National Defence Défense nationale

DEFENSIO PER SCIENTIAM

WHY COLD-WET MAKES ONE FEEL CHILLED: A LITERATURE REVIEW

AD-A203 452

by

Rita M. Crow

DEFENCE RESEARCH ESTABLISHMENT OTTAWA
TECHNICAL NOTE 88-22

Canada

June 1988
Ottawa

National Defence Défense nationale

WHY COLD-WET MAKES ONE FEEL CHILLED: A LITERATURE REVIEW

by

Rita M. Crow
Environmental Protection Section
Protective Sciences Division

DEFENCE RESEARCH ESTABLISHMENT OTTAWA
TECHNICAL NOTE 88-22

PCN
051LC

June 1988
Ottawa

ABSTRACT

This paper reviews physiological experiments which have been carried out to determine if heat loss from the body is greater in cold-wet, temperatures and humidities. It also reviews the effect of solar radiation the interaction of skin and humidity and skin and temperature and other postulations for the cold-wet sensation. It concludes that the best explanation for the chilling effect of cold-wet is the penetration of fine water-vapour aerosols into clothing which reduces its insulation. Experiments would be needed to confirm this.

RÉSUMÉ

Cette note technique présente une revue des expériences physiologiques effectuées dans le but de déterminer si la perte de chaleur du corps humain est plus importante dans les conditions de température et d'humidité rencontrées en climat froid et mouillé. On examine aussi l'effet de la radiation solaire, l'interaction entre la peau et l'humidité, entre la peau et la température de même que certains postulats ayant été émis en ce qui concerne la sensation froid-mouillé. On conclut que la meilleure explication pour l'effet refroidissant du froid-mouillé vient de la pénétration d'un fin aérosol de vapeur d'eau au travers des vêtements résultant en une diminution de l'isolation thermique. Des expériences additionnelles seront nécessaires pour confirmer cette hypothèse.

INTRODUCTION

Considerable research has been directed towards protecting the soldier in cold-dry conditions, rather than cold-wet conditions. The prediction of heat and moisture transfer is relatively straightforward in cold-dry conditions since environmental moisture can be ignored. Further, the physiological evaluation of cold-dry in clothing, sleeping bags and tents can be carried out in cold chambers where there is no need to control humidity since it is always low under cold-dry conditions. Cold-wet conditions are not so easy to simulate indoors, so have tended to be ignored. Recently the Canadian Forces has asked that cold-wet as well as cold-dry conditions be addressed. A literature search found no formal definition of cold-wet, but rather, attempts to try to explain why it makes one feels so cold. This paper reviews the work done to determine what factors make cold-wet conditions so chilling.

PHYSIOLOGICAL EXPERIMENTS

One of the explanations as to why one feels "chilled-to-the-bone" in cold-wet conditions has been that damp air is a better conductor of heat than dry air and so conducts heat away from the body, leaving it feeling cold. In the late fifties, Iampietro at Natick, Renbourne in the UK and Burton in Canada all conducted physiological studies to test this idea.

Iampietro et al (1) exposed nude subjects to dry bulb temperatures of 10 and 15.5°C, relative humidity of 30 and 95% and wind speeds of 16 km/h and less than 1.6 km/h. They measured skin and rectal temperatures and oxygen consumption, calculated heat production and used questionaires to obtain subjective responses. They found that relative humidity had little or no effect on either the physiological or the subjective responses. Wind had the greatest effect and the dry bulb temperatures had a marked, but somewhat lesser effect. The authors say that the results of this study do not necessarily rule out a physiological basis for cold-wet sensations and so Iampietro (2) did similar experiments with lightly clothed, rather than nude, subjects. He used dry bulb temperatures of 4.4°C and 10°C and relative humidities of 30 and 100%. He also found that the relative humidity had no effect on the physiological responses measured while the wind and dry bulb temperature did.

Renbourne et al (3) exposed clothed men at rest to either of two conditioning 'indoor' environments, a British cool, moist one and an American warm, dry one for 45 minutes. The men were then exposed to a cold environment (2.2°C or 36°F) at a moderate and a high relative humidity, 50% and 80% respectively. Renbourne measured skin and rectal temperatures, the clothing temperature gradients, nude body weight change, metabolic rate and collected subjective responses. No objective or subjective physiological difference of practical importance was found as a result of relative humidity except that the chest was slightly warmer at the higher humidity.

In Burton's experiments (4), unclothed subjects rested for 100 minutes in rooms set at 8.8°C (48°F) and at 14.4°C (58°F) with nominal humidities of 30 or 80%. Burton found that the mean skin temperatures were the same for the two humidities and that there was a significant rise in rectal temperature at the lower humidity. He attributed this to vasoconstriction and to a greater increase in metabolic rate because shivering was greater and more severe at the lower humidity. He also found the sensation of cold to be greater at the lower relative humidity. He suggested that the paradox of a greater sensation of cold and metabolic response at low humidities, though skin temperatures and heat loss were independent of humidity could be due to the uptake of moisture in the skin at high humidities which causes an increased thermal conductivity in the region of the receptors. At the end of the exposures, the average skin temperature was about 22°C in the 8.8°C environment and about 25°C in the 14.4°C environment.

So why did the researchers not find any significant difference in the physiological responses at low and high humidities? Renbourne et al (3) concluded that there is no basis for the supposition that moist air is either a better thermal conductor or a more efficient heat convector than dry air. Further, since they could not show that the physiological difference between dry-cold and damp-cold is not due to properties of humid air, then they thought that it must be due to associated weather or climatic differences. They concluded that data from physical models and from physiological experiments in climatic chambers cannot be directly transposed into the realities of the fighting soldier in the field. Iampietro concurred with this, pointing out that it was important to recognize the limitations of chamber studies in differentiating between dry-cold and wet-cold. The chamber does not simulate radiation or precipitation. The radiative loss from the body to the chamber walls and ceiling at a given ambient temperature are the same whether the humidity is high or low. Iampietro noted that the fluctuations in out-of-doors climatic conditions versus the constant steady-state of the chamber could alter subjects' responses. He suggested that if the differences in cloud cover, indirect radiation and solar radiation between cold-wet and cold-dry conditions could be simulated, then it might be possible to see the physiological responses of the subjects. Renbourne pointed out that a fine precipitation in the form of mist (water particles of about 50μ) exists in humid cold conditions and it can penetrate clothing to impair its thermal insulation and that the sorption of heat of clothing is closely bound up with cold-damp conditions.

None of the researchers had trouble controlling the temperature in the chambers, but all had trouble controlling the humidity. In Renbourne's study, the amount of absolute moisture in the air at the upper limit of the lower humidity and the lower limit of the higher humidity were similar. In Iampietro's first experiment, the absolute moisture in the air at the two temperatures also were similar at low humidities. In Burton's experiments, four out of the nine experiments at the "low" humidity had similar amounts of absolute moisture in the air whether the temperature was 8.8 or 14.4°C. It is suggested that the similarity in test conditions may account for the similarity of test results. Alternatively, the differences in humidity may have been too subtle to produce a measureable physiological difference.

Gooderson (5) included precipation in his study where he exposed clothed subjects to 6°, 20 mph wind and 30 mm/h rain for 75 minutes and then to -8.5°C with no wind in a cold chamber for 6 h. The subjects did get cold and individuals having to be withdrawn from the experiment included the majority of those wearing the Korean boot as well as a minority of those wearing the Mukluk/NBC overboot. Leakage occurred up the arms, down the neck and at pressure points at the knees (from crawling) and in the middle of the back and waist from the rucksack and belt. Gooderson found that one of the problems was in keeping the subjects dry while active.

Woodcock (6) did some theoretical calculations on the effect of ambient temperature and humidity on heat transfer through insulation. He concluded that ambient humidity had very little effect on the sensation of cold-wet above 12°C or below -14°C. Between these two temperatures, liquid condensation would occur in clothing, reducing its insulative value. Below -14°C, frost rather than liquid would form. Since frost is a solid, it would not spread as water could to decrease further the clothing insulation. He says that a man will not feel cold while he is active and sweating and that the sensation of damp-cold will normally occur when he is inactive and at a low rate of metabolic heat generation. Presumably Woodcock means inactive after sweating when there is condensation in the clothing.

SOLAR RADIATION

It is known that solar radiation is absorbed by water vapour, but it is also scattered by it. It is estimated that 10% of solar radiation is scattered by water vapour in all directions, including back out into space. Aerosols of water in clouds reflect incident solar energy. The upper surface of a stratus cloud cover can reflect 70% of the radiation incident upon it. Still more is reflected in the cloud (7). Thus, under cloudy conditions, much less solar radiation reaches the earth than under clear conditions. Albedo, the fraction of the incident energy which is reflected by a surface, varies considerably with the terrain. The albedo of bare ground is 7 to 20% and for snow is 46 to 86%. The radiation reflected by the snow is partially scattered back to the ground by the atmosphere. This is particularly pronounced when it is overcast because the radiation is strongly reflected back towards the ground by the base of the clouds (8). Thus, one will receive more solar radiation when there is snow on the ground (i.e. cold-dry) than when the ground is bare, especially on cloudy days (i.e. cold-wet).

Woodcock (6) also points out the importance of solar radiation which increases the temperature of clothing and so reduces the condensation occurring in it. He says that clothing may feel damp due to lack of solar radiation and not because of the high relative humidity in the environment.

Breckenridge and Goldman (9,10,11)) have proposed a physiological model to include solar radiation on a clothed man, based on results of experiments. From August to December (10), they carried out 72 experiments to measure the solar load, out of doors, on manikins dressed in the United States fatigue uniform. They measured solar loads of 16 to 171 W/m^2. They repeated the experiments during April and March with the manikins wearing the cold-wet uniform and measured solar loads of 0.5 to 71 W/m^2 (11).

It has been suggested that one feels as if the ambient temperature is 5°C warmer than it really is when there is solar radiation. This is not based on scientific evidence and should be verified.

THE SKIN AND HUMIDITY

As mentioned earlier, Burton (4) put forth the theory that the chilling effect of cold-wet is due to the re-absorption of the sweat by the skin, especially at high humidities. Cassie (12) also expounded this theory, based on a comparison between the physical properties of a keratin membrane and the skin. He had shown that, between 10% and 20% regain, the diffusion coefficient of keratin increases sharply. Therefore, he concluded that an increase in relative humidity would also give an increased diffusion coefficient in skin. Thus, under high humidity conditions more moisture would diffuse to the skin surface and evaporate from it than under low humidity conditions. He also based this conclusion on the fact that evaporation from a colloidal bag filled with water decreases as the wind speed increases because the higher wind speed maintains a lower relative humidity at the surface of the bag. He went on to consider the effect of temperature on skin. He explained that at low temperatures, the blood capillaries near the surface of the skin remain unfilled and so the skin behaves like a thick membrane. As the temperature increases, the capillaries fill up so that the skin can have a greater heat loss. The filling of these capillaries reduces the membrane effect of the skin, and evaporation is now more akin to evaporation from a free surface. Higher relative humidity of the surrounding air reduces the rate of evaporation.

Cassie goes on to say that in cold-wet conditions with low temperatures and high humidities, the skin will act like a thick keratin membrane which will readily pass moisture through it. As this moisture evaporates, the relative humidity surrounding the skin increases. If the clothing over the skin does not permit the water vapour to pass readily to the outside air, the relative humidity next the skin will increase and the skin will lose more heat by evaporation. This is a snowball effect, for as the water vapour accumulates, the body increases its evaporation to give an even greater accumulation. Thus, Cassie says, at low temperatures, when the air next to the skin is damp, evaporation increases as does heat loss, giving rise to the complaint of feeling colder on a damp day than on a dry day.

Another 'textile' theory which can be put forth for the sensation of cold-wet is that when one goes from a relatively dry, warm indoor environment to a damp, cold outdoor environment, the exposed skin on the face will act like typical wool fabric, that is, produce heat due to the absorption of water. However, this phenomenon may not be real since the absolute humidity outside is considerably less than indoors and the face temperature, although cooling somewhat, does not cool to ambient as a wool fabric would. Thus, the relative humidity at the face would probably be considerably lower outdoors than indoors and no absorption of water vapour, and thus production of heat would occur.

Lamke and Wedin (13) studied how the temperature and humidity of surrounding air influenced evaporation from normal skin. They compared evaporation at 28°C and 20, 40 and 80% relative humidities. They expected to find lower evaporation in the more humid environment because of the reduced capacity of the ambient air to take up more water. However, they found that evaporation from the skin remained unchanged at the different humidities. They explained this by the fact that the water supply to the skin's surface at 28°C is insignificant compared with the evaporation and transport capacity of the passing air which would easily carry away this water, whether the air is dry or moist. They give as another contributory factor, that the skin is hydrophilic and contains more water when the humidity is higher. This causes a higher degree of water penetration out through the moist skin. This agrees with Cassie's theories.

Spruit and Malten (14) studied the water-vapour loss through skin from the back of a cadaver and found that it decreased as the environmental air became more humid. They also found an increase in permeability with increasing humidity, although not so much as to offset the reduced water-vapour loss.

McIntyre and Griffiths (15) exposed 72 people to 23 and 28°C and three levels of humidity, 20,50 and 75%. At both temperatures, the subjects distinguished between the humidities on evaluative scales. Both the low and high humidities were found more oppressive and uncomfortable than 50%. The highest humidity was found more oppressive, more uncomfortable and more moist. The combined 28°C, 20% R.H. condition was preferred to the other combinations of temperature and humidity.

Buettner (16) showed that when atmospheric vapour pressure is above 2800 Pa, water vapour passes into the skin (negative insensible perspiration). However, the temperature at which the saturation vapour pressure is 2800 Pa is about 23°C. If Buettner's results were correct, then people in hot humid climates should look like wrinkled prunes. One can only conclude that Buettner's experimental method may be somewhat suspect.

THE SKIN AND TEMPERATURE

Another theory is that the sensation felt when going outside into a cold-wet environment is related to the cooling of the face. Steegmann (17) found that the facial sites cooled by convection are usually ranked from the forehead (warmest) through malar, cheek and chin to nose (coldest). When cooled by still air, the sites tend to retain the same ranking, but there is more variation in the ranking. He assumed that "facial skin cools passively by local direct action of cold on the tissue itself with cooling resistance coming arterially from deep-body heat and possibly modified by occasional low-grade vasodilation".

When LeBlanc et al (18) measured the skin temperature of the face, they found that the cheek cools faster than the nose and the nose faster than the forehead, so that the forehead was the warmest and the cheek, coolest. The cooling effect of the wind was at a maximum at wind speeds between 4.5 and 6.7m/s (16.2 to 24.12 km/h) and cold winds produce a significant decrease in heart rate. They found a very significant correlation between face cooling and subjective evaluation of cold discomfort, with maximum comfort at about 33°C and a sharp decrease in comfort at 15°C. There is no mention of humidity in this study.

OTHER REASONS FOR THE COLD-WET SENSATION

Renbourne (19,20) took a particular interest in cold-wet, including writing a historical survey of it. He notes that more than two centuries ago, it was suspected that the effects of a temperate winter involved much more than the physical properties of humid air and even its effects on clothing and skin. He goes on to describe the experiences of Moricheau Beaupré, a French army surgeon during the disastrous Russian campaign of 1812.

> "He (Beaupré) divided cold into 'real' and 'sensible' the former representing that of the environment, and the latter the sensations (which could be modified by the 'nervous power') felt by the body. 'Real' cold was of a dry or damp nature. In dry cold the atmospheric temperature fell to freezing point or below, the air contracted and its water vapour greatly diminished. Hence, he argued, its oxygen must be greater; and since, furthermore, the insensible persoiration of the lungs increased (that of the skin decreased), respiration was enhanced and the whole body stimulated to greater activity. He said "Dry cold is a sign of a durable or little variable atmospheric state; no evaporation from the ground occurs, the heavens are sere, the air light, cheery, pure and clear; this condition is salutary to man. Humid cold is characterized by a less depression of temperature but it holds its aqueous vapour. The humid state is noxious and is the most dangerous enemy of the animal economy; it produces effects altogether opposed to the former."

Renbourne comments that although Beaupré was well aware that the difference between dry and damp-cold depended on weather and climate and not simply on humidity alone, Beaupré failed to stress the importance of barometric pressure, the sun and the wind. Renbourne himself suggested that damp cold may be associated with the interacting variables of a weather front, that is, a falling barometer, a changing air temperature (between 1.7 and 10°C), generalized clouds, an increased electrical state of the atmosphere, gusty winds and the likelihood of rain. He points out that, in contrast, dry-cold may occur with a rising barometer, a stable lower temperature, clear skies, little wind and bright sunlight. He says that cold hands and feet are a symptom of dry-cold and being cold all over a symptom of cold-damp.

He goes on to cite some authors who assumed that the factors constituting a weather front may have an effect on the higher nervous centre, with resulting changes in pulse rate, blood pressure, blood cells etc. As a result, water retention in the tissues could, conceivably, explain the clinical phenomena associated with the body acting as "a cosmic resonator". Then there are the psychological aspects of weather. Bright colours and a clear sky produce, in some individuals, a feeling of warmth. Renbourne supposes that perhaps in the absence of sun and the presence of cloud, the thought of impending rain may in a similar way induce a feeling of cold or of damp.

Books have been written on the anecdotical effect of weather on humans. One such is Persinger's "The Weather Matrix & Human Behaviour" (21). In it, he comments that frontal systems cause human beings to adjust, during which time the living system can display physiological, chemical, endrocine, humoral (blood-related) or behavioural responses and that a given air mass contains a variety of different physical and chemical parameters which can stimulate the human being. They include temperature, relative humidity, barometric pressure, wind speed, air ions, electromagnetic waves, aerosols and organic materials. He notes that these factors can influence local geophysical conditions to release soil gases, alter electric fields or change the relative acidity of the air. According to Persinger, the important triad is temperature, relative humidity and barometric pressure, since "single correlational analyses are prone to critical intrinsic flaws". He suggests including confounding factors such as snowfall, rainfall and wind speed and if possible, temperature, humidity, barometric pressure, sunshine hours, wind speed and direction, geomagnetic activity, solar measures (X-ray bursts) and lunar phase.

Persinger correctly explains that warm air contains more moisture than cold air. Unfortunately he forgets this when he explains the phenomenon of cold-wet. He says that "sudden influxes of cool and very humid air significantly accelerate the rate at which heat is lost from the skin and lungs. The increased water content of the cold air (!) acts like a heat sink. Heat energy from the body is absorbed by the cold water vapour, resulting in relatively quicker drops in peripheral body temperature. Even when the hypothalamic centers compensate for these losses, the humid, cool air continues to quickly absorb biologically generated heat energy."

Persinger does make some interesting comments, such as the fact that the color gray is associated with depressions or "blahness" and blue with cheery, emotive feelings and that these are conditioned responses. He notes that October, November, March and April are the months with greatest changes in temperature and that in Bavaria, a few hours after a cold front with rain showers passes, the barometric pressure begins to rise, the temperature falls steeply, the humidity remains relatively high and the people report an uncomfortable penetrating cold.

Rosen (22) has written another anecdotical book on weathering. In it, he quotes Wilder's Law which says that your reaction to any stimulus depends on your prior level of arousal or excitation. In this present context, this may mean that, if once in your life, you got "chilled to the bone" and the weather conditions were "cold-damp", then the next time you encounter similar weather conditions, you recall the sensation of being chilled without actually being physiologically chilled.

Low temperatures are associated with cold-dry. The threat to well-being is obvious and is immediately sensed on the face. Measures are taken to reduce exposure or increase clothing insulation. In cold-wet, this may or may not be true. The threat is insidious and a heat debt may result. Osczevski (23) has shown that cold injury rates in military exercises in the cold-wet range can be twice the rate experienced at -30°C.

CONCLUSIONS

Experiments and postulation have not given satisfactory proof or explanations for what makes one "chilled to the bone" in cold-wet conditions. It is considered that the best explanation is that given by Renbourne, namely that fine water particles exist in cold-wet conditions and these penetrate clothing to reduce insulation. This author would add that it is the sensation of these aerosol particles hitting the face which identifies for the person that he is in cold-wet conditions. These theories could be proven or otherwise by exposing fabric or a face to a cool, aerosol-laden atmosphere and noting any changes in thermal resistance for the fabric and damp sensations in the latter. The lack of solar radiation around 0°C may also contribute to the chilled sensation, since as Goldman and Breckenridge have shown (10), solar radiation can add considerable heat to the body.

REFERENCES

1. P.F. Iampietro, D.E. Bass, E.R. Buskirk and J.A. Vaughan. Heat Exchange of Men in the Cold: Effect of Humidity, Temperature and Windspeed. Technical Report EP-99, Environmental Protection Research Division, HQ Quartermaster Research and Engineering Command, US Army Quartermaster R&E Center, Natick Mass, 1958.

2. P.F. Iampietro and E.R. Buskirk. Effects of High and Low Humidity on Heat Exchanges of Lightly Clothed Men. J. Appl. Physiol., 15, 2, pp. 212-214, 1960.

3. E.T. Renbourne, A.M. Reid, D.R. Gilling. A Contribution to the Physiology of Damp Cold - An Aspect of Temperature Climate. Part I. An Investigation on Clothed Men Under Indoor Conditions. CDC on Clothing and General Stores, Australia, 1959.

4. A.C. Burton, R.A. Snyder and W.G. Leach. Damp Cold vs Dry Cold. Specific Effects of Humidity on Heat Exchange of Unclothed Man. J. Appl. Physiol., 8, pp 269 - 268, 1955-1956.

5. C.Y. Gooderson, Protection of the Soldier from Wind and Rain. UK-25, 12th CDC(OCCE), Ghana 1978.

6. A.H. Woodcock, Wet-Cold II, A Theoretical Interpretation of the Sensation of Damp Cold Experienced by Clothed Man. Environmental Protection Branch Report No. 199, Office of the Quartermaster General, Department of the Army, Feb. 1953.

7. Principles of Environmnetal Physics by John L. Monteith. Edward Arnold (Publishers) Ltd., London, England. 1980.

8. Compendium of Meteorology, Edited by T.F. Malone. American Meteorological Society, Boston, Mass. Waverlty Press Inc. Baltimore, Md. 1951.

9. J.R. Breckenridge and R.F. Goldman, Effect of Clothing on Bodily Resistance Against Meteorological Stimuli. Progress in Biometeorology, Division A, Progress in Human Biometeorology: Effects of Weather and Climate on Human Diseases, Chapter 7, Section 19, pp 194-208.

10. J.R. Breckenridge and R.F. Goldman, Solar Heat Load in Man. J. Appl. Phys., 31, 5, pp 659 - 663, 1971.(2)

11. J.R. Breckenridge and R.F. Goldman, Human Solar Heat Load, Trans. Amer. Soc. Heat.Refrig.Air Cond.Eng. Trans, 78: pp 110-119, 1972 (/).

12. A.B.D. Cassie, Characteristics for Warmth in Underwear Fabrics. JTI V.40, 1949 P444-P453.

13. L.O. Lamke and B. Wedin, Water Evaporation from Normal Skin Under Different Environmental Conditions. Acta Dermatovener (Stockholm) 51: 111-119, 1971.

14. D. Spruit and K.E. Malten, Humidity of the Air and Water Vapour Loss of the Skin. Dermatologica, 138, pp 418 - 426, 1969.

15. D.A. McIntyre and I.D. Griffiths, Subjective Responses to Atmospheric Humidity. Environmental Research, 9, pp 66-75, 1975.

16. K. Buettner, Diffusion of Water and Water Vapor Through Human Skin. J. Appl. Physiol., 6, pp229 - 242, 1953-54.

17. A.T. Steegmann, Human Facial Temperatures in Natural and Laboratory Cold. Aviat. Space Environ. Med., 50 3, pp 227-232, 1979.

18. J. LeBlanc, B. Blais, B. Barabé and J. Côté, Effects of temperature and wind on facial temperature, heat rate, and sensation. J. Appl. Physiol. 40, 2, pp 127-131, 1976.

19. E.T. Renbourn, "A Contribution to the Physiology of Damp Cold. An Aspect of Temperate Climate. Part 2. The Chills of Damp Cold. An Historical Survey, UK 5. Presented at the 6th Commmonwealth Defence Conference on Clothing and General Store, Australia, 1959.

20. E.T. Renbourne, Materials and Clothing in Health and Disease, History, Physiology and Hygiene, Medical and Psychological Aspects. H.K. Lewis & Co. Ltd., London, 1972.

21. M.A. Persinger, Weather Matrix & Human Behaviour, Praeger Pubs., New York, 1980

22. Stephen Rosen, Weathering, M. Evans and Co. Inc., New York, 1979.

23. R.J.Osczevski, Delusions of Adequacy: Protective Clothing on Peacetime Military Exercises. Symposium on the Operation of Weapon Systems and Platforms in Harsh Environments held in Brighton, UK. 13 - 17 May 1985. Commonwealth Defence Science Organisation.

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM
(highest classification of Title, Abstract, Keywords)

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.)
DEFENCE RESEARCH ESTABLISHMENT OTTAWA
Department of National Defence
Ottawa, Ontario K1A 0Z4

2. SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable)
UNCLASSIFIED

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C,R or U) in parentheses after the title.)

WHY COLD-WET MAKES ONE FEEL CHILLED; A LITERATURE REVIEW (U)

4. AUTHORS (Last name, first name, middle initial)

CROW, Rita M.

5. DATE OF PUBLICATION (month and year of publication of document)
JUNE 1988

6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.)

6b. NO. OF REFS (total cited in document)

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

TECHNICAL NOTE

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant)
051LC

9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)

10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)
DREO TECHNICAL NOTE NO. 88-22

10b. OTHER DOCUMENT NOS. (Any other numbers which may be assigned this document either by the originator or by the sponsor)

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

(X) Unlimited distribution
( ) Distribution limited to defence departments and defence contractors; further distribution only as approved
( ) Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved
( ) Distribution limited to government departments and agencies; further distribution only as approved
( ) Distribution limited to defence departments; further distribution only as approved
( ) Other (please specify):

12. DOCUMENT ANNOUNCEMENT (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in 11) is possible, a wider announcement audience may be selected.)

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both offical languages unless the text is bilingual).

This paper reviews physiological experiments which have been carried out to determine if heat loss from the body is greater in cold-wet temperatures and humidities. It also reviews the effect of solar radiation the interaction of skin and humidity and skin and temperature and other postulations for the cold-wet sensation. It concludes that the best explanation for the chilling effect of cold-wet is the penetration of fine water-vapour aerosols into clothing which reduces its insulation. Experiments would be needed to confirm this.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

COLD-WET
PERCEPTION
PHYSIOLOGY
PSYCHOLOGICAL EFFECTS
LITERATURE SURVEY