National Defence Défense nationale

THE VERTICAL AND HORIZONTAL WICKING OF WATER IN FABRICS (U)

by

Rita M. Crow and Malcolm M. Dewar

DEFENCE RESEARCH ESTABLISHMENT OTTAWA
REPORT NO. 1180

Canada

July 1993
Ottawa

Best
Available
Copy

National Défense
Defence nationale

THE VERTICAL AND HORIZONTAL WICKING OF WATER IN FABRICS (U)

by

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

DEFENCE RESEARCH ESTABLISHMENT OTTAWA
REPORT NO. 1180

PCN
051LC

July 1993
Ottawa

Abstract

This paper attempts to clarify the term "wicking" which is the movement of water in the capillaries of a fabric. It differentiates between "regain" , the amount of water vapour a fabric absorbs from the air and the amount of liquid water a fabric holds. The hydrophilic or water-loving and the hydrophobic, or water-hating properties of fibres are discussed in relation to their regain. Finally, the drying times of a wide range of fabrics are discussed in terms of the initial amount of water in the fabric, the regain and fibre type.

Résumé

Le présent rapport tente d'éclairer le sens de l'expression "effet mèche" ("wicking") qui est le mouvement de l'eau dans les capillaires d'un tissu. Ce rapport nous permit d'établir la différence avec "teneur en humidité", qui est la quantité de vapeur d'eau qu'un tissu absorbe de l'air et la quantité d'eau liquide qu'un tissu peut retenir. Il est également question des propriétés hydrophiles et hydrophobes des fibres en relation avec leur teneur en humidité. Finalement, les temps de séchage d'une gamme étendue de tissus sont présentés selon la quantité initiale d'eau contenue dans le tissu, la teneur en humidité et le type de fibre.

EXECUTIVE SUMMARY

This paper explains the term "wicking" which is the movement of water in the capillaries of a fabric. It illustrates the difference between "regain", the amount of water vapour a fabric absorbs from the air and the amount of liquid water a fabric holds. The hydrophilic or water-loving and the hydrophobic, or water-hating properties of fibres are discussed in relation to their regain. Finally, the drying times of a wide range of fabrics are discussed in terms of the initial amount of water in the fabric, the regain and fibre type.

It was concluded that the amount of water a fabric freely picks up is independent of fibre type and thus, of regain. Fibres with high regains may or may not be hydrophilic; fibres with low regains may or may not be hydrophobic. The time required for a fabric to dry is independent of fibre type and so of fibre regain. Rather, the time required for a fabric to dry depends on the amount of water in the fabric, that is, the more water there is in a fabric initially, the longer it will take to dry.

INTRODUCTION

Articles and advertisements in the popular press present confusing information on fibres and fabrics which are used in sportswear. Some articles and advertisements state that certain fabrics draw perspiration away from the skin by wicking and so one's skin stays dry. (It is not clear where this perspiration goes once it is draw off the skin.) Other articles and advertisements say that because synthetic-fibre fabrics do not absorb moisture, they never get wet, so one's skin stays dry. This is in contrast to natural fibres which, they imply, absorb moisture and so stay wet longer. Exponents of natural fibres, such as cotton, wool and silk, claim that these fibres are best because they do absorb sweat.

The confusion in these articles and advertisements arises in several ways. First is the mis-definition and misunderstanding of the term "wicking". Second is the confusion created when "regain" or the amount of water a fibre absorbs from water vapour in the air is applied to the amount of liquid water a fabric holds. Third is the often incorrect perception that fibres which have high regains are hydrophilic or water-loving and fibres which have low regains are hydrophobic, or water-hating. Finally, there is the misperception that natural fibres which have high regains take longer to dry than those with low regains.

The following will address the above, based on the work we have carried out at the Defence Research Establishment Ottawa.

WICKING

The term "wicking" originated with lanterns and lamps. An oil lamp has a wick, usually a braided or woven cotton fabric, which moves the fuel from its reservoir up to the flame by capillary action. More recently, the term "wick" has been turned into a verb from a noun and its meaning expanded to include the movement of any liquid, including water, along a capillary. Figure 1a shows a capillary which is present between fibres in a yarn. "Wicking" is defined as the movement of large amounts of water by capillary action through such interfibre capillaries in the yarns of a fabric.

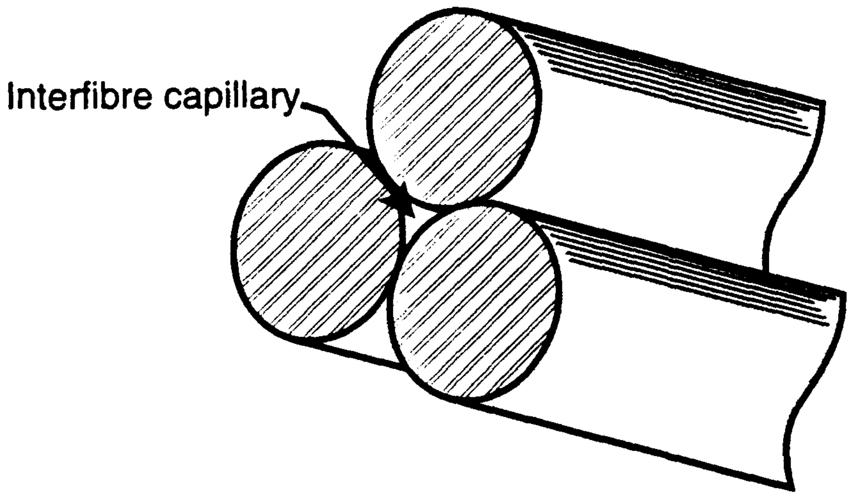

Figure 1a. Illustration of an interfibre capillary.

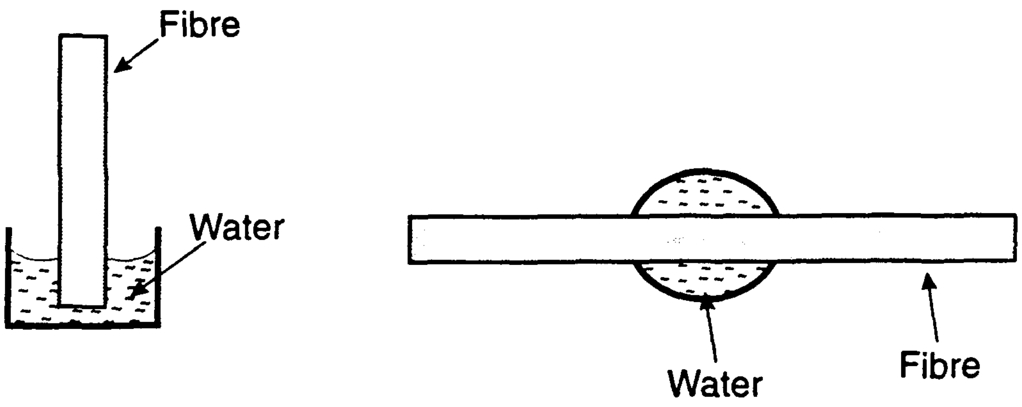

Figure 1b. The interaction of a fibre with water.

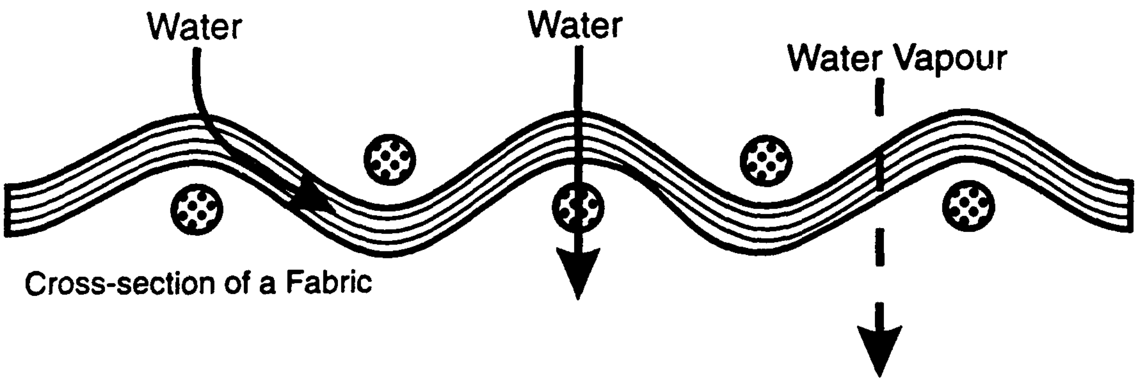

Figure 1c. Wicking of water through a fabric.

When a yarn or a strip of fabric is placed in a reservoir of water, the water will wick up the yarn or fabric. However, when a fibre alone is placed in a water reservoir, a meniscus forms around the fibre and no wicking occurs, as shown in Figure 1b. When a water drop is put on the fabric, the water enters the yarns in the fabric and wicks out through it (Figure 1c). But, when a drop of water is placed on the fibre alone, it beads up to surround the fibre to form a droplet (Figure 1b). In neither instances does the water move or wick along the fibre since a fibre does not have the large capillaries a yarn does. Thus the manufacturer's claim that their fibre wicks is incorrect. It is the **yarn** made from their fibre which wicks.

Liquid perspiration on the skin can either evaporate from the skin's surface and pass through the clothing covering the skin as water vapour, or the liquid perspiration can penetrate the fabric by entering the yarns of the fabric on one side and physically move or "wick" through the yarns to the other side of the fabric from where it would evaporate. This is illustrated in Figure 1c.

REGAIN

"Regain", or more properly "moisture regain" is defined by the Canadian Standard (1) as the mass of moisture present in a specimen expressed as a percentage of the dry mass of the specimen. Traditionally, the moisture in the textile specimen is measured after it has been conditioned in an atmosphere of 20°C and 65% relative humidity (called a standard atmosphere). Therefore, the term "conditioned" means that the fabric has freely picked up water vapour from the air and is in equilibrium with the water vapour in the air. The equation for regain is as follows:

$$\%\ Regain = \frac{M_1 - M_2}{M_1}\ x\ 100$$

where M_1 is the initial mass of the (conditioned) specimen
M_2 is the mass of the specimen after oven drying

Water molecules from the atmosphere can be absorbed chemically by fibres at the hydroxyl groups of cellulosic fibres such as cotton and viscose or at the carboxyl and/or amine groups of wool, silk and nylon (Figure 2a). These fibres have high regains. Fibres such as polypropylene and polyester do not chemically absorb water vapour from the air because they have few or no water-bonding sites (Figure 2b). These fibres have low regains. Fibres that readily absorb water vapour from the atmosphere are termed "hygroscopic". Trouble arises when a fabric's hygroscopic nature is confused with its hydrophilicity, i.e. whether or not it will wick water.

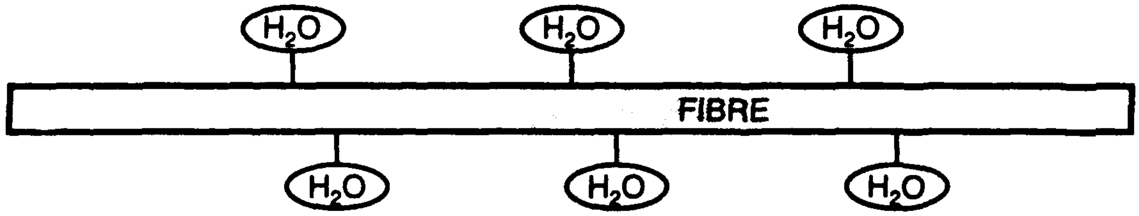

Figure 2a. Fibre with many sites to which water molecules can chemically bond.

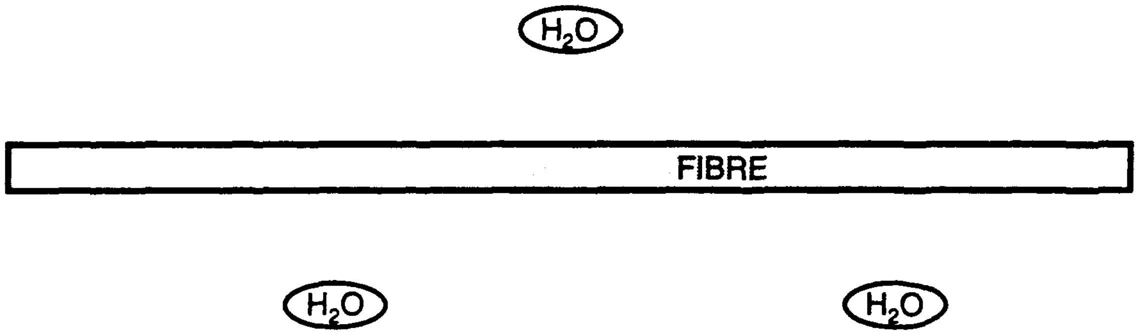

Figure 2b. Fibre with no water-bonding sites.

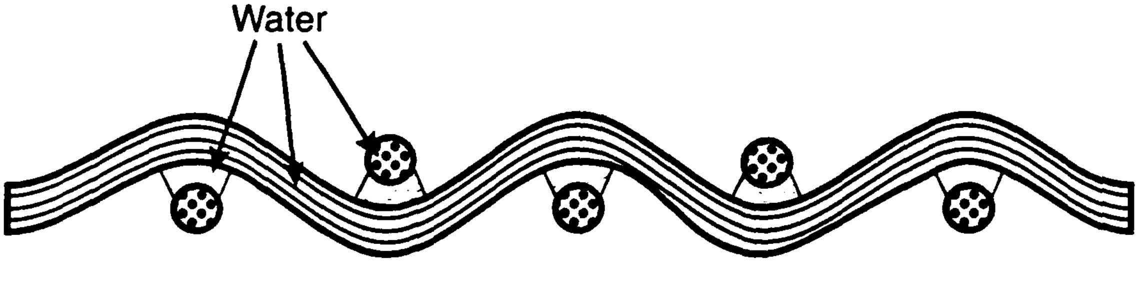

Figure 3. Water between the fibres in the yarns and between the yarns in the fabric.

Confusion arises when the term "regain" is applied to liquid water. When a fabric is either immersed in water, or picks up water, say perspiration, the fibres in the yarns in the fabrics are surrounded by liquid water. The water enters the spaces between the fibres in the yarns and between the yarns in the fabric (Figure 3). The sites which attracted water molecules from the atmosphere are now under layers and layers of water molecules (Figure 4a). The low regain fibres are also covered with water (Figure 4b). The regain property of the fibre is no longer relevant.

In our experience, we have encountered very few fabrics which will not wet out when immersed in water, especially when some detergent has been added, as would occur in laundering. Since the majority of sportswear, including that made from polypropylene, is washable, then water **must** go into their yarns and fabrics in order to remove dirt and so clean them.

HYDROPHILICITY/HYDROPHOBICITY

Traditionally in textiles, one thinks of wool and the synthetic fibres such as polyester and polypropylene as being hydrophobic and fibres such as cotton and rayon as being hydrophilic. However, experiments we carried out did not totally agree with this (2). We measured the equivalent critical surface tension of 58 fabrics varying in fibre content and construction as received from Testfabrics, New Jersey. The fabrics having the lowest surface tensions and therefore the most hydrophobic were a fiberglass, a nylon and all the wools. The moisture regain values (3) for these three fibres are given as 0%, 4.5% and 13.6% respectively. The fabrics which had the highest surface tension and were thus the most hydrophilic were a polyester, an acrylic, an acetate and almost all the cottons. The moisture regain values (3) for these fibres are 0.4%, 1.5%, 6.5% and about 8% respectively.

These results show that hydrophobic fabrics can be made from fibres which have either low or high regains; likewise hydrophilic fabrics can be made from fibres which have either low or high regains. One of the reasons for this seemingly inconsistency is that finishes can be applied to or removed from fibres to change their water-loving or water-hating properties. Cotton fabrics which are used for rainwear have hydrophobic finishes applied to them to impart water-repellent properties. Over time, these finishes tend to wear off, be dry-cleaned or washed off, becoming "rainwear" in name only. Softeners are routinely added to synthetic fabrics to make them less harsh. Softeners tend to make these fibres more hydrophilic. Extremely hydrophilic finishes are applied to polypropylene sportswear or underwear to make it "wettable". However, because the majority of such finishes are merely physically coated onto the fibre, not chemically attached, they tend to wash off quite readily during the first laundering, leaving a hydrophobic material.

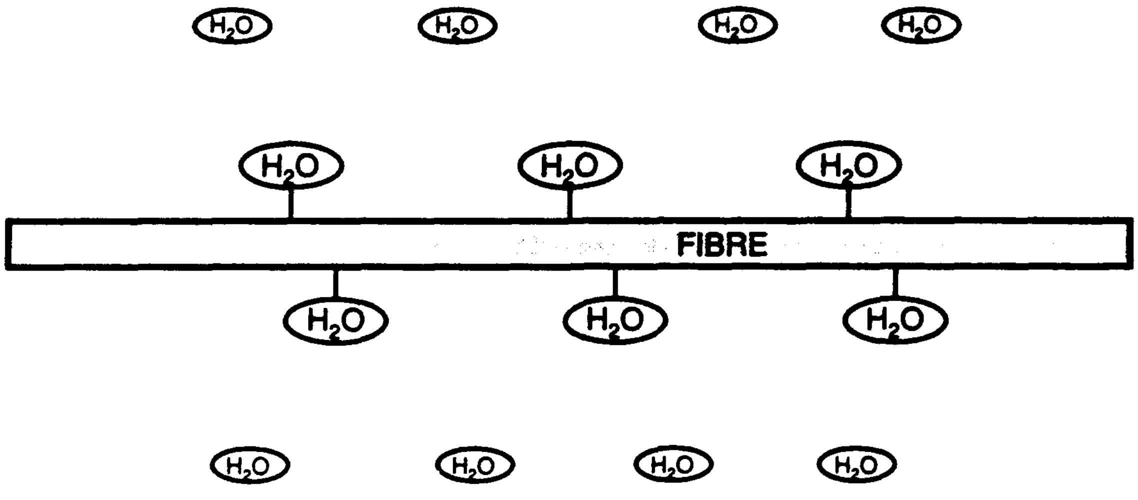

Figure 4a. High regain fibre surrounded by layers of water molecules.

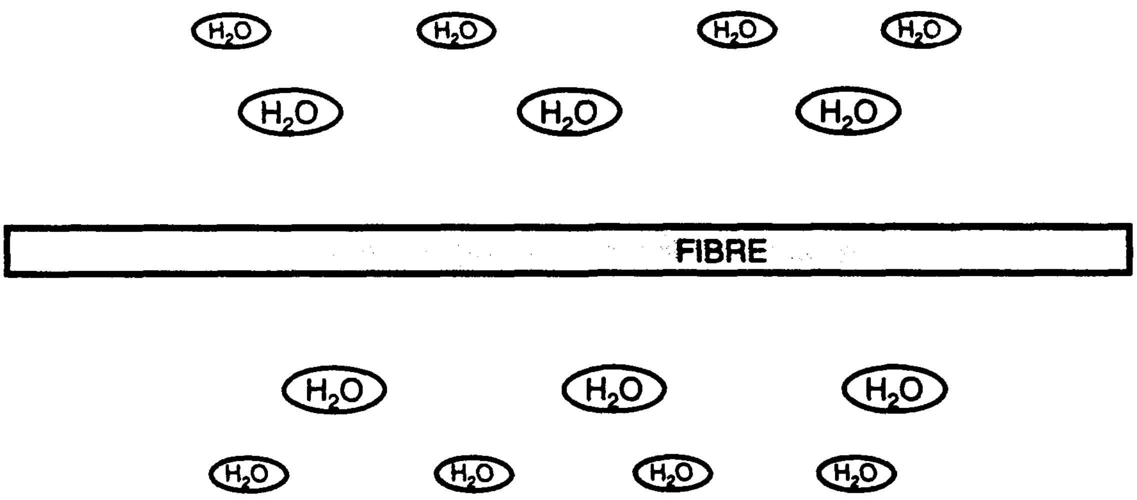

Figure 4b. Low regain fibre surrounded by layers of water molecules.

DRYING OF FABRICS

To determine whether or not fabrics made from synthetic yarns were "drier" than natural fibres, we conducted an experiment to measure the drying rates of natural and synthetic fabrics to determine if the fibre type and thereby the regain affects the drying rate. The fabrics chosen included a wide range of fibres, constructions (both knits and woven fabrics) and weights (362 to 71 g/m^2). The Goretex used was the nylon shell, nylon tricot laminate. The Dermoflex was a nylon fabric with a water-vapour permeable water-proof coating.

Figure 5 shows a linear relationship between the time to dry and the initial mass of water in the specimen. In other words, the more water there is in the fabric to begin with, the longer it takes the fabric to dry. This Figure also shows that the amount of water held by a fabric is independent of fibre type. The fabrics which held the most water, and almost the least water were made from the synthetic fibre nylon. The natural fibres, cotton and wool, held similar amounts of water as the synthetics. The "magic" polypropylenes behaved no differently than the other fibres, namely, their drying rates were in proportion to the amount of water they initially held.

Figure 6 shows that there is no relationship between the initial amount of water in the specimen and its regain with the plotted values scattered over the graph. The most diverse are the two nylons with identical percent regains but one initially having ten times the amount of water in it and thus taking ten times longer to dry than the other. There is no correlation between the time the fabric takes to dry and its regain at standard conditions (Figure 7).

CONCLUSIONS

It can therefore be concluded that:

1. Wicking only occurs in yarns, not in fibres.

2. The amount of water a fabric freely picks up is independent of fibre type and thus of regain.

3. Fibres with high regains may or may not be hydrophilic; fibres with low regains may or may not be hydrophobic.

4. The time required for a fabric to dry is independent of fibre type and thus fibre regain.

5. The time required for a fabric to dry depends on the amount of water in the fabric, the more water there is in a fabric initially, the longer it will take to dry.

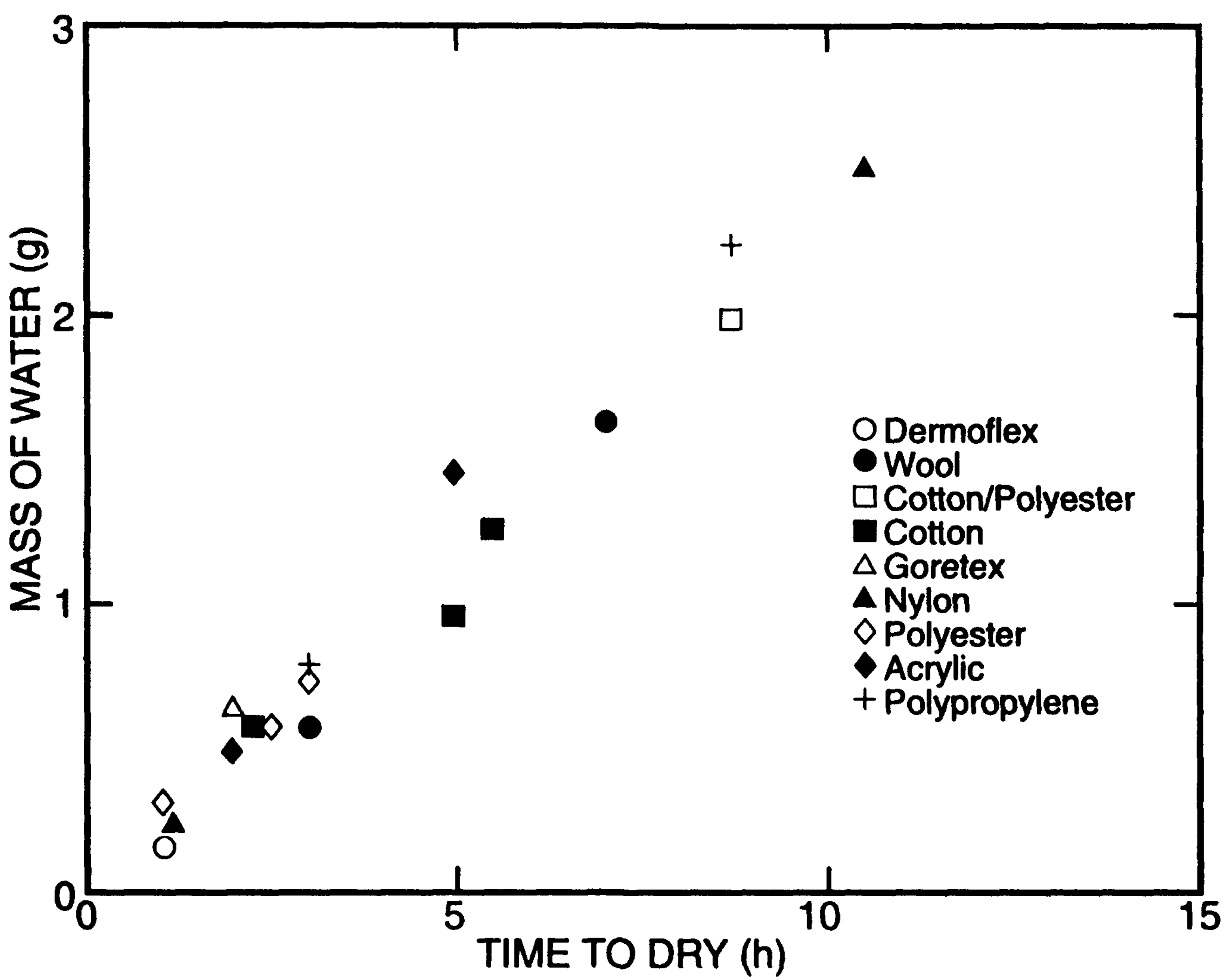

Figure 5. The linear relationship between time to dry and the initial mass of water in the fabric for a range of fabrics made from various fibre types.

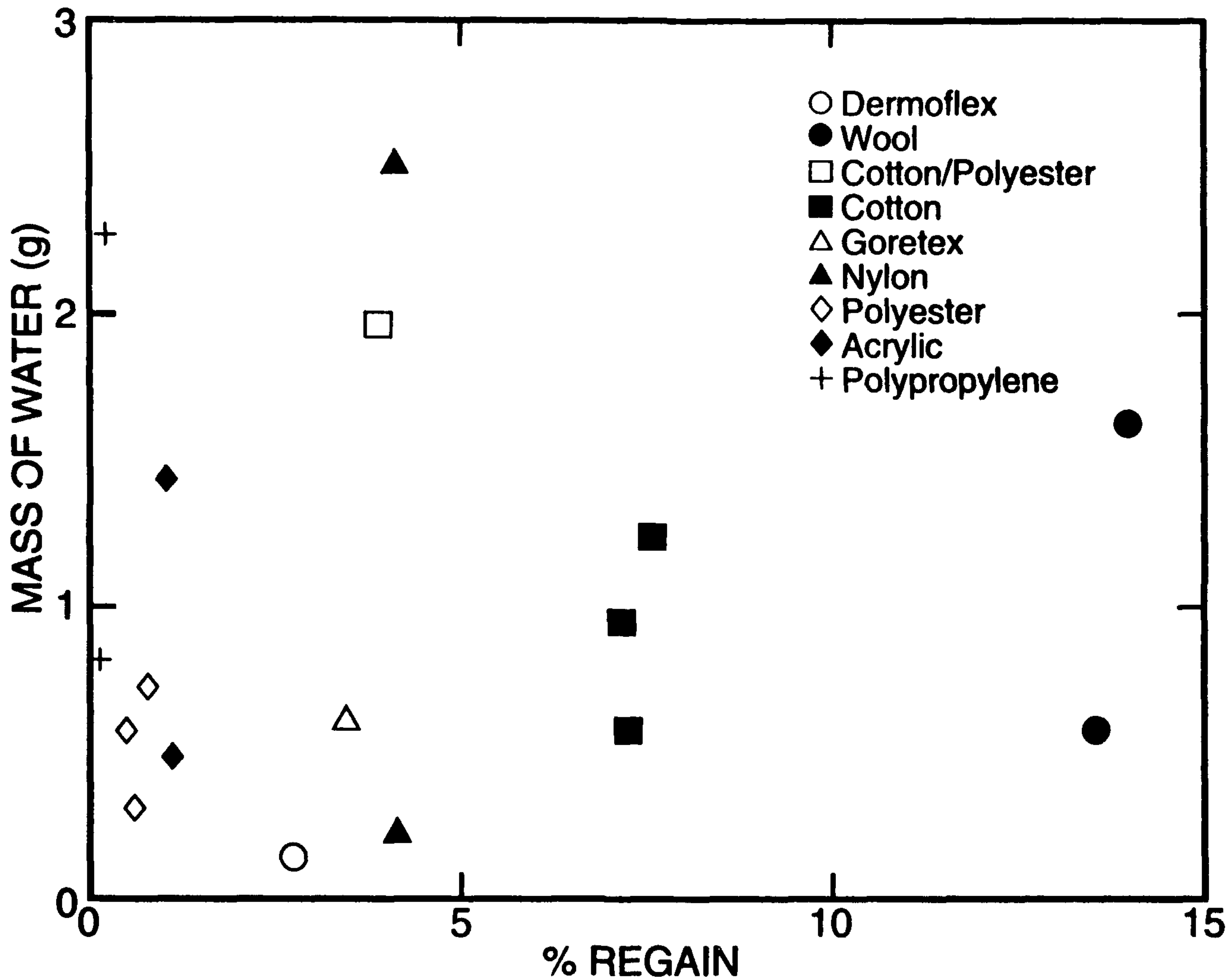

Figure 6. This illustrates the lack of correlation between initial mass of water in the fabric and its percent regain.

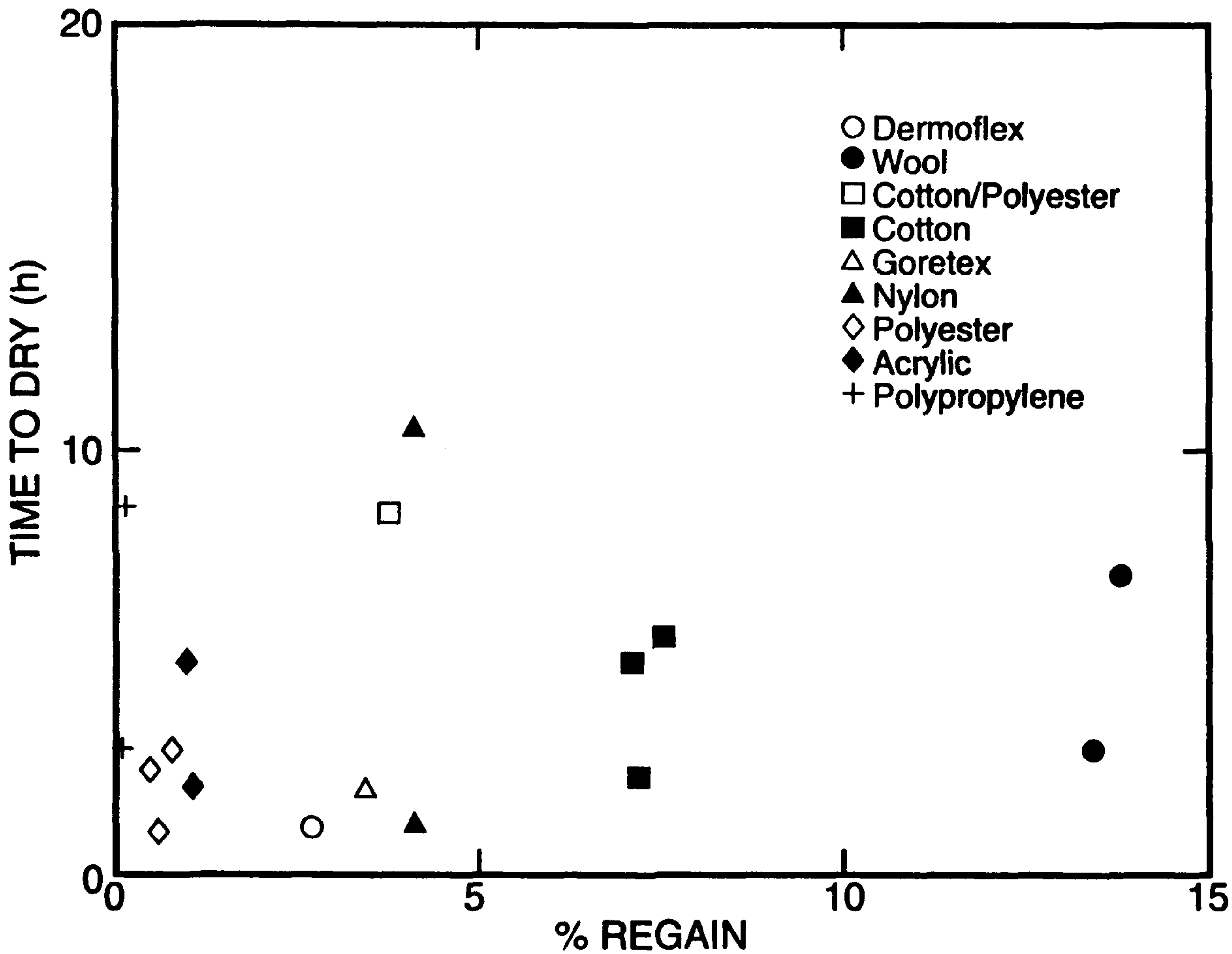

Figure 7. This illustrates the lack of correlation between the time to dry and percent regain for the range of fabrics.

REFERENCES

1. CAN/CGSB-4.2 "Determination of Moisture in Textiles" Method No 3.

2. R.M. Crow and M.M. Dewar. "Liquid Transport Across Fabric Layers". DREO Report 1002, 1989.

3. CAN/CGSB-4.2 "Canadian Commercial Moisture Regain Values" Method No 0.

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.) Department of National Defence Defence Research Establishment Ottawa Shirleys Bay, 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 or U) in parentheses after the title.)

Wicking, Regain, Hydrophilicity, Hydrophobicity and Drying of Textiles (U)

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

CROW, Rita M., DEWAR, Malcolm M.

5. DATE OF PUBLICATION (month and year of publication of document) July 1993	6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.) 14	6b. NO. OF REFS (total cited in document) 3

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.)

DREO Report

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

Defence Research Establishment Ottawa

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) 51LCEP	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 REPORT 1180	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.)

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), or (U). It is not necessary to include here abstracts in both offical languages unless the text is bilingual).

This paper attempts to clarify the term "wicking" which is the movement of water in the capillaries of a fabric. It differentiates between "regain", the amount of water vapour a fabric absorbs from the air and the amount of liquid water a fabric holds. The hydrophilic or water loving and the hydrophobic, or water-hating properties of fibres are discussed in relation to their regain. Finally, the drying times of a wide range of fabrics are discussed in terms of the initial amount of water in the fabric, the regain and fibre type.

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.)

textiles
wicking
regain
hydrophobicity
hydrophilicity
drying