

Mine Rescue Ensembles for Underground Coal Mining

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Project Goals

- Develop appropriate design and performance requirements for ensembles worn by mine rescue teams during emergency response
- Establish a best practice/guidance document and produce recommendations for standards for mine rescue ensembles

Background

- Historically, there has been no consistency in protective clothing & equipment worn by various mine rescue teams, although they could respond to the same event (Fig.1 & 2).
- No guidance documents, standards or recommended best practices exist that establish minimum design and performance criteria.
- There are established standards for similar tasks and hazards:
 - NFPA 1977-2011: Standard on Protective Clothing and Equipment for Wildland Fire Fighting
 - NFPA 1951-2007: Standard on Protective Ensembles for Technical Rescue Incidents
 - NFPA 1971-2007: Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting

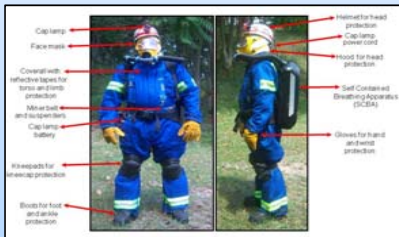


Fig.1 Components of a typical mine rescue ensemble



Fig.2. Different types of mine rescue ensembles used in the U.S.

Materials

Mine rescue ensemble elements tested in Phase I^(*)

Component	Type-I	Type-II	Type-III
Garments	6.0 oz/yd ² 65/35 PET/Cotton	9.0 oz/yd ² FR Cotton	6.0 oz/yd ² Nomex®/IIIA
Helmets	Low Profile Miner Helmet	Regular Miner Helmet (ANSI/ISEA Z89.1-2009)	N/A
Hoods	6.0 oz/yd ² Nomex®	8.5 oz/yd ² Nomex®	6.0 oz/yd ² 80/20 FR Rayon/Nomex®
Gloves	Regular Leather Miner Glove	Technical Rescue Glove (non FR) (96/4 PET/Spandex gloves with nylon coating)	Firefighter Glove (NFPA1971-2007)

^(*) Testing was conducted on the most commonly used materials by mine rescue workers in the U.S. underground coal mining, which were identified through the field study, n=1 for each type.

Procedure



Field Study

- Identification of use & needs to determine specific hazards faced by mine rescuers
- Observation of over 100 teams at national & local mine rescue competitions, and trainings



Phase-I Bench-scale Testing

- The performance testing of the most commonly used elements of mine rescue ensembles
- Test methods: Methods specified NFPA, ASTM, & AATCC standards



Phase-II: Whole Garment-Manikin Testing

- Evaluation of thermal insulation and evaporative resistance properties of the most commonly used ensembles
- Test methods: ASTM F1291-05 & ASTM F2370-05



Report

- Prepare recommended minimum design assessment and performance criteria
- Submit recommendations to Standards Committees

Preliminary Results

Garments^(**)

Test	Type-II	Type-III	NFPA 1951-2007 Requirement
Material / Conditioning	FR Cotton AR Laundered	Nomex® IIIA AR Laundered	
Fabric Weight (oz/yd ²)	10.3	6.5	N/A
Thermal Protective Performance (cal/cm ²)	11.9	13.7	14.6
Heat & Thermal Shrinkage Resistance (%)	-0.4	-0.9	-0.5
Tear Resistance (N)	39	42	250
Breaking Strength (N)	566	509	1058
Cleaning Shrinkage Resistance (%)	N/A	-4.3	N/A
Abrasion Resistance (N)	378	418	339
Water Absorption (%)	64	91	64
Afterflame (s)	0.58	0.49	0
Char Length (mm)	74	79	69
Total Heat Loss Q _t (W/m ²)	688	634	677
Radiant Heat Resistance	9.7	11	7.4

^(**) Results shown in this table include only the data for the warp direction. Results for fill direction are not reported here due to the space limitation but available upon request. Launderings were conducted in accordance with NFPA 1951-2007. "AR" shows "As Received" condition. The testing of Type-I garment has not been completed yet.

Helmets

- Both low profile and regular miner helmet failed in flame resistance and heat resistance tests conducted according to NFPA 1951-2007.
- Type-I low profile helmet failed in top impact resistance test and Type-II regular miner helmet failed in electrical insulation test conducted according to NFPA 1951-2007.
- Both types passed the physical penetration requirements of NFPA 1951-2007.

Hoods^(**)

Test	Type-I	Type-II	Type-III	NFPA 1971-2007 Requirement
Material / Conditioning	100% Nomex® AR Laundered	100% Nomex® AR Laundered	80/20 FR Rayon / Nomex® AR Laundered	
Fabric Weight (oz/yd ²)	6.0	N/A	8.5	N/A
Heat & Thermal Shrinkage Resistance (%)	-1.1	-1.2	-0.42	1.8
Burst Strength (N)	771	N/A	655	N/A
Cleaning Shrinkage Resistance (%)	N/A	-4.4	N/A	-1.37
Afterflame (s)	0.66	0.5	1.24	0.56
Char Length (mm)	31	30	48	37
Seam Breaking Strength (N)	1331	N/A	1300	N/A

^(**) Results shown in this table include only the data for the warp direction. Results for fill direction are not reported here due to the space limitation but available upon request. Launderings were conducted in accordance with NFPA 1971-2007. "AR" shows "As Received" condition.

Gloves

- Type-II technical rescue glove failed flame resistance test conducted according to NFPA 1951-2007 as it melted and dripped (Fig.3).
- Type-I leather gloves shrunk excessively during the laundering (NFPA 1951-2007).
- Type-III firefighter glove failed NFPA 1951-2007 glove hand function test.
- Type-I and II do not have any barrier for liquid and viral penetration.
- Type-II technical rescue glove failed NFPA 1951-2007 puncture resistance, heat and thermal shrinkage resistance, and thermal protective performance tests.



Fig. 3. Burning glove during flame resistance test

Future Work

- Finalize the research proposal
- Complete the data collection for Phase I and Phase II
- Document the findings and determine the minimum performance & design requirements based on field study, test results & other studies
- Publish the findings and share the results with Standards Development Organizations

Partnerships



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