ALTERNATIVE SEAM TYPES FOR CANADIAN FORCES COMBAT CLOTHING

by

Rita M. Crow and Malcolm M. Dewar

DEFENCE RESEARCH ESTABLISHMENT OTTAWA
TECHNICAL NOTE 85-20

July 1985
Ottawa

This document has been approved for public release and sale; its distribution is unlimited.
ALTERNATIVE SEAM TYPES
FOR CANADIAN FORCES COMBAT CLOTHING

by

Rita M. Crow and Malcolm M. Dewar
Environmental Protection Section
Protective Sciences Division
ABSTRACT

This paper recommends that a minimum seam strength rather than a fixed percent seam efficiency be used as a criterion for acceptable seam strength in Canadian Forces (CF) fabrics. The minimum seam strengths are calculated based on a working stress of 3500 N/m and a factor of safety of 4 for the CF lightweight combat and the twill fabrics and of 6 for the CF heavyweight combat fabric. Seam types which meet this criteria and could be used as alternatives to the double-lap seam in CF clothing made from these fabrics are given.

Keywords: Combat Uniforms, Seaming, Optimization, Tensile Strength.

RESUME

Les auteurs recommandent qu'un indice numérique minimal, plutôt qu'un pourcentage fixe, serve de critère d'évaluation de la solidité des coutures, à l'égard des vêtements destinés au personnel des Forces canadiennes (FC). Ainsi, l'indice minimal de résistance des coutures est calculé par rapport à une tension (en situation de travail) de 3,500 N/m; un indice de 4 s'applique aux tissus servant à la confection de la tenue légère de combat et les sergés de toile et de 6, dans le cas des tissus lourds entrant dans la fabrication des tenues de combat des FC. Les auteurs précisent en outre les types de coutures dont les caractéristiques répondent à ces critères et qui peuvent être employées en remplacement des coutures doubles, dans la confection des vêtements destinés au personnel des FC.
INTRODUCTION

In a DCGEM-sponsored task to determine if alternative seam types could replace the commonly-used double-lap seams in Canadian Forces (CF) clothing, the question was raised as to how strong seams have to be in clothing. In a 1952 study, Frederick at Natick had stated that the seam strength, for the end uses he was considering, should be 80% of the fabric strength. The recommendation arising from the DCGEM-sponsored task (1) was that the criteria of 80% seam efficiency be revalidated because of the progress made in technology since Frederick's work, resulting in stronger, more durable sewing threads, seams and fabrics.

The approach taken to this problem was: to determine where maximum stresses occur in clothing and thus in seams (2, 3); to find a reliable method to measure these maximum stresses (4); and to determine the maximum stresses which would occur in the seams of various CF garments which presently have double lap seams, namely the CF combat shirt and trousers and the CF flying coveralls (5). This has been done and the maximum stress which occurs in clothing was found to be about 3500 N/m. The maximum stresses occur in the back trouser and coverall seam when the subject squats and across the shoulders in the shirt and coverall top when the subject crosses his arms in front of him.

This paper concludes the study by answering the question of how strong seams have to be in clothing, (re-evaluating the criteria of 80% seam efficiency) and determining if alternative seam types could replace the commonly-used double-lap seam in the CF combat clothing.

Required Seam Strength

In order to arrive at a criterion for the seam strength required for the CF combat shirt and trousers, made from the lightweight fabric and for the coveralls, made from the twill fabric, we turned to the field of engineering and its factor of safety, $f_s$, which is defined as

$$f_s = \frac{S_m}{s_w}$$

where $S_m$ is the strength, taken here to be the required maximum seam strength and $s_w$ is the allowable or typical working stress, now known to be approximately 3500 N/m (5).
The value assigned to $f_s$, in arbitrary but accepted engineering practice assumes a value between 1.5 and 4 for ductile materials which are defined as those materials with an elongation greater than 5%, i.e. textiles. In the Machinery's Handbook (6), a table of general recommendations for the values of the factors of safety is presented. This information is summarized in Table 1.

In order to select the appropriate $f_s$, it is necessary to categorize seams and their wearing conditions according to the descriptors given in Table I. Because of the variabilities in such things as sewing thread strength, sewing machine performance, operator skill and quality control standards, seams cannot be categorized as "reliable" but rather "ordinary" or "less tried". Loading conditions for seams would be categorized as "not severe" since there is a limit to how much a person can stress clothing which he would wear, or fit into. Further, we found the loading conditions, or the maximum stress in clothing to be 3500 N/m which is small relative to the CF fabric strengths of 15,000 to 26,000 N/m.

It is not as easy to define confidently the environmental conditions, taken here to mean the conditions which cause deterioration of the seam strength in wear. Very little is known about how fabrics actually deteriorate in wear, let alone seams made in these fabrics. Thus "difficult" would be the best descriptor here. Taking the worst possible case, i.e. "difficult" environmental conditions, a factor of safety of 4 would be appropriate for seams. Therefore $S_m$ is calculated to be 4 times $s$, which is 3500 N/m to give a value of 14,000 N/m for the minimum seam strength for the two CF fabrics we are considering here.

Although we did not measure the stress in clothing made from the heavyweight combat fabric, we had recorded its load-elongation curve and carried out preliminary load versus stress calibrations with it. We found these properties to be similar to those of the lightweight combat fabric with the exception, of course, that the heavyweight combat fabric is 40 to 50% stronger than the lightweight combat fabric. Therefore, we conclude, that the maximum stresses which would occur in the clothing made from it would be similar to those measured in the other combat clothing. However, this fabric is stronger, heavier and has more abrasion resistance than the lighter version. Therefore, it would be expected to have a longer life expectancy than the lightweight combat fabric as it would be exposed to "difficult" environmental conditions for a longer length of time before it failed. Therefore, a greater factor of safety would be required for its seams. In the absence of details of wear life of the heavyweight combat fabric, prorating its strength to the factor of safety for the lightweight fabric seems reasonable. This would give it a factor of safety of 6, and thus, a minimum acceptable seam strength of 21,000 N/m.
### TABLE 1

**SUMMARY OF GENERAL RECOMMENDATIONS FOR VALUES OF FACTOR OF SAFETY (FROM MACHINERY'S HANDBOOK, (6))**

<table>
<thead>
<tr>
<th>$f_s$</th>
<th>APPLICATION</th>
<th>TYPE OF MATERIAL</th>
<th>LOADING CONDITIONS</th>
<th>ENVIRONMENTAL CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3 to 1.5</td>
<td></td>
<td>HIGHLY RELIABLE</td>
<td>NOT SEVERE</td>
<td>NOT SEVERE</td>
</tr>
<tr>
<td>1.5 to 2</td>
<td></td>
<td>RELIABLE</td>
<td>NOT SEVERE</td>
<td>NOT SEVERE</td>
</tr>
<tr>
<td>2 to 2.5</td>
<td></td>
<td>ORDINARY</td>
<td>NOT SEVERE</td>
<td>NOT SEVERE</td>
</tr>
<tr>
<td>2.5 to 3</td>
<td></td>
<td>LESS TRIED</td>
<td>NOT SEVERE</td>
<td>NOT SEVERE</td>
</tr>
<tr>
<td>3 to 4</td>
<td></td>
<td>NOT RELIABLE</td>
<td>NOT SEVERE</td>
<td>NOT SEVERE</td>
</tr>
<tr>
<td>3 to 4</td>
<td></td>
<td>RELIABLE</td>
<td>DIFFICULT</td>
<td>DIFFICULT</td>
</tr>
</tbody>
</table>
Re-validation of 80% Seam Efficiency

If we calculate the percent seam efficiency using the 14,000 N/m and the 21,000 N/m values, we find the lightweight fabric requires seam efficiencies of 56 and 65, the twill 67 and 93 and the heavyweight fabric 52 and 54% for the warp and weft directions respectively. (To avoid confusion, Figure 1 shows the sense of warp and weft directions). The higher seam efficiencies are found for the weft simply because the weft is traditionally weaker than the warp in a woven fabric. Herein lies the problem of using percent seam efficiencies. The majority of seams in the CF combat clothing are in the warp direction and as we found, are stressed the most in the weft direction, i.e. across the shirt and coverall top back and arm seam and the trouser or coverall centre back seam.

Therefore, stronger seams are required in the weft direction than in the warp direction. By applying a percentage rather than a fixed minimum value, one may obtain weft seams which are weak and warp seams which are very strong and over-designed.

As stated in the introduction, one of the reasons for the re-validation of the 80% seam efficiency was that fabrics which are stronger and more durable than those in use in 1952 are now available. In fact, the fabrics used in the CF combat clothing have been designed or selected mainly to withstand high levels of abrasion and to have high tear strengths. Abuse almost always takes place in areas of "fabric only". Severe abrasion occurs mainly in the knee and elbow areas where no seams exist. Tears or rips, caused by snagging, occur randomly over the clothing. Since seams take up such a small area of the total clothing area, the chances of a seam rather than the fabric being torn is small. Therefore, it would appear to be more practical to quote minimum seam strengths for combat clothing (rather than percent seam efficiencies based on the strength of the fabric) since we are designing clothing seams for the stress put on them and have included a factor of safety to ensure seam integrity despite their decline in strength during the life of the garment.

Applying the criterion of a minimum seam strength (11,000 N/m or 21,000 N/m) to the results of the seam breaking strengths, as listed in Table 2, we find the double-lap seam in all three fabrics and directions well exceeds this criterion. The only other seam which exceeds this value is the stitch-and-serge with topstitching for the lightweight fabric. No other seam type is strong enough to be used in the twill fabric, although the stitch-and-serge with topstitching comes close and could be used if one is prepared to accept a lower margin of safety. All seam types except the stitch-and-serge would be acceptable for the heavyweight combat fabric.
Figure 1: Illustration of the Warp and Weft Directions of Seam.
TABLE 2

SEAM AND FABRIC PARAMETERS

<table>
<thead>
<tr>
<th>SEAM TYPE</th>
<th>BREAKING STRENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LIGHTWEIGHT FABRIC</td>
</tr>
<tr>
<td></td>
<td>WARP</td>
</tr>
<tr>
<td>DOUBLE-LAP</td>
<td>21,570</td>
</tr>
<tr>
<td>SAFETY</td>
<td>NO SAMPLE</td>
</tr>
<tr>
<td>SAFETY AND TOPSTITCH</td>
<td>16,610</td>
</tr>
<tr>
<td>STITCH-AND-SERGE</td>
<td>7,870</td>
</tr>
<tr>
<td>STITCH-AND-SERGE WITH TOPSTITCH</td>
<td>16,020</td>
</tr>
<tr>
<td>FABRIC ALONE</td>
<td>25,040</td>
</tr>
<tr>
<td>MINIMUM SEAM STRENGTH</td>
<td>14,000</td>
</tr>
<tr>
<td>PERCENT MINIMUM SEAM EFFICIENCY</td>
<td>56</td>
</tr>
</tbody>
</table>

1. Measured in accordance to ASTM D 1683-81 "Standard Test Method for Failure in Sewn Seams of Woven Fabrics" and ASTM D 1682-64 (Reapproved 1975) "Standard Methods of Test for Breaking Load and Elongation of Textile Fabrics" (Grab test using 2.54 cm wide jaws)
CONCLUSIONS

Based on a minimum seam strength, the alternative seam which could be used instead of the double-lap seam in the lightweight combat fabric is the stitch-and-serge with topstitching. In the heavyweight combat fabric, the safety stitch, with or without topstitching and the stitch-and-serge with topstitching are suitable alternatives to the double-lap seam. No other seam type is strong enough for the twill fabric, although the stitch-and-serge with topstitching is almost sufficient. It is recommended that garments be made using these alternative seam types and that they be tested to see if, in fact, minimum seam strengths of 14,000 and 21,000 N/m rather than a minimum seam efficiency of 80% is adequate.

REFERENCES

This paper recommends that a minimum seam strength rather than a fixed percent seam efficiency be used as a criteria for acceptable seam strength in Canadian Forces (CF) fabrics. The minimum seam strengths are calculated based on a working stress of 3500 N/m and a factor of safety of 4 for the CF lightweight combat and the twill fabrics and of 6 for the CF heavyweight combat fabric. Seam types which meet this criteria and could be used as alternatives to the double-lap seam in CF clothing made from these fabrics are given.
### INSTRUCTIONS

1. **ORIGINATING ACTIVITY:** Enter the name and address of the organization issuing the document.

2a. **DOCUMENT SECURITY CLASSIFICATION:** Enter the overall security classification of the document including special warning terms whenever applicable.

2b. **GROUP:** Enter security reclassification group number. The three groups are defined in Appendix M of the DRB Security Regulations.

3. **DOCUMENT TITLE:** Enter the complete document title in all capital letters. Titles in all cases should be unclassified. If a sufficiently descriptive title cannot be selected without classification, show title classification with the usual one-capital-letter abbreviation in parentheses immediately following the title.

4. **DESCRIPTIVE NOTES:** Enter the category of document, e.g. technical report, technical note or technical letter. If appropriate, enter the type of document, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.

5. **AUTHOR(S):** Enter the name(s) of author(s) as shown on or in the document. Enter last name, first name, middle initial. If military, show rank. The name of the principal author is an absolute minimum requirement.

6. **DOCUMENT DATE:** Enter the date (month, year) of establishment approval for publication of the document.

7a. **TOTAL NUMBER OF PAGES:** The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. **NUMBER OF REFERENCES:** Enter the total number of references cited in the document.

8a. **PROJECT OR GRANT NUMBER:** If appropriate, enter the applicable research and development project or grant number under which the document was written.

8b. **CONTRACT NUMBER:** If appropriate, enter the applicable number under which the document was written.

9a. **ORIGINATOR'S DOCUMENT NUMBER(S):** Enter the official document number by which the document will be identified and controlled by the originating activity. This number must be unique to this document.

9b. **OTHER DOCUMENT NUMBER(S):** If the document has been assigned any other document numbers (either by the originator or by the sponsor), also enter this number(s).

10. **DISTRIBUTION STATEMENT:** Enter any limitations on further dissemination of the document, other than those imposed by security classification, using standard statements such as:
   - (1) "Qualified requesters may obtain copies of this document from the defense documentation center."
   - (2) "Announcement and dissemination of this document is not authorized without prior approval from originating activity."

11. **SUPPLEMENTARY NOTE:** Use for additional explanatory notes.

12. **SPONSORING ACTIVITY:** Enter the name of the departmental project office or laboratory sponsoring the research and development. Include address.

13. **ABSTRACT:** Enter an abstract giving a brief and factual summary of the document, even though 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 end with an indication of the security classification of the information in the paragraph (e.g., the document itself is unclassified) represented as (TS), (SI), (C), (R), or (U). The length of the abstract should be limited to 20 single-spaced standard typewritten lines; 7½ inches long.

14. **KEY WORDS:** Key words are technically meaningful terms or short phrases that characterize a document and could be helpful in cataloging the document. Key words 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 be used as key words but will be followed by an indication of technical context.

### KEY WORDS

<table>
<thead>
<tr>
<th>COMBAT UNIFORMS</th>
<th>SEAMING</th>
<th>SAFETY FACTOR</th>
<th>OPTIMIZATION</th>
<th>TENSILE STRENGTH</th>
</tr>
</thead>
</table>