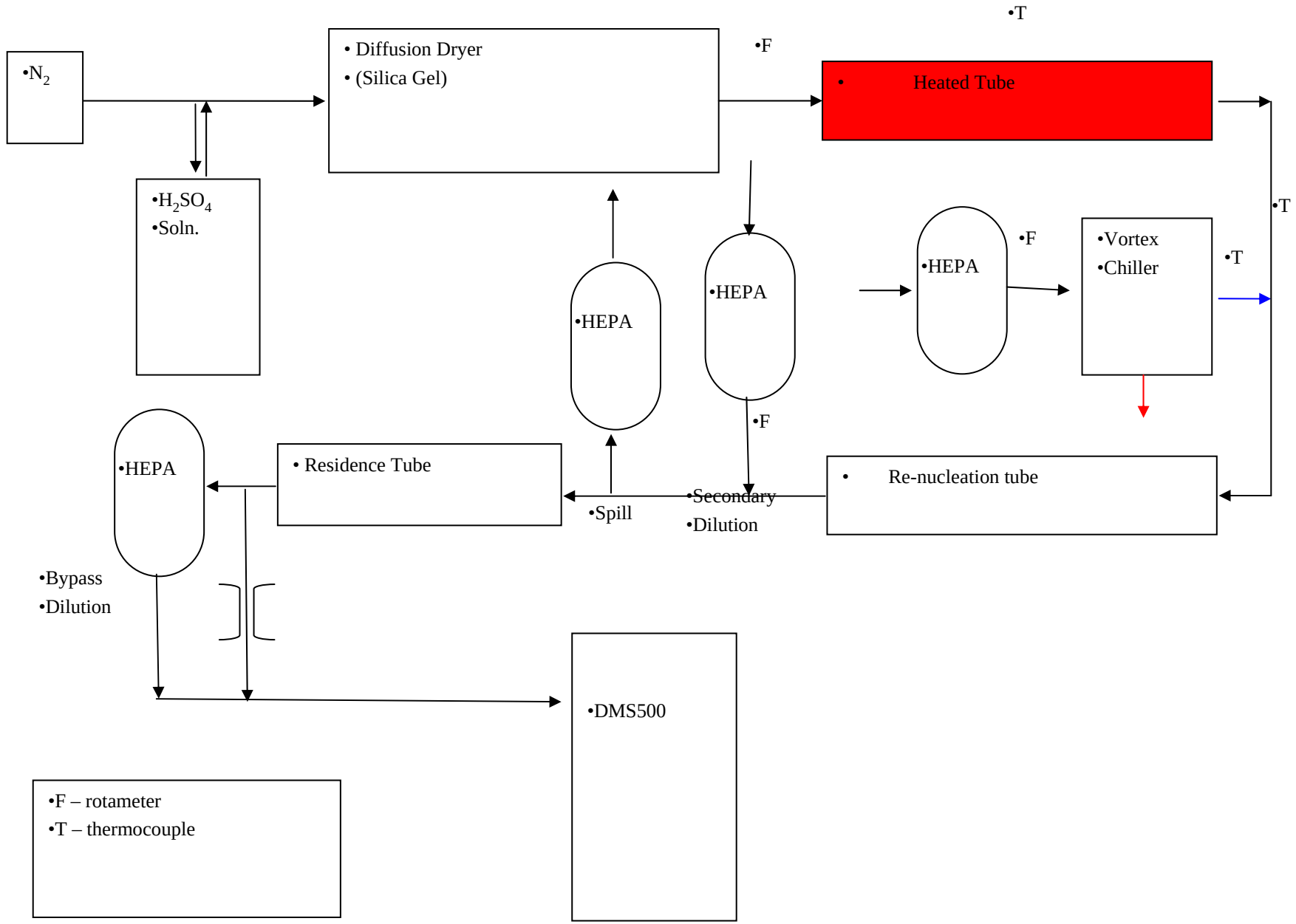
SO_2

- Regulate from Gas Cylinders

NO_y

- NO, NO_2: Regulate from Gas Cylinders
- HNO_3: Produce using Lemar-Sinclair generator or nebulizer
- PAN: Although identified as desirable, workshop participants agreed that it should be disregarded
  - Contribution very small
  - Very unstable to work with

SULFATE GENERATION



CHARACTERIZING THE EXPOSURES

Exposure characterization focuses on composition of atmosphere <u>in the animal chambers</u>

Periodic "intensive" characterization:

- **Include all analyses in protocol used for other NERC exposures**
- **Special consideration for metals:**
  - **Standard protocol limits analysis to PM-associated metals**
  - **This study will need to include speciation for Cr, Zn, As, Fe, and Hg, including metals in the vapor-phase**

Daily Monitoring (used for managing the exposures:

- **Real-time sulfate**
- **Particle mass concentration**
- **Particle size**
- **SO_2**
- **NOy**

BRIDGING BETWEEN NERC AND TERESA

Toxicological Evaluation of Realistic Emissions of Source Aerosols Application to Power Plant-Derived $PM_{2.5}$

- DOE Award DE-FC26-03NT41902
- Respiratory effects of transformed emissions from stack
- Completed work in Midwest, and moving to Southeast
- Measurements are complementary to those of NERC
  - Respiration during short, single exposure
  - Detection of immediate oxidative reactions in tissue

EPRI is funding LRRI to develop the chemiluminescence method and apply the "TERESA" exposures and measurements to several NERC exposure atmospheres

- We will do this for both PRB and LSCA coals during pilot stage
- Will also do lung lavage and histopathology

This will build an interpretive "bridge" between the two programs

SUMMARY

1. **We are well on our way toward accomplishing the work**

   On schedule so far

   Strategies are in place to continue on pace

2. **Conducting the work within the framework of NERC will provide considerable added value**

   Meticulous planning with broad consensus

   Highly leveraged funding

   Demonstrated capability

   Direct comparisons to other source emissions

   DOE/NETL partnership in moving "mixtures science" forward

3. **Advice is welcome**

   We are confident that we are on the right track