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than now exists. Students of government are much given to speaking generally of the more or less of some characteristic such as centralization, morale, or respect for law as applied to phenomena that could be analyzed in terms of specific behaviors either of officials or of private citizens. The remarkably high correlations obtained from the rating of the landmarks of this scale and its predecessors suggest that some sharper specification and prevision within tested limits can be made available to the student of government, politics, and law. Indeed, the development to which this scale points is not limited to inquiry concerning behavior in governance. In so far as investigators in the other social sciences are concerned with specific behaviors which invite their curiosity because of some important characteristic, they should find suggestion from this scale for the development of instrumentation useful in their fields of inquiry.

THE IDENTIFICATION OF CLOTH ASH

J. D. LAUDERMILK*

A branch of scientific evidence, which to the best of the writer's knowledge, has been but little worked upon, is that of the identification of textile fabrics which have previously been ashed. It can readily be understood how, in certain cases, the identification of such ashed fabrics could be of importance, either in connection with evidence which had been burnt with the intent to destroy it, or in the event of clothing or other textiles being burnt from accidental causes. A case of the first type can be cited in that of the Northcott[1] murder ranch near Wineville, California. Here the finding of the partly burned remains of a Boy Scout's khaki hat was interpreted as important evidence by the prosecution. As an example of the second class, the Maddux Airplane catastrophe near San Clemente, California, may be mentioned.

The present paper purposes to show that in many instances. where the remaining ash has not been destroyed by crushing, solution, or other causes, the nature of the original fabric can be identified.

Classes of Fibers.

In regard to their derivation, textile fibers may be divided into the following classes. (A) The animal fibers such as wool and silk.

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[1]Northcott, Gordon S., warrants served Sept. 9, 1928.

(B) The vegetable fibers, as cotton, linen, jute, hemp, ramie, etc. (C) Artificial fibers, as cuprite, viscose, nitrocellulose and pyroxylin silks. The fibers in the last group consists of cellulose treated by various chemical processes.

A fabric woven of these fibers, may have the warp and weft yarns composed of fibers of the same type, or it may be a mixture of different fibers. Mixtures of cotton and linen, or wool and silk are common, while mixtures of silk or cotton and the artificial fibers frequently occur.

The Residues From Burnt Animal Fibers.

An ashed fabric bears certain definite characteristics deriving from the nature of the fiber of which it has been woven. Wool and silk, unless the latter has been heavily weighted, swell in burning, to a black, vesicular mass of slag-like appearance. All indication of the weave in the case of these materials is lost, unless sufficient incombustible matter, such as sizing, weighting, etc., was present in the original cloth to preserve the weave pattern. This may also be preserved in an ash remaining from cloth which has been much soiled. Sometimes the low grades of woolens known as shoddy are intermixed with vegetable fiber (jute) to such an extent that the weave is preserved by the carbonized vegetable fibers. These wool-vegetable mixtures may resemble the ash of cloth woven from vegeable fiber alone, but microscopical examination will show the masses of fused wool intermixed with the web resulting from the vegetable fibers.

With the exception of the chars resulting from some grades of felt, which have a typical appearance, being as a rule, less vesicular than wool chars in general, the only identification possible in the case of the unweighted fibers, is that of determining wool char from that of silk. In this instance, the decision depends on the presence of certain condensed, and perhaps more or less oily rėsidues containing sulphur, which remain in the vesicles of the wool char. These residues persist as long as any of the char is unconsumed. The wool fiber, consisting as it does of keratin, contains sulphur as an essential constituent, and if the char is of wool origin, sulphur compounds will be present in the vesicles. This element is absent from the composition of the silk fibroin, hence, no sulphur reaction is obtained from chars of that substance. The following analyses of wool and silk, as well as that of the completely ashed materials are given for comparison.

Analyses of Wool and Silk

A. Wool keratin. Analysis from Thorpe, Frank Hall, Ph.D., "Outlines of Industrial Chemistry," page 443.

B. Silk (Tussah). Analysis from Matthews. J. Merritt, Ph.D., "The Textile Fibers, Their Physical, Microscopical, and Chemical Prop's." John Wiley & Sons, N. Y. and London., page 94.

C. Silk (mulberry). Thorpe loc cit., page 55.

A. Wool keratin		B. Silk (Tussah)		C. Silk (mulberry)	
C	49.25	C	47.18	C	47.78
H	7.57	H	6.30	H	6.23
N	15.86	N	16.85	N	18.90
S	3.66	O	29.67	O	26.04
O	23.66				
	100.00		100.00		98.95

Ash Analyses.

D. Lincoln wool. Matthews, loc. cit., page 34.
E. Raw tussah silk. Matthews, loc cit., page 94.

D. Lincoln wool	Per cent
Potassium oxide	31.1
Sodium oxide	8.2
Calcium oxide	16.9
Aluminum oxide, Ferric oxide	12.3
Silica	5.3
Phosphoric acid	trace
Carbonic acid	4.2
Chlorine	trace
Sulphuric anhydride	20.5

E. Raw tussah silk	Per cent
Potash, K_2O	31.68
Soda, Na_2O	12.45
Lime, CaO	13.32
Magnesia, MgO	2.56
Alumina, Al_2O_3	1.46
Silica, SiO_2	9.79
Phosphoric acid, P_2O_5	6.90
Carbonic acid, CO_2	11.14
Hydrochloric acid, HCl	2.89
Sulphuric acid, SO_3	8.16

Regarding the presence of sulphur in the ash from silk; Matthews says, page 95. . . . "The presence of sulphates in this ash is somewhat remarkable, as this constituent does not occur in ordinary silk. The presence of alumina is also remarkable. as this element is seldom a constituent of animal tissues." . . . Matthews suggests that most of the mineral matter found is derived from adhering impurities, and is not a constituent of the silk itself. The writer has never observed the occurrence of sulphur in the ash of pure silk, although many samples have been examined with that possibility in mind.[2]

[2]*Application of the sulphur test to char samples.* Ten milligrams of the finely powdered char is mixed with twice its weight of sulphur-free sodium carbonate. The mixture is shaken to the bottom of a four inch "Pyrex" test-tube. The bottom of the tube is heated in a Meker burner until complete fusion of the contents results. The tube is held in a horizontal position during the process. At the beginning of the operation, white fumes, consisting of the water content of the sodium carbonate and unidentified sulphur-containing

Samples of wool char which had been exposed to atmospheric action for at least five years, have shown the presence of sulphur under the previously mentioned test.

While the absence of sulphur in a char from a fabric of animal origin is a positive indication that the substance under observation is not wool char, and so must necessarily be that of silk, its presence is not an indication that silk was absent in the original cloth, since a wool and silk mixture would of course produce a char in which sulphur would be found.

Indications of Unaltered Fibers in Chars.

Although complete incineration of wool or unweighted silk destroys all indication of the weave of the cloth, it is not uncommon to find particles of the fabric in the interior of the charred mass which have been preserved to such a degree that the weave pattern may be found. It has been observed in some cases that individual fibers taken from parts of the char protected by buttons, seams or folds, or by contact with metallic surfaces, have retained the color of the original cloth. The presence of color in such fibers cannot in all cases be interpreted as an actual remainder of the original color, since the possibility of chemical change in the dye under the action of heat, moisture, and sulphurous gases (when wool is present), must be borne in mind.

Characteristics of the Ash of Weighted Silk.

More frequently than not, silk is weighted by the addition of

gases (in the case of wool char) are given off. The fumes are tested with lead acetate paper, the slightly moist paper being introduced into the mouth of the tube. A blackening of the paper indicates the presence of sulphur in the fumes. The tube is allowed to cool and two cubic centimeters of water are added. A strip of polished silver about four centimeters long is placed in the solution, and the fused mass allowed to dissolve without heating. If sulphur is present, the part of the silver immersed in the solution will develop a discoloration which may vary from light brown to black depending on the amount of sulphur in the char. If after standing for twelve hours no color is shown, it may be reasonably assumed that traces of sulphur are absent. This test has shown strongly positive indications of sulphur in two milligrams of wool ash.

In making the above test the following precautions should be observed. The sodium carbonate must be absolutely sulphur free, and a blank test made at the time the char is being tested. If the tube is held horizontally, contamination by sulphur from the gas flame is not likely to occur. Complete fusion of the soda-char mixture must result if the test is to be considered conclusive.

Solution of the fused mass is allowed to take place in the cold in order to avoid spattering the upper part of the silver strip, which is to be kept bright for comparison. In cases where but a trace of sulphur is present, the pale color produced could be easily overlooked if the stain entirely covered the strip.

metallic salts to the boiled-off silk. These salts are commonly those of tin,[3] iron, aluminum and magnesium, less frequently salts of lead. The weighting substances are, as a rule, added to replace the weight lost in boiling the raw fiber to remove the sericin. The presence of these metallic salts in large amounts furnishes a protective coating to the fiber, the contours of the fibers and the yarns being remarkably preserved (Fig. 1). Fabrics so preserved produce on first ignition, a black web which shows no indication of fusion of the silk fibers. On continued ignition the web burns to white and may itself resemble a white silk fabric, every detail of the weave being preserved. A heavy percentage of iron oxide in the remains of burnt silk may represent the iron content of the mordant used in dyeing, or it may derive from an originally black fabric which had been dyed with logwood and catechu over an iron ferrocyanide base, since this method is still sometimes preferred to aniline blacks. In wool and silk mixtures the black web frequently shows globules of the fused wool char intermixed with the mineral matter from the silk weighting.

The Ash of Vegetable Fibers.

The identification of the ash resulting from fabrics woven from vegetable fiber does not present the difficulties which are met with in the case of chars resulting from fibers of the first class. This is especially true of cotton. Cotton fabrics which are ashed in an open fire are commonly carbonized at first. If incineration has proceeded no further, the resulting product is a more or less flexible carbon web which retains the original weave pattern of the cloth. Such carbonized material presents a resistance to decay which is much greater than that of the original cloth. Carbonized cloth of this type, from the prehistoric lake dwellings of Switzerland, shows the weave pattern perfectly preserved after centuries of submergence in the water of the lake.[4]

With the exception of very thin materials which burn at once to the ash, the carbonized web is not completely consumed unless it

[3]A transient yellow-brown color while hot, but changing to white again on cooling indicates the presence of stannic oxide in the ash. Frequetly such ash is insoluble in hydrochloric acid, but can be brought into solution by fusion with sodium carbonate. The sodium stannate can then be decomposed with hydrochloric acid, and the solution tested for tin with gold chloride solution. If tin is present a purple precipitate results. With traces of tin the solution develops a reddish color.

[4]Tyler, John M., "The New Stone Age in Northern Europe." Charles Scribners and Sons, 1931, page 83.

is exposed to a relatively prolonged action of the fire with access of abundant oxygen. Only such prolonged burning produces a true cotton ash, representing the mineral matter present in the cloth, both that resulting from the fibers and from the mordants, sizing, dyes, etc.

Although commonly grayish, the ash from linen, hemp, jute and the other related fibers, is sometimes of a pale brownish color as distinguished from the ash of cotton which is generally white. This is of course without regard to such modifying factors as mordants and other substances which may impart other colors to the ash, such as the reddish ash which frequently results from the incineration of khaki. In general, either cotton or linen cloth, if completely bleached and untreated with dyes, sizes or filling, will produce a white ash.

While an examination of the carbonized material should always be made in order to determine certain surface finishes such as "moire" which are lost in ashing, much more can be determined from mounts made from completely ashed material, such preparations being air mounts, since any medium such as water, glycerine or balsam destroys the fiber ash, either by surface tension or solution. The completely ashed material is, of course, more fragile than the relatively durable carbon web.

From the completely ashed material, the following facts regarding the original fabric are obtained. (A) The type of fiber composing the yarns. (B) The weave, such as plain weave, twill, etc. (C) The type of cloth, as muslin, duck, whipcord, etc. (D) The degree of wear by the abundance of the nap, since this is rapidly lost in laundering. (E) Frequently some idea of the strength of the original cloth, from the "count," provided sufficient remains of the warp and weft are present. (F) In some cases the method of figuring the cloth, such as yarn dyed, printed, discharged, etc.

Finer Structure of the Ash of Vegetable Fiber.

Cotton Ash. The longitudinal twist of the cotton fiber is perhaps its most specific characteristic. Hanausek[5] says, regarding this property: . . . "Since no other fiber, that is no bast fiber, is twisted in this manner, fibers which show this characteristic can be identified as cotton with absolute certainty." The ashed fiber usually retains sufficient indication of this twisted structure for its identifica-

[5]Hanausek, Dr. T. F.. "The Microscopy of Technical Products," John Wiley and Sons, 1907, page 61.

tion in mixtures of cotton and other fibers. The center of the fiber tends to burn through more rapidly than the border. This causes the terminations of the fibers to show, in many cases, a short fork, where the less consumed sides project beyond the burned-out central portion.

Finer Structure of the Cotton Fiber Ash. Under a high magnification, the ash is seen to consist of chainlike aggregates of closely connected particles of mineral matter (Fig. 2). Optical methods frequently show the presence of quartz granules intermixed with the other constituents; this probably results from dust adhering to the fibers. In the case of fibers which are less completely burned, groups of black, more or less parallel bundles of carbonized material are seen intermixed with the mineral matter of the ash. The long axes of the carbon particles tend to follow the contour of the fiber. A heavily sized or weighted fiber sometimes preserves the shape of the cotton fiber intact. It is the last two types of fiber which show the forked termination previously mentioned. Where ashing has been more complete, the fork is lost, due perhaps, to partial fusion of the constituents.

Analysis of Cotton Ash.[6]

F. Cotton ash

Potassium carbonate	33.22	Magnesium phosphate	8.73
Potassium chloride	10.21	Magnesium carbonate	7.81
Potassium sulphate	13.02	Calcium carbonate	20.26
Sodium carbonate	3.35	Ferric oxide	3.40

Finer Structure of the Linen Fiber Ash. Magnified 175 times. the ash from linen is seen to have much the same granular structure as cotton (Fig. 3). The principal point of difference lies in the contours of the filaments, and in the habit of the fiber groups. Linen filaments are always straighter than those of cotton and are never crinkled, the appearance of twisted bands being absent. Short parallel bundles of fibers are common, and individual fibers are frequently split lengthwise. Terminations of the fibers are usually angular breaks which may be jagged. The ash of linen lacks the tenacity of that resulting from cotton, which latter will commonly bend without breaking. The linen fiber nearly always shows the

[6]Cotton ash. Analysis from Mitchell and Prideaux, "Fibers Used in Textile and Allied industries," Scott, Greenwood and Sons, London, 1910, page 95. Analysis of average ash components of ten varieties. Analysis by Davis Dreyfus and Holland.

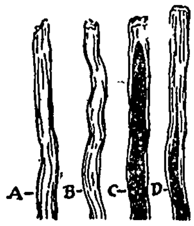

Figure 1.

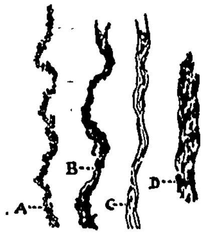

Figure 2.

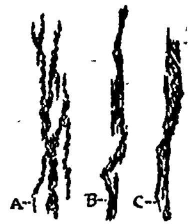

Figure 3.

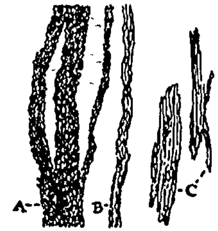

Figure 4.

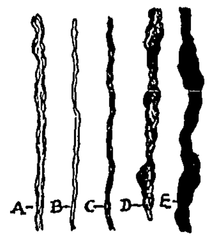

Figure 5.

Fig. 1, Ash of weighted silk. A and B are fibers preserved by weighting materials. C and D, less completely ashed. Fig. 2, Cotton ash. A, chain-like aggregates of particles. B, less completely ashed fibers. C, heavily weighted fiber. D, carbon particles in fiber ash. Fig. 3, Linen ash. A, completely ashed fiber. B and C less completely ashed fibers. Fig. 4, Jute ash. A, chain-like aggregates of granules. B, a single highly ashed filament. C, particles of broken fiber. Fig. 5, Artificial silk. A and B, fibers completely ashed, but their forms preserved by the weighting. C, D and E, less completely ashed.

bending as a series of angular breaks. If a preparation of the two types of ash is examined microscopically the difference is apparent at once. A microscopical comparison of the two types of ash is shown below.

	Cotton	*Linen*
Appearance	Twisted bands.	Straight filaments.
Contours	Crinkled.	Relatively smooth.
Terminations	Frequently forked.	Jagged, angular breaks.
Cleavage	Do not split lengthwise.	Frequently split.
Tenacity	Fibers bend without breaking.	Angular breaks.
Condition of the ashed yarns	Intertwined strands and reticulated masses of fibers. Long fibers common. Breadth of filaments usually uniform.	Bundles of short fibers lying more or less parallel. Long fibers seldom found. Breadth of fibers not uniform.

The greater tenacity of cotton ash, as compared with that from linen, may readily be shown by tapping sharply an air mount of the substances. The linen ash shatters at once; the fibers break down in masses of short fragments. The cotton ash remains relatively intact under this treatment. Figures 6 and 7 show the appearance of the ash of the two fibers under the effect of jarring. Hemp and jute also show the same tendency to shatter.

Finer Structure of the Jute Fiber Ash. This fiber is most commonly met with in the form of burlap or gunny, but is sometimes found intermixed with low grades of woolen cloth as previously mentioned. Finer grades are frequently used in drapery material, either alone or mixed with cotton as in some grades of "monk's cloth." Jute, being derived from the bast fiber of a dicotyledonous plant is closely related to linen, the ash of which the ignited fiber resembles, but the form of the original fiber is more completely retained by jute than by linen. The general appearance of the ashed jute fiber is coarser than that of linen and details are retained to a much greater degree (Fig. 4).

The Ash of Artificial Fibers.

These fibers are prepared from wood pulp (viscose), or in some cases from cotton (nitrocellulose and cuprammonia silks). They may be used alone in knitted goods, such as sweaters, hosiery, cravats, etc., or in cloth. In the latter event the fiber is seldom used save with the admixture of cotton, wool or true silk. Incineration in the case of these fibers is frequently complete, little or no ash remaining. In some instances, however, a considerable ash may result. As a general condition, when woven with wool or pure silk, traces of these

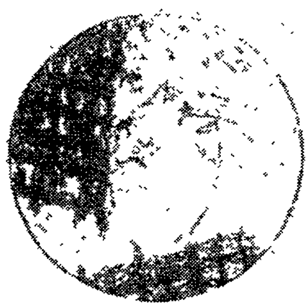

Fig. 6. Cotton.

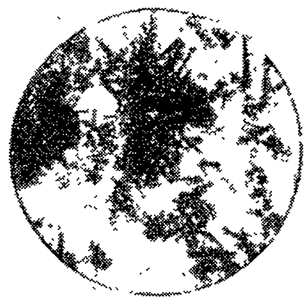

Fig. 7. Linen.

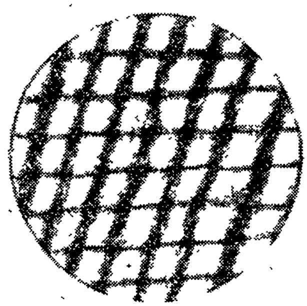

Fig. 8. Muslin.

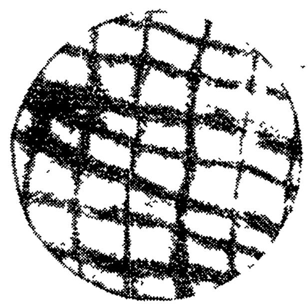

Fig. 9. Crepe.

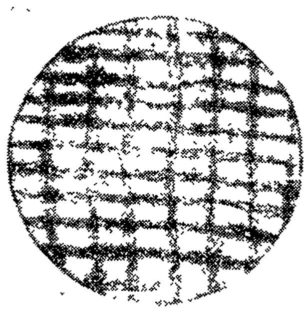

Fig. 10. Gingham.

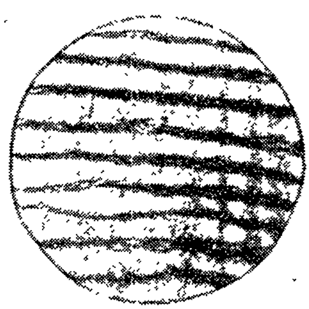

Fig. 11. Chambray.

fibers will be found with the ash remaining from the artificial fiber. The presence of copper in a suspected ash of this type may be considered as conclusive when all the other factors agree. Faust[7] states that the ash of cuprammonium silk, always, and viscose, sometimes, shows the presence of this element. Naturally when woven with weighted silk the remains of the natural fiber will be preserved. Ash resulting from artificial silk is shown as Figure 5.

Examples of Types of Ash Patterns.

Because of the enormous number of weaves which already exist and are being constantly added to, it is necessary to have permanent mounts of both the normal cloth, and standard ash samples of the same fabrics. An unknown sample can then be determined microscopically by comparison with the standards. Although a great variety of weaves exist, this chaos of types can be reduced to four fundamental types, plain weave, twill, satin and damask or Jacquard. All of these may be varied greatly to produce different effects but once the basic type has been determined, its identification becomes less difficult.

Fig. 6. Ashed cotton fabric (duck) after jarring the preparation.

Fig. 7. Linen ash after jarring.

Fig. 8. Coarse muslin sacking (plain weave). The remains of the coarse warp yarns are shown as running from top to bottom of the photomicrograph, while the lighter filling yarns run from side to side. The same orientation of warp and weft is maintained in the other figures.

Fig. 9. Japanese crepe, warp and weft of nearly equal size. The right and left twist of the warp and filling yarns, is not shown in the figure, but is evident in the mount on microscopical examination.

Fig. 10. Gingham plaid. At A-A-A-A are shown yarns which being protected by the dyeing material, have not ashed so completely as the unprotected part of the pattern.

Fig. 11. Gingham (chambray). White and blue yarns. The fainter or more completely ashed vertical yarns are those of the undyed warp, while the darker horizontal yarns are those of the dyed filling.

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[7]Faust, Dr. O., "Artificial Silk," Sir Isaac Pitman and Sons, Ltd., London. 1929, page 70.

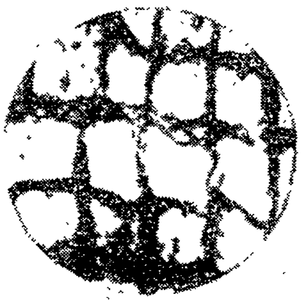

Fig. 12. Buckram.

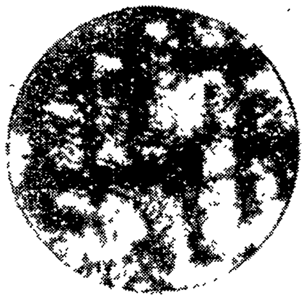

Fig. 13. Outing Flannel.

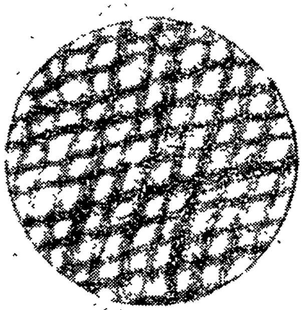

Fig. 14. Lawn.

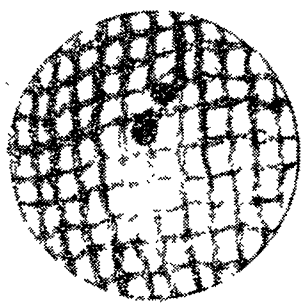

Fig. 15. Lawn (cotton).

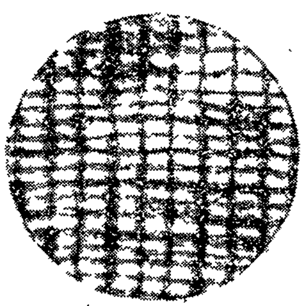

Fig. 16. Poplin.

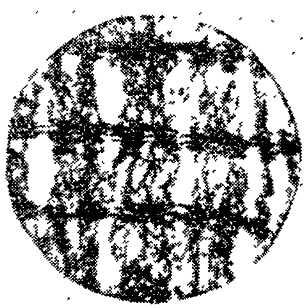

Fig. 17. Duck.

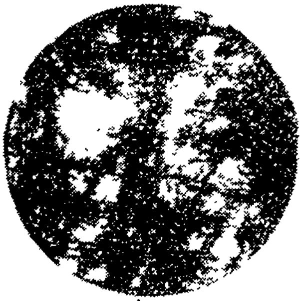

Fig.18. Whipcord.

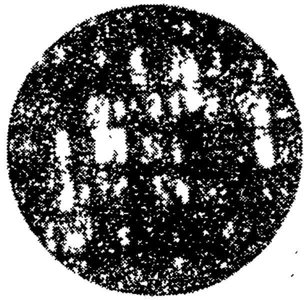

Fig.19. Gabardine.

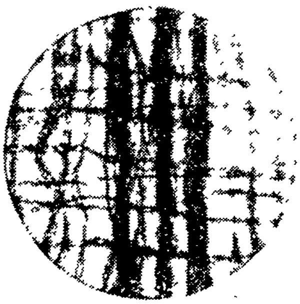

Fig.20. Bedford Cord.

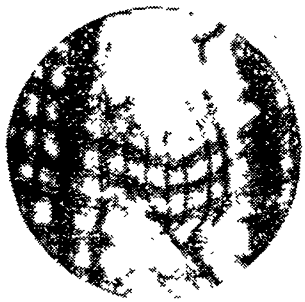

Fig.21. Madras.

Fig.22. Huck.

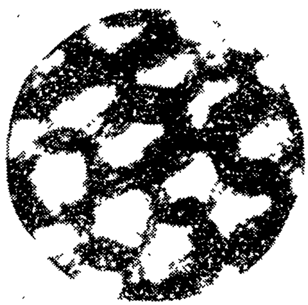

Fig.23. Knit.

Fig. 12. Buckram. A coarsely woven fabric in which the heavy glazing has protected the yarns.

Fig. 13. Outing flannel (cotton). Abundance of nap indicates a fabric which has not been much laundered.

Fig. 14. Handkerchief linen (lawn).

Fig. 15. Lawn (cotton). The original fabric had been dyed blue and figured with a white dotted pattern produced by a discharge process. The remains of the pattern is shown as the paler area at the center of the photomicrograph. The two dark objects near the right center are residues from the sizing material.

Fig. 16. Poplin. A plain weave in which heavy warp yarns are shot over with two lighter weft yarns.

Fig. 17. Duck. Here two light warp yarns are shot over with a single coarse weft yarn.

Fig. 18. Whipcord. A twill weave with a pronounced diagonal pattern, related to gabardine.

Fig. 19. Gabardine.

Fig. 20. Bedford cord (cotton). The three dark yarns near the center of the figure, result from the ash of the coarse and tightly drawn cord yarns of the warp. In this case the greater preservation of the yarn is due to their tight twist, this has caused them to burn more slowly than the finer slack yarns of both the warp and weft.

Fig. 21. Madras. The central and more completely burned part of the sample results from an undyed stripe of mercerized material, this was bordered by two coarser dyed yarns.

Fig. 22. Huck. A union weave of cotton and linen. The vertical yarns which are of cotton, when compared with the linen filling, show the difference of appearance of the two types of fiber when in the same fabric. The irregular spacing of the linen yarns is an indication of the rough surface typical of this type of cloth.

Fig. 23. Knit. This weave has neither warp nor weft, but is woven from a continuous yarn. The weave is distinguishable at once from all other types.