Nanoparticle Occupational Safety and Health (NOSH) Consortium

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DuPont Engineering Research and Technology

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Agenda

- Overview of Nanoparticle Occupational Safety and Health (NOSH) Consortium
- Consortium Goals and Objectives
  - Synthesis of well-characterized aerosol nanoparticles
  - Aerosol chamber studies to investigate
    - Aerosol behavior as a function of time
    - Interactions of aerosol nanoparticles with surfaces
  - Filter media barrier efficiency as a function of particle diameter and time
- Progress on Deliverables
- Publications

NOSH Consortium Timeline and Motivation

- 2003: DuPont Nanotechnology Safety Discovery Process
- 1Q2004: Benchmarking with P&G on NanoSHE Knowledge Gaps
- 2Q2004: Nanoparticle Occupational Safety and Health Proposal Defined and Launched; Founding Members = DuPont, P&G, Intel, Dow
  - Founding members selected common issues that focus upon providing knowledge and developing tools to help individual practitioners make better judgments on risks and controls for particular business situations
    - What is known about nanoparticles in the work environment?
    - What do we need to know in order to manage safely and effectively the technology within our businesses?
    - What engineering controls, work practices, and management systems are appropriate?
  - Broadly communicated and 30 organizations expressed “interest”
- 4Q2004: Project Peer Reviewed by Expert Panel
- 3Q2005: NOSH Consortium Formally Established

NOSH Consortium

16+ international organizations, including:

- DuPont
- Procter & Gamble
- Dow Chemical
- Intel Corporation
- Air Products & Chemicals, Inc.
- Degussa
- Rohm & Haas
- PPG
- GE
- Health & Safety Executive (UK)
- Environmental Defense
- NIOSH
- Department of Energy Office of Science

NOSH Leadership:

- Gordon Peters - P&G:
  - Consortium Chair
- Michele Ostraat - DuPont:
  - Technical Leader
  - Project Co-Leader
- Keith Swain - DuPont:
  - Project Co-Leader

NOSH Consortium

Common Issues

- Many companies and organizations are involved in similar aspects of nanotechnology

Expected Benefits

- Answers to key questions will benefit broad audience
- Goal is to determine best practices to protect all workers

Distribution of Results

- Findings will be distributed and published

Diversity

- Pool resources to improve opportunities for success
- Diverse group will provide wide spectrum of ideas and bring new perspectives to consortium

Credibility

- Process will be validated and peer reviewed

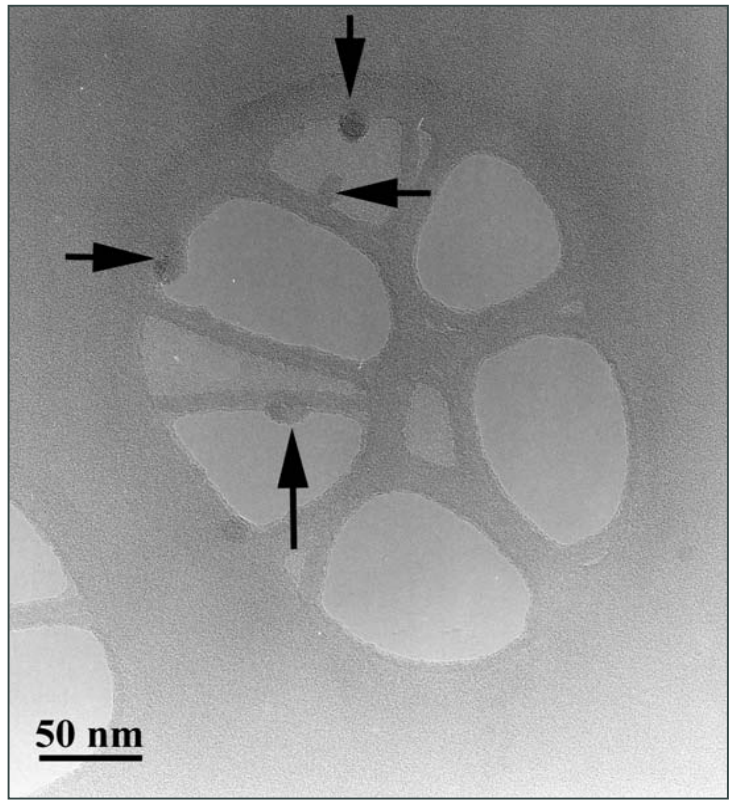
Goals and Scope of Deliverables

- **Deliverable 1:**
  - **Generate Well-Characterized Aerosol Nanoparticles of Various Chemistries**
  - **Evaluate Instrumentation to Measure Aerosol Nanoparticles**
  - **Characterize Aerosol Behavior as a Function of Time**
- **Deliverable 2:**
  - **Develop a Portable Air Sampling Method for Daily Monitoring of R&D and Manufacturing Settings**
- **Deliverable 3:**
  - **Measure Filtration and Barrier Efficiency of Filter Media to Specific Engineered Nanoparticles**

Deliverable 1: Aerosol Nanoparticles

- **Generate stable, well-characterized aerosols of solid nanoparticles**
  - **< 100 nm**
  - **TiO_2, SiO_2, TEOS@SiO_2, Ag, Citric Acid, PSL, Montmorillonite Clay**
- **Evaluate instrumentation to measure aerosol nanoparticles**
- **Characterize aerosol behavior as a function of time**
  - **Rate of dispersion**
  - **Rate of aggregation**
  - **Rate of particle loss**

SiO_2



Deliverable 2: Portable Air Sampler

- Objective:
  - Detect and measure aerosol nanoparticles
  - Classify based upon particle diameter
  - Monitor air quality for nanomaterials to evaluate workplace controls and determine their relative effectiveness

- Desired Features Include:
  - Low cost
  - Limited size resolution - 2 to 5 size bins < 100 nm
  - Simple to operate
    - Minimal training to collect and interpret data
    - Minimal maintenance
  - Robust and reliable in wide variety of operating environments
    - High/Low particle concentrations
    - Particle chemistry independent

Deliverable 3: Quantify Filtration Efficiencies

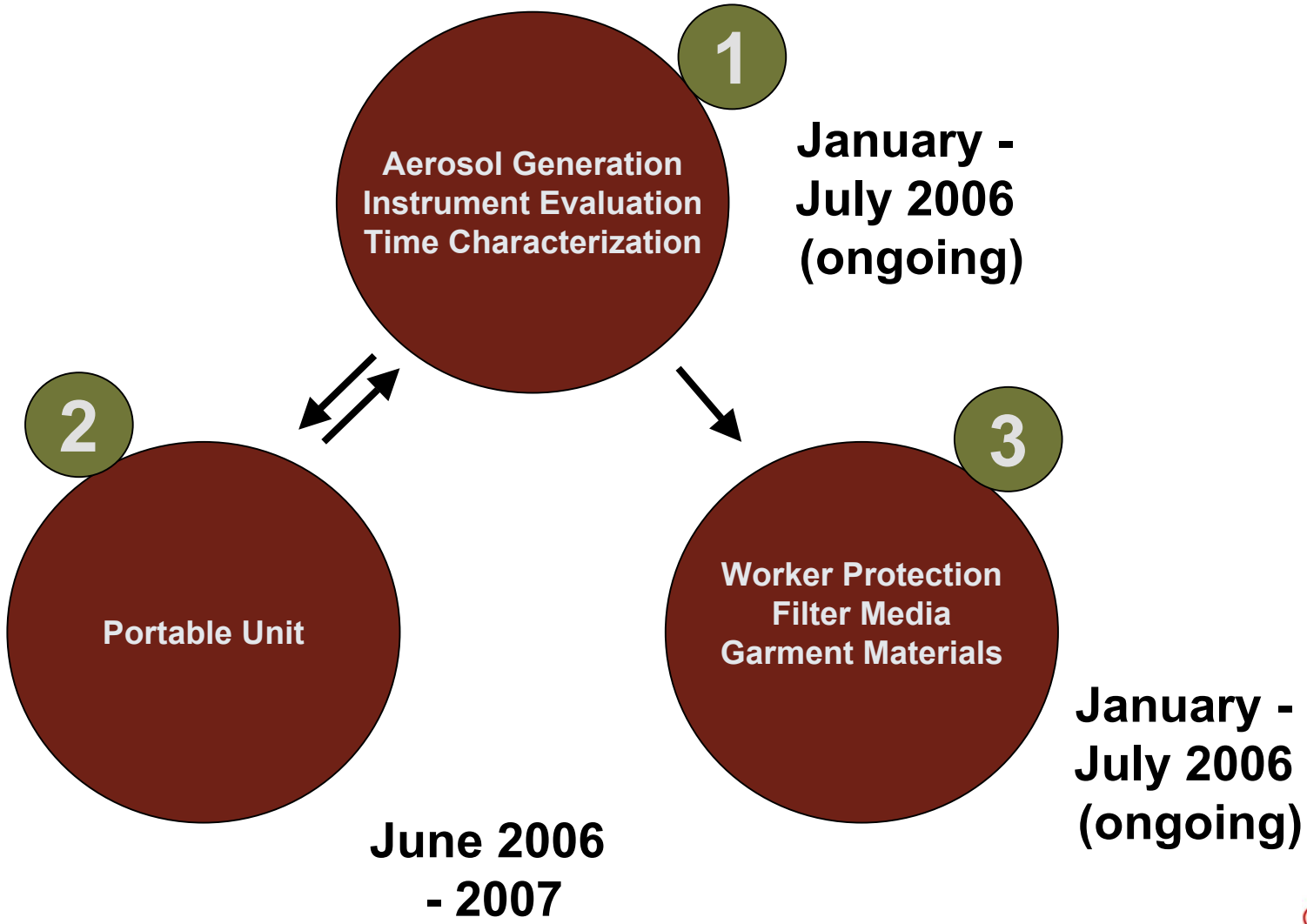
- **Measure interaction between aerosol nanoparticles and filter media**

- **Test penetration efficiency of nanoparticles to filter media**
  - Quantitate media filtering capability and characteristics to:
    - Specific engineered nanoparticles (< 100 nm)
    - Different surface chemistries
    - Exposure time
    - Particle size and size distribution
    - Charged and uncharged aerosol nanoparticles

Consortium Product and Goals

- Dissemination of all experimental conditions, protocols, and results
  - Aerosol synthesis
  - Commercial instrument evaluation
- Workshops
  - Instrument vendors to evaluate characterization equipment
  - Filter media vendors to evaluate filter media
- Consultation for additional testing
  - Studies with additional engineered nanoparticles
  - Examination of specific filter media
- The products of this research will help in the understanding of how to
  - Measure nanoparticle exposure in the workplace
  - Assess engineering controls
  - Monitor work practice effectiveness
- Creation of a fact-based workplace exposure analysis

Timing of Deliverables



Deliverable 1

- Generate Well-Characterized Aerosol Nanoparticles of Various Chemistries
- Evaluate Instrumentation to Measure Aerosol Nanoparticles
- Characterize Aerosol Behavior as a Function of Time

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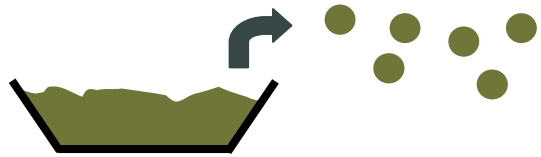
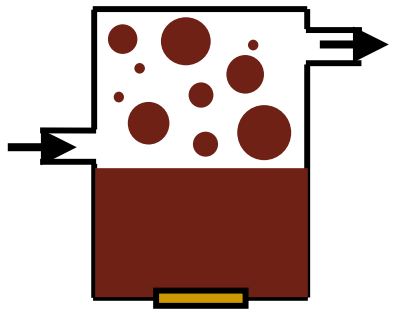
Aerosol Synthesis

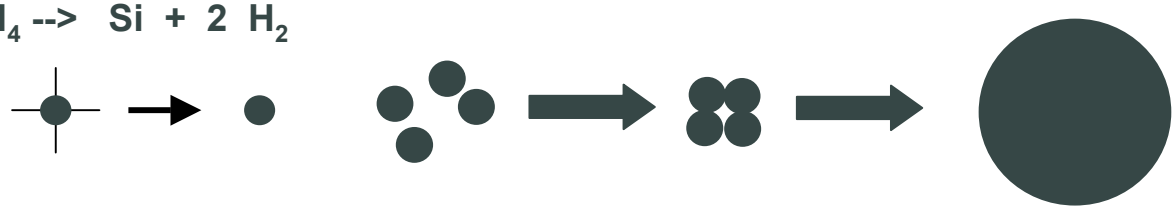
- *In Situ* Aerosol Generation Methods
  - Solid Precursors
    - Thermal Evaporation



  - Liquid Precursors
    - Spray Pyrolysis



  - Gas Precursors
    - Thermal Decomposition
      - SiH_4 --> Si + 2 H_2



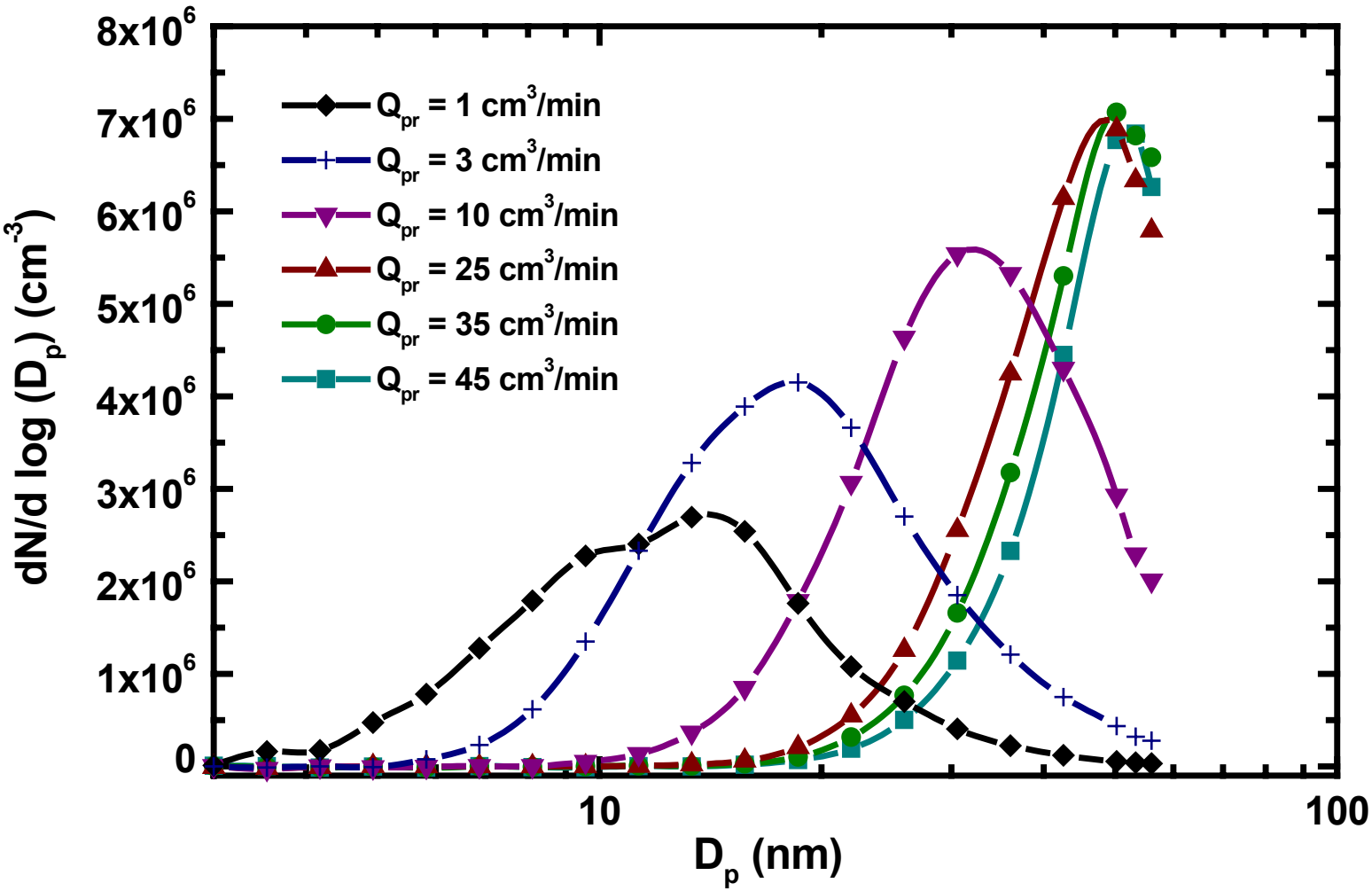
- Reaerosolization Generation Methods
  - Disperse material into gas - Montmorillonite clay

Aerosol Synthesis and Characterization: SiO_2

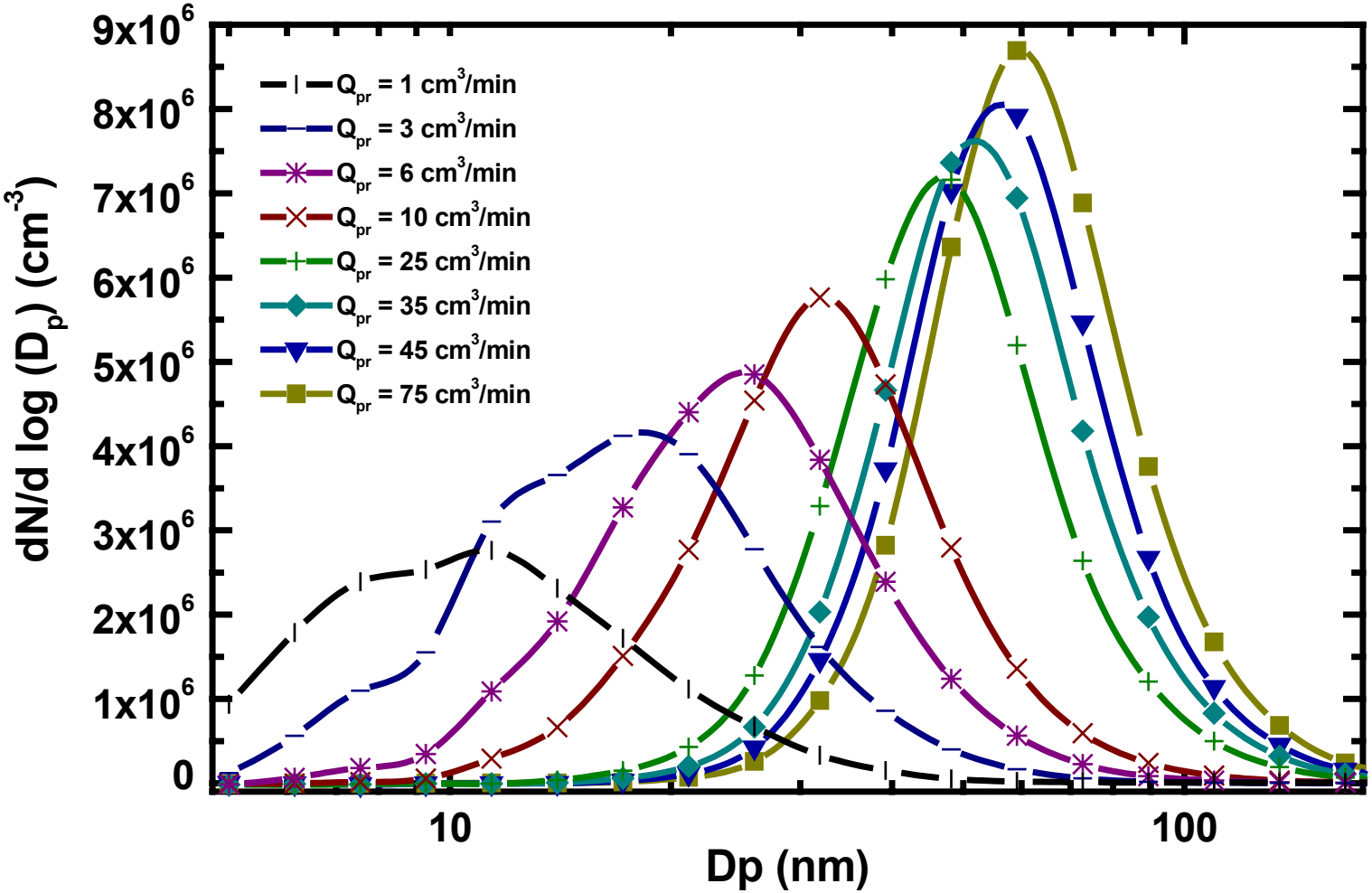
Nanoparticle Synthesis

Classification and Detection

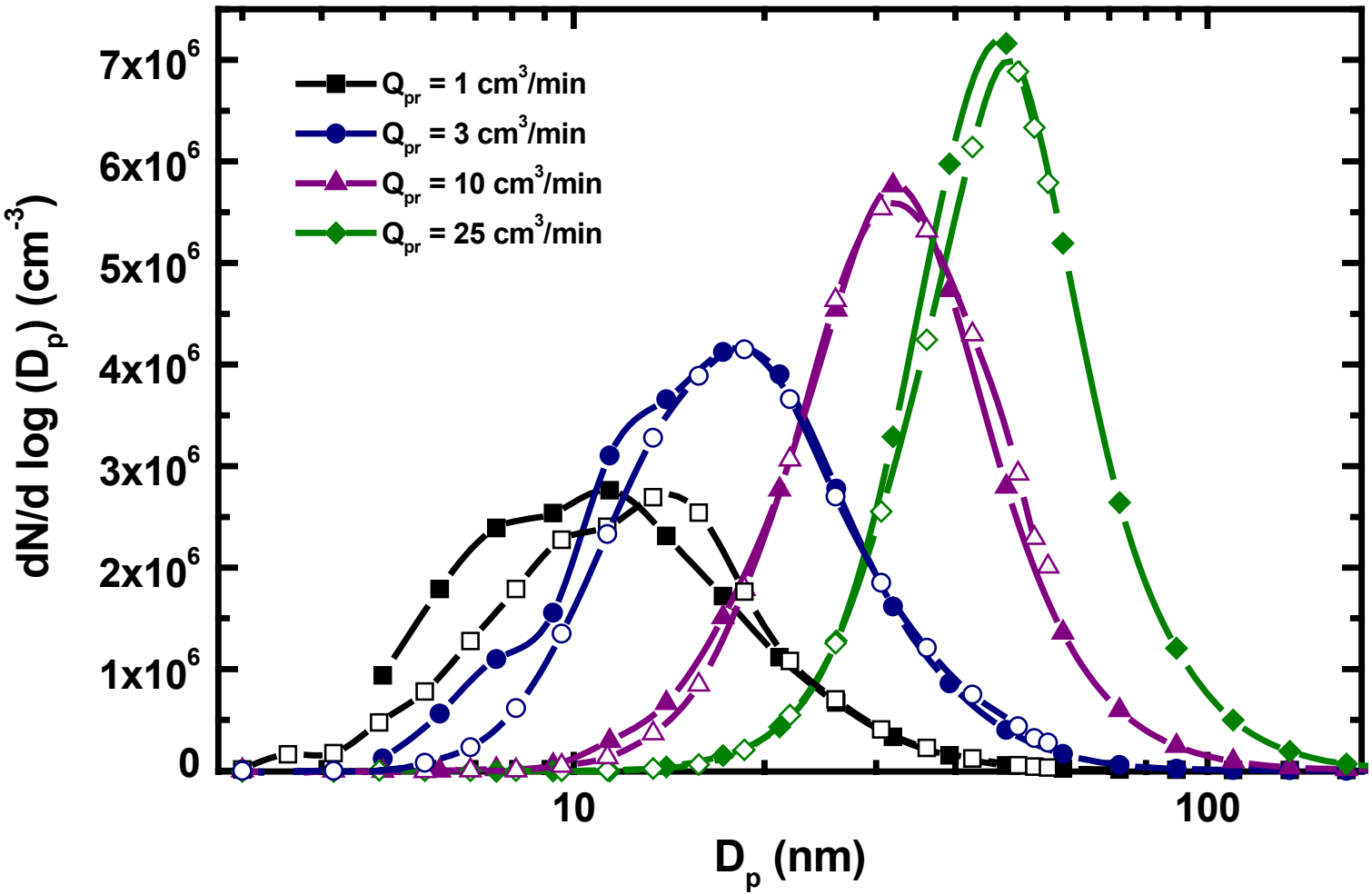
SiO_2 Aerosol Nanoparticles - Nano-DMA



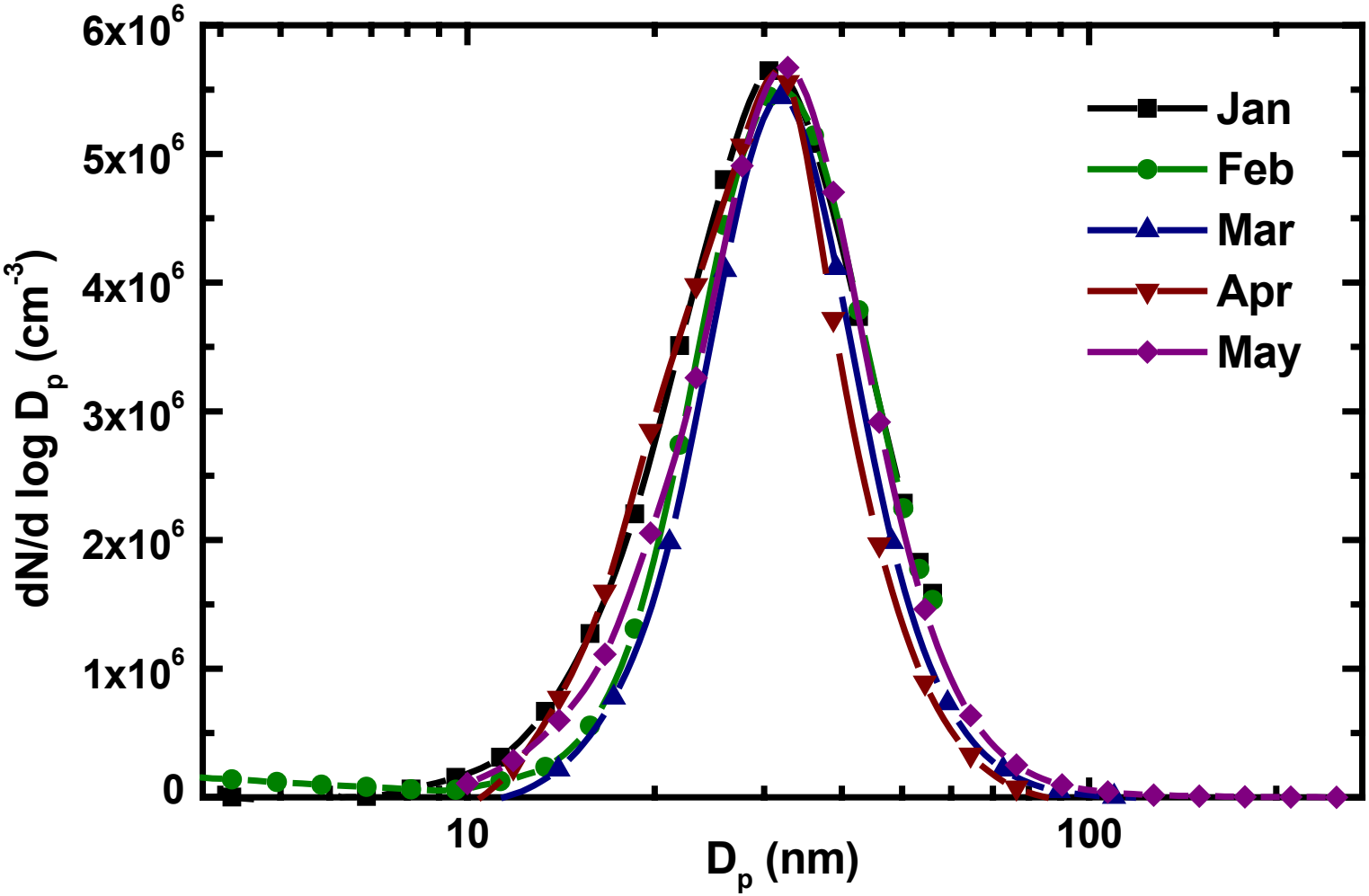
SiO_2 Aerosol Nanoparticles - Long-DMA



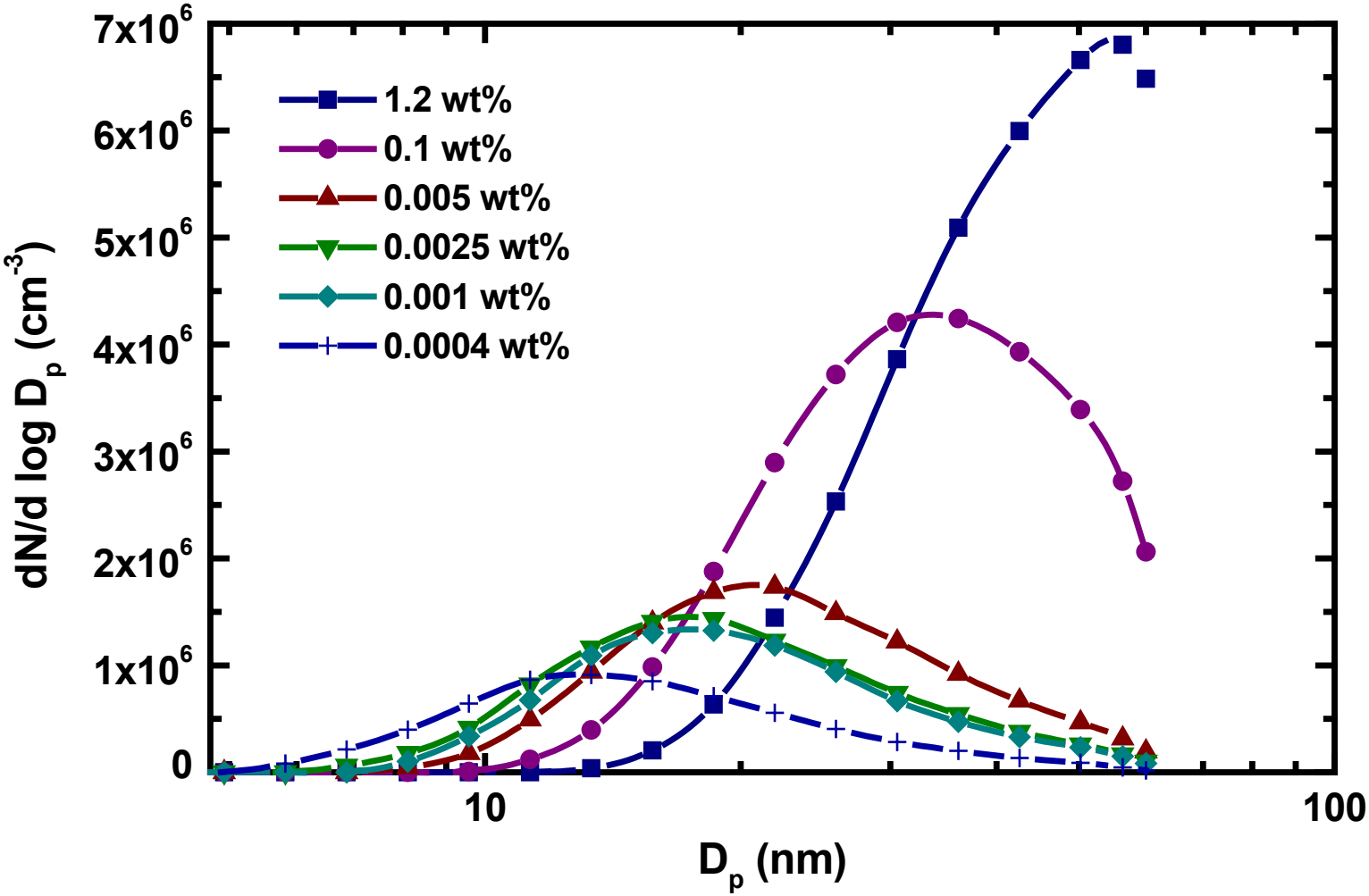
SiO_2 Aerosol Nanoparticles - Nano- and Long-DMA



Long Term Stability of Aerosol Nanoparticle Synthesis

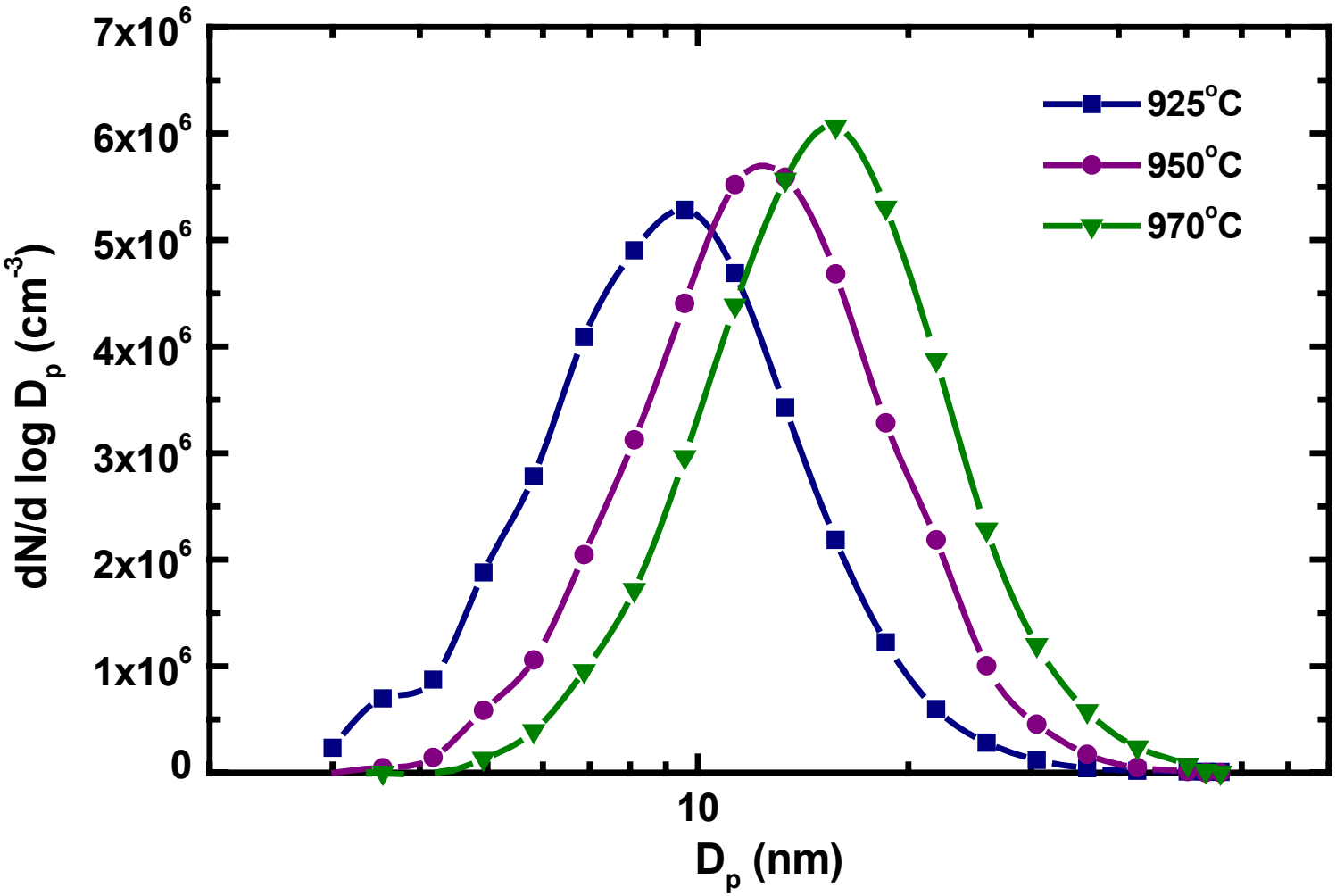


Citric Acid Aerosol Particle Size Distributions



Increase concentration to increase particle diameter and concentration

Silver Aerosol Particle Size Distributions

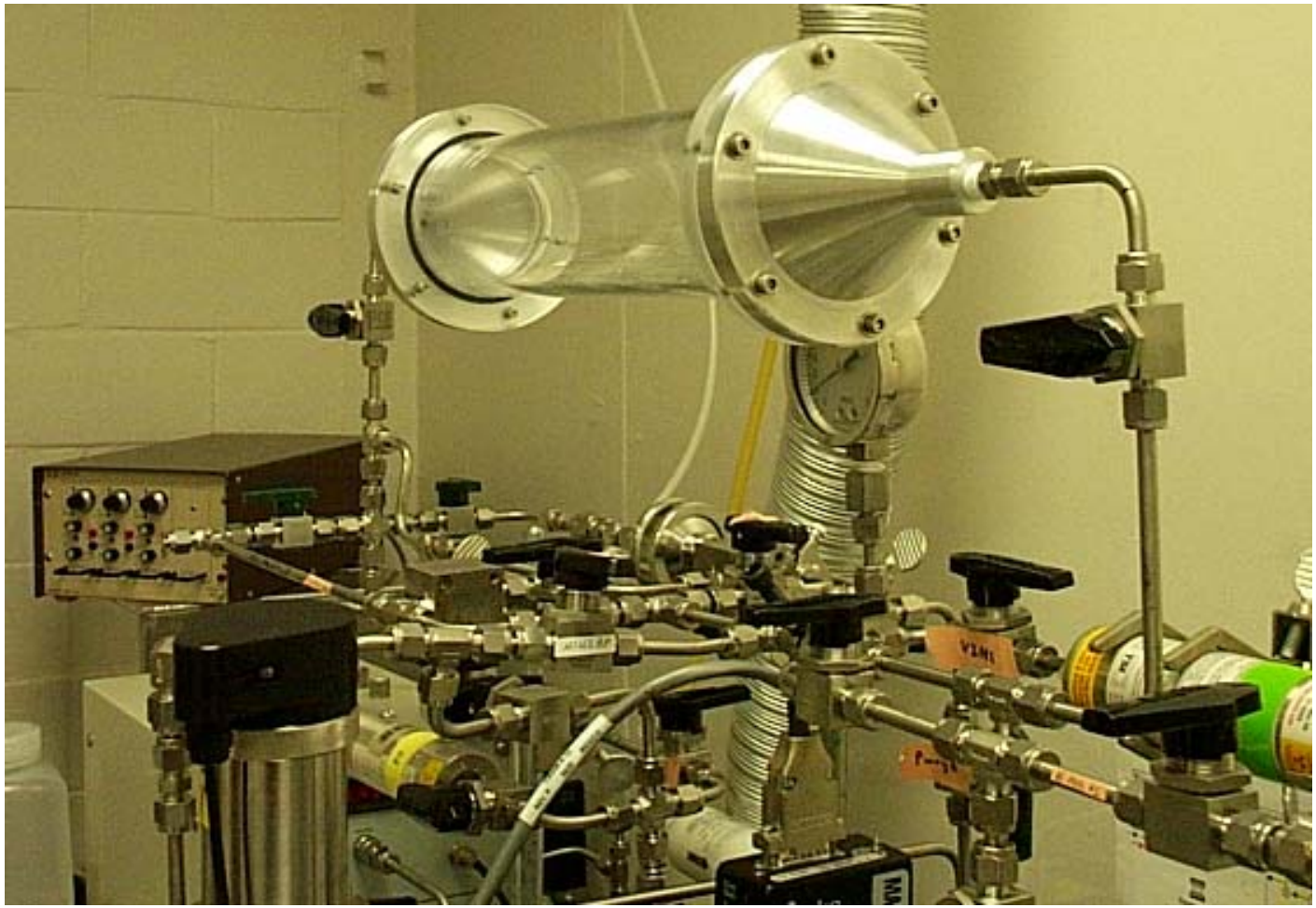


Increase temperature to increase particle diameter and concentration

Aerosol Chamber Experimental Plan

- **Goal:** Understand aerosol behavior as a function of time
- Want to assess fate of aerosol nanoparticles
- Identify and quantify rate of aerosol transport
- Identify and quantify loss mechanisms as function of
  - Particle diameter and particle size distribution
  - Number concentration
  - Charge state of aerosol nanoparticles

SiO_2 Aerosol Nanoparticle System with Chamber



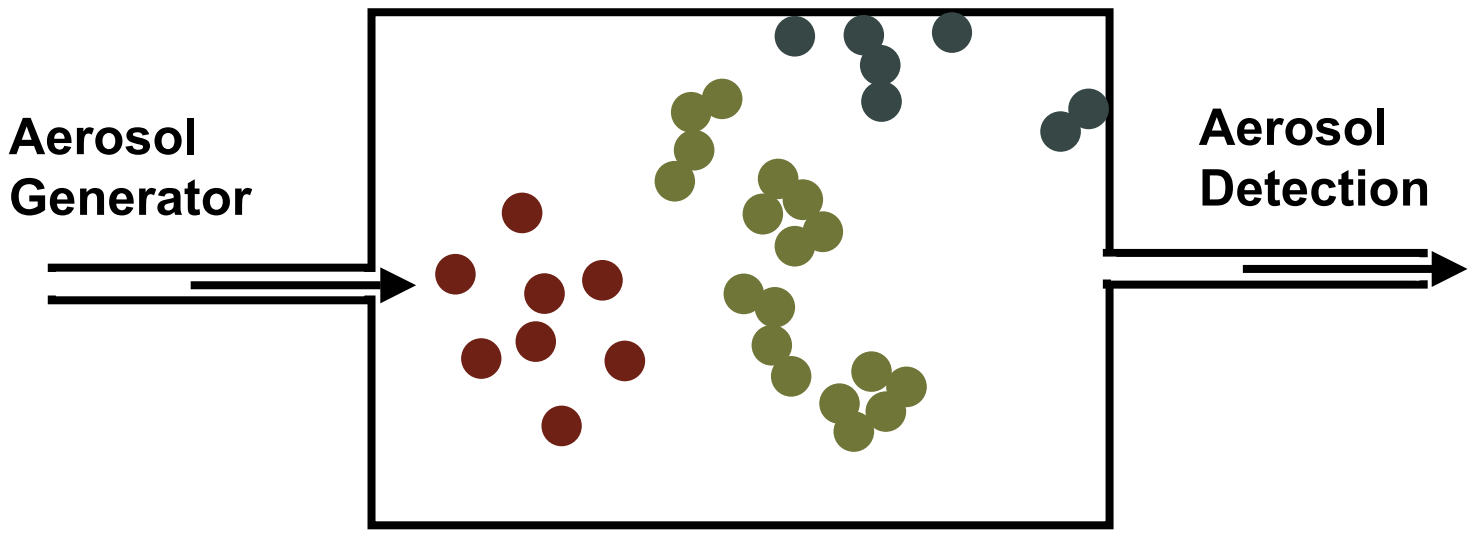
Aerosol Characterization as a Function of Time

Goal: Assess fate of aerosols in "open" environments

Rate of particle diffusion

Rate of particle coagulation

Rate of particle loss to fixed surfaces



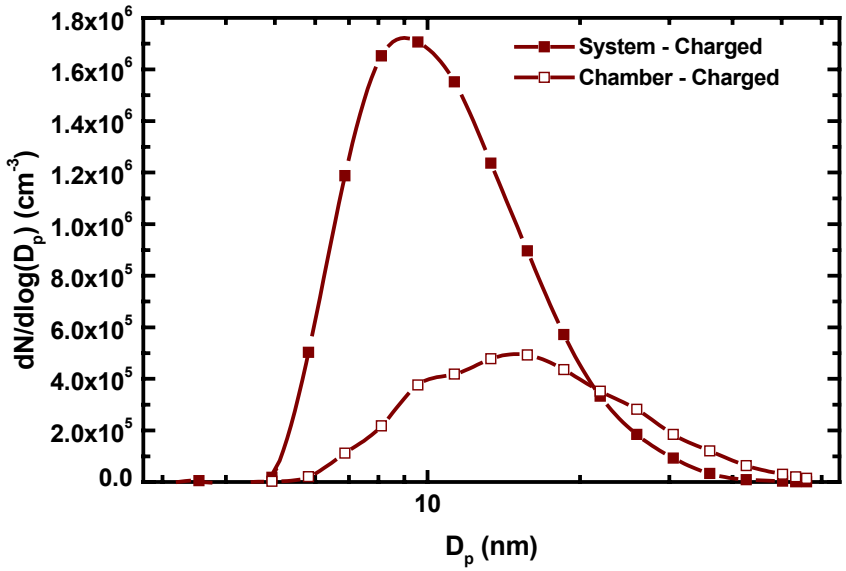
Factors in Loss Mechanisms

- **Loss mechanism defined as any mechanism that**
  - Removes aerosol nanoparticles from gas
  - Increases particle size to > 100 nm
- **Assessing loss mechanisms is not trivial**
  - Loss mechanisms are dependent upon several factors
  - Aerosol particles can be lost by multiple loss mechanisms

- **Plan: Isolate aerosol behavior mechanisms using variables with highest level of influence**
  - Rate of particle diffusion
  - Loss due to fixed surfaces
  - Loss due to coagulation

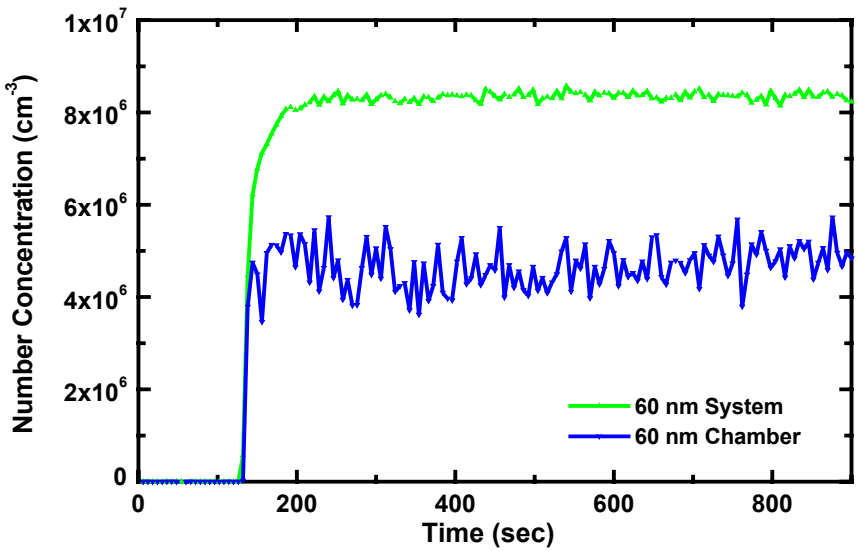
Two Types of Data Presentation

Particle Size Distributions



Particle Coagulation

Time Series at Constant Diameter



Steady state number concentration
Time to reach steady state
Rate of diffusion

Deliverable 2

- **Develop a Portable Air Sampling Method for Daily Monitoring of R&D and Manufacturing Settings**

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Portable Aerosol Nanoparticle Monitor

- Two areas of focus
- Internal development within NOSH Consortium
- External efforts
  - Instrument vendors
  - Academic groups

- If developed internally, NOSH Consortium would license design to external organization to manufacture and sell portable aerosol nanoparticle monitors

- Goal: To have a commercial instrument that fulfills the needs of the occupational safety and health community

Commercial and Academic-Developed Instruments

- **Data from instrument vendor that supports**
  - **~ 2-5 discrete size bins < 100 nm**
  - **Concentration range from $1x10^1$ - $1x10^7$ particles/cm^3**
- **Understanding of resolution, sensitivity limits of equipment**
  - **Particle chemistries**
  - **Particle concentrations**
- **Data correlation between new instrument and an existing commercial instrument**
  - **Comparison of new instrument with SMPS or ELPI**

Testing Protocols

- **Demonstrate performance with well-characterized aerosol nanoparticle source**
  - Ideal lab conditions and well-controlled environment
- **Monitor aerosol in different environments**
  - With experienced aerosol technician
  - With experienced non-aerosol industrial hygienist technician
  - After minimal hands-on training or by reading the instrument manual
  - Compare with existing aerosol instrumentation data
  - Compare data collected between users
- **Transport instrument to for measurement and testing**
  - Pack, ship, and reassemble instrument at remote sites

Deliverable 3

- Measure Filtration and Barrier Efficiency of Filter Media to Specific Engineered Nanoparticles
- **Specific information on methodology and filter performance will be published

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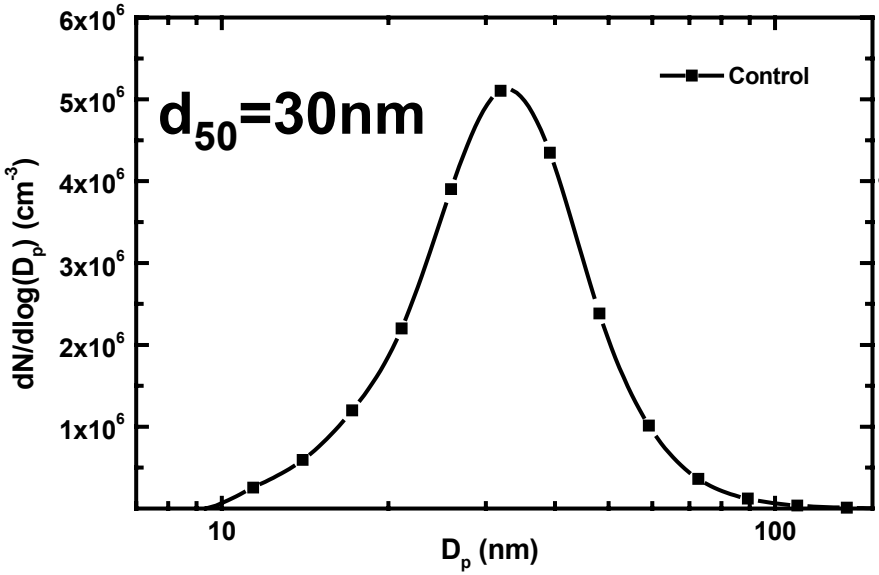
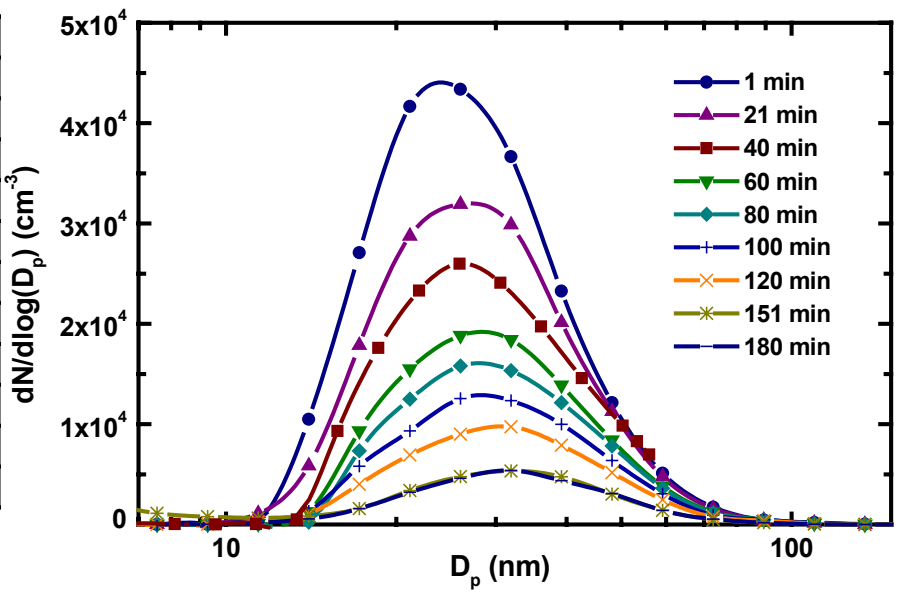
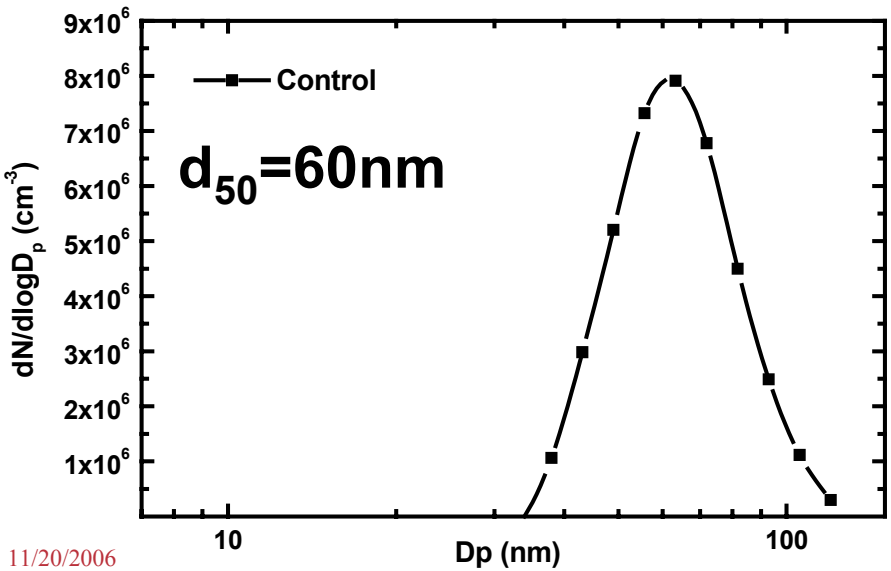
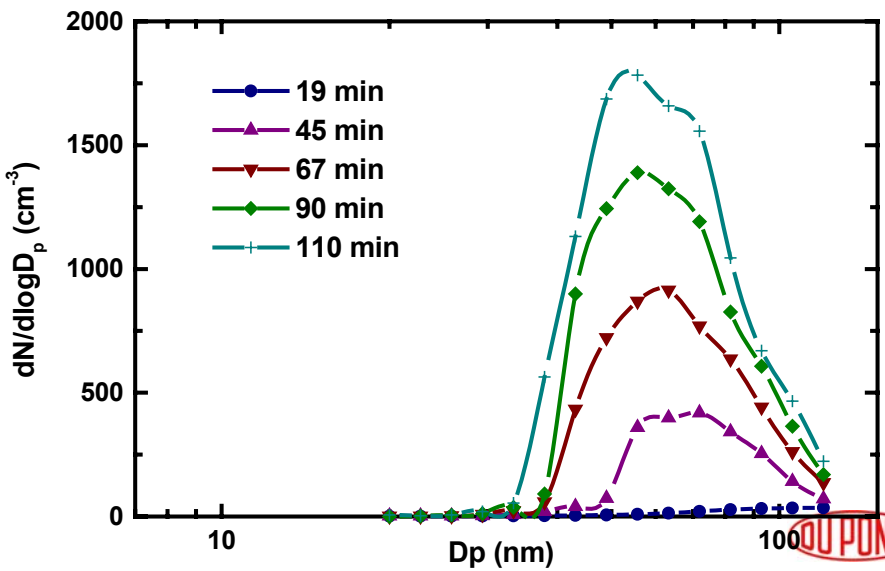
N95 at 30 nm and 60 nm





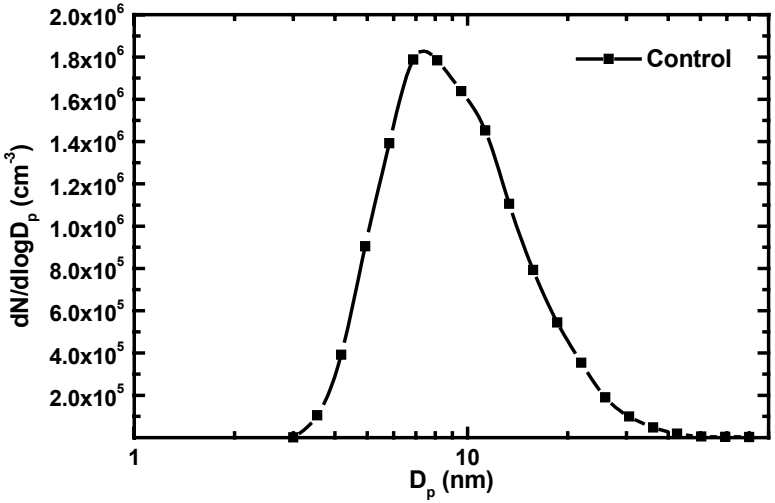
Uncharged

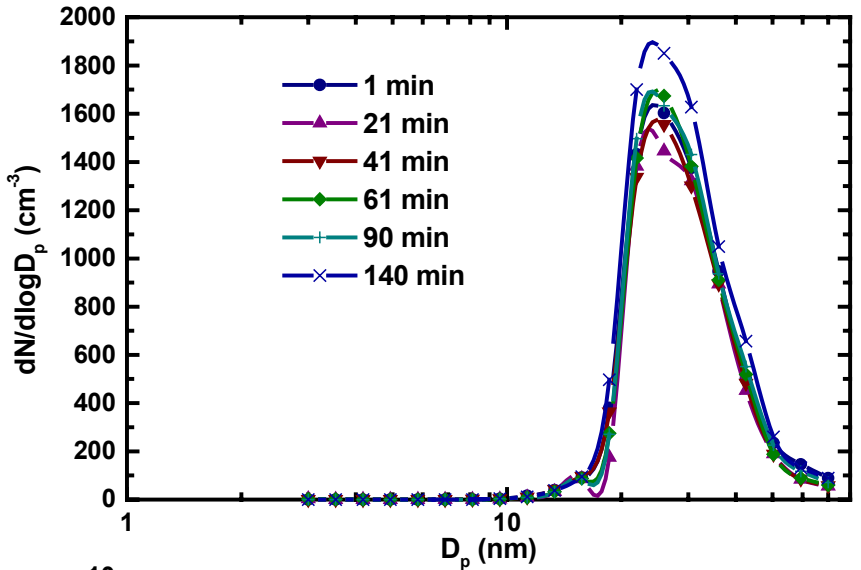




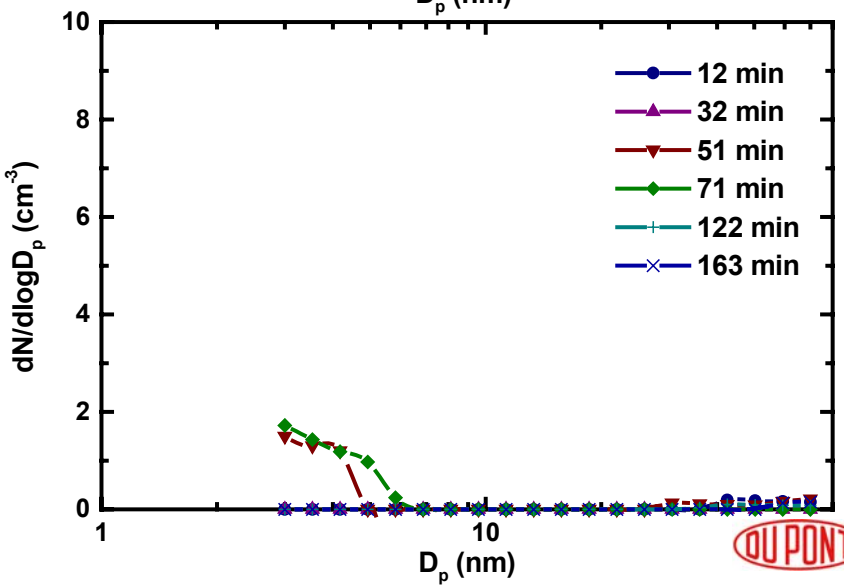
Charged

N95 at 10 nm



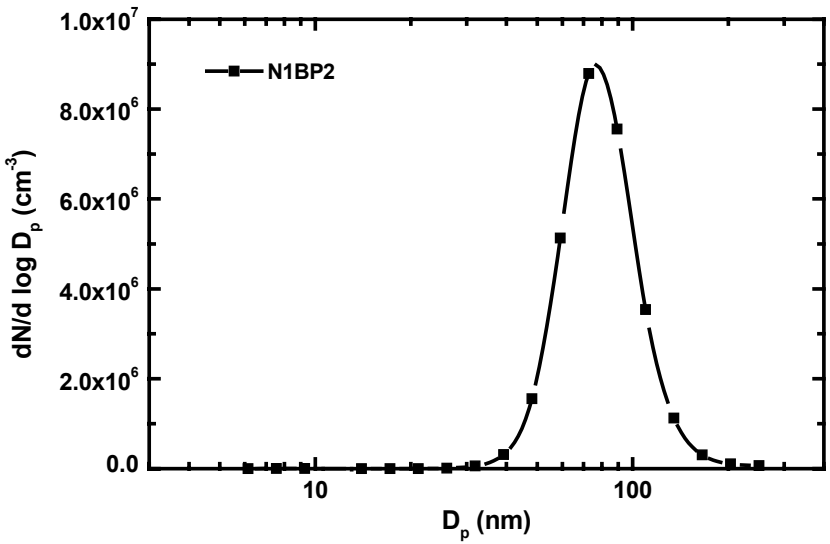


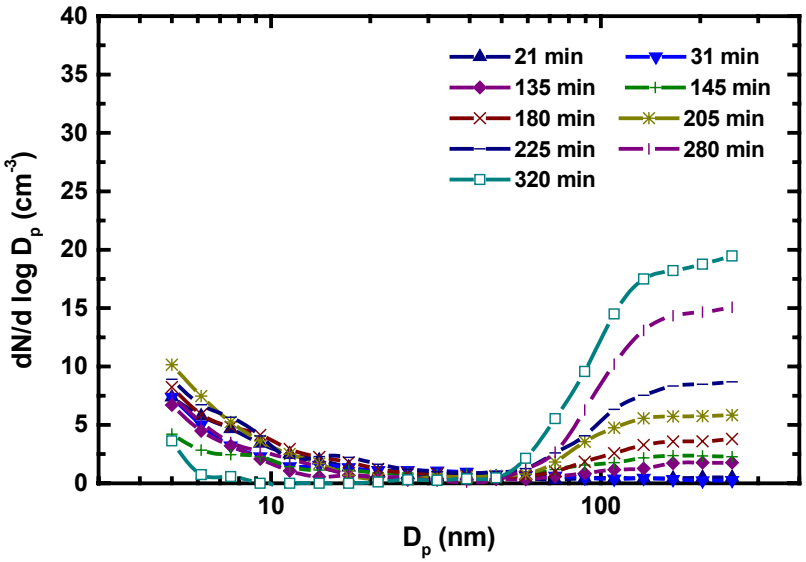
Uncharged

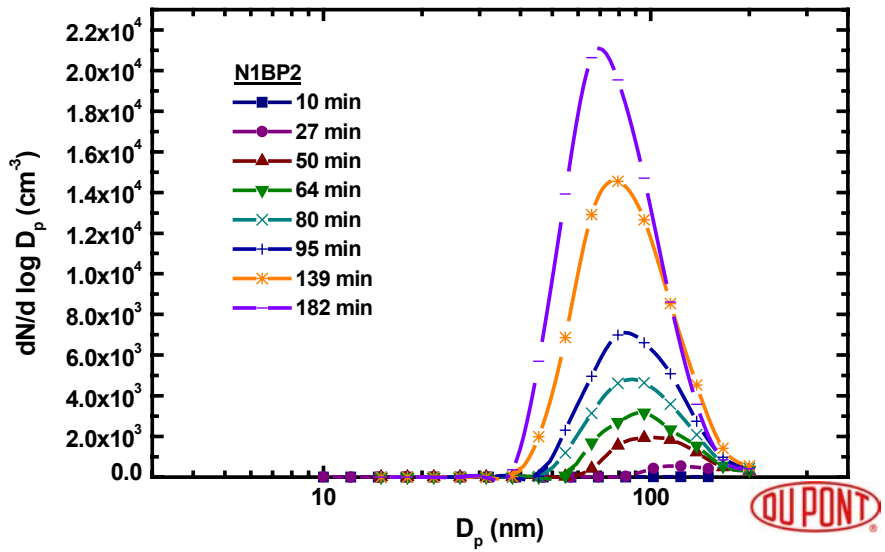


Charged

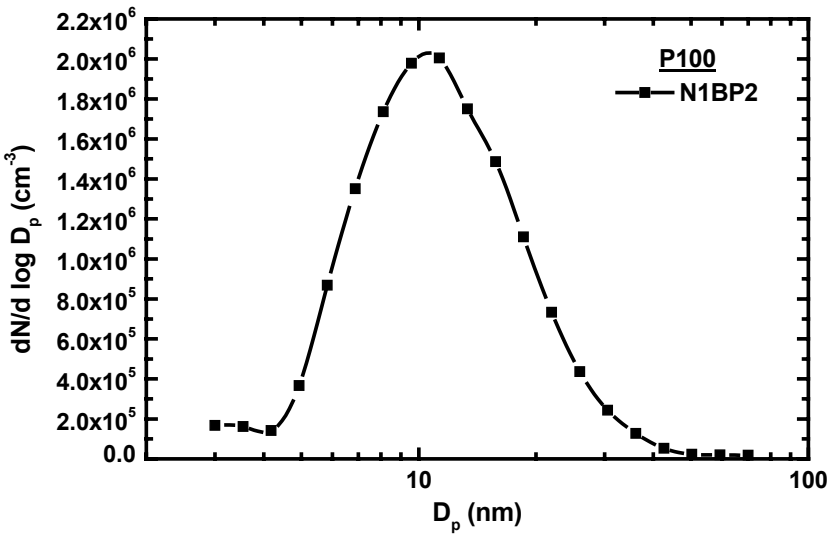
N100 at 60 nm - 2 Different Vendor Media

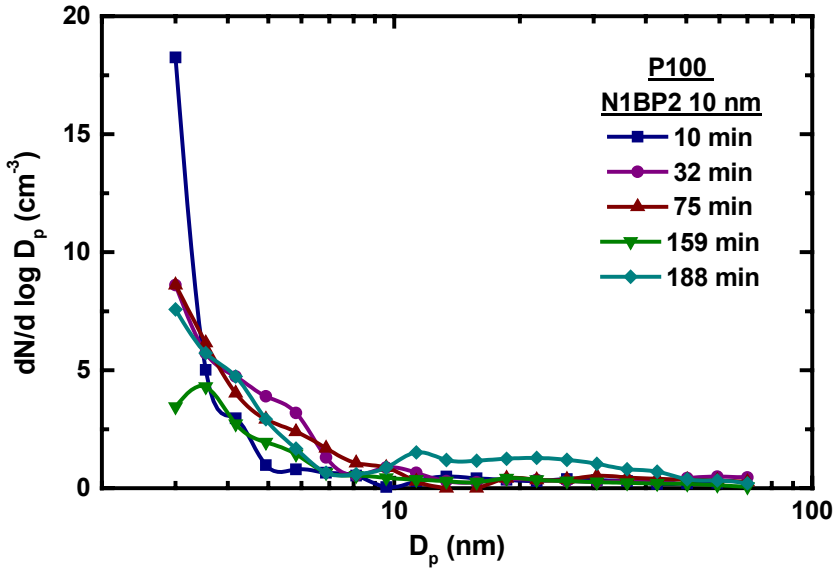


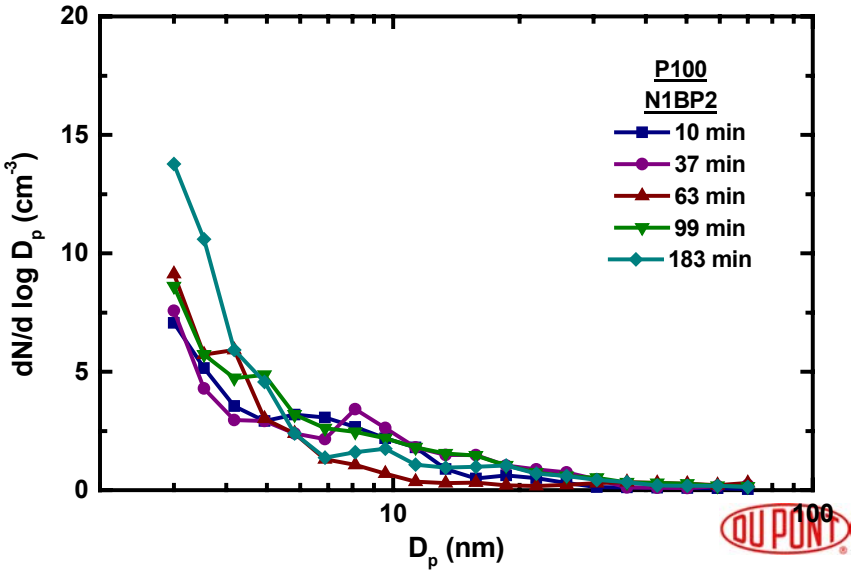




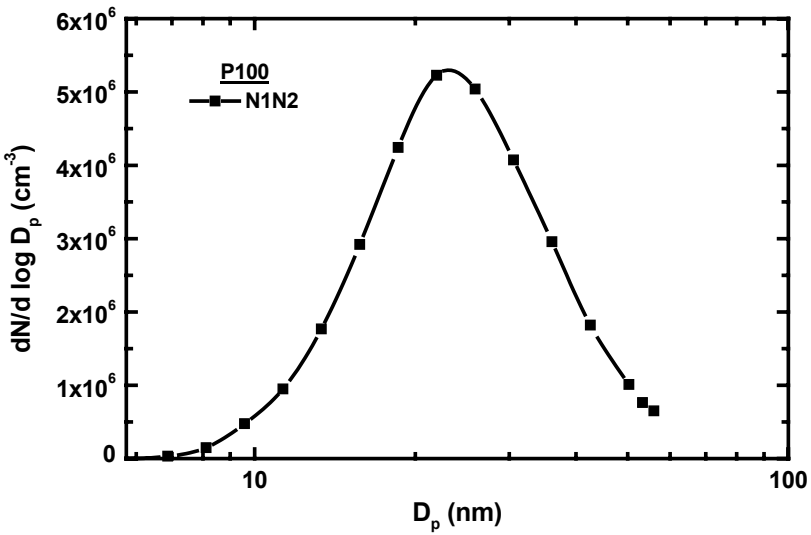
P100 at 10 nm - 2 Different Vendor Media

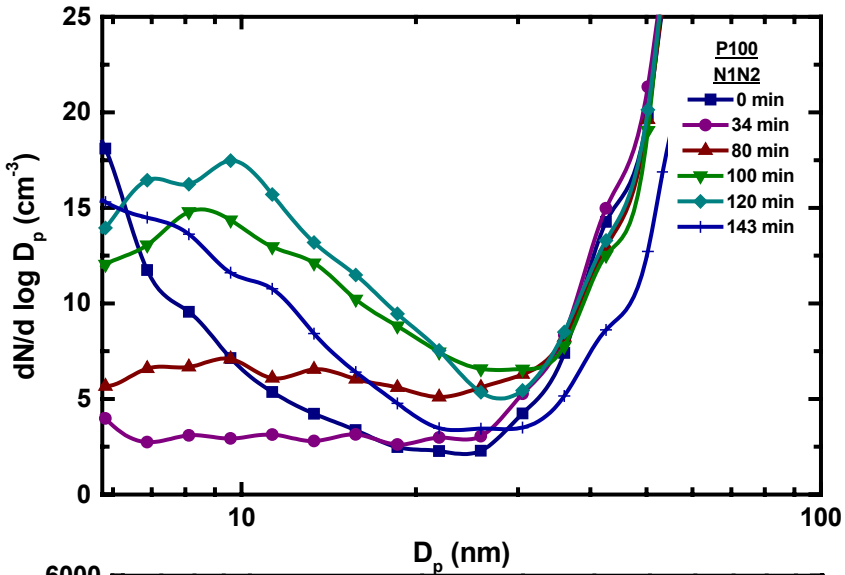


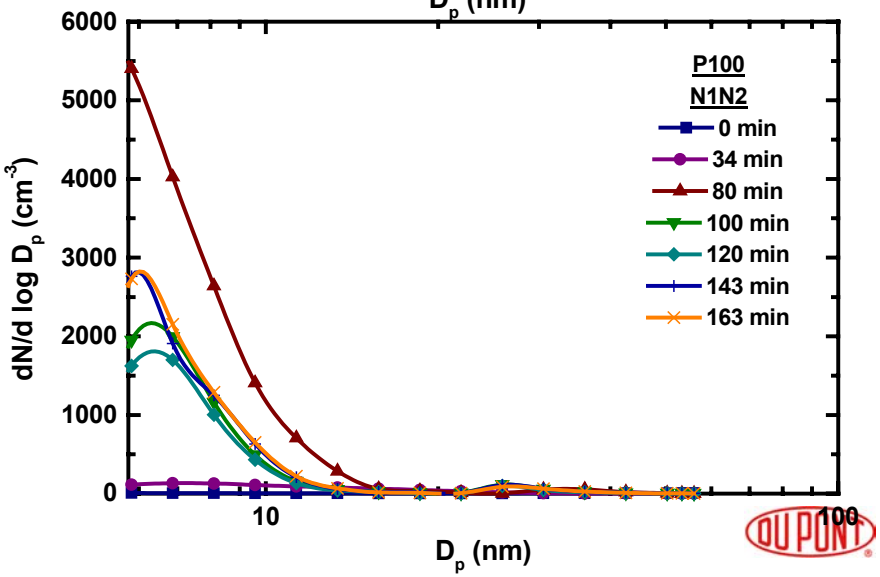




P100 at 30 nm - 2 Different Vendor Media







Publication Status

- SiO_2 Aerosol Nanoparticle Reactor for Occupational Safety and Health Studies

- Versatile Aerosol Nanoparticle Reactor and Filter Housing Characterization Capability for Occupational Safety and Health Studies

- Filter Media Filtration Results on SiO_2 Aerosol Nanoparticles with d_{50} = 10 nm, 30 nm, and 60 nm for charged and uncharged aerosol nanoparticles
  - N95 paper in final draft
  - N100 paper in draft
  - P100 paper in early draft - reproducing specific data sets

- Aerosol Chamber Results

Summary

- NOSH Consortium objectives and deliverables are targeted for completion in 2007
- On track to meet objectives of NOSH Consortium
  - Portable aerosol nanoparticle monitor remains a technical challenge
- Consortium structure ideal for this type of effort
  - Diverse viewpoints
  - Critical goals and objectives identified by broad audience
  - Disclosure and information exchange among members is rapid
- Opportunities for further work are being identified

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