

# Study and design of fire protective clothing for winter rescue

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**Abstract.** The object of this work was to improve fireman's fighting efficiency for winter rescue. Firstly, relative standard and background of fire protective clothing for rescue was reviewed. Secondly, different types of clothing were studied according to different structure. Thirdly, fire protective clothing with anti-icing performance and thermal retention performance for rescue was designed. Further study should focus on the new clothing's actual application in northern east fire brigade.

## 1. Introduction

Fire protective clothing for rescue could be used to protect fireman's body, neck, arm, wrist and leg during the emergency response. This clothing equipment didn't need China Compulsion Certification like fire protective clothing for firefighting. Recent study focused on new material or new technique's introduction on fire protective clothing to improve its working efficiency or flexibility [1]. According to Ga 633-2002, three layers composed of this clothing including outer layer, waterproof breathable layer and comfortable layer.

Table 1. The main parameters of fire fighting clothing for rescue.

Layer	Parameters	Data
Outer layer	After flame time	< 2 s
Outer layer	Damaged length	< 100 mm
Outer layer	Spray rating	=3 and >3
Outer layer	Breaking strength	> 350 N
Outer layer	Tear strength	> 25 N
Outer layer	Heat stability	180 °C
Waterproof breathable layer	Hydrostatic pressure	> 17 kPa
Waterproof breathable layer	Water vapor permeability	> 5000 g/(m <sup>2</sup> *24h)
Comfortable layer	Flame resistance	No melting

Compared with fire protective clothing for fire-fighting with dark navy outer layer, this fire protective clothing for rescue had orange red or tigerlily outer layer. This color could attract more attention in emergency, whose pantone number was 17-1456 TCX with RED 225, GREEN 93 and BLUE 68 [2]. For example, the fireman with red fire protective clothing for Shandong Shouguang's flood rescue in August 26<sup>th</sup>, 2018.





Figure 1: The pantone color and firemen with fire protective clothing for rescue.

## 2. Different clothing structures

According to the pieces of clothing, there were two types including pant and jacket clothing, jumpsuit clothing. According to composed structure, there were two clothing types including unlined clothing and lined clothing.

### 2.1. The unlined clothing

The unlined clothing was the clothing with only one layer. The outer layer was essential, so the unlined clothing for rescue should be only one outer layer without any waterproof breathable layer or comfortable layer. This unlined clothing was light and breathable. But if there were water or rain, this clothing would be easily saturated. To deal this problem, this unlined clothing could be modified further with the waterproof and breathable performance on the outer layer by introducing other material or technique.



Figure 2: The inner composite PTFE membrane of outer layer.

For example, the composite PTFE membrane could be used as the red orange outer layer's inner side. Then its hydrostatic pressure could increase to 17 kPa and the water vapor permeability could reach 5000 g/(m<sup>2</sup>\*24h). Compared with the lined clothing with outer layer and waterproof breathable layer, this modified unlined clothing's waterproof and breathable performance might be more easily affected by washing and drying process. This PTFE membrane attaching to the outer layer's inner side was easily scratched during cleaning.

### 2.2. The lined clothing

The lined clothing was the clothing with all the outer layer, waterproof breathable layer and comfortable layer. Although this lined clothing for rescue couldn't be used in the fire scene like the dark navy clothing for firefighting, this lined clothing still had better thermal protective performance compared with the unlined clothing. This clothing could be used in the rescue needing waterproof performance. And the PTFE membrane on the waterproof breathable layer wasn't easily scratched because the membrane didn't attach to the outer layer directly [3]. The other part of the waterproof breathable was the fabric felt to support PTFE membrane, which was close to the outer layer or the

comfortable layer. In recent study, the new material could be also used to replace the traditional fabric felt in the waterproof breathable layer.

Table 2. The relative parameters of polyimide.

Testing programs	Parameters	Data
Far-infrared performance	Normal emissivity	0.88
Antimicrobial performance	Staphylococcus aureus	71%
Antimicrobial performance	Escherichia coli	76%
Combustion toxicity	Smoke density	1 Dm
Combustion toxicity	HCN, HF, HCl, NO <sub>x</sub> , SO <sub>2</sub>	<2 ppm
Hydrolytic resistance	Strength retention	82%

For example, the polyimide felt with better properties could replace the traditional fabric felt [4]. The polyimide fiber not only met the demands of outer layer's after flame time, damaged length, breaking strength, tear strength and heat stability, but also had the newly added performances including far-infrared performance, antimicrobial performance, combustion toxicity and hydrolytic resistance.

### 3. Design of new lined clothing for winter rescue

The unlined clothing could be used for summer rescue because of its light and breathable. The lined clothing could be used for winter rescue because of its relative warm. However, to the winter's rescue, the equipment's anti-icing performance and warmth retention performance should be redesigned [5].

#### 3.1. The anti-icing performance of the outer layer in lined clothing

In winter, the fireman's outer shell might contact with the water and the water might turn into ice on the outer layer's surface. This might decrease fireman's working efficiency. To solve this problem, the coating with anti-icing performance was added onto the outer layer's outer surface. And the color of the coating was red orange, the adding weight was 20-30 gsm and the color aberration was higher than 4. Then the anti-icing force between the ice and outer layer was tested using electronic universal material testing machine or push and pull meter [6]. This force would decrease from 76.0 N/dm<sup>2</sup> to 22.5 N/dm<sup>2</sup>.



Figure 3: The testing machine for deicing force.

#### 3.2. The warmth retention performance of waterproof breathable layer in lined clothing

In winter, the environment temperature was quite low. Compared with the outer layer and comfortable layer, the waterproof breathable layer had better warmth retention performance because of the felt. The thickness of this felt could be adjusted [7]. For example, the thickness of the waterproof breathable layer could increase from 70 gsm to 105 gsm to improve the thermal retention performance. The fabric felt's thermal conductivity could be 0.048 W/(m·K), which was higher than air's thermal

conductivity 0.026 W/(m·K). The other material polyimide felt also had a low thermal conductivity which could be used as waterproof breathable layer.

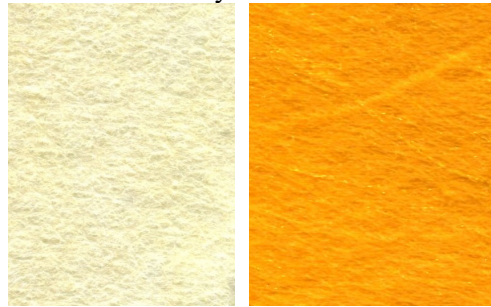


Figure 4: The fabric felt and polyimide felt.

#### 4. Conclusion

In this paper, the fire protective clothing for rescue was reviewed according to the standard firstly. Secondly, different clothing types included unlined clothing type for summer and lined clothing type for winter. Thirdly, the lined clothing type for winter was further designed. The anti-icing performance could be improved using coating technique. The thermal retention performance could be increased using thickness changing or other material's replacing. The further study should focus on the new designed clothing's actual application in northern east brigade.

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