
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)

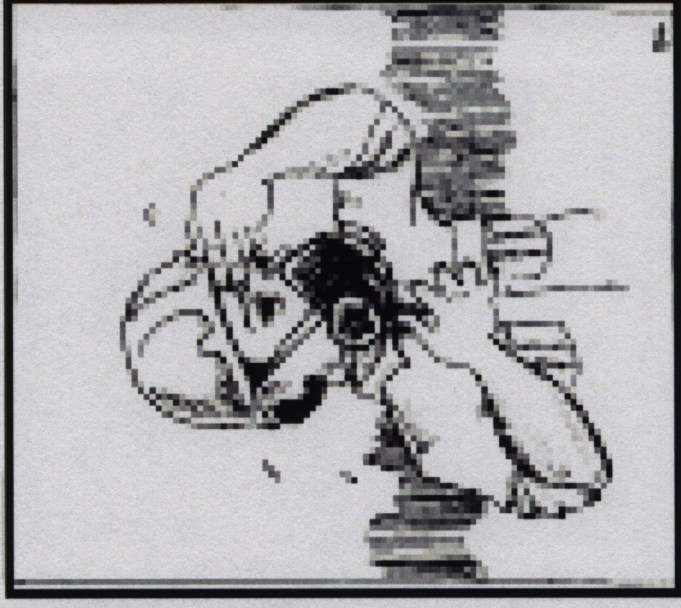
Protection & Performance

Presentation Overview

- Existing standards
 - Human factors
 - User attitudes and practices (questionnaire)
 - Performance parameters (studies)
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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
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Are *lab results*
the same as
real world experiences?

Which human factors are important?

Questionnaire to assess user attitudes and practices

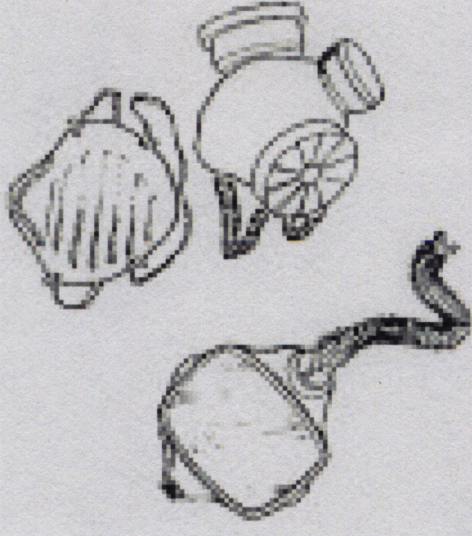
- Statistics provide quantitative analysis
 - User comments provide qualitative analysis
-

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



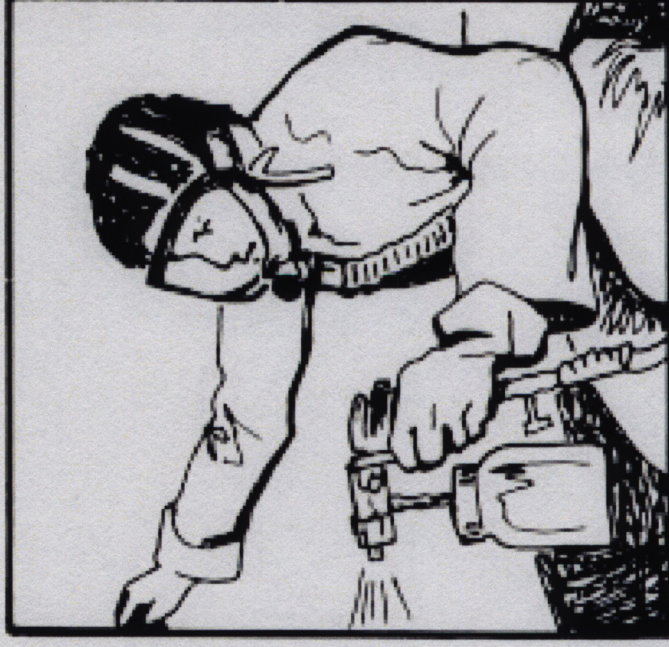
User Groups

- 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

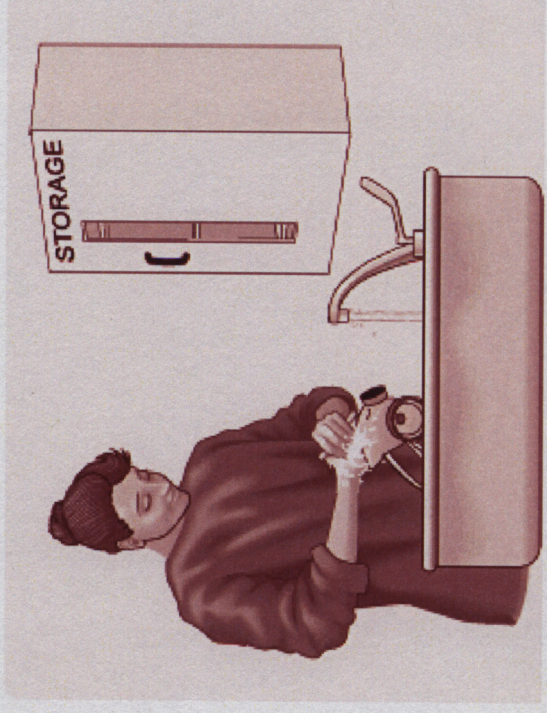


User Attitudes

- 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:

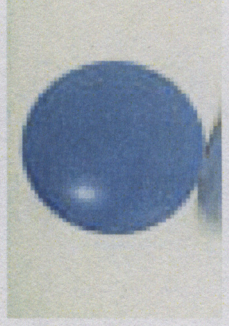
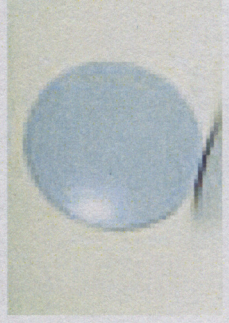
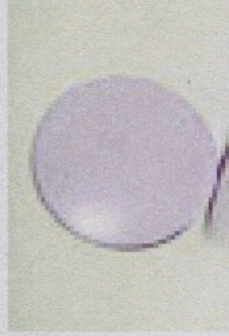
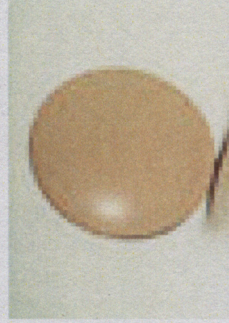
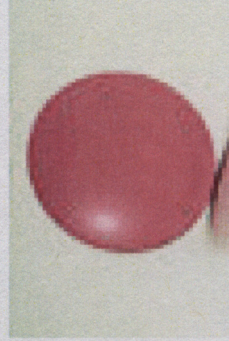
Personality and Performance

- Effect of personality on performance while wearing a respirator
 - Methodology:
 - Myers-Briggs personality type indicator test
 - Physical performance testing
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Planned Research:

Vision Study

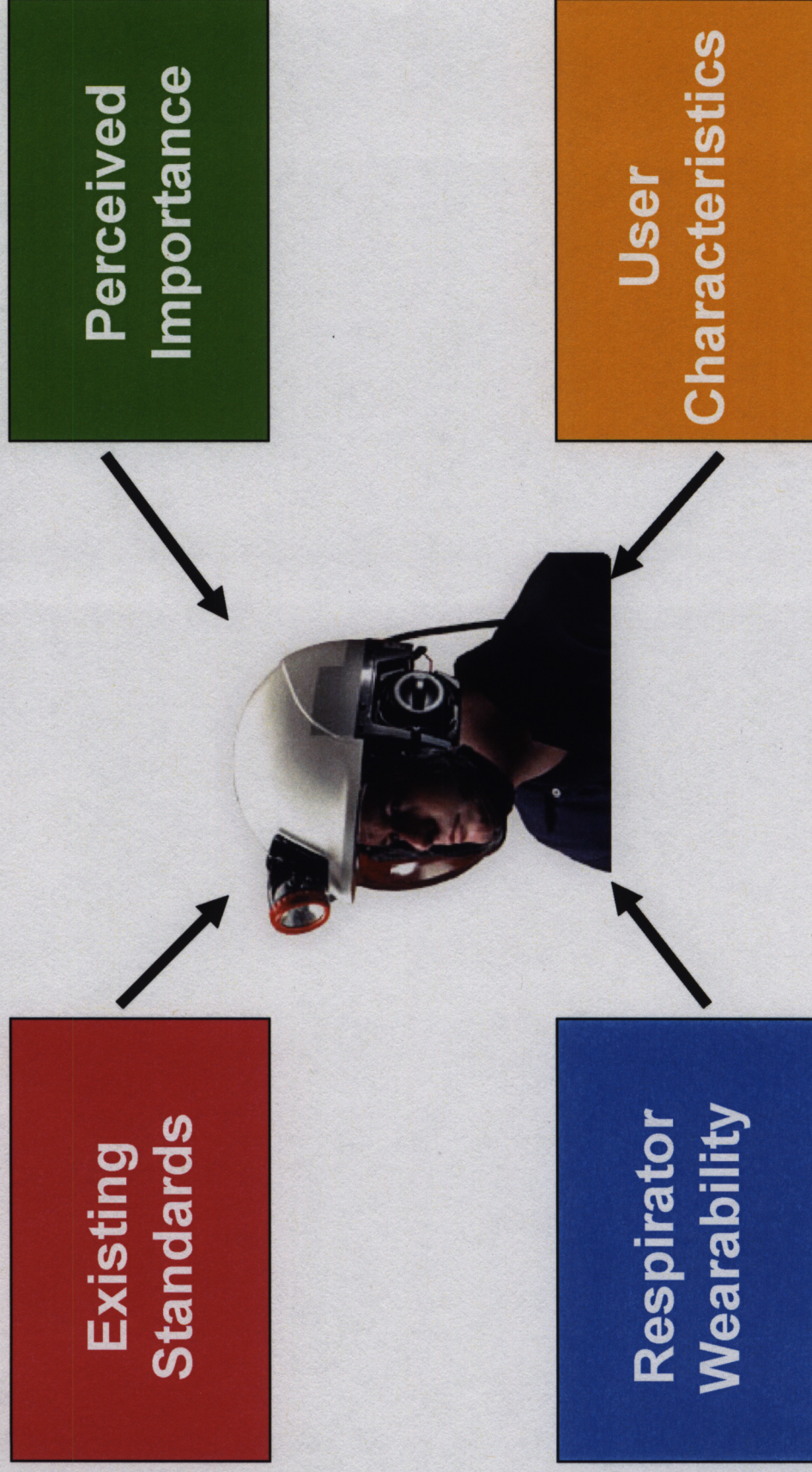
- Assess performance aspects and emotional state related to lens color
- Methodology:
 - Cognitive testing with tinted glasses
 - Control condition included



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
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Multifunction PAPR Approach



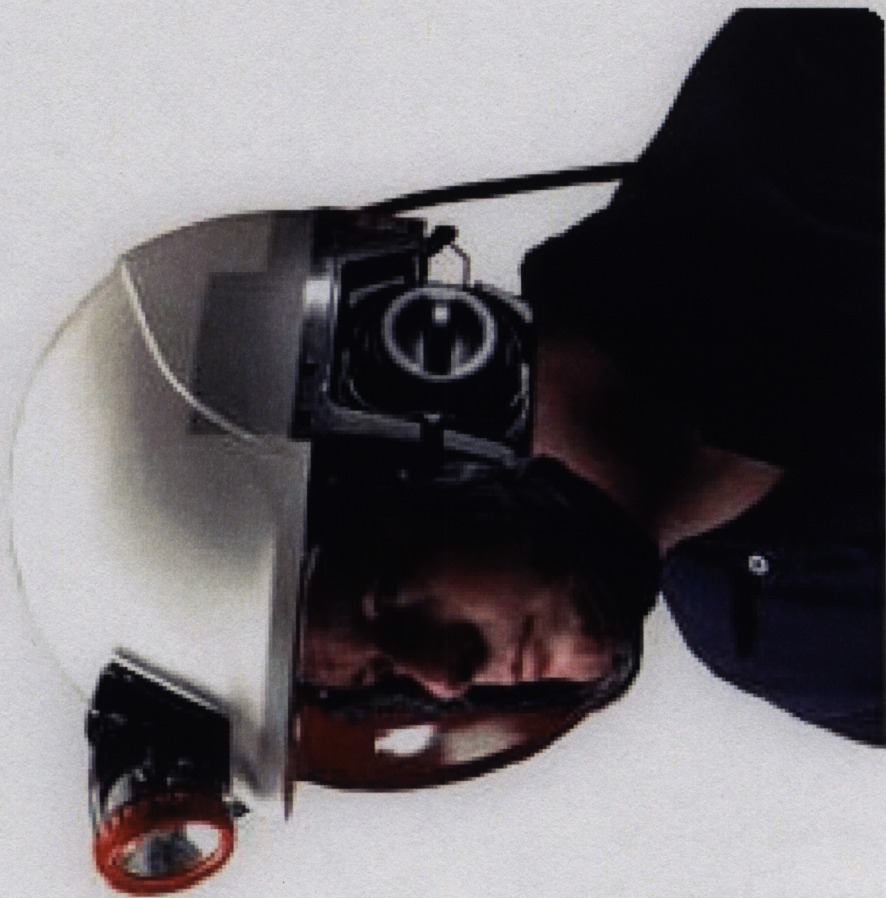
Multifunction PAPR

- 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

- $\text{Dose} = \text{FR} * c * t$

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
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Treadmill Testing

- Exercising at 80-85% of VO_2 max is characterized by:
 - 15-20 minute maximum duration
 - Subject sensitivity to respiration
 - High breathing flow rates
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Treadmill Testing



Test 1:

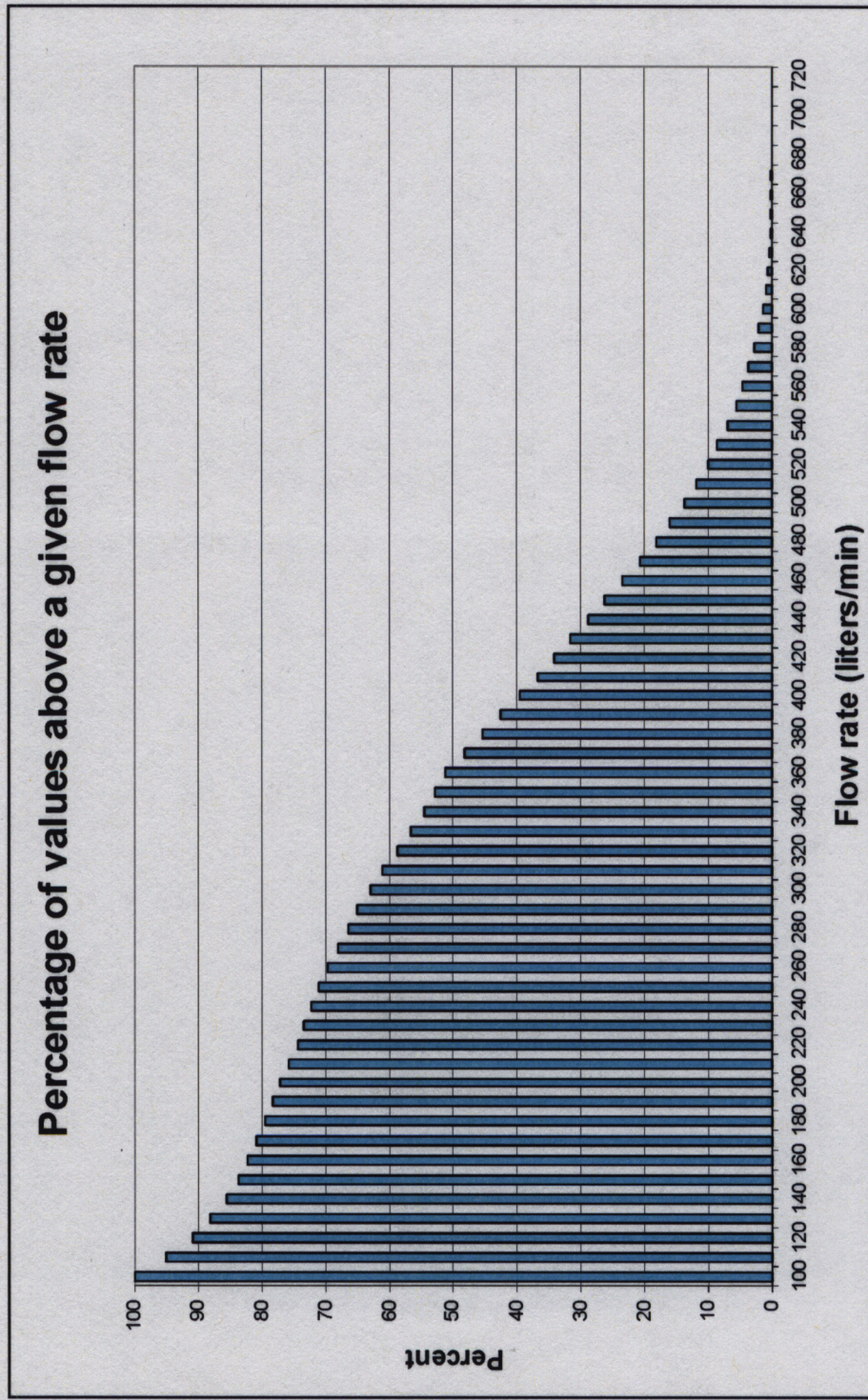
SEA Tight-fitting PAP

- 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



Test 2:

Half mask with Fleish pneumotach

- Measures pressure drop (ΔP) over a known, very low resistance (r) during breathing
 - Treadmill testing at 80-85% of VO_2 max
 - Calculates breathing flow rate from:
$$\text{FR} = \Delta P / r$$
-

Direct Assessment of “Overbreathing”

- Measures over breathed air flow directly
 - No comparison of flow rates required
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Test 3:

Portable Breathing Chamber

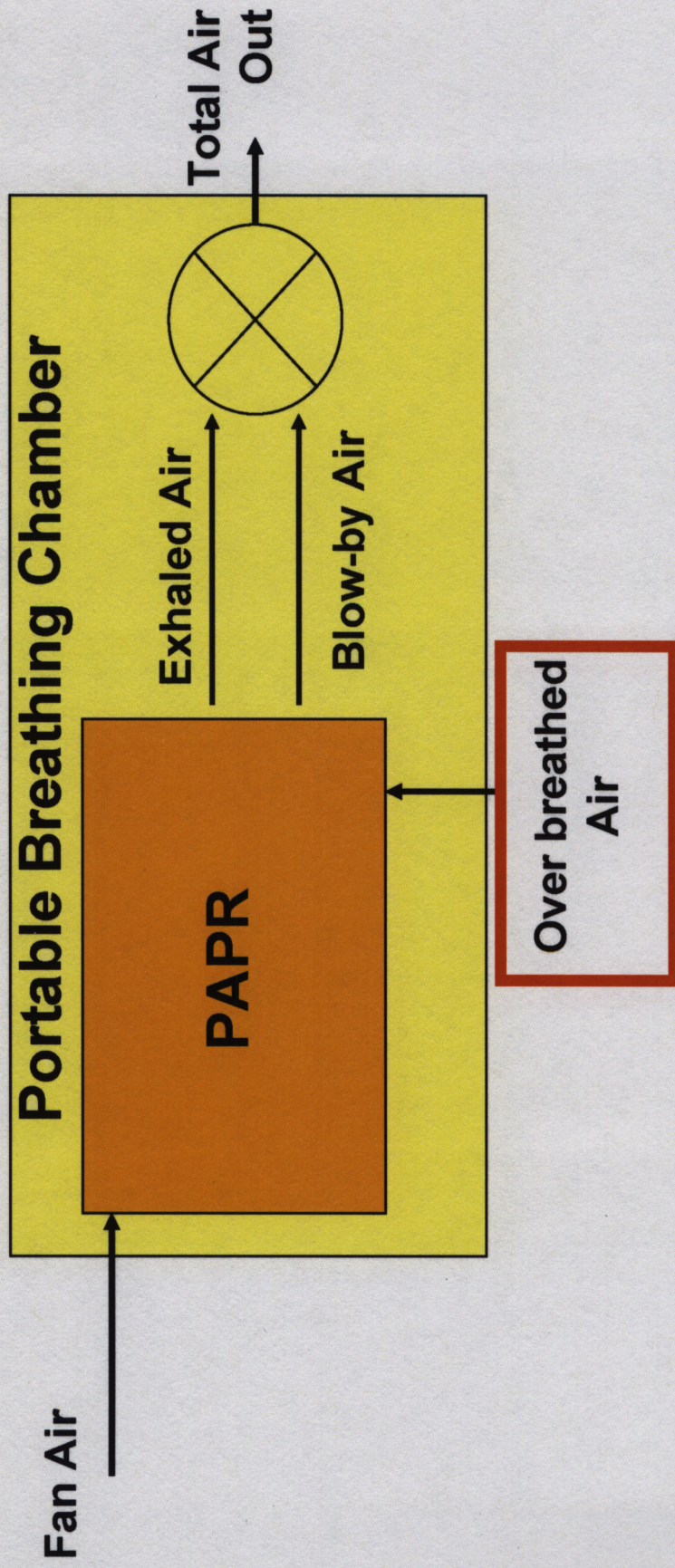
- Encloses head and mask
- Has separate inlet for fan air
- Measures net air flow in and out of mask

Portable Breathing Chamber



Direct Assessment of “Overbreathing”

- “Over breathed air” may be measured directly



Multifunction PAPR

Loose-fitting —→ exposure issues

Tight-fitting —→ performance issues

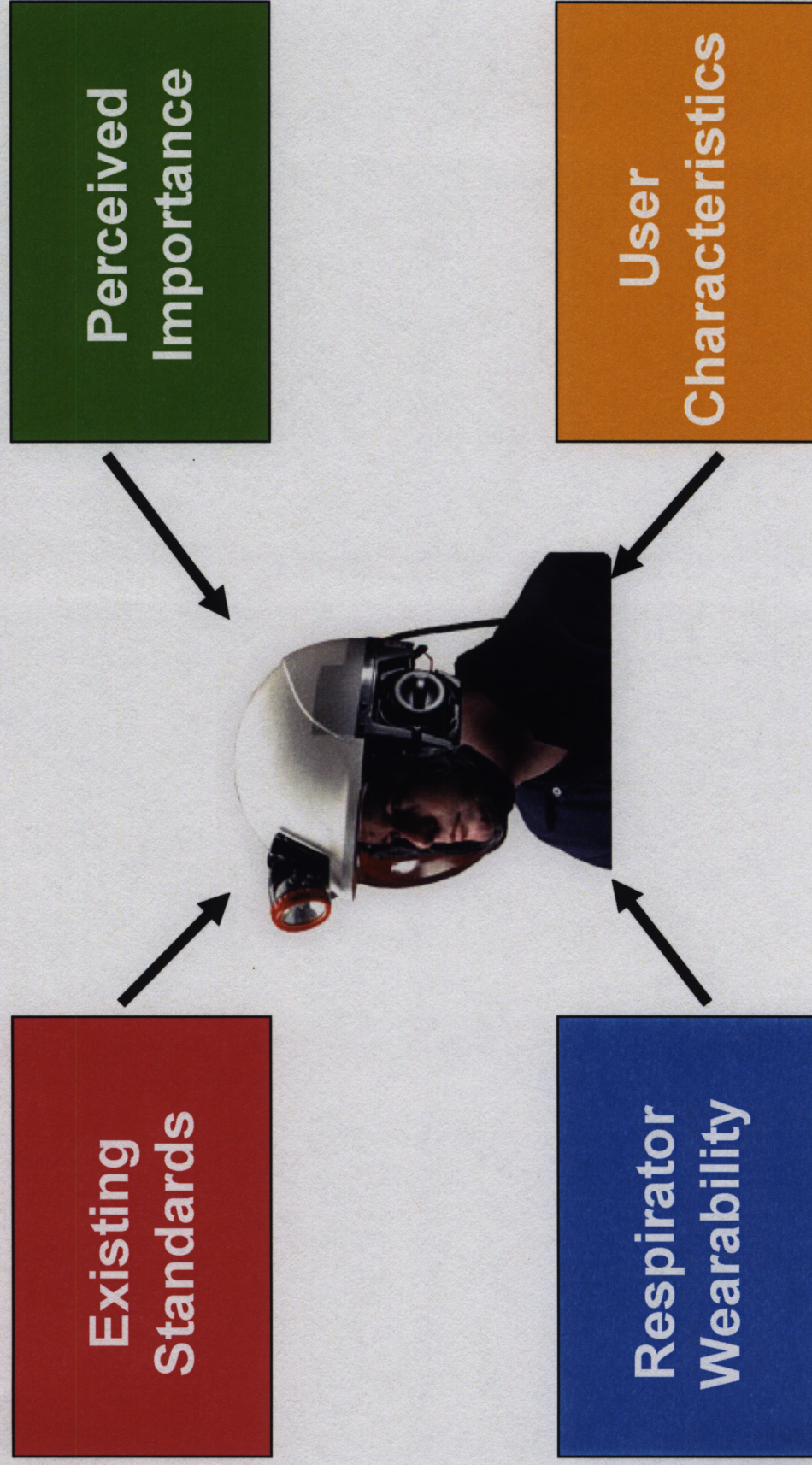
Concerns for Tight-Fitting PAPR

- When $FR > FN$, subject draws extra air through filters
 - Equivalent resistances study
 - Adjust fan motor and flow rate
 - Measure effect on performance time
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Summary

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



Phase 1: Gather Information

(3 months)

- Interview device manufacturers, users, NIOSH/MSHA
 - Determine important equipment qualities and work scenarios
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Phase 2: Develop General Criteria

(15 months)

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

(3 months)

- Obtain comments
 - Determine if modifications are necessary
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Phase 4: Final Report

(3 months)

- **Detail results**
 - **Specify draft standards**
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Consultations and Acknowledgements

- NIOSH
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 - Noise Pollution Clearinghouse
 - OSHA
 - SBCCOM
 - SEA
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