

## NEW TECHNOLOGIES FROM THE USSR:

### RESTORING BOOK PAPER AND DRYING WATER WETTED BOOKS

Larissa B. Shapkina, Adolph A. Leonovich, Michael K. Nikitin,  
Maya V. Apreleva, Oleg A. Gromov, Vladislav K. Donchenko,  
Alexander I. Kalinin, and Vladimir P. Sokolov

#### 1. INTRODUCTION

Nearly 400,000 books, periodicals, and newspapers were lost during the February 15, 1989, fire at the Library of the USSR Academy of Sciences in Leningrad (now St. Petersburg). The methods being used to save the remaining 300,000 water or fire damaged books are being published in the "Proceedings of the Symposium: Conservation and Disaster Recovery: International Cooperation at the Library of the USSR Academy of Sciences, September 24-28, 1990." Two of the new methods are being reported here because their technology is unknown in the USA, and these two methods could be modified into techniques that conservators could use for restoring individual books.

The Library of the Academy of Sciences was founded in 1714, by Peter the Great. This Library, containing more than 19 million books and manuscripts, is one of the great libraries of the world. Its books were collected by the scientists, librarians, politicians, statesmen, and leaders of Russia during the past 300 years. Particularly notable collections include the 1.5 million rare books, the 20,000 manuscripts, and the over 6 million Russian copyright publications commencing in 1783.

The largest fire disaster in Library history occurred at the Academy's Library in February 1988. Every fifth book, almost 3.6 million books, was affected by water, smoke, or high humidity and temperature during those awful days. Initial estimates indicate the Library lost 400,000 of its books and one third of its newspaper collections. Nearly 200,000 books were identified as requiring restoration.

The achievements in disaster recovery at the Library of the USSR Academy of Sciences between February 1988 and June 1991 may be summarized as follows:

Achievement 1. Most of the Library's collections, 14 million books in the first three weeks, were inspected or dried in the Library or in the 36 cooperating institutions. The drying techniques used included conventional air drying, absorption, and micro-wave or high frequency drying. Using special instructions, readers dried an additional 18,000 books in their homes. About 200,000 water-wetted books were stabilized by freezing. These 200,000 frozen books were dried by the new technique that will be discussed later in this report.

Achievement 2. All the damp, water-wetted, and frozen books were dried by early 1991.

Achievement 3. An in-house, mass fumigation process reduced the time to treat all the books from two years to one month.

Achievement 4. All areas of the Library that were damaged during the fire were cleaned and repaired.

Achievement 5. A new fire security system has been designed and will be put into operation.

Achievement 6. Approximately 400 books have received complete treatment, but more than 199,600 remain to be restored.

Achievement 7. Co-sponsored with The Library of Congress and Getty Conservation Institute, The Symposium "Conservation and Disaster Recovery: International Cooperation at the Library of the USSR Academy of Sciences, Leningrad, USSR, Sept. 24-28, 1990. Forty-nine experts from Austria, Canada, Finland, Germany, Scotland, USA, and USSR, presented 42 papers on the prevention of and recovery from archive and library disasters.

The Library has received assistance from many Soviet and international libraries and institutions. Particularly helpful foreign organizations included UNESCO, International Federation of Library Associations, International Council for Archives, The Library of Congress, Getty Conservation Institute, German Friends of the Library, and the national libraries of many countries.

On the status of recovery work, approximately one half of the recovery work was completed in early 1991. The remaining work, excluding the books requiring restoration, is expected to be completed in 1992.

## 2. METHOD 1: RESTORING BOOK PAPER BY DRY LEAF CASTING

### 2.1 Comparison of Dry and Wet Leaf Casting

The dry or air leaf casting process is easily understood by comparing it to the wet or water leaf casting process. Both processes have similar principles and philosophy. The holes in documents and leaves of books are eliminated by filling these holes with replacement paper fibers. These new fibers are bonded together and to the original fibers.

The principle difference between the dry and wet techniques is that air, not water, is the medium. Air is used to separate the fibers and to carry them into the holes that must be filled. This substitution of air for water leads to other differences between the dry and wet methods:

Difference 1: The natural paper fibers used in the wet process are replaced with modified paper fibers that have occasional droplets of a very stable acrylic/silicone thermoplastic on their surfaces. The purpose of these thermoplastic droplets is to bond both the replacement to each other and to the original fibers. These thermoplastic resin droplets are used instead of (1) the hydrogen bonds formed between paper fibers and (2) the strengthening additives that are normally used in wet leaf casting.

Difference 2: The dry method includes a brief heat pressing treatment following leaf casting to bond the replacement and original fibers together.

Difference 3: The dry method avoids the possibility of introducing heavy metal ions into the paper during leaf casting.

Difference 4: The dry process is reversible using solvents, for example, acetone.

Difference 5: The dry process may be used to restore documents that the wet process would damage.

Difference 6: The dry process involves fewer steps and uses less equipment than the wet process, e.g., fiber preparation and water removal.

The remainder of this section on restoring book paper by dry leaf casting will describe laboratory scale equipment and research results.

## 2.2 Components and Procedures in Dry Leaf Casting

The dry process involves three major steps as shown in

Figure 1:

1. Prepare and apply the thermoplastic treatment to the paper fibers.
2. Dry leaf casting the replacement paper fibers into the holes or on thin areas of paper documents.
3. Bond replacement fibers together and to the original paper fibers.

Step 1: Preparing the replacement paper fibers commences with dissolving the acrylic/silicone co-polymer in a solvent, e.g., acetone. Then the Co-polymer solution is applied to bleached, sulfate paper fibers. The treated fibers are dried in air. The solution of thermoplastic polymer in acetone is dilute, about 1.5 percent solids. The chain length of the silicone polymer averages approximately 2,000 monomer units; the acrylic polymer is longer, about 7,000 units.

Step 2: Uses a specially designed aerodynamic, apparatus to leaf cast the replacement fibers into holes. The main component is a reinforced wire mesh document holder mounted in the center of the apparatus. Air is exhausted by a fan mounted at the bottom, and fibers are introduced from the top. The rate of air flow is determined by pressure drop, approximately 90 mm. Hg., below atmospheric pressure under the paper document.

Step 3: Used a hydraulically operated, electrically heated press with a modified stainless steel platen, to bond the composite document into an integral paper unit. A pressure of approximately 0.5 kg/cm<sup>2</sup> and a treatment time of 3 minutes at a temperature of 100 °C may be used for most book papers.

## 2.3 Results

The formula for the co-polymer of acrylic/silicone was selected on the basis of adhesion, that is, bonding strength, and resistance to ultra violet (UV) light aging. We selected an 80:20 ratio of the acrylic to the silicone polymer (See Tables 1 and 2 for data).

Research studies indicate an increase in the preliminary moisture content of the replacement fibers improves the properties of paper strengthened by dry leaf casting. Results of subsequently treating the replacement fibers with a mixture of 1.5 percent of the acrylic/silicone co-polymer dissolved in an acetone solvent gives the strongest paper. Figure 2 presents results using different mixtures.

Studies with an electron microscope do indicate that the addition of moisture in the treatment increases the number of adhesion (bonding) points.

The Chemical-Biological Laboratory of the Russian Museum in Leningrad independently evaluated the resistance of the replacement fibers to fungi. These fungi were obtained from books and documents. Test specimens of both untreated and thermoplastic treated pulps were inoculated with fungi. Standard test methods and evaluation on a scale of 0 to 5 were used.

The use of the heated press in the dry leaf casting process made it possible to include treatment with a heat sensitive tissue. A thin layer of the acrylic/silicone Co-polymer was applied to tissue paper, and the tissue bonded to the leaf cast paper during heat pressing. Standard folding endurance and tensile strength tests indicate that the dry leaf casting process produces an increase in folding endurance and strength, as shown by Figures 3 and 4.

A series of measurements of different papers indicated dry leaf casting does not affect the physical dimensions of paper.

#### 2.4 Conclusions on Dry Leaf Casting

The principal conclusions from this dry leaf casting research, when compared to wet leaf casting, are:

Conclusion 1. Papers that wet treatments may damage can undergo dry leaf casting without preliminary protection from water.

Conclusion 2. Less equipment is necessary because large quantities of water do not need to be stored or transferred.

Conclusion 3. The physical dimensions of paper protected by dry leaf casting are not changed.

Conclusion 4. Dry leaf casting offers an alternative method of filling missing areas of paper.

## 3.0 METHOD 2: DRYING WATER DAMAGED LIBRARY MATERIALS

### 3.1 Introduction

This manual freeze drying technology was developed by the USSR Ecological Safety Research Center to dry approximately 200,000 books at the Library of the USSR Academy of Sciences. The requirements established for the manual freeze drying were:

Requirement 1. A simple, reliable procedure that non-professional staff members could operate under guidance by professional conservators.

Requirement 2. Applicable at or near the disaster location.

Requirement 3. Capable of being installed and operated with ordinary heating and ventilating equipment and instruments.

Requirement 4. Suitable for drying most, if not all, library books and periodicals.

Requirement 5. Minimize the changes in chemical and physical dimensions of books during drying.

Requirement 6. Produce straight text blocks and bindings requiring only fumigation before dry books can be returned to the library.

### 3.2 Preparation For Drying

The water-wetted books were taken to a freezer and frozen as quickly and as straight as possible.

Groups of 10 to 15 frozen books of similar size were selected to make parcels measuring approximately 8 by 10 by 12 in. (20 by 25 by 30 cm.).

These parcels were very tightly bound together with an absorbent cloth wrapper. These wrappers could be made from cotton toweling. Each wrapper had an outside pocket for each of the six sides of the parcel. These pockets were filled with clean sawdust from local sawmills as an additional absorbent and insulator. There were no special requirements established for the sawdust and toweling.

The books were trucked from the freezer location in Leningrad to the library where drying occurred.

Six teams of workers were organized from a group of 52 staff members to transfer the books (1) from the freezer, (2) into the dryer, (3) out of the dryer, (4) inspect the books after drying, (5) return the books to their original location in the Library's Collection, and (6) supervise and control the drying equipment and operation.

### 3.3 Drying Rooms

The drying rooms contained shelving for over 300 bundles of books, that is, 3000 to 4500 books per cycle.

The normal drying cycle lasts one week. Operating temperature and relative humidity are checked once per hour. Drying occurs at 30 °C plus or minus 5 °C and 30 percent relative humidity, plus or minus 5 percent.

The air is circulated vigorously during drying. A positive air pressure is maintained inside the drying room.

Ventilating fans were installed to continually exhaust air from the room and maintain drying conditions at 30 °C (86 °F) and 30 percent relative humidity.

Books which were not completely dry after one week were dried for a second week.

### 3.4 Important Steps For Manually Freeze Drying Books

Based on my experience in helping install and working in all parts of this drying process, the important steps for successful freeze drying of books in the Library of the USSR Academy of Sciences were:

Step 1. Stabilizing the wet books by freezing.

Step 2. Preparing the wrapping bandages from absorbent cloth with outside pockets to hold the sawdust absorbent that we used.

Step 3. Tightly wrapping 10 to 15 frozen books inside the special bandages for drying. The books were tied tightly together and could not move or change dimensions as they dried.

Step 4. Wrapping the books quickly at the freezer location and quickly moving the books to the drying room.

Step 5. Operating the drying room at 30 °C (86 °F) and 30 percent relative humidity during the seven day drying week.

Step 6. Re-wrapping the books after one week immediately

and continuing the drying if all the books in one parcel were not dried.

Step 7. In this drying process, the books are dried evenly from inside to outside.

Step 8. As a precaution, the books are fumigated after drying to kill any fungi that might begin to develop during the drying week.

Step 9. Five teams worked only one day each week to (1) pack and bring the books from the freezer to the dryer, (2) remove the books from the dryer, (3) inspect the dried books, (4) re-load the dryer, and (5) return the dried books to the Library's collections.

Step 10. One smaller, three person team worked 24 hours per day every day. Their extra responsibilities were to check and adjust drying room conditions, equipment, temperature, and relative humidity hourly; and monitor the condition of books during and after drying constantly prior to their return to the Library collections.

Step 11. An advantage of this drying process is books can be straightened after drying because they are not absolutely bone dry when they are removed from the dryer.

Step 12. Scientists from the USSR Ecological Safety Research Center (another group) were responsible for fumigation after drying and I did not work in this step of the Process. Reports on the fumigation techniques that were used are given in the Abstracts and the Proceedings of the Leningrad Symposium.

#### 4.0 ACKNOWLEDGEMENTS

I am deeply grateful to my fellow authors and their institutions for their assistance in preparing this report; to the Library of the USSR Academy of Sciences, the Getty Conservation Institute, The Library of Congress for permission to share presentations of the Leningrad Symposium; to Dr. Adolph A. Leonovich, my Scientific Leader, and Dr. Valerii Leonov, Director of the Library of the USSR Academy of Science for their encouragement and guidance; and to Igor Lyssenko, Managing Director, Foundation for Social Development and Revitalization of Russia - St. Petersburg for official support; and to the Book and Paper Group of the American Institute of Conservation and Wei T'o Associates, Inc. for inviting me.



## 5.0 REFERENCES

5.1. Abstracts and Program of the Symposium "Conservation and Disaster Recovery: International Cooperation at the Library of the USSR Academy of Sciences," Leningrad, USSR, September 24-28, 1990. Marina del Rey, CA: Getty Conservation Institute, September 1990, 78 pp.

5.2 "Proceedings of 'Conservation and Disaster Recovery: International Cooperation at the Library of the USSR Academy of Sciences,' September 24-28, 1990, Leningrad, USSR." Marina del Rey, CA: Getty Conservation Institute, In press.

5.3 Contact Larissa B. (nee Shapkina) Smith, 224 Early St., Park Forest, IL 60466, directly with specific questions or for additional references in Russian.

## 6.0 AUTHORS

Larissa B. Shapkina was Section Head, Restoration Division, Department of Hygiene and Book Restoration, Library of the USSR Academy of Sciences, Leningrad. (Ms. Shapkina is the USA representative of The Foundation for Social Development and Revitalization of Russia, a not for profit foundation established to assist and support all activities that improve the environment, cultural development, economy, and otherwise benefit the Russian people.) The additional authors contributing to "2. Method 1: Restoring Book Paper by Dry Leaf Casting" are Dr. Adolph A. Leonovich, Head, Department of Cellulose Chemistry and Physical Chemistry, Forest Technical Academy, Leningrad; Dr. Michael K. Nikitin, Head, Chemical/Biological Laboratory, State Russian Museum (SRM), Leningrad; and Ms. Maya V. Apreleva, Scientific Researcher, Chemical/Biological Laboratory, SRM. The additional authors contributing to "3.0 Method 2: Drying Water Damaged Library Materials" were Dr. Oleg A. Gromov (deceased), formerly Head, Microbiology Laboratory, USSR Ecological Safety Research Center (ESRC); Dr. Vladislav K. Donchenko, Chief, ESRC; Dr. Alexander I. Kalinin, Laboratory Head, ESRC; and Mr. Vladimir P. Sokolov, Laboratory Head, ESRC.

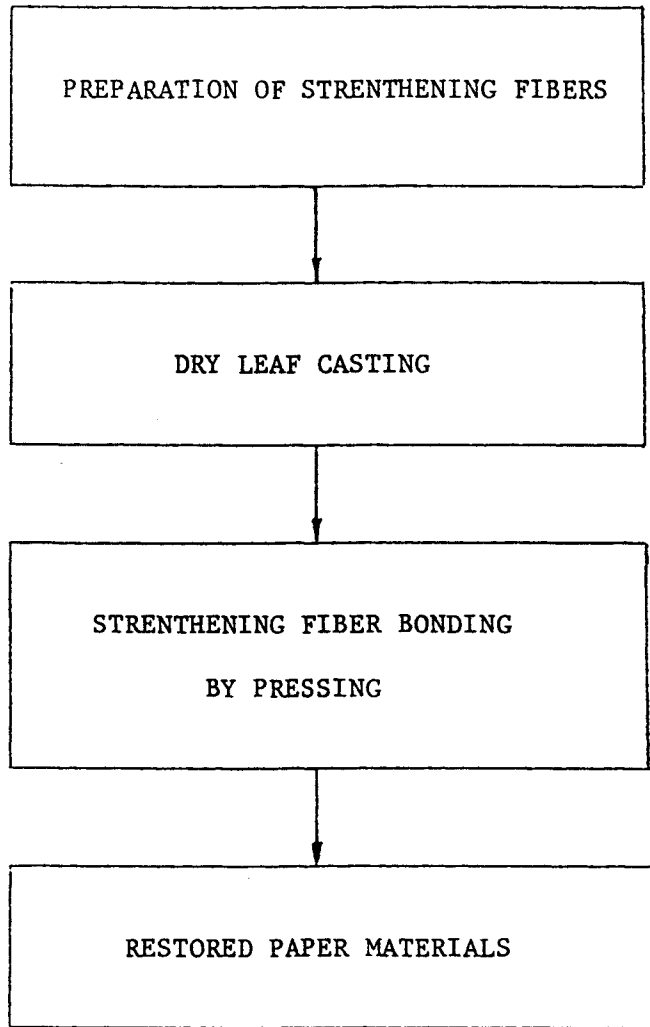


Fig. 1 Operation scheme of paper pulp restoration process by dry leaf casting.

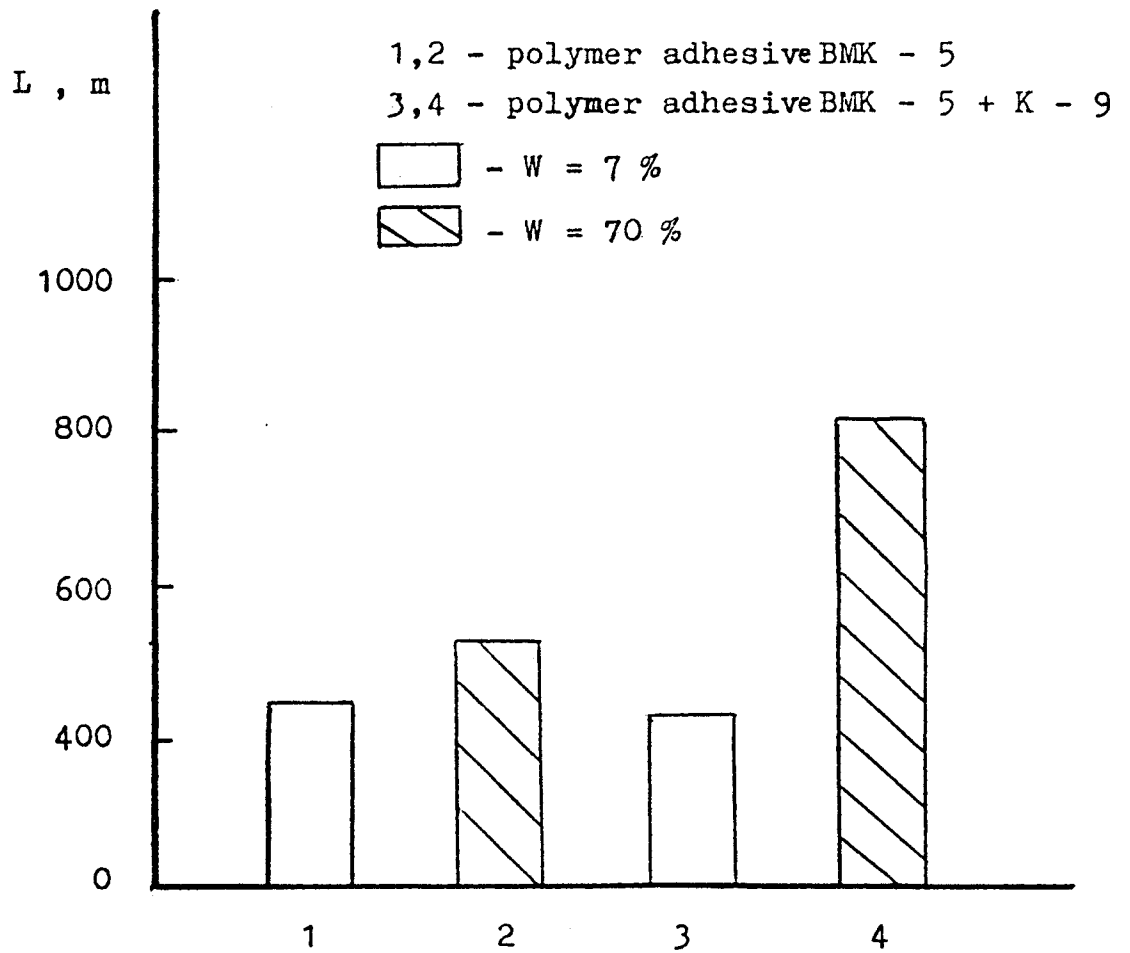


Fig. 2 Change cross breaking length (L,m) of dryformed paper at 7% and 70% moisture content (W,%).

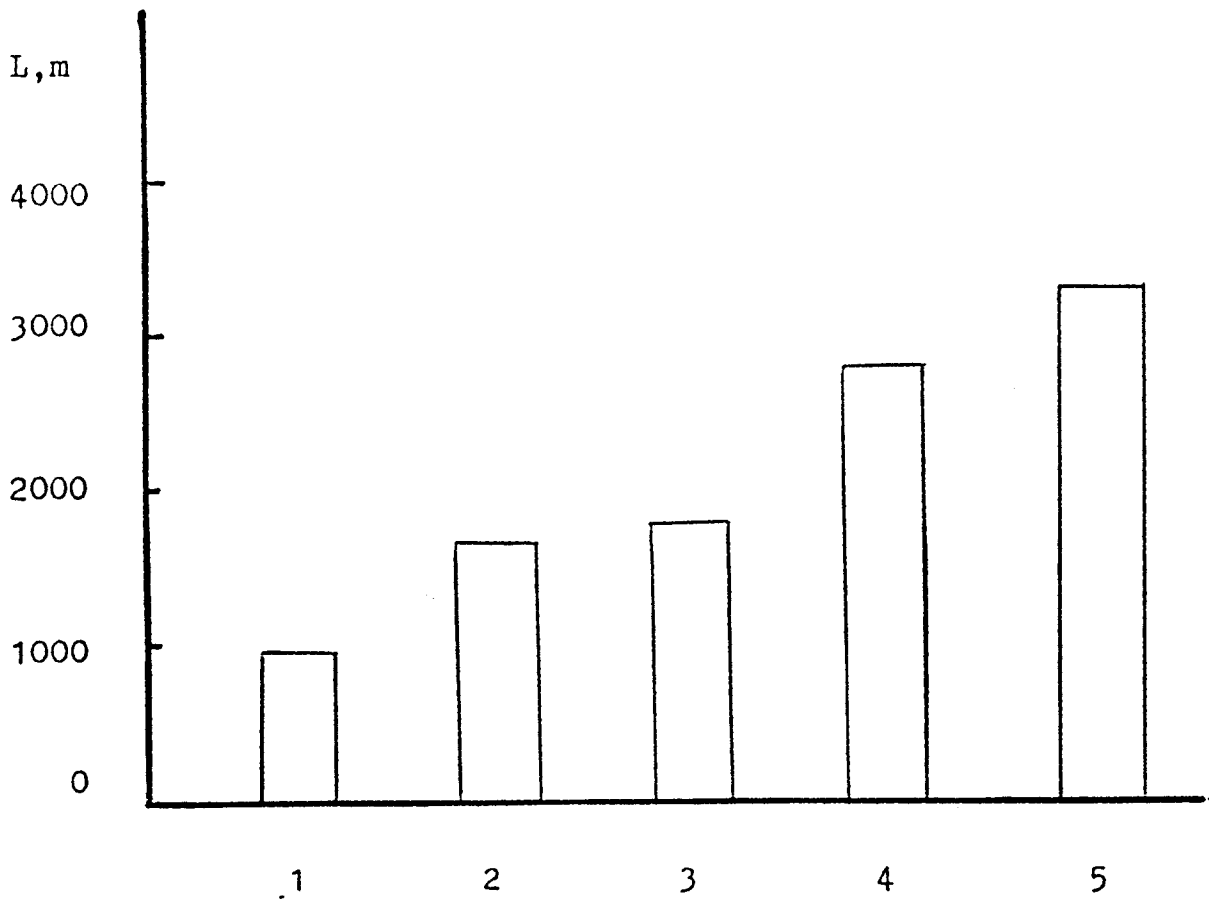


Fig. 3 Change of cross breaking length (L,m) (machine direction) of printing restored paper after strengthening by laminating with transparent polymer containing paper:

- 1 - initial paper;
- 2 - initial paper + tissue paper of kind 1;
- 3 - initial paper + tissue paper of kind 11;
- 4 - initial paper + mica paper of kind 1;
- 5 - initial paper + mica paper of kind 11.

The paper kind 1 is obtained by putting the mixture of organic and silicon polymers at paper moisture content 70%; the paper of kind 11 - at paper moisture content 7%.

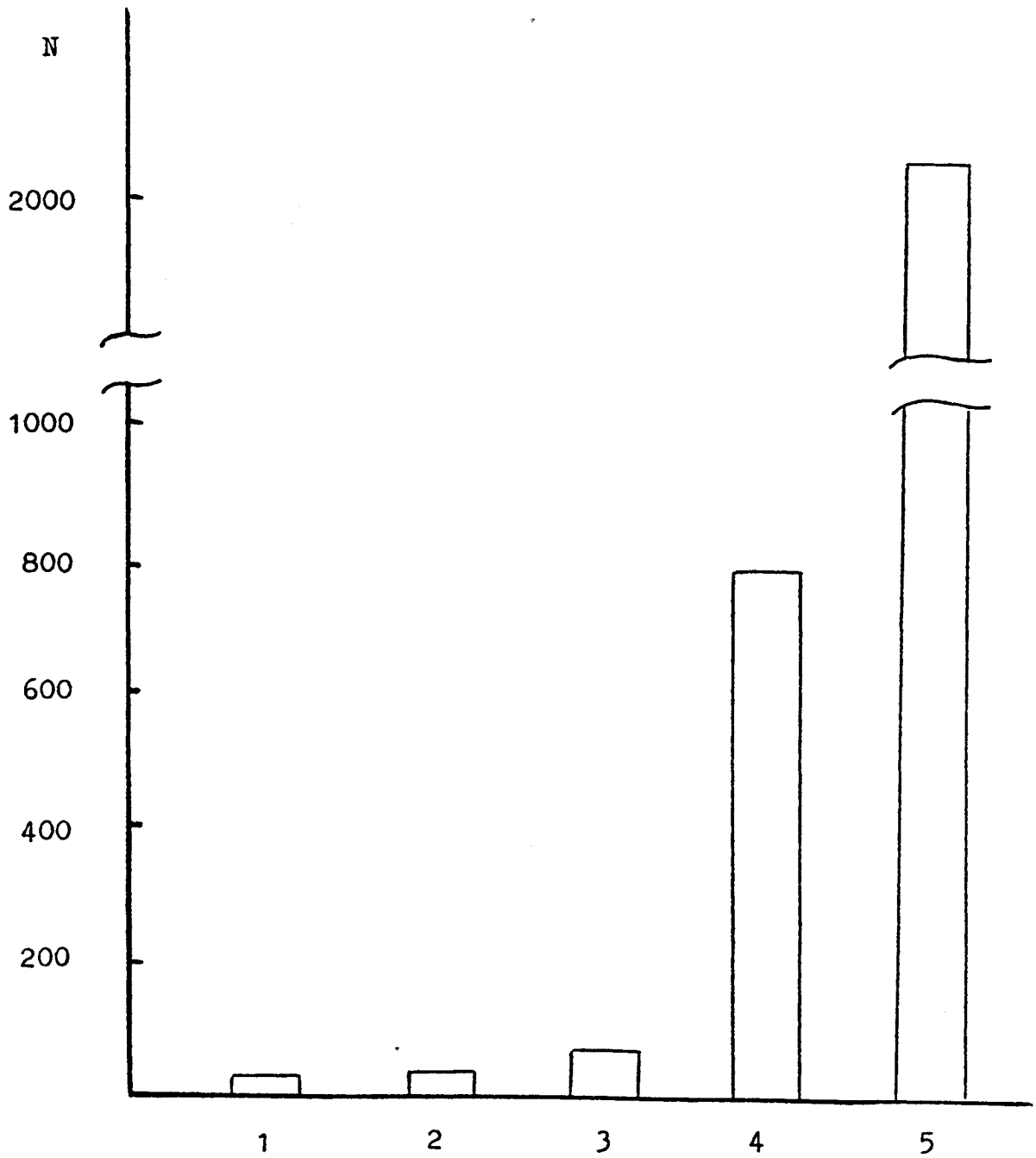


Fig. 4 Increase in printing paper folding endurance (machine direction) from lamination with transparent paper containing polymers. Specimens 1,2,3,4 and 5 are identified in Fig. 3.

Tabl. 1. Polymers supplied for dry leaf casting.

Polymer	Formula	
BMK - 5	$\left[ \begin{array}{c} \text{CH}_3 \\   \\ -\text{CH}_2 - \text{C} - \\   \\ \text{COOC}_4\text{H}_9 \end{array} \right]_m$	$\left[ \begin{array}{c} -\text{CH}_2 - \text{CH} - \\   \\ \text{COOH} \end{array} \right]_n \quad m : n = 1 : 1$
K - 9	$\left[ \begin{array}{c} \text{C}_6\text{H}_5 \\   \\ -\text{Si} - \text{O} - \\   \\ \text{C}_6\text{H}_5 \end{array} \right]_m$	$\left[ \begin{array}{c} \text{CH}_3 \\   \\ -\text{Si} - \text{O} - \\   \\ \text{CH}_3 \end{array} \right]_n \quad m : n = 2 : 1$

Tabl. 2. Results of UV-aging of polymer's films.

Polymer	Polymer/water contact angle ( $Q^\circ$ )			Degree of changing	
	before UV-aging, $Q_1^\circ$	after 100 hours, $Q_2^\circ$	after 100hours, $Q_3^\circ$	$Q_2^\circ/Q_1^\circ$	$Q_3^\circ/Q_1^\circ$
BMK - 5	77	26	16	0.33	0.21
K - 9	98	96	94	0.98	0.96
BMK - 5 + K - 9 ( 80 : 20 )	96	92	69	0.98	0.72
BMK - 5 + K - 9 ( 50 : 50 )	98	94	86	0.96	0.88
BMK 5 + K - 9 ( 20 : 80 )	98	96	92	0.98	0.94