INSTRUMENTS TO MEASURE COTTON CONTAMINATION
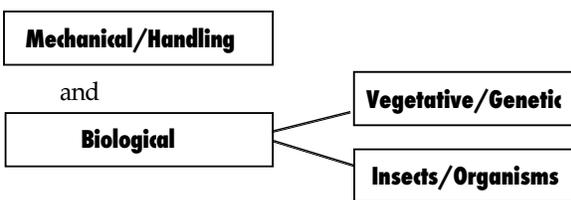
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Introduction

The primary purpose of this report is to clarify the current and evolving situation in instrumentation designed to provide commercially useful measurements of contamination in cotton fibers. This task necessarily includes a discussion of the meaning and scope of cotton contamination and of the types of measurement technology used. These are followed by a brief explanation of the instruments that are known to be either currently available or under development.

Kinds of Contamination

The simplest and most common concept of cotton contamination is "trash" or "foreign matter" (which may be either organic or inorganic in composition). As with any diverse problem that is subjected to measurement, however, solutions require a more detailed classification. Communications with various people reveal various ideas about what constitutes contamination. A useful qualitative indication of the things generally considered to be contaminants is provided by the survey questionnaire on "Cotton Contamination & Foreign Matter" from the International Textile Manufacturers Federation (ITMF). A summary of the contaminants listed in this survey is given in Appendix I.

The basic sources or causes of cotton contamination may be given as follows:

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┌──────────────────────┐
│ Mechanical/Handling  │
└──────────────────────┘
        and
┌──────────────────────┐        ┌──────────────────────┐
│      Biological      │────────│  Vegetative/Genetic  │
└──────────────────────┘    \   └──────────────────────┘
                             \   ┌──────────────────────┐
                              \──│  Insects/Organisms   │
                                 └──────────────────────┘
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The mechanical/handling sources are intended to capture all the ways that machine inadequacies and human errors may result in contamination. The biological sources naturally divide into vegetative/genetic and insect/organisms.

An expansive listing of the various kinds of contamination coming from all sources is the following:
- Foreign objects & materials (fibers, yarns, fabrics, paper, oil, metal, rust, rubber, etc.)
- Trash (leaf, bark, bracts, non-cotton vegetation, etc.)
- Motes, seeds & seed-coat fragments
- Dirt & dust
- Entomological sugars
- Physiological sugars
- Neps
- Short fibers
- Dead/immature fibers
- Discoloration

This listing of ten contaminant categories extends the boundaries of what constitutes contamination well beyond the limits that some people in the cotton/textile industry would normally include. A minimal list would include only "trash," "entomological sugars," "foreign objects and materials," and "dirt and dust" Nevertheless, textile manufacturers increasingly view neps, short fibers, fiber fragments, and dead/immature fibers as contamination of the good cotton fibers. Even discoloration of the fibers (e.g., spotted cotton) may be seen as a contamination caused by insects, secondary bacterial invasions, weathering, etc.

Most of the contaminants listed above may be caused by or come from more than one source. For example, seed-coat fragments may be due primarily to a genetic tendency for pieces of the seed coat to come loose with the fiber, or it may be due primarily to an inadequate ginning process that mechanically breaks the seeds. Unfortunately, many gins around the world actually leave entire seeds in the lint. Also, the primary source of excessive dead/immature fibers may be vegetative if genetic/climate causes are paramount; but the problem may also be caused primarily by insect damage to the developing cotton bolls.

Note that the sugars, which cause stickiness of cotton fibers, are divided into the physiological and the entomological sugars. It is generally understood that stickiness problems in textile processing caused by each of these are quite distinct, with the insect sugars being much more detrimental and the processing problems caused by them much more acute.

Commercial Measurement Technologies

Throughout the first half of this century, cotton properties were assessed commercially in a manner largely unchanged for hundreds of years; i.e., by subjective human judgement. During the 1960s, the micronaire was the first instrument measurement to penetrate the commercial arena and become a part of contractual, pricing arrangements in markets. Manually operated instrument measurements of strength of fiber bundles (e.g., Pressley and Stelometer measurements) were shown to be useful during the 1940s and 1950s; commercial (high speed) measurements of bundle strength became feasible in the 1970s with the development of the MCI High Volume Instrument (HVI). Around this time, new electro-optical techniques of measurement became commercially feasible, with one manifestation being the fiber length measurement used in the HVI. All of the instrument development since has become inextricably tied to advancements in the power of electronic digital computers.

The technologies useful for rapid measurement of contaminants in cotton are largely the same ones that have become increasingly useful for measuring other fiber properties. Until recent years, however, the only objective measure for contamination of raw cotton fibers was mechanical separation, followed by weighing and inspection. The convergence of computerization and electro-optical measurement technology during the last twenty years has yielded the capability to obtain rapid, quantitative measurements of contamination. Some developments are currently available, while others are still in the pre-commercial stage. They

promise to further revolutionize the quantitative measurement of cotton contamination.

The technology described by the term "electro-optics" was brought about by the rapid emergence, in the 1960s and 1970s, of:
• improved detectors of electromagnetic radiation—especially light in the visible and near infrared portions of the spectrum,
• improved analog and digital electronics (with the latter enabling the computer revolution),
• the laser and other improved sources of light, and
• improvements in optical elements.

At the present time three distinct electro-optical technologies deserve to be emphasized for the measurement of fiber contamination:

<u>**Light scattering**</u> – The interactions of one or more entities, or particles, with a beam of light are examined. A fiber or contamination particle is presented to the beam, usually after being separated aeromechanically and transported pneumatically or mechanically, and the light that is removed from the beam is measured and related to the physical characteristics of the particle.

The type or mode of scattering of the light signals is typically classified as "extinction," "forward scatter," "right-angle scatter," or "backscatter." This is done based on the measured "solid angle" (with respect to the incident beam) at which light is collected and subsequently directed to a photodetector. All of these types or modes of measurement are commonly referred to as light scattering. Each has relative advantages in different situations. Extinction mode sensing is a somewhat special case because it requires only that the reduction in light beam power be measured. The other light scattering measurements require a more sophisticated measurement of the amount of light removed or relocated. Therefore, extinction mode sensing permits the simplest measurement apparatus and is most commonly used for contamination measurements.

Light scattering technology is used in the Zell-

weger Uster AFIS®, the Premier RapidTester®, and the Lintronics FCT® (Fiber Contamination Tester). In these instruments, light-sensitive sensors measure extinction or near forward scattering of light signals, thereby enabling interpretations about contaminants associated with cotton fibers (and therefore about contaminants in representative lots of cotton).

Image analysis – New developments in this technology promise to enable vastly improved measurement of fiber characteristics, including contamination. More than most electro-optical techniques, this emulates the human eye. Indeed, image analysis techniques have been a basis of objective measurements for more than a century. But the development of the "Charge-Coupled Device" (CCD) video camera—in combination with high-speed computers—is revolutionizing image-based measurements.

The basic power of the technology is proportionate to the number of discrete picture elements, or "pixels," into which an image can be spatially digitized. This is expressed as the "resolution" afforded by the digital camera. Fortunately, resolution has grown exponentially in recent years and is now at levels that enable the identification of small contamination particles. This makes the technology useful at magnifications that are impossible for the human eye. A researcher in this arena has observed that this advancement in digital resolution, together with the information processing possible with high-speed computers, reminds him of the old saying: "A picture is worth a thousand words." Now, however, it becomes: "An image is worth a million bytes."

This technology has been widely used in laboratory research measurements for many years. Furthermore, its application to measurement of contamination has been institutionalized during the past decade in the form of HVI trash meters. With computer-enhanced applications, it now promises to become a more convenient tool for high-volume, real-time measurements of various fiber contaminants. In addition to providing the basis for trash measurements from existing high-volume instrument lines, video image analysis techniques are used in the Lintronics FCT® to measure trash, neps, and seed-coat fragments. It is also used in the SDL H2SD® (High-speed Stickiness Detector) to measure stickiness of cotton fibers. The technology is also likely to see increased use in the opening lines of textile mills, in order to detect foreign objects and materials, in order to automatically eject them before the cotton reaches the carding machine.

Near infrared reflectance (NIR) – This technology utilizes near infrared radiation, which has wavelengths just beyond the red portion of the visible spectrum (i.e., from about 700 to 3,000 nanometers). The radiation is directed onto a sample and the "reflected" light is detected. These detected signals contain information about the physical properties of the sample. Frequently the information about the sample in the detected light is very subtle; therefore, many measurements over a wide range of wavelengths are required to get reliable information. The necessary "redundancies" in NIR information are ideally handled with digital computers. Commercial NIR instruments were fundamentally impractical until (a) computer prices imploded and (b) computational power exploded.

NIR technology has been tried for many fiber property measurement applications, but with generally disappointing empirical results. It was even incorporated into high-volume instrument lines during the 1980s, in a failed attempt to measure fiber maturity. Experimental work is currently being done to evaluate its usefulness in measuring the sugars and waxes associated with cotton fibers. However, no commercial instruments utilizing NIR to measure contaminants are currently available. As with other aspects of imaging technology, NIR may find applications in the detection of contaminants in the opening lines of textile mills.

A Synopsis of Instruments Available

Table 1 contains a listing of currently available instruments versus the types of contaminants measured by them. In each case, a checkmark (✔) is used to denote that the instrument is used to measure the contaminant in some fashion. Footnotes are used to indicate the type of technology used for measurement.

It is possible, of course, that some developments on measuring contaminants are now in progress but unknown to the author. The author's request in this regard is twofold: (1) please excuse the omissions and (2) please inform the author about the work.

The reader should be aware that not all of the measurements indicated with the instruments in Table 1 are fully developed and reliable. Thus, the Premier RapidTester is still in a "development phase" and its basic measurement features are expected to evolve substantially in the months ahead. The Lintronics FCT, and the SDL H2SD are in early commercial release, so that most changes are expected to be of a "fine tuning" nature. The only way

to know the exact, current capabilities of the instruments listed here is to contact the companies that manufacture and market them. Appendix II provides information on the companies that market the instruments identified in Table 1.

It should be noted that Table 1 does not contain a category for "foreign objects and materials." While these are common contaminants in cotton coming from less developed countries—and do occasionally occur in cottons from any country—their occurrence is so random that sampling and instrument testing for them is not an effective way to detect and control them in manufacturing processes. These will probably have to be handled with a variety of on-line detectors, which are used to activate automated mechanisms for removing the contaminants from the manufacturing lines.

In order to further explain the information in Table 1—and to clarify the nature and precision of the measurements obtained—it is conve-

Table 1: Instruments Available versus Cotton Contaminants Measured

Instruments	Cotton Contaminants							
	Trash	Dirt	Neps	Seed-coat Fragments	Short Fibers	Immature Fibers	Insect Sugars	Plant Sugars
Uster HVI	✔[1]				✔[2]			
Premier AFT	✔[1]				✔[2]			
Uster AFIS	✔[2]	✔[2]	✔[2]	✔[2]	✔[2]	✔[2]		
Premier RapidTester	✔[2]	✔[2]	✔[2]	✔[2]	✔[2]	✔[2]		
Uster MDTA	✔[3]							
Shirley Analyzer	✔[3]							
Lintronics FCT	✔[1]		✔[1]	✔[1]			✔[2]	
CIRAD SCT							✔[4]	
SDL H2SD							✔[1]	
HPLC							✔[5]	✔[5]

[1] **Uses image analysis.**
[2] **Uses light scattering.**
[3] **Uses manual weighing.**
[4] **Uses visual inspection.**
[5] **Uses liquid chromatography.**

nient to organize commentary according to four groups of cotton contamination; i.e., according to "trash and dust," "neps and seed-coat fragments," "short fibers and dead/immature fibers," and "stickiness."

Trash & Dust

- The most widely used instruments for measuring trash are the high-volume instrument lines: the *Uster HVI* and the *Premier AFT*. These are the fastest measurements available, but are the least precise and least repeatable of the objective instruments available. (They are, however, much better quantitative measurements than subjective human judgements.)
- The *Uster AFIS* not only provides total "trash" measurements; it separates the "dust" and "microdust" from the "trash" based on the size of particles detected.
- The *Premier RapidTester* also has the capability to measure the size distribution of trash particles, but not to the very small particle sizes that the *AFIS* provides. Indeed, the *RapidTester* is still in a state of development, with only six functioning units at this time. A potential advantage it has is the ability to measure a much larger sample of fibers (about 10 grams versus about ½ gram for the AFIS). Only larger samples or more replications can reduce sampling error, a problem that afflicts all trash measurements.
- The *Lintronics FCT* employs image analysis to provide measures of total trash particles and of size distributions of the particles. The size categories are currently limited to those that would generally be visible to the human eye. The *FCT* also uses somewhat larger fiber samples, about 5 grams.
- The primary instruments for mechanical separation of the trash and dust from the cotton lint are the *Uster MDTA* and the *Shirley Analyzer*. These are very useful laboratory instruments; however, they cannot be classified as "rapid" or "high-volume" instruments. With careful operation and accurate weighing, they certainly do provide accurate results and valuable reference tests to compare with any of the other instruments described above.

Neps & Seed-coat Fragments

- Both the *Uster AFIS* and the *Premier RapidTester* were designed from the beginning with an objective of measuring neps and seed-coat fragments. Distinction is made based on size criteria and results are quite sensitive to the interpretive algorithms used with the electro-optical sensors.
- The *Lintronics FCT*, utilizing interpretative algorithms with video images, detects and measures neps and seed-coat fragments based on size, shape and shade.

Short Fibers & Dead/Immature Fibers

- The only instrument currently providing reliable measurements of short fibers and immature fibers is the *Uster AFIS*. The *Premier RapidTester* is also capable of these measurements, but further development is required.
- Both the *Uster HVI* and the *Premier AFT* provide estimates of short fiber content; however, reliability and repeatability are generally considered to be inadequate for either marketing or quality-control decisions.

Stickiness

- The *SCT* (Sticky Cotton Thermodetector), a manually operated instrument, provided the first viable measurements of point stickiness in cotton fibers. It was developed by CIRAD (*Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement*), in Montpellier, France. It has seen significant use in Europe, Africa, and Asia. However, it is too slow and too subjective (sticky spots are counted by human operators) to satisfy the needs of the global market.
- The *Lintronics FCT* is the first commercially available instrument that is capable of rapid measurement of sticky spots contained in a sample of cotton. Counting of the sticky spots, as well as the size distribution of the spots, is based on algorithmic interpretation of the blocking of laser signals.
- The *SDL H2SD* (High Speed Stickiness Detector) is the heir of the *SCT* and is

expected to be available commercially as of 1999. It has been automated to a great degree and has incorporated an image analysis system to count and size the sticky spots in a sample of cotton.

- The *HPLC* (High Performance Liquid Chromatography) instrument probably should not be included among the commercial instruments for measuring stickiness. Nevertheless, it is a valuable laboratory tool for determining the kinds and levels of different sugars present on cotton fibers. In the years ahead, it will probably be an integral part of the process of calibrating and interpreting results from the commercial stickiness instruments. It is made by multiple companies and is used to identify and quantify molecules from many different substances and compounds.

Conclusion

This report on methods of measuring cotton contamination is meant to inform the reader about the measurement technology and the commercial instruments that employ such technology. Although much good progress has been made, much more is needed. It is hoped that this paper will stimulate more constructive, scientific dialogue between the global sectors of cotton production and textile manufacturing. Improved measurements of contamination—i.e., measurements that are both quantitative and verifiable—are a necessary part of progress toward (1) the prevention of contamination by the production sector and (2) the management of contamination problems by the marketing and manufacturing sectors.

Appendix I: ITMF Survey on Cotton Contamination

The International Textile Manufacturers Federation (ITMF) is an organization representing global textile manufacturing industry. Its address is as follows:

Postfach
CH – 8039 Zurich
Switzerland
Tel: +41-1) 201 7080
Fax: (+41-1) 201 7134
e-mail: secretariat@itmf.org

One of its basic purposes of the ITMF is to promote the improvement of raw materials used by the industry in making textiles. To this end, it conducts a biannual survey of contamination problems encountered by global textile manufacturers. The survey questionnaire used is titled "Cotton Contamination & Foreign Matter." It explicitly asks for responses about the seriousness of contamination from the following:

Fabrics made of:
- woven plastic
- plastic film
- jute/hessian
- cotton

Strings made of:
- woven plastic
- plastic film
- jute/hessian
- cotton

Organic matter:
- leaves, feathers, paper, leather

Inorganic matter:
- sand/dust
- rust
- metal/wire

Oily substances/chemicals:
- grease/oil
- rubber
- stamp color
- tar

Stickiness
Seed-coat fragments

The foregoing categories are not intended to serve as a classification system for contaminants. Rather, they were derived from a general understanding over the world about the kinds of contamination that are important to textile manufacturers. Therefore, these categories may be altered if it is deemed necessary for getting meaningful responses about contamination from different parts of the world.

The **Zellweger Uster** company markets the Uster MTDA, the Uster HVI and the Uster AFIS. The company is home-based in Switzerland, where a large line of instruments for measuring and monitoring the quality of textile materials is made. However, the MTDA is manufactured by the Hollingsworth Corporation in the U.S., while the HVI and the AFIS are made in Zellweger Uster's U.S. subsidiary. Address information for each is given below.

Home Office:

    Zellweger Uster (A Division of Zellweger Luwa AG)

    Wilstrasse 11

    CH – 8610 Uster

    Switzerland

    Tel: (+41 1) 943 2211

    Fax: (+41 1) 940 7079

U.S. Manufacturing & Development:

    Zellweger Uster, Inc.

    456 Troy Circle

    P.O. Box 51270

    Knoxville, Tennessee   37950-1270

    Tel: (+1 423) 588 9716

    Fax: (+1 423) 588 0914

U.S. Sales & Service:

    Zellweger Uster, Inc.

    2200 Executive Street

    Charlotte, North Carolina   28266-8188

    Tel: (+1 704) 392 7421

    Fax: (+1 704) 393 1706

The **Premier Polytronics** company manufacturers and markets both the AFT and the RapidTester. The AFT is made at the home base in India, while the RapidTester has been developed and is currently manufactured in the U.S. subsidiary. Address information for each is given below.

Home Office:

    Premier Polytronics Ltd.

    304 Trichy Road, Singanallur

    Coimbatore – 641 005

    India

    Tel: (+91 422) 573548

    Fax: (+91 422) 573651

U.S. Development Affiliate:

    Shaffner Technologies, Inc.

    725 Pellissippi Parkway

    Knoxville, Tennessee   37932

    Tel: (+1 423) 966 2732

    Fax: (+1 423) 966 2750

The **Lintronics** company, based in Israel, manufactures and markets the FCT. Address information is as follows:

    Lintronics Ltd.

    28 HaBarzel Street

    P.O. Box 1295

    Arad   89113

    Israel

    Tel: (+972 7) 974553

    Fax: (+972 7) 955892

The **SDL** company currently markets the Shirley Analyzer, the SCT, and the H2SD; it is arranging to have the H2SD manufactured in England. (The only three existing units were manufactured in Montpellier, France, under the direction of CIRAD, which developed the instrument.)   Address information for the home office and the U.S. subsidiary is given below:

Home Office:

    SDL International Ltd.

    Crown Royal Shawcross Street

    P.O. Box 162

    Stockport SK1 3JW

    England

    Tel: (+44 161) 480 8485

    Fax: (+44 161) 480 8580

U.S. Sales Office:

    SDL America Inc.

    4209G Stuart Andrew Boulevard

    Charlotte, North Carolina   28217

    Tel: (+1 704) 521 8832

    Fax: (+1 704) 521 8791

Participation in Beltwide Cotton Conferences

Five people representing the ITC traveled to the Beltwide Cotton Conferences in Orlando, Florida, January 4-7, 1999. A total of seven papers were presented at four different conferences there.