Fiber Orientation Measurement

System Manual

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Fiber Orientation Measurement

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Notice

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Introduction

The purpose of this manual is to provide an introduction to the Fiber Orientation Measurement, models Q4223-51, and Q4223-52.

ATTENTION

The terms *FotoFiber*, *Fiber Orientation sensor*, and *FotoFiber sensor*, refer to the *Fiber Orientation Measurement*. These terms may be used interchangeably in this manual.

Audience

This manual is intended for use by engineers or process engineers and assumes that the reader has some knowledge of the operation of a paper machine and a basic understanding of mechanical, electrical and computer software concepts.

About this manual

This manual contains 12 chapters and four appendixes.

Chapter 1, **System Overview**, describes operating principles and system specifications.

Chapter 2, **Fiber Orientation of Paper and Paperboard**, describes what paper fiber orientation is, how the papermaking process can affect it, and how to rectify some common fiber orientation problems.

Chapter 3, **EDAQ**, describes the principles and operation of the Ethernet Data Acquisition (EDAQ) board.

Chapter 4, **Installation**, describes installation and set up tasks for the system.

Chapter 5, **Operation**, describes operation of the system.

Chapter 6, **Software**, describes software configuration parameters for the system software.

Chapter 7, **Detailed Sensor Structure**, describes the internal structure, electronics, pneumatics, and software, of the sensor, and describes sensor hardware configuration.

Chapter 8, **Preventive Maintenance**, describes recommended ongoing preventive maintenance tasks.

Chapter 9, **Tasks**, describes procedures for maintenance, diagnostic, and troubleshooting tasks.

Chapter 10, **Troubleshooting**, describes symptoms, alarms, possible causes, and links to associated diagnostic or troubleshooting tasks.

Chapter 11, **Storage, Transportation, and End of Life**, describes methods for storing, transporting, and disposing sensor components.

Chapter 12, **Glossary**, describes the terms and acronyms used in this manual.

Appendix A, **Part Numbers**, lists the component part numbers for this system.

Appendix B, **Standard Targets**, describes the targets used for focusing and calibrating system components.

Appendix C, **LabVIEW 2010 Run-Time**, describes procedures for downloading and installing the LabVIEW 2010 Run-Time engine.

Appendix D, **Intelligent Sensors Software**, describes procedures for obtaining and installing the Intelligent Sensors software.

Related reading

The following documents contain related reading material.

Honeywell Part Number	Document Title / Description
	K. Niskanen (ed.), Paper Physics, 2nd ed., volume 16 of Papermaking Science and Technology, Paperi ja Puu Oy, Helsinki Finland, 2008. (Chapters 1, 5, 6, 9.)
	H. Paulapuro (ed.), Paper and Board Grades, volume 18 of Papermaking Science and Technology, Paperi ja Puu Oy, Helsinki Finland, 2000. (Chapters 1, 2.)
	W. Scott and J. Abbott, Properties of Paper: An Introduction, 2nd ed., TAPPI Press, Atlanta Ga. 1995. (Chapters 3, 4, 8.)
	J. Shakespeare, "Tutorial: fibre orientation angle profiles - process principles and cross-machine control" Proceedings TAPPI 1998 Process Control Electrical & Instrumentation (16-19 March, Vancouver BC), p.593-636.

Conventions

The following conventions are used in this manual:

ATTENTION	Text may appear in uppercase or lowercase except as specified in these conventions.

`Boldface`	Boldface characters in this special type indicate your input.
`Special Type`	Characters in this special type that are not boldfaced indicate system prompts, responses, messages, or characters that appear on displays, keypads, or as menu selections.
Italics	In a command line or error message, words and numbers shown in italics represent filenames, words, or numbers that can vary; for example, filename represents any filename. In text, words shown in italics are manual titles, key terms, notes, cautions, or warnings.
Boldface	Boldface characters in this special type indicate button names, button menus, fields on a display, parameters, or commands that must be entered exactly as they appear.
lowercase	In an error message, words in lowercase are filenames or words that can vary. In a command line, words in lowercase indicate variable input.
Type	Type means to type the text on a keypad or keyboard.
Press	Press means to press a key or a button.

`[ENTER]` or `[RETURN]`	`[ENTER]` is the key you press to enter characters or commands into the system, or to accept a default option. In a command line, square brackets are included; for example: **`SXDEF 1`** `[ENTER]`
`[CTRL]`	`[CTRL]` is the key you press simultaneously with another key. This key is called different names on different systems; for example, `[CONTROL]`, or `[CTL]`.
`[KEY-1]-KEY-2`	Connected keys indicate that you must press the keys simultaneously; for example, `[CTRL]-C`.
Click	Click means to position the mouse pointer on an item, then quickly depress and release the mouse button. This action highlights or "selects," the item clicked.
Double-click	Double-click means to position the mouse pointer on an item, and then click the item twice in rapid succession. This action selects the item "double-clicked."
Drag X	Drag X means to move the mouse pointer to X, then press the mouse button and hold it down, while keeping the button down, move the mouse pointer.
Press X	Press X means to move the mouse pointer to the X button, then press the mouse button and hold it down.
ATTENTION	The attention icon appears beside a note box containing information that is important.
CAUTION	The caution icon appears beside a note box containing information that cautions you about potential equipment or material damage.
WARNING	The warning icon appears beside a note box containing information that warns you about potential bodily harm or catastrophic equipment damage.

1. System Overview

The Fiber Orientation Measurement is a sensor that measures and characterizes the distribution of fiber orientation angles on the surface of paper, paperboard, or any similar sheet material. For an introduction to fiber orientation in paper and paperboard, and its causes and effects in the papermaking processes, see Chapter 2.

This chapter provides an overview of the sensor structure and operating principle. The key features of the sensor are:

- based on high-speed digital imaging and real-time analysis
- passively-contacting measurement
- consists of illumination and detector units mounted in the same sensor head
- sensor models exist for installation on the top or bottom side of the sheet for measurement of the selected sheet surface
- two sensors of the appropriate models can be installed opposite one another for two-sided measurements
- can be used by Experion MX systems with RAE R600 or newer (with latest updates)

1.1. Characterization of fiber orientation

The Fiber Orientation sensor measures the statistical distribution of fiber angles at each measurement point. This distribution is then reduced to two parameters:

- angle of average orientation: this is what is often referred to as the fiber orientation angle
- anisotropy of orientation: this describes the extent to which the fibers are oriented near the average angle

These parameters are communicated to the Experion host from every measurement location, and are used for building profiles. In addition to these parameters, the entire statistical distribution is communicated periodically to the Experion host. The distribution of fiber angles is explained in more detail in Chapter 2.

1.2. Installation location vs. dust

It is strongly recommended that a Q4223-5x Fiber Orientation sensor be located downstream from any sensor that is sensitive to dust (such as Color Measurement), because it contacts the sheet and may cause dust issues, especially in sheets with high filler content. For this reason, it is not recommended to install FotoFiber into the first (upstream side) measurement location in a 4-pack or 6-pack. It is preferably installed into the last (downstream side) measurement location, so that dust issues do not arise in other sensors. However, sensors which generate large quantities of dust, such as the Caliper and Optical Caliper sensors, should be downstream from the FotoFiber sensor.

1.3. FotoFiber sensor: main modules

The FotoFiber sensor consists of either one or two fiber orientation measurement modules (FOMM). If there is only one FOMM (see Figure 1-1), the fiber orientation backing module (FOBM) is located opposite it in the other head of the scanner.

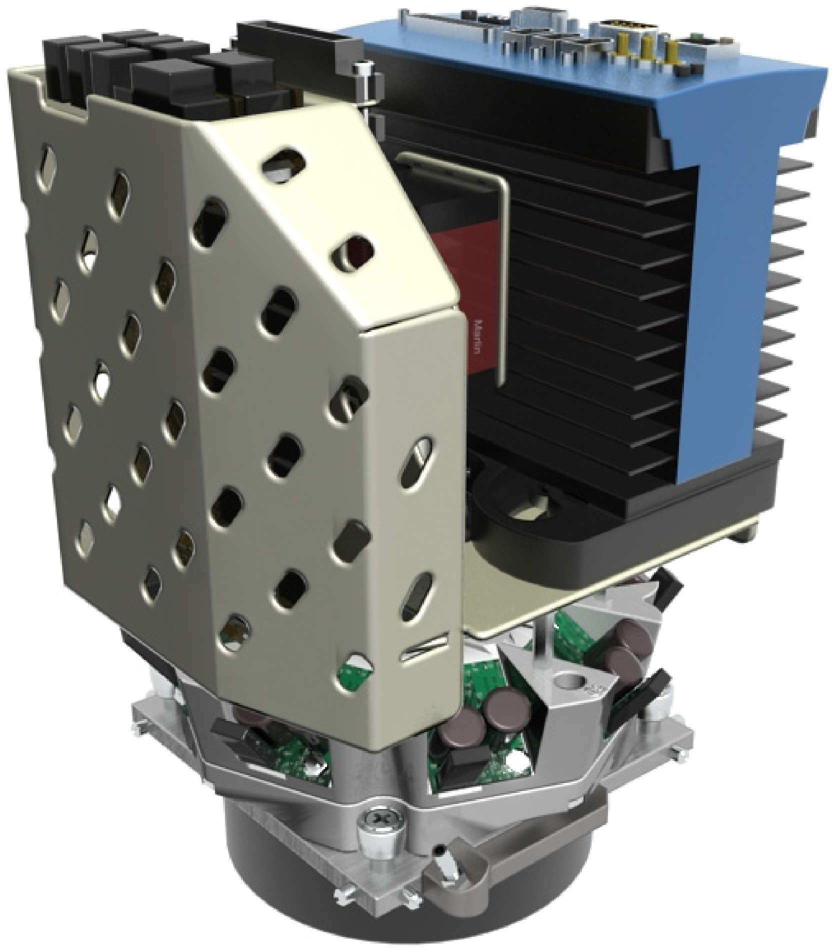

Figure 1-1 The Fiber Orientation Measurement Module

In a two-sided sensor, the FOMM units on each side of the sheet differ slightly.

In a single-sided sensor, the structure of the FOMM and FOBM units depends on which one is to be installed above the sheet. The differences pertain only to the window and sheet-bearing rings.

The FOMM:

- outputs short, directionally unbiased, annular flashes of white light
- captures images of the surface of the paper or paperboard web
- computes surface fiber orientation distribution and parameters
- communicates with Experion MX via the Measurement Sub System (MSS)

The FOBM:

- is a passive unit
- assists in stabilizing web

1.3.1. The fiber orientation measurement module

The external electrical connections, switches, and LEDs of the Q4223-5x FOMM are shown in Figure 1-2. Camera and optics are on the center-line of the sensor, flanked by the processor module on one side, and by two PCBs on the other.

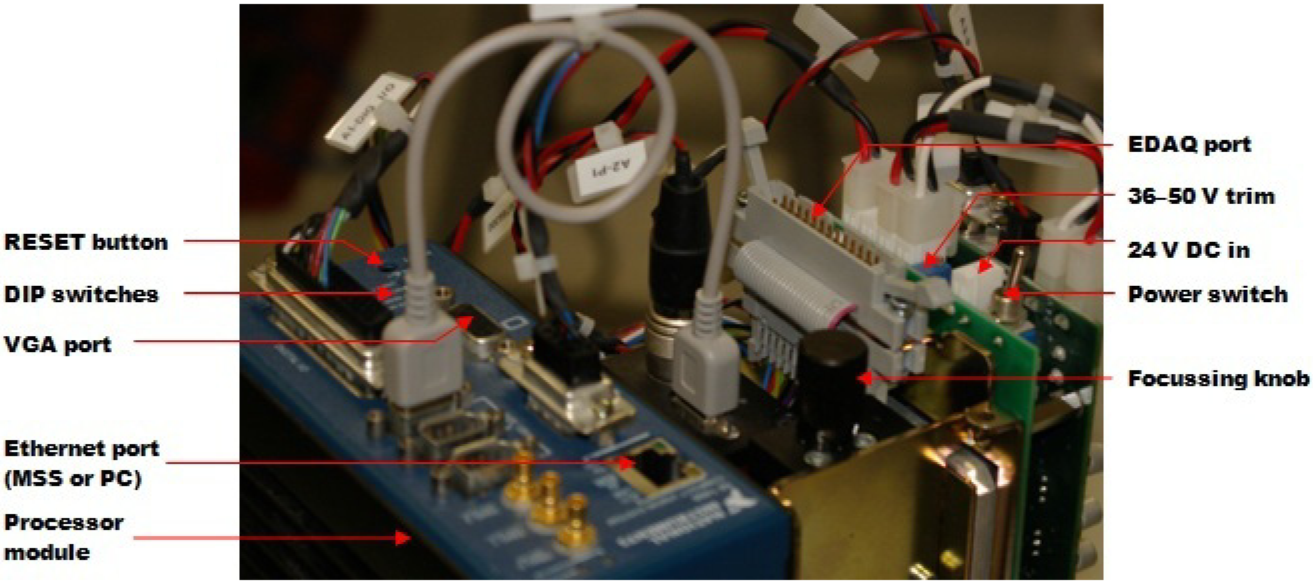

Figure 1-2 Fiber Orientation Measurement Module Components

The FOMM performs all measurement functions of the sensor. It communicates with the MSS using the Ethernet port on its processor module. The connections providing 24 V DC power and EDAQ communication are part of the integral wiring harness for the sensor.

There is a switch to power the FOMM on and off. The FOMM is protected by a fast-acting fuse rated at 5 A. The current draw of the FOMM is between 1.0 A and 1.1 A at 24 V DC during normal operation, and should never exceed 1.2 A. The current draw is less than 0.9 A while the sensor is starting up.

Depress **RESET** on the processor module for a couple of seconds to perform a soft reboot of the FOMM (a reset might be needed during firmware updates). A series of DIP switches on the processor module determine the operating mode of the FotoFiber sensor. The default operation (Experion MX measurement mode) is achieved by setting all the DIP switches to the *off* position.

The VGA port provides diagnostic information during Experion MX measurement, for example, timestamp, last mode request/status, internal parameters, and so on. This feature can be utilized in troubleshooting, but is not suitable for use in a scanning operation (see Subsection 10.2.5.1).

The Ethernet port on the processor module is used for communication with the MSS over the sensor LAN. It can be used simultaneously for access to the web server in the sensor by a PC connected to that LAN, allowing sensor internal operating states to be monitored and problems to be diagnosed. The web server can display the same diagnostic information as would be displayed via the VGA port, except for the boot-up messages (see Section 10.2.1).

With a direct connection to a PC, the Ethernet port can be used to install firmware updates to the Fiber Orientation Measurement (see Section 9.7). It can also be used in this way in PC control mode, where various functions of the sensor can be tested. The sensor can be operated outside the scanner using a PC. For example, the quality control test performed by the factory, and some other special service procedures, use this port (see Subsections 10.2.5.2, and 10.2.5.3).

The status LEDs on the processor module report various states of the FOMM. They are helpful in troubleshooting. There are additional status LEDs on the strobe control PCB that indicate some error states.

The illumination and imaging systems in the Fiber Orientation Measurement have been designed to minimize internal reflections and entry of extraneous light to maximize contrast in the images.

When a two-sided sensor is installed, the sheet stabilizer of the FOMM in the upper head is a pair of crescents, as shown in Figure 1-3. In environments where the dust levels are high, the upstream arc of the pair can be removed and replaced by a flat insert, flush with the blank surface (this reduces dust generation).

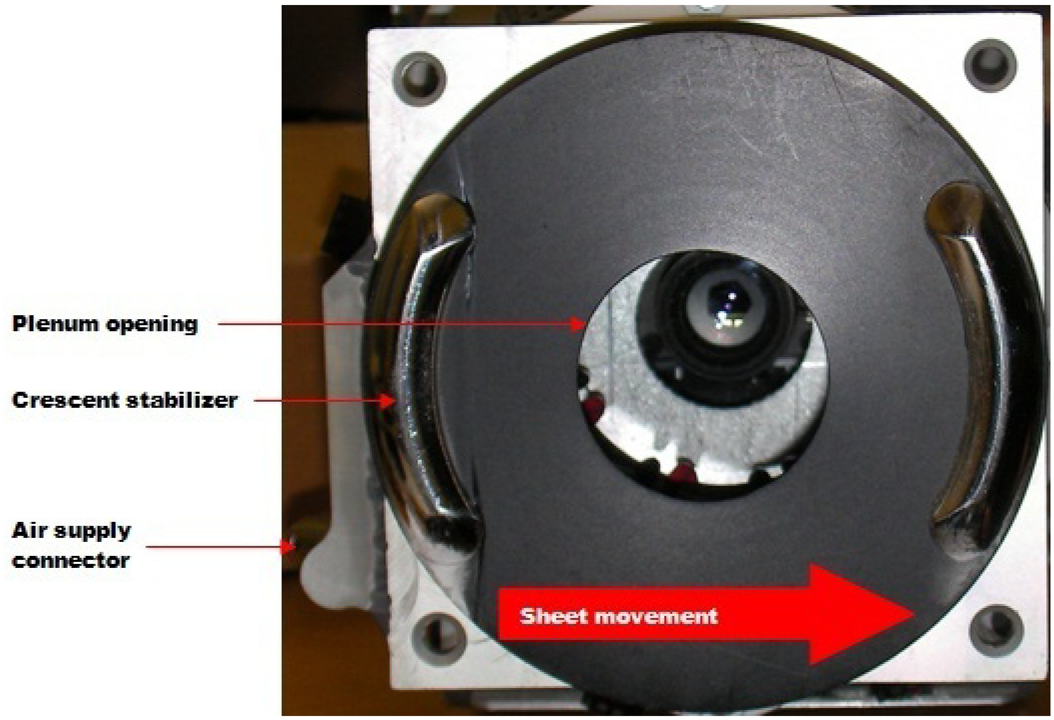

Figure 1-3 Sensor Gap (upper head)

A 6 mm (0.24 in.) thick borosilicate glass window is located inside the plenum, and is kept clean by a transverse air flow across the window surface inside the plenum. Note the direction of sheet movement, and that the air supply connector must always be on the upstream side of the sensor.

When a single-sided FOMM is installed in the upper sensor head, the sheet stabilizer is a complete ring located close to, and concentric with, the plenum opening. It is similar in size to the horseshoe shape shown in Figure 1-4, except it that is a full circle.

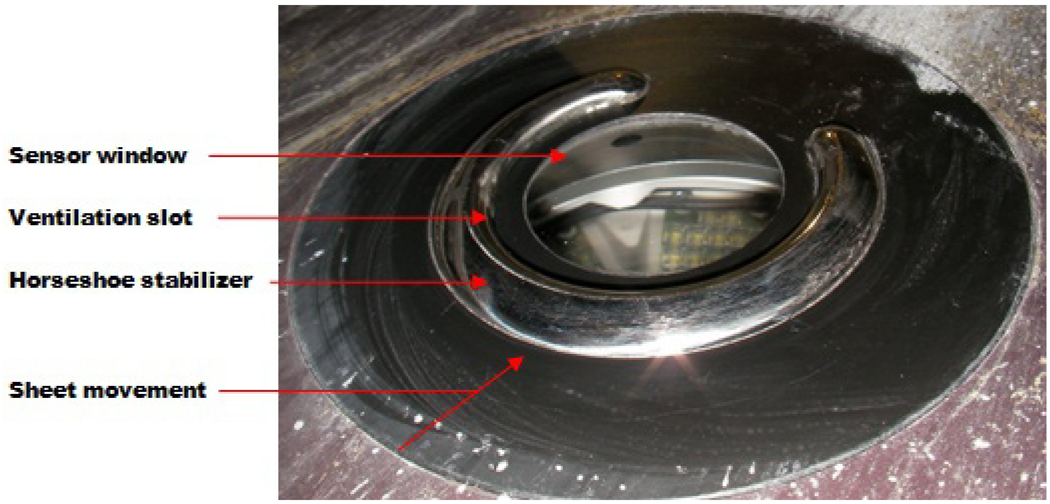

Figure 1-4 Sensor Gap (lower head)

When a single-sided or two-sided FOMM is installed in the lower head, the protective glass window is flush to the sensor head faceplate, and the sheet stabilizing ring is replaced by a ventilated horseshoe shape. Note the direction of movement of the sheet relative to the horseshoe.

In the single-sided measurement, the FOBM has a crescent-shaped stabilizer similar to that shown for the FOMM in Figure 1-3. This allows the heads to be separated without overlap of the stabilizing elements on the two heads.

1.3.2. The fiber orientation backing module

This module is required only for single-sided measurements with a single FOMM. For dual-sided measurements, two FOMM modules are used instead.

There are no electronic or active mechanical components in the FOBM. It comprises a blank with one or two sheet-stabilizing crescents. One crescent is used in high-dust mills, in which case the FOBM should always be installed so that the crescent is positioned on the downstream side.

1.3.3. Matching the modules

The FOMM for an upper head has an open plenum rather than a window near the sheet. If it is part of a one-sided sensor, it has a circular ring around the opening.

If it is part of a two-sided sensor, it has arcs spaced upstream and downstream of the plenum opening. In high-dust environments, the upstream arc can be removed and replaced by a flat insert, flush with the blank surface (this reduces dust generation).

The FOMM (one-sided or two-sided sensor) for a lower head always has a horseshoe-shaped ring around a window. The FOBM is always a blank, with arcs spaced near its upstream and downstream edges. This is the case whether it is in the upper or lower head. In high-dust environments, the upstream arc can be removed and replaced by a flat insert, flush with the blank surface (this reduces dust generation).

Figure 1-5 shows various FOMM and FOBM configurations.

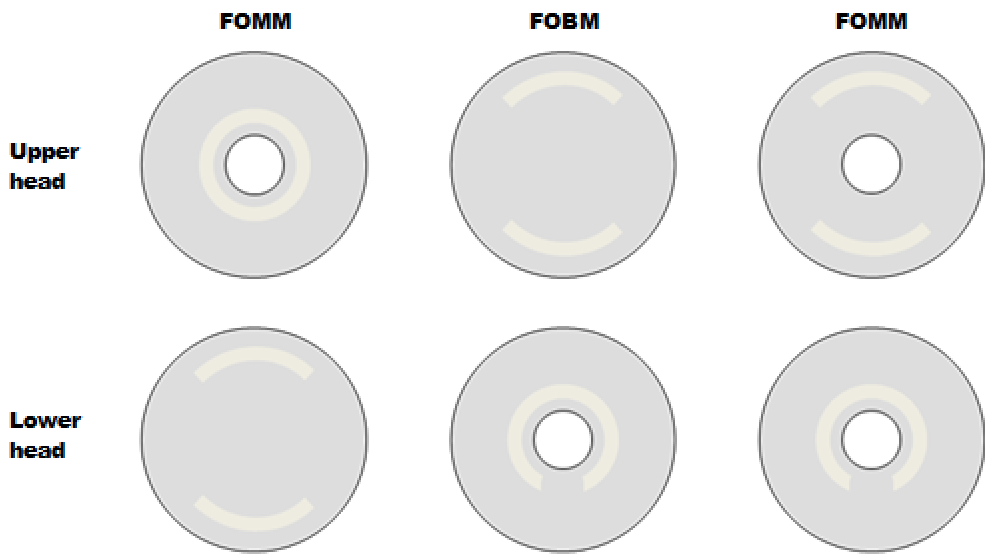

Figure 1-5 Module Configurations

1.4. Operating principles

The measurement of surface fiber orientation is based on digital imaging and image analysis performed in the Q4223-5x sensor. The Fiber Orientation Measurement traverses over the running paper web inside the scanner head. The sensor is mounted on one side of the sheet, flush to the scanning head front plate. There is a 10 mm (0.4 in.) open gap between the FOMM and the opposing FOBM, or the second FOMM, in which the web moves. Each FOMM (or FOBM) has a shaped ring to constrain the sheet position to near the middle of the 10 mm (0.4 in.) gap.

The FOMM takes digital images of the web. The web is epi-illuminated with short light pulses emitted by a ring light in the FOMM . The pulses are timed to occur during the camera exposure. Images of the web are analyzed by mathematical algorithms in the FOMM. The results (the measured fiber orientation distribution, and a parametric representation of the distribution) are sent to Experion MX for building trends and profiles. Also, images of the sheet are periodically sent accompanied by their histograms and fiber orientation parameters.

The operation principles of the Fiber Orientation sensor in Experion MX systems is shown in Figure 1-6.

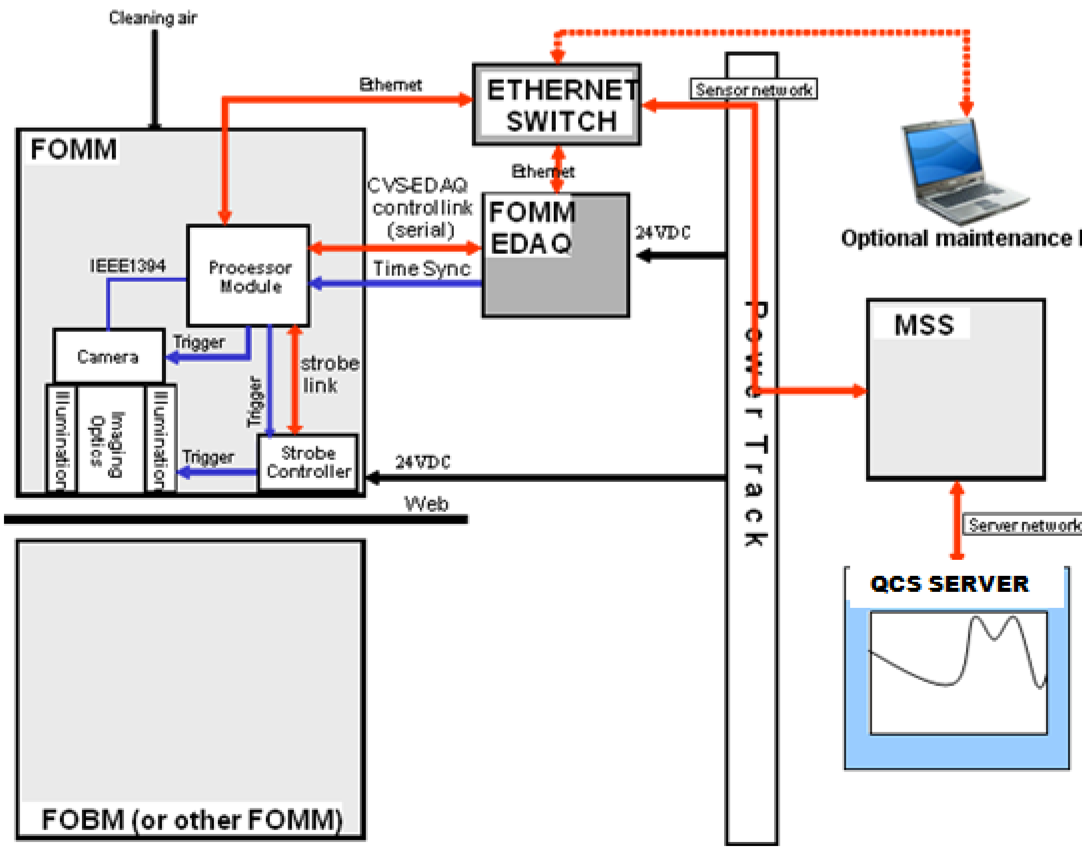

Figure 1-6 Operation Principles

Note that the FOBM is completely passive and has no connections.

The sensor needs 24 V DC power and oil-free pressurized air, but does not require water. Internal operation of the sensor is controlled by the processor module of the FOMM. It receives the IP address and timing information from the EDAQ through a serial link, which employs CSLP (Camera Sensor Link Protocol) for communication. Ethernet communication is subsequently established with the MSS using the Ethernet port of the processor module.

The initial communication between MSS, EDAQ, and the FotoFiber sensor is shown in Figure 1-7. Initially, the FotoFiber sensor does not have a valid IP address, position code, or function code. The sensor requests the IP address of its processor module, the sensor position code, and sensor function code from the EDAQ via the serial link (item 1). The EDAQ sends the requested information as a response (item 2). Initially, the MSS does not know the FotoFiber sensor IP address, position code, or function code. The sensor broadcasts the IP address, position code, and function code on UDP port 2222 (item 3). Other nodes on the sensor bus ignore these broadcast messages, but the MSS receives them.

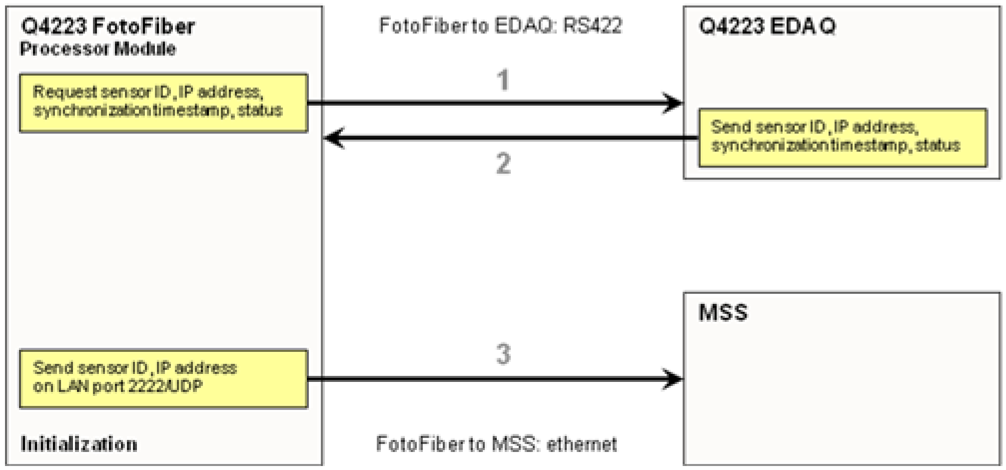

Figure 1-7 Initial Communication

Items 1, 2, and 3 in Figure 1-7 are repeated once per second until the MSS opens a connection to the sensor. The MSS uses the information provided in item 3 to establish a TCP connection with the sensor on TCP port 2224. The TCP communication is for a range of messages, including those unique to the FotoFiber as well as standard Foto sensor messages.

Both the EDAQ link and the Ethernet link are used subsequently, as shown in Figure 1-8. The sensor receives the system timestamp once per second via the EDAQ serial link. Either side can close the connection.

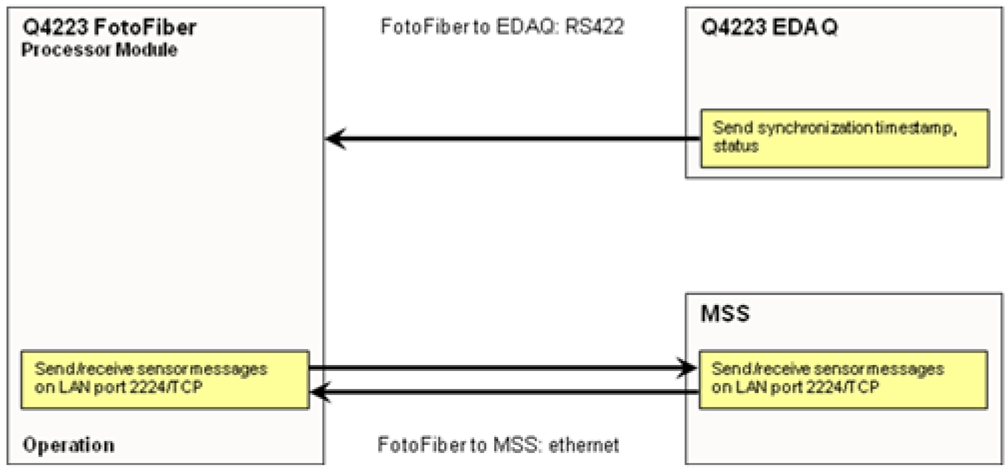

Figure 1-8 Ongoing Communication

The Q4223-5x processor module receives operating parameters and mode commands, and reports slice data and standardization data back to the MSS over the Ethernet link. It also reports alarms and other statuses back to the MSS, and allows access to internal diagnostics from other nodes on the local sub-net.

The Experion MX server gathers fiber orientation measurement data and provides standard tools for displaying the data as profiles, trends, colormaps, and so on. Software in the Experion MX includes special tools for displaying on-line polar histograms and surface images. Also, there is a sample measurement mode which can be used when the sensor is offsheet.

The processor module operates a monochrome industrial camera with two connections:

- IEEE 1394b-a cable for power, image transfer, and configuration
- a camera trigger cable

The camera is configured automatically for different grades and operation modes by the processor module. Imaging by the camera and illumination by the FOMM is timed by triggering from the processor module. A special high-resolution low-distortion macro lens projects a sharp image of the web surface on the CCD chip of the camera. Images are transferred to the processor module, which calculates the fiber orientation distribution and its parametric description from the images.

The FOMM includes eight pulsed white light LED panels, each with 24 LEDs, which have individual lenses to maximize illumination intensity on the paper.

Electrically, the 24 LEDs are arranged in eight parallel lines, each containing three LEDs in series. The LED panels are each driven by a dedicated PCB which controls the pulse length and strength. The individual strengths are modulated using calibration curves so that the illumination is directionally uniform (no directional bias).

The LEDs are synchronized to produce pulses with very precise agreement in timing, differing by no more than a few nanoseconds. The intensity and duration of the light pulses are configured by the processor module of the FOMM through a serial link to the strobe controller, which governs the LED driver boards. The strobe controller generates a light pulse with the configured characteristics every time it receives a trigger pulse from the processor module.

The general layout of the Fiber Orientation sensor is shown in Figure 1-9.

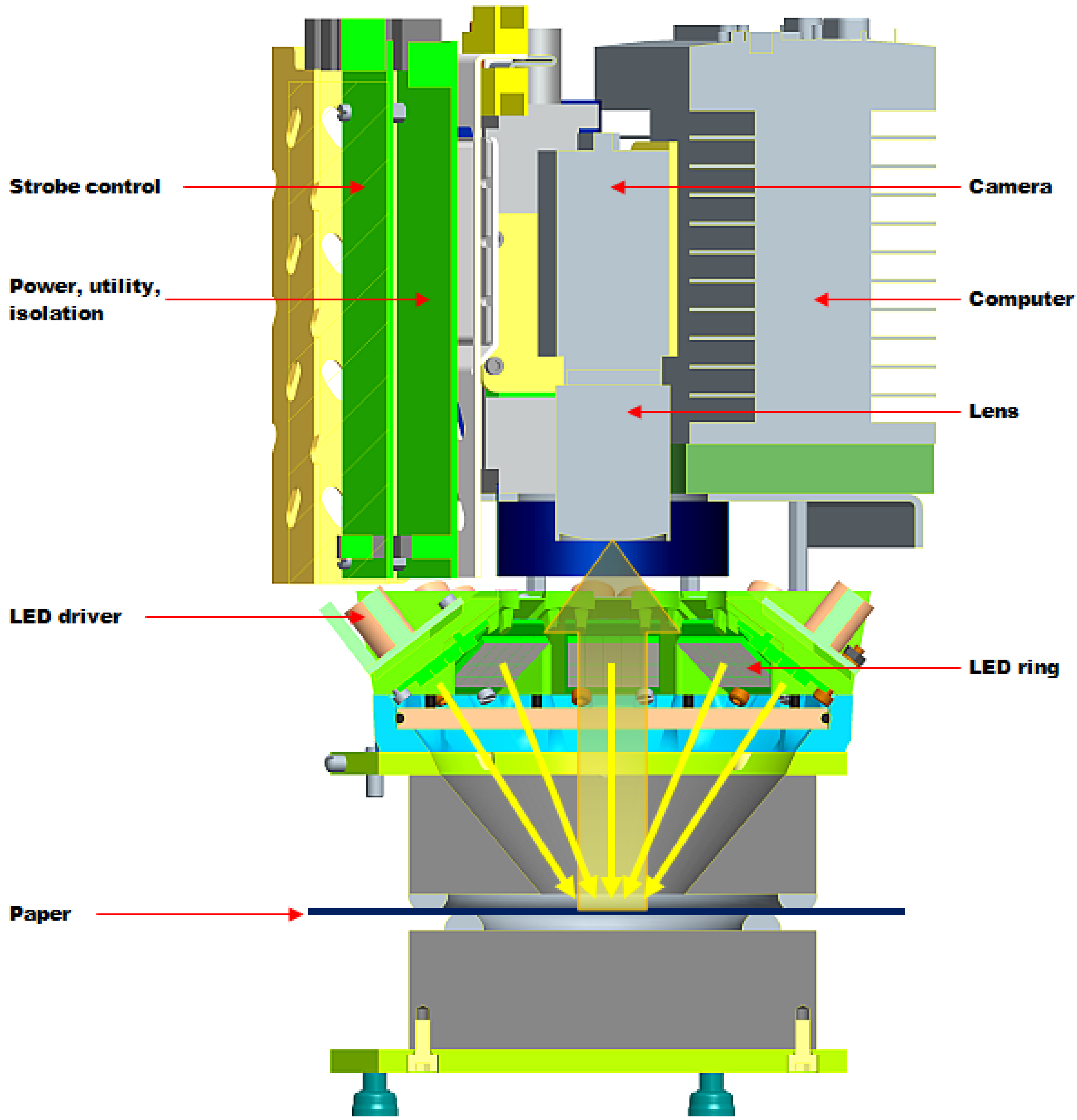

Figure 1-9 General Layout of the FotoFiber Sensor (single-sided)

In addition to the normal Experion MX operation mode, the sensor can operate in a PC controlled mode. This is selected by rebooting the sensor with the **USER1** DIP switch on the processor module set to the ON position.

The PC controlled mode is used in the factory testing procedure, but can also be used by Honeywell technicians in the field for some maintenance and troubleshooting purposes. In this mode, the processor module and a PC are directly connected together with an Ethernet cable, replacing the connection from the FOMM to the MSS (the FOMM Ethernet port is shown in Figure 1-2). Special software on the PC can be used to control the functions of FotoFiber sensor in this mode.

1.5. Image analysis

The image acquired by the Fiber Orientation sensor during its measurement modes is analyzed using proprietary methods (disclosed in *U.S. patent 7,695,592*), which are outlined in this section. The analysis result is the polar histogram of the surface fiber angle distribution, and the parameters fitted to the distribution. Two of the fitted parameters are the main measurement results: the average fiber orientation angle, and the fiber orientation anisotropy.

1.5.1. Image preprocessing

The illumination compensation at each end of scan ensures that the overall gray level of images is generally constant, and that the illumination is equal from all directions. There is no need to adjust the image before analysis. The image is 16-bit grayscale to ensure sufficient precision.

1.5.2. Pixel angles and amplitudes

A fractional order gradient operator is applied to the image along each axis, producing an X-enhanced image and a Y-enhanced image. The gradient operator is 1/2 order by default (in this instance, it is a semi-derivative operator), but other strictly positive fractional or whole orders can be employed. The X-gradient operator includes smoothing in the Y-direction, and the Y-gradient operator includes smoothing in the X-direction. These operations are applied to a circular region of the image J, producing directionally enhanced images H_x and H_y:

$$H_x = D_x^{½} J \qquad H_y = D_y^{½} J$$

Equation 1-1

For a random sample of the pixels in a circular annulus, centered in the image, an angle θ and squared amplitude p^2 are computed:

$$\theta = \tan^{-1}\left(\frac{H_y}{H_x}\right)$$

Equation 1-2

$$p^2 = (H_x)^2 + (H_y)^2$$

Equation 1-3

The annulus is typically a disk, and usually about 30% of the pixels in the disk are analyzed. The gradient operator is renewed at the start of each scan. Changes to the gradient order or smoothing parameters are not effective until the next scan. The random mask is created when the sensor boots, and is optionally renewed at each standardization. Changes to the annulus dimensions or to the pixel sampling fraction are not effective until the mask is renewed.

1.5.3. Polar histogram and parameters

A polar histogram $r(\varphi)$ is constructed using 1-degree wide data boxes. For every analyzed pixel, the squared amplitude p^2 is accumulated into the bin indicated by its angle θ. The square root is taken of the final accumulated value in each bin:

$$r(\varphi) = \sqrt{\sum \left\{ p^2 \,\middle|\, \varphi_{k-½} \le \theta < \varphi_{k+½} \right\}}$$

Equation 1-4

This yields the measured polar histogram. A smooth curve approximation is also fitted to the measured histogram, using least-squares:

$$\hat{r}(\varphi) = 1 + e\cos(2\varphi - 2\alpha)$$

Equation 1-5

This curve form is a good fit to the surface orientation distributions typically encountered in paper. At low anisotropies it is nearly elliptical, while at higher anisotropies it is bilobate. The fitted parameters are:

- α the average fiber orientation angle in the image
- e the anisotropy of the orientation distribution

Note that the curve form used in Equation 1-5 is appropriate only to paper and other formed materials with low to moderate surface anisotropy. It becomes inappropriate for distributions with anisotropy values greater than approximately 0.30 (which are not encountered in paper). The measured angle histogram remains valid, however, for materials with quite high anisotropy (up to approximately 0.9), and the fitted angle also remains correct.

A fitting residual and some other diagnostics are also computed. The *MD/CD* ratio and *Max/Min* ratio of the fitted distribution are computed from the average angle and anisotropy:

$$\frac{Max}{Min} = \frac{1+e}{1-e} \qquad \frac{MD}{CD} = \frac{1+e\cos\alpha}{1-e\cos\alpha}$$

Equation 1-6

The image processing for a typical surface image of uncoated paperboard is illustrated in Figure 1-10. In the polar histogram plot (item 6), the green trace indicates the measured distribution of orientation angles, while the yellow trace indicates the fitted curve and the main axis of the fitted curve (the direction of the average fiber orientation angle α). Note that the intermediate images are not accessible in the sensor.

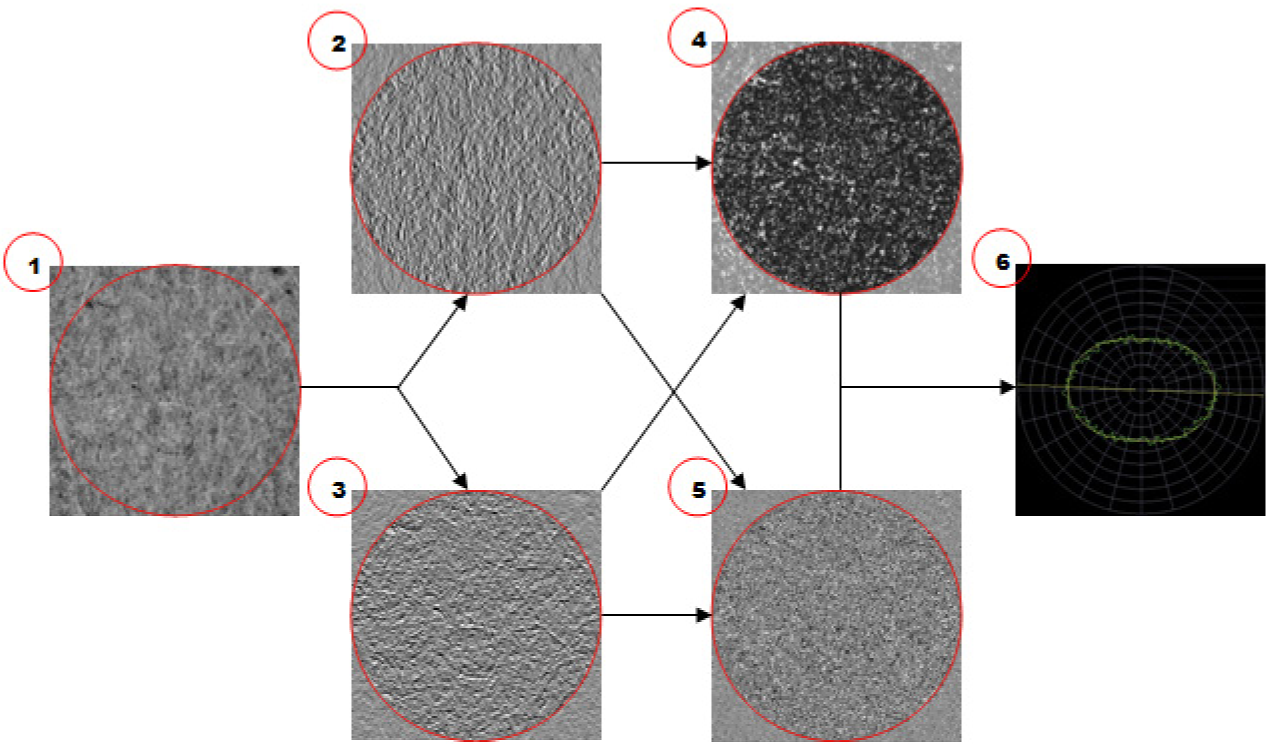

Figure 1-10 Processing for a Measured Image

Table 1-1 lists the descriptors and equations for the items shown in Figure 1-10.

Table 1-1 Descriptors and Equations

Item	Descriptor	Equation
1	Image	J
2	Semi-gradient	$D_x^{1/2}J$
3	Semi-gradient	$D_y^{1/2}J$
4	Amplitude	$(D_x^{1/2}J)^2 + (D_y^{1/2}J)^2$
5	Angle	$tan^{-1}((D_y^{1/2}J)/(D_x^{1/2}J))$
6	Polar histogram	$r(\varphi)$

1.6. Specifications

- range: angle - 90 degrees to + 90 degrees
- anisotropy: 0.0 to 0.35

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> The sensor will measure anisotropy on samples where the anisotropy is almost zero. However, the orientation angle is undefined as anisotropy approaches zero. Orientation angle measurements on samples of very low anisotropy are mostly random, and are dominated by minor differences in image statistics between measurement locations.

- repeatability (2-sigma): angle: ± 0.1 degree for samples with anisotropy of 0.10 or higher (provided angle is not too close to ± 90 degrees, due to numerical effects of angle definition)
- anisotropy: ± 0.0025 or 2.5% of reading, whichever is greater
- accuracy (2-sigma): angle: ± 0.2 degrees for samples with anisotropy of 0.10 or higher (provided angle is not too close to ± 90 degrees, due to numerical effects of angle definition)
- anisotropy: ± 0.005 or 5% of reading, whichever is greater
- dynamic correlation (2-sigma): not defined

- correlation with TSO: uncoated grades, angle: ± 1 degree for samples with anisotropy of 0.10 or higher (provided angle is not too close to ± 90 degrees, due to numerical effects of angle definition)
- Coated grades, correlation not defined
- maximum ambient temperature: 100° C (212 °F) when located in a temperature-controlled sensor enclosure; temperature inside enclosure about 40–45 °C (104–113 °F)
- measurement area: approximately 8 mm (0.31 in.) diameter disk

ATTENTION

The deviation from specification at angles close to ± 90 degrees is apparent rather than actual, and is a consequence of a discontinuity in the definition of orientation angle such that + 90 degrees is the same as - 90 degrees. If the sample is re-oriented with respect to the sensor so that the measured angle is not too close to ± 90 degrees, the specified repeatability, accuracy, and correlation with TSO can be achieved for that sample.

2. Fiber Orientation of Paper and Paperboard

Fiber orientation is a critical property of several grades of printing paper and packaging paperboard. It contributes to twist and curl, and other deviations from flatness. Poor orientation can also cause problems in sheet handling in printers and copiers, and lead to unacceptable misregister in color printing.

2.1. Fiber orientation

Paper and similar products are formed of networks of fibers which are intertwined in a thin sheet. An image of such a sheet is shown in Figure 2-1, which is an image of paper surface epi-illuminated with annular light (the image is taken with FotoFiber sensor, with the contrast enhanced). The fibers are laid approximately flat in the sheet, because the sheet is thinner than the length of a typical fiber. The fibers also are aligned at many different directions. Although the alignment is random, more fibers are aligned in some directions than others.

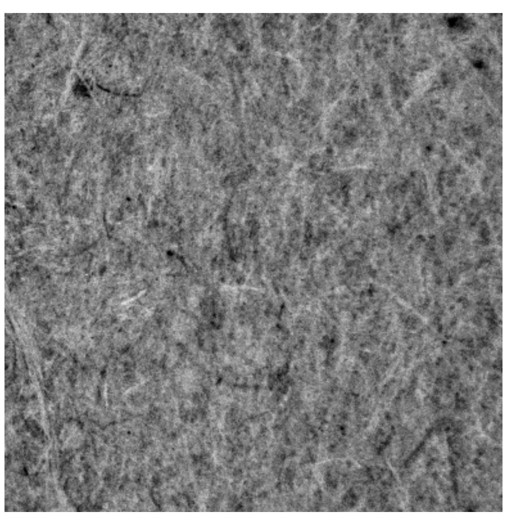


Figure 2-1 Paper Surface

If each individual fiber in the image were isolated, and its angle measured, a histogram could be constructed for the number of fibers at each angle. This histogram describes the fiber orientation distribution. Fiber orientation distributions are usually characterized using two parameters:

- average angle: the average angle of fibers, which is also the angle of the major axis of the histogram
- anisotropy: the degree to which fibers tend to be aligned in the same direction

Normally, the zero angle is chosen to be the machine direction. Usually, positive angles are clockwise from the machine direction, when the paper is viewed from above. In some mills, the positive direction for angles may be counterclockwise.

If the fibers are uniformly distributed in all directions, the anisotropy is zero. If all of the fibers were aligned in exactly the same direction, the anisotropy would be unity (this is not physically achievable for paper). Normally, the anisotropy of paper is fairly low, but not zero.

The fibers used to make paper are predominantly obtained from softwood trees such as pine and hemlock, or from hardwood trees such as aspen and eucalyptus, or from plants such as cotton. The typical widths of individual fibers vary from approximately 15–50 µm, and lengths vary from approximately 2–5 mm (0.08–0.19 in.). *Fines* may be much shorter, and include fragments of fibers produced in refining operations.

In addition to the fibers, there can be fillers such as starch, clay, or chalk. These can affect the strength of bonding between fibers, and also affect the transmission or reflection of light from the sheet. Some fillers, such as clay, also affect the printing properties of the paper.

Filler materials vary widely in composition, with particle sizes generally much smaller than the scales of the fibers. Chalk is commonly employed, and may be used either as precipitated calcium carbonate (PCC), with a particle size well below 1 µm, or as ground calcium carbonate (GCC), with a particle size of about 1–3 µm. Titanium dioxide (TiO2) is used in lesser quantities with micron-scale particles. Various types of clay are also employed in some grades with plates less than 1 µm thick and a few microns in diameter.

In this manual, the term *fiber orientation* is defined as the distribution of alignment directions discernible at the paper surface. The term *fiber orientation angle* refers to the average angle of the distribution. The term *fiber orientation anisotropy* refers to the anisotropy of the distribution.

The two surfaces of a sheet may have different fiber orientation distributions, even if the sheet is formed in a single layer. If the sheet is formed in a single layer, as is typical of most paper grades, the fiber orientation on both surfaces will usually be similar, but not identical. A sheet consisting of several layers that are formed separately, as is typical for many paperboard grades, can have very different fiber orientation on its surfaces.

2.2. The importance of fiber orientation

There are two properties of cellulose fibers which determine most of the consequences of fiber orientation distributions in paper:

1. When dry fibers are wetted, they expand much more in thickness than in length. When moist fibers are dried, they shrink much more in thickness than in length.

2. The tensile strength of a fiber (along its length) is much greater than the strength of bonds holding it to other fibers.

From the first property, note that fiber orientation is going to affect the dimensional stability of paper as it is dried in the paper machine, and when it is wetted by, for example, inking, or dried by, for example, heating or in processing, or when the humidity changes in the environment when, for example, in a box in storage.

From the second property, note that many strength properties of paper and paperboard will be affected by fiber orientation distributions. If the fibers are not aligned in the expected way, the strength of paper or paperboard may be less than expected. Alternatively, the direction of greatest strength may not match the required direction for, for example, stacking boxes.

2.2.1. Shrinkage effects, single layer

The effect of shrinkage on a disk of paper illustrates the two principal characteristics of the fiber orientation distribution. When a slightly moist circular disk of paper is dried from, for example, more than 10% moisture to approximately 2% moisture, it will deform into an approximately elliptical shape. Some possible outcomes are shown in Figure 2-2, with shrinkage exaggerated for clarity.

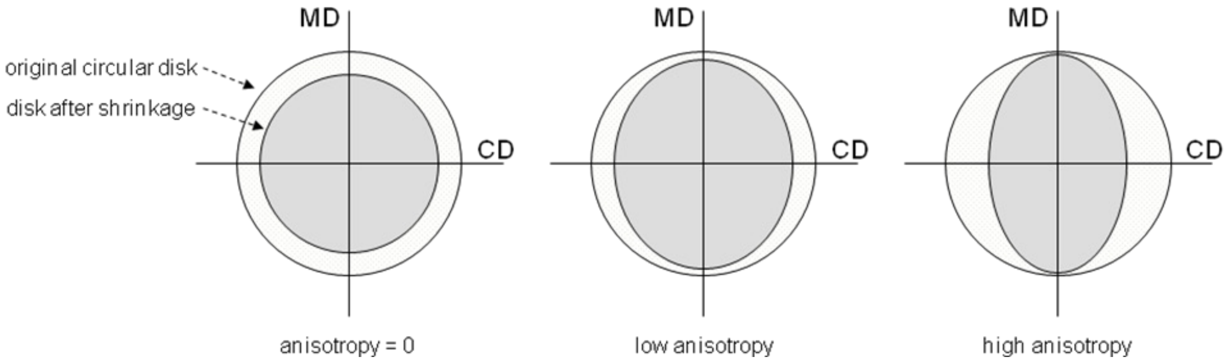


Figure 2-2 Fiber Orientation Anisotropy

Figure 2-2 shows the effect of fiber orientation anisotropy on shrinkage of a circular disk of paper. As the anisotropy increases, the fibers are more aligned in the machine direction, and the shrinkage in the cross-machine direction increases. The example shown of zero anisotropy is not achievable with machine-made paper; however, it can be closely approximated with hand-made paper.

In Figure 2-2, the average orientation angle was in the machine direction (the machine direction is normally chosen as the zero angle). However, the local orientation angle, which is the average angle over some small region of paper, often deviates from the machine direction. This is shown in Figure 2-3 for shrinkage of circular disks of similar anisotropy, with shrinkage exaggerated for clarity.

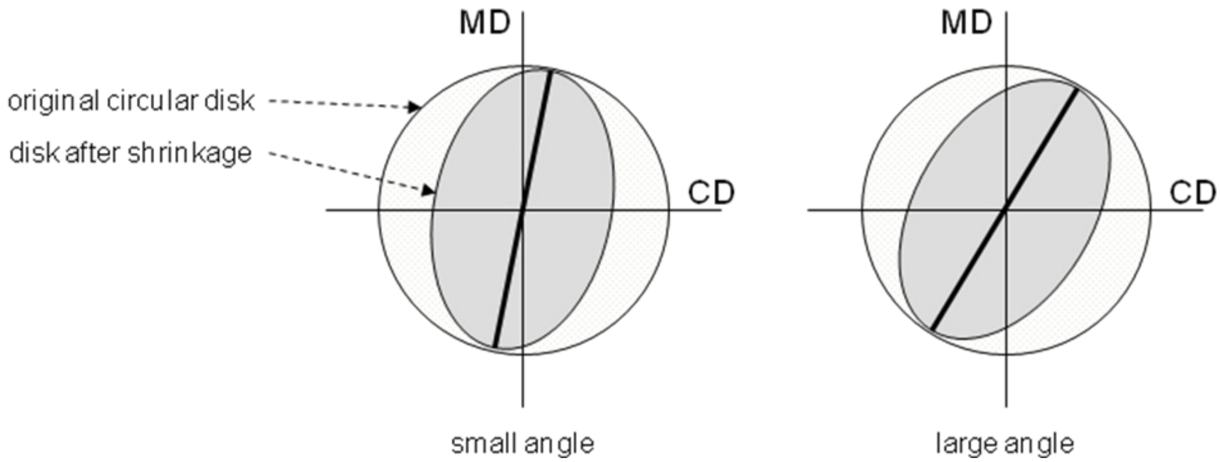


Figure 2-3 Fiber Orientation Angle

Figure 2-3 shows the effect of fiber orientation angle on shrinkage of a circular disk of paper. For a given anisotropy, the axis of the shrunk ellipse deviates from the machine direction in accordance with its average fiber orientation angle.

2.2.2. Shrinkage effects, multi-layer

If a sheet is made by splicing together two or more layers that are formed separately, the layers may not have exactly the same fiber orientation distribution. In particular, the two surface layers may differ in their anisotropies, in their fiber orientation angles, or both.

2.2.2.1. Anisotropy difference: curl

If the surface layers differ in their anisotropies, the disk will usually curl on shrinking. This is caused by the shrinkage being greater in one surface layer than in the other. If the fiber orientation angles are similar, the shrinkage will occur in the same direction on both surfaces.

If the surfaces were unconstrained, they would shrink to different sizes. Because the shrinkage in each layer is constrained by the other layer, the aggregate shrinkage is an intermediate level, and the sheet tends to curl towards the side with the greater shrinkage and anisotropy, as depicted in Figure 2-4. The axis of curl depends on the average fiber orientation angle.

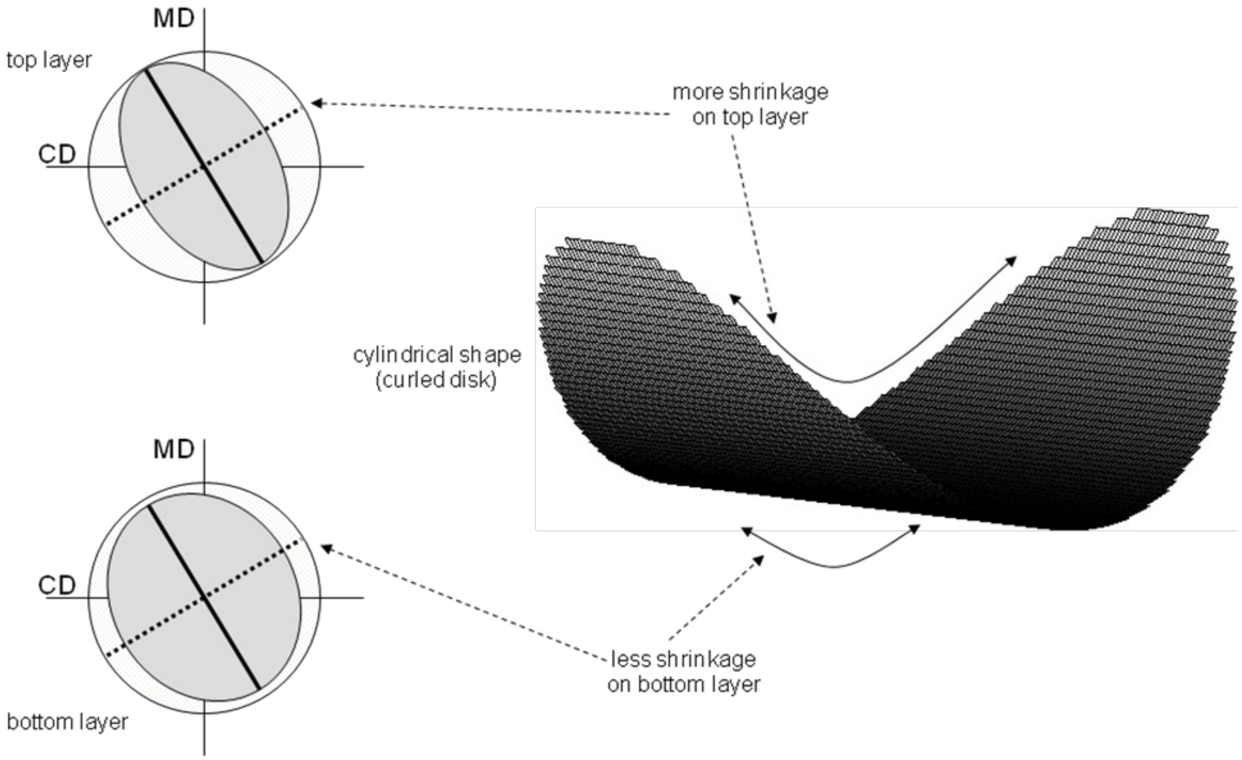


Figure 2-4 Differing Surface Shrinkage (1 of 2)

Figure 2-4 shows the effect of a difference in surface fiber orientation anisotropy on shrinkage of a circular disk of paperboard. Curl can occur for other reasons, related to the construction and operation of the dryers. If the sheet is dried more through one surface than the other, it will tend to curl towards that surface. This curl is also caused by the shrinkage of fibers on drying, and tends to occur if a high rate of drying is used in the later stages of uni-run type drying sections.

2.2.2.2. Angle difference: twist

If the surface layers differ in their average fiber orientation angles, the disk will usually twist into a saddle shape on shrinking. This is because the axes of shrinkage are different in the two surface layers. Figure 2-5 shows how this occurs, where the two layers have similar anisotropy and shrink approximately the same amount. If a disk from a surface layer were allowed to shrink freely, it would deform into an ellipse. Because the surface layers have different average fiber orientation angles, they would shrink along different axes if they were free to do so. However, the two layers are bound together, so the shrinkage of each layer is constrained by the other. The result is a deformation of the combined disk into a saddle shape, where the twist or skewness of the saddle is determined by the difference between the average fiber orientations of the surface layers. The extent of the twist depends on the amount of anisotropy in the layers.

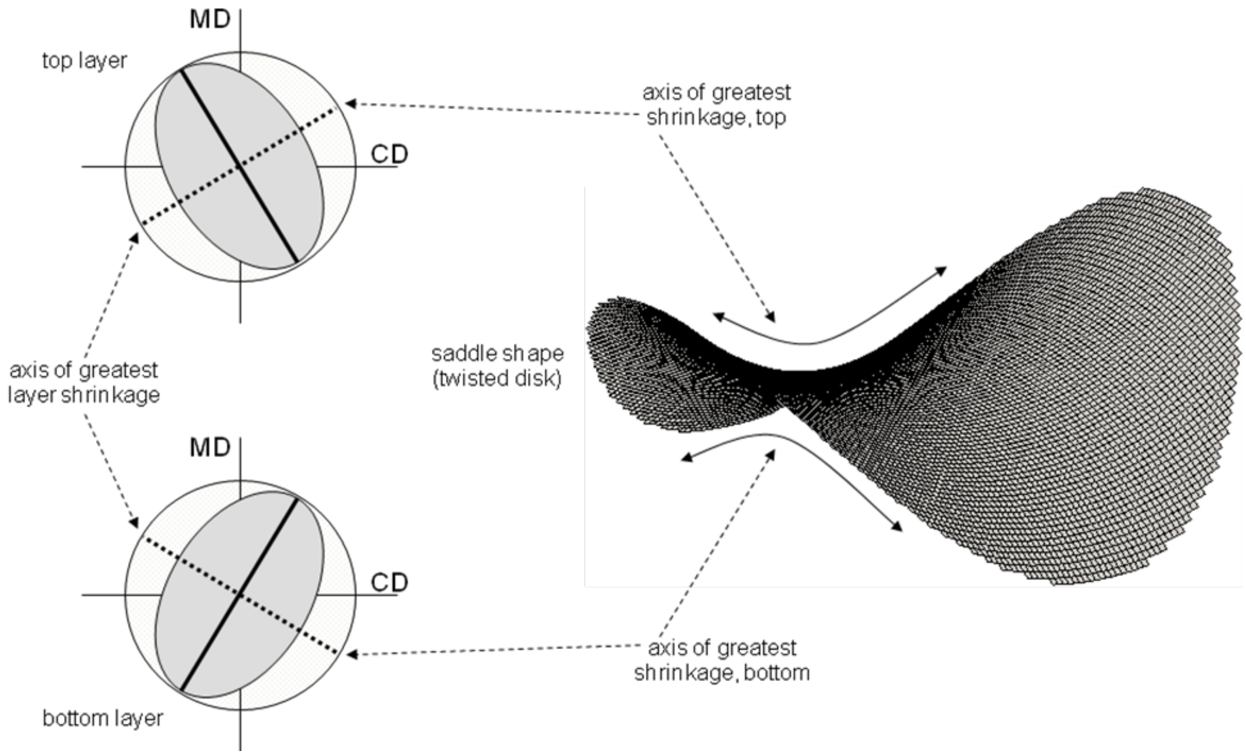


Figure 2-5 Differing Surface Shrinkage (2 of 2)

Figure 2-5 shows the effect of difference in surface fiber orientation angle on shrinkage of a circular disk of paperboard. If the feedstock used for both surface layers is similar, and those layers are formed using similar headboxes and similar forming sections at similar anisotropies, the twist may be predicted as the difference between the surface fiber orientation angle profiles (referred to as a twist proxy). However, if one layer is formed at quite low anisotropy while the other is formed at fairly high anisotropy, the fiber orientation angle profile of the high anisotropy layer can be used as a twist proxy whether the feedstocks are similar or not. Intermediate cases where the feedstocks differ between the surfaces, but both have significant anisotropy levels, must be dealt with on a case-by-case basis, and forming a reliable twist proxy may be a nontrivial task involving considerable time and effort, and requiring numerous process measurements.

2.2.2.3. Composition and layering

In addition to the fiber orientation distribution, different layers may also differ in composition. The fiber types and filler types or quantities need not be the same in all layers, and this will have an effect on the degree of shrinkage, twist, or curl that occurs in particular situations. Also, each layer may have a different mass or thickness. If layers have different fiber orientation distributions and also differ in their basis weights, the layer with the greater basis weight will have a greater effect on the net deformation of the sheet.

For sheets made of three or more layers, the surface layers usually predominate in determining the deformation of the sheet. This is partly because being further from the central plane of the sheet they can exert a greater bending moment around the central plane. It is also partly because the surface layers tend to have better quality fibers with fewer fines, so shrinkage effects are more evident.

If all layers have similar fiber orientation angles and anisotropies, a disk will shrink as if it were made of a single layer. Twist and curl will generally not occur (there can be secondary effects from differences in material composition). However, there may still be problems caused by incorrect anisotropy, or by deviation of the fiber orientation angle from the machine direction.

2.2.3. Strength effects

Fibers have high tensile strength along their length, but the bonds attaching them to other fibers are weaker. The strength of bonds between fibers is affected by many parameters, including the types of fillers and special additives in the stock from which the sheet is formed, and the thermal and mechanical processing of the sheet after the forming section. The strength of fiber-to-fiber connections is never as strong as the intrinsic internal strength of fibers.

There are many different mechanical properties which can be called the *strength* of paper or paperboard, and their relative importance varies among different grades. Tensile strength is important, especially for roll-fed printing grades, burst strength for sack grades, and bending stiffness for some packaging grades.

2.2.3.1. Tensile stiffness

If the fibers are distributed uniformly in all directions, the tensile stiffness will also be equal in all directions in the plane of the sheet. This is achievable only with hand-made sheets of paper which can have anisotropy close to zero.

If the fibers are distributed nonuniformly, the tensile stiffness will be greatest in the direction of the average fiber orientation angle, and weakest at right angles to that direction. The difference in strength in these two directions will increase as the anisotropy increases. Some of the initially formed bonds between fibers are broken through stretching in the paper machine. As the paper is dried, new bonds may subsequently be formed. As a result, the difference between maximum and minimum tensile stiffness can be quite large.

2.2.3.2. Bending stiffness

Bending stiffness of a three-layer paperboard is determined (approximately) by the tensile stiffness of the two surface layers, and the thickness of the filler layer between them. In general, the filler layer has lower strength characteristics than the surface layers, and contributes much less to bending stiffness, even if it contributes most of the mass of the sheet.

If the fibers are distributed uniformly in all directions in both surface layers, the bending stiffness will also be equal in all directions in the plane of the sheet; however, this is not achievable.

If the fibers are distributed nonuniformly, but distributed similarly in both surface layers, the bending stiffness will be greatest in the direction of the average fiber orientation angles, and weakest at right angles to that direction. The difference in bending stiffness in these two directions will increase as the anisotropy increases. If the fibers are distributed differently in the two surface layers, issues of twist and curl can arise, as described in Subsection 2.2.2.

Printing papers have a bending stiffness index (per kilogram) comparable to that of aluminum. Folding boxboard has a bending stiffness index about four times greater than aluminum. Corrugated containerboards typically have bending stiffness indices several hundred times higher than aluminum.

2.3. Fiber orientation in paper and paperboard grades

Paper is typically a single-layer product, with numerous grades commonly used for particular printing purposes.

Paperboard is typically a multi-layer product, commonly used in packaging, which may or may not need to be printable. Some other grades may be made as single or multiple layers.

Fiber orientation and related properties such as twist and curl are important for many grades of paper and paperboard.

Tissue and specialty grades of paper are not discussed in this manual.

2.3.1. Fiber orientation in printing papers

Printing paper grades may be broadly divided into two categories:

1. Grades to be used in sheet-fed devices, such as inkjet or laser printers, photocopiers, some offset printing lines, and so on.

2. Grades to be used in roll-fed devices, such as commercial printing presses for newspapers or magazines.

2.3.1.1. Sheet-fed printing grades

Sheet-fed grades include office grades used in laser printers, inkjet printers, and related devices such as photocopiers and sheet-fed offset printers. The common requirement is for accurate and consistent handling of single sheets with free edges through a process with high positional reproducibility.

In toner-based devices, such as laser printers and copiers, and in wax-transfer devices, such as some color printers, the sheet is typically exposed to high temperatures during printing. This causes deformation through incremental drying. In color devices, there are typically three or four sequential applications of toner or wax, each accompanied by heating. If the deformation is nonuniform, or if the shrinkage has a significant machine direction component, for example, a large fiber orientation angle, the dots applied in the second and subsequent print passes may be shifted relative to the dots of the first print pass. This is referred to as misregister of printed images.

In liquid-ink devices, such as inkjet printers and copiers, the sheet is wetted by an aqueous ink and given a short time to dry. During the wetting and subsequent drying, there is initially an expansion of the fibers, followed by shrinkage which may differ from the expansion. Generally, multiple inks can be applied in a single pass, but the quantity of ink used may vary greatly from sheet to sheet, for example, sparse text versus photographic printing. Because multiple inks are applied simultaneously, misregister generally does not occur (or is not caused by the paper). However, there may be other distortions if a large amount of ink is applied to a region with a large fiber orientation angle. The local expansion will have a significant component in the machine direction, and the next pass of the print head may overlap the expanded previous pass, leading to a band-type defect in the printed image.

In sheet-fed offset printers, the sheet is passed through a series of presses in each of which a roll is used to apply an ink of a single color in a particular pattern. Typically, there are four presses (one each for cyan, magenta, yellow, and black inks), but the number can vary. The ink used in each pass may be nonaqueous or have a lower water content than used in inkjet printers. As a result, the hygroexpansion of the sheet is less than for an inkjet process, but may still be significant, and a brief drying generally takes place between the presses.

A common issue in sheet-fed devices is jamming of the sheets as they are transported between processes in the device. This can occur if there is any tendency to twist or curl, because one edge or corner of the sheet may deviate out of the intended path, and the sheet becomes stuck or torn in passing between mechanisms in the device. This effect is rather less in offset print devices than in inkjet or toner print devices.

Another common problem caused by poor fiber orientation is stack leaning in the output tray. If the sheets deform out of square, or if they deform such that there is curl or twist, the output stack will not remain straight when more sheets are dropped onto it. This causes problems, especially in automated systems for handling printer output such as automated collating and binding devices.

2.3.1.2. Roll-fed printing grades

Roll-fed grades include newsprint, SC, and gravure papers. Their common requirement is to be handled at relatively high speed without paper breaks. For this, they require good tensile strength, and are typically made with medium to high rush or drag. This orients fibers in the machine direction, giving a high anisotropy and high strength in the machine direction. As a result, fiber orientation angles are usually low.

Although dimensional issues are not very severe with low orientation angles, these grades may need to pass through multiple printing stages with repeated prewetting, inking, and drying steps. The prewetting is usually uniform across the sheet, and may occur before each inking step, or just once before the first inking step. Each inking step applies a different color ink (typically, cyan, magenta, yellow, black) in an image pattern. The quantities applied may vary between inks, and the quantity of each ink may also vary across the sheet. If the images of sequentially applied inks are not precisely aligned, the printed result may be unacceptable. This misalignment is called misregister, and it is the principal quality issue for fiber orientation in roll-fed printing grades. It applies only to grades to be used in color or other multi-inking processes.

Poor orientation may also contribute to tension problems (especially on edge rolls), leading to increased incidence of sheetbreaks. A newsprint machine may handle several dozen webs simultaneously, joining the printed outputs synchronously to build a multi-page publication. Obviously, a sheetbreak in just one web can cause a significant interruption to printing production. This affects monochrome printing as well as color printing processes.

2.3.2. Fiber orientation in paperboard grades

Paperboard grades are predominantly used in packaging materials.

2.3.2.1. Folding boxboard

Folding boxboard is made in two or more layers. Typically, at least one surface must be printable and is coated. It is used for making items such as boxes for foodstuffs, cigarette packages, cosmetics, and so on.

Both fiber orientation angle and anisotropy must be within limits in the surface layers. Twist must be avoided, to prevent problems in folding into dimensionally correct boxes. If twist is excessive, the boxes will be skewed during folding, leading to unacceptable box shapes. Alternatively, twist can cause inadequate glue adhesion leading to failure during packing or transport of the boxes.

Some degree of curl is usually desirable in folding boxboard. However, the curl must be on the intended axis and must be outward relative to the final box. This facilitates insertion of items into the box, and withdrawal of items from the box, by consumers, without requiring an oversized box.

2.3.2.2. Liquid packaging

Liquid packaging is a specialized form of folding boxboard, used to directly contain milk, fruit juices, wine, and so on for transport and storage. The box is glued to be watertight, and those intended for long term use generally have linings of metal and/or plastic.

Liquid packaging grades are always coated; otherwise, paper cannot tolerate being wetted, and one surface must typically be printable. There is often a requirement to withstand refrigerated transport and storage. The materials must all be food-safe if the contents are intended for human consumption, as is usually the case.

The fiber orientation requirements of liquid packaging are similar to those for folding boxboard, except that curl is not as beneficial. Twist must be avoided, so that the shape and volume of the carton are correct.

2.3.2.3. Corrugating medium and linerboard

Corrugating medium and linerboard are used to make containerboard, in which two or more sheets of linerboard are separated by sheets of corrugated medium. The layers are glued together. Boxes made from containerboard must be safe to handle, and stackable to a given height, while each carries a given payload, for example, the bottom box does not get crushed, and the stack does not lean or twist, and so on.

Corrugating medium, such as fluting, is generally made in a single layer. Its fundamental requirement is that it should be easily corrugated and have adequate glue adhesion. It must be easily joined by gluing to liner layers, and is required to carry tensile loads between the liner layers. The glue used in making containerboard is usually an aqueous starch-based material, which wets the adhesion point, and dries on setting.

Corrugating medium requires low fiber orientation angles, because its axis of maximum strength should be along the direction joining the two liners. If angles are large, there can be a torsional effect between the liners when the faces of the corrugated box are subjected to a load. This will cause deformation of the box, and reduced load-bearing and stacking performance.

Corrugating medium also requires uniformity in anisotropy and bending stiffness. This ensures reliable corrugation, because the corrugation axis is normally perpendicular to the machine direction, and variation in bending stiffness would give rise to variation in the geometry of the resulting fluting. Irregular fluting shape may cause regions where the corrugating is not glued adequately to the liner, leading to greatly reduced strength and dimensional integrity of boxes made with containerboard.

Linerboard may be made as a single layer or as multiple layers. It must retain its planar shape during conversion to containerboard, and must provide the necessary strength and dimensional stability thereafter.

Linerboard requires low fiber orientation angles. Otherwise, the axis of maximum strength will not correspond to the manufacture axis of a box, leading to twist or lean of boxes when stacked. It also requires low twist and curl, so that it does not deform out of plane during the joining to corrugating medium, leading to greatly reduced strength of the containerboard box. Twist and curl must also be avoided to reduce the risk of glue detachment later during use of the box, as the environmental humidity changes.

2.3.2.4. Sack

Sack is used in making paper bags, such as for groceries and other small items, or for bulk materials such as cement, fertilizer, or animal feed. In some cases, the bag uses multiple layers (possibly including non-paper layers) joined together only at the seam and which may be stitched or glued. Some grades need to be printable on one side.

Ideally, sack would be nondirectional in its strength properties. So, it is usually made with fairly low anisotropy. The fiber orientation angle is relatively unimportant, provided the anisotropy is low. Sack is usually made as a single-ply sheet, so twist and curl are relatively uncommon, or not problematic.

An expansion press is often installed in the drying section of sack machines. This device compresses and expands the sheet in the machine direction as it passes between a compressible roll and a hard roll. The operation breaks fiber-to-fiber bonds which have been strained by shrinkage and stretching during early drying stages. It allows unstrained bonds to reform in subsequent drying. As a result, the tensile energy absorption, or burst strength, of the sheet is increased. However, the relationship between fiber orientation structure and strength is changed significantly. Further discussion of this effect is beyond the scope of this manual, and is largely irrelevant, because sack is generally made with low anisotropies and its fiber orientation angles are unimportant.

2.4. Tensile stiffness orientation

Measurement of fiber orientation is uncommon in paper mills. Traditionally, there have been no reliable measurements for this property, despite its importance in many grades. However, most paper mill laboratories have an instrument for measuring tensile stiffness orientation (TSO), which is related to fiber orientation. Makers of multi-layer paperboard rarely measure TSO.

2.4.1. Measurement of tensile stiffness orientation and index

The principle for measuring TSO relies on the paper acting as an elastic membrane, in which the tensile stiffness determines the speed of propagation of mechanical waves. Rather than measuring a calibrated stiffness directly, a tensile stiffness index (TSI) is measured. A circular disk of paper is clamped around its edges, and an ultrasound pulse is generated at its center. Detectors around the edge of the disk record the time taken for the pulse to reach the edge in different directions. An alternative construction sends pulses across the whole width of the disk, with pulses sequentially generated at multiple points around the edge of the disk. Faster propagation corresponds to a higher TSI value.

The TSO is usually described using an average angle, at which the TSI is greatest, and a parameter for the anisotropy. Typically, the ratio of maximum to minimum TSI is used, or the ratio of TSI in the machine direction to TSI in the cross direction. For measurements at a single location, some TSO instruments will also display a polar histogram of the TSI in different directions.

Paper mill laboratories typically have an automated system which analyzes a strip of paper for several properties, often including TSO. The device steps the paper strip through each measurement instrument in sequence, and produces a report with profiles of each measured property.

2.4.2. TSO and fiber orientation

The TSO angle is strongly related to the fiber orientation angle. This is because the tensile strength along a fiber is greater than the bonding strength across fibers. For single layers of uncoated paper which have low or moderate amounts of filler, the TSO angle and fiber orientation angle are normally in good agreement (profile amplitudes may differ between TSO angle and fiber orientation angle, but the profile shapes will be quite similar). For single layers with higher filler amounts, the agreement is not as good.

For most printing grades, a surface fiber orientation angle measurement made with a FotoFiber before coating will usually be in good agreement with a TSO angle measurement made in the laboratory.

For paperboard sheets consisting of several layers, the situation is more complicated. If the layers can be reliably separated, analyzing each layer separately will usually indicate good agreement between the TSO angle and the fiber orientation angle. However, production of multi-layer sheets usually employs binding agents such as starch to prevent delamination of the sheet. These additives are usually included in the furnish to one or more layers, so that the layers bind together strongly in the presses and early drying sections. It can be rather difficult to cleanly separate the layers–each will tend to have holes or sections with only partial mass, and sections with clumps of an adjacent layer attached. The TSO measurements of one or more layers will consequently be unreliable or impossible to make. If the starch is added as a spray in the forming section, however, it can be temporarily shut off to facilitate separation of layers taken from a sample.

The TSO of a multi-layer sheet is generally uninformative for the critical properties of twist and curl. These require measurement of the surface layers, rather than of the whole sheet. Consequently, laboratories must attempt the time-consuming manual separation of layers before making a TSO measurement on each single layer. Success in separating layers is far from certain, and nearly impossible for grades such as liquid packaging. It may be necessary to withdraw the layer binding agents from the stock near the end of a reel, if a laboratory measurement is planned, in order to facilitate better separation of layers in the laboratory. Obviously, such a change to the furnish will also have consequences for product quality.

Direct measurement of the surface fiber orientation gives a reliable estimate of the properties of the surface layer (or of both surface layers if a two-sided FotoFiber is used). This has been found to correlate well with TSO angle measurements of single-layer sheets, and with measurements of TSO angle of surface layers of multi-layer sheets, at least in those cases where the surface layers could be separated from the sheet.

2.4.3. TSI ratio and anisotropy

The TSI ratio is related to the fiber orientation anisotropy. However, the relationship is less direct than for TSO and fiber orientation angle.

The maximum to minimum ratio for TSI corresponds to the fiber orientation anisotropy, or the maximum to minimum ratio for the fiber orientation distribution. An increase in the TSI ratio will almost always be accompanied by an increase in the fiber orientation anisotropy (and the maximum to minimum orientation ratio). However, the numerical values are not strictly comparable, and neither are the relative amounts of change in either of the values.

A similar correspondence exists for the machine direction to cross direction ratios of TSI and of orientation distribution.

2.5. Fiber orientation in the papermaking process

The fiber orientation of paper is predominantly established in the forming section, where the jet from the headbox impinges on the wire.

2.5.1. Headbox jet and forming section

The paper machine headbox produces a thin, smooth jet of a dilute fiber suspension. This jet must have the correct speed and land on the moving wire at the correct angle and in the correct place.

The jet speed is often characterized and controlled either as jet-to-wire ratio, meaning, as a ratio to the wire speed, or as rush-drag, meaning, as an offset to the wire speed. If the jet speed exceeds the wire speed, its offset is positive and it is said to be in rush, or rushing. In this case, the jet-to-wire ratio is greater than unity. If the jet speed is less than the wire speed, its offset is negative and it is said to be in drag, or dragging. In this case, the jet-to-wire ratio is less than unity.

2.5.1.1. Jet speed accuracy

The nominal jet speed value must be treated with caution, and even some suspicion. Often, a simplified calculation is performed based on the pressure difference between the headbox nozzle pressure P_{nozzle} and the machine hall pressure P_{hall}. The simplest calculation of jet speed J is:

$$J = C_{jet}\sqrt{P_{nozzle} - P_{hall} + C_{nozzle}}$$

Equation 2-1

where C_{jet} is a composite discharge coefficient for the headbox and C_{nozzle} is a compensation factor for the position of the pressure gauge in the nozzle. In practice, headbox vendors supply modified versions of this relation, in which C_{jet} and/or C_{nozzle} may be changed based on the slice opening and temperature.

A similar relation can be used, employing the pressure drop across the turbulence generator, to compute the headbox flow per unit width of the turbulence generator, and dividing by the slice opening S to obtain the average jet speed.

$$J = \frac{C_{turbo}\sqrt{P_{turbo} - P_{nozzle}}}{S}$$

Equation 2-2

where C_{turbo} is a composite discharge coefficient for the turbulence generator and P_{turbo} is the pressure at the inlet of the turbulence generator tube bank. The factor C_{turbo} is less variable than C_{jet}, so the total headbox flow can be reliably estimated with such a relation, but the calculation of jet speed becomes reliant on accurate knowledge of the average slice opening S, which usually is affected by thermal and other disturbances.

In reality, the jet consists of a suspension of fibers and fines whose consistency and composition can change, and its temperature typically exceeds 40 °C (104 °F). The apparent viscosity of the jet thus varies somewhat due to consistency, composition (fiber and filler types), and temperature. The jet is also affected by the nozzle geometry and presence of vanes, as well as by the projection of the slice apron and the total slice opening. In combination, these can significantly change the distribution of velocities in the jet and influence the landing position and slope of the jet impinging on the wire.

Some headbox vendors supply sophisticated relations for estimating jet speed, often specific to particular headbox designs. Such relations may require numerous measurements and have many terms and calibration constants for compensating effects of temperature and variations in operating conditions. Within their calibration limits, these relations are better than the simple calculations shown above but will still exhibit varying errors depending on operating conditions and accuracy of inputs. Outside those calibration limits, they are less reliable, and may even perform worse than the simple relations in some circumstances.

Computed jet speeds are usually not consistently accurate or consistently erroneous. At some machine operating points, the computed speed may be quite accurate, and at others it may be in error by several meters per minute. Consequently, the displayed values for rush-drag or jet-to-wire ratio should not be unconditionally accepted as true.

Jet speed changes of as little as 1 meter per minute (0.0167 m/s) can have significant effects on fiber orientation in some rush-drag states. The jet speed displayed in the control system, even if computed with some sophistication, might not have a high degree of accuracy. Computed jet speeds should be taken as rough approximations only in any attempt to understand or manipulate the fiber orientation of paper.

2.5.1.2. Jet angle and fiber orientation angle

The slice nozzle surfaces are finely machined, but always have some deviations from perfect flatness. Similarly, the turbulence generator has small imperfections. Together, this means that even with a perfectly uniform slice, there will be a nonuniform flow through the nozzle, and while the flow is predominantly along the nozzle, there will be various quite small flow components across the nozzle.

The slice is not perfectly uniform across the machine. In addition to small geometric imperfections in the slice lip and slice apron, the slice lip is usually deformable, and is equipped with screws for adjusting its shape across the machine.

One consequence of changing the slice lip shape is that the jet becomes thicker where the slice opening is widened, and thinner where it is narrowed, making the flow from the slice significantly nonuniform. However, because the flow through the turbulence generator is very nearly uniform across the headbox, this causes cross-flows to be established in the headbox nozzle, which redistribute the flow to the nonuniform slice opening. The cross-flows persist in the jet and their effect on fiber orientation is depicted in Figure 2-6.

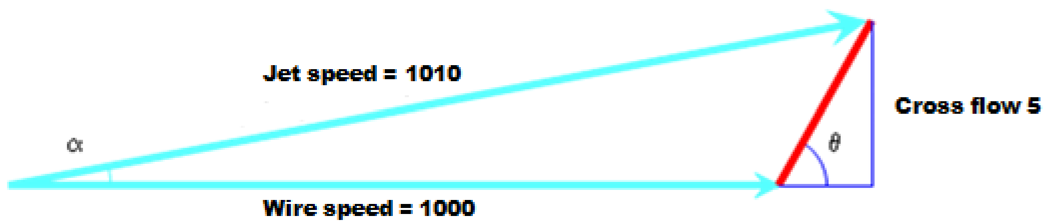


Figure 2-6 Effect of Small Cross Flow on Fiber Orientation Angle

In Figure 2-6:

- jet angle: $\alpha = 0.283$ degrees
- orientation angle: $\theta = 26.6$ degrees

Cross flows in the jet which are quite small in comparison to the total jet speed can have a large effect on the fiber orientation. This is because the jet speed and wire speed are not greatly different, and a cross flow may be comparable to the difference between jet speed and wire speed. The general relation between cross flows in the jet and the fiber orientation angle θ is:

$$\theta = \tan^{-1}\left(\frac{J_{CD}}{J_{MD} - W}\right)$$

Equation 2-3

where J_{CD} and J_{MD} are respectively the cross-machine direction and machine direction components of the jet velocity, and W is the wire speed.

In Figure 2-6, there is rush of about 10 m/min (32.8 ft/min), and a cross flow of 5 m/min (16.4 ft/min) gives rise to a fiber angle of 26.6 degrees. In fact, a cross flow of just 1 m/min (3.28 ft/min) in the jet would result in a jet angle of only 0.06 degrees, but a fiber angle of approximately 5.7 degrees, which is greater than the allowed quality limit in most paper or paperboard grades. Note that if there were drag instead of rush, the jet angles would be mostly unchanged, but the fiber angles would be reversed, -26.2 degrees for 5 m/min (16.4 ft/min) cross flow, and -5.7 degrees for 1 m/min (3.28 ft/min) cross flow.

2.5.1.3. Jet turbulence and fiber orientation anisotropy

Figure 2-6 and Equation 2-3 describe the situation for a single element of the jet with uniform jet velocity, or for an average over some region in time. In practice, there are fluctuations in the jet velocity over small scales in position and time. These turbulent fluctuations can be visualized as a distribution of velocity vectors added to the average jet velocity, resulting in a distribution of fiber angles around the average. This is schematically shown in Figure 2-7, where the thin red lines indicate orientations of fibers laid down by individual flow elements, and the thin blue arrows indicate local velocity vectors.

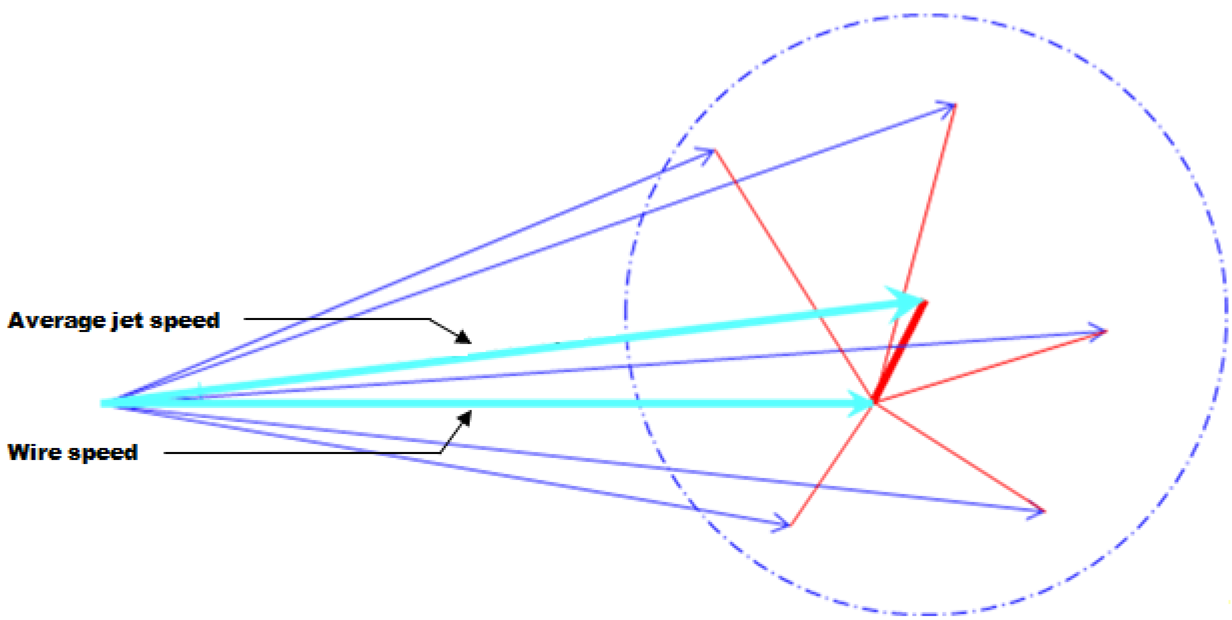


Figure 2-7 Effect of Turbulence in Jet on Distribution of Fiber Orientation Angles

In Figure 2–7:

- high turbulence = low anisotropy
- low turbulence = high anisotropy

The wire speed and the average jet speed are shown as thick cyan lines in Figure 2-7, and the average orientation is the thick red line. Clearly, the greater the amplitude of turbulent fluctuations (dashed blue circle) relative to the difference between the wire speed and the average jet speed, the lower the anisotropy will be. The average orientation will not be affected by turbulence, which only affects the anisotropy.

2.5.1.4. Slice lip and fiber orientation angle

Ideally, the jet is straight, across the whole width of the headbox. In practice, this cannot be achieved. Even with a perfectly straight slice lip, there are local variations in the jet speed and angle due to:

- intrinsic nonuniformity in flow through the turbulence generator
- imperfections in construction of the slice channel
- thermal deformation of the slice channel and slice support beam
- deformation of slice channel due to pressurization of an insufficiently rigid headbox

There are also local variations in single-pass retention across the wire for many reasons, so that even if the jet were uniform, there would be a non-flat weight profile.

In practice, the slice lip shape must be manipulated to counteract the nonuniformities in flow, and possibly to compensate for the nonuniformity in retention. In a dilution headbox, the dilution system can be used to regulate the basis weight; however, it is the slice lip which can affect the flow field in the jet, and the fiber orientation profile.

If one slice screw is moved, it causes a smooth change to the slice lip shape, and corresponding changes in the jet thickness and dry weight profiles. It also induces local cross flows to start in the headbox nozzle, and these persist into the jet. The responses in dry weight and jet angle to a change in one slice lip screw are shown in Figure 2-8.

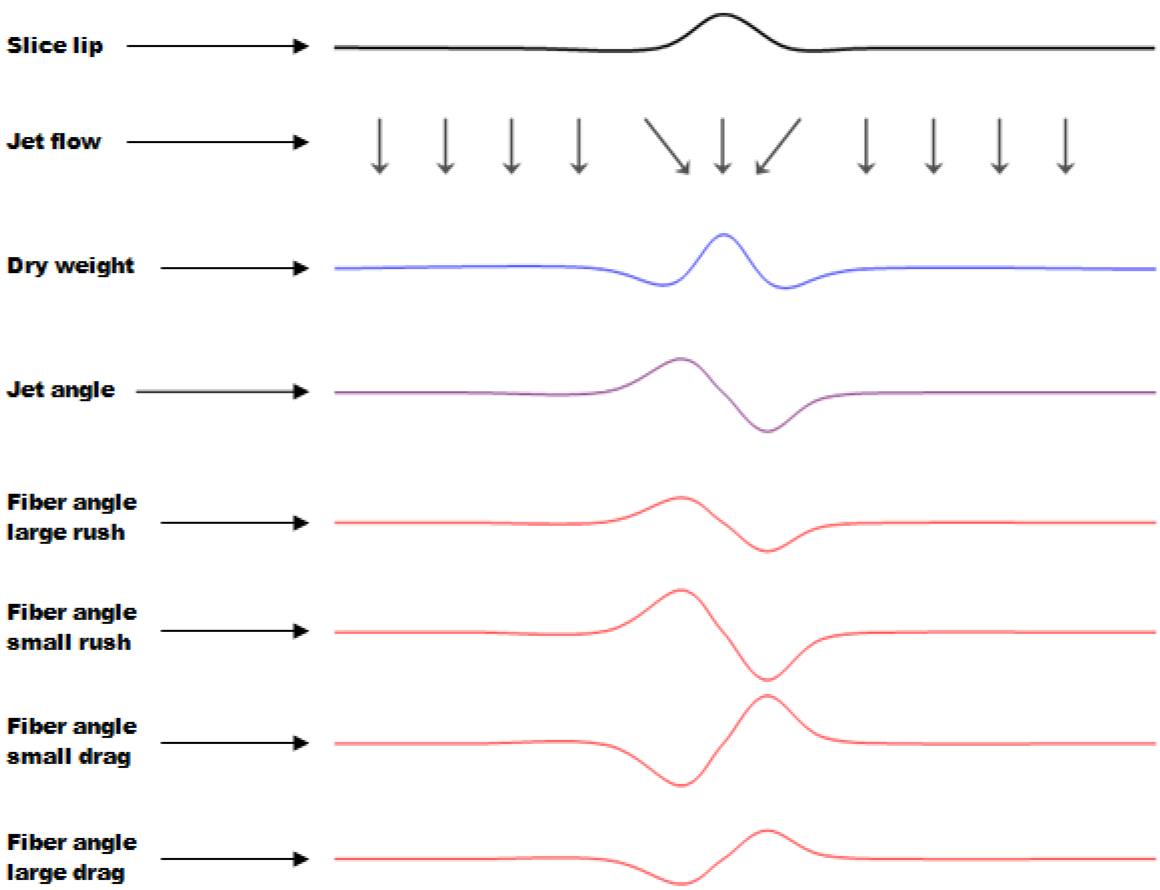


Figure 2-8 Effect of Slice Lip on Dry Weight and Jet Angle

The change in jet angle will cause a change in fiber orientation angle. This will be a multiple of the jet angle change, where the magnitude and sign of the multiplier depends on the rush-drag in the forming section. The multiplier will also depend on the turbulence in the jet, for example, from vanes in the slice nozzle, and in the forming zone, for example, from impingement angle.

In general, it behaves approximately as depicted in Figure 2-9. Note that the figure depicts a normalized ratio as a fraction of the maximum ratio.

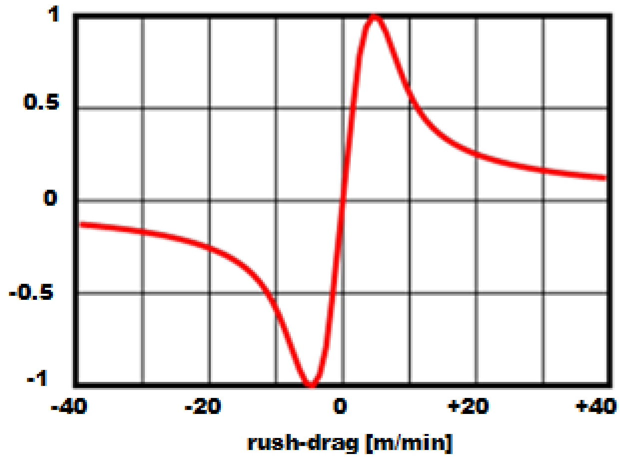


Figure 2-9 Normalized Ratio of Fiber Orientation Angle Response to Jet Angle Response

In practice ratios from jet angle to fiber orientation angle are quite large, with maximum values exceeding 100. If the jet turbulence is low, the curve will have much sharper peaks, located closer to the zero point. If the jet turbulence is high, the curve will be smoother, with extrema further from the zero point. The maximum ratio will be large when turbulence is low, and small when turbulence is high.

Because the jet angle is generally not known, it is more useful to calibrate the process as either one of the following:

1. A simple gain for the fiber orientation from the slice lip.

2. A ratio of the fiber orientation gain to the dry weight gain for slice movements.

In either case, the variation of gain with rush-drag will follow the same normalized curve such as is shown in Figure 2-9.

If the fiber orientation response amplitude is expressed as being relative to the slice lip movement amplitude, then the process gain at a given rush-drag will depend on the wavelength of the pattern of movements made in the slice lip. However, this variation in gain with wavelength will be very similar to the variation in the dry weight response gain with wavelength. Consequently, if the fiber orientation response amplitude is expressed as being relative to the dry weight response amplitude, the process gain at a given rush-drag state will be approximately constant across wavelengths.

If the entire slice is moved in broad patterns, the response is also broad. This is due to the nonlinear aspect of the hydrodynamics in the headbox slice channel and jet. In particular, if the slice is slightly tilted, so that it is more open on one side than the other, the entire jet will have a lateral velocity component towards the more open side. This can cause the average fiber orientation to deviate from zero across the whole sheet.

The anisotropy of the sheet is largely unaffected by changes to the slice lip. However, very large changes to the slice lip shape can produce significant local effects in anisotropy.

2.5.1.5. Headbox deformation and fiber orientation angle

There are two common issues which affect the headbox nozzle shape:

- thermal deformation due to temperature changes
- mechanical deformation due to pressure changes

The stock pumped through the headbox is typically at a temperature of at least 50 °C (122 °F). This high temperature is required to keep viscosity and surface tension low, which assists in dispersing fibers and in draining on the wire. However, the associated heating of the headbox can deform it from its manufactured shape. Typically, the nozzle will expand on heating, so that the slice support beam will be deformed. When heated, a slice opening which is uniform at low temperatures will become larger in the middle of the headbox than at the edges.

Almost all headboxes are equipped with a thermal compensation system, which attempts to keep the headbox nozzle geometry constant as the headbox temperature changes. Generally, this is achieved by pumping water at a controllable temperature through a sleeve around the headbox nozzle. By adjusting the temperature of the circulated water, the nozzle shape can be kept close to its undeformed shape. In some cases, only the temperature of the water is measured. In others, there may be a measurement of the nominal displacement of the slice beam at one or more points across the headbox.

Typically, improper thermal compensation of the headbox leads to a characteristic S shape in fiber orientation, as shown in Figure 2-10. Positive bending is often seen after a machine startup, especially if the slice was leveled during the shutdown, when the headbox is at a lower temperature and unpressurized.

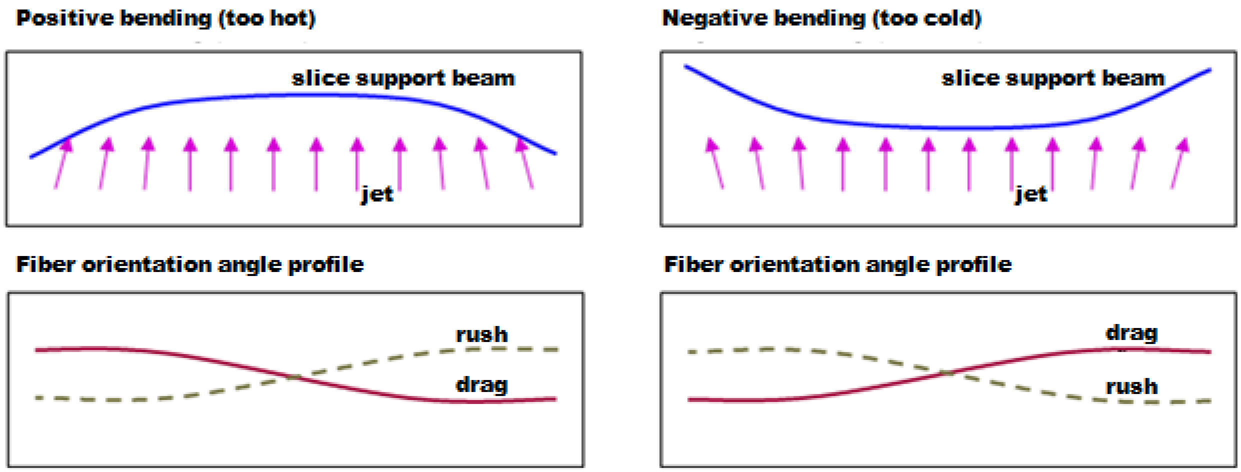


Figure 2-10 Effect of Improper Thermal Compensation on Fiber Orientation Angle Profile

The effect is opposite in rush and drag, and the amplitude of the effect will vary just as for other slice lip changes in Figure 2-9.

Similarly, when the headbox is pressurized to produce a jet of the required speed, the nozzle is under a uniform load that can expand the opening more near the center than near the edges. After a startup, this has a similar effect to the positive bending case shown in Figure 2-10.

During operation, the headbox pressure may be adjusted upwards or downwards, to accommodate changes in the jet speed, for example, for a grade change. Assuming the fiber orientation angle profile is flat before the pressure change, a pressure reduction may lead to a negative bending, while a pressure increase may lead to positive bending. These cases are similar to those shown in Figure 2-10 for thermal bending. The rigidity of the headbox is a major factor, and this effect may be quite small for some headboxes.

2.5.1.6. Edge flows and fiber orientation angle

Some headboxes are equipped with controllable edge flows. These provide the flow into the headbox nozzle at the edge regions of the headbox, so that the flow into the nozzle at the edges is controllable independently of the flow into the main part of the nozzle. Because the flow through the slice is essentially the same across the whole machine (because of equal pressure across the nozzle), any excess or deficit in flow supplied to the edge regions will result in a compensating cross-flow, which will persist into the jet.

When a change is made to the edge flows, the response will be approximately as shown in Figure 2-11. Note that the response amplitude will depend strongly on the rush-drag state of the forming section, just as for slice lip changes in Figure 2-9. However, the shape and extent of the response at a particular jet speed are influenced by the slice opening, which determines the acceleration of the headbox flow in the nozzle. In general, at small slice openings, the response extends further into the sheet than at large slice openings.

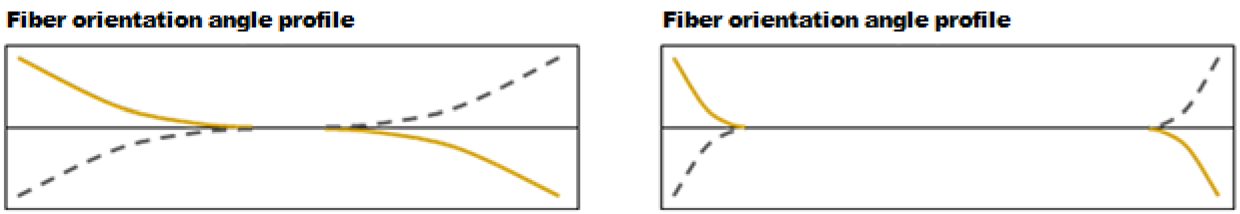


Figure 2-11 Fiber Orientation Angle Responses to Increase in Edge Flows

Figure 2-11 shows the fiber orientation angle responses to increase in edge flows. Left: small slice opening; right: large slice opening. The solid lines and the dashed lines are for rush and drag, respectively.

2.5.1.7. Rush-drag, and fiber orientation anisotropy

When the jet speed exceeds the wire speed, it is said to be rushing the wire (or in rush), and has a jet-to-wire ratio greater than unity. When the jet speed is less than the wire speed, it is said to be dragging the wire (or in drag), and has a jet-to-wire ratio less than unity.

When the jet speed and wire speed are approximately the same, the anisotropy of the sheet will be low. Any cross-flows in the jet will cause relatively large orientation angles. When the jet speed differs from the wire speed by a large amount, the anisotropy will be high, whether the jet is in rush or in drag. Cross flows in the jet will cause relatively small orientation angles. An example of the relation between rush or drag and anisotropy is shown schematically in Figure 2-12. Note that this relation depends strongly on the machine and can be quite different for different forming sections or for different operation of the same forming section.

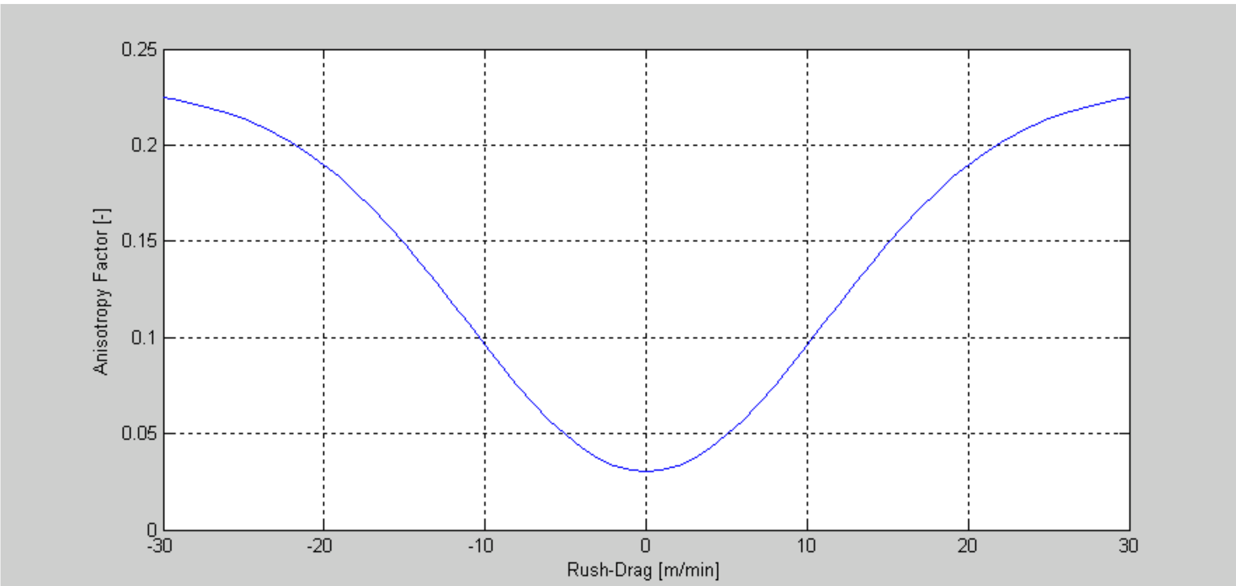


Figure 2-12 Example of Variation of Anisotropy with Rush or Drag

The variation in anisotropy factor is shown in Figure 2-12. The curve will be very similar for the TSI MD/CD ratio. Indeed, some paper mills might already have numerous such curves, obtained using their laboratory TSO measurement device for different operating conditions or grades.

There are many other influences on the anisotropy in addition to rush or drag. For example, if the turbulence in the jet is high, the anisotropy will be lowered. Jet turbulence is determined in part by the design of the tips of the vanes in the headbox nozzle, and to a lesser extent from the turbulence generator, the degree of acceleration in the nozzle (affected by total slice opening) and aerodynamic damping of the jet. The anisotropy of the sheet formed on the wire is further influenced by the impingement angle of the jet, leading to turbulence in the forming region. The jet impingement angle can be manipulated by changing the projection of the slice apron beyond the slice lip, and (especially if the slice lip is inclined) by the total slice opening.

Note that in machine-made paper, the anisotropy will not reach zero, even if the jet speed is the same as the wire speed. This is because the jet always has some variation in its local speed at different levels through its thickness. The core of the jet has a higher speed than its surfaces, partly because of shear forces as the jet detaches from the slice apron and the slice lip. The surfaces are also subject to aerodynamic drag which reduces the acceleration they experience by shear forces from the core of the jet. This is shown in simplified form in Figure 2-13, leaving out the effect of vanes in the headbox nozzle.

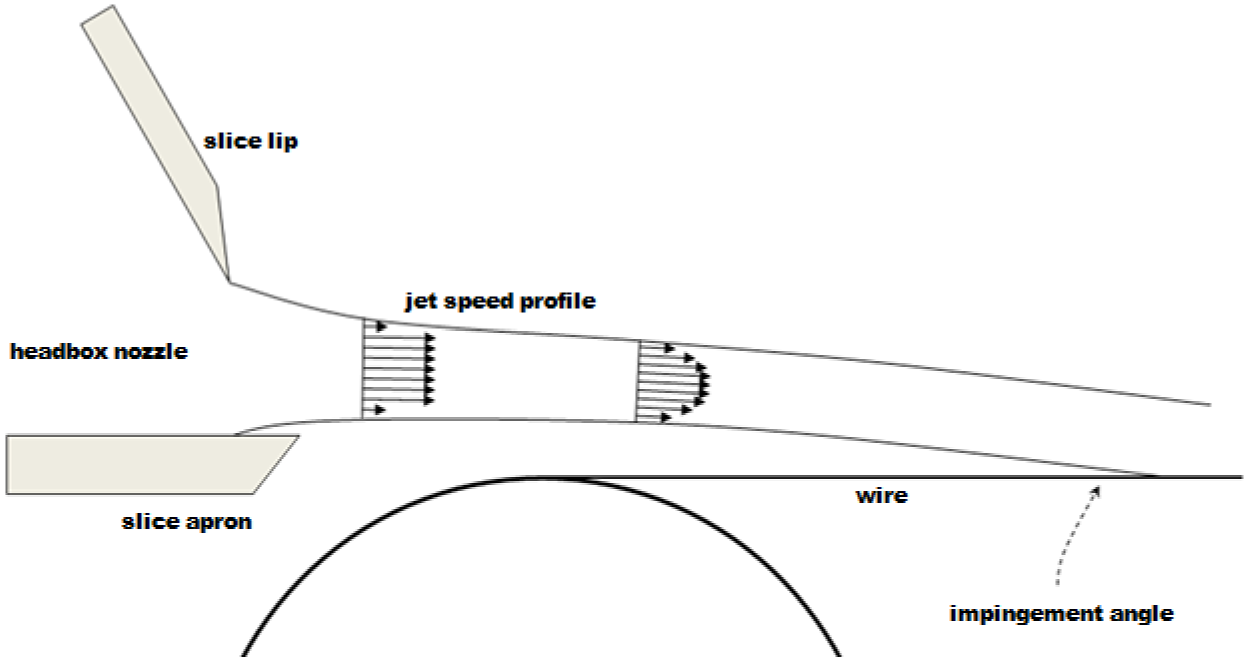


Figure 2-13 Evolution of Jet Speed Distribution Through Jet Thickness

Even with an average local jet speed quite close to the wire speed, there will be some elements of the jet in rush, while others are in drag. Typically, when the jet-to-wire ratio is very close to unity, the core of the jet is in rush while the surfaces are in drag. This distribution of speeds will depend on the turbulence in the jet (due in part to vane tips in the headbox nozzle). When the local jet speed differs more from the wire speed, it will be almost all in rush or almost all in drag, but to varying extents.

2.5.2. Pressing, drying, and finishing

The fiber mat laid down during forming is not greatly altered in the dry end. However, there are some deformations due to the drawing and nonuniform shrinking of the viscoeleastic sheet.

2.5.2.1. Pressing and drying

The sheet is drawn (stretched) to maintain tension for conveying it from cylinder to cylinder across open gaps. When the moisture content is high, the sheet deforms viscously under tension, and it is stretched permanently by each draw, especially in the large draw from the wet press to the drying section.

As the moisture content is reduced in drying, the elastic strength of the sheet increases, and tension can be maintained without further plastic deformation. The mechanical behavior of the sheet changes from being predominantly viscous, leaving the presses, to being predominantly elastic at the reeler.

As the sheet is dried below approximately 40% moisture content, it begins to shrink due to the hygroexpansivity of cellulose fibers. Because it is being drawn in the machine direction, shrinkage effects are observed in the cross-machine direction. Most of the shrinkage occurs in open gaps where the sheet is not constrained by contact with drying fabrics. The shrinkage is always greater near the edges of the sheet than near the center, because the sheet is less constrained positionally near the edges in open gaps.

The net effect of the shrinkage and drawing on sheet structure is shown in Figure 2-14. The fiber mat deforms in such a way that a square (or circular) region in the sheet at the wet end becomes slightly narrower and elongated at the dry end, becoming a rectangle (or ellipse). The effect is to slightly increase the orientation anisotropy and to slightly reduce the orientation angles. This effect is always greater near the edges of the sheet than near the center.

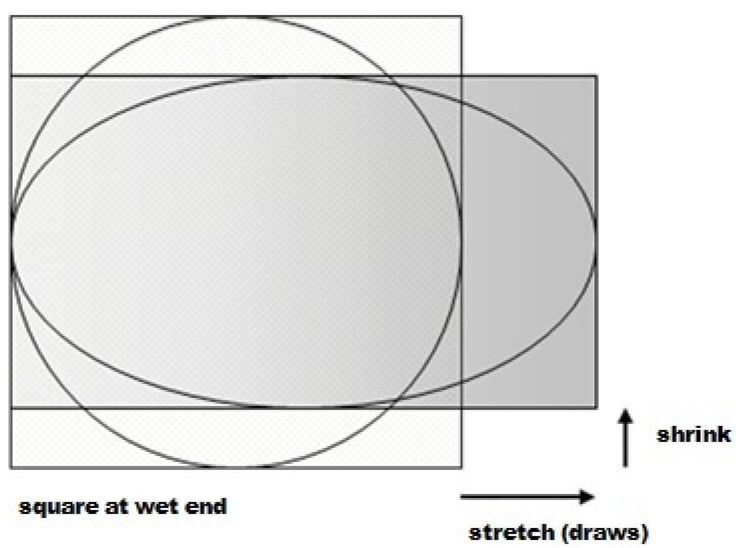


Figure 2-14 Deformation by Drawing and Shrinkage

The plastic deformation, especially the large draw occurring between the presses and the dryers, has an effect on the strength properties of the paper. By deforming the sheet so that fibers move relative to one another, many inter-fiber bonds are broken. New bonds are formed during the drying process, but the strength axes can differ only slightly from the orientation axes because of this deformation.

2.5.2.2. Coating

Coating does not affect the orientation of fibers within the sheet. However, it can have a great effect on the visibility of fibers at the surface of the sheet. It also adds material which can contribute to the strength of the sheet, but usually changing strength equally in all directions.

Film coating applies a light aqueous suspension of starch and other chemicals to the surface of the sheet. Typically, it does not completely obscure the surface of the base sheet, but tends to fill many of the pits or gaps between surface fibers.

Because the surface fibers are partly obscured by film coating, it is recommended that surface fiber orientation be measured before the size press for best measurement accuracy. However, it is possible to obtain satisfactory FotoFiber measurements after the size press, provided the amount of sizing applied to the paper is not excessively large.

Blade coating adds a very smooth layer of minerals and/or polymers to the paper. Often, the coating mix includes clay and latex. In addition to filling pits and gaps in the surface, it tends to completely cover all of the surface with a significant thickness of coating, so that the base sheet surface is completely hidden.

Because the surface is usually completely obscured by blade coating, it is necessary to measure the surface fiber orientation before any blade coating operations.

2.5.2.3. Calendering

Calendering does not affect the orientation of fibers within the sheet. However, it can have a great effect on the visibility of fibers at the surface of the sheet. It also modifies the strength distribution of the sheet.

Soft calendering compresses paper significantly. It also tends to flatten the surface features of the sheet, and introduces small scale glossiness. The effects are similar, but less pronounced, with precalenders, which are often employed before a film coater.

Because soft calendering reduces visibility of fibers at the surface, it is strongly recommended that surface fiber orientation be measured before soft calendering. However, it is possible to obtain satisfactory FotoFiber measurements after a mild pre-calendering operation.

In addition to greatly compressing the sheet, supercalendering or gloss calendering significantly changes the sheet surface, employing high temperatures and pressures, often accompanied by remoisturizing at the surface beforehand. The effect is to flatten and chemically alter the surface fibers and other surface material. If the sheet has been blade-coated before calendering, the fibers are already invisible. On lightly film-coated, or uncoated, sheets (such as SC paper), the visibility of surface fibers is greatly reduced, and glossiness of the surface further impedes measurement.

Because the surface is altered, and visibility of fibers is greatly diminished, it is necessary to measure surface fiber orientation before any gloss calendering or supercalendering operations.

2.6. Solving fiber orientation problems

The FotoFiber measurements, together with a basic understanding of the processes affecting fiber orientation and the quality requirements of the grade being produced, can be used to help a mill solve problems related to fiber orientation. A full treatment of this topic is beyond the scope of this manual, but some useful approaches to process optimization are outlined. It is important to remember that changes to the fiber orientation angle profile will also affect the basis weight and caliper profiles, so the objective of the mill must always be to achieve an acceptable balance between paper properties.

2.6.1. Offset in FO angle

In some cases, the FO angle profile average can deviate from zero. A small deviation is generally not a problem, but if the profile average is a few degrees from zero, it can have a considerable impact on quality. This may occur in combination with other shapes in the fiber orientation profile, which can be tackled separately.

The fundamental reason for a nonzero average angle is that the jet has a lateral velocity component across the whole sheet. There are several potential process causes for this situation. Other local variations in jet angle may also occur and lead to a non-flat FO angle profile, but the profile average is linked to the average jet angle across the machine.

2.6.1.1. Header balance

On older headboxes, an unbalanced main header can lead to nonuniform flow through the turbulence generator. This results in a cross-flow in the slice nozzle across the entire headbox. The result is that the average FO angle may deviate from the machine direction by a few degrees.

Balancing the main header will solve this problem (if it is actually caused by an unbalanced header). Usually, there is a manual valve for controlling the recirculation from the main header. If a change in the setting of this valve causes a change in the average of the FO angle profile, it can be used to control the average FO angle. Note that the nominal balance point (usually judged visually from movement of stock in a sight tube) may not correspond to a zero average fiber orientation, and the setting for zero FO angle may depend on the operating point. The optimal adjustment to balance may depend on the process operating conditions.

This is not an issue on modern headboxes, which have higher pressure drops across the turbulence generator, or which have large machine direction flow accelerations in the slice nozzle. In that case, manipulating the header recirculation valve has little or no effect on the average FO angle; however, a header which is severely unbalanced can have an effect even with modern headboxes.

2.6.1.2. Overflow balance

Some headboxes are equipped with an air-pad stilling chamber between the manifold and the turbulence generator, which serves to equalize pressure across the inlet to the turbulence generator, and the air pressure and liquid level are used as part of the headbox pressure control system.

To prevent the liquid level from fluctuating too rapidly, the stilling chamber is usually equipped with an overflow trough across the full width of the headbox. The flow into this trough is removed for recirculation with outlets on both sides of the headbox. The outlets have valves which may be manually set. If the setting of the valves is incorrect, the outflow may be asymmetric, leading to a level difference across the stilling chamber, and a flow difference across the turbulence generator. This will result in either a tilted basis weight profile, or an offset in the fiber orientation angle profile and, possibly, a tilted anisotropy profile.

The overflow valves should be adjusted to minimize the level difference across the inlet of the turbulence generator.

2.6.1.3. Edge flows

On narrow machines, up to approximately four meters in width, the responses to the edge flows may meet or overlap in the center of the sheet, provided the slice opening is not too large. In this case, it is possible to control the average FO angle using the difference between edge flows. At large slice openings, the edge flows influence just the edge regions of the sheet.

The effect on the jet angle profile of movements to individual edge flows for a narrow machine is shown in Figure 2-15, left. It is assumed that the slice opening is fairly small. The resulting effect in FO angle will depend on whether the machine is operating in rush or in drag. Provided the edge responses overlap to some extent, the entire jet can have its angle changed by moving the edge flows in combination, as shown in Figure 2-15, right.

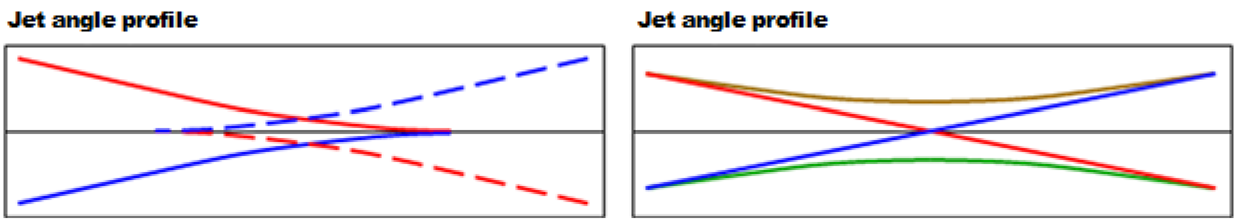


Figure 2-15 Edge Flow Effect on Jet Angle (narrow machine)

- left, individual responses: red = increase, blue = decrease, solid = back edge flow, dashed = front edge flow
- right, combined responses: brown = front decrease, back increase, green = front increase, back decrease, red = both increase, blue = both decrease

The average jet angle can be moved by changing the difference between the edge flows by moving them by opposite amounts. The jet can be shifted towards the front of the machine by reducing the front edge flow and increasing the back edge flow. It can be shifted towards the back of the machine by increasing the front edge flow and reducing the back edge flow.

Alternatively, the entire jet angle profile can be tilted by increasing both edge flows, which will increase the angle at the back and reduce the angle at the front. Similarly, reducing both edge flows will decrease the angle at the back and increase the angle at the front.

On wider machines, edge flows affect only the edge regions of the sheet. Edge bleed valves, found on some older headboxes, are not effective across the entire sheet, even on quite narrow machines.

ATTENTION

A few older designs of headbox were equipped with controllable flows for extracting stock out of the edges of the headbox. These should generally be set to the minimum value or, if feasible, closed off completely. Any nonzero outward flow will likely exacerbate fiber orientation problems more than it alleviates weight problems caused by nonuniform shrinkage.

2.6.1.4. Slice lip

Local changes to the slice lip, as shown in Figure 2-8, affect the fiber orientation locally, but have no effect on the average fiber orientation. This is true for any change which does not affect the average slope of the slice across the machine.

If the slice is given a slight tilt across the machine, however, the jet angle will be shifted across the entire machine, causing a change in the average fiber orientation angle. This is shown in Figure 2-16. Tilting the slice causes the jet to have a lateral velocity component towards the side on which the slice is more open. This will either increase or decrease the FO angle, depending on whether the jet is in rush or in drag, and the gain from jet angle to FO angle will vary with rush-drag in the same way as for other changes to the slice lip (see Figure 2-9).

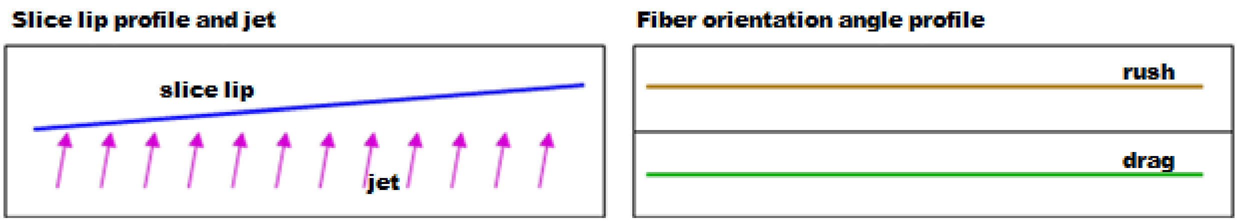


Figure 2-16 Effect of Tilting the Slice

Even if the slice positional measurements indicate that the slice lip is flat, it might have a slight slope for other reasons. Typically, there is a beam on which the slice lip actuators are mounted, and this beam can be moved at the edges, either manually or through automation. Also, the slice opening depends not just on the upper lip, but also on the lower lip, or slice apron. The slice apron is nominally flat, and can be shifted in the machine direction, but not vertically. An unexpected tilt in slice opening across the machine may be caused by:

- asymmetric thermal deformation of the slice support beam
- asymmetric thermal deformation of the headbox apron
- mechanical issue such as stiction or backlash with a support beam positioner
- miscalibration of position measurement for a support beam positioner

If stiction or backlash is present, one end of the entire slice may fail to respond to small movements, or to changes in direction of movement. Also, it may occasionally move by a significant amount, even though its nominal movement was much smaller. Thermal deformations can lead to a significantly different slice opening profile when starting up after a machine shutdown.

2.6.2. S-profile in FO angle

An S-profile occurs commonly, both in single-ply sheets and on the surfaces of multi-layer sheets. It happens most often with conventional headboxes, but can occur with dilution headboxes.

There are several possible causes, including:

- poor headbox rigidity, causing nonuniform slice opening after a change to headbox pressure
- improper setting for thermal compensation, causing a nonuniform slice opening after a machine startup
- use of slice to flatten basis weight or a related profile, for example, whiteness of a multilayer grade, with a nonuniform shrinkage profile, leading to a nonuniform slice opening

2.6.2.1. Headbox thermal compensation

If the S-profile occurs after a machine startup, especially if the slice was leveled during the shutdown, the primary suspicion of cause should be on the thermal compensation for the headbox nozzle. Depending on the available instrumentation, either the temperature setpoint or the displacement setpoint should be adjusted.

The required direction and amplitude of adjustment may not be clear, so it is advisable to make a small adjustment first. Because the thermal mass is quite large, and there is a substantial flow-through of hot stock, the response is typically quite slow. Allow at least 20 minutes before judging if the action taken was in the correct direction. Allow approximately one hour for the system to reach steady-state after a change. The steady-state responses will resemble those shown in Figure 2-10.

2.6.2.2. Headbox mechanical deformation

If the S-profile occurs whenever the headbox pressure is changed, and without any movement to the slice lip actuators, it is likely due to mechanical deformation of the nozzle. Headbox pressure changes occur whenever the jet speed is changed, such as for changes to rush-drag or to machine speed. If the change in the fiber orientation angle profile is large enough to notice, the headbox lacks sufficient rigidity for the operating conditions.

The preferred approach in this case is to use the thermal compensation system (see Subsection 2.6.2.1) to counteract the mechanical deformation, after each significant change to headbox pressure.

The thermal system should have enough capacity to cancel moderate mechanical deformations, but in some cases a headbox of low rigidity may deform mechanically beyond the capacity of the thermal compensation system. In these cases, it may be necessary to adjust the slice lip actuator profile also.

2.6.2.3. Interaction between shrinkage and dry weight control

The most common reason for S-profiles in fiber orientation angle during a steady grade run is that the slice is in a *frown* shape, which causes inward flows in the jet near the edges. This situation arises because there is greater shrinkage near the edges of the sheet than near the center, so, to get a flat basis weight profile at the reel, it is necessary to have the jet form a lighter sheet near the edges, for example, before the shrinkage occurs (see Figure 2-17). The amplitude of the slice shape will depend mostly on the difference in shrinkage between the edges of the sheet and the center of the sheet.

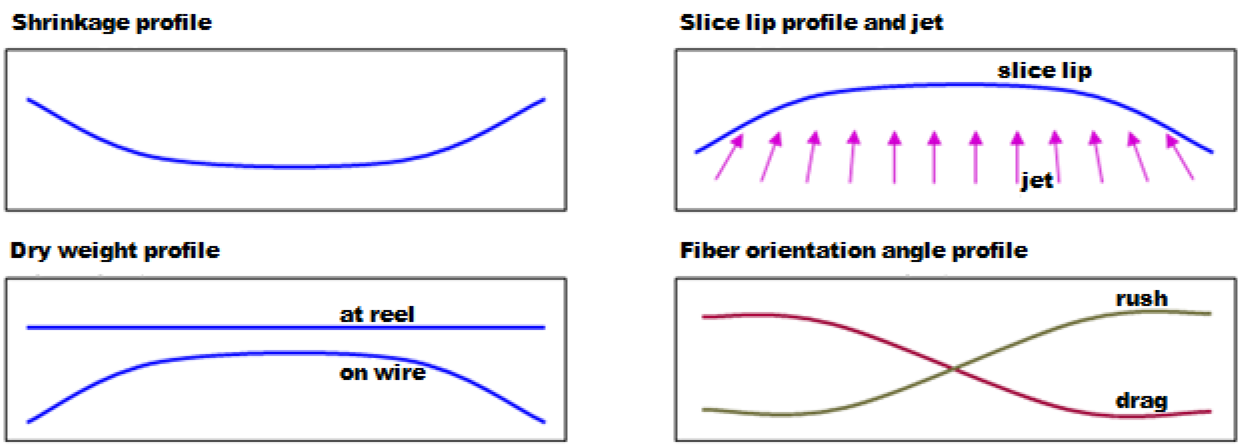


Figure 2-17 Profile Interaction

Always check the rush-drag to determine the direction of movement needed in the jet to correct the fiber orientation angle difference. If the S-profile is smooth over the whole sheet, it can probably be countered using the thermal management system, as in described Subsection 2.6.2.1.

If it is necessary to move the individual slice actuators, check that the slice lip is free to move in the region needing correction. Actuators may be near a high or low limit, or the pattern of actuator positions may be close to the local bending limit. In these cases, the allowed movement might be constrained. The bending limit should not be exceeded during any action; the movement size and the order of actuator movements should avoid cases where adjacent actuators exceed the bending limit, even temporarily.

If the headbox is equipped with a dilution system, the dry weight and caliper profiles can be kept flat, even with a wide range of slice opening profiles. In that case, it should be possible to keep the slice straight, but due to deformation of the slice nozzle under hydraulic pressure, an apparently flat slice may effectively be in a frown shape. Also, thermal and other deformations to the slice apron, and/or to the slice support bar, can induce a variety of local imperfections in the jet velocity field.

2.6.2.4. Adjust edge flows

If the headbox is equipped with controllable edge flows, they can be used to modify the jet angle near the edges of the sheet. Whether the edge flows should be increased or decreased will depend on the rush-drag state of the forming section, and the fiber orientation angle to be corrected. It is best to convert the fiber orientation angle correction (plus/minus) into a jet direction correction (inward/outward) at each edge:

- reducing an edge flow will reduce the inward component of jet velocity
- increasing an edge flow will increase the inward component of jet velocity

Take a conservative approach to the amplitude of edge flow correction. Several small corrective steps are safer than attempting a single large step. The response to edge flows can vary in extent depending on the total slice opening. It may affect a very small region near the edge, or it may extend almost two meters into the sheet (see Figure 2-11). The gain for responses to edge flow changes depends strongly on the rush-drag value, as it does for slice responses (see Figure 2-9). A modest error in the estimated jet speed may lead to a large underestimate or overestimate in the response amplitude.

Achievable corrections will extend over part of the sheet near each edge. The width of the corrected region will depend on many factors, especially the total slice opening, as shown in Figure 2-18, which shows correction of fiber orientation angle using edge Flows, with the dotted line representing large slice opening, and the dashed line representing small slice opening.

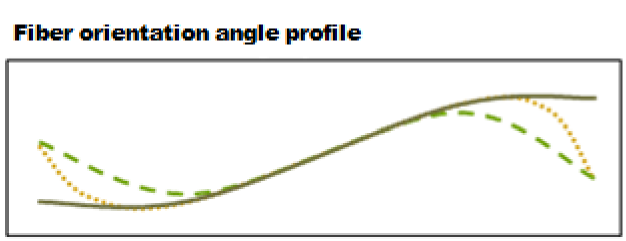


Figure 2-18 Correction of Fiber Orientation Angle

ATTENTION

> A few older designs of headbox were equipped with controllable flows for extracting stock out of the edges of the headbox. These should generally be set to their minimum value or, if feasible, closed off completely. Any nonzero outward flow will likely exacerbate fiber orientation problems more than it alleviates weight problems caused by nonuniform shrinkage.

2.6.2.5. Adjust slice shape

If the slice shape is adjusted on a conventional headbox making a single-ply grade, there will be an effect on the dry weight and caliper profiles as well as on the fiber orientation angle profile. With a dilution headbox, this can be corrected independently using the dilution system, provided it has sufficient capacity. With a conventional headbox, the effect on dry weight and caliper (and potentially on run-ability) must be taken into account.

On multi-layer machines, it is not possible to separate the dry weight profile into contributions from each headbox. Thus, a correction to a surface layer slice lip will have an effect on the weight of that layer. The total weight profile may be correctible using the dilution system on a filler layer, but properties related to the surface layer weight may be influenced. For example, the brightness profile of a white-top linerboard will be affected by changes to the slice lip of the top headbox.

Approach changing the slice lip shape as a search for a compromise between the fiber orientation angle profile and other profiles, such as dry weight, caliper, or brightness. In general, a smooth change to dry weight is much more acceptable than a rough or sharp change of similar amplitude. However, mill criteria for acceptable deviations from flatness in dry weight or brightness must be taken into account before attempting any slice lip changes. Greater deviations in dry weight can be tolerated in sheet-fed printing grades than in roll-fed printing grades, for example, and boxboard to be printed/converted from sheets or narrow rolls can tolerate greater deviations than linerboard to be converted in wide rolls.

By making a smooth change to the slice, especially near the sheet edges, the typical frown shape can be reduced or removed. The effect shown in Figure 2-17 can be improved to that shown in Figure 2-19.

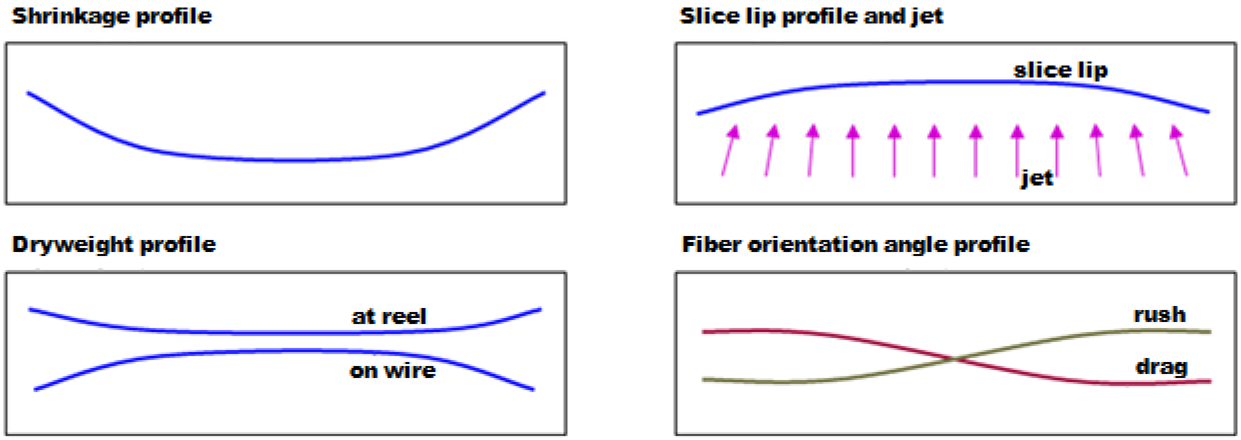


Figure 2-19 Effect of Partially Flattening the Slice Lip on Fiber Orientation Angle and Dry Weight Profiles

If a headbox is equipped with controllable edge flows, the edge flows should be used first to bring the fiber orientation angles at the edges to near zero. This reduces the amplitude of slice lip movement needed near the edge, and consequently reduces the disturbance to other profiles. At the same time, it can give a better fiber orientation angle profile than slice lip movement alone (see Figure 2-20). This recommendation is for both conventional headboxes and dilution headboxes.

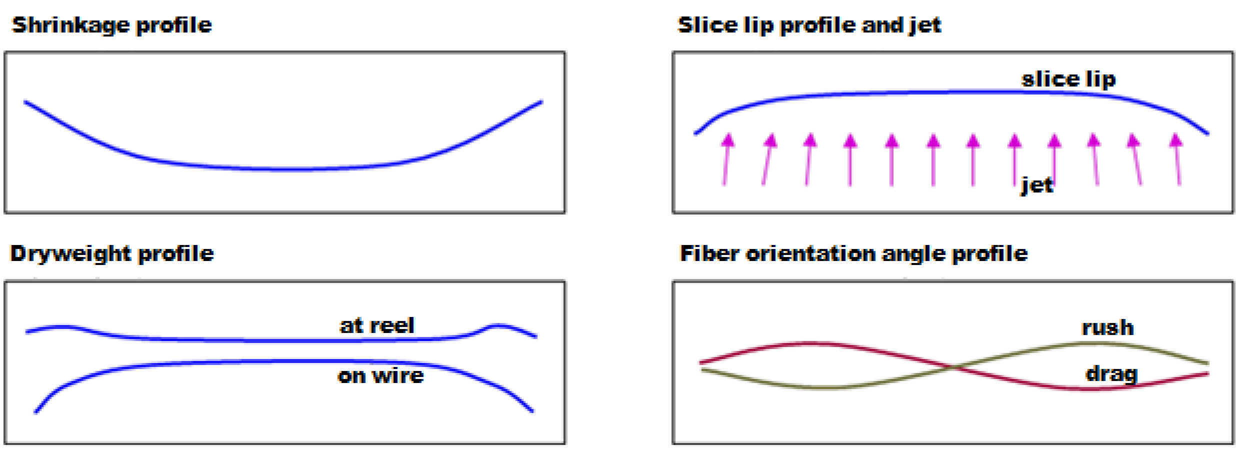


Figure 2-20 Effect of Slice Lip with Edge Flows Already Adjusted

2.6.3. Twist or curl problem in multi-layer paperboard

There is a significant correlation between twist and differences in surface layer fiber orientation, as described in Subsection 2.2.2.2, and shown in Figure 2-5.

There is also a relation between cross direction curl and differences in surface layer anisotropy, as described in Subsection 2.2.2.1, and shown in Figure 2-4.

Note that twist, machine direction curl, and cross direction curl may be conflated in some mills and described as warp or flatness issues. Descriptions of problems in such terms should be treated with caution. It is necessary to divide problems into twist, machine direction curl, and cross direction curl, because all three types of problem have different process causes and require very different solutions.

If the mill is experiencing a quality problem with twist in the paperboard, there is almost certainly a difference between the fiber orientation angles on the two surface layers. There may additionally be a difference in their anisotropies. While the fiber orientation angle profiles should, ideally, be flat on both surfaces, it is a difference in local fiber orientation angle which is associated with twist. Twist and curl often occur together (a certain amount of cross direction curl is desirable in some grades, such as folding boxboard).

The strategy for eliminating twist is always to reduce the fiber orientation angle difference wherever there is a twist problem. If the fiber orientation profile is significantly worse on one surface than the other, try to improve the worse surface first. This has the advantage that you need to work with only one headbox slice. It may also have secondary benefits on machine operation. Normally, the fiber orientation profiles are comparable in amplitude on both surfaces, and it is preferable to make approximately equal and opposite changes on both headboxes.

Always check the rush-drag to determine the direction of movement needed in the jet to correct the fiber orientation angle difference. Also, check that the slice lips in both surface headboxes are free to move in the region needing correction. Actuators may be near a high or low limit, or the pattern of actuator positions may approach the local bending limit. In these cases, the allowed movement amplitudes may be constrained, and it may be necessary to make locally greater corrections in one headbox than the other.

ATTENTION

Care should be taken in interpreting laboratory measurements involving drying or humidification of samples. If the sample is square, or is not dried or humidified uniformly on both surfaces, then its deformation may suggest twist is present when only curl exists.

Also, the result of even a uniformly dried or humidified sample may be misinterpreted in laboratory analysis. The FotoFiber measurements should be used to check the validity of conclusions drawn from laboratory twist measurements. For example, if the FotoFiber measurements indicate that fiber angles are near zero degrees on both surfaces, a laboratory indication of twist may actually be the result of machine direction curl toward one surface, and cross direction curl toward the other surface.

2.6.3.1. Curl

Curl may occur in machine direction or in cross direction. These are caused by different effects in the process, and solving them requires different approaches. Typically, a curl problem is identified in the laboratory, as there is no direct online measurement of curl.

Machine Direction Curl: This curl means that a sample of paper will curl up or down in the direction of travel. An originally straight line across the cross direction will remain straight, but an originally straight line along the machine direction will become curled upwards or downwards.

Cross Direction Curl: This means that a sample of paper will curl up or down across the width of the machine. An originally straight line across the cross direction will become curled upwards or downwards, but an originally straight line along the machine direction will remain straight.

Machine direction curl is not caused by fiber orientation or anisotropy; machine direction curl is caused by having too rapid a drying rate in the last drying stage on the machine.

As the sheet passes over a drying cylinder, it receives an increment of thermal energy through the surface in contact with the hot drying cylinder. When the sheet detaches from the drying cylinder, it will lose moisture through evaporation. Most of the moisture will be lost through the surface which was heated. The sheet will thus be given a tendency to curl in the machine direction towards the most recently heated surface. If the drying rate is small on the last few drying cylinders, the resulting machine direction curl tendency will be small.

To address machine direction curl, adjust the drying sections so that the last few cylinders can be operated with lower steam pressure. In some circumstances, a soft calender operated at high temperature may also behave as a drying device and affect the machine direction curling tendency.

ATTENTION

Machine direction curl should be reduced to acceptable levels before tackling any cross direction curl or twist issues, especially if the need for actions to correct cross direction curl or twist is determined primarily from laboratory measurements.

Cross direction curl is caused by forming the two surface layers of the sheet with anisotropies that do not give similar shrinkage for the stock used in that layer. Typically, the surfaces are formed with the same stock and different anisotropies, so that the anisotropy difference indicates the tendency for cross direction curl (see Subsection 2.2.2.1). The anisotropy of a layer is largely determined by the rush or drag value (see Subsection 2.5.1.7), but also with an influence from the turbulence at impingement of the jet onto the wire (see Subsection 2.5.1.3).

Cross direction curl issues should not be dealt with until after machine direction curl has been reduced to acceptable levels, because a combination of machine direction curl and cross direction curl may be misinterpreted as twist in a laboratory, especially if the machine direction curl and cross direction curl are in opposite directions.

Cross direction curl is always expected to affect the entire profile to a similar extent. If there are significant local differences in cross direction curl, there is probably a headbox problem that needs to be rectified. For general cross direction curl issues, the usual approach in multi-layer grades is to adjust the rush or drag of one or both surface layers.

If the sheet is curling in the correct direction, but is curling too much in cross direction, the difference in rush or drag between the two surfaces should be reduced. This will bring the anisotropy values closer together and reduce the tendency to curl. This assumes that *both* surfaces are either in rush or in drag. If one is in rush and the other in drag, the difference in absolute values of rush or drag should be reduced.

If the sheet is curling in the correct direction, but is *not* curling enough in cross direction, the difference in rush or drag between the two surfaces should be increased. This will bring their anisotropy values further apart and increase the tendency to curl. This assumes that *both* surfaces are either in rush or in drag. If one is in rush and the other in drag, the difference in absolute values of rush or drag should be increased.

If the sheet is curling in the wrong direction in cross direction, the rush or drag should be increased on the surface which is on the outside of the curl, and/or the rush or drag should be decreased on the surface which is on the inside of the curl. The anisotropy values and absolute values of rush or drag need to be approximately swapped between the two surfaces (assuming equivalent furnish and forming units).

In some cases, it may not be practical to adjust the rush-drag value, because of its large effect on other properties, such as strength ratio or formation. Some effect on cross direction curl may be achieved by adjusting the L/b ratio of the headbox (this is the only method available on single-ply grades). Changing the apron position, L, while keeping the slice opening, b, constant, will change the impingement angle and landing zone of the jet on the wire and forming board. On a twin-wire former it will shift the impingement zone relative to the gap. Changing the slice opening, b, while keeping the apron position, L, constant, will additionally change the headbox consistency, the wire tension, and the mechanical load on the wire drives. Both changes affect formation and drainage as well as turbulence and cross direction curl. However, there are no general relations to suggest whether a given change in L/b might increase or decrease cross direction curl. An experimental trial and error approach is required in each machine.

2.6.3.2. Broad twist issue

A broad twist issue is one in which the twist is in the same direction over a significant part of the sheet, and exceeds quality acceptance limits in much of that area. If the twist exceeds quality limits over a broad area, but with direction of twist changing every few actuator zones, it should be treated as several narrow twist issues that happen to be adjacent.

If a broad twist issue occurs over almost the entire sheet, or over one half of the sheet, the procedures in Subsection 2.6.2 can be employed to reduce fiber orientation angle differences.

If a broad twist issue extends over several slice actuator zones in width, but only over a portion of the sheet, a different approach is required. Reducing the fiber orientation angle requires changing the lateral movement of the jet, which involves putting a slope in the corresponding region of the slice lip. The slice actuators outside that region must also be moved, but in a shape which tapers gradually back to zero.

The slope on the slice outside the region to modify should be significantly less than the slope inside that region. The result is shown in Figure 2-21, which shows using upper and lower headbox slice lips to make opposite jet angle adjustments over a region for twist correction. The effect on the dry weight profile is not shown, but should be taken into consideration when deciding slice movement amplitudes.

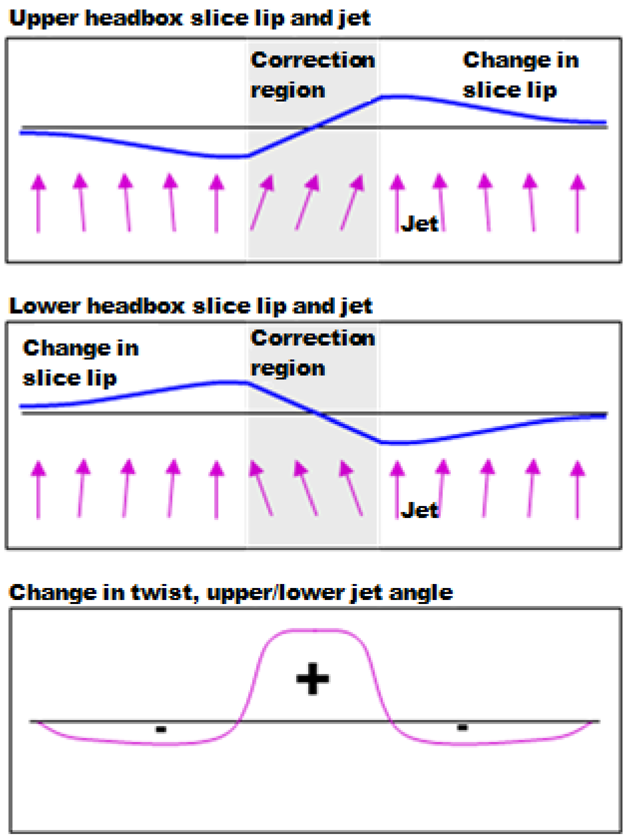


Figure 2-21 Twist Correction

The following procedure can be used:

1. At the center of the region to modify, leave the slice actuator in its current position (no movement).
2. Move the actuators progressively in greater amounts upwards from the center to one edge of the region to modify.
3. Move the actuators progressively in greater amounts downwards from the center to the other edge of the region to modify.
4. Beyond the edges of the region to modify, move the actuators progressively in smaller amounts, until reaching a point where the movement amount would be negligible.

Quite often, a positive twist issue in one region of the sheet will occur with a negative twist issue elsewhere in the sheet. In this case, all actuators between the two regions can move by a similar amount as shown in Figure 2-22, which shows using upper and lower headbox slice lips to make opposite jet angle adjustments over multiple regions for twist. The effect on the dry weight profile is not shown, but should be taken into consideration when deciding on slice movement amplitudes.

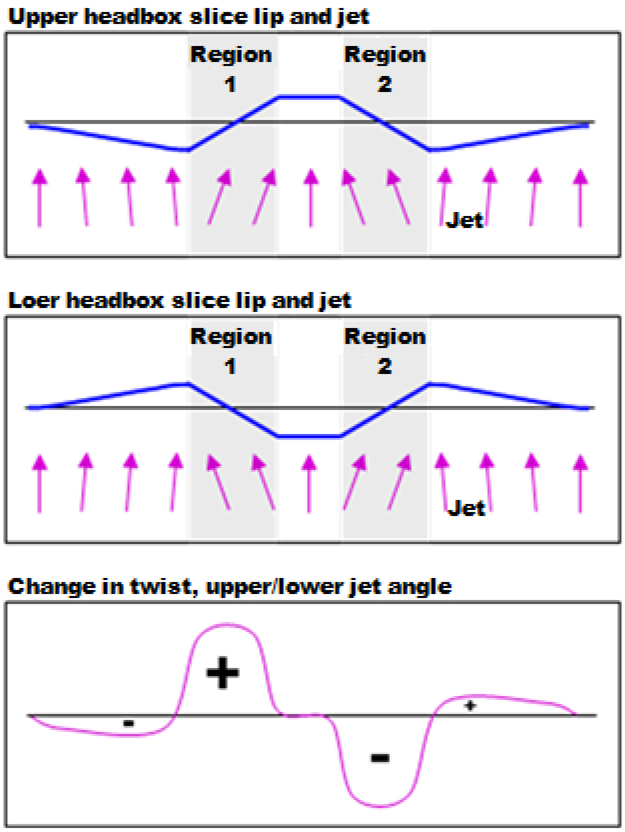


Figure 2-22 Opposite Jet Angle Adjustments

2.6.3.3. Local twist issue

Because the twist problem can be local, affecting just a narrow region of the sheet, the approach of making smooth changes to the slice lip may not always be appropriate. If the twist issue is at an edge of the sheet, the headbox edge flows may be useful in reducing fiber orientation angle differences (see Subsection 2.6.2.4).

If a narrow local change is to be made to a jet using the slice lip, the following procedure should be used:

1. To locally direct the jet more towards the front of the machine, increase the slice opening at the nearest actuator nearer the front, and reduce the slice opening at the nearest actuator nearer the back.

2. To locally direct the jet more towards the back of the machine, reduce the slice opening at the nearest actuator nearer the front, and increase the slice opening at the nearest actuator nearer the back.

3. If the actuator movements needed were large, or would lead to large local bending in the slice lip, the neighboring actuators can be moved by a smaller amount to avoid reaching the slice bending limit. This can also avoid introducing a twist issue adjoining the corrected area.

Figure 2-23 shows three possible slice movement patterns, and consequent jet angle changes, used for correcting local twist issues. The standard narrow correction pattern is shown on the left. Variations to reduce the bending effect, or to mitigate effects on neighboring areas, are shown center and right.

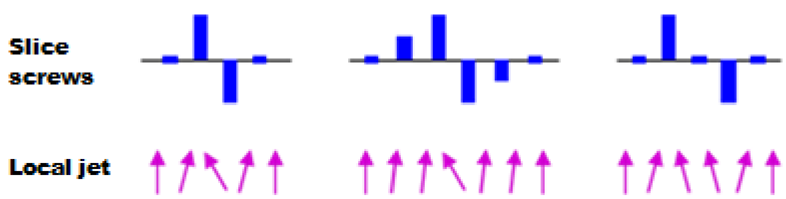


Figure 2-23 Slice Movement Patterns

The opposite changes should be made to the jets from both surface headboxes. Adjustment patterns for a single headbox are shown in Figure 2-23.

2.6.4. Unexpected response amplitude

In making a change to the slice lip to improve the fiber orientation angle, the response observed may differ from the expected response. The difference can be quite large, and be in direction as well as in magnitude. If the direction appears to be the opposite of the expected direction, check the definitions of positive and negative angles, to ensure that the process and measurement directions are fully understood and properly applied.

The primary cause for unexpected response amplitudes is that the forming section is at a different rush-drag state than its expected value. The calculated jet speed (and consequent estimate of rush or drag) must be treated as an approximation, and can easily be in error by a few meters per minute. As shown in Figure 2-9, a small change in the rush or drag can cause the fiber orientation response amplitude to change by a large amount. The sensitivity to rush or drag errors is greatest in machines with low turbulence in the forming region, as occurs when there are no vanes in the slice nozzle, or the jet impingement angle on the wire is small.

The solution is to persuade the mill to calibrate the true jet speed. It is not practical to attempt control of fiber orientation angles without knowledge of the true rush or drag value.

2.6.5. Calibration of true jet speed

There are at least four methods for calibrating true jet speed, with differing costs and convenience.

Method 1

In some cases, the headbox manufacturer can supply a customized calculation for the jet speed, which is often accurate enough within a specific range of operating states. Outside of its range of validity, however, it can produce significantly erroneous estimates. Due to process optimizations, headboxes are usually operated at or beyond their initial specifications within a few years. A customized relation which was accurate when the headbox was commissioned might not be accurate after the production rate has been subsequently optimized.

Method 2

A direct measurement of the jet (laser-Doppler, laser cross-correlation, and so on) can be installed on open *Fourdrinier* formers, but not on gap-formers. This is typically very expensive, and its accuracy depends on further calibration by its supplier.

Method 3

At each major operating point for the machine (wire speed, slice opening), the mill can construct a calibration as follows:

1. Step the headbox pressure in increments over a range which is expected to extend from drag to rush and includes the nominal operating pressure.

2. At each headbox pressure, measure the exact sheet width at a convenient location after the drying section, but before the coaters or calenders. This measurement must be reasonably meticulous.

3. Plot the sheet width versus headbox pressure or nominal jet speed. The actual zero point (jet speed equals wire speed) occurs when the sheet

width is maximum, and the calculated jet speed should be corrected by an offset to match this.

Method 4

At each major operating point for the machine (wire speed, slice opening), the mill can construct a calibration as follows:

1. Put the scanner with FotoFiber sensors into a fixed position near the middle of the sheet.

2. Step the headbox pressure in increments over a range that is expected to extend from drag to rush and includes the nominal operating pressure. Record the surface anisotropy at each setting when steady-state is reached.

3. Plot the surface anisotropy versus headbox pressure or nominal jet speed. The actual zero point (jet speed equals wire speed) occurs when the surface anisotropy is minimum, and the calculated jet speed should be corrected by an offset to match this.

Method 4, employing the online FotoFiber measurements, is faster and less labor-intensive than Method 3, because it does not require manual measurement of sheet width, and takes only a few minutes to perform. Method 3 could be recommended to a mill as a standard procedure after a grade change. The two methods are usually in close agreement; Method 4 yields a curve similar to Figure 2-12 for each headbox with a minimum at the zero point. Method 3 yields a curve with a maximum at the zero point rather than a minimum.

Also, on a multi-layer machine, Method 3 must deal with each headbox sequentially, and becomes quite time-consuming. Method 4 can calibrate both surface headboxes simultaneously using the FotoFiber sensors. It is quite common for supposedly identical headboxes to require different offsets in jet speed.

Mills with the laser-based measurements of jet speed (Method 2), often do not rely on them for accurate rush-drag assessments. The experimental approaches (Method 3 and Method 4) are considered more reliable.

3. EDAQ

The EDAQ board is responsible for converting all analogue and digital signals to and from sensors to Ethernet.

It replaces the functionality of the National Instruments™ cards seen in previous Honeywell scanner systems.

The board is based on an ARM CPU running the Linux operating system and a Field-Programmable Gate Array (FPGA) that controls real-time data acquisition.

The EDAQ contains software licensed under third party licenses including the Gnu Public License (GPL). A copy of that software and its source code can be obtained from *http://www.honeywell.com/ps/thirdpartylicenses* or found on the Experion MX distribution media under *C:\Program Files\Honeywell\Experion MX\MSS\SenLan\Images\GPL*.

The EDAQ board contains a large number of input/output (I/O) systems, including:

- analog inputs (16 inputs of 12 bits @ 4 kHz and 8 inputs of 10 bits @ 1 Hz)
- analog outputs (2 @ 12 bits)
- digital inputs (16 @ 24 V logic)
- digital output (16 @ 24 V logic)
- frequency input (400 Hz to 500 kHz)
- three serial ports
- USB (presently unused)
- Ethernet

Except for a few dedicated signals such as the green light (radiation safety), all sensor signals connect through the EDAQ to the new Experion MX MSS by Ethernet.

The EDAQ contains sensor-specific code for all sensors. All EDAQs, including the frame controller (FC) EDAQ (in the endbell), and the head alley EDAQ, are identical and can be interchanged.

This chapter gives a brief overview of the EDAQ board and some of the diagnostic information. More detail is provided in the *Experion MX MSS & EDAQ Data Acquisition System Manual* (p/n 6510020381).

3.1. Physical layout

Figure 3-1 and Figure 3-2 show the EDAQ PCBA as it is mounted next to a sensor. To the left are the digital and analog I/Os, which connect directly to a sensor. Below these two large connectors is a 16-pin expansion connector that is only used when the EDAQ is attached to the FC expansion board.

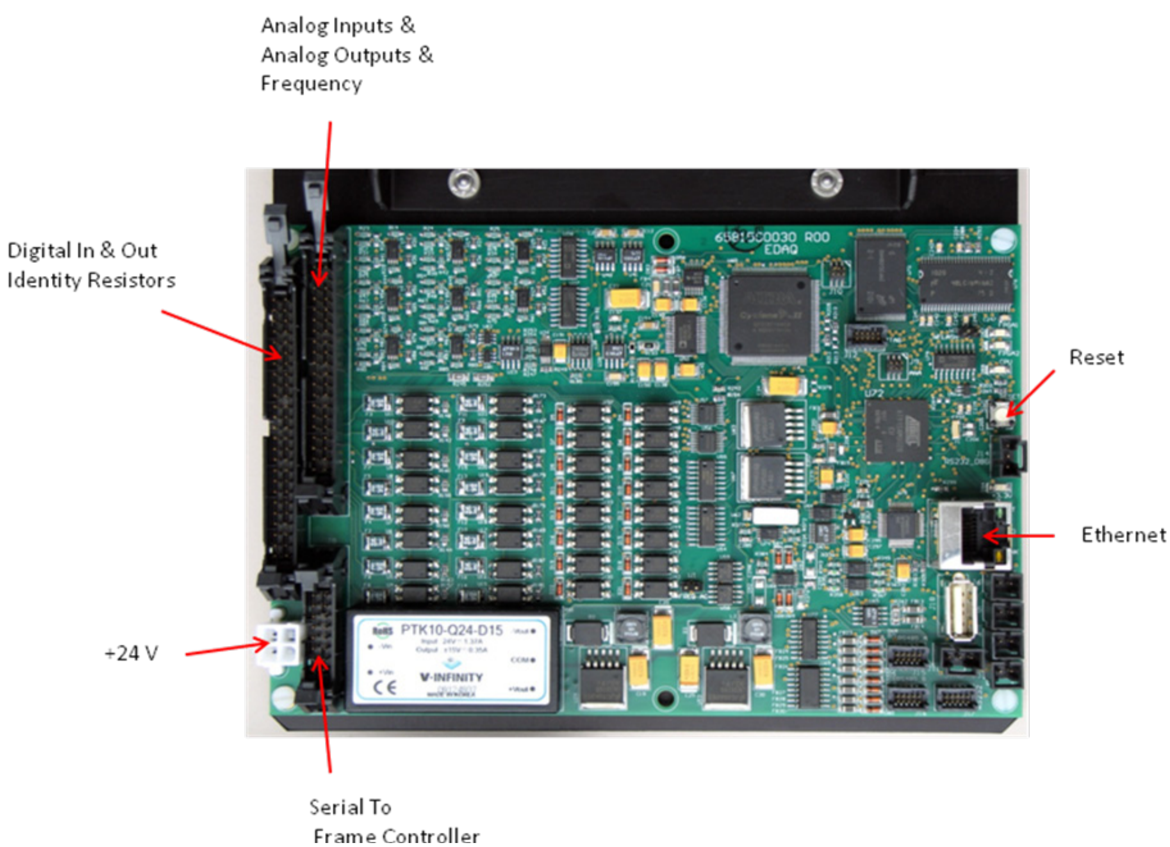


Figure 3-1 EDAQ Board

As shown in Figure 3-2, J1 is the large 50-pin connector on the far left. J2 is the smaller 40-pin connector. J8 on the lower left is used for the FC only. To the right are the Ethernet port, some diagnostic LEDs, serial connections, and temperature inputs. There are no test points for use in the field. A serial debug port is available (115200 kb/s, no flow control, 8N1) that may be connected to any PC running a serial terminal program. For diagnostic purposes, service personal may be asked to connect a serial cable between the debug port and the RS-232 of any neighboring EDAQ.

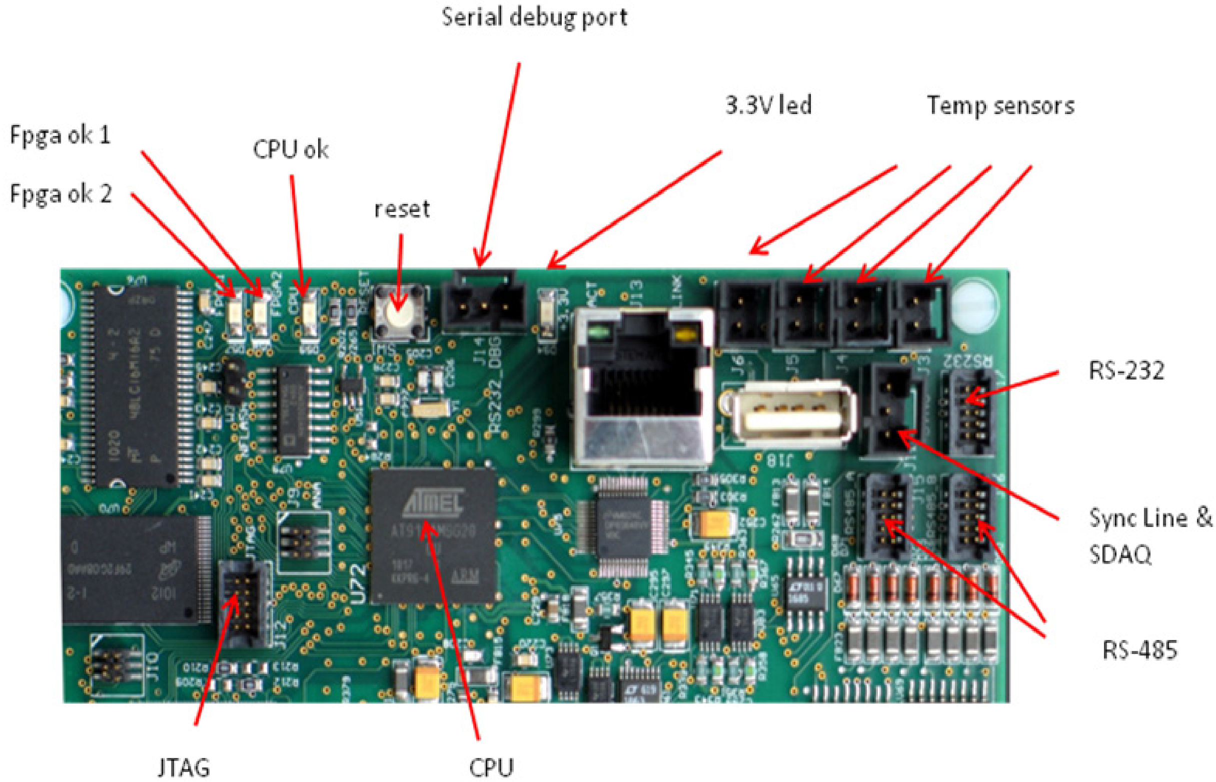


Figure 3-2 EDAQ Board: Ports and Diagnostic LEDs

3.2. Hardware status information

There are four diagnostic LEDs on the EDAQ (see Figure 3-2).

- The *3.3 V LED*. When lit, this indicates that all power supplies on the board are functional. The signal is derived from the 3.3 V power supply, which in turn is derived from the 15 V power supply, which is derived from the + 24 V input.
- The *CPU OK LED*. This LED is under control of the central ARM CPU. It will be lit when the main sensor application (edaqapp) is running on the CPU.
- The *Fpga ok 1* (not used at present).
- The *Fpga ok 2*. This LED will blink if the FPGA is loaded and running code.

The Ethernet connector contains two LEDs:

- amber indicating a good link to the switch
- green indicating activity on the network

3.3. EDAQ reset

A soft reset of the EDAQ may be performed through a Web interface running on the scanner MSS. This interface may be accessed from a QCS operator station.

A hardware reset can be performed by pressing the white button next to the debug cable. This resets both the CPU and FPGA, and is equivalent to a power on/off.

3.4. EDAQ sensor identification and IP addressing

Assuming the firmware (flash code) is the same, all EDAQs are identical. EDAQs can be freely interchanged between sensors and the scanner endbell.

Each EDAQ contains all the code for all supported sensors, and loads the appropriate software depending on the identification ID code read at boot time. Two resistors are used to uniquely identify the EDAQ.

For sensor-connected EDAQs, there is a sensor model resistor embedded in the cable harness connecting the sensor to the EDAQ. This resistor determines the function code. Function codes are unique for each sensor model to the extent that the EDAQ needs to differentiate the models. For example, all Source 9 basis weight measurement sensors presently have the same function code, regardless of radioactive isotope.

In addition, the head power distribution board has a resistor for each EDAQ platform connector. This determines the position of the EDAQ in the head. The EDAQ can self-identify both its position and function.

Refer to your scanner system manual to troubleshoot the EDAQ if it does not identify itself properly (or to find the correct resistor values).

Every EDAQ has a unique IP address on the scanner network. If the EDAQ can identify its position, it will set its IP address to 192.168.0.*XYZ* (where *XYZ* is the position number in the head). The FC-EDAQ always sets itself to IP number 192.168.0.2. The MSS is always 192.168.0.1 on the scanner network, and usually 192.168.10.*n*+100 (where *n* is the number of MSSs on the same MX Experion network) on the Experion MX LAN. The MSS is assigned 192.168.10.101 at the factory, but this can be set to any IP address by using the MSS Web page. Refer to your scanner system manual.

If an EDAQ fails to determine a position, it requests an address of the local DHCP server (which is either running on the FC-EDAQ or the MSS). Any laptop will get an IP address when plugged into any of the scanner Ethernet switches.

3.5. Obtain status information

An overall status page is available from a QCS operator station under the **MSS Setup Diagnostics** tab (select the **MSS Summary** display).

On the left side of the **MSS Summary** display, as shown in Figure 3-3, is the list of expected EDAQs with three types of status indicators (from left to right).

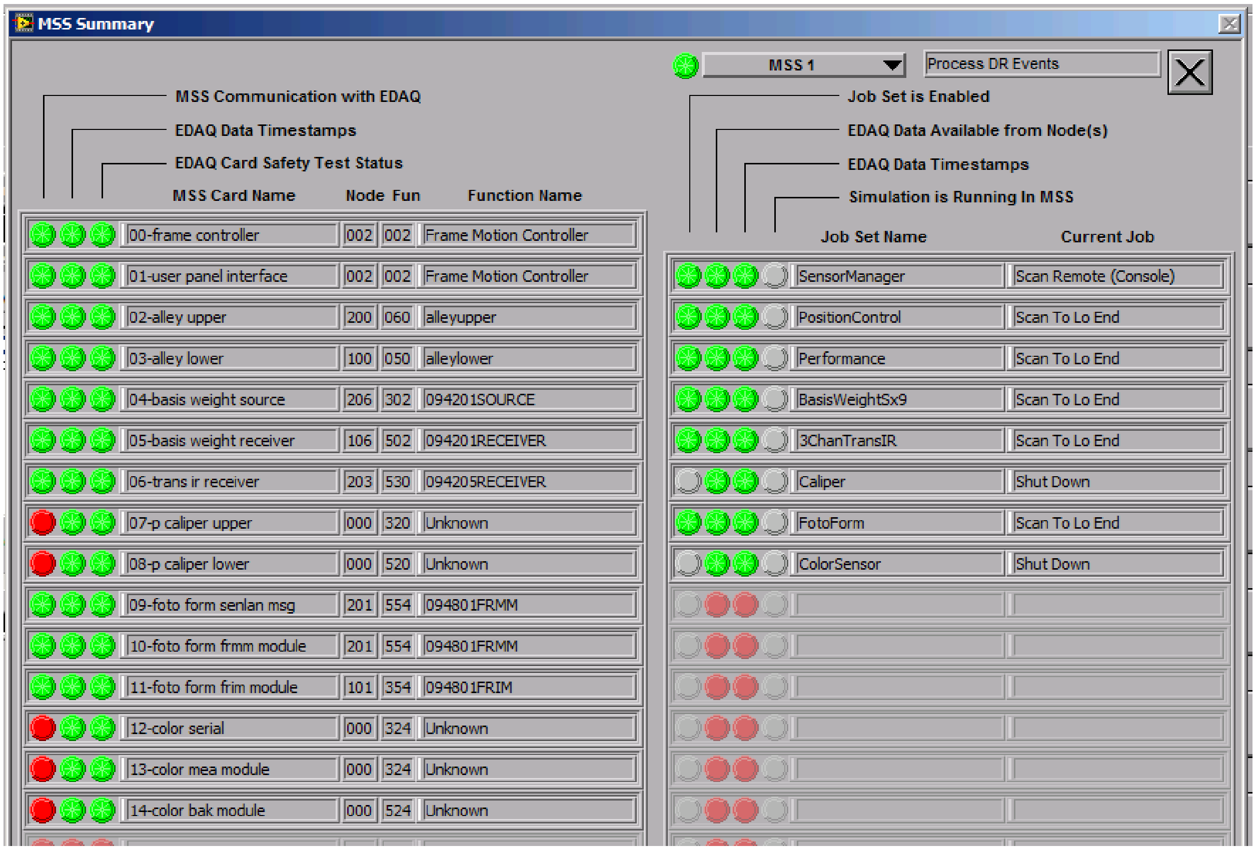


Figure 3-3 MSS Summary

Table 3-1 MSS Summary Display Status Indicators and Descriptions

Column	Description
MSS Communication with EDAQ	EDAQ is communicating (through the EDAL protocol) with the MSS
EDAQ Data Timestamps	Data that the MSS is expecting from that EDAQ is being supplied at the expected rate
EDAQ Card Safety Test Status	EDAQ is not reporting any errors such as interlock or motion control issues

Sensors that are part of the QCS database, but are not enabled on the scanner, appear in the left column indicators in red, for example, *07-caliper upper* in Figure 3-3.

3.6. MSS and EDAQ web pages

More detail is available on the MSS and the EDAQs, which all run Web servers and can display server pages containing information on the state of the system. As a general rule, consult the MSS Web pages first. They are accessible in three different ways:

- go to the **MSS Diagnostic** tab, click on **MSS Monitor**, choose the appropriate MSS, and click on **MSS Web** page
- open a browser on any computer connected to the Experion MX level network, and use the address *http://192.168.10.101/mss.php (*the first MSS on the LAN), or the address set up for the MSS in the Experion MX system
- open a browser on any computer connected to the scanner LAN switch, and use the address *http://192.168.0.1/mss.php* or *http://192.168.10.101* (for the first MSS on the system)

Figure 3-4 shows **PHP MSS Page** (the main MSS Web page).

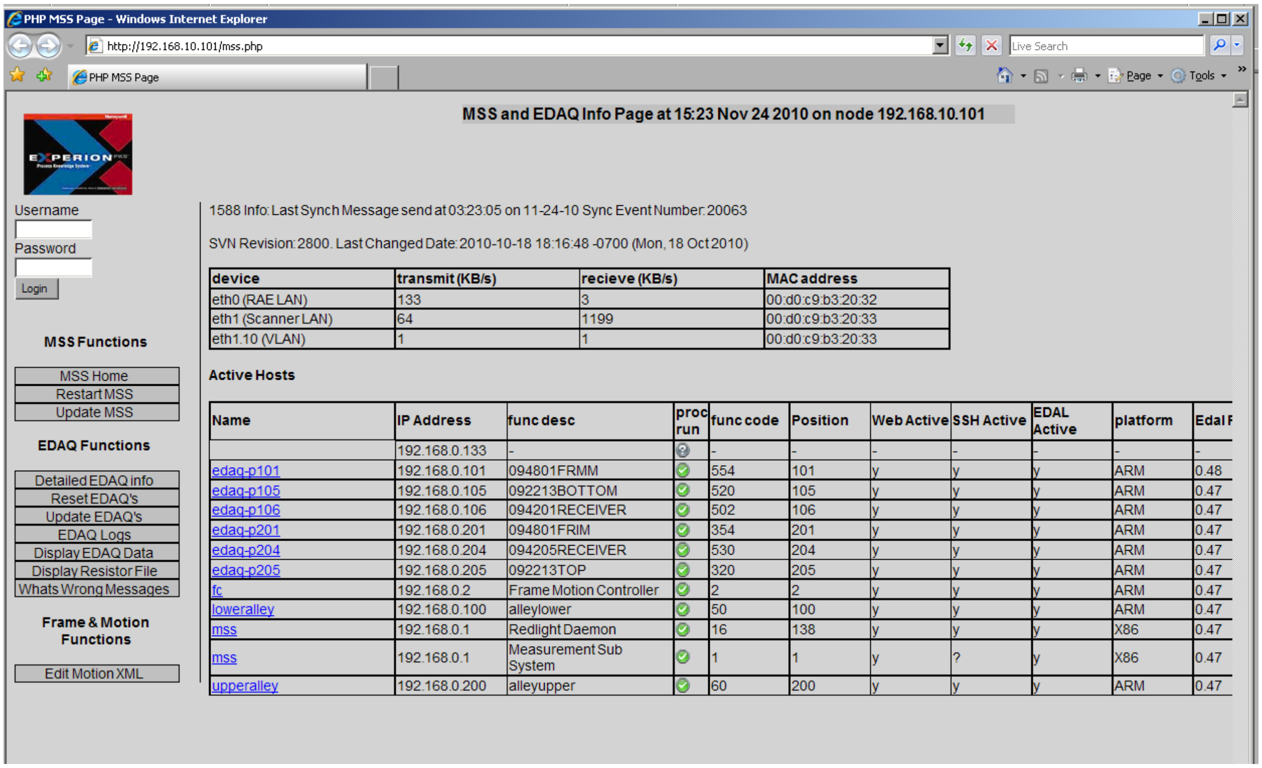


Figure 3-4 PHP MSS Page

The left panel shows a column of options divided into:

- **MSS Functions**
- **EDAQ Functions**
- **Frame and Motion Functions**

Enter the username (`admin`) and password (`hmxresult`) for advanced diagnostic options that are not necessary for normal operation and not discussed in this manual.

The main area shows two tables. The top table contains transmission volume information to and from the MSS. The device labeled **eth1 (scanner LAN)** typically shows it receiving a few MBs. The MAC addresses of the MSS are also shown–the **eth0 (RAELAN)** address is the one required in the setup.

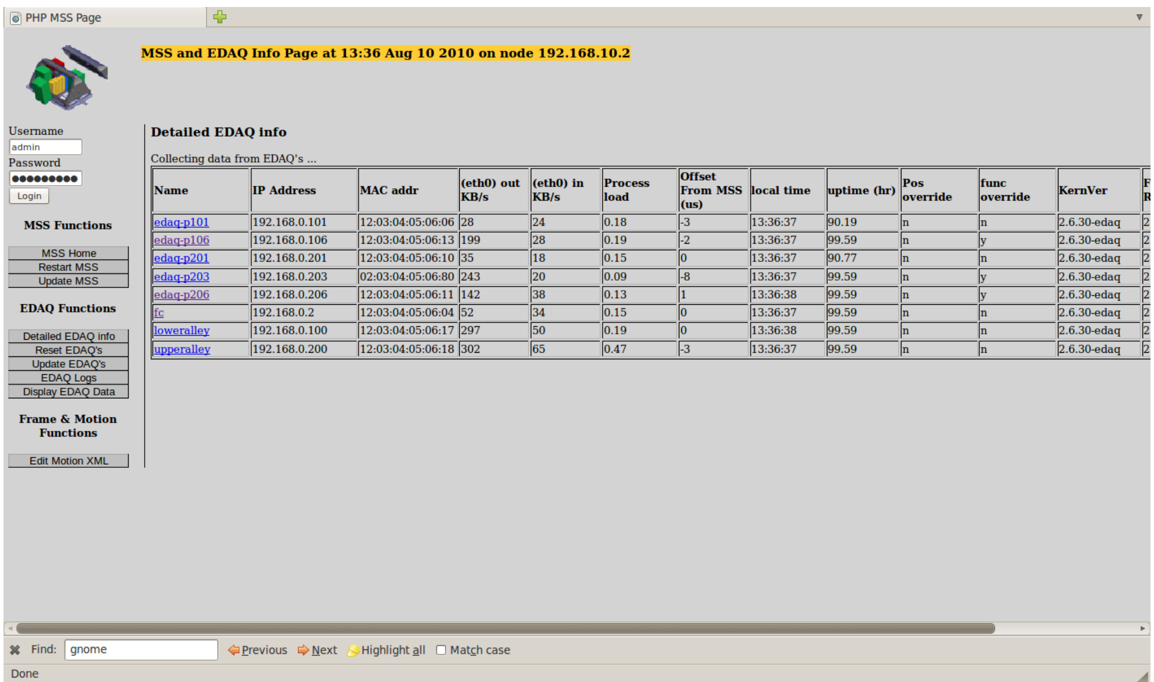
The second table lists all EDAQs discovered on the scanner LAN, their IP numbers, a brief description (related to model number), a program status column, the associated function code and position code, and whether the communication protocols are running (http, SSH, and Edal, the proprietary sensor data transmission protocol).

The EDAQ network name is specified by edaq-p*XYZ* where *XYZ* is both its position and last octet of the IP address. The EDAQs attached to the head power distribution boards are known as *upper* and *lower* alley respectively. The FC-EDAQ is known as *fc*.

The **proc/run** status column is green if all processes known to run on the EDAQ are present. Hovering the cursor over the status indicator calls up a list of running and stopped processes.

More detailed information on each EDAQ can be obtained by clicking **Detailed EDAQ info** on the left panel.

The resulting table (see Figure 3-5) shows a number of technical details that are not discussed in this document. Important columns include **Process load** (usually less than 0.5), **local time** (matches MSS time clock shown at top), and **Offset From MSS (µs)** (less than 50 µs a few minutes after start up).



Name	IP Address	MAC addr	(eth0) out KB/s	(eth0) in KB/s	Process load	Offset From MSS (us)	local time	uptime (hr)	Pos override	func override	KernVer
edaq-p101	192.168.0.101	12:03:04:05:06:06	28	24	0.18	-3	13:36:37	90.19	n	n	2.6.30-edaq
edaq-p106	192.168.0.106	12:03:04:05:06:13	199	28	0.19	-2	13:36:37	99.59	n	y	2.6.30-edaq
edaq-p201	192.168.0.201	12:03:04:05:06:10	35	18	0.15	0	13:36:37	90.77	n	n	2.6.30-edaq
edaq-p203	192.168.0.203	02:03:04:05:06:80	243	20	0.09	-8	13:36:37	99.59	n	y	2.6.30-edaq
edaq-p206	192.168.0.206	12:03:04:05:06:11	142	38	0.13	1	13:36:38	99.59	n	y	2.6.30-edaq
fc	192.168.0.2	12:03:04:05:06:04	52	34	0.15	0	13:36:37	99.59	n	n	2.6.30-edaq
loweralley	192.168.0.100	12:03:04:05:06:17	297	50	0.19	0	13:36:38	99.59	n	n	2.6.30-edaq
upperalley	192.168.0.200	12:03:04:05:06:18	302	65	0.47	-3	13:36:37	99.59	n	n	2.6.30-edaq

Figure 3-5 Detailed EDAQ Information: Partial Display

4. Installation

FotoFiber sensors may be delivered with a new scanner, or added to a suitable existing scanner. Both single-sided and two-sided installations are possible. It may also be necessary to remove a sensor for certain maintenance operations from time to time.

4.1. Installation requirements

Before installing the FotoFiber sensor, ensure that the Experion MX Q4000 scanner head meets the following requirements:

- A spare sensor location exists in the head, without any dust-sensitive sensor located downstream of the spare location. Preferably the spare sensor location is on the downstream side of the head. The sensor location should be available in both heads, even for a one-sided installation.

- Compressed air is available in the head manifold, with a spare capacity of 30 L/min (1.06 scfm). For a two-sided installation, this air supply must be available in both heads. For a one-sided installation, it must be available in the head in which the FotoFiber is to be installed.

- At least two Ethernet sockets are available in each head in which a FotoFiber is to be installed.

- Suitable version of Experion MX host software: RAE R600 or later with current updates (see Section 6.2).

Consult Honeywell QCS-TAC if these requirements are not met.

4.1.1. Required materials

The materials needed are not the same for single-sided (Q4223-51) and two-sided (Q4223-52) installation, but there are some common items.

Single-sided sensor, model Q4223-51

- one FotoFiber sensor upper measurement head
- one sensor baseplate (with EDAQ)
- one FotoFiber backing module
- one sensor baseplate (no EDAQ)
- two Ethernet communication cables
- one FotoFiber air installation tube assembly

Two-sided sensor, model Q4223-52

- one FotoFiber sensor upper measurement head
- one FotoFiber sensor lower measurement head
- two sensor baseplates (with EDAQ)
- four Ethernet communication cables
- two FotoFiber air installation tube assembly

Common: single-sided or two-sided sensor

- one calibration and focus chart
- one FotoFiber test specimen assembly
- one LENS**PEN**®
- Small amount of thread locking compound

4.1.2. Preparation and tools

Physically installing a single-sided Q4223-51 sensor requires approximately 10 minutes. Approximately five minutes will be needed for installing the blank opposite it in the other head. Physically installing a two-sided Q4223-52 takes approximately 10 minutes for each side, for a total of 20 minutes. These should be considered absolute minimum times for locations with easy access, and it is advisable to reserve a longer time, especially if it is necessary to perform the installation on a running machine or in a scanner without easy access.

Preferably, installation of sensors takes place during a sufficiently-long shutdown, but it is also possible to install in a running machine, provided the scanner can be offline for a long enough time. A two-sided FotoFiber may be installed into a running system in two separate operations, provided that when the scanner is to be operated with only one FotoFiber, either that FotoFiber is powered down or there is a suitable backing unit opposite it in the other head. This allows the interruption to scanning to be divided into two time periods, which may be more suitable for the mill.

The scanner head must be safely offsheet for the time needed, and the environment should not be subject to droplets, condensation, or dust during the installation. It is recommended that installation of a FotoFiber be performed during a machine shutdown.

ATTENTION

It is essential that a working air supply be connected to FotoFiber immediately on installation, and before any attempt to scan the sheet (whether FotoFiber is powered on or not). Traversing the sheet without a cleaning air flow to the sensor may result in rapid and severe dirt build-up, necessitating removal of the sensor for major cleaning.

The following tools should be at hand:

- long handle roundhead hexagonal key sets (metric and imperial)
- screwdrivers (small flathead and long Phillips #3)
- voltmeter with thin probes
- sharp, small knife or other cutting tool

Handling the sensor will leave fingerprints and other marks on the window of a lower sensor, so clean the sensor windows immediately after installation. The LENS**PEN** and clean compressed air (mill air or canned optical-quality air) should be available.

4.1.3. Optional hardware set-up

The sensor should be received from the factory in a focused state, and with its zero angle noted in the sensor report. If this is the case, there is no need for the optional set-up steps. However, if there is some reason to think the sensor has been handled or moved poorly or excessively, or that the camera or lens was moved or replaced, check the focus and/or the zero angle parameter before installation. To establish the zero angle, see Subsection 9.4.2 using the FotoFiber test specimen assembly. To perform focusing, see Subsection 9.5.1.

4.1.4. On-site spare parts

A small number of spare parts are generally supplied with the FotoFiber. These should be stored in a suitable place on-site, in a container clearly marked as *Q4223 FotoFiber Spares* or something similar:

- one LED driver PCB
- one LED panel PCB
- one spare strobe control cable (from cable set p/n 08770600)

The other items supplied with FotoFiber, such as the LENS**PEN**, the FotoFiber Calibration & Focus Chart, and the FotoFiber test specimen assembly (both the block assembly and the holder assembly) may be stored in the same place as the spare parts. The FotoFiber Calibration & Focus chart should be stored in a way that ensures it will not receive any markings, scratchings or creases.

4.2. Install the sensor

4.2.1. Check alignment and fit

The FotoFiber as delivered from manufacturing may need to be checked and configured, because it may be installed into a different sensor location than was planned for during its manufacture. Because the PCBs are easily damaged, they should be stored in a static-free robust package.

ATTENTION

> The air supply to the FotoFiber must be introduced on the upstream side of the sensor. In other words, the air must move into the sensor in the same direction as the movement of the sheet through the sensor gap. The air must not be introduced from the downstream side, or in either cross-machine direction. This requirement holds for sensors in the upper head and in the lower head. The approved alignment of the air supply inlet relative to the paper movement is shown in Figure 4-1.

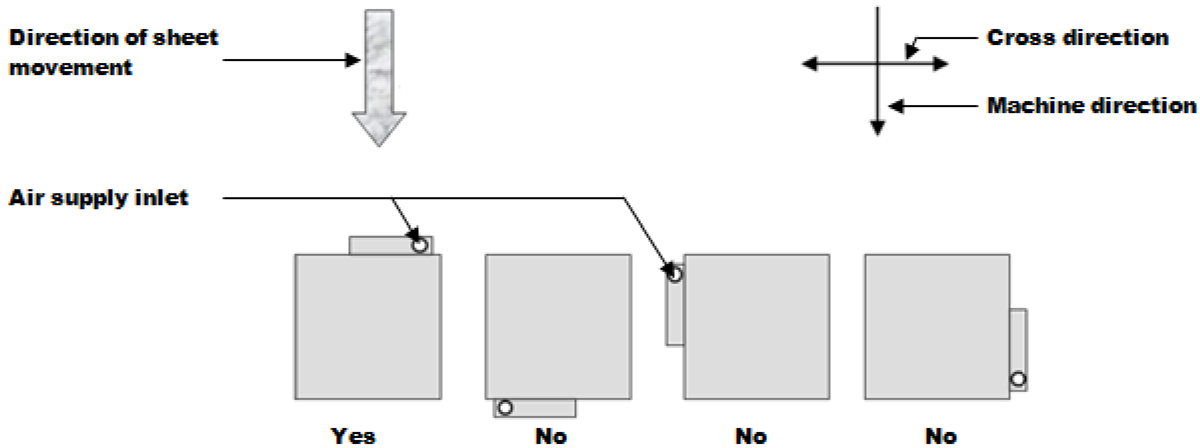


Figure 4-1 Approved Alignment of FotoFiber in Head

Due to the provided cable lengths, the upper structure of the FotoFiber can be installed only in a single configuration, with its processor module adjacent to the EDAQ. This is always the correct alignment of the upper section of the sensor, and all sensors will be delivered from manufacturing in this configuration. As a consequence, bit 4 of configuration parameter 53 (see Subsection 6.3.4.2) must always be set to 1 for a Fiber Orientation sensor in the MX scanner.

However, if the air supply inlet is not on the correct side of the sensor for its intended installation position (depicted at the left in Figure 4-1), a rotation is needed of the FotoFiber lower assembly relative to its upper assembly.

4.2.1.1. Rotate lower section relative to upper section

Rotating the lower section relative to the upper section should only be attempted with the sensor removed from the head, on a stable surface, and in a clean environment.

The upper section and lower section can be separated by removing four bolts holding the light source assembly (upper polymer octagon) to the window holder (lower polymer octagon).

To access one of the bolts, it is necessary to swing the processor module out on its hinged base, as shown in Figure 4-2, left (prototype is shown; the final construction is only trivially different), ensuring that the sensor does not fall over.

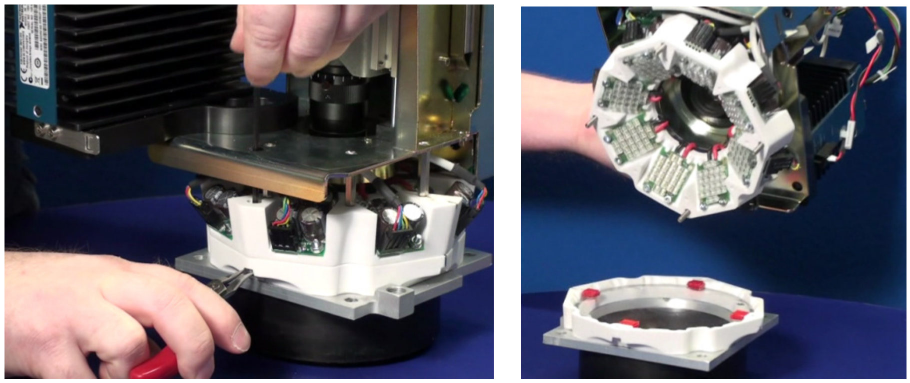


Figure 4-2 Separating Upper and Lower Sections

To locate the bolts at the protruding corners of the octagons, locate the four nuts in the small recesses in the lower surface of the lower polymer octagon. Hold each nut with a small pliers, or other suitable tool, while loosening the bolt with a long hex key.

When all four bolts are fully loosened and the nuts removed, lift the upper section off the lower section (see Figure 4-1, right). Leave the bolts in place to assist in repositioning the upper section on the lower section. A rotation should be chosen that allows the FotoFiber to fit in the head (usually 180 degrees, but ± 90 degrees is also possible).

When the upper part is replaced on the lower part with the desired rotation, replace the nuts on the bolts. Apply thread locking compound when fastening the nuts onto the bolts.

4.2.2. Mechanical installation

Mechanical installation involves removing two existing blank baseplates opposite one another, then installing and fastening the FOMM and FOBM units, or installing two FOMM units opposite each other. If it is a single-sided FotoFiber, a suitable FOBM with sheet-bearing rings must be mounted opposite it.

The FOMM and FOBM are supplied from the factory already mounted on baseplates to facilitate installation. For the FOMM, the baseplate also has an EDAQ installed.

A typical FOMM is shown in Figure 4-3, mounted on a baseplate with the EDAQ. It is viewed from the downstream side, so the air inlet tube is not visible (always on the upstream side).

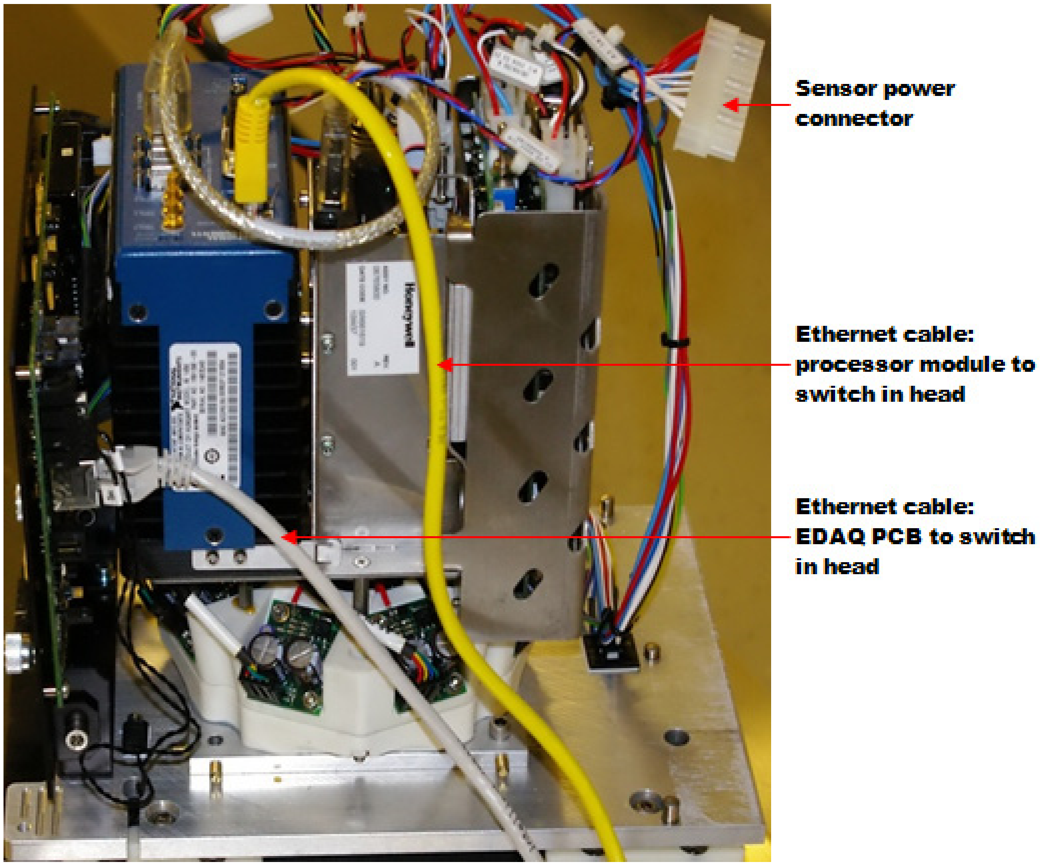


Figure 4-3 FOMM on Baseplate With the EDAQ

Note that if an FOBM is used, it is entirely passive. It has no connections for electrical power or communication or air.

4.2.3. Connections inside the head

There are four connections to be made between the sensor and the head:

- power
- two Ethernet communication lines
- air

CAUTION

> The power switch for the FotoFiber sensor should remain in the *off* position until the entire installation is complete. Preferably, the power cable should be the last connection to be made.

4.2.3.1. Power connector

The standard sensor power connector is used, and should be plugged into the socket in the head which corresponds to the sensor location. A null terminator may need to be removed first. Figure 4-4 shows a null connector on the left, and a Q4233-5x connector on the right.

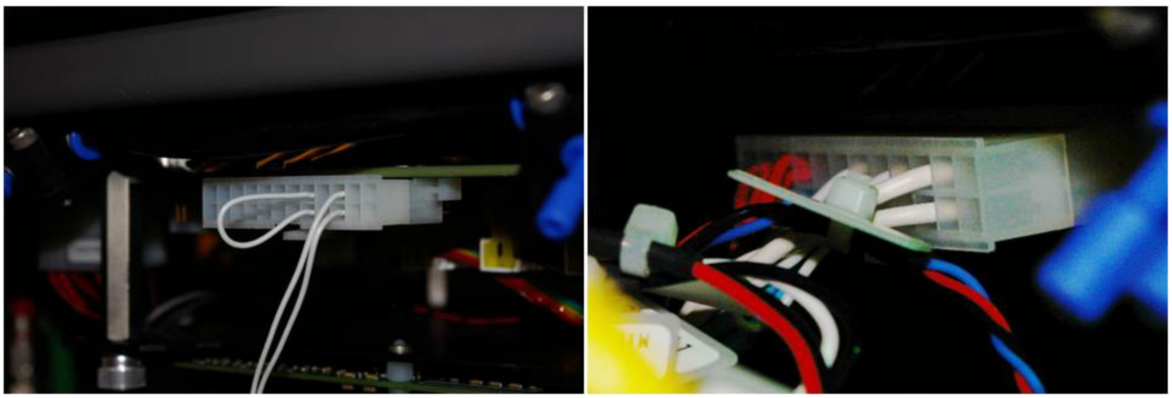


Figure 4-4 Power Connectors Inside Head

The wiring attached to the Fiber Orientation Measurement power connector conveys 24 V DC power to the sensor. It also relays the sensor identity to the MSS, and notifies the sensor that the scanner is the Q4000 type.

4.2.3.2. Ethernet communication

Plug the two Ethernet cables into free ports in the switch inside the head, and verify that the other end is securely inserted into the appropriate socket in the sensor.

In Figure 4-3, the yellow Ethernet cable is for the FOMM processor module, and the white Ethernet cable is for the EDAQ (cable color shown is optional).

4.2.3.3. Air supply

The Q4223-5x sensor requires oil-free clean compressed air to operate. The Q4000 scanner head contains a central manifold at one side supplying such air, with 6 mm (0.24 in.) quick connect sockets. Usually, one of the quick connect sockets supplies air to other manifolds, with 4 mm (0.16 in.) fittings, closer to the sensors. However, the Q4223-5x requires a 6 mm (0.24 in.) fitting to provide sufficient air flow.

The standard provision for the Q4223-5x includes 6 mm (0.24 in.) polyurethane tubing suitable for attaching to a 6 mm (0.24 in.) quick connect socket as shown in Figure 4-5, right (manifold with blue quick connects), with the other end attached to a nipple on the Q4223 as shown in Figure 4-5, left (air hose connection to Q4223-5x).

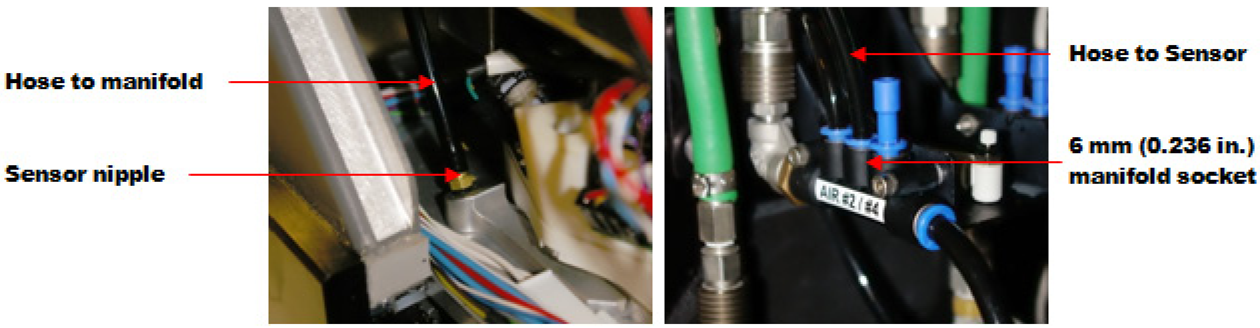


Figure 4-5 Air Connections for Q4223-5x in Q4000 Sensor Head

The air hose provided is longer than required, and shortened during installation, but leaving some slack length (any left over length of hose is secured neatly inside the head). The extra length allows the sensor to be moved partly before removing the air hose, which may be useful in some circumstances.

4.3. Hardware configuration

4.3.1. Hardware checks

The sensor hardware should have been correctly configured during post-manufacture testing at the factory. However, the following items should be checked after the installation is complete:

- The cleaning air-flow to the sensor should be felt at the outlet from the sensor. To check the air flow, hold your hand across the plenum opening of an upper head sensor, or in front of the air slot in the horseshoe of a lower head sensor.

- The trimmed DC output from the power and isolation PCB should be in the range of 49–49.5 V DC. Check and adjust if necessary (see Subsection 9.6.1.2).

- Check the camera focus during operation, after the sensor has reached a normal working temperature. If necessary, adjust the focus (see Section 9.5).
- The window should be clean and free from dirt or smears from handling during installation. This is especially important for the window of a lower head sensor. Inspect and clean if necessary (see Section 9.1).

4.3.2. Sensor parameters

Sensor software parameters are configured using the **FotoFiber Engineering** display, as described in Subsection 6.3.4. For most parameters, the default values will be acceptable, but some are site-dependent. Before proceeding, check that the values configured in Experion MX are sensible, such as the default values shown in Table 6–13, Table 6–14, Table 6–15, and Table 6–16.

The parameters in Subsection 4.3.2.1 through Subsection 4.3.2.5 must always be checked before operating the sensor after installation. Correct values are dependent on the installation and may differ from the default values.

4.3.2.1. Magnification parameter

The magnification of the camera lens is parameter 13 in Subsection 6.3.4.2, with 0.45 as the default value. Typically, the lens magnification is set in the factory to 0.45× which is suitable for grades containing hardwood fibers, softwood fibers, or a mixture of hardwood and softwood fibers. The default magnification is suitable for all grades of paper.

However, if the machine will always produce grades that contain almost exclusively softwood fibers, the sensor performance can be optimized by setting the lens magnification to approximately 0.40× (this might require removing the camera from the sensor for adjustment of the lens), and the parameter can be updated to match the actual magnification.

Similarly, if the machine will always produce grades that contain almost exclusively hardwood fibers, the sensor performance can be optimized by setting the lens magnification to approximately 0.50× (this may require removing the camera from the sensor for adjustment of the lens), and the parameter can be updated to match the actual magnification.

ATTENTION

If the lens magnification is changed, the sensor must be refocused immediately, before the sensor is taken into use (see Subsection 9.5.1). Failure to achieve adequate focus within the travel of the focusing stage indicates that the change in magnification away from the default was too large.

ATTENTION

If the lens magnification is changed significantly (more than 0.05×), update illuminator calibration at the first convenient opportunity (see Subsection 9.5.2). Note that illuminator calibration requires a significant amount of time.

4.3.2.2. Standardization parameters

ATTENTION

Set the standardization parameters so that an onsheet scanning standardization can be performed, even if scanning standardization is to be disabled.

The number of flashes measured per channel is parameter 25 in Subsection 6.3.4.2, with 5 as default value. The number of flashes skipped while changing active channels is parameter 24, with 3 as the default value.

The minimum scan time, T_{min} (minimum number of seconds measuring onsheet) expected on-site must be known. This minimum should take the possibility of scanning between fixed limits into account, as well as edge-to-edge scanning.

ATTENTION

If the minimum scan time T_{min} is expected to be less than 12 seconds, either reduce the scan speed to achieve a longer T_{min}, or reduce the values for parameters 24 and/or 25. In this case, see Subsection 10.2.2.2 for the calculation of suitable values for parameters 24 and 25.

If the minimum scan time T_{min} is expected to exceed 12 seconds, then it may be possible to increase parameter 25, giving more reliable channel efficiency factor measurements. However, the number of flashes remaining for all channels to be used together, F_{rem}, must be adequate:

$$F_{rem} = \left(T_{min} - 1.8\right)\#5 - 8(\#24 + \#25)$$

Equation 4-1

The 1.8 second offset represents time taken for nine strobe state transitions (switching channels on or off). F_{rem} should be at least as large as parameter 25, but if it exceeds parameter 25 by more than 30, then parameter 25 can be increased. If parameter 25 is 10 or more, there is no further need to increase it, even if F_{rem} is quite large. The calculation can be understood by referring to the standardization procedure in Section 5.4. The default value of 3 for parameter 24 is adequate, and does not need to be increased (it can be reduced if necessary).

4.3.2.3. Strobe delay

In a two-sided sensor installation, both sensors receive the same initial tick message, which can have jitter of ± 5 ms, ± 10 ms, or ± 15 ms. It is necessary to delay the strobing of one sensor by a sufficient amount to prevent flash-through disturbances on occasional scans.

For one sensor only, in a two-sided sensor, the strobe delay from initial tick (parameter 51 in Subsection 6.3.4.2) should be set to 32000 µs. The other sensor should have zero for its parameter 51 value.

For a single-sided sensor, parameter 51 is largely irrelevant, but should be set to zero.

4.3.2.4. Clockwise/counterclockwise as positive

Each mill has a convention for the positive direction for angles. The zero direction is always the machine axis. A positive angle may be defined as being in the counterclockwise direction from the machine axis, viewed from above the wire.

The mill convention must be obtained by consulting the mill laboratory personnel. It may also require observing how a cross direction strip is taken from the reel and how it is handled as it is brought to the laboratory and analyzed in the laboratory. Keep track of top/bottom surfaces, drive/tending edges, and headbox-to-reel direction on the sample.

The angle convention for FotoFiber is set using bit 8 of the sensor options bitfield (parameter 53 in Subsection 6.3.4.2). In a two-sided sensor installation, one sensor will have clockwise as positive, while the other will have counterclockwise as positive. The default (bit 8 is zero) is for counterclockwise angles to be positive, as viewed by the sensor camera.

4.3.2.5. Zero angle

This is parameter 16 in Subsection 6.3.4.2. It is used to compensate for combined deviations in the alignment of the machine direction in the image compared to the true machine direction axis.

The variation in alignment of the image detector inside the camera is typically up to ± 1 degree for most camera models. The alignment of the camera inside the

FotoFiber can vary by up to ± 0.5 degrees, due to tolerances in mechanical fixtures such as the angle bracket on which it is mounted. The alignment of the FotoFiber inside the head can also vary by up to ± 0.5 degrees, due to tolerances in mechanical fixtures. The combined alignment deviation will not change significantly when the sensor is removed from, and remounted in, the head; however, the change may be significant if the camera or its mounting fixture is removed and remounted in the sensor. The zero angle must be checked if the FotoFiber camera or its mounting fixture is replaced.

The zero angle is expressed in degrees in the mill coordinate system. Use the factory-supplied value if it is provided. Otherwise, the parameter should be initially set to zero, and can later be estimated to bring the FotoFiber average angle into agreement with the mill average TSO angle (on a single-layer grade). It may need to be updated if significant maintenance operations are performed on the FotoFiber involving remounting the camera in the sensor. The procedure for establishing this parameter is described in Subsection 9.4.2.

ATTENTION

Parameter 16 can be assessed only after the clockwise/counterclockwise bit is set correctly. If the clockwise/counterclockwise bit is changed, the sign of the zero angle will change, and preferably the zero angle should be re-assessed.

4.3.3. MSS and Experion MX parameters

4.3.3.1. Basic RTDR parameters

The real-time data repository (RTDR) parameters should be checked and corrected if necessary, as described in Subsection 6.2.2 and Subsection 6.2.3. Remember that parameters must be set separately for each FotoFiber in the system:

- Ensure that the light controller is PP880, as described in Subsection 6.2.2.1.
- Check the integration times for sample and reference measurements, as described in Subsection 6.2.2.2.
- Ensure that the directories for saving images sent by FotoFiber are defined correctly, as described in Subsection 6.2.2.3. Verify that the directories exist on the QCS server. For a dual-sided FotoFiber, check that directories exist with corresponding parameters for both sensors.
- Ensure that the machine speed scaling has been properly set up, as described in Subsection 6.2.3, to produce a value in meters per second.

4.3.3.2. Sensor job set for MSS

The MSS Job Set IO for FotoFiber should already be set up correctly; however, check the **MSS Job Set IO Setup** display for the FotoFiber sensor. Figure 4-6 shows the **MSS Job Set IO Setup** display for FotoFiber, showing auto-calculated offset.

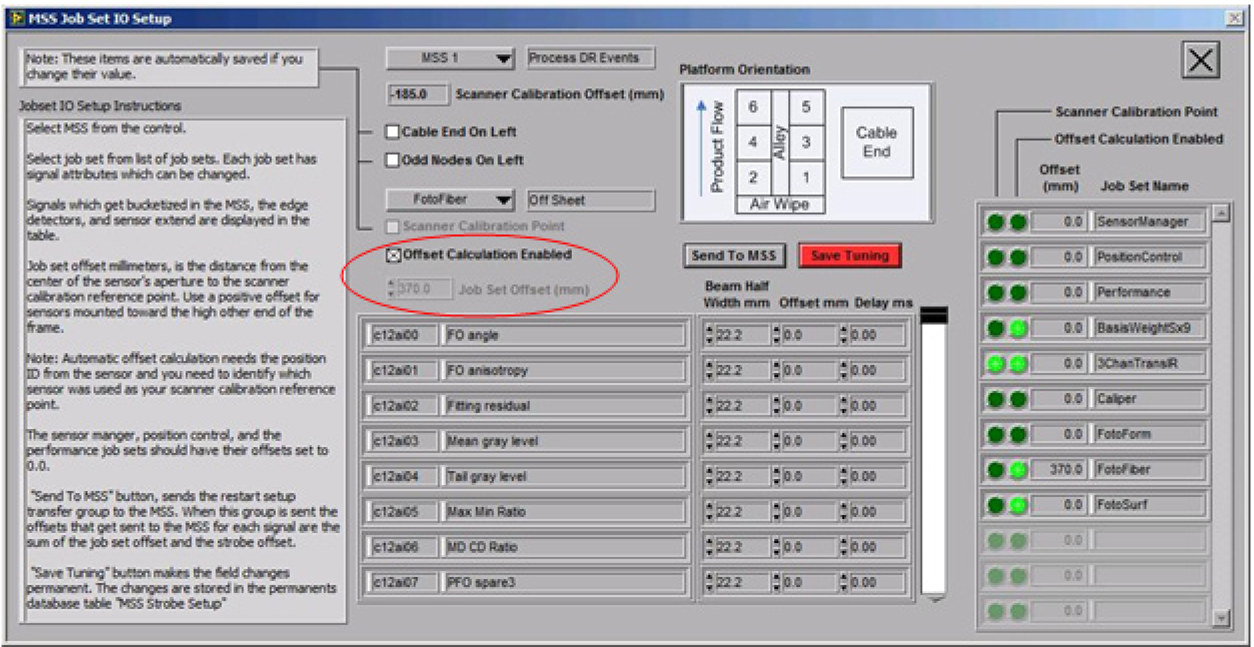


Figure 4-6 MSS Job Set IO Setup Display

For each FotoFiber in the system, check that **Offset Calculation Enabled** is selected. The **Job Set Offset (mm)** is typically either 0.0 mm or ± 370 mm.

Also check the three groups of numbers (**Beam Half Width mm**, **Offset mm**, and **Delay ms**) to the right of every measurement listed for each FotoFiber (you might need to scroll down to see some items):

- **Beam Half Width mm** (first column) is set to 22.2 for all measurements
- **Offset mm** (second column) is set to 0.0 for all measurements
- **Delay ms** (third column) is 0.0 for all measurements

If any changes are made to these parameters, click **Save Tuning** and **Send to MSS** for that FotoFiber.

4.3.4. Measurement parameters

The default parameters in the measurement setup are not always correct. They should be checked and modified if necessary. Figure 4-7 shows the **Measurement Setup** display for **Top FO Angle**.

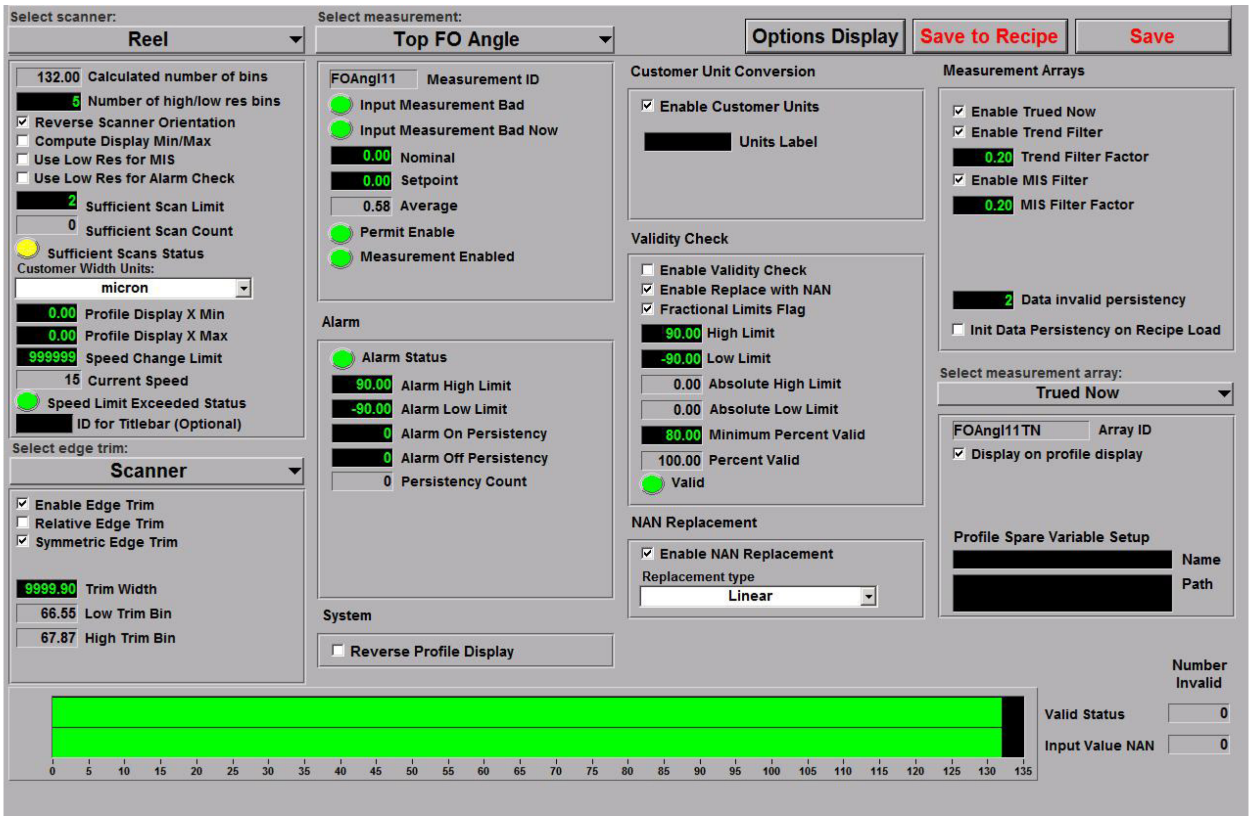


Figure 4-7 Measurement Setup Display (Top FO Angle)

Typical values for some of the measurement setup parameters for the Q4223-5x measurements are shown in Table 4-1. Note that the validity check is usually disabled for these measurements, and that the **Trued Now** profile is preferred over the **Now** profile for displays.

Table 4-1 Parameter Values

Parameter	FO Angle	FO Anisotropy	Max/min Ratio	MD/CD Ratio	Fitting Residual
Nominal	0.0	0.10	1.22	1.22	0.05
Setpoint	0.0	0.10	1.22	1.22	0.05
Alarm High Limit	90.0	0.50	2.00	2.00	0.20
Alarm Low Limit	-90.0	0.00	1.00	1.00	0.00
High Limit (Validity)	90.0	0.50	2.00	2.00	0.20
Low Limit (Validity)	-90.0	0.00	1.00	1.00	0.00

4.4. Sensor start-up

4.4.1. Communication to Experion MX

After the Q4223-5x FotoFiber is installed and communication has been configured for the MSS, check that the communication is working correctly, and enable communication if required.

To check communication:

1. Navigate to the **Scanner Sensor Status** display, and select the correct MSS and FotoFiber sensor (see Figure 4-8).

Figure 4-8 Scanner Sensor Status Display

2. The communication software should auto-enable, but if it is not enabled, manually enable the sensor. It might be necessary to manually enable it more than once after the sensor is installed.

3. If communication cannot be enabled, for example, the status reverts to disabled a few seconds after being enabled, troubleshoot the problem (see Subsection 10.2.5.1).

4. With communication to the Experion MX working, proceed to Subsection 4.4.2.

4.4.2. Post-startup checks

The reference and sample functions are used to verify that basic sensor functions are working while the paper machine is shut down, or if the scanner can be kept offsheet. If there are two FotoFibers, the same steps can be repeated for each.

1. Navigate to the **Sensor Maintenance** display, and select the appropriate FotoFiber sensor (see Figure 4-9).

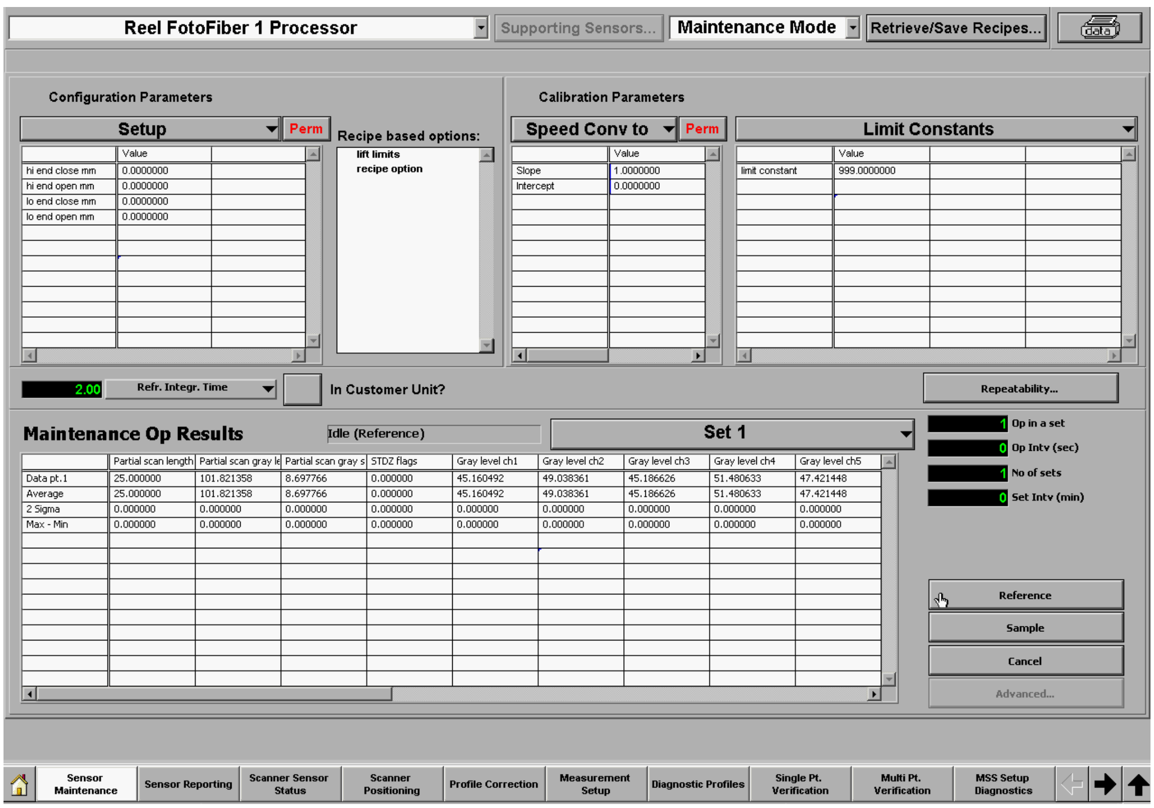


Figure 4-9 Sensor Maintenance Display (maintenance mode)

2. Put the scanner in maintenance mode and, if necessary, retrieve a production recipe.

3. Using the drop-down arrow (**Bkgnd. Integr. Time** in Figure 4-9), check **Refr. Integr. Time** and **Sampl. Integr. Time**, and update the parameters if required (see Figure 4-10). These are the same parameters as are set up in Subsection 6.2.2.2.

   Refr. Integr. Time = 30 seconds

   Sampl. Integr. Time = 4 seconds

Figure 4-10 Set Integration Times

4. Insert any plain piece of uncoated paper or paperboard into the sensor gap, preferably near white in shade, and without any markings, then shoot a reference (see Figure 4-9).

5. Inspect the resulting data, some of which is visible in the lower part of Figure 4-9.

6. It may be necessary to scroll the slider sideways to see all of the channel data, as shown in Figure 4-11.

	Gray level ch5	Gray level ch6	Gray level ch7	Gray level ch8	Gray factor ch1	Gray factor ch2	Gray factor ch3	Gray factor ch4	Gray factor ch5
Data pt.1	47.421448	46.691605	45.703934	44.205414	0.963710	1.046463	0.964268	1.098580	1.011958
Average	47.421448	46.691605	45.703934	44.205414	0.963710	1.046463	0.964268	1.098580	1.011958
2 Sigma	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Max - Min	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

	Gray factor ch1	Gray factor ch2	Gray factor ch3	Gray factor ch4	Gray factor ch5	Gray factor ch6	Gray factor ch7	Gray factor ch8	
Data pt.1	0.963710	1.046463	0.964268	1.098580	1.011958	0.996384	0.975307	0.943329	
Average	0.963710	1.046463	0.964268	1.098580	1.011958	0.996384	0.975307	0.943329	
2 Sigma	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	
Max - Min	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	

Figure 4-11 Typical Reference Data for a Single Reference

The gray levels should not be markedly different for each channel (the actual gray levels will depend on the sample being used), and all of the gray factors should be fairly close to unity. If any channel factor is at or near a limit (range 0.6–1.6), or if any channel gray level is less than 15, or if the ratio of the highest gray level to the lowest is greater than 3, the reference should be repeated. If the problem recurs, maintenance may be required for the sensor. If a particularly dark paper sample is used, all channel gray levels might be low. Try to use a sample which is not too dark.

7. Insert another piece of paper or paperboard into the measurement gap (it is preferable to use a sample with clear directional markings for this test). One possibility is to use the area of the Calibration & Focus Target which has straight lines (see Figure B–1). Position the area with markings in the sensor gap, and shoot a sample (see Figure 4-9), and note the measurement for **FO Angle**.

8. Rotate the patterned sample by an amount which can be easily judged (it is best to rotate by a fairly large angle, such as 45 degrees or 90 degrees), and shoot it again, keeping the patterned area in the measurement gap.

9. Note the change in the measured FO angle, which should be similar to the angle the sample was rotated by. For computing the change in the measured angles, recall that an angle of + 90 degrees, and an angle of - 90 degrees are essentially the same, so wraparound occurs at that angle For example, if the first measurement is 60 degrees, and the sample is rotated approximately 45 degrees, the second measurement could be near 15 degrees or near - 75 degrees.

10. If either of the measured angles is close to ± 90 degrees, there may be an issue with averaging inside the sensor, and Steps 7 and 8 should be repeated, avoiding the ± 90 degrees sample orientation

11. Note that the sample integration time can be set to longer or shorter values than the default of four seconds; however, it should not be set shorter than three seconds.

4.4.3. Establish site-specific parameters

The sample shoot test can be used with the Calibration & Focus Target (see Figure B–1), to ensure that the machine direction/cross direction, and clockwise/counterclockwise settings are appropriate for each sensor, and in agreement with mill conventions. Note that the zero angle parameter must be established separately (see Subsection 9.4.2).

To establish parameters:

1. With the FotoFiber sensor in maintenance mode, ensure that the sample integration time is set to a suitable value, such as four seconds.

2. Position the straight lines section of the Calibration & Focus Target in the sensor measuring spot so that the lines are approximately in the machine direction. Ensure that the patterned side of the target is facing the FotoFiber for which the parameters are to be established.

3. Make a single sample measurement as described in Subsection 4.4.2.

   If the measured angle is close to zero degrees, the MD/CD setting (bit 4 of parameter 53, described in Subsection 6.3.4.2) is correct; however, if it is close to ± 90 degrees, or if the value is smaller but the sigma is very large, for example, the average contained angles near + 90 degrees and - 90 degrees, change the MD/CD setting using the **FotoFiber Engineering** display.

   Send the updated parameters to the sensor and repeat Step 3 before proceeding to Step 4.

4. Reposition the target so that the straight lines section is in the measuring spot with the lines oriented in the direction for which angles are positive.

5. Make a single sample measurement as described in Subsection 4.4.2.

   If the sign of the measured angle is in agreement with the mill laboratory definition of the positive direction for angles, the clockwise/counterclockwise setting (bit 8 of parameter 53, described in Subsection 6.3.4.2) is correct.

   If the sign of the measured angle is opposite to the mill laboratory definition, change the clockwise/counterclockwise setting using the **FotoFiber Engineering** display. Send the updated parameters to the sensor, and repeat Step 5.

   Establish the default values for the channel factors, and set them as parameters 31–34 and 40–43 on the **Fiber Orientation Measurement Engineering** display (see Figure 6–17).

ATTENTION

> Establishing default channel factors is a requirement rather than a recommendation if it is intended to operate the Fiber Orientation measurement with scanning standardization disabled (bit 0 set to OFF and bit 2 set to ON in parameter 53 in Subsection 7.3.4.1).

To establish default values for the channel factors:

1. Select a piece of paper or paperboard from recent production. It is important that this piece be representative of typical production in color and lightness, and that it be free of creases, scratches, or other markings. It is also preferable that it represents typical production at the measurement location and not at some other part of the machine.

2. Put the scanner into maintenance mode.

3. Insert the piece of paper or paperboard into the sensor gap, ensuring that its two surfaces are facing the same way as during production (upper versus lower surface). It may be advisable to secure the sheet in place if the sensor is tilted or there are significant airflows in the area; however, securing it must not cause any curvature of the surface at the region to be measured.

4. Select the appropriate Fiber Orientation sensor and ensure that its reference integration time is set to a suitable value such as 30 seconds.

5. Make a series of at least 10 reference measurements, and record the average values for **Gray factor ch1** to **Gray factor ch8**, as shown in Figure 4-11.

6. Enter the recorded values in the corresponding channel factor parameter values, 31–34, and 40–43, in the **FotoFiber Engineering** display (see Figure 6–17). Ensure that the correct Fiber Orientation sensor was selected in the **FotoFiber Engineering** display.

7. Note that the button for copying channel factors on the **FotoFiber Engineering** display (item 10 in Figure 6–17) will copy the values from the most recent standardization or reference. It will not copy the average of the factors from a series of standardization or reference operations.

8. Click **SEND** (item 3 in Figure 6–17) to both send the parameters to the sensor and to save the parameter values in the permanents database.

9. If there are two Fiber Orientation sensors, repeat Steps 4–8 for the other sensor.

4.5. Remove the sensor

Removing the sensor from the head is the reverse of installing it. Removal of the sensor is needed for some kinds of service operations, as well as whenever a significant repair is needed.

To remove the sensor:

1. Ensure that the sensor carriage is in the offsheet position, with interlocks set to prevent inadvertent scanning, and open the covers to gain access to the sensor.

2. Switch the power to the sensor off using the switch on the power and isolation PCB.

3. Disconnect the sensor power connector shown in Figure 4-4, right.

4. Disconnect the two Ethernet cables (for the EDAQ and the processor module) from the Ethernet switch inside the head.

5. Remove the air hose from the quick release manifold connectors shown in Figure 4-5, and plug them to prevent loss of air pressure to other devices.

6. Remove the entire baseplate containing the Q4223-5x (EDAQ, FotoFiber, wiring, air hoses, and so on) from the scanner head.

7. Insert a suitable blank into the head to fill the gap (if the scanner is to be operated without the Q4223-5x).

   If the scanner is to be operated with only one sensor from a two-sided Fiber Orientation measurement, the blank must have a support ring or arc which complements the remaining sensor. A null connector must be fixed to the sensor as shown in Figure 4-4, left.

5. Operation

This chapter describes the operation modes of the Fiber Orientation Measurement.

5.1. Initialization

When the sensor starts up, it performs these steps:

1. Checks **USER1** switch position:

   If on, the sensor issues a message to the VGA monitor, and reboots in maintenance mode.

   If off, the sensor loads its firmware proceeds to Step 2.

2. Initializes the internal system of message queues, and other software initializations.

3. Checks Experion MX relay position:

   If set for Experion MX, the sensor sets host type to MX and proceeds to Step 4.

   If set for Da Vinci, the sensor sets host type to Da Vinci and proceeds to Step 6.

4. Establishes a serial link with the EDAQ; receives IP address; starts receiving time synchronization data.

5. Establishes Ethernet link with MX host; starts sending *Alive and Well* messages; requests configuration parameters; proceeds to Step 7.

6. Establishes serial link with MSS; starts sending *Alive and Well* messages; requests configuration parameters.

7. Waits for configuration parameters.

8. When configuration parameters are received, initializes camera, strobe, and FPGA to appropriate modes; if necessary, sets default values to optional configuration parameters; reports firmware version; sets initial values to operating states; creates blank image buffers of appropriate sizes.

9. Exchanges *Alive and Well* messages with MSS while waiting for further commands.

5.2. Onsheet scanning operation

Scan procedure:

1. Prepare scan.

2. Do slice measurements at 10 Hz, and gather scan average of image intensity.

3. Pass data to end-of-scan operations.

Slice measurement (at 10 Hz):

1. Take an epi-illuminated image of the web.

2. Apply mathematical algorithms to the corrected image to calculate the fiber orientation histogram and its parametric representation (see Section 1.4).

3. Communicate the measured fiber orientation parameters to the Experion MX host.

Detailed measurement (at 0.5 Hz) consists of the following additional step:

4. Send computed measured histogram, and its fitted histogram and fiber orientation parameters to Experion MX system for operator display.

Image communication (optionally performed at one or more specified locations in the scan) consists of the following additional step:

5. Send measured image, computed measured histogram, and its fitted histogram and fiber orientation parameters, to Experion MX system for operator display.

5.3. End-of-scan operation

All parameters of imaging (including camera and light pulse parameters) are adjusted at end-of-scan:

- auto-adjust light pulse length, based on machine speed, to keep the amount of motion blur within acceptable limits
- auto-adjust light source total intensity and the camera gain, based on scan average, in order to have a constant signal level (mean graylevel) from the camera
- balance the levels used in each illuminator channel, to keep directional uniformity of illumination, using channel efficiency factors from standardization

This allows significant grade changes without any preparation; the sensor adjusts itself automatically to changes in light absorption and reflection of the web.

5.4. Standardization

The purpose of standardization is to compensate the illumination channels for differences in intensity (as seen by the camera) due to mild dirt build-up, aging of components, and changes in the color of the paper. It will also indicate malfunctioning or aberrant performance of an illuminator channel.

ATTENTION

> The Fiber Orientation sensor must perform standardization onsheet. It must use the current production paper as its standardization reference. Internal references are neither supplied nor needed.

When a manual or scheduled standardization is initiated for the other sensors, the Fiber Orientation sensor sets an internal flag to specify whether its next scan will be for standardization. The flag is set to the same value as the scanning standardization enabled parameter flag (bit 1 of engineering parameter 53). If this flag is on, the next scan will be a standardization scan; otherwise, it will be a normal measurement scan. The sensor waits approximately one second, then sends a standardization finished message to the MSS.

The standardization message contains the most recent standardization results, which might be from the most recent reference operation (if any), or from the most recent scanning standardization attempt (if any), or from the most recent single point standardization (if any), or the default parameters received from the host (if no standardization or reference was attempted after the sensor was booted). This data is used to create a new fiber orientation standardization record in the standardization database. The message also contains a flag for the fiber orientation standardization trends in Experion MX to ignore the data.

If the scanning standardization flag is *not* set, the sensor performs normal measurement scans with its existing factors. If the standardization flag is set, the sensor performs the following standardization sequence (when the next scan starts):

1. Sets camera to standardization mode (stores current gain, and sets gain to four).

2. Disables all strobe channels.

3. Waits until onsheet.

4. For each strobe channel, in a predetermined sequence:

   enables the channel and sets the channel strength to the average channel level used in the last scan

   captures and discards a number of images (quantity determined by engineering parameter 24)

   captures a number of images (quantity determined by engineering parameter 25), and computes the average of their mean gray levels

   computes the raw ratio of the average graylevel to the calibration graylevel for the same pulse length and strength

   disables the channel

5. Computes channel efficiency factors by dividing raw ratios by average of all raw ratios.

6. Sets error or warning flags if necessary:

   if any channel graylevel is out of range (set by engineering parameters 27 and 28), sets an error flag

   if any channel factor is out of range (0.6–1.6), sets a warning flag and limits the factor to the allowed range

7. Sets camera to scan mode, restoring the pre-standardization gain.

8. Enables all strobe channels.

9. For the rest of the scan:

   captures and discards a number of images

   captures and counts the remaining images as combined images

   computes the average of the mean gray levels of these images

10. Sets error or warning flags if necessary:

    if the combined graylevel is out of range (set by engineering parameters 27 and 28), sets an error flag

    if the number of combined images is less than 5, sets a warning flag

11. Reports the following data to the MSS:

    warning and error flags

    number of gray scan images

    channel graylevels

    channel factors

12. If there were no error flags, sets next scan to be a measurement scan; otherwise, sets next scan to be a standardization scan.

Standardization must complete in a single traverse; it cannot be split over multiple traverses. The time required onsheet in a single traverse for standardization depends on several of the configuration parameters and preferably exceeds 12 seconds (see Subsection 4.3.2.2).

The channel factors, channel graylevels, number of combined images, and combined image mean graylevel for the most recent standardization are shown on the **FotoFiber Standardization** display (see Subsection 6.3.2). The display also has trends of these values and of the error and warning flags. These trends will include all successful standardizations and all failed attempts at standardization.

5.4.1. Standardization database

The scanning standardization data (if any) are also sent in the standardization report for the next scheduled standardization, and are placed into the standardization database. There will be exactly one fiber orientation standardization record in the standardization database for each scheduled standardization of other sensors, even though the standardization data entered was obtained earlier.

If standardization succeeds after one or more failed attempts, the results of only the successful scanning standardization will be recorded in the database. However, if scanning standardization does not succeed, the record will contain results from the last failed scanning standardization before the subsequent standardization request for other sensors.

If scanning standardization is disabled, the fiber orientation record in the standardization database will contain one of the following:

- the default factors
- the factors sent as parameters
- the result of the most recent standardization after the sensor was booted

The most recent standardization could be one of the following:

- a reference operation in maintenance mode
- a scanning standardization performed before scanning standardization was disabled
- a single point standardization

5.5. Onsheet single-point operation

The Fiber Orientation sensor also has a single-point measurement mode. The sensor does not distinguish between single-point mode and fixed-point mode, it operates identically in both modes.

The procedure involves an onsheet adjustment of illumination, followed by an onsheet standardization, before measurement begins. This is because it might start single-point mode after being offsheet, and needs to adjust illumination to fit current production. Using single-point mode for standardization might be useful if scanning standardization must be disabled and samples of the sheet at the measurement location are not easily obtained.

Single-point procedure (after the sensor has reached the designated single-point position onsheet):

1. Adjust the illumination intensity to achieve the target graylevel (maximum three iterations allowed).
2. Using existing channel factors, balance the illumination.
3. Perform a standardization using the illumination conditions established in Steps 4 to 8 in Section 5.4 giving new channel factors
4. Report the standardization data the MSS, as in Step 11 of Section 5.4, except that the reported values and flags for the combined images are those corresponding to Step 1 in this procedure.
5. The next scan is set to be a standardization scan if scanning standardization is enabled; otherwise it is set to be a measurement scan.
6. Rebalance illumination using the new channel factors.
7. Do slice measurements at 10 Hz.

Slice measurement (at 10 Hz):

1. Take an epi-illuminated image of the web.
2. Apply mathematical algorithms to the corrected image to calculate the fiber orientation histogram and its parametric representation (see Section 1.4).
3. Communicate the measured fiber orientation parameters to the Experion MX host.

Detailed measurement (performed at 0.5 Hz) consists of the following additional step:

4. Send computed measured histogram, its fitted histogram and the fiber orientation parameters that are derived from it, to the Experion MX system for operator display.

Image communication (performed every 20 seconds during single-point measurement) consists of the following additional step:

5. Send measured image, computed measured histogram, and its fitted histogram and fiber orientation parameters, to the Experion MX system for operator display.

5.6. Reference mode

The Fiber Orientation sensor has a reference measurement feature available as an offsheet function in the Experion MX maintenance mode.

A reference measurement should always be performed before making sample measurements, preferably using one of the samples to be measured, or a sample of color and lightness which is representative of the set of samples to be measured.

A reference measurement can also be used for standardization of the sensor if scanning standardization is disabled. In this case, the reference should use a sample taken from the current production, and should be performed whenever there is a significant change in the color or lightness of the paper.

To take a reference measurement:

1. Configure Experion MX system to maintenance mode.
2. Set *Reference Integration Time* to at least 30 seconds (the default).
3. Place the sample into the sensor gap in the same orientation as the paper web (machine direction and cross direction, as in the paper web).
4. Push the **Sample** button.
5. Look at the results gathered on the **Maintenance** display (see Figure 4–11).

When the reference button is pressed, the sensor performs the following reference sequence, which is similar to the scanning standardization sequence:

1. Initializes imaging system:

   sets camera to scan mode

   sets pulse length according to nominal machine speed for sample mode

   sets all channels to initial level

2. Finds a suitable illumination level, by repeating a maximum of three times:

   captures a number of images, and computes the average of their mean graylevels

   adjusts channel levels to bring graylevel to target

3. Sets error flag if the graylevel is out of range.

4. Sets camera to standardization mode; stores current gain, and sets gain to maximum.

5. Switches off all strobe channels.

6. For each strobe channel, in a predetermined sequence:

   enables the channel and sets the channel strength to the average channel level used in the last scan

   captures and discards a number of images (quantity determined by engineering parameter 24)

   captures a number of images (quantity determined by engineering parameter 25), and computes the average of their mean graylevels

   computes the raw ratio of the average graylevel to the calibration graylevel for the same pulse length and strength

   disables the channel

7. Computes channel efficiency factors by dividing raw ratios by average of all raw ratios.

8. Sets error or warning flags if necessary:

   if any channel graylevel is out of range (set by engineering parameters 27 and 28), sets an error flag

   if any channel factor is out of range (0.6–1.6), sets a warning flag and limits the factor to the allowed range

9. Sets camera to scan mode (restores gain).

10. Enables all strobe channels.

11. Reports the following data to the MSS:

    warning and error flags

    number of gray scan images

    channel graylevels

    channel factors

12. Sets mode to idle.

There is always an adequate number of images used for gray determination, so the corresponding warning flag is off. The reported error flag for the combined images is the same as from Step 3.

5.7. Background

The Fiber Orientation sensor does not have a background function.

5.8. Sample measurement

The Fiber Orientation sensor has sample measurement available as an offsheet function in the Experion MX maintenance mode. The orientation angle measured in sample mode will depend on the alignment of the sample in the measurement gap.

A reference measurement should be made on one specimen to allow the sensor to adjust the illumination parameters correctly before starting the sample measurements; otherwise, the image could be severely overexposed or underexposed, leading to an unreliable measurement.

The specimen chosen for the reference can be randomly chosen if all of the specimens are of similar color and lightness, and is preferably near the average color and lightness if there is some variation among the specimens. When making a series of sample measurements on specimens of similar color and lightness, there is no need to make another reference measurement; however, if sample measurements are to be made on specimens with greatly differing color or lightness, a separate reference step should be performed before each series of specimens of similar color and lightness, and using a specimen characteristic of that series.

To take a sample measurement:

1. Configure Experion MX system to maintenance mode.
2. Set *Sample Integration Time* to at least three seconds (the default is four seconds, which averages more raw readings).
3. Place the sample into the sensor gap in the same orientation as the paper web (machine direction and cross direction, as in the paper web).
4. Push the **Sample** button.
5. Repeat Steps 3–4 until all samples have been measured.
6. Look at the results gathered on the **Maintenance** display (see Figure 4–9).

6. Software

In this chapter, the details of FotoFiber software are described.

6.1. Functional overview

An overview of FotoFiber software is shown in Figure 6-1.

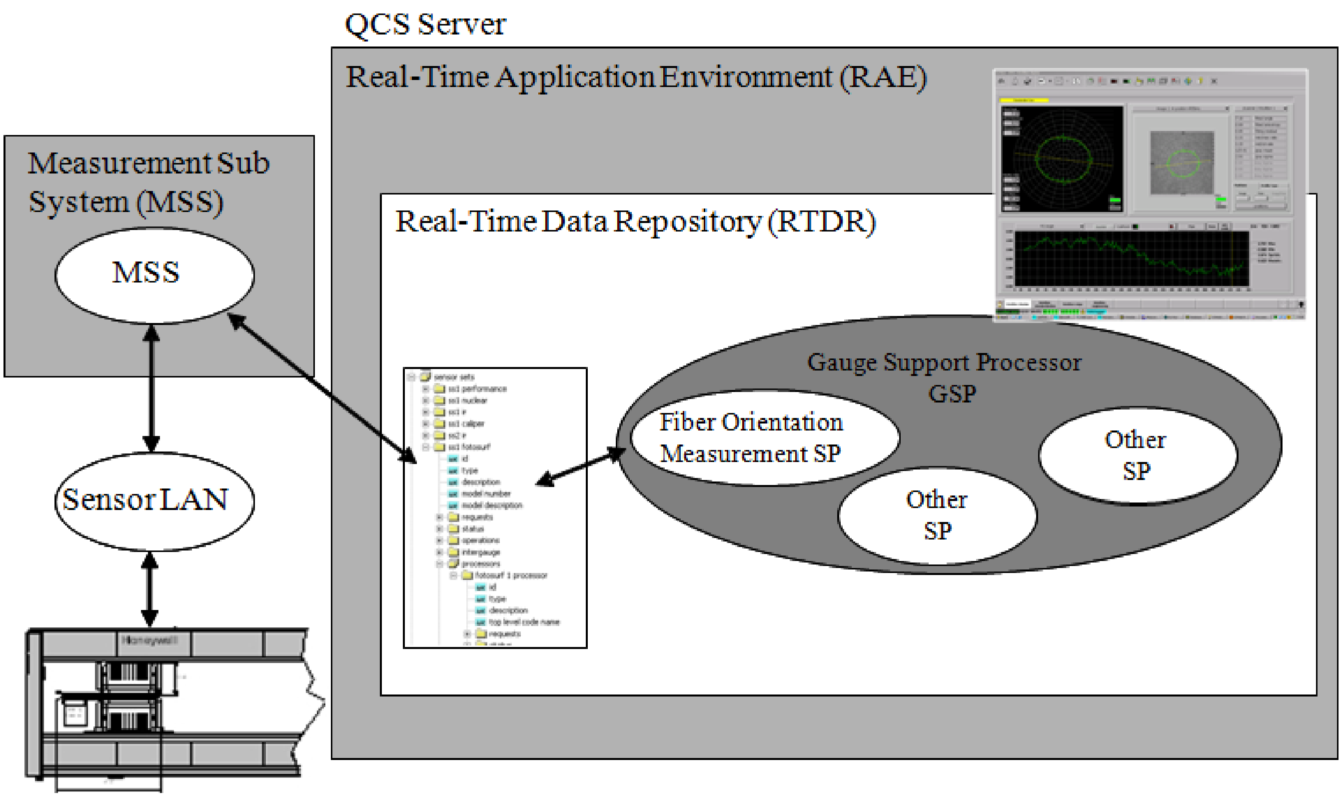


Figure 6-1 Fiber Orientation Measurement Software

6.1.1. Data flow

Each Experion MX FotoFiber sensor is connected to Experion MX via the sensor LAN (100 Mbit/s Ethernet). All communication to and from the sensor is done via this link, with messages adhering to the Camera Sensor Link Protocol (CSLP).

6.1.1.1. Camera sensor link messages

Camera Sensor Link data is located in the *scannerX/mss/ssX FotoFiber/setup* RTDR record, where X = sensor set number. The message types are shown in Table 6-1 and Table 6-2.

Table 6-1 Message Types: FotoFiber to MSS

Message	**Type**	**Bytes**	**Sensor-to-RTDR**
Configuration Data Request	10_H/16	1	---
Alive and Well	30_H/48	4	---
Mode Status	11_H/17	1	---
Stdz Data	12_H/18	80	Standardize Data Buffer
Slice Data	13_H/19	44	OFSxAIA… OFSxAIJ (in RTDR at *ScannerX/mss/ssX fotofiber/sensor inputs/*)
End of Scan Data	14_H/20	40	End Of Scan Data Buffer
Image Data	15_H/21	20001	Image Data Buffer 1–5
Diagnostic Data	16_H/22	40	Diagnostic Data Buffer
Versatile Data	32_H/50	Max 2Mb	Versatile Data Buffer

Table 6-2 Message Types: MSS to FotoFiber

Message	**Type**	**Bytes**	**RTDR-to-MSS**
Configuration Data	20_H/32	220	Configuration Data Buffer
Alive and Well	30_H/48	4	Process Data (First item is Line speed in meters per second. This is sent to the sensor in the alive and well message.)
Mode Change Request	21_H/33	1	---
Diagnostic Request	22_H/34	2	---
Initial TIC Count	23_H/35	1	---
Trigger Image	24_H/36	5	---
Recipe Parameters	31_H/49	80	Recipe Data Buffer
Versatile Data	32_H/50	Max 2Mb	Versatile Data Download

The FotoFiber sends a *Configuration Data Request* message, after the TCP link is established to the MSS. The MSS sends a *Configuration Data* message in response, and sends both the *Configuration Data* and *Recipe Parameters* messages each time the grade recipe is changed or on request from the **FotoFiber**

Engineering display. The FotoFiber does not use recipe-based parameters, so the Recipe Parameters message is ignored.

The FotoFiber and the MSS send the *Alive and Well* messages to each other every four seconds. The message from the MSS also contains the machine speed in meters per second.

The *Stdz Data* message is sent, after a short delay, in response to a mode request for standardization or reference from the MSS. If the request was for reference, the contents of the message are the results of the reference operation. If the request was for standardization, the contents of this message are the results of the last performed standardization (in scan or single-point), or reference. If no standardizations or references are performed after the sensor booted, the message contains default standardization data.

The MSS sends *Mode Change Request* messages at the start and end of each scan, single-point, standardization, reference, and sample mode. The *Mode Status* message is sent by the FotoFiber in response to these messages.

At the start of a scan, the MSS also sends an *Initial TIC Count* message for synchronization, and will send *Trigger Image* messages as required for image acquisition. During the scan, the FotoFiber sends *Slice Data* messages for every measurement, and sends *Image Data* messages in response to the image requests. The *End of Scan Data* message is sent shortly after the end of each scan.

Within the Versatile Message type, there are a number of supported sub-types. These are listed in Table 6-3 and Table 6-4.

Table 6-3 Versatile Message (32_H/50) Subtypes: FotoFiber to MSS

Message	Type	Bytes	Sensor-to-RTDR
Stdz Data	12_H/97	80	Standardize Data Buffer or Reference Data Buffer
Image Data (Histogram)	15_H/21	2916	--
Diagnostic Data	16_H/22	40	Diagnostic Data Buffer
Configuration Data	20_H/32	220	Configuration Data Buffer
Strobe Parameters	65_H/101	44	--

Table 6-4 Versatile Message (32_H/50) Subtypes: MSS to FotoFiber

Message	Type	Bytes	RTDR-to-MSS
Initialize Communication	63_H/97	0	--
Force to Idle Mode	64_H/98	0	--
Reboot Request	65_H/99	0	--

The Versatile Message, *Configuration Data*, is sent in response to receiving configuration parameters. It contains the same configuration data as was received, except that the FotoFiber firmware version is used to replace whatever value was received for parameter 4.

The Versatile Message, *Stdz Data*, is sent after a standardization while the sensor is scanning or in single-point mode, and contains the results of that standardization. The same message is sent after the normal standardization message in reference mode, and contains the same data.

The Versatile Message, *Image Data*, is sent periodically through each scan or single-point operation, and one or more times in a sample measurement. It contains the polar histogram of a selected measurement together with the parametric fit to that measurement.

The Versatile Message, *Strobe Parameter*, is sent after the end of each scan after performing a reference mode standardization, and after the initial standardization in single-point. It contains the strobe settings and camera gain used to rebalance the illumination.

The Versatile Message, *Diagnostic Data*, is sent by FotoFiber in response to a corresponding *Diagnostic Request* message from the MSS.

The Versatile Message, *Force to Idle Mode*, and Versatile Message, *Reboot Request* are sent by the MSS when the corresponding button is clicked on the **FotoFiber Engineering** display.

The Versatile Message, *Initialize Communications*, has no effect and is ignored on MX systems. The button to generate this message is grayed-out on the **FotoFiber Engineering** display.

6.1.2. Sensor processor

The sensor processor of the Fiber Orientation Measurement is located under *C:\Program Files\Honeywell\Experion MX\Gauging\Labview Vis\Processors\Precision FotoFiber* folder and it handles all data sent from the sensor.

The correspondence between the sensor processor activity, the sensor inputs child record, and the VI that handles data is shown in Table 6-5.

Table 6-5 Correspondence: Sensor Processor ↔ Sensor Inputs Child Record

Sensor Processor Activity	**Sensor Inputs Child Record**	**Handled by VI**
Maintenance Background	Background	Not in use
Maintenance Reference	Reference	*SP PFOx Reference.vi*
Maintenance Sample	Sample	*SP PFOx Single Point.vi*; *SP PFOx Sample Image Data.vi*
Production Background	Background	Not in use
Production Standardize	Reference	*SP PFOx Reference.vi*
Production Single Point	Single Point	*SP PFOx Single Point.vi*
Production Periodic Measurement	Periodic	*SP PFOx Single Point.vi*
Production EOS Forward and Production EOS Reverse	Scan	*SP PFOx End of Scan.vi*; *SP PFOx Image Data.vi*
Production Buffered Single Point	Buffered Single Point	*SP PFOx Buffered Single Point.vi*
Scan Forward	Scan	*SP PFOx End of Scan.vi*
Scan Reverse	Scan	*SP PFOx End of Scan.vi*

6.2. RAE Configuration

The Q4223-5x Fiber Orientation Measurement software is a standard feature of the following RAE versions, and later revisions.

- RAE R610

Software to support the Q4223-5x Fiber Orientation Measurement can be added to the following RAE versions by installing the Fiber Orientation Measurement add-on package:

- RAE R600
- RAE R601
- RAE R602
- RAE R603

If your system is among the add-on compatible versions, contact Honeywell QCS-TAC for assistance to get the Fiber Orientation Measurement add-on package.

Instructions for installing the add-on package are included with the package, and are not dealt with in this manual.

If your system is an earlier version than those listed above, it will need to be upgraded to a suitable version before the Fiber Orientation Measurement can be installed. It is recommended that any upgrade be to the newest version of RAE.

6.2.1. Add FotoFiber to the system

One or more Fiber Orientation sensors must be added to the system definition, and the system database must then be recrunched:

1. Open the **Configuration Data Repository Browser** (**Configuration Browser** in the application menu).
2. Go to the */Systems/SysXxxx/framepackages/Same*, or *Similar Spot/frames/scannerX/sensorsets/*.
3. Right-click on the sensorsets and select **Add Object**.
4. Select *Fiber* from the sensor list, and choose either a top or bottom sensor as the **sensorset Template**, then click **Save** (Figure 6-2 shows a bottom sensor selected).

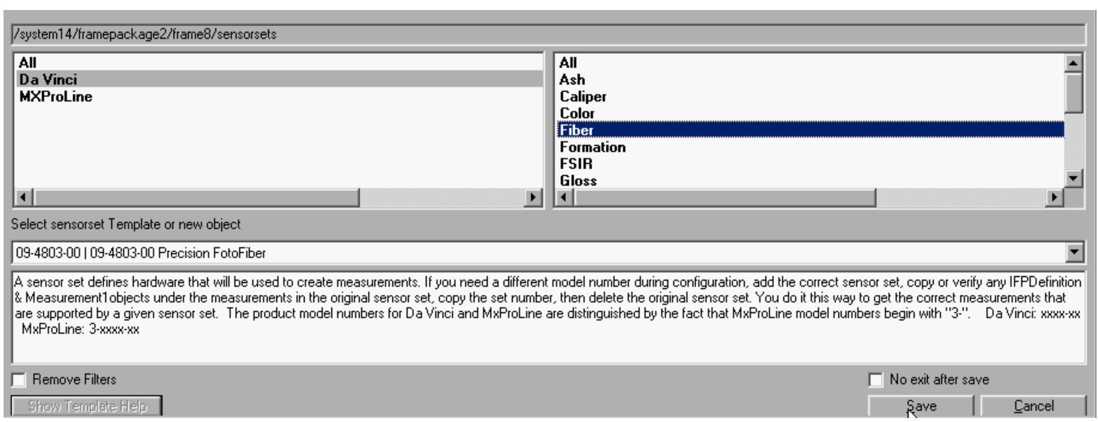


Figure 6-2 Adding a Q4223-5x FotoFiber Object

5. A *Fiber Orientation - EDAQ* sensor is added to the sensor set of the selected system. Note that the option mask for this sensor is always zeros, and should be left unchanged.
6. Check the set number for the added sensor (see Figure 6-3). The software build should give the correct value by default; however, if there are two FotoFiber sensors in the same scanner, they must have different set number values, typically 1 and 2. Note that the values for

other parameters will be determined during installation of the sensor hardware, as part of the MSS configuration (see Subsection 4.3.3).

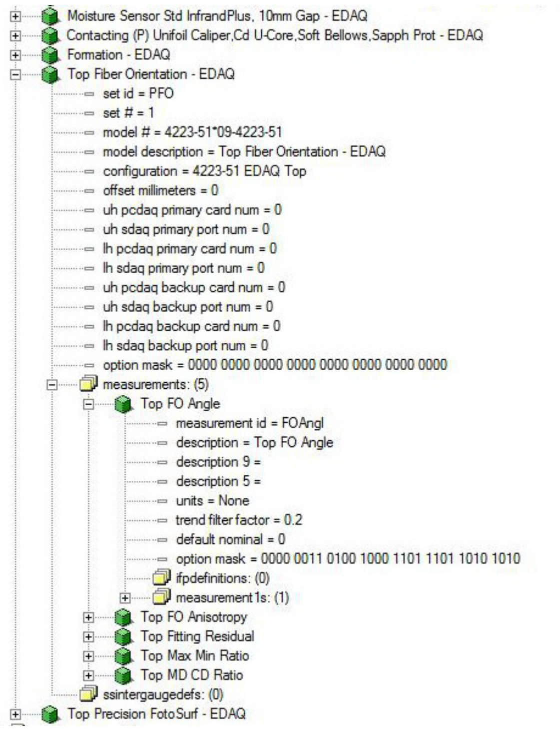


Figure 6-3 FotoFiber Parameters in the Configuration Browser

7. The FotoFiber options can be inspected for each of the measurements produced by the sensor. Figure 6-4 shows the **Edit Options for Top FO Angle** dialog.

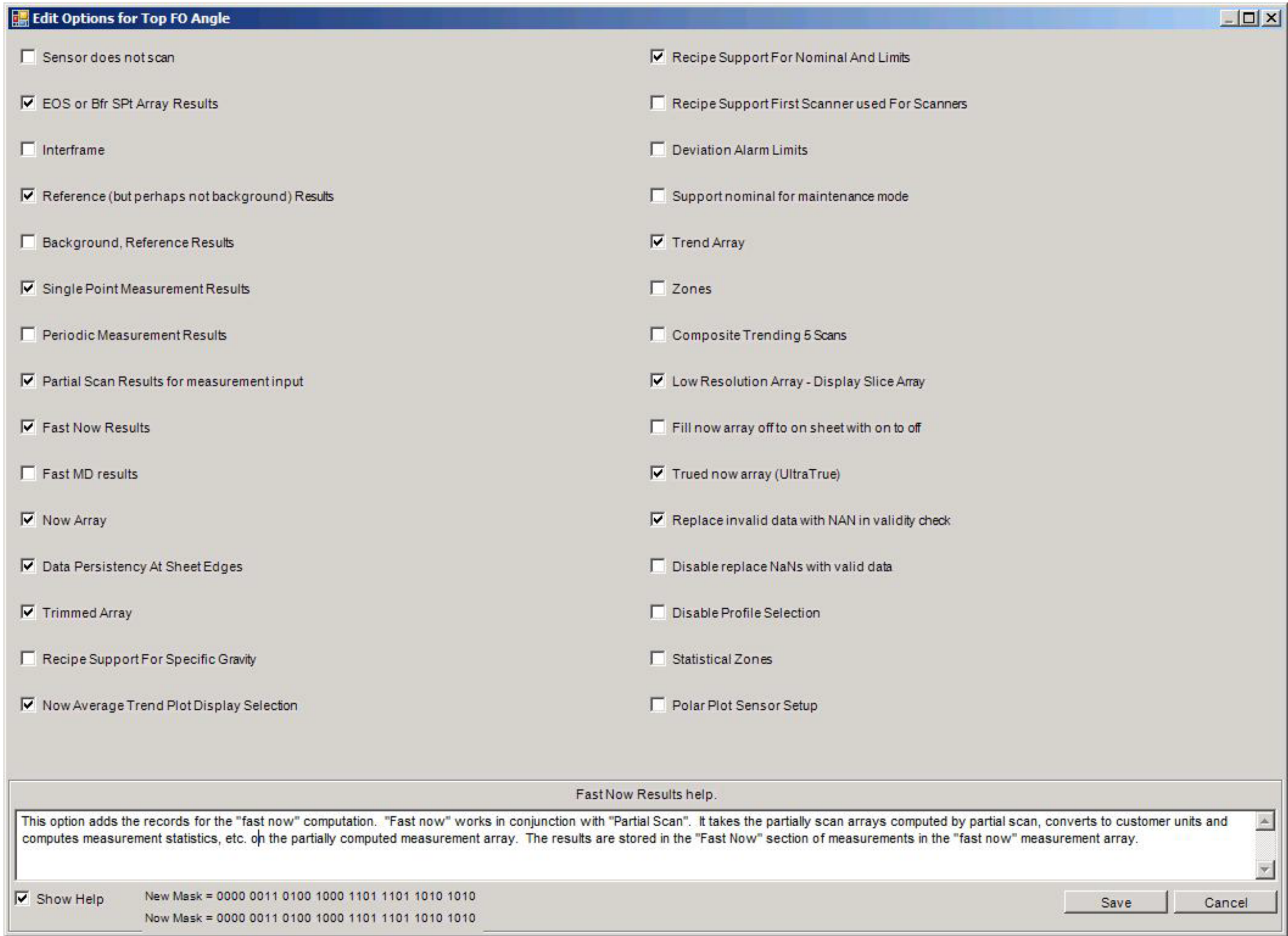
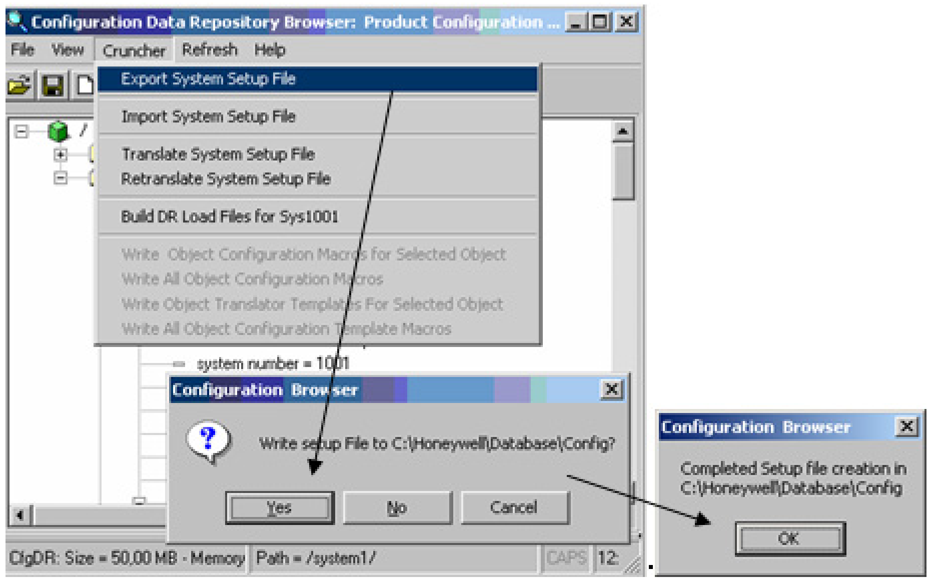


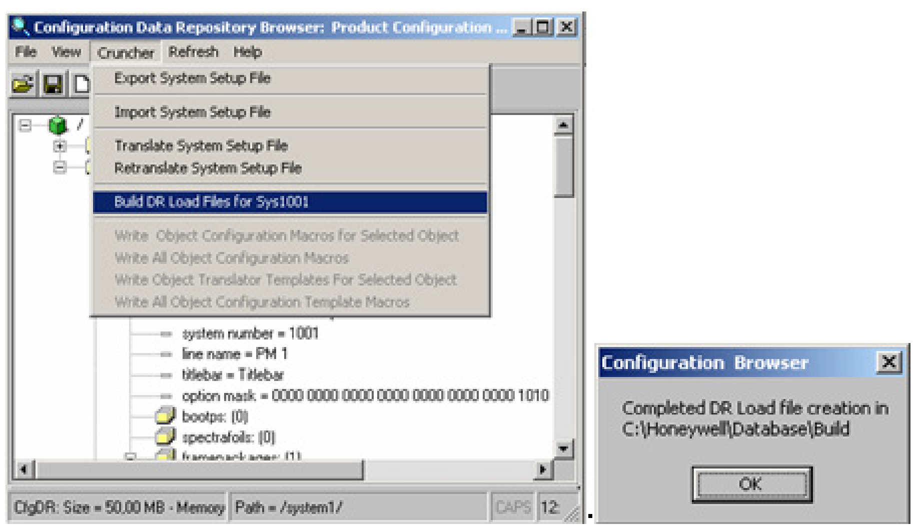
Figure 6-4 Edit Options for Top FO Angle Dialog

8. In the **Configuration Data Repository Browser**, select **Cruncher**, then select **Export System Setup File**.

9. Click **Yes**, then **OK** in the **Configuration Data Repository Browser** pop-ups.



10. Select **Cruncher**, select **Build DR Load Files for SysXxxx**., then click **OK** in the popup.



6.2.2. Set configuration parameters

Some basic parameters must be checked using the RTDR browser, and any changes must be saved to permanents database using the **Set perm** button. They are defined separately for each FotoFiber sensor in the system.

6.2.2.1. Light controller type

Light controller type is defined by the *scannerX/mss/ssX FotoFiber /FotoFiber X processor/configuration parameters/cnfg parameters* RTDR parameter with index zero, where X = sensor set number.

There are two choices: 1=PP810, or 2=PP880 (default=2). This must not be changed from the factory setting. FotoFiber always uses PP880, and this parameter must always be set to 2 (see Figure 6-5).

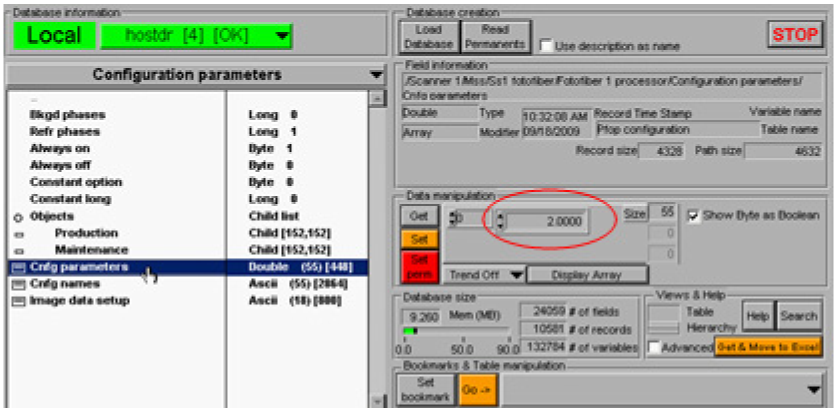


Figure 6-5 Light Controller Type (must be 2)

This step must be repeated for each Q4223-5x sensor in a system.

6.2.2.2. Sample and reference integration times

Check the default integration times for sample mode and reference mode, and changed if necessary. The RTDR parameters are expressed in milliseconds, and should be:

- */scanner X/mss/ssX fotofiber/setup/Reference time ms*: 30000
- */scanner X/mss/ssX fotofiber/setup/Sample time ms*: 4000

These steps must be repeated for each Q4223-5x sensor in a system.

6.2.2.3. Image data definitions

The image data folder and file names are defined in the RTDR array of ASCII strings */scannerX/mss/ssX fotofiber/fotofiber X processor/configuration parameters/image data setup*, as shown in Figure 6-6. Default values are set by the build file (*BuildOFSP.mac*) and they do not need to be changed.

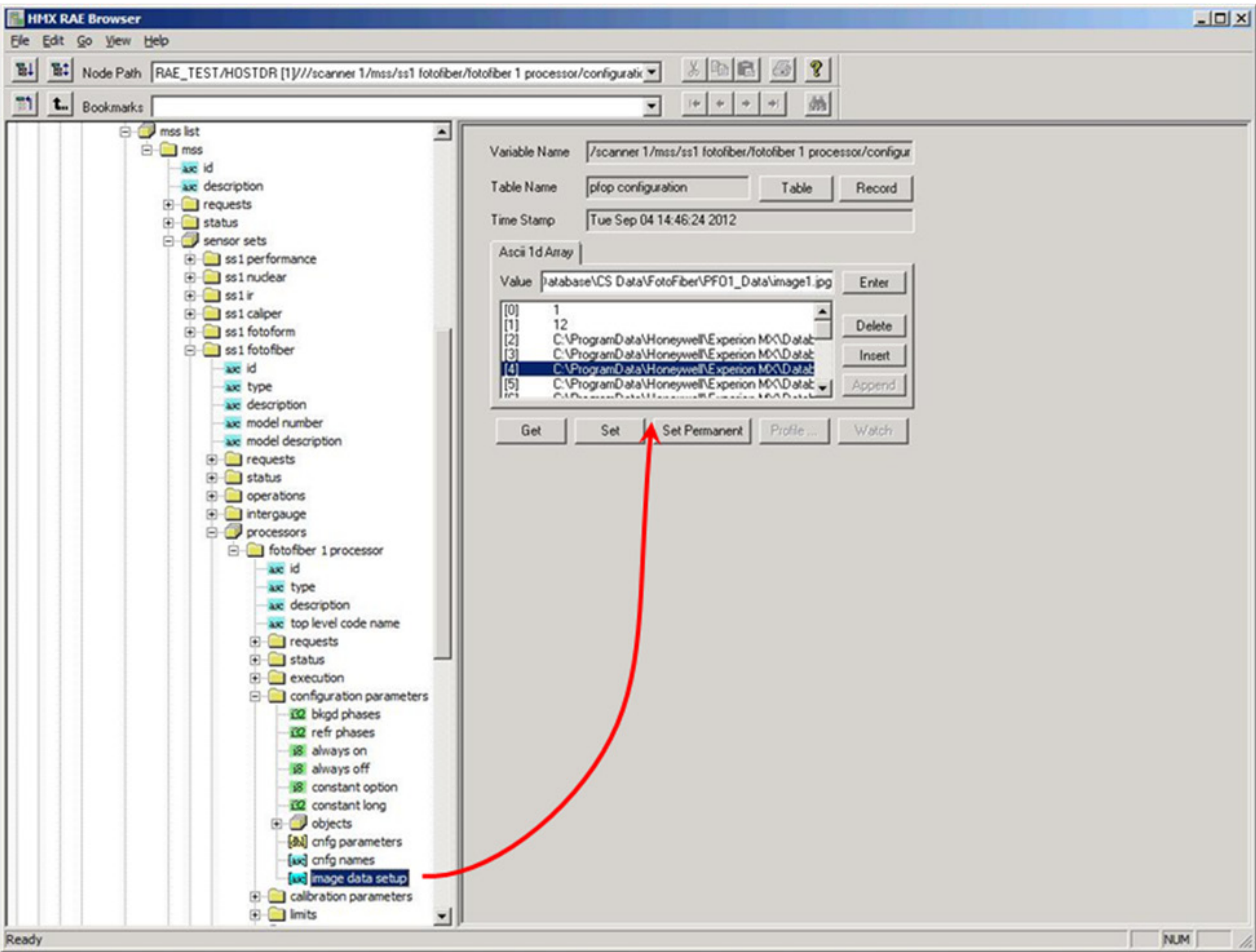


Figure 6-6 HMX RAE Browser: Image Data Setup Strings for FotoFiber 1

The file names start at offset 4 for the JPEG files, and offset 9 for the corresponding data files. They are strings specifying relative paths of the image files appended to the contents of the environment variable %MXRTDB% (typically, *C:\ProgramData\Honeywell\ExperionMX\Database*), yielding composite strings such as *C:\ProgramData\Honeywell\ExperionMX\Database\CS_Data\FotoFiber\PFO1_Data\image1.jpg*

The image files are named from *image1.jpg* to *image5.jpg* for each sensor. All of these would have *PFO2_Data* instead of *PFO1_Data* in their directory names for images from a second FotoFiber sensor.

6.2.3. Set line speed scaling

FotoFiber needs to receive current line speed in units of meters per second (line speed is typically in the range 5–25 m/s) from Experion MX for proper exposure adjustment. As the line speed available in RTDR parameter *./scannerX/status/scan data/speed* might not always be in these units, a scaling is needed:

Line Speed [m/s] = speed * speed slope + speed intercept

RTDR parameters *./scanner X/mss/ssX fotofiber/Fotofiber X processor/Calibration parameters/speed slope*, and *./scanner X/mss/ssX fotofiber/Fotofiber X processor/Calibration parameters/speed intercept* need to be configured in order to get correct scaling (see Figure 6-7).

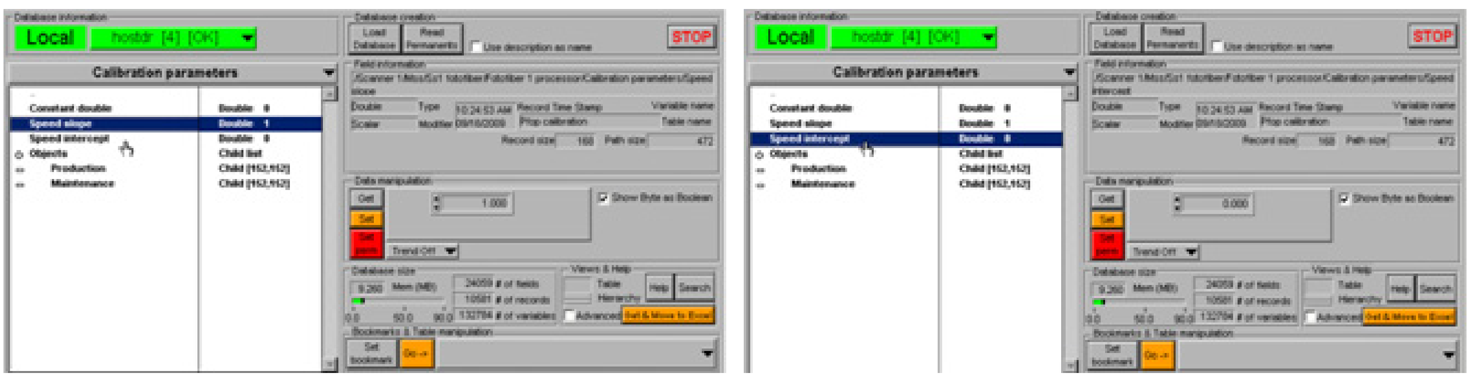


Figure 6-7 Slope and Intercept for Speed Calibration

Reading, scaling, and writing the scaled line speed to *./scannerX/mss/ssX fotofiber/setup/Process* data buffer RTDR parameter is performed by *SP PFOx Read Line Speed.vi* (see Figure 6-8).

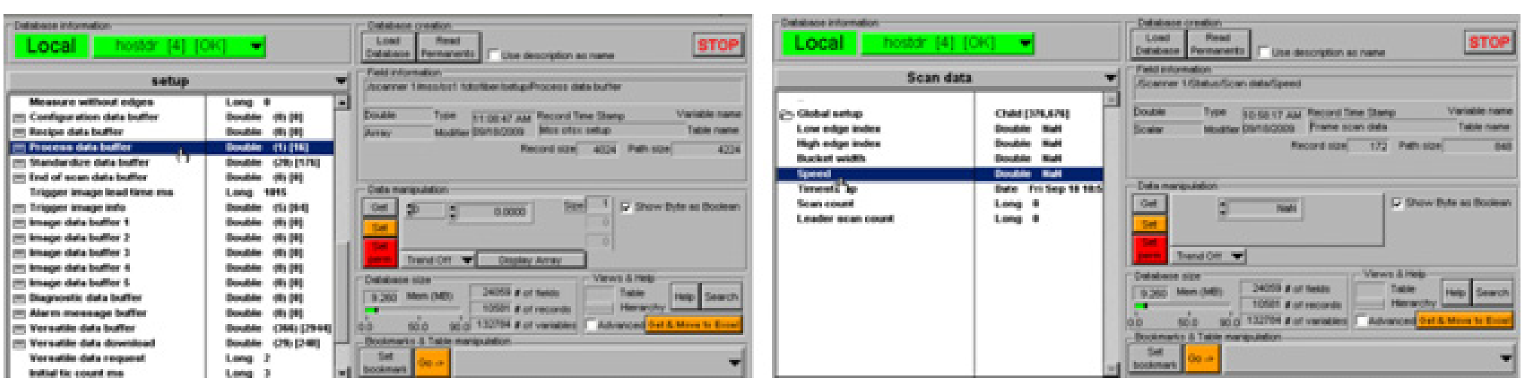


Figure 6-8 Process Data and Line Speed in RTDR

These steps must be repeated for each Q4223-5x sensor in a system.

6.3. User interface

Q4223-5x Experion MX FotoFiber displays are located under the FotoFiber display category. There are four displays:

1. The **FotoFiber Display**, display (see Figure 6-9).
2. The **FotoFiber Standardization** display (see Figure 6-15)
3. The **FotoFiber Edge** display (see Figure 6-16).
4. The **FotoFiber Engineering** display (see Figure 6-17).

Images and descriptions of these displays are provided in this section. The related VIs are listed in Table 6-6.

Table 6-6 FotoFiber Displays

Display	**File Name**	**Type**
FotoFiber Display	*Precision FotoFiber Display.vi*	Display
FotoFiber Standardization	*Precision FotoFiber Standardization.vi*	Display
FotoFiber Edge	*Precision FotoFiber Edge.vi*	Display
FotoFiber Engineering	*Precision FotoFiber Engineering.vi*	Display
Image Positions	*PFO Image Positions.vi*	Pop-up

In RAE R600, the FotoFiber displays are located at:

C:\Program Files\Honeywell\Experion MX\Gauging\Labview Vis\Displays\Precision FotoFiber

In RAE R600, the pop-ups are located at:

C:\Program Files\Honeywell\Experion MX\Gauging\Labview Vis\Displays\Precision FotoFiber\Sub Level

6.3.1. FotoFiber display

The **FotoFiber Display** (see Figure 6-9) is designed to provide thorough, real-time status of the surface fiber orientation. The surface fiber orientation measurement is displayed as a polar histogram plot, with parametric description of the polar histogram displayed in numeric form and as a profile. On-line surface images are shown from one or more definable cross direction positions of the web. The **FotoFiber Display** is the most important display for analyzing the current state of fiber orientation.

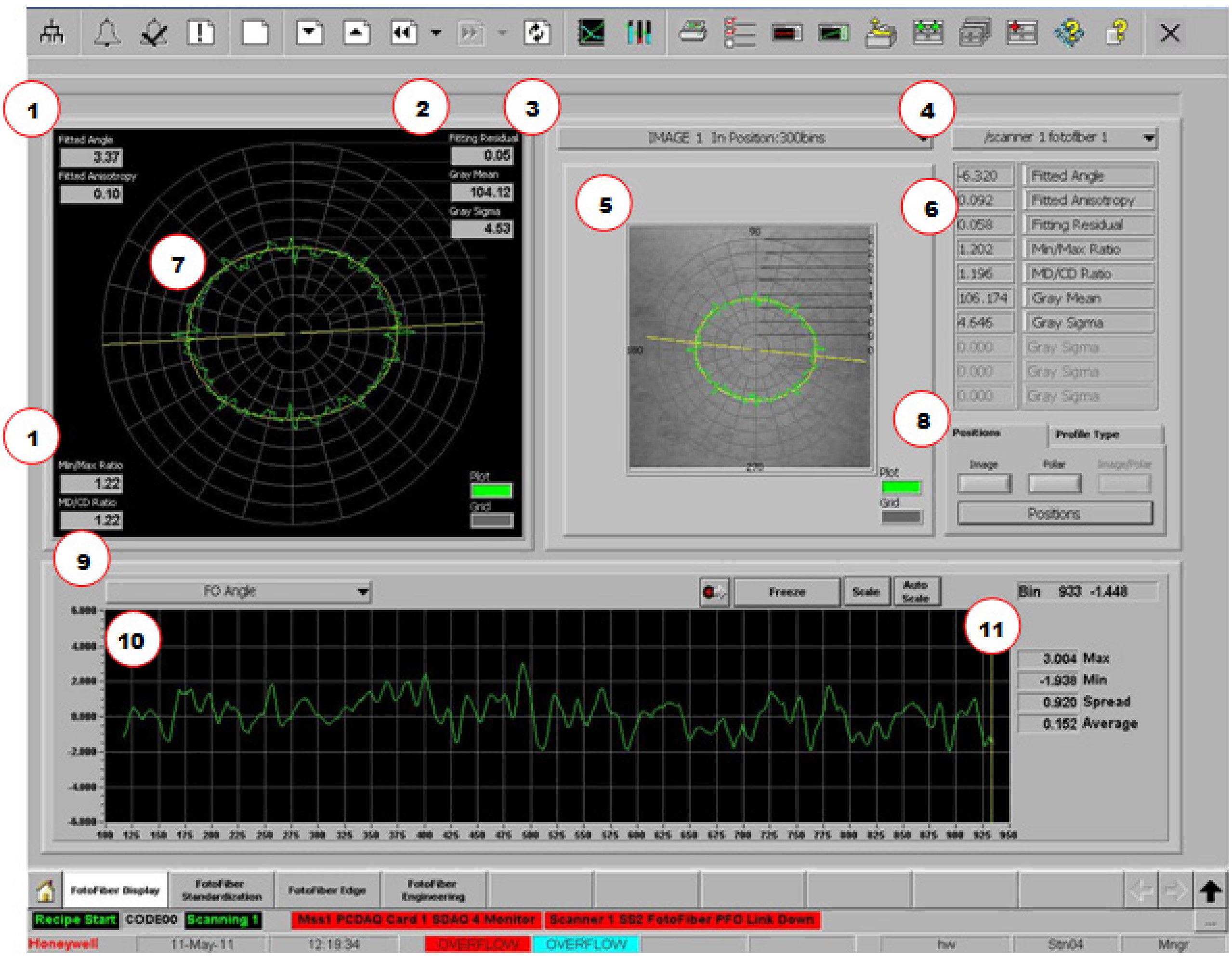


Figure 6-9 FotoFiber Display

Table 6-7 lists and describes the items shown in Figure 6-9.

Table 6-7 FotoFiber Display Items

Item	Description
1	Measurement summary for current polar histogram
2	Image attributes and quality of fitting
3	Selection among defined image positions for display
4	FotoFiber sensor selection drop-down arrow
5	Selected image and/or its polar histogram
6	Measurement summary for selected image
7	Current polar histogram of fiber angle distribution
8	Image display properties and cross direction positions
9	Selection of fiber orientation property to plot
10	Profile of selected fiber orientation property
11	Statistics of selected property profile

6.3.1.1. FotoFiber sensor selection

All FotoFiber sensors installed to the system are listed under the FotoFiber selection drop-down arrow (see Figure 6-10). A system can have one FotoFiber, or multiple FotoFibers, on one or more scanners to a maximum of two per scanner. Select the one that is to be monitored. The selection can be changed at any time. Only one FotoFiber sensor can be monitored at a time on any operator station.

Figure 6-10 FotoFiber Sensor Selection Drop-down Arrow

6.3.1.2. Current polar histogram of fiber angle distribution

The polar plot shows graphically the distribution of fiber angles in a single measurement. It is typically updated every two seconds while scanning or in fixed-point measurement, and shows the result of the most recent measurement at that time.

Each direction in the plot corresponds to the same direction in the sheet. The machine direction is horizontal, with direction of movement to the right, and the clockwise direction usually corresponds to the clockwise direction in the sheet viewed from above. Larger distances from the center for a particular angle indicate a higher frequency of occurrence of that angle.

The green curve indicates the occurrence of each angle in the measurement. The yellow curve shows the fitted approximation to the measurement. The yellow straight line indicates the major axis of the fitted curve, and the average orientation of the fibers.

At very high anisotropy values, the curve will start to develop two distinct lobes (see Figure 6-11, left). A curve which is nearly circular, or only slightly oval, indicates a relatively low anisotropy (see Figure 6-11, right). More typically, anisotropy is between 0.10 and 0.15, or slightly outside that range giving a slightly elongated curve (see Figure 6-11, center). Values above 0.30 are very uncommon.

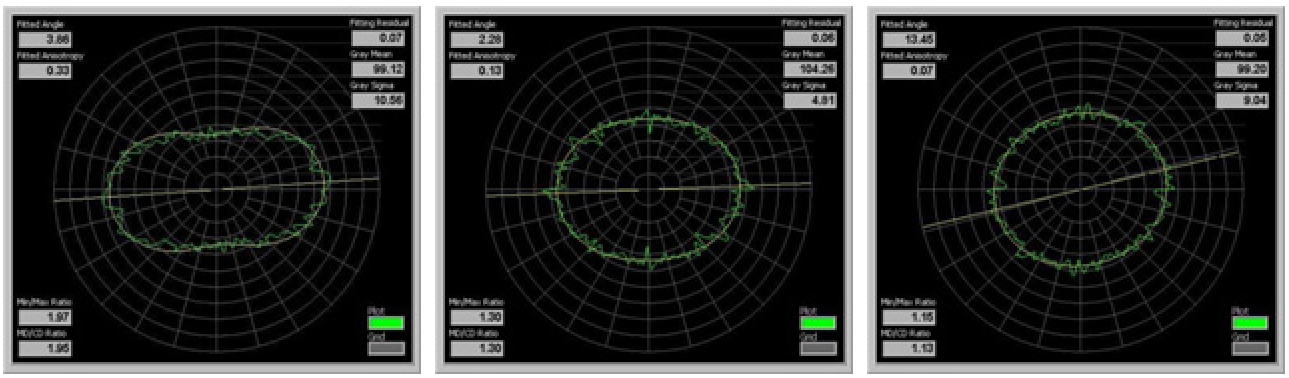


Figure 6-11 Anisotropy: High (left), Typical (center), Low (right)

An angle at the machine direction is horizontal. An angle at the cross-machine direction is vertical. By convention, positive orientation angles are counterclockwise in the polar plots. Unless there is a problem in the process, large angles usually only occur at low anisotropies.

6.3.1.3. Measurement summary for current polar histogram

Several numeric properties are shown on the polar histogram. These indicate values of parameters computed from the histogram, including the principal fiber orientation parameters, which are listed in Table 6-8. The primary measurements of fiber orientation angle and anisotropy are in the upper left of the polar histogram, and the derived measurements of **Max/Min Ratio** and **MD/CD Ratio** are in the lower left.

Table 6-8 Orientation Parameters: Polar Histogram

Parameter	Description
Fitted Angle	The average orientation angle of the measured distribution
Fitted Anisotropy	The degree of anisotropy of the measured distribution
Max/Min Ratio	Ratio of greatest and smallest widths of the curve
MD/CD Ratio	Ratio of curve width at 0 degrees to curve width at 90 degrees

6.3.1.4. Image attributes and quality of fitting

The **Fitting Residual** for the histogram curve, and the **Gray Mean**, and **Gray Sigma** of the raw image are displayed on the upper right of the polar histogram. These items are of diagnostic interest only, and are not shown if you are logged in as *Operator*.

Table 6-9 Fitting Residual, and Image Attributes

Parameter	Description
Fitting Residual	Indicates how closely the curve fits the measurement
Gray Mean	Average graylevel of the image
Gray Sigma	Contrast level of the image

6.3.1.5. Image display properties and cross direction positions

A FotoFiber sensor can deliver up to four images per scan from different cross direction positions for visual assessment on the **FotoFiber Display**.

ATTENTION

It is recommended that in most cases only one image should be delivered per scan for each FotoFiber due to the high load of image compression for communication. If the scan time exceeds 20 seconds, a second image can be delivered.

The positions are configured in the **Image Positions** pop-up (see Figure 6-12) that can be called up by clicking the **Positions** button on the **FotoFiber Display** (see item 5, Figure 6-9). The positions are given as distances, in millimeters, from the low end offset, smallest value to highest. The positions are fixed relative to the scanning frame, but not to the web if the web width or position change. If you do not want images from all four positions, enter zero as the distance to omit the image. Values of cross direction positions are limited between the current web edges. The edges of the web are read from the RTDR parameters:

- The lower limit: *./scannerX/mss/unit info/low end offset mm*
- The upper limit: *./scannerX/mss/hi other end/scan position*

If any of the values is outside the limits an error message is shown (see Figure 6-12, right). In that case enter valid values to the invalid fields and click **ENTER** on the pop-up.

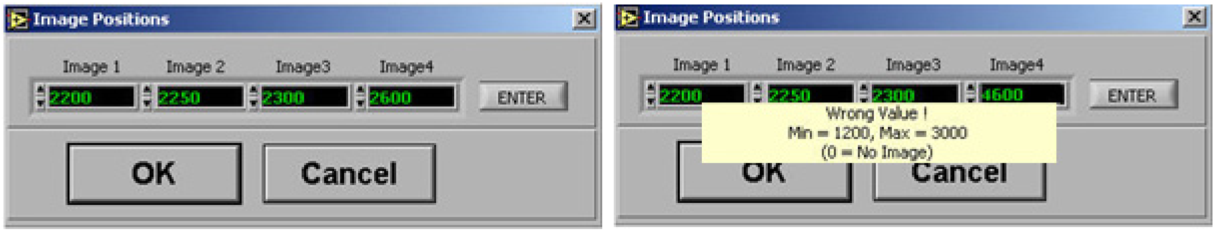


Figure 6-12 Image Positions Pop-up: Valid (left); Error Message (right)

6.3.1.6. Measurement summary for the selected image

The numerical values of the summary values are shown for whichever image is selected. These are the same items as indicated in Subsection 6.3.1.3, and Subsection 6.3.1.4, but referring to the selected image.

6.3.1.7. Selection of cross direction position for the on-line image

One of the preconfigured image positions defined in Figure 6-12 can be monitored at a time on the **FotoFiber Display** as the on-line image. The drop-down menu (see item 7 in Figure 6-9) is used to select the image position, as shown in Figure 6-13.

Figure 6-13 Cross Direction Position Selection Drop-down Menu

If a position is not defined (zero is entered as the position), the text *IMAGE x In Position: No Image!* is shown in that row.

ATTENTION

It is recommended that image positions should be separated by approximately five seconds of scan time, and should not be closer to the edge of the sheet than approximately three seconds of scan time. This is due to the additional load placed on the sensor in processing images.

If the scanner is in single-point measurement, only image 5 is displayed. The position of image 5 is the single-point position, and this image is updated every 20 seconds.

6.3.1.8. Selected image and/or polar histogram

Either the selected image, its polar histogram, or both can be displayed. If both are displayed, the polar histogram is superposed on the image. Make the selection by clicking either **Image** or **Polar** above the **Positions** button (see item 5 in Figure 6-9).

6.3.1.9. Selection of fiber orientation profile to plot

The profile plot can display any of the special profiles associated with a FotoFiber sensor, including:

- FO Angle
- Anisotropy
- Max/Min Ratio
- MD/CD Ratio

6.3.1.10. Profile of selected property

The **FotoFiber Display** profile is customized to show a cross direction-smoothed trend profile of any of the FotoFiber measured variables. Typically the fiber orientation angle or the fiber orientation anisotropy profiles are displayed, as shown in Figure 6-14.

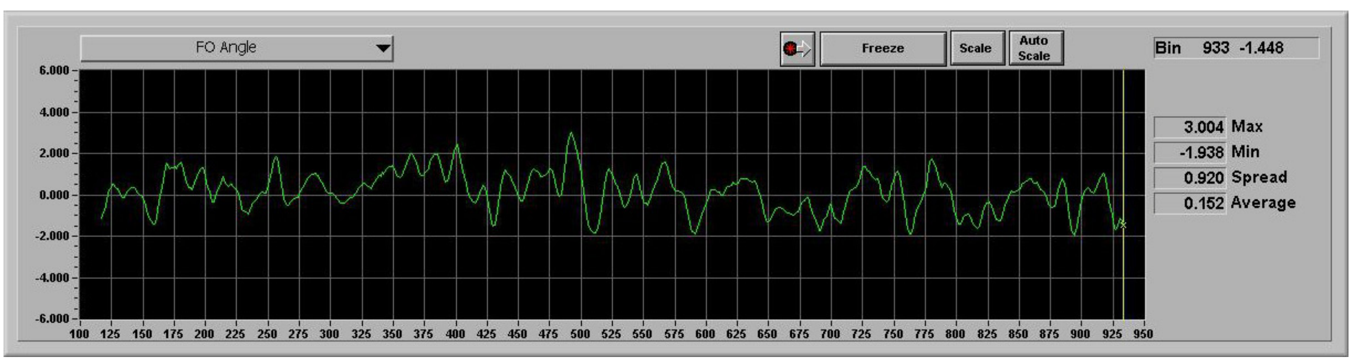


Figure 6-14 Cross Direction Profile (FO angle)

The profile is constructed by smoothing the trend profile for the measurement. The smoothing parameters are set on the **FotoFiber Engineering** display (see item 8 in Figure 6-17, also see Subsection 6.3.4.4), and apply to all profiles produced by the same FotoFiber sensor.

6.3.1.11. Statistics of selected profile

The statistics of the selected profile are plotted to its right, as seen in Figure 6-14. These are the maximum, minimum, spread, and average of the profile. The spread is the 2-sigma value for the profile.

6.3.2. FotoFiber standardization display

The task of standardization is to determine the relative efficiencies of the eight illumination channels under current operating conditions. The current operating conditions include the strobe pulse length, average strobe channel level, and the current paper being measured. As described in Section 5.4, FotoFiber standardization occurs onsheet (if it is enabled), in the first traverse after other sensors have standardized offsheet.

The **FotoFiber Standardization** display is shown in Figure 6-15. Results for offsheet references in maintenance mode are shown as well as those for onsheet standardization attempts, in scan mode or single-point mode.

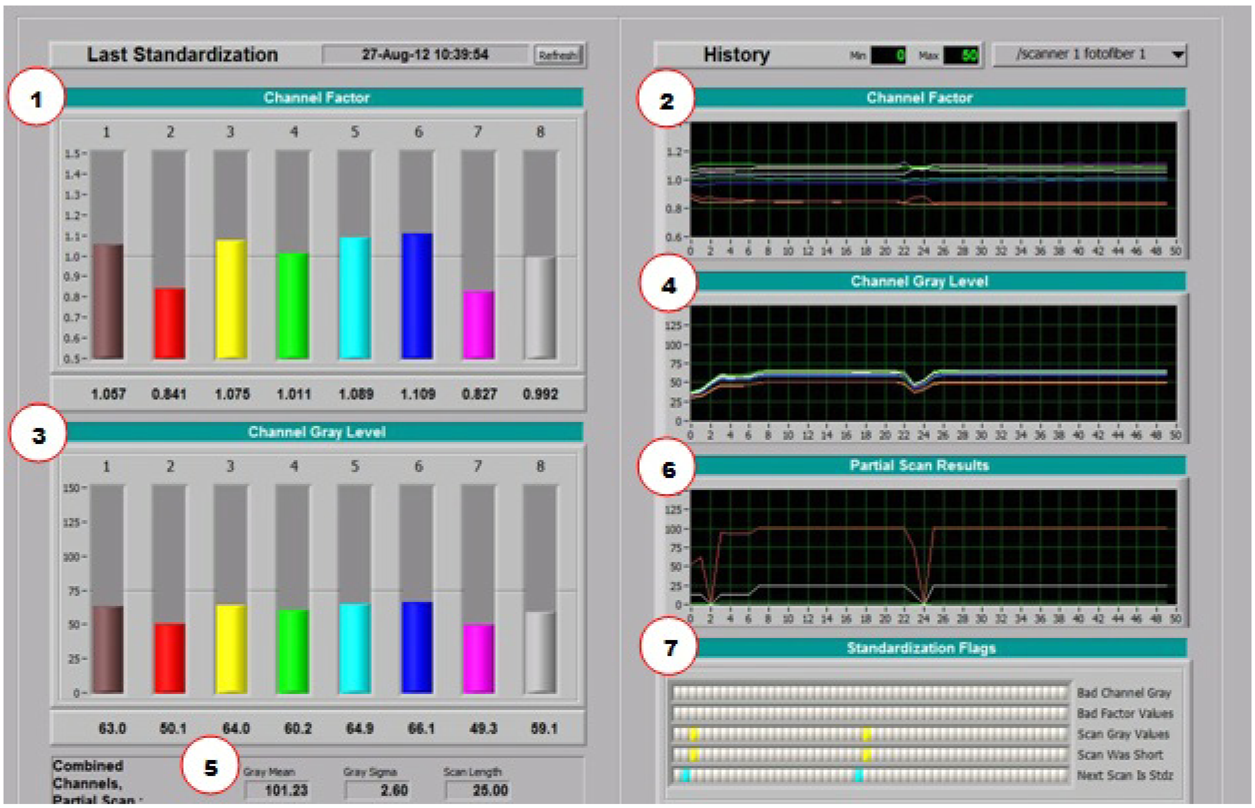


Figure 6-15 FotoFiber Standardization Display

If standardization fails (as can happen after a machine startup, or if a major grade change occurs while the sensor is offsheet), it repeats the standardization. Because

FotoFiber standardization does not obstruct scanning operation of any other sensor, there is no penalty in performing repeated standardizations.

Table 6-10 lists and describes the items shown in Figure 6-15.

Table 6-10 FotoFiber Standardization Display Items

Item	Description
1	Channel factor at the last successful standardization, shown as bar graphs with numerical values beneath. These indicate the relative efficiency of each channel compared to its calibration data. They are used to compensate for variations in sheet color as well as dust on the illumination window and aging of components. The channel factors should remain between 0.6 and 1.6 for proper operation of the sensor.
2	A trend of channel factor values in the last 50 successful standardizations. Colors of traces match those of the bars in Item 1.
3	Channel graylevels at the last successful standardization, shown as bar graphs with numerical values beneath. These indicate the absolute illumination level achieved by each channel with identical parameters. The absolute levels achieved should be in the acceptable range for proper operation of the sensor (typically between 25 and 225, adjustable using parameters 27 and 28 in the **FotoFiber Engineering** display in Subsection 6.3.4).
4	A trend of channel graylevels in the last 50 successful standardizations. Colors of traces match those of the bars in Item 3.
5	Statistics for the partial scan operating all channels together at the nominal settings in the last successful standardization scan: mean graylevel, mean gray sigma (image contrast), and length of partial scan. The mean graylevel should be close to the target (typically 100, but set using parameter 26 in the **FotoFiber Engineering** display in Subsection 6.3.4), and the scan length should be at least 5 and preferably more than 20. The mean gray sigma is typically small (1–5% of the mean graylevel), and will vary depending on the grade of paper being measured.
6	A trend of the mean graylevel, mean gray sigma (image contrast), and length of partial scan for the last 50 successful standardizations. The plot scale must be set differently to optimize presentation of each parameter, because their values are greatly different (typically differing by two orders of magnitude).
7	A trend of warning and error flags for the last 50 standardization attempts, whether successful or not. Because flags are shown from unsuccessful standardizations as well as successful standardizations, this trend does not necessarily have a one-to-one correspondence with the other trends, which contain only results from successful standardizations.

The standardization flags are:

- **bad channel gray**: An error causing standardization to fail. If this persists in normal operation, sensor maintenance is required. Colored red if the flag is set.
- **bad factor values**: A warning indicating that one or more channel factors were out of range. If this warning persists, sensor maintenance might be required. Colored yellow if the flag is set.

- **scan gray values**: An error causing standardization to fail. If this persists in normal operation, sensor maintenance is required. Colored red if the flag is set.
- **scan was short**: A warning indicating that there were not enough measurements during the standardization. If this warning persists, the sensor or scanner parameters might need to be adjusted. Colored yellow if the flag is set.
- **try stdz again**: A notification that the sensor will attempt to standardize again after a failed standardization. This often occurs on the first standardization after a machine startup, or occasionally after a grade change in which the sensor was offsheet (causing the illumination parameters to be inappropriate). If the initial sensor state is far from the state appropriate to current operating conditions, it may take a few attempts to reach a successful standardization. This flag is set only if one of the error flags is set. Colored blue if the flag is set.

If any standardization error or warning flags occur repeatedly, troubleshooting is required to determine and rectify the cause (see Subsection 10.2.2.1).

Although the trends for channel factors and graylevels are generally smooth for scanning standardizations, they can change if the machine grade or speed is changed. Significant changes might also occur when a reference is performed in maintenance mode, depending on the specimen used.

6.3.3. FotoFiber edge display

While at the sheet edge at each end-of-scan, the processor module of the FotoFiber sensor recomputes its illumination parameters, and communicates the updated parameters to the sensor strobe controller. The computation is based on the scan average of the graylevel of the just-completed scan, the calibration curves for each illumination channel, and the channel factors from the last successful standardization. Similar rebalancing calculations are performed after a reference operation, and after the standardization in single-point mode. The results of the edge calculations are sent to the Experion MX, and are shown in the **FotoFiber Edge** display (see Figure 6-16).

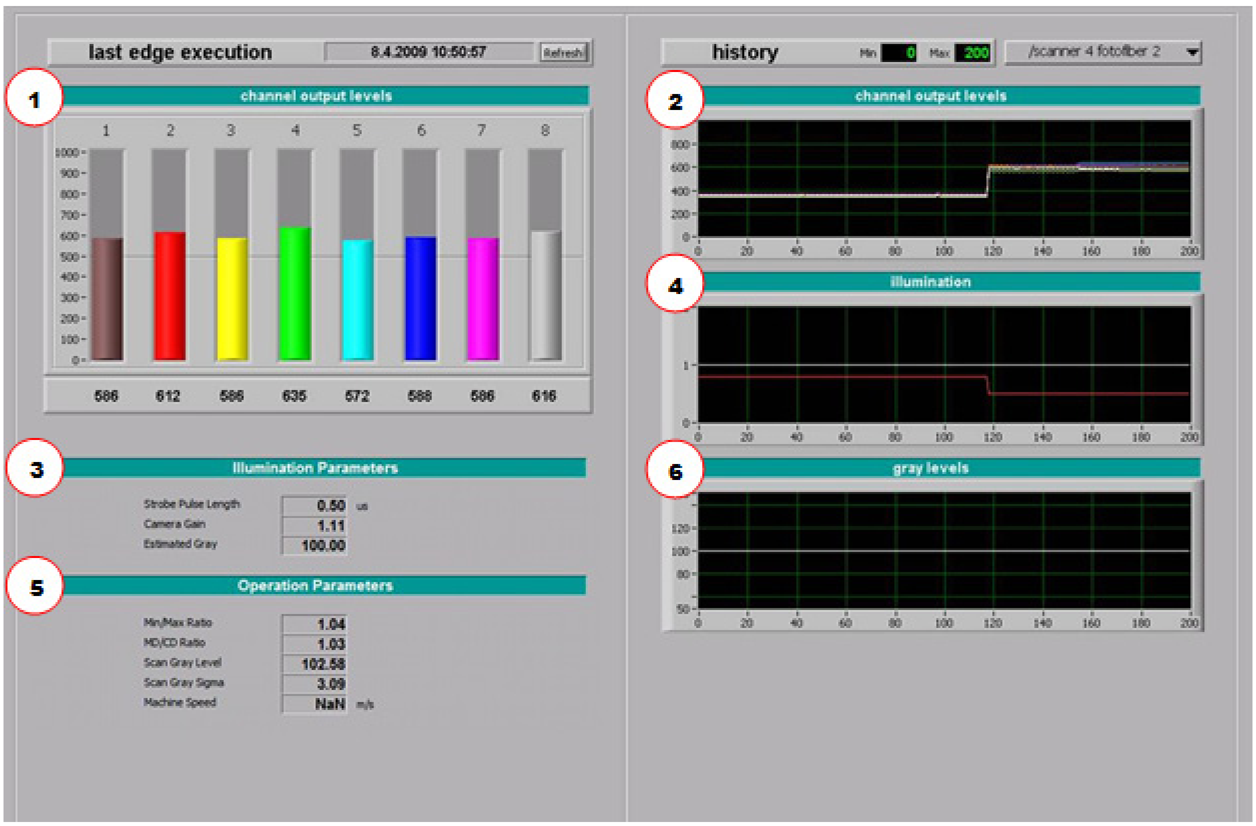


Figure 6-16 FotoFiber Edge Display

Table 6-11 lists and describes the items shown in Figure 6-16.

Table 6-11 FotoFiber Edge Display Items

Item	Description
1	Current illumination channel output levels (integer 0–999), shown as bar graphs with numerical values beneath. These indicate the relative electrical discharge through the different LED panels.
2	A trend of the channel output levels for the last 50 end-of-scan computations. Colors of traces match those of the bars in item 1.
3	Common parameters: • strobe pulse length, which is the same for all channels, in the range 0.2–1.5 μs • camera gain, or sensitivity boost factor, in the range 1.0–2.0 • the estimated graylevel for the next scan
4	A trend of the strobe pulse length (red), and the camera gain (gray), for the last 50 end-of-scan computations. They are plotted on a common scale for convenience.
5	Scan average of selected parameters. The graylevel and machine speed values might be useful in troubleshooting.
6	A trend of the estimated graylevel (red), and the actual graylevel (gray), for the last 50 end-of-scan computations. Normally the two traces are very closely coincident, and can only be separated if the scale is narrowed to a very small range.

The trends for channel output levels should be fairly smooth in normal operation. However, speed or grade changes may cause fairly rapid changes in the output levels. Speed changes may also be accompanied by simultaneous changes in the pulse length, as seen in the trends in Figure 6-16.

6.3.4. FotoFiber engineering display

The **FotoFiber Engineering** display (see Figure 6-17) is a tool for configuring and diagnosing the FotoFiber sensor.

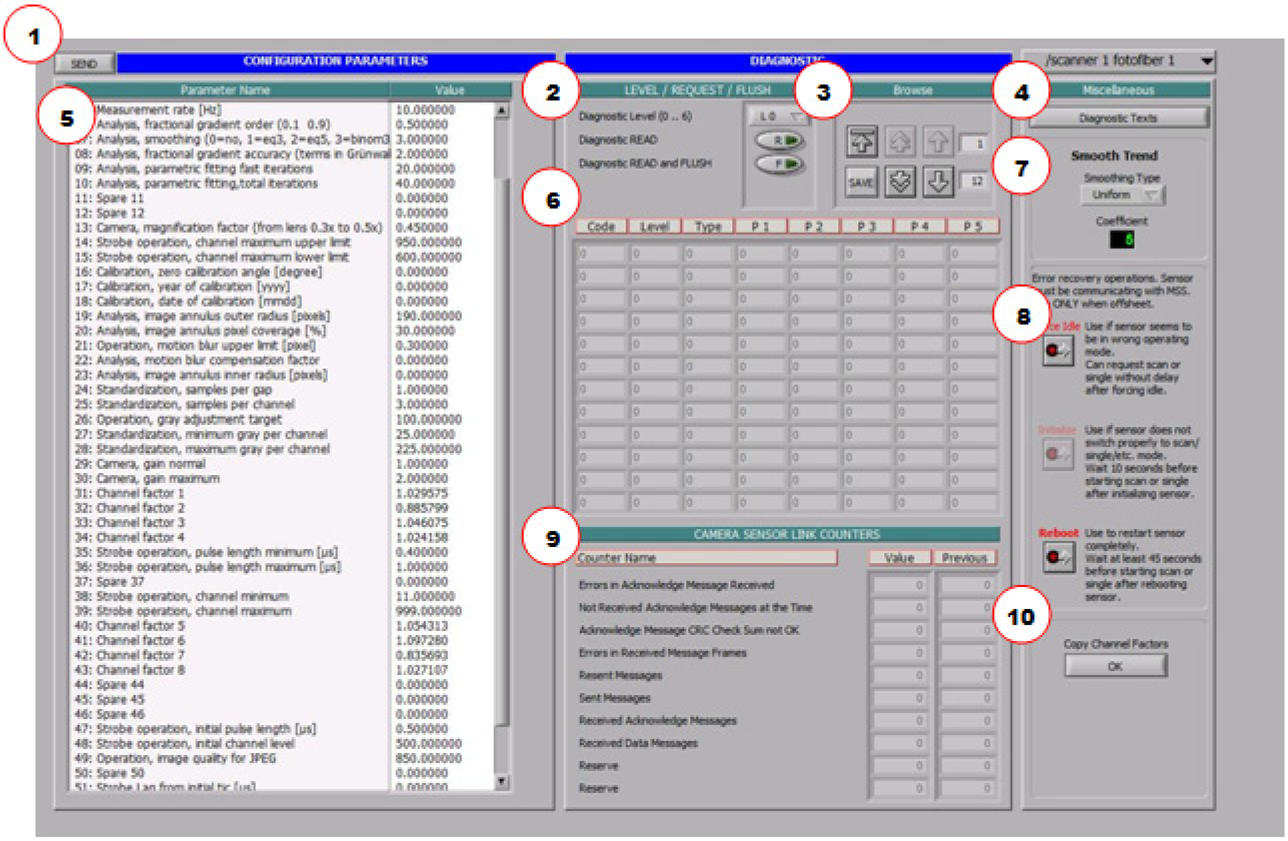


Figure 6-17 FotoFiber Engineering Display

Table 6-12 lists and describes the items shown in Figure 6-17.

Table 6-12 FotoFiber Engineering Display Items

Item	Description
1	Configuration parameters **SEND** button
2	Diagnostic level, request, and flush controls
3	Diagnostic data browse and **SAVE** buttons
4	FotoFiber sensor selection drop-down arrow
5	Configuration parameters
6	Diagnostic data
7	Cross direction smoothing parameters
8	Buttons for special sensor actions

Item	Description
9	Camera sensor link counters
10	Copy channel factors **OK** button

The FotoFiber sensor to be configured or diagnosed is selected for this display from item 1, the drop-down arrow, in the same way it is on the **FotoFiber Display** (see Subsection 6.3.1.1). Items 2 and 3 handle FotoFiber configuration through customizing and uploading configuration parameters. States of FotoFiber can be traced using items 4–6. Camera Sensor Link data is summarized in item 7. The smoothing for special profiles (see Subsection 6.3.1.10) in the **FotoFiber Display** is controlled using item 8, and some commands to recover form abnormal states are issued with the buttons in item 9.

Some elements of the **FotoFiber Engineering** display are valid only for FotoFiber with firmware version 2.2 or newer. The firmware version is reported by the sensor and displayed as configuration parameter 5 (which cannot be changed). Operation of the Q4223-5x with Experion MX requires firmware version of 2.2 or greater.

6.3.4.1. Configuration parameters

FotoFiber functionality can be adapted and customized through the configuration parameters, item 2 in Figure 6-17. Configuration parameters are sent to the sensor automatically at FotoFiber sensor startup. When FotoFiber is already running, the configuration parameters can be sent to the sensor by clicking **SEND** (item 3). You must do so after making changes to the parameters.

Changing some of the parameters might have complicated consequences, and they should not be changed without consulting the sensor development team.

FotoFiber has 54 configuration parameters, presented in detail in Table 6-13, Table 6-14, Table 6-15, and Table 6-16. Note that the **FotoFiber Engineering** display must be scrolled to see all of the parameters.

Parameter 53 falls into three categories because it is a bitmask.

The parameters shown in Table 6-13 either cannot be changed, or should never be changed.

Table 6-13 FotoFiber Configuration Parameters (1 of 4)

Index	CNFG Parameters	CNFG Names
0	2	LED controller type (1=PP810, 2=PP880)
1	90.0	Polar Rotation [deg]
4	n/a	FotoFiber Firmware Version
21	0.3	Operation, motion blur upper limit [pixel]
22	0.0	Analysis, motion blur compensation factor
38	11	Strobe operation, channel minimum
39	999	Strobe operation, channel maximum

The parameters shown in Table 6-14 should not be changed, except under explicit direction of QCS-TAC personnel or the sensor developers. Changes may have profound effects on sensor operation including causing it to crash.

Table 6-14 FotoFiber Configuration Parameters (2 of 4)

Index	CNFG Parameters	CNFG Names
3	0.0	Diagnostic OFF/ON (0=Off, 1–3=On)
5	10	Measurement rate [Hz]
6	0.5	Analysis, fractional gradient order (0.1–0.9)
7	3	Analysis, smoothing (0=no, 1=eq3, 2=eq5, 3=binom3, 4=binom5)
8	2	Analysis, fractional gradient accuracy (terms in Grünwald series)
9	20	Analysis, parametric fitting, fast iterations
10	40	Analysis, parametric fitting, total iterations
14	950	Strobe operation, channel maximum upper limit
15	600	Strobe operation, channel maximum lower limit
19	190	Analysis, image annulus outer radius [pixels]
20	30.0	Analysis, image annulus pixel coverage [%]
23	0	Analysis, image annulus inner radius [pixels]
27	25.0	Standardization, minimum gray per channel
28	225.0	Standardization, maximum gray per channel
29	1.0	Camera, gain normal
30	2.0	Camera, gain maximum

Index	CNFG Parameters	CNFG Names
35	0.3	Strobe operation, pulse length minimum [μs]
36	1.0	Strobe operation, pulse length maximum [μs]
47	0.5	Strobe operation, initial pulse length [μs]
48	400	Strobe operation, initial channel level
49	850	Operation, image quality for JPEG
53	91	Sensor options bitfield (0–65535): • bit 1: 2 Renew pixel mask after standardization • bit 3: 8 Record diagnostic narrative • bit 5: 32 Fitting curve form (0=bilobe, 1=ellipse) • bit 6: 64 Enable change of measurement rate • bit 7: 128 Disable image analysis
54	1500	Operation, minimum EOS delay [ms]

The parameters shown in Table 6-15 are not used, and changes will have no effect on sensor operation.

Table 6-15 FotoFiber Configuration Parameters (3 of 4)

Index	CNFG Parameters	CNFG Names
2	0.0	Reserved 2
11	0	Spare parameter 11
12	0	Spare parameter 12
37	0	Spare parameter 37
44	0	Spare parameter 44
45	0	Spare parameter 45
46	0	Spare parameter 46
50	0	Spare parameter 50
53	91	Sensor options bitfield (0–65535): • bit 9: 512 spare bit 9 • bit 10: 1024 spare bit 10 • bit 11: 2048 spare bit 11 • bit 12: 4096 spare bit 12 • bit 13: 8192 spare bit 13 • bit 14: 16384 spare bit 14 • bit 15: 32768 spare bit 15

The parameters shown in Table 6-16 can be changed in normal commissioning, troubleshooting, or maintenance of the sensor.

Table 6-16 FotoFiber Configuration Parameters (4 of 4)

Index	CNFG Parameters	CNFG Names
13	0.45	Camera, magnification factor (from lens 0.3x to 0.5x)
16	0.0	Calibration, zero calibration angle [degree]
17	0000	Calibration, year of calibration [yyyy]
18	0000	Calibration, date of calibration [mmdd]
24	3	Standardization, samples per gap
25	5	Standardization, samples per channel
26	100.0	Operation, gray adjustment target
31	1.0	Standard factor 1
32	1.0	Standard factor 2
33	1.0	Standard factor 3
34	1.0	Standard factor 4
40	1.0	Standard factor 5
41	1.0	Standard factor 6
42	1.0	Standard factor 7
43	1.0	Standard factor 8
51	0	Strobe delay from initial tic [µs]
52	10.0	Sample, pseudo machine speed [m/s]
53	91	Sensor options bitfield (0–65535): • bit 0: 1 Enable standardization during scan • bit 2: 4 Use standard factors, supplied as parameters • bit 4: 16 Machine direction axis in image (0=Y, 1=X) • bit 8: 256 Angles are clockwise (0=anticlockwise, 1=clockwise)

Parameter changes do not take effect until the sensor is idle, or at the end of a scan. Parameter changes made during a scan (whether measurement scan or standardization scan), or during single-point, reference, or sample modes are deferred until the sensor is idle or at the end of a scan. A few parameters take effect only at standardization.

6.3.4.2. Normally adjustable parameters

Some of the parameters in Table 6-16 are described here in more detail. The focus is on those which are potentially in need of adjustment in the field. The initial setting of several of these parameters is described in Subsection 4.3.2, and are performed after installation.

13: Camera, magnification factor

This informs the sensor of the optical magnification of the attached macro lens. It is needed for correct computation of pulse lengths (which depend on image scale as well as machine speed). The standard lens is adjustable from 0.3–0.5× magnification, and is usually set to about 0.45×, as being suitable for sheets of hardwood fibers and sheets with a mix of hardwood fibers and softwood fibers. If the installation is measuring sheets which always contain only softwood fibers, it may be possible to reduce the magnification (values below 0.35× are not recommended, even for softwood-only machines), in which case this parameter should be changed to match the optical magnification set on the lens.

16: Calibration, zero calibration angle

This parameter defines the zero angle for the camera. The camera mounting brackets result in a small amount of rotational uncertainty in the camera alignment, and the camera construction leads to an additional small rotational uncertainty in the alignment of image axes. That does not change after the camera is installed, and this parameter must be identified whenever the FotoFiber camera or camera mounting is changed (see Subsection 9.4.2).

17: Calibration, year of calibration [yyyy], and

18: Calibration, date of calibration [mmdd]

These two parameters indicate which set of illuminator calibration data should be used. The two integers define the name of the directory holding the calibration files in the FotoFiber. The factory calibration directory is year = 0000 and date = 0000, and should remain valid for several years if no illuminator components are changed. If a recalibration is performed in the field, the calibration data will be in a different directory, named according to the date of calibration, such as 20110829 for a calibration performed on 29 August 2011 (see Subsection 9.5.2).

24: Standardization, samples per gap, and

25: Standardization, samples per channel

These two parameters determine how many images should be discarded (samples per gap) when changing illumination channels during a standardization scan, and how many images should be averaged (samples per channel) when testing each illumination channel. There is usually no need to change them. However, if the scan time is less than about 15 seconds onsheet, they should both be reduced; otherwise standardization may never complete successfully. They should be reduced if the standardization *Scan Was Short* warning is received during standardization (item 7 in Figure 6-15). If the standardization succeeds and the standardization scan length (item 5 in Figure 6-15) exceeds the number of samples per channel by more than 100, one or both parameters can be increased. It is preferable to increase the samples per channel parameter, and there is never any need to make samples per gap larger than three (see Subsection 4.3.2.2, and Subsection 10.2.2.2).

26: Operation, gray adjustment target

This is the target for the graylevel of images as measured by the camera. It is used in the edge calculations in determining the strobe channel levels to use. The estimated graylevel appearing in item 3 in Figure 6-16 will equal this quantity, unless the strobe reaches an operating limit. The default value of 100 is acceptable in most cases.

31: Standard factor 1

32: Standard factor 2

33: Standard factor 3

34: Standard factor 4

40: Standard factor 5

41: Standard factor 6

42: Standard factor 7

43: Standard factor 8

These are the factors which the sensor uses if bit 2 of the options bitfield (parameter 53) is on, and bit 0 is off. These factors are overwritten by a reference operation, so it may be necessary to re-send the parameters if a reference is performed on a sample which is not representative of actual production.

51: Strobe delay from initial tic

This is meaningful only for two-sided measurements. For a single-sided measurement, it should be set to zero. For two sided measurements, one of the sensors should have a zero for this parameter, and the other should have a value of 32000. The result is that one of the sensors delays by 32 ms in its strobing from the initial message sent by the MSS at the start of a measurement mode. In Da Vinci systems, there is jitter of about 15 ms in message timing from the MSS; in Experion MX systems, the jitter is lower but more variable. This delay in one sensor prevents simultaneous flashing by the two sensors.

52: Sample, pseudo machine speed

This is the value used as a machine speed in computing the strobe length for sample mode and reference mode operations offsheet. It has a default of 10 m/s, and can be left at that value or changed to a value in the production speed range of the mill.

53: Sensor options bitfield

This is a bitfield which controls certain diagnostic or debugging features of the FotoFiber. Most of these are reserved for development use. However, it also contains four bits of interest during normal setup:

bit 0 (2^0=1): Enable standardization during scan. If this bit is on, for example, the bitfield value is an uneven number, the sensor will attempt to standardize in the first scan after other sensors have standardized offsheet. To prevent this, make the bitfield value an even integer instead, for example, if the bitfield value is 67 change it to 66. With scanning standardization disabled, the sensor can be standardized only in reference mode offsheet. It is recommended that only one of bit 0 and bit 2 be on.

bit 2 (2^2=4): Enable use of channel factors sent as parameters (parameters 31–34, and 40–43). If this bit is on, the standard factors sent to the FotoFiber will be taken into use on the next scan. The factors are sent when the FotoFiber boots, and on any other occasion that the parameters are updated. This bit is generally on only if standardization during scan is disabled, for example, bit 0 is off. If it is on, the factors measured during a suitable reference operation should be entered into the parameters. It is recommended that only one of bit 0 and bit 2 be on.

bit 4 (2^4=16): Machine direction axis in image. Normally, this is set to 1 because the long axis of the camera (the X-axis) will be in the machine direction. If a FotoFiber sensor must be installed into a sensor head in which space is constrained, for example, by the presence of nonstandard equipment, it may be necessary to rotate the upper assembly of the sensor in order to fit it in. In this case, the normal machine direction and cross direction axes will be switched in the camera, and this bit should be set to 0. The value to add or subtract is 16 for bit 4. When the sensor is rotated 90 degrees during installation, if the bitfield is 83, change it to 67, or if the bitfield is 339, change it to 323.

bit 8 (2^8=256): Angles are clockwise. The positive direction for orientation angles may already be established at the mill. This bit can be set to make the FotoFiber agree with mill convention. In a two-sided measurement, one of the sensors must be use clockwise angles as positive, the other must use counterclockwise. This is because one is upside-down relative to the other.

Note that if bit 0 and bit 2 are both off, the FotoFiber will have default factors (all equal to unity) when it boots, and will operate with those factors until a standardization is performed in single-point, or as an offsheet reference in maintenance mode. It is therefore recommended that exactly one of bit 0 and bit 2 be on.

Commonly encountered values for the bitfield are:

- 91 scanning standardization enabled:

  factors sent as configuration parameters are ignored

  clockwise angles are positive

- 94 scanning standardization disabled:

  factors sent as configuration parameters are used

  clockwise angles are positive

- 347 scanning standardization enabled:

  factors sent as configuration parameters are ignored

  anticlockwise angles are positive

- 350 scanning standardization disabled:

  factors sent as configuration parameters are used

  anticlockwise angles are positive

6.3.4.3. Parameters adjustable only on advice from QCS-TAC or sensor developers

For adjustment of all other defined parameters (including bits other than bit 0, bit 2, bit 4, and bit 8 in parameter 53, the sensor options bitfield), it is necessary to contact QCS-TAC or the sensor developers for guidance. Some of these parameters can have a major effect on sensor operation, and a feasible change to one of them might require specific patterns of change to other parameters as well. However, for some problems, it may be helpful to change one or more of them with suitable advice.

CAUTION

> Adjustment of many of these parameters to inappropriate values, or to inappropriate combinations of values, can compromise measurement performance or crash the Q4223-5x sensor processor module. The difference between an inappropriate value and an optimum value may not be large or obvious. If QCS-TAC recommends a set of parameter changes, it is important to send all of those changes simultaneously to the sensor, and preferable to do so while the sensor is offsheet and in idle mode.

3: Diagnostic (OFF/ON)

This parameter determines whether diagnostic data is sent to the MSS. If it is zero, no data is sent. If it is 1, 2, or 3, a number of counters are sent to the MSS (see Subsection 6.3.4.6). Normally, this parameter is zero.

5: Measurement rate [Hz]

This parameter defines the speed at which the FotoFiber operates the strobe and camera. Increasing it is likely to require changes to one or more of parameters 9, 10, 19, 20, and/or 23 to avoid CPU overload. The rate is initialized to 10 when the sensor boots, and changing it is effective only if bit 6 of parameter 53 is on. Changes take effect only when the other sensors standardize. Inappropriate adjustment can crash the sensor. Normally, this parameter is 10.0.

6: Analysis, fractional gradient order (0.1 - 0.9)

7: Analysis, smoothing (0=no, 1=eq3, 2=eq5, 3=binom3, 4=binom5)

8: Analysis, fractional gradient accuracy (terms in Grünwald series)

These three parameters define the mathematical operators to be applied to the image in its X- and Y-axes (see Subsection 1.5.2). Inappropriate adjustment can crash the sensor. Normally, these parameters are 0.5, 3, and 2, respectively.

9: Analysis, parametric fitting, fast iterations

10: Analysis, parametric fitting, total iterations

These two parameters define the least-squares fit to the polar histogram derived from each image, giving the FO angle and anisotropy for that image (see Subsection 1.5.3). Inappropriate adjustment can crash the sensor. Normally, these parameters are 20 and 40, respectively.

14: Strobe operation, channel maximum upper limit

15: Strobe operation, channel maximum lower limit

These two parameters delimit the optimization of strobe operation which occurs ate each end of scan. There is no specific rationale for adjusting these parameters away from their default values, which are 950 and 600, respectively.

19: Analysis, image annulus outer radius [pixel]

20: Analysis, image annulus pixel coverage

23: Analysis, image annulus inner radius [pixel]

These three parameters define the size of the image region to be analyzed, and the density of analysis. They affect the CPU load during measurement. There is no specific rationale for adjusting parameter 23. Changes take effect when the sensor boots or (if bit 1 of parameter 53 is on) when other sensors standardize. Inappropriate adjustment (especially to parameters 19 and 20) can crash the sensor. Normally, these parameters are 190, 30.0, and 0, respectively.

27: Standardization, minimum gray per channel

28: Standardization, maximum gray per channel

These two parameters define the acceptable range of graylevels for each illuminator channel strobed individually during standardization or reference. They also define the acceptable range of graylevels for all illuminator channels strobed simultaneously during standardization or reference. There is no specific rationale for adjusting these parameters. Inappropriate adjustment can compromise sensor performance and/or give rise to spurious errors during standardization or reference. Normally, these parameters are 25.0 and 225.0, respectively.

29: Camera, gain normal

30: Camera, gain maximum

These two parameters define the acceptable range of camera gain during measurement operation (higher gains can be used during standardization). Inappropriate adjustment of these parameters can compromise sensor performance. Normally, these parameters are 1.0 and 2.0, respectively.

35: Strobe operation, pulse length minimum [μs]

36: Strobe operation, pulse length maximum [μs]

These two parameters define the acceptable range of strobe pulse duration during measurement operations. Inappropriate adjustment of these parameters can compromise sensor performance. Normally, these parameters are 0.3 and 1.0, respectively.

47: Strobe operation, initial pulse length [μs]

48: Strobe operation, initial channel level

These parameters define the default illumination used after the sensor is booted. The pulse length will be adjusted almost immediately based on the machine speed (if the machine is running). The channel level will be adjusted after the first scan (whether measurement or standardization). If the initial level is entirely wrong, the first scan will be discarded and the second scan will be greatly improved. It is recommended that the values be left unchanged, as any other values would lead to a similar number of instances when the first traverse after booting the sensor must be discarded. Normally, these parameters are 0.5 and 400, respectively.

49: Operation, image quality for JPEG

This parameter defines the amount of compression which will be used at first for each image sent as a JPEG. If the resulting JPEG is too large, it will be recompressed at lower quality until its size is acceptable. Inappropriate adjustment can lead to continuous or sporadic CPU load problems, or to unnecessary loss of detail in the displayed images. Normally, this parameter is 850.

53: Sensor options bitfield

The following bits in this bitfield should be adjusted only under guidance of TAC or the sensor developers:

bit 1 (2^1=2): Renew pixel mask after standardization. If this bit is on, the random sample of pixels to be analyzed in the image annulus (see parameters 19, 20, and 23) will be refreshed when the other sensors standardize. The random sample will not be refreshed for standardization in single-point mode, unless the single point was immediately preceded by the other sensors standardizing, or for references. If this bit is off, the random sample is selected when the sensor boots. Normally, this bit should be on.

bit 3 (2^3=8): Record diagnostic narrative. If this bit is on, the diagnostic narrative texts that are sent to the VGA monitor port are also recorded to a circular buffer within the sensor. The most recent 1024 texts are preserved in this buffer, and can be inspected using the web monitor. Normally, this bit should be on.

bit 5 (2^5=32): Fitting curve form. For measurements made on paper and paperboard, this bit should always be off.

bit 6 (2^6=64): Enable change of measurement rate. If this bit is on and parameter 5 is changed, the new strobe rate will be applied at the next standardization of the other sensors. If this bit is off, the changes to parameter 5 are ignored. Normally, this bit is on.

bit 7 (2^7=128): Disable image analysis. If this bit is on, images will be acquired in the usual way in each mode, but images acquired in measurement scans, in sample operation, and in the measurement phase of single-point operation will not be analyzed, and dummy measurement data will be reported instead. In standardization scans, in reference operation, and in the illumination adjustment phase and the standardization phase of single-point operation, images will be processed in the usual way. This bit is useful in diagnosing some kinds of problem. Normally, this bit is off.

54: Operation, minimum EOS delay [ms]

This is the amount of time the sensor will wait after finishing a scan. It is the delay between starting recomputation of its strobe parameters (from the machine speed and average graylevel), and sending of the scan average data. Normally, this parameter is 1500.

6.3.4.4. Cross direction smoothing parameters

The special profiles shown on the **FotoFiber Operator** display are smoothed versions of the trend profiles. The smoothing is performed by applying either Gaussian, binomial, or uniform weighting filters to the trend profile. The same smoothing parameters are used for all profiles from the same FotoFiber. They can be set differently for each FotoFiber sensor, but it is recommended that they be similar for all FotoFibers.

If the smoothing type is changed, the effect of the smoothing coefficient is different. For a Gaussian filter, the coefficient is the number of profile cells used as the dispersion parameter of the filter. For a binomial or a uniform filter, the coefficient is the number of profile cells on either side of the cell to average.

For a given value of the smoothing parameter, the degree of smoothing is:

uniform > binomial > Gaussian

6.3.4.5. Buttons for special sensor actions

For Q4223-5x FotoFiber firmware version 2.2 or newer, some special actions can be taken from the **FotoFiber Engineering** display. The FotoFiber firmware version is reported by the sensor and appears as parameter 4 in Subsection 6.3.4.1. These actions are not needed in normal operation, but they might be included in QCS-TAC instructions for troubleshooting.

ATTENTION

Do not use the buttons described in this section unless the sensors are offsheet, and the sensor must be operating in normal mode, meaning the **USER1** DIP switch was in the *off* position when last booted, and must be communicating with the MSS, meaning it is enabled on the **Scanner Sensor Status** display (see Figure 4–8).

Force Idle: This action will stop any active tasks in the FotoFiber. It can be used if the sensor appears to be an inappropriate operating mode (such as measuring while offsheet). Its effect is immediate, and does not require a recovery time before requesting scanning or single point or fixed point operation.

Initialize: This action causes the FotoFiber to briefly cease communication with the MSS, then resume communication. It can be used if MSS commands do not appear to be reaching the FotoFiber. It has the effect of causing both ends of the link to initialize, and to exchange their parameters. Due to the time involved, it is necessary to wait at least 10 seconds before requesting any action from the scanner, such as scanning, single-point, or fixed point operation.

ATTENTION

The **Initialize** button has no effect in Experion MX systems which use Ethernet communication between MSS and the sensor, and it is grayed-out on that platform. It is intended for use only on platforms such as Da Vinci which use RS422 for communication between MSS and the sensor.

Reboot: This action causes the FotoFiber to reboot, and reload its firmware, reset its camera and strobe, and initialize its data links. Because rebooting is a lengthy process, it is necessary to wait at least 45 seconds (recommended time is 55 seconds) before requesting any action from the scanner, such as scanning, or single-point or fixed point operation. If the **USER1** DIP switch has changed position, the sensor will boot twice, with a brief pause between boots, and the waiting time must be increased correspondingly to a minimum of 95 seconds (recommended time is 115 seconds).

6.3.4.6. Sensor diagnostic

The FotoFiber sensor saves diagnostic information of sensor function. This is sent to the MSS if the diagnostic is non-zero. Information consists mainly of mode changes and mode statuses. Diagnostic information is divided in to seven diagnostic levels (0–6) listed in Table 6-17.

Table 6-17 Diagnostic Levels

Level	Description
0	Unused
1	Post Master
2	State Machine
3	Unused
4	Unused
5	Unused
6	Camera Sensor Link Counters

The **DIAGNOSTIC** dialog is shown in Figure 6-18.

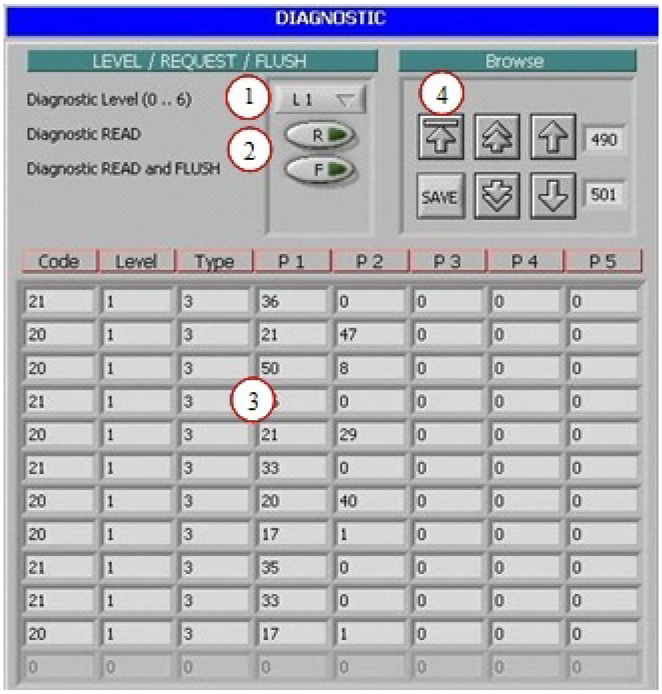


Figure 6-18 DIAGNOSTIC Dialog

Table 6-18 lists and describes the items shown in Figure 6-18.

Table 6-18 DIAGNOSTIC Dialog Items

Item	Description
1	Diagnostic level (0–6) selection
2	**Diagnostic READ**, and **Diagnostic READ and FLUSH** buttons
3	Diagnostic data table
4	Diagnostic data browsing buttons: home, page up, previous line, **SAVE**, page down, next line

The diagnostic level is selected using the drop-down arrow (item 1). As the level is selected, or whenever the **Diagnostic READ** or the **Diagnostic READ and FLUSH** button (item 2) is clicked, the diagnostic data table (item 3) is updated. The **Diagnostic READ** button only reads the data. The **Diagnostic READ and FLUSH** button also clears the data buffer. The diagnostic data table can be browsed using the home, page up, page down, previous line, and next line directional buttons (item 4). The contents of the diagnostic data is described in Table 6-19.

If you want to save diagnostic data for later analysis, or troubleshooting, click **SAVE** to call up the **File Dialog** dialog (see Figure 6-19), from which an ASCII file can be generated. The arrangement of the file is identical to the diagnostic data table.

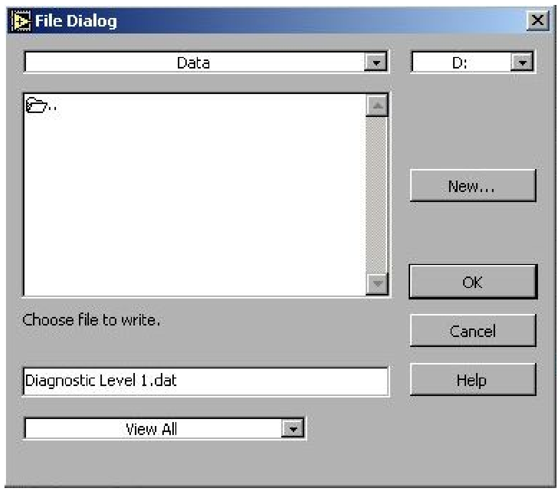


Figure 6-19 File Dialog, Dialog

Table 6-19 lists and describes the contents of the diagnostic data table shown in Figure 6-18 (identify the function of the sensor whose diagnostic is shown–there are ten codes for all sensor functions).

Table 6-19 Diagnostic Data Table Items

Diagnostic Data	Description
code 10–19	Camera Sensor Link Diagnostic
code 20–29	Post Master Diagnostic
code 20–39	State Machine Diagnostic
code 40–49	Init Diagnostic
code 50–59	Scan Diagnostic
code 60–69	Standardize Diagnostic
code 70–79	Edge Diagnostic
code 80–89	Sample Diagnostic
code 90–99	Single Diagnostic
code 100–109	Light Diagnostic
code 110–119	Launcher Diagnostic
code 120–129	Parameter Diagnostic
code 130–139	Diag Diagnostic
Level	Diagnostic level
Type	Data type
P1–P5	Diagnostic parameters to where diagnostic data is saved

As shown in Table 6-19, only diagnostic levels 1, 2, and 6 are currently in use. Selecting any of the unused levels (3, 4, or 5), or level 6, leaves the diagnostic data table grayed-out and filled with zeros.

Selecting level 6 updates the Camera Sensor Link counters (see item 9 in Figure 6-17, and Figure 6-20) just below the diagnostic data table. These counters report the status of Camera Sensor Link (between FotoFiber and MSS). If any of the error counts starts to accumulate, there is some problem with the link. In normal conditions the counters should remain zero.

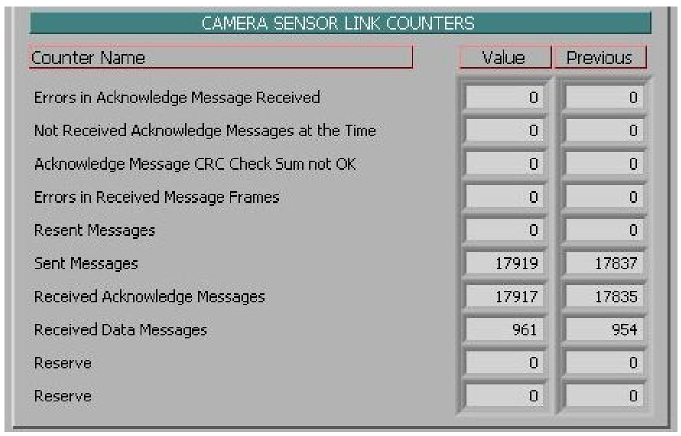


Figure 6-20 CAMERA SENSOR LINK COUNTERS Dialog

7. Detailed Sensor Structure

This Chapter describes selected details of the FotoFiber sensor structure.

7.1. Power connections

The power connections, and the power switch in the off position, are shown in Figure 7-1.

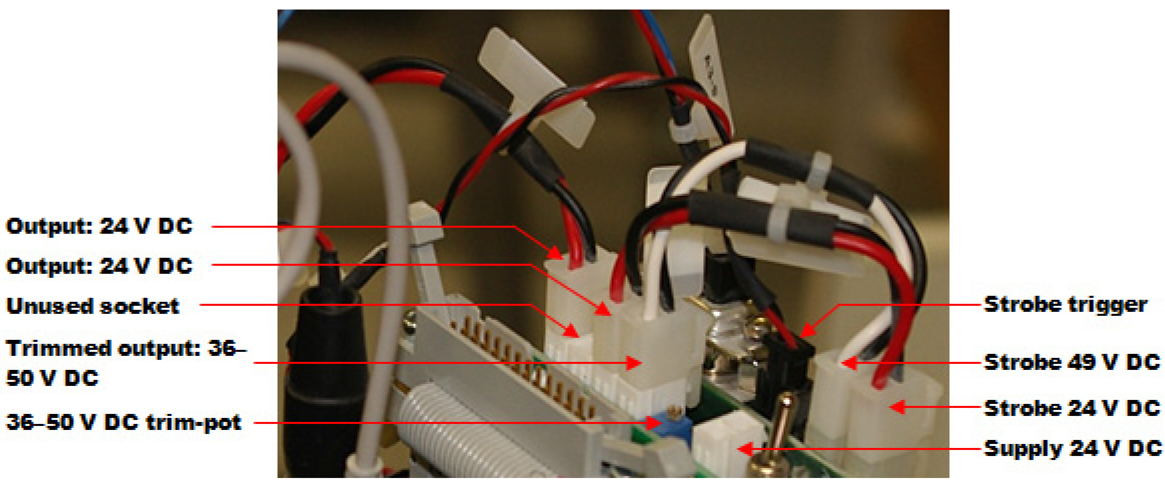


Figure 7-1 FOMM DC Internal Power Connections

There is a single 24 V DC power input to the FotoFiber power and isolation PCB that supplies power for all sensor functions. The power and isolation PCB has a DC/DC converter which supplies clean 24 V DC power to three output sockets. Two of these output sockets are used; the third is an unused spare. The PCB also has an output trim-pot adjustable from 36–50 V DC, which is used by the strobe control PCB and is normally set to 49–49.5 V.

ATTENTION

> Normally, the 49 V connection uses black and white conductors, and the 24 V connections use black and red conductors; however, note carefully the relative positions of the 49 V and 24 V sockets on both PCBs shown in Figure 7-1, and always ensure that they are properly connected before powering up the sensor.

The FOMM uses the standard sensor connector that supplies power to the sensor. The cable harness attached to this connector already routes power appropriately to the power and isolation PCB and to the EDAQ.

CAUTION

> Note that all of the power input and output sockets are of the same type, so some care is necessary in choosing which connector to use. Connecting a 24 V device to the 36–50 V DC socket could permanently damage the device.

Power supply requirements:

- 24 V DC ± 10%
- Current max 1.5 A (typically 1.0–1.1 A in operation)

Connector type: Molex Mini-Fit Jr Crimp Power Connector, 5559 Panel Mount Plug. Manufacturer part no: 39-01-2021.

Table 7-1 lists and describes the pins on the power supply.

Table 7-1 Power Supply

Pin	FOMM Power Supply
1	+ 24 V DC
2	GND for 24 V DC

Note that Pin 1 on the sockets is the pin closer to the PCB. The polarity of the plug must match that of the socket.

24 V DC outputs

These are three identical Molex sockets. Two are used; the third is spare, but all three are equivalent in function. One is used to supply power to the processor module, another supplies 24 V DC to the strobe control PCB.

36–50 V DC output

This supplies power to drive the LED panels for illuminating the sheet. The RMS current is only a few milliamps. It should be set within the range 49–49.5 V DC at the factory, but can be adjusted using the trim-pot.

CAUTION

> The 36–50 V DC connector is identical in appearance to the 24 V DC connectors, but is the one adjacent to the output trim-pot. The 24 V and 48 V sockets should be clearly marked on both PCBs.

The conductors on the cable for the 36–50 V DC connector are black (-) and white (+), rather than the black and red used in the 24 V DC cables.

Output trim-pot for 36–50 V DC

This trim-pot is used to adjust the maximum voltage used to drive the LEDs. It can be adjusted using a small flathead screwdriver (see Subsection 9.6.1.2).

7.2. Communication connections

7.2.1. Camera sensor link

The camera sensor link (CSL) communication between the Q4223-5x FotoFiber sensor and the MSS is by Ethernet at 100Mbit/s. The FotoFiber processor module has a standard RJ45 connector for a Cat5 cable to the switch in the scanner head.

There is also a fast serial link to the EDAQ PCB for exchange of initialization data such as IP address, and for exchange of time synchronization messages. The link is full-duplex, and communication speed is 76800 bit/s. The processor module output signal is at TTL-level (0–5 V) which is converted in the power and isolation PCB to RS422. The RS422 is a four wire connection that allocates two wires for transmitted data, and two wires for received data. Output signals are isolated from the sensor power supply.

The FOMM connector is similar to the 4215 Color sensor signal connector. The CSL is used for communication between the FOMM and MSS.

Provision has been made for communication with a companion device, and for sending a fast analog trigger for synchronization with the companion device. These are not in use in FotoFiber sensors.

The FOMM connector carries these signals, and is part of the FotoFiber wiring harness in MX systems. It connects to the large socket near the center of Figure 7-1:

- connector type: 3M cable plug 26-pole; manufacturer part no 4626-6000

Table 7-2 Pin and Signal Description

Pin	Signal	Description
1–14		Not in use
15	FOMM TX+	CSLP link between sensor and MSS; RS422
16	FOMM TX-	CSLP link between sensor and MSS; RS422
17	FOMM RX+	CSLP link between sensor and MSS; RS422
18	FOMM RX-	CSLP link between sensor and MSS; RS422
19		Not in use
20		Not in use
21	Comp A	Communication link to companion device; RS 485
22	Comp B	Communication link to companion device; RS 485
23	Sync Trig+	Trigger to companion device; 24 V fast binary signal
24	Sync Trig-	Trigger to companion device; 24 V fast binary signal
25		Not in use
26		Not in use

7.2.2. Light control link

The processor module controls FOMM light parameters via the light control link. The strobe control PCB reports its operating parameters to the processor module, and the processor module sends new parameters. Some parameters are relevant only during standardization scans or during maintenance operations; others are relevant whenever the strobe is operating.

The link is half-duplex RS232, and communication speed is 9600 bit/s. Standard 9-pin D subminiature connectors are used at both ends of the link, but only three of the pins are in use (pins 2, 3, and 5).

7.2.3. Light trigger

The processor module triggers light on via a triggering line. The trigger signal is a very short pulse, with a typical length of 20 µs. The light pulse length is controlled by strobe parameters, and is typically less than 1.0 µs. That precisely timed pulse is sent to all the LED driver PCBs simultaneously, limiting jitter in flash timing to below 10 ns. The trigger signal is TTL-level (0–5V), which is converted to a 24 V isolated signal in the power and isolation PCB. That isolated signal is then delivered to the strobe control PCB. Only two wires are needed for the light trigger signal.

7.2.4. Camera trigger

The camera exposure is triggered by the processor module. The signal can be TTL level (0–5V) or isolated level (24V), set using a jumper, with default TTL level. The pulse duration is very short, typically 20 µs. The camera trigger occurs about 10 µs before the light trigger, ensuring that the camera exposure is active when the strobe is discharged.

7.3. LEDs

7.3.1. Strobe control PCB LEDs

There are several LEDs on the strobe control PCB (see Figure 7-2).

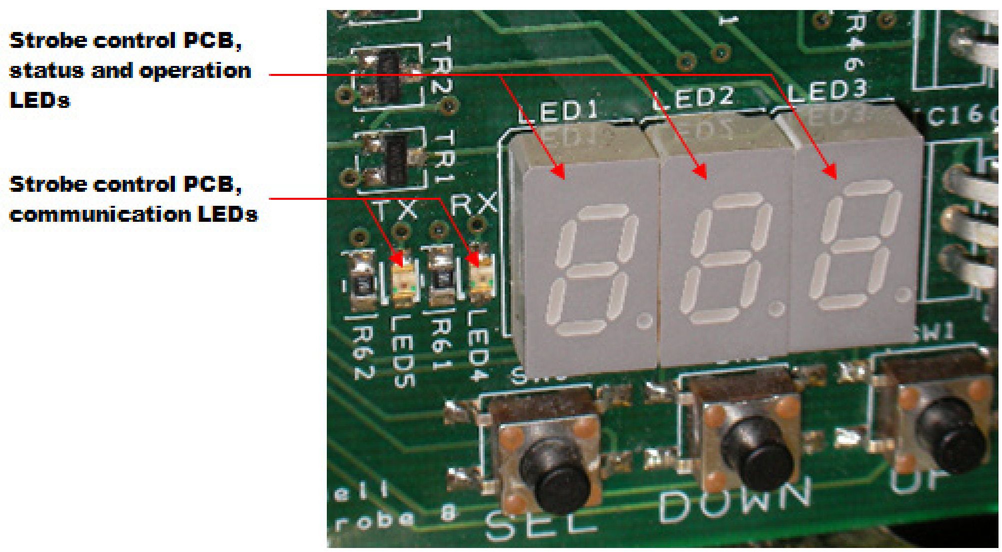


Figure 7-2 Strobe Control PCB LEDs

7.3.2. Strobe control PCB status and operation LEDs

The strobe controller status and operation display is a three-digit digital LED display. When the sensor is powered on, the strobe control PCB executes a selftest. It briefly displays, first, its model number (always 880), then its firmware revision number, for example, 003. It then performs some self-diagnostics.

If an error condition is found, it displays the error number preceded by the letter E, for example, E04. Spurious errors are occasionally generated if the power is rapidly cycled off and on. If an error occurs, power-down the sensor for about a minute, then power-up. If the error is persistent, the PCB might need to be replaced, in which case, contact QCS-TAC for further guidance.

During normal operation, alternating horizontal line triplets (**- - -**) are displayed, but when a strobe trigger is received, the text, **PUL**, is briefly displayed.

7.3.3. Strobe control PCB communication LEDs

These are two small LEDs on the strobe control PCB. They flash whenever data is transferred between the strobe control PCB and the processor module over the light control link. Typically, this happens when the strobe is initialized after sensor power-on, during end-of-scan adjustments to strobe levels, during a standardization scan, during offsheet sample and reference measurements, and during specific maintenance operations such as strobe recalibration.

7.3.3.1. Pushbuttons below operation display

There are three pushbuttons located below the operation display LEDs:

- **SEL**
- **DOWN**
- **UP**

These are used only in bench testing of the strobe control PCB, or in testing the strobe function using an external trigger instead of the trigger from the processor module. They may be used in advanced sensor diagnosis under guidance from QCS-TAC or a sensor developer, but are not needed in any normal sensor maintenance or troubleshooting.

The **SEL** pushbutton, if held for a few seconds, will activate the pushbutton functions.

Initially, a channel number will be shown on the display, starting with channel 1, and after a brief delay the output level for the channel will be displayed. The output level can be adjusted from 0–999 with the **UP** and **DOWN** buttons. Pushing **SEL** again will set the level, and change the display to the next channel number.

After the eight channels have been processed, pushing the **SEL** button sequentially will show, in turn:

- pulse length
- pulse delay
- channel mask
- debounce

Each of these can be adjusted with the **UP** and **DOWN** pushbuttons, before using the **SEL** pushbutton to proceed to the next item.

7.3.4. CVS-1456 LEDs and DIP switches

This section describes the appearance and function of the LEDs and DIP switches on the National Instruments CVS-1456 processor module (see Figure 7-3).

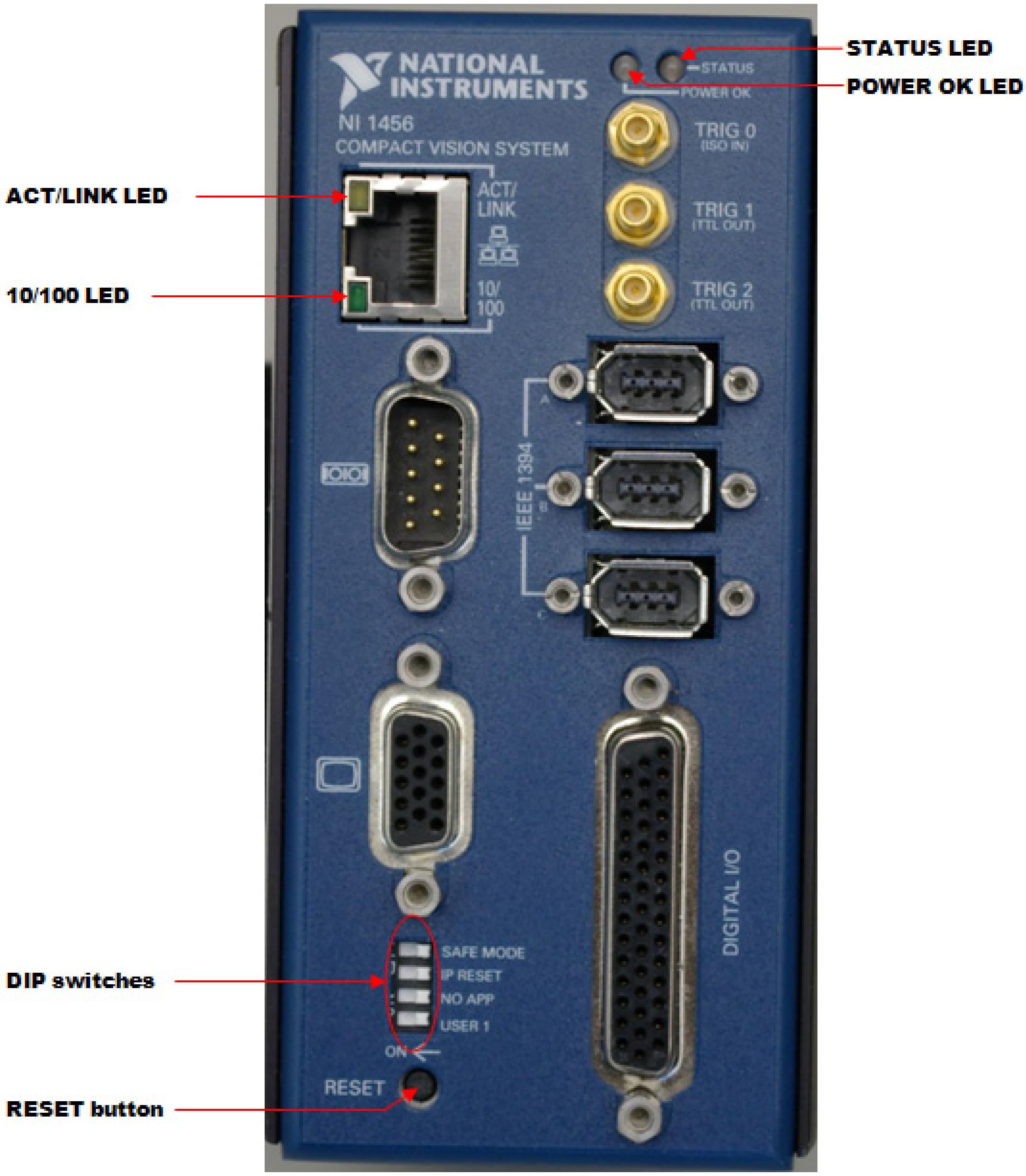


Figure 7-3 CVS-1456 Processor Module: LEDs and DIP Switches

7.3.4.1. STATUS LED

The orange **STATUS** LED remains *off* under normal operating conditions. It periodically flashes a specific number of times to indicate error conditions or certain DIP switch settings. The **STATUS** LED remains *on* if the processor module detects an internal error.

7.3.4.2. POWER OK LED

Under normal operating conditions, the **POWER OK** LED remains green while the processor module is powered on. The green **POWER OK** LED indicates that the processor module main power input is receiving a suitable voltage and current, and that the processor module is not in a fault state. The red **POWER OK** LED indicates that the processor module has shut down because of a fault state. A fault state occurs when the user shutdown input is set, the processor overheats, or the watchdog timer expires.

7.3.4.3. ACT/LINK LED

The orange **ACT/LINK** LED blinks when the processor module receives data from or transmits data to the network through the Ethernet connection. Unrelated network activity causes this LED to blink occasionally, even when the processor module is inactive.

7.3.4.4. 10/100 LED

The green **10/100** LED is *on* when the network provides 100 Mbit/s support and the processor module is communicating at 100 Mbit/s. If the 100 Mbit/s LED is *off*, the processor module Ethernet link is not operating at 100 Mbit/s.

7.3.5. DIP Switches

The FotoFiber sensor has four DIP switches on the processor module in the FOMM (see Figure 7-3). To enable a DIP switch, move it to the left to the ON position, and then reset the processor module by depressing the **RESET** button for at least two seconds, then releasing it.

Table 7-3 lists the processor module DIP switch default settings.

Table 7-3 DIP Switch Settings

DIP switch	Setting
SAFE MODE	OFF
IP RESET	OFF
NO APP	OFF
USER 1	OFF

SAFE MODE: The **SAFE MODE** DIP switch is used to reconfigure TCP/IP settings and to download or update software from the development computer. Downloading incorrect software to the processor module may cause it to hang during restart or become inaccessible over the network. Powering on or resetting the processor module in safe mode starts the processor module, but does not start the embedded LabVIEW Run-Time engine. This mode allows communication over Ethernet (such as by using FTP) to install new files. To resume normal operations, restart the processor module with the **SAFE MODE** switch in the *off* position.

IP RESET: The **IP RESET** DIP switch is used to clear the processor module IP settings. Move the **IP RESET** switch to the ON position and reset the processor module. Use **IP RESET** to reset the TCP/IP settings when moving the system from one subnet to another, or when the current TCP/IP setting is invalid. Resetting the processor module with the **IP RESET** switch in the ON position resets the IP address to 0.0.0.0. You can then set up a new network configuration for the processor module from a development machine on the same subnet, or you can use an Ethernet crossover cable to connect the processor module directly to the development computer. Resetting the IP address is used in sensor manufacture, but is not necessary in the field.

NO APP: The **NO APP** DIP switch is used to prevent the processor module from automatically running programs at startup. If this switch is the ON position when the processor module starts, the processor module loads the LabVIEW Run-Time engine, but does not load the FotoFiber application or the default Vision Builder application. If the processor module becomes inaccessible due to an incorrect startup program, enable the **NO APP** switch and reset the processor module. The correct application file can then be loaded using FTP.

USER 1: The **USER 1** DIP switch is used at boot time to select between normal operation and maintenance operation of the sensor. If the **USER 1** switch is in the *off* position, the sensor will boot normally with scanning measurement firmware. If the **USER 1** switch is in the ON position, the sensor boots with different firmware, which supports a number of special maintenance and diagnostic procedures, as well as calibration and test measurement (see Section 9.3 and Section 10.2.4).

CAUTION

Improper use of the **IP RESET** switch can render a FotoFiber unresponsive to normal maintenance operations, so use only the **USER 1** switch unless instructed otherwise by TAC personnel or sensor developers.

7.4. Fuse, switches, jumpers

7.4.1. Fuse

FotoFiber has one fuse, located near the power switch on the power and isolation PCB (see Figure 7-4). In the event of a serious hardware misconfiguration, such as reversed polarity or overvoltage, this fuse will protect the rest of the FotoFiber circuitry. A replacement fuse is supplied as a spare part with the FotoFiber sensor.

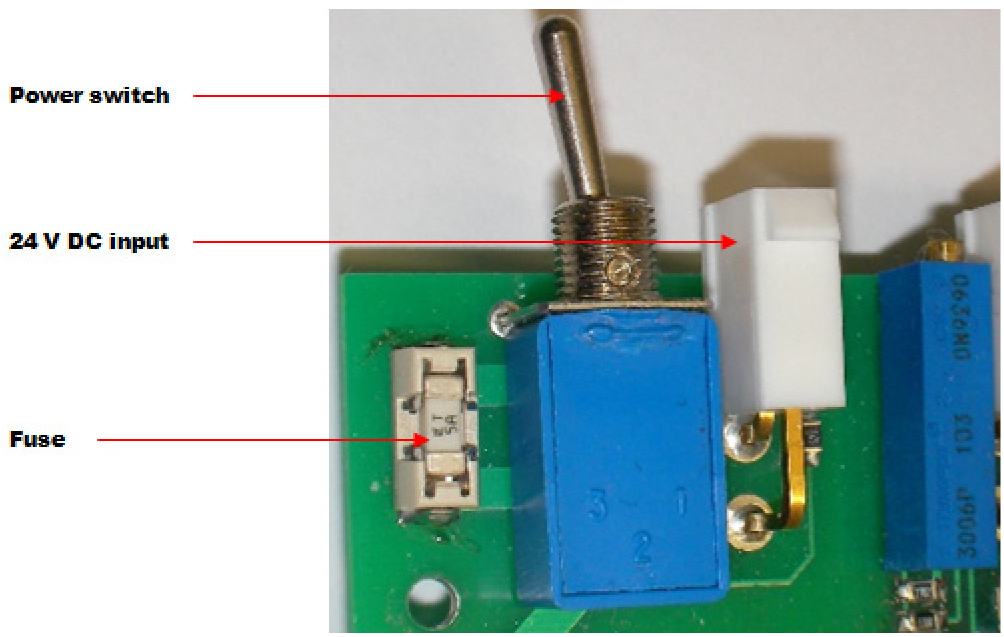


Figure 7-4 Power and Isolation PCB (1 of 2)

7.4.2. Power switch

The FotoFiber has a power switch on the power and isolation PCB, located beside the 24 V DC input power socket as shown in Figure 7-4. In that figure, the power switch is in the *off* position.

Use the power switch to power-off the sensor before disconnecting the external communication and power cables. The FotoFiber sensor must be powered down, and the external power cable disconnected, before attempting to disconnect any of its internal cables.

7.4.3. Jumpers

There are several jumpers on the power and isolation PCB, but only one is significant to FotoFiber operation. The jumper is not accessible unless the sensor is dismantled to replace the strobe control PCB or the power and isolation PCB. There should be no need to change the jumper setting, unless the jumper became dislodged during transport of a replacement power and isolation PCB.

Jumper J1 is the 3-pole jumper located closest to the camera trigger output connector. It selects between TTL and 24 V isolated output levels for the trigger signal sent to the camera. The standard camera used in the FotoFiber can accept either TTL or 24 V trigger signaling, so the position of this jumper is not critical. By default, the sensor is shipped with the jumper on the two poles closest to the camera trigger output connector to select the TTL 5 V level as shown in Figure 7-5.

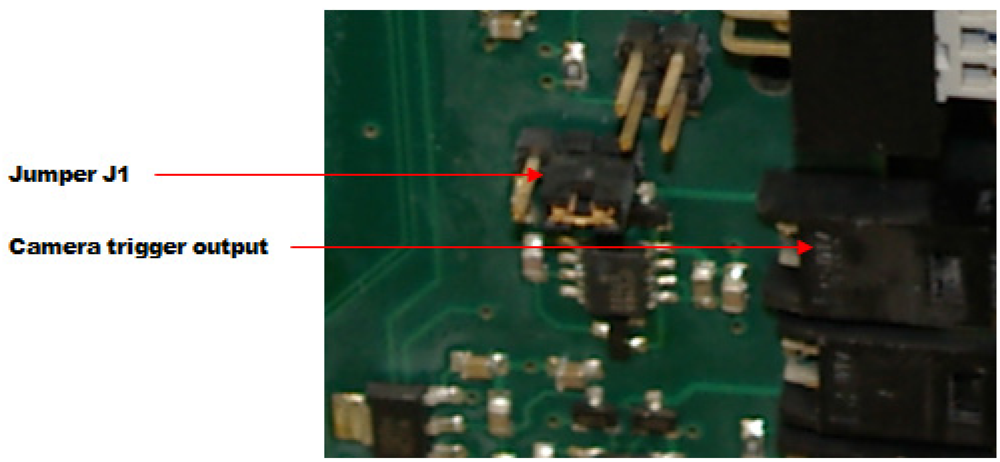


Figure 7-5 Power and Isolation PCB (2 of 2)

7.5. Special PCBs

The FotoFiber contains four purpose-built PCBs. With some kinds of sensor problems, diagnosis may include examining these boards. The figures in this section are provided to help clarify communication when diagnosis is assisted by QCS-TAC.

7.5.1. LED panel PCB

There are eight LED panel PCBs, each powered by an LED driver PCB. The back of the panel is shown in Figure 7-6.

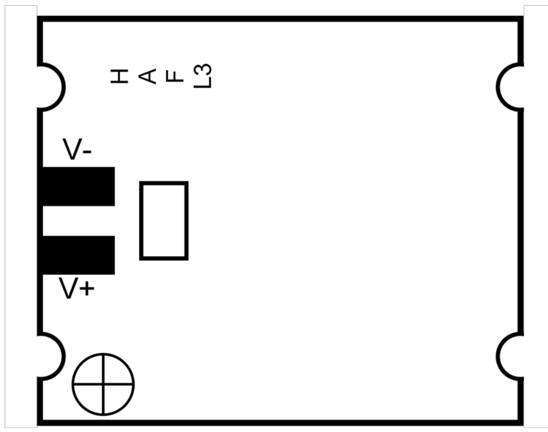


Figure 7-6 LED Panel PCB (back)

Conductors leading from the LED driver PCB are soldered to pads at V+ (red #16 gauge conductor) and V- (black #16 gauge conductor). The solder connections are vulnerable if the sensor is subjected to mechanical shock or severe vibration for an extended time.

There are 24 LEDs on the front of this PCB, each with a lens. The lenses can become detached if the sensor is subjected to mechanical shock or severe vibration. They can be re-attached using Super Glue® (see Subsection 9.6.7).

The LED panel PCBs are approximately 32 mm (1.25 in.) long and 17 mm (0.66 in.) wide, and contain the identifier, *HAFL3*.

7.5.2. LED driver PCB

There are eight LED driver PCBs (see Figure 7-7), one for each LED panel.

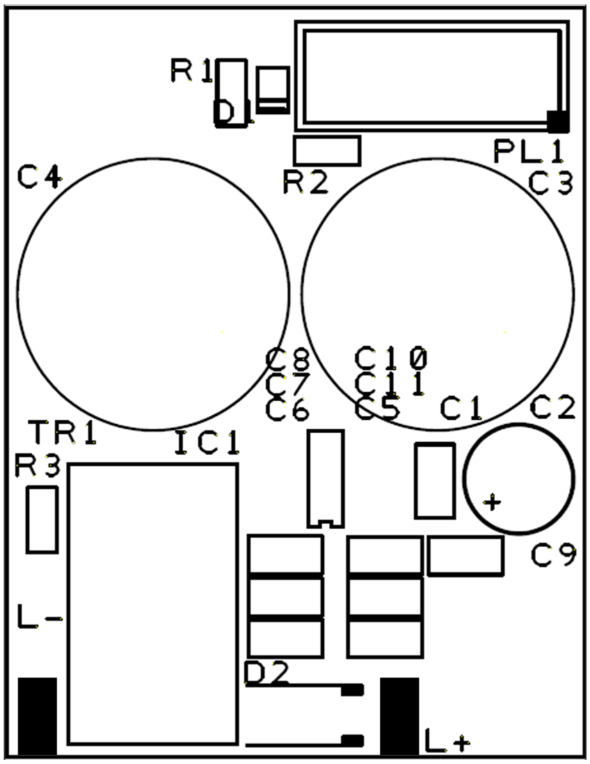


Figure 7-7 LED Driver PCB

Each LED driver PCB has a cable to the strobe control PCB connected in the socket at PL1. There are two lengths of cable, ordered as a set. The cables can be dislodged from or loosened in their sockets if the sensor is subjected to mechanical shock or severe vibration.

Conductors leading to the LED panel PCB are soldered to pads at L+ (red conductor) and L- (black conductor). These solder connections are vulnerable if the sensor is subjected to mechanical shock or severe vibration.

Mishandling of the sensor resulting in lateral forces on capacitors C3 and C4 or socket PL1 may cause them to be electrically separated from the PCB. These components protrude beyond the polymer octagons comprising the light source assembly.

The LED driver PCBs are approximately 34 mm (1.34 in.) long and 22 mm (0.86 in.) wide.

7.5.3. Strobe control PCB

The strobe control PCB has a TTL trigger input at socket PL11 (*Trig*), a 24 V DC supply at CONN1 (24 V), and a trimmed 49 V DC supply at CONN2 (see Figure 7-8). Note the revision number under the *FastStrobe 8* marking, to the left of the **SEL** button, if needed by QCS-TAC to assist in problem solving.

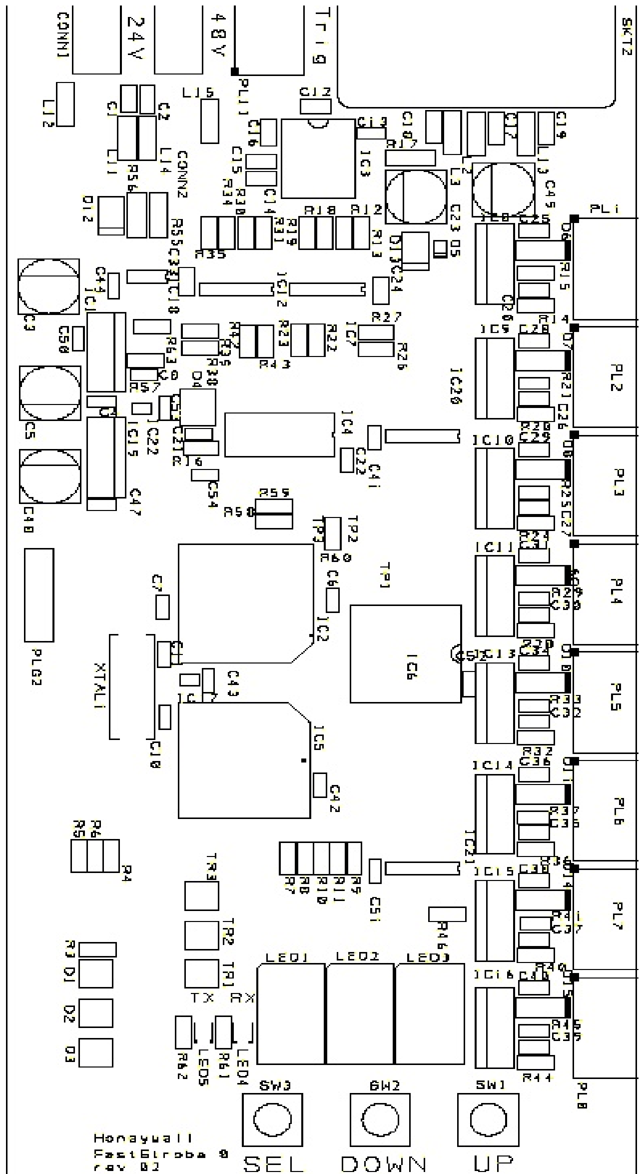


Figure 7-8 Strobe Control PCB

Sockets PL1 to PL8 have cables leading to the LED driver PCBs, while SKT2 has a RS232 serial link to the processor module.

7.5.4. Power and isolation PCB

The power and isolation PCB (see Figure 7-9) is located behind the strobe control PCB. Only its connectors are accessible in normal maintenance.

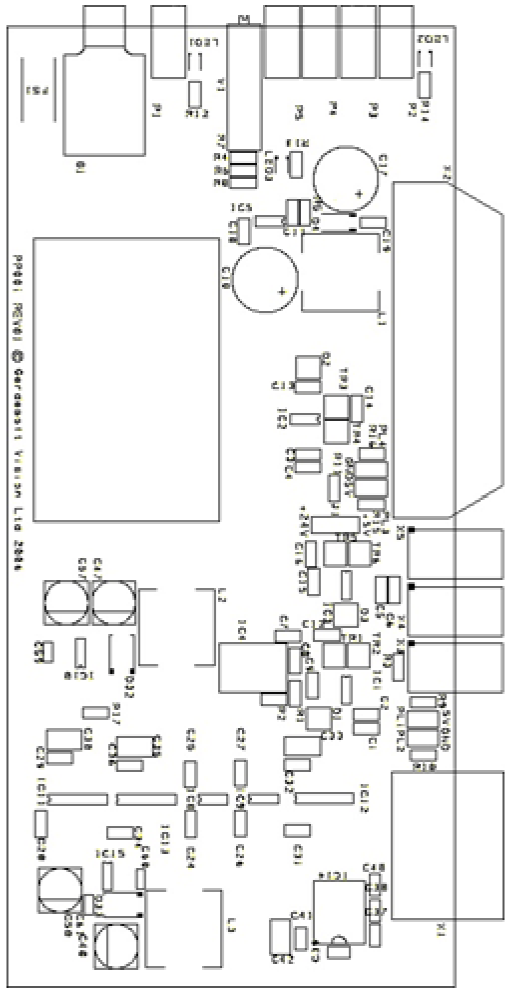


Figure 7-9 Power and Isolation PCB

The power and isolation PCB is 150 mm (5.9 in.) long and 70 mm (2.75 in.) wide, but its connectors protrude approximately 8 mm (0.31 in.) on the long side and about 4 mm (0.15 in.) on the short side. The switch protrudes about 16 mm (0.63 in.). Jumper J1 is on this PCB.

7.6. Pneumatics

A standard 6 mm (0.236 in.) air hose is required to provide cleaning air flow to the sensor. In the upper sensor construction, this is used to clean the window inside the plenum, and to purge the plenum of any dust. In the lower sensor construction, this is used to clean the window near the sheet, and to blow dust out of the horseshoe ring.

The air-hose connector is a standard nipple, attached to the flange plate of the sensor (see Figure 7-10). The 6 mm (0.236 in.) air hose is pressed securely onto this nipple.

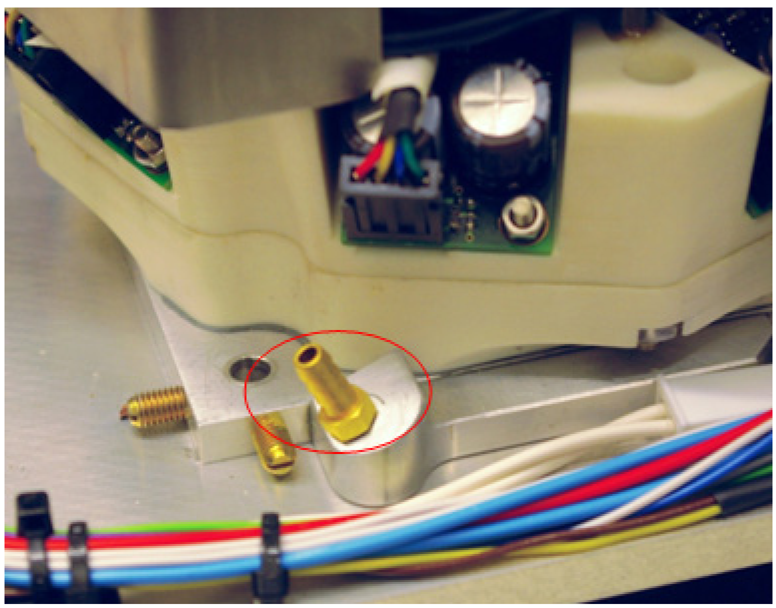


Figure 7-10 Air Connector

8. Preventive Maintenance

Typically, the cleaning schedules must be established on a case-by-case basis, and may differ significantly between machines. The frequency at which sensor standardization and operating parameters are recorded will generally conform to customer practice.

The noise assessment schedule may be affected by contractual obligations.

For a comprehensive list of spare parts and associated product numbers, see Appendix A.

The recommended preventive maintenance schedule is shown in Table 8-1. The letter *X* indicates the recommended interval, an *X* in multiple intervals indicates that the interval should be adjusted according to circumstances, and *AR* indicates *as required*.

Table 8-1 Preventive Maintenance Internal Checklist

Procedure	**Daily**	**Weekly**	**Months**		**Years**			**Task Details**
			1	6	1	2	5	
Sensor cleaning								Section 9.1
Clean lower head sensor	X	X						Subsection 9.1.1.1
Clean upper head sensor		X						Subsection 9.1.1.2
Clean backing module		X						Subsection 9.1.1.3
Clean lens and inner surface of window in lower head sensor	AR							Subsection 9.1.2.1
Clean lens and either surface of window in upper head sensor	AR							Subsection 9.1.2.2
Operating Parameters								Section 9.2
Check standardization results	X							Subsection 9.2.1

Procedure	**Daily**	**Weekly**	**Months**		**Years**			**Task Details**
			1	6	1	2	5	
Record operating parameters	X	X						Subsection 9.2.2
Alignment and accuracy								Section 9.4
Zero angle					X			Subsection 9.4.2
Accuracy					X			Subsection 9.4.3
Measurement stability and noise			X					Subsection 9.4.4
Focus and calibration								Section 9.5
Focus procedure					X			Subsection 9.5.1
Calibrate illuminators					X			Subsection 9.5.2
Offline copy of calibration					X			Subsection 9.5.3
Field repairs and adjustments								Section 9.6
Check conditioned 24 V DC output					X			Subsection 9.6.1.1
Check and adjust trimmed 49 V DC output					X			Subsection 9.6.1.2
Replace fuse	AR							Subsection 9.6.2
Check and reseat camera trigger jumper	AR							Subsection 9.6.3
Check LED cable seating	AR							Subsection 9.6.4
Repair or replace LED panel and/or LED driver PCBs	AR							Subsection 9.6.5
Re-glue lower sensor window	AR							Subsection 9.6.6
Re-glue lens onto LED panel PCB	AR							Subsection 9.6.7
Update firmware								Section 9.7
Replace individual firmware files	AR							Subsection 9.7.1
Load all firmware	AR							Subsection 9.7.2

9. Tasks

9.1. Sensor cleaning

9.1.1. External cleaning

A LENS**PEN**® is supplied with the FotoFiber sensor installation kit, and a replacement can be ordered as a spare part or acquired from photographic equipment stores. Always remember to replace the cap on the LENS**PEN** after each use, and to then give the cap a half turn. Accumulated dust should be shaken off the brush after use, and the brush should then be retracted inside the LENS**PEN**. It should be stored upright, with the brush end upwards. Replace the LENS**PEN** at least once per year, even if it has not been used, because its reservoir of cleaning fluid will dry out.

Clean, oil-free compressed air should also be available for cleaning the sensor window. If mill compressed air is not available, or is not of suitable quality, canned air can be obtained from photographic equipment stores or optical suppliers. Optical tissues and lens cleaning fluid should be available in case of need.

It is good practice to clean both the upper and lower units simultaneously, whether the sensor is two-sided (two FOMM) or single-sided (one FOMM and one FOBM). If time is limited, the upper unit needs be cleaned less often than the lower unit.

9.1.1.1. Clean lower head sensor

A lower head sensor needs regular cleaning. The frequency is dependent on the mill, and may vary from once per shift to once per week.

Activity Number:	Q4223-52-ACT-001	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Operator
Priority Level:	Average	**Cautions:**	None
Availability Required:	Scanner offsheet	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	Once per shift up to once per week
Duration (time period):	5 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
Required Tools:	Part Number	Quantity	Lead Time
	• 54000353; LENS**PEN** • lens cleaning tissues and fluid		

To clean the lower head sensor externally:

1. Take the sensor head offsheet for maintenance (set safety interlocks to prevent scanning), and separate the heads.
2. Remove bulk loose material from the sensor and its surroundings using compressed air across the surface of the head.
3. Remove or loosen dust on the window and horseshoe ring using the brush end of the LENS**PEN**.
4. If there is material adhering strongly to the window or horseshoe, for example, oil, starch, or coating material, remove it using optical cleaning fluid and tissues.
5. Remove any smears or fingerprints from the window using the pad end of the LENS**PEN**, rubbing in small circles or a spiral pattern over the window.
6. Inspect the window for scratches. Replace a window that has clear scratches at the next shutdown.

7. Visually inspect the camera lens and the inner surface of the window for dirt within the sensor. If necessary, clean the internal surfaces at the next shutdown.

Cleaning the window of a lower head sensor using a LENS**PEN** is shown in Figure 9-1. In the image on the left, the brush end is swept across the window, horseshoe, and surroundings to remove loose dust. In the image on the right, the pad is rubbed across the window with circular or spiral movements, keeping the pad flush against the window. Remember to rotate the cap after putting it back on the LENS**PEN**.

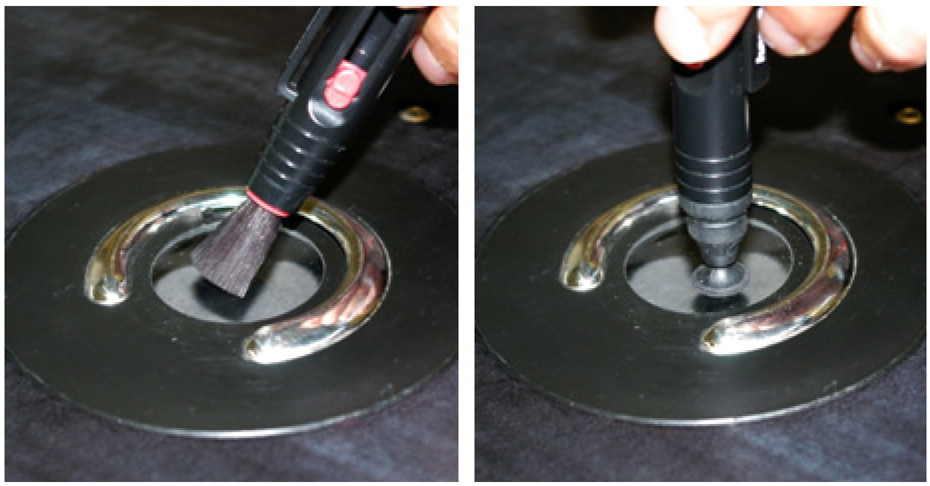


Figure 9-1 Clean Lower Head Sensor With a LENSPEN

9.1.1.2. Clean upper head sensor

Upper head sensors are less prone to dust accumulation than lower head sensors. Their need for cleaning is lower, but it is often convenient to clean both sensors at the same time in a two-sided installation.

Activity Number:	Q4223-52-ACT-002	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Operator
Priority Level:	Average	**Cautions:**	None
Availability Required:	Scanner offsheet	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	Once per week
Duration (time period):	5 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	

Required Parts:	Part Number	Quantity	Lead Time
Required Tools:	Part Number	Quantity	Lead Time
	• 54000353; LENS**PEN** • lens cleaning tissues and fluid		

To clean the upper head sensor externally:

1. Take the sensor head offsheet for maintenance (set safety interlocks to prevent scanning), and separate the heads.
2. Remove bulk loose material from the sensor and its surroundings using compressed air tangential to the surface.
3. Remove or loosen dust on the recessed window and the sheet ring or arcs using the brush end of the LENS**PEN**.
4. Visually inspect the recessed window for strongly adhering dirt. If necessary, clean the recessed window at the next shutdown.
5. Visually inspect the camera lens for dirt within the sensor. If necessary, clean the internal surfaces at the next shutdown.

Using canned air (optical quality, obtainable from photographic equipment shops and optical suppliers) to clean the window and plenum of an upper head sensor is shown in Figure 9-2. Note that an extension tube on the air-can nozzle allows the compressed air to be accurately directed at the surface of the window inside the plenum.

Figure 9-2 Clean Upper Head Window and Plenum With Canned Air

9.1.1.3. Clean backing module

Clean the backing module whenever a one-sided sensor is cleaned.

Activity Number:	Q4223-52-ACT-003	**Applicable Models:**	Q4222-51
Type of Procedure:	Maintain	**Expertise Level:**	Operator
Priority Level:	Average	**Cautions:**	None
Availability Required:	Scanner offsheet	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	Once per week
Duration (time period):	5 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time

Required Tools:	Part Number	Quantity	Lead Time
	• 54000353; LENS**PEN** • lens cleaning tissues and fluid		

To clean a backing module:

1. Take the sensor head offsheet for maintenance (set safety interlocks to prevent scanning), and separate the heads.
2. Remove bulk loose material from the backing module and its surroundings using compressed air tangential to the surface.
3. Remove or loosen dust on the FOBM surface and its sheet ring or arcs using the brush end of the LENS**PEN**.

9.1.2. Clean internal surfaces

Use a LENS**PEN** and clean compressed air if it is necessary to clean internal optical surfaces of the FotoFiber sensor. This is normally unnecessary, but may be required if the interior of the head is exposed to dust. This could happen, for example, if the environment becomes dusty due to mill operational mishaps or other unexpected incidents while the head is open for maintenance.

Dust should be removed from general surfaces inside the head using a vacuum cleaner and/or by blowing with clean compressed air.

To clean internal optical surfaces of the FotoFiber, it is necessary to remove the sensor from the head (see Section 4.5), and bring it to a clean dry environment. Depending on the severity of dirt build-up inside the sensor, it may be necessary to partly disassemble the unit to access optical surfaces.

9.1.2.1. Clean lens and inner surface of window in lower head sensor

Activity Number:	Q4223-52-ACT-004	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	None
Availability Required:	Scanner offsheet	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	If required
Duration (time period):	60 minutes	**# of People Required:**	1

Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
Required Tools:	Part Number	Quantity	Lead Time
	• 54000353; LENS**PEN** • lens cleaning tissues and fluid • hex wrenches		

The outer surface of the window of a lower sensor can be cleaned as described in Subsection 9.1.1.1. To access the inner surface of a lower sensor window for cleaning (with the sensor in a clean dry environment):

1. Make an alignment mark on both octagonal polymer parts with a felt pen. This step may not be needed if suitable alignment marks are present from earlier maintenance.

2. Open the four bolts, holding the upper and lower octagonal parts together, with a hex key. A small needle-nose pliers may be needed to hold the nuts and prevent them from turning (see Figure 4–2, left). The processor module must be swung out on its hinged base to access one of the bolts.

3. Place the nuts and bolts into a container where they will not be affected by strong air flows

4. Gently separate the upper and lower parts of the sensor. Hold only the stronger parts of the sensor–do *not* apply any force to the connectors or components on the small LED driver PCBs, because they are easily damaged by lateral forces.

The inner surface of the window can be accessed via the plenum. When cleaning with compressed air and the brush end of the LENS**PEN**, be sure to remove any dust adhering to the ring clip above the window. Use the pad end of the LENS**PEN** to remove any smears from the window.

The lens can be cleaned in a similar fashion while in-place on the camera. Use optical quality compressed air and the brush end of the LENS**PEN** to remove dust, then apply the pad end of the LENS**PEN** to remove any smears. Ensure that any dust removed from the lens does not adhere to the newly cleaned window.

Reassembly is the reverse of the disassembly procedure. Ensure that the marks made on the octagonal polymer parts are aligned.

After the sensor is replaced in the head, clean the outer surface of the sensor window to remove smears or finger prints which might result from handling the sensor.

9.1.2.2. Clean lens and either surface of window in upper head sensor

Activity Number:	Q4223-52-ACT-005	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	None
Availability Required:	Scanner offsheet	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	if required
Duration (time period):	60 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
	16000235 thread locking compound		
Required Tools:	Part Number	Quantity	Lead Time
	• 54000353; LENS**PEN** • lens cleaning tissues and fluid • hex wrenches		

The window of an upper sensor is recessed above the open plenum. The outer surface of the window on an upper sensor may require cleaning from time to time. To remove the inner window from an upper sensor for cleaning (also see Subsection 4.2.1.1):

1. Make an alignment mark on both octagonal polymer parts with a felt pen. This step may not be needed if suitable alignment marks are present from earlier maintenance.

2. Open the four bolts, holding the upper and lower octagonal parts together, with a hex key. The bolts are in the protruding corners of the polymer octagons. A small needle-nose pliers may be needed to hold the nuts and prevent them from turning.

3. Place the nuts and bolts into a container where they will not be affected by strong air flows.

4. Gently separate the upper and lower parts of the sensor. Hold only the stronger parts of the sensor, and do *not* apply any force to the connectors or components on the small LED driver PCBs.

5. With the lower part of the sensor on a clean flat surface, carefully pry the window free from the holder. Do not use forces which might scratch or break the window. A flat-head screwdriver may be used for this (see Figure 9-3).

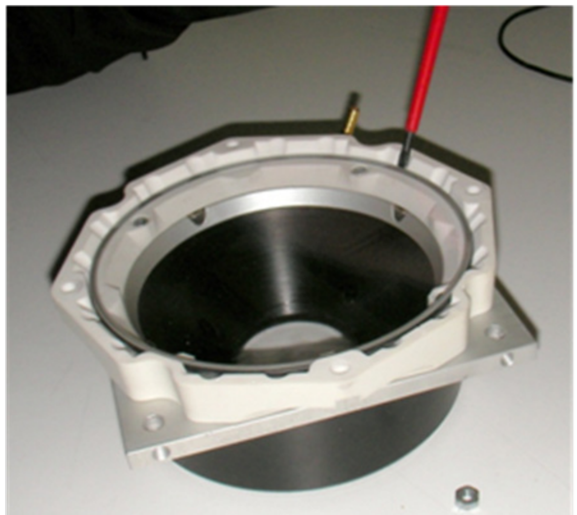


Figure 9-3 Remove Upper Sensor Window

6. Clean the window first with optical-quality compressed air directed across one surface, then the other surface.

7. Use the brush end of the LENS**PEN** to remove any remaining particles from both surfaces of the window.

8. Use the pad end of the LENS**PEN** to remove smears from each surface, including any finger prints left from handling the window (hold the window only by its edges for this step).

The lens can be cleaned in a similar fashion while in-place on the camera. Use optical quality compressed air and the brush end of the LENS**PEN** to remove dust, then apply the pad end of the LENS**PEN** to remove any smears. Ensure that any dust removed from the lens does not adhere to the newly cleaned window.

Reassembly is the reverse of the disassembly procedure. After pressing the window into place in the holder, it might be necessary to clean smears off its upper surface. Ensure that the marks made on the octagonal polymer parts are aligned when the polymer octagons are joined.

When attaching the nuts onto the bolts to hold the upper and lower polymer octagons together, thread locking compound should be applied to the threads of each nut.

9.2. Working with operating parameters

9.2.1. Check standardization results

Activity Number:	Q4223-52-ACT-006	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Operator
Priority Level:	Average	**Cautions:**	None
Availability Required:		**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	daily
Duration (time period):	1 minute	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
Required Tools:	Part Number	Quantity	Lead Time

The **FotoFiber Standardization** display (see Figure 6–15) should be inspected on any operator station:

- check that here are no red or yellow standardization flags from recent standardizations (right end of trend of flags)
- check all channel factors are between 0.7 and 1.4

Note that if the machine has recently started, or if maintenance has been performed on the FotoFiber sensor, it is normal that there may be up to three standardizations immediately afterwards with red or yellow flags.

If any channel factor is outside the 0.7–1.4 range, maintenance should be scheduled. If any factor has reached 0.6 or 1.6, maintenance is required.

9.2.2. Record operating parameters

Activity Number:	Q4223-52-ACT-007	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Operator
Priority Level:	Average	**Cautions:**	None
Availability Required:		**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	for each major grade
Duration (time period):	5 minute	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
Required Tools:	Part Number	Quantity	Lead Time

The operating parameters of the sensor are found on two of the displays, the **FotoFiber Edge** display, and the **FotoFiber Standardization** display. Those parameters should be recorded after each major change in machine operation (speed or grade). For a machine which makes essentially the same grade, the values should be recorded approximately once per week.

The **FotoFiber Edge** display:

- current output levels for each illuminator channel
- machine speed sent to sensor, expressed in meters per second
- camera gain
- graylevel achieved in images

The **FotoFiber Standardization** display:

- standardization factors for each illuminator channel
- graylevel achieved for each illuminator channel
- number of measurements in combined illuminator scan

- graylevel achieved in combined illuminator scan
- standardization flags

The simplest method is to take a screenshot of the displays.

9.3. Preparing maintenance setup

Some maintenance procedures can be performed with the sensor in the scanner head (provided there is either a FOBM or a second FOMM opposite it), or on a clean flat surface. Others can be performed only with the sensor removed from the scanner head, preferably on a laboratory bench. However, it is strongly recommended that illuminator calibration be performed with the sensor outside the head, on a bench in a clean workspace.

9.3.1. Set-up on bench

If maintenance is performed on a bench, an external power supply must be available to provide at least 1.5 A of clean 24 V DC, and there must be a suitable connector for connecting to the FotoFiber.

Activity Number:	Q4223-52-ACT-008	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	None
Availability Required:	Sensor removed from scanner	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	
Duration (time period):	60 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
	A 24 V DC power supply A two-conductor cable with connector for the power supply at one end and Molex connector 39-01-2021 at the other		
Required Tools:	Part Number	Quantity	Lead Time
	• laptop with Honeywell Intelligent Sensors software		

Connector type: Molex Mini-Fit Jr Crimp Power Connector, 5559 Panel Mount Plug, manufacturer part number 39-01-2021.

Table 9-1 Power Supply Pin Assignment

Pin	Description
1	+ 24 V DC
2	24 V DC GND

Note that Pin 1 on the socket is the pin closer to the PCB.

ATTENTION

The external power polarity should be verified before proceeding.

With the sensor power switch in the **OFF** position, the **USER1** DIP switch should be set to the ON position. The other DIP switches should be in the *off* position. The power connector should be plugged into the 24 V input socket on the power and isolation PCB; the socket closest to power switch (see Figure 1–2).

A PC or laptop with the Intelligent Sensors software should be connected using a standard Cat5 or Cat6 Ethernet cable to the Ethernet port on the processor module. The PC should have IP address 169.254.100.100 for the wired Ethernet port, and *all other network interfaces must be disabled*. The Intelligent Sensors software should be started, and then the FotoFiber should be powered-on.

The FotoFiber sensor will boot twice (this takes almost two minutes), during which time the Intelligent Sensors software will indicate **busy**, and waiting for communication, as shown in Figure 9-5. There may be a further delay of up to a minute for the PC and the FotoFiber to establish communication and set up shared data structures over the network.

Figure 9-4 Intelligent Sensors Software Sensor Status Indicator (busy)

After communication is fully established, the status will change to **ready**, as shown in Figure 9-6.

Figure 9-5 Intelligent Sensors Software Sensor Status Indicator (ready)

ATTENTION

Do not start any procedures or click any menu items until the status is **ready**. Starting any procedure before the status is **ready** will cause the PC and the FotoFiber to become uncoordinated.

9.3.2. Set-up in head

If maintenance is performed within the scanner head, the sensor should be powered-off using its switch, and the **USER1** DIP switch on the processor module should be set to the ON position. The other DIP switches should be in the *off* position.

Activity Number:	Q4223-52-ACT-009	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	None
Availability Required:	Sensor removed from scanner	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	
Duration (time period):	10 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
Required Tools:	Part Number	Quantity	Lead Time

A PC or laptop with the Intelligent Sensors software should be connected using a standard Cat5 or Cat6 Ethernet cable to the Ethernet port on the processor module. The PC should have IP address 169.254.100.100 for the wired Ethernet port, and *all other network interfaces must be disabled*. The Intelligent Sensors software should be started, and then the FotoFiber should be powered-on.

The FotoFiber sensor will boot twice (this takes a minute or so), during which time the Intelligent Sensors software will indicate **busy** status. After communication is established, the status will change to **ready**.

ATTENTION

> Do not start any procedures or click any menu items until the status is **ready**. Starting any procedure before the status is **ready** will cause the PC and the FotoFiber to become uncoordinated.

9.4. Check alignment and accuracy

Before installation, the alignment of the sensor must be checked, and an appropriate value inserted for the zero angle parameter. Also, assessment of measurement accuracy and stability can be performed periodically. This requires removing the sensor from the head, and setting up for maintenance on the bench, as in Subsection 9.3.1.

9.4.1. Set up alignment and accuracy tests

Sensor alignment and accuracy are assessed using the FotoFiber test specimen holder assembly, with the FotoFiber sensor mounted in the FotoFiber test specimen block assembly, as shown in Figure 9-6.

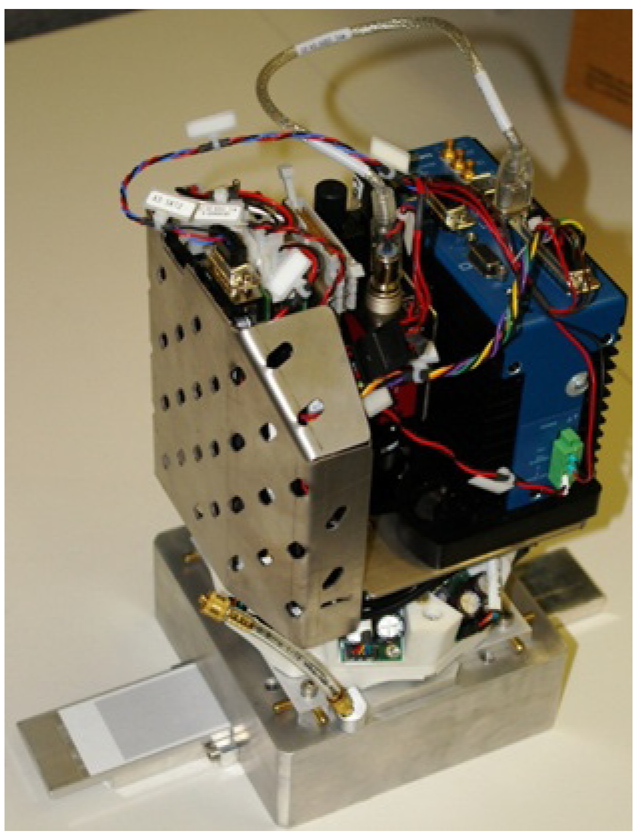


Figure 9-6 FotoFiber Bolted Onto Test Specimen Block Assembly

These operations are always carried out with the sensor on a clean flat surface outside the scanner head, as described in Subsection 9.3.1

9.4.2. Establish zero angle

Establishing the zero angle is a Honeywell service operation. It is not required during normal operation of the sensor. The zero angle must be measured before installation of the sensor, and is typically available from the factory report accompanying a newly delivered sensor. However, the parameter must be updated if the sensor camera or the camera mounting apparatus is replaced.

Activity Number:	Q4223-52-ACT-010	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	None
Availability Required:	Sensor removed from scanner	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	Once per year
Duration (time period):	15 minutes	**# of People Required:**	1
Prerequisite Procedures:	Set-up on bench	**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
	Cat5 Ethernet cable 6581800251; test specimen block assembly 6581800252; test specimen holder assembly		
Required Tools:	Part Number	Quantity	Lead Time
	• laptop with Honeywell Intelligent Sensors software		

The procedure **Fiber Orientation Measurement**, on the **Fiber Orientation** menu of the Intelligent Sensors software, is used. The fiber orientation measurement display is shown in Figure 9-7. It displays the polar histogram and fitted curve on the left, with the fitted fiber orientation parameters. **Orientation** and **Anisotropy** are shown in the upper left area of the display, and **MD/CD** and **Max/Min** in the lower left. In the upper right area of the display is the live image being analyzed, with the graylevel **Histogram** in the bottom center of the display. Trends of the orientation angle and anisotropy are shown in the bottom right area of the display.

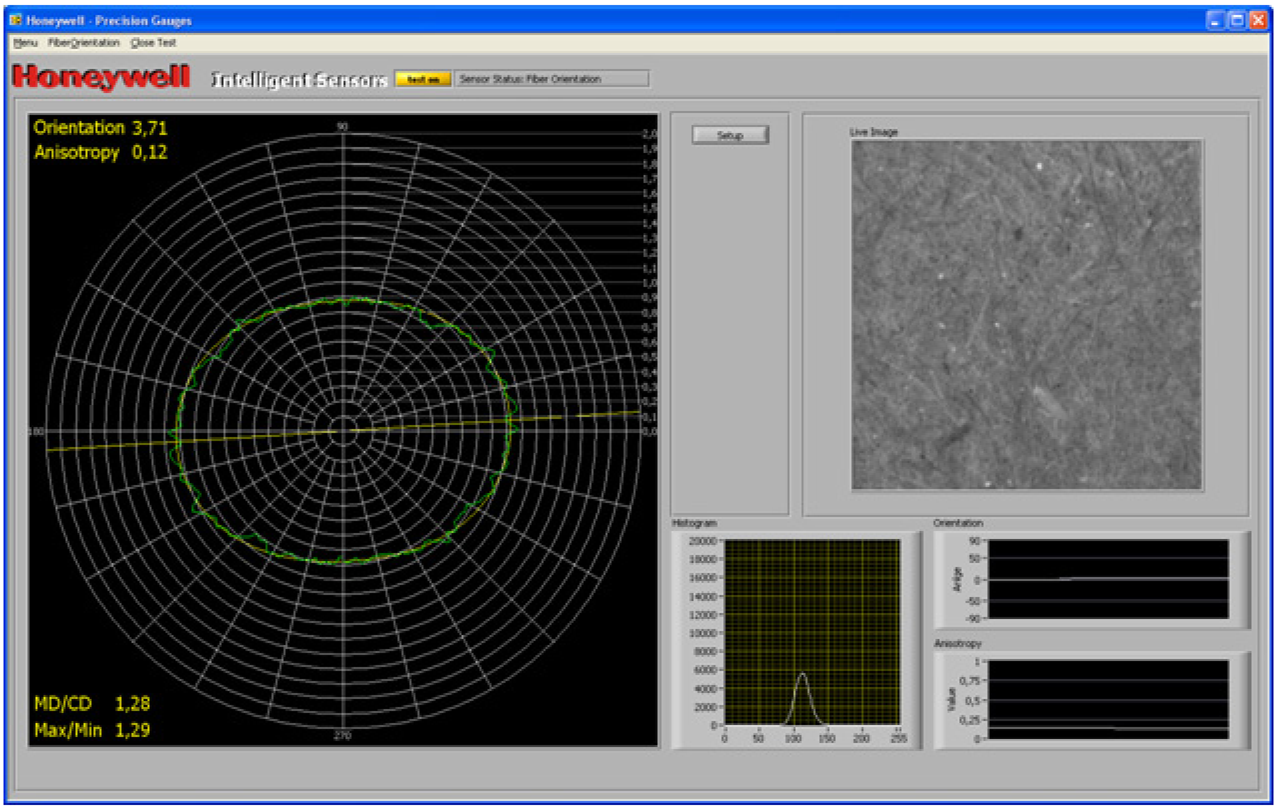


Figure 9-7 Intelligent Sensors Software: Fiber Orientation Measurement Display

Click **Setup** in the upper center area of the fiber orientation measurement display to call up the setup dialog (see Figure 9-8) in the area beneath the button.

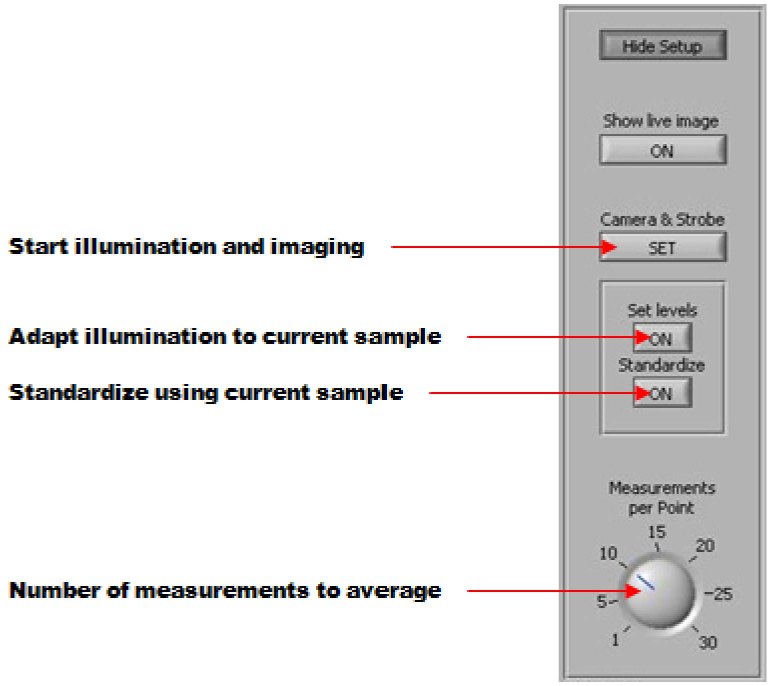


Figure 9-8 Setup Dialog

The number of raw measurements to average in each displayed measurement result (polar histogram, parameters, and trends) can be controlled using the **Measurements per Point** dial. The default is 10 measurements per average. The measurement will automatically restart averaging with the new averaging parameter whenever the parameter is changed.

The *Fiber Orientation Measurement* function is used to establish the zero angle:

1. Mount the FotoFiber sensor on FotoFiber test specimen block assembly using the screw holes nearest the corners. Ensure that the air inlet for the sensor is on a side which does not have a protrusion.

2. Connect a PC to the sensor using an Ethernet cable, and start the FotoFiber maintenance software on that PC. Set the **USER1** switch on the FotoFiber processor module to the ON position.

3. Connect the power to the sensor, switch it on, and wait for the sensor to boot (it will boot twice, automatically).

4. Insert the FotoFiber test specimen holder assembly into the slot of the FotoFiber Test specimen block assembly, ensuring that the surface with straight lines is uppermost, and slide it so that the lines perpendicular to the long axis are beneath the sensor (see Figure 9-9).

To minimize uncertainty, align the holder in contact with the side of the block on which the FotoFiber sensor air inlet is positioned.

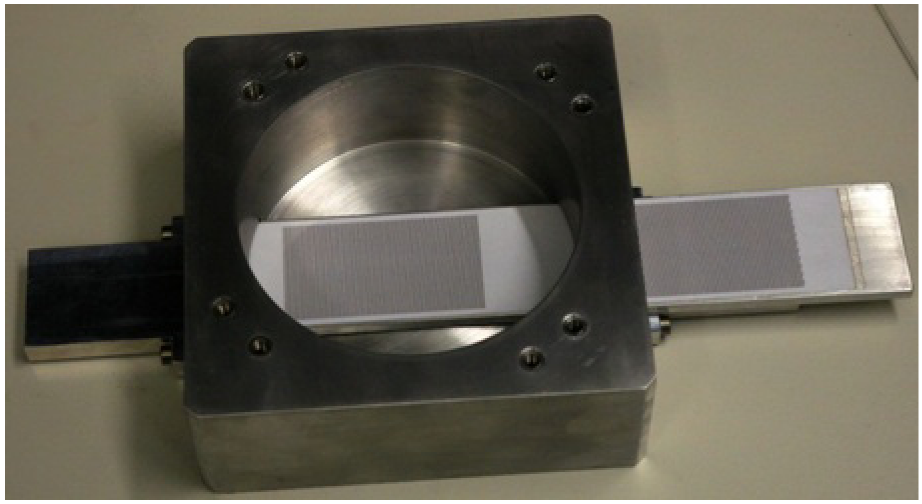


Figure 9-9 Specimen Holder

Figure 9-9 shows the specimen holder positioned in the block for zero angle assessment (the FotoFiber sensor is removed for clarity).

5. After the maintenance software is communicating with the FotoFiber (see Figure 9-5), start the **Fiber Orientation Measurement** function from the **Fiber Orientation** menu.

6. If the setup panel is not visible, click **Setup** to call it up. Set the **Measurements per Point** dial to 30 or more by dragging it around. Ensure that the **Set levels** button shows **ON**, and the **Standardize** button shows **OFF**.

7. Under **Camera & Strobe**, click **SET**. The measurement will cease updating on the polar histogram as the illumination level is adjusted. That takes several seconds, during which the brightness of the displayed live image will change. Measurement updates will resume after the illumination levels have been adjusted.

8. Wait a few seconds until the measured angle is stable, then record its value. At least five such values should be recorded after sliding the holder within a range of a few millimeters, and an average value calculated. This is the zero angle to use (parameter 16 under Subsection 6.3.4.2).

ATTENTION

Click the **Close Test** menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

9.4.3. Assess accuracy

The sensor accuracy may be assessed from time to time, as agreed with the customer. It is recommended that the accuracy be assessed after any major maintenance operation, such as replacement of a camera or an illuminator. It can be assessed easily whenever the zero angle is assessed.

Activity Number:	Q4223-52-ACT-011	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	None
Availability Required:	Sensor removed from scanner	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	Once per year
Duration (time period):	15 minutes	**# of People Required:**	1
Prerequisite Procedures:	Set-up on bench	**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
	Cat5 Ethernet cable 6581800251; test specimen block assembly 6581800252; test specimen holder assembly		
Required Tools:	Part Number	Quantity	Lead Time
	• laptop with Honeywell Intelligent Sensors software		

The *Fiber Orientation Measurement* function is used to assess the accuracy of the FotoFiber sensor by following Steps 1–6 in Subsection 9.4.2, then:

1. Wait a few seconds until the measured angle is stable, then record its value. A few values should be recorded after sliding the holder to within a range of a few millimeters, and an average value calculated. This should be similar to the zero angle in use (parameter 16 of Subsection 6.3.4.2).

2. Slide the FotoFiber test specimen holder assembly across the slot of the FotoFiber test specimen block assembly, so that the lines at an angle to the long axis are beneath the sensor (see Figure 9-9). To minimize uncertainty, align the holder in contact with the side of the block on which the FotoFiber sensor air inlet is positioned.

3. Wait a few seconds until the measured angle for the new position is stable, then record its value. A few values should be recorded after sliding the holder to within a range of a few millimeters, and an average value calculated.

4. The difference between the average values obtained in Step 1 and Step 3 should be 15 degrees ± 0.2 degrees. Note that due to the manufacturing process of the FotoFiber test specimen holder assembly, the difference in angle between the two sets of straight lines may be 14.9 degrees rather than 15 degrees.

ATTENTION

Click the **Close Test** menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

9.4.4. Assess measurement stability and noise

Assessing the long-term stability of the sensor requires repeating the zero angle measurement at intervals over a long period. This relies on the procedures described in Subsection 9.4.2. Note that the zero angle parameter is not used when the sensor boots in maintenance mode, so changes in the zero angle parameter will not affect the long term stability.

Activity Number:	Q4223-52-ACT-012	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	None
Availability Required:	Sensor offsheet	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	Once per month
Duration (time period):	15 minutes	**# of People Required:**	1
Prerequisite Procedures:	Set-up in head	**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
Required Tools:	Part Number	Quantity	Lead Time
	• 08773300; focusing and calibration target • adhesive tape		

Assessing the short-term stability, in this instance, noise, of the sensor involves a series of tests performed with the sensor in the scanner head during a machine shutdown, or similar opportunity lasting 30 minutes or more.

To assess stability:

1. Put the scanner offsheet. Navigate to the **Sensor Maintenance** display, select the appropriate FotoFiber sensor, and put the scanner in maintenance mode (see Figure 4–9). If necessary, retrieve a production recipe.

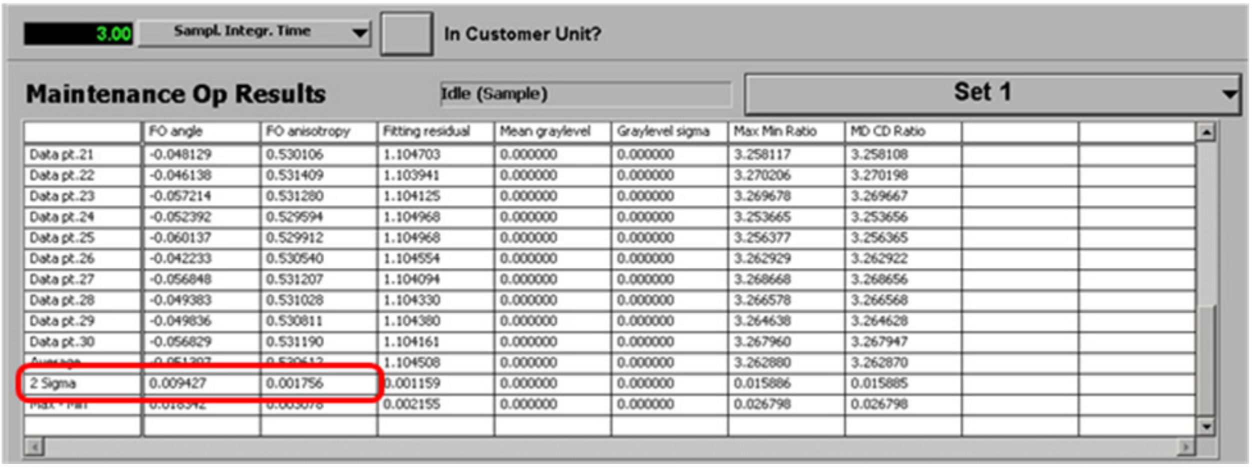
2. Separate the scanner heads, and place the FotoFiber Calibration & Focus Target so that the area with straight lines is in the measurement spot of a FotoFiber sensor, and aligned so that the straight lines are oriented not too far from the machine direction (within ± 15 degrees). Tape the target in place, so that it cannot accidentally be moved–use tape at the four corners and/or edges of the target. Use tape that can be easily removed later. Ensure that the FotoFiber Calibration & Focus Target is suitably immobilized, but flat, not curved or warped, in the measurement location. Re-unite the heads and ensure the scanner is offsheet.

3. Using the drop-down arrow on the **Sensor Maintenance** display (see Figure 4–9), check the sample integration time (should be set to not less than three seconds), and update it if needed (see Figure 4–10). This is one of the parameters that were set up in Subsection 4.3.3.1.

   Sampl. Integr. Time = 4

4. Take one set of 30 samples by entering 30 into the **Op in a set** field on the **Sensor Maintenance** display (ensure that **No of sets** is 1), then click **Sample**.

5. The noise of the sensor is the 2-sigma value of this set of measurements, shown at the lower left in Figure 9-10. Note that the average **FO angle** of the set is largely irrelevant, because the target is likely to be taped in a different orientation for each test. For the data in this example, the noise in the FO angle measurement is 0.009427, and the noise in the FO anisotropy measurement is 0.001756. Both of these values are good.



	FO angle	FO anisotropy	Fitting residual	Mean graylevel	Graylevel sigma	Max Min Ratio	MD CD Ratio		
Data pt.21	-0.048129	0.530106	1.104703	0.000000	0.000000	3.258117	3.258108		
Data pt.22	-0.046138	0.531409	1.103941	0.000000	0.000000	3.270206	3.270198		
Data pt.23	-0.057214	0.531280	1.104125	0.000000	0.000000	3.269678	3.269667		
Data pt.24	-0.052392	0.529594	1.104968	0.000000	0.000000	3.253665	3.253656		
Data pt.25	-0.060137	0.529912	1.104968	0.000000	0.000000	3.256377	3.256365		
Data pt.26	-0.042233	0.530540	1.104554	0.000000	0.000000	3.262929	3.262922		
Data pt.27	-0.056848	0.531207	1.104094	0.000000	0.000000	3.268668	3.268656		
Data pt.28	-0.049383	0.531028	1.104330	0.000000	0.000000	3.266578	3.266568		
Data pt.29	-0.049836	0.530811	1.104380	0.000000	0.000000	3.264638	3.264628		
Data pt.30	-0.056829	0.531190	1.104161	0.000000	0.000000	3.267960	3.267947		
Average	[illegible]	[illegible]	1.104508	0.000000	0.000000	3.262880	3.262870		
2 Sigma	0.009427	0.001756	0.001159	0.000000	0.000000	0.015886	0.015885		
Max - Min	[illegible]	[illegible]	0.002155	0.000000	0.000000	0.026798	0.026798		

Figure 9-10 Noise Assessment

9.5. Check focus and calibration

Focusing and calibrating the sensor are Honeywell service operations, and should not be required during normal operation of the sensor.

These procedures require a PC or laptop with an Ethernet connector and FotoFiber diagnostic software, as well as the FotoFiber Calibration & Focus Target (see Figure B–1).

9.5.1. Set up focus procedure

Focusing is needed if the camera, lens, or their mounting unit is replaced. It may also be needed if the sensor focus is inadvertently changed.

1. Set-up the sensor for focusing.
2. Start imaging, and center the target.
3. Use the focusing wizard.

Activity Number:	Q4223-52-ACT-013	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	None
Availability Required:	Sensor offsheet	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	Once per year
Duration (time period):	20 minutes	**# of People Required:**	1
Prerequisite Procedures:	Set-up on bench Set-up in head	**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
	Cat5 Ethernet cable		
Required Tools:	Part Number	Quantity	Lead Time
	• laptop with Honeywell Intelligent Sensors software • 08773300; FotoFiber Calibration & Focus Target		

9.5.1.1. Focus sensor

Focusing can be performed with the sensor in the head, as shown in Figure 9-11, left, or on a bench, right. The corresponding setup procedure in Section 9.3 should be followed.

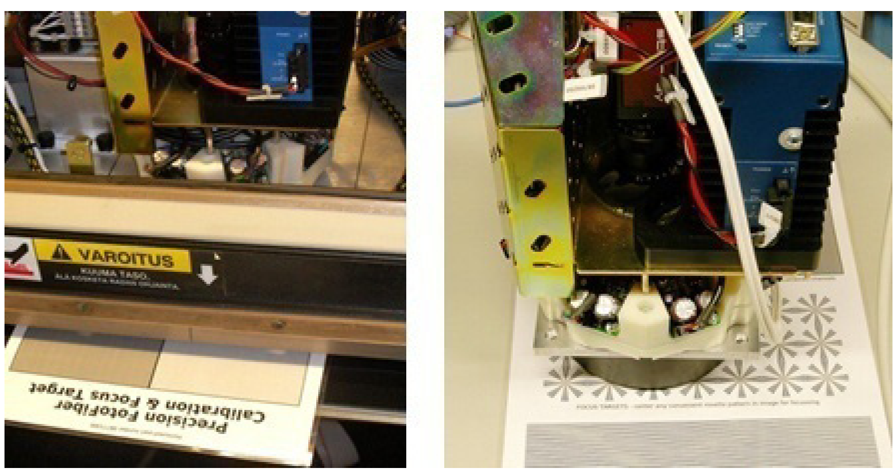


Figure 9-11 Position the Focus Target (left: in the head; right: on a bench)

Approximately center the focusing target rosette pattern in the image, then the assisted focusing test can be used.

For focusing with the sensor outside the head, place the target on the bench with the printed side facing up, with the FotoFiber placed on top of it above the group of rosette patterns.

For focusing with the sensor in the head, insert the target into the sensor gap, with the printed side facing the sensor to be focused, and positioned so that the rosette patterns are approximately in the sensor measurement area.

9.5.1.2. Acquire image, and center target

1. On the PC software, select **Operate PP880 and camera** from the **Fiber Orientation** menu. Under the **Camera** tab on the **Operate PP880 and Camera** pop-up, Click **Change Settings** (see Figure 9-12) to start image acquisition.

Figure 9-12 Operate PP880 and Camera

The imaging will initially have default strobe parameters, and the image is likely to be too dark to discern properly.

2. Under the **Strobe** tab of the display, verify that the **Equalize Channels** indicator is on (yellow), and that the other eight channel selector indicators are also all on (yellow). If any are off (dark gray), switch them on by clicking on the indicator. Verify that the **Pulse duration [µs]** is approximately 0.5, the default value (see Figure 9-13).

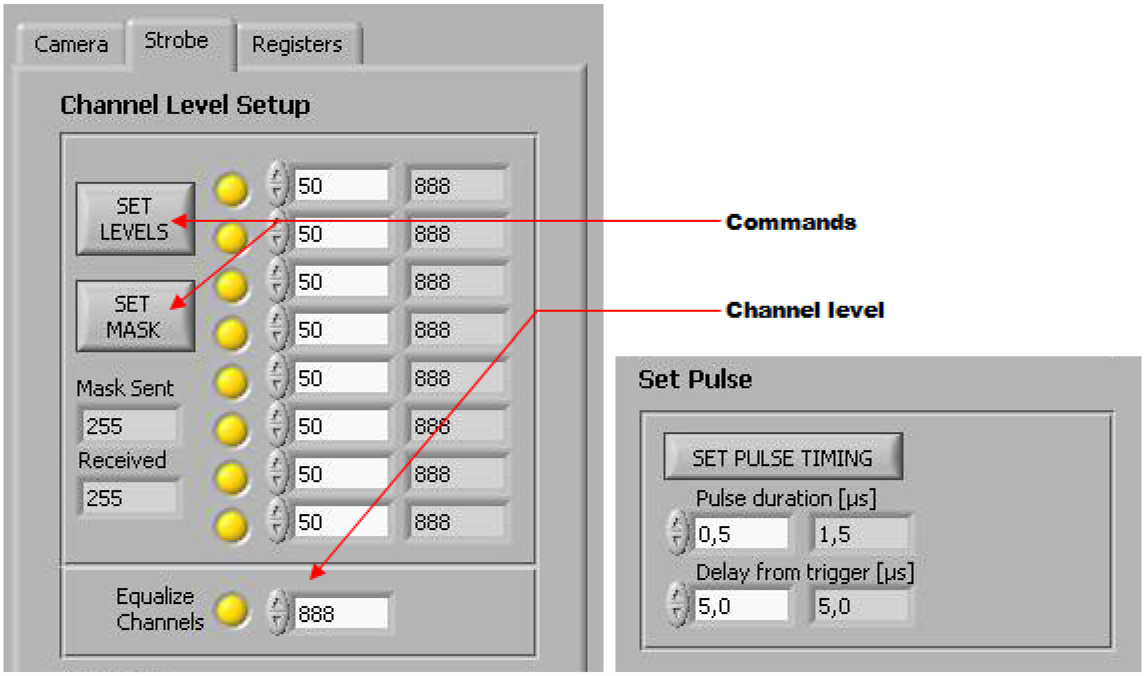


Figure 9-13 Strobe Parameter Adjustment (left: channel levels; right: pulse length)

3. Set a value such as 300 or 400 in the **Equalize Channels** textbox, and click **SET LEVELS**, and **SET MASK**. Commands are communicated slowly, so it may be necessary to wait a few seconds between these clicks, or to click the buttons again after a short wait.

4. The image should now be bright enough to see properly. If desired, the level can be adjusted again, but it is not necessary to optimize the image brightness, provided the image can be seen reasonably well.

5. Move the target until a rosette is approximately centered in the image, and note that the direction of movement in the image may differ from the direction of movement of the target.

ATTENTION

Click the **Close Test** menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

9.5.1.3. Apply focusing wizard

After closing **Operate PP880 and Camera**, select **Focusing Wizard** from the **Fiber Orientation** menu. The strobe pulse strength will be automatically adjusted, taking a few seconds. The image shown may vary from very bright to very dark during this procedure.

When the image is shown with a focus rating scale, it is ready for focus adjustments:

1. Click **Reset** on the **Focusing** display (see Figure 9-15), then turn the focus knob until the image of the rosette is quite blurred (see Figure 9-14, and Figure 9-15, left).

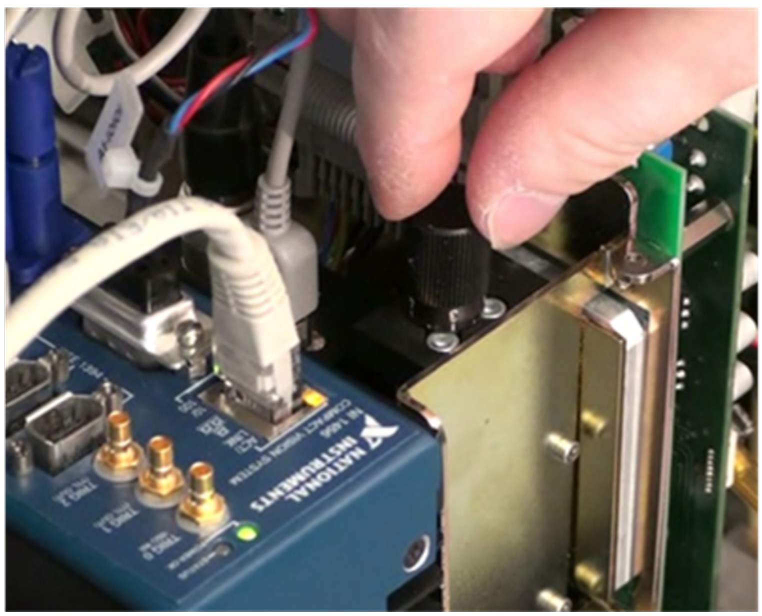


Figure 9-14 Focus Knob

2. Turn the focus knob the other way, and watch both the indicator dial (when the image is in focus, the indicator value will be 100), and the center of the pattern in the image. When the image is well focused, the rectangular array of nine dots at the center of the rosette should be clearly discernible (see Figure 9-15, right).

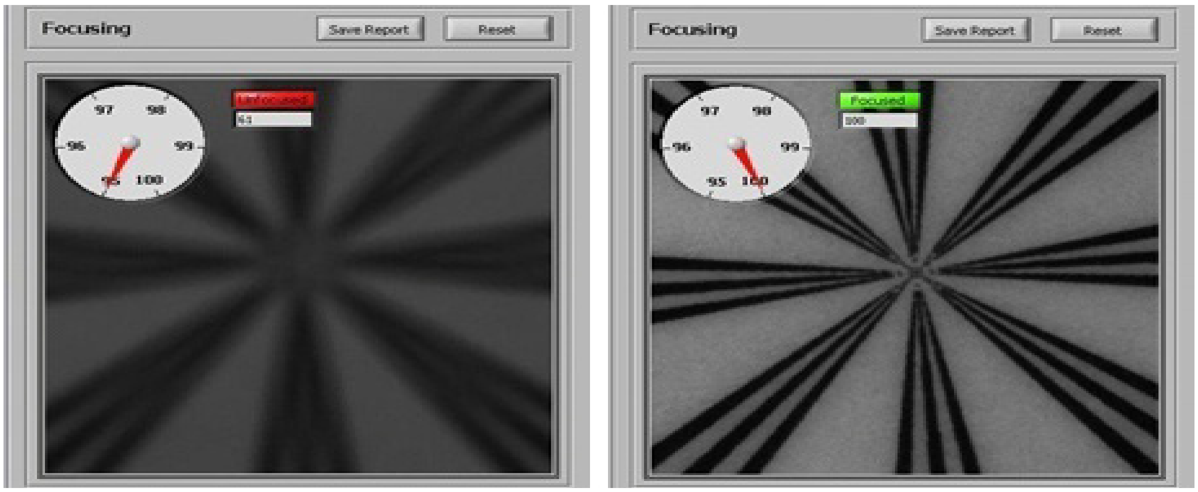


Figure 9-15 Focus Wizard (left: unfocused; right: focused)

3. When the focus is good enough, click **Save Report** to record the final image. This step is required if the focus procedure was performed in conjunction with the illuminator calibration procedures in Subsection 9.5.2. Note that clicking **Save Report** saves the image exactly as it appears at that time.

ATTENTION

Click the **Close Test** menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

9.5.2. Calibrate illuminators

Illuminator calibration is a Honeywell service operation. It is required if any illuminator component is replaced (LED panel PCB, or LED driver PCB). It may also be performed occasionally to compensate for changes, with age, in component performance.

Activity Number:	Q4223-52-ACT-014	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	None

Availability Required:	Sensor offsheet	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	Once per year
Duration (time period):	120 minutes	**# of People Required:**	1
Prerequisite Procedures:	Set-up on bench	**Post Procedures:**	Set up focus
Required Parts:	Part Number	Quantity	Lead Time
	Cat5 Ethernet cable		
Required Tools:	Part Number	Quantity	Lead Time
	• laptop with Honeywell Intelligent Sensors software • 08773300; FotoFiber Calibration & Focus Target		

Illuminator calibration involves testing of all illuminator channels, even if components were replaced in only one channel:

- set-up the sensor for illuminator calibration, and defocus the sensor
- calibrate combined illuminators
- calibrate individual illuminators
- generate a report of the calibration
- re-focus sensor, and update parameters in Experion MX

Calibrating the illuminators requires a PC or laptop with an Ethernet connector and FotoFiber Intelligent Sensors software, as well as the FotoFiber Calibration & Focus Target.

9.5.2.1. Set up illuminator calibration

It is strongly recommended that illuminator calibration be performed with the sensor outside the head. Ideally, calibration should be performed in a clean workspace not subject to large or sudden variations in lighting, for example, no flashing light sources nearby. Preferably, the sensor should be shielded from *all* bright illumination sources during this procedure.

1. Prepare the testing environment as for focusing, including a suitable 24 V DC power supply and power cable, and a suitable PC with Ethernet cable and Intelligent Sensors software as described in Subsection 9.3.1.

2. On the processor module, move the **USER1** DIP switch to the ON position.

3. Start the Intelligent Sensors software and power-on the FotoFiber, then wait until communication has been established with the sensor (see Figure 9-5).

4. Start imaging, and center a focus target as described in Subsection 9.5.1.2, then defocus the image by turning the focus knob several times. Ideally, the resulting image of the rosette pattern will be quite blurred, as in Figure 9-15, left.

ATTENTION

Click the **Close Test** menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

9.5.2.2. Calibrate combined illuminators

In this procedure, the medium gray (30%) area of the Calibration & Focus Target should be positioned beneath the sensor, as shown in Figure 9-16. The target and sensor should not be moved while the test is in progress. All illuminator channels receive pulses of the same amplitude and duration, and the graylevel is measured by the camera.

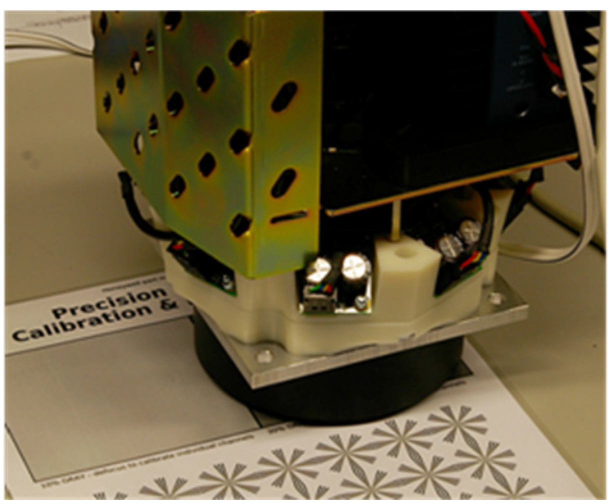


Figure 9-16 Sensor and Target

ATTENTION

It is essential that the ambient lighting should be subdued during the test, and must not be changed significantly while the test is in progress. In particular, there should be no other strobe or flashing lights nearby, and there should be no bright light sources of any kind. Normal fluorescent lamps flash at 100 Hz or 120 Hz. Shield the sensor from flashing lights or bright ambient lighting by placing a curtain or other suitable barrier between the FotoFiber and the potential extraneous light sources. External light entering the sensor during calibration may cause the calibration results to be unacceptable.

1. Select **Calibrate all combined channels** from the **Fiber Orientation** menu. The default directory used for saving data is *C:\Calibrate\00000000*, which is reserved for factory use. Change the directory name before test data is saved (it is recommended that you change the name before starting the test to avoid mishaps).

2. Click **Initialize**. The graphs should all receive zero curves. It is possible to view data from previously saved calibrations by entering the corresponding directory name and clicking **Load Files**. If previous calibration data is loaded, click **Initialize** again before starting the test.

ATTENTION

Use the date of calibration as the subdirectory name rather than *00000000*. Format the date in the numeric form of *yyyymmdd*, as shown in Figure 9-17, (directory *20090828* contains a calibration performed on 28 August 2009). This must be a subdirectory of the *C:\Calibrate* directory, and the subdirectory will be created if necessary. The same directory name must be used for both the **Calibrate all individual channels** procedure, and the **Calibrate all combined channels** procedure. Deviation from these guidelines is likely to result in sensor malfunction and measurement failure.

Figure 9-17 Date of Calibration as Subdirectory

3. Click **Start Test**. The LEDs in the sensor should now start a sequence of flashes at varying durations and amplitudes.

4. A green indicator will appear on the **Start** button, and the currently active pulse length will be shown beneath, as shown in Figure 9-18.

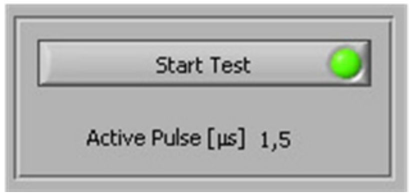


Figure 9-18 Start Test: Active Pulse

5. A live image and histogram will also be periodically updated on the display (shown on the right in Figure 9-19).

6. The test takes between 10 and 15 minutes to complete, depending on the sensor configuration. The green indicator will vanish from the **Start** button when the test is complete, and the measured curves will appear in the graphs, as shown in Figure 9-19.

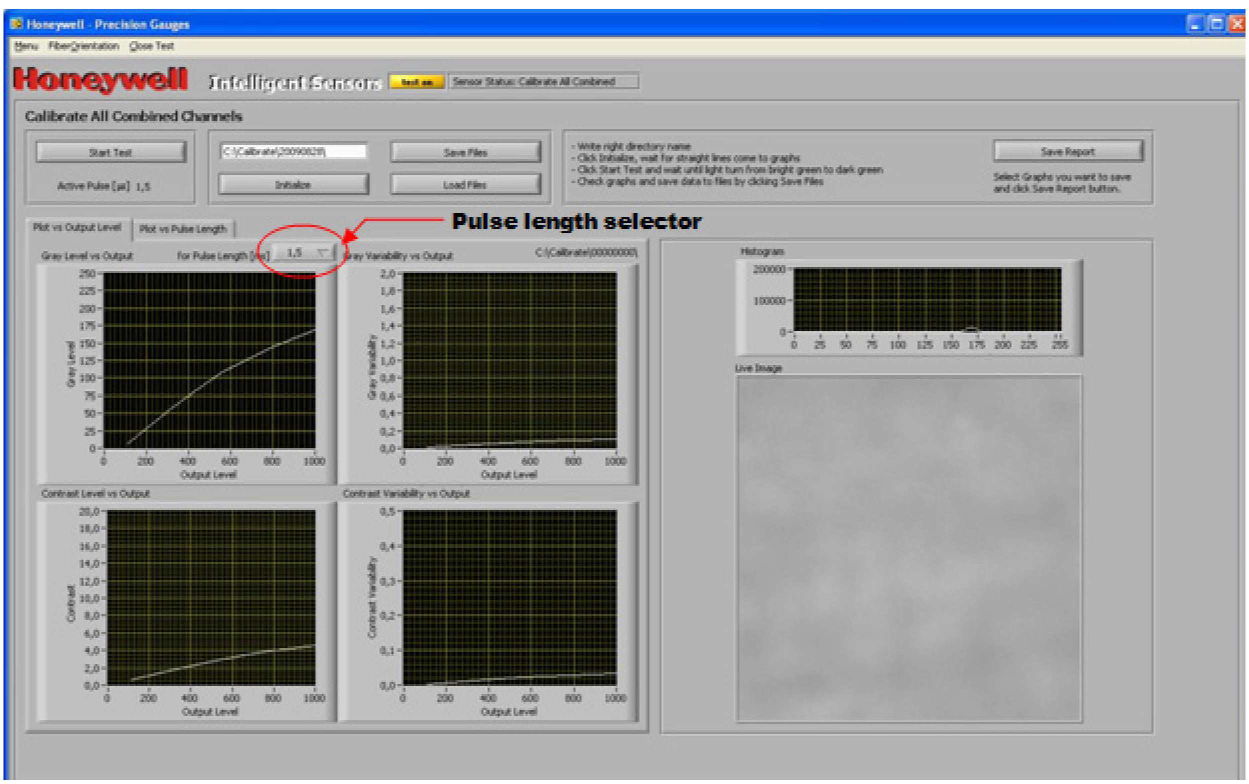


Figure 9-19 Calibrate All Combined Channels: Plots vs Output Level

7. Inspect the plots under the **Plot vs Output Level** tab (see Figure 9-19). For each pulse length, the **Gray Level vs Output** (upper left) curve should be smoothly increasing with the output level, and the **Gray Variability vs Output** (upper center) curve should not have any large spikes upward. The intercept of these curves should be slightly to the

right of the 0,0 point on the chart. For the maximum pulse length, the graylevel maximum should be between 100 and 250.

8. Inspect the plots under the **Plot vs Pulse Length** tab (see Figure 9-20). That data is the same data as shown in Figure 9-19, viewed on different axes. For each output level, the **Gray Level vs Pulse Length** (upper left) curve should be increasing approximately linearly with pulse length for each output level, with intercepts quite close to the 0,0 point. The **Gray Variability vs Pulse Length** (upper left) curve should not have any large upward spikes.

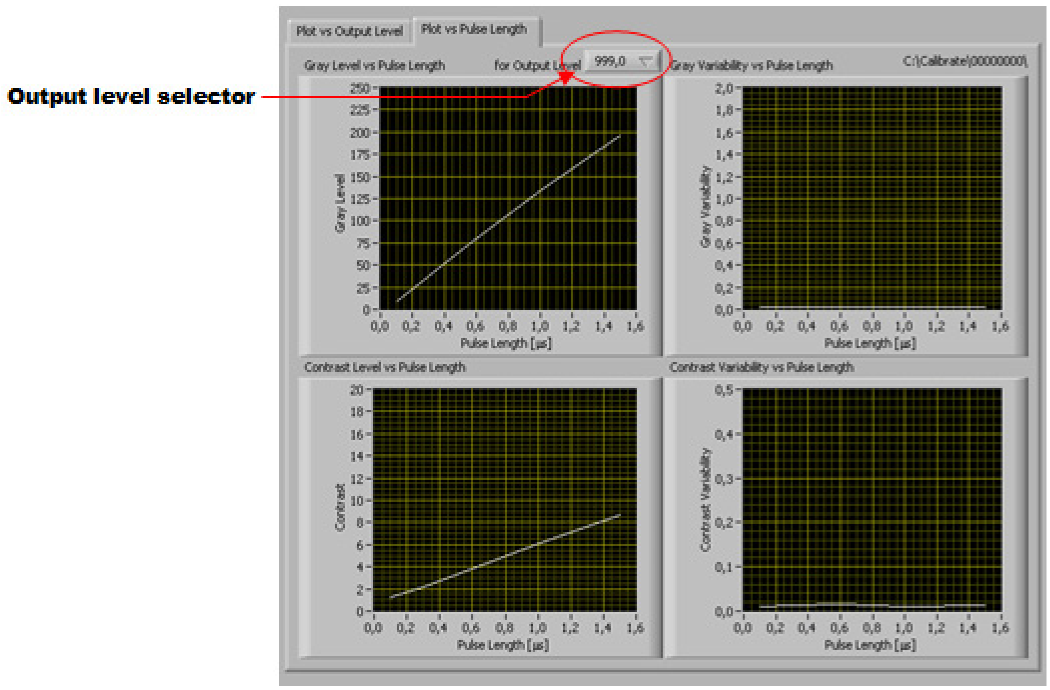


Figure 9-20 All Combined Channels: Plots vs Pulse Length

9. If these criteria are met, check that the directory name is suitable, then click **Save Files** (see Figure 9-19) to save the data; otherwise, the test should be repeated. The result graphs should also be saved by clicking **Save Report** in the upper right. Note that clicking **Save Report** will save the block of four plots exactly as they appear at that time.

10. If the calibration is accepted, select a high output level and a long pulse length on the respective tabs, because these tend to be the most informative plots. If the calibration was not acceptable, select the output level and pulse length which most clearly show the reason for not accepting the result. This may be useful if QCS-TAC support is needed.

ATTENTION

Click the **Close Test** menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

9.5.2.3. Calibrate individual illuminators

In this procedure, the light gray (10%) area of the Calibration & Focus Target should be positioned beneath the sensor, as shown in Figure 9-21. The target and sensor should not be moved while the test is in progress. Each illuminator channel in turn receives pulses of a given amplitude and duration, and the graylevel is measured by the camera.

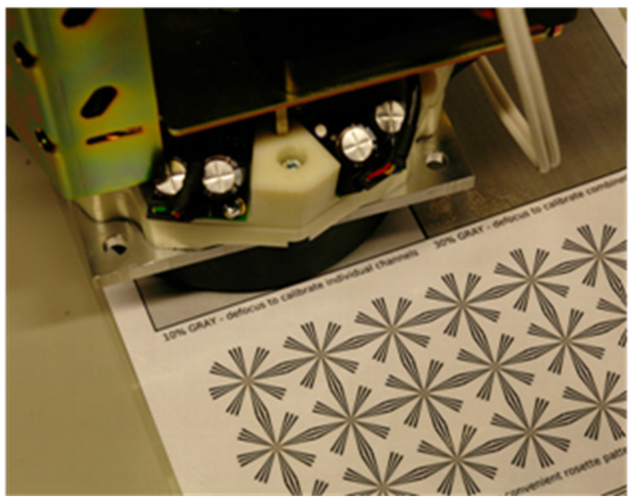


Figure 9-21 Sensor and Target Position

ATTENTION

It is essential that the ambient lighting should be subdued during this test, and must not be changed significantly while the test is in progress. In particular, there should be no other strobe or flashing lights nearby, and there should be no bright light sources of any kind. Normal fluorescent lamps flash at either 100 Hz or 120 Hz. Shield the sensor from flashing lights or bright ambient lighting by placing a curtain or other suitable barrier between the FotoFiber and the potential extraneous light sources, or perform the tests in a room which remains dark throughout the test. External light entering the sensor during calibration may cause the calibration results to be unacceptable.

1. Select **Calibrate all individual channels** the **Fiber Orientation** menu. The default directory used for saving data is *C:\Calibrate\00000000*, which is reserved for factory use. Change the

directory name before test data is saved (it is recommended that you change the name before starting the test to avoid mishaps).

2. Click **Initialize**. The graphs should all receive zero curves. It is possible to view data from previously saved calibrations by entering the corresponding directory name and clicking **Load Files**. If previous calibration data is loaded, click **Initialize** again before starting the test.

ATTENTION

> Use the date of calibration as the subdirectory name rather than *00000000*. Format the date in the numeric form of *yyyymmdd*, as shown in Figure 9-17, (directory *20090828* contains a calibration performed on 28 August 2009). This must be a subdirectory of the *C:\Calibrate* directory, and the subdirectory will be created if necessary. The same directory name must be used for both the **Calibrate all individual channels** procedure, and the **Calibrate all combined channels** procedure. Deviation from these guidelines is likely to result in sensor malfunction and measurement failure.

3. Click **Start Test**. The LEDs in the sensor should now start a sequence of flashes at varying durations and amplitudes.

4. A green indicator will appear on the **Start** button, and the currently active channel number and pulse length will be shown beneath, as shown in Figure 9-22.

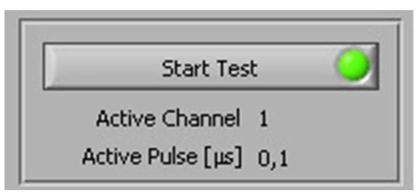


Figure 9-22 Start Test: Active Channel and Pulse

5. A live image and histogram will also be periodically updated on the display (see Figure 9-23).

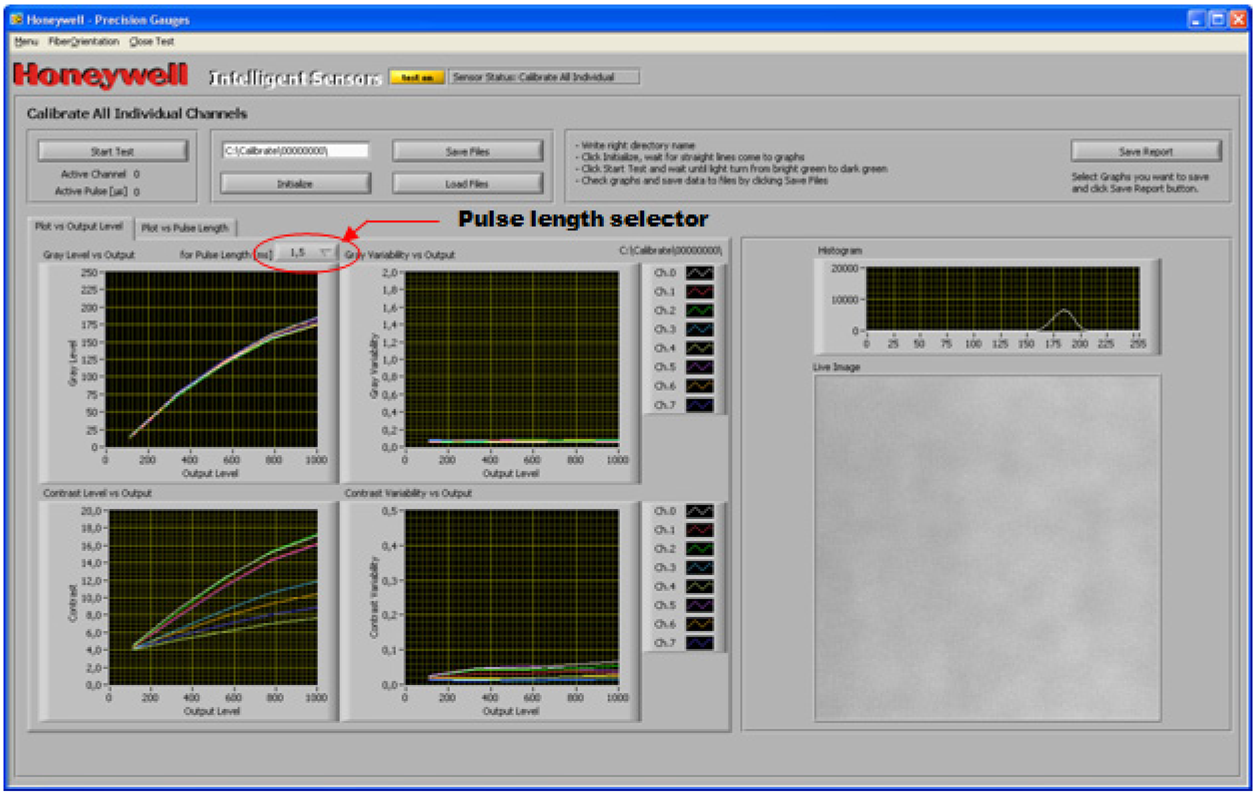


Figure 9-23 Calibrate All Individual Channels: Plot vs. Output Level

6. The test takes between 35 and 50 minutes to complete, depending on the sensor configuration. The green indicator will vanish from the **Start** button when the test is complete, and the measured curves will appear in the graphs, as shown in Figure 9-23.

7. Inspect the plots under the **Plot vs Output Level** tab (see Figure 9-23). For each pulse length, the **Gray Level vs Output** (upper left) curve for each channel should be smoothly increasing with output level, and all eight curves should be fairly close together. The intercept of these curves should be slightly to the right of the 0,0 point on the chart. For the maximum pulse length, the graylevel maximums should all be between 100 and 250. For each pulse length, the **Gray Variability vs Output** (upper center) curve for each channel should not have any large spikes upward.

8. Inspect the plots under the **Plot vs Pulse Length** tab (see Figure 9-24) The data is the same data as in Figure 9-23, viewed on different axes. For each output level, the **Gray Level vs Pulse Length** (upper left) curve for each channel should be increasing approximately linearly with pulse length, with intercepts quite close to the 0,0 point. All eight

curves should be fairly close together. For each output level, the **Gray Variability vs Pulse Length** (upper right) curves should not have any large upward spikes.

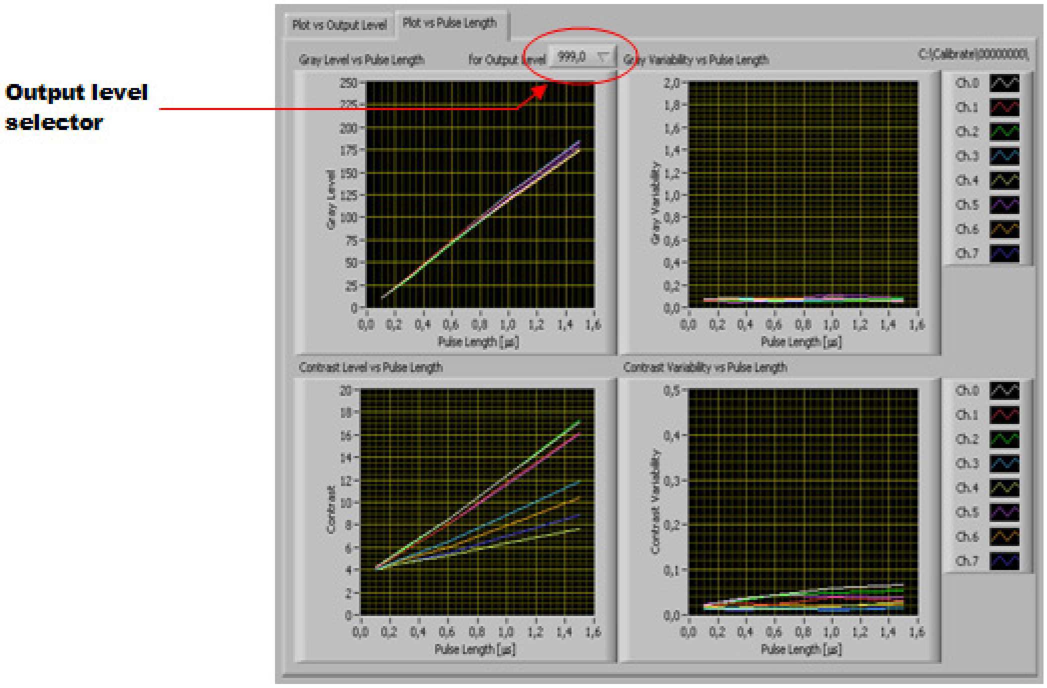


Figure 9-24 All Individual Channels: Plot vs. Pulse Length

9. If these criteria are met, check that the directory name is suitable, then click **Save Files** to save the data; otherwise, the test should be repeated. Click **Save Report** to save the result graphs.

10. Note that clicking **Save Report** will save the block of four plots exactly as they were most recently viewed. If the calibration is accepted, select a high output level and a long pulse length on the respective tabs, because these tend to be the most informative plots.

11. If the calibration is not acceptable, even after repeated calibration attempts, select the output level and pulse length which most clearly show the reason for not accepting the result, before generating a report. It may be helpful to send this report to QCS-TAC when requesting assistance.

ATTENTION

Click the **Close Test** menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

9.5.2.4. Apply report builder

The procedures for focusing (see Subsection 9.5.1), and for calibrating illuminators (see Subsection 9.5.2) have **Save Report** buttons, which should be clicked at the end of each of these procedures.

Starting the **Report Builder** procedure on the **Fiber Orientation** menu calls ups the **REPORT Builder** dialog shown in Figure 9-25. The sensor serial number, or other sensor identifier such as mill, scanner, upper/lower sensor, should be entered into the text box. The test results to include are specified with the radio buttons on the right. Note that only the calibration tests and the focusing test are supported for FotoFiber. Do not select **Illumination & Dirt**.

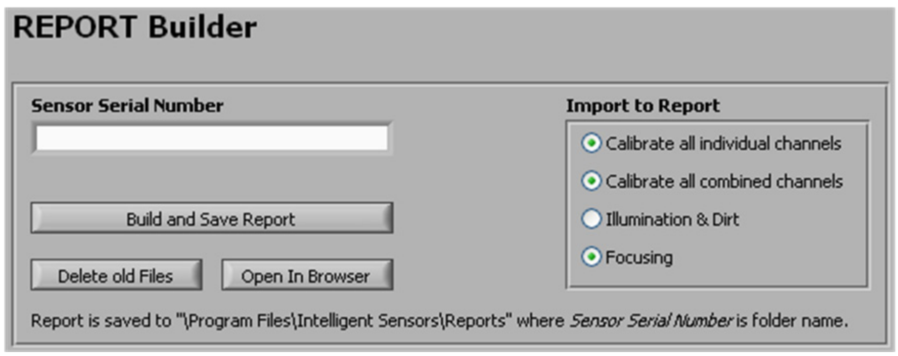


Figure 9-25 Calibration REPORT Builder Setup

Click **Build and Save Report** to place the saved images from the selected procedures into a single HTML file. The HTML file can be viewed in a browser. Preferably, whenever the calibration is changed or the sensor ID refocused, the appropriate report should be generated. A printed copy of the report can be included with other sensor calibration reports on site.

Figure 9-26 shows a sample calibration report.

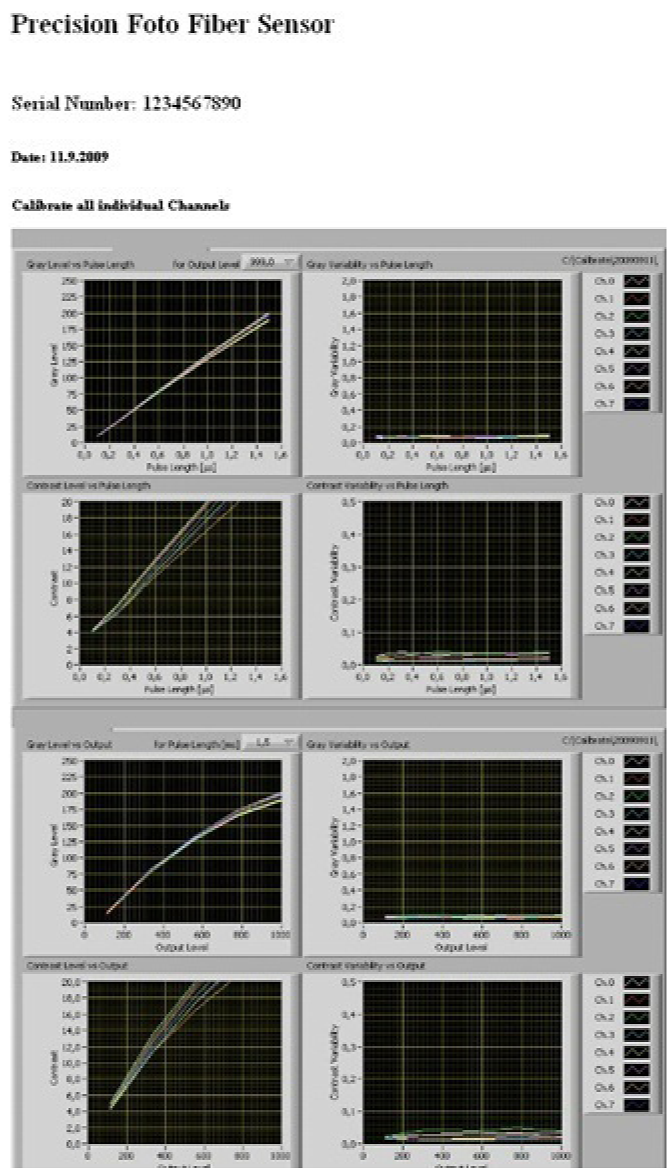


Figure 9-26 Sample Calibration Report (1 of 2)

Figure 9-27 shows a sample calibration report with acceptable illuminator calibration curves.

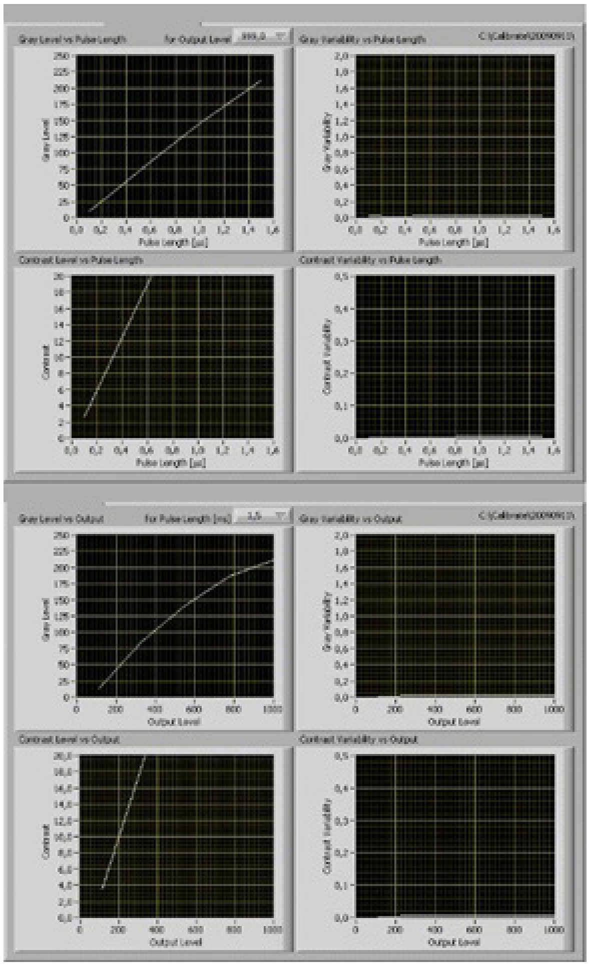


Figure 9-27 Sample Calibration Report (2 of 2)

Figure 9-28 shows a focus check.

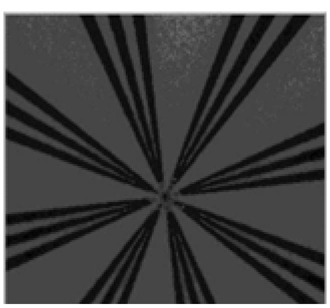


Figure 9-28 Focus Check

The files saved by the test procedures are created in a temporary directory. After the report is built, these files can be deleted by clicking **Delete old Files**. Do not delete the files until after the report has been built.

9.5.2.5. Refocus FotoFiber, and enable new calibration

When the calibration procedures are complete, the camera should be focused again (see Section 9.5). Remember to save the focus report. The **USER1** DIP switch on the processor module should then be switched to the *off* position.

If the calibration data was acceptable in both tests (individual illuminators and combined illuminators), and was saved into the same directory, it can be used by the FotoFiber instead of its original factory calibration. To do this, the complete date used to form the subdirectory name must be entered into parameters 17 and 18 on the **FotoFiber Engineering** display (see Section 6.3.4), and sent to the sensor.

9.5.3. Preserve offline copy of calibration

It is useful to preserve an offline copy of the calibration files after each calibration is performed. Keep a copy of the entire FotoFiber *C:\Calibrate* directory tree in a suitable location on the Experion MX server. These files may prove useful in:

- diagnosing unexpected measurement results
- preserving calibration if the entire FotoFiber firmware needs to be updated, or the FotoFiber processor module needs to be replaced (as described in Subsection 9.7.2)
- monitoring long-term changes in performance of FotoFiber illumination channels

Activity Number:	Q4223-52-ACT-015	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	None
Availability Required:		**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	Once per year
Duration (time period):	10 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	

Required Parts:	Part Number	Quantity	Lead Time
	Cat5 Ethernet cable		
Required Tools:	Part Number	Quantity	Lead Time
	• laptop		

The files can be copied via FTP onto a PC using, for example, Windows Explorer to open one of the addresses:

- *ftp://169.254.100.102/CALIBRATE* when the sensor is booted with the **USER1** switch in the ON position. In this case, an Ethernet cable must directly connect the laptop and the FotoFiber processor module, and the sensor head must be off-sheet.

- *ftp://192.168.0.236/CALIBRATE* (or similar IP address as indicated by MSS) when the sensor is booted with the **USER1** switch in the *off* position. In this case, the laptop can be connected to the Ethernet switch in the scanner end-bell, and the sensor head need not be off-sheet.

Alternatively, a text-mode FTP program can be used in a command terminal, to connect to 169.254.100.102 or 192.168.0.236 (username: **`anonymous`**; no password needed).

The *CALIBRATE* directory always has a *00000000* subdirectory containing the original factory calibration files. There may be one or more other directories containing calibration data from specific dates, each named *yyyymmdd*, numerical year, month, day of the calibration. Typical contents of the *CALIBRATE* directory are shown in Figure 9-29.

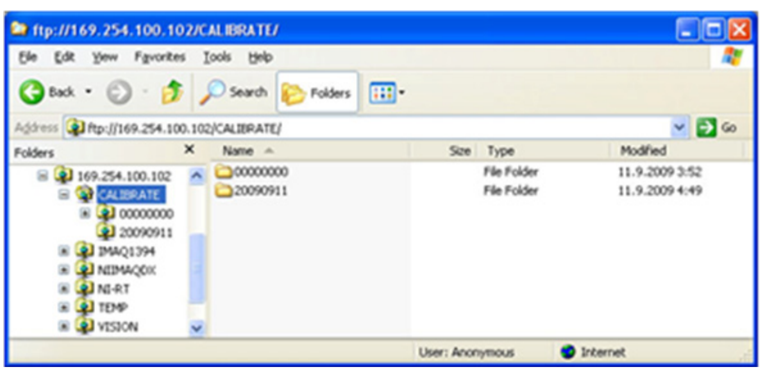


Figure 9-29 Typical CALIBRATE Directory Contents

The files in a particular calibration directory are shown in Figure 9-30. The selection of files will not change unless calibration setup parameters are modified.

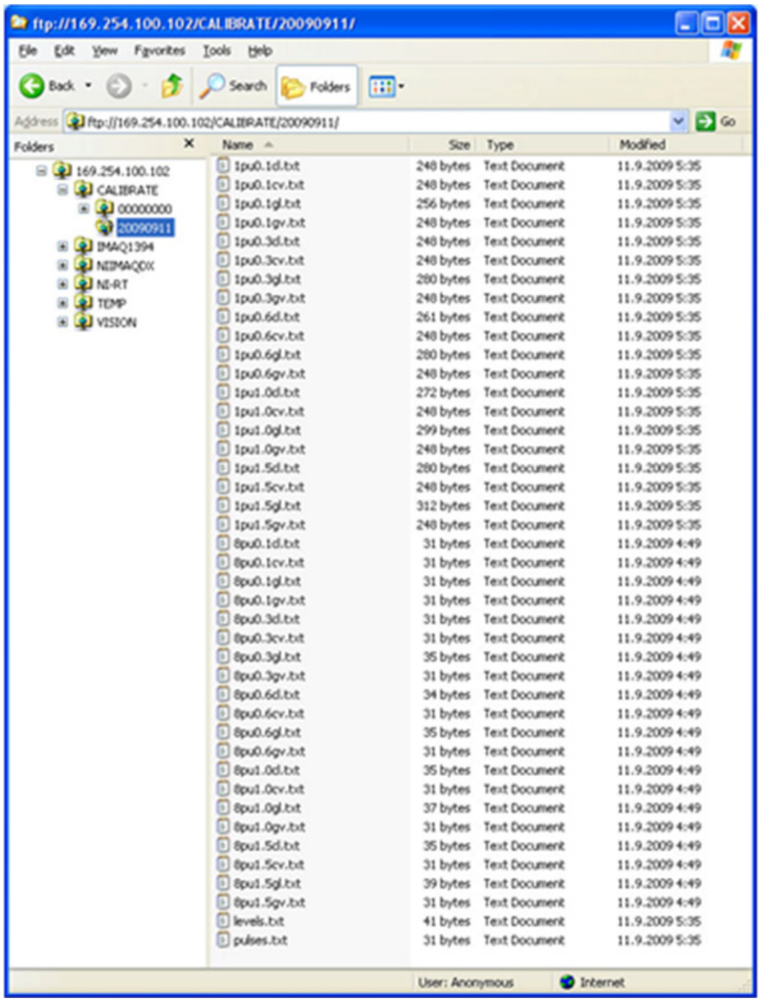


Figure 9-30 Calibration Files

9.6. Make field repairs and adjustments

9.6.1. Check voltages from utility PCB

The utility PCB provides 24 V power for the processor module, and provides both 24 V and 49 V power to the strobe controller, as described in Section 7.1. These output voltages must be within acceptable limits.

9.6.1.1. Check conditioned 24 V DC output

The 24 V DC level is taken from the block of three conditioned 24 V DC output sockets on the power and isolation PCB. These outputs have common wiring, so it is usually sufficient to check the voltage at the unused socket while the FotoFiber sensor is powered-up and running.

Activity Number:	Q4223-52-ACT-016	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	Avoid short circuits
Availability Required:	Sensor offsheet	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	Once per year
Duration (time period):	5 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
Required Tools:	Part Number	Quantity	Lead Time
	• voltmeter with thin probes		

The voltage can be checked, with the head offsheet, by carefully connecting voltmeter probes to the pins in the unused socket (see Figure 7–1). Exercise care to avoid accidental short-circuits that could cause damage to the sensor. Any level between 21.5–26.5 V is acceptable, but a level of 24 V ± 0.5 V is expected.

9.6.1.2. Check and adjust trimmed 49 V DC output

The trimmed output is located beside the trim-pot. The cable for the trimmed output will usually have a white conductor for the + 49 V line to distinguish it from the other power lines.

Activity Number:	Q4223-52-ACT-017	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	Avoid short circuits
Availability Required:	Sensor offsheet	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	Once per year

Duration (time period):	10 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
Required Tools:	Part Number	Quantity	Lead Time
	• voltmeter with thin probes • small flat head screwdriver		

This voltage should be in the range 49–49.5 V, and can be adjusted using the trim-pot if necessary. Note that one full clockwise rotation of the trim-pot increases the voltage by approximately 1.5 V. To check and adjust this voltage:

1. Switch off the sensor power using the switch shown in Figure 1–2.

2. Disconnect the 49 V power connector from the socket on the strobe control PCB, leaving the other end of the cable connected to the trimmed output socket on the power and utility PCB.

3. Position a voltmeter near the sensor, and ensure that the probes can easily reach the disconnected end of the 49 V cable.

4. Power on the FotoFiber with the switch, and wait approximately one minute for the boot to complete.

5. Measure the voltage at the disconnected end of the 49 V cable (Figure 9-31). Exercise care to avoid accidental short-circuits that could damage the sensor.

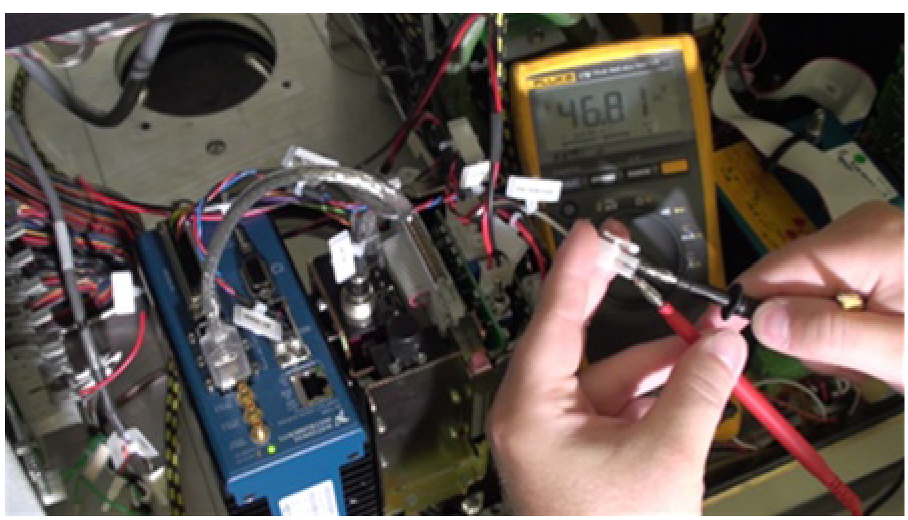


Figure 9-31 Measure Trimmed Output Voltage

6. If the voltage is in the range 49–49.5 V, no adjustment is needed. If it is outside this range, it needs to be adjusted. To adjust the voltage, use a small screwdriver to turn the trim-pot as shown in Figure 9-32. The trim-pot location can also be seen in Figure 1–2. One full clockwise turn increases the voltage by approximately 1.5 V.

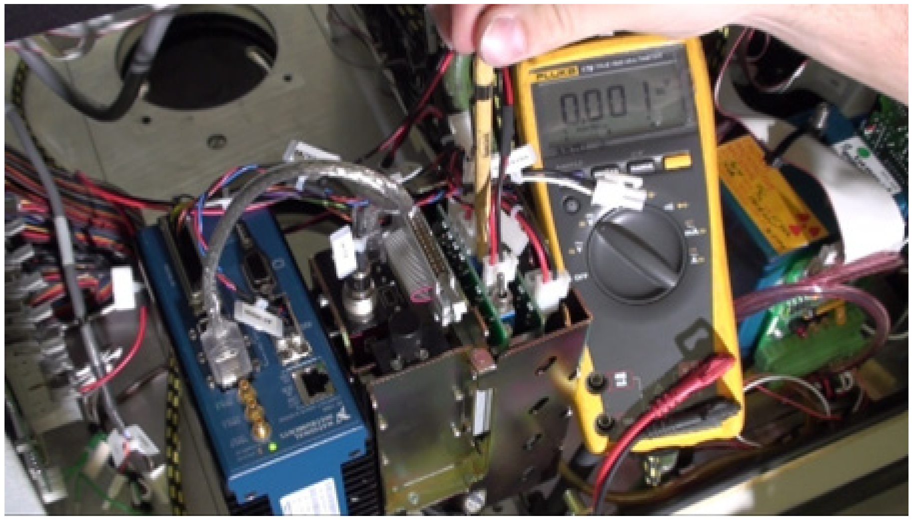


Figure 9-32 Adjust Voltage Trim-pot

7. When the trimmed voltage is within range, switch off the sensor power, and reconnect the 49 V cable to the appropriate input on the strobe control PCB.

8. The sensor is ready to be powered up.

9.6.2. Replace fuse

The sensor is equipped with a fuse to protect it against potential problems or errors in the power connection, such as reversed polarity or severe voltage spikes. It may be necessary to replace the fuse in some circumstances. An extra fuse is supplied as a standard spare part with the FotoFiber sensor.

This procedure requires that the strobe control PCB be removed from the utility PCB. It is advantageous to also check the jumper at J1 on the utility PCB at the same time (see Subsection 9.6.3).

Activity Number:	Q4223-52-ACT-018	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	

Availability Required:	Sensor removed from scanner	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	If required
Duration (time period):	45 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
	51600543; fuse		
Required Tools:	Part Number	Quantity	Lead Time
	• set of long-handled hex keys • set of flat head screwdrivers • set of Philips head screwdrivers • small needle-nose pliers (preferably bent-nose)		

It is necessary to remove the strobe control PCB to gain access to the fuse on the Utility PCB. The cables can be left connected to both PCBs during this operation.

After the strobe control PCB is removed, the fuse can be taken out of its socket on the utility PCB (see Figure 7–4) using a needle nose pliers, and replaced with a new fuse.

The strobe control PCB can then be remounted above the utility PCB, and the sensor reinstalled in the head.

ATTENTION

Check the polarity of the 24 V power supply before reconnecting it to the input on the utility PCB. If the polarity is reversed, the new fuse will immediately be blown. On the connector bringing 24 V power, pin 1 should be positive. Pin 1 on the socket is the pin closer to the PCB.

9.6.3. Check and reseat camera trigger jumper

The camera can accept triggering at TTL or isolated levels, for example, 5 V or 24 V. The jumper at J1 on the utility PCB is used to select between those options. If the jumper is missing, or improperly seated, there is a possibility that the camera triggering may not work correctly.

Activity Number:	Q4223-52-ACT-019	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	

Availability Required:	Sensor removed from scanner	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	If required
Duration (time period):	45 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
Required Tools:	Part Number	Quantity	Lead Time
	• set of long-handled hex keys • set of flat head screwdrivers • set of Philips head screwdrivers • small needle-nose pliers (preferably bent-nose)		

It is necessary to remove the strobe control PCB to gain access to jumper J1 on the utility PCB. The cables can be left connected to both PCBs during this operation.

Check that the jumper is installed, and properly seated (see Figure 7-5). Needle-nose pliers can be used to reseat the jumper.

The strobe control PCB can then be remounted above the utility PCB, and the sensor reinstalled in the head.

9.6.4. Check LED cable seating

If the sensor is subjected to poor handling or mechanical shock or severe vibration, one or more of the cables from the strobe control PCB to the LED driver PCBs may become poorly seated.

Activity Number:	Q4223-52-ACT-020	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	
Availability Required:	Sensor removed from scanner	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	If required
Duration (time period):	45 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	

Required Parts:	Part Number	Quantity	Lead Time
Required Tools:	Part Number	Quantity	Lead Time
	• set of long-handled hex keys • small needle-nose pliers (preferably bent-nose)		

The individual connectors at the LED driver PCB end of the cables should be removed from their sockets in the LED driver PCBs, then reinserted. Similarly, individual connectors at the strobe controller PCB end of the cables should be removed from their sockets in the strobe controller PCB, then reinserted.

The needle-nose pliers can be used to remove and reinsert the connectors. It is recommended that a single connector be removed and reinserted before moving to the next connector.

9.6.5. Repair or replace LED panel and/or LED driver PCBs

If the sensor is subjected to poor handling or mechanical shock or severe vibration, it is possible that one or more of the solder points on the LED panels or LED driver PCBs might be damaged, resulting in failure of one or more channels at standardization. Typically both the channel factor flag and the channel gray flag will be ON for the affected channels.

Activity Number:	Q4223-52-ACT-021	Applicable Models:	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	
Availability Required:	Sensor removed from scanner	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	If required
Duration (time period):	120 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
	• 20100080; LED driver PCB • 20100081; LED panel PCB • 5 cm each of red and black 12 gauge wire • lead-free solder		

Required Tools:	Part Number	Quantity	Lead Time
	• 16000235; thread locker • set of flat head screwdrivers • set of Philips head screwdrivers • small needle-nose pliers • precision soldering iron		

It is also possible that an LED panel PCB or LED driver PCB will degrade with age to the point where it must be replaced. The symptoms will be a progressive downward drift in the channel factor.

Repairing or replacing components in the light source assembly requires an entire day. Use static-proof bags and small containers to hold the circuit boards, cables, and screws that are removed from the sensor. Have a supply of labels on hand, and clearly label all parts as they are removed. If possible, use a camera to record the initial cable and circuit board configuration. Allow as much time for reassembly as for disassembly, because it may be necessary to inspect the photos.

It is necessary to partly dismantle the sensor to gain access to the light source assembly:

1. Unplug the cables from their sockets in the strobe control PCB and LED driver PCBs.

2. Unplug the 24 V, 48 V, trigger, and light control link cables from the strobe control PCB.

3. Remove the strobe control PCB from the struts attaching it to the power and utility PCB.

4. Remove the metal floor and the upper parts of the sensor. There are six screws to remove, five connected to struts mounted on the light holder, and one into a threaded insert in the light holder.

5. Before removing the struts from the light holder, mark the threaded insert that holds a screw (see Figure 9-33, left). The light holder can then be detached from the base of the sensor, by removing the bolts as described in Subsection 4.2.1.1.

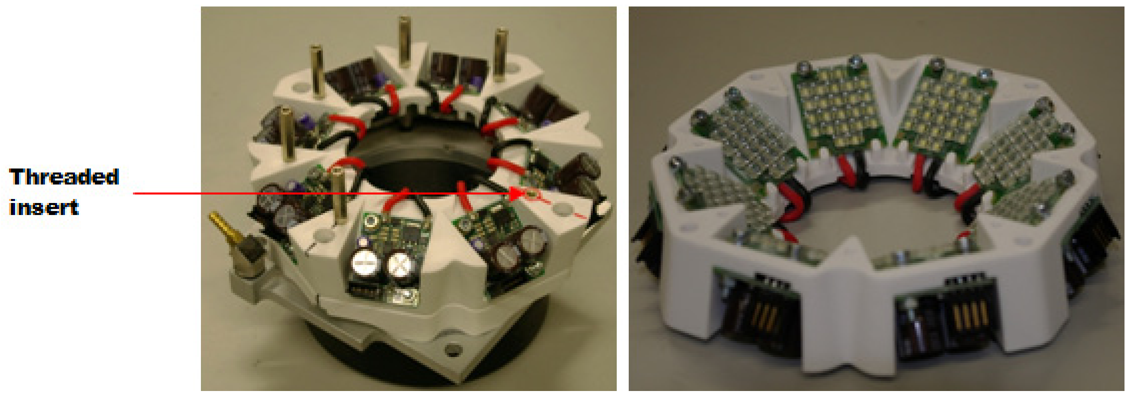


Figure 9-33 Light Assembly

Figure 9-33 shows a light assembly removed from the sensor. The strobe control PCB is installed above the indicated hole.

In re-assembling the sensor, the steps are the reverse of those taken to disassemble it. Pay careful attention to putting the eight cables running from the strobe control PCB to the LED driver PCBs in exactly the same sockets they were originally. The default assignment is shown in Figure 9-34. PL1–PL8 indicate which strobe control PCB socket to use. The indicated threaded hole is the one which is under the strobe control PCB, and does not receive a strut.

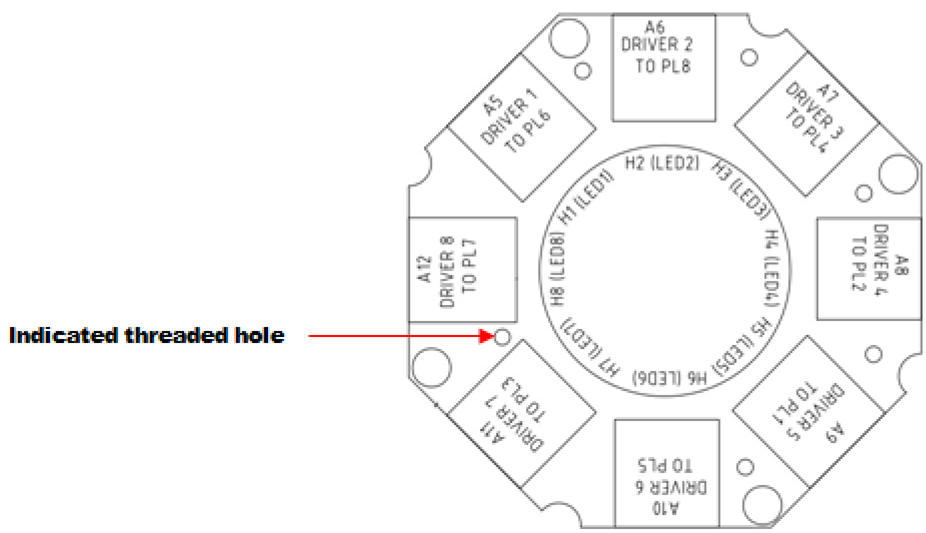


Figure 9-34 Strobe Control Cable Assignment

When attaching the nuts onto the bolts to hold the upper and lower polymer octagons together, a thread locking compound should be applied to the threads of each nut.

9.6.6. Re-glue lower sensor window

The lower sensor window may become dislodged during an unusually vigorous cleaning, or if the sensor has been exposed to chemicals that degrade the adhesive. If it becomes dislodged, remove the sensor and re-glue the window.

Activity Number:	Q4223-52-ACT-022	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	
Availability Required:	Sensor removed from scanner	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	If required
Duration (time period):	120 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
	16000361; adhesive 16000235; thread locker		
Required Tools:	Part Number	Quantity	Lead Time
	• set of long handle hex keys • set of flat head screwdrivers • set of Philips head screwdrivers • small needle-nose pliers • X-Acto knife		

To access the lower sensor window, separate the upper and lower sections of the sensor, as described in Subsection 4.2.1.1, giving access to the window from the inside. In addition to being glued, the window is held in place by a circular clip in an annular recess. This clip must be removed to remove the window, so that all old adhesive can be cleaned from the rim of the window and the aperture of the sensor. A suitable internal circlip pliers (not a circlip expander or external circlip pliers) is recommended. The clip may also be removed using a long needle-nose pliers, preferably bent-nose, but this requires some skill to avoid damage to the clip.

All of the old glue should be removed from the window edge and from the sensor plenum. A small sharp knife may be used for this, but ensure that you avoid damaging the polymer plenum. If solvents are used to remove old adhesive or other residues, the parts should be allowed to fully dry before applying new adhesive to the edges of the window, and firmly locating it with pressure for several seconds.

9.6.7. Re-glue lens onto LED panel PCB

One or more of the lenses might become dislodged from an LED panel PCB due to vibration or other mechanical shocks, possibly combined with aging of the existing adhesive. This is more likely to happen to an upper sensor than for a lower sensor. If a lens becomes dislodged, locate and retrieve it from the sensor, then re-glue it.

Activity Number:	Q4223-52-ACT-023	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	
Availability Required:	Sensor removed from scanner	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	If required
Duration (time period):	100 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
	16000361; adhesive 16000235; thread locker		
Required Tools:	Part Number	Quantity	Lead Time
	• set of long handle hex keys • set of flat head screwdrivers • set of Philips head screwdrivers • small needle-nose pliers • tweezers, preferably fine		

Repairing or replacing components in the light source assembly requires an entire day. Use static-proof bags and small containers to hold the circuit boards, cables, and screws that are removed from the sensor. Have a supply of labels on hand, and clearly label all parts as they are removed. If possible, use a camera to record the initial cable and circuit board configuration. Allow as much time for reassembly as for disassembly, because it may be necessary to inspect the photos.

The dislodged lens should be located and retrieved from the sensor. This is usually just a matter of inverting the sensor above a clean flat surface, and turning the sensor until the loose lens falls out. The lens is made of a nonconductive material and is very lightweight, and it cannot damage the other components of the sensor. If the lens appears to be stuck, it can be retrieved later after dismantling the sensor, but be observant in case it falls out during the dismantling procedure.

To replace the lens, it is necessary to partly dismantle the sensor to gain access to the light source assembly:

1. Unplug the cables from their sockets in the strobe control PCB and LED driver PCBs.

2. Unplug the 24 V, 48 V, trigger and light control link cables from the strobe control PCB.

3. Remove the strobe control PCB from the struts attaching it to the power and utility PCB.

4. Remove the metal floor and the upper parts of the sensor. There are six screws to remove, five connected to struts mounted on the light holder, and one in a threaded insert in the light holder.

The dislodged lens should be held from the sides with the tweezers, and given very small drops of adhesive on its legs at the bottom. It should be promptly placed above one of the exposed emitters on the LED panel PCB. Figure 9-35, left, shows an LED panel PCB with two missing lenses, beside a single lens. The upper surface of a lens is flat, while the lower surface has legs. In practice, the replacement is carried out with the LED panel PCB in the light source assembly, as shown in Figure 9-33.

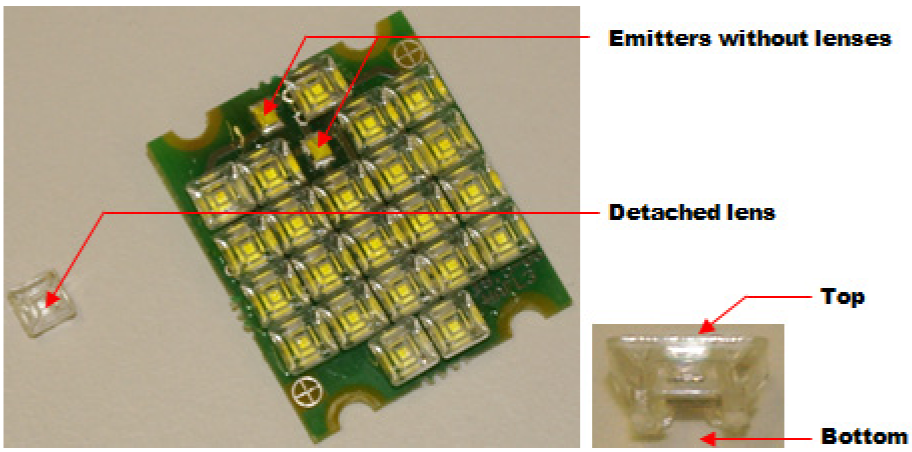


Figure 9-35 LED Panel and Detached Lens (right: side view of lens)

In re-assembling the sensor, the steps are the reverse of those taken to disassemble it. Pay careful attention to putting the eight cables running from the strobe control

PCB to the LED driver PCBs in exactly the same sockets they were originally in. The default assignment is shown in Figure 9-34. PL1–PL8 indicate which strobe control PCB socket to use. The indicated threaded hole is the one that is under the strobe control PCB, and does not receive a strut.

9.7. Update firmware

A firmware update for the Q4223-5x sensor might involve replacing just one or two individual files in the sensor, or replacing the firmware in its entirety. A firmware update might be needed in conjunction with a future MSS or Experion MX upgrade, or to add new functionality or to address a site-specific problem.

The original firmware might need to be reloaded onto the FotoFiber if the processor module needs to be replaced (a new processor module ordered as a spare part will not be delivered loaded with FotoFiber firmware), or if it appears that an existing file has become corrupt.

If the entire firmware is to be replaced or reloaded in the field, it should be done using the Intelligent Sensors software package, as described in Subsection 9.7.2. If just a few files are to be replaced, this can be accomplished simply by transferring the required files from a PC as described in Subsection 9.7.1.

9.7.1. Replace individual firmware files

If only a few files are to be replaced, detailed instructions will be provided with the update package, listing the files to be replaced and the directories where they are to be placed. Typically this will be *STARTUP.RTEXE* and/or *FACTORY.RTEXE*, both of which are in the *C:\NI-RT\STARTUP* directory in the FotoFiber processor module.

This procedure can usually be carried out with the sensor in the scanner head, during a brief shutdown or a long sheetbreak.

Activity Number:	Q4223-52-ACT-024	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	
Availability Required:	Sensor removed from scanner	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	If required
Duration (time period):	15 minutes	**# of People Required:**	1

Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
	Cat5 Ethernet cable		
Required Tools:	Part Number	Quantity	Lead Time
	• laptop		

Replacing a few files is typically performed with the sensor within the scanner head. The sensors should be taken offsheet, and the scanner drive disengaged. Then the head can be opened. The **SAFE MODE** DIP switch on the processor module should be set to the ON position, and all other DIP switches should be set to the *off* position. The sensor is then rebooted by momentarily depressing the **RESET** button adjacent to the block of DIP switches. The FotoFiber will boot once, taking about 20 seconds (some firmware is not loaded in safe mode, so the boot time is shorter than normal, but measurement and maintenance operations are unavailable).

The IP address of the sensor will depend on what mode it was previously booted in. If it had a connection to the MSS in an Experion MX system, its IP address will be 192.168.0.238 or similar (obtain from MSS EDAQ Info display). If it was previously booted in maintenance mode (**USER1** switch ON), or was connected to the MSS in a Da Vinci system, its IP address will be 169.254.100.102.

A PC or laptop should be connected using a standard Cat5 or Cat6 Ethernet cable to the Ethernet port on the processor module. The PC should have IP address 192.168.0.99 or 169.254.100.100 for the wired Ethernet port, whichever corresponds to the network containing the Q4223-5x. The remainder of this section assumes 169.254.100.100 for the PC and 169.254.100.102 for the Q4223-5x.

1. Open a command shell on the PC, for example, *CMD.EXE*, and change to the directory where the replacement firmware files are. In this shell, issue the command:

   ```
   ftp 169.254.100.102
   ```

2. Log in anonymously by hitting the `ENTER` key when prompted for username, and again when prompted for password.

3. Change to the directory in the FotoFiber processor module where the files are to be replaced (this should be in the instructions provided with the new firmware files). Rename the existing files so that they can be restored later if needed

4. Copy the new files to the FotoFiber. For example, assuming that the file *STARTUP.RTEXE* is to be replaced in directory *C:\NI-RT\STARTUP*, the following commands would be given one at a time in the ftp program:

```
cd /NI-RT/STARTUP

rename STARTUP.RTEXE STARTUP.RTEXE.SAVED

binary

send STARTUP.RTEXE

bye
```

5. After the files have been transferred, the Ethernet cable can be disconnected from the FotoFiber and the PC.

6. The **SAFE MODE** DIP switch should be set to the *off* position, and the FotoFiber rebooted by momentarily depressing the **RESET** button adjacent to the block of DIP switches. The FotoFiber will boot once, taking almost a minute to load its full firmware.

7. The head can be closed and the scanner drive re-engaged. Scanning or single-point operation should not be requested until approximately one minute after the FotoFiber reboot started. If the firmware version number has changed in the update, the new version number will be reported as parameter 4 on the **FotoFiber Engineering** display (see Figure 6–17).

ATTENTION

Although a text-mode FTP program was used in this example, it is possible to use almost any convenient FTP program instead, including GUI-based FTP programs. One GUI-based FTP program which is suitable is the free and open-source FileZilla program, which can be obtained from *http://sourceforge.net/projects/filezilla* for Windows, Linux, and Mac OS X.

9.7.2. Load all firmware

It is recommended that this procedure be carried out with the sensor removed from the scanner head; however, it can be performed with the sensor in the scanner head during a shutdown of several hours. A laptop may need to have a fully charged battery and/or to have access to external power.

If a new processor module is to be installed in the sensor, the firmware can be loaded onto it before or after it is installed in the sensor; however, the processor module has an uncommon power connector, so it may be more convenient to install it in the sensor first, and load the firmware afterwards.

ATTENTION

> If there has been no change to the sensor illumination hardware, or to its camera and lens, the calibration data is expected to remain valid. The calibration data should be retrieved from the existing processor module, or from the directory it was copied to in the QCS server (see Subsection 9.5.3). It can either be sent to the processor module after the firmware is updated, or can be incorporated into the firmware file structure in the *CALIBRATE* directory.

Activity Number:	Q4223-52-ACT-025	**Applicable Models:**	Q4223-51; Q4223-52
Type of Procedure:	Maintain	**Expertise Level:**	Technician
Priority Level:	Average	**Cautions:**	
Availability Required:	Sensor removed from scanner	**Reminder Lead Time:**	
Overdue Grace Period:		**Frequency (time period):**	If required
Duration (time period):	90 minutes	**# of People Required:**	1
Prerequisite Procedures:		**Post Procedures:**	
Required Parts:	Part Number	Quantity	Lead Time
	Cat5 Ethernet cable		
Required Tools:	Part Number	Quantity	Lead Time
	• laptop with Honeywell Intelligent Sensors package		

9.7.2.1. Confirm firmware version

Ensure that the correct firmware version is available. If necessary, contact QCS-TAC for guidance on firmware versions.

If the standard firmware is to be installed on a new processor module, a copy is supplied with the Intelligent Sensors software, and can be found in the directory *C:\Program Files\Intelligent Sensors\Fiber Image* on the PC.

If a new version of firmware is to be installed, you should have received a copy as part of a system upgrade, or in conjunction with support for a site-specific issue.

9.7.2.2. Set up hardware

With the FotoFiber power switch in the *off* position, the **IP RESET** DIP switch and the **SAFE MODE** DIP switch on the processor module should both be set to the ON position. The other DIP switches should be in the *off* position.

A 24 V DC power supply and power cable, as described in Subsection 9.3.1, are required, and should be connected to the FotoFiber.

A PC or laptop with the Intelligent Sensors software should be connected using a standard Cat5 or Cat6 Ethernet cable to the Ethernet port on the processor module. The PC must have IP address 169.254.100.100 and its other network interfaces must be disabled (see Appendix D.2).

9.7.2.3. Deploy firmware

The Intelligent Sensors software should be started, and then the FotoFiber should be powered on. The FotoFiber will not load any application firmware when it is booted with the **SAFE MODE** DIP switch in the ON position.

Start the firmware loader from the Intelligent Sensors software menu (see Figure 9-36).

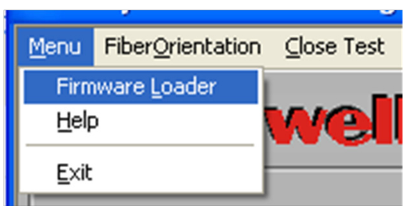


Figure 9-36 Intelligent Sensors Menu: Firmware Loader

The firmware loader window is shown in Figure 9-37, left. The quick help box summarizes the steps needed to deploy the firmware. Click the folder button beside the path textbox, and navigate to the directory containing the FotoFiber firmware (see Figure 9-37, right). When the correct directory is displayed, click **Current Folder**.

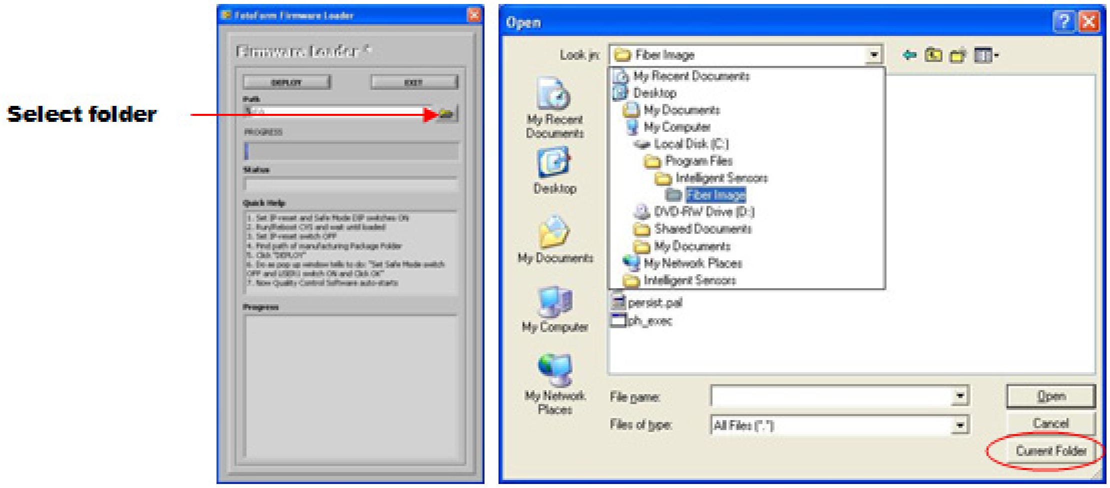


Figure 9-37 Firmware Loader (left); Selecting Fiber Image (right)

Check that the correct directory appears in the path textbox, then click **Deploy** to start deploying the firmware to the FotoFiber (see Figure 9-38, left). Progress messages will be displayed in the lower text box. During the procedure, it will be necessary to change the DIP switch configuration, and the program will prompt for the change (see Figure 9-38, center) at the appropriate time. Make the DIP switch changes before clicking **OK**, because the FotoFiber will reboot shortly after you click **OK**.

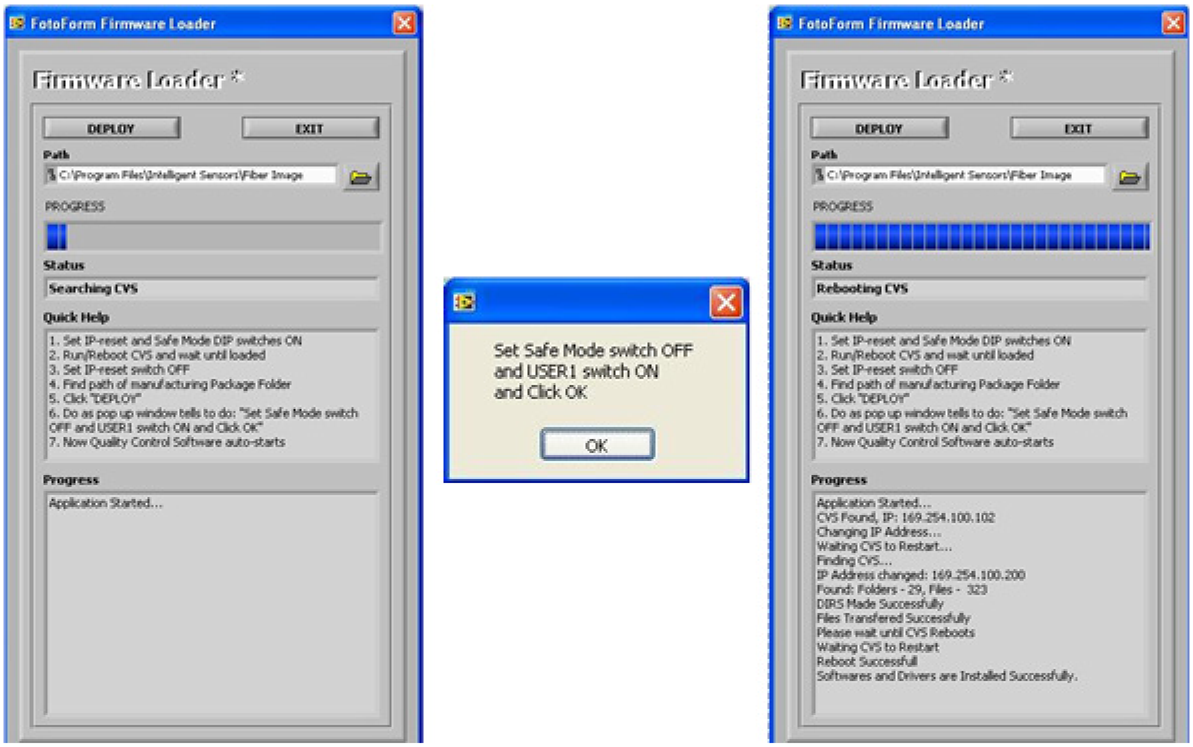


Figure 9-38 Firmware Deployment

When the firmware deployment is complete, the progress text will contain the message *Software and Drivers are Installed Successfully* (see Figure 9-38, right). Note that a FotoFiber is temporarily given the IP address 169.254.100.200 during firmware update, but this is always automatically reverted to the default FotoFiber IP address 169.254.100.102 when the firmware update is complete.

Perform calibration and focusing after the firmware has been updated. The sensor will contain only default calibration data, which is probably not optimal for any particular sensor. However, if the previous calibration data was saved (see Subsection 9.5.3), and is considered to be valid, it can be transferred to the sensor using FTP. Recall that if a recalibration is performed, the complete date of calibration might need to be updated as parameters 17 and 18 respectively on the **FotoFiber Engineering** display (see Subsection 6.3.4), to match the directory containing the calibration data.

10. Troubleshooting

This chapter is divided into two sections listing possible issues with the Fiber Orientation Sensor:

- Section 10.1 Alarm Based Troubleshooting, listing steps to be taken in response to a specific alarm generated in the Experion MX system.
- Section 10.2 Non-alarm Based Troubleshooting, listing steps that may not be related to a specific alarm in the Experion MX system.

10.1. Alarm based troubleshooting

Depending on system configuration, your Experion MX system may display only some of these alarms.

10.1.1. Sensor Down

Symptom	Possible Causes	Solutions
Link to FotoFiber is not working	The FotoFiber sensor is not enabled on the scanner sensor status display	Enable the sensor on the appropriate scanner sensor status display. See Subsection 4.4.1
	The FotoFiber sensor is not powered on	Switch on sensor power using power switch. See Figure 1-2
	FotoFiber sensor fuse is blown	Replace fuse. See Replace fuse.
	An Ethernet cable is not seated properly or has failed	Re-seat both ends of the two Ethernet cables for the sensor inside the head (shown in Figure 4-3). One cable is from the Ethernet switch to the EDAQ, the other is from the Ethernet switch to the sensor processor module. Replace these cables if failure recurs.
	FotoFiber power cable is not connected	Connect the power cable. See Figure 4-4.

10.1.2. Channel gray out of range during STDZ

Symptom	Possible Causes	Solutions
At least one illumination channel has a measured gray level outside the allowed operating range, when the illumination channels are strobed individually. This can occur during a scanning standardization, during a single-point standardization, or during an offsheet reference. The reported values can be seen in the FotoFiber Standardization display (Subsection 6.3.2).	If it occurs only during a scanning standardization, it may be caused by a very short STDZ scan, in which case the Short STDZ with combined channels alarm will also occur	Follow procedure given for Short STDZ with combined channels
	Incorrect machine speed being sent to FotoFiber sensor, causing an inappropriate pulse length to be used.	Check the machine speed being sent to the FotoFiber sensor (see the **FotoFiber Edge display**, Subsection 6.3.3). This should be in meters per second, and should not exceed 30. It may be necessary to adjust the slope and intercept, see Subsection 6.2.3
	Nonstandard gray limits are in use.	Check the limits in use (parameters 27 and 28 in the **FotoFiber Engineering display**, Subsection 6.3.4). The default range is from 25 to 225. If significantly different values are in use, contact QCS-TAC for further support.
	One or more strobe control cables is poorly seated. In this case, one channel will have a near-zero gray value. The Channel factor out of range during STDZ alarm will generally occur also.	Check and re-seat the cables for all eight illuminator channels. See Check LED cable seating.
	One LED panel or its driver PCB has failed, or the electrical connection between them has failed. In this case, one channel will have a near-zero gray value. The Channel factor out of range during STDZ alarm will generally occur also.	Repair or replace the LED panel and/or the LED driver PCB. See Repair or replace LED panel and/or LED driver PCBs.

10.1.3. Channel factor out of range during STDZ

Symptom	Possible Causes	Solutions
At least one illumination channel has an efficiency factor outside the allowed operating range, when the illumination channels are strobed individually. This can occur during a scanning standardization, during a single-point standardization, or during an offsheet reference. The reported values can be seen in the FotoFiber Standardization display (Subsection 6.3.2). Note that the allowed operating range is from 0.6 to 1.6 always.	One or more strobe control cables is poorly seated. In this case, one channel will have a near-zero gray value. The Channel gray out of range during STDZ alarm will generally occur also.	Check and re-seat the cables for all eight illuminator channels. See Check LED cable seating.
	One LED panel or its driver PCB has failed, or the electrical connection between them has failed. In this case, one channel will have a near-zero gray value. The Channel gray out of range during STDZ alarm will generally occur also.	Repair or replace the LED panel and/or the LED driver PCB. See Repair or replace LED panel and/or LED driver PCBs.
	Local dirt build-up is blocking the illuminator. This may affect a lower sensor but can also affect an upper sensor if the air channel becomes blocked, or if an environmental dirt issue occurred while the head was open.	Inspect the optical surfaces of the affected sensor, and clean if necessary. See Clean lower head sensor and/or Clean upper head sensor and/or Clean lens and inner surface of window in lower head sensor as appropriate.
	The alarm occurs intermittently, but channel factors are near their limits when it does not occur.	If the FotoFiber has been in service for more than a year, recommend to the mill that an illuminator channel recalibration (see Calibrate illuminators) be scheduled for an upcoming shutdown.
	A ***very unusual*** shade is being produced, which has one or more narrow features of large amplitude in its reflectance spectrum.	No action needed, if factors revert to within the allowed range on resumption of normal shades. Note, however, that this will occur only on ***very unusual*** shades, and then only if the illumination subsystem is near a limit.

10.1.4. Combined gray out of range during STDZ

Symptom	Possible Causes	Solutions
The gray level measured with all channels strobed simultaneously is out of its operating range. This can occur during a scanning standardization, during a single-point standardization, or during an offsheet reference.	If it occurs for scanning STDZ, the standardization scan may be too short for the given parameters. In this case, the Short STDZ with combined channels alarm will also occur	See Short STDZ with combined channels alarm
	If it occurs for scanning STDZ, incorrect machine speed being sent to FotoFiber sensor, causing an inappropriate pulse length to be used.	Check the machine speed being sent to the FotoFiber sensor (item 5 in Figure 6-16). This should be in meters per second, and should not exceed 30. It may be necessary to adjust the slope and intercept. See Subsection 6.2.3.
	Nonstandard gray limits are in use.	Check the limits in use (parameters 27 and 28 in the **FotoFiber Engineering display**, Subsection 6.3.4). The default range is from 25 to 225. If significantly different values are in use, contact QCS-TAC for further support.
	The strobe signal is not reaching either the illuminator or the camera, causing a near-zero gray level. Combined gray out of range during STDZ alarm will generally occur also.	Check and re-seat the strobe trigger cables (see Figure 7-1). Check and re-seat the camera trigger jumper. See Check and reseat camera trigger jumper.
	The illuminator system is underpowered.	Check the trimmed 49V DC output, and adjust if necessary. See Check and adjust trimmed 49 V DC output.
	Dirt build-up is blocking the illuminator and/or the camera.	Inspect the optical surfaces of the affected sensor, and clean if necessary. See Clean lower head sensor and/or Clean upper head sensor and/or Clean lens and inner surface of window in lower head sensor as appropriate.

10.1.5. Short STDZ with combined channels

Symptom	Possible Causes	Solutions
There are too few measurements during standardization with all channels strobed together. This can occur during a scanning standardization.	The scan speed has been increased and/or the sheet has become significantly narrower and/or the scanner is scanning between fixed limits and/or the measurement rate has been changed. In some cases this alarm may also cause the Combined gray out of range during STDZ alarm to occur. In extreme cases it may additionally cause the Channel gray out of range during STDZ alarm to occur.	See Subsection 4.3.2.2 to establish new values for parameters 24 and 25 in the **FotoFiber Engineering** display (see Subsection 6.3.4). Be sure to use the current measurement rate (parameter 5 in the **FotoFiber Engineering display**, see Subsection 6.3.4) if that has changed.

10.2. Non-alarm based troubleshooting

10.2.1. Diagnostic monitoring

The FotoFiber sensor contains a web server which is active when the sensor is booted normally, for example, booted with all DIP switches in the *off* position. It is not active when the sensor is booted in maintenance mode, for example, with the **USER1** DIP switch in the ON position.

To access the web server, connect a PC to the Ethernet switch in the Q4000 scanner endbell using a standard Ethernet cable. The indicated cable in Figure 10-1 leads to the PC. The PC network settings should be IP = 192.168.0.99 with netmask = 255.255.255.0 or similar. It is possible to access the monitor from a virtual machine (VM) on the PC, provided it is configured properly: VM network settings are IP = 192.168.0.98, netmask = 255.255.255.0.

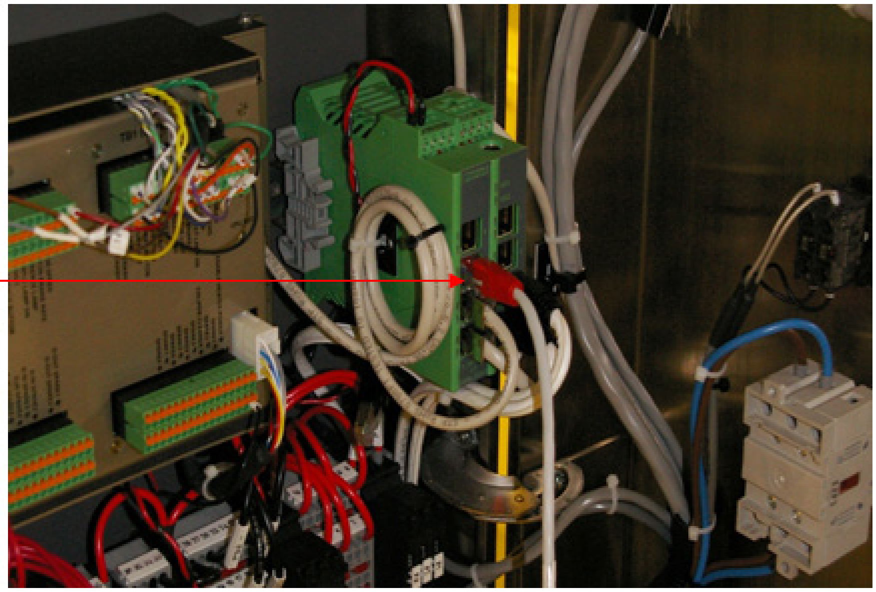


Figure 10-1 Ethernet Connection

The monitor provides a number of tabs which show the current operating state of the Q4223-5x. It is therefore quite useful for diagnosing operating problems, and use of the monitor may be requested by TAC or sensor developers during remote support.

Install LabVIEW Run-Time 2010 to the PC, or VM before connecting to the monitor. It is sufficient to install the minimum Run-Time, provided it is suitable for the operating system to be used on the PC or VM (32 bit or 64 bit, Windows, or Linux, and so on). The Run-Time will install a plug-in for the default browser on the operating system which enables that browser to access remote LabVIEW displays.

Instructions for installing LabVIEW Run-Time 2010 package can be found at the National Instruments web site, http://www.ni.com. For a typical installation procedure, see Appendix C.

At the time of writing this manual, the appropriate packages for both 32-bit and 64-bit LabVIEW Run-Time 2010 on Windows were downloadable from http://joule.ni.com/nidu/cds/view/p/id/2294/lang/en.

ATTENTION

> It is possible to have multiple versions of LabVIEW Run-Time installed simultaneously on a PC.
>
> The version to be installed should match the browser in use; 64-bit versions of Windows Vista and Windows 7 generally have the 32-bit browser by default, and will require the 32-bit version of the LabVIEW Run-Time.

10.2.1.1. Connect to monitor

To connect, access the *Monitor.html* web page on the appropriate sensor using a browser such as Microsoft Internet Explorer. The IP address of the sensor can be obtained from the EDAQ web pages on the QCS server (see Section 3.6), such as 192.168.0.236, and the web address is *http://192.168.0.236/Monitor.html*.

If the correct browser plug-in is not installed on the PC, attempting to connect to the monitor will result in a mostly empty display (see Figure 10-2). The mostly blank empty rectangle below the text, *Fiber Orientation Sensor*, indicates that the browser lacks the correct plug-in.

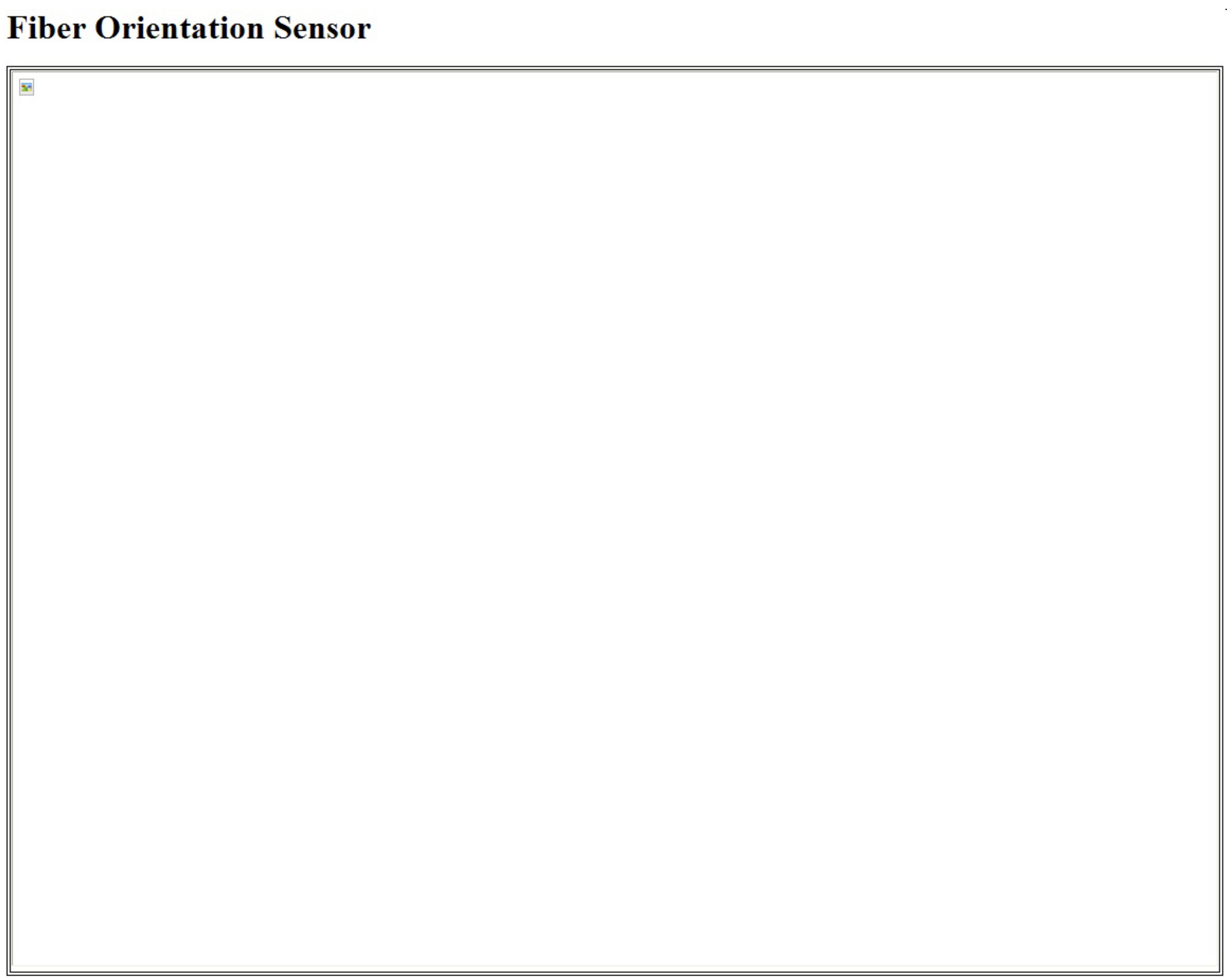


Figure 10-2 Connected to Monitor; Browser Plug-in Missing

ATTENTION

Most of the web page will not be visible until the browser plug-in is available. The correct version of the LabVIEW Run-Time 2010 package must be installed to provide the browser plug-in.

If the plug-in is installed, the rectangle in the display below the text, *Fiber Orientation Sensor*, will instead be colored and show progress of the panel being downloaded (see Figure 10-3).

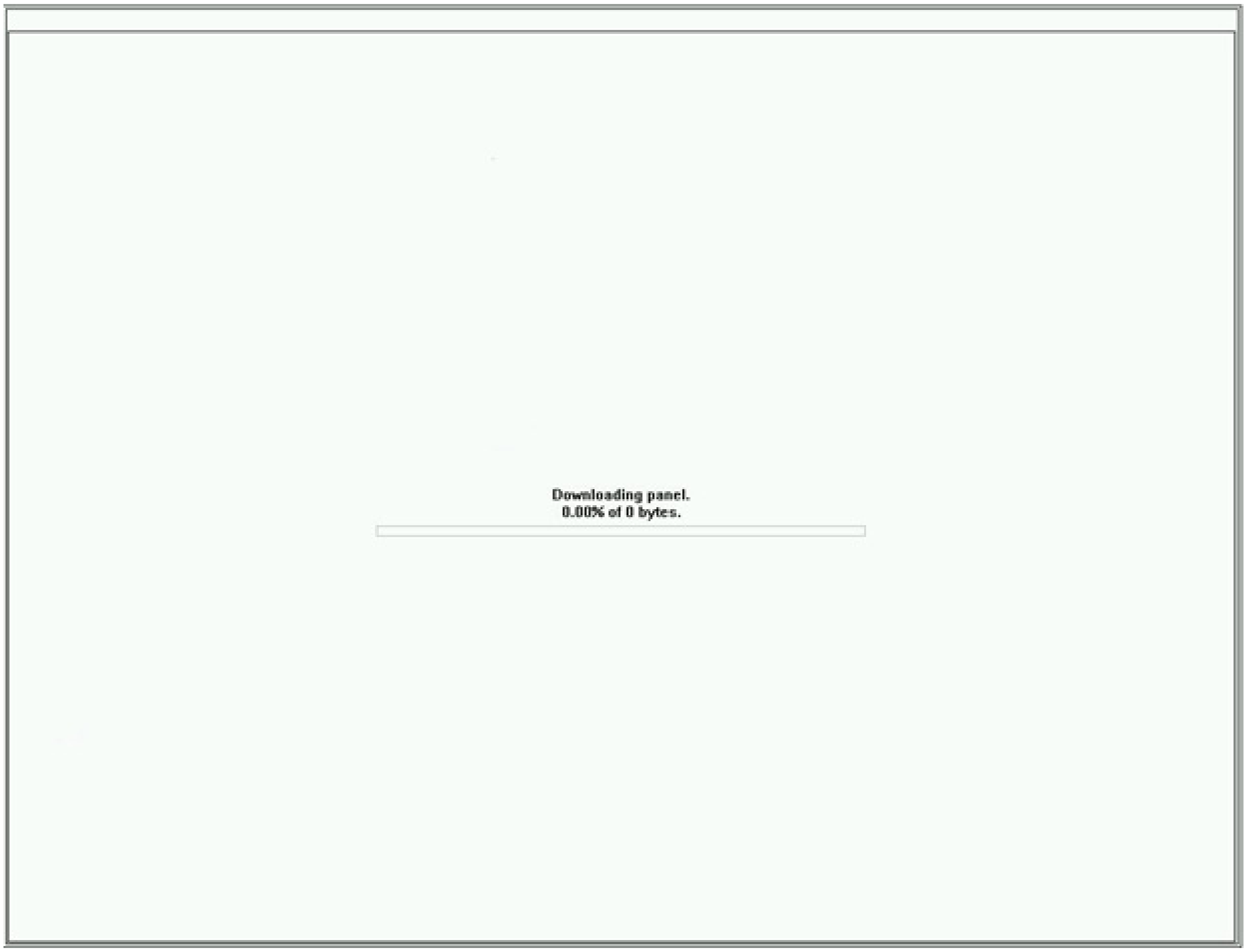


Figure 10-3 Connected to Monitor; Correct Plug-in

The display shown in Figure 10-3 is followed by the actual monitor display.

Other connection errors

Other error messages may appear instead of the *Downloading Panel* message. These include:

- *404 Not found*: The browser could not find the web page. Perhaps the wrong IP address or a misspelled Web page was used, or the Ethernet cable is improperly connected. Check that the FotoFiber is powered on and properly connected, and that it was booted in normal mode, with its **USER1** switch in the *off* position. Check also that the Ethernet cable is not faulty, and is properly seated in both the PC and a port of the Ethernet switch in the scanner endbell.

ATTENTION

> If there is a fault in the sensor hardware relay indicating that the host is an Experion MX system, the sensor might boot Da Vinci firmware instead. In this case, the sensor will not appear on the MSS EDAQ page, and the sensor IP address will be 169.254.100.102 always. If a 404 error is encountered, try to connect to *http://169.254.100.102/Monitor.html* instead. In this case, a direct cable to the Ethernet port in the processor module is needed, which is only feasible when the scanner head is offsheet.

- *Remote panel connection exceeds maximum number of licenses*: Only one PC at a time can connect to a FotoFiber Web server. This is a restriction of the license for certain parts of the Web server software.
- *Server 192.168.0.236 has disconnected client for unknown reason*: This usually occurs only if the sensor is rebooted, whether by command, power switch, or the **RESET** button.
- *Remote panel connection refused by specified server: Make sure LabVIEW Web Server is enabled on specified server*: Either the wrong sensor is being addressed (the connection is to a sensor which is not a FotoFiber), or the FotoFiber was booted in maintenance mode with the **USER1** switch in the ON position. Check that the IP address is correct, and that the FotoFiber is booted in its normal mode. The Web server is always enabled on FotoFiber sensors.

10.2.1.2. Common items

The monitor has several tabs that display different items. There is a common block of data on the left, which is shown in all tabs (see Figure 10-4).

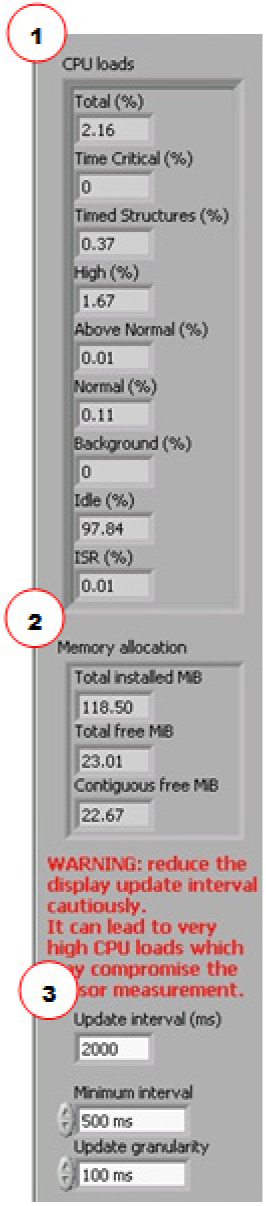


Figure 10-4 Monitor Tabs: Common Items

Table 10-1 lists and describes the items shown in Figure 10-4.

Table 10-1 Monitor Tabs: Common Items

Item	Description
1	**CPU loads**: total and breakdown for various classes of activity
2	**Memory allocation**: memory installed and available
3	Update intervals (ms): update parameters for monitor

The total CPU load should never exceed 90%, and should, preferably, be less.

ATTENTION

The update interval controls how often the monitor is updated. There is no benefit in making it longer than the default of 2000 ms. When making it shorter, it should be noted that the CPU load will be increased at short intervals. For instance, the CPU load is increased by approximately 5% if an update interval of 100 ms is chosen, and allowed by the value of the minimum interval.

To prevent inadvertently entering too low an interval, the minimum interval places a lower bound on the update interval. It can be chosen only from a set of values:

- 100 ms
- 150 ms
- 250 ms
- 500 ms (default)
- 1000 ms
- 2500 ms

The monitor can run only on multiples of the update granularity value. This represents another minimum for the update interval. It can be chosen only from a set of values:

- 50 ms
- 100 ms (default)
- 200 ms
- 300 ms

- 400 ms
- 500 ms

10.2.1.3. Sensor parameters and calibration

One of the monitor tabs provides access to sensor parameters. Another shows calibration parameters.

Parameters

The display for the **Parameters** tab is shown in Figure 10-5. It lists the configuration parameters currently loaded in the FotoFiber sensor, and provides brief descriptions of the more important parameters and bitfield options.

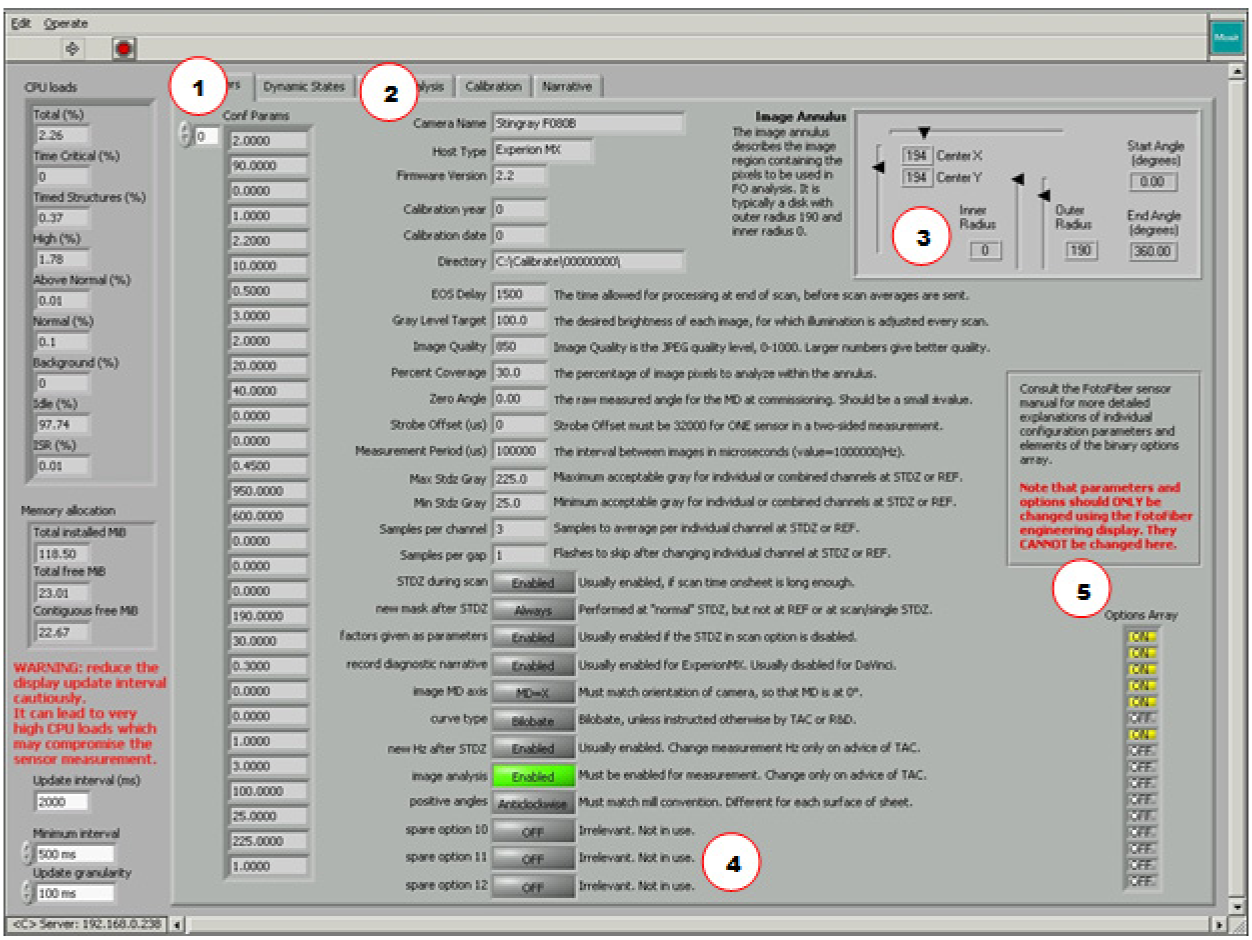


Figure 10-5 Parameters Tab Display

Table 10-2 lists and describes the items shown in Figure 10-5.

Table 10-2 Parameters Tab Display Items

Item	Description
1	Scrollable list of configuration parameters, in the same order as in the **FotoFiber Engineering** display (see Figure 6–19), all expressed in floating point format
2	Selected environment and interpreted configuration parameters, with brief explanatory text
3	Definition of image annulus for analysis (usually a disk)
4	Explained values in options bitfield
5	Expanded options bitfield, parameter 53

ATTENTION

If the FotoFiber has not yet received its parameters from the MSS, the data shown on this tab will mostly be default values. The Host Type and Firmware Version should be correct, but even the Camera Name string will not be available. If any of the parameters has an unexpected value, it is advisable to view the **Dynamic States** tab to check whether the sensor is still waiting for parameters (as shown in Figure 10-7) before deciding on further action.

Calibration

The display for the **Calibration** tab is shown in Figure 10-6. It contains four charts which show the data measured during calibration of the illuminators and camera.

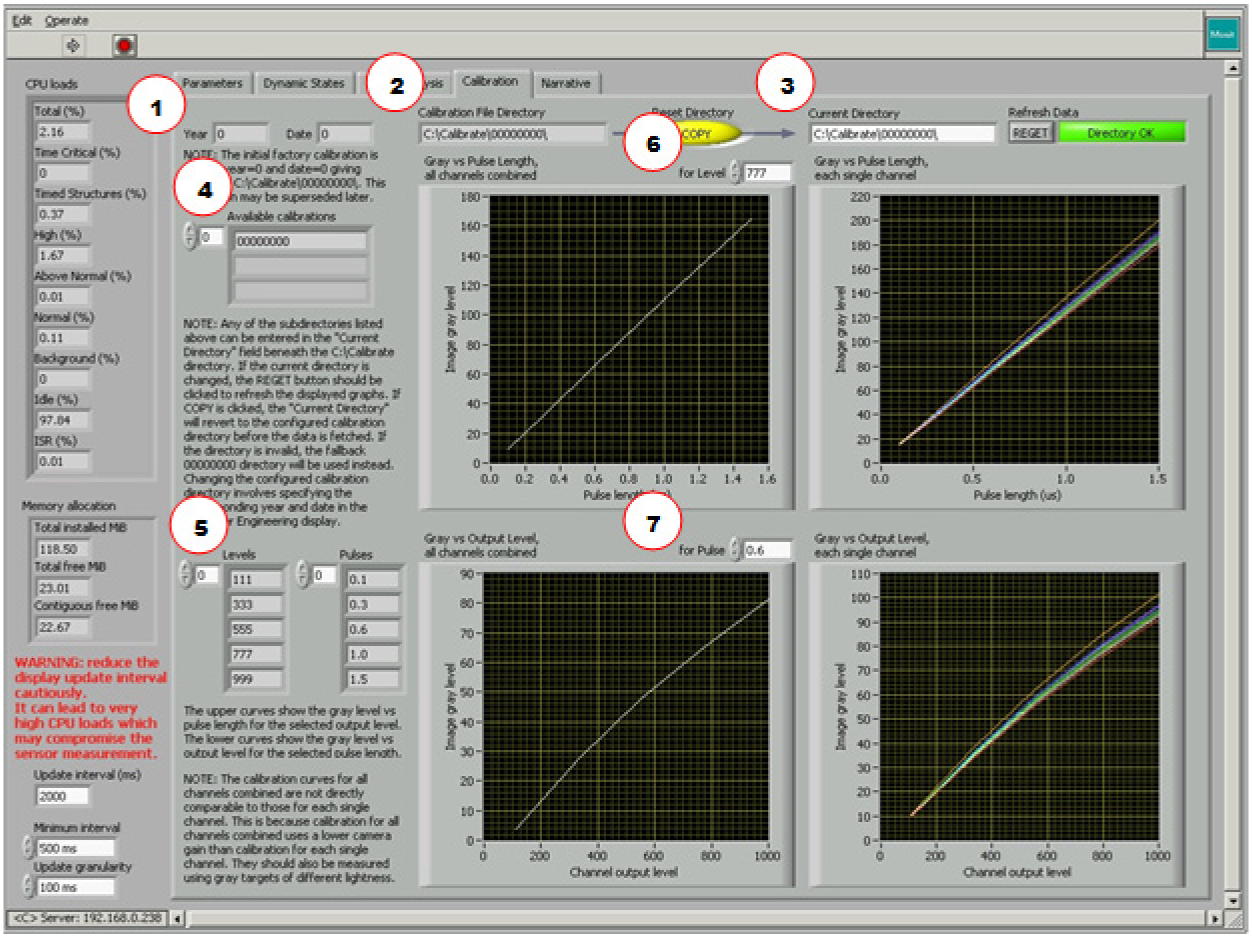


Figure 10-6 Calibration Tab Display

Table 10-3 lists and describes the items shown in Figure 10-6.

Table 10-3 Calibration Tab Display Items

Item	Description
1	Year and date of active calibration data
2	Active Calibration File Directory, and **COPY** button to copy that directory to the displayed directory
3	Currently displayed directory, and status of data in that directory
4	List of available calibration directories

Item	Description
5	Scrollable lists of output levels and pulse lengths for which data exists in the currently displayed directory
6	List box for selecting an output level, with graphs plotting gray values against pulse length for the selected output level
7	List box for selecting a pulse length, with graphs plotting gray values against output level for the selected pulse length

The pair of charts on the left show single traces for all illuminators operated simultaneously, while those on the right show eight individual traces for each illuminator used individually. The upper pair of charts plot graylevel against pulse length for a selected output level. These are nearly straight lines, with intercepts near the 0, 0 point.

The lower pair of charts plot graylevel against output level for a selected pulse length. These are curved lines whose intercepts are slightly to the right of the 0, 0 point. The output level corresponds to the voltage used to drive the LED panels, from approximately 6–48 V. The current through the LEDs increases more than linearly with voltage, but the light generated increases less than linearly.

10.2.1.4. Dynamic states

The display for the **Dynamic States** tab indicates the values of several counters and variables, as well as the most recent results of standardization. After the sensor has booted, but before it has communicated with the MSS, its mode is *waiting for parameters*, as shown in Figure 10-7. Most of the data is either missing, or set to default values (nearly all of the values under the **Parameters** tab will also be defaults in this mode).

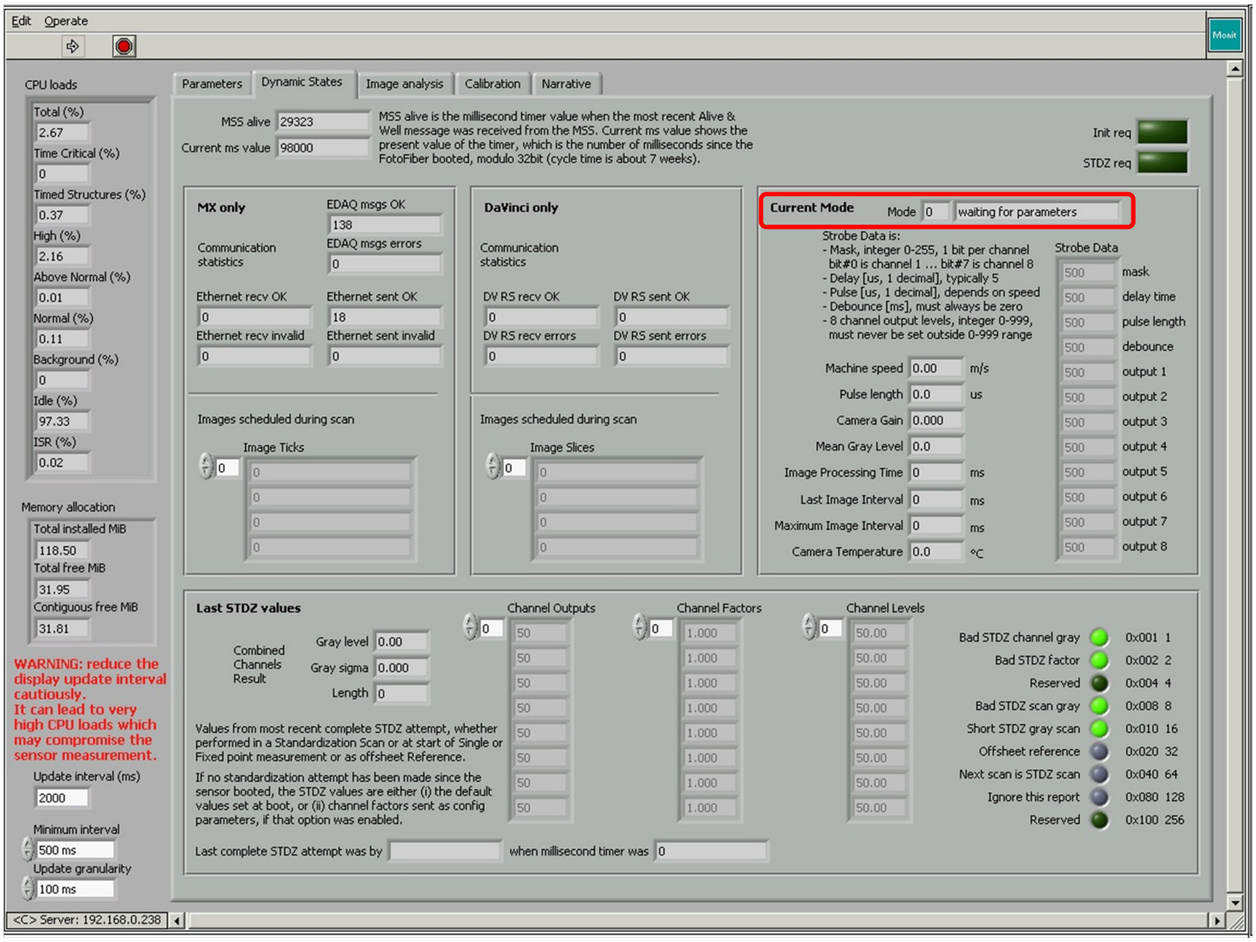


Figure 10-7 Dynamic States Tab Display

If the *waiting for parameters* mode persists, check the **Scanner Sensor Status** display to determine if the sensor is enabled (see Figure 4–8). All operating modes for the Q4223-5x are listed in Table 10-4.

Table 10-4 Operating Modes

Item	Description
0	waiting for parameters
1	Idle

Item	Description
2	Reference
3	Standardization
4	Sample
5	Scan
6	Single Point

When the sensor has received its configuration data, and is operating in another mode, the **Dynamic States** tab display will contain more data (see Figure 10-8).

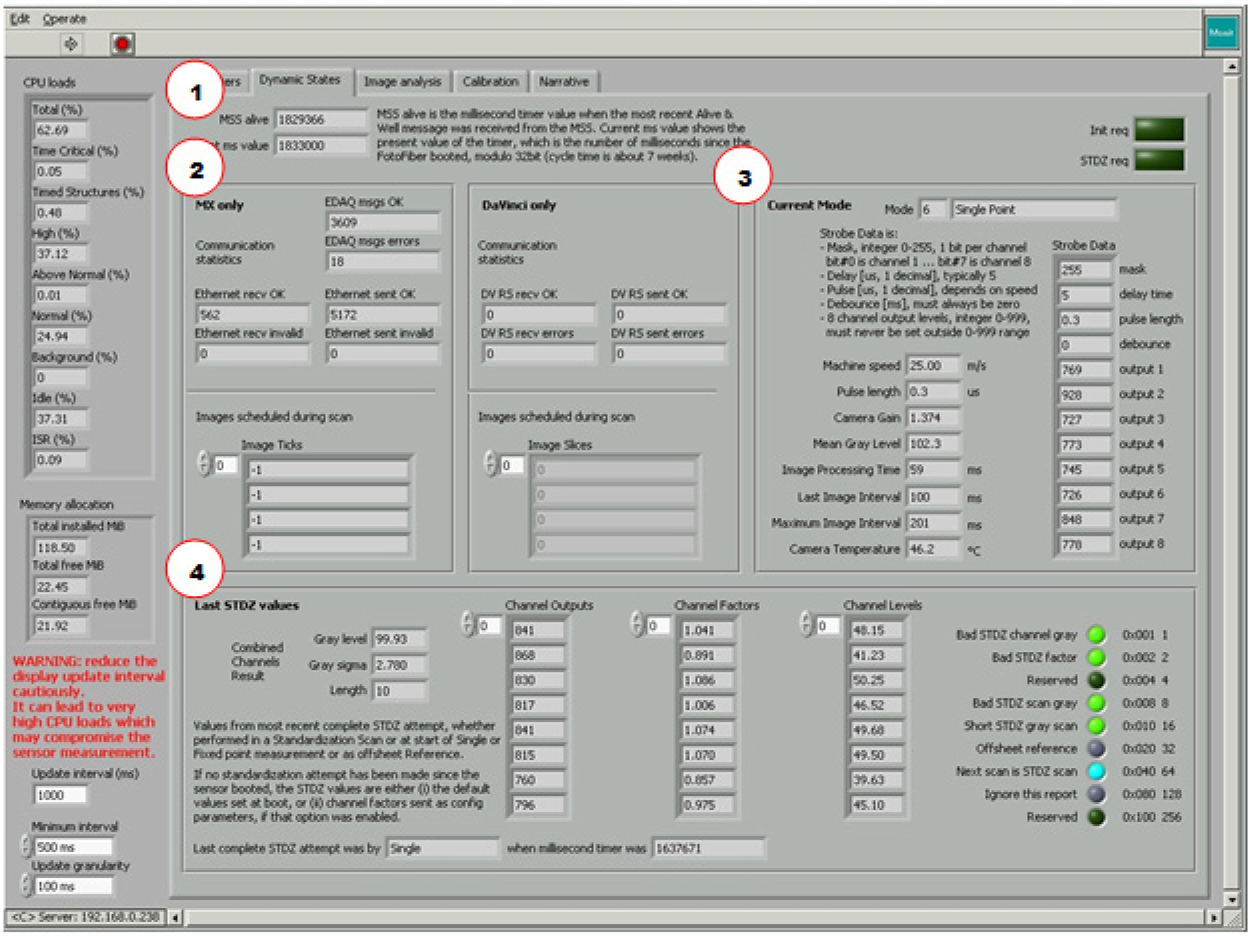


Figure 10-8 Dynamic States Tab Display: Single Point Mode

Table 10-5 lists and describes the items shown in Figure 10-8.

Table 10-5 Dynamic States Tab Display: Items

Item	Description
1	Timer values
2	Communication counters

Item	Description
3	Current low-level measurements and outputs
4	Last standardization results

Timer values

The timer values are the number of milliseconds since the sensor finished booting. The upper value is the timestamp of the most recent *Alive and Well* message from the MSS, while the lower value is the current timestamp.

These timer values are produced by the internal clock in the FotoFiber processor module, and are not corrected by external time synchronization messages. The internal clock may exhibit drift of up to ± 1 second per day. Note that these are unsigned 32-bit integer values, and will thus wrap around through zero approximately every seven weeks of continuous operation (in principle, every 49 days, 17 hours, 2 minutes, 47.296 seconds).

Communication counters

The communication counters are in two groups, one for use with Experion MX scanners, and the other for use with Da Vinci scanners.

With Experion MX scanners, the communication with the MSS is by Ethernet, after the sensor receives its IP address by RS422 from the EDAQ. The upper pair of counters indicate the number of EDAQ messages received, and the number of error messages. The lower four counters indicate the number of successful and unsuccessful messages received from, and sent to, the MSS.

With Da Vinci scanners, the communication with the MSS is by RS422. The counters show the successful and unsuccessful messages received from, and sent to, the MSS.

Current low-level measurements and outputs

The group on the right contains the current strobe parameters. The pulse length, and the eight channel outputs, might change for each scan, or for each single point or batch of samples. During a standardization scan, or a reference, the mask will change several times. At other times, the mask should always be 255.

The group on the left shows values for a number of inputs or computed values, such as the computed pulse length. The bottom value, for camera sensor temperature, should not exceed 55 °C (131 °F) for reliable operation of the sensor. If the camera temperature is higher, the cooling in the sensor head may be inadequate. The image interval is normally approximately 100 ms, but the first interval in single-point may be twice as long. The image processing time is preferably below 60 ms. If it is higher, it might be necessary to check and modify some of the image analysis parameters listed Subsection 6.3.4.3 (contact QCS-TAC for assistance if nonstandard values are to be used).

Last standardization results

The results of the most recent standardization are shown in a block across the bottom of the display. At the bottom of this area is an indication of when that standardization took place. On the left is a summary of the combined channel results of a standardization scan or reference, or the result of graylevel adjustment for single point.

In the middle of the area are three columns listing the channel outputs used in the last standardization, the channel efficiency factors, and the graylevels obtained using single illumination channels.

On the right is a group of statuses for the standardization result. Error flags are indicated in green or red, warning flags in green or yellow, and notification flags in gray or blue. Spare flags are dark green.

The status bits shown in Figure 10-8 are for a successful standardization in single point mode. The notification that the next scan will be a standardization scan is because scanning standardization is enabled (normal).

A successful standardization during scanning would result in a display as shown in Figure 10-9. Note that the next scan is not flagged as a standardization scan, because the standardization succeeded.

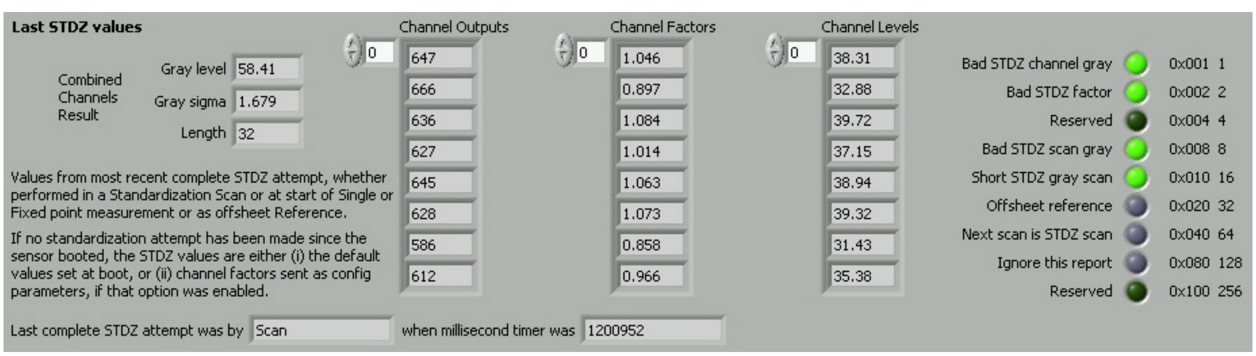


Figure 10-9 Successful Standardization in Scan Mode

Other groups of status bits are shown in Figure 10-10 for different types of standardization outcome.

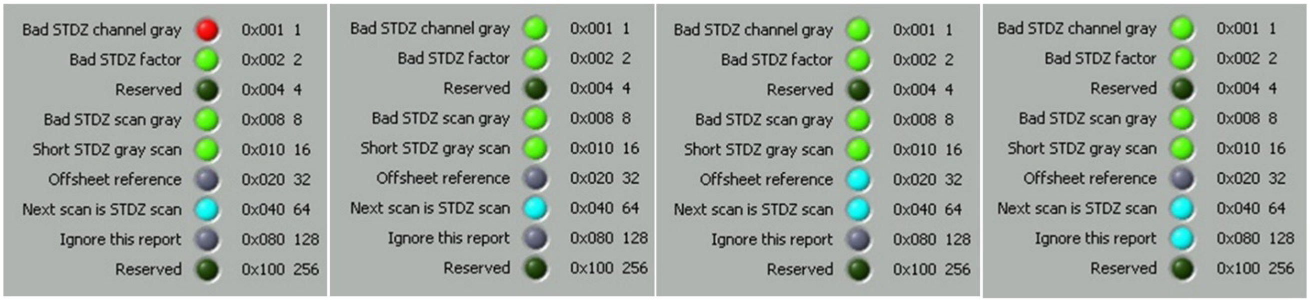


Figure 10-10 Standardization Flags for Various Outcomes

On the left is a typical failure; standardization will be repeated on the next scan. The inner left is for a successful standardization in single point, while the inner right is for a successful standardization in reference mode. Note that in these two cases, the next scan can be set to be a standardization scan, even though the standardization was successful. On the right is the set of flags sent in the standardization report; no actual standardization is performed, so the *ignore this report* flag is on. The rest of the report contains the flags and results obtained from the previous standardization. Note that in all cases, scanning standardization is enabled so the next scan is flagged as a standardization scan.

10.2.1.5. Diagnostic narrative

Optionally, the sensor will record a narrative of significant messages from various internal processes, as shown in Figure 10-11. This is enabled by bit 3 of parameter 53 in the **FotoFiber Engineering** display, which is normally on for FotoFiber sensors in Experion MX systems (this bit is on for all displays in this section).

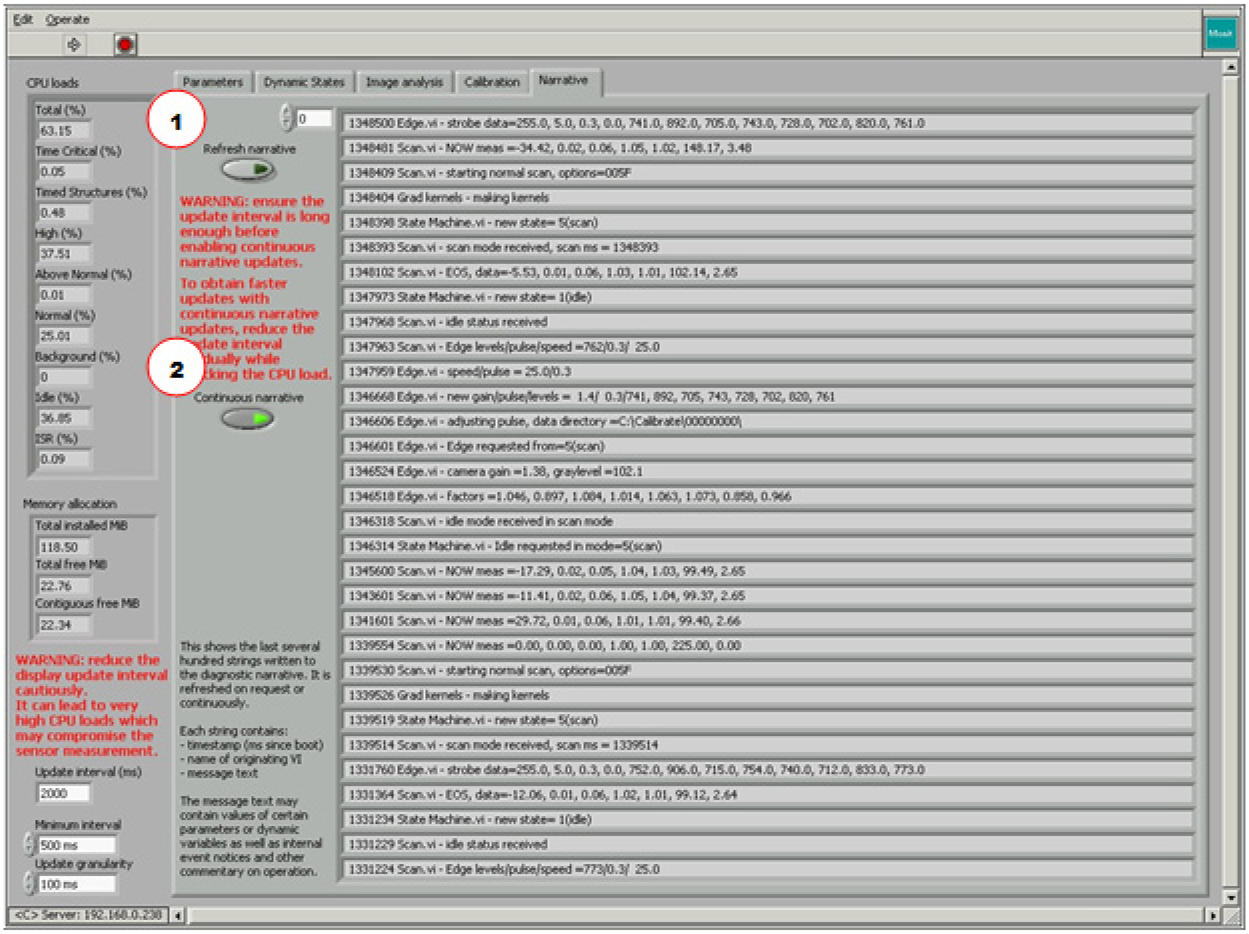


Figure 10-11 Narrative Tab Display

Table 10-5 lists and describes the items shown in Figure 10-8.

Table 10-6 Narrative Tab Display Items

Item	Description
1	**Refresh narrative** button
2	**Continuous narrative** button

Each message is:

- number of milliseconds since sensor booted

- originating process (name of VI file)
- message contents, including event notices and/or numerical values

Note that the number of milliseconds since the sensor booted uses the internal clock in the FotoFiber processor module, which is not corrected by external time synchronization messages, and the internal clock may exhibit drift of up to ± 1 second per day. It is an unsigned 32-bit integer value which wraps around roughly every seven weeks of continuous operation (in principle, every 49 days, 17 hours, 2 minutes, 47.296 seconds).

There are up to 1024 messages in the buffer, with the most recent shown at the top. The buffer can be scrolled to view older messages using the list box (item 1 in Figure 10-11). There is also a button (just below the list box) which updates the snapshot of these message strings when clicked. At item 2 in Figure 10-11, there is a button which switches the update between snapshot and continuous modes (green = continuous). Scrolling through the messages is more convenient when continuous updating of the narrative is off.

Sensor initialization and parameters

The first four narrative strings are generated during sensor initialization, as shown in Figure 10-12. Note that these messages are unconditionally recorded, as they are generated before the sensor parameters are received. Even if recording diagnostic messages is disabled, these four messages will exist.

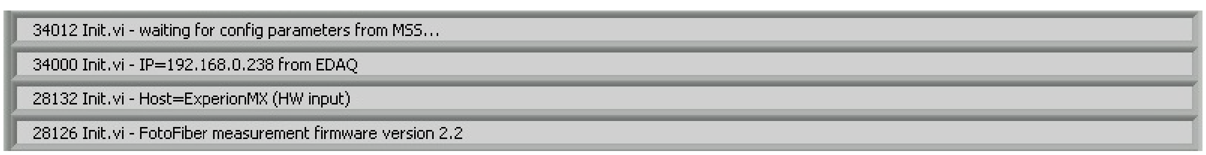


Figure 10-12 Diagnostic Narrative: Sensor Initialization

In particular, the firmware version, host type, and IP address should match those on the parameters tab after the parameters are received. If the host is not recognized as Experion MX, the IP address will be 169.254.100.102.

The subsequent messages (see Figure 10-13) record the receipt of parameters from the MSS, and the initialization of sensor hardware.

```
46220 Edge.vi - strobe data=255.0, 5.0, 0.5, 0.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0
45248 Init.vi - initialization complete
45230 Init.vi - received factors=1.030 0.886 1.046 1.024 1.054 1.097 0.836 1.027, no limitation needed
44475 Init.vi - initializing FPGA, Hz=10.00
43113 Init.vi - initializing images, camera model =Stingray F080B
42150 Parameters.vi - Config parameters received and distributed
42144 Parameters.vi - factors=1.030 1.046 0.886 1.024 1.054 1.097 0.836 1.027
42140 Parameters.vi - analysis annulus inner=0, outer=190
42135 Parameters.vi - EOS delay=1500, gray target=100.0, zero angle=0.000000
42129 Parameters.vi - option mask=004F, JPEG q=850, strobe Hz=10.00, strobe delay=   0
42111 Init.vi - initializing PP880, level=500, pulse=0.5
```

Figure 10-13 Diagnostic Narrative: Sensor Parameters

Sensor at offsheet standardization

When other sensors standardize offsheet, the Q4223-5x reinitializes the FPGA, optionally changing the measurement rate to the value of parameter 5 (if enabled by bit 6 of parameter 53), and optionally prepares for a standardization scan (if enabled by bit 0 of parameter 53). It also optionally creates a new random image mask for subsequent image analysis (if enabled by bit 1 of parameter 53). It sends the most recent standardization results to the MSS, with the *Ignore this report* flag set. Typical narrative messages are shown in Figure 10-14.

```
2474790 Standardization.vi - ignore old/default STDZ data sent, flags =C0
2474270 Edge.vi - strobe data=255.0, 5.0, 0.3, 0.0, 784.0, 945.0, 746.0, 796.0, 769.0, 771.0, 887.0, 818.0
2473737 State Machine.vi - new state= 1(idle)
2473732 Scan.vi - Edge levels/pulse/speed =814/0.3/  25.0
2473641 Edge.vi - recreating image mask
2473632 Edge.vi - speed/pulse = 25.0/0.3
2472350 Edge.vi - new gain/pulse/levels =  1.3/  0.3/784, 945, 746, 796, 769, 771, 887, 818
2472288 Edge.vi - adjusting pulse, data directory =C:\Calibrate\00000000\
2472284 Standardization.vi - re-initializing FPGA, Hz=10.00
2472278 Edge.vi - Edge requested from=3(standardization)
2471882 Scan.vi - STDZ request received
2471878 Standardization.vi - STDZ scan requested
2471504 State Machine.vi - new state= 3(standardization)
```

Figure 10-14 Diagnostic Narrative: Offsheet Standardization

Sensor in reference and sample modes

With the scanner in maintenance mode, a sample operation results in narrative messages such as those shown in Figure 10-15.

```
3114729 State Machine.vi - new state= 1(idle)
3114670 Sample.vi - measurement ended
3114544 Sample.vi - idle mode received in sample mode
3114539 State Machine.vi - Idle requested in mode=4(sample)
3113862 Sample.vi - NOW meas =-8.28, 0.04, 0.07, 1.08, 1.07, 101.99, 2.29
3111862 Sample.vi - NOW meas =-82.83, 0.01, 0.07, 1.02, 0.98, 102.01, 2.28
3109894 Sample.vi - starting measurement
3109889 Grad kernels - making kernels
3109884 State Machine.vi - new state= 4(sample)
3109879 Sample.vi - sample mode received, ms = 3109879
```

Figure 10-15 Diagnostic Narrative: Sample Mode

Similarly, a reference operation results in narrative messages such as those shown in Figure 10-16.

```
2991375 State Machine.vi - new state= 1(idle)
2991322 Reference.vi - STDZ sequence ended
2990700 Reference.vi - idle mode received in reference mode
2990695 State Machine.vi - Idle requested in mode=2(reference)
2990572 Reference.vi - adjusted gain/levels=  1.0/509, 626, 473, 512, 486, 485, 570, 525
2990483 Reference.vi - STDZ ref, STDZ data sent, flags =60
2989918 Reference.vi - STDZ ref, factors =1.051, 0.870, 1.104, 1.008, 1.089, 1.065, 0.848, 0.963
2989912 Reference.vi - STDZ ref, gray levels =63.68, 52.71, 66.87, 61.06, 65.95, 64.52, 51.34, 58.33
2989748 Reference.vi - STDZ, channel =7
2989248 Reference.vi - STDZ, channel =3
2988748 Reference.vi - STDZ, channel =6
2988248 Reference.vi - STDZ, channel =2
2987749 Reference.vi - STDZ, channel =5
2987249 Reference.vi - STDZ, channel =1
2986749 Reference.vi - STDZ, channel =4
2986249 Reference.vi - STDZ, channel =0
2985753 Reference.vi - STDZ, channel gain=4.000
2984730 Reference.vi - STDZ, pulse/levels =0.6 / 537, 547, 524, 519, 532, 519, 485, 508
2984710 Reference.vi - starting STDZ, data directory =C:\Calibrate\00000000\
2984556 Reference.vi - channel mean=521.4, gray level=100.5
2980758 Reference.vi - gray adjustment, pass=1
2976988 Reference.vi - gray adjustment, pass=0
2975638 Reference.vi - starting, gain=1.0, pulse length=0.6
2975622 State Machine.vi - new state= 2(reference)
2975617 Reference.vi - reference mode received, ms = 2975617
```

Figure 10-16 Diagnostic Narrative: Reference

Sensor in scanning mode

In scanning mode, the sensor will conduct a scanning standardization on its first scan after being offsheet (if scanning standardization is enabled by bit 0 of parameter 53), with a narrative such as is shown in Figure 10-17.

```
1419644 Scan.vi - STDZ scan, STDZ data sent, flags =00
1419219 Scan.vi - STDZ scan, combined gray =2293.229, from  32 measurements
1419088 Scan.vi - idle mode received in scan mode
1419084 State Machine.vi - Idle requested in mode=5(scan)
1415916 Scan.vi - starting gray level measurement
1415912 Scan.vi - STDZ scan, gain=1 for gray scan
1415392 Scan.vi - STDZ scan, factors =1.045, 0.894, 1.088, 1.009, 1.068, 1.069, 0.856, 0.971
1415385 Scan.vi - STDZ scan, gray levels =46.05, 39.40, 47.95, 44.45, 47.04, 47.10, 37.71, 42.78
1415220 Scan.vi - STDZ scan, channel =7, mask =255
1414720 Scan.vi - STDZ scan, channel =3, mask =128
1414220 Scan.vi - STDZ scan, channel =6, mask =  8
1413720 Scan.vi - STDZ scan, channel =2, mask = 64
1413220 Scan.vi - STDZ scan, channel =5, mask =  4
1412720 Scan.vi - STDZ scan, channel =1, mask = 32
1412220 Scan.vi - STDZ scan, channel =4, mask =  2
1411720 Scan.vi - STDZ scan, channel =0, mask = 16
1411225 Scan.vi - STDZ scan, gain=4 for channels
1410181 Scan.vi - STDZ scan, pulse/levels =0.3 / 795, 822, 784, 772, 795, 772, 721, 753
1410162 Scan.vi - starting STDZ scan, data directory =C:\Calibrate\00000000\
1409589 State Machine.vi - new state= 5(scan)
1409585 Scan.vi - scan mode received, scan ms = 1409585
```

Figure 10-17 Diagnostic Narrative: Scanning Standardization

After a successful standardization scan, or if scanning standardization is disabled, the sensor will conduct repeated normal measurement scans, each with narrative such as is shown in Figure 10-18. Note that much of this narrative is actually for the operations performed between scans, when the strobe is adjusted based on data from the previous scan.

```
1348102 Scan.vi - EOS, data=-5.53, 0.01, 0.06, 1.03, 1.01, 102.14, 2.65
1347973 State Machine.vi - new state= 1(idle)
1347968 Scan.vi - idle status received
1347963 Scan.vi - Edge levels/pulse/speed =762/0.3/  25.0
1347959 Edge.vi - speed/pulse = 25.0/0.3
1346668 Edge.vi - new gain/pulse/levels =  1.4/  0.3/741, 892, 705, 743, 728, 702, 820, 761
1346606 Edge.vi - adjusting pulse, data directory =C:\Calibrate\00000000\
1346601 Edge.vi - Edge requested from=5(scan)
1346524 Edge.vi - camera gain =1.38, graylevel =102.1
1346518 Edge.vi - factors =1.046, 0.897, 1.084, 1.014, 1.063, 1.073, 0.858, 0.966
1346318 Scan.vi - idle mode received in scan mode
1346314 State Machine.vi - Idle requested in mode=5(scan)
1345600 Scan.vi - NOW meas =-17.29, 0.02, 0.05, 1.04, 1.03, 99.49, 2.65
1343601 Scan.vi - NOW meas =-11.41, 0.02, 0.06, 1.05, 1.04, 99.37, 2.65
1341601 Scan.vi - NOW meas =29.72, 0.01, 0.06, 1.01, 1.01, 99.40, 2.66
1339554 Scan.vi - NOW meas =0.00, 0.00, 0.00, 1.00, 1.00, 225.00, 0.00
1339530 Scan.vi - starting normal scan, options=005F
1339526 Grad kernels - making kernels
1339519 State Machine.vi - new state= 5(scan)
1339514 Scan.vi - scan mode received, scan ms = 1339514
```

Figure 10-18 Diagnostic Narrative: Scanning Measurement

Sensor in single point mode

In single point mode, the Q4223-5x starts by adjusting its output to achieve a desired level. A typical narrative is shown in Figure 10-19.

```
1632017 Single.vi - channel mean=819.5, gray level= 99.9
1631255 Single.vi - gray adjustment, pass=2, level reached= 99.9
1627456 Single.vi - gray adjustment, pass=1, level reached= 97.4
1623658 Single.vi - gray adjustment, pass=0, level reached= 51.2
1619297 Single.vi - starting, gain=1.0, pulse length=0.3
1619282 State Machine.vi - new state= 6(single)
1619277 Single.vi - single mode received, ms = 1619277
```

Figure 10-19 Diagnostic Narrative: Single Point Level Adjustment

After the level adjustment is complete, the sensor standardizes, with narrative messages such as those shown in Figure 10-20.

```
1638024 Single.vi - gain/levels=  1.4/769, 928, 727, 773, 745, 726, 848, 778
1637954 Single.vi - STDZ single, STDZ data sent, flags =40
1637378 Single.vi - STDZ single, factors =1.041, 0.891, 1.086, 1.006, 1.074, 1.070, 0.857, 0.975
1637372 Single.vi - STDZ single, gray levels =48.15, 41.23, 50.25, 46.52, 49.68, 49.50, 39.63, 45.10
1637208 Single.vi - STDZ, channel =7
1636708 Single.vi - STDZ, channel =3
1636208 Single.vi - STDZ, channel =6
1635708 Single.vi - STDZ, channel =2
1635208 Single.vi - STDZ, channel =5
1634709 Single.vi - STDZ, channel =1
1634209 Single.vi - STDZ, channel =4
1633709 Single.vi - STDZ, channel =0
1633213 Single.vi - STDZ, channel gain=4.000
1632191 Single.vi - STDZ, pulse/levels =0.3 / 841, 868, 830, 817, 841, 815, 760, 796
1632171 Single.vi - starting STDZ, data directory =C:\Calibrate\00000000\
```

Figure 10-20 Diagnostic Narrative: Single Point Standardization

After the standardization, measurement proceeds for as long as single point is active, with continuous narrative such as in Figure 10-21.

```
1660951 Single.vi - NOW meas =-46.66, 0.01, 0.06, 1.02, 1.00, 102.42, 2.78
1658952 Single.vi - NOW meas =-23.00, 0.01, 0.06, 1.01, 1.01, 102.37, 2.79
1656953 Single.vi - NOW meas =-40.55, 0.00, 0.06, 1.01, 1.00, 102.38, 2.79
1654953 Single.vi - NOW meas =-32.46, 0.02, 0.06, 1.04, 1.02, 102.35, 2.79
1652953 Single.vi - NOW meas =-20.49, 0.02, 0.05, 1.04, 1.03, 102.32, 2.79
1650954 Single.vi - NOW meas =-53.53, 0.03, 0.06, 1.05, 0.99, 102.29, 2.78
1648955 Single.vi - NOW meas =-8.95, 0.01, 0.07, 1.01, 1.01, 102.24, 2.78
1646955 Single.vi - NOW meas =53.69, 0.01, 0.06, 1.01, 1.00, 102.19, 2.79
1644956 Single.vi - NOW meas =49.24, 0.00, 0.06, 1.01, 1.00, 102.14, 2.77
1642956 Single.vi - NOW meas =-41.71, 0.02, 0.06, 1.05, 1.01, 102.10, 2.77
1640957 Single.vi - NOW meas =22.90, 0.01, 0.06, 1.02, 1.02, 102.03, 2.78
1638896 Handle & Send.vi - quality=850, size= 8731, retry=0
1638876 Single.vi - long AVG =-0.06, 0.00, 0.00, 0.00, 0.00, 0.34, 0.01
1638870 Single.vi - NOW meas =-19.31, 0.01, 0.06, 1.02, 1.02, 101.64, 2.78
1638859 Single.vi - sending NOW & image, index =5
```

Figure 10-21 Diagnostic Narrative: Single Point Measurement

10.2.2. Standardization issues

10.2.2.1. Persistent error/warning flags

Standardization error flags might occur in the first standardization after a machine start-up, or after a grade change in which the sensor was offsheet. The sensor will repeat the standardization attempt until successful. If an error flag persists in several consecutive standardizations, the standardization is failing and it is essential to determine the cause and fix the problem.

10.2.2.2. Short scan

This flag warns that the sensor may be vulnerable to a particular type of standardization failure. If the scan length at standardization (item 5 in Figure 6–15) is very short, the standardization result may not be reliable. Although this is a warning flag, it can occur in combination with standardization failure due to the scan time being too short for standardization to complete. If the scan length becomes zero, the last standardization step using all illuminator channels together cannot be completed, and standardization of one or more individual channels may also have been incomplete. If that happens, there are likely to be additional warning or error flags.

ATTENTION

> This warning may also occur if the initial values entered in Subsection 4.3.2.2 are no longer valid. This could occur, for example, if the scan speed has been increased, or if the scanner is set to scan a significantly narrower portion of the sheet than was expected when the initial values were computed. It may also happen if the job set for the FotoFiber has a significantly incorrect value for the sensor offset.

Referring to the standardization procedure in Section 5.4, it is clear that the standardization can be completed only if the scan time is long enough for each of the eight channels to be processed individually, and for at least five images to be taken with all eight channels used simultaneously.

The time taken for each channel is determined by the measurement rate, parameter 5 in the **FotoFiber Engineering** display (see Subsection 6.3.4), together with the number of flashes to use per channel, parameters 24 and 25.

There is also a delay of 200 ms in the light control link each time the illuminator state is changed, causing a total of 1.8 second delay. The minimum onsheet time needed for standardization to complete is:

$$T_{min} = \frac{8(\#24 + \#25) + 5}{\#5} + 1.8$$

Equation 10-1

With default values (measurement rate #5 = 10Hz, samples per gap #24 = 3, samples per channel #25 = 5), T_{min} is about nine seconds. The recommended onsheet measurement time should be at least two seconds longer than this.

If the machine is relatively narrow, and the scan speed is relatively high, it is possible that the scan time is less than 10 seconds. In this case, standardization may fail to complete. If the short scan flag is on, fewer than five images were obtained with all channels flashing simultaneously. If the scan length is zero, standardization failed.

Check that the measurement rate (parameter 5) is 10 Hz. If it is less than 10 Hz, contact QCS-TAC for guidance. If the measurement rate is 10 Hz, or it cannot be increased to 10 Hz (bit 6 of parameter 53 is usually on), then do one of the following:

- reduce the scan speed so that the scan time is at least 12 seconds, even with the narrowest sheet; this is the preferred approach, but may not always be feasible
- reduce the samples per gap, parameter 24
- reduce the samples per channel, parameter 25

Contact QCS-TAC for guidance if it is necessary to change parameter 24 to less than 2, or to change parameter 25 to less than 4 (their default values are 2 and 5 respectively). Provide QCS-TAC with a good estimate of the onsheet measurement time, which is typically two or more seconds less than the time between successive end-of-scan events.

If the machine is largely making similar grades all of the time, there is another alternative. This is to disable the scanning standardization and enable use of the channel factors sent as configuration parameters:

1. Perform a standardization on a representative grade, so that the standardization factors shown on the **FotoFiber Standardization** display (item 1 in Figure 6–15) are acceptable. This can be either:

   Using offsheet reference with the scanner in maintenance mode.

   In a single-point measurement during operation.

2. Save the standardization factors to the configuration data using the button on the **FotoFiber Engineering** display (item 10 in Figure 6–17). Check that the values of parameters 31–34 and 40–43 correspond to those in the **FotoFiber Standardization** display.

3. Change the sensor options bitfield, (parameter 53, so that bit 0 is off, and bit 2 is on. This will disable scanning standardization, and cause the sensor to use the factors which are supplied as parameters.

4. Send the factors to the FotoFiber sensor using the **SEND** button on the **FotoFiber Engineering** display (item 3 in Figure 6–17). This will also save the parameter values into the permanents database.

ATTENTION

> If scanning standardization is disabled, the sensor will operate with the factors it is given. It is important that the factors sent as parameters be approximately correct. Note that if Steps 1 and 2 are not performed in this procedure, all factors will default to unity.

ATTENTION

> If a reference is measured with the scanner in maintenance mode and scanning standardization disabled, the resulting factors will be used until the sensor receives new factors (by single-point or reference or configuration parameters).

If scanning standardization is disabled and a reference is measured that is not representative of current production, take one of the following actions:

- send the parameters to the sensor again using the **SEND** button on the **FotoFiber Engineering** display
- measure a reference using a sample representative of current production
- perform a single-point measurement on current production as soon as onsheet measurement is resumed

Scan gray values

Check the mean graylevel (item 5 in Figure 6–16).

If the mean graylevel is greater than 225:

- The illumination subsystem is probably malfunctioning. Contact QCS-TAC for further support in diagnosing the problem.

If the mean graylevel is less than 25:

1. Check the machine speed being sent to the FotoFiber (item 5 Figure 6–16). This should be in meters per second, and should not exceed 30. High machine speeds lead to short strobe pulse lengths. If the machine speed value appears to be incorrect, the cause of the incorrect value should be traced and corrected (see Subsection 6.2.3). Abnormally

large speed values may result from use of incorrect units such as feet per second or meters per minute.

2. Inspect the sensor window. There may be a heavy dirt accumulation which needs to be cleaned.

3. Check the lens aperture. In some cases this can be seen easily by looking through the sensor window towards the lens (see Figure 1–3). In other cases it will require removing the camera and lens from the sensor (see Section 9.2). The lens aperture ring should be set and locked at F/4. If there is some play range in the F/4 setting, the ring should be locked at the more open end of the range, so that it appears approximately as shown in Figure 10-22; the aperture is nominally just under 9 mm (0.35 in.).

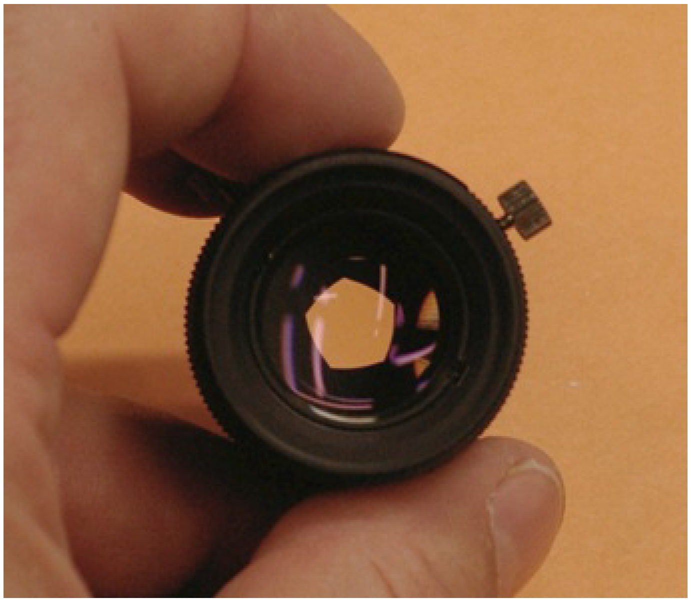


Figure 10-22 Lens Aperture, Set to F/4 (the locking screw is visible at the side)

4. Check the shade being produced. If it is a very dark shade and the machine speed is high, the sensor may be out of its operating range. This is not a problem with the sensor, and normal function will resume when the shade is less dark or the machine speed is reduced. If operation with dark shades at high machine speeds is absolutely essential, the maximum camera gain can be adjusted (configuration parameter 30 in the **FotoFiber Engineering** display). However, this should be attempted only with QCS-TAC guidance and approval.

5. If the shade is not particularly dark, the machine speed value is realistic, and the window is reasonably clean, then the illumination

system is probably malfunctioning. Contact QCS-TAC for further support in diagnosing the problem.

Channel gray values

If the scan gray values error flag is set, the channel gray values error flag is also likely to be set. If both flags are set, follow the steps in Subsection Scan gray values. The steps given here assume that the scan gray values error flag is not set.

Check the limits for the minimum and maximum gray per channel (configuration parameters 27 and 28 in the **FotoFiber Engineering** display). The minimum limit is normally 25, and the maximum limit is normally 225. If the actual limits are significantly different, then contact QCS-TAC for further support. The limits may have been inadvertently mis-configured in earlier maintenance, or may have been set to nonstandard values to overcome a site-specific issue.

If the minimum and maximum limits are normal, check the individual channel graylevels (item 3 in Figure 6–15). If the channel gray values flag is set, one of the channels will have a graylevel value greatly different from the others.

If the graylevel for one channel is greater than the maximum level, and the others are not, the illumination subsystem is malfunctioning (the strobe control PCB may need to be replaced). Contact QCS-TAC for further support in diagnosing the problem.

If the graylevel for one channel is less than the minimum level, and the others are not, the channel with the low graylevel has failed. Remove the sensor from the head for further diagnosis. The failure mode is probably one of the following:

- Loose cable from strobe controller to LED driver PCB. Check that all cables from the strobe controller to the LED driver PCBs are properly seated in their sockets.

- Failed cable from strobe controller to LED driver PCB. Test continuity of conductors in the suspect cable; replace the cable if necessary.

- Broken solder for one of the conductors joining LED panel PCB to LED driver PCB. Inspect all soldered connections on the light source assembly, and repair solder points if necessary (see Subsection 9.6.5).

- Failed LED panel PCB. Typically, some of the emitters will work and some will not during test operation. A few may appear abnormally bright. Replace LED panel PCB if necessary (see Subsection 9.6.5).

- Damaged LED driver PCB. This can occur if the sensor has been handled improperly. One of the two large capacitors on the LED driver

PCB may be dislodged and thus electrically disconnected. In this case, the channel will work, but with drastically reduced light output. Alternatively, the connector for the cable on the LED driver PCB may be dislodged making it electrically disconnected. In this case, the channel will probably not work and will not flash. In either case, replace the LED driver PCB if necessary (see Subsection 9.6.5).

- Failed LED driver PCB. If the MOSFET on the LED driver fails, it produces DC current at 15 mA instead of sub-µs pulses of 100 A or more. In this case, some or all of the emitters on the connected LED panel will be continuously on, but not very bright. Replace the LED driver PCB if necessary (see Subsection 9.6.5).

10.2.2.3. Diverging channels

The eight illumination channel output levels are adjusted during operation to produce uniform illumination intensity. The levels are adjusted using their calibration curves and the channel factors from standardization. These values will normally differ between channels, but not by a large amount. The sensor can operate quite satisfactorily even with fairly large channel to channel differences in levels or factors.

However, large or steadily increasing differences between channels may indicate an approaching problem with the sensor, and should be investigated before sensor performance is affected.

Channel output levels

In general, the output levels will differ between channels due to differences in components and so on. However, the differences between individual channel levels should normally be only a fraction of their average level.

If the difference between the highest channel output level and the lowest channel output level (item 1 in Figure 6–16) exceeds 50% of the average channel output level:

- For an upper sensor, check the recessed window for local dirt obscuring one or more LED panels, and clean if necessary (see Subsection 9.1.2.2).

- Visually inspect the LED panels (look through the sensor window) to see if the mini-lenses have been detached from any LED emitters. If some have fallen off, the mini-lenses should be recovered from inside the sensor and reattached to the emitters using Super Glue (see Subsection 9.6.7).

- Check the 49 V trimmed output from the power and isolation PCB to the strobe control PCB, and adjust if necessary (see Subsection 9.6.1.2). If the voltage is lower than 49 V, the strobe channels will become saturated at less than their maximum setting. If it is significantly less than 49 V it may cause inadequate illumination whenever some of the channels are operating near their maximum (parameter 14 in Figure 6–17, default value 950). Note that for regulatory reasons, this should not be set to above 49.5 V.

Channel factors

In general, the channel factors will differ between channels, due to differences in spectrum and aging effects on components. However, all of the factors should be close to unity.

If any factor exceeds 1.6, or is less than 0.6, the standardization must be considered unreliable. If the channel factors are diverging, it is better to intervene before they reach those levels.

If the largest factor exceeds 1.4, or the smallest is lower than 0.7:

- Is an unusual strongly-colored grade being produced? Due to spectral variation among LEDs, factors may diverge during production of some very strongly colored shades (where the reflectance spectrum has large transitions over narrow spectral ranges). The factors will revert to normal ranges when the extreme shade is not being produced. Shades which can cause this are very uncommon, but it is not a problem if the factors revert to within the 0.7 to 1.4 range when production returns to normal shades.

- If channel output levels are also diverging, perform the same checks as in Subsection Channel output levels.

- If the FotoFiber has been in service for more than a year since its last calibration, recommend to the mill that a channel recalibration be scheduled for an upcoming shutdown.

10.2.3. Unexpected measurement results

If the orientation angle or anisotropy values appear to be incorrect, or if their profiles have unusual shapes, the problem may be due to diverging channels, as described in Subsection 10.2.2.3. However, there might be other causes.

10.2.3.1. Abnormal anisotropy values

Is the anisotropy value real? Always view the computed jet-to-wire ratios and rush-drag differences with some skepticism. The surface anisotropy can be affected by the stock mix and the impingement angle, as well as the rush-drag. Inquire from the operators if the slice opening or the slice apron position have been changed.

To verify that the anisotropy is responding to the process, ask the operators to briefly change the headbox pressure to see if the measured anisotropy changes.

To address problems with anisotropy measurement, check the image on the **FotoFiber Display** (Figure 6–9). If there is dirt on the image it will affect the anisotropy. In general, streaky marks will cause elevated anisotropy values, while smears or smooth dirt build-up will cause lowered anisotropy values.

Inspect the sensor window, and clean it if necessary. Dirt accumulation on the window is the primary cause of anisotropy errors. A uniform layer of dust on the window causes reduced anisotropy measurement values without affecting angle measurement. Streaks of dirt often cause increased anisotropy and bias the measured angles. If this problem occurs regularly, the airflow to the sensor should be checked, and the sensor cleaning schedule might need to be adjusted. If the dirt build-up is consistent and rapid, even with a high flow of cleaning air, the environment may not be suitable for a FotoFiber.

If the sensor window is clean, but the image is particularly blurred, it is advisable to check the sensor focus at the next opportunity.

10.2.3.2. Offset in profile average angle

Note that the average angle in raw scans will usually differ between forward and backward traverses. This is because the sheet path through the sensor gap is not tangential to the sheet stabilizing rings, so it gets deflected slightly in passing through the FotoFiber Measurement gap. This deflection depends on the speed and direction of scanner movement, as well as on the tension in the sheet.

ATTENTION

Variability in the profile average should always be judged from the scan average of the *trued* scan, which is an average of sequential forward and backward traverses. This eliminates the forward versus backward shift in the angle profile, which depends on scan speed as well as sheet tension. It is not uncommon for the angle profile average to differ by several degrees between forward and backward scan directions, while the angle profile shape is essentially the same.

If the offset is relatively small (one to two degrees) and does not change much, it may be due to misalignment of the sensor. The alignment may change whenever the camera or camera mounting apparatus is repaired or replaced, or the sensor is dismantled and reassembled (see Subsection 4.3.2.5 and Subsection 9.4.2).

If the offset is large (five degrees or more) and changes only very slowly, sensor alignment alone does not explain it. In some cases, there may be a systematic error in the laboratory measurement procedure which is used for setting the slice lip. For example, the cross direction strip might be taken at a slight angle to true cross direction, or be fed into the TSO analyzer at a slight angle (perhaps manifested as a shift-to-shift variation), or the TSO analyzer may be misaligned or mis-calibrated. In other cases, it may be caused in part by a misalignment of the whole jet (grade-to-grade variation) due to errors in slice positioning. See Subsection 2.6.1 for a description of possible process adjustments.

If the offset is variable in magnitude, and varies over short periods, it may be due to inadequate tension in the sheet. If the sheet is not flat in the measurement gap, FotoFiber cannot measure the fiber orientation accurately. In this case, the FO angle profile will usually also exhibit a lot of short term variation in shape. Note that when tension fluctuations start to occur, they are often followed by sheet breaks.

10.2.3.3. Jumps in whole profile

In a two-sided installation, if the coordination between the upper and lower sensors is incorrect, the entire profile (fiber angle and/or anisotropy) from one or both sensors will be intermittently anomalous. When this happens, approximately one scan in every 20–100 will seem to jump in amplitude and level across the entire sheet, but revert to normal in the next scan.

This type of anomaly occurs when both sensors flash during the camera exposure of one sensor, causing flash-through which biases the information content in the image and causes an elevated graylevel. Because the gauges maintain very precise timing internally, if flash-through occurs for one measurement in a scan, it will occur through the entire scan.

Check the strobe delay from initial tic parameter (parameter 51 in the **FotoFiber Engineering** display) for each sensor. In one sensor, this parameter should be zero. In the other sensor, it should be approximately 32000 seconds. In Da Vinci systems, there is jitter of up to 15 ms in the messages from the MSS to the sensors (synchronization of messages to sensors is typically ± 0 ms, ± 5 ms, ± 10 ms, or ± 15 ms), so there must be a large enough timing offset added in one sensor to prevent flash-through. If the parameter is already at 32000 seconds, switch the delay between the sensors–change parameter 51 from 0 to 32000 for one sensor, and from 32000 to 0 for the other. In Experion MX systems, the jitter is more variable but over a narrower range.

10.2.3.4. No image updates

If the image is not being updated on the **FotoFiber Display**, determine whether or not the image position is valid. If it is not within the measured part of the sheet, no image will be sent by FotoFiber. It is recommended that image positions should not be defined close to the edges of the sheet. Intermittent communication problems can arise due to collision of the image data messages with end-of-scan handshaking messages.

10.2.4. Miscellaneous issues

10.2.4.1. Sensor fails to operate

There are several potential causes for a sensor being inoperative.

Improper DIP switch setting

This can occur if the **USER1** switch is inadvertently left in the ON position, or if the **NO APP** or **SAFE MODE** switches are in the ON position. Check the DIP switches and correct if necessary. The sensor should be rebooted if the DIP switches are changed. If the **USER1** switch is changed, the sensor must boot twice.

If the **NO IP** switch was in the ON position, it may be necessary (after switching **NO IP** to the *off* position) to reset the sensor three or four times, changing the **USER1** switch position between each reset (allowing the sensor to boot twice between each change of the USER1 switch). This may take more than 10 minutes in total.

Bad power connection or fuse blown

If the sensor appears to have no power, check that its power connector is properly seated (see Figure 4–4), and its power switch is in the ON position. Correct if necessary.

CAUTION

Switch the sensor power switch to the **OFF** position before attempting to reseat the power connector.

If the power is properly connected, and the switch is **ON**, check if there is 24 V on the spare output from the utility PCB (see Subsection 9.6.1.1). If the voltage is zero, the fuse shown in Figure 7–4 is probably blown. Replace it using the procedure in Subsection 9.6.2.

Wrong or bad trigger to camera

The Stingray camera can accept triggering at TTL (5 V) or isolated (24 V) levels. The processor module always produces a TTL trigger, and this is converted on the utility PCB. A jumper at J1 on the utility PCB selects between the two levels, as shown in Figure 7–5.

If this jumper is missing or is not seated correctly, the camera may or may not receive a trigger signal. The sensor will boot correctly in measurement mode or in maintenance mode, but will not acquire images. The first image acquisition will time out, after which it will acquire blank images. Standardization and numerous other operations will also fail.

Inspect the jumper and reseat it if needed using the procedure in Subsection 9.6.3.

10.2.4.2. Incorrect strobe pulse length

The strobe pulse duration is shown in item 3 of the **FotoFiber Edge** display (see Figure 6–16). It is computed based on the machine speed, magnification, and the allowed degree of blurring (parameter 21 in Subsection 6.3.4.2).

If the pulse is too long, the image will be blurred in the machine direction. The angles will be reduced in amplitude, and the anisotropy values will be increased. This will often be evident by inspecting the image.

If the pulse is too short, the camera gain will be elevated and the graylevel of the images may be lower than the target graylevel (both being visible on the **FotoFiber Edge** display).

Typically, an error will cause the pulse length to be forced to its maximum or minimum limit. There are at least two possible causes for pulses which are too long or too short:

- Blur limit (parameter 21 in Subsection 6.3.4.2) set higher than 0.5 or lower than 0.2. Its default value of 0.3 is probably acceptable in all cases.
- Incorrect speed supplied, or speed supplied in incorrect units. The machine speed (item 5 in Figure 6–16) should be in meters per second.

An incorrect value can cause inappropriate pulse lengths. Check the conversion factors and data sources set up in Subsection 6.2.3.

10.2.4.3. Intermittent communication failure

Intermittent communication failure can be caused by defining an image position close to either edge of the sheet, and/or by defining too many image positions with a short scan. If an image message is still being sent when the end-of-scan handshaking occurs (delayed from end-of-scan by the value of parameter 54), the messages may interfere.

Check that the number of images being sent per scan is not excessive (not more than one per 5 seconds of onsheet measurement time), and that no image position is defined too close to a sheet edge or too close to another image position. Even though the Ethernet communication can handle high data transfer rates, the Q4223-5x sensor itself is limited in its ability to process images for sending.

10.2.4.4. FotoFiber issues in and after single-point

Two related issues may be noticed after FotoFiber has been used in single-point or fixed-point measurement, as a result of a problem with the MSS Job Set for FotoFiber prior to 2012. They are largely cosmetic, but can affect data reliability (at the end of a fixed-point measurement or at a transition between fixed-point positions) and analysis of fixed-point measurements:

- If the FotoFiber is measuring in single-point or fixed-point mode, and is sent offsheet (by the endbell pushbutton, operator display, or automatically due to sheetbreak), the sensor remains in measurement mode until a new measurement mode is commenced, for example, scan, single-point, or sample. The FotoFiber keeps flashing its LEDs and sending measurement data, both while moving to the offsheet position and after the offsheet position is reached. This can cause the datalogger to include spurious data in a fixed-point collection.

- If the FotoFiber is measuring in single-point or fixed-point mode, and the measurement position is changed, the sensor remains in measurement mode while moving to the new position. The sensor also does not restandardize when the new position is reached. This can cause the data in the second position to be less reliable, and can cause the datalogger to briefly include spurious data in a fixed-point collection, and can cause fixed-point spectral analysis to give briefly incorrect results. It may also be difficult to separate two or more sequential single-point or fixed-point data collections directly from the datalogger data.

The recommended fix for these issues is to ensure the Job Set for FotoFiber in the MSS is the most current version. This will request the measurement to cease immediately when the scanner moves from a single-point or fixed-point position, and will request standardization when each new position for single-point or fixed-point measurement is reached.

10.2.4.5. Scanner halts at end-of-scan

This may occur at the end of the first measurement scan after standardization, or at the end of the first traverse after resetting the FotoFiber.

Scanner halts after standardization

The FotoFiber must perform a number of calculations and make adjustments to its strobe control parameters at the end of every scan. A delay value is defined to allow these calculations and adjustments to be made (parameter 54 in Subsection 6.3.4.2). If the delay is inadequate, the FotoFiber will not be ready for the next start of scan, and will not be able to perform the correct handshaking with the MSS at the end of that scan.

If this occurs, it is necessary to increase the EOS delay (default 1500 ms, which should be adequate in all cases). To restore movement to the scanner, disable the FotoFiber in the Experion MX. To restore function to the FotoFiber, take the scanner offsheet, and reset the FotoFiber either by cycling its power switch or by pressing the soft-reset button. Allow enough time (typically 45–55 seconds) for the FotoFiber to reboot fully before starting a scan. If the reset is performed by cycling the power switch, ensure that the powered-off state lasts at least 10 seconds.

Scanner halts after FotoFiber reset

When the FotoFiber is reset, it requires 45–55 seconds to boot and initialize communications with the MSS, and receive its parameters from the QCS server. If the **USER1** DIP switch has changed position since the previous reset, the FotoFiber will reboot twice (with a change of active firmware), requiring almost two minutes. If the scanner commences scanning or fixed-point measurement before the FotoFiber is fully ready, it will not be able to perform the correct handshaking with the MSS.

If this happens, but communication exists between the FotoFiber and the MSS, the FotoFiber can be rebooted using the button on the **FotoFiber Engineering** display. This must be done while offsheet.

If this occurs and there is no communication with the MSS (sensor cannot be enabled on the **Scanner Sensor Status** display, Figure 4–8), take the scanner offsheet and reset the FotoFiber by cycling its power switch or by pressing the soft-reset button. If the reset is performed by cycling the power switch, ensure that the powered-off state lasts at least 10 seconds.

After rebooting the FotoFiber by either method, it is essential to allow sufficient time for the FotoFiber to complete its boot-up (1–2 minutes, depending on whether or not the **USER1** DIP switch has changed position) before starting any measurement mode.

10.2.5. Function testing

Function testing procedures can be used to test the illuminators and the camera of the FotoFiber, and to test the measurement capability in maintenance mode. Some function monitoring can be performed by using a VGA monitor. Function testing requires a PC or laptop with an Ethernet connector and FotoFiber diagnostic software (see Appendix D). The procedures can be carried out with the sensor in the head, or on a bench, and the setup for function testing is the same as for focusing (see Section 9.3).

10.2.5.1. VGA output

The FotoFiber VGA port of the processor module is used to display firmware-related messages on boot-up. In measurement mode, for example, with the **USER1** switch in the *off* position, the FotoFiber also produces a diagnostic narrative from active operations on the port. To assist in troubleshooting, QCS-TAC may request that the VGA output be monitored. With the sensors offsheet, and the covers removed from the head, it is possible to connect a VGA monitor to the VGA port. The monitor must be externally powered.

CAUTION

It is essential to prevent scanning while a VGA monitor is connected to the FotoFiber. Scanning while a VGA monitor is connected will lead to a sheetbreak, possibly accompanied by damage to the paper machine, scanner, sensor, or VGA monitor. Use hardware interlocks, and ensure that it is not possible for scanning to be remotely started.

The output to the VGA monitor will show boot-up messages that can be useful in assisted troubleshooting guided by QCS-TAC or the sensor developers. Issues which can be detected in this way include:

- processor module failure
- corrupt firmware, executable files, or configuration files

- communication failure with MSS
- inconsistent configuration data sent by MSS

On every boot, the MAC address of the Ethernet adapter is shown, together with its assigned IP address. In maintenance mode (**USER1** DIP switch in the ON position), there is no diagnostic narrative after booting.

Boot after USER1 switch changed

On booting after the **USER1** DIP switch has changed position, the FotoFiber must set different firmware to active, then boot again. The second boot will use firmware corresponding to the new position of the **USER1** DIP switch. In this case, the VGA output will appear similar to what is shown in Figure 10-23. The messages will differ slightly based on the firmware version in the FotoFiber sensor. The firmware version is different for maintenance mode and for measurement mode.

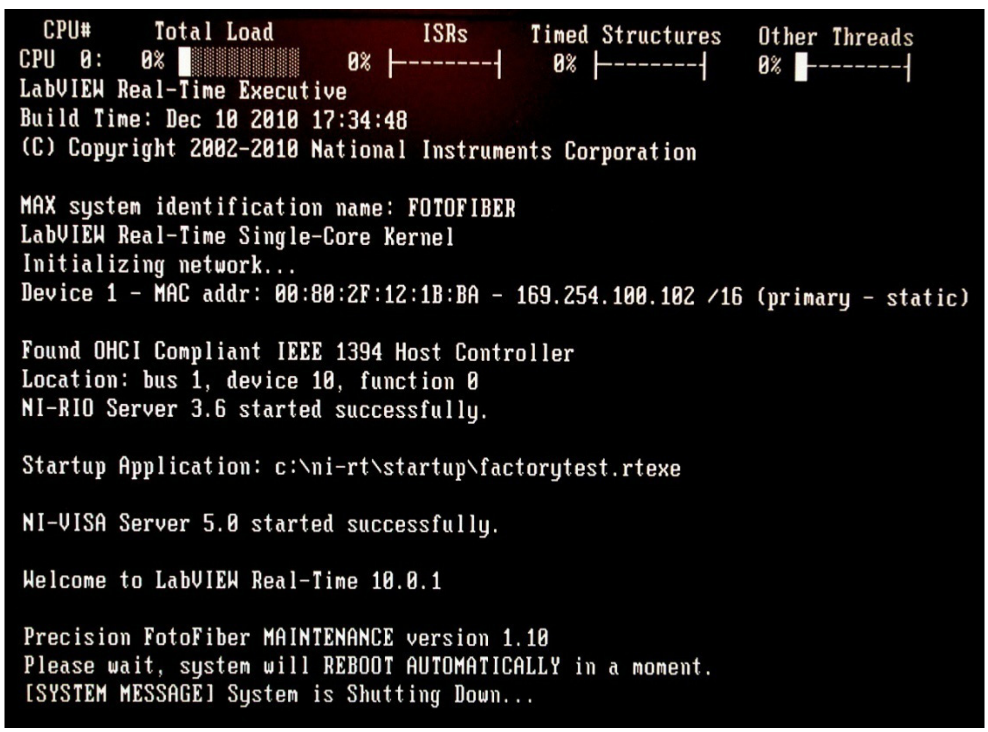


Figure 10-23 Diagnostic Monitor: Boot After USER1 DIP Switch Changed to the *off* Position

Note also that there is a delay of a few seconds between the message, `Please wait, system will REBOOT AUTOMATICALLY in a moment`, and the actual reboot.

The example in Figure 10-23 is for the first boot when the sensor is switched to measurement mode (**USER1** DIP switch in the *off* position), after being in maintenance mode. The subsequent boot will look the same as a normal boot in measurement mode or maintenance mode, depending on the setting of the **USER1** switch.

Similarly, the first boot after the sensor is switched to maintenance mode (**USER1** DIP switch in the ON position) is shown in Figure 10-24. The subsequent boot will look the same as any normal boot in maintenance mode.

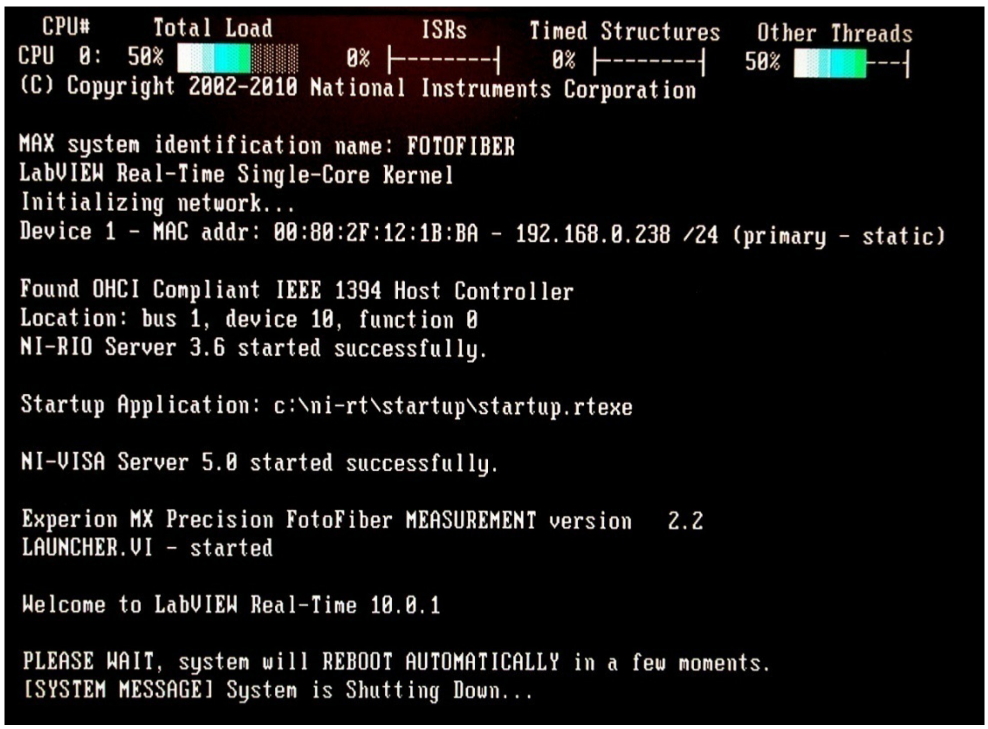


Figure 10-24 Diagnostic Monitor: Boot After USER1 DIP Switch Changed to ON

Maintenance mode, normal boot

The VGA output for a normal boot in maintenance mode is shown in Figure 10-25. The messages will differ slightly based on the firmware version in the FotoFiber sensor (Figure 10-25 shows a maintenance mode boot with maintenance firmware version 1.10).

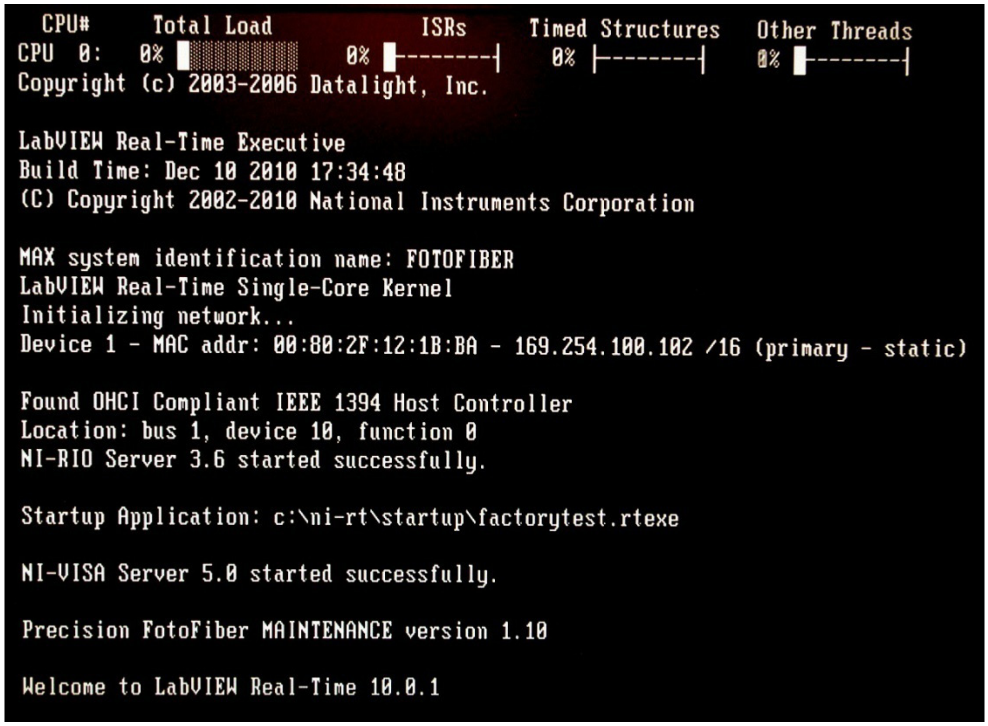


Figure 10-25 Diagnostic Monitor: Normal Boot in Maintenance Mode

Note that there is no further diagnostic narrative after booting in maintenance mode.

Measurement mode, normal boot

In measurement mode (**USER1** DIP switch in the *off* position), the VGA output at startup is typically as shown in Figure 10-26. There is then a pause, which may last a few seconds, as the sensor waits for configuration parameters to be sent by the MSS. When the parameters are received, the diagnostic narrative continues as shown in Figure 10-27. The messages will differ slightly based on the firmware version in the FotoFiber sensor (Figure 10-26 and Figure 10-27 show a measurement mode boot with firmware version 2.2).

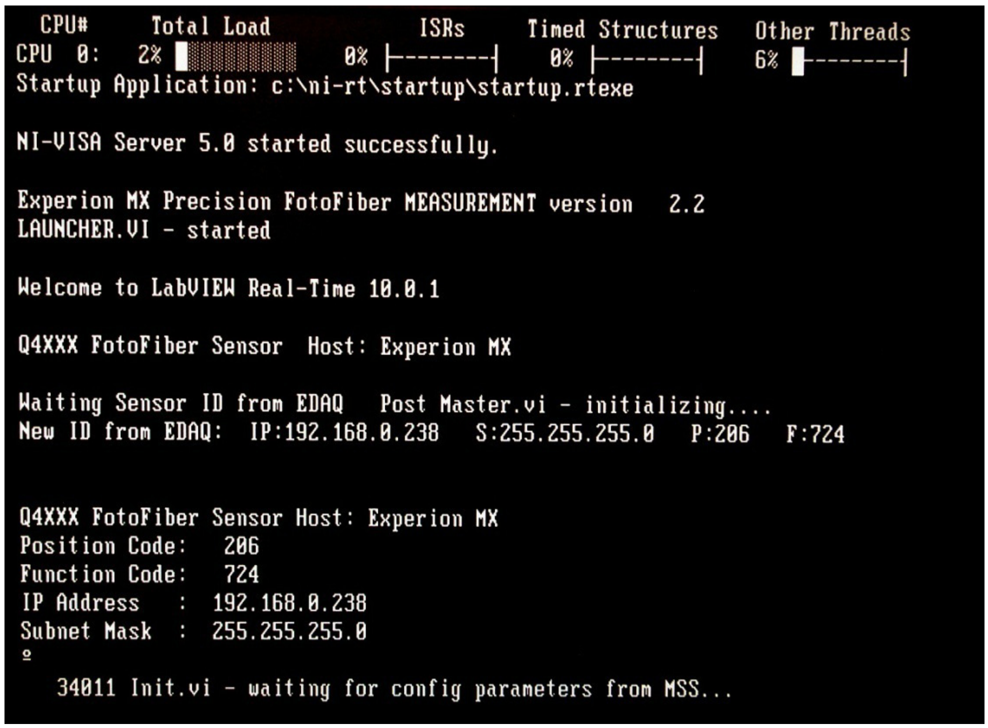


Figure 10-26 Diagnostic Monitor: Normal Boot in Measurement Mode, Waiting to Receive Configuration Parameters from MSS

When the parameters are received, the diagnostic narrative continues as in Figure 10-27. A number of significant configuration parameters are listed, and the camera model is identified (usually the Stingray F080B, but in Figure 10-28 it is a Marlin F080B). Some notable parameters shown are, with equivalents in Table 6–14, Table 6–15, and/or Table 6–16:

- option mask ↔ parameter 53
- JPEG q ↔ parameter 49
- strobe Hz ↔ parameter 5
- EOS delay ↔ parameter 54

- gray target ↔ parameter 26
- zero angle ↔ parameter 16

The parameters that are displayed will depend on the firmware version as well as on the camera model. For example, the values of channel factors which are sent as parameters will generally be shown for firmware versions 2.2 and later.

Note the two graphical characters which alternate across the lower lines of the display, and also occur inside the indicated oval in Figure 10-27. These are printed when the sensor sends its *Alive and Well* message to the MSS, and when the sensor receives an *Alive and Well* message from the MSS:

- the underlined ordinal character (º): FotoFiber → MSS
- the *box corner* character (╜): MSS → FotoFiber

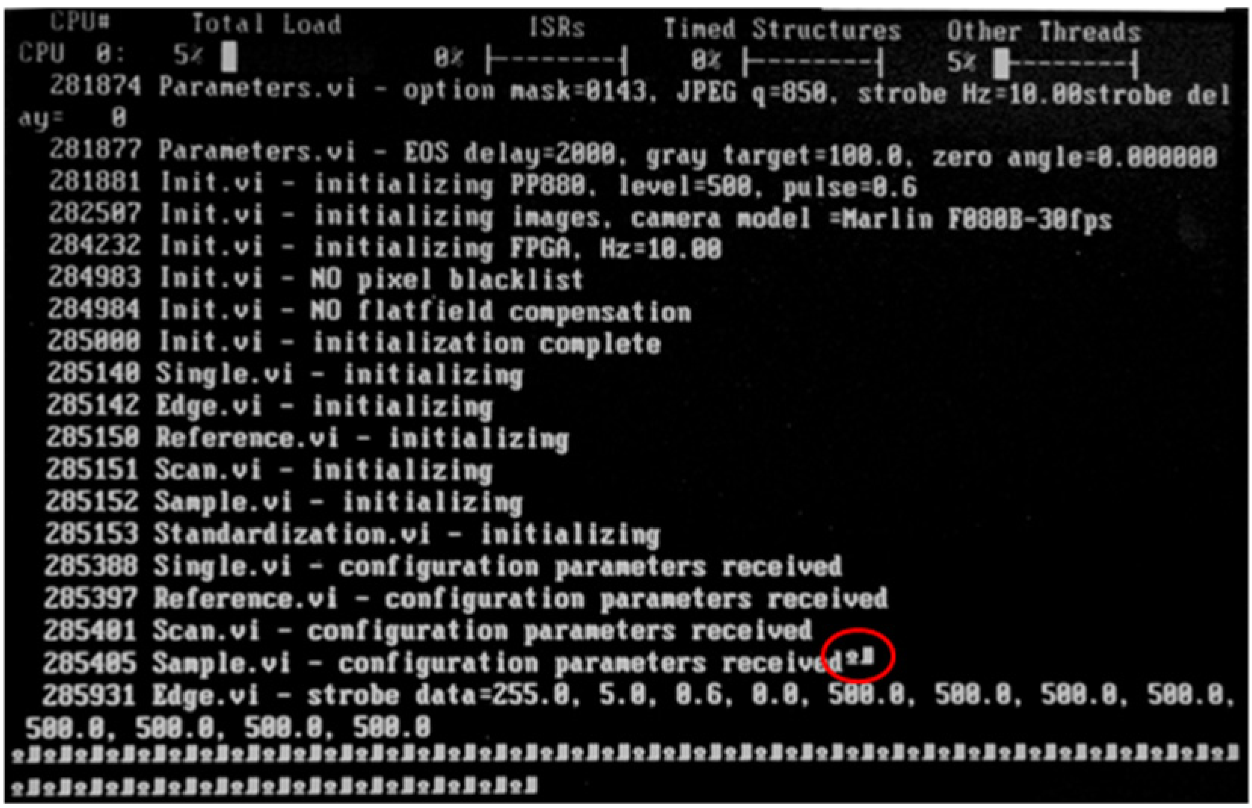


Figure 10-27 Diagnostic Monitor: Processing Configuration Parameters Received from MSS

The *Alive and Well* messages should occur roughly every four seconds, and will normally appear appended to the text messages, interspersed through the messages for any procedure.

Reference mode

Reference mode performs first a graylevel adjustment, with diagnostic narrative such as that shown in Figure 10-28. Up to six passes may be used for graylevel adjustment.

```
693334 Reference.vi - recipe parameters received
693335 Scan.vi - recipe parameters received
693337 Single.vi - recipe parameters received
693338 Sample.vi - recipe parameters received
693425 Reference.vi - reference mode received, ms =  693425
693439 Reference.vi - starting, gain=1.0, pulse length=0.8º‼
694790 Reference.vi - gray adjustment, pass=0º‼º‼
702992 Reference.vi - gray adjustment, pass=1º‼º‼
711240 Reference.vi - gray adjustment, pass=2º‼º‼
719489 Reference.vi - channel mean=812.4, gray level=100.2
719490 Reference.vi - flatfield compensation disabled
```

Figure 10-28 Diagnostic Monitor: Reference Mode Gray Adjustment

This is followed by standardization, which sequentially checks each illumination channel with diagnostic narrative such as shown in Figure 10-29. The resulting channel efficiency factors and the recommended camera gain and illumination channel levels for measurement are shown.

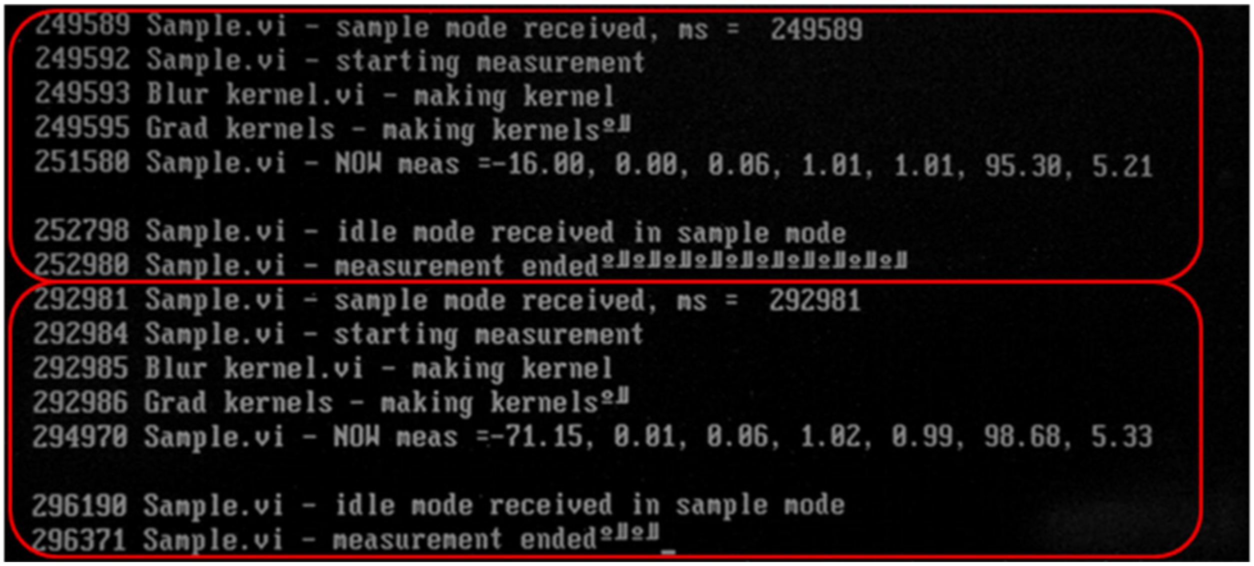
```
  581019 Reference.vi - starting STDZ, data directory =C:\Calibrate\00000000\
  581027 Reference.vi - STDZ, pulse/levels =0.8 / 907, 927, 947, 941, 887, 936,
868, 873
º‼
  583589 Reference.vi - STDZ, channel gain=4.000º‼
  586080 Reference.vi - STDZ, channel =0
  588330 Reference.vi - STDZ, channel =4º‼
  590580 Reference.vi - STDZ, channel =1
  592830 Reference.vi - STDZ, channel =5º‼
  595080 Reference.vi - STDZ, channel =2
  597330 Reference.vi - STDZ, channel =6º‼
  599580 Reference.vi - STDZ, channel =3º‼
  601830 Reference.vi - STDZ, channel =7
  601987 Reference.vi - STDZ ref, factors =1.032, 1.104, 0.938, 1.099, 1.063, 0.
886, 0.887, 0.991

  602604 Reference.vi - STDZ, STDZ data sent, flags =00
  602637 Reference.vi - adjusted gain/levels=  1.1/772, 741, 890, 756, 740, 932,
 861, 775

  602797 Reference.vi - idle mode received in sample mode
  603387 Reference.vi - STDZ sequence ended
```

Figure 10-29 Diagnostic Monitor: Reference Mode Channel Standardization

Pairs of *Alive and Well* messages to and from the MSS are interspersed throughout the narrative.

Sample mode

Typical diagnostic narrative output is shown in Figure 10-30 for shooting a sample. Two successive sample measurements are shown.



```
249589 Sample.vi - sample mode received, ms =  249589
249592 Sample.vi - starting measurement
249593 Blur kernel.vi - making kernel
249595 Grad kernels - making kernelsº‼
251580 Sample.vi - NOW meas =-16.00, 0.00, 0.06, 1.01, 1.01, 95.30, 5.21

252798 Sample.vi - idle mode received in sample mode
252980 Sample.vi - measurement endedº‼º‼º‼º‼º‼º‼º‼º‼º‼º‼
292981 Sample.vi - sample mode received, ms =  292981
292984 Sample.vi - starting measurement
292985 Blur kernel.vi - making kernel
292986 Grad kernels - making kernelsº‼
294970 Sample.vi - NOW meas =-71.15, 0.01, 0.06, 1.02, 0.99, 98.68, 5.33

296190 Sample.vi - idle mode received in sample mode
296371 Sample.vi - measurement endedº‼º‼_
```

Figure 10-30 Diagnostic Monitor: Sample Mode Measurements

The values listed in the NOW measurement are, in the order they are listed:

- fitted FO angle, in degrees
- fitted FO anisotropy
- fitting residual
- max/min ratio
- machine direction/cross direction ratio
- mean graylevel
- graylevel sigma (contrast)

Pairs of *Alive and Well* messages to and from the MSS are interspersed throughout the narrative.

No communication with MSS

If the FotoFiber does not appear to be communicating with the MSS, the diagnostic output can help isolate the problem.

The sequence of characters at the bottom of the screen indicates that the sensor is sending *Alive and Well* messages to the MSS. However, in Figure 10-31 there are no characters indicating that it is receiving the corresponding *Alive and Well* messages from the MSS. Either the MSS is not operating, not configured properly, or there is a problem with the communication line.

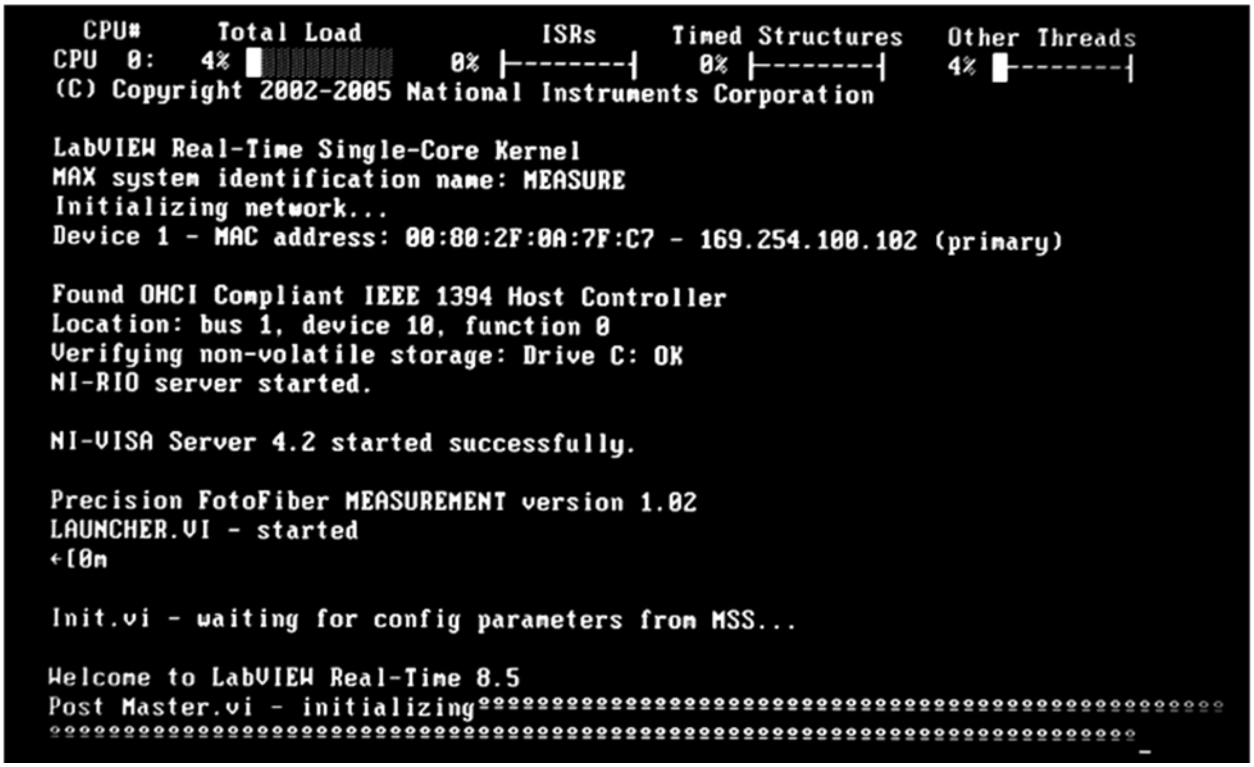


Figure 10-31 Diagnostic Monitor: FotoFiber Booted, but No Communication with MSS

Note that with firmware version 1.11 and newer in Da Vinci systems, if the FotoFiber does not receive five sequential *Alive and Well* messages from the MSS, it will reduce the rate at which it sends *Alive and Well* messages to the MSS to once every 20 seconds. The rate will revert to once every four seconds as soon as it receives an *Alive and Well* message. In Experion MX systems, this reduction in sending *Alive and Well* messages does not occur.

With firmware 2.2 and newer, the diagnostic output indicates the host type detected through hardware. One possible source of communication problems is that the host is improperly detected, for example, the hardware indicates Da Vinci when the sensor is in an Experion MX. This must be corrected by fixing the wiring harness. A more common situation in Experion MX systems is that the sensor has not been enabled in the **Scanner Sensor Status** display (see Figure 4–8). If the sensor is not enabled, there will be no communication from the MSS in an Experion MX system.

If there are *Alive and Well* messages going in both directions, as shown at the bottom of Figure 10-27, the communication link is working. In this case, if the sensor does not appear to communicate with the Experion MX, the MSS probably expects a different sensor on the port, and might have sent inappropriate configuration parameters to the FotoFiber. The assignment of IP addresses and the identification of the sensor in the MSS should be checked, and corrected if necessary. For example, the resistor which identifies the sensor may be marginal, and its value may need to be overridden in the MSS setup.

10.2.5.2. Illuminators and camera

Using the FotoFiber on a bench, and a laptop with Honeywell Intelligent Sensors software, the procedure **Operate PP880 and Camera** on the **FotoFiber** menu of the Honeywell Intelligent Sensors software can be used to test the camera and illuminators, and to test communication between the processor module and the strobe controller.

This procedure is separate from the focusing and calibration procedures described in Section 9.5, and can be used to test individual illumination channels, camera operation, and lens problems. It would normally be done under guidance from QCS-TAC, and the steps involved will vary with the problem being examined.

When the procedure is started, the camera may not have suitable parameters, and may not be acquiring images. Under the **Camera** tab, shown in Figure 10-32, the shutter time (in integer microseconds) and the camera gain (1.00 to 4.00) may be entered. The default values of 20 for **Shutter [µs]** and 1,00 for **Camera Gain** are suitable for all standard test purposes. If these values are changed, clicking **Change Settings** button will apply the new settings. It will also restart image acquisition, whether the parameters are changed or not.

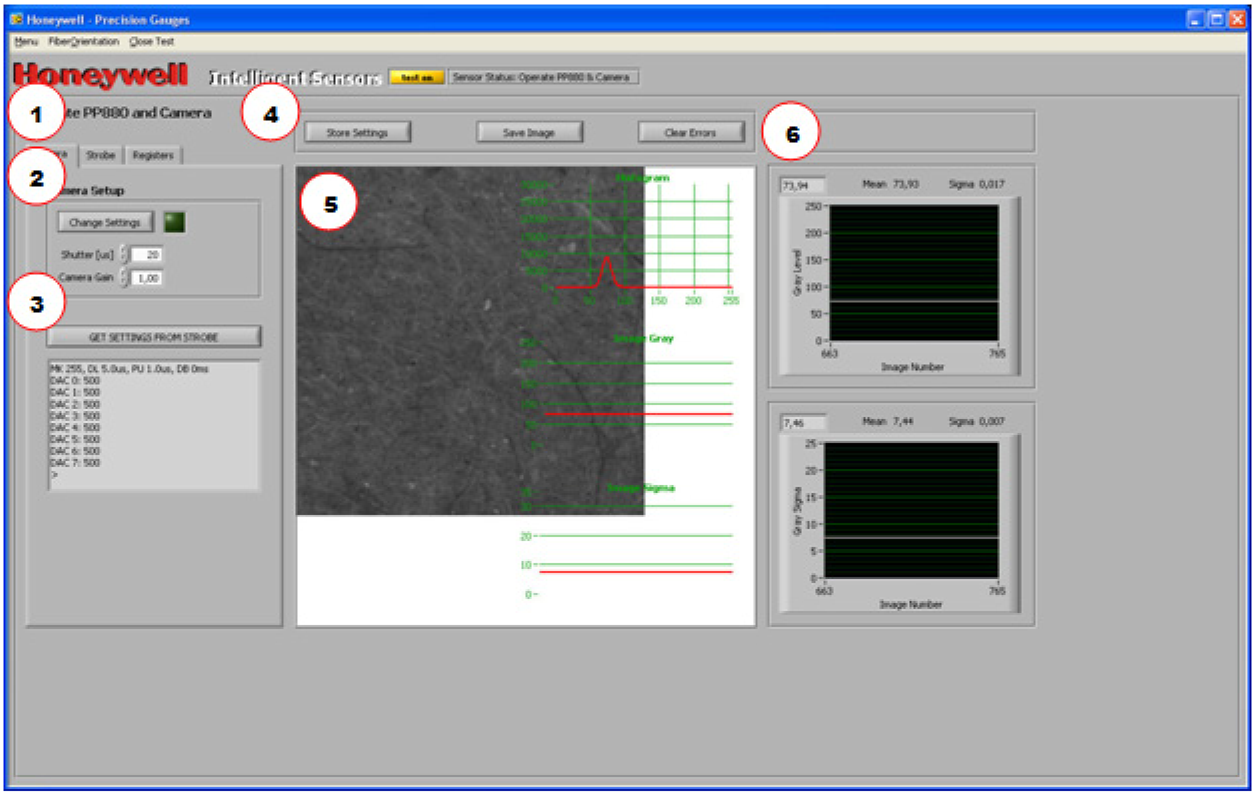


Figure 10-32 Operate PP880 and Camera, Camera Tab Display

Table 10-7 lists and describes the items shown in Figure 10-32.

Table 10-7 Operate PP880 and Camera, Camera Tab Display: Items

Item	Description
1	Tab selector
2	Camera parameters and activation button
3	Strobe parameter request and message buffer
4	Buttons for saving image or settings
5	Live image area with statistics
6	Statistics trends for images

The current image and its statistics are displayed, together with a trend of statistics from recent images.

Clicking **GET SETTINGS FROM STROBE** on the camera tab will cause the processor module to request the strobe controller to report its current settings. The communication between these two modules is in ASCII text, and the message received from the strobe controller will be displayed in the box beneath the button. The message is composed of items separated by commas. Each item has a prefix and a value, as shown in Table 10-8.

Table 10-8 Strobe Link Message Items

Item	Typical Value	Value Range	Description
MK	255	0–255	Bitmask for active channels
DL	5.0μs	0–10.0μs	Delay from trigger edge to strobe
PU	0.5μs	0–2.5μs	Strobe pulse length
DB	0ms	always 0ms	Debounce (trigger repeat inhibit)
DAC 0:	500	0–999	Output level for channel 0
DAC 1:	500	0–999	Output level for channel 1
DAC 2:	500	0–999	Output level for channel 2
DAC 3:	500	0–999	Output level for channel 3
DAC 4:	500	0–999	Output level for channel 4
DAC 5:	500	0–999	Output level for channel 5
DAC 6:	500	0–999	Output level for channel 6
DAC 7:	500	0–999	Output level for channel 7

Note that the delay and pulse are in microseconds (µs), with precision of 0.1 µs. The debounce function is not required, and the debounce parameter should always be zero. With some versions of the firmware in the strobe controller, the debounce parameter is forced to zero and its value is not communicated.

Note also that while illuminator channels are numbered from 1–8 in the **FotoFiber Standardization** display (see Subsection 6.3.2) and the **FotoFiber Edge** display (see Subsection 6.3.3), they are numbered 0–7 in the strobe control interface. The active channel bitmask uses 2N to enable channel N, with N from 0–7.

The strobe tab is shown in Figure 10-33. It allows the pulse duration (range 0.1–2.0 µs) and the delay from trigger to pulse (range 0.1–20.0 µs) to be entered into the data boxes with white backgrounds, and activated with the **Set Pulse Timing** button. When activated, the currently active values are reported back into the data boxes with gray backgrounds.

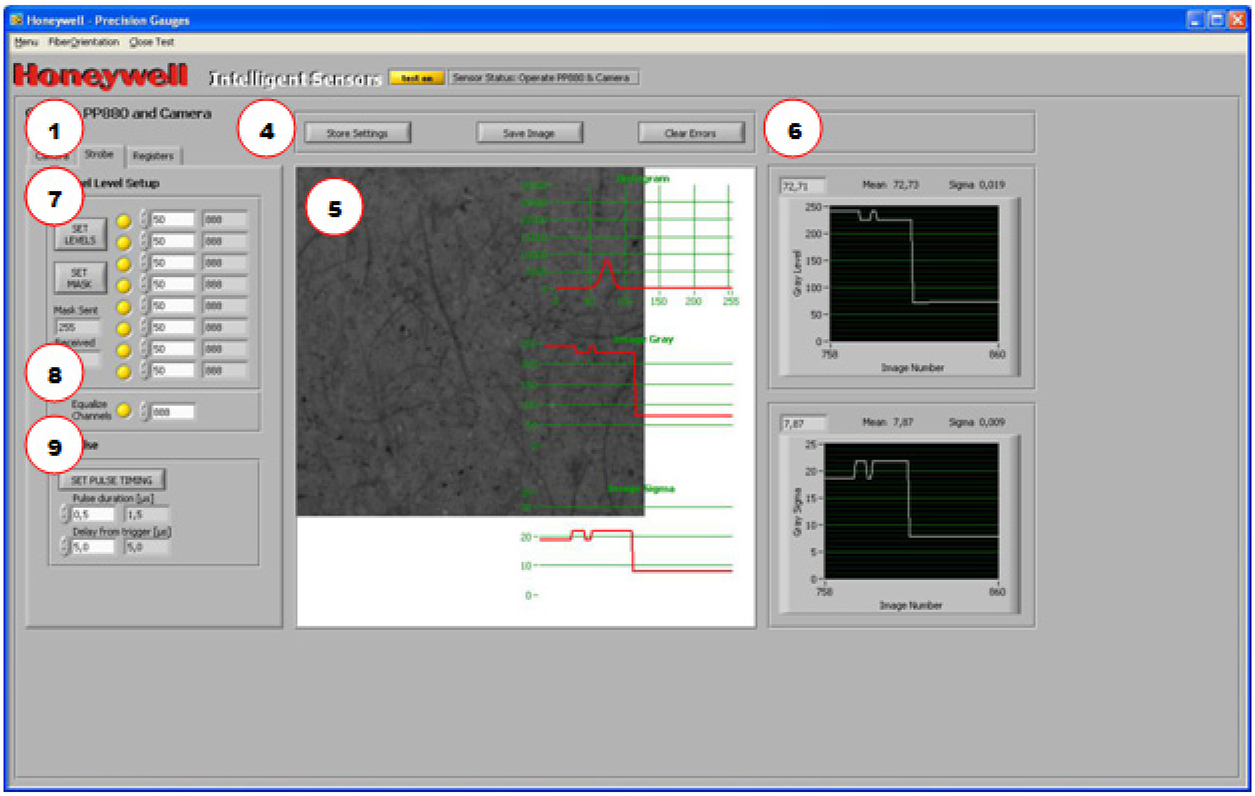


Figure 10-33 Operate PP880 and Camera, Strobe Tab Display

Table 10-9 lists and describes the items shown in Figure 10-33.

Table 10-9 Operate PP880 and Camera, Strobe Tab Display: Items

Item	Description
1	Tab selector
4	Buttons for saving image or settings
5	Live image area with statistics
6	Statistics trends for images
7	Parameters for individual illuminator channels and activation buttons
8	Equalization of all channels
9	Strobe timing parameters and activation button

A common value can be used for all illuminator channel levels, if the equalize channels indicator is set ON (yellow). If it is OFF (dark gray), the equalize value is ignored, and values must be set individually for each channel. The **Set Levels** button sends either the common value to all channels, or sends their individually specified values, depending on the state of the equalize indicator. The currently active values are reported back for all channels and shown in the data boxes with the gray background.

Each channel has an indicator which is set to determine whether it is active or not (ON = yellow, OFF = dark gray). The **Set Mask** button sends a channel mask specifying the active channels to the strobe controller (see Figure 10-34).

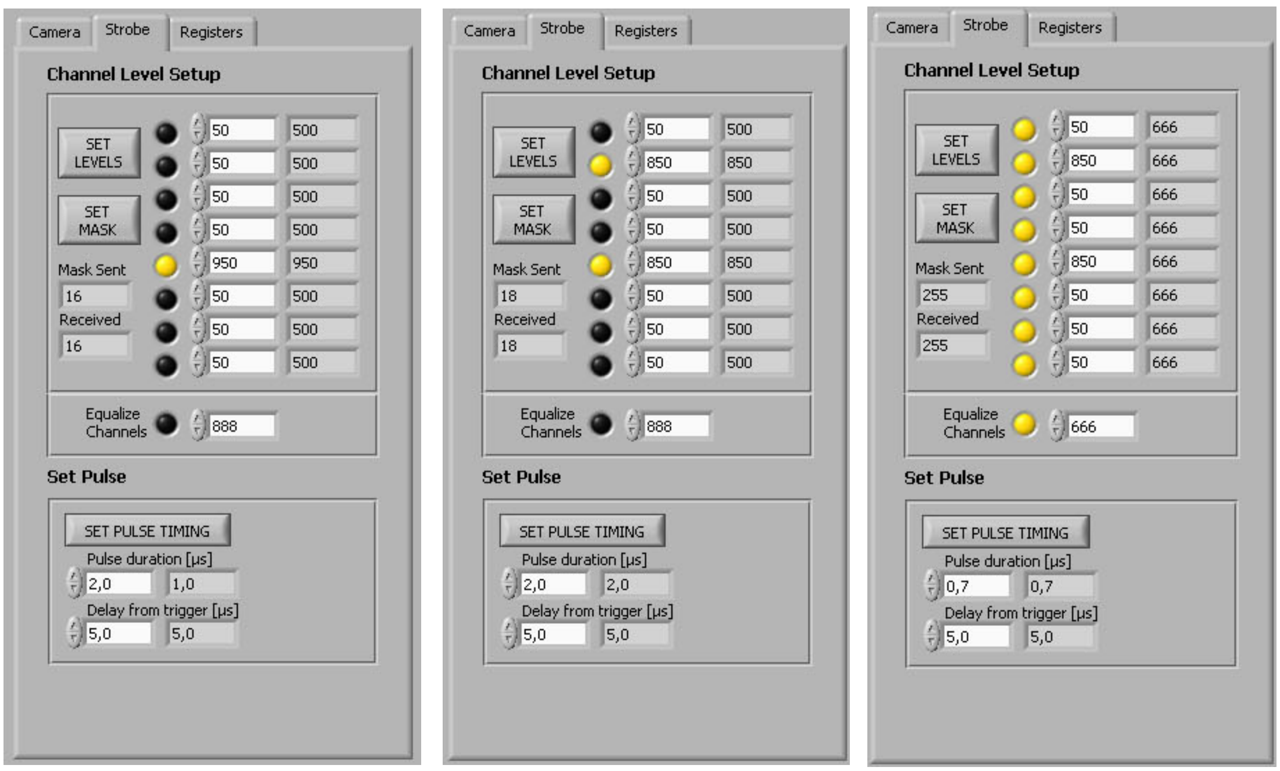


Figure 10-34 Channel Control Using Mask and Levels

Figure 10-34 shows left: channel 5 on at 950; center: channels 2 and 5 on at 850; right: all channels on and equalized at 666.

The **Registers** tab is used for inspecting or modifying camera registers (see Figure 10-35). It should be used only with guidance from QCS-TAC or the sensor developers.

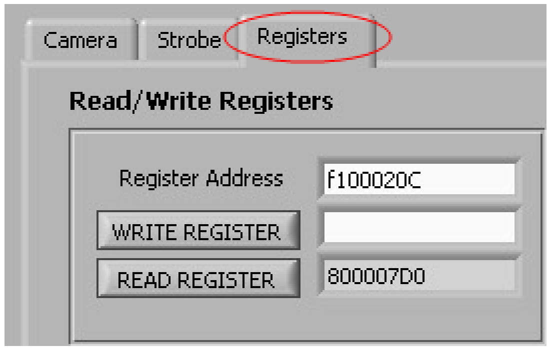


Figure 10-35 Camera Registers Tab

A selection of IIDC register addresses and their standard contents is listed in Table 10-10. All entries are in hexadecimal.

Table 10-10 Selected IIDC Registers and Contents

Register Address	Default Contents	Description
F1000208	80000000	Timebase selector
F100020C	80000005	Extended shutter
F1000250	80000000	Shading correction
F1000300	80020000	Input trigger 1 pin control
F1000320	80020000	Output pin control
F1000340	80000000	Delayed integration enable
F1000400	80000000	Trigger delay

The address of a register is entered in hexadecimal (IIDC 1.31 standard registers, and vendor-specific registers for the camera). All register addresses and register contents are 32 bit. Clicking **READ REGISTER** will display the register contents in hexadecimal in the field beside the button. To modify the register contents, enter a new hexadecimal value in the text field beside the **WRITE REGISTER** button, then click **WRITE REGISTER**.

ATTENTION

Click the **Close Test** menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

10.2.5.3. Measurement capability

Select **Fiber Orientation Measurement** on the **Fiber Orientation** menu of the Honeywell Intelligent Sensors software to make measurements of fiber orientation in maintenance mode.

ATTENTION

The **Fiber Orientation Single Point** procedure is similar, but is useful only if the sensor is deployed in a laboratory apparatus with a paper handling device. It is not useful for sensors intended to be mounted in a scanner head, whether they are in the head or on a bench for maintenance.

The fiber orientation measurement display on the laptop is shown in Figure 10-36. It displays the polar histogram and fitted curve on the left, with the fitted fiber orientation parameters (**Orientation** angle, and **Anisotropy** in the upper left; **MD/CD**, and **Max/Min** ratios in the lower left). On the upper right is the live image being analyzed, with its graylevel **Histogram** in bottom center. Trends of the **Orientation** angle and **Anisotropy** are shown in the bottom right area of the display.

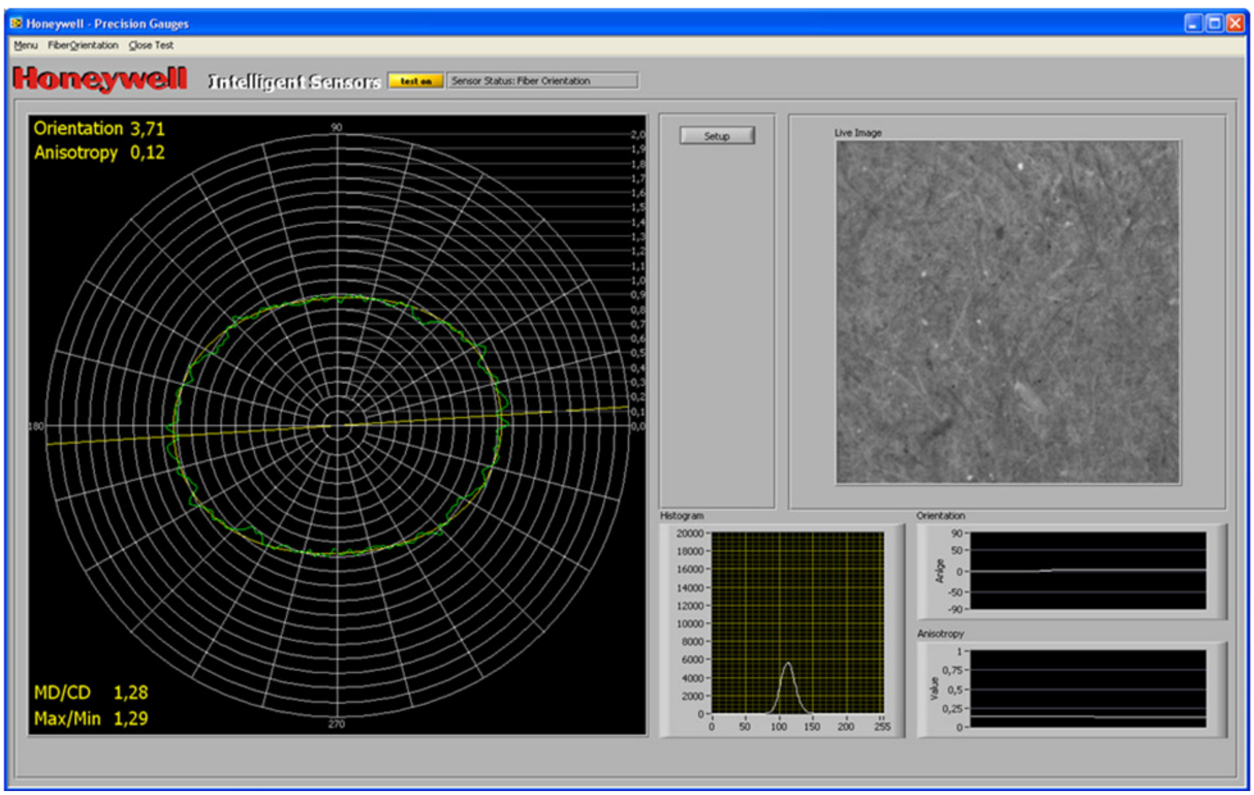


Figure 10-36 Fiber Orientation Measurement Display

Click **Setup** in the upper center to call up the setup panel (see Figure 10-37) in the area beneath the button.

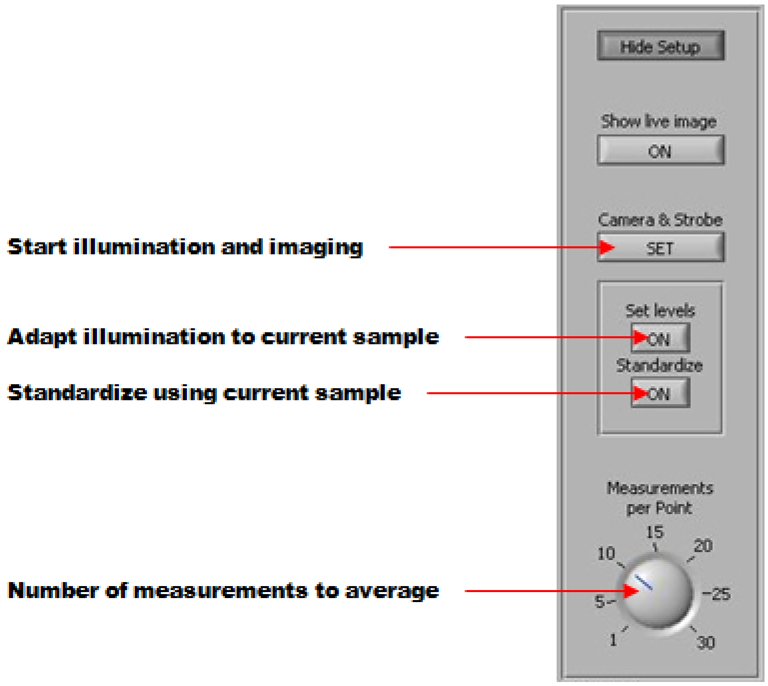


Figure 10-37 Measurement Display Setup Panel

When a measurement session is started, it is advisable to go through the setup. Click **Standardize** with a typical sample inserted. This will request the sensor to check the efficiencies of each channel for illuminator balancing.

If samples of rather different color or brightness are to be measured, it is recommended that the **Set levels** button be clicked after changing to a sample of different brightness or graylevel. This will request the sensor to adapt the illuminator strengths to the current sample.

The selected tests (standardization and/or level adaptation) will be performed when **SET** is clicked. Normal measurement will resume afterwards, using the newly obtained settings.

The number of raw measurements to average in each displayed measurement result (histogram and parameters) can be controlled using the **Measurements per Point** dial. The default is 10 measurements per average.

ATTENTION

Click the **Close Test** menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

11. Storage, Transportation, and End of Life

This chapter summarizes Honeywell policy with regards to the storage and disposal of components of the FotoFiber Measurement.

11.1. Storage and transportation environment

In order to maintain integrity of system components, storage and transportation of all equipment must be within the parameters shown in Table 11-1.

Table 11-1 Storage and Transportation Parameters

Duration of Storage	Acceptable Temperature Range	Acceptable Humidity Range
Short term (less than one week)	-20–60 °C (-4–140 °F)	10–90% non-condensing
Long term	-10–50 °C (14–122 °F)	10–90% non-condensing

11.2. Disposal

Honeywell supports the environmentally conscious disposal of its products when they reach end of life or when components are replaced.

All equipment should be reused, recycled, or disposed of in accordance with local environmental requirements or guidelines.

This product may be returned to the Honeywell manufacturing location, and it will be disposed using environmentally friendly methods. Contact the factory for further details and instructions.

Except where identified in this chapter, the sensor does not contain hazardous or restricted materials.

Guidelines for disposal of equipment by Honeywell or the customer for sensor-specific materials are as described in Subsection 11.2.1.

11.2.1. Solid materials

- remove all non-metallic parts (except plastic) from the sensor and dispose of through the local refuse system
- recycle plastic parts
- wires and cables should be removed and recycled; copper may have value as scrap
- electrical and electronic components should be recycled or handled as special waste to prevent them from being put in a landfill, because there is potential for lead and other metals leaching into the ground and water
- metals should be recycled, and in many cases have value as scrap

12. Glossary

Actuator	Mechanical or electronic device that performs the control action in a control loop
Angle	See Fiber Orientation Angle
Anisotropy	See Fiber Orientation Anisotropy
Bin	The smallest measurement zone on the frame. Also called Bucket or Slice.
Cable End	Location of the electronics and/or the entry point for communications and power on the scanner
CD Curl	A form of curl in which the curl direction is across the sheet, and the curl axis is in the machine direction. In other words, the front and back edges of a sample are deflected away from the center line of the sample. CD Curl is usually indicative of a difference in anisotropy between the two surfaces of the sheet.
Compact Vision System (CVS)	Vendor name for the processor module of the FotoFiber sensor
Cross Direction (CD)	Used to refer to those properties of a process measurement or control device that are determined by its position along a line that runs across the paper machine. The cross direction is transverse to the machine, but usually relates to a position along the length of the paper machine.
Cross Direction Spread	Variation in the profile data equal to twice the standard deviation of the measured variable
Curl	The tendency for a sheet to curl from planar into a cylindrical shape when the humidity is changed. The direction of curl is generally either in the machine direction or the cross direction. See CD Curl and MD Curl.
Da Vinci	A quality control system (QCS)
Downstream	Towards the reel, or in the direction of travel of the sheet

Ethernet Data Acquisition Board (EDAQ)	Digitization and control board used on each sensor on the Experion MX platform
FastStrobe8 PCB	An alternative designation for the strobe control PCB in the FotoFiber sensor. A synonym for the PP880 PCB.
Fiber Orientation	Used to refer either to the distribution of fiber angles in some area of the sheet (see Fiber Orientation Distribution), or to parameters describing that distribution (see Fiber Orientation Angle, and Fiber Orientation Anisotropy)
Fiber Orientation Angle	The arithmetic average of the angles in a Fiber Orientation Distribution. Usually obtained as a fitting parameter by fitting a curve to a measured Fiber Orientation Distribution.
Fiber Orientation Anisotropy	An indication of the extent to which fibers in a particular Fiber Orientation Distribution are aligned in the same direction. For a uniform distribution in which all angles are equally common, the anisotropy is zero. Usually obtained as a fitting parameter by fitting a curve to a measured Fiber Orientation Distribution.
Fiber Orientation Distribution	The statistical distribution of fiber angles (in the plane of the sheet) in some region of the sheet. Usually characterized as a polar distribution indicating the number of fibers in a range of angles (typically 1 degrees wide) from − 90 degrees to + 90 degrees.
Flatness	An ambiguous term encountered in some board mills to indicate the absence of problems due to twist, CD curl, or MD curl (lack of flatness is synonymous with warp problems). The term is deprecated for discussion of process issues. The unambiguous terms CD Curl, MD Curl, Twist, and Twist-Curl should be used instead.
FOBM	Fiber orientation backing module
FOMM	Fiber orientation measurement module
FotoFiber	Alternative name for the Fiber Orientation Measurement. Sometimes used as a synonym of the Q4223-5x.
Front Side	See Tending Side
Gauge Support Processor (GSP)	A software layer in the Experion MX host, which manages the status and measurements of a sensor as sent by the MSS
LED	Light emitting diode
Light Emitting Diode	An illuminator with high speed response capable of short intense light pulses
Linux	Computer operating system running on the EDAQ CPU as well as the MSS computer
Machine Direction (MD)	The direction in which paper travels down the paper machine
Management Information System (MIS)	System or subsystem that collects and manages information on the paper production

MD Curl	A form of curl in which the curl direction is along the sheet, and the curl axis is across the sheet. In other words, the upstream and downstream edges of a sample are deflected away from the middle of the sample. MD Curl is usually indicative of a high rate of drying in the last dryer sections.
Measurement Sub System (MSS)	A node in the Experion MX which controls the Q4000 scanner and interfaces to the sensors in that scanner
Motor End	Location of the motor on the scanner
Motor End Support	Formed steel channel welded to the upper and lower box beams at the motor end
MXOpen	Obsolete software QCS
Passline	Distance from sensor window to paper web
PP880 PCB	An alternative designation for the strobe control PCB in the FotoFiber sensor. A synonym for Honeywell FastStrobe8 PCB.
PP881 PCB	An alternative designation for the utility PCB in the FotoFiber sensor
Processor Module (PM)	The computer module which performs the image analysis and communication functions of the FotoFiber sensor. Also known as the CVS.
Q4223	A FotoFiber sensor together with an EDAQ and a baseplate for the Q4000 scanner. Can be used as a synonym for the FotoFiber sensor alone.
Quality Control System (QCS)	A computer system that manages the quality of the paper produced
Real-Time Application Environment (RAE)	The system software used by Da Vinci and Experion MX QCS to manage data exchange between applications (with Performance CD being one of them)
Real-Time Data Repository (RTDR)	The database managed by RAE to store system data, and data for individual applications
Scan Position	A constant position (in millimeters) measured from the cable end
Sensor Set	The term used in the **Sensor Maintenance** display to describe a set of sensors working together on a scanner to perform one measurement
Slice	See Bin
Smoothing Width	A value that determines the amount of averaging that will be applied to a measurement bin
Standardize	An automatic periodic measurement of the primary and auxiliary sensors taken offsheet. The standardize measurements are used to adjust the primary sensor readings to ensure accuracy.
Streak	A narrow cross-directional section of paper where a measured quality deviates significantly from the average of the entire width of the paper. Also an area in an array of cross-directional measurements that deviates more than a certain amount from its surroundings. The amount of allowed deviation can be set up as an absolute number, or as a percentage.

Tending Side	The side of the paper machine where the operator has unobstructed access. Also called Front Side.
Tilt angle	Angle between sensor window and paper web in degrees. The sensor determines tilt angle in both the machine direction and the cross direction.
Trend	The display of data over time
Twist	The tendency of a sheet to deform from planar into a saddle shape when the humidity is changed. It is usually indicative of difference in fiber orientation angles between the two surfaces of the sheet.
Twist Curl	A combination of twist with CD curl and/or MD curl
Upstream	Towards the headbox, or in the opposite direction to the travel of the sheet
Utility PCB	An alternative designation for the PP881 PCB in the FotoFiber sensor
Warp	An ambiguous term encountered in some board mills to refer to twist and/or MD curl and/or CD curl, for example, an absence of flatness. This term is deprecated for discussion of process issues. The unambiguous terms CD curl, MD curl, twist, and twist-curl should be used instead.

A. Part Numbers

The FotoFiber sensor component part numbers listed in Table A-1 are provided for reference purposes.

Table A-1 Part Numbers

Part Number	Name
39-01-2021	Molex Mini-Fit Jr Crimp Power Connector, 5559 Panel Mount Plug
07848200	FotoFiber plenum window
08766200	FotoFiber backing module
08769200	FotoFiber harness assembly, digital I/O cable
08769300	FotoFiber harness assembly, processor module power cable
08769400	FotoFiber harness assembly, serial link cable
08769500	FotoFiber harness assembly, strobe trigger cable
08769600	FotoFiber harness assembly, 24 V supply cable
08769700	FotoFiber harness assembly, 48 V supply cable
08769800	FotoFiber harness assembly, camera FireWire
08769900	FotoFiber harness assembly, camera trigger cable
08770000	FotoFiber harness assembly, link to MSS
08770100	FotoFiber light source assembly
08770500	FotoFiber harness assembly, signal gender changer
08770600	FotoFiber harness assembly, LED cable set
08773300	FotoFiber Calibration & Focus Target
16000235	Thread locking compound
16000361	Adhesive
20100078	Power and isolation PCB
20100079	Strobe controller PCB
20100080	LED driver PCB
20100081	LED panel PCB
25000770	Compact linear unit, 50 mm stroke
25000774	FotoFiber plenum window O-ring
38002007	Lens, C-mount

Part Number	Name
38100009	Camera, IEEE 1394b, CCD, b/w, XGA
51600543	Fuse, very fast, surface mount, 5 A, 6.10 x 2.69 mm
54000353	LENS**PEN**
60000940	IEEE 1394b-a cable
61000092	Screw-on type air connecter; 1/8 inch
6510030120	Commissioning target, or test specimen target pattern
6556900031	Tubing, 6 mm polyurethane
6561430047	Ethernet communication cables
6581700247	FotoFiber lower bushing window
6581700338	Test specimen holder
6581800251	FotoFiber test specimen block assembly
6581800252	FotoFiber test specimen holder assembly
6581800297	FotoFiber air installation tube assembly

B. Standard Targets

B.1. Calibration and focus target

The calibration and focus target has three areas, shown in Figure B-1, that are used in maintenance procedures.

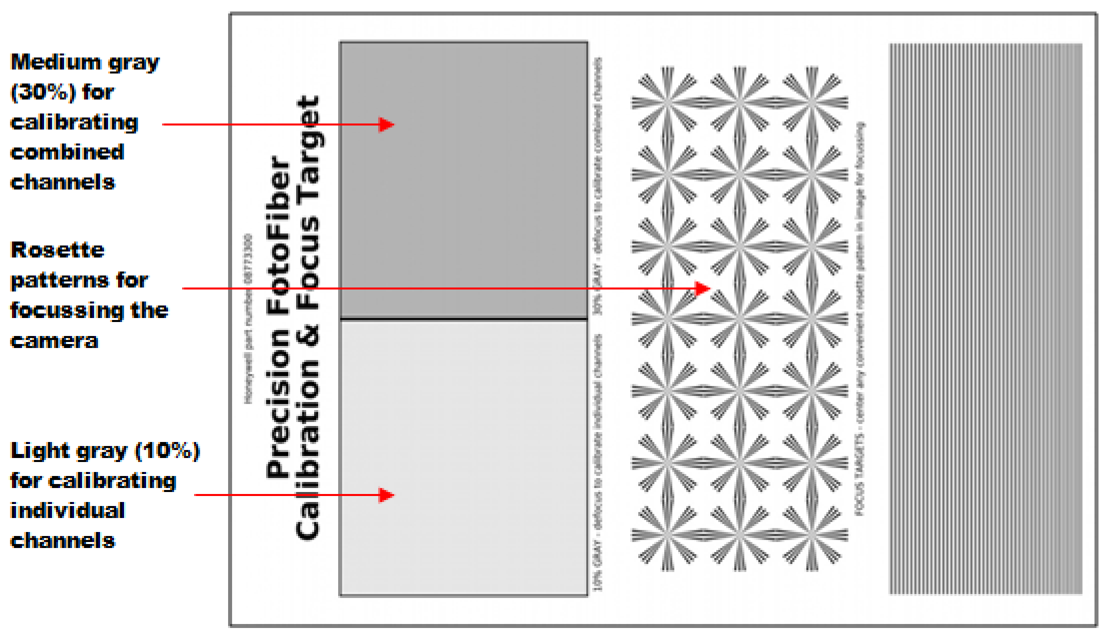


Figure B-1 FotoFiber Calibration & Focus Target

The three areas are:

- medium gray rectangle, 30% gray, used for calibrating the illuminators when all are used in combination
- light gray rectangle, 10% gray, used for calibrating individual illumination channels
- rosette pattern area, used in focusing the optics

The target should be kept flat, never folded or rolled up, and kept in a clean dry place with the LENS**PEN** and other on-site spare parts, preferably in a clean envelope. To be useful, the focus target requires high resolution printing. The reduced size version shown in Figure B-1 would not be adequate for testing the focus of the sensor optics.

B.2. Commissioning target

The commissioning target, or test specimen target pattern, is a laminated printout which is generally supplied mounted on the test specimen holder, forming the test specimen holder assembly. The pattern has three areas as shown in Figure B-2.

Figure B-2 Test Specimen Target Pattern

The three areas are:

1. STRAIGHT: An array of parallel straight lines, 0.07 mm (0.002 in.) thick and separated by 0.7 mm (0.02 in.), at precisely 90 degrees to the long axis of the part.

2. A blank area between the straight and skewed lines.

3. SKEW: An array of parallel straight lines, 0.07 mm (0.002 in.) thick and separated by 0.7 mm (0.02 in.), at precisely 75 degrees to the long axis of the part.

The arrays of parallel lines are used to determine the zero angle of the sensor, as described in Subsection 9.4.2, and for assessing the accuracy of the sensor, as described in Subsection 9.4.3. The blank area is used for standardization of the sensor prior to running these tests.

C. LabVIEW 2010 Run-Time

This section describes the installation of the LabVIEW 2010 Run-Time package on a 32-bit Windows XP system. Installation on other systems would differ in some details. Access to the internet is required. LabVIEW 2010 Run-Time installs a browser plug-in, which is required for viewing Web pages on the Q4223-5x sensor internal server.

C.1. Download the software

Either the minimal or standard versions of LabVIEW 2010 Run-Time are suitable. The download is substantially smaller for the minimal package. If the only purpose for installing the package is to view the Q4223-5x Web pages, the minimal package is sufficient.

Both run time packages can be found by searching for *LabVIEW 2010 Run-Time* at *http://www.ni.com*, using a Web browser. If necessary, the *Downloads* section of the results can be selected, but the packages will normally be visible near the top of the results, as shown in Figure C-1, where *LabVIEW Run-Time Engine 2010 - (32-bit Minimum RTE) - LabVIEW 2010 Run-Time Engine (Minimum) (32-bit) for Windows* is outlined.

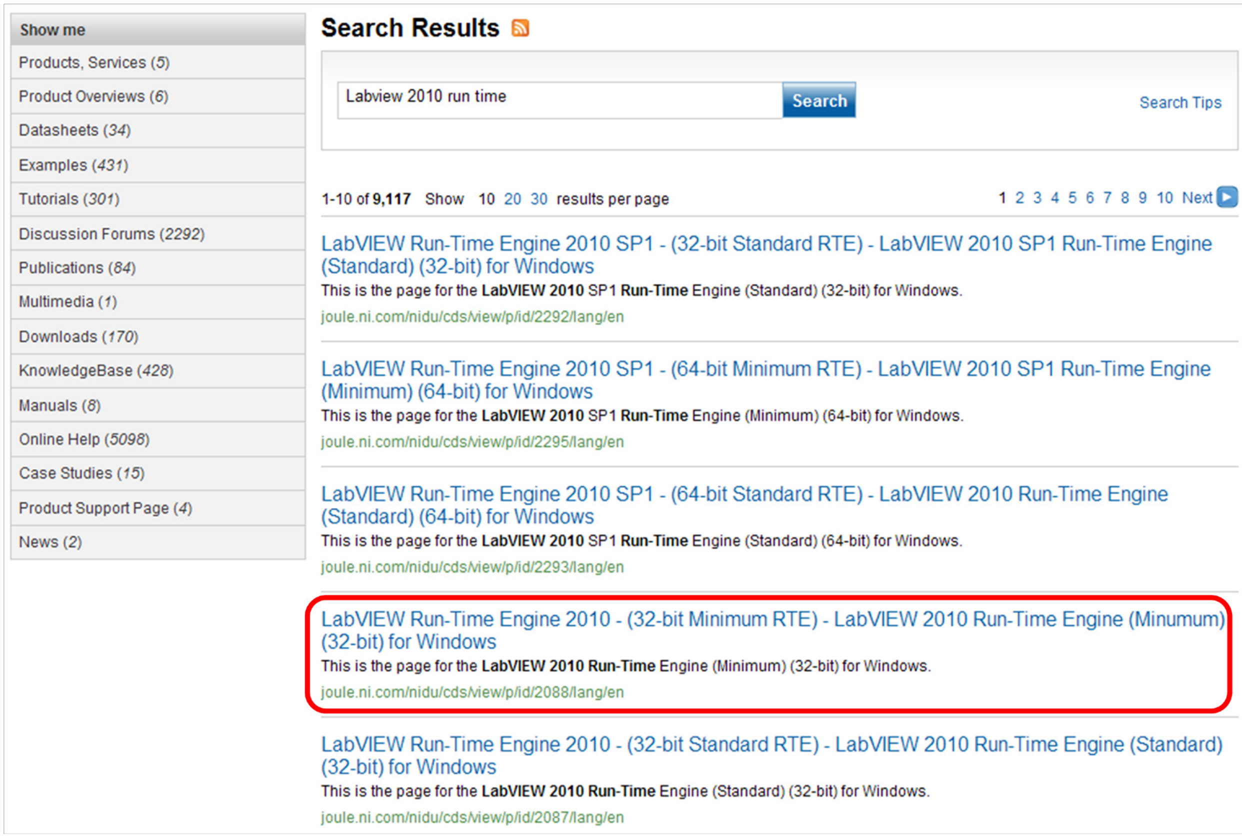


Figure C-1 National Instrument Search Results

Clicking on any of the links for LabVIEW 2010 Run-Time Engine will result in similar pages being displayed, showing the selected package for download, as shown in Figure C-2. Further down that Web page are instructions for installation.

LabVIEW 2010 Run-Time Engine (Minumum) (32-bit) for Windows

Available Downloads:

Standard Download: LVRTE2010min.exe (40.67 MB)

Download Language: Chinese (Simplified); English; Korean; German; Japanese; French
Product Line: LabVIEW
Version: 2010
Release date: 08-01-2010
Software type: Run-Time
Operating system: Windows 7; Windows 7 64-bit; Windows Server 2003 R2 32-bit; Windows XP; Windows Vista; Windows Vista 64-bit; Windows Server 2008 R2 64-bit
Available in Update Service: No

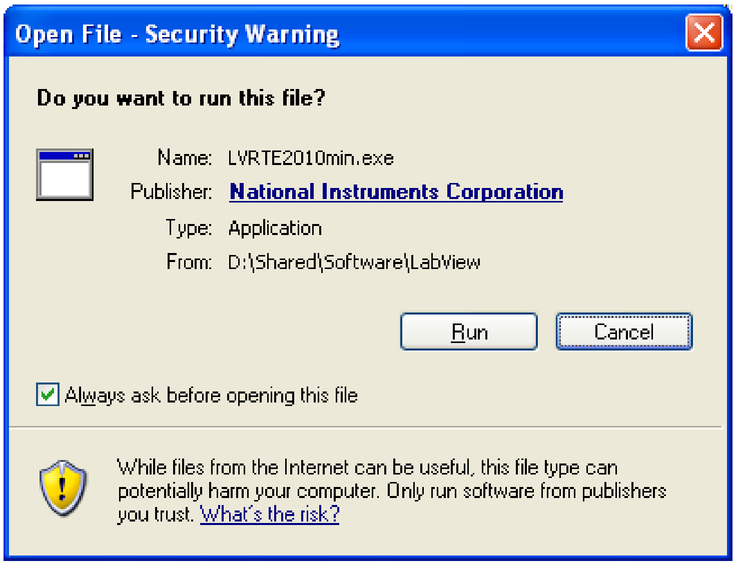
Figure C-2 Available Downloads

The package should be downloaded to a suitable location.

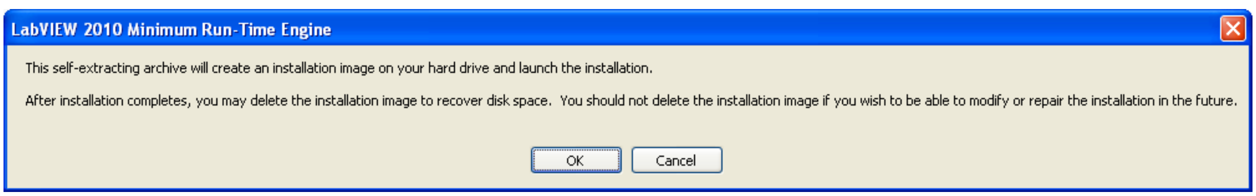
C.2. Extract and run the installer

To install LabVIEW 2010 Run-Time:

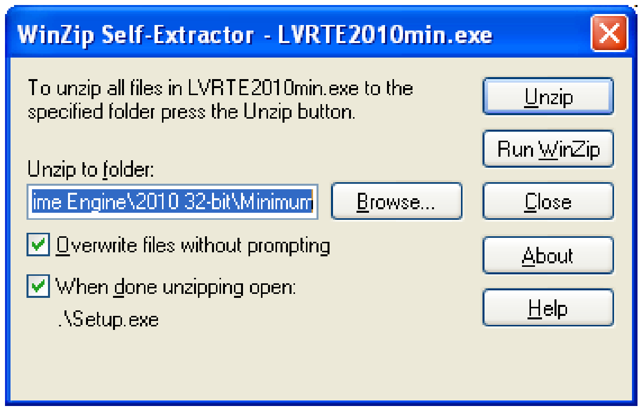
4. When the download is complete, click **Run** to open the file. This may call up an **Open File - Security Warning** pop-up. If that happens, click **Run** (the file is safe to be run).



5. The self-extracting archive notifies you that it will create an installation image on the hard drive. Click **OK** to proceed.



6. Depending on the archiving tools installed on the PC, another dialog box may appear asking whether the archive should self-extract, or whether another archive tool should be used. For example, if WinZip is installed, the **WinZip Self-Extractor** dialog appears. Click **Unzip** to allow the archive to self-extract.



7. After the extraction is complete, the setup file is automatically run, calling up the dialog shown Figure C-3, left. Click **Next** to call up the dialog shown in Figure C-3, right. The defaults are acceptable; click **Next** to proceed.

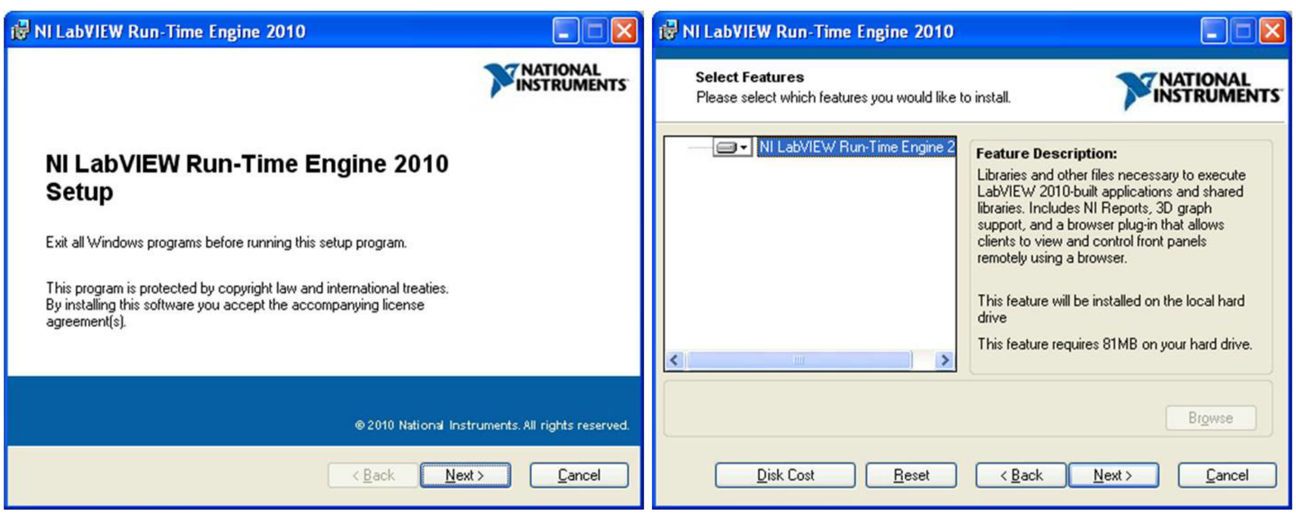


Figure C-3 NI LabVIEW Run-Time Installation: Features

8. It is necessary to accept the license agreement shown in Figure C-4, left. To begin installation, click **Next** as shown in Figure C-4, right.

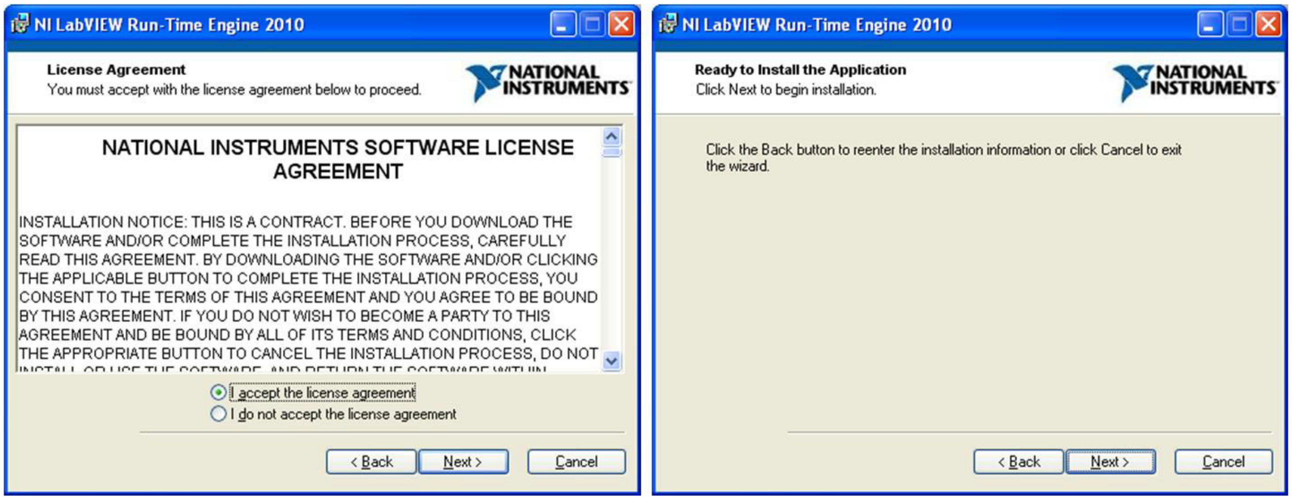


Figure C-4 LabVIEW Run-Time Installation: License Agreement

9. After starting installation, a progress bar is displayed, as shown in Figure C-5, left. A notification appears when the installation is complete, as shown in Figure C-5, right. Click **Finish**.

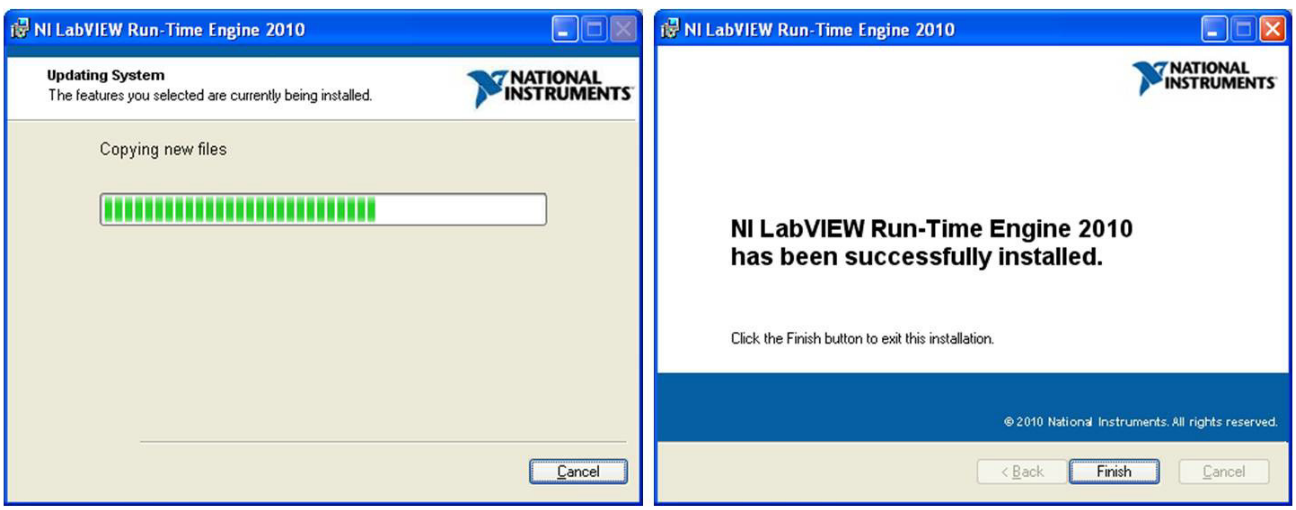
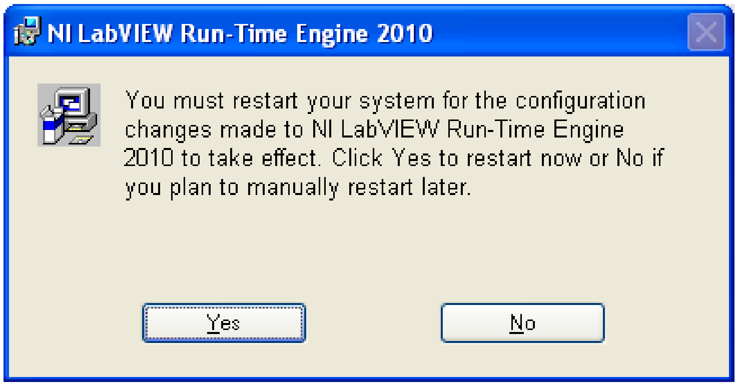


Figure C-5 LabVIEW Run-Time Installation: Progress and Completion

10. An additional dialog might appear if it is necessary to reboot the PC; click **Yes**.



D. Intelligent Sensors Software

Several of the maintenance and troubleshooting procedures require a PC with the Honeywell Intelligent Sensors software package installed. This software is provided only to attendees of the FotoFiber sensor training course, which includes instruction on use of the software. The items needed for installing the software are:

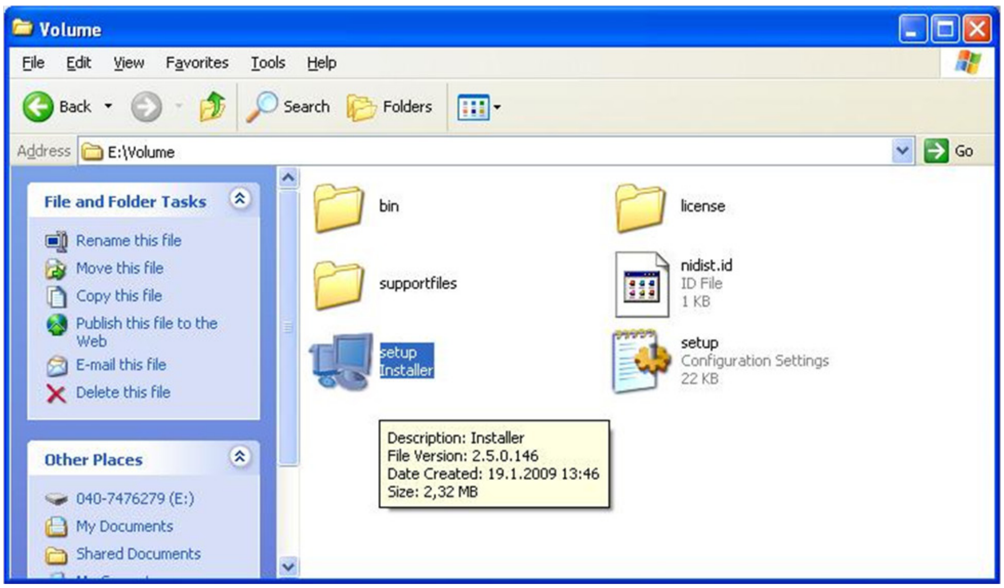
- PC or laptop. Recommended minimum configuration is a Pentium class processor with 1 GB RAM, SVGA display, RJ45 wired Ethernet port (at least 10 Mbit/s), and at least 200 MB of free disk space.
- Microsoft Windows (version XP or newer, with service packs), installed on the PC or laptop.
- Media containing the Intelligent Sensors installation package. If the installation package is copied to the hard disk, it requires an additional 200 MB of disk space.

It is possible in many cases to install the Intelligent Sensors software into a Virtual Machine (VM) on a PC, but that configuration is not supported, and a successful setup in a VM might require additional steps not covered in this manual.

D.1. Install Intelligent Sensors software

To install the software on a suitable PC:

1. Using a file browser, such as Windows Explorer, navigate to the installation package folder and run the *setup.exe* file. The EXE file extension might be hidden in Windows Explorer.



2. The installer will start and, after it has initialized, will suggest directories for installation as shown in Figure D-1, left. Accept the defaults, and click **Next** to call up the software license agreement as shown in Figure D-1, right. Click **Next** to proceed.

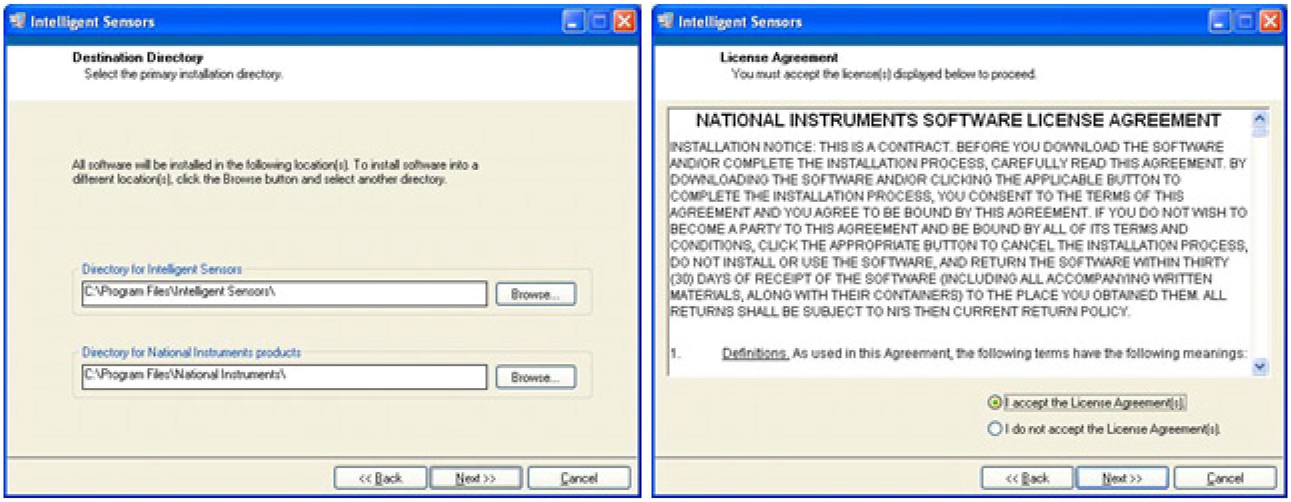


Figure D-1 Installation Directories and License Agreement

3. The operations to be performed will be summarized (there may be multiple operations), as shown in Figure D-2, left. Click **Next** to install. A process indicator will be called up, and when the installation is complete, the **Installation Complete** notification, as shown in Figure D-2, right, will appear. Click **Finish**.

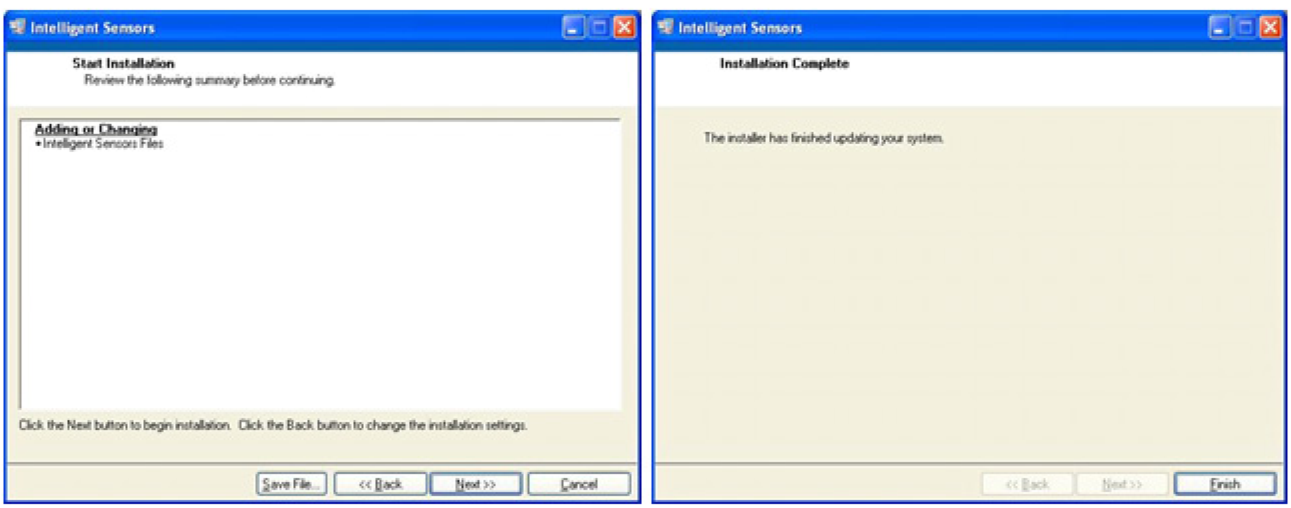


Figure D-2 Installation Summary, and Installation Complete

4. It might be necessary to reboot the PC before using the Intelligent Sensors software.

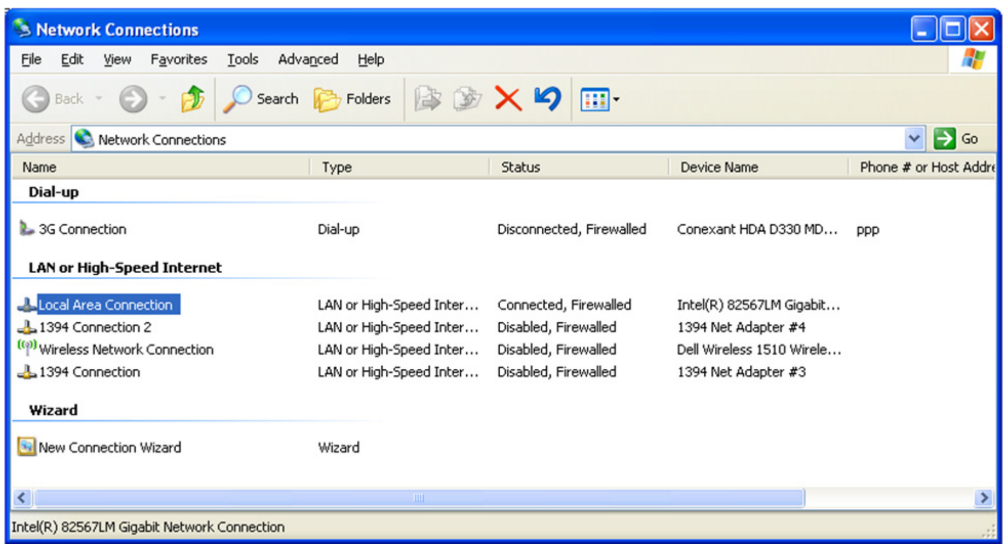
D.2. Using Intelligent Sensors software

D.2.1. Preparation

A Cat5 or Cat6 Ethernet cable (both UTP and STP are acceptable) is needed for connecting the PC to the FotoFiber. The cable may be the normal type, or a crossover type.

Before using the Intelligent Sensors software, the following preparations must be made on the PC (settings, network connections):

1. Disable all network interfaces except one wired Ethernet adaptor. Ensure that WLAN adapters are disabled, any 3G dial-up interfaces are disconnected and disabled, and that networking is disabled for IEE1394 (FireWire) interfaces, if any.



2. For the remaining Local Area Connection, open the properties dialog, as shown in Figure D-3, right, and scroll down to select **Internet Protocol (TCP/IP)**. Click **Properties** for the LAN interface, and set the TCP/IP properties as shown in Figure D-3, left. The IP address must be 169.254.100.100, and the Subnet mask must be 255.255.0.0 (Windows will set this automatically).

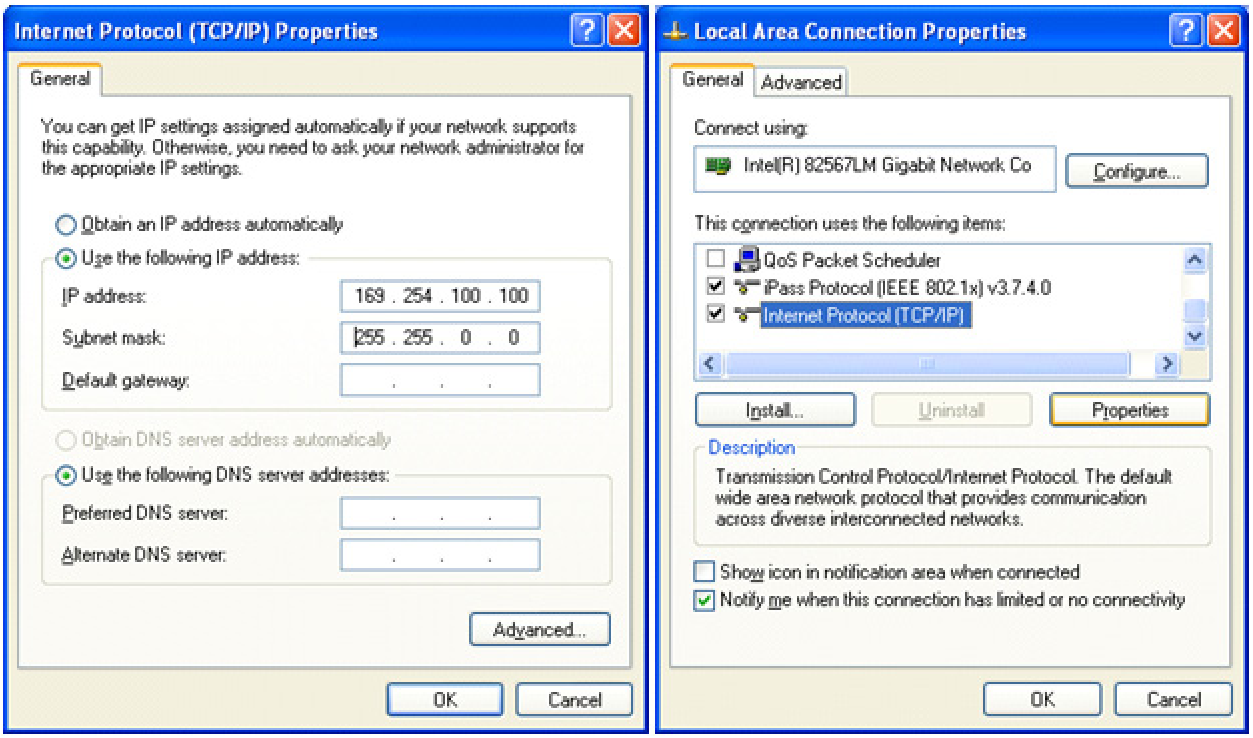


Figure D-3 Set IP Parameters for Wired LAN

D.2.2. Starting the program

The **Programs** sub-menu on the Windows **Start** menu lists an entry for the Intelligent Sensors software, as shown in Figure D-4. Start the program, and wait a few seconds for it to initialize.

Figure D-4 Start Intelligent Sensors Software

The status string near the top center of the display window should contain the message **Sensor Status: Waiting for Sensor**, as shown in Figure D-5.

Figure D-5 Sensor Status: Waiting for Sensor

If there is no text after the words **Sensor Status** (see Figure D-6), the network is probably misconfigured on the PC. Check that the IP address has been set correctly, and that all other network interfaces are disabled.

Figure D-6 Sensor Status (misconfigured)

D.2.3. Establishing a link to FotoFiber

With the FotoFiber power switch in the *off* position, the **USER1** DIP switch on the processor module should be set to the ON position. The other DIP switches should be in the *off* position (if needed for a maintenance procedure, the program will indicate any other DIP switch changes).

A PC or laptop with the Intelligent Sensors software installed should be connected using a standard Cat5 or Cat6 Ethernet cable connected to the Ethernet port on the processor module. Start the Intelligent Sensors software, then power-on the FotoFiber.

If the **USER1** DIP switch was changed, the FotoFiber sensor will boot twice (the active firmware is selected based on the **USER1** switch). If it was not changed, the FotoFiber will boot only once. During the boot, the Intelligent Sensors software will indicate **busy**, and the sensor status will indicate **Waiting for Sensor** (see Figure D-7). There may be a further delay of up to one minute for the PC and the FotoFiber to establish communication and set up shared data structures over the network.

Figure D-7 Intelligent Sensors Software Sensor Status Indicator (busy)

After communication is fully established, the sensor status will change to **Sensor Ready!** (see Figure D-8).

Figure D-8 Intelligent Sensors Software Sensor Status Indicator (ready)

ATTENTION

Do not start any procedures or click any menu items until the sensor status shows **Sensor Ready!**. Starting any procedure before the sensor and PC have properly established communication will cause the PC and the FotoFiber to become uncoordinated.

D.2.4. Software parameter set-up

There are several parameters used to define the camera and strobe states to use in calibration, focusing, and function testing. These can be inspected and modified using the **Foto Orientation Setup** display (see Figure D-9; bench measurement is circled). The default values are acceptable for all of these parameters.

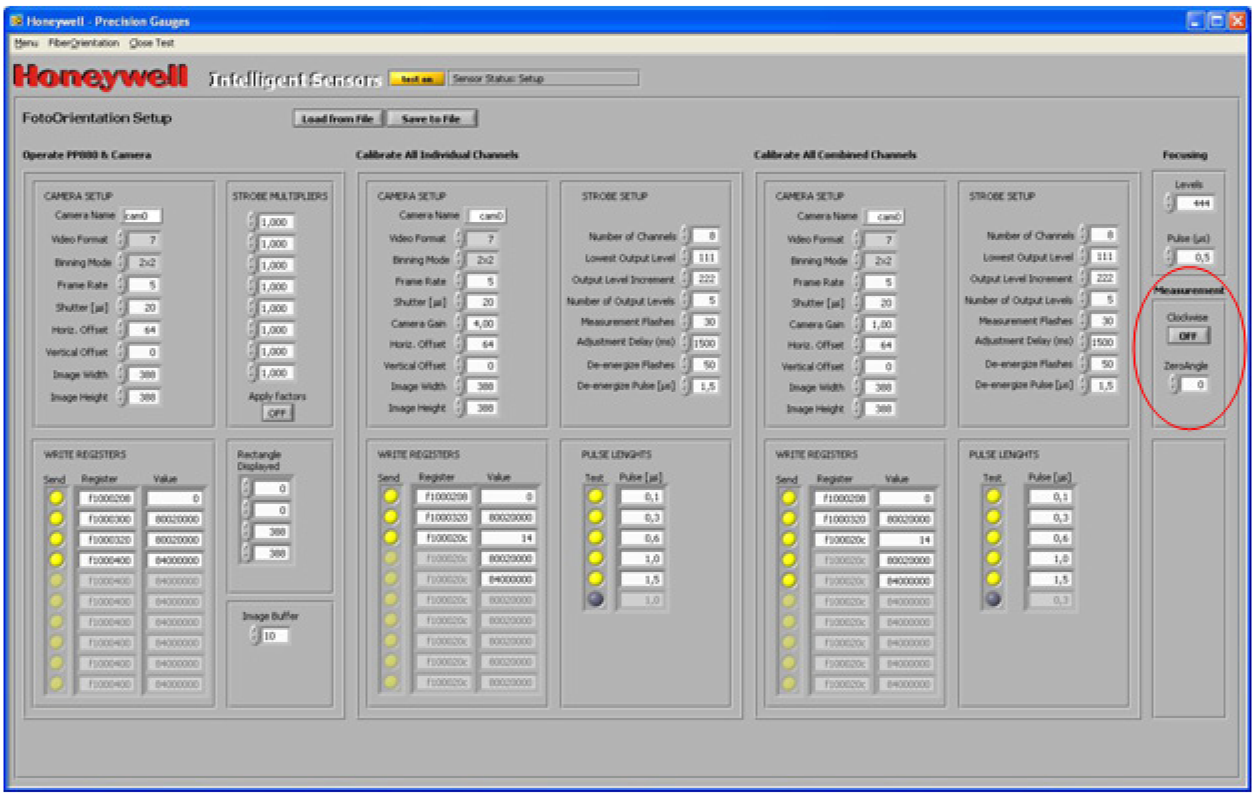


Figure D-9 Calibration and Testing Parameters

If the FotoFiber is to be used as a bench measurement device outside the scanner, the direction of positive angle may need to be changed by clicking the **Clockwise** button (**ON** = clockwise angles positive, **OFF** = counterclockwise angles positive).

The zero angle may also need to be adjusted, following the procedure in Subsection 9.4.2. Operation as a bench measurement device is not a supported product function, so it is rarely necessary to change these parameters.

CAUTION

Do not change any other parameters, except as instructed by QCS-TAC, or the sensor developers. Inconsistent camera setup or improper settings for registers may disable the sensor.