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THE EVALUATION OF EXPERIMENTAL FABRICS AS ALTERNATES FOR STANDARD WOOL FABRICS

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Development of Alternate Fabrics to Conserve Wool

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SUMMARY

Mt. Washington Feasibility Test

A small scale field test has been carried out to assess the improvement in protection against cold that can be expected from using vapor barrier films over certain parts of the underwear of the standard combat cold weather ensemble. Of the clothing assemblies tested, those in which either the limbs or the torso of the underwear was covered by a vapor impermeable film showed promise in two comfort areas. Compared with an assembly in which the barrier covered the body more completely, they appeared to alleviate heat stress of the active soldier. They were also effective in providing additional insulation against chilling

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in comparison with the standard vapor permeable ensemble for men at rest in the cold. Assemblies in which the membrane covered only the armpits and crotch of the underwear did not appear to differ in behavior from the standard ensemble. These field tests were in agreement with previous laboratory findings on a clothed "sweating" cell in which partial coverage of the underwear with a vapor barrier produced improved resistance to chilling and a reduction of the overheating problem. In addition, the laboratory studies had shown that increased insulation in the assemblies was due to restriction of sweat moisture to the underwear layer so that the moisture could not penetrate the insulating layers immediately over the impermeable film. This type of moisture distribution in assembly layers was also found in the field, indicating that the same mechanism was in operation in the real case.

The field test plan involved sending the subjects around a prescribed walking course, to provide an exercise level which would result in moderate sweating, and then allowing them to sit at rest in the cold. The McGinnis scale method used for assessing the subjective sensations of the subjects was found to be most useful in evaluating overheating tendencies of the exercising men. On the other hand, finger temperature measurements were most successful in appraising the extent and speed of chilling of the men at rest. As would be expected, fluctuations in weather and individual differences in physiological response created some problems in isolating the main effects due to garment types. However, by using the finger temperature data in terms of a cooling curve "rating" technique, it was possible to remove most of the interaction effects of weather and subject. Both the experimental techniques and the data handling methods used in the test appear to have general value for other cold weather field studies of clothing comfort.

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DETAILS

A FEASIBILITY STUDY OF THE USE OF
MOISTURE IMPERMEABLE MEMBRANES FOR PARTIAL BODY
COVERAGE IN COLD WEATHER CLOTHING

A. Introduction

1. Laboratory Basis for the Study

Laboratory work on the insulation of cold weather garment assemblies (Reports 15 and 16) has indicated that increased thermal protection can be achieved by inclusion of a moisture vapor impermeable layer and that the effect is most pronounced when the impermeable layer is placed as close as possible to the skin side of the assembly. At the same time, adequate ventilation in these assemblies, placed over a heavily sweating cell, seems possible if some holes or gaps are left in the impermeable layer. Increased insulation in both cases is apparently due directly to the fact that moisture transfer from the skin surface is limited and thus the clothing is kept dry.

2. General Nature of the Proposed Field Study

It was proposed that a feasibility study of these principles in actual clothing on subjects under cold stress be tried. The test would consist of modifying the standard cold weather ensemble to include a thin impermeable layer and these ensembles would be worn in a cold outdoor environment. Comfort of the wearers would be assessed by means of finger temperature measurements and by means of the recently proposed "McGinnis" scale subjective method. A test cycle would be devised to provide vigorous exercise, sufficient to induce sweating of the subjects, followed by rest and hence chilling in the cold. The subjects and garments would be weighed to determine the amount of moisture collected by each garment item from perspiration during the test.

3. Main Purposes of the Study

It has been visualized that such a study could serve several purposes in a program aimed at obtaining more functional cold weather garment assemblies:

(a) First, a simple practical way in which to evaluate the results from laboratory tests is needed. Thus, such a feasibility study would become part of the larger program aimed at providing correlation between field and laboratory testing and would be particularly valuable because so little information is available in the area of clothing insulation and comfort.

(b) Specifically, it is important to determine whether the use of partial body coverage with a water vapor impermeable membrane does result in a more comfortable cold weather garment assembly as indicated in the laboratory experiments.

(c) Finally, it is valuable to learn how McGinnis scale subjective rating and finger temperature measurements correlate in assessing "heat stress" and "chilling" sensations of a clothed subject.

4. The Plan of Operation

A formal plan for such a feasibility study was drawn up. Those concurring in its formation included Messrs. R. Woodbury and J. Vanderbie of the Operations Programming Office, Mr. T. Bailey who took charge of having the experimental underwear prepared, Dr. McGinnis and Lt. V. Allen of the Human Resources Branch, E.P.D., who were responsible for subjective testing, Mr. L. Weiner and Mr. C. Monego of the Textiles Engineering Laboratory and Mr. E. A. Snell who coordinated arrangements with the Field Evaluation Agency at Fort Lee.

A tentative test plan was submitted to FEA in October, 1955, and a final plan in December, 1955. Thence the test became FEA 55103, entitled "Underwear, Experimental, Representing Various Amounts of Moisture Impermeable Material," to be performed in the vicinity of the Agency's Mt. Washington test site. According to the plan, the FEA would supply 6 test subjects and 3 administrative assistants plus all clothing except the experimental underwear. Full support in setting up and equipping the test site was also to be supplied. Finger temperature measuring equipment was to be provided by these laboratories, while the experimental underwear data recording gear would be obtained from the Natick laboratories. The final test starting date was set for February 13, 1956.

B. Experimental

1. Preparation of the Test Site

After examination of a number of areas near Mt. Washington, an advance party of six finally selected the Glen flats at the base of the mountain as the most appropriate test site. A figure eight walking course one mile long was laid out with the aid of a weasel for packing down the snow. At the cross of the figure eight a Janesway hut was set up to be used as a clothes changing shelter as well as to house the scales and recording equipment. With the aid of the base camp meteorologist, a weather station was set up just outside the Janesway hut to measure air temperature (thermograph), radiation temperature (globe thermometer), and wind velocity (ML-80 anerometer). Adjacent to the weather station a bench was placed on which subjects could sit during the cooling portion of the experimental run. At the base camp a hut was provided in which the garments used in each test run could be dried. Test personnel and technical assistants were housed at the base camp.

2. Cold Weather Garments Used

The experimental underwear consisted of standard upper and lower garments to which a thin Mylar sheet was sewn covering various portions of the body, as indicated in Table 1. The underwear types with complete coverage, D, and no coverage, E, were included as controls to aid in determining what range of comfort factors might be assessed by the experimental techniques adopted. Underwear of all 5 types was provided for each test subject.

Other clothing in the ensemble consisted of standard items; shirt, trousers, socks, boots, leather gloves with wool liners, overpants, field jacket without liner, and a winter field cap. Each man was provided with two complete sets of these items, one for morning and one for afternoon runs, and they were worn only during the course of the run, as described in the next section.

3. The Test Procedure

Prior to the test, all subjects were given an orientation sheet (Exhibit A - Appendix) to familiarize them with the general outline of what they were expected to do. In response to a question of how long they would be expected to sit out in cold (item 3), they were told that a fixed time would be chosen for all men which would be not too severe for the man who chilled the most. It was found necessary to reemphasize the "no smoking" requirement on a number of occasions.

At the beginning of each test day the subjects selected the appropriate underwear and outerwear clothing items from the storage racks in the drying hut and then they were transported by truck to the test site shelter. While the subjects rested quietly within the shelter, all clothing items to be worn by each man were preweighed by technical assistant #1. These weights were recorded on the test data sheet for each subject (Exhibit B - Appendix) and indeed all recording operations were continued on the same sheet until the end of that run.

While this was being carried out, technical assistant #2 took weather readings outdoors to ascertain a suitable starting time for the first man. The first man was then weighed nude and, after donning the test garments, proceeded outside for a ten minute rest period before starting the walking course. Near the end of this period technical assistant #2 made a reading of the finger temperature of this first man using a small thermistor element which could be held between the thumb and index finger. Simultaneously, the first subject was questioned by the psychologist concerning his feeling of comfort using the McGinnis scale (Exhibit C - Appendix). The man then set out to walk the course, timing himself from markers set at 5 minute intervals along the way. This whole procedure was repeated with each man at five minute intervals until all were out walking the course. Weather readings were continued at regular intervals.

As each man crossed back near the shelter after completing the first loop, his comfort was again rated using the McGinnis scale mounted on a large board, which the test subject could see as he approached. On completion of the course his subjective sensations were again rated and then he sat on the bench outside the shelter for the cooling portion of the run. Finger temperatures were taken approximately every 10 minutes and further subjective ratings approximately every 20 minutes. At the end of 40 minutes of total cooling, or 50 minutes on the warmer days, the subjects then proceeded back into the shelter. There they were weighed with and without clothes and the test garments were reweighed. After the last man had completed his chilling run, all were transported back to the base camp and the test clothing hung up to dry. The whole procedure was repeated in the afternoon.

4. The Experimental Design

An attempt was made to randomize the distribution of different underwear types between subjects on successive test days. The underwear samples were used in such an order that each set had at least 48 hours to dry between successive runs. The final experimental design used is given in Table 2, showing the distribution of the 5 underwear types among 6 men for 12 runs. The test was called off on the afternoon of the fifth day because of heavy snow. This resulted in some imbalance of plan not entirely corrected by an additional run on the morning of the seventh day. However, each underwear type was worn at least 14 times.

C. Results in General

1. Variations in Weather

One of the reasons the Mt. Washington test site is valuable for winter field testing is based on the constancy of weather conditions, and indeed a survey of the camp records indicated that weather during the period of this test was unusually uniform. However, there were some variations from day to day and also between morning and afternoon runs, and these are indicated by the weather summary in Table 3. For the purposes of evaluating the effect of the weather on comfort factors of the test, the test periods were classified as "cold," "moderate" and "warm." This classification was based on a broad inspection of the consummate effects of temperature, sun, and wind for each day. As will be seen in later examination of the data, the decision to obtain weather readings right at the site of the test was well justified.

2. Typical Response of a Subject to Exercise and Chilling

As an indication of the type of comfort information that was obtained over the course of the test, the finger temperature and McGinnis scale data are summarized for Subject 2 in Table 4. Several types of behavior which occurred with all of the subjects are noteworthy. From the beginning of the course to the end, the finger temperature and McGinnis scale ratings rose appreciably, indicating the extent of heating resulting from walking rapidly through the snow. Subsequently, during the rest period, the finger temperatures and McGinnis ratings decreased, in some instances to quite a low level after 50 minutes of cooling. This general type of behavior was noted for all subjects on all days irrespective of the garment assembly worn.

A closer examination of the McGinnis and finger temperature values showed that there was not a one to one correspondence between the two systems and that this was apparently due to the difference in sensitivity of the two methods in the warm and cold regions. Although the finger temperature method was very sensitive to chilling differences between men on cold and warm days, the McGinnis scale readings in the chilling period tended to approach the same values, i.e., a rating of 3 or 4 for most cases.

On the other hand, the finger temperature method tended to rate the warm sweating men quite similarly as would be expected as the skin approached deep body temperature. In some instances the sweat produced caused the temperature sensing resistor to be "shorted" slightly. This resulted in some apparently high finger temperature readings, greater than 35°C. as for example in the 4 AM run of Table 4. On the other hand, the McGinnis scale rating technique appeared to be at its best in the warm-hot comfort range as is discussed in the next section.

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3. McGinnis Scale Ratings as a Measure of Heat Stress

The McGinnis scale values taken immediately after the men had completed walking the course were classified according to weather (Table 3), and these results are shown in Table 5. Under "cold" conditions all of the assemblies kept the wearers comfortable while exercising, while under "warm" conditions all men, except those wearing the control underwear with no vapor barrier, tended to get fairly hot after walking a mile in the snow. The days of "moderate" weather tended to give the best differentiation between the assemblies as indicated by McGinnis scale ratings. Assemblies with underwear samples C and E showed no tendency for overheating, while those with A and B samples showed only slight overheating, and the ensemble containing D showed severe heat stress. These assemblies were thus rated in order of the body coverage by impermeable film, the greatest coverage giving highest heat stress, as shown in earlier laboratory studies. No appreciable difference between assemblies with underwear types with limb coverage (A) or torso coverage (B) was noted.

Some comment should be made on the statistical significance of these figures. Taking all the data, one can clearly demonstrate the extreme differences between assembly E - full coverage - and assemble E - no coverage - but in general it is difficult to sort out the remaining assemblies on this basis other than they are nearer to behavior of E than D. In general there are too few runs in each weather category to make a similar analysis worthwhile on this basis, but indications from the average values of the McGinnis ratings and finger temperature results discussed later give a very consistent picture of the behavior of these experimental assemblies under real conditions.

4. Moisture Collection in Different Clothing Types

It was possible, in the laboratory examination of clothing assemblies in which a vapor impermeable membrane was used, to determine how the flow of moisture from the sweating skin was altered by the presence of the membrane. Indeed restriction of moisture from the insulating layers of these assemblies was offered as the most likely explanation of the improved insulating value of this clothing design.

Weight changes in the underwear (1st) and neighboring layer (2nd) of the cold weather ensembles were obtained during the course of feasibility runs. This evidence is summarized in Table 6 for all assembly types and under the three classes of weather encountered. Unfortunately weight changes in the outermost layers were complicated by snow on many of the uniforms so this information was not included.

Moisture collection in the underwear was small in cases C and E, moderate in A and B and large in type D, again in proportion to the area of the body covered by the impermeable membrane. For example, with underwear type B in which only the upper garment was covered with a film, 5 to 20 times as much water was caught in this section as in the uncovered lower half of the underwear. These effects were most pronounced in runs made on "warm" days, indeed very little sweating occurred in some assemblies on the "cold" days. Thus, clearly, as in the corresponding laboratory experiments, body moisture was collected beneath the impermeable membrane in proportion to the area covered.

Moisture transferred to the second layer (and presumably to layers further out) was therefore hindered by the underwear sections having a plastic membrane, as is clearly shown in Table 6. Indeed for the assembly using "completely covered" underwear D, there was some drying of the outer layers during the course of the experiment, as shown by the negative moisture values. Greatest moisture transfer to the second layer occurred in the assemblies with little or no membrane, C and E respectively, particularly in runs on "warm" days. Overall transfer to the 2nd layer of assemblies containing underwear types A and B was, for the most part, small, an agreement with laboratory findings. The general level of moisture pickup by the outer layers in the field runs was not as large as in the laboratory, presumably because the sweating was not nearly so severe, and there was no opportunity to weigh the garments immediately after the exercise period. These data clearly showed, however, that partial coverage of the body with a water vapor impermeable film over the underwear layer could lower the collection of sweat in outer garments. In addition, little tendency was shown for the moisture to transfer from wet (membrane covered) to dry (membrane uncovered) areas in the same underwear sample.

5. Finger Temperatures of Chilled Subjects

The finger temperature cooling curve of a man under cold stress is not a simple function and often defies direct analysis in terms of a single representative temperature reflecting the overall response. However, as has been done in laboratory work, the lowest temperature reached can be used as a rough indicator of the insulating power of the garments used.

In Table 7 are summarized the average lowest finger temperature values for the field runs classified according to underwear type and weather. In general there was least temperature fall with the assemblies containing fully membrane covered underwear D. Greatest temperature drop in runs on "warm" and "moderate" days occurred in assemblies C and E. All final finger temperatures were low on the cold days, indicating again the rather large effect of weather conditions on the results obtained. If, for this analysis, we accept the grand average as the best indication of the relative effectiveness of these assemblies as insulators, then the partial coverage systems A, B, and C fall between the least insulating sample, E, and highest insulating sample, D. The underwear with either limbs (A) or torso (B) areas covered by a membrane show slightly greater total chilling than the complete coverage control (D). On the other hand, the sample covered only at armpits and crotch chilled almost as far as the no membrane control (E).

Clearly then, from the resistance shown to overheating (Table 5) and from the maintenance of insulation (Table 7), the cold weather assemblies containing underwear with extremities in a membrane cover (A) and torso covered (B) would both be possible types of improved functional design. The tendency for the pants in outer layers of type B (Table 6) to collect moisture might have to be considered further if severe sweating or chilling were encountered.

D. Cooling Curve Rating as an Index of Chilling

1. The Rating Method

A number of attempts were made to treat the finger temperature cooling data in an analytical fashion that would result in a useful chilling index. These were found to be difficult to handle because of the strong interaction of weather and subject sensitivity with those differences brought about by the cold weather assemblies themselves. Concern was also expressed over the fact that the exact time of fall-off in these finger temperature curves could have been missed in the 10 minute interval between readings. In addition, short time fluctuations of skin temperature due to the body heat regulating mechanism could also lead to a source of error. Reference was then made to earlier chilling experiments in which temperatures had been used as a cooling index.

In the experiments carried out in the Philadelphia Q.M. Depot Cold Rooms in 1954, finger temperature readings were taken approximately every four minutes, with results of the type shown in Figure 1. (For a more detailed description see Report 13, p. 12-15.) In this work, shirts of different types were compared on lightly clad men lying at rest in a cold room at 60°F. From the rates of chilling and final finger temperatures it was estimated that the cold stress on these men was not greatly different from the men in the Mt. Washington test. Hence it was possible to draw some general conclusions from the curves of Figure 1 which could apply to the field test finger temperature curves.

These detailed cooling curves indicated first of all that the short time fluctuations did not seriously depart from the general form of the cooling curve. Secondly, a set of points chosen with ten minute intervals represented the general shape of the curves quite accurately. Differences in response between individual subjects were found to be quite important in interpreting the results. In addition, these studies showed that the sudden drop off of the cooling curve was most closely related to the sensation of chilling recorded by the subjects.

Thus a study of these earlier runs suggested that it might be possible to relate the finger temperature cooling curves of the present test to some sort of chilling index which would make use of all of the experimental points. Ratings were chosen from 1 to 6 and, to conform with the McGinnis scale convention, a low index was chosen to represent an abrupt cooling cycle. Three curves from the Mt. Washington runs are given in Figure 2 along with assigned ratings showing the ranges chosen. A curve with no temperature drop off would be rated 6.

A subjective rating of all the curves was tried in which the suddenness of cooling, the temperature level of cooling, and the extent of cooling were all considered. The results for two independent judgments of all the curves are shown under S-1 and S-2 in Table 8. Certainly it appeared that an unambiguous rating of the curves was possible. As these ratings corresponded most closely to visual integration of the areas under each curve, the areas were calculated separately. These areas were then divided into six groups to correspond to six rating classes into which all the cooling curves could be placed. The results for two area-rating divisions are given under I-1 and I-2 in Table 8. The overall agreement with subjective rating was remarkably good. Thus this general technique for using all the finger temperature data from the cooling portion of the feasibility runs appeared to warrant further consideration. Classification of the rating data in terms of weather, subject, and cold weather assembly was accordingly attempted.

2. Cooling Curve Rating and Its Relation to Weather

In connection with classification of the finger temperature cooling curves according to weather, an attempt was made first to devise a single index which would lump the various weather elements of wind and radiation together. Quite a number of "exposure indices" have been proposed by various workers, including the "wind-chill" index of Siple developed from measurements in the Antarctic. One of the most complete approaches to this problem has been worked out by Dr. A. C. Burton of the University of Western Ontario Medical School. In a paper before the Fourth Commonwealth Defense Conference on Clothing and General Stores in 1953, he presented a discussion on "Assessment of the Thermal Demand of the Environment". This included charts for calculating the equivalent still shade temperature from air temperature, cloudiness, and wind velocity values. Using his charts and assuming that the resting men in the cooling portions of the tests had a metabolic activity of about 1 MET, the weather data from the Mt. Washington test site was reexamined.

From the wind velocity and metabolic activity the "Thermal Wind Decrement", or adjustment for exposure to wind, was calculated. From the difference between the temperatures of the globe and air thermometers, a cloudiness value was estimated for each run period. The cloudiness values and wind velocities were then used to calculate the "Thermal Radiation Increment", using Burton's scale for khaki-colored clothes.

A summary of this work in which the raw weather data were normalized by correcting for differences in wind and radiation is given in Table 9. By comparing these figures with the average raw weather data (Table 3), several interesting facts can be observed. In general, the effect of wind on the equivalent temperature was quite sizable and not in general balanced by the radiation contribution, except on bright moderately still days, e.g., 4 A.M. More often the corrections for radiation were about half those for wind and, being opposite in sign, only partly cancelled the effect of the wind. On cloudy days the effect of radiation was, as one would expect, small, e.g., 6 P.M. In general, the values of equivalent still shade temperature over the course of a run remained quite constant.

The still shade temperatures were listed in order of increasing value in Table 10. It was interesting to find that the still shade values divided the runs into three classes corresponding to the "cold", "moderate", and "warm" divisions of Table 3. The cooling curve ratings for each run (Table 8) were then added up for each run period and also listed in Table 10. Not only did the cooling curve rating technique divide the runs according to the same three weather classifications but placed each, as with the still shade temperatures almost exactly in order of increasing value. Clearly, the cooling curve rating technique could distinguish the effects of weather on the chilling of the men with some precision. This provided, then, a possible approach for removing the weather influence from the results where comparisons of the insulation of the different cold weather assemblies was involved.

3. Chilling Sensitivity Differences between Subjects

The tendency for some of the test subjects to cool more easily than others was apparent as the runs progressed, and indeed quite large differences in response are not uncommon in physiological testing. Accordingly, the cooling curve ratings were classified according to the subject and these results are summarized in Table 11.

The curve ratings have been listed according to the number of curves in each rating category. Clearly subjects 3 and 5 experienced more curves of low rating than high, while subject 2 tended to give high rating curves. This was borne out also in the rating totals given in the last column of the table. Thus, subjects 3 and 5 were more sensitive to cold while wearing an average assembly on an average day, while subject 2 tended to be least sensitive of the group studied. It is interesting to note that subject 6 had very broad distribution of curve ratings, indicating quite a different type of subject sensitivity altogether. In general it was evident that a single figure rating technique oversimplifies the problem of comparing people's physiological responses with one another. In any case, the subject classification of ratings is a first approximation toward bringing the responses of each to the same base level for comparison purposes.

4. Average Rating as a Measure of Clothing Insulation

A comparison could also be made of the effectiveness of insulation of the cold weather assemblies employing the different underwear samples by using the cooling curve rating technique. Such a comparison has been made in Table 12, using the frequency of distribution of the curve types as in the previous table. The distribution figures and the total rating values indicate that low rating curves are most common in runs with assemblies of type C and type E. On the other hand, high rating curves are most prevalent with the assemblies employing underwear type D. Distribution of curve types for the assemblies with underwear A and B are very broad but the total rating values lie between the extremes of the other types.

An examination of the average rating values for all assemblies in each underwear type shows that they fall into the same three groups as were observed earlier in low finger temperature data (Table 7). The three groups are:

greatest chilling - types C and E

moderate chilling - types A and B

least chilling - type D.

These again correspond inversely to the area of the impermeable membrane used in covering the underwear. Statistically, the averages for assemblies A and B have little significance because of the widespread distribution of curve rating types for each. However, the effects of weather and subject sensitivity are large effects (cf. Tables 10 and 11) nd tend to mask the differences due to assembly type. It is worthwhile, therefore, to try to remove these extraneous influences using the curve rating technique so as to define,more clearly, the garment effects.

5. Improved Ratings by Adjustment for Weather and Subject

Average cooling curve ratings for each run period were calculated by dividing the sum values in Table 10 by the number of subjects and these are listed in Table 13. Similarly the average cooling curve ratings for each test subject were calculated from the total rating figures in Table 11 divided by the total number of run periods and these too are given in Table 13.

In order to normalize the effect of weather and subject variations on the cooling curve rating of a single run, the average values in Table 13 were considered in reference to an average cooling curve rating of 3. For example, if the weather average on a certain day, say 1 A.M., was 2.6 then 0.4 would have to be added to the individual curve ratings to correct for the weather effect, Similarly if the particular subject tended to cool with an average rating of 3.2 (#1 in Table 13), then 0.2 would have to be subtracted from the individual cooling curve ratings for that subject to normalize for the difference in subject response.

The cooling curve ratings of all 72 runs were accordingly readjusted in this manner and then classified again according to garment assembly as shown in Table 14. Corrections for weather and subject definitely narrowed the distribution of curve classes for each assembly (cf. Table 12), although average ratings were not greatly changed. Cooling was apparently most sudden with the assemblies having little or no impermeable membrane over the underwear layer (C and E), while the slowest cooling was observed with assembly D, with a membrane over both upper and lower underwear garments. The assemblies with underwear B, in which only the upper underwear garment was covered with a water barrier film, produced only moderate chilling of the test subjects. This was clearly better behavior than

C but not as good as D. The experimental assembly with the arms and the legs of the underwear covered with the vapor barrier (type A) gave a wide variety of cooling curve types. This could possibly be due to a change in physiological response of the body from having the arms and legs kept warm or perhaps the variation was related to whether or not the subjects held their arms close to the body during the cooling test. Apparently a few more cooling runs with this particular sample would have been particularly valuable in distinguishing it more clearly from the other experimental types used. On the average, however, the assembly of this type was still in an intermediary range in its overall chill protection value. Certainly all the methods tried tended to rate the thermal insulating value of the assemblies in the same order.

E. Conclusions

In summarizing what has been learned from this "feasibility" field test, it is important to consider the findings in terms of the original goals outlined in the introduction. Starting with one of the specific aims, how finger temperature and subjective McGinnis ratings correlate to give a measure of comfort in cold weather clothing studies, a number of conclusions can be drawn:

(1) Although the overall response of the methods to heating and chilling is roughly the same, an exact correlation between the two is not possible. This apparently arises mainly from the fact that the McGinnis scale is sensitive in the comfortable to hot range where finger temperatures approach a constant value and the finger temperature method is sensitive in the chilly to cold range where the cold men do not appear to distinguish different degrees of cold sensation, at least in this test situation.

(2) It appears then that the two methods for comfort evaluation in such

clothing studies are complementary in their action and hence both are very valuable in the overall analysis. Possible improvements in these techniques are discussed in the next section.

The second specific aim of these studies was to determine whether the general results of cold weather garment assessment, found in the laboratory for assemblies containing an impermeable membrane, would hold for real garments in practical tests on subjects. Good agreement has been found in at least three areas:

(1) The use of partial body coverage with a water vapor impermeable membrane placed on the underwear layer reduces appreciably the tendency for heat stress on an active body, compared with assemblies with a completely enveloping impermeable layer.

(2) The same type of partial coverage is apparently successful in reducing the chilling tendency of the wearer at rest in the cold in comparison with the present permeable multilayer ensemble, as was also predicted in laboratory trials.

(3) The role played by the membrane in restricting the passage of perspiration to the outer insulating layers is apparently the same in field practice as on the laboratory scale.

Finally, the experimental test program has indicated a number of things about general field testing of cold weather clothing which are worth considering in future work, e.g.,

(1) A simple "sweat" and "chill" test of this type is feasible with very little modification in present field practice procedures. The finger temperature measuring and subjective chart techniques are simple and rapid and easily adapted to the specific needs of this type of field testing. Certainly elimination of the skin temperature harness provides greater facility in handling

garments, test subjects, and test variations.

(2) For the comparison of cold weather ensembles in which the differences between assemblies are small, a cold room controlled environment test seems advisable because of the rather large influence of the weather on this type of testing. The problems of differences in the response of individuals to heat stress and chill are, of course, not solved by going to cold room studies, but the chances are much greater that this complex variable can be evaluated under controlled climatic conditions. The alternative in this testing would be to use more men and to run the test longer, both expensive changes and more difficult to administer. However, the techniques used for weather analysis in this report appear to be sufficiently powerful that data from a large scale test could be handled adequately.

There is another area which deserves some comment in discussing the conclusions from this feasibility test. The careful planning and successful completion of this test was a direct result of close and complete cooperation provided by the personnel of the different agencies and Quartermaster divisions involved. Continuation of this new material evaluation and clothing design program will be greatly aided by further tests of this cooperative type.

F. Proposals for Future Work

The specific results of this feasibility test suggest that "partial coverage" cold weather garment systems employing a water vapor impermeable membrane should be looked at in greater detail, both in the field and in the laboratory. It would appear that some of these specific systems such as the assembly with torso coverage (B) or limb coverage (A) should be examined further in controlled cold chamber studies on men. In addition, practical ways should be sought to apply the vapor barrier principle to present clothing items, for example in the preparation of a plastic coated underwear garment with the proper areas sealed from moisture.

In the area of general cold weather testing, it appears that the finger temperature method using a thermistor element for assessing chilling could be used much more effectively and accurately in conjunction with a portable recorder. A similar element for estimating water content of the clothing layers would also be valuable. Two such elements are being developed by the American Instrument Co. and the Minneapolis Honeywell Regulator Co. It is apparent also that an improvement in the McGinnis subjective method at the cold end, for example, by expansion of the scale would be of considerable aid in verifying the general results obtained by skin temperature measurements.

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TABLE 1, REPORT 20

UNDERWEAR VARIATIONS IN COLD WEATHER GARMENT ENSEMBLES[a] USED IN MT. WASHINGTON FEASIBILITY TEST

Assembly Designation	Portion of Underwear Covered with a Water Vapor Impermeable Membrane
A	Arms and legs
B	Torso (upper garment excluding arms)
C	Crotch and armpits
D	Complete (all of upper and lower sections)
E	None (Standard Underwear)

[a] The other garments used in the cold weather ensemble were shirt, trousers, over-pants, field jacket with no liner, gloves with wool liners, and winter field cap.

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TABLE 2, REPORT 20

FINAL EXPERIMENTAL DESIGN
MT. WASHINGTON FEASIBILITY TEST

Date	Day	Period	Underwear Type Worn by Subject					
			1	2	3	4	5	6
2/14/56	1	AM	D	B	E	C	A	A
		PM	A	E	D	B	C	D
2/15/56	2	AM	E	C	B	A	D	B
		PM	B	A	C	D	E	C
2/16/56	3	AM	A	E	D	B	C	D
		PM	C	D	A	E	B	E
2/17/56	4	AM	B	A	C	D	E	C
		PM	D	B	E	C	A	A
2/18/56[a]	5	AM	C	D	A	E	B	E
2/19/56	6	AM	D	B	E	C	A	A
		PM	E	C	B	A	D	B
2/20/56	7	AM	B	A	C	D	E	C

[a] No runs were made on the afternoon of the fifth day because of heavy snow.

TABLE 3, REPORT 20

WEATHER VARIATIONS - MT. WASHINGTON
FEASIBILITY TEST

Average Values of Temperature and Wind Velocity

Day and Period	Air Temperature °F	Radiation Temperature °F	Wind Velocity mph
		I. Called "Cold" Days	
3 AM	16.1	21.2	14.8
3 PM	20.2	27.0	9.4
5 AM	19.9	22.0	9.4
		II. Called "Moderate" Days	
6 PM	27.0	30.8	10.7
6 AM	26.0	40.8	14.2
4 AM	15.0	41.0	2.9
4 PM	25.1	31.6	2.8
7 AM	26.8	39.3	4.1
1 AM	31.2	47.3	8.0
		III. Called "Warm" Days	
2 PM	38.1	39.5	5.4
1 PM	36.5	45.5	4.1
2 AM	37.2	45.0	3.0

~~LIMITED USE DOCUMENT~~

TABLE 4, REPORT 20

MT. WASHINGTON FEASIBILITY TEST
SUBJECT #2. FINGER TEMPERATURE AND McGINNIS SCALE DATA

Day & Period	1 AM			1 PM			2 AM			2 PM		
Underwear	2-B			2-E			2-C			2-A		
	time	°C	MS	time	°C	MS	time	°C	MS	time	°C	MS
St.Course	9:25	27.3	6	2:05	30.7	6	9:55	35.2	6	2:10	32.5	6
End Course	9:57	36.9	10	2:40	34.0	9	10:26	34.0	10	2:41	31.7	11
Cooling	12	33.7		10	33.5		10	33.0		10	30.8	
time	22	29.3		20	32.0	5	19	33.7	7	20	31.2	5
	31	28.1		29	32.0		29	33.0		33	31.4	
	41	28.1		39	25.3	5	39	30.9	5	43	30.7	5
	46	23.7	3	49	24.4	4	49	29.1	5	48	27.9	4

Day & Period	3 AM			3 PM			4 AM			4 PM		
Underwear	2-E			2-D			2-A			2-B		
	time	°C	MS	time	°C	MS	time	°C	MS	time	°C	MS
St.Course	9:40	20.1	4	2:10	25.4	4	9:47	30.5	6	1:50	33.0	7
End Course	10:08	31.5	9	2:38	30.8	10	10:15	34.0	9	2:18	37.1	10
Cooling	9	26.5		13	25.6		8	30.0		9	36.7	
time	19	27.6	4	22	18.8	4	18	32.0	4	19	32.2	5
	29	16.1		32	12.8		28	20.8		29	28.8	
	40	11.9	3	40	11.8	3	38	14.4	3	39	29.3	4
										49	19.1	4

Day & Period	5 AM			6 AM			6 PM			7 AM		
Underwear	2-D			2-B			2-C			2-A		
	time	°C	MS	time	°C	MS	time	°C	MS	time	°C	MS
St.Course	10:20	27.6	5	9:25	27.6	6	2:20	30.4	7	9:20	28.8	7
End Course	10:50	31.2	9	10:03	31.7	10	2:55	32.5	10	9:55	33.2	10
Cooling	11	29.1		10	29.3		15	30.7		13	33.5	
time	21	27.0	4	21	27.6	6	26	26.5	4	23	31.2	5
	32	22.9		31	24.4		37	17.7	3	33	30.1	
	38	16.4	3	39	25.1	5	48	11.6	3	43	28.6	5
				50	19.0	4				50	25.1	5

LIMITED USE DOCUMENT

TABLE 5, REPORT 20

McGINNIS SCALE RATINGS IMMEDIATELY
AFTER COMPLETING COURSE

Weather	Run	McGinnis Ratings for Assemblies with Underwear[a)] A	B	C	D	E
"Cold"	3 AM	8	7	7	7,8	9
	3 PM	6	9	8	10	4,8
	5 AM	8	8	10	9	8,8
	Averages	7.3	8.0	8.3	8.5	7.4
"Moderate"	6 PM	11	8,10	10	10	10
	6 AM	10,11	10	10	11	9
	4 AM	9	8	6,8	11	7
	4 PM	8,10	10	8	10	7
	7 AM	10	9	9,9	12	8
	1 AM	10,11	10	8	11	8
	Averages	9.2	9.3	8.5	11.9	8.2
"Warm"	2 PM	11	11	9,10	10	9
	1 PM	10	8	12	11,12	9
	2 AM	9	11,11	10	11	7
	Averages	10.0	10.2	10.2	11.0	8.3

a) In these underwear samples the impermeable membrane was placed over: A - limbs, B - torso, C - armpits and crotch, D - all areas, E - none of the areas.

LIMITED USE DOCUMENT

TABLE 6, REPORT 20

MOISTURE DISTRIBUTION IN THE FIRST AND SECOND CLOTHING LAYERS AT THE COMPLETION OF THE CHILLING EXPERIMENTS[a]

Underwear in Assembly (Impermeable)		Weather "Cold"		Weather "Moderate"		Weather "Warm"	
		shirt %	pants %	shirt %	pants %	shirt %	pants %
A (limbs)	1st layer[b]	0.0	1.8	5.7	7.5	6.4	7.5
	2nd layer	0.0	-0.1	0.3	0.1	1.4	0.6
B (torso)	1st layer	6.2	1.6	8.8	0.7	10.7	1.2
	2nd layer	0.1	0.5	0.1	0.5	0.3	0.5
C (armpits, crotch)	1st layer	0.0	0.7	0.9	1.3	1.3	2.4
	2nd layer	0.7	0.4	1.1	0.4	0.8	1.2
D (all)	1st layer	7.8	3.9	16.7	12.0	15.7	14.5
	2nd layer	-1.1	-0.8	-0.8	-0.6	-1.9	0.3
E (none)	1st layer	0.2	0.2	0.5	0.9	1.1	2.2
	2nd layer	0.7	0.4	0.7	0.5	0.7	1.0

a) Average values for all men based on initial weights of individual clothing items.

b) 1st layer - underwear, 2nd layer - shirt and serge trousers.

TABLE 7, REPORT 20

AVERAGE LOWEST FINGER TEMPERATURE VALUES
OBSERVED AT THE END OF THE COOLING PERIOD

Underwear in Assembly	Weather "Cold" °C	Weather "Moderate" °C	Weather "Warm" °C	Grand Average °C
A	12.2	15.2	24.9	17.4
B	8.5	15.2	28.0	17.2
C	8.5	13.6	23.0	15.1
D	15.1	18.4	26.2	19.9
E	11.0	12.9	21.1	11.3

LIMITED USE DOCUMENT

TABLE 8, REPORT 20

COOLING CURVE RATING - A COMPARISON OF SUBJECTIVE AND INTEGRAL METHODS

Curve Number	Subjective S-1	Subjective S-2	Integral[a] I-1	Integral[a] I-2	Curve Number	Subjective S-1	Subjective S-2	Integral[a] I-1	Integral[a] I-2	Curve Number	Subjective S-1	Subjective S-2	Integral[a] I-1	Integral[a] I-2
1	3	4	4	3	25	1	2	1	1	49	1	1	1	1
2	3	3	2	2	26	2	2	3	3	50	3	3	2	2
3	2	3	3	3	27	3	3	3	3	51	2	1	2	2
4	1	1	2	2	28	1	1	2	2	52	1	1	2	2
5	2	1	2	2	29	1	2	3	3	53	5	5	5	4
6	2	3	3	3	30	3	3	4	3	54	5	5	6	5
7	4	4	3	3	31	6	6	5	5	55	1	1	1	2
8	3	5	6	5	32	3	4	4	4	56	2	3	4	3
9	3	3	3	3	33	6	6	6	5	57	1	2	2	2
10	3	3	3	3	34	3	4	3	3	58	6	6	6	5
11	2	2	2	2	35	6	6	6	6	59	5	5	5	5
12	6	6	5	4	36	6	5	5	5	60	3	4	4	4
13	5	6	5	5	37	1	1	1	1	61	5	5	5	4
14	1	1	1	1	38	1	2	2	2	62	3	3	3	3
15	1	1	1	1	39	3	2	2	2	63	6	6	5	5
16	5	3	3	3	40	5	5	5	4	64	3	2	2	2
17	3	3	3	3	41	1	1	2	2	65	3	4	3	3
18	2	3	3	3	42	4	5	5	4	66	6	5	4	4
19	4	4	4	4	43	3	4	3	3	67	3	3	3	3
20	6	6	4	4	44	3	3	3	3	68	1	1	1	1
21	1	2	2	2	45	6	5	4	4	69	5	5	4	4
22	1	1	1	1	46	2	2	2	2	70	3	2	3	3
23	3	5	5	4	47	3	3	3	3	71	6	5	5	4
24	1	1	1	1	48	1	3	2	2	72	6	6	5	5

a) Areas in C° min. under each cooling curve between 0 and 40 min. and down to 0°C were calculated. For I-1, integral values areas were rated <700=1, 700-900=2, 900-1150=3, 1150-1300=4, 1300-1400=5, >1400=6. For I-2, integral values areas were rated <750=1, 750-900=2, 900-1100=3, 1100-1250=4, 1250-1350=5, >1350=6.

LIMITED USE DOCUMENT

TABLE 9, REPORT 20

RADIATION AND WIND CORRECTIONS TO EXPOSURE CONDITIONS - MT. WASHINGTON FEASIBILITY TEST

Day and Period	Time	Air Temperature °F	Thermal Radiation Increment °F	Thermal Wind Decrement °F	Equivalent Still Shade Temperature °F
1 AM	9:[illegible]3	[illegible]	5	12	[illegible]
	10:03	[illegible]	5	[illegible]	[illegible]
	10:46	[illegible]	5	12	[illegible]4.5
	11:20	[illegible]	4	12	[illegible]
			Average Still Shade Temperature		24.9
1 PM	2:42	36.0	4	11	29.0
	3:25	36.0	2	11	27.0
	3:55	36.0	2	8	30.0
			Average Still Shade Temperature		28.7
2 AM	10:37	37.0	6	8	35.0
	11:07	39.0	4	10	33.0
	11:40	41.0	6	8	39.0
			Average Still Shade Temperature		35.7
2 PM	2:15	39.5	1	11	29.5
	3:27	36.0	2	11	27.0
	3:50	36.0	1	11	26.0
			Average Still Shade Temperature		27.5
3 AM	8:50	12.5	1	14	-0.5
	9:35	15.0	1	14	2.0
	10:10	17.0	1	13	5.0
	10:45	20.0	3	13	10.0
	11:05	20.2	3	13	10.2
			Average Still Shade Temperature		5.3
3 PM	2:45	21.0	3	12	12.0
	3:15	19.0	1	13	7.0
	3:40	18.0	1	12	7.0
			Average Still Shade Temperature		8.6

(Continued)

Continued
TABLE 9, REPORT 20

RADIATION AND WIND CORRECTIONS TO EXPOSURE CONDITIONS - MT. WASHINGTON FEASIBILITY TEST

Day and Period	Time	Temperature °F	Thermal Radiation Increment °F	Thermal Wind Decrement °F	Equivalent Still Shade Temperature °F
4 AM	9:35	12.0	11	8	15.0
	10:25	16.5	9	8	17.5
	11:10	[illegible]	9	10	20.5
			Average Still Shade Temperature		17.7
4 PM	2:30	25.0	4	10	19.0
	3:18	25.0	4	8	21.0
	3:26	25.0	4	8	21.0
			Average Still Shade Temperature		20.3
5 AM	10:37	19.5	1	12	8.5
	11:17	20.0	1	12	9.0
	11:45	20.0	1	12	9.0
			Average Still Shade Temperature		8.8
6 AM	9:57	26.0	2	13	15.0
	10:25	27.0	3	13	17.0
	11:12	27.0	3	14	16.0
			Average Still Shade Temperature		16.0
6 PM	2:30	27.0	1	13	15.0
	3:45	26.0	1	13	14.0
	4:09	27.0	1	13	15.0
			Average Still Shade Temperature		14.7
7 AM	9:50	26.0	3	11	18.0
	10:31	27.0	6	10	23.0
	11:00	28.0	9	8	29.0
			Average Still Shade Temperature		23.3

TABLE 10, REPORT 20

CLASSIFICATION OF TEST DAYS
ACCORDING TO WEATHER USING STILL SHADE
TEMPERATURES AND TOTAL COOLING CURVE RATING VALUES

Class of Day	Day and Run	Still Shade Temperature °F	Cooling Curve[a] Ratings, Sum
"Cold"	3 AM	5	9
	3 PM	9	9
	5 AM	9	10
"Moderate"	6 PM	15	14
	6 AM	16	15
	4 AM	18	15
	4 PM	20	19
	7 AM	23	18
	1 AM	25	22
"Warm"	2 PM	28	30
	1 PM	29	28
	2 AM	36	33

a) Sum of the ratings of all curves obtained on each test day. Actually values S-1 from Table 8 were used in calculating the sums although any other cooling curve rating of this table could have been used equally well.

LIMITED USE DOCUMENT

TABLE 11, REPORT 20

A COMPARISON OF SUBJECT TYPE
USING COOLING CURVE RATING VALUES

Subject Number	Number of Curves Having Rating						Total[a] Rating
	1	2	3	4	5	6	
1	4	0	3	2	1	2	38
2	0	2	3	1	4	2	49
3	5	1	4	0	2	0	29
4	2	3	2	1	0	4	42
5	6	1	3	1	0	1	27
6	1	2	5	0	1	3	43

a) Total ratings were calculated by multiplying the number of ratings in each rating class by the rating itself and adding these products together. This was equivalent to adding up all the cooling curve ratings for each subject on all days.

TABLE 12, REPORT 20

A COMPARISON OF GARMENT ASSEMBLIES CONTAINING DIFFERENT UNDERWEAR TYPES, USING COOLING CURVE RATING VALUES

Underwear Type Used	Number of Curves Having Rating 1	2	3	4	5	6	Total[a] Rating	Average[b] Rating
A	5	1	4	0	2	3	47	3.1
B	6	0	1	1	3	3	47	3.1
C	3	3	5	2	1	1	43	2.8
D	1	1	5	1	1	5	61	4.0
E	3	4	5	1	0	0	36	2.5

a) Assemblies with underwear types B, D, and E were worn 14 times and those with types A and C were worn 15 times. This total is normalized to 15 wearings.

b) The total rating averaged for 15 wearings.

TABLE 13, REPORT 20

COOLING CURVE RATING ADJUSTMENT
VALUES FOR WEATHER AND SUBJECT

Day and Period	Average[a] Rating	Subject Number	Average[b] Rating
1 AM	2.6		
1 PM	4.1	1	3.2
2 AM	5.5		
2 PM	5.0	2	4.0
3 AM	1.5		
3 PM	1.5	3	2.4
4 AM	2.5		
4 PM	3.1	4	3.5
5 AM	1.6		
6 AM	2.5	5	2.2
6 PM	2.3		
7 AM	3.0	6	3.5

a) Sum of the cooling curve ratings from Table 10 divided by the number of subjects, i.e., six.

b) Total cooling curve rating of Table 11 divided by the number of runs, i.e., twelve.

TABLE 14, REPORT 2?

GARMENT ASSEMBLY COMPARISON USING
COOLING CURVE RATINGS ADJUSTED FOR WEATHER AND SUBJECT

Underwear Type Used	Number of Curves Having Rating Ranges[a] 1.4 & less	1.5-2.4	2.5-3.4	3.5-4.4	4.5-5.4	5.5 & above	Average Rating
A	2	6	3	2	2	0	2.7
B	1	3	5	5	0	0	3.0
C	1	6	6	2	0	0	2.5
D	0	0	7	2	3	2	4.0
E	1	7	3	3	0	0	2.4

a) These ranges were chosen to correspond as closely as possible to the six ranges of Table 12.

APPENDIX REPORT 20

SUPPLEMENTARY CHARTS

Exhibit A. Orientation Sheet for Subjects

Exhibit B. Field Data Sheets

Exhibit C. McGinnis Scale for Subjective Assessment of Comfort

LIMITED USE DOCUMENT

EXHIBIT A

2 February 1956

FEASIBILITY STUDY OF
COLD - WEATHER CLOTHING

The study in which you are to take part is to explore ways of improving cold-weather clothing. The sweat produced by your body is picked up by the uniform's material and heat is lost more easily. You will wear undergarments with material so placed as to reduce the amount of sweat that gets to your clothing.

The value and success of this study will depend upon your cooperation and the accuracy of your observations.

As a test participant the following will be your job:

1. Upon arrival at test site, you will be given a set of test garments. We will weigh you and upon a given signal you will begin the walking course.

2. You will walk a measured course for approximately 45 minutes wearing a specific uniform.

3. After the exercise period you will be seated and finger temperatures will be taken periodically.

4. Throughout the test period, questions relative to your experience of comfort will be asked.

5. Following the rest period the test run will terminate by taking your weight and the weight of the test garments.

6. Two such runs will be conducted each day.

The success of this test will depend also on your cooperation in keeping your body in a rested and healthy state. We therefore ask you to refrain during this one week of testing from:

a. Use of alcoholic beverages
b. Smoking during the test hours

Furthermore; get a full night's sleep, have a good breakfast, and have a good lunch.

LIMITED USE DOCUMENT

DATA SHEET

EXHIBIT B

DATA SHEET

JOINT QMC-HRL
FEASIBILITY STUDY OF
COLD WEATHER CLOTHING

(1)

1. Name ____________________ Date __________

Code ______________ Test Starting Time __________

2. CLOTHING IDENTIFICATION

Underwear ______________ Other __________

3. PRECOURSE DATA

Weights

Time __________

Nude __________ Underwear
Shirt __________
Drawers __________

1st layer
Shirt __________
Trousers __________

2nd layer
Jacket liner __________
Pants liner __________

3rd layer
Jacket shell __________
Pants shell __________

Socks (pr) __________

Weight of man clothed __________

Temperature

Thermistor No. ________ Reading ________ Temperature ________

4. COURSE DATA

Time
Leaves tent ________ Starts course ________ Finishes course ________

Other __________

Weights

Weight of man clothed __________ Time __________

QMRD Form OT-36
30 Jan 1956

Continued
EXHIBIT B

DATA SHEET   DATA SHEET

JOINT QMC-HRL
FEASIBILITY STUDY OF
COLD WEATHER CLOTHING

(2)

5. POST COURSE DATA

Temperature

Time	Thermistor No.	Reading	Temperature
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________

Weights

Weight of man clothed ________ Time ________

Underwear Layer
Shirt ____
Drawers ____

1st Layer
Shirt ____
Trousers ____

2nd Layer
Jacket Liner ____
Pants Liner ____

3rd Layer
Jacket Shell ____
Pants Shell ____

Weight of man nude ________

6. COMMENTS

~~LIMITED USE DOCUMENT~~

EXHIBIT C

McGINNIS SCALE

I AM:

1. SO COLD I AM HELPLESS
2. NUMB WITH COLD
3. VERY COLD
4. COLD
5. UNCOMFORTABLY COOL
6. COOL BUT FAIRLY COMFORTABLE
7. COMFORTABLE
8. WARM BUT FAIRLY COMFORTABLE
9. UNCOMFORTABLY WARM
10. HOT
11. VERY HOT
12. ALMOST AS HOT AS I CAN STAND
13. SO HOT I AM SICK AND NAUSEATED

Figure 1, Report 20.

Finger Temperature Cooling Curves, Philadelphia Q.M. Depot Cold Room, June, 1954

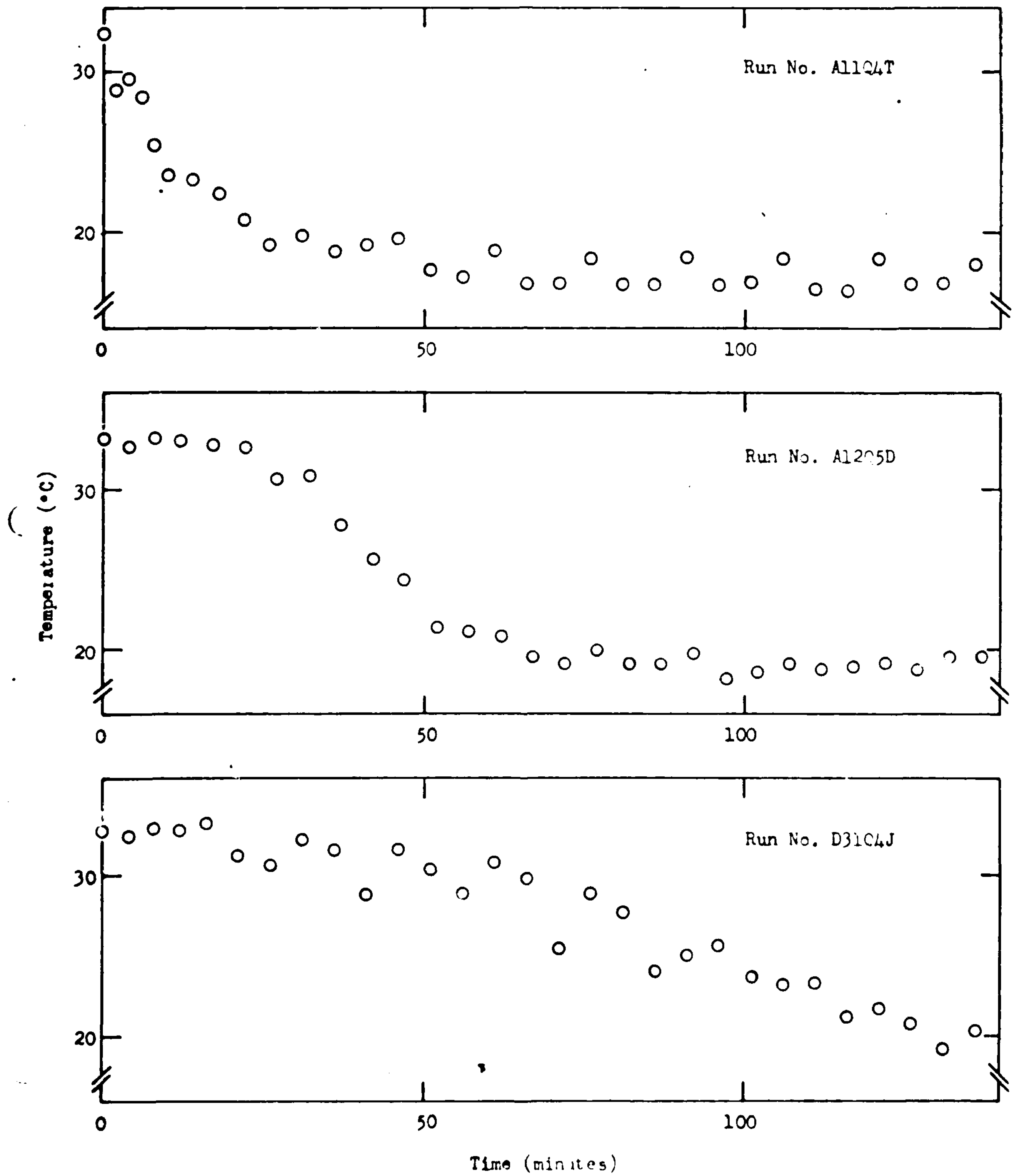

Figure 2, Report 20.

Finger Temperature Cooling Curves,
Mt. Washington Feasibility Test, February, 1956