NPPTL Mission . . .

To prevent work-related illness and injury by ensuring the development, certification, deployment, and use of personal protective equipment and fully integrated, intelligent ensembles.

This will be accomplished through the advancement and application of personal protective technology standards.
AGENDA

Thursday, October 12, 2006

• Research Topics - Poster Session

• Standards Development - Presentations

Friday, October 13, 2006

• PPT Cross Sector

• Research Projects – Presentations
Meeting Objective
To provide program information to our stakeholders and customers.
NIOSH/NPPTL Personal Protective Technology Programs

- Recap of 1st Two Days
- NIOSH Personal Protective Technology Program
NIOSH Divisions & Laboratories

- Office of the Director, NIOSH
- Office of Extramural Programs
- Pittsburgh Research Laboratory (PRL)

**National Personal Protective Technology Laboratory (NPPTL)**

- Division of Respiratory Disease Studies (DRDS)
- Division of Safety Research (DSR)
- Health Effects Laboratory Division (HELD)
- Education and Information Division (EID)
- Division of Applied Research and Technology (DART)
- Division of Surveillance Hazard Evaluation and Field Studies (DSHEFS)
- Office of Compensation Analysis and Support (OCAS)
- Research to Practice (r2p)
- Spokane Research Laboratory
# NIOSH Research Program Portfolio

<table>
<thead>
<tr>
<th>Industry Sectors</th>
<th>Cross Sector Programs</th>
<th>Emphasis Areas</th>
</tr>
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<tbody>
<tr>
<td>• Agriculture, forestry, and fishing</td>
<td>• Authoritative Recommendations Development</td>
<td>• Economics</td>
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<tr>
<td>• Construction</td>
<td>• Cancer, reproductive, cardiovascular, neurologic &amp; renal diseases</td>
<td>• Exposure assessment</td>
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<td>• Healthcare and social assistance</td>
<td>• Communications and information dissemination</td>
<td>• Engineering controls</td>
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<td>• Mining</td>
<td>• Emergency preparedness/response</td>
<td>• Work life initiative</td>
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<td>• Manufacturing</td>
<td>• Global collaborations</td>
<td>• Occupational health disparities</td>
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<td>• Services</td>
<td>• Health hazard evaluation (HHE)</td>
<td>• Small business assistance and outreach</td>
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<td>• Transportation, warehousing, and utilities</td>
<td>• Hearing loss prevention</td>
<td>• Surveillance</td>
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<tr>
<td>• Wholesale and retail trade</td>
<td>• Immune, dermal and infectious diseases</td>
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</tbody>
</table>
PPT Cross Sector Membership

- Cross Sector Manager - Les Boord, NPPTL
- Program Coordinators
  - Maryann D’Alessandro, NPPTL
  - Jeff Welsh, PRL
- Program Assistant Coordinator
  - Angie Shepherd, NPPTL
- Roland Berry Ann, NPPTL
- George Bockosh, NPPTL
- John Kovac, NPPTL
- Bill Haskell, NPPTL
- Charles Oke, NPPTL
- Ed Fries, NPPTL
- Nina Turner, DSR
- Chris Coffey, DRDS
- Lynda Ewers, DSHEFS
- Chuck Kardous, DART
- John Sammarco, PRL
- Ken Williams, NPPTL
- Ron Shaffer, NPPTL
- Jon Szalajda, NPPTL
- Heinz Ahlers, NPPTL
- Bill Hoffman, NPPTL
- Bill Newcomb, NPPTL
PPT Cross Sector
PPT Program Plan – Action Timeline

• 1Q 2006 (Oct 2005 – Dec 2005)
  – PPT Cross Sector leadership meet bi-weekly
  – Develop draft mission, vision, definition and logic model and discuss strategy for PPT Cross Sector

• 2Q 2006 (Jan 2006 – Mar 2006)
  – PPT Cross Sector Team established
    • NPPTL Program Managers, Epidemiologist, Standards Coordinator
    • NPPTL Branch Chiefs
    • NIOSH Division volunteers and solicited participants
  – Begin monthly cross sector meeting
  – Develop draft logic model (Value creation system)
Mission Statement –

To prevent work-related injury and illness by advancing the state of knowledge and application of personal protective technologies.

Vision Statement –

Be the leading provider of quality, relevant and timely PPT research, training and evaluation.

PPT Definition –

The technical methods, processes, techniques, tools and materials that support the development and use of personal protective equipment worn by individuals to reduce the effects of their exposure to a hazard.
PPT Cross Sector
PPT Program Plan – Action Timeline

• 1Q 2006
  – Finalize Mission, Vision, Definition, Logic Model with Team
  – Begin monthly meetings in Feb 2006
  – Develop Quad Charts for all PPT Projects
  – Begin evidence package development and web site development

• 2Q 2006
  – Identify Sector and General Goal Development Leads
  – Review sector strategic goals and/or initial sector strategy
  – Review injury, illness and fatality data and Draft Sector Descriptions to identify priority PPT needs aligning to surveillance data as well as stakeholder and user needs.

• 3Q 2006
  – Consult with RAND on Evidence Package development
  – Develop PPT Draft Goals, expected performance measures, outputs, and outcomes
PPT Draft Goal 2

• 2.0 Develop informational materials to provide guidance to identify appropriate PPE for all life cycle stages.
  – 2.1 Develop working agreements with appropriate stakeholders to collaborate on developing selection and use guidance documents
  – 2.2 Collaborate with appropriate stakeholders on PPE guidance and training
    • 2.2.1 Collaborate with stakeholders and appropriate standards-setting bodies on the guidance documents needed for respiratory protection
    • 2.2.2 Collaborate with stakeholders and appropriate standards-setting bodies on the guidance documents needed for protective clothing and ensembles
    • 2.2.3 Collaborate with stakeholders and appropriate standards-setting bodies on the guidance documents needed for hearing protection PPE
    • 2.2.4 Collaborate with stakeholders and appropriate standards-setting bodies on the guidance documents needed for head protection PPE
    • 2.2.5 Collaborate with stakeholders and appropriate standards-setting bodies on the guidance documents needed for eye and face PPE
  – 2.3 Collaborate with stakeholders and appropriate standards-setting bodies on the guidance documents needed for PPE decontamination
PPT Draft Goal 1

• 1.0 Identify and develop performance requirements and evaluation criteria for PPT to achieve harmonized standards to improve the quality and performance of PPE through all lifecycle stages.
  – 1.1 Develop working agreements with appropriate standards development organizations for collaboration.
  – 1.2 Participate on appropriate standards-setting bodies to improve the quality and performance of personal protective equipment (PPE)
    • 1.2.1 Participate on appropriate standards-setting bodies for respiratory protection equipment
    • 1.2.2 Participate on appropriate standards-setting bodies for protective clothing and ensembles
    • 1.2.3 Participate on appropriate standards-setting bodies for hearing protection PPE
    • 1.2.4 Participate on appropriate standards-setting bodies for head protection PPE
    • 1.2.5 Participate on appropriate standards-setting bodies to address issues related to eye and face PPE
  – 1.3 Provide input on the performance requirements and test methods needed to provide appropriate PPE
PPT Draft Goal 3

- 3.0 Conduct research to address personal protective technology (PPT) knowledge gaps and improve existing technologies.
  - 3.1 Identify performance requirements needed to prevent inhalation exposures
  - 3.2 Identify performance requirements needed to prevent dermal exposures
  - 3.3 Identify performance requirements needed to prevent hearing exposures
  - 3.4 Identify performance requirements needed to prevent traumatic injuries to the head
  - 3.5 Identify performance requirements to prevent traumatic injuries to the eye and face
PPT Program Plan – Action Timeline

  - Evidence package development
    - Develop history of program, compendiums
    - Quad charts for each program serve as foundation of web site and presentation
  - Links from quad charts to provide additional information
    - Consult with RAND on strategy and evidence package development
    - Finalize Goals and Performance Measures
      - Incorporate partner and stakeholder lists and letters
- 2Q 2007 (Jan 2007 – Mar 2007)
  - Continue to refine and finalize evidence package
- 3Q 2007 (May 2007)
  - Evidence package to National Academies
NIOSH Personal Protective Technology Programs

We want your feedback!

Les Boord
NIOSH / NPPTL
E-mail: zfx2@cdc.gov
Phone: 412-386-6111

Thank you!!!
National Personal Protective Technology Laboratory

GENERAL REMARKS ON THE NPPTL RESEARCH PROGRAM

Ron Shaffer
Chief, Research Branch
NPPTL Public Meeting
October 13, 2006
Research Focus Areas

- Respiratory Protection
- Sensors & Electronics – Integration with PPT
- Protective Clothing & Ensembles
- Human Performance
Respiratory Protection Research

• Aerosol/Filtration Studies
  – Nanoparticles
  – Bioaerosols

• Respirator Fit Test Research
  – Facial anthropometrics

• Influenza Pandemic
  – Reusability of filtering facepiece respirators (FY07 new start)
Sensors & Electronics Research

- Develop/Integrate Chemical Sensors for Real-Time Determination of Respirator Cartridge Service Life
- Respirator Cartridge End-of-Service Life Modeling
Protective Clothing & Ensembles Research

- Decontamination Efficacy of Chemical Protective Clothing (CPC)
- Improved Criteria for Emergency Medical Protective Clothing and Equipment
- Development of Bench and MIST Protocols for Particulate Penetration Measurements of Protective Clothing and Ensembles
- Validation of PPE Preconditioning Methods (FY07 New Start)
Human Performance Research

- Project HEROES – Physiological/Ergonomic Evaluation of Firefighter PPE Prototype with Advanced Chem/Bio Protection

- Physiological Models and Countermeasures
  - Test methods to assess the physiological “burden” of PPE ensembles
  - Embedded cooling garments to reduce the heat stress of firefighters
  - Evaluate portable physiological monitoring equipment (e.g., sensor vest)

- Metabolic Evaluation of N95 Respirators with Protective Coverings (FY07 new start)
Summary

• Standards focus – ASTM, NFPA, ISO
• Diverse mix of PPT research projects from the 4 research focus areas
• R2P through partnerships
Quality Partnerships Enhance Worker Safety & Health

Visit Us at: http//www.cdc.gov/niosh/npptl/default.html

Disclaimer: The findings and conclusions in this presentation have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

Thank you
National Personal Protective Technology Laboratory

End-of Service Life Sensor Program

Jay Snyder, NIOSH

October 13, 2006
Presentation Overview

- NIOSH/NPPTL End of Service Life Program
- NIOSH Cartridge Simulator
- CMU Sensor Development
Respirator Cartridge Change Schedules

- Employers are required to use end-of-service indicator when available
- As an alternative- must develop cartridge / canister change schedules based on
  - Manufacturer recommendations
  - Breakthrough test data
  - Mathematical models
- Reliance on odor thresholds are not permitted as the primary basis for determining the service life
- Service life data affected by temperature, humidity, air flow through the filter, work rate, and presence of other chemicals
Summary of Models

- Single vapor with relative humidity effects
- Reactive gas
- Multi-vapor with relative humidity effects
4.3.1. Data demonstrating that the ESLI is a reliable indicator of sorbent depletion less than or equal to 90% of service life. The data shall include the results of a flow-temperature study at low and high temperatures, humidities, and contaminant concentrations which are reasonably representative of actual workplace conditions where it is anticipated that a given respirator will be used. A minimum of two contaminant levels must be utilized for each study, including the limit level (permissible exposure limit, threshold limit value, etc.) and the limit level times the assigned protection factor for the respirator type.
Inside the normal white surface was replaced with dark brown, crusty material approximately $\frac{1}{8}$ to $\frac{1}{4}$ inch thick.

Source: Roy McKay, University of Cincinnati
Multiple Solvent Assault with a Break

Acetone 365ppm/ TCE 325ppm/ Xylene 275ppm: 3M7251/ 32LPM
Pulsed

Minutes

ppm Effluent

0 100 200 300 400 500 600

30 min. run
Overnight Pause

Acetone
TCE
Xylene

CDC Workplace Safety and Health
NIOSH NPPTL Research to Practice through Partnerships
Final 6-12-06
ESLI Sensor Concept

Saturation indicators

Controller

Embedded MEMS sensors

(cross-section)
External Peer Review

- Conducted 05/13/2005
- Seven external reviewers

Recommendations

- Continue CMU sensor development
- Expand experimental program to determine effects of sensor placement, temperature, and humidity
Cross Section of Cartridge Simulator
Cartridge Simulator
Simulator with Sensor
Loading the Cartridge Simulator
Simulator Breakthrough Data

CCI4 1000 ppm : Carbon 50g.: Air 32 LPM (50RH)

- wo. Sensor: 5ppm - 96 min.
- w. Sensor: 5ppm - 75 min.
Simulator Data with GC Probe

CCI4 1000 ppm: Carbon 50g. (w. Sensor): Air 32 LPM: RH 50

- Full Bed: 5 ppm at 88 min.
- 1/2 Bed: 5 ppm at 44 min.
Packed Simulator Response to RH

Relative Humidity 75% / Carbon 50g / 30 LPM

% RH

Seconds
Temperature Data from Carbon Bed

Humidity Temperature Test

- RH 60
- RH 80
- RH 30
- IPA on
- IPA off

Degrees Celsius

Minutes
4th Gen NIOSH Sensor Layout

Bridge circuit configuration with one reference, one exposed sensor

Chips fit three separate bridges to accommodate different polymers

SU8 epoxy creates cavity for encapsulating reference sensor

Spiral electrode design modified to ensure polymer from ink jetted splat covers active electrodes

Active electrodes

Extra spread patterns

SU-8 covering

2.65 mm
Spiral ChemFET Cross Section

- Jetted polythiophene channel
- Gold source and drain electrodes
  - 4 µm lines, 3 µm spaces (channel length)
- Si wafer acts as gate electrode for field-effect action

SU-8

40 µm

500 Å SiO₂

600 Å Au / 20 Å Ti

Jetted polymer

Si wafer
4rd Gen NIOSH Sensor

TO-5 Package with Sensor Array

0.25 inches

6-Sensor Array Design

2.65 mm
Complete TO-5 Package
Sensor Package and Electronics

Sensor in TO-5 package, mounted on PCB with modulator/bridge circuit

- Gore-Tex Filter
- Temperature/Humidity Sensor
Preliminary Sensor Data

- Introduced flow through ampoule with no IPA
- Start of breakthrough
- IPA turned on
- Turned off IPA flow

PolyMEEM (L12) sensor output voltage vs. time (sec)
End-of-Service-Life Detection System

- ChemAlert™ Filter (cross-section)
- Embedded Coils
- Embedded wireless sensors
- Filter/mask electrical interface
- Data Reception
- RF Power Transmission
- Face mask unit
- ESL indicators

CDC Workplace Safety and Health
NIOSH
NPPTL Research to Practice through Partnerships
Work with Respirator Manufacturers

- 3M
- Draeger
- Mine Safety Appliance
- Moldex-Metric Inc.
- North Safety Products
- Scott Health & Safety
- Sundstrom Safety AB
- Survivair
Sensor Program Newsletter

NPPTL
Sensor Program Update

Progress during the past six months of the program has resulted in redesign. The sensor package and associated electronics have been changed to accommodate several problems identified during the evaluation of the 4th array package that had been used. The revised sensors have been configured in a six chemoresistive system according to figure 1 at the bottom. The chemiresistors are arranged in pairs to form voltage dividers, providing three independent sensor signals. Chemiresistors in each divider will be covered with the same modified polyethylene. One chemiresistor will be exposed to the environment to react analytically in the gas stream. The other one will be sealed and used as a reference. This should reduce thermal and electrical interferences. The configuration will permit the use of up to three different polymers which can be compared side by side. This configuration will be packaged in an 8-pin TO-5 package which is shown in figure 2.

The electronics used to power and generate data from the sensor package has been redesigned. The new sensor circuit in the TO-5 package has been changed in three primary ways. The voltage divider configuration nulls the temperature offset to first order. This is accomplished by placing a sensor reference (with the anode-exposure blocked) in the divider. Second, the divider is driven in ac operation. Third, the ac modulation is driven in a bipolar arrangement so that the output with no analytic stimulus will result in a zero ac and dc output.

The polymer resistivity is a function of dc bias across the sensor, and gives rise to a drift in the baseline voltage output of a dc driven sensor system. By driving with ac modulated input, the sensors do not experience a dc voltage bias and therefore the baseline drift over time is decreased. A second motivation for the ac modulation is the ability to move the sensor signal to a modulation frequency that separates the signal from other environmental influences that occur near dc. These interfering disturbances at dc are then filtered.

A respirator cartridge simulator that accommodates these sensors has been constructed (figure 3). It has a 2.5 or 5.0 cm bed depth and will be used to test and characterize sensor systems in a carbon bed prior to distribution to volunteer respirator manufacturers.
Microvelcro attaches backside of sensor package to interior lining of fabric.

Sensor covered by porous protective mesh.

Sensor control & detection module.

Coil & wiring to control module woven into fabric.
Personal Protective Equipment End-of-Service Life

• Questions?
• Comments!

Disclaimer

The findings and conclusions in this presentation are those of the author and do not necessarily represent the views of the National Institute for Occupational Safety and Health.
NPPTL Respirator Fit Test Panels

Ziqing Zhuang, Ph.D.

National Institute for Occupational Safety and Health

NPPTL Public Meeting
October 13, 2006, Pittsburgh, PA
Acknowledgment

Ronald Shaffer, Ph.D.
Bruce Bradtmiller, Ph.D.
Dennis Viscusi
Raymond Roberge, M.D.
Lauren Stein
Latoya Williams
Alex Reddington
Dennis Groce
Importance of Test Panels

- Anthropometric panels of facial dimensions are relied upon to provide sizing reference for respirators in many applications
  - APF establishment
  - Respirator design and development
  - TIL certification and standards
  - Research standards
History of LANL Panels

- No survey of facial dimensions of the U.S. civilian workers
- The facial anthropometry was assumed to be representative of U.S. adults
- Face length, face width, and lip length
### LANL 25-Member Panel for Full-Facepiece Respirators

<table>
<thead>
<tr>
<th>Face Width (mm)</th>
<th>117.5</th>
<th>126.5</th>
<th>135.5</th>
<th>144.5</th>
<th>153.5</th>
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<th>Face Length (mm)</th>
<th>93.5</th>
<th>103.5</th>
<th>113.5</th>
<th>123.5</th>
<th>133.5</th>
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</table>
### LANL 25-Member Panel for Half-Mask Respirators

<table>
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<tr>
<th>Lip Length (mm)</th>
<th>34.5</th>
<th>43.5</th>
<th>52.5</th>
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**Face Length (mm)**

- 25-Member Panel for Half-Mask Respirators
Panel Applicability Problem

• Concern raised:
  – Demographics of the U.S. population has changed over the last 30 years
  – Military data may not fairly represent the diversity of face sizes
Panel Applicability Problem

• **Scientific Evidence:**
  
  - Leigh measured 1,467 employees (1975)
  
  - Bureau of Mines surveyed 48 male mine rescue workers (1978)
  
  - Lip length is not appropriate (Oestenstad, 1990, 1992)
  
  - NIOSH found that 16% of Civilian American and European Surface Anthropometry Resources (CAESAR) subjects were outside the limits of the LANL panel for full-facepiece respirators (2002)
Background

• NIOSH created an anthropometric database detailing the face-size distributions of the current U.S. respirator users

• The 1967-68 Air Force survey data is not reflective of the anthropometric distribution of the current U.S. workers (Zhuang et al., 2004)

• New respirator fit test panels need to be developed
Objective

• Develop respirator fit test panels representative of the current U.S. workforce
Methods

- 2003 NIOSH anthropometric survey of respirator users (Zhuang and Bradtmiller, 2005)

- Stratified sampling plan
  - Two gender strata
  - Four race strata
  - Three age strata

- 3997 subjects

- Weighting factors (2000 U.S. census)

- 19 traditional measurements and 3D scanning
Two Approaches

- Bivariate distribution (two dimensions)
- Principal component analysis
Criteria for Selecting Dimensions

- The dimensions are relevant to respirator fit
  - Literature review
  - Expert opinion
- The dimensions excluded can be predicted by the dimensions included in the PCA
- The number of dimensions is reasonable
- Dimensions that are difficult to measure and/or highly variable are excluded
Principal Component Analysis: Theory

PCA defines a new coordinate system using linear combinations of the original variables to describe trends in the data.
Results

- Literature review revealed that several dimensions were found to have correlation with respirator fit (Zhuang et al., 2005)
- ISO Technical committee 94, Subcommittee 15, Working groups 2-3, joint project group 2 came up with a list of 9 dimensions
- Lip length is not appropriate for defining test panel for half-mask respirators
NIOSH Bivariate Panel

- 10-cell panel
- 25 subjects
- At least two subjects for each cell
- Matching the distribution of the population
- Face length and face width were selected to define the bivariate panel for both half-masks and full-facepiece respirators
<table>
<thead>
<tr>
<th>Face Length (mm)</th>
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## NIOSH Bivariate Panel

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### Face Width (mm)

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### NIOSH Bivariate Panel

**Total = 97.7%**

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<td>134.5</td>
<td>5.2%</td>
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<td>8.7%</td>
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<td>144.5</td>
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<tr>
<td>158.5</td>
<td>7.1%</td>
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Dimensions Used in the PCA Panel

- Minimum Frontal Breadth
- Face Width
- Bigonial Breadth
- Face Length
- Interpupillary Breadth
- Head Breadth
- Nose Protrusion
- Nose Breadth
- Nasal Root Breadth
- Subnasale-Sellion Length
### $R^2$ values for Multiple Regressions between Dimensions Excluded from the PCA Model and the 10 Dimensions Included in the PCA Model

<table>
<thead>
<tr>
<th>Face Dimensions</th>
<th>$R^2$</th>
<th>p-value</th>
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<tr>
<td>Maximum Frontal Breath</td>
<td>0.83</td>
<td>&lt; 0.01</td>
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<tr>
<td>Bitragion Chin Arc</td>
<td>0.69</td>
<td>&lt; 0.01</td>
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<tr>
<td>Bitragion Subnasale Arc</td>
<td>0.66</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Neck Circumference</td>
<td>0.66</td>
<td>&lt; 0.01</td>
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<tr>
<td>Bitragion Frontal Arc</td>
<td>0.61</td>
<td>&lt; 0.01</td>
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<td>Head Circumference</td>
<td>0.44</td>
<td>&lt; 0.01</td>
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<tr>
<td>Lip Length</td>
<td>0.43</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Head Length</td>
<td>0.42</td>
<td>&lt; 0.01</td>
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<tr>
<td>Bitragion Coronal Arc</td>
<td>0.38</td>
<td>&lt; 0.01</td>
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# Principal Component Analysis (Males and Females)

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<tr>
<th>PC</th>
<th>Eigenvalue</th>
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<th>% Total Variance</th>
<th>Cumulative %</th>
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<td>7</td>
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<td>8</td>
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<td>9.515</td>
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<tr>
<td>10</td>
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<td>10.000</td>
<td>1.8</td>
<td>100.0</td>
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## Principal Component Analysis (Males and Females)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Eigenvectors PC 1 (42%)</th>
<th>Eigenvectors PC 2 (16%)</th>
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<tr>
<td>Minimum Frontal Breadth</td>
<td>0.3433</td>
<td>-0.1530</td>
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<td>Face Width</td>
<td>0.4265</td>
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<td>Bigonial Breadth</td>
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<td>Interpupillary Breadth</td>
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<td>Head Breadth</td>
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<tr>
<td>Nose Protrusion</td>
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<td>Nose Breadth</td>
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<td>Nasal Root Breadth</td>
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<tr>
<td>Subnasale-Sellion Length</td>
<td>0.1937</td>
<td>0.5843</td>
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</table>
Scatter Plot of PC1 & PC2

Long/Narrow Nose
Long Face

Shape

Small Face
Short/Wide Nose

Small
Overall Size
Large

First Principal Component
Second Principal Component
## 25-Member PCA Panel

<table>
<thead>
<tr>
<th>Cell</th>
<th>Male (%)</th>
<th>Female (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>7.8</td>
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<td>9.9</td>
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<tr>
<td>8</td>
<td>11.1</td>
<td>6.6</td>
<td>8.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>95.3</strong></td>
<td><strong>97.6</strong></td>
<td><strong>96.8</strong></td>
</tr>
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</table>
## 25-Member PCA Panel

<table>
<thead>
<tr>
<th>Cell</th>
<th>Male</th>
<th>Female</th>
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<tbody>
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<tr>
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<td>3</td>
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</tr>
<tr>
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</tr>
<tr>
<td>8</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13</strong></td>
<td><strong>12</strong></td>
<td><strong>25</strong></td>
</tr>
</tbody>
</table>
Comparison of the Two Panels

- Bivariate Panel
  - Easy to understand and use
  - May not exclude unusual faces, e.g., large nose
  - Need to measure 91 subjects on average to fill the panel (min=34 and max=264)

- PCA Panel
  - Complicated and more measurements
  - Likely to exclude unusual faces
  - Need to measure 58 subjects on average to fill the panel (min=28 and max=144)
  - Dimensions included in the model are correlated with those excluded
Conclusions

- Two panels were developed
- Respirators designed to fit these panels are expected to accommodate more than 95% of the current U.S. civilian workforce
- Both panels represent an improvement over the LANL panels used today
- Certification bodies, standards organizations, and manufacturers need to select the appropriate panel for their particular needs
Future Research

- Differences among age, race and gender
- Comparison between the bivariate and PCA panels using NIOSH TIL data
- Headforms
- Chinese anthropometric database
- 3-D parameters
Journal Publications


## Presentations


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Thank You

Any questions?

Contact
ZZhuang1@cdc.gov
412-386-4055
Penetration of Nanoparticles Through Respirators and Protective Clothing

Ron Shaffer, Pengfei Gao, and Samy Rengasamy

National Personal Protective Technology Lab
Research Branch
Pittsburgh, PA 15236
Email: RShaffer@cdc.gov
Phone: 412-386-4001
Overview

• Nanotechnology

• NIOSH “Approaches to Safe Nanotechnology” Document

• Nanoparticle Penetration Through Respirators and Respirator Filter Media

• Nanoparticle Penetration Through Protective Clothing and Fabrics
What are Nanoparticles?

Nanoparticles are particles having a diameter between 1 and 100 nm (0.001-0.1 µm)

Adapted from: Guidance for Filtration and Air-Cleaning Systems to Protect Building Environments from Airborne Chemical, Biological, or Radiological Attacks, DHHS (NIOSH) Publication No. 2003-136.
Nanoparticles - Health Concerns

- Airborne nanomaterials can be inhaled and deposited in the respiratory tract
- Nanomaterials can enter the blood stream and translocate to other organs
- Mass doses of insoluble ultrafine particles (<100 nm) are more potent than larger particles of similar composition in causing pulmonary inflammation and lung tumors in laboratory animals
- Studies have shown that changes in the chemical composition, structure of the molecules, or surface properties of nanomaterials can influence their potential toxicity
- Workers exposed to fine and ultrafine particles have reported lung function decrements and adverse respiratory symptoms

http://www.cdc.gov/niosh/topics/nanotech/
NIOSH Nanotechnology Research Committee (NTRC)

NIOSH has identified 10 critical topic areas to guide knowledge gaps, developing strategies, and providing recommendations.
Impact on PPE

- Concerns have been raised that nanoparticles could penetrate through PPE at higher rates than larger particles
  - High priority need according to EPA, HSE, others

- NIOSH/NPPTL initiated research to address these concerns for:
  - Air purifying respirators (APR)
  - Protective clothing

- NIOSH Partnerships
  - MOU with DuPont; ASTM & ISO committee membership
Filtration Theory
Project Overview

- Contract awarded to University of Minnesota (March 2005)
  - Construct a nanoparticle penetration test system
  - Measure penetration of particles (<300 nm) through various types of filter media
  - Verify that filtration theory holds for the smaller nanoparticles
- Contract final report (April 2006)
- Follow-up NPPTL project plans (Oct 2006-Sept 2009)
  - Construct nanoparticle test system at NPPTL
  - Validate previous work with NIOSH approved respirators
  - Effect of particle size on face seal leakage
Nanoparticle Penetration Test System

Filter Media
Filter Efficiency
H&V Fiberglass Filter Media

Filter Efficiency
Electret Filter Media

Filter Efficiency
Electret Filter Media – Combined Data

Report Summary

- Findings from the NIOSH contract with U. of Minnesota’s Center for Filtration Research:
  - Penetration through filter media decreased with decreasing particle size (< 20 nm)
  - Filtration data supported the classical single-fiber filtration theory down to 3 nm size
  - No evidence for thermal rebound
Interim Recommendations

- Respirators may be necessary when engineering and administrative controls do not adequately prevent exposures
  - There are no specific exposure limits for airborne exposures to engineered nanoparticles
  - The decision to use respiratory protection should be based on professional judgment
  - Preliminary evidence shows that for respirator filter media there is no deviation from the classical single-fiber theory for particulates as small as 2.5 nm in diameter
  - It is likely that NIOSH certified respirators will be useful for protecting workers from nanoparticle inhalation

http://www.cdc.gov/niosh/topics/nanotech/
Protective Clothing

- No guidelines are currently available on the selection of clothing and gloves for the prevention of dermal exposure to nanomaterials

- Little data has been published on the penetration of nanoparticles through protective clothing
  - ASTM standard F1671 uses 27 nm bacteriophage to evaluate penetration of bloodborne pathogens
  - Penetration of 0.48 µm particles through 8 fabrics ranged from 0-31% [Shalev et al. 2000]

- NPPTL initiated research to develop methodology for standardizing bench-scale and man-in-simulant test (MIST) procedures for aerosol penetration (including nanoparticles)

http://www.cdc.gov/niosh/topics/nanotech/
Recent Studies on Aerosol Penetration of Fabric Swatches

- **RTI (James Hanley)**
  - Oleic acid & KCl test aerosols (15 nm - 3 µm)
  - Wind speeds 14, 32, and 64 mph; 90° F, 60% RH.
  - Aerosol penetration of permeable fabrics is particle size dependent.

- **Battelle (Kent Hofacre)**
  - Modified TOP 8-2-501 (aerosol penetration test method)
  - KCl test aerosol (10 nm - 10 µm); Wind speeds 8 & 23 mph; 90° F, 40% RH.
  - Penetration consistent with filtration theory
    - MPPS 100 to 400 nm; % penetration ranged < 5% to 60%

Initial NPPTL Project Focus

• Develop a passive aerosol sampler (PAS) to determine penetration through protective clothing materials with minimal flow
  – Active sampling methods may overestimate particle penetration due to additional driving force
  – Samplers should not disturb PPE-wearer environment

Test Operations Procedure (TOP)-10-2-022
Chemical Vapor and Aerosol System-Level Testing of Chemical/Biological Protective Suits.
PAS Concept

- Magnetic sampler (FeNdB magnet)
  - Small size (18 mm diameter x 3 mm)
  - No sampling flow
  - Minimal particle loss during handling

- Challenge particle--iron oxide (II, III)
  - Magnetic susceptibility
  - Spherical particles
  - Low toxicity (OSHA PEL: 10 mg/m3)
  - Inexpensive
  - Wide range of particle sizes

- Colorimetric method, SEM, TEM, or magnetic susceptibility
Characterization of PAS Response

- Aerosol concentration measured by filter cassette sampling
  - 0.3 to 2.5 mg/m$^3$, 45 minutes

- Particle sizes estimated by light scattering (110 to 280 nm)

- Two sampler prototypes
  - Prototype 1: 18 mm x 3 mm disc
  - Prototype 2: 6 mm x 2 mm disc

Aerosol Test Chamber
Sampler Response

Sample loading versus aerosol concentration

King and Gao, A Passive Aerosol Sampler for Evaluation of Personal Protective Ensembles, Presented at the 2005 Advanced Personal Protective Equipment Conference, Blacksburg, VA.
Penetration Study using Swatch

ASTM F739 Cell

- Glass cell conditions
  - 30 minute exposure
  - ≥ 50 mg/m³ iron oxide
  - Micron-sized particles
  - Ambient conditions

- Test fabric
  - Nomex (5 oz.) open weave

- Prototype 1
# Protection Factor

\[ PF = \frac{(23-1.7)}{(5.4-1.7)} = 5.8 \]

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<thead>
<tr>
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<th>Std Dev</th>
<th>N</th>
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<tr>
<td>Parafilm</td>
<td>1.7</td>
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<tr>
<td>Open (no fabric)</td>
<td>23</td>
<td>14.6</td>
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King and Gao, A Passive Aerosol Sampler for Evaluation of Personal Protective Ensembles, Presented at the 2005 Advanced Personal Protective Equipment Conference, Blacksburg, VA.
Generation of Monodisperse Nanoaerosols Using a Differential Mobility Analyzer (DMA)

Particle diameter = 100 nm
Elapsed time = 2 hours
Mean concentration = 9260/cm³
CV = 0.8 %
Summary of PAS Concept Development

- The prototype PAS based on magnetic sampling allows zero-flow collection and sensitive detection of iron oxide aerosols

- PAS demonstrates proportional response, but additional characterization is necessary

- Applicability for bench-scale fabric penetration tests has been shown

- Further development is currently underway

- Need to analyze and incorporate results from military studies into NIOSH recommendations
Quality Partnerships Enhance Worker Safety & Health

Visit Us at: http://www.cdc.gov/niosh/npptl/default.html

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Thank you
NIOSH Certification Test

- **N- designated respirators:**
  - NaCl particles with a count median diameter (CMD) of $0.075 \pm 0.020 \mu m$ and a geometric standard deviation (GSD) of less than 1.86
  - 95% of the particles in the range of 22 nm – 259 nm
  - Mass median diameter of ~240 nm

- **For R- and P- designated respirators:**
  - DOP particles with a CMD of $0.185 \pm 0.020 \mu m$ and a GSD of less than 1.60

- **Particles penetrating through the filter are measured simultaneously using a forward light scattering photometer**
NaCl Particle Size Distribution

CMD = 75 nm  
GSD = 1.86
Studies at High Flow Rates

- NIOSH requirements were met at 85 L/min constant flow rate
- Penetration of particles in the 20 to 700 nm range tended to increase with increased flow rates
- Most penetrating particle size (MPPS) shifted to 50-100 nm for N95 respirators
Reusability of Filtering Facepiece Respirators

Jon Szalajda, Samy Rengasamy, Raymond Roberge, Ron Shaffer, Evanly Vo, Dennis Viscusi

October 13, 2006
Background – Planning Efforts

2005/2006 – CDC internal request for proposals related to influenza pandemic research

- NPPTL develops Respiratory Protection Research for Infection Control Proposal and receives CDC program funding

2006 – DHHS requests an IOM committee examine issues relative to the potential reuse of medical masks and N95 respirators in the event of an influenza pandemic

During a pandemic, healthcare workers and the general public will have increased reliance on disposable N95 FFR for infection control.

According to a report from the National Academies’ Institute of Medicine (IOM)*, during an influenza pandemic over 90 million N95 FFR will be needed to protect workers in the healthcare sector during a 42 day outbreak. Additional respirators would be needed by the general public.

*http://www.iom.edu/CMS/3740/32033/34200.aspx
Background – IOM

• Some of the recommendations in the IOM report indicate that DHHS should conduct research to:

  – understand the efficacy of simple decontamination methods that could be used without negative effects on respirator integrity

  – understand the risks associated with handling a respirator that has been used for protection against a viral threat (e.g., study the likelihood that the exterior surface of the respirator might harbor pathogenic microorganisms and thus serve as a fomite)
Reusability of Filtering Facepiece Respirators

Task 1: Effect of decon on FFR filter performance

Task 2: Develop STP for measuring the efficacy of FFR decon

Task 3: Survivability of virus simulant on FFR

Task 4: Reaerosolization of virus on FFR

Task 5: Assessment of decon strategies for FFR

Task 6: Effect of decon on FFR fit

Task 7: Final Report
Reusability of Filtering Facepiece Respirators

NPPTL will give consideration to anti-viral technologies in this research study using the following hierarchy for selection of candidate FFR products and prototypes*:

- FFR certified to 42 CFR 84 requirements,
- FFR in process of being certified to 42 CFR 84
- FFR is a prototype or a commercially available product that has not been submitted to NIOSH for certification from a manufacturer who has received NIOSH certification for other respiratory protection products
- FFR prototype contains a unique technology for disinfecting or sterilizing infectious aerosol particles trapped on the exterior surface of the FFR and complements the diversity of technologies already considered in the research design

*Federal Register Notice, September 26, 2006, Vol. 71, Number 186, page 56151-56152
# Reusability of Filtering Facepiece Respirator – Project Schedule

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<th>FY2008</th>
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<td>Task 7</td>
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</table>
Project Expected Outcomes

• Improved guidelines and recommendations for respiratory protection against influenza and other infectious aerosols
  – Performance data on FFR that incorporate decontamination capabilities
  – Potential modifications for NIOSH and CDC recommendations

• Improved test methods and performance requirements for respiratory protection used by national and international standards development organizations
  – ASTM Method of a decontamination procedure for FFR
Quality Partnerships Enhance Worker Safety & Health

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National Personal Protective Technology Laboratory

Scientific Excellence Focus

Maryann D’Alessandro
Associate Director for Science

Academia - SDOs - Government Laboratories – Unions – Labor - Manufacturers
Quality Performance Initiatives

• Evaluations
  – National Academies involvement in NPPTL
  – Scientific information product review
  – Benchmarking

• Customer and Market Knowledge
  – Standards Development Committee Involvement
  – Public Meetings and feedback
  – Customer Satisfaction Groups (Focus Groups)

• Customer Relationships and Satisfaction
  – Customer Satisfaction Survey (CSS)
  – Direct Customer involvement

Academia - SDOs - Government Laboratories – Unions – Labor - Manufacturers
National Academies Involvement in NPPTL

- **Committee on PPE for the Workforce (COPPE)**
  - Three open meetings in FY06
  - Meeting 1 FY07: Oct 23-24, 2006
  - Workshop: Feb 2007 – **PPE during an Influenza Pandemic: Research, Standards, Certification and Testing Directions**

- **Review of Anthropometrics Survey and Respirator Panel Modifications**
  - Three open meetings in FY06
  - Final report due October 2006
  - Jan – Mar 2006 - **Support to HHS for Committee on the Development of Reusable Facemasks for Use During an Influenza Pandemic**

- **Review of BLS Survey of Respirator Use**
  - Three open meetings in FY06
  - Final report due October 2006

- **National Academies Evaluation of Personal Protective Technology (PPT) Cross Sector**
  - Evidence Package to National Academies Spring 2007
  - National Academies Evaluation June 2007
NPPTL Customer Satisfaction Survey

*Method:* The Surveys

- Manufacturer & User Surveys
- Survey instruments include:
  - demographic items
  - OPM’s core customer satisfaction items
  - NPPTL-specific items
- Surveys pilot-tested in October 2005
- OMB approval for distribution to public: Dec 2005
- Online administration: Dec 5 - 23, 2005
- Analyze results
- Act on results
- Monitor and evaluate progress
Customer Service Dimensions and Outcomes

**Service Dimensions**
- Access
- Courtesy
- Knowledge
- Timeliness
- Reliability
- Choice
- Tangibles
- Recovery
- Quality of specific services

**Organizational Outcomes**
- Customer Loyalty
- Willingness to Recommend
- Organizational Effectiveness
- Perceived Value

---

Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
NPPTL Research to Practice through Partnerships
### NPPTL Customer Satisfaction Survey Results

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<tbody>
<tr>
<td>Original Population</td>
<td>666</td>
<td>262</td>
</tr>
<tr>
<td>Undeliverables</td>
<td>44</td>
<td>19</td>
</tr>
<tr>
<td>Population</td>
<td>622</td>
<td>243</td>
</tr>
<tr>
<td>Responses</td>
<td>185</td>
<td>75</td>
</tr>
<tr>
<td>Final Response Rate</td>
<td>30%</td>
<td>31%</td>
</tr>
</tbody>
</table>
Guidelines for Interpreting Results

Favorability of Results

- **Excellent**: 90% - 100% favorable
- **Good**: 80% - 89% favorable
- **Acceptable**: 66% - 79% favorable
- **Marginal**: 50% - 65% favorable
- **Critical**: 0% - 50% favorable
<table>
<thead>
<tr>
<th>Category</th>
<th>Favorable</th>
<th>Neither</th>
<th>Unfavorable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Courtesy</td>
<td>91%</td>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>Tangibles</td>
<td>80%</td>
<td>16%</td>
<td>8%</td>
</tr>
<tr>
<td>Knowledge</td>
<td>79%</td>
<td>17%</td>
<td>4%</td>
</tr>
<tr>
<td>Access</td>
<td>77%</td>
<td>14%</td>
<td>9%</td>
</tr>
<tr>
<td>Reliability</td>
<td>71%</td>
<td>20%</td>
<td>8%</td>
</tr>
<tr>
<td>Choice</td>
<td>65%</td>
<td>25%</td>
<td>10%</td>
</tr>
<tr>
<td>Quality</td>
<td>63%</td>
<td>29%</td>
<td>7%</td>
</tr>
<tr>
<td>Timeliness</td>
<td>58%</td>
<td>29%</td>
<td>12%</td>
</tr>
<tr>
<td>Recovery</td>
<td>56%</td>
<td>28%</td>
<td>16%</td>
</tr>
</tbody>
</table>
Benchmarks: Manufacturers

- High Benchmark
- Low Benchmark
- NPPTL-Manufacturers
NPPTL CSS Results: Users

Quality: 89% Favorable, 9% Neither, 2% Unfavorable
Tangibles: 81% Favorable, 15% Neither, 20% Unfavorable
Timeliness: 77% Favorable, 22% Neither, 1% Unfavorable
Courtesy: 76% Favorable, 22% Neither, 1% Unfavorable
Choice: 75% Favorable, 21% Neither, 2% Unfavorable
Knowledge: 72% Favorable, 24% Neither, 2% Unfavorable
Access: 71% Favorable, 23% Neither, 2% Unfavorable
Reliability: 70% Favorable, 26% Neither, 2% Unfavorable
Recovery: 54% Favorable, 39% Neither, 7% Unfavorable

Favorable □ Neither □ Unfavorable
Benchmarks: Users

High Benchmark ▲ Low Benchmark ● NPPTL-Manufacturers

- Recovery: 77% (High), 44% (Low), 54% (NPPTL)
- Reliability: 97% (High), 70% (Low), 71% (NPPTL)
- Access: 91% (High), 40% (Low), 72% (NPPTL)
- Knowledge: 88% (High), 46% (Low), 75% (NPPTL)
- Choice: 83% (High), 37% (Low), 76% (NPPTL)
- Courtesy: 93% (High), 51% (Low), 77% (NPPTL)
- Timeliness: 94% (High), 49% (Low), 77% (NPPTL)
- Tangibles: 91% (High), 35% (Low), 81% (NPPTL)
- Quality: 94% (High), 42% (Low), 89% (NPPTL)

NPPTL-Manufacturers
Results: Dimension Profiles
Now that we have the survey results where do we go from here?

- **Identify areas to improve within branches**
- **Create the Customer Satisfaction Groups**
  - Keep customers satisfied on an ongoing basis
  - Provide customers easy way to voice concerns/complaints
  - Provide customers easy way to seek more information
Customer Satisfaction Groups

• Get Customer input on a regular basis
  – Groups are a resource for direct customer contact
  – Allows for regular input in keeping up with the changing personal protective equipment market

• Customer Satisfaction Group Results
  – Verify NPPTL improvement areas
  – Verify marketplace opportunities
  – Recommend action plans on specific issues involving NPPTL
Customer Satisfaction Activity at NPPTL

Customer Satisfaction Groups

• Three meetings in 2006
  – Manufacturers – Washington, DC - Apr 2006
  – Fire Services – Pittsburgh, PA - Sept 2006

• Three meetings in 2007
  – Health Care
  – Manufacturing
  – Manufacturers
Actions to Address Manufacturers’ Issues

- **Quality**
  - ISO 17025 Certification Project
  - Improving standard application form (SAF)
  - Improving and posting standard test procedures (STPs)
  - Involvement in SDOs to address color coding issues
  - Input on Manufacturer’s meeting agenda

- **Timeliness**
  - Streamlining certification process
  - Meeting lead time
  - Clarify meaning of 90 day approval

- **Recovery**
  - Improving methods for handling requests for additional information
  - Moving forward to install more CBRN testing at NIOSH
  - Adding additional filter penetration testing equipment
  - Manufacturers Arbitration Group
    - Composed of NPPTL experts not directly involved in issue of concern

- **Research updates**
  - Monthly updates on listserv and ENews
Next Steps

• Continue to act on results
• Monitor and evaluate progress
• Conduct the Second NPPTL Customer Satisfaction Surveys for Manufacturers and PPE Users.
  – JAN 2007 Finalize survey wording
  – FEB 2007 Obtain names and email addresses for customers
  – MAR 2007 Administer survey
  – APR 2007 Provide executive briefing and feedback reports
Quality Partnerships Enhance Worker Safety & Health

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Visit Us at: http://www.cdc.gov/niosh/npptl/default.html

Disclaimer: The findings and conclusions in this presentation have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy

Thank you
Recovery

Problems and complaints are resolved quickly with minimal effort on the customer’s part and problems do not recur.

• Problems and complaints are resolved quickly.
• Problems and complaints are resolved with minimal effort on the customer’s part.
• There are well-defined systems for linking customer feedback and complaints to employees who can act on this information.
• I am satisfied with the way the staff handles problems or mistakes.
• The staff is flexible in finding solutions to problems.
Quality

What the customer receives from the service provider or the perception of excellence of the product or service received.

• How would you rate the overall quality of service you received?
• From the list of services below, how would you rate the quality of each specific type of service?
Timeliness

Promptness in receiving or providing promised materials and/or service.

- Overall, NPPTL personnel provide timely service.
- (Other items were customized for this dimension. These items are not used to calculate a dimension score.)