REPORT NO. M-2037

DATE 2 April 1943

FR-2037

SUBJECT

EFFECT OF IRON INCLUSIONS IN ASBESTOS ON ELECTRICAL CHARACTERISTICS OF INSULATING MATERIAL - DETECTION OF IRON PARTICLES BY X-RADIOGRAPHY

NAVAL RESEARCH LABORATORY

BELLEVUE, D. C.

U. S. GOVERNMENT PRINTING OFFICE 16-21906

2 April 1943 N.R.L. Report No.M-2037

NAVY DEPARTMENT

Report on

Effect of Iron Inclusions in Asbestos on Electrical Characteristics of Insulating Material - Detection of Iron Particles by X-Radiography.

NAVAL RESEARCH LABORATORY
ANACOSTIA,STATION
Washington, D. C.

Number of pages: Text-4 Tables-1 Plates-13

Authorization: BuShips tests no. S62(11)(DYS-3) Nov. 28, 1940. Oct. 14, 1941 (Sp. Div. No. 9 BuShips Proj. order 678141).

Date of Tests: Nov. 1941 - June 1942.

Prepared by:

H. F. Kaiser - Physicist

M. Elliet - Assoc. Chemist

C. T. Klee - Contract Employee

Reviewed by:

F. M. Walters, Jr., - Supt. Metallurgy Div.

P. Borgstrom - Supt. Chemistry Div.

Approved by:

A. H. Van Keuren, - Rear Admiral, USN
Director

Distribution: BuShips - 6
File - 6

eb

ABSTRACT

Fine metallic particles present in fabric tapes used for electrical insulation may be detected by x-radiography using soft radiation and fine grained film, enlargements from which will show the metallic particles to better advantage than a microscope. Tests were made with this method of a number of commercial asbestos tapes and impregnated tapes used for cable wrapping.

TABLE OF CONTENTS

	Page
Abstract	
Authorization	1
Statement of Problem	1
Experimenta Methods	1
Conclusion	3

APPENDICES

	Plates
Arrangements for Radiography af Insulating Tapes and Cables	1

	Radiographs
Asbestos Tape Sample Containing 40 mesh Iron Fillings (8.5X)	2
Prints of Radiographs of 14 Cable sheath and Roving Samples (See Table I)	3
Cable Wrapping Specimen No. 4C Enlarged 6.9X	4
" " " No. 3C " "	5
" " " No. 2A " "	6
" " " No. 4B " "	7
Asbestos Tape Sample XC (Source Unknown) 6.5X	8
" " " (1X.015) Raybestos "	9
" " " (1X.025) " "	10
" " " No.2671 Keasby and Mattison 6.5X	11
Samples of Plates 8-11 Compared at Unit Magnification	12
Section of Cable Radiographed with Molybdemum Radiation	13

AUTHORIZATION

1. The radiographic studies described in this report are a part of a project to study the effect of iron inclusions in asbestos on the electrical characteristics of insulating material. Authorized by BuShips letter No. S62 (11) (DYS-3) Nov. 28, 1940. BuShips Letter S62 (11) (355) Oct. 14, 1941. Sp. Div. No. 9, authorized a study of effect of iron inclusions on insulating properties aided by the application of x-ray micro-radiography.

STATEMENT OF PROBLEM

2. The aim of the work is to reveal by x-radiography the presence of metallic particles in various commercial samples of asbestos tape, and to establish, if possible, some relationship between the size and distribution of these particles and the electrical properties of the insulating material made from such tape.

3. The presence of metallic particles in fabrics may be determined by other methods than the one described herein, such as chemical tests, and microscopic examination. Each method also has limitations, but the x-ray method possesses certain advantages that will be evident from the radiographs obtained. The principle of the method is essentially that employed in microradiography, that is, a thin test specimen is placed very close to a recording film having a very fine grained emulsion and a shadowgraph of this test object is made, using x-radiation of such wavelength, that as high a contrast as possible will be developed between the constituents of different densities within the test sample. The processed film is then viewed at a magnification which will allow all details of the structure to be seen. Film materials are available with such fine grain size that very high magnification may be employed. In these tests no very high magnification was required, and it was possible to use somewhat faster film material such as fine grain motion picture film in place of the extremely fine grain film used in microradiography.

EXPERIMENTAL METHODS

4. The arrangement used in making these tests is shown in Plate 1(a), where are shown the x-ray tube (which was a tube with iron anti-cathode in most of these tests) and an adjustable stand holding the film and specimen cassette, which is an ordinary movie film printing frame fitted with a thin bakelite front. In this holder, the asbestos tape sample is placed against the bakelite, and the film is laid upon the sample with emulsion side in direct contact with the sample. The holder was set at a distance of 12-15 inches from the x-ray tube with its bakelite front toward the tube. Exposure time varied, but satisfactory densities were obtained with Fe radiation on 1-2 hrs. exposure when using fine grained motion picture film. In the very first trials, use was made of a special Eastman film suited for microradiography, which film required considerably longer exposures.

It was found that the enlargement required to show plainly the particles present was not great, so use was made of fine grained 35 mm. motion picture film. This film was developed in a special fine grained developer (Defender Panthermic "777"). Other kinds of radiation were tried: copper, molybdenum, and tungsten, but these, with the exception of copper, gave radiographs which were entirely too low in contrast to be of use for this purpose. With the copper-target tube radiographs could be made in a few minutes which were nearly as good as those obtained with the softer iron radiation.

5. During this work, an attempt was made to show the condition of the insulating wrappings of a heavy three conductor cable by direct radiography. The method is illustrated in Plate I (B). Due to the thickness of the cable, it was obviously impossible to employ the softer radiations, such as FeK and CuK radiation. On fairly long exposures with MoK rays, it was possible to obtain a radiograph of the cable, in which the presence of particles could be noted, although the contrast in general was low, as may be seen in Plate 13. The direct contact method is to be preferred where possible.

6. The sizes of the particles in the radiograph may be determined in a number of ways. The simplest of these is the inclusion of a small piece of wire of known length and diameter from which the magnification may be determined by measurement of the image of the wire standard on the print. By use of wires of both high and low density or atomic number it is possible at the same time to judge qualitatively, the density of the particle. The difficulty with this method is that no direct indication of the nature of the particle is obtained. Thus particles of two different metals of nearly the same atomic number and size, will give about the same absorption, except in cases where the frequency of the radiation used is just sufficient to excite the fluorescent K radiation of the element of the particle. In this case the particle absorbs strongly and reradiates. Effective use of the method requires operation of the x-ray tube at a low potential (near 8000 volts) at which the x-rays generated are of low intensity. It is possible to resort to diffraction methods to determine the nature of the particles if these are present in sufficient amount. This is generally not the case. By a microscopic technique, enough particles could be collected to be analyzed by x-ray diffraction, or micro-chemical analysis. Such a process would be tedious and time consuming to say the least. Plate 2 shows a radiograph of a portion of an asbestos tape sample in which was deliberately embedded iron fillings of 40 mesh size. Particles of this size are easily distinguished from any other particles which may be present in the material. The fibres of the fabric itself are just visible and, even under longer exposure, do not appear in strong contrast. Embedded in these are numerous crystalline particles and fibres which definitely do not appear to have the density of iron particles. The radiograph also shows that particles of considerable fineness may be shown; some of those visible being around 0.0001 inch or smaller in diameter. With

increased magnification even these can be made measurable. The group of views in Plate 3, shows radiographs (taken with the above technique) of insulation wrappings taken from cables (see table 1 for identifications). Small metallic particles of various sizes may be noted along with the fibrous texture of the insulation. Many of the larger particles discussed above, and noted in asbestos tape, may also be seen in the insulation wrapping. The particle structure seen in the insulation wrapping can thus be associated with that to be found in the asbestos tape from which it was made.

7. To illustrate, by example, some types of asbestos tape having various degrees of "cleanliness", plates (8-11) have been included. (See table of Contents for Identification). For sake of better comparison, the film strips from which the enlargements were made, were recopied in plate 12 side by side. In many cases, metallic particles are large enough to be seen without any additional magnification. These film strips may then serve as comparison standards against which the cleanliness of a given tape sample may be judged directly. In practice it would be possible to make an x-ray inspection of such tapes during the process of manufacture. A permanent record of the structure would be obtained. It is evident that the denser metallic particles are shown in this way to better advantage than is possible by direct examination with the microscope. The radiographic tests described above, were supplemented by some electrical break-down tests to determine, if possible, the relationship between the iron particles present, and the break-down voltage. These tests were carried out on the untreated asbestos tapes. No correlation between the presence of the iron particles and the electrical break-down was observed. It was noticed that the break-down followed a tortuous path through the fibres of the tape, but the concentration of particles was no greater along the path than in other parts of the sample.

8. Some of the larger particles were located in the tape sample with the help of the radiograph, and removed mechanically from the samples. Most of these were black needlelike crystals, decidedly magnetic and were identified as magnetite crystals.

CONCLUSIONS

9. By use of soft x-radiation employed for x-ray diffraction work, such as copper and iron K-radiation, if is possible to make radiographs of fabric samples used for electrical insulation, which may be magnified to show the presence of metallic particles of considerable fineness. This method does not extend to positive identifications of these particles, but a qualitative indication of their density is possible. Denser metallic particles are shown to better advantage by this method than in an optical microscope. The method is simple and can easily be made a good routine test having the advantage of permanent record.

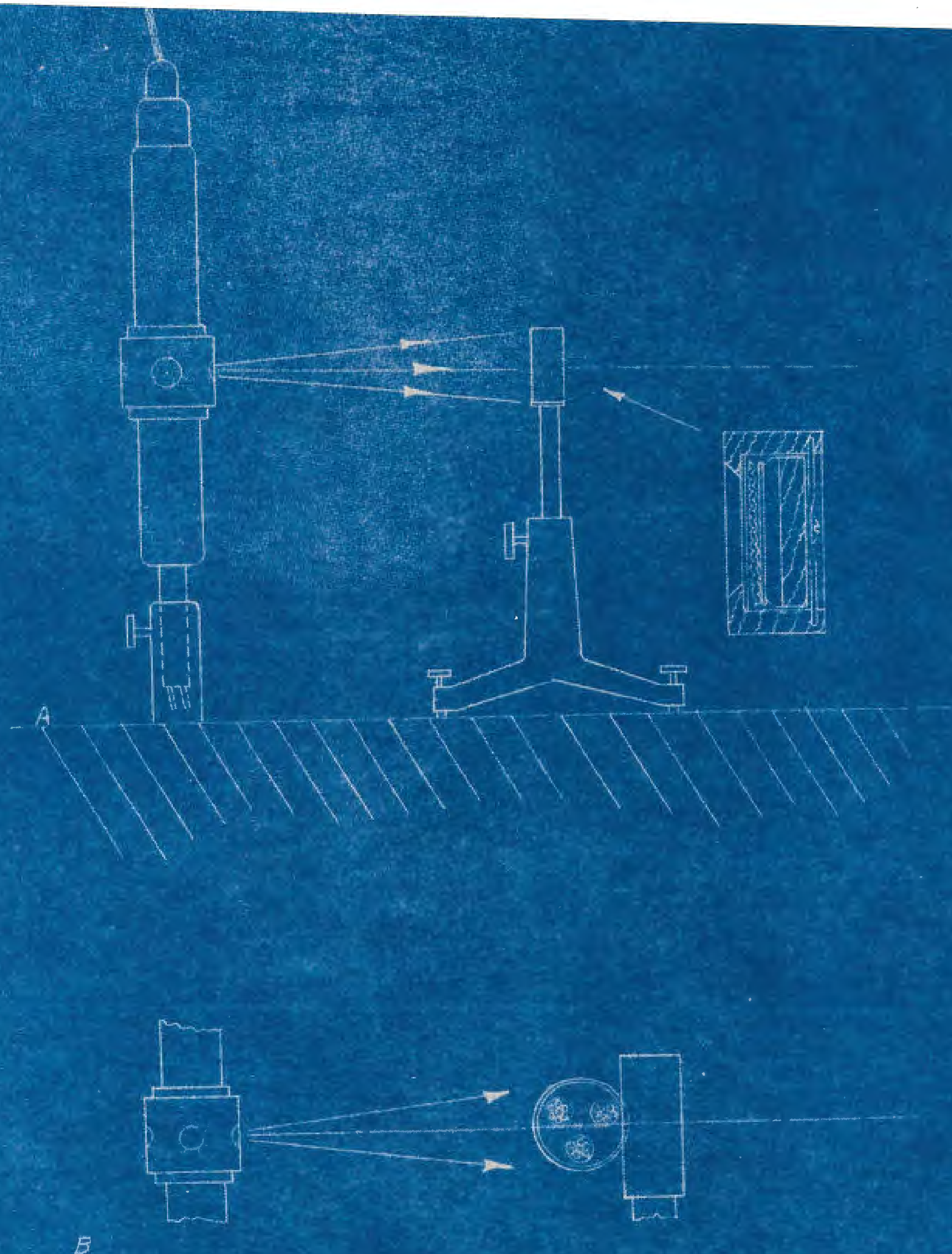
10. Studies on electrical discharges through open asbestos tape samples, did not show any correlation between the distribution of

metallic p articles and the path of the discharge through the tape. This conclusion is based on fine sized particles distributed fairly uniform ily throughout the sample.

TABLE I

Identification of asbestos tapes removed from THFA-60 cables. Radiographs are shown on plate 3 and plates 4, 5, 6, and 7.

Number	Manufacturer	Section
1A	Collyer Insulated Wire Co.	Outer Sheath
1C	Collyer Insulated Wire Co.	Conductor cover
2A	Natl. Elec. Prod. Corp.	Outer sheath
2B	" " " "	Inner sheath
2C	" " " "	Conductor cover
3B	Okonite Company	Inner sheath
3C	" "	Conductor cover
4A	General Cable Corp.	Outer sheath
4B	" " "	Inner sheath
4C	" " "	Conductor cover
5A	General Elec. Co.	Outer sheath
5B	" " "	Inner sheath
5C	" " "	Outer Conductor cover
5D	" " "	Inner Conductor cover

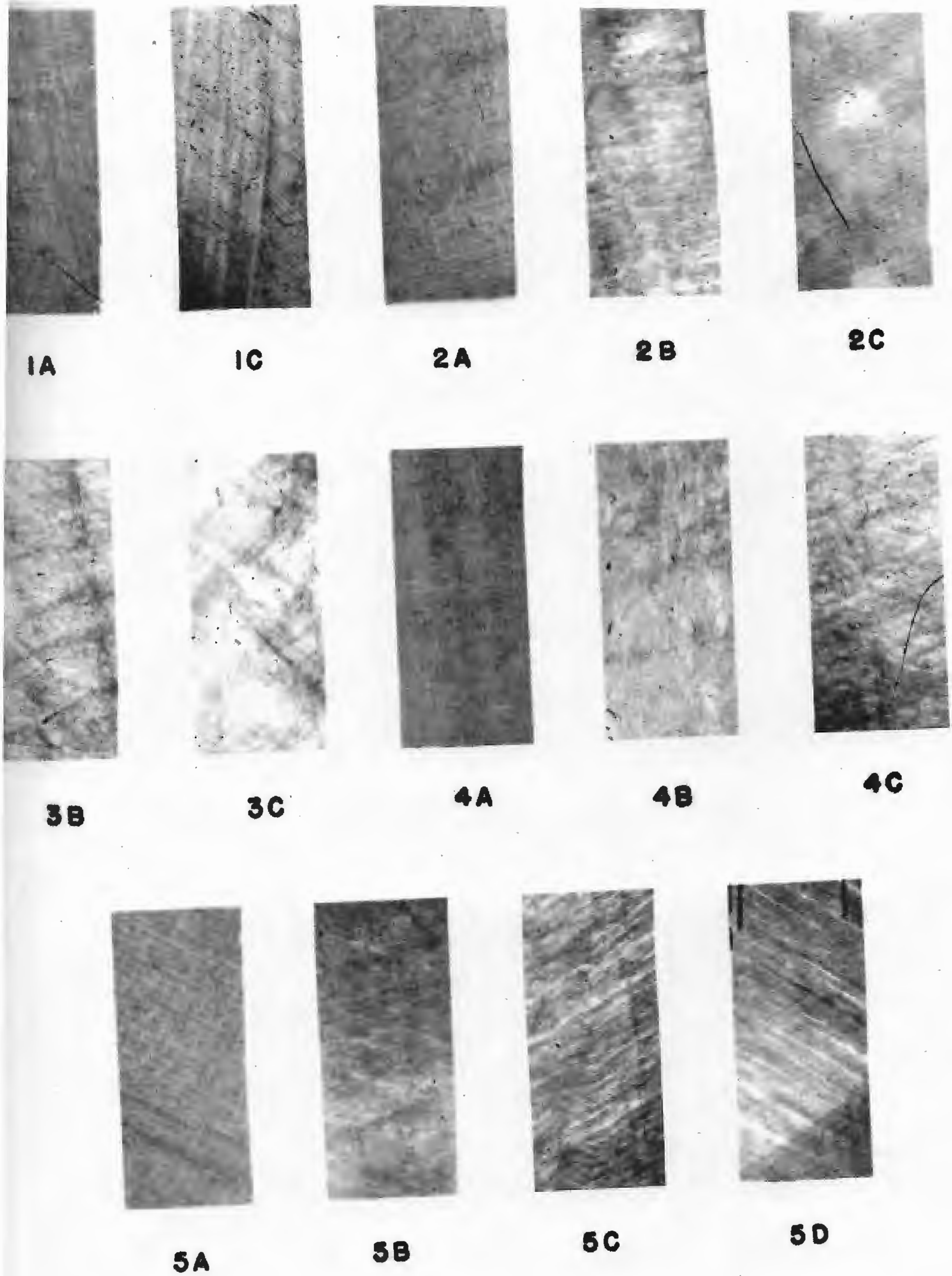


ARRANGEMENTS FOR RADIOGRAPHY OF
INSULATING TAPES & CABLES

PLATE I

8.5X

PLATE 2



CABLE WRAPPING SPECIMENS (SEE TABLE I)

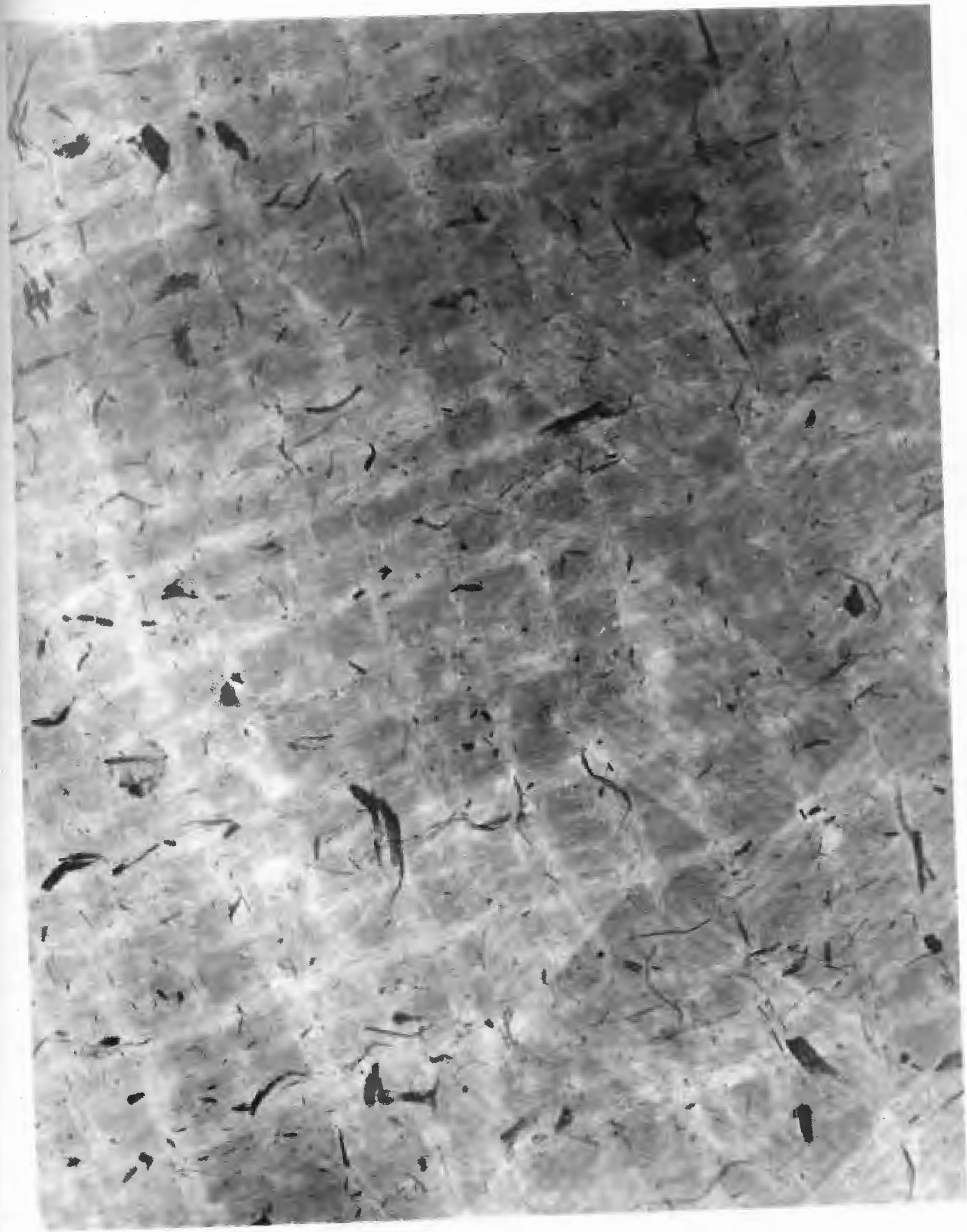
PLATE 3

SPEC. 5C 6.9 X

PLATE 4

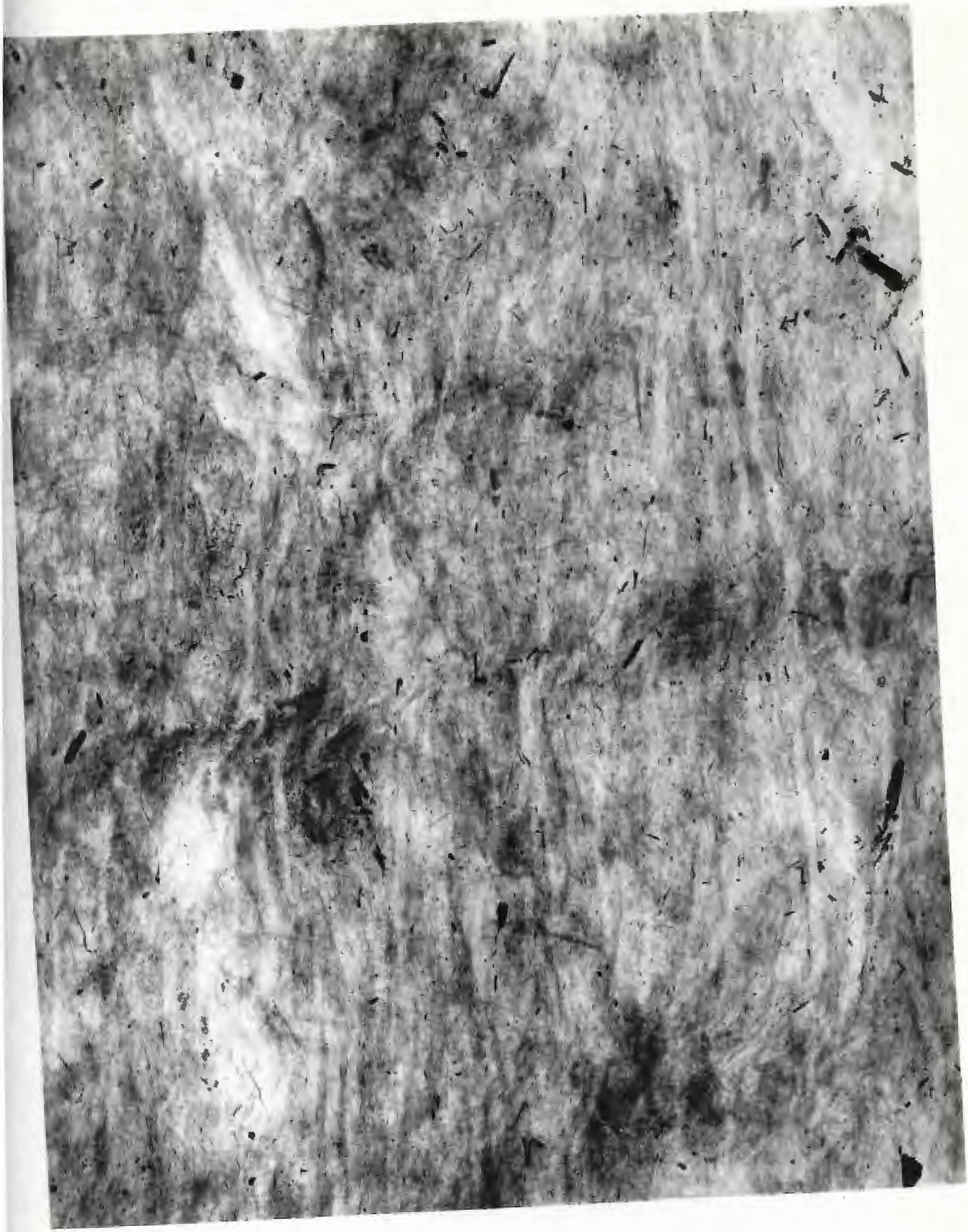
SPEC.3C 6.9 X

PLATE 5



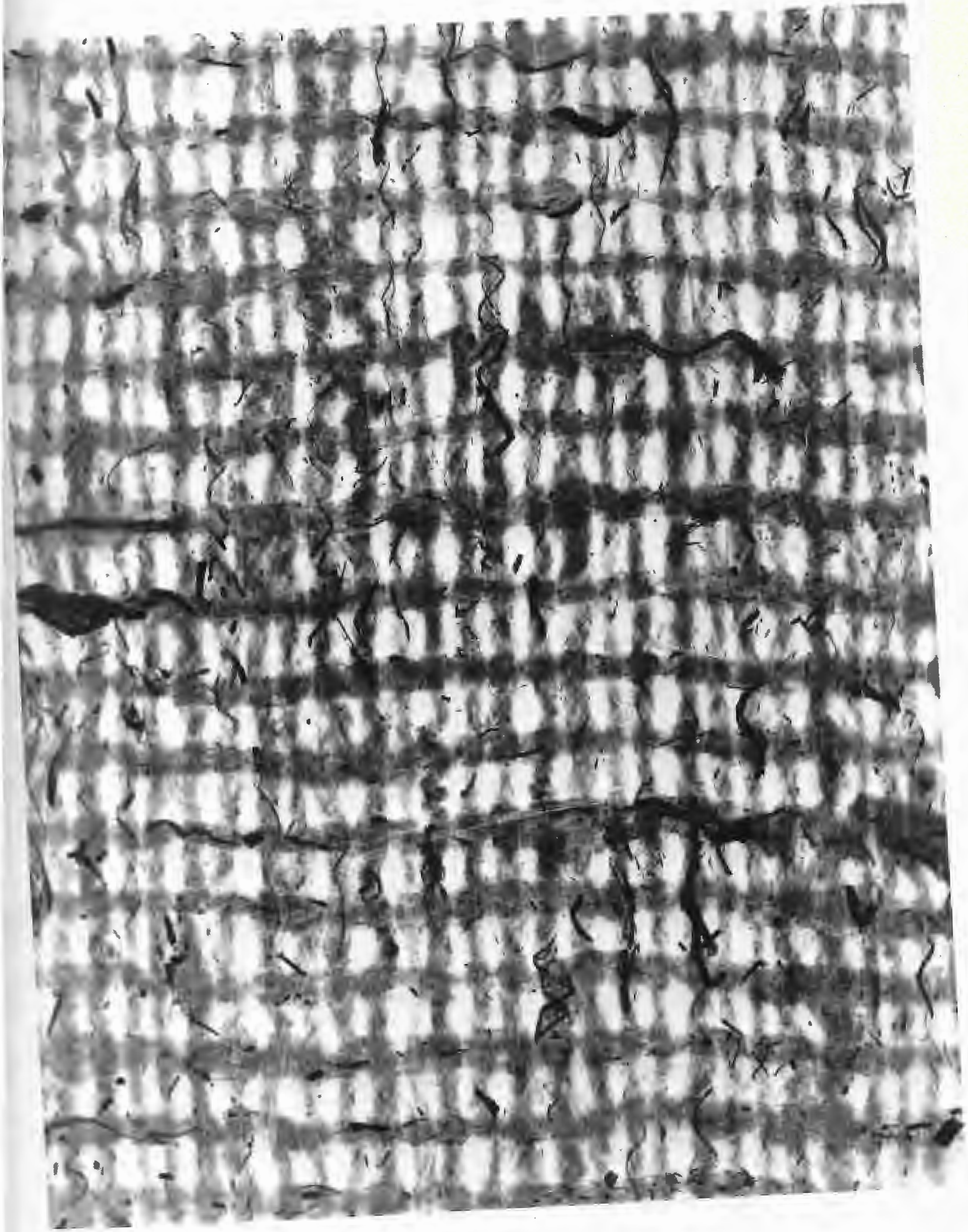
SPEC. 2A 6.9X

PLATE 6



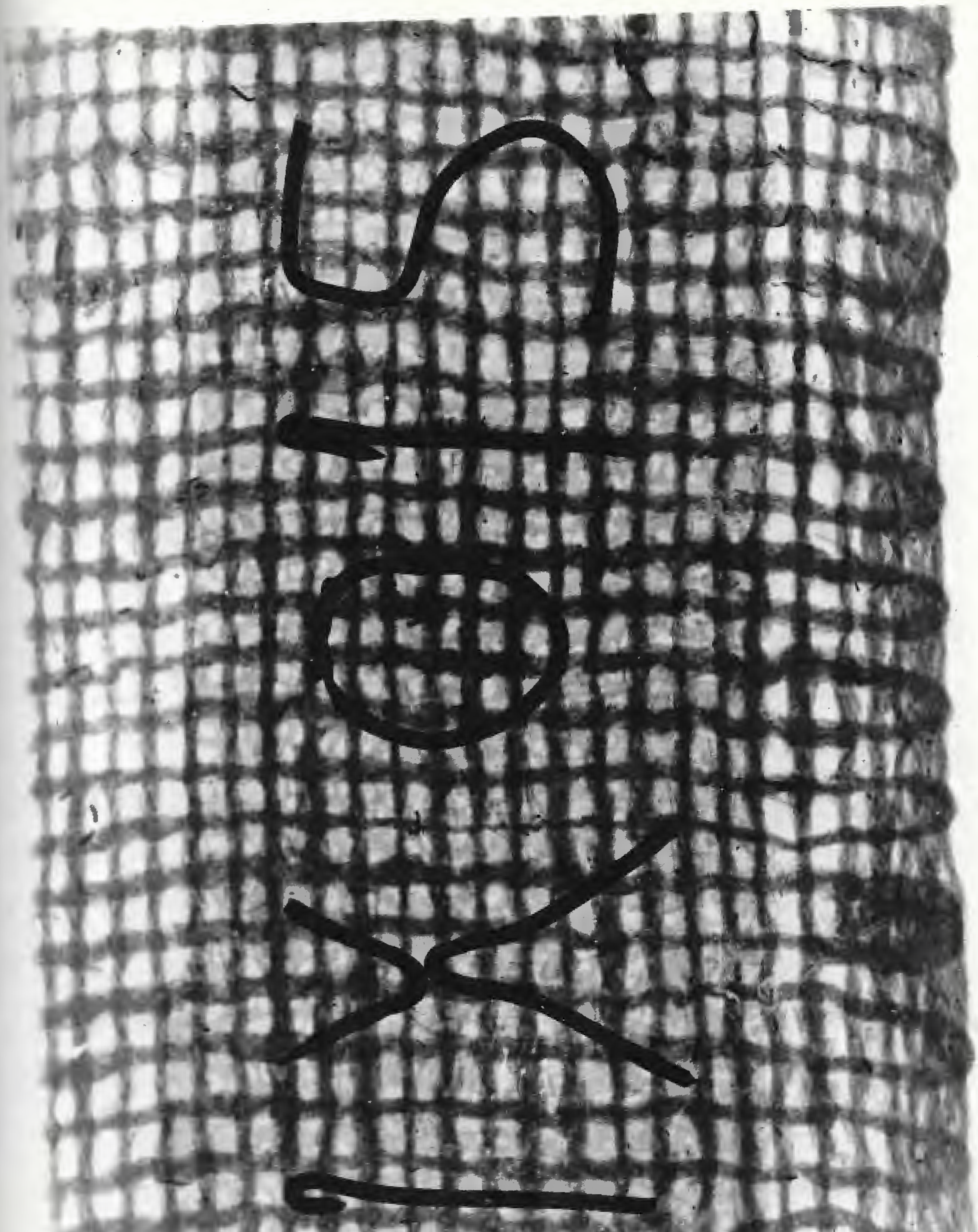
4B 6.9X

PLATE 7



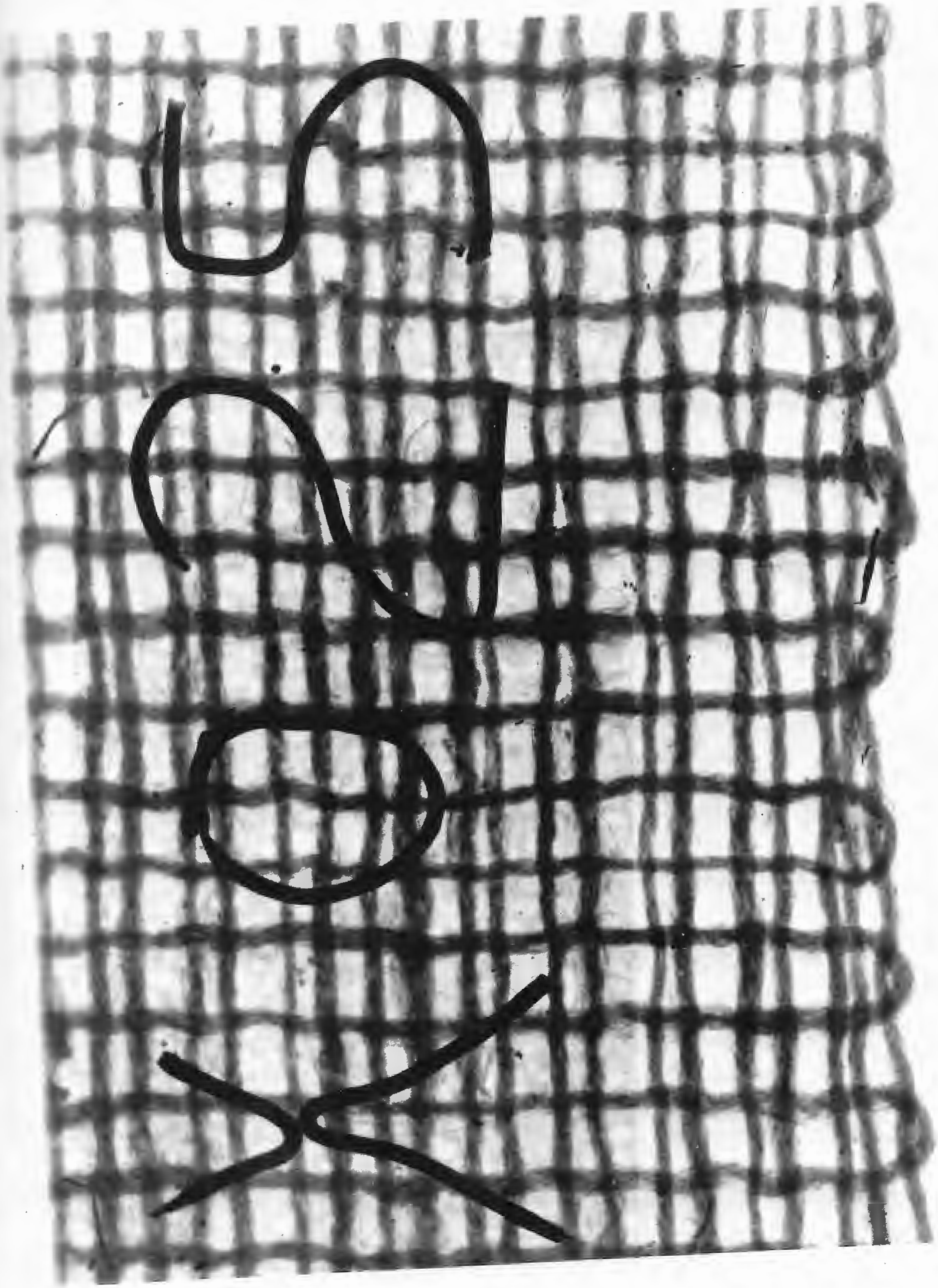
XC 6.5X

PLATE 8



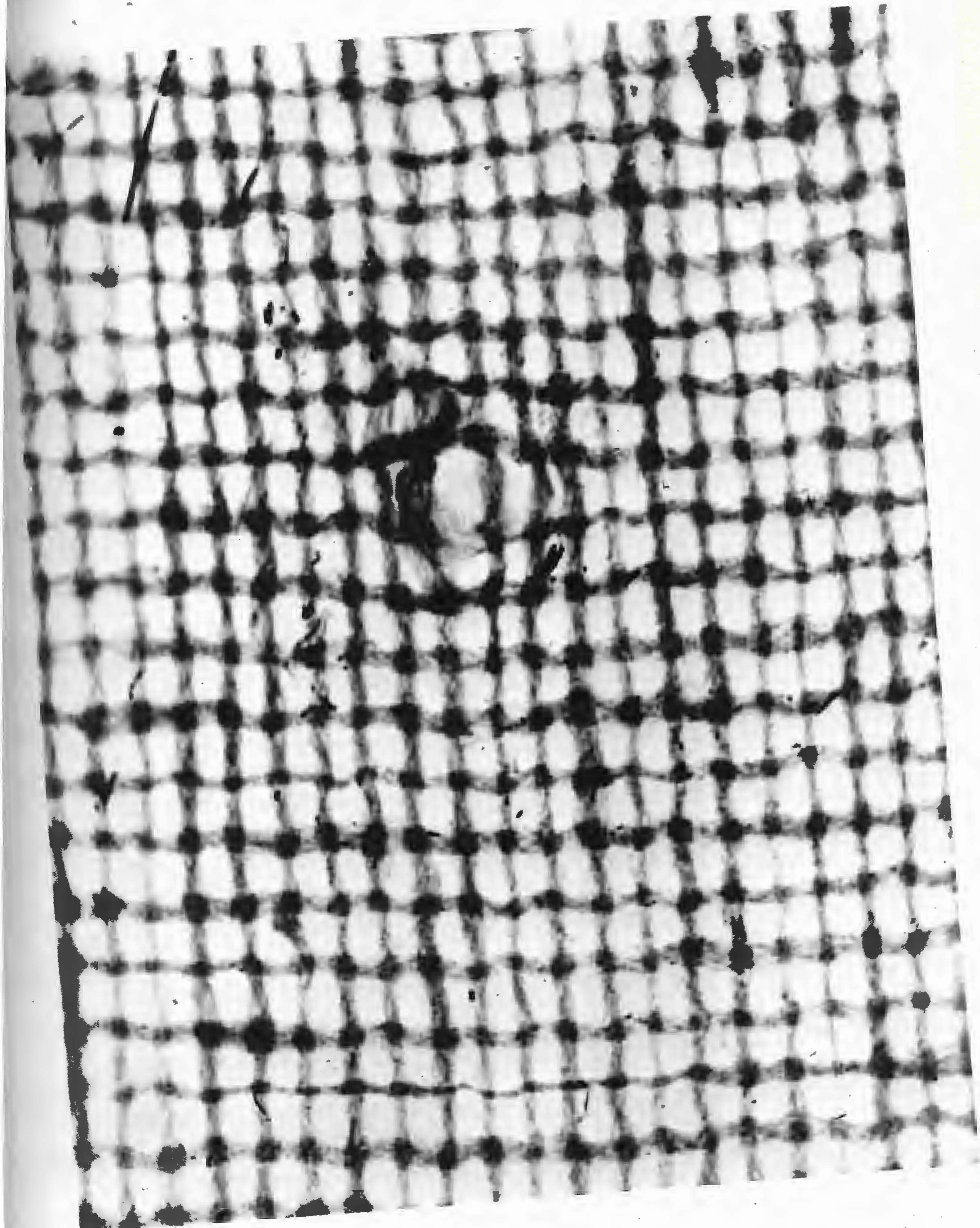
6.5 X

PLATE 9



6.5 X

PLATE 1(



2671 6.5X

PLATE 11

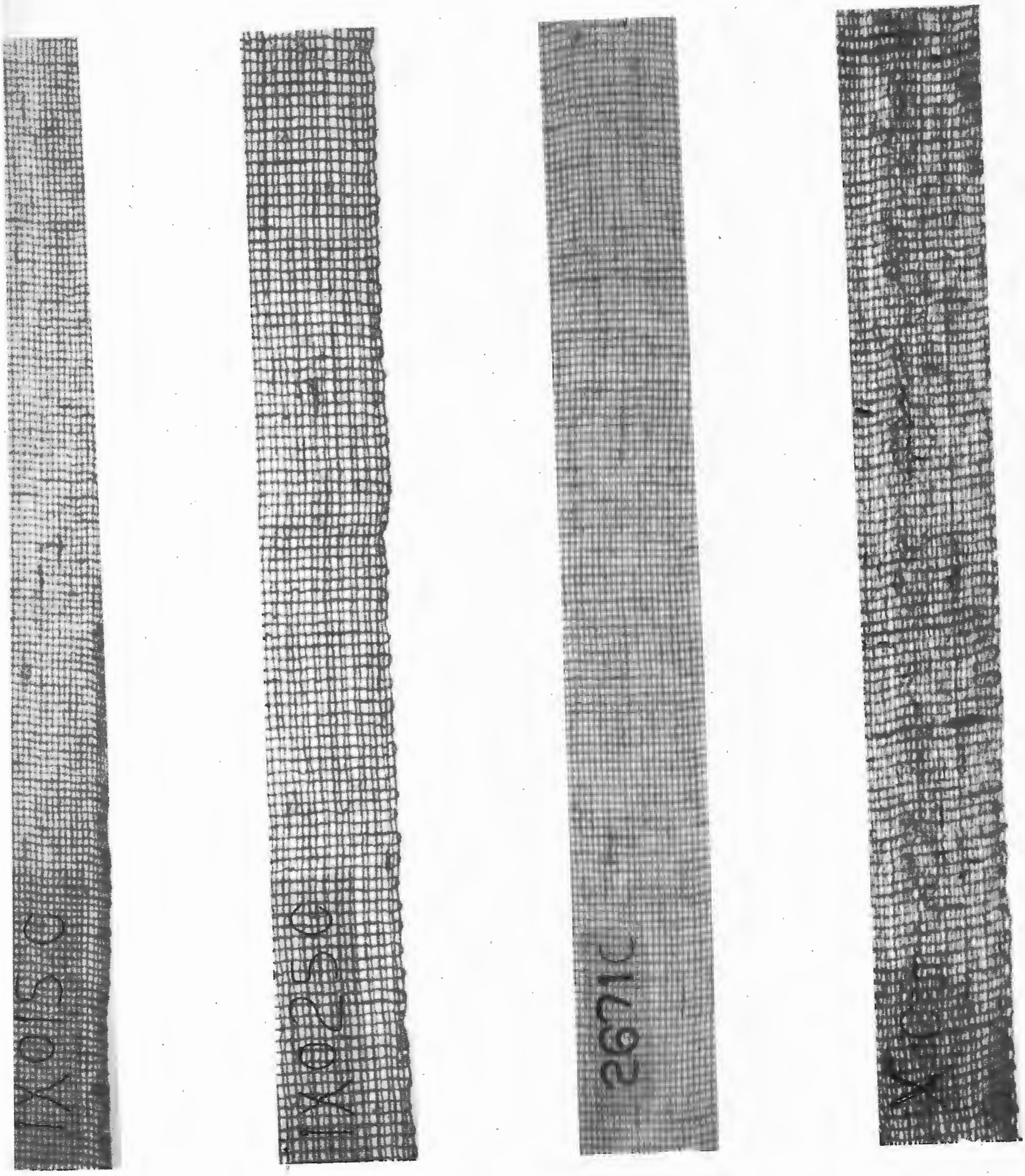


PLATE 12

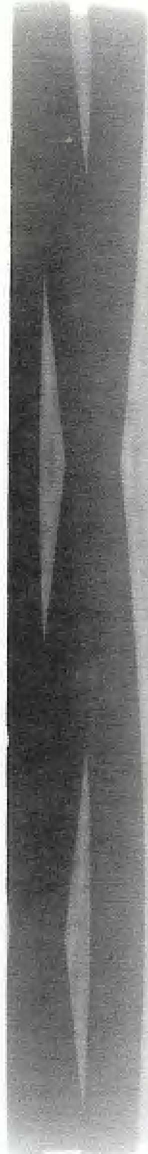


PLATE 13