WILDERNESS ESSAY

Mountain Clothing and Thermoregulation: A Look Back

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Introduction

At the time humans began exploring the upper reaches of the world's highest mountain ranges in the early 20th century, knowledge about survival in extreme climates was undergoing rapid development. Early polar exploration provided a bedrock of understanding that mountaineers were able to build on. Whereas Norwegians such as Fridtjof Nansen and Roald Amundsen seemed to have perfected the art of travel in the Arctic and Antarctic by the late 19th/early 20th century, British polar explorers such as Dr John Rae and Francis McClintock respected the lessons of cold weather native living and travel before 1850. Some early Himalayan mountaineers, such as Martin Conway, also went to the Arctic. It thus seems reasonable to suggest that some early synergy existed between polar exploration and mountaineering regarding clothing and equipment.¹

By the end of the second decade of the 20th century, tailored Burberry windproof climbing suits were becoming somewhat commonplace, having been advertised in publications such as the *Alpine Journal* since 1901.¹ As such, it is a misperception that tweed jackets and knickerbockers were standard attire for high altitude Himalayan exploits up through the period of the Everest expeditions of the early 1920s. Burberry gabardine windproof suits were actually ideal for mountaineering, as they were lightweight, tough, and breathable. Harold Raeburn, one of the most distinguished mountaineers of his generation and in charge of the climbing clothing and equipment for the 1921 Everest reconnaissance, recommended the use of gabardine, not least for its power to repel snow.² This essay offers a look at just how effective such clothing likely was for the early Himalayan pioneers operating in the hostile environment found on the world's highest peaks.

“RECONSTRUCTING” THE PAST

In May 1999, a dedicated search expedition located the body of well-known British mountaineer George Mallory on Mt. Everest (8848 m). He was found at an altitude of approximately 8200 m on the north face of the mountain, 75 years after he had last been seen alive. Mallory was frozen in a position of self-arrest at the bottom of a scree slope, having obvious signs of a broken leg and an injury to his head as a result of a fall. The American climbers that the British Broadcasting Corporation (BBC) had recruited to do the search removed his clothing and possessions after finding him. Subsequent to reading a Committal Service that had been brought to the mountain, they buried his body under the abundant rocky debris found nearby.

The clothing fragments removed from Mallory's body have fortunately become more than just a museum piece. Outdoor clothing experts Mike Parsons and Mary Rose were inspired to undertake a research venture, the Mallory Clothing Replica Project (MCRP), which scientifically analyzed and replicated Mallory's 1924 mountaineering clothing to provide an improved understanding of its performance capabilities in extreme conditions.³

Parsons and Rose approached the Textile Conservation Centre at the University of Southampton for advice on preservation and replication of the 1924 clothing. Most fortunately, a grant of £29 355 was obtained from the UK Mountain Heritage Trust and £3300 from Pasold Research Fund in 2003 for the replication work. Nearly 3 years of scientific analysis (including scanning electron microscopy and x-ray spectroscopy) and detective work from the Universities of Southampton, Derby, Leeds, and Lancaster was necessary to convert Mallory's clothing fragments into testable replicas.

This project was ultimately about understanding the 1920s-era clothing's position in mountaineering history and the ever-evolving innovation process. Replicating the fabrics and garments was challenging for a number of reasons, not the least of which was that the Lancashire cotton industry had been in decline since the 1920s.

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Fabrics such as the Burberry windproof, the wool flannel and silk woolen vest, the cotton long-johns, and the puttees were custom made and most garments hand-knitted for the project. Modern silks, for instance, had to be specifically treated, or degummed, to match the procedures used in the 1920s.

An understanding of just how windproof the fabrics were and the degree of insulation they provided was sought before full replication of the garments. As a result, the Performance Clothing Research Centre at the University of Leeds tested the materials as thoroughly as modern fabric samples are tested. They concluded that Mallory was sufficiently well insulated to operate effectively on Everest, provided he was moving and not forced to bivouac. The Textile Conservation Centre surmised that he was wearing:

a hand-knitted jumper, two other hand-knitted fragments (perhaps one of which was part of his leggings), three pairs of socks, a blue and white shirt, a vest that is in a fibre blend with silk, and his puttees [a long narrow piece of cloth wound tightly around the lower leg] which might be cashmere rather than sheep wool.³

Further analysis of the fragments confirmed that Mallory was wearing a Burberry windproof climbing suit made of densely woven fine cotton as an outer layer. This material was considered one of the most “high performance” fabrics of the era.

The replica garments required extensive photographic research and visits to archival collections to better understand the features of 1920s-era mountaineering clothing before design patterns were drawn so as to pay particular attention to the detail of styling and finish. The garments were intended to be fully testable in field conditions once their construction was complete. However, the question remained how the replica garments would compare with modern clothing systems worn at high altitude.

Part of the answer to this question was provided in 2006, when the opportunity arose to do some field testing of the finished replica product near 6400 m on the north side of Everest (Figure). In the 2007 *Alpine Journal*, Graham Hoyland, the “garment tester,” commented on the experience:

We climbed up on to the glacier and did some tests. First I cut some steps with the 1920s ice-axe. I immediately found that the layers of silk that I was wearing slid easily against the wool layers, giving me great freedom of movement. Then I reached up to take a hold on the ice above my head. The patented pivot sleeve of the Burberry jacket allowed me a full reach without dragging the shirt-tails out of the breeches. Before too long I was feeling almost too

Figure. Field testing of the actual replica garment produced by the Mallory Clothing Replica Project near 6400 m on the north side of Mt. Everest in 2006. Photo reproduced courtesy of Graham Hoyland.

hot. Not for nothing was this gear developed for polar expeditions.⁴

After extensive testing of this sort, Hoyland—a veteran of many expeditions to Everest—was very confident that Mallory and Irvine could have reached the summit comfortably wearing this clothing—on a reasonably fair day.

Shortly thereafter, George Havenith, Professor of Environmental Physiology and Ergonomics at the United Kingdom’s Loughborough University Human Thermal Environments Laboratory, became interested in the replica clothing. Havenith, an expert in human thermoregulation, was curious enough to offer to extensively test the insulation and wind protection of the clothing in his environmental ergonomics laboratory.⁵ One of the reasons that Havenith’s curiosity was stimulated by the replica of Mallory’s clothing was because he had just completed a thorough laboratory investigation of the clothing worn by Scott’s and Amundsen’s respective teams during their 1911 South Pole journeys in Antarctica. More specifically, Havenith not only compared the polar clothing worn by Scott with that of Amundsen, but also examined how both outfits measured up against modern fabrics and apparel. Although the insulation value of the 2 outfits was very similar, the friction levels

within one set of clothing vs the other were distinctly different. This significantly impacted both the ergonomic efficiency and the subsequent long-term energy expenditure of the wearer. This difference in the clothing systems of Scott and Amundsen occurred specifically because the apparel of the Scott party consisted of layers of coarse fabrics (primarily wool), whereas Amundsen's team wore layers of slippery furs fashioned from what Amundsen had learned from Eskimos in arctic North America. Simply because of clothing, Scott and his companions would thus have been expending up to 20% more energy than Amundsen while traveling in the Antarctic. In addition, given that Scott's team manhauled sleds while Amundsen used dogs to pull theirs en route to and from the South Pole, the total energy expenditure of Scott and his companions would have been considerably greater. These factors were no doubt of crucial importance in the end, as Scott and his entire polar party expired out on "the ice" during their desperate retreat from the Pole.

This demonstration of dedication to historical aspects of outdoor clothing and its thermoregulatory capabilities convinced the UK Mountain Heritage Trust (who held the Mallory outfit) to allow Havenith to put the replica 1924 clothing through its paces at Loughborough University's Environmental Ergonomics Laboratory.⁵

The tattered remains of clothing collected from Mallory's corpse showed that his outfit consisted of 6 layers on the upper body and 4 on the lower body—composed of alternating strata of silk, cotton, and wool. After Havenith and his laboratory staff had determined the proper layering order with the help of the photographs and reports from the scene of the body "discovery" in May 1999, the replica clothing was placed on a "thermal" mannequin. This mannequin allowed for the simulation of skin temperature (to replicate someone climbing at high altitude) and could measure heat loss in 32 distinct body zones. Havenith's findings showed that by virtue of the aforementioned layering system Mallory used, the insulation value of the clothing per unit weight was approximately 30% better than Scott's and Amundsen's polar garments—and only slightly lower in absolute insulation value (because of its light weight) than the clothing worn to the South Pole. Furthermore, the evaluation of the Mallory replica outfit by Loughborough's Environmental Ergonomics Laboratory supports Hoyland's assertion that if the weather and winds had remained stable during the June 8, 1924, summit attempt, the attire would have offered adequate protection in air temperatures down to -30°C . Unfortunately, the last reported sighting of Mallory and Irvine high on the peak during the day of their summit attempt (by expedition member Noel Odell) was made during changing weather.

Odell, climbing in support of Mallory and Irvine on the day of June 8, reported a "rather severe blizzard" beginning around 2 PM.⁶

To put this June 1924 mountain weather phenomenon into perspective, Moore, Semple, and Sikka⁷ used previously unanalyzed meteorologic data collected daily during the 1924 Everest expedition, sea-level pressure maps from the period, and a modern reconstruction of the 3-dimensional state of the atmosphere during the first half of the 20th century to examine atmospheric conditions surrounding Mallory and Irvine's summit attempt on June 8, 1924. The analysis suggests that the attempt occurred during a period that experienced a drop in barometric pressure of 18 mbar as a result of the passage of an upper-level trough between June 6 and June 9. The structure of the disturbance was similar to that seen during other extreme weather events on Everest. Moore et al⁷ proposed that this drop in pressure is equivalent to adding over 350 m of altitude to the mountain. In addition to adding more "physiologic altitude" to Everest, very unsettled and stormy weather is also associated with pressure drops of this magnitude. To put an 18-mbar pressure drop into proper perspective, one must be aware that during the infamous *Into Thin Air* storm in May 1996,⁸ the magnitude of the pressure drop at the summit was estimated to be 10 to 14 mbar.⁹ Another similarity with the 1996 storm is also worthy of mention. During this late 20th-century event, the stormy weather was of short duration, but was followed by an extended period of high winds near the summit associated with a localized region of high winds embedded within the subtropical jet stream. Odell mentioned that the blizzard on June 8, 1924, lasted approximately 2 hours. When he climbed high on June 9 and June 10, looking for Mallory and Irvine, he noted that strong winds persisted throughout both days.⁶ Because the 18-mbar pressure drop was measured at the 5000-m base camp in June 1924,¹⁰ it is plausible that the drop may have been even larger near the summit on the days in question, possibly by as much as 30%.⁷

Perhaps not surprisingly, Havenith's Environmental Ergonomics Laboratory was able to confirm that Mallory's outfit offered substantially less insulation against the cold than the special high altitude clothing used by modern climbers (about 40% less).⁵ This fact, combined with the likely cold and windy conditions Mallory and Irvine encountered during their summit attempt, suggests some degree of hypothermia may have been present that day in these Everest pioneers. It seems possible that Mallory and Irvine's core temperature may have been low enough at some point during their descent to high camp that, coupled with exhaustion, dehydration, and

deteriorating weather, an accidental fall may have been difficult to avoid.

Nonetheless, in apparent agreement with Hoyland's comments from the above-quoted 2007 *Alpine Journal* article,⁴ Havenith was very impressed with the layering aspects of Mallory's clothing. Similar in concept to the aforementioned ergonomic efficiency of Amundsen's 1911 polar clothing, Mallory's 1924 outfit alternated layers of coarse wool with "slippery" fabrics such as silk. This fabric combination allowed great freedom of movement, with very little restriction, at a subsequent low energy cost.

Conclusions

The clothing used by the members of the pioneering Everest expeditions of the early 1920s may in some respects be seen as primitive by today's standards. However, we should consider the results of the field observations and scientific laboratory investigations discussed in this article as evidence that those who initially explored the highest realms of the Himalayas were not necessarily ill-clothed for the job at hand. By the 1920s, state-of-the-art fabrics for the cold, windy conditions found on the world's highest mountains had been informed by years of travel in the polar regions. Early Himalayan pioneers modified polar clothing for high mountain use with some success, judging by close examination and testing of the fabrics replicated from the

clothing remnants found on the body of Everest pioneer George Mallory in 1999.

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