Designation: D7310 – 11

Standard Guide for Defect Detection and Rating of Plastic Films Using Optical Sensors[1]

This standard is issued under the fixed designation D7310; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide is intended to provide suggested approaches and criteria for the observation and reporting of defects in various types of plastic film, by means of an optical scanning system.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—There is no known ISO equivalent to this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D883 Terminology Relating to Plastics

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *defect*—for the purpose of this guide any entity in the film that is large enough to be detected by an optical sensor and is either polymeric in nature or caused by degradation, external contamination, undispersed additives or pigments, or similar sources.

4. Significance and Use

4.1 Defects in film are not acceptable to the end-user as there is a reduction in the fitness-for-use in many applications. This document is intended to be a guide to assist users in the inspection and observation of defects.

4.2 This guide is applicable in a laboratory environment as a quality control or as a research tool. It is also appropriate for use in any commercial process used to produce film including calendering and solvent casting.

4.3 This guide is also suitable for use as an evaluation or screening tool for materials intended to be used in other processes where defects of this nature are also critical, such as fiber spinning and non-wovens.

4.4 The individual user must establish the relationship between the criteria and acceptance for fitness-for-use and the observed defects, as it varies by polymer and application. This is attained by the collection of data over a time-period to establish acceptable control limits.

5. Apparatus

5.1 *Extruder*—A device for melting polymer that produces a flat or blown (tubular) film with sizes varying from lab-scale to production-scale.

NOTE 2—Although this technique is utilized for many different processes used for producing films, the extrusion systems described in the following section represent the more prevalent process used. This is not to imply that the guidance provided for utilizing this type of instrumentation cannot be applied to other processes or other applications.

5.1.1 *Flat Film Extrusion*—An extrusion system that produces a flat film that is quenched immediately after extrusion by means of one or more cooling devices such as an air knife, chill roll or water bath.

5.1.2 Blown or tubular extrusion – An extrusion system that produces a tubular "bubble" of film from a circular die, usually equipped with an air-ring to cool the polymer.

5.2 *Screen Pack*—Although commonly used in commercial or semi-commercial environments, screen packs are not generally used in laboratory units intended for research or quality functions.

5.3 *Defect Detection System*—An optical scanning system with a light source, an analog or digital camera, and an image processor. The optical characteristics of the camera are critical for detecting small (30 μm) defects and it is important that the instrument manufacturer be informed of the detection needs when choosing a system.

NOTE 3—Other types of detection systems than the ones described in this guide are available, but are outside the scope of the guide and are not defined.

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[1] This guide is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.19 on Film, Sheeting, and Molded Products.

Current edition approved Dec. 1, 2011. Published January 2012. Originally approved in 2007. Last previous edition approved in 2007 as D7310 - 07. DOI:10.1520/D7310-11.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

5.3.1 *Transmission Mode (Transparent or Translucent Film Configuration)*—The camera is located directly across from the light source with the film passing between them. With this system, the film is illuminated and the camera captures images of the defects and sends them automatically to the image processor, which measures the size and frequency of the defects. Fig. 1 is a basic outline of this setup.

5.3.2 *Reflection Mode (Opaque Film Configuration)*—The light source and camera are both located above and at equal angles, typically 45°, to the film. This allows the camera to detect the defect images by reflectance off the film, and the images are sent to the processor that measures the size and frequency of the defects. Fig. 2 depicts a basic outline of this type of setup.

6. Procedure

6.1 *Extrusion*

6.1.1 *Laboratory Environment*—Laboratory determinations are much more controlled than determinations conducted online in production environments. Their applicability is more suited to research and quality functions, and consequently, the requirements and control levels are more stringent.

6.1.1.1 *Extruder Conditions*—In order to count defects in extruded film, the proper temperatures, especially in the die zone, must have been reached. In general, it is best for the set point temperature to be at or above the melt point of the polymer, but not enough above it to cause degradation of the material.

NOTE 4—Specific extruder conditions and preconditioning of material, such as drying, if required, are determined by the system used and the material being evaluated, in conjunction with guidance provided by the instrument manufacturer, material supplier, or material specification. In addition, the extruder screw speed shall be set such that the residence time of the polymer is adequate to entirely melt and mix the polymer, but not long enough to cause degradation (less than 10 minutes is best to prevent formation of defects in the extruder).

NOTE 5—One method for determining residence time is to introduce a different pigmented polymer into the extruder and measuring the time required for the pigment to travel from the throat, or point of introduction, to the final product.

The relation of the screw speed (extruder output) and take-up speed shall be set to produce film of suitable thickness to measure defects. After these conditions are determined, the same conditions must be used consistently to ensure repeatable results for a given type and grade of material. A nitrogen blanket is recommended on the feed throat to eliminate oxygen in the extruder.

6.1.1.2 *Purging*—The extruder shall be cleaned thoroughly prior to the introduction of the material to be evaluated. This is accomplished by introducing some form of concentrate additive mixture, such as an antioxidant, prior to introducing the sample, or simply running a clean, highly stable, compatible material through the extruder until the film appears clear or when the defect count, as measured by the optical monitoring system, has stabilized. After introducing the material to be evaluated into the extruder, allow enough time for the preceding material to completely purge. If studies of similar materials are being performed, the purge time is established prior to subsequent evaluations. (See Appendix X1 for guidelines on the use of a Control Resin.)

NOTE 6—The need for adequate equilibration cannot be overstressed. Not only must care be taken to provide adequate time for the system to stabilize after purging, but also to allow adequate monitoring time in cases where intermittent defect flurries occur in a stable system due to non-uniformity of the sample itself (see Appendix X2).

6.1.2 *Production (Commercial) Environment*

6.1.2.1 The general purpose of optical sensors used in a production environment is continual monitoring, both for the consistency of the product and to detect any disturbances in the systems or processes that introduce an unacceptable level of defects.

6.1.2.2 *Extruder Conditions*—When monitoring film produced on a commercial scale, the extruder conditions shall be determined by the constraints of the production requirements, that is, conditions are not changed from the normal operating conditions for the purpose of defect detection. When the intent is to evaluate the film for defects, it is important to have processes in place to ensure that proper operating guidelines are followed. Variables such as temperature, film gauge, etc. must be taken into account to achieve repeatable results.

6.1.2.3 *Purging*—It is normally not possible to purge production extrusion equipment with any cleaning or reference material. In this case, the system must be set up to produce commercially acceptable product and the monitoring system

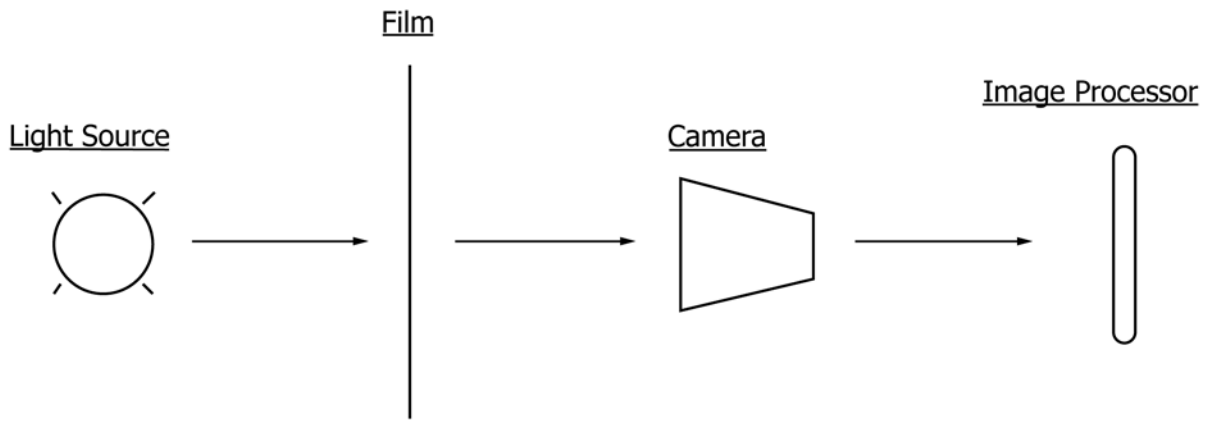

FIG. 1 Transmission Mode (Clear/Translucent Film)

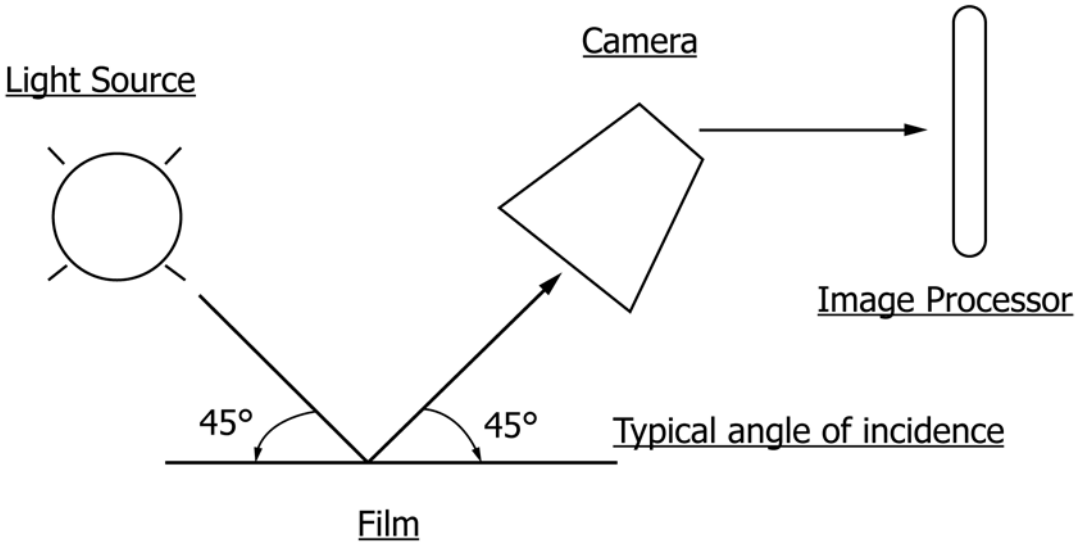

FIG. 2 Reflection Mode (Opaque Film)

essentially serves to track deviations from the acceptable levels. In this case, the acceptable levels shall be determined by the accepted fitness-for-use set by the application or by agreement between supplier and user.

NOTE 7—It is also possible to monitor commercial quality by taking a sample of film and evaluating it using an offline system. However, this will not provide continuous monitoring nor will it necessarily be representative of the entire commercial production quantity.

6.2 Evaluation of Defects

NOTE 8—General best practice guidelines and possible sources of test error are found in Appendix X1.

6.2.1 For laboratory evaluations, produce a sufficient quantity of film to ensure the defect frequency has stabilized.

NOTE 9—It is critical that the surrounding area not be disturbed during the evaluation, as dust and other foreign particulate matter are prone to causing erroneous measurements. Cover the extruder hopper during the evaluation to prevent the inclusion of any foreign materials.

6.2.2 Monitor the film with the optical scanning system.

6.2.3 Observations

6.2.3.1 Record the results of the measurement of defects as detected by the specific inspection system.

6.2.3.2 Categorize and count the defects according to size classes or other specifications as defined by internal standards or agreement between supplier and user.

(a) Typical units for reporting include defects per square meter (or square foot), defect area in parts per million (PPM defect area = total defect area/total area measured), or any other method as defined by internal standards or agreement between supplier and user.

NOTE 10—Examples of data presentation for film defect detection and monitoring are shown in Appendix X3. The examples of the reports are from the same optical scanner and are provided as a means of demonstrating the type of information available.

7. Report

7.1 Complete sample identification

7.2 Date of sample testing

7.3 Method of Evaluation

7.3.1 Equipment Type (Lab or Production; Flat or Blown; etc.)

7.3.2 Scanner Mode (Transmission or Reflection (and angles of camera and light source to the film for reflection))

7.4 Film thickness

7.5 Area of film inspected

7.6 Defect observation and size

7.6.1 Method of Observations (measurement), based on internal requirements, the accepted fitness-for-use set by the application, or by agreement between supplier and user.

8. Keywords

8.1 cast film; defect; extrusion; optical scanner; tubular film

APPENDIXES

(Nonmandatory Information)

X1. GENERAL GUIDANCE AND TROUBLESHOOTING

INTRODUCTION

This appendix is offered to assist laboratories in conducting defect detection of plastic films using optical sensors. It is an aid used to identify the root-cause of problems caused by equipment, environment, or testing technique, but not intended to be an all-inclusive troubleshooting checklist. Although most of these points apply to laboratory use, it is feasible to apply some of the principles to a production environment.

X1.1 *Control Resin*—The use of a control material cannot be over-emphasized. Best practice includes securing a sufficient quantity of material that is used on a regular basis to confirm the consistency of the system operation. It is also important that the control resin contain minimal defects in order to be able to assess the cleanliness of the system. The observable measurement obtained using the control resin is also used to establish control charts, which provide another tool to assess the consistency of the system. If wide varieties of materials are tested on the same instrument, it is advisable to select an appropriate range of materials to be used as controls. Control resin baseline values are best established on a clean extruder and die. If inconsistencies are observed that are not assignable to any identified cause, inspection and cleaning of the screw and die is recommended.

X1.2 *Purge Resin*—A suitable purge resin must be selected based on its ability to properly clear the system of any residual material but still be able to be purged, in turn, by the material(s) being tested. The use of special additives or compounds is effective but care must be taken to ensure they are properly cleaned out of the system. If wide varieties of materials are tested on the same instrument, a range of different purge materials is normally required.

X1.3 *Purging Procedure*—The purge resin must be processed until all remnants of the preceding material have been removed. There are a number of methods used to determine when purging is adequate including:

X1.3.1 Visual observation for changes in clarity or color

X1.3.2 Stabilization of extrusion pressures or motor loads if changes occur after adding the purge material

X1.3.3 Use of a color tracer

X1.4 *Extruder and Die Temperature Controllers*—Proper and consistent control of processing temperatures is critical. Under-heating results in poor or nonhomogeneous melting and mixing while overheating results in degradation.

X1.5 *Operating Conditions*—Standard operating conditions must be established for each category or type of resin. These conditions include:

X1.5.1 Temperature settings (extruder, die, and rolls),

X1.5.2 Film gauge,

X1.5.3 Output rate,

X1.5.4 Extruder and line speed (drawdown),

X1.5.5 Web tension,

X1.5.6 Scan duration,

X1.5.7 Cooling (Air ring or knife, chiller, etc.).

X1.6 *Shutdown Procedure*—Purging with a well-stabilized material prior to shutdown minimizes degradation of the material. It is advisable to slowly ramp down the temperatures prior to actual shutdown. Use a separate shut down resin after purging to allow a gradual ramp down of extrusion temperatures to an appropriate temperature before shutdown is helpful. Monitor torque and pressures so that no equipment damage due to excessive pressures occurs while the extrusion temperatures are decreasing.

X1.7 *Startup Procedure*—The initial warm-up temperature settings must be below the operating settings and allowed to stabilize (soak) for a limited time (approximately 30 minutes has been found to be satisfactory) to minimize degradation of material when starting with a cold system. Temperatures are then raised to the operating settings and allowed to stabilize prior to startup. Immediately setting the temperatures at their operating levels and/or using excessive soak times, can result in material degradation.

X1.8 *Screw and Barrel Wear*—Although not expected in laboratory equipment, progressive wear affects the ability of an extrusion system to achieve a homogeneous melt. Periodic monitoring of the throughput rate of a standard or control material is also used as a tool to monitor wear, as a progressive decrease in throughput with time is indicative of possible screw and/or barrel wear. This guideline is used in both a laboratory or production environment.

X1.9 *Cleanliness (internal)*—Build-up and subsequent degradation of material on the screw or in the die will ultimately affect the readings. A sign of internal contamination, necessitating a breakdown and inspection of the system, is the lack of a control resin to stabilize within a reasonable time (typically two hours).

X1.10 *Calibration of Optical Sensor*—Consistent use of a control resin(s) is one method to monitor the consistency of the sensor. However, if the system becomes contaminated this is

not effective. Another method is to incorporate a known amount of an inorganic material of known particle size into a clean control resin. Glass beads, which are available in diameters of < 50 µm, or the capture of a marked defect image by the detector and same piece of film with the same defect marked for manual measurement with a certified eyepiece, have been used for this purpose. It is advisable to check with the equipment manufacturer for appropriate calibration and recalibration procedures.

X1.11 *Die Lip Build-up*—Periodically observe the condition of the die lips to ensure that a buildup is not occurring. As buildup loosens from the die, random particles adhere to the web and are detected by the sensor.

X1.12 *Air-borne Contamination*—Make all efforts to keep the area dust-free, and use a cover over the extruder hopper to reduce the risk of contaminants in the sample.

X1.13 *Sample Handling*—Use proper care and a minimal amount of handling from the time the sample is taken until it is loaded in the extruder. Containers should be clean and covered. Avoid containers such as unlined paper bags.

X1.14 *Duration and Number of Determinations per Sample*—Contaminated or nonuniform samples do not necessarily exhibit a homogeneous distribution of defects. Because of this, it is critical that the scanning time be of sufficient length to adequately capture any flurries or outbreaks. A minimum of ten minutes scanning time is enough for most cases. For critical or sensitive applications, it is recommended to perform multiple determinations (at least two, but preferably three).

X2. EXAMPLES OF PURGING EFFECTS AND NEED FOR EQUILIBRIUM

X2.1 See Fig. X2.1 and Fig. X2.2.

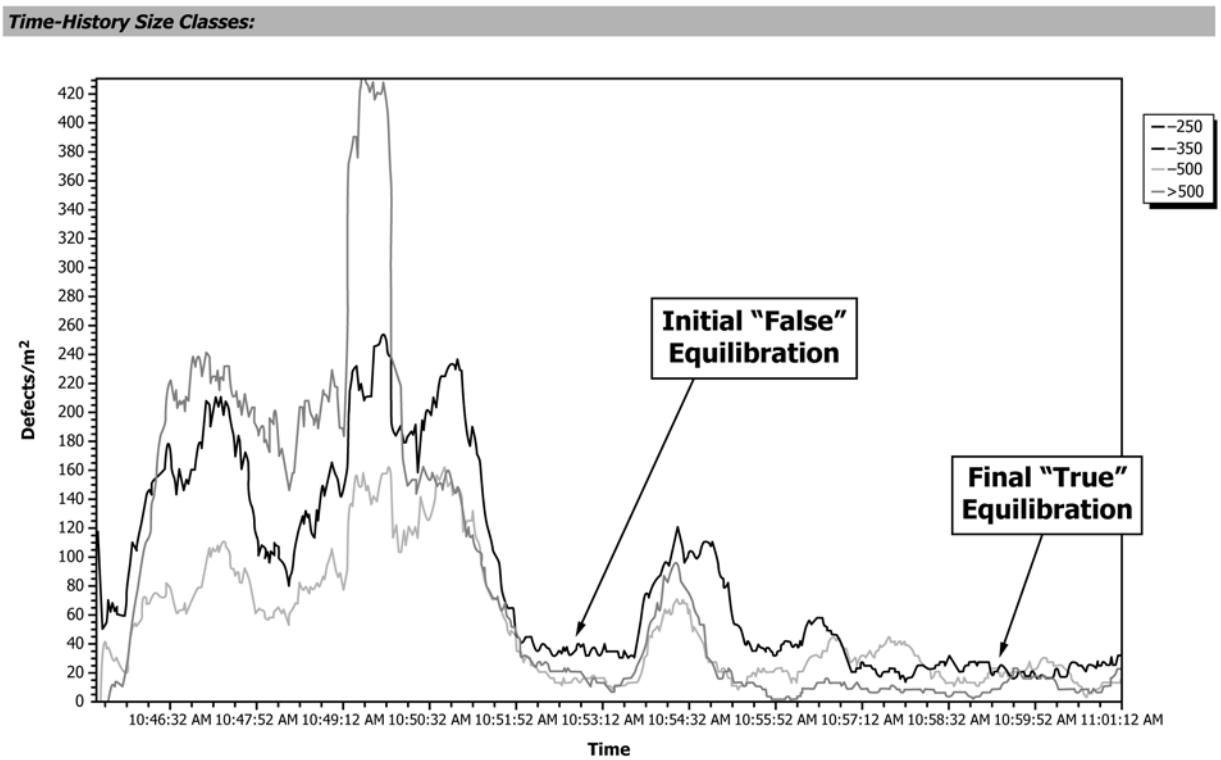

FIG. X2.1 Showing Purge Followed by a "False" Equilibrium before Final Equilibrium

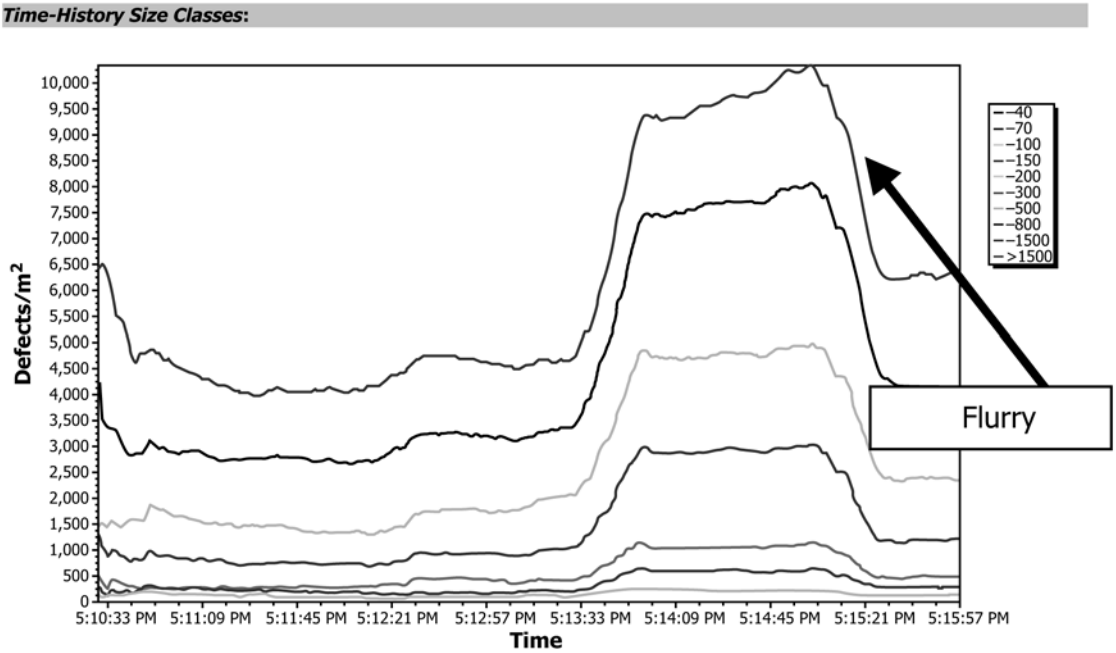

FIG. X2.2 Showing Non-Uniformity in a Sample as Evidenced by a Flurry of Defects

X3. EXAMPLES OF DATA PRESENTATION FOR FILM DEFECT DETECTION AND MONITORING

X3.1 See Figs. X3.1-X3.3.

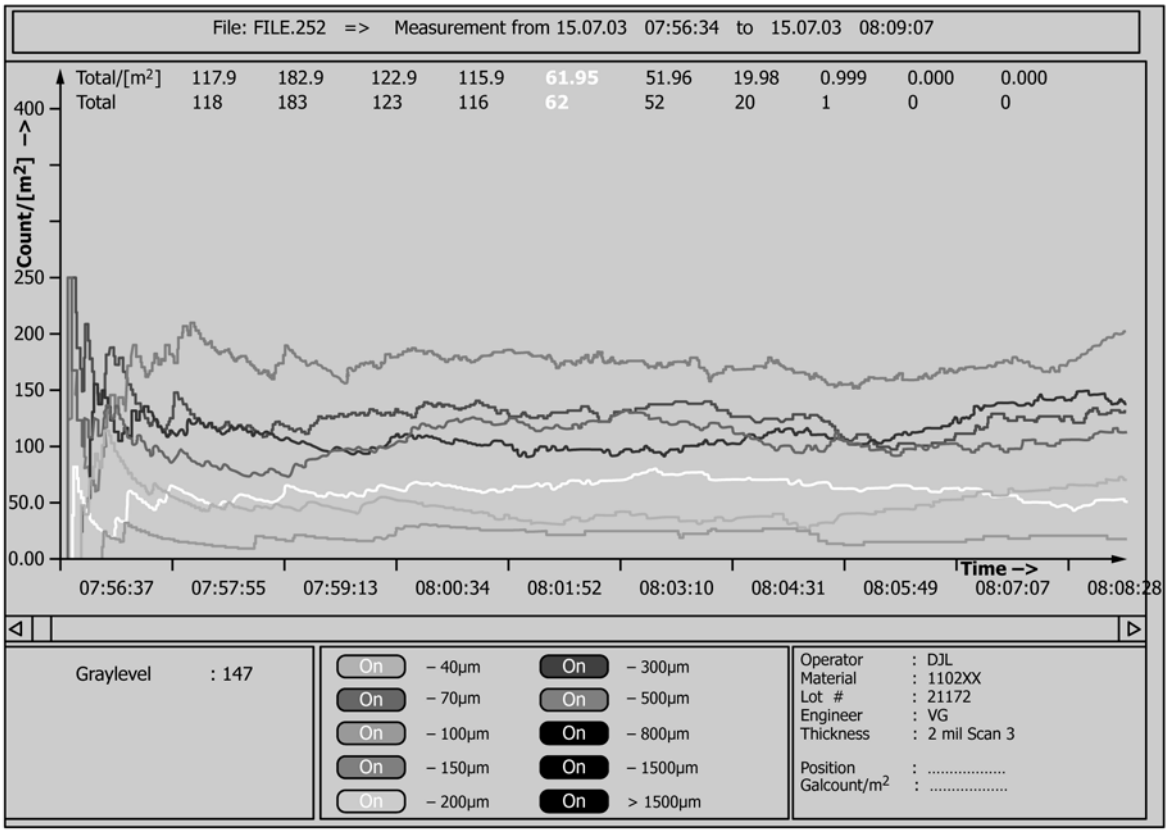

FIG. X3.1 Example of Report

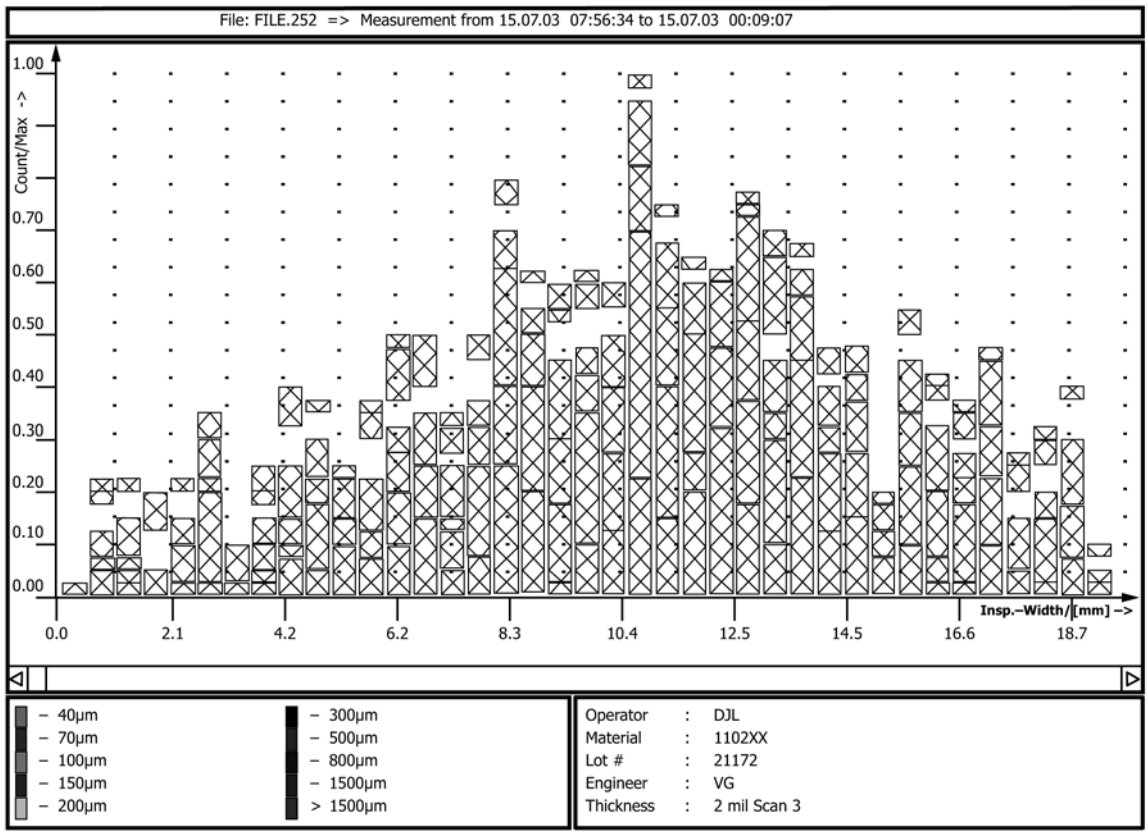

FIG. X3.2 Example of Report

Protocol from Tuesday 15.07.2003 07:56:34 to Tuesday 15.07.2003 08:09:07 => FILE.252 (2.5)

Operator	: DJL	parcel length	: 13.31 mm	mean greylevel	: 147	mean thickness	: 0 µm
Material	: 1102KX	parcel width	: 19.97 mm	mean filter	: 100	mean defect diameter	: 100 µm
Lot #	: 21172	inspected parcels	: 251 (251)	mean film speed	: 3.47 m/min	mean defect area	: 0.013 mm^2
Engineer	: VG	inspected area	: 1.00 m^2	mean integ. time	: 0.000 ms	total defect area	: 8.57 mm^2
Thickness	: 2 nil Scan 3	inspected length	: 43.57 m	mean clarity	: uncal. / 0.00 %	=>	8.5681 ppm

size/[µm]	total	total/[%]	avg/[m^2]	min/[m^2]	max/[m^2]	stdev	level 88 avg/[m^2]	SF –1.8 avg/[m^2]	SF –3.5 avg/[m^2]	SF –6.5 avg/[m^2]	SF >6.5 avg/[m^2]	cumulative avg/[m^2]
– 40	118	17.48	117.91	92.80	147.97	16.70	117.91	117.91	0.00	0.00	0.00	556.56
– 70	183	27.11	182.86	152.99	200.64	9.63	182.86	169.87	12.99	0.00	0.00	373.70
– 100	123	18.22	122.90	97.81	140.45	10.85	122.90	118.91	3.00	1.00	0.00	250.80
– 150	116	17.19	115.91	92.80	137.94	13.23	115.91	111.91	3.00	0.00	1.00	134.89
– 200	62	9.19	61.95	42.64	80.26	8.52	61.95	58.95	3.00	0.00	0.00	72.94
– 300	52	7.70	51.96	27.59	72.73	11.63	51.96	41.97	6.99	3.00	0.00	20.98
– 500	20	2.96	19.98	12.54	27.59	4.54	19.98	11.99	6.00	2.00	0.00	1.00
– 800	1	0.15	1.00	0.00	2.51	1.25	1.00	0.00	1.00	0.00	0.00	0.00
– 1500	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
> 1500	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--.--
Total	675	100.00	674.47	581.86	724.82	33.92	674.47	631.50	35.97	6.00	1.00	674.47

Name	total	total/[%]	avg/[m^2]	min/[m^2]	max/[m^2]	Name	total	total/[%]	avg/[m^2]	min/[m^2]	max/[m^2]
SMALL	540	80.00	539.57	456.46	581.86	MEDIUM	134	19.85	133.89	110.35	142.96
LARGE	1	0.15	1.00	0.00	2.51						

remarks:

FIG. X3.3 Example of Report