Human Factors Aspects of Multifunction Powered Air Purifying Respirators

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Contract Objective

Recommend certification procedures for multifunction powered air purifying respirators (PAPRs)
Protection & Performance
Presentation Overview

- Existing standards
- Human factors
- User attitudes and practices (questionnaire)
- Performance parameters (studies)
Human Factors

- Respiration
- Communication
- Vision
- Heat exchange
- Personal procedures
- Physical configuration
- Anxiety
Past research results have shown *human performance* is related to *respirator characteristics.*
Summary of Past Findings

- Wearers cannot work as long nor as hard
- **Heat** affects comfort and acceptability
- **Anxious** people should not wear respirators
- **Respiration** a problem at high work rates
- Simplify **communications** procedures
- **Vision** effects critical
Are lab results the same as real world experiences?
Which human factors are important?

Questionnaire to assess user attitudes and practices

- Statistics provide quantitative analysis
- User comments provide qualitative analysis
Questionnaire General Categories

- Medical history
- Respirator types
- User groups
- Work activities
- Attitudes
- Practices
Respirator Types

- Half facepiece dust mask
- Half facepiece, filter cartridge
- Full facepiece, filter cartridge
- Full facepiece, blower and cartridge
- Loose fitting, blower and cartridge
- Full facepiece, air supplied with hoses
- Self contained breathing apparatus
User Groups

- Miners
- Fire and rescue
- Construction
- Agriculture / landscaping
- Medical personnel
- Manufacturing / industry
- Pest management
- Other groups
Work Activities

- Duration of respirator use
- Frequency of use
- Type of work activities
- Contaminant type
User Attitudes

- Factors affecting respirator selection
- Reasons for premature removal
- Perceived exertion during use
- Perception of comfort
- Perception of necessity
User Practices

- Frequency of actual use vs. needed use
- Maintenance / cleaning schedule
- Replacement of respirator and parts
- Knowledge of fit testing
Questionnaire *responses* lead to a better understanding of *important human factors.*
Some users are more affected by respirators than others.
How is performance related to:

Emotional state?
Temperament?
Mood?
Outlook?
Personality?
Motivation?
Coping mechanisms?
Planned Research: Personality and Performance

Effect of personality on performance while wearing a respirator

Methodology:
- Myers-Briggs personality type indicator test
- Physical performance testing
Planned Research:

Vision Study

- Assess performance aspects and emotional state related to lens color

Methodology:
- Cognitive testing with tinted glasses
- Control condition included
Continuing Research:

Modeling to Predict Performance Time

- Determine which parameters affect performance time with respirator use
- Develop model to predict performance time based on input parameters
Multifunction PAPR

- Configuration: tight or loose-fitting face piece
- Respiratory protection
- Vision protection
- Hearing protection
- Head protection
Tight Fitting PAPR
Loose Fitting PAPR
Multifunction PAPR

Tight-fitting (performance issues)

Loose-fitting (exposure issues)
What is “Overbreathing”?

- Instantaneous breathing rate exceeds airflow supplied by fan
- Contaminated air bypasses filters and enters mask
- Exposure may be an issue for some contaminants
Why is “overbreathing” important?

- Exposure to acute chemical hazards
- Becomes a concern at higher work rates
- Instantaneous breathing rates may greatly exceed average flow rates during work
Exposure to Contaminants

- Dose = FR * c * t
  
  FR - breathing flow rate
  c - concentration
  t - time

- Permissible exposure levels (PELs) given by OSHA

- Threshold limit values (TLVs) suggested by the ACGIH
Indirect Assessment of "Overbreathing"

- Measure instantaneous breathing rates during exercise

- Compare breathing flow rates (FR) with flow rates supplied by PAPR fan (FN)

- If FR > FN, then overbreathing occurs
Treadmill Testing

- Exercising at 80-85% of VO2 max is characterized by:
  - 15-20 minute maximum duration
  - Subject sensitivity to respiration
  - High breathing flow rates
Treadmill Testing
Test 1: SEA Tight-fitting PAPR

- Treadmill testing at 80-85% of VO$_2$ max
- Data logger records instantaneous pressure and air flow rate measurements
SEA Flow Rate Frequency Distribution
Sample Data

Percentage of values above a given flow rate

Flow rate (liters/min)
Test 2: Half mask with Fleish pneumotach

- Measures pressure drop (\(\Delta P\)) over a known, very low resistance (\(r\)) during breathing
- Treadmill testing at 80-85% of \(\text{VO}_2\) max

Calculates breathing flow rate from:

\[
FR = \frac{\Delta P}{r}
\]
<table>
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<tr>
<th>Measures over breathed air flow directly</th>
<th>No comparison of flow rates required</th>
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Direct Assessment of “Overbreathing”
Test 3: Portable Breathing Chamber

- Encloses head and mask
- Has separate inlet for fan air
- Measures net air flow in and out of mask
Portable Breathing Chamber
Direct Assessment of "Overbreathing"

"Over breathed air" may be measured directly

- Portable Breathing Chamber
- Exhaled Air
- Blow-by Air
- Total Air Out
- Fan Air
- Over breathed Air

PAPR
Multifunction PAPR

Loose-fitting exposure issues

Tight-fitting performance issues
Concerns for Tight-Fitting PAPR

- When FR > FN, subject draws extra air through filters

- Equivalent resistances study
  - Adjust fan motor and flow rate
  - Measure effect on performance time
Summary

- Performance certification
  - New standards may be necessary
- Focus on user
- Protection certification
  - Existing standards may be used
- Focus on mask
Multifunction PAPR Approach

Existing Standards

Perceived Importance

Respirator Wearability

User Characteristics
Phase 1: Gather Information

(3 months)

- Interview device manufacturers, users, NIOSH/MSHA

- Determine important equipment qualities and work scenarios
Phase 2: Develop General Criteria
(15 months)

- Performance testing
- Review existing standards
Phase 3: Propose Standard Tests

(3 months)

- Obtain comments
- Determine if modifications are necessary
Phase 4: Final Report
(3 months)

- Detail results
- Specify draft standards
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