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QMAX RELATIONSHIP TO PERCEIVED COMFORT AS MEASURED BY THE CALM SCALE

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This investigation compares the evaluation of perceived fabric comfort using the Comfort Affective Labeled Magnitude (CALM) scale and the objectively measured instantaneous heat flow (Qmax) as measured using the KES-F7 Thermolabo II. A set of 36 fabrics was selected and evaluated using the two methods. The results indicated a high degree of agreement between the results of the two methods. This agreement is particularly significant because CALM measures principally tactile factors and, in contrast, Qmax measures thermal transfer.

15. SUBJECT TERMS

KES	COMFORT	THERMAL CONDUCTIVITY
CALM	THERMAL	INSTANTANEOUS HEAT FLOW
KES-F7	KAWABATA	LABELED MAGNITUDE SCALE
q MAX	HEAT TRANSFER	COMFORT AFFECTIVE LABELED MAGNITUDE SCALE
QMAX	THERMOLABO II	KAWABATA EVALUATION SYSTEM FOR FABRICS(KES-F)
FABRICS	THERMAL TRANSFER	KES F(KAWABATA EVALUATION SYSTEM FOR FABRICS)
TACTILE	TEXTILE PROPERTIES	
TESTING	TEST AND EVALUATION	
TEXTILES	KES INSTRUMENTATION	

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Preface

This investigation compares the evaluation of perceived fabric comfort using the Comfort Affective Labeled Magnitude (CALM) scale and the objectively measured instantaneous heat flow (Qmax) as measured using the KES-F7 Thermolabo II.

Qmax measures the instantaneous heat transfer when the surface of the fabric is contacted by a sensor. This measurement is related to the warm/cool feeling an individual would sense when contacting a fabric surface and, if found comparable to CALM determinations, could greatly reduce the time and effort required to collect fabric comfort data and eliminate unsuitable candidate fabrics.

A set of 36 fabrics was selected and evaluated using the CALM scale and Qmax measurement. The study was limited to flat woven and single knit fabrics. Since Qmax is influenced by fabric geometry, heavily textured fabrics were not evaluated using this method.

This research was funded by the Department of Defense University Research Initiative. The grant award number was W911QY-04-1-0001. The funding agency was NSRDEC; the program supported was Warrior Systems Technologies.

Introduction

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Purpose and Scope

A long-term objective for the Laboratory for Engineered Human Protection is to research the relationships between comfort, protection, and performance to determine which unique combinations of these factors are optimal for military and civilian first-responder protective garments. As part of this multidisciplinary approach to designing military garments, one essential assessment is determining perceived comfort, the human emotional response that accompanies the perception of the tactile and thermal environment. Existing research has made clear the influence of perceived comfort on quality perception (Holbrook 1983), garment acceptance (Abraham-Murali and Littrell 1995), and performance (Bell, Cardello, and Schutz 2003).

This investigation compares the evaluation of perceived fabric comfort using the Comfort Affective Labeled Magnitude (CALM) scale and the objectively measured instantaneous heat flow (Qmax) as measured using the KES-F7 Thermolabo II.

Qmax measures the instantaneous heat transfer when the surface of the fabric is contacted by a sensor. This measurement is related to the warm/cool feeling an individual would sense when contacting a fabric surface and, if found comparable to CALM determinations, could greatly reduce the time and effort required to collect fabric comfort data and eliminate unsuitable candidate fabrics.

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Following this introduction, this report contains:

- a description of the methods and procedures
- a presentation of the results and a discussion of those results

- conclusions drawn from the results
- recommendations for further study
- a list of works cited
- an appendix illustrating the CALM scale

Background

The perception of comfort realized when handling a fabric is a subjective tactile sensation. Researchers at the U.S. Army Natick Soldier Research, Development & Engineering Center (Natick) developed a labeled magnitude scale of measurement for the assessment of fabric comfort. This scale, the Comfort Affective Labeled Magnitude (CALM) scale, is a reliable, easy-to-use scale for quantifying the human experience of tactile comfort. The scale is a 200-point standardized labeled magnitude scale, 100 mm in length and bounded by the labels “Greatest Imaginable Discomfort” and Greatest Imaginable Comfort” (see Appendix A).

Participants indicate their rating of comfort by placing a mark across the vertical line scale at the point corresponding to their rating. The measurement from the bottom of the scale to the point marked by the participant is the numeric estimate for comfort. The CALM scale was used in a series of psychophysical studies to provide reliable comfort ratings of a variety of military fabrics (Cardello, Schutz, and Winterhalter 2002; Bell, Cardello, and Schutz 2003; Cardello, Schutz, and Winterhalter 2003; Schutz, Cardello, and Winterhalter 2005). The resulting comfort data were then compared to Kawabata physical measurements and sensory handfeel properties of the same fabrics to obtain a predictive relationship among these measured variables (e.g., Cardello, Schutz, Winterhalter 2002). Results showed that the Kawabata and sensory measurements were strong predictors of the comfort responses from panelists, indicating that the comfort of a garment could be predicted by its physical and sensory characteristics.

These studies also demonstrated the feasibility and practicality of the CALM scale for providing accurate, reliable estimates of perceived tactile comfort of fabrics. This technique, while highly effective, requires extensive resources in manpower and time. Qmax objectively measures the instantaneous heat transfer as the instrument contacts the fabric surface.

Methods and Procedures

Note: Except for values for which no unit of measure is relevant, SI units of measure are used in this section.

CALM Testing

The CALM testing methodology is briefly summarized here. A full technical description of the methodology can be found in a companion technical report, "Further Evaluation of the Reliability and Validity of the CALM Scale for Assessing the Tactile Comfort of Fabrics" (Pierce 2008).

The CALM scale was used to provide evaluations of perceived comfort of 50 test fabrics. A subset of 36 was considered suitable for this CALM/Qmax comparison. (The other fabrics were excluded because their construction made them less suitable for reliable Qmax measurement.)

These fabrics were identified by the textile researchers at the LEHP Materials Evaluation Laboratory and selected to provide a broad range of fabrics with different sensory characteristics. Fabrics were tested in 5 different testing sets ranging from 9 to 15 different fabrics (4 of the fabrics were tested with 11 additional fabrics not included in the present study). Each set was evaluated by 50 participants in individual testing sessions consisting of 2 to 12 participants.

Participants were recruited from faculty, staff, and students of the Philadelphia University community and were "naïve" to the purpose; they were not trained in textile technologies or experienced in the garment industry. All respondents were pre-screened for any hand disorders or medical conditions that might affect tactile sensitivity. All participants were treated in accordance with the American Psychological Association's Code of Ethical Conduct for researchers (APA 2002).

For each sequence, the textile laboratory team assumed primary responsibility for the care and preparation of the fabric samples. All samples were cut into testing swatches and coded with a three-digit code in the upper right corner of the fabric.

Samples and an accompanying CALM data sheet were placed individually in manila testing folders that were also marked with the three-character identification code. A total of 20 sets of samples for each fabric set were created using this procedure and were used for testing.

Upon arrival at the testing facility, participants were assigned to specific seats in the testing room, with the provision that no two participants sit close enough to allow for possible sharing of information. The researchers provided introductory comments regarding the study. Participants read and signed the consent form, then washed their hands with alcohol gel hand sanitizer prior to testing.

Participants in a group were instructed on the proper use of the CALM scale. They were then given the first test folder and asked to handle the fabric *ad libitum* on the testing side only before indicating the degree of comfort on the enclosed CALM scale.

After the assessment was completed, the first folder was removed and the second one was given to the participant. Each subsequent testing folder was presented individually until all fabrics in the set had been rated. The order of presentation of fabric samples was determined in advance through randomization procedures and differed for each participant. Upon the completion of the study, the researcher thanked the participants for their time and explained the general purpose of the study.

Qmax Measurement

Qmax is the measurement of instantaneous heat transfer from the surface of a fabric when contacted by a measuring device. The contacting surface (Qmax probe) is heated to 10 °C above the temperature of the contacted surface (usually 20 °C), and the instantaneous heat flow is measured. The measurement simulates the sensation a human evaluator would notice when first touching a surface. The thermal conductivity of the contacted surface and the surface geometry determine the instantaneous heat loss to the contacting surface. High rate of heat loss indicates a cool feeling and lower heat loss indicates a warm feeling.

The contacting device consists of a thin 3 cm x 3 cm copper plate with a sensitive temperature-measuring device.

The plate and sensor are housed in an insulated box (T–box) with a total mass of 90 g. This results in a contacting pressure of 10 g/cm sq. The plate and sensor are heated to a temperature that corresponds to 10

°C above ambient (usually 20 °C). This is also the temperature (20 °C) of the surface being evaluated. The T-box is placed on a heated surface (BT-box), a guarded hot plate, and allowed to stabilize at a temperature 10 °C above ambient. The temperature of the BT-box is controlled by setting the temperature adjustment on the instrument. The heated T-box is then placed on the surface to be measured and the heat loss during the first 0.2 sec is recorded. Qmax is expressed in Joules per square centimeter per second (J/cm sq/sec).

Qmax measurements were conducted in a conditioned laboratory (65% relative humidity and 20 °C) following the instructions provided by the manufacturer of the KES-F7 Thermolabo II. A minimum of five determinations per fabric were collected. Data from the two methods were then compared to determine if there was any agreement.

Results and Discussion

To compare the two sets of measurements (CALM and Qmax), it was necessary to find a scale that would allow for direct comparison of the data points. The CALM data was rescaled to a range of 1–5, a scale frequently used to describe evaluations of perceived fabric characteristics. In this scale (1–5), a value of 1 indicates the least desirable outcome and a value of 5 indicates the most desirable outcome.

The Qmax measurements, which ranged from 0.1–0.3 J/cm sq/sec were also scaled to a range of 1–5. In this rescale, 1 is the coolest and 5 indicates the warmest.

The ambient conditions under which the Qmax measurements and CALM assessments were made were very similar. As stated previously, Qmax measures the heat loss when a surface heated to 10 °C above ambient (usually 20 °C) comes into contact with a fabric surface at ambient. CALM testing was conducted at approximately 20 °C, and the human evaluators' skin temperatures were 10 to 15 °C above the temperature used in the evaluation room. Under these conditions it was reasonable to assume that a "warmer" fabric would have a more "pleasant" feeling. Hence warmest fabrics, as measured by Qmax were selected as the highest rated when compared to the CALM ratings.[1]

1 If the CALM evaluations were conducted at a higher ambient temperature, it is possible that fabrics rated as "cooler" by Qmax might have a higher CALM rating. This would be an interesting subject of further study.

Table 1 lists the fabrics evaluated and the results for CALM and Qmax. CALM measurements are based on a minimum of fifty determinations for each fabric. Qmax results are based on at least five determinations for each fabric. Figure 1 shows the relationship between the two data sets.

Correlation analysis resulted in an r=0.63.

The data sets generated by very different methods, perceived vs. objective, show solid agreement. This seems to indicate that the properties measured with Qmax are strongly related to the initial sensations detected by an evaluator handling a fabric. Because CALM assessments are the result of a combination of sensations including, touch, appearance, manual manipulation, and temperature, it is interesting that temperature, as measured by Qmax, has a relatively high agreement with the complex CALM assessment

Table 1. Fabrics' CALM and Qmax Data (Mean and Scaled)

Fabric ID	**Fabric Type**	**Qmax Mean**	**Qmax Scaled**	**CALM Mean**	**CALM Scaled**
31A	Plain	0.2325	2.51	-19.2	2.02
43W	Rip-stop	0.2125	2.81	-18.0	2.05
96K	Plain	0.25	2.25	-17.6	2.06
62L	Rip-stop	0.285	1.73	-17.2	2.07
55U	Twill	0.272	1.92	-17.2	2.07
56S	Rip-stop	0.2635	2.05	-12.4	2.19
11P	Rip-stop	0.268	1.98	-9.2	2.27
98H	Rip-stop	0.167	3.50	-9.2	2.27
94D	Rip-stop	0.271	1.94	-8.4	2.29
51U	Satin	0.2845	1.73	-4.4	2.39
14N	Twill	0.2075	2.89	-6.4	2.34
59Q	Rip-stop	0.277	1.85	0.4	2.51
10L	Rip-stop	0.2685	1.97	0.4	2.51
73C	Plain	0.2875	1.69	2.8	2.57
17C	Plain	0.203	2.96	2.8	2.57
79X	Twill	0.2785	1.82	7.2	2.68
13P	Plain	0.157	3.65	9.2	2.73
96T	Twill	0.27	1.95	10.0	2.75
16C	Rip-stop	0.2455	2.32	12.4	2.81
10R	Rip-stop	0.203	2.96	14.8	2.87
34G	Plain	0.1825	3.26	21.6	3.04
53N	Plain	0.2225	2.66	23.2	3.08
98N	Twill	0.206	2.91	23.2	3.08

Fabric ID	Fabric Type	Qmax Mean	Qmax Scaled	CALM Mean	CALM Scaled
55L	Twill	0.2495	2.26	26.4	3.16
19N	Plain	0.151	3.74	28.8	3.22
14F	Twill	0.255	2.18	31.6	3.29
11A	Plain	0.2135	2.80	32.8	3.32
12T	Twill	0.2045	2.93	32.8	3.32
11S	Plain	0.2235	2.65	33.2	3.33
11J	Knit	0.1605	3.59	45.6	3.64
15B	Oxford	0.2085	2.87	47.2	3.68
14V	Plain	0.1715	3.43	48.0	3.70
21K	Knit	0.147	3.80	49.2	3.73
45X	Knit	0.1465	3.80	49.2	3.73
65C	Knit	0.199	3.02	52.8	3.82
22J	Knit	0.146	3.81	80.8	4.52

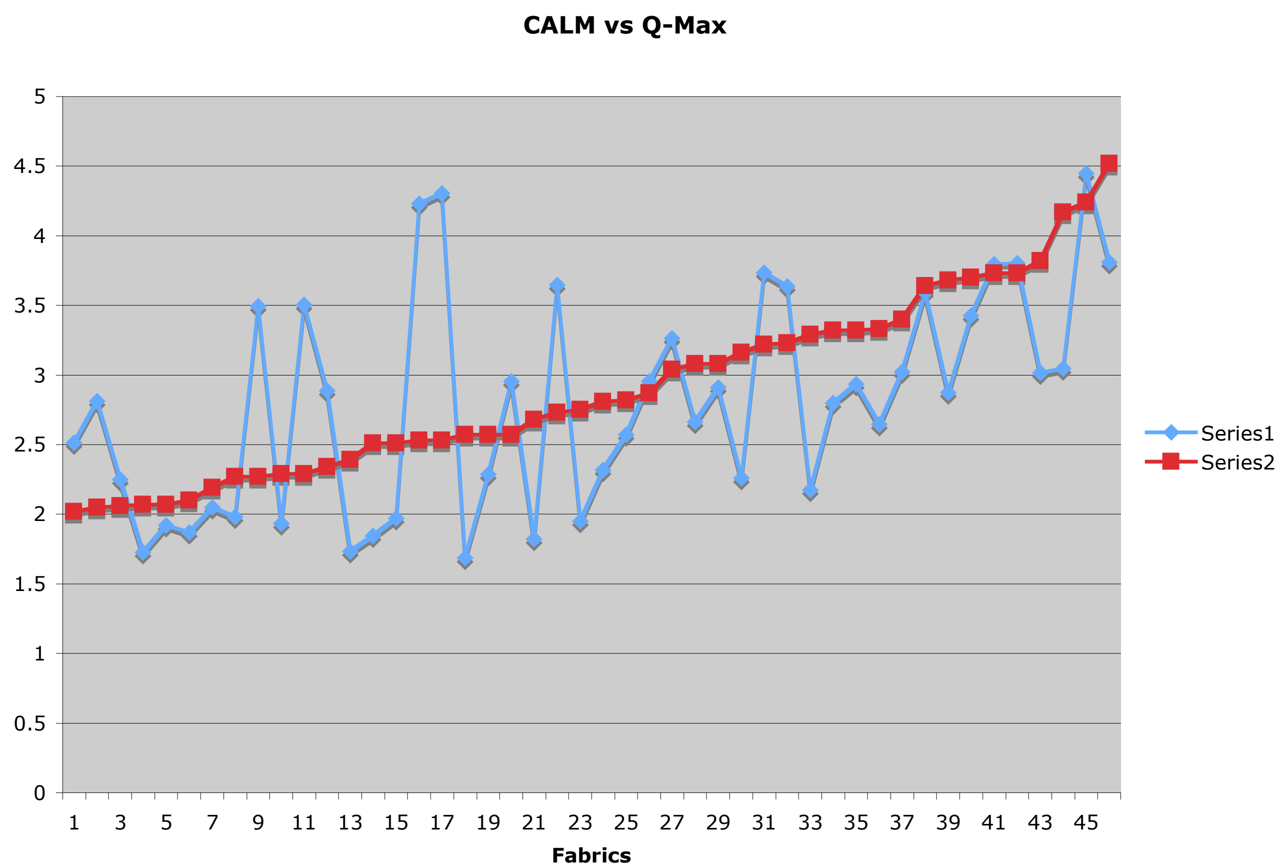

Figure 1. Graph of CALM and Qmax Values. Series 1 is Qmax. Series 2 is CALM.

Conclusions

For flat woven and single knit fabrics, using the fairly rapid Qmax measurement can complement use of the CALM scale to provide a more complete picture of the characteristics of fabrics.

The human evaluator will never be replaced by technology; however, the Qmax measurements could be used to eliminate unlikely candidate fabrics and reduce the expenditure of resources required by the CALM method.

Recommendations

It is recommended that other physical measurements of fabrics be examined for their correlation with the results of CALM assessment and that Kawabata Evaluation System mechanical parameters be combined with Qmax to examine their correlation with CALM assessments.

Additional CALM testing should be conducted at higher ambient temperatures to determine if fabrics rated as “cool” by Qmax are preferred by CALM evaluators under those conditions.

It is further recommended that perceived comfort be considered as an important adjunct to objective measures of fabric construction.

This document reports research undertaken at the U.S. Army Combat Capabilities Development Command Soldier Center, Natick, MA, and has been assigned No. Natick/TR-22/011 in a series of reports approved for publication

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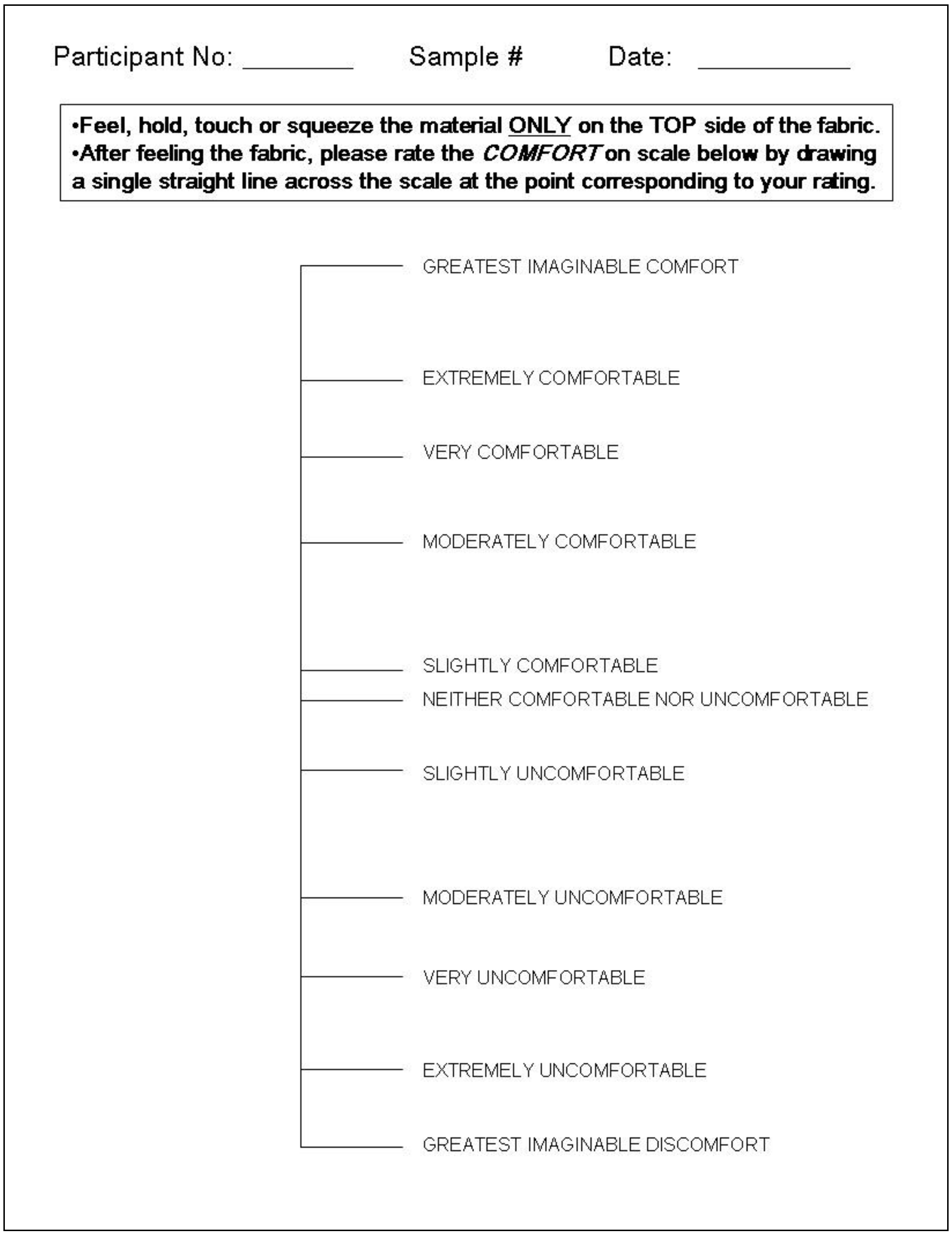
Appendix A – Comfort Affective Labeled Magnitude (CALM) Scale Used for the Comfort Assessment of Fabrics in the Present Study


Participant No: ________ Sample # Date: ___________

•Feel, hold, touch or squeeze the material <u>ONLY</u> on the TOP side of the fabric.
•After feeling the fabric, please rate the *COMFORT* on scale below by drawing a single straight line across the scale at the point corresponding to your rating.

Figure A1. CALM Scale Used for This Study (not shown actual size).

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