International Society for Respiratory Protection
19th International Conference
Denver, Colorado
September 16 – 20, 2018



Photo Credit: Visit Denver / Bryce Boyer

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Schedule at a glance

Sunday, September 16, 2018			
9:00 AM - 3:00 PM	ISRP Board of Directors Meeting		Board Room Lobby Level
5:00 PM – 9:00 PM	Welcome Reception ***Sponsored by 3M***		Pool Deck– 4th floor
Monday, September 17, 2018			
8:30 AM - 8:50 AM	Welcome, Preliminaries, and Introduction		Confluence Ballroom
8:50 AM – 9:45 AM	Keynote Address: Dr. John Howard		Confluence Ballroom
9:45 AM – 10:40 AM	Roundtable: Historical Perspectives and Future Possibilities for Respiratory Protection ***Sponsored by Kanomax, USA***		Confluence Ballroom
10:40 AM – 11:00 AM	Break		Confluence Foyer
11:00 AM – 12:30 PM	Roundtable continued: Historical Perspectives and Future Possibilities for Respiratory Protection		Confluence Ballroom
12:30 PM – 1:30 PM	Lunch		Platte River Room
1:30 PM – 3:30 PM	Roundtable: Respiratory Innovations in Healthcare and Emergency Response ***Sponsored by The S.E.A. Group***		Confluence Ballroom
3:30 PM – 3:50 PM	Break		Confluence Foyer
3:50 PM – 5:10 PM	Roundtable continued: Respiratory Innovations in Healthcare and Emergency Response		Confluence Ballroom
6:00 PM	Off-site Social Event ***Sponsored by Calgon Carbon Corporation***		Wynkoop Brewery
Tuesday, September 18, 2018			
8:30 AM – 8:40 AM	Preliminaries and Introduction		Confluence Ballroom
8:40 AM – 9:00 AM	Keynote Address: Michael Clayton, 3M UK		
9:00 AM – 10:30 AM	Technical Session		Confluence Ballroom
10:30 AM – 10:50 AM	Break ***Sponsored by TSI, Inc.***		Confluence Foyer
10:50 AM – 12:30 PM	Posters and Exhibits **Poster Session *Sponsored by CleanSpace Technology Pty, Ltd.***		Confluence Foyer
12:30 PM – 1:30 PM	Lunch		Platte River Room
1:30 PM – 3:00 PM	Posters and Exhibits	Technical Session	Confluence Foyer
3:00 PM – 3:20 PM	Break ***Sponsored by OHD USA, Inc.***		Confluence Foyer
3:20 PM – 5:30 PM	Technical Session		Confluence Ballroom

Wednesday, September 19, 2018		
8:30 AM – 8:40 AM	Preliminaries and Introduction	Confluence Ballroom
8:40 AM – 9:00 AM	Keynote Address: Dr. Hyunwook Kim	Confluence Ballroom
9:00 AM – 10:40 AM	Roundtable: Respiratory Protection Use by Wildland Firefighters and Impacted Community Members ***Sponsored by Moldex-Metric, Inc.***	Confluence Ballroom
10:40 AM – 11:00 AM	Break ***Sponsored by ICS Laboratories Inc.***	Confluence Foyer
11:00 AM – 12:00 Noon	Roundtable continued: Respiratory Protection Use by Wildland Firefighters and Impacted Community Members	Confluence Ballroom
12:00 Noon – 12:30 PM	Annual General Meeting	Platte River Room
12:30 PM – 1:30 PM	Lunch	Platte River Room
1:30 PM – 3:30 PM	Technical Session	Confluence Ballroom
3:30 PM – 4:00 PM	Announcements for Evening	Confluence Ballroom
6:00 PM	Awards Dinner and Line Dancing ***Sponsored by Molecular Products, Inc.***	Confluence Ballroom
Thursday, September 20, 2018		
8:30 AM – 8:40 AM	Preliminaries and Introduction	Confluence Ballroom
8:40 AM – 10:40 AM	Technical Session	Confluence Ballroom
10:40 AM – 11:00 AM	Break ***Sponsored by ANSI-accredited USTAG***	Confluence Foyer
11:00 AM – 12:30 PM	Technical Session	Confluence Ballroom
12:30 PM – 1:30 PM	Lunch	Platte River Room
1:30 PM - 2:10 PM	***Technical Session***	***Confluence Ballroom***
2:10 PM – 2:20 PM	***2020 Conference Information***	***Confluence Ballroom***
2:20 PM – 2:40 PM	***Break*** ***Sponsored by Shigematsu Works Co. Ltd.***	***Confluence Foyer***
2:40 PM – 4:00 PM	***Technical Session***	***Confluence Ballroom***
4:00 PM	**Conference Closing**	**Confluence Ballroom**
Friday, September 21, 2018		
8:15 AM – 1:00 PM	NOAA David Skaggs Research Center Tour ***Sponsored by International Safety Equipment Association (ISEA)*** **(pre-registration required)**	off-site
The bus will leave the Lawrence Street entrance of the hotel at 8:15 AM. Travel time is approximately 45 minutes. The tour is 90 minutes, followed by visit to the gift shop. Bus will leave NOAA at 12:15 PM and return to the hotel around 1:00 PM.		

Electronics Policy

To respect each other's time and to help ensure we stay focused on the presentations and discussions we have all travelled here for, we ask that:

- Phones be silenced.
- If you need to take a call, please step outside of the meeting room

Planning Committee Members

Mike Parham, Conference Co-Chair
Maryann D'Alessandro, Conference Co-Chair
Judi Coyne, Meeting Planner
Dave Doughty
Jamie Hern
Bill King
Colleen Miller
Bill Newcomb
Josh Scott
Dan Shipp
Simon Smith
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Technical Committee Members

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Richard Metzler
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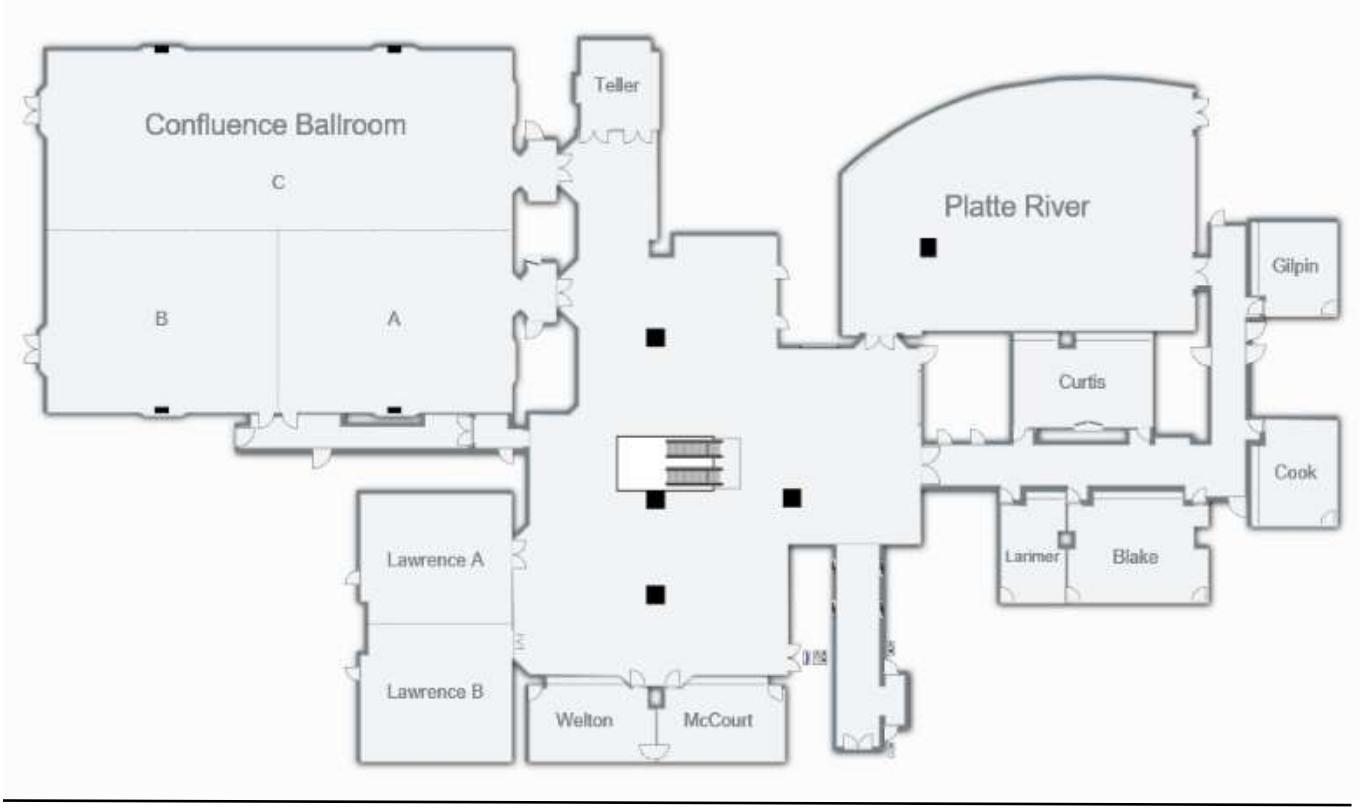
JSP Ltd.

The Westin Denver Downtown Floor Plan

Registration will be held on the lobby level on Sunday from 12:00 Noon until 4:00 PM and from 4:45 PM until 9:00 PM on the 4th Floor at the Pool Deck.

Registration will take place on the mezzanine for the rest of the week.

With the exception of the Welcome Reception and the off-site Social, all activities will be held on the **Mezzanine Level**



Welcome Reception – Sunday, September 16, 2018

Sunday, September 16, 2018 5:00 PM– 9:00 PM

Pool Deck – Fourth Floor

Rainy weather contingency location – Augusta Room- Lobby Level

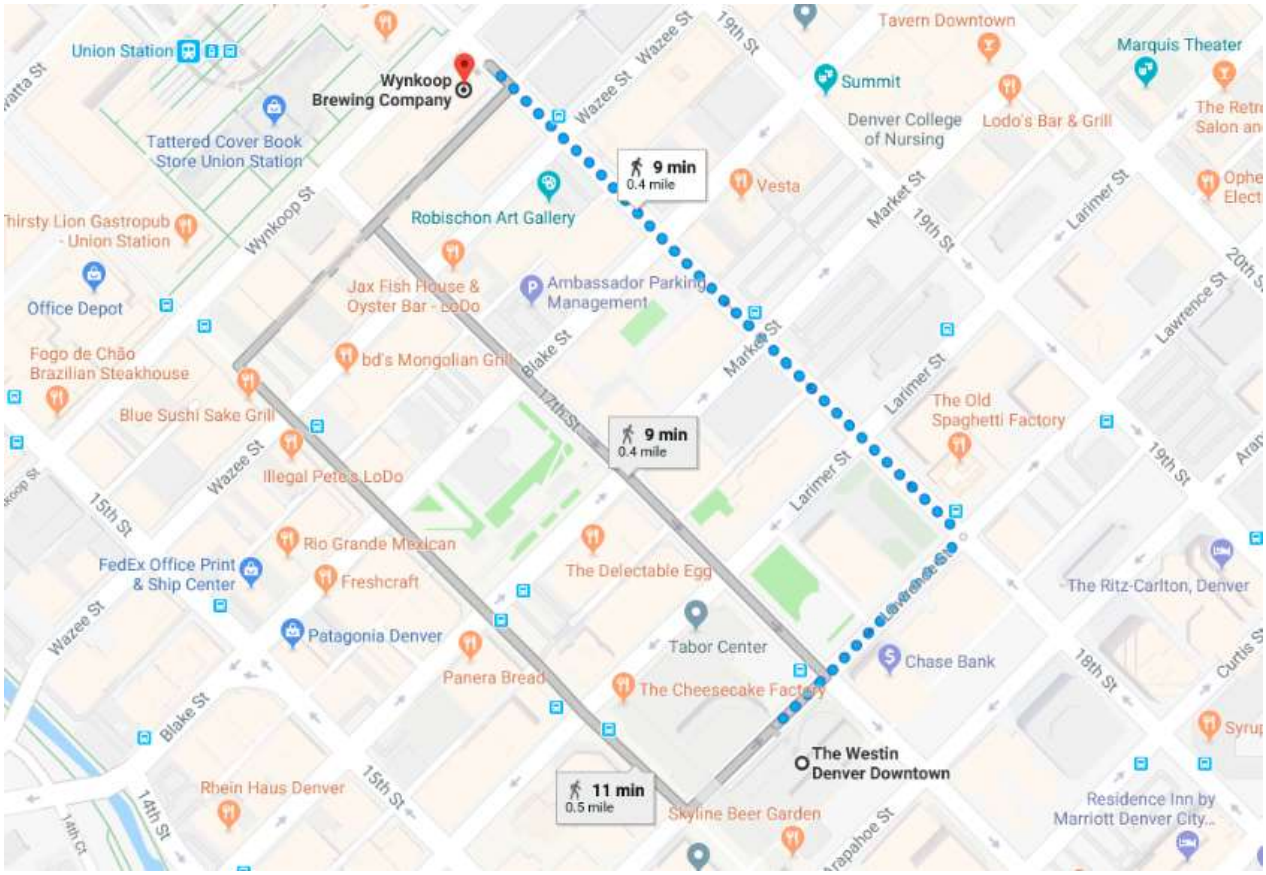
Welcome Reception sponsored by 3M

Off-site Social Event 6:00 PM

Wynkoop Brewing Company, 1634 18th St, Denver, CO 80202

Drinks and Heavy Snacks. Dress Code: Casual

Walking: ~9 min | Taxi / Car Share Service: ~4 min
Exit hotel on to Lawrence Street.
Turn Right. Proceed two blocks to 18th Street.
Turn Left. Proceed 5 blocks. Wynkoop Brewing is on the left.



Off-site social sponsored by Calgon Carbon Corporation

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Welcome to the 19th ISRP International Conference in Denver!

Dear Colleagues:

I am excited to welcome you all to our 19th biennial conference. The amazing venue chosen for this year's conference will allow delegates to enjoy a great social occasion to complement the intense technical activities the conference has scheduled. Please also take advantage of all that the wild city Denver has to offer.

I would also like to extend a warm welcome to our keynote speakers, invited guests, and to delegates who are attending the conference for the first time. I hope you all find it a rewarding and enjoyable experience.

The Americas Section conference team has worked extremely hard to organize what will be a great conference week. They have created an excellent technical program covering a range of topics, so there should be something of interest to everyone. On behalf of the entire ISRP Society, I would like to thank them all for their hard work over the last two or more years. Thank you!

We have a rich and varied technical program scheduled this week, plus a well-supported exhibition showing the best in new products and innovations from the leading manufacturers and other institutions. There is truly something for everyone!

It has been an absolute privilege and honor to serve as President of the International Society for the past two years and I look forward to continuing as the Past President. As I step down and Michael Parham takes over the helm, we experience exciting times for ISRP. I see ISRP playing an increasing role in providing education on respiratory protection, with the help of our website and our journal.

This conference brings together experts in the field of respiratory protection from all around the world and provides a great opportunity to share and exchange knowledge and ideas in all areas of respiratory protection. During the week, there will be lots of opportunity to renew old acquaintances and make new friends with similar professional interests.

Enjoy the conference!

Lars Ronner

President ISRP 2016 - 2018

A Little Bit about Denver … Some Fun Facts

Denver brews more beer than any other city in the U.S. with over 200 different beers brewed daily.

In Denver's rarified air, golf balls go about 10% farther than they would at sea level.

In 1902, the police at Denver's Union Station stated enforcing a "no kissing" rule on the platforms because it slowed down the trains.

Denver is one of the 12 U.S. cities to have teams from four major sports (baseball, hockey, football, and basketball).

Denver has been named the "Baby Boomer Capital of America" boasting a higher number of baby boomers than any other U.S. city.

The dome of the Colorado state capitol is plated with real 24K gold.

Denver is nicknamed the Mile High City because it sits at an elevation of exactly one mile, or 5,280 feet (1,609 meters).

Denver has the 10th largest downtown in America.

Denver is ranked among the best cities for singles in the U.S.

Denver currently has more marijuana dispensaries than Starbucks stores.

When viewed from above, the 400,000 pieces of granite paving on the pedestrian walkway of the 16th Street Mall resemble the skin of a diamondback rattlesnake.

The population of Denver has more than doubled since 1960.

Denver is one of the sunniest cities in the U.S. with 300 annual days with some sunshine each year.

The Colorado Rockies' Coors Field is one of the best ballparks in the U.S. for home runs. Because of its high elevation and the dry air, the balls fly much farther when hit than in other stadiums. The field has twice broken the record for major league home runs hit in a single ballpark in one season.

The Denver mint is the single largest producer of coins in the world. You can tell if a coin is made in Denver by a D mark.

In Denver, it is unlawful to lend your vacuum cleaner to your neighbor.

Denver's bright blue sky really is bluer than many other cities. Because of the elevation, the air has less water vapor than it would at a lower altitude, making for a gorgeous sky!

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Monday, September 17, 2018

8:30 AM - 8:40 AM	Welcome Lars Ronner, President ISRP
8:40 AM – 8:50 AM	Preliminaries and Introduction Dr. Maryann D'Alessandro, Chair, ISRP Americas Section
8:50 AM – 9:45 AM	Keynote Address Dr. John Howard, Director National Institute for Occupational Safety and Health
9:45 AM – 10:40 AM	Roundtable: Historical Perspectives and Future Possibilities for Respiratory Protection ***Sponsored by Kanomax, USA***
10:40 AM – 11:00 AM	Break
11:00 AM – 12:30 PM	Roundtable continued: Historical Perspectives and Future Possibilities for Respiratory Protection
12:30 PM – 1:30 PM	Lunch
1:30 PM – 3:30 PM	Roundtable: Respiratory Innovations in Healthcare and Emergency Response ***Sponsored by The S.E.A. Group***
3:30 PM – 3:50 PM	Break
3:50 PM - 5:10 PM	Roundtable Continued: Respiratory Innovations in Healthcare and Emergency Response
6:00 PM	Off-site Social Event – Wynkoop Brewery ***Sponsored by Calgon Carbon Corporation***

Roundtable: Historical Perspectives and Future Possibilities for Respiratory Protection

Sponsored by Kanomax, USA

Roundtable Chair: Richard W. Metzler, Richard W. Metzler, Inc.

In the United States, the U.S. Bureau of Mines issued the first respirator approval on January 15, 1920. The ISRP Denver Conference is approaching the Centennial of Respiratory Conformity Verification (now known as the NIOSH Respirator Approval Program). The talks in this session will provide historical, present, and future perspectives for each topic. The objective is to report on the roots and evolution of respiratory protection in the United States, including the earliest activity, the current state, and present forecasts of future possible developments.

American National Consensus Standards in U.S. Respiratory Protection – Past and Present

James S. Johnson, JSJ Associates

The historical role of the American National Standards Institute (ANSI) in conformity assessment and respiratory protection standards will be discussed. The status of current respiratory protection standards associated with the Respiratory Protection Committee, Z88, will be presented. Over the past few years, the Z88 Committee and its standards transferred among ANSI-accredited standards development organizations including the American Industrial Hygiene Association (AIHA), the American Society of Safety Engineers (ASSE), and currently ASTM International. Discussion will also include future perspectives for the development of national respiratory protection standards with the current Secretariat, ASTM International.

National Fire Protection Association Conformity Assessment of U.S. Fire Service Personal Protective Equipment and Respirators

Patricia Gleason, Safety Equipment Institute, Affiliate of ASTM International

Since 1992, NFPA standards for emergency services protective clothing and equipment have included extensive requirements for third party certification. Since that time, certification programs have operated to provide the necessary checks and balances demanded by the fire service community. As an example, a program was initiated for the testing and certification of Self-Contained Breathing Apparatus utilizing the performance standard, NFPA 1981, Open Circuit Self-Contained Breathing Apparatus for Fire Fighters. Since the initiation of this program, there have been hundreds of thousands of certified SCBA's available to emergency responders. To ensure the greatest possible protection, the Safety Equipment Institute (SEI) and the National Institute for Occupational Safety and Health (NIOSH) have maintained a close dialogue on issues of mutual interest, and in particular has worked cooperatively with NIOSH with the addition of NIOSH requirements for chemical, biological, radiological, and nuclear protection.

An Exemplary Approach to Applying the Personal Protective Equipment Conformity Assessment Framework

Maryann D'Alessandro, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

The National Institute for Occupational Safety and Health (NIOSH) Respiratory Protective Device Approval Program is founded on the principle of *permissibility* established in the early 1900s with the U.S. Bureau of Mines Approval Programs for mining products and respiratory protective devices. Today, the contemporary conformity assessment (CA) term, "Certification" refers to a conformity declaration by an independent third party. The NIOSH certificate of approval involves a governmental independent third party CA and declaration of conformity. Personal protective equipment CA in the U.S. has evolved over the 20th century into a diversity of programs and requirements ranging from national voluntary consensus-based programs to governmental regulatory programs encompassing first party, self-declarations of conformity to certification (3rd party independent) declarations of conformity. This talk will briefly describe the history of the conformity assessment framework and how the framework is driving the Respirator Approval Program into the future using the recent collaboration with the Food and Drug Administration as a case study.

U.S. Military Respiratory Protection

David Caretti, U.S. Army Edgewood Chemical and Biological Center

The U.S. Army Edgewood Chemical Biological Center (ECBC) celebrated its 100th anniversary in 2017. Since its inception, ECBC has been a leader in developing respiratory protective devices for the Army and Joint Service. However, when the United States entered World War I in April 1917, the Army was ill-prepared for chemical warfare and did not have a viable protective mask in the arsenal for the forces deployed to Europe. An initial attempt to make copies of the British Small Box Respirator (SBR) was completed by the Bureau of Mines in the Department of the Interior, but without success. As such, soldiers were issued either an SBR or a French M2 mask when they arrived in France. Undeterred by the initial failure at fabricating a U.S. mask, efforts persisted. This led to the fielding of five different masks over the short time of U.S. involvement in the war. The best of these was the Kops Tissot Monro (KTM) Mask with a stockinette-covered rubber facepiece, a canister that added felt as a mechanical filter against smoke particles, and a head-harness pad that fit on the crown of the head. Between World Wars I and II, evolutionary improvements to military respirators continued under the Chemical Warfare Service of the Army. In 1939, the U.S. Army developed a lightweight training mask with a fully molded rubber facepiece that was so popular and effective that it was standardized as the M2 series of service masks. There were over 8 million of these masks produced during World War II. Other mask systems developed during the war included the M3 Diaphragm mask, the M3 Lightweight mask, which was one pound lighter than the M2A2, the M4 Lightweight mask, and the M9 series mask in 1947. The acceptance of the M9 and M9A1 by soldiers well into the 1960s led to the redesignation of the masks for special purpose (e.g., depot operations) usage after the fielding of M17 series of masks. In fact, the M9 Special Purpose mask was in-service until 1993; the M9A1 remained in-service until 1997. The M17 mask changed to norm of using a separate side-mounted filter canister by placing filter elements in left and right cheek pouches inside the mask's facepiece. This design also eliminated the chances of snagging a side-mounted canister on something that could pull the mask away from the face. The next major mask development for the Army was the M40 series, which provided better vision, service life, comfort and easier maintenance compared to the M17. The M40 series mask was first used on a limited basis during Operation Desert Storm in 1990 and was the primary mask in-service for Operation Iraqi Freedom. The most recent ECBC - developed mask is the M50 Joint Service General Purpose Mask (JSGPM), which was designed to reduced user encumbrances while significantly enhancing protection. Due to the joint service application of the mask, the JSGPM was one of the most heavily tested pieces of personal protective equipment in the Department of Defense to ensure it met the diverse needs among all branches of the U.S. Military. Today, ECBC continues to explore

technologies for improving military respiratory protective devices and is preparing to work with soldiers, airmen, seamen, and marines to provide the respirators needed for protection of future threats.

Chemical, Biological, Radiological, and Nuclear Respiratory Protection: The New Frontier in Respiratory Protection

Jon Szalajda, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

Prior to 2001, there were no standards for emergency response personnel in the United States for respiratory protective devices for a full range of expected chemical, biological, radiological, and nuclear (CBRN) terrorist threats. Under Federal regulations, emergency response personnel are required to use respirators approved by the National Institute for Occupational Safety and Health (NIOSH) for the expected hazards. Standards were needed to protect against CBRN threats. Neither industrial nor military respirators provided protection from the entire complement of potential CBRN respiratory hazards. Since 2001, CBRN standards have been developed for five classes of respirators: Open-Circuit Self-Contained Breathing Apparatus, Air-Purifying Respirators, Air-Purifying Escape Respirators, Self-Contained Escape Respirators, and Powered Air-Purifying Respirators.
NIOSH CBRN respirator standards and NFPA standards were the first adopted by the Department of Homeland Security (DHS). DHS uses these standards to award grant monies for the purchase of PPE for the first responder community. The NIOSH CBRN standards have been referenced in national and international consensus standards. Multiple manufacturers hold multiple approvals of CBRN respiratory protective devices (RPD).
In 2014, NIOSH initiated a project to assess if CBRN approved RPD capabilities can protect against evolving chemical and radiological hazards that have been identified since the original CBRN hazard assessment was performed. This presentation will review the NIOSH CBRN standards development process and provide an update on the current hazard assessment evaluation.

Future Respiratory Protection Needs of Special Populations

Mike Clayton, 3M, UK

In many people's minds Respiratory Protection Equipment (RPE) often means a 'dust mask' and for many of these, their image of a 'dust mask' can range from a simple paper mask, which in fact may be a medical type mask, to a high efficiency disposable filtering facepiece. To others, respiratory protection conjures up images of firefighters' breathing apparatus. Today we have a large range of RPE, which has developed over many years. This presentation will touch upon the historical drivers that have resulted in the RPE we have today and will explore how RPE will have to advance, either driven by regulation or innovation, to meet the requirements of the future diverse and aging workforce.

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Roundtable: Respiratory Protective Device Innovations in Healthcare and Emergency Response Events

Sponsored by the S.E.A. Group

Roundtable Chair: Maryann D'Alessandro, National Institute for Occupational Safety and Health, National Personal Protective Technology Laboratory, ISRP Americas Section Chair

Respiratory protective device (RPD) innovations in healthcare and emergency response events include a number of strategies. Strategies include innovation advancements associated with 1) approved RPDs, 2) prototype RPDs, and 3) materials and strategies for next generation RPDs. A fourth component supports the development of models concerning early advanced notice to manufacturers and hospitals to improve the matching of supply and demand of RPDs and facemasks during a pandemic event. This Roundtable will include invited speakers from all four aspects of innovation. National and International partners have been involved in a number of activities to address RPD innovation. The activities were developed as lessons learned from the H1N1 pandemic and the subsequent H7N9 crisis, as well as from recommendations provided in the Institute of Medicine 2008 and 2011 reports. The two reports collectively provided over 20 recommendations to innovate and strengthen personal protective equipment design, testing, and certification. The Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Centers for Diseases Control and Prevention Influenza Coordination Unit, Centers for Disease Control and Prevention Strategic National Stockpile, the Occupational Safety and Health Administration, the Food and Drug Administration, and the Biomedical Advanced Research and Development Authority as well as non-governmental partners led and continue to direct advancements described below.

Background in U.S. Healthcare and Emergency Response Respiratory Protective Device Needs

Mark Shirley, Sutter Health

Protecting healthcare workers from droplet and aerosol transmissible diseases is complicated by a multitude of variables. These include workplace safety culture, worker understanding of exposure risks, respiratory protection program oversight, product availability/accessibility, donning/doffing competency, and human factors such as comfort, fit, usability and ease of communication. During both rapid and slow onset emergencies the impact of these variables are magnified. Issues related to human factors and how respirator innovation can help address those issues will be discussed.

Respiratory Protective Devices: Tools to Maximize the Readiness of Healthcare and Emergency Response Respiratory Protective Device Users

Barbara Braun, The Joint Commission

The National Institute for Occupational Safety and Health, The Occupational Safety and Health Administration, the Joint Commission and the California Department of Public Health collaborated to develop a number of tools to maximize the readiness of healthcare. These tools and the "*Hospital Respiratory Protection Programs: Usefulness of Resources and Informational Gaps*" effort to (1) assess the perceived usefulness of existing resources related to respiratory protection, and (2) to identify situations whereby clarification with clinical application of respiratory protection might be needed will be discussed.

Implementing the Personal Protective Equipment (PPE) Monitoring System to Understand Respirator and PPE Best Practices in Healthcare

Mary Yarbrough, Vanderbilt University

A PPE Monitoring system was implemented across the U.S. to understand how respirators and other PPE are being used during emergency response scenarios. Data were collected regarding best practices using four methods:

1) interviews with stakeholders at existing Ebola Virus Disease (EVD) programs;
2) incorporation of a report describing effective use of respirators;
3) interviews with subject matter experts; and
4) extensive literature review on EVD personal protective equipment.

Twenty-seven actionable recommendations were developed in the domains of program administration, hazard assessment, PPE selection and fit, procurement, communication and training, equipment integrity, and program evaluation. These recommendations should guide hospital PPE programs and stakeholders on the consistent incorporation of PPE management best practices into comprehensive occupational protection plans across all patient care venues.



Project BREATHE and Elastomeric Respirator Use in U.S. Healthcare

Lewis Radonovich, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

U.S. healthcare personnel (HCP) have sought improved respiratory protective devices (RPD) that meet their needs and do not interfere with occupational duties. Between 2008 and 2016, the National Institute for Occupational Safety and Health collaborated with the Veterans Health Administration and private sector respirator manufacturers to shepherd new RPD to the U.S. healthcare workplace. This multi-phase effort, called Better Respiratory Equipment using Advanced Technologies for Healthcare Employees (Project BREATHE), utilized a Cooperative Research and Development Agreement that concluded with a randomized clinical study comparing tolerability of new prototype respirators to commonly used N95 respirators. The Project BREATHE results and lessons learned will be discussed. Additionally, Dr. Radonovich will discuss an effort undertaken by NIOSH to assess the feasibility of using of elastomeric respirators for routine care delivery and/or during public health emergencies in which healthcare systems experience shortages of N95 respirators.

Availability and Storage of Elastomeric Respirators Used by Healthcare Workers

Stella Hines, University of Maryland

Consistent availability, ease of access, and assurance of storage are potential barriers to implementation of elastomeric respirator (ER) use in hospital respiratory protection programs (RPPs). As part of a larger effort to determine the feasibility and acceptability of reusable respirators in healthcare, we surveyed ER users from five organizations within a medical system where ERs are included as one component of the RPP to understand use practices regarding storage and respirator availability.

Methods: All healthcare workers (HCWs) involved in the RPPs were invited to participate in an electronic survey in fall of 2016. Respondents completed the survey either via a direct email-embedded link or through an access code on study-supplied laptops during clinical unit visits by the study team.

Results: 1152 HCWs completed the survey, of whom 24% were current ER users at the time. 94% of ER users reported that their ER was “always” or “usually available” at time of need. When asked about respirator storage location, 65% reported storing their respirators nearby while the remainder reported other locations on campus, in their cars, at home, or “other.” Fifty-eight percent reported storing their respirators correctly, in a sealed bag and protected from deformation, and 19% reported storing their ERs not in a sealed bag, but protected so it retains its shape (such as hanging from a hook.)

Conclusions: The majority of ER users stored their ERs conveniently in the patient care area, yet some did not. This may reflect practices of “unit-based” workers, who perform the work tasks in a single general location, like nurses, versus more “transient” workers, who see patients all over the hospital, like doctors. Equipping this latter population poses a challenge in assuring ease of access for ER use. Less than two-thirds of ER users store their respirators as expected, potentially limiting the lifespan of the filter. Both inconvenient and improper storage may inhibit timely and optimal ER use in hospital settings. To optimize use of ERs in healthcare, solutions for convenient and appropriate immediate access and longer-term storage should be developed, potentially including standardized, location-based strategies.

Control Banding Strategies to Reduce the Demand for Respiratory Protective Devices During Emergency Response Scenarios

Margaret Sietsema, University of Illinois, Chicago

Protecting workers during a public health emergency (e.g., infectious disease outbreak, pandemic influenza, etc.) involves utilizing appropriate control measures to minimize the transmission of infections from person-to-person. While much attention is placed on respiratory protective devices (RPDs), less information is available about alternative control strategies. Governmental and professional society guidance tends to focus on workers in the

highest exposure risk categories, leaving questions unanswered about lower risk workers. Because the demand for RPDs may be larger than the available supply during public health emergencies, as demonstrated by the Severe Acute Respiratory Syndrome (SARS) in 2002 and 2003, and the 2009 H1N1 influenza, increased attention is needed on RPD prioritization. Workers with tasks resulting in the highest levels of exposures should be given priority access. Alternative control options should be emphasized for workers with job tasks and functions that result in lower levels of exposure. This project uses a structured framework, called "control banding" to guide the selection of hazard controls using available data, observations, and assumptions based on experience and decision logic. Control banding is a system for organizing qualitative and quantitative information and providing a decision logic for selection of appropriate suites of control technologies that can be selected from "bands" of hazards. In FY17, the University of Illinois at Chicago and the National Institute for Occupational Safety and Health (NIOSH) finished a draft of a control banding paper describing the process for selection of controls for aerosol transmissible infectious disease organisms and is currently undergoing internal and external peer-review. In the paper, a process is laid out describing how to classify four variables of aerosol transmissible risk (toxicity, exposure duration, exposure frequency, and exposure concentration). Each of the four variables is aggregated into a single control band where the user can select appropriate control measures for their workplace. This model focuses on reducing exposure first at the source, second at the pathway, and third at the receptor. The paper presents a framework to demonstrate mechanisms to protect low, medium, and high-risk employees using a variety of control strategies while saving RPDs for the highest risk employees. NIOSH's National Personal Protective Technology Laboratory in collaboration with the NIOSH Emergency Preparedness and Response Office, and the CDC Influenza Coordination Unit is leading this work

Innovative Devices to Meet Healthcare Worker Needs

Alex Birrell, CleanSpace Technology Pty. Ltd.

Current powered air-purifying respirator (PAPR) approval requirements were developed in 1972 for industrial use and exposures. Since 1972, the use of PAPRs has grown and expanded into other workplaces including healthcare environments. Recently CleanSpace developed a device displaying many of the features desired by healthcare workers. The platform technology based on principles commonly used in current consumer and medical device technology. Developed by a team of respiratory biomedical engineers, CleanSpace's latest model (approved in Europe) is the lightest and most compact powered respirator in the market. The Generation 3 device incorporates many of the features requested by healthcare workers and removes cables and hoses that complicate donning, doffing, and cleaning. The key objective of the device's design is to overcome barriers to wider and more effective PAPR use in the healthcare setting and facilitate patient care and healthcare worker protection.

Innovative Prototypes and Engineering Development Models

Michael Parham, Scott Safety/3M US
Sundaresan Jayaraman, Georgia Institute of Technology

In 2011, the Veterans Health Administration published a document from a federal-wide working group identifying desired features of a respiratory protection device (RPD) for healthcare. The objective was to facilitate the development of advanced technologies for the next generation of healthcare worker RPDs that are more comfortable and tolerable. Over the past six years, different federal organizations have independently funded the development of innovative prototype RPDs, and performed minimal evaluations to assess their feasibility for the healthcare environment. Three promising prototype devices have been developed, each having its own merits. While significant U.S. federal resources have gone into the development of these prototype devices, funds have not been provided to sustain the continued evaluation, laboratory testing, human subject testing, field testing, NIOSH approval, FDA clearance, and production of these devices. Two of the three prototypes will be presented.

Building a Better Respirator Using Advanced Technology and Innovation

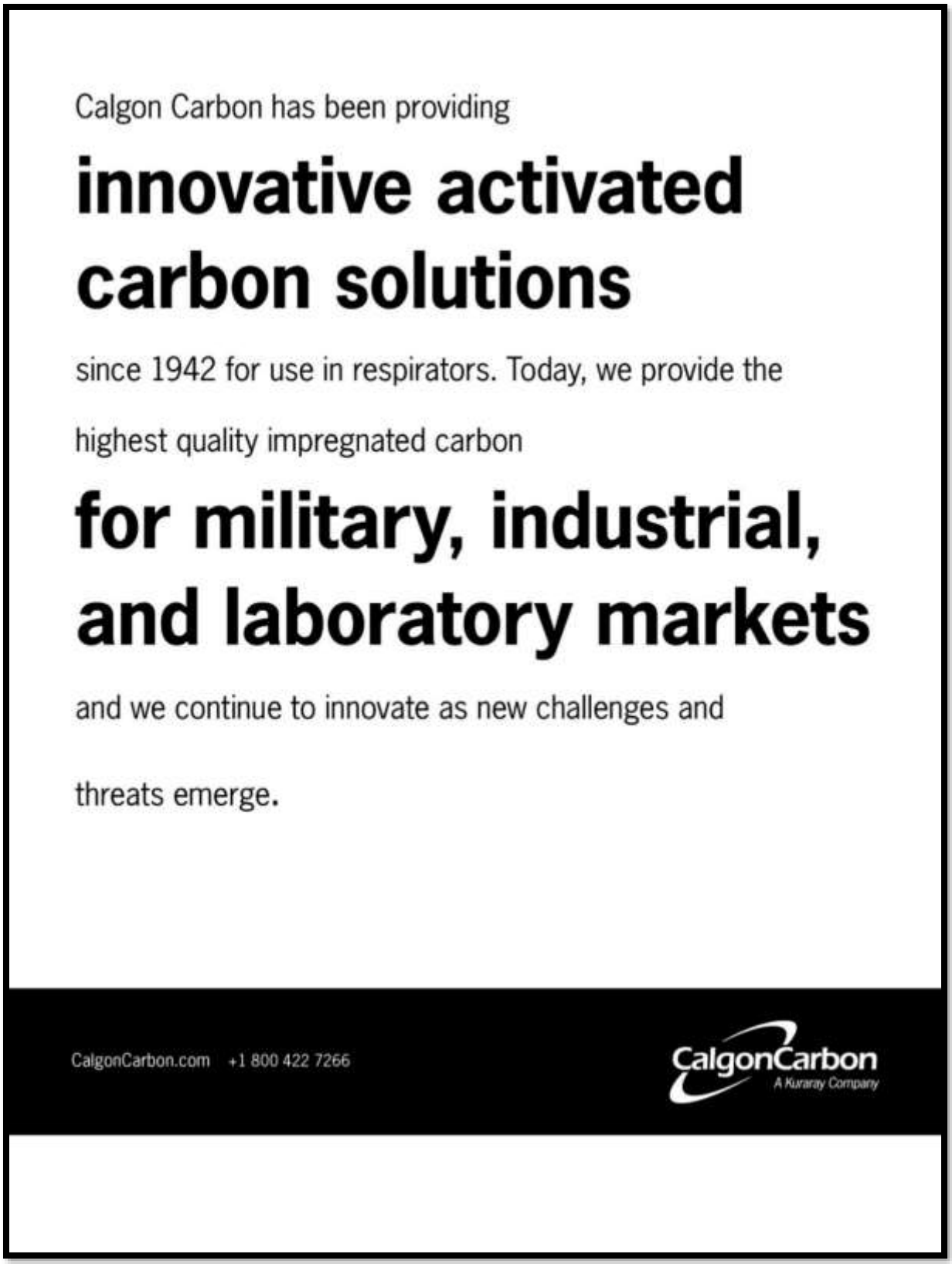
Brian Heimbuch, Applied Research Associates

The U.S .Department of Health and Human Services, Office of the Assistant Secretary for Preparedness and Response, Biomedical Advanced Research and Development Authority (BARDA) awarded a contract to Applied Research Associates, Inc. (ARA) in September 2017, to advance the development of respirators that can be reused at least 100 times during public health emergencies. (Contract # HHSO100201700032C, "Advanced Development of Reusable Respiratory Devices.") Under the 15-month base period, the ARA team will develop/utilize state-of-the-art materials in filtration technology and respirator design that tolerate ≥ 100 autoclaving and washing cycles. Preliminary data has shown multiple media candidates are available that withstand 100 autoclave cycles with very little decay in filtration performance. As part of this project, the ARA team will also obtain healthcare worker (HCW) input, and incorporate their feedback into the respirator design through iterative prototyping. This research builds on a decade of ARA research focused on mitigating a shortage of respirators during a pandemic. Most notably was an effort performed for the Food and Drug Administration (Contract # HHSF223201400158C) in which ARA evaluated the performance of elastomeric and N95 respirators after multiple decontamination cycles. These data, which are a combination of laboratory studies and HCW outreach, provided the foundation to develop a better respirator for HCWs. The novel respirator will reduce stockpiling and distribution costs and could ensure a wider availability of respirators during influenza pandemic and other public health emergencies. The respirator is also being developed at a cost point to be used routinely within hospitals during non-pandemic settings.



Off-site Social Event 6:00 PM

Sponsored by Calgon Corporation Wynkoop Brewing Company, 1634 18th St, Denver, CO 80202



Tuesday, September 18, 2018

8:30 AM – 8:40 AM	Preliminaries and Introduction	
8:40 AM – 9:00 AM	Keynote Address: Michael Clayton, 3M UK	
9:00 AM – 10:30 AM	Technical Session	
10:30 AM – 10:50 AM	Break ***Sponsored by TSI Inc.***	
10:50 AM – 12:30 PM	Posters and Exhibits Poster Session ***Sponsored by CleanSpace Technology Pty. Ltd.***	
12:30 PM – 1:30 PM	Lunch	
1:30 PM – 3:00 PM	Posters and Exhibits	Technical Session
3:00 PM – 3:20 PM	Break ***Sponsored by OHD USA, Inc.***	
3:20 PM – 5:30 PM	Technical Session	



Tuesday Technical Session 9:00 AM – 10:30 AM

Fit Testing of Stockpiled Respirators

Dana Rottach, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

N95 filtering facepiece respirators (FFRs) have been stockpiled in large quantities for use during public health emergencies. Many of these respirators have now been in storage for over a decade. As these respirators age, the material properties of the components may change and affect the fit characteristics. Face seal leaks can lead to decreased protection from respiratory hazards. We have performed OSHA-style fit testing on human subjects with two sizes each of two popularly stockpiled N95 FFR models retrieved from various stockpiles for comparison with freshly purchased samples. Stockpiled respirators ranged in age from 13 years to 6 years. There have been concerns that aging in storage may affect material properties of respirator components. The respirator component most likely to degrade in a manner that would affect fit is the elastic strap. The models tested both use two fixed (non-adjustable) straps; one using a polyisoprene compound and the other an unknown thermoplastic elastomer. Previous tensile testing on polyisoprene straps from stockpiled respirators did not find any changes in elastic properties considered likely to affect fit. OSHA requires users undergo annual fit testing for each model of tight-fitting respirator such as these FFR to show fit compatibility of the user and the respirator. In the same way that fit testing provides confidence in the fit performance of freshly manufactured FFRs, users that have been fit-tested on fresh models should expect to have similar fit with respirators from stockpiles. Preliminary results do not show clear impact of storage on fit, though analysis is ongoing. Across all models tested, the percentage of test subjects able to achieve a passing fit test score did not decrease for stored FFRs compared to fresh FFRs. This study has been performed under NIOSH Institutional Review Board clearance number 16-NPPTL—1XP.

Determine the Utility of Stockpiled Products to Protect Workers

Lee Greenawald, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

During the H1N1 and H7N9 pandemics, supply chain shortages occurred. With 18 million U.S. healthcare workers, this resulted in a reliance on stockpiled personal protective equipment (PPE). PPE is currently stockpiled at hospitals as well as at the county, city, state, and federal level. Given the variable resources that these entities have at their disposal, the environmental conditions under which the PPE is stored is also quite variable. Despite our nation's reliance on this stockpiled PPE, there is an absence of data to demonstrate that these PPE remain protective under these varied storage conditions. Further complicating this matter is the issue of shelf life. Manufacturers never produced these PPE products for the purpose of being stockpiled for many years at a time. Recognizing that their products are being included in stockpiles, liability concerns exist for manufacturers, which have begun specifying shelf lives for their products despite the infancy of advanced aging research/methodologies for PPE. As a result, some PPE has a shelf life while other PPE does not. It is unclear when to discard PPE that does not have a shelf life designation, and it is unclear if PPE with a shelf life designation will not be protective if the shelf life has passed. Stockpiling and replacing PPE inventory comes at a significant cost. It is critical that we understand the implications of storage conditions over time on the ability of PPE to remain protective.

Hydrogen Peroxide Vapor Decontamination for Reuse of N95 Filtering Facepiece Respirators

Aaron Richardson, Battelle Memorial Institute

Healthcare professionals commonly use filtering facepiece respirators (FFRs). In the event of a pandemic (e.g. influenza), large numbers (one estimate is 90 million over a 6-week period) of FFRs will be used by healthcare workers for protection, resulting in a shortage of new FFRs. Consensus Statement 7 of the Project BREATHE report recommends that respirators should be capable of being repeatedly decontaminated during a crisis for up to 50 cycles without causing damage to the respirator. Research presented here investigated use of hydrogen peroxide vapor (HPV) decontamination, which is an industry standard decontaminant used in research, pharmaceutical, and medical facilities. Complete decontamination (6-log reduction) of whole, intact FFRs contaminated with a robust biological indicator, G. stearothermophilus spores, by either liquid droplet deposition or aerosol filtration was demonstrated after multiple cycles (up to 50) of biological exposure/decontamination. The performance of the FFR was evaluated after exposure to up to 50 HPV cycles in increments of 10 cycles. Performance tests included inert aerosol collection efficiency, biological aerosol collection efficiency, inhalation resistance, and respirator fit on a manikin head form. No visible degradation was observed after exposure to 10 or 20 HPV cycles. However, after 30 HPV cycles, it was observed that that elastic material in the straps fragmented when stretched. Conversely, the aerosol collection efficiency (both inert and biological) and the air flow resistance were not affected by the HPV exposure. This pilot study successfully demonstrated the feasibility of FFR decontamination and reuse and established testing methods for future investigation of additional decontamination technologies. As this was a pilot study, only one brand of N95 FFR, the Model 1860 (3M, St. Paul, MN), was used to assess the feasibility of the approach. It is recommended to characterize the impact of the HPV decontamination cycle on the performance of other N95 FFR brands/models, especially those with different filtration media. In addition, it is recommended to test using organism of interest within the healthcare community to further demonstrate the efficacy of the HPV decontamination cycle and optimize it operation.

A Manikin-Based Assessment of Powered Air-Purifying Respirators

Michael Bergman, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

Objective: The National Institute for Occupational Safety and Health (NIOSH) has initiated efforts to update the approval standards for powered air-purifying respirators (PAPRs). PAPRs with loose-fitting facepieces require a minimum airflow of 170 Lpm for NIOSH certification. To support standards development, this preliminary study used an advanced headform to assess the performance of two models of loose-fitting PAPRs at different breathing work rates and PAPR flowrates.

Methods: Two models of NIOSH-approved loose-fitting PAPRs (Models A and B) were evaluated. The PAPRs were mounted onto a medium-sized NIOSH-designed static advanced headform mounted onto a torso and connected to a breathing machine. Faceseal leakage of sodium chloride aerosol was assessed by a particle counting method over a 2-minute sample period. High efficiency particulate air (HEPA)-filtered supplied-air was delivered to the PAPR facepieces using a mass flow regulator with digital controller. Combinations of different work rates (LOW: 25 Lpm, MODERATE: 48 Lpm, and HIGH: 88 Lpm) and supplied-air flowrates (50 – 215 Lpm) were assessed. Manikin penetration factors (mPF) were calculated as the ratio of the test chamber concentration to the in-facepiece concentration. Geometric mean (GM) and 5th percentile mPFs were calculated. A 5th percentile GM mPF > 250 (i.e., 10 times greater than the OSHA assigned protection factor of 25) was chosen as the benchmark for acceptable performance. Analysis of variance tests were used to assess the variables affecting mPF.

Results: Work rate, supplied-air flowrate, and their interaction significantly affected PAPR performance. At the LOW work rate, Models A and B achieved acceptable performance for flowrates from 206 – 62 and 215 – 75 Lpm, respectively. At the MODERATE work rate, Models A and B achieved acceptable performance for flowrates from 206 – 125 and 215 – 125 Lpm, respectively. At the HIGH work rate, neither model could achieve acceptable

performance at flow rates < 170 Lpm.

Conclusions: Acceptable respirator performance was observed at the LOW and MODERATE work rates for supplied-air flowrates down to the range of approximately 75 Lpm and 125 Lpm, respectively. PAPRs may be able to be designed with blower motors delivering < 170 Lpm for some workplace applications.



Exhibits 10:50 AM – 12:30 PM and 1:30 PM - 3:00 PM

Exhibitor	Booth Number
Molecular Products	1
NIOSH NPPTL	2
3M	3
ICS Laboratories	4
The S.E.A. Group	5
National Jewish Health	6
Kanomax USA	7
Nextteq	8
Sibata	9
Federal Resources / Mine Survival / ATOR	10
Assay Technology	11
Core Protection Systems Limited	12
OHD USA Inc.	13
Calgon Carbon Corporation	14
TSI Inc.	15
CleanSpace Technology Pty. Ltd.	16

Poster Presentations 10:50 AM – 12:30 PM and 1:30 PM - 3:00 PM

Poster Session Sponsored by CleanSpace Technology Pty. Ltd.



Complete your ballot for best poster and deposit in the ballot box at the registration desk. Voting closes at noon on Wednesday. Your ballot is in your program book.



Poster Title	Presenter
A Comparison of U.S. NIOSH Constant Flow and ISO Dynamic Methods for Breathing Resistance of Current Respiratory Protective Devices	Bill King
Acceptable Inspired CO_2 in the Presence of the Breathing Resistance Imposed by a Respiratory Protective Device	Dan Warkander
Adsorption and Decomposition Characteristics of Methanol Vapor on Silica Gel Thermally Sprayed with Titanium Dioxide Photocatalyst	Hajime Hori
Assessment of the Impact of the Five ISO Head Sizes on Breathing Resistance, Work of Breathing and Dead Space of Respiratory Protective Devices	Krysztof Makowski
Burn Saver Device	Girish Srinivas
Cleaning and Disinfection Practices Among Elastomeric Respirator Users In Healthcare	Stella Hines
Compare the Performance of Two Wet Bulb Thermocouple Designs Used During Performance Evaluations of Closed-Circuit Escape Respirators	Dave Cowgill
Development of a Speech Intelligibility Requirement for Powered Air-Purifying Respirators	Andrew Palmiero
Best Poster **Diesel Particulate Matter Penetration through PAPR Filters**	**Jane Whitelaw**
Exhaled Airflow Characteristics for a PAPR w/ Loose Fitting Hood as Related to Surgical Use	Larry Green
Exploring the Concept of a Wearable Closed-Circuit Mining Escape Respirator: A Human Factors Perspective Case Study	Rohan Fernando
Methods for Real-Time Respirator Leakage Detection	Caitlyn McClain
Nuisance-Level Organic Vapor Adsorption: Evaluating the Performance of a Commercial Paint Odor	Margaret Summers
Quality Assurance Sampling Plans in U.S. Stockpiles for Attribute Data: A Computer Simulation to Examine the Accuracy of Different Sample Sizes at Recovering True Production Lot Percent Defective	Patrick Yorio
Streamlined Process for the NIOSH Approval of N95 Filtering Facepiece Respirators Used in Healthcare Settings	Heidi Sewchok
Update Canadian National Standard for Selection, Use and Care of Respirators CAN/CSA Z94.4-18	Eva Dickson

Poster Abstracts

A Comparison of U.S. NIOSH Constant Flow and ISO Dynamic Methods for Breathing Resistance of Current Respiratory Protective Devices

Bill King, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

For evaluating breathing resistance of respiratory protective devices (RPD) U.S. NIOSH uses constant flow +/-85 L/min (which as peak flow corresponds to a ventilation rate, V_E = 27 L/min) for all air-purifying respirators (APR), tight-fitting powered APR (blower off) and supplied-air respirators (SAR) (at required air-line supply flow). Breathing resistance requirements (pressure limits) in 42 CFR Part 84 vary with certain design aspects (*e.g.* APR design and filter type). ISO published a dynamic method for recording pressure-volume (P-V) data during sinusoidal flow and proposed volume-averaged, peak pressure and elastance limits for all RPD (any design) and ventilation rates (10 to 135 L/min). To compare results and requirements, both methods were applied to available as-received APR and SAR (53 largely U.S. NIOSH-approved configurations). All APR (seven full-facepiece, 38 half-mask, and nine powered) and SAR (three self-contained and six airline) met both U.S. NIOSH and proposed ISO requirements at ISO work rate 1 (35 L/min). With U.S. NIOSH considered across all designs, maximum inspiration limits were comparable whereas U.S. NIOSH expiration limits were lower than proposed ISO limits. At ISO work rate 2 (65 L/min) six full-facepiece APR with combination filters (high efficiency particulate/chemical sorbent) exceeded ISO inspiration limits. At ISO work rate 3 (105 L/min) these were joined by two (of eleven) elastomeric half-mask APR with high efficiency particulate filters and one (of three) tight-fitting PAPR with similar results at ISO work rate 4 (135 L/min). Filtering facepiece, hooded powered APR, self-contained pressure-demand SAR met requirements at all work rates. Airline SAR exceeded ISO limit(s): two (of four) constant flow at work rate 2; one at work rate 3; two constant flow, two pressure demand at work rate 4.
Overall APR constant flow inhalation resistance correlated with ISO pressure(s) at all work rates. However, pressures over the flow range showed distinctly different first and second order flow-dependence for each design with both coefficients for full facepiece > elastomeric half-mask > filtering facepiece APR.

Acceptable Inspired CO_2 in the Presence of the Breathing Resistance Imposed by a Respiratory Protective Device

Daniel Warkander, U.S. Navy Aerospace Medical Research Laboratory

The CO_2 in inspired gas can come from two sources: from the breathing gas itself and from a respiratory protective device's (RPD) dead space which traps some exhaled CO_2 from a previous exhalation. Limits on the CO_2 levels in inspired gas have been developed and published. A summary in Table 2 in ISO 16976-3:2011(E) (similar to other standards) states that an inspired level of 5% (at 1 atm) is considered acceptable for 8 hours at rest and for 15 minutes at an extremely high work rate. In addition, 1.5% can be tolerated indefinitely at rest and for an unknown time at a very high work rate. It must be noted that these limits were developed in situations with no or minimal breathing resistance. In such situations, the body's normal response of increasing the minute ventilation to maintain the CO_2 level in the body would not be hampered by breathing resistance. Breathing resistance of some degree will always be present in an RPD. Breathing resistance tends to lower the minute ventilation. Obviously, breathing resistance and inspired CO_2 act in opposite ways on the human.
Recent empirical research, combined with results from previous studies, have added to the understanding of the combined effects of inspired CO_2 and breathing resistance. Based on this new information, the new revision of ISO 16976-3 has added limits on inspired CO_2 when breathing resistance typical of an RPD is present. The effect of workload is included: at rest the inspired CO_2 can be up to 2.5%, but at 35 and 65 L/min it must not exceed 2%

and it must the below 1.5% at or above minute ventilations of 105 L/min. These limits will benefit the wearers of RPD.

Adsorption and Decomposition Characteristics of Methanol Vapor on Silica Gel Thermally Sprayed with Titanium Dioxide Photocatalyst

Hajime Hori, University of Occupational and Environmental Health, Japan

Activated carbon is widely used as an adsorbent in cartridges and canisters for organic vapors. Although activated carbon has a strong adsorption affinity to many organic vapors, affinity to some polar compounds, such as methanol, is extremely weak. Silica gel is much better than activated carbon, but adsorption capacity of silica gel is not enough for respirator cartridges. Recently, the use of titanium dioxide photo catalyst has been increasing for decomposition of volatile organic compounds in indoor and outdoor environments. By using photo catalyst with silica gel, extension of breakthrough time is expected. In this study, we made a new material, that is, an adsorbent thermally sprayed with titanium dioxide photo catalyst. Adsorption and decomposition characteristics of methanol on such materials were investigated experimentally. Two kinds of photo catalyst (TiO2) that is, for ultraviolet (UV) rays (F6) or for visible rays (MTB500B) were thermally sprayed on silica gel. The adsorbent with photocatalyst was packed with glass cylinder and UV or visible light was emitted. Then, 300 ppm of organic vapor was introduced into the packed bed at a flow rate of 30 L/min, and outlet air was sampled with auto gas sampler and the vapor concentration was determined with a gas chromatograph equipped with a flame ionization detector. As a control, a breakthrough test without light emission was completed. Breakthrough characteristics of adsorbents for UV and for visible light were not different significantly. Maximum breakthrough concentration without light emission was higher than inlet one. This was not observed in the case with light emission. Breakthrough time did not extend significantly by light emission, but maximum breakthrough concentration decreased with decreasing air flow rate. The cause for this might be decomposition of solvent by the photo catalyst. Based on the experimental results, the decomposition rate constant was determined experimentally.

Assessment of the Impact of the Five ISO Head Sizes on Breathing Resistance, Work of Breathing and Dead Space of Respiratory Protective Devices

Krysztof Makowski, Central Institute for Labour Protection, National Research Institute

The philosophy of the new ISO series of standards for respiratory protective devices (RPD) is based on human physiology and updated anthropometrics. Accordingly, the classification of RPD is changed completely in comparison to the current EN standards. The new ISO classification scheme is directly linked to "the severity of work" (workload). Different test methods of assessment of the carbon dioxide content of the inhaled air - dead space of RPD facepieces - were introduced as well. Another new element related to anthropometrics, with respect to European and different national standards, is the use of five headforms introduced for RPD testing, instead of the previous used Sheffield model. They were introduced to improve the fit and comfort of the facepieces. Given the changes, it was considered advisable to check how the combination of the new test methods with five forms may impact the assessment of currently used respiratory protective devices.
Tests were carried out using a new test stands designed and built in accordance with the requirements of the new ISO standards. Tests were performed at an airflow rate corresponding to the moderate physical exercise – 50 l / min at artificial lung setting of 2.5 l / stroke and 20 cycles / min. The results of the completed work of breathing and carbon dioxide content in the inhaled air testing for selected respirators indicated, among others, the following main elements:

1) the highest values of the work of breathing were obtained for respirators which shape and size were matched to the respective headform providing maximum tightness, translating directly to the effectiveness of protection,

2) the lowest values of carbon dioxide content in the inhaled air were recorded for respirators when the shape and size were matched to the respective headform providing maximum tightness, what in turn translates into more comfortable use of properly fitting RPD.

The carried out tests point out that in respiratory protective devices, the most important is the proper fitting of the facepieces both during use and during tests and confirmed the need to introduce five headforms for the assessment of RPD.

Burn Saver Device

Girish Srinivas, TDA Research

Modern turnout gear is designed to protect firefighters from heat, falling debris and other hazards and it works so well that firefighters can sometimes work in conditions so severe that their PPE may fail without warning. TDA's Burn Saver is designed to provide firefighters with advance warning by detecting conditions that thermally degrade SCBA facepieces. TDA Research has developed a Burn Saver that firefighters can wear to warn them when they are in environments where either the air temperature or the radiant heat load is high enough to cause their SCBA facepiece to degrade. In Phase I TDA demonstrated, that our sensors could detect changes in radiant heat flux in well under 10 seconds and that we could measure the ambient air temperature in less than 1 minute. In Phase II, TDA performed a detailed thermal analysis of the sensors, optimized their design, and iteratively designed, built and tested three generations of prototypes. All of the prototype Burn Saver devices were tested in-house in a calibrated, heated wind tunnel. Their responses to changes in infrared radiation (IR) and air temperatures were measured. In the case of the 3 rd Generation Burn Saver devices live fire tests were conducted by a local fire department in their Class-A fire training facility. At the end of the Phase II project TDA delivered an optimized Burn Saver device to the Department of Homeland Security (DHS). During the following one year long Phase II option period, TDA will be supplying DHS and other potential users with 10 units for evaluation. At the completion of the one-year option, we will have submitted the 4th Generation Burn Saver devices to the National Fire Protection Association (NFPA) for certification

Cleaning and Disinfection Practices Among Elastomeric Respirator Users In Healthcare

Stella Hines, University of Maryland School of Medicine

Background: Cleaning and decontamination are potential barriers to implementation of elastomeric respirator (ER) inclusion in hospital respiratory protection programs (RPPs). As part of a larger effort to determine the feasibility and acceptability of reusable respirators in healthcare, we surveyed ER users from five organizations within a medical system where ERs have been included as one component of the RPP inventory since 2009 in order to understand self-reported cleaning and disinfection practices.

Methods: All healthcare workers (HCWs) involved in the RPPs were invited to participate in an electronic survey in fall of 2016. Respondents completed the survey either via a direct email-embedded link or through an access code on study-supplied laptops during clinical unit visits by the study team.

Results: 1,152 HCWs completed the survey, of whom 24% were current ER users at the survey time. Most ER users (90%) reported that their ER was "clean," and almost 80% reported "usually" or "always" wiping the respirator with an alcohol pad or disinfectant wipe after each use. However, 69% of these users "rarely" or "never" removed their respirator's filters and washed the respirator with soap and water, the expected practice according to manufacturer recommendations.

Conclusions: Cleaning and decontamination of reusable ERs is a potential barrier to feasibility and acceptance of ER use in settings where exposure to contact transmissible microbial pathogens is a concern, such as healthcare. Most ER users report regularly wiping down their masks with alcohol or disinfectant wipes, but very few ever wash their masks with soap and water. Practical and effective cleaning and disinfection strategies should be developed

in order to improve acceptability of ER use in healthcare settings and promote uptake by RPP decision makers. Funded by CDC-NIOSH grant #1R21OH010868-01.

Compare the Performance of Two Wet Bulb Thermocouple Designs Used During Performance Evaluations of Closed-Circuit Escape Respirators

Dave Cowgill, ATOR Labs, Federal Resources

This research will examine the equivalence of two wet bulb thermocouple designs: NIOSH's baked clay probe versus a cotton sock probe. Test data will be collected over varying breathing rates and rebreather units. 4Hz data is generated from ATOR Laboratory's Automated Breathing Metabolic Simulator and will be examined to determine correlation between the two sources. If equivalence is evident, the cotton sock design may be preferred for future research due to its simpler manufacturing and maintenance.

Development of a Speech Intelligibility Requirement for Powered Air-Purifying Respirators

Andrew Palmiero, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

A powered air-purifying respirator (PAPR) is a respirator that uses a battery-operated blower and HEPA filters (only in the U.S.) to provide the wearer with purified air through a tight-fitting facepiece, a loose-fitting hood, or a loose-fitting helmet. Several industries such as law enforcement, healthcare and aviation rely on the use of PAPRs and the need to communicate verbally to perform their job duties safely and maintain operational efficiency. There is currently no NIOSH-approved test method or requirement to evaluate speech intelligibility (SI) for both loose and tight-fitting PAPRs, making the impacts on user safety, usability and operational performance unknown. The objectives of this effort are to:

1) quantitatively assess the SI of four different NIOSH-approved PAPR models (one loose-fitting PAPR with helmet, one half-mask PAPR, one tight-fitting PAPR and one loose-fitting PAPR) using the Modified Rhyme Test (MRT),
2) characterize their sound level spectra and frequencies
3) determine the degree to which sound interference levels (SIL) play a role in the overall performance and SI of each PAPR and
4) establish and validate a test method and requirement for PAPR SI.

Human test subjects will be utilized to evaluate four different NIOSH approved PAPR models under the following four experimental conditions: Speaker and Listener with no PAPR, Speaker and Listener both wearing PAPRs, Speaker with a PAPR, Listener without a PAPR and Speaker without a PAPR, Listener with a PAPR. All four experimental conditions will be randomly assigned and different word lists will be used for each trial to avoid any duplication. Sound levels in decibels (dB) and the frequency spectrum generated by each PAPR (motor, blower, alarms if any) will be measured under A weighting to determine the SIL for each PAPR as well.
IRB Protocol 18-NPPTL-02XP.

BEST POSTER : Diesel Particulate Matter Penetration through PAPR Filters

Jane Whitelaw, University of Wollongong

Respiratory protection is a widely used control in many industries, including both underground and open cut mining, to protect workers from exposure to diesel emissions.
Recent research undertaken by Burton, Whitelaw and Jones (CSHST 2015-16 Project 20634 & WorkCover). Applied Research grant 2015/005356) evaluated penetration of DPM through eight commonly used respirator filters, at the flow rate designated in the standard, as well as at two higher flow rates representative of medium to heavy work. The results indicate that when challenged with DPM, measured as elemental carbon, the filtering efficiency

assumed by P2 certification (<6%) in Australia was not achieved for some respirators. We found that DPM penetration through some of the P2 respirators commonly used in mining; exceeded the filtering efficiency for P2 certification in Australia after a reasonably short wear time. Powered air purifying respirators (PAPRs) are also used extensively in mining workplaces, and may be used increasingly due to changing standards on recommendations on work rates outlined in ISO/TS 16976-4:2012. Without data on PAPRs, our knowledge is incomplete and there is uncertainty around whether wearers of these devices are adequately protected.
This study was conducted t*o determine whether currently utilised powered air purifying respirators (PAPRs) effectively filter out Diesel Particulate Matter and provide worker protection; by challenging PAPR filters used in mining workplaces with DPM; and by measuring the EC and the sizes of particles that are penetrating the filters to determine whether that poses an additional health risk for workers.* The effectiveness of respiratory protection was evaluated in accordance with AS/NZS 1716. Further analysis of three filter models was undertaken using current NaCl and Paraffin standards certified methods and challenge aerosols, to enable comparison with the study results. These studies raise concerns regarding the adequacy of the respiratory protection commonly provided against DPM and highlights the importance of continuing evidence based research to ensure respiratory protection provided to workers prevents inhalation of DPM and subsequent serious health effects.

Exhaled Airflow Characteristics for a PAPR w/ Loose Fitting Hood as Related to Surgical Use

Larry Green, Syntech, International

It is accepted that powered air purifying respirators (PAPRs) are either used or desired to be used by healthcare providers during surgical procedures on patients with highly infectious diseases. By examining the sources of particulate exhaust from various types of commonly used respiratory coverings, this study will look at the potential to increase or decrease contamination in the surgical site, possibly resulting from the use of the coverings by health care workers. Common forms of non-respirator surgical masks will be used as a baseline and compared to surgical N95 type filtering facepiece respirators, PAPRs, and other surgical helmet systems. Sub-micron sized sodium chloride particulates will be used as the exhaust tracer and tracked with a condensation particle counter and an aerosol mass monitor. Preliminary results: A preliminary evaluation has indicated some practices can have an impact on particulate exhaust. These will be explored further.

Exploring the Concept of a Wearable Closed-Circuit Mining Escape Respirator: A Human Factors Perspective Case Study

Rohan Fernando, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

As the mining industry transitions from Self Contained Self Rescuers (SCSR) approved under 30 CFR 84 subpart H to Closed Circuit Escape Respirators (CCER) approved under the more rigorous subpart O criteria, CCERs for underground coal mine escape in the United States are bulkier, larger, and heavier than comparable SCSRs. Furthermore, none of the approved CCERs incorporate communication or switchover design elements as suggested in National Academy of Science reports or the Mine Improvement and New Emergency Response Act of 2006 (MINER Act). While some mineworkers are able to wear shorter duration Cap 1 units where the size and weight increase is minimal (switching in an emergency to a Cap 3 unit from a nearby cache), other workers, due to work type or location, require a longer duration Cap 3 unit that, with available approved CCER units, is not wearable. Currently this situation is addressed by the continued use of a SCSR; to gain the benefits of a CCER, a new technology or form factor is required. This paper outlines a case study that evaluates the pros and cons of a backpack design format with an emphasis on human factors design criteria. Specifically, it explores the challenges of moving from the design requirements to an updated deployable prototype. It focuses on updated features of the design including single pull deployment, a facepiece for communication, a docking valve for switchover, and incorporating front and back wearability and improving material durability, breathability, and visibility

Methods for Real Time Respirator Leakage Detection

Caitlin McClain, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

Current respirator fit test methods do not readily allow for detection of leaks during respirator use. The ability to obtain respirator leakage/fit information during use would be useful to verify respirator efficacy and potentially improve it. In a preliminary study, we monitored aspects of respirators worn by subjects at rest while simultaneously measuring aerosol-based fit. The methods used included infrared thermography (IR) for surface temperatures (e.g. Roberge and Harber), IR spectrally filtered for carbon dioxide (CO_2), sensors for ultrasound (e.g. King and Szalajda), and facepiece pressure measurement. Each of the methods used in the study have demonstrated the ability to detect respirator faceseal leaks. For the IR and CO_2 methods, video image analysis demonstrates both methods can detect temperature fluctuations around the seal, revealing leaks. IR video revealed temperature fluctuations above/below the skin's average temperature as air flowed through the leaks, alternately warming/cooling adjacent skin, respectively. The CO_2 in exhaled breaths was detected by the temperature around faceseal leaks rising in uniform fluctuations above average skin temperature. In the ultrasound method, leaks sites were indicated as present when ultrasound levels were higher than the baseline amount exiting through the mask body. The pressure methods, when measured during normal breathing, revealed that when leaks were present around the faceseal, in-mask pressure was lowered. Each of these methods was run in conjunction with a PortaCount® to determine the extent to which the methods correlate with fit. Due to analyses still being run to determine the exact correlation between these methods and fit, further testing and analysis will be needed to determine the exact correlation between these methods and respirator fit.

Nuisance-Level Organic Vapor Adsorption: Evaluating the Performance of a Commercial Paint Odor Respirator

Margaret Summers, University of Alabama at Birmingham

Carbon-containing, or "paint odor" particulate respirators contain an adsorbent system consisting of powdered activated carbon held in place by a non-woven polypropylene web, often without the use of additional binder material. These carbon-polypropylene webs are light weight and often exhibit favorable pressure drops, allowing for incorporation into N95 respirators that offer relief from organic vapors at very low (or "nuisance") concentrations. However, the performance of this air-purifying element has not been clearly established by the literature. In order to estimate the adsorption capacity of one of these devices, the adsorbent component from a commercially-available "paint odor" respirator (3M #2097) was challenged with a representative organic vapor (toluene) at a nuisance-level concentration. Breakthrough experiments were performed at the odor threshold of toluene (8 ppm) at a flow rate of 6.6 LPM (Temperature 22-25 ºC, RH 40-45%). The adsorbent media from the selected respirator was loaded into a stainless-steel sample chamber; downstream concentrations were then monitored using a photo-ionization detector. Breakthrough curves were generated for three different bed weights of adsorbent. A single layer of the 3M #2097 adsorbent media (approximate carbon weight 0.138 g) was sufficient to reduce the concentration of toluene by 90% for at least one hour under the given test conditions. It was also promising that the commercial filter media demonstrated accordance with the Wheeler-Jonas equation under the given test conditions. The experiment will be expanded to include different challenge contaminants and conditions more typical of N95 respirator use (i.e., higher temperature and relative humidity). Furthermore, as a proposed innovation, our planned research will generate breakthrough curves for non-woven activated carbon fiber (ACF) configurations as an alternative adsorbent in carbon-containing N95 respirators.

Quality Assurance Sampling Plans in U.S. Stockpiles for Attribute Data: A Computer Simulation to Examine the Accuracy of Different Sample Sizes at Recovering True Production Lot Percent Defective

Patrick Yorio, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

Stockpiles in the U.S. support healthcare workers and the public with supplies of equipment and consumables. Many stockpiled products, such as personal protective equipment (PPE)—including respirators, require testing to ensure the promised performance to the end user. Degradation processes associated with prolonged storage are often complex, and usually depend upon factors outside of the manufacturer's knowledge. Accordingly, an increasing fraction of manufacturers specify a recommended shelf life for their products. Incorporating periodic performance testing at the stockpile level may allow facilities to provide proof of effective performance for products both with no labeled expiration and those beyond the manufacturer's labeled shelf life. In general, there is an absence of guidance regarding the number of individual product units that stockpile managers should test to make determinations regarding the continued viability of the product. With large numbers of samples tested confidence in the accuracy increases. However, destructive testing of large quantities results in significant waste and high test expenses. A formula-based solution to the problem is limited given the distribution of sample fail-rates will vary by sample-size and by the true percent defective within a lot. Thus, we used a computer model to elucidate the relationship between sample-size and accuracy of the measured stockpile status. We created a list of zeros and ones reflecting the number of respirators within a lot that 'failed' (ones) and those that 'passed' (zeros) a performance test—e.g., the tests used by NIOSH for respirator approval. We used a production lot size of 100,000 with failure rates set to 1%, 5%, and 15%. We used sample sizes that ranged from 5 to 100. For each sample size, random sub-sets of the production lot were selected. Through statistical comparisons, our results showed that sample-sizes could be grouped together by similarities in the consistency of how accurately they estimate the true percent lot defective. The groupings highlight the benefits and limitations inherent in different sample size choices, which allow stockpile managers to strategically blend their choice into the overall design of quality assurance programs including the parameters for a reoccurring performance testing schedule of their stockpiled products.

Streamlined Process for the NIOSH Approval of N95 Filtering Facepiece Respirators Used in Healthcare Settings

Heidi Sewchok, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

In order to streamline and harmonize the regulatory activities regarding the approval of N95 filtering facepiece respirators for use in healthcare settings a Memorandum of Understanding (MOU) was created between the U. S. Food and Drug Administration (FDA) and the National Institute for Occupational Safety and Health (NIOSH). The MOU led to the creation of a new respirator protection classification to encompass the NIOSH and FDA requirements for N95 filtering facepiece respirators. Respirators approved by NIOSH under the MOU will be approved with the protection of N95-F. NIOSH administers the respirator approval program through the National Personal Protective Technology Laboratory (NPPTL). In order to be used in occupational settings in the United States, a respirator must have NIOSH approval, as required by the Occupational Safety and Health Administration (OSHA) under 29 CFR 1910.134. The Food and Drug Administration (FDA) administers the 510(k) premarket notification program through the Center for Devices and Radiological Health (CDRH). If a respirator is to be used in a healthcare setting, it is considered a medical device and must gain clearance through the FDA's 510(k) process, as required the Federal Food, Drug, and Cosmetic Act (FD&C Act). Respirators that meet the specifications outlined in the MOU can be submitted for NIOSH approval at the new N95-F protection level. In order to be

NIOSH-approved as N95-F respirators, devices must meet the requirements in 42 CFR Part 84 Subpart K and, in addition, must also meet the requirements of medical devices outlined by the FDA in the FD&C Act.

Update Canadian National Standard for Selection, Use and Care of Respirators CAN/CSA Z94.4-18

Eva Dickson, Royal Military College

Canada's national standard CAN/CSA Z94.4 has been in place for several decades, providing guidance on implementation of respiratory protection programs (RPPs) at the federally, and in some cases provincially, regulated level. The standard includes extensive information on fit testing methods, detailed selection processes (based on using equipment from the NIOSH list), and all of the roles and responsibilities within an RPP. An updated edition will be available this fall that includes additional work in the areas of use of the control-banding approach to select respirators for bioaerosol protection, addition of rigorous comfort assessment protocols to fit testing, and competency checklists for fit testers. Work for the next edition has been proposed to include further consideration of the following issues: significance of interfering equipment when validating fit; additional respirator styles and fit testing equipment; further consideration of the selection and use of respirators within the healthcare setting; and incorporation of ISO respirator performance standards published by ISO TC94 SC15. The scope of the standard as it fits within Canada's suite of national standards for personal protective equipment will also be outlined.

Tuesday Technical Session 1:30 PM – 3:00 PM

Comparing Different Organizations' Limits on Breathing Resistance as Imposed by Respiratory Protective Devices

Dan Warkander, U.S. Navy Aerospace Medical Research Laboratory

For mostly historical reasons the allowed breathing resistance in a respiratory protective device varies with the type of device. For instance, European regulations for a self-contained closed-circuit escape device (EN 13974, §6.19.5) allow a peak inspiratory pressure of -8 cm H2O (-8 mbar, -0.8 kPa, half of total) at 35 L/min, but for a CO removing device rated for 30 minutes (EN 404, §6.18.4) it can be 50% higher (-12 cm H2O, -12 mbar, -1.2 kPa) at 30 L/min. Relatedly, NIOSH regulations for closed-circuit devices (42 CFR 84, part O §84.303) allow peak inspiratory pressures of -10 cm H2O (-1 kPa, half the total) at 34 through 62.5 L/min. However, for an open circuit demand respirator (42 CFR 84, part H §84.90) the peak inspiratory pressure can only be a 1/3 as high (-3.2 cm H2O, -0.3 kPa) at 40 L/min. There are similar variations for expiratory peak pressures. In contrast, people's tolerance of breathing resistance does not change with the type of breathing device. It does not matter whether it is an air-supplied device, a filtering facepiece or a closed-circuit device, the muscles don't change. When writing respiratory protective standards, ISO put the wearer's needs and abilities first. This approach is reflected in ISO's limits on Work of Breathing (ISO 16976-4) where the limits are device independent. The limits vary with wearer workload (as determined by the minute ventilation) because they are based on empirical measurements. In addition, the limits treat inspiratory resistance separately from expiratory resistance because different muscles are involved. Limits on Work of Breathing or breathing resistance should be based on people's tolerance, not the respiratory protective device.

Determination of Breathing Rates for Respirator Wearers in an Australian Smelter

Jane Whitelaw, University of Wollongong

Objective: The objective of this research is to evaluate the workplace breathing rates for negative pressure RPDs across varying work rates in the Australian Metalliferous Mining Industry.
Method: Smelter workers used their normal negative pressure Respiratory Protective Devices (RPDs) and performed their normal work duties across an entire shift while their breathing rates, heart rate and core temperature were monitored for comparison with the recommended limits in ISO/TS 16976-1. This research was made possible by the recent development and validation of a portable personal data-logger to measure breathing rates through a respirator while workers perform normal work activities. See previous methodology paper from ISRP 2016: http://ro.uow.edu.au/cgi/viewcontent.cgi?article=3759&context=sspapers
Results: It was found that working at a higher work rate produced more pronounced effects of RPD use, and more distinct the changes in wearer's breathing pattern. The physiological effects and perceived burden of use also became more pronounced. The results provide the first real time analysis of breathing rates of negative pressure RPD wearers performing normal duties in a smelter workplace. Interestingly, they were not always consistent with those specified in ISO standards that had been primarily determined from laboratory tests.
Conclusions: While laboratory tests give an indication of the use of respiratory protection it is no substitute for workplace studies where the study participants are seasoned RPD users performing their normal work duties. Studies using simulated activities and non-industry cohorts should also be critically evaluated to discern whether they are truly representative of the workplace use of RPDs. Wearers of RPDs at higher work rates are under considerable strain and RPD program administrators should consider the individual's physiological capacity, as well as the work rates the wearer will be subjected to in the course of their work activities. It is envisaged that this research will inform international standard development and end users in the appropriate selection and use of respiratory protection and assist in improving the respiratory and cardiovascular health of workers in heavy industry.

Past, Present, and Future (?) Methods for Evaluating Respirator Fit Performance

Craig Colton, 3M U.S.

In the early 1900s, the U.S. Bureau of Mines began approving respirators that met specified test conditions for safety, practicability, and efficiency. These test conditions were described in documents called schedules. The first devices approved were self-contained mine rescue breathing apparatus, Schedule 13 (March 5, 1919) and Gas Masks, schedule 14 (May 22, 1919). Other respirator types were added later. Many of the early performance tests (man tests) evaluated overall performance (total performance) where fit was one of the variables contributing to the result. Later, tests were designed to evaluate fit performance specifically using chemical agents or test aerosols, probably the most well-known being coal dust in the 1930s. Isoamyl acetate emerged as a test agent for certification by 1965. Some of the test methods required the use of "surrogate" or modified respirators instead of the actual respirator marketed. The concept of "checks" to evaluate an individual wearer's fit appear to have developed and evolved from these checks, called fit tests. Over the years, improved fit tests for individual wearers were developed. These tests are influencing certification requirements. The National Institute for Occupational Safety and Health is working to revise its fit requirements. Europe uses inward leakage tests to evaluate fit on a panel of people and a total inward leakage test that measures respirator penetration from all sources, fit leakage being included. Europe requires fit testing on certain individual wearers. ISO respirator standards propose to use an inward leakage as well, and requires individual fit testing for each wearer of a tight-fitting respirator. While all fit tests are designed to evaluate fit, they appear to be used for two different purposes: determination of a respirator's "fit capability" for a population of people or for ensuring a respirator's fit on a specific wearer. The overall development and key changes of these requirements over the almost past 100 years will be reviewed.

Respirator Fit Capability Test for Full-Facepiece Air-Purifying Respirators

Ziqing Zhuang, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

Objective: An ASTM subcommittee on respiratory protection (F23.65) is currently developing a national consensus standard for assessing respirator fit capability (RFC) of half-mask air-purifying particulate respirators. The objectives of this study were to evaluate if the test methods developed for half-mask respirators are applicable to full-facepiece respirators, and to assess the capability of existing full-facepiece air-purifying respirators to fit their intended users.

Methods: Benchmark RFC test data were collected for three families of full-facepiece air-purifying respirators on (a one-size-only system, a two-size system, and a three-size system). All respirator filtration media were P100 class. Respirators were outfitted with a sampling probe to collect an in-mask particle concentration sample in the breathing zone of the wearer. Each of the six respirator facepieces was tested on the National Institute for Occupational Safety and Health 25 member bivariate fit test panel. The RFC test assessed face seal leakage by using PortaCount® Plus and the Occupational Safety and Health Administration fit test protocol. Two donnings per subject per respirator facepiece were performed. The panel passing rate (PPR) (number or percentage of the 25 subject panel achieving acceptable fit for at least one of two donnings) was determined for each family by specified fit factor levels of 500, 1,000, and 2,000.

Results: For a required fit factor level of 500, the PPRs for three-, two-, and one-size families were 100%, 79% and 88%, respectively. As the required fit factor increased from 500 to 1,000 or 2,000, the PPRs decreased slightly. When >= 75% (19/25 subjects) of panel subjects was the PPR pass/fail criterion, all three families passed the required fit factor levels of 500 and 1,000.

Conclusions: This study concluded that the test methods developed for half-mask respirators are also appropriate for the RFC test of full-facepiece respirators. The full-facepiece respirators tested are capable of fitting more than 75% of the intended user populations.

Tuesday Technical Session 3:20 PM – 5:30 PM

Recent Advances in New Generation Fit Testing Instrumentation

William (Bill) Hill, AccuTec-HIS, Inc.

Accurately measuring the fit of a respiratory protection device has always been a primary concern of administrators of respiratory protection programs. From the early efforts involving challenge agents such as banana oil or lachrymator agents for an olfactory-based subjective decision to bizarre methods such as spraying an aerosol of coal dust directed at a test subject for a visual indication of mask seal, the science has advanced to truly quantitative, objective measurements of the fit of the respirator-to-face seal. From its origins as a strictly military program, fit testing has evolved into a near-universal methodology. Governing authorities in the United States and other countries have recognized that respiratory protection devices should be provided and used by all workers who may be exposed to respiratory hazards. These agencies also understand that in order to achieve the goal of effective respiratory protection for these workers, ongoing training and respirator fit testing is necessary. Respirator fit testing has traditionally been viewed as an annoying, time-consuming, yet necessary process. Choices of fit test instruments have been very limited in comparison to other types of advanced devices used by safety and health professionals. Two of the major criteria for designing newer instrumentation would be eliminating inconvenience and potential for human error wherever possible. Careful attention to input from regular users of fit test instruments should be part of any new design. Recent developments in fit testers include optics designed to be as efficient as possible, allowing a greater split ratio to reduce contamination. Other in-field conveniences include PC communication for remote diagnosis to reduce downtime associated with maintenance and service. The elimination of particle classification techniques for N95 testing reduces the chance of having too few particles to complete the test. Remote communications using WiFi, Ethernet, and USB, as well as stand-alone operation in a single form factor were also considered valuable attributes of a new generation device.

Exploring Utility of an Optical Particle Counting Method for Quantitative Respirator Fit Testing

Bingbing Wu, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

Currently, the aerosol-based quantitative respirator fit testing is conducted using a TSI PortaCount®, which utilizes the condensation particle counting (CPC) principle and measures particles in a size range of 0.02 to >1 µm, following a U.S. OSHA-approved protocol, or similar protocols approved by other countries' regulatory agencies. The objective of this study was to explore an alternative method, which is based on optical particle counting (OPC) and has recently been incorporated in a new instrument, MT-05U Fit Tester (Sibata Scientific Technologies, Tokyo, Japan). The study was performed in accordance with the ANSI standard Z88.10-2010 for evaluating new fit test methods. The MT-05U detected particle sizes of ≥0.3 µm. The PortaCount® served as the reference instrument. The fit factors were measured with the two instruments operating in parallel. The evaluation was conducted with four types of respirators, namely N95 and P100 filtering facepiece respirator (FFRs) as well as half- and full-facepiece elastomeric respirators. Each type was represented by four to five different models and tested on the National Institute for Occupational Safety and Health 25 member bivariate fit test panel. When testing with N95 FFRs, the PortaCount® operated in N95-Companion mode and MT-05U was examined using two operating size ranges: ≥0.3 µm and ≥0.5 µm. The results demonstrated that the new instrument utilizing the OPC method is suitable for the fit testing of respirators. With the lower particle size detection limit of 0.3 µm, the new instrument could identify inadequate fits of all four types of respirators with sensitivity (probability of identifying inadequate fits) between 0.98 and 1.00, exceeding the ANSI mandatory requirement of ≥0.95. Additionally, the new instrument was capable of correctly classifying acceptable fits with specificity (probability of acceptable fits passing the new fit test method) of 0.81 - 0.90, exceeding the ANSI advisory criterion of ≥0.5. It was concluded

that the optical particle counting could be successfully deployed as an alternative method for quantitative respirator fit testing.

Towards a Continuous Assessment of Fit

Alexander Virr, CleanSpace Technology Pty. Ltd.

Fit testing (either qualitative or quantitative) has been widely used for over 20 years and is internationally recognized as best practice for tight fitting respirators. However, the cost and time required to conduct fit tests often limits their use to once per year. This leaves long periods during which the wearer's mask requirements may change, resulting in a deterioration in the protection offered by their respirator. Qualitative methods (such as the Bitrix test) can be used with greater frequency and less cost, but rely on the active cooperation of the user and require that they stop their normal activities. This paper presents a methodology for estimating an indicative level of fit more frequently (for instance once per day or more), based on parameters already collected by some breath-responsive PAPRs. Such an indicative estimate could be used, for instance, to warn the user if their fit appeared poor. Thus warned, the user could investigate the issue via a traditional fit test. Such capability might make an excellent supplement to the gold standard fit test, filling in the gaps between tests and warning if extra testing was required.

Wednesday, September 19, 2018

8:30 AM – 8:40 AM	Preliminaries and Introduction
8:40 AM – 9:00 AM	Keynote Address: Dr. Hyunwook Kim
9:00 AM – 10:40 AM	Roundtable: Respiratory Protection Use by Wildland Firefighters and Impacted Community Members ***Sponsored by Moldex-Metric***
10:40 AM – 11:00 AM	Break ***Sponsored by ICS Laboratories, Inc.***
11:00 AM – 12:00 Noon	Roundtable Continued: Respiratory Protection Use by Wildland Firefighters and Impacted Community Members
12:00 Noon – 12:30 PM	Annual General Meeting
12:30 PM – 1:30 PM	Lunch
1:30 PM – 3:30 PM	Technical Sessions
3:30 PM – 4:00 PM	Announcements for Evening
6:00 PM	Awards Dinner and Line Dancing ***Sponsored by Molecular Products, Inc.***



Roundtable: Respiratory Protection Use by Wildland Firefighters and Impacted Community Members

Sponsored by Moldex-Metric, Inc.

Roundtable Chair: Colleen Miller, National Institute for Occupational Safety and Health, National Personal Protective Technology Laboratory

Multiple fatal wildland fires have been documented for over 150 years with the majority of these fires occurring in the western U.S. and Australia[1]. In 2017, the western U.S. suffered one of the most active and devastating wildland fire seasons in recent history. Wildfires that ravaged Northern California in October led to 44 deaths and the destruction of over 8,400 structures, including homes and businesses, making their mark as the most destructive wildfires in California's history. Then, in early December, the fast-moving Thomas fire swept into the city of Ventura, burning 50,000 acres and forcing 27,000 people to evacuate[2]. Respiratory protective devices are not required for use by wildland firefighters in the U.S., and citizens living in areas impacted by the wildland fire smoke are often concerned about how to properly select and use a respirator.

On September 14, 2017, the U.S. Secretary of Agriculture Sonny Perdue announced that wildland fire suppression costs had exceeded $2 billion, making fiscal year 2017 the most expensive year on record[3]. When local and state government costs are included, the U.S. spends in excess of $4.5 billion annually to combat wildland fires. Not included is information or cost estimates for illness incurred by firefighters or civilians due to wildland fire exposure. This round table will provide:

1) background about wildland fire exposure,
2) discussion of the need for surveillance,
3) research into the use of respiratory protective devices, and
4) perspectives from firefighters, citizens, and respirator manufacturers.

Background and Overview of Wildland Fires and Exposures and Health Effects

George Broyles, U.S. Forest Service
Tim Reinhardt, Wood Environment & Infrastructure Solutions, Inc.

Smoke exposure data among U.S. wildland firefighters for carbon monoxide, respirable particulate, and respirable crystalline silica are presented from a field surveillance program between 2009 and 2012. Models to predict fireline-average exposure to each inhalation hazard were developed and fit to the available data. The models identify important factors that might be considered in designing future data collection and interpreting the margin of safety for similar exposure groups. Task-based data collection will be the most useful because the work activity representing the majority of fireline time, the position up- or downwind of the fire, the proportion of time this combination represented, and the crew type were all significant factors in the models for carbon monoxide and for respirable particulate matter. The wind position versus the fire was not important for respirable quartz exposure. Each year, the general public and wildland firefighters in the United States are exposed to smoke from wildland fires. As part of an effort to characterize health risks of breathing this smoke, a review of the literature

[1] Gabbert, B. Infamous Wildland Fires Around the World by Calendar Date, Revised July 2, 2013.

[2] http://www.latimes.com/projects/la-me-california-fire-seasons/

[3] https://www.usda.gov/media/press-releases/2017/09/14/forest-service-wildland-fire-suppression- costs-exceed-2-billion

was conducted using five major databases, including PubMed and MEDLINE Web of Knowledge, to identify smoke components that present the highest hazard potential, the mechanisms of toxicity, review epidemiological studies for health effects and identify the current gap in knowledge on the health impacts of wildland fire smoke exposure. Respiratory events measured in time series studies as incidences of disease-caused mortality, hospital admissions, emergency room visits, and symptoms in asthma and chronic obstructive pulmonary disease patients are the health effects that are most commonly associated with community level exposure to wildland fire smoke. A few recent studies have also determined associations between acute wildland fire smoke exposure and cardiovascular health end points. These cardiopulmonary effects were mostly observed in association with ambient air concentrations of fine particulate matter (PM2.5). However, research on the health effects of this mixture is currently limited. The health effects of acute exposures beyond susceptible populations and the effects of chronic exposures experienced by the wildland firefighter are largely unknown. Longitudinal studies of wildland firefighters during and/or after the firefighting career could help elucidate some of the unknown health impacts of cumulative exposure to wildland fire smoke, establish occupational exposure limits, and help determine the types of exposure controls that may be applicable to the occupation.

New Methods of Assessing Carbon Monoxide Exposure Using a Modified Occupational Exposure Limit and Some Barriers to Reducing Exposure

Joshua Scott, Colorado School of Public Health, Center for Health, Work and Environment

To protect workers from hazardous substances or conditions in the workplace, agencies including the Occupational Safety and Health Administration and the National Institute for Occupational Safety and Health develop and periodically revise their occupational exposure limits (OELs) and recommended exposure limits (RELs). When developing the OELs for carbon monoxide (CO), all organizations use a derivation of the Coburn-Forster-Kane (CFK) equation to ensure that workers' carboxyhemoglobin levels (COHb) do not exceed 3.5 – 7 percent, or the level where harmful effects may initiate. The CFK equation takes into account numerous variables such as duration of exposure, diffusion rates in a worker's lungs, blood volume, and barometric pressure. All current OELs were developed assuming an 8 to 10 hour sedentary work shift at sea level. During wildland fire suppression, many of the assumptions used to develop OELs for CO may be inaccurate for firefighters, as they may be required to complete long, arduous work shifts at differing elevations. Previous research has indicated the need for OELs to be adjusted for wildland firefighters during wildland fire suppression activities to ensure shift length, physical exertion level, and elevation are taken into consideration. This presentation will

1) systematically categorize job tasks based on physiological variability to determine whether an adjusted OEL for CO is needed to better protect this emergency response workforce,
2) describe the development of OEL reduction factors based on workload variability, altitude, shift length and a recommended equation constant change to produce individual fire-adjusted CO OELs and a single reduced OEL protective for all wildland firefighters and,
3) characterize exposure to CO based on individual fire-adjusted OELs for wildland firefighters in the western U.S. and offer recommendations to better control hazardous CO exposure.

Research Proposal in Response to the Department of Homeland Security Broad Agency Announcement for Wildland Fire Respiratory Protection

Girish Srinivas, TDA Research

Existing respiratory protection solutions for wildland firefighting are either too bulky/cumbersome, too hot, provide insufficient protection, do not allow for strenuous activity, or do not provide extended, wear respiratory protection for the multiple hours a firefighter in the field must endure. Without effective options, many firefighters wear no protective equipment, or wear simple cotton bandanas; the resulting exposure to toxins and particulates in the environment raises their risk for cancer and other short- and long-term health issues. The

proposed solution will be a new piece of equipment worn by responders that is lightweight and offers a low-profile so it does not negatively impact the amount of gear a wildland firefighter can carry, the firefighters' range of motion, or their ability to communicate. The device will not prevent wildland firefighters or other responders from safely performing their duties.

Consensus Standards for Wildland Firefighter Respiratory Protection

Rick Swan, International Association of Fire Firefighters

In 2012, the National Institute for Occupational Safety and Health (NIOSH) announced a process to begin issuing certificates of approval for respirators to use during wildland firefighting operations. The process included a Memorandum of Understanding between NIOSH's National Personal Protective Technology Laboratory (NPPTL) and the Safety Equipment Institute to cooperatively coordinate certification programs to evaluate candidate respirators for compliance to NFPA 1984-2011, *Standard on Respirators for Wildland Firefighting Operations*, which includes Tentative Interim Amendment (TIA) No. 11-1. To date, NIOSH has not received any applications. Additionally, the International Organization for Standardization (ISO) Technical Committee 94 (TC94) Personal Safety – Protective Clothing and Equipment Subcommittee 14 Firefighters' Personal Equipment is developing standards for wildland firefighters' personal protective equipment, including ISO 16073-10, a performance standard for respiratory protection. This effort aligns with the work of TC94 SC15 Respiratory Protective Devices (RPD) and the development of ISO 17420-2, a performance standard for Filtering RPD.

Knowledgeable Civilian/Impacted Community Perspective – 2017 U. S. Wildland Fire Season

Jeff Birkner, Moldex-Metric, Inc., and Resident of California

During the 2017 Wildland Fire Season, the National Institute for Occupational Safety and Health (NIOSH) received 23 requests regarding personal protective equipment, with 15 of those requests occurring in October. Four of the total requests were relating to respirators for wildland firefighters (what respirator should they wear, and if there are NIOSH-approved respirators for wildland firefighting). Several requests were received from the Washington State Health Department, California State Health Department, and fire and emergency services. Other inquiries to NIOSH, from the public, asked what the appropriate respirator to use is, and what PPE should be worn for cleaning up areas after a fire. As a subject matter expert and Resident of California, I would like to share my perspectives about the following:

1) the types of hazards associated with wildland fires,
2) what OSHA requires,
3) the types of respiratory protection available,
4) manufacturer responsibilities,
5) use of analogous situations in making proper choices and thus the research required by firefighting organizations,
6) path forward for
    a. the public
    b. responders


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• Larger surface area of the wave design means more airflow.
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Wednesday Technical Session 1:30 PM – 3:30 PM

Key Considerations Regarding use of Respiratory Protection by the Public

Nikki McCullough, 3M U.S.

Respiratory protection has been used by the public (e.g. non-occupational use) for many years during natural disasters and disease outbreaks, such as for exposures to volcanic ash, during flood and hurricane cleanup, for wildfire smoke, and during outbreaks such as H1N1, SARS, and MERS. The considerations regarding use of respirators by this population vary by situation and geography but include the following:

1) lack of exposure limits,
2) relevance of occupational performance and selection and use standards,
3) broad population characteristics,
4) lack of basic understanding of respiratory protection,
5) challenges with dissemination and training,
6) health agency with authority, and
7) multiple procurement channels and packaging.

These considerations will be discussed with regard to how they have been addressed during past disasters and outbreaks, including specific examples. Proposals for short- and long-term approaches to these factors will be explored.

Translating Lessons Learned from Respirator Use at Work to Non-Occupational Use of Respirators

Harold Boyles, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

The mission of the National Institute for Occupational Safety and Health (NIOSH) is to promote safe and healthy working conditions by conducting research and providing recommendations to diminish hazardous situations within occupational settings. However, there are situations in which the same respiratory hazards that can be faced by workers are also a potential concern to the public. Examples of respiratory hazards of interest to the general public include air pollution, wildfires, indoor mold growth after a flood, and bioaerosols such as bacteria and viruses. Respirators are one method for reducing personal exposure to particulate respiratory hazards. NIOSH has been certifying respirators and conducting research on these devices for over 40 years. Along with our collaborators in government, industry, and academia, we have accumulated a wealth of knowledge on how respirators perform in workplace settings. In the last decade, respirator use by the general public (i.e., non-occupational settings) has become a more frequent topic of debate as public health officials at the local, state, and federal level consider which public health and non-pharmaceutical interventions to recommend. With colleagues from the Centers for Disease Control and Prevention, we have developed several information products to assist state and federal public health agencies, and other safety professionals, by translating the lessons we have learned from respirator use at work to respirator use by the general public. This presentation will provide an overview of those information products and ideas for future research.

Making the Case for Public Respirator Standards

Jessica Hauge, 3M U.S.

Air pollution is one of the many environmental respiratory hazards that impacts both occupational and general populations. Exposure to air pollution is a global problem that contributes to the environmental health burden of disease - the financial impact on countries and regions of deaths and diseases caused by environmental factors.[1] Although efforts have been undertaken to mitigate air pollution levels, progress is slow.[2] Members of the public

who are affected by poor air quality have been turning to respiratory protection to try to help decrease their exposure to certain air pollution constituents. In many parts of the world, regulatory and non-regulatory standards address respirator performance criteria, selection, and use practices. However, globally, respiratory protection standards that currently exist typically have an occupational focus. This can present some challenges to members of the public who endeavor to select respiratory protective devices:

1) occupational standards are written to inform selection by health and safety professionals,
2) respirator selection and use standards include requirements for oversight and training from supervisors or occupational health and safety professionals,
3) and finally, most occupational respirator performance standards and fit panel grids were established based on occupational populations.

Targeted respirator standards for the general public, based on the scientific principles of respiratory protection that have been established and developed within the occupational health community, are needed on a global scale.

1. World Health Organization. Ambient Air Pollution: A global assessment of exposure and burden of disease. World Health Organization. 1-131 (2016).
2. World Bank - World Development Indicators. Brauer, M. et al., for the Global Burden of Disease Study 2015 (2016).

Respiratory Protective Equipment for Emergency Escape: Legal Status and Innovations

Małgorzata Okrasa, Central Institute for Labor Protection, National Research Institute

Respiratory protective equipment for escape is intended to be used for a short-duration in case an emergency occurs at the workplace. It should be either carried by individual workers or located at strategic points throughout worksite areas where there is a risk of fire, release of toxins or the environment is highly volatile. There is a variety of emergency escape devices on the market starting from simple filtering devices with hood or half-masks and filter self-rescuers from carbon monoxide with mouthpiece assembly to more complex ones such as self-contained breathing apparatuses with compressed-air, compressed oxygen or chemical oxygen. In order to properly identify the right respirator for escape purposes, a number of factors have to be taken into account. In particular, the selection should be based on the specific type of hazard that may appear during emergency (smoke, oxygen deficiency, toxic substances), characteristic features of the worksite (available space, access to temporal rescue locations), time needed for safe egress from the dangerous area and abilities/disabilities of the workers [1]. The specifics of the hazards that may occur in case of emergency can vary, thus it is hard to foresee all of the aspects that may possibly be relevant to the safety of workers in such situations. The dynamic progress in the domains of electronics and information and telecommunication technologies gives interesting opportunities for development of new respiratory protective devices enriched with novel smart materials and wearable electronics that would improve the efficiency of the evacuation [2]. Thus, the aim of this paper is to present the issues related with the use of such equipment and possible developments in this area.

1) Varsamis, Occupational Health & Safety, July 2017.
2) Podgórski, Majchrzycka, Dąbrowska, Gralewicz, Okrasa, International Journal of Occupational Safety and Ergonomics 23:1 (2017), 1-20.

The paper is based on the results of Phase IV of the National Program “Safety and working conditions improvement”, financed in the years 2014–2016 in the field of research and development work by the Ministry of Science and Higher Education and the National Centre for Research and Development.

Awards Dinner 6:00 PM

Previous Award Winners

Art Johnson Award

2018 Award Recipient	**Bingbing Wu**
2016 Award Recipient	Florence Janvier
2014 Award Recipient	Margaret Sietsema

Bill Revoir Award

2018 Award Recipient	**Michael Clayton**
2016 Award Recipient	Graham Bostock
2014 Award Recipient	William Newcomb
2012 Award Recipient	Leo Steenweg
2008 Award Recipient	Dr. Yoshimi Matsumura
2006 Award Recipient	Goran Berndtsson
2004 Award Recipient	Richard W. Metzler
2002 Award Recipient	Don Wilmers
1999 Award Recipient	Jack Vanchuk

Bob Bentley Bursary Award

2016 Award Recipient	Jamie Drew
2014 Award Recipient	Nick Hunter
2012 Award Recipient	David Gurden and Varun Kapoor
2010 Award Recipient	Suzanne H. Pelfrey
2006 Award Recipient	Nadine Haupt
2002 Award Recipient	Suzanne Calder
2000 Award Recipient	Stefan Sandbacka

Hyatt Award

2018 Award Recipient	**Ziqing Zhuang**
2016 Award Recipient	Ian Maxwell
2014 Award Recipient	Craig Colton, Andy Capon
2012 Award Recipient	Wolfgang Drews
2008 Award Recipient	Gerry Wood
2006 Award Recipient	Richard W. Metzler
2004 Award Recipient	Kaisaburo Shigematsu
2002 Award Recipient	Jacques van Bokhoven

Japan – Young Japan Prize

2016 Award Recipient	Dr. Kazunori Ikegami

2018 Awards to be Presented

In the interest of time, the awards will be presented during dinner. Please feel free to continue to enjoy your dinner as the awards are presented.
Awards are listed in alphabetical order, but may not be presented in this order.

Bingbing Wu
Art Johnson Award
Americas Section Award

Jane Whitelaw
Best Poster Award

Michael Clayton
Bill Revoir Award
Society Award

Bob Bentley Bursary Award
European Section Award

Dr. Ziqing Zhuang
Hyatt Award
Society Award

*****The ballots are included in the program book, and once completed with **one** selection, should be deposited in the ballot box at the registration desk. Remember only vote for one poster.

Thursday, September 20, 2018

8:30 AM – 8:40 AM	Preliminaries and Introduction
8:40 AM – 10:40 AM	Technical Session
10:40 AM – 11:00 AM	Break ***Sponsored by ANSI-accredited USTAG***
11:00 AM – 12:30 PM	Technical Session
12:30 PM – 1:30 PM	Lunch
1:30 PM - 2:20 PM	*Technical Session*
2:10 PM – 2:20 PM	2020 Conference Information
2:20 PM – 2:40 PM	*Break* *Sponsored by Shigematsu Works Co., Ltd.*
2:40 PM – 4:00 PM	*Technical Session*
4:00 PM	*Conference Closing*

Thursday Technical Session 8:40 AM – 10:40 AM

Development of Realistic Performance Evaluations for High Performance Chemical, Biological, Radiological, and Nuclear Respirators, and Use in Standardized Testing

Eva Dickson, Royal Military College

Abstract not released for inclusion in program.

Respiratory Protection Performance: Impact of a Ballistic Helmet Integration Kit

Daniel Barker, U.S. Army, Edgewood Chemical and Biological Center

Ballistic helmets and chemical, biological, radiological, and nuclear (CBRN) respirators are typically designed independent of one another and therefore are not optimally compatible or integrated, potentially reducing operational effectiveness. To address this challenge, a conversion kit was developed to integrate an existing U.S. Department of Defense respirator (Avon Protection M50) with a current ballistic helmet (Gentex Advanced Combat Helmet.) With the kit installed, the wearer is able to don the respirator without removing the ballistic helmet, thereby maintaining tactical protection. The operational performance and protection capabilities of this integration conversion kit were evaluated, and compared to the same helmet and respirator worn in a traditional non-integrated manner. Protection factor (PF) testing was performed on both the integrated and non-integrated configurations using a sodium chloride (NaCl) aerosol challenge and a TSI PortaCount®. The study included ten voluntary test participants. Each PF trial included ten operationally-relevant exercises. Statistical analysis (α=0.05) demonstrated no statistically significant difference between the overall PFs for the integrated and non-integrated systems. More than 95% of the overall PFs for both configurations were greater than 2,000. Fluorescent aerosol screening tests (FAST), and man-in simulant tests (MIST) testing illustrated that the integrated kit improved percutaneous protection.

Review of Breathing Apparatus Incident Investigations

Nick Baxter, Health and Safety Executive

Breathing Apparatus (BA) is used in many industries including paint spraying, petrochemical, confined spaces entry, the fire service, and in both working applications and for escape purposes. The correct implementation of the hierarchy of control puts PPE (including BA) firmly as the last resort. In many industries, BA is often the only line of defense against toxic hazards and irrespirable atmospheres and in the unfortunate instance of a failure, the consequences can be severe and potentially fatal. The Health and Safety Executive's Science Division (HSE SD) has carried out an extensive number of incident investigations on behalf of HSE and commercially for a variety of industries. Several examinations of BA involved in fatal investigations with the fire service have provided no evidence of significant failure or malfunction of the BA during the incidents, and no evidence of them failing to perform their intended primary function. This is extremely encouraging demonstrating that BA used in the extreme environments of firefighting will still perform to the highest standards. Many BA involved in fatal investigations with significant fire damage have been tested, demonstrating that afterwards they still perform within the breathing resistance requirements of the relevant standards. As the majority of investigations indicate that BA works effectively and provides adequate protection to the wearer, this leads to the conclusion that something else must be at fault. Outcomes of investigations include incorrect donning procedures relating to inadequacies in training or lack of refresher training, poor procedures/practices followed, incorrect cleaning procedures resulting in water ingress, poor maintenance, issues with air quality, and the practicalities of how the equipment is actually used in working applications. Many investigations have also highlighted deficiencies in the corresponding performance standards. These have been brought to the attention of the appropriate standards committees with recommendations accepted and standards changed. This presentation gives an overview,

describes the common findings arising from our investigations, and describes areas where improvements in the respiratory protection equipment programs are required.

A New Standard for Selection of Respiratory Protection for Intervention in Drug Laboratories

Simon J. Smith, 3M Canada

Clandestine drug synthesis laboratory operations are a growing problem worldwide. Such operations can be small scale – such as in a residence or vehicle, and large scale – approximating the scale of an industrial laboratory. They are the focus of law enforcement operations – and intervention may be in premises where chemicals are actively being used, in inactive and stored laboratories, in tableting operations grow operations and chemical extraction from biological materials. There multiple drug types and many hundreds of potential syntheses, so advance knowledge of the nature of the hazard and its scale may be limited. The first indication of a laboratory is a fire in about half of all cases, and a synthesis operation is only discovered after the preliminary response. Responders face a range of physical hazards as well as the probability of exposure to toxic materials through inhalation and skin contact. They need to select personal protective equipment and operating protocols that are appropriate to the hazards, but a high priority is placed on minimizing encumbrance by protective equipment so that personnel are not overburdened and have their ability to execute their functions impeded unnecessarily. With respect to respiratory protection, since advance knowledge of the type and potential levels of hazards while desirable is not always possible, selection decisions have to be made on the best available knowledge. Equipment classifications, which address industrial workplace applications, do not necessarily address the range of hazardous compounds, which may be encountered. It might be considered that such operations approach the uncertainty of CBRN response. Intervention in drug operations also has the potential for large changes in exposures over the course of the operation and flexibility in response is essential. Availability of a range of levels of personal protective equipment and comprehensive guidance information is therefore highly desirable to allow selection of the optimum combination of protection and minimal burden. In Canada, guidance is being proposed in a new Canadian Standard – CSA Z1640: "Personal Protective Equipment for Investigating and Dismantling Clandestine Drug Laboratories." This standard is scheduled to be released in 2018.

Respiratory Protection for Firefighters During Overhaul Operations

Girish Srinivas, TDA Research

After a structural fire has been knocked down, firefighters carry out salvage and overhaul operations to check for and extinguish any smoldering hot spots. Early on in the overhaul operations, firefighters wear their self-contained breathing apparatus (SCBA), but later on, it is common practice to remove the SCBA when the carbon monoxide (CO) concentration (measured by a hand held unit) drops to below the 8 hour OSHA PEL of 35 ppm. Unfortunately, CO concentrations do not correlate with the concentrations of other harmful chemicals or particulates in the overhaul environment. Therefore, we need a respirator system that can be used to protect firefighters against both chemical vapor and particulate hazards during the later stages of overhaul. The new technology must be capable of protecting against airborne hazards while being much lighter and more comfortable than the traditional SCBA, durable, require minimum maintenance, have low operating costs, and must be reasonably priced and affordable to smaller local fire departments. At the end of this project, TDA Research will deliver specialized prototype filters to the Department of Homeland Security (DHS) for removing the particulates and chemical vapor hazards during fire overhaul that can be used on a wide variety of air purifying respirator (APR) and powered air purifying respirator (PAPR) platforms. TDA and our commercial partner have tested large number of candidate activated carbon materials and particulate filters against a wide variety of chemical and particulate contaminants that are typically found during fire overhaul. The particulate filter is a HEPA material and the activated carbon is a mixture of acid gas, ammonia/amine, organic vapor, and multigas carbons that were optimized using statistically designed mixture experiments. The prototype canisters also have an optional room-temperature CO oxidation catalyst module for CO protection (CO is oxidized to CO_2). We are

currently fabricating prototype filter cartridges that will be tested in an Operational Field Assessment with the DHS in the fall of 2018.

Fentanyl Aerosol Filtration Efficiency of an N95 Respirator Filter

Kent Hofacre, Battelle Memorial Institute

First responders (e.g., law enforcement officers, emergency medical service) can encounter Fentanyl and its analogs as solid powders that can be aerosolized. The National Institute for Occupational Safety and Health, National Personal Protective Technology Laboratory has provided initial guidance regarding the use of PPE for various job categories of those who may encounter Fentanyl powders, but there is little supporting data regarding the performance of respirator filters against Fentanyl aerosols. This presentation describes a novel test method to measure Fentanyl (and an analog of Carfentanil) aerosol penetration of an N95 filter over a range of flow rates. The method provides for unambiguous quantification by collecting all of the aerosol in the N95 filter effluent air stream using a glass fiber filter that was subsequently analyzed by liquid chromatography with mass spectrometry (LC/MS) to quantify the penetrating Fentanyl aerosol. The method was also employed using a potassium chloride (KCl) salt aerosol of similar size to compare to the filtration efficiency using an inert aerosol. Lastly, penetration was measured using a method similar to NIOSH's measurement method for comparison. Results will be presented that demonstrate comparable penetration of the inert KCl aerosol as measured by the new method with that of the Fentanyl and Carfentanil aerosols, further supporting the particle-is-a-particle concept as it pertains to aerosol filtration. The measured KCl, Fentanyl, and Carfentanil aerosol filtration efficiencies (mass median aerodynamic diameter of ~0.3 µm) were >95% at 50 LPM. Aerosol filtration efficiency increased as the airflow rate through the filter decreased. These preliminary results are an initial indication that respirator filters perform as expected against Fentanyl (and its analogs) aerosols, and that the method of direct quantification of all penetrating aerosol is consistent with the NIOSH measurement method. It is recommended that the method of complete collection and quantification of filter penetration be applied to other respirator and filter types such as filtering facepiece respirators and P100 filters to expand the reference dataset and provide further support and confidence to the performance of respirator filters against Fentanyl and an analog aerosol.



Thursday Technical Session 11:00 AM – 12:30 PM

Update of ISO TC 94 SC 15 Respiratory Protective Devices

Geoff Betsinger, 3M, U.S.

Overview of the National Institute for Occupational Safety and Health Respirator Approval Program

Jeffrey Peterson, National Institute for Occupational Safety and Health,
National Personal Protective Technology Laboratory

The National Institute for Occupational Safety and Health (NIOSH) National Personal Protective Technology Laboratory (NPPTL) certifies conformance of respirators in the United States to requirements codified in federal regulations. ***Title 42, Code of Federal Regulations, Part 84*** (42 CFR 84) includes requirements for atmosphere-supplying and air-purifying respirators. NIOSH NPPTL uses established Standard Operating Procedures~~,~~ policies, guidance documents such as the Standard Application Procedures, and Standard Test Procedures to ensure NIOSH- approved respirators meet the minimum requirements described in 42 CFR 84. This presentation will provide an overview of the NIOSH Respirator Approval Program, including an update about recent activities:

1) Company Action planning to improve the efficiencies of the National Institute for Occupational Safety and Health (NIOSH) Respirator Approval Program,
2) Assessing conformance of N95 filtering facepiece respirators for use in healthcare settings in accordance with the Memorandum of Understanding between NIOSH and the U.S. Food and Drug Administration ,
3) Implementing the NIOSH bivariate anthropometric panel,
4) Updating policies to recognize National Fire Protection Association (NFPA) 1986 Standard on Respiratory Protection Equipment for Tactical and Technical Operations,
5) Integrating consensus standards, such as NFPA 1987 Standard on Combination Unit Respirator Systems for Tactical and Technical Operations, into the NIOSH Respirator Approval Program,
6) Supporting other priority NIOSH National Personal Protective Technology Laboratory standard development initiatives.

New European Regulation for Personal Protective Equipment – Essential Aspects of the Transition Period

Gabriele Troescher, 3M Deutschland GmbH

The new European Regulation for Personal Protective Equipment PPE (Regulation (EU) 2016/425) applies since 21 April 2018. During the transition period until 21 April 2019, all economic operators in this area (manufacturers, notified bodies, distributors...) need to ensure that the provisions of the PPE regulation are met for all PPE. As all respiratory devices fall under risk category III (i.e. "risks that may cause very serious consequences such as death or irreversible damage"), the change is central for this product group and its trade in the European Economic Area. It is essential that all economic operators work hand in hand to allow a smooth transition and to provide safe PPE to all users. This presentation gives a condensed overview concerning the changes, mainly from a manufacturer's point of view. After a description of these changes, relevant consequences for economic operators will be discussed.

NFPA 1987 Combination Unit Respirator Standard Development Update

Clint Mayhue, Avon Protection Systems

The National Fire Protection Association (NFPA) was approached in 2015 to develop a standard to test and certify Combination Unit Respirators (CUR) for non-firefighting emergency services. These services include tactical law enforcement, confined space, and hazardous materials operations amongst other uses. A CUR is defined as a breathing apparatus, which at a minimum includes open circuit SCBA capabilities along with at least one of the other protection modes of APR and/or PAPR. Up until now, an apparatus with multiple modes of protection could have only been approved by NIOSH to the lowest level of respiratory protection available. The new NFPA 1987 standard will allow CUR to be certified for use in the various modes of operation and will ensure the mode transfer actions are safe for the user by maintaining the proper level of respiratory protection. NFPA 1987 is the first NFPA standard to incorporate the appropriate NIOSH requirements directly into the NFPA standard. NIOSH had begun working on a CUR standard in the mid-2000s but due to resource constraints, this work was never finished. NIOSH and NFPA were given the vehicle to work together to develop the CUR performance standard from the National Technology Transfer and Advancement Act of 1995 to adopt voluntary consensus standards wherever possible. NIOSH industrial and CBRN testing requirements will be contained within the NFPA 1987 document alongside NFPA tests designed to appropriately challenge the unique aspects of a CUR. This presentation will share highlights of the NFPA 1987 standard, as it is today, the work remaining to complete the standard, and the projected completion dates.

Developments in the ISO Respiratory Protective Device Standard for Standardized Filter Mechanical Connectors

Michael Parham, 3M U.S.

Standardized mechanical connectors between filters and respiratory inlets are specified in several national and international standards including EN148-1, ISO17420-3, and the National Institute for Occupational Safety and Health (NIOSH) Standard for CBRN Full-Facepiece Air-Purifying Respirators, Section 3 on Mechanical Connector and Gasket. Commonly known as '40mm' threads, these standardized connectors enable many practical applications, dependent upon national regulations. From emergency interoperability to commonality of filters for use on large industrial sites, the standardized connector has served to minimize the burden of maintaining respirator stockpiles. The purpose of this presentation is to share recent developments in international standards and help understand how the standardized connector will be applied in the upcoming ISO Respiratory Protective Device standards. The standardized connector of EN148-1, ISO 17420-3, and the NIOSH Standard for CBRN Full-Facepiece APR Mechanical Connector and Gasket while similar are not the same. The intention of use for the standardized connectors in each standard differs significantly. Existing use cases of standardized connectors in respiratory protection will be presented along with how the changes to applicable standards potentially may and may not impact their use in the future.

Thursday Technical Session 1:30 PM – 2:10 PM

Safely Furthering Composite Pressure Cylinder Use in Self-Contained Breathing Apparatus (SCBA) Service

Brian Burks, Digital Wave Corporation

In the United States, the carbon fiber composite pressure cylinders which are integral members of SCBA apparatus are designed to a U.S. Department of Transportation (DOT) design standard known as the DOT-CFFC. The aforementioned cylinders are operated under DOT Special Permits. In the DOT-CFFC standard, the CFFC-3 clause allows for a service life of 30 years, provided certain requirements are met. Certain DOT-CFFC special permit holders attempted to gain a 30-year approval[4] but were denied due to a lack of in-service inspection methodology that assured the DOT of continued safe operation. For this presentation, results from three (3) studies[5,6,7] on the continued usage of DOT-CFFC cylinders beyond a fifteen (15) year service interval will be presented. For the studies, over 300 cylinders were donated by fire departments from around the country which had experienced fifteen (15) years of service. These cylinders were subjected to burst testing (to determine if strength was degraded), fatigue cycle testing (to simulate furthered service), impact and notch tolerance testing (to intentionally degrade cylinder performance and verify the efficacy of the Modal Acoustic Emission (MAE) requalification method for composite cylinders), as well as aggressive environmental exposure (fire impingement, chemical exposure, hard water exposure, etc.). Results from the studies indicated that cylinders which had experienced a fifteen (15) year service life in the field, still met all at time of manufacture requirements for burst strength and fatigue cycle performance. Furthermore, MAE requalification was shown to far more effectively evaluate a cylinder's integrity (i.e., diminished burst or fatigue cycle performance) as compared to the traditionally utilized requalification methods for composite cylinders of hydrostatic testing and visual inspection. The results of these research programs were the granting of DOT-SP 16320, which enables the originally allotted 30-year service life by requiring a MAE requalification of the cylinders.

Finalization of the ISO Technical Specification for Chemical, Biological, Radiological, and Nuclear and Radiological Nuclear Respiratory Protective Devices

Simon J. Smith, 3M Canada

The International Organization for Standardization (ISO) exists to facilitate international coordination and unification of industrial standards. Within the overall programme to develop performance requirements for respiratory protective devices, work is in progress for Chemical, Biological, Radiological, and Nuclear (CBRN) and Radiological Nuclear (RN) applications. The specification aims to incorporate the best current knowledge to address human factors, protection requirements, operational needs and compatibility with other equipment. Work has been under way for five years and is close to finalization. The target user group includes the police, fire and emergency medical services, primary health care (first receiver), search and rescue, sampling and detection

[4] https://www.luxfercylinders.com/press-releases/concerning-life-extension-of-dot-cffc-carbon-composite-cylinders

[5] https://www.phmsa.dot.gov/technical-resources/hazmat-technical-resources/use-modal-acoustic-emission-mae-life-extension-civilian-self-contained-breathing-apparatus-scba-dot-cffc-cylinders-pdf

[6] https://www.phmsa.dot.gov/technical-resources/hazmat-technical-resources/self-contained-breathing-apparatus-scba-composite-cylinder-environmental-exposure-effects-on-dot-cffc-cylinders-with-modal-acoustic-emission-examination-pdf

[7] https://www.phmsa.dot.gov/technical-resources/hazmat-technical-resources/fatigue-life-improvement-dot-cffc-composite-cylinders

teams, and workers with specific roles during response. Content is being developed in consultation with the responder user community.

Proposed requirements include:

1) Three classifications for:
    - First on-scene responders in an unknown environment,
    - On-scene responders in a characterized environment,
    - First receivers remote from an incident.
2) CBRN escape devices for the regular workforce
3) Test methods and criteria for permeation protection from aggressive agents
4) Facilitating simple logistical choices including optional standardized connections between system components and for the same type of filters to be used directly on facepieces and on powered air devices

Requirements are also in prospect covering respirators specifically for workplaces and emergencies involving radiological-nuclear materials. An expert subgroup has provided input and laboratory studies have been executed. Proposals include:

1) No specific requirements for supplied breathable gas RPD for radiological-nuclear applications
2) Current elastomeric materials are not subject to methyl iodide permeation at concentrations two orders of magnitude above recorded exposure levels
3) The highest level of particulate filtration in the ISO standard is mandatory
4) A test method and specification (evaluated by a test laboratory) for filtration efficiency of radioactive methyl iodide
5) “RN” requirements can be combined with industrial gas capabilities to serve the needs of laboratories in various roles in the nuclear industry

The result of the task group activity will be the definition of performance criteria for CBRN- and RN-capable respiratory protective devices and for escape systems for incorporation into the ISO Respiratory Protective Device Standard as a technical specification.

Thursday ISRP 2020 Information 2:10 PM – 2:20 PM

ISRP 2020 Conference
27th September to 1st October 2020
Pembroke College, Oxford, UK





For the 20th ISRP International Conference the European Section is taking the society to Pembroke College, Oxford. Pembroke combines historic 17th and 18th Century parts with a modern conference facility seating over 150 people. It occupies a central location in the City of Oxford. There are single en-suite rooms in the modern block with some double rooms in older buildings round the quadrangle. There are also many 4* and 5* hotels within walking distance.



Oxford is on the Thames about 60 miles (100 km) west of London. The University is one of the most famous in the World, having been founded in the 12th Century with some buildings from the 11th Century. Oxford is the 7th most visited City in UK by "overnight overseas" tourists and combines a "historic centre of learning in a vibrant modern city".

We look forward to welcoming our colleagues here in September 2020

Thursday Technical Session 2:40 PM – 4:00 PM

Air-Purifying Sorbent Design and Selection for Respiratory Protective Equipment

James Hern, Molecular Products Inc.

Respiratory protective equipment including respirators, collective protection systems, and indoor air-purifying filters require sorbents capable of removing gases and vapors of concern. The sorbents are a critical component of these devices and their ability to meet performance goals. The very wide range of applications, evolving filter designs, standards, and materials have an impact on the design, manufacture, and selection of these sorbents. Design considerations must include gas and vapor removal performance, but also the range of different adsorbates, regulatory compliance, end use product designs and purposes, and global considerations on the source of raw materials as well as cost.

Improving Gas-Phase Filters for Indoor Air Quality

Richard Mackay, Molecular Products, Inc.

While Respiratory Protective Equipment (RPE) often suggests respirators worn to protect an individual from hazardous substances in the air, it also applies to filters for Indoor Air Quality (IAQ). Gas phase filtration in PPE is more highly regulated than gas phase filtration in collective protective equipment, but that may be changing with the introduction of new standards, such as Chinese Standards GB/T 18883 and 18801, which specify Indoor Air Quality Standards and Air Cleaner Standards. With clear requirements for portable indoor gas phase filters improving the quality of indoor air, this has the potential of opening up tremendous opportunity in IAQ worldwide. The technology is equally as effective in offices, stores, and warehouses as it is in restaurants and residential buildings. In this presentation, results of two studies on improving gas phase filters are shown. The first study shows how the choice of carbon impregnants can improve filter properties. The second illustrates the variables associated with fabrication of carbon-filled filters and their associated performance. For each of these studies, three test gases representing three different classes of gas types were used.

1) Cyclohexane (as a benchmark for organic vapors)
2) Nitrogen dioxide (as a benchmark for acidic gases)
3) Formaldehyde

Each gas type above is recognized as commonly present in either outdoor urban air pollution (smog) or indoor air pollution (cooking, odors, off gassing from construction materials, etc.). Results are presented in terms of breakthrough and gas capacity.

Accuracy Improvements in Service Life Testing Using Fourier Transform Infrared Spectroscopy

Charles (Gus) Manning, Assay Technology

Laboratory evaluation of cartridge breakthrough times is crucial to making respirator service life predictions. The accuracy of such tests is highly dependent on a lab's ability to continuously control and measure concentrations of gases and vapors in flowing streams. Any deviation from desired gas concentrations, flow rates, humidity, and temperatures in the chemical challenges presented to cartridges, or errors in measuring low-level breakthroughs in effluent have immediate, adverse effects on the accuracy of projected service lives. Due to the instability of many test gases in cylinder storage and during testing, frequent reanalysis of challenge agents at each stage of testing is desirable. Fourier transform infrared spectroscopy (FTIR) provides a unique method of gas phase chemical analysis in which multiple components may be simultaneously analyzed in a flowing stream across a

range of concentrations. Further, provided the test cell is kept clean, FTIR calibrations, based upon infrared absorption constants, remain constant over time reducing the frequency of recalibration required. Since FTIR facilitates the verification of chemical challenge agent concentrations, in-process agent concentrations, and provides sensitive and selective detection of breakthrough species, FTIR use provides a substantial improvement in the overall accuracy of service life determinations. As part of the project of implementing FTIR, our lab performed a variation (error) analysis on each analytical process and analyzed the propagation of errors to demonstrate the magnitude of accuracy improvement in service life determination. The presentation describes practical examples of multiple uses of FTIR in service life testing and illustrates the benefits derived.

Evaluation of Effect on Nanofiber Deposition to Airfilter Collection Performance

Hisashi Yuasa, Koken Ltd. Hanno Lab

Nanofiber (NF) composited filters are of great interest in the field of air filtration as a new medium to improve the filtration performance. Compared to the conventional micrometer sized fibers, the filtration theory predicts that NFs contribute to an increase in collection efficiency and a reduction in pressure drop. However, the filtration efficiency of actual NF filters is often lower than the predicted based on the single fiber filtration theory because uniform packing of NFs is quite difficult for the mass production. This study investigated the effects of the inhomogeneity of NFs on filtration performance when they are laminated on micrometer fiber filters. The test filters were prepared by two kinds of wet process, liquid filtration and gravity setting method, with NFs (d_f= 0.35μm) and micrometer sized fibers (d_f=3.1μm). Collection efficiency was measured using NaCl particles ranging from 10 to 500nm at the airflow rate 0.05-0.15m/s. As a result, the inhomogeneity factors of NF layered test filters ranged from 6.5 to 10.5 for the liquid filtration and from 2.5 to 5.2 for the gravity setting. Furthermore, measured particle penetration was in good agreement with the predicted accounting for the inhomogeneous packing of NF layer, suggesting that the correction with inhomogeneous factor is valid for the NF layered filters. However, no correlation between the inhomogeneity factor and quality factor was observed.



Friday, September 21, 2018 8:15 AM – 1:00 PM

8:15 AM – 1:00 PM	NOAA David Skaggs Research Center tour (pre-registration required)	Off-site
The bus will leave the Lawrence Street entrance of the hotel at 8:15 AM. Travel time is approximately 45 minutes. The tour is 90 minutes, followed by visit to the gift shop. The bus will leave NOAA at 12:15 PM and return to the hotel around 1:00 PM.		

The tour includes stops at the Space Weather Prediction Center, ESRL Global Monitoring Division for information on the carbon dioxide record, the National Weather Service Forecast Office, and Science on a Sphere.

Security Procedures for Visitors

- Visitors are required to sign in and receive a visitor badge from the Visitors Center.
- Visitors to the site who are **U.S. citizens** must present a **U.S. photo ID**, such as a current state driver's license (exceptions below).
- **Foreign Nationals** must present a valid **passport or a permanent resident ID** ("green card").
- All IDs must be originals only – no photocopies accepted.
- Effective July 21, 2014, under the REAL ID Act of 2005, federal agencies can only accept a state-issued driver's license or identification card for access to federal facilities if issued by states that are REAL ID compliant or have an extension.
  - **The Visitors Center <u>will not accept</u> drivers' licenses from these states and territory:**
    - American Samoa
    - Minnesota
    - Missouri
    - Washington
  - **The Visitors Center will, however, accept <u>Enhanced IDs</u> from the following states:**
    - Minnesota
    - Washington
  - If a visitor presents an ID from one of the non-compliant states on the list, they will have to present another form of ID (below) or they will be denied access to the site. **There will be no exceptions made to this policy.**
  - **Other accepted forms of ID** include:
    - Passport
    - Passport card
    - DOD CAC card
    - Federal Agency HSPD-12 IDs
    - Veterans ID
    - Military ID
    - Military Dependents ID
    - Trusted Traveler card - Global Entry, SENTRI, or NEXUS
    - Transportation Workers Identification Credential (TWIC)
    - To receive a visitor badge, all visitors are required to park next to the Visitors Center and enter. Security personnel will make a badge and conduct screening. Security personnel will also inspect vehicles prior to entrance of the site.

Photography of any kind is not permitted on the site.

Speaker and Poster Presenter Biographical Sketches

Keynote Speakers

John Howard has been the Director of the National Institute for Occupational Safety and Health and the Administrator of the World Trade Center Health Program in the U.S. Department of Health and Human Services since 2002. Dr. Howard earned a Doctor of Medicine from Loyola University of Chicago; an MPH from the Harvard University School of Public Health; a Doctor of Law from the University of California at Los Angeles; and a Master of Law in Administrative Law and Economic Regulation, and an MBA in Healthcare Management, both degrees from The George Washington University in Washington, D.C.

Mike Clayton joined 3M UK in May 2018 and now leads a team of PPE subject matter experts providing technical and application support to a broad customer base across Europe and wider. Mike is also chair of the UK British Safety Industry Federation Respiratory Protection Product Group. Previously, he served as the PPE Team Lead for the Health and Safety Laboratory (HSL). He has over 30 years' experience in the field of PPE and has served in numerous ISRP leadership roles over the years, including President from 2014-2016. The Health and Safety Laboratory (HSL) is one of the world's leading providers of workplace health and safety research, training and solutions. HSL is the laboratory of the U.K. Government's Health and Safety Executive set up to identify, understand, and help to prevent whatever can go wrong in the workplace.

Hyunwook Kim serves as the President of Korean Society for Respiratory Protection and Professor of the Department of Preventive Medicine at the Catholic University of Korea. Dr. Kim earned his PhD and Master degrees from West Virginia University. He served as the 9th President of Korea Industrial Hygiene Association (2007-2009), and the dean of the Graduate School of Public Health at the Catholic University of Korea (2013-2015). Currently, he serves as a director of Korea Occupational Safety and Health Agency (KOSHA) and advisory committee members of the Ministry of Labor and the Ministry of Environment. He was decorated a medal of honor (Order of Service Merit) for his excellent services in the field of occupational health in 2017.

Platform and Poster Presenters

Daniel Barker- Daniel Barker is the Chief of the Respiratory Protection Branch at the Edgewood Chemical Biological Center. Mr. Barker has over twenty-three years' experience conducting Human Systems Integration (HSI) research and providing HSI consultation to a diverse collection of Department of Defense, Department of Homeland Security, and other industrial programs. Over the past 12 years, Mr. Barker's work has primarily focused on respiratory protection research and design with focus on the impact of respiratory protection and personal protective equipment on wearer performance and system efficacy. Daniel has authored or co-authored over 35 publications and holds two patents. His work has been featured in Popular Mechanics, CNN, The Army Times, and other news outlets. Mr. Barker holds a B.S. in Mathematical Sciences from Loyola University, Maryland and an M.S. in Systems Management from the Florida Institute of Technology.

Nick Baxter is a Breathing Apparatus (BA) specialist working in the Health and Safety Lab's Personal Protective Equipment (PPE) team providing technical expertise and leading both project and incident investigations. Since joining the PPE team in 2006, Nick has developed knowledge and understanding of Respiratory Protective Equipment (RPE), PPE and has specialized his expertise in the area of BA. Nick has experience leading RPE and in

particularly, high profile BA incident investigations for HSE, and has carried out independent investigations directly for the fire service. Nick has practical experience testing BA against standard requirements, operating breathing simulators and associated equipment, conducting RPE performance testing, and carrying out studies involving human subjects. Nick is also competent at performing fit tests and is Fit2fit accredited. He is a member of the British Standards Committee for RPE and has contributed to the development of the emerging ISO Standards for Respiratory Protective Devices.

Michael Bergman is an Associate Service Fellow at NIOSH's National Personal Protective Technology Laboratory with experience in the fields of respirator use, policy, and research. His research interests include respirator fit testing, aerosol filtration, and developing new advanced respirator fit test headforms to better simulate the anthropometric sizes, skin, and head and facial movements of people. He has routinely performed human subject fit test data collection for numerous NIOSH laboratory studies. Mr. Bergman received an M.S. in Public Health from the University of Massachusetts at Amherst.

Geoff Betsinger has been working in the Occupational Health field for over 20 years. His current position is Technical Manager, Regulatory Affairs in the 3M Personal Safety Division. He is has served as President of the International Society for Respiratory Protection, and is the Technical Chair for American National Standards Institute (ANSI) U.S. Technical Assistance Group (USTAG) to ISO TC94 SC15 Respiratory Protective Devices, and is the Chair of ISO TC94 SC15. Prior to joining 3M, Geoff served as a commissioned officer in the U.S. Navy Medical Service Corps specializing in Industrial Hygiene. Geoff has authored, co-authored, and presented numerous papers in the Occupational Health Field and has presented at numerous conferences and seminars. He is certified by the American Board of Industrial Hygiene, has a Bachelor of Science degree in Chemistry from the University of Wisconsin-Eau Claire, and a Master of Science Degree in Public Health from the University of Minnesota.

Jeff Birkner is a Certified Industrial Hygienist and holds an M.S. degree in Environmental Health Sciences, a B.A. in biology from New York University and a Ph.D in Environmental Health Sciences from UCLA. He has more than 30 years of experience in the practice of Industrial Hygiene. He has done laboratory research, worked in public health, and private industry. He received his Certification in Comprehensive Practice in 1987, and has been a member of AIHA since 1980. Dr. Birkner worked for two years as an Assistant Scientist with the New York City Department of Health in the Bureau for Radiation Control where he enforced city, state, and federal regulations for health facilities possessing radiation-producing equipment. He worked as a Health Physicist/Industrial Hygienist for one and a half years with the major contractor for the Los Alamos National Laboratory in New Mexico where he performed radiation risk assessments, all types of training, and all types of exposure monitoring. He also served as president of the International Society for Respiratory Protection from 1991 to 1993 Dr. Birkner has worked for Moldex-Metric as VP of Technical Services where he has worked for the past 31 years. Moldex manufactures respiratory and hearing protection equipment. He deals extensively with OSHA, NIOSH, EPA, legal issues, and in-house health and safety. He oversees Moldex's Quality Assurance program, Tech Services, and training of sales representatives and distributors. Dr. Birkner sits on various ANSI/ASTM committees, is a member of the respirator committee of the AIHA and currently acts as Chair for the respiratory standard group for International Safety Equipment Association (ISEA).

Alex Birrell has worked in senior roles in the technology sector for over 20 years. She has previously held management roles in acute care facilities in Renal Medicine and Diabetes Centres. While completing her PhD in Medicine, she ran a research facility at Royal Prince Alfred Hospital (Sydney's largest teaching hospital) with clinical collaborations with pharmaceutical and medical device companies. On completing an executive MBA, Dr. Birrell joined the tier one accounting firm, Pricewaterhouse Coopers in the Finance/Technology Practice. She co-founded and is the director of an organisation, Heads Over Heels, that delivers executive network connections to woman-lead fast growth technology businesses. Dr. Birrell sits on the Board of Trustees for Museum of Arts and Applied Sciences that operates three museums that hold a globally recognised collection spanning technology, medicine, science, design, and space exploration. Dr. Birrell is currently the CEO and a Director of CleanSpace Technology

Pty Ltd, a company that designs and manufactures a new generation of respiratory protection devices. Dr. Birrell has a PhD (Medicine), MBA (Business) and Bachelor of Veterinary Medicine.

Barbara Braun is currently Associate Director, Health Services Research, in the Division of Healthcare Quality Evaluation at The Joint Commission. In her position, she is involved with designing and implementing collaborative projects related to quality of care and multi-site infection prevention research funded by the Center for Disease Control (CDC) and the Agency for Healthcare Research and Quality with partners at several academic medical centers. She is a member of the CDC National Institute of Occupational Safety and Health (NIOSH) National Occupational Research Agenda Healthcare and Social Assistance Sector Council, which is charged with developing an industry-specific research agenda for the nation, and is co-leader of The Joint Commission/JCR/OSHA Alliance activities. She has been involved in Joint Commission research, evaluation, and performance measurement activities for more than 20 years. Prior to this position, she worked for the Veterans Administration health services research department in Hines Illinois on projects related to home care, long term care, and infectious diseases. She received a PhD from the University of Illinois Medical Center, School of Public Health, Chicago, IL. She is a certified Green Belt in Robust Process Improvement, a blended form of lean and six sigma methodologies, and is an adjunct faculty member in the Masters in Healthcare Administration program at the University of Illinois at Chicago School of Public Health.

Harold Boyles received a Medical Laboratory Technology degree from George Washington University, he received his Bachelor of Science in Nursing from Alderson-Broaddus College, and finally he obtained his Masters in Healthcare Administration from Independence University. Harold is a six year United States Navy Veteran where he begin his medical career as a Hospital Corpsman, he then transitioned to the United States Army in the West Virginia National Guard as a Combat Medic for three years. Finally, Harold accepted a Commission in the United States Public Health Service where he was detailed to the Federal Bureau of Prisons and the Centers for Disease Control and Prevention National Institute for Occupational Safety and Health for the last 15 years. He is currently the Deputy, Research Branch at the National Personal Protective Technology Laboratory.

George Broyles is a Fire & Fuels Project Leader for the Forest Service (FS) National Technology and Development Program. George manages projects submitted to the Fire and Aviation management Steering Committee, National Wildland Coordinating Group (NWCG) Committees and the FS Fire and Aviation Management Director. Some of his most recent work has been the Wildland Firefighter Smoke Exposure, Fireline Production Rates and Hydrogen Sulfide Monitor Evaluation, and the wildland firefighter hearing assessment project. Prior to his current position, he worked in the Black Hills National Forest. He holds an A. S. in Horticulture, a B.S. in Sociology and a Masters in Natural Resources. He is the Chair of NFPA 1977, Protective Clothing & Equipment for Wildland Fire Fighting, a member of NWCG Risk Management Committee's Smoke Exposure Task Group, and the NIOSH National Occupational Research Agenda Council for the Public Safety Sector.

Brian Burks received his Master's and PhD degrees in Mechanical Engineering from the University of Denver. After completing his degrees, Brian was awarded a National Research Council post-doctoral fellowship from the National Academy of Sciences. Brian completed his post-doctoral fellowship at the National Institute of Science and Technology in Boulder, CO. Brian has a background in composite materials analysis and inspection, failure investigation, and continued fitness for service evaluation. He lives south of Denver, CO with his wonderful wife, a gregarious three-year-old daughter, and a second daughter arriving on Halloween.

David Caretti earned an MS Degree in Applied Anatomy and Physiology in 1989 from Boston University and a B.S. Degree in Biology from The Pennsylvania State University in 1987. He has over 26 years of experience in respiratory protection research at the U.S. Army Edgewood Chemical Biological Center (ECBC). Mr. Caretti has authored 35 articles in peer-reviewed scientific journals and 42 government technical reports that detail findings regarding human performance during respirator wear, human factors associated with military and commercial individual protective equipment, and protective assessments of novel respirator designs. He is a member of the

Journal of the ISRP Editorial Board, and currently serves as the Chief of the Chem Bio Protection and Decontamination Division of ECBC's Research and Technology Directorate.

Craig Colton is a former spray paint respirator wearer, and a certified industrial hygienist in the Technical Service/Regulatory Affairs group of the 3M Personal Safety Division. In 1978 at the OSHA Training Institute, he discovered it was more fun to experience respirators from the front side than the backside, teaching a 2-week long respirator training course. He has conducted workplace protection factor studies and other field investigations requiring the wearing of respirators. His front-side activities have involved teaching respiratory protection classes, implementing a quantitative fit testing program for OSHA, and regulatory (OSHA-NIOSH) and standards (ANSI, ASTM, NFPA and ISO) work.

David Cowgill is the Scientific Director and founder of ATOR Laboratories, a testing house specializing in the evaluation of respiratory protection equipment and the manufacture of Automated Breathing Metabolic Simulators. David developed his appreciation RPD in his home state of Rhode Island, volunteering for 5 years as a firefighter and an Emergency Medical Technician. His education then continued at Gulf Coast College, where he studied computer science and robotics. This led to a 33-year career at the Navy Experimental Diving Unit, where David developed metabolic simulators to evaluate breathing apparatus employed underwater and in special operations, conducted accident investigations for various government and civilian agencies, and contributed authorship to the Navy's Unmanned Test Manual. David has been involved with the U.S. Technical Advisory Group to the ISO for the past 6 years and hopes to inspire future generations' involvement and participation within the ISRP.

Maryann D'Alessandro has served as the Director of the National Institute for Occupational Safety and Health (NIOSH) National Personal Protective Technology Laboratory (NPPTL) since March 2012, and was previously the Associate Director for Science for NPPTL. Maryann provides leadership to the NIOSH PPT Core and Specialty Program where she serves as the Manager leading the effort to align PPT initiatives with user needs across all workplace industry sectors. Within the Personal Protective Technology (PPT) Program, Maryann has served as the catalyst for aligning surveillance, research, standards, certification, outreach and intervention activities to improve workplace safety and health. Prior to joining NIOSH in 2003, she had a short academic career at the University of Pennsylvania's Department of Bioengineering, and served 15 years with the U.S. Army in biomedical sensors, communications, and intelligence systems research and development. Maryann holds Electrical Engineering degrees from the Florida Institute of Technology (B.S.), Fairleigh Dickinson University (M.S.), and Georgia Institute of Technology (Ph.D.). During her free time, Maryann enjoys spending time with her family and friends; attending plays and musicals; engaging in outdoor activities such as hiking and biking; and serving as an Associate Sister of Divine Providence. Maryann has been in several leadership roles with the ISRP and currently serves as the America's Section Chair.

Eva Dickson has been a specialist in the area of respiratory and body protection for high hazard agents for more than 25 years. She is a Defence Scientist reporting to Defence Research and Development Canada Suffield Research Centre (DRDC), stationed at the Royal Military College of Canada (RMCC) as an Adjunct Associate Professor. She has been actively involved in every aspect of individual protection from requirements and standards development, research and development of new materials and designs, qualification and evaluation including methods development, life cycle management support, training, commander's guidance, and support to procurement. The projects her group executes support clients worldwide, including DRDC's primary client, the Canadian Armed Forces, as well as first responders, industry, and international partners.

Rohan Fernando is Senior Research Engineer at the National Institute for Occupational Safety and Health, National Personal Protective Technology Laboratory. Rohan is the principle investigator for Breathing Air Supplies. He is investigating enabling technologies for improvement of breathing air supplies in escape, rescue and shelter systems in underground mining. A mechanical engineer by profession with more than 20 years' experience in

breathing protection/ life support technology involved in individual apparatus and collective protection system design, production, installation, servicing and marketing in the government and commercial sectors. Prior to joining NIOSH in 2011, he worked at Draeger Safety both in the United States, and Singapore as Technical Manager, Product Manager, Portfolio Manager in Breathing Gas, Diving and Aerospace divisions. He also worked at Avon Protection Systems as Program Manager for Rebreathers. He earned his mechanical engineering degrees from the University of Nebraska- Lincoln (M.S.), research area being experimental multi-phase flow, and the University of Manchester, England, U.K. (BSc.(Honors)). He is a member of the American Society of Mechanical Engineers and ImechE (UK) and is registered as a Chartered Engineer (CEng) in the U.K.

Patricia Gleason currently serves as President of the Safety Equipment Institute (SEI), a subsidiary of ASTM International. She has over 25 years' experience in the standards and conformity assessment industry. In this position, Ms. Gleason currently serves as Chairman of Board of the American National Accreditation Board (ANAB). SEI operates ISO/IEC 17065 accredited certification programs for over 60 types of safety and protective products used and by millions of workers in the fire and emergency services industry, and by recreational consumers of sports and athletic equipment. SEI certifies virtually every NFPA 1981 SCBA used by the fire service. In 2016, SEI became a subsidiary organization of the American Society for Testing and Materials (ASTM), and Ms. Gleason is the Vice President of Certification for ASTM International. Ms. Gleason serves on the ANSI Accreditation Committee, the ANSI Conformity Assessment Committee, and the ANSI International Conformity Assessment Committee. She also serves on various standards development organization's Technical Committees that publish performance standards for the National Fire Protection Association (NFPA), the American Society for Testing and Materials (ASTM), and the National Institute of Justice (NIJ). Ms. Gleason received her MBA from Marymount University and her BS from Frostburg State University. She is the recipient of the American National Standards Institute Gerald H Ritterbusch Conformity Assessment Medal in 2015, and Distinguished Service Award in 2006.

Larry Green is a research and development engineering manager at Syntech International, Bio-Medical Devices, Inc. He holds a Bachelor of Science in Mechanical Engineering from Cal State University Long Beach. He has more than 15 years' experience in Tooling Design, Machine Operations, and Statistical Process Control. He has more than 25 years' experience in research and development and manufacturing process development for PAPRs and medical protective garments. He also has 3 years' experience in additive manufacturing (3-D printing). Larry has been issued 11 U.S. patents. He received his initial training on respirators by wearing a half-mask respirator for 50 hours a week for four years when what was state-of-the-art engineering controls were insufficient to handle the smoke generated by a new process. Mr. Green is a member of the ISRP, ASTM, and AAMI.

Lee Greenwald is a Physical Scientist with the National Personal Protective Technology Laboratory (NPPTL) of the National Institute for Occupational Safety and Health (NIOSH). Lee received her B.S. in Forensic Chemistry from Ohio University and a Ph.D. in Chemistry from West Virginia University. Lee has worked with NPPTL for 8 years. Her initial experience involved conducting a variety of respirator certification tests as part of NIOSH's Respirator Approval Program. She has since conducted research on developing inexpensive end-of-service-life indicating technology for toxic gases, evaluating personal protective equipment (PPE) from stockpiles after long-term storage, assessing chemical contaminants found on fire fighter turnout gear, and evaluating the protective performance of PPE against emerging chemical and narcotic agents of interest.

Jessica Hauge is an Application Engineer for 3M's Personal Safety Division, where she conducts respirator-related research, helps design respiratory protection products, and provides support and training to respirator wearers, assigners, and fit testers. Prior to joining 3M's Personal Safety Division, Ms. Hauge worked as an industrial hygienist with 3M's Corporate Industrial Hygiene group, managing projects related to conducting hazard evaluations, field exposure assessments, hazard characterization, and PPE assignment and fit testing. Ms. Hauge has served as Secretary of the International Society for Respiratory Protection since 2016.

Brian Heimbuch has a Bachelor of Science degree in Microbiology from Montana State University and a Master of Science degree in Molecular Biology from Lehigh University. Brian has over 28 years' combined experience working in the pharmaceutical industry and Federal Government contracting. Mr. Heimbuch is currently the Division Manager for Applied Research Associates' Engineering Science Division in Panama City, Florida where he oversees a diverse research portfolio. Mr. Heimbuch's personal research interests include biological aerosols pertaining to disease transmission, barrier protection, pandemic preparedness, biological defense, and respiratory protection. Brian currently leads a team of researchers focused on multiple approaches for mitigating a respirator shortage during a pandemic. A portion of this effort is dedicated to developing better respirators for the health care industry. Mr. Heimbuch is an author on over 30 peer- reviewed journal articles and is an inventor on six United States patents.

James Hern began his career in the field of respiratory protection in 1991 in Canada, working for manufacturers of personal protective equipment, with a focus on military and civil respiratory protective equipment design and development, sorbent research, production technology and scale-up. Work experience includes research and applied development in academic, industrial and military research laboratories. Dr. Hern participated in research contracts and technical support for U.S. Department of Defense contracts for C2A1 production, and Canadian Department of National Defense respirator technology and novel sorbent research. Dr. Hern joined Molecular Products Inc. in Boulder, Colorado in 2011 as Research and Development Manager where he has focused on development of activated carbon sorbents for air purification applications in military, CBRN and industrial products.

William (Bill) Hill has been involved in fit test instruments since 1975. He consulted with the group of engineers and scientists, which produced the first quantitative fit tester during its initial development. Bill has a B.S degree in Biology and Chemistry from the University of New Mexico. Currently he is the Chief Technology Officer at AccuTec-IHS.

Stella Hines is an Assistant Professor at the University Of Maryland School Of Medicine in Baltimore. She is an Occupational Medicine physician and a Pulmonologist. She has received research funding from CDC-NIOSH to study the acceptability and feasibility of elastomeric respirator use in healthcare, and from the United States Department of Defense and the Department of Veterans of Affairs for research related to exposure-related lung disease. She previously served as the Medical Director of Employee Health for the outpatient clinical practices at the University of Maryland and now serves as Associate National Medical Director for the Building Trades National Medical Screening Program for former construction workers of Department of Energy sites.

Sundaresan Jayaraman is Kolon Professor in the School of Materials Science and Engineering at the Georgia Institute of Technology. He is also the Founding Director of the Kolon Center for Lifestyle Innovation at Georgia Tech. A pioneer in bringing about convergence between textiles and computing, his group's research has led to the realization of the world's first Wearable Motherboard™ (Smart Shirt) and the groundbreaking paradigm of "Fabric is the Computer." The first Smart Shirt is now part of the Archives of the Smithsonian Museum in Washington, DC. Prior to Georgia Tech, Professor Jayaraman had the privilege of working with Dan Bricklin and Bob Frankston, the Co-Creators of the world's first spreadsheet – VisiCalc®. He is a recipient of the 1989 Presidential Young Investigator Award from the National Science Foundation (NSF) for his research in the area of computer aided manufacturing and enterprise architecture. Professor Jayaraman is actively engaged in studying and defining the roles of engineering design, manufacturing and materials technologies in public policy for the nation.

James S. Johnson worked at the Lawrence Livermore National Laboratory (LLNL) from 1972 through 2006. His position from November 2000 to 2006 was section leader of the Chemical and Biological Safety Section of the Safety Programs Division. Throughout his career at LLNL, Dr. Johnson was involved with respiratory protection and personal protective equipment as the respiratory program administrator, research scientist, and division and

section manager. He is an AIHA fellow; a member of the NFPA Technical Correlating Committee on Fire and Emergency Services Protective Clothing and Equipment; a member of the NFPA Respiratory Protection Equipment Committee; past chair of the International Society for Respiratory Protection (ISRP), past Americas Section Chair, past ISRP Journal Editor; Secretariat chair of the ANSI Z88 for Respiratory Protection (now ASTM Subcommittee F23.65); and an ongoing member and past chairman of the AIHA Respirator Committee. Dr. Johnson retired from LLNL on July 1, 2006, and is now a part-time consultant. He taught a one-semester industrial hygiene class at Chabot/Las Positas Community College from 1982 to 2014, and a variety of respiratory protection training classes. Dr. Johnson was a member of the IOM Standing Committee on Personal Protective Equipment for Workplace Safety and Health 2009 to 2014 and is currently a member of IOM Committee on the Use of Elastomeric Respirators in health care.

Bill King is currently a physical scientist at the National Institute for Occupational Safety and Health, National Personal Protective Technology Laboratory. Bill earned a PhD in analytical chemistry from Purdue, and worked in industry, including eight years as senior chemist/supervisor in the MSA safety products chemistry group. He also consulted for respirator sorbent suppliers, while both assistant professor/chemistry department chair at Waynesburg College and senior chemist at ViRoLac Industries developing material characterization methods. In 2004, after a visiting faculty appointment developing sorbents for high-temperature fuel gas with the Department of Energy, he joined NPPTL working on protective ensembles. Dr. King is an ISRP Americas Section board director, and member of the American Chemical Society, division of Chemical Health and Safety. Among his research interests are development and application of real-time respirator fit methods.

Richard Mackay is a Senior Research Scientist at Molecular Products. He is involved in new product development, investigating modifications to existing products to meet new demands, as well as developing new materials focused on addressing future needs.

Krzysztof Makowski graduated from the University of Lodz with a degree in Experimental Physics in 1993 and started to work at Central Institute for Labour Protection – National Research Institute (CIOP-PIB) in the Department of Personal Protective Equipment in Laboratory of Respiratory Protective Devices. Since 2008, he has worked as a Senior Researcher and Technical Specialist. Krysztof is currently responsible for managing research projects realised in CIOP-PIB within the framework of the Polish Governmental Program connected with the development of new solutions for respiratory protective devices (RPD), new test methods, training programs, and guidance for RPD users and OHS managers. He is also responsible for testing and certification of RPD. He is also involved in works of RPD standardisation (TC 79 and ISO SC 15) and implementation of EN and ISO Standards on the Polish market. On the Notified Bodies VG2, he is responsible for preparing, realisation, and coordination of international interlaboratory tests. He is also an Auditor and Technical Expert in the field of quality system in laboratories and in enterprises.

Charles R. (Gus) Manning received his PhD in Analytical Chemistry from the University of Kansas. Since founding Assay Technology in 1981, his work has focused on test method development for air sampling and respirator testing. Dr. Manning is a Certified Industrial Hygienist, a Fellow of the AIHA, and a Past Chair of the AIHA Respiratory Protection Committee. He is currently the President at Assay Technology, which operates the Miller-Nelson Respirator Cartridge Test Lab.

Clint Mayhue is currently the Global Principal Engineer for Innovation at Avon Protection Systems. Mr. Mayhue holds a Bachelor of Science in Mechanical Engineering from Georgia Tech. He has over 20 years' experience designing and developing respiratory protection equipment and thermal imaging cameras for ISI and Avon Protection Systems as a New Product Development Professional (NPDP). His career has covered design, management, innovation landscaping, and navigating the regulatory approval process for dozens of respiratory products throughout his career. Clint was responsible for orchestrating the development of the Deltair SCBA, winning the Industrial Designers Society of America 2014 Gold award in the Research category in addition to the

coveted People's Choice Award for all products designed worldwide that year. Mr. Mayhue has been a long time member of multiple NFPA committees and has been instrumental in helping shape the NFPA 1981, 1986, and the draft 1987 standards.

Caitlin McClain is a Regular Fellow at the National Institute for Occupational Safety and Health's National Personal Protective Technology Laboratory in Pittsburgh, Pennsylvania. She graduated from West Virginia University with a bachelor's degree in Exercise Physiology and a master's degree in Safety Management. She has been working with William King looking at respirator work of breathing as well as detection of respirator leakage since 2015.

Nicole (Nikki) Vars McCullough is the Global Application Engineering and Regulatory Affairs Manager for 3M's Personal Safety Division. She has worked in occupational health and safety for over 25 years. Nikki has a masters and doctorate in Occupational and Environmental Health from the University of Minnesota, and is a Certified Industrial Hygienist. She has presented at many conferences, published in peer reviewed journals, and holds several patents for personal protective equipment.

Richard Metzler has over 40 years' experience in the Federal safety and health product approval programs. He is a respiratory protection consultant and past Director of NIOSH's, National Personal Protective Technology Laboratory. His experience includes managing laboratories and establishing Federal regulations, national and international respiratory protective equipment standards. Rich holds a Bachelor of Science Degree in Systems Engineering from Wright State University in Dayton, Ohio, and a Master's degree in Industrial Engineering from the University of Pittsburgh. He is a member, past Director, and past President of the International Society for Respiratory Protection (ISRP); member of ANSI/ASSE Z88 Respiratory Protection Committee, Chairman of ANSI/ASSE/Z88.2 Practices for Respiratory Protection Subcommittee; member and past Chairman AIHA Respiratory Protection Committee; past Administrator U.S. ANSI ISO, TC 94/SC 15 TAG - Respiratory Protective Devices, and past Chairman for the air-purifying respirator standards project group. Rich led regulatory reform efforts at NIOSH promulgating 42 CFR 84 respirator approval regulations.

Colleen Miller is a Physical Scientist and the Acting Deputy Chief for the Conformity Verification and Standards Development Branch at the National Personal Protective Technology Laboratory, a division of the U. S. National Institute for Occupational Safety and Health. Colleen is an ISRP Society Director and the outgoing Vice Chair and incoming Chair of the ISRP Americas Section. Since 2008, Ms. Miller has been actively involved in respiratory standard development activities and as a member of the ANSI-accredited US Technical Advisory Group (USTAG) to ISO TC94/SC15. She represents NIOSH as the USTAG Administrator.

Malgorzata Okrasa is a researcher at the Central Institute for Labour Protection – National Research Institute, the Department of Personal Protective Equipment, Laboratory of Respiratory Protective Devices. She holds a PhD in physics from the University of Lodz, Poland. Her research interests focus on the measurement techniques related to the assessment of the effectiveness of respiratory protective devices (RPDs) against bioaerosols; manufacturing, functionalization and testing methods of composite nonwoven structures used for the construction of filtering RPDs as well as aspects related to respiratory protection for emergency escape.

Andrew Palmiero is a Physical Scientist at the National Personal Protective Technology Laboratory (NPPTL) in Pittsburgh, PA. He holds a B.S. in Exercise Physiology from the Indiana University of Pennsylvania and a Master's degree in Homeland Security and Public Health Preparedness from Penn State University. Mr. Palmiero has been at NPPTL for 10 years focusing on different aspects of respiratory protection, post-market assessments, human subject testing and speech intelligibility of various facial personal protective equipment

Michael Parham is a Senior Product Development Specialist for the 3M Personal Safety Division. He received both a Bachelor of Science in Chemical Engineering and Master of Chemical and Biomolecular Engineering at the Johns Hopkins University of Baltimore, Maryland. He has 15 years of experience in respiratory protection research and

development. Part of the 3M Scott Safety acquisition, he was previously the Chief Engineer for Industrial Personal Protective Equipment for Scott Safety. Prior to joining Scott, he served as a principal investigator for the CBR Filtration team of the U.S. Army Edgewood Chemical Biological Center.

Jeffrey Peterson is Branch Chief, Conformity Verification and Standards Development Branch, National Personal Protective Technology Laboratory, National Institute for Occupational Safety and Health. Mr. Peterson has over 27 years of technical expertise in the area of respiratory protection. He began his career with NIOSH in 1991 where he performed testing and research in support of standards development efforts for Title 42, Code of Federal Regulation, Part 84 (42 CFR 84). After the implementation of 42 CFR 84 in 1995, Mr. Peterson remained with the respirator certification program as a General Engineer where he utilized his knowledge and skills to address and resolve technical issues and customer concerns related to approving and testing respiratory protection equipment. He became the team lead for respirator certification in 2006 where he coordinated technical and policy reviews for certification projects. In 2010, Mr. Peterson became the Deputy Branch Chief for the branch that administers the NIOSH Respirator Approval Program and he currently serves as the Branch Chief where he provides technical leadership, project management and administrative support for all projects related to respirator certification activities mandated by 42 CFR 84.

Lew Radonovich is a Medical Officer and Senior Physician Scientist at the National Personal Protective Technology Laboratory in the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. He has approximately 20 years of clinical practice experience and 15 years of human subjects and policy research experience. His research focus over the past 15 years has been the clinical science of respiratory protection and surge capacity for public health emergencies, with an emphasis on translation of science to frontline healthcare. Formerly he was the Director of the National Center for Occupational Health and Infection Control in the Veterans Health Administration. He is board certified in internal medicine and has advanced training in clinical pharmacology and clinical investigation. He previously held faculty appointments at the University of Pittsburgh and Johns Hopkins University.

Tim Reinhardt has experience as a wildland firefighter with the U.S. Forest Service, and years of full time and now occasional research characterizing wildland fire emissions, determining markers of atmospheric transport, evaluating potential public exposures to smoke, and the occupational exposure and control of firefighters' exposure to smoke and dust. He provided technical input to the NFPA group developing the wildland firefighter respiratory protection standard NFPA 1984. He has over 34 years of experience in evaluating and controlling exposures to respirable silica, hazardous waste site constituents, motor vehicle emissions, and other inhalation hazards. He applies a broad working knowledge of regulatory and consensus codes to help clients recognize, evaluate and control hazards to employees, the public and the environment.

Aaron Richardson is a Senior Research Scientist at Battelle and has 18 years of experience evaluating respiratory protection systems, with an emphasis on aerosol filtration media. He has extensive experience characterizing the performance of aerosol filtration media against both inert and biological aerosols studying the effects of flow rate and particle size. He has also led aerosol studies based on head form or human subject testing to assess respirator leakage or fit. These studies have required significant laboratory effort to generate and characterize challenge aerosols. Mr. Richardson is a co-author on seven peer-reviewed publications relevant to the evaluation of respirator performance against aerosols.

Dana Rottach has been a physical scientist at National Personal Protective Technology Laboratory (NPPTL) for eight years, and is currently researching respirator stockpile issues. Dr. Rottach has degrees in materials engineering, chemical engineering, physics, and mathematics. Prior to joining NPPTL, he worked in biophysical modeling and neuroscience.

Heidi Sewchok is a Physical Scientist in the Conformity Verification and Standards Development Branch at the National Personal Protective Technology Laboratory (NPPTL), a division of the National Institute for Occupational Safety and Health (NIOSH). Ms. Sewchok conducts initial review of applications in the NIOSH Respirator Approval Program and is training to complete product audits and final reviews. Prior to joining the Conformity Verification and Standards Development Branch, she was an intern at NIOSH NPPTL for five years working in both the Policy and Standards Development Branch, and the Evaluation and Testing Branch. She has a B.S. degree in Biology from the California University of Pennsylvania, and M.P.H. from George Washington University.

Joshua G. Scott is an Assistant Professor at the Colorado School of Public Health, Department of Environmental Health and Associate Director of Education for the Center for Health, Work & Environment. In the Center for Health, Work & Environment, Josh leads a team of dedicated health and safety experts aimed at delivering quality learning opportunities for professionals responsible for occupational health protection and health promotion. The Center's continuing education program is responsible for local, regional, national and international conferences, online courses, webinars and in person and web-based trainings. Josh also teaches graduate level courses and seminars in Total Worker Health® leadership, interdisciplinary learning, occupational stress, and workplace well-being. Prior to joining the Center's team, Josh was a consultant for the National Institute for Occupational Safety and Health where he worked on guidance for conformity assessment of personal protective equipment, wildland fire fighter respiratory hazards, and user interfaces for products and standards information. Josh was also a faculty member at the University of Notre Dame teaching health education, nutrition, stress management, and exercise physiology. He has an MS in exercise physiology and a PhD in Interdisciplinary Health Science from Western Michigan University.

Mark Shirley has over 20 years of environmental health and safety experience within the healthcare field. He currently serves as an Environmental Risk Consultant in the Office of the General Counsel at Sutter Health in Sacramento California. In this role, he provides leadership and guidance to Sutter Health Affiliates across a broad range of environmental health, safety and emergency management operations in support of risk mitigation, regulatory compliance and organizational resiliency. Mark received his master's degree in Environmental Management from the University of San Francisco and his bachelor's degree in Ornamental Horticulture from California Polytechnic State University San Luis Obispo. He is a Board Certified Safety Professional and a Certified Hazardous Materials Manager.

Margaret Sietsema is a research assistant professor at the University of Illinois at Chicago working to advance innovations in respiratory protection. Dr. Sietsema earned her MS and PhD in Industrial Hygiene at the University of Illinois at Chicago. She was the ISRP Americas Section Arthur Johnson Award recipient and participated at the ISRP Prague Conference in 2014. Following completion of her PhD, Dr. Sietsema spent one year working as a fellow in the Research Branch of the National Personal Protective Technology Laboratory, a division of the National Institute for Occupational Safety and Health. Her research interests are in the development of methodology for real-time respirator fit analysis and control banding approaches for novel infectious disease outbreaks.

Simon Smith has been involved in respiratory protection research for over 30 years. He is currently a research specialist at 3M Canada in Brockville, Ontario, which is a research centre and manufacturing plant for respirator filters. Following a 1985 doctoral thesis on novel carbon treatments for respirator uses, he obtained a Visiting Fellowship at the Royal Military College of Canada, working on adsorbents and test methods, and then joined Racal Filter Technologies in Brockville in 1989 as laboratory manager. After the Racal health and safety business was acquired by 3M in 1998, Simon became a researcher with responsibility for new product development and evaluation. This work focuses on research in adsorbents, filter products and test method development for world-wide industrial, military and emergency response applications. Recent areas of interest are development of specialized filters and respirator systems for emergency responder applications and development of standards. Simon is a former president of the International Society for Respiratory Protection, and currently serves on the Americas Section board. He is currently convener of the International Organization for Standardization TC94 SC15

Working Group 7-CBRN which is creating an international standard for respiratory protective devices for responders to chemical-biological-radiological-nuclear emergency events as well for needs in the nuclear industry. He is also involved in Canadian standards development for safety equipment, including those for CBRN responders, clandestine laboratory intervention and was recently chairs of the Canadian Standards Association Biological Aerosols Working Group.

Girish Srinivas is a Partner and Vice President, at TDA Research, Inc. He has been with TDA, an 85-person technology development company in Colorado for 25 years and has more than 29 years of experience in process, device development, chemical engineering and catalysis R&D. As a major Partner, he is involved in managing all aspects of the business including TDA's R&D projects, strategy, and commercialization activities. Girish has a PhD in Chemical Engineering and an MBA. Girish has been developing and commercializing personnel protection equipment for firefighters and the DoD for more than 10 years.

Margaret Summers is a Certified Physician Assistant with a background in outpatient pediatric care; she has also worked as an Environmental Scientist for the Drug Enforcement Administration's Environmental Health and Safety Department. In 2016, Margaret was granted a PhD traineeship in Industrial Hygiene through the Deep South Center for Occupational Safety and Health at the University of Alabama at Birmingham. Her research interests include the prevention of heat-related illness in the occupational setting and the evaluation of worker respiratory protection devices.

Rick Swan is the Director, Wildland Firefighting Safety & Response for the International Association of Fire Fighters (IAFF). He is responsible to provide technical support for IAFF legislative, administrative and research actions on Urban Interface/Wildland issues that advance fire fighter health & safety, training, and working conditions. I retired as a CAL FIRE Deputy Chief with 33 years of experience. I started as a Firefighter and have Program experience in Operations, Aviation, Camp, Paramedic and the Fire Marshal. I was responsible for 22 fire stations, over 500 paid and volunteer fire fighters. I have over 25 years as a union leader for CAL FIRE Local 2881 representing the more than 6000 men and women of CAL FIRE, reaching the position of General Vice President. I represent the IAFF on many National Fire Protection Association (NFPA), and International Organization of Standards (ISO) Personal Protective Clothing and Equipment committees and several current DHS/FEMA research programs.

Jon Szalajda became the Deputy Director for the National Personal Protective Technology Laboratory (NPPTL) division of NIOSH in September 2015. Since joining NPPTL in 2001, Jon has held various leadership roles in the organization. Some of his duties included being responsible for developing and promulgating new approval Personal Protective Equipment (PPE) related standards and regulations, including NIOSH's Chemical, Biological, Radiological, and Nuclear (CBRN) respirator standards. Prior to coming to NIOSH, Jon was a proposal manager for Bombardier Transportation and was the systems manager for the M40 Mask program with the Department of the Army. He holds a BS degree in Chemical Engineering from Penn State and MS degrees in engineering from the George Washington University and the University of Pittsburgh. He has worked in the field of respiratory protection and PPE for over 30 years. Jon is currently a member of NFPA Respiratory Protection Technical Committees, the Vice-Chairman of the ASTM F23.65 committee on Respiratory Protection, and a past president of the AIHA Respiratory Protection Committee.

Gabriele Troescher studied Chemical Engineering in Karlsruhe (Germany) and received her doctor's degree in photochemistry in 2002. For almost ten years, she worked for the German Standardization Institute DIN, specializing in Implants for Surgery, which are regulated in the European Economic Area under the Medical Devices Regulation. In 2012, she joined 3M Deutschland GmbH as Regulatory and Standardization Affairs Specialist with a focus on respiratory protection. She was elected chairperson of the DIN national standardization mirror committee for respiratory protection in 2017.

Alexander Virr is Chief Technology Officer at CleanSpace Technologies Pty Ltd, a manufacturer of powered respirators and accessories. Along with a team of biomedical engineers and industrial designers, Mr. Virr is responsible for the design direction and development of a range of innovative and proprietary respirators and algorithms – CleanSpace™ technology and Airsensit™. Prior to CleanSpace, Mr. Virr held senior engineering roles at ResMed (NASDAQ: RMD), a leading manufacturer of medical devices and a global leader in the treatment of breathing disorders such as sleep apnea. Mr Virr holds over 100 international patents, mostly related to breathing assist, flow control respirator systems, and regularly acts as an expert witness and adviser in the medical respiratory device market. Mr Virr and his team have developed and launched several innovative respiratory protective devices in the last 5 years, that have been certified in major markets around the world.

Dan Warkander has over 30 years' experience of testing of respiratory devices and to determine their effects of the wearers. For the last ten years he has been working with ISO to write standards for humanly acceptable levels of work of breathing and acceptable levels of inspired CO_2. He has also helped to write test methods to determine them in standardized and repeatable ways. He is the Convener of the Human Factors Group (WG5). Dr. Warkander holds a dozen patents related to RPD.

Jane Whitelaw is a Certified Occupational Hygienist, Certified Industrial Hygienist and Fellow of AIOH. She had over 25 years' experience in heavy industry before moving into teaching and research at the University of Wollongong, where she is Coordinator of the Occupational Hygiene Specialization in the postgraduate Work Health & Safety program. She is a member of the AIOH Education committee and the AIOH representative on the AOHSEAB (Australian Occupational Health and Safety Accreditation Board) and previously served on two Australian Standards Committees (SF9 &SF10) publishing AS/NZS 1715 Selection, Use and Maintenance of Respiratory Protective Equipment and AS/NZS 1716 Respiratory Protective Devices. She has supervised two Higher Degree Research students to completion in the field of respiratory protection: Carmen Smith "Respirator face piece re-breathing of carbon dioxide" and Kerrie Burton "The effectiveness of Respiratory Protection against Diesel Particulate Matter." Jane's research interests are in Protecting Worker Health from Chemical and Physical Hazards, and her major grants and research have been in evaluating the Efficacy of Respiratory protection. She is currently a PhD candidate at the University of Wollongong in the Faculty of Medicine.

Bingbing Wu received her Ph.D. in Industrial Hygiene from the Department of Environmental Health, University of Cincinnati in 2018. Throughout her doctoral training. She worked at the Center for Health-Related Aerosol Studies. Her primary focus was on respirator-related research, including the development and evaluation of a novel, portable, low-cost monitor capable of assessing the performance of respirators in real-time. In addition, she explored the Optical Particle Counting method with respect to its application for quantitative respirator fit testing. Her educational background also includes Chemical Engineering and Statistics. She has authored or coauthored seven peer-reviewed journal publications. She has won four of American Industrial Hygiene Foundation awards as a Ph.D. student. In her free time, Bingbing enjoys nature, and her favorite hiking trails are Angels Landing at Zion National Park, and Echo Canyon Trail at Camelback Mountain.

Mary Yarbrough the Executive Director of Health and Wellness at Vanderbilt University Medical Center in Nashville, TN. Dr. Yarbrough joined the Vanderbilt faculty following a career in preventive medicine at the state, national and international levels. She translated these experiences into a holistic occupational model that integrates workplace, personal, and psychosocial services to influence health and safety. As director of Health and Wellness for both the Vanderbilt University and Medical Center, Dr. Yarbrough has responsibility faculty and staff occupational programs: Work/Life Connections–EAP; Occupational Health; and Health Plus, the faculty/staff health promotion program. In 1999, Dr. Yarbrough began the Vanderbilt Faculty and Physician Wellness Program to address the growing needs of professionals coping with stress, depression, addiction, and other emotional and behavioral issues. The program has worked with over 3000 University and Medical Center faculty and physicians since its inception, providing evaluation, skill-based training, coaching, counselling, and monitoring for addictions post treatment. Dr. Yarbrough received her B.Sc. in Biomedical Engineering and her MD from Vanderbilt

University. She completed her residency in Internal Medicine at Vanderbilt and in Preventive Medicine at Johns Hopkins University. She has faculty appointments in Internal Medicine and Preventive Medicine, is boarded by the American Board of Preventive Medicine in both Occupational Medicine and Public Health, and is also boarded by the American Board of Internal Medicine.

Patrick Yorio received a Ph.D. from the school of Research Methodology (measurement, research design, and statistics) at the University of Pittsburgh with a minor in Organizational Behavior and Human Resources Management through the Katz Graduate School of Business in 2014. He had over fifteen years of experience in private consulting, academic teaching and research, and in research through the U.S. National Institute for Occupational Safety and Health' Pittsburgh Mining Research Division (PMRD) prior to joining NIOSH's National Personal Protective Technology Laboratory (NPPTL) as a health statistician. He has published empirical and theory building articles in journals such as the Academy of Management, Risk Analysis, Accident Analysis and Prevention, Safety Science and many others. His research focuses on deriving organizational, programmatic, and policy solutions to pressing issues in occupational safety and health. Many of his research articles have received formal recognition by the academic community and publishers as outstanding contributions based on the number of citations and downloads.

Hisashi Yuasa has been with KOKEN Ltd. for 20 years, and a member of the Board of Directors of ISRP since 2014. He received his Doctor of Philosophy in Engineering at Kanazawa University. His research field covers aerosol engineering, development and evaluation of all type of respiratory protective devices. One of his achievements is the development of the Breath Recoding and Simulation System being used in Japanese Self-defence force, University of Cincinnati, and NIOSH NPPTL. He was commended as the winner of best paper award at the 14th ISRP International conference.

Ziqing Zhuang is a team leader in the Research Branch of the National Personal Protective Technology Laboratory, National Institute for Occupational Safety and Health (NIOSH). He is the Editor for the Journal of the International Society for Respiratory Protection. He serves as an ANSI expert on the ISO TC94 SC15 respiratory protective device standards committee. Dr. Zhuang received a Ph.D. degree in Industrial Engineering from West Virginia University in 1995. He has more than 25 years of research experience in respiratory protection. He has more than 80 peer-reviewed journal publications. Results from his research projects have, to date, substantially impacted U.S. and international policies, procedures, and standards for respiratory protective devices. Manufacturers and academicians have used respirator fit test panels and 3D digital headforms resulted from his research as tools in fit test research and in designing, sizing and testing new personal protective devices.

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