Winterwear must be warm-It must also be arc protective?

'What is it you want to buy?' the Sheep said at last, looking up for a moment from, her knitting. 'I don't quite know yet' Alice said, very gently. I should like to look all round me first, if I might.' 'You may look in front of you, and on both sides, if you like,' said the Sheep: 'but you can't look all round you-unless you've got eyes at the back of your head.'

Many in the industry find themselves in the same predicament as Alice in Wonderland when purchasing winterwear for utility workers. That's because some say sales people are about as helpful as the sales sheep in Lewis Carroll's *Through the Looking Glass*.

No piece of clothing came under more fire with the new OSHA clothing requirements [29 CFR 1910.269 (1) (6) (iii)] than winter outerwear-except maybe underwear. To the electric-utility worker working in winter, weather poses all the safety hazards that come with ice, snow, dampness, and cold. Arc protection is something else.

The primary objective in winter is to stay warm and dry. This can be the difference between productivity and non-productivity and life and death. The OSHA standard adds the imperative that clothing must not be capable of ignition in the event of an electrical arc.

First, it should be noted that most cotton-shell winter wear-if it does not ignite-inherently provides major protection from the thermal hazards of electric arc. But information initially available on commonly used winter wear was scant and indeterminate. The OSHA standard brought up the question: Would a 100% cotton coverall with polyester fill and a nylon lining protect from electrical arc, or would it "increase the extent of injury?" But only unconfirmed anecdotes circulated. One told of coveralls, shells intact, and molten linings running out of the legs; another of workers living after their coveralls burned off of them. Many utilities decided that the hazard of arcs is not as imminent as that of frostbite and chose to remain with their tried and tested winter wear (Fig 1), hoping that available information would be sorted out in time.

The good news is that more definitive information is now available on the safe uses of the most popular coveralls in regard to electric arc conditions. Many utility workers are able to reasonably use their existing clothing with little risk of ignition, if the lining is not exposed. But the industry wants A winter wear that doesn't trade off warmth and price for reduced ignition risk. Louisville Gas & Electric Co (LG&E), Louisville, KY, began working with other utilities and clothing manufacturers to find some creative, cost-effective solutions to the winterwear problem. (LG&E and

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1. Conventional winter coveralls, known in the trade as Carhartt's, are preferred by many line workers and provide good protection form electric arcs, but both the shell and the non-flame-resistant polyester fill could ignite under some arc conditions

2. Warmth, moisture transport from the body, wind and rain resistance are what workers needs to work well. Many flame-resistant winter garments costing twice as much don't come close to conventional winter coveralls for warmth and comfort

3. Non-flame resistant wool jacket, with flame-resistant cotton shell (Millworks Manufacturing) survived a 30 kA/10 cycles arc 12 in. away. Both inside and outside of jacket were exposed

Table 1 Shell options for winter wear

Fabric	Wear Characteristics	Flame Resistant?	Warmth	Cost
12-oz. 100% cotton duck fabric Carhartt (6) Walls(7)	Excellent 12-oz. wring-spun duck is the best for wear. There are cheaper imitations.	Only up to tested limits. Risk of ignition. Slow burning because of heavy cotton weave.	Excellent wind protection. Fair water protection.	Least Expensive
FR-treated cotton duck fabrics Indura(5)	Poor compared to most of the others.	FR-treated cottons. Treatment for life of the garments.	Comparable to cotton.	Moderate, low-initial price. Wear-life factor.
FR-treated Cotton/nylon blend fabrics BanWear® (1) or Indura Tufstuf® (5)	Excellent. Both of these fabrics will most likely wear longer than cotton. Nylon adds abrasion resistance.	FR-treated cottons. Treatment for the life of the garment.	Excellent wind protection. Fair water protection.	More expensive than cotton.
Nomex(2) 6-10 oz. materials available.	Good wear as a shell in heavy weights. At least a 7.5 oz. is recommended	Yes, inherently FR. Not recommended for use when welding.	Not great by itself. System should have a moisture barrier and/or external treatment. Gortex® laminates available.	Moderate to Expensive
Modified cellulose/aramid blends Kermel(8), Nomex(2) Rayon blends	Good wear in heavy weights. Might be a good choice for linings. Usually used for shirts, pants and switching jackets.	Yes, inherently FR. Not recommended for use when welding.	Slightly warmer feeling than pure aramids. Requires moisture barrier and/or external treatment.	Expensive
PBI/Kevlar(3)	Good wear characteristics.	Yes, inherently FR. Not recommended for use when welding.	Similar to other aramids. Requires moisture barrier and/or external treatment.	Expensive. Limited colors.

Table 1 Linings options for winter wear

Fabric	Wear Characteristics	Flame Resistant?	Warmth	Cost
Polyester fill with nylon lining Carhartt(6) Walls (7)	Excellent. Quality quilting holds up to washing well. Very lightweight.	Prohibited by OSHA if not used within test limits. Exposed linings may ignite and melt.	Excellent wind and water protection.	Very inexpensive. Special shells and linings could provide advantages while protecting from ill effects.
Wool	Good to excellent. Shrinkage can be controlled with proper laundering.	100% wool is inherently FR. FR treatment may be desirable.	Excellent for wind and water protection. Wool warm when wet.	Price is very competitive with many other FR garments. Weight may be slightly higher.
Modified acrylics with FR cotton linings Modiquilt® (5)	Good to excellent.	Inherently and treated	Good. Slightly better than aramids because of moisture transport	Less expensive than aramids.
Nomex® Batting/lining combinations Q-9® et. al.	Excellent	Yes, inherently FR.	Q-9 is too light. Choosing a good shell is imperative. Very lightweight.	More expensive

The Nomex® Q-9 lining was originally designed for thermal protection for firefighting clothing and is not recommended for protection from the cold. Layering becomes key if using this type of lining in winterwear. Many technological advances have come about since this article was originally published including aramid/wool blends, Nomex® fleeces, and many other insulative batting options.

Table 1 Result of the LG&E/Montana Power study on winter wear

Overall/jacket descriptions	Warmth factors	Other factors	Arc test results
12 oz. Carhartt or Walls duck shell with polyester fill and nylon lining	Very warm	Most cost-effective followed closely by BanWear®/Wool option	Mixed. No second degree burns predicted until after ignition of outer shell.
SafeWear Technologies (11) 12 oz. BanWear® shell with 13 oz. FR Wool Lining from Woolrich (10)	This received the overall best rating of all the FR coveralls. Several preferred them to the non-FR.	Slightly heavier than others. Special care required for wool washing. One washing produced no shrinkage problem.	No second degree burns, even with breakopen of outer shell. Very protective.
12 oz. BanWear® shell with Nomex® Q-9® lining.	This was third place in warmth.	Workers mentioned that this felt similar to the Carhartt but not as warm as the two above.	Same as above.
6 oz. Nomex® shell with Nomex® Q-9® lining.	The coverall was too light to provide the expected warmth. This option requires more layering.	Concern over shell wear unfounded in the first year of use. Moisture barriers and heavier shells could help performance. Not recommended for welding operations.	Same as above.

Note: The Nomex® shell of a 6 oz. weight offered at competitive price to the other options and was the most popular FR coverall offered by the sponsoring manufacturer, SafeWear Technologies, Inc. Clanton, AL. A 10 oz. Nomex® shell is also available from most manufacturers.
The 13 oz. wool used in coveralls made by Millworks Mfg. Ltd. (4), distribution from Buffalo, NY, has been exposed to an ATPV test with excellent results. This lining alone will frequently prevent second-degree burns from electrical arc up to the level expected from almost 16 kA/10 cycles or 20 cal/cm2 (50% probability of second-degree burn at 20.4 cal/cm2). The non-FR wool tested did not pass the ASTM F-1506 vertical flame test with less than 6 in. char length, but an FR version of the wool is available from Woolrich, Inc. (10).
(1) Itex Inc, Aurora, CO; (2) DuPont Advanced Fiber Systems, Wilmington, DE; (3) Hoechst Celanease Inc. Charlotte, NC; (4) Millworks Manufacturing, Toronto, ON, Canada; (5) Westex Inc. Chicago, IL; (6) Carhartt Inc. Dearborn, MI; (7) Walls Industries, Inc. Cleburne, TX; (8) Kermel Inc. Marietta, GA; (9) Southern Mills Inc, Union City, GA; (10) Woolrich Inc, Woolrich, PA (11) SafeWear Technologies, Clanton, AL.

Montana Power Co, Butte, MT, ran field tests this past winter on three options (Table 3).

Wool has surprising properties

Ed Hildreth, Manager of Employee and Public Safety, Montana Power, Butte, MT, suggested testing wool and silk, both commonly used in ski apparel and commonly worn by their workers. LG&E's tests of wool shirts, socks, and face masks showed that the wool itself was very flame-resistant. (All wool used for electric arc exposure should be tested by ASTM Standard F-1506 or the electric arc test PS57 to ensure flame resistance under arc conditions). Great care must be taken in choosing face masks since many use elastic for eyeholes, which poses the risk of melting around the eyes. Neither the wool nor the silk that LG&E tested ignited under the electric arc conditions (16 kA/10 cycles/12-in. arc gap/12-in. distance to arc). Wool shirts alone are not very arc protective since they readily break open, but they are in compliance with the OSHA standard if they do not continue to bum and can add protection as a layer for winter use. Silk "cowboy-type" scarves tested are both protective and flame resistant.

The initial data spurred LG&E's search for wool-lined overalls, coveralls, and jackets. When the utility began broadcasting this information to clothing manufacturers, wool-lined items were available as specialty items or for clothing in the steel industry but, to date, after consulting with the clothing data, several companies specializing in electric-utility clothing have started offering these coveralls.

The inherent flame resistance of wool has long been documented (you've never heard of a sheep dying from smoking in bed), but has rarely been acknowledged by the flame-resistant-fabric industry. Part of the reason is the difficulty in using wool with synthetic fabric systems because of shrinkage differences. According to LG&E's testing on shirt-weight wool and wool jacket linings, there is no need for flame-retardant (FR) treatments for most wool products to protect from arc ignition (some finishes of wool, not designed for industrial use, do require flame- retardant treatment, but these are usually light-weight fashion wool). FR treatments are added to wool for specific applications in the steel industry, but LG&E's testing resulted in no ignition of either FR or non-FR wool. The wool tested also had no after-flaming, which is apparent in most FR fabrics. Some disadvantages remain, but linings of wool or wool blends may make up much of electric-utility arc-protective clothing for winter wear in the next few years.

What makes a coverall warm?

Joe Ricci, Health & Safety Specialist, Hydro-Quebec, Montreal, QE, Canada who has done extensive field testing of winterwear, points out that the most important factors for warmth in winter are:

- Moisture transport from the body.
- Insulative value of the garment system.
- Wind resistance of the garment system.
- Keeping the shell dry in snow or freezing rain conditions.

Hydro-Quebec uses a multilayer 7.5-oz. Nomex® shell winterwear with a non-FR polyester batting for warmth, an FR moisture barrier film, and a non-FR cotton lining, but the utility is still considering other garments including those made of wool. Hydro-Quebec's winterwear and an experimental wool alternative system have performed well in arc tests. Because there are several factors related to what keeps a person warm, most winterwear must offer trade-offs, especially in moisture-transport/wind-resistance capabilities. This is why most winterwear systems combine a wind-resistant shell with an insulative batting and a lining which, at the least, does not hinder moisture transport. The most difficult balance is between wind-resistance and moisture-transport. Some combinations of fabrics create a vapor barrier that blocks wind but does not allow body moisture out. The result is that in periods of lessened activity, the moisture may freeze, adding to discomfort caused by the dampness next to the skin. The best systems protect from external moisture and wind, while helping transport internal moisture away from the body. Wool, interestingly enough, has the added effect of actually producing heat when wet. Surveying the available options (Tables 1 and 2), many utilities will continue to choose non-flame resistant coveralls simply because flame-retardant options are either cost-prohibitive or simply not warm enough. The primary considerations in winterwear design are:

1. Shell, the outer layer which should be resistant to:
   - Wear,
   - Wind.
   - Water.

2 Lining/fill, usually part of a batting/liner fill which should:
   - Provide warmth.
   - Not add substantially to the weight.
   - Wick away moisture (or at least not inhibit moisture transport).

3. An optional moisture barrier may be needed (some systems do not require this option to be viable; other systems must have one for low temperatures).

While options are becoming more readily available which offer protection from the many hazards of electric-utility work, definitive answers are still a bit out of reach. But reasonable solutions are available to offer warmth and protection from electric arc for utility workers. ■

Hugh Hoagland is now R&D Director for NASCO Industries, Inc. and author of several papers and articles on the electric arc and its effect on clothing, rainwear, and personal protective equipment. Hugh is also a member of the following committees.

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Member F-23 Petrochemical Clothing Standard Taskforce

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