How To Guide 2014
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2014 HOW TO GUIDE

This How To Guide is a special advertising section designed to help you make decisions when purchasing quality equipment and products. Companies that are experts in their field present suggestions, ideas, tips and general practical information to help you do your job better.

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How-To Test Packaging

Packaging takes many forms and is made from a variety of materials depending on the product it is designed to protect. That may include bottles for beverages, sealed bags to keep food fresh, or biomedical packaging designed to keep a product sterile. Each packaging type requires an array of tests to fully determine whether or not it is able to perform the function desired for the particular packaged product.

Water, soda, and juice bottles, for example, come in a variety of shapes and sizes and are subjected to a range of tests such as structural rigidity to make certain they won’t rupture when filled or fold over when stacked and a burst tested to determine at which the point the bottle fails when filled with fluid.

Dimensional measurements such as height are done to make certain the bottles will go through production lines without jamming. Wall thickness dimensions are taken at various points to ensure consistency for structural integrity. Since bottles are commonly stacked on top of each other and shipped on pallets, a top-load test is required to test rigidity and determine whether or not the bottle is able to withstand stacking forces.

These tests are typically conducted by a digital force tester configured with compression platens that apply a force to the top of the bottle. The height of the bottle can be taken by programming the tester to move its crosshead down to a force low enough to just touch the top of the bottle.

The next stage compresses the bottle down to a programmed displacement point where a force reading is taken. Initial bottle height and force at that displacement point must fall within a tolerance range defined by the quality department to assure the users that the bottles perform the desired function for the fluid they hold.

The seals used on packaging for foods such as yogurt, cookies, potato chips and cereal, are extensively tested to ensure their proper performance. These seals may be adhered together or pressure sealed.

How often has someone had a snack bag rip open instead of the seal, leaving the food to fall out of the bag. This happens when the seal is much stronger than the bag material that is sealed together. Peel testing is done by pulling apart the seals to determine the strength of the seal. The testing generates valuable information for determining the bag’s structural integrity when forces are applied.

There are different types of peel tests and a variety of results that require a testing system such as a Lloyd LS1 testing machine. A common test is to cut a strip one inch wide and four inches long with the seal in the middle, commonly called a T-Peel. The ends are placed in the grips for the specimen to be pulled apart at a pre-
programmed test speed so that the material is uniformly pulled apart. Common results include Maximum Force and Average Peel, which in some cases is called Peel Strength or Seal Strength.

Burst strength testing is a test done to check the integrity of the entire bag. The sealed bag is compressed between two platens to record the maximum force prior to bursting. This test helps ensure that the chips remain fresh and aren’t broken when force is applied when the bags are stacked or packed together.

These are just a few examples of the tests done on packaging to protect the packaged product, to maintain its freshness, or determine the “use-by” date commonly stamped on the package.

Ametek

- Materials testing machines
- Force measurement equipment
- Hardness testers
- Polymer testers
- Temperature and signal calibrators
- Pressure indicators
- Deadweigt testers

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How to Select Illumination For Microscopy and Imaging

Proper lighting is as important as magnification for microscopy and video inspection. Image quality can be enhanced by improving illumination, rather than investing in a higher-resolution camera or more advanced software.

This guide describes illumination types and products for various applications.

DIRECTIONAL
Point source lighting, such as from LEDs or fiber optic light guides, is concentrated, intense and flexible. It’s recommended for inspecting and measuring flat objects or those with a matte finish. Glare and shadows limit its suitability for examining other surfaces.

Shadowing and glare can occur, though ring lights reduce shadowing when mounted behind a lens – called coaxial illumination. Our 72-LED microscope ring light has brightness and sector controls. Aven also supplies fiber optic ring lights, a Dual Pipe Light Guide and two fiber optic illuminator models.

GLANCING
This point source alternative aims light at a sharp angle to highlight an object’s surface details and structure – and ideal way to check opaque items and spot defects in parts with depth. Drawbacks of angled illumination are hot spots (“blooming”) and shadows on areas behind the angle of incidence, requiring rotation for a different view.

DIFFUSE
This type of illumination, such as from fluorescent ring lights, casts light broadly – cutting glare and assuring even brightness. Diffuse illumination and diffuse axial illumination (using a beam splitter to reflect light) are best for imaging of large shiny items from.

ULTRAVIOLET
UV light excites fluorescence in adhesives, laminates, conformal coatings and other materials. Some materials fluoresce differently under short-wave UV light versus long-wave (near-infrared), so purpose-specific illumination should be used.

SPECIALITY ACCESSORIES
• Darkfield: A fiber optic darkfield attachment or line light guide directs light so it enters a mineral, glass or plastic specimen through edges perpendicular to the lens. Internal and surface details gain sharp contrast, making flaws more visible.
• Backlight: Our fiber optic backlight produces a high-contrast silhouette to increase edge contrast and measurement accuracy if inspection of surface details isn’t needed.
• Polarizer: A polarizing filter or adapter reduces glare and brings out surface defects for accurate measurement and inspection of shiny surfaces. Aven has a contrast-enhancing polarizer that threads onto a fiber optic ring light model.

Illumination has a direct impact on costs, accuracy and productivity. As with larger production workplace investments it’s helpful to consult a supplier specializing in optical instruments and professional tools, as Aven has done since 1983.

By Mike Shahpurwala, mike@aventools.com

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High Performance Precision Tools For Microscopy Inspection & Assembly In Industrial, Scientific & Research Applications
We specialize in instruments for inspection, imaging, measurement, alignment and positioning to support any quality assurance needs. Aven has inspection systems for a quick quality check or high magnification detailed component assembly and measuring.

Our experienced staff can assist in creating a custom solution tailored to your requirements.
How to Effectively Verify Bolts in Automotive Assembly

Robots are critical to the speed and efficiency of automotive production lines. They help control costs and ensure the quality of today’s automobiles by quickly and reproducibly performing repetitive tasks such as part handling and welding. But to ensure the quality of the end product, every aspect of every part—planes, slots, holes, gaps, studs, etc.—has to be correctly sized and precisely located. There was a time when testing and measuring of those features could be done manually, but to keep up with today’s robotic assembly lines, measurement too has had to be automated.

Bolts and studs welded to sheet metal have been a particular challenge. Their absence, typically due to improper welds, can cause problems further down the line. Similarly, if they are misplaced by even a small amount, parts won’t line up properly, affecting the vehicle’s fit and finish. And improper angle of attachment will cause difficulty when attaching adjacent components.

The speed and repeatability of robotic assembly makes it an ideal application for optical measurement. However, optical technology has to address several challenges. First, material—copper, steel, or aluminum for example—affects a bolt’s optical properties, which fortunately is somewhat consistent. More critical is the fact that manufacturing processes can create unanticipated changes in the bolt’s surface and appearance. Welding can leave dark soot and raised spots on the surface. Small defects in the bolt itself can change surface reflectivity as can stress marks, grease, or other foreign materials.

Any measuring technology, laser or otherwise, that relies on reflection from the bolt itself will be negatively influenced by these varying characteristics. A new alternative, one that eliminates these problems completely, has been introduced and patented by ZEISS Automated Inspection. It uses angled non-laser light to...
project shadows of the bolt onto the sub-surface and measures those instead. Obviously, if the bolt is missing there will be no shadow, and if the bolt is incorrectly positioned or improperly angled the shadows will indicate this. By using two light sources from different angles, this approach accurately measures a bolt’s position in three dimensions. An algorithm collects and analyzes the data, working much like a GPS to “triangulate” precise position and orientation and compare it to CAD specifications. This solution easily identifies any unacceptable variation ensuring a more robust and trouble free process control.

Because shadows are unaffected by the condition of a part’s surface, the technology is virtually foolproof, catching any flaw and generating no false positives. It works on any bolt or stud, either threaded or unthreaded, and can measure accurately to +/- 0.2mm. Viewing two different shadows of the same object provides immunity from reflectivity variables, and collecting the data through a single camera reduces cycle time.

For more information please contact Gerrit deGlee, Product Sales Manager, at 1-800-327-9735 or gerrit.deglee@zeiss.com.
How to Improve Accuracy Using Video Optical Comparator Technology

Optical comparators are a mainstay of shop-floor measurement, with their rugged construction and large viewing screen. Traditional comparators project images of parts using a combination of the proper illumination, lenses, and mirrors in order to make measurements. Vision measurement systems offer the advantages of full automation and highly functional software, but cannot match a comparator for shop floor toughness. Now, advances in video technology enable us to embed a high resolution video camera into the optics of a traditional comparator.

Embedding a camera in the optics of a comparator allows the system to function as a traditional analog comparator or as a fully automatic vision system. The internal video camera is positioned to view the image formed by the comparator optics, allowing parts to be digitally analyzed and measured instantly on a separate computer screen. Automating inspections saves time and eliminates potential variability from multiple operators.

Accuracy is also improved through the use of advanced video measuring software by measuring hundreds of points per feature in the time a typical edge sensor will measure a few. Measurement software not only allows for accurate measurement of a range of feature geometries, it can also apply dynamic tolerances, construct features from multiple measurements, and compare actual measurements directly to CAD models. CAD integration can decrease program setup time by allowing the operator to create entirely automatic measurement routines, directly from a CAD file.

VidiProbe™, from Certified Comparator Products (CCP) pairs fully automatic video measuring technology with a traditional optical comparator. The integrated high resolution video camera is positioned to view the image of the part formed by the comparator optics, allowing the image to be measured with Measure-X® 2D software. The VidiProbe option is available on 14”, 16”, and 20” comparators.

CCP also offers c-vision™ Video Contour Projector which gives you the proven design of a profile projector with the accuracy of a video measurement system. c-vision gives you a greater magnification range than a traditional comparator but still offers a high capacity carrying load needed for measurement of large, heavy parts. Low mag has a 3” field of view, similar to a 30” projector with a 10x lens.

Certified Comparator Products
1174 Grange Hall Road
Beavercreek, OH 45430
www.certifiedcomparator.com
Transform the Traditional

VidiProbe™ transforms a CCP optical comparator into an automatic vision system with QVI® digital camera technology. Use your comparator in the traditional way, or switch to video for a closer look with digital zoom and Measure-X® 2D software. Get high accuracy and high speed in an easy to use system.

Phone: 937-426-9677
www.certifiedcomparator.com
How to Create a Reliable Calibration Labeling System

A successful gage calibration system can be effective only if you can readily and easily identify gages and when they need calibration and the key to proper gage identification is a reliable labeling system. Calibration labels communicate critical calibration information and due dates to gage operators and gage labeling is critical to compliance with many standards organizations.

Using a perfectly legible and appropriately durable label, any gage and its calibration status can be quickly determined at a glance, eliminating guesswork, improving productivity and reducing costs.

With hand-written labels, if you don’t take special care to write legibly with an appropriate writing utensil, wrap the label in a protective sleeve and appropriately position the label to avoid excess wear, the label becomes stained, smeared and illegible. Hand-written labels result in wasted time in the field, duplication of efforts and a risk of not being ISO compliant.

Using off-the-shelf labels versus custom-printed labels may be dictated by factors beyond your control, such as ISO 9000, ISO 14000, FDA or ISO/IEC 17025 requirements, internal company specifications or outside calibration house needs.

With high-resolution, custom-printed, laminated labels, none of these issues arise. Printing labels directly from your calibration software ensures legibility, accurate information on the label and consistency with the database and if the labels are a high-quality material and laminated, they are far more durable as well. Custom labels are printed on an as-needed basis; neither materials nor time are wasted. And, if you perform calibrations in the field, there are portable calibration label printers available as well.

Beyond the information included on the label, it is important to consider the other factors that can affect your labeling system as well as how the labels integrate with your calibration tracking system. Here are some points to consider when setting up a labeling system:

**SHOULD THE LABELS BE PERMANENTLY AFFIXED OR REMOVABLE?**
A bar-coded Gage ID label, for instance, is considered permanent, as gage IDs rarely, if ever, change. However, even “permanent” labels can still be removed with some effort and using a product that removes adhesive residue. Other permanent types of labels may be Inactive Gage labels or No Calibration gage labels.

Calibration labels, on the other hand, are removed and replaced at the time of calibration. Depending on the instrument’s environment, this type of label may need a stronger adhesive, but will still need to be somewhat easy to remove. You should test the label to be sure that the temporary adhesive is strong enough to prevent the label from repeatedly falling off and having to be reattached. Labels that don’t attach properly will eventually end up on the floor or the sole of someone’s shoe.

Calibration Issue labels are used to track cycles and usage information for the instrument. Every time such a gage is issued, the estimated calibration due date changes, requiring a new label. Because these labels are
changed quite often, a weaker adhesive is usually sufficient.

Regardless of the types of labels you choose, be sure that the surface for the label is clean and dry and, if possible, slightly roughened to allow for ideal adhesion.

WHAT INFORMATION MUST BE INCLUDED ON EACH LABEL?
If the same information is required for all gages in all departments, one standard label type may work; if the amount of information differs, several different types of labels may be required.

WILL LABEL COLOR PLAY A ROLE IN THE LABELING SYSTEM?
Labels can be color-coded to distinguish instruments by department, building, month of calibration, etc. at a glance.

EVALUATE THE ENVIRONMENT IN WHICH YOUR GAGES ARE USED TO HELP YOU DETERMINE WHICH TYPE OF LABEL YOU NEED.
Should the labeling material be paper, laminate or polyester? A high-quality laminated label will stand up to water, oil, temperature extremes, abrasion and chemicals. Some label printers automatically apply the laminate material over thermal ink printing, resulting in a highly durable product that will stand up to the harshest environments.

Various label types may be required depending on application: standard adhesive, extra strength adhesive, tamper proof, flexible tape for labeling over edges or around curved surfaces, etc.

HOW DOES LABELING INTEGRATE WITH YOUR CALIBRATION SYSTEM?
Many of today’s calibration software programs feature the ability to print labels directly from the software database. The main advantages of a direct connection between the calibration database and a label printer are the minimization of data entry errors, excellent readability and durability of labels and time savings.

Properly labeling your instruments and using a comprehensive calibration management software solution will allow you to effectively track all of your instruments. Your calibration software should include issue/return tracking functionality and if you have a barcode reader and have used bar-coded labels, you can scan the gage’s barcode, automatically populating the gage’s information, saving even more time and ensuring data accuracy.

This type of functionality allows you to track each instance of a gage being loaned out or sent out for calibration or repair and its return to the crib; you will be able to locate any gage at any time and run detailed reports to identify which gages are used most often and by whom.

Though a gage label seems like such a simple thing, it is a cornerstone of a successful calibration system. Spend some time analyzing your needs and developing a labeling system that will serve your needs now and in the future.

ABOUT THE AUTHOR:
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CyberMetrics Corporation
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How to measure the length of a shaft precisely?

Measurement of shafts could be done for 2 reasons:
- one to make sure that all the shafts either received or manufactured are similar, comparable to one another,
- second, the most common, to make sure that the shaft is within manufacturing specs.

While a direct reading can be done with calipers, a most precise method is by comparison. This implies the use of a comparative measurement instrument and a precise setting method and/or calibration method.

Comparative measurement instruments are designed to read the delta between the part being measured against the master used to set the instrument. Therefore the precision of the reading directly depends on the setting/calibration method and the instrument selected.

The instrument will have to rest stable on the part so the technician’s impact is minimal. One of the best designs is a prism support so the gage rests self-centered on the diameter.

Also, as the shaft can present different diameters, it would be a great attribute that the gage has adjustable supports.

Setting the Instrument:

Various ways could be used to set the instrument:
- Master part
- Customized Masters
- Horizontal setting bench
- Assembly of gage blocks

Prepare the instrument close to the final desired dimension so it doesn’t need much adjustment during the setting process. Make sure that the contact surfaces on the setting method are clean from any unwanted particles (dirt, oil...). Place the instrument onto the setting method. Zero the indicator or set it to the desired data.

The setting time is about 5 to 10 minutes depending on the type of gages and their sizes. To this you have to add the necessary time to prepare the setting method. Be careful, this operation can vary from 2 minutes (Horizontal Setting Bench) to 15-20 minutes if using a gage block assembly.

Note: Whichever manner is used to set it the instrument, bear in mind that to obtain the optimal results, your instrument should be set in the same position as it will be used to measure the part.

In some cases, such as multi-diameter shafts, some additional kits would be needed to “duplicate” the different diameters by adjusting the height of the supports.
After setting the indicator, remove the instrument and head towards the part. Place the gage on top of the shaft, making sure that the fixed point is in contact on the opposite side.

Leave the instrument to rest and read the indicator.

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Easy-METRIC’s Gages

VERY LIGHT
These Carbon Gages allow HIGH PRECISION measurements, with a constant HIGH REPEATABILITY.

CARBON TECHNOLOGY
Thanks to the unique Carbon Properties, minimal Thermal Expansion (0.4µm/deg/m), thus needing No SOAKING Time!

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As Carbon is Chemical Resistant, this Gages can be used either in the Lab or in the Workshop.

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Thanks to our Unique design, the number of Configurations is nearly unlimited (Drops, Side, Grove, Ball Race, Oil Diam)

Easy-METRIC’s Carbon based range of Measuring Solutions are especially designed for users confronted with precision measurement problem on parts ranging from 8 in to 26 ft (200 mm to 8 meters) - Easy-METRIC’s product line also includes Setting Benches and Factory Masters.

CONTACT US TODAY FOR MORE INFORMATION OR TO SET UP A DEMO AT YOUR FACILITY (312.428.6619 or info@easymetric.com)
How to Eliminate Check Fixtures with 3D Measurement Technology

Manufactures have long faced a dilemma. Given the critical nature of the final products they build, all parts and sub-components need to be free of defects. However, manufacturers need to keep their costs down and efficiency up in order to remain competitive in the marketplace. These conflicting objectives have allowed ‘check fixtures’ to become prevalent.

Simply put, a check fixture is a device that, when fixed in place, allows production parts to be inspected by comparing the part to the geometry and features of the fixture. These fixtures, used in conjunction with hand tools to take any additional required measurements, have long provided a balance between part integrity and the need to keep costs down on the manufacturing floor. Nevertheless, check fixtures have several drawbacks:

1. **Upfront Time and Expense:** Upfront expenses are typically anywhere from $40,000 – $140,000 to design and build a check fixture with potential costs being even higher if the part is large, complex, or needs to be reworked before final release to the factory.

2. **Difficulty Acquiring Quantitative Data**: Traditional check fixtures make it nearly impossible to collect individual part attributes and characteristics quantitatively so that statistical analysis can be run, trends identified, and manufacturing processes adjusted before parts fall out of spec.

3. **The Uniqueness of each Check Fixture**: For every individual part a company builds which requires a check fixture, a brand new one needs to be designed and fabricated.

4. **Space Constraints & Maintenance Costs**: Once a program is completed or there is an interruption in the production of a particular part, check fixtures must be stored for further use, sometimes for an indefinite period of time. This often means hundreds or even thousands of square feet devoted to storing check fixtures.

Given the expense and limitations of check fixtures as well as the large time investment required to make and maintain them, it is not surprising that some companies have turned to the latest technology to help them eliminate check fixtures from their processes. The solution that many of them have found is combining modular tooling, which can be used to build holding fixtures, with portable CMMs (Coordinate Measuring Machines). Modular tooling can consist of a base plate with tapped holes set up in a grid pattern that allows screws, standoffs, clamps and other holding and fastening items to be attached to it. In other versions plates with parallel rows of T-slots are used to position the part which is then held by self-wedging tension clamps or some other similar method. These items can be fastened in an almost unlimited number of different ways in order to hold thousands of different parts. A set of modular tooling large enough to hold tabletop sized parts usually requires a relatively small upfront investment usually on the order of $5,000 or less.

However, even though this provides a convenient way to hold parts, without a better measurement method the modular tooling does not provide a lot of additional value.
to the manufacturer. Check fixtures still need to be built, verified, maintained and stored in the same fashion as before even if their final form is somewhat simplified because the modular tooling provides an easier and more efficient holding method. To get rid of the fixtures themselves, portable CMMs are crucial.

Portable CMMs come in many forms, the most common of which are articulating arms, laser trackers and hand-held 3D laser scanners (which are articulating arms with laser scanners positioned at the end of them). The choice of which technology to use is dependent upon the parts being measured and the information needed from the parts. The costs to purchase, install and shakedown these solutions can range from as low as $20,000 up to approximately $150,000 depending on the individual manufacturer’s needs. To a large extent, the startup costs are a function of the part size; the larger the part, the higher the startup costs. This is analogous to the costs associated with check fixtures themselves. In general, the larger the manufactured part, the larger the required check fixture and the more the check fixture costs. This means that in almost all cases, the modular tooling provides an easier and more efficient holding method. To get rid of the fixtures themselves, portable CMMs are crucial.

ARTICULATING ARMS
These devices use an internal coordinate system located in the base of the arm to calculate position data of a spherical probe. This probe is located at the tip of the last in a series of three tubes connected end to end that protrudes from the base. The tubes are connected by freely rotating joints. This gives the arm its name – the product looks like and moves similarly to a human arm, except that the portable CMM can boundlessly rotate while the human arm has limited rotation.

Points in space are digitized by touching the probe to a feature and pushing a button to capture the point’s location. The sphere’s diameter is known with a high degree of certainty which allows the software to account and compensate for it. This ensures that features such as diameters of holes are measured accurately and do not add the probe diameter to the measured value. Articulating arms usually employ a robust inspection software package that allows previously hard to measure items like true position, concentricity and hole to hole distance to be quantified in less than one minute, thus rendering the check fixture obsolete in most cases.

Laser trackers also measure the position of a spherical probe, but unlike an arm, the probe is not connected directly to the laser tracker. This probe, commonly known as a Spherically Mounted Retroreflector (SMR), is usually hand-held or mounted on the end of a machine tool or robot. The laser tracker emits a laser beam which is bounced off of a retroreflector or corner cube mounted at the center of the probe. The return beam reenters the laser tracker where the distance to the target can be determined using interferometry or phase shift analysis. In addition, the horizontal and vertical angles to the probe are determined using precision angular encoders attached to the mechanical axis of a gimbaled beam steering mechanism. Using the two angle measurements and distance determined using the laser, the laser tracker can report the coordinate location of the probe to extremely high accuracy levels. In addition, the laser tracker can follow or track the target as it moves in real time. This unique feature, coupled with the laser tracker’s ability to measure points up to 1,000 times per second, enables the user to digitize data on complex surfaces and measure the location of moving objects.

HAND-HELD 3D LASER SCANNERS
These devices mount on the end of a traditional articulating arm CMM and project a laser line on the part to be inspected. The part reflects the light back toward the scanner where some of it is captured by a camera. The distance between the laser and the camera is known with a high degree of certainty. Through standard triangulation methods, three-dimensional locations can be determined. By employing a typical laptop or desktop computer, enough data is captured to allow software to create a 3D model of the part which can then be compared directly to the CAD model of the part. In addition to being able to quantify features, dimensions, and GD&T callouts, individual points can be quantified in terms of their deviation from the model.

By utilizing modular tooling fixtures and portable CMMs, manufacturers can eliminate the need for many or all check fixtures in their factories. The solution pays for itself as soon as a check fixture that would normally need to be built, is no longer required. In addition, the modular tooling and portable CMM solution eliminates the need for storage, maintenance and rework costs for check fixtures not currently in use. However, and perhaps most important of all, the portable CMM solution yields actionable, quantifiable data that manufacturers can use in a six sigma and/or lean manufacturing environment to improve their products and become more profitable.
How to Use Borescopes for Internal Visual Inspection

By Dr. Douglas Kindred, President and Chief Scientist, Gradient Lens Corporation

Fast, reliable, internal visual inspection is an irreplaceable quality assurance procedure for manufacturers of mission-critical parts and assemblies from fuel and hydraulics systems to vital medical parts. The process starts with selecting the right borescope for the specific inspections you need to conduct. Diameter, length, and direction-of-view are key factors, as is the selection of a rigid, flexible, or video borescope. The following will start you in the right direction.

RIGID AND FLEXIBLE BORESCOPES

Rigid Borescopes
Rigid Borescopes have superior sharpness and detail because they use traditional glass optics. Choose a Rigid Borescope when the entry path is straight. Rigid Borescopes have better image quality, and are more durable and less expensive, than flexible scopes.

Flexible Fiber Optic Borescopes
Flexible Borescopes use optical glass fibers to relay the image. Resolution depends on the number of fibers and their diameter. Each fiber forms a pixel in the final image. When your entry path is curved, you’ll need a Hawkeye® Classic, Pro, or Blue Flexible Borescope. Flexible Borescopes can also offer 2- and 4-way articulation.

VIDEO BORESCOPES

Portable Video Borescopes
Our newly redesigned, fully portable, Hawkeye® V2’s are brighter, have higher resolution, and are more durable than most comparable videoscopes on the market today. The Hawkeye V2 is available in diameters of 4 and 6 mm, offers 4-way articulation, and is priced starting at $8995. The V2 can also easily capture photos, and video footage, for storage, documentation, or email transmission. Made in the USA.

Benchtop Video Systems
Any Rigid or Flexible Hawkeye® Borescope can be connected to our Luxxor® Video Camera, effectively making any Hawkeye borescope a portable videoscope! Your borescope can then connect to any laptop or desktop computer, or video monitor, allowing for on-screen viewing, computer storage, and documentation. Inspection video footage, and still images, can be archived, or sent to others via email.

For repetitive inspection of parts, you can also add a Hawkeye® Video Slide* to hold the part, and borescope, in a fixed, but easily adjustable, position during inspection.
How to Use Borescopes for Internal Visual Inspection
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**Flexible Fiber Optic Borescopes**
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**Metal Machining & EDM**
Metal machinists can inspect for burrs, defects, surface finish irregularities, and more, even inside deep or narrow bores.

![Button rifled .204 Ruger as seen with a Hawkeye Pro Slim 17”](image)
![Diesel injector body taken with a Hawkeye Pro Hardy 7”](image)
![Burr in a cross hole in an ABS brake manifold viewed with a Hawkeye Pro Slim 7”](image)

A hydraulic sleeve is examined using a Hawkeye Pro Hardy 12” borescope and a Luxxor Video Camera system.

**Welding**
The quality and integrity of any weld, even in long tubes or complex parts, can be quickly evaluated.

![Weld in 3/4” stainless steel tube using a Hawkeye Pro Hardy 7”](image)
![Welded and drawn tube viewed with a Hawkeye Pro Slim 7”](image)
![Defects in medical arterial stent as seen with a Hawkeye Pro Slim 12”](image)

A welded tube is examined using a Hawkeye Pro Slim 7” borescope.

**Casting**
Quickly check for voids, sand and other defects even inside complex castings.

![Void in casting, after machining, seen with a Hawkeye Pro Hardy 7”](image)
![Interior of aluminum casting viewed with a Hawkeye Pro Flexible with 90° adapter](image)
![Interior of aluminum casting viewed through a Hawkeye Pro Hardy 7”](image)

A complex casting is inspected using a Hawkeye Pro Flexible borescope.

WEB: gradientlens.com  PHONE: 800.536.0790  E-MAIL: info@gradientlens.com
Your process is producing parts that don’t all meet your customer’s specifications. You’re not happy. Your customer is not happy. Your boss is not happy. Fortunately, after some hard work, you finally find a way to improve the process.

However, you want to perform the appropriate statistical analysis to verify your results and easily explain the process improvements to your boss. What should you do?

The solution is before and after process capability analysis, performed with statistical software such as Minitab.

A process capability analysis evaluates how well process outputs meet specifications. For example, a photocopier maker requires rubber rollers to be between 32.523 cm and 32.527 cm wide to avoid paper jams. Capability analysis reveals how well the manufacturing process meets these specifications, and provides insight into how to improve it.

**BEFORE AND AFTER PROCESS CAPABILITY ANALYSIS**
Assessing process capability before and after making process changes can be a valuable and easy way to prove improvements were made, while also ensuring your process is still meeting specification limits and producing “good” parts.

But before assessing processing capability, you must first ensure your process is stable—you can’t predict the performance of an unstable process! But you can predict, and improve on, a stable process.

The following example illustrates how one group of engineers used control charts and capability analysis to assess a process and then prove they improved it.

**USING PROCESS CAPABILITY TO ASSESS A PROCESS**
An extruded parts maker needed to verify their process was running between the lower spec limit of 17.5 hardness units and the upper limit of 22.5 hardness units, with the target value of 20. To collect data for their analysis, operators randomly selected three extruded parts at regular intervals, and recorded the hardness of each part (see Fig. 1).

Engineers then used Minitab’s Capability Sixpack™ to evaluate the stability and capability of the manufacturing process in meeting the aforementioned customer requirements (see Fig. 2).
The control charts revealed a stable process with all points falling within the control limits. However, the histogram showed that many measurements fell outside the specification limits, with 73,603 parts per million defective (overall). With more parts falling above the upper spec limit than below the lower limit, the engineers concluded that the process mean must be shifted. Also, the histogram shows that variation needed to be reduced in order to reduce the number of defective parts and improve the capability of the process.

**USING PROCESS CAPABILITY TO VERIFY IMPROVEMENTS**

The engineers adjusted the process to reduce the variation and obtain a process mean closer to 20. So once again, operators collected 30 parts using the same sampling method, and measured the hardness of the parts.

The engineers then ran a before and after capability analysis to see how their improvements successfully shifted the process mean and reduced variation (see Fig. 3).

Minitab’s Assistant helps you determine the approach you should take and which statistical analysis to perform to get the information you need.

The Assistant can also help you with basic graphical analysis, measurement systems analysis, hypothesis tests, regression, creating control charts, and even design of experiments. You can see all of what the Assistant has to offer by trying Minitab 17 free for 30 days—download the trial at www.minitab17.com.

Minitab 17 gives you the statistical power to improve quality and the confidence to know you’ve done it right.

The engineers were happy to see their adjustment to the process reduced the PPM from 73,603 to 2,681 – a 96% reduction in percent out of spec—and the process mean shifted from 20.820 to 20.037, along with reduced variation. Best of all, the engineers had statistical proof and graphs to easily explain the process improvements to their boss!

If you need to perform capability analysis, check out the Assistant in Minitab 17 Statistical Software:

**Minitab Inc.**

Visit www.minitab.com for software tutorials, including Quick Start exercises that show you how to analyze data using the Assistant, as well as blog posts, case studies, upcoming webinars, and more.
How to Reduce Manufacturing Costs Using Large-Field-of-View Measuring Technology

In today's competitive manufacturing environment, reducing costs while ensuring high quality is everyone’s goal.

New large-field-of-view measurement and inspection technology from RAM Optical Instrumentation can reduce inspection and measurement time and speed up the flow of vital process control information, improving yield and process uptime.

Large-field-of-view measuring systems combine the latest high resolution digital video cameras with specially designed optics and lighting to produce high accuracy images of small parts up to 4-inches in size. Onboard digital image processing software instantly analyzes and measures the entire part image all at once.

Because large-field-of-view systems image large areas, there is no need for a moving stage. Entire parts can be measured in the time it takes to place them on the machine and press the button. Large-field-of-view technology uses digital zooming to instantly enlarge the image for a closer look at very small features. The simplicity of large-field-of-view systems means programming time is reduced as well.

Along with decreasing inspection time, large-field-of-view technology can also reduce overall inspection costs. Automatic part ID and Autocorrelate capabilities enable parts to be measured without special fixtures or tooling. Simply place a part on the machine in any orientation to measure it. With no need for part holding fixtures, the system can measure any part, any time with no tooling changeover.

Large-field-of-view measuring systems are ideal for inspecting injection-molded medical devices. Dimensional integrity is of high importance in virtually all medical applications, even for disposable items. The ability to quickly identify and monitor areas of variability such as short shot, flash and sink can prevent costly scrap before it becomes a problem.

QVI® SNAP™ large-field-of-view system from RAM Optical Instrumentation makes identifying and measuring these potential flaws fast and easy. SNAP’s software converts common CAD formats directly into measurement routines for easy program set-up. In one case study, SNAP completed a full medical device part measurement with over 600 data points, 29 times faster than a conventional automatic video measurement system.

Every manufacturing operation is continually looking for ways to reduce their operating costs while improving quality. To reduce your quality inspection costs and increase yield, consider the SNAP large-field-of-view measurement system from RAM Optical Instrumentation.
QVI® SNAP™ – The New Way to Measure Small Parts

- One Button Operation
- Auto Part ID
- Large Field of View for Multi Part Measurements

Measurements Made Simple. www.ramoptical.com/SNAP
How to Effectively Manage Supplier Quality Across the Supply Chain

Markets and manufacturing practices have evolved and companies now work with an increasing number of global manufacturing and supply partners. As companies have pursued this broadened supply chain strategy, the ability to manage quality risk has become more challenging.

Quality issues can surface at any point in the supply chain and production process. It is imperative to catch quality issues as early as possible in the supply chain. The costs of unresolved supplier quality issues can be devastating if they are discovered after a product has been introduced to the market. Therefore, it is critical to identify quality issues early in the supply chain to manage quality related costs and risk.

In this new paradigm, quality management does not end at traditional corporate boundaries. As companies become more and more dependent on suppliers, they must assess and manage quality in the supply chain to reduce business risks and prevent revenue losses. Here are four best practices for effectively managing quality across the enterprise and beyond the four walls of the factory.

1. BROADEN THE SCOPE OF SUPPLIER ASSESSMENTS
Most companies restrict supplier performance measurement and monitoring to less than 1/3 of the total supply base. Organizations typically focus supplier measurement and monitoring on:
   • Suppliers that comprise the largest portion of spend
   • Suppliers that have a strategic relationship with

Cloud computing can turn the concept of fully integrated quality management for supply chains into a reality.

   • Suppliers that have a strategic relationship with the client company

Failing to measure the majority of the supplier base means companies lack visibility on the level of quality

IN THE CLOUD: QUALITY ACROSS THE ECOSYSTEM
From a technology perspective, cloud computing – and particularly the software-as-a-service (SaaS) model – provides an ideal medium for collaboration on quality.

In the SaaS model, suppliers essentially log in to a manufacturer’s existing EQMS system and enter data via the same screens and in accordance with the same business rules as those that prevail internally (with strict access and privilege restrictions).

Communications related to specific quality processes like NCMRs and CAPAs take place within the same environment so they can be appropriately routed and tracked.

Cloud computing can turn the concept of fully integrated quality management for supply chains into a reality.
in the supply chain. As a result, companies are more exposed to potential quality incidents and cost increases that can negatively impact profit and brand reputation. Companies need to invest in infrastructure that enables broader visibility into the supplier base.

### 2. DEFINE CLEAR MEASUREMENT PROGRAMS
The majority of companies measure supply chain partner performance in specific areas:
- Quality
- On-time delivery
- Service
- Price
- Total cost
- Contract compliance
- Responsiveness

However, measuring these performance areas can be challenging if the organization has a large number of suppliers, disparate data sources, and/or limited systems and analytical tools.

To ensure consistent goals and metrics for supply partners, it’s important to have an effective quality management system in place that provides the ability to trace, manage and report on supplier performance. According to a study conducted by Aberdeen, just over half of enterprises leverage automation tools to support measurement and monitoring of suppliers.

### 3. INVEST IN INFRASTRUCTURE
A key challenge of ensuring quality in the supply chain is communication. Many companies maintain decentralized supplier quality functions to be responsive to needs of a specific function area or business unit. While this approach can ensure responsiveness to issues, it often also is characterized by limited information/best practice sharing that could provide better economies of scale. Furthermore, many companies still maintain processes that are supported with email and fax, and maintain data in isolated and siloed repositories. In short, the tools and techniques for managing quality in the supply chain have not kept pace with the evolution of the supply chain itself.

Leading manufacturing companies are investing in infrastructure that more tightly connects their supplier ecosystem and automates what were manual or disconnected processes. By implementing an Enterprise Quality Management Solution (EQMS), these companies are now enabling process-based communications such as escalations and approvals, and automating quality workflows delivers improved visibility and control. This in turn translates into a lower cost of quality from reduced detection costs and avoided recalls.

### 4. CLOSING THE LOOP
Managing supplier related non-conformances and corrective actions is a key challenge for manufacturers. Many companies attempt to manage these critical interactions with old communication methods (e.g. email) or systems (e.g. ERP, PLM) that are not built to manage quality issues.

Leading companies are leveraging technology to connect and integrate suppliers into quality management processes. These companies are extending the features and benefits of internal quality management systems to suppliers with the aim of streamlining communication and facilitating faster resolutions.

Integrating the supply chain participants into the quality management ecosystem provides a single point of truth for both suppliers and manufacturers, and a trusted source from which manufacturers could easily extract data for purposes of supplier evaluation and management. Workflows and processes to support quality would be standardized for all the members of a supply chain, so that it would be easy for everyone concerned with an NMRS or CAPA to understand where things stood. In addition, communications would be centralized, including automated notifications related to moving a process forward (e.g. reminders or approvals).

With these best practices in place, manufacturing organizations can detect and resolve quality issues before they become costly, thereby improving supply chain efficiency and profitability.

Sparta Systems, Inc.
For more information about Enterprise Quality Management Solutions and how to improve efficiencies across the supply chain: www.spartasystems.com
How To Gain Control Over Hand Tools In Your Assembly Process

Despite having 21st century technology, we still use assembly processes that were firmly rooted in the early 20th century. Control over the assembly sequence is vital in creating sophisticated, customized, high quality products.

The assembly sequence is often left to the worker, who may or may not assemble the product in the required sequence. Assembly sequence control is vital, but how do you gain control of that process? While you may not be able to control the worker, you can control the tools. Control is easy with a DC nut-runner or tools connected to a processor.

What about hand tools? How can you control them to gain assembly sequence control? Radio equipped hand tools and communicating controllers have proven to be a very viable solution to gaining control of the assembly sequence. This recent development has brought the assembly process into the 21st century.

**RADIO CONTROL**

A torque controller and radio equipped hand tools create a system that provides robust communication between controller and tools. The type of radio that is used is important. Bluetooth technology is great for your car, but applying Bluetooth in a factory setting creates major drawbacks.

One drawback is battery life. How long does the battery in a cell phone and/or Bluetooth earpiece last? How long would those same type of batteries last in an industrial application? It is the Bluetooth communication protocols that limit battery life.

Channel hopping is another drawback. Where only one Bluetooth device is functioning there little channel hopping. When multiple Bluetooth radios are in close proximity, channel hopping becomes a nightmare.
XBee radios operating on 12 channels within the 2.4GHz frequency is a superior alternative. There is no channel hopping and battery life is much longer.

**HOW DOES IT WORK?**
The controller organizes groups of fasteners, tools and specification information into parameters. The parameters are organized into numbered jobs.

The controller brings up a job number and the associated parameters in a predetermined, hard sequence. Both the controller and tool direct the worker on the required assembly activity. Since one tool is assigned to a parameter, the controller activates only the tool associated with the current parameter.

No matter how many times a worker tries to use a suspended state tool, the controller only recognizes activity from the active tool.

The controller and the tool provide the worker with visual and auditory feedback on progressing through the parameter. A batch total and batch count are provided so the operator is always aware of where they are in completing a parameter.

In addition, visual and auditory feedback is given as each fastener is tightened. Different and immediate feedback is provided for conforming and nonconforming torque event. The batch count should not advance with a non-conforming event. As a parameter is completed, the controller should advance to the next parameter in the sequence.

The same circuit providing feedback should also generate report data with each torque event, date and time-stamped. Hand tools can no longer get out of hand.

These radio-controlled systems add value connected to the MES or operating as a stand-alone system. Either scenario provides both control and valuable data.

The sequence of assembling highly customizable equipment like tractors, heavy equipment, or aircraft is no longer in the hands of uncontrollable hand tools.

Companies have implemented these radio controlled, hand tool systems to reduce rework and warranty costs. While the ROI for these initiatives is very viable, the larger return comes from improving throughput and worker productivity.

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Visit the Newton Metre Channel on YouTube.
How To Close the Loop on the Digital Manufacturing Workflow

CAD-Based inspection software helps CAD, GD&T (Geometric Dimensioning and Tolerancing) datums, and measuring devices work together to ensure design intent and eliminate the need for 2D inspection drawings, while closing the loop on digital workflow. These are all important considerations when moving towards a Model-Based Definition (MBD) environment. CAD-Based inspection is a good practical first step toward the goal of a complete MBD environment.

The central concept embodied in MBD is that the 3D CAD model provides all of the detailed product information necessary for all aspects of the product life cycle. Engineers have wanted to harness the power of MBD for years.

In a 2005 presentation, Terrence McGowan of Boeing, stated, “The 3D model should contain everything needed from design to manufacturing, in particular, GD&T.” What this means for manufacturing and inspection is that they pull all dimensions and tolerances from the 3D CAD model instead of a 2D paper drawings. Making the CAD model the authority removes ambiguity, conflict and doubt that arise when drawings and models co-exist. With authority bestowed on the CAD model, MBD eliminates errors that result from referencing an incorrect source and makes processes more efficient. No more searching to determine correct revision levels.

In the context of the enterprise, the benefits are many and diverse. MBD is the single information source to build and maintain products, and it integrates into processes from cradle to grave. Providing definition for operations throughout the product lifecycle, there are simply too many benefits to name. Yet, to summarize MBD’s impact, one only has to look at the goals of leading aerospace companies when they began their pursuits of MBD:

- Improve quality
- Accelerate time-to-market
- Decrease time and expense

GD&T and CAD-based inspection is a great place to start when moving towards MBD. It moves the CAD model from design to a manufacturing orientation. It opens the door to many advantages where software can automate and validate steps in the simulation, manufacturing and inspection processes.

**CAD-BASED INSPECTION AND GD&T**

A necessary component of CAD-based inspection and the MBD approach to product design is GD&T, a universal symbolic and tolerancing language. Last updated in 2009, GD&T has been rigorously studied and applied by thousands of manufacturers around the world. It is often considered essential for communicating design intent — that is, that parts from technical drawings have the needed form, fit, function, and interchangeability.

The recent update includes changes in feature design, datum references and degrees of freedom, surface

Verisurf X CAD-Based inspection software uses ASME Y14.5-2009 GD&T symbols as part of its CAD interface. CAD-based GD&T annotations can be imported as part of the CAD file if supported by the program, or added to the CAD model with Verisurf X.

Verisurf X illustrates high and low tolerance deviations on associated CAD model GD&T specs.
boundaries and axis methods of interpretation, profile tolerances, the symbols and modifiers tools.

In manufacturing the direction of CAD is to 3D, however not all CAD programs provide intelligent GD&T data. Here, “intelligent” means computer readable, thereby capable of feeding downstream applications. There are two GD&T definition-data formats. Potentially confusing, both are labeled “3D annotation,” but one format is purely for display, while the other provides intelligence back to the CAD model.

The distinction is that in the display format, Tolerancing associated to the model is in the form of text. In other words, humans must interpret the GD&T information, opening the door to potential errors. The display or presentation format is similar to typing a math equation in Microsoft Word. It conveys information, but the computer cannot use it in calculations. In conversation, this approach is commonly referred to as “decorating the model.”

What makes the effort of applying GD&T to 3D models worthwhile? As part of the MBD approach, it helps users leverage data throughout product development, cutting time from processes and improving them, while avoiding investment in 2D drawings. It can even be said that 3D GD&T data provides a form of “artificial intelligence” for manufacturing and inspection.

Verisurf X provides a common software platform to drive all digital metrology devices. Benefits include, reduced training time across multiple devices, consistent reporting formats, and support for upstream enterprise databases.

3D CAD-BASED INSPECTION
GD&T defines quality requirements, and inspection then confirms these requirements are being met. For CAD-based inspection to occur, there must be GD&T representation and the inspection software must be able to import the data from the native CAD software. When intelligent GD&T data is not available, users must be able to add it to the CAD model in the inspection software.

CAD-based inspection involves inspecting physical part measurements against the CAD model. This process can be dependent or independent of how or where Tolerancing is defined on the CAD Model. Consider, for example, inspection software such as Verisurf X from Verisurf Software Inc. It connects to and controls measuring devices such as scanners and laser trackers as well as stationary and portable coordinate measuring machines (CMMs). It also accommodates both presentation and intelligent GD&T specs from CAD models. Intelligent GD&T datums are imported directly from the native CAD software with the 3D model and provide nominal dimensions. For presentation annotations, the quality or manufacturing engineer uses Verisurf to add GD&T specifications to the 3D model. Importing information from a native CAD package as a 3D CAD model with GD&T representation is a good example of moving towards an MBD environment.

Verisurf X uses the CAD model as the nominal definition to generate custom reports in industry standard formats, including GD&T constraints and color deviation maps. A Database Write feature in the program formats and sends inspection information to SPC applications and PLM databases used by major manufacturers. The feature also supports Microsoft Access and SQL Server database formats for combining Verisurf inspection data with numerous enterprise databases.

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How to Measure Flexible Printed Electronics

While still in their infancy, flexible printed electronics offer the potential for enormous growth, replacing circuit boards and conventional wiring in a wide variety of applications. Emerging technologies allow complex circuits to be printed on flexible substrates at very high speeds.

The small size (10 – 100 microns) of these devices and the speeds at which they can be produced (in excess of 600 feet per minute) point to non-contact optical measurement as the preferred technique to ensure quality and reliability.

VIEW Micro-Metrology pioneered many of the techniques for optical non-contact measurement of printed circuit boards and micro-circuits found in MEMs, recording heads and semiconductors. These same technologies are now being applied to high speed measurement of flexible printed circuits.

Flexible substrate materials pose the first challenge. These materials can be delicate and sensitive to changes in temperature and humidity. They must be handled gently, yet also held securely without damage during inspection.

Besides being delicate, flexible printed electronics may be printed on transparent or opaque materials, sometimes using inks that are not easily imaged using visible light. These materials demand that the imaging optics and illumination be extremely versatile to handle the range of situations that come up in manufacturing.

In terms of dimensional measurements, there are four main factors requiring characterization and monitoring:

**CHANNEL WIDTH**

Channel width is the number one critical dimension that must be controlled. Traditional line width or line-to-line vision measurement routines can be used with a high resolution camera, but the image analysis must account for edge roughness and grain size to provide accurate measurements.
STRIPE HEIGHT
Stripe height of the printed ink is the second most critical dimension. Average uniformity is important for controlling resistivity, as are min and max heights and especially local maxima which can literally poke-through, creating an interlayer short. Depending on the ink, stripe height can be measured using an integral laser or white light interferometer with a spot size and resolution suited for the stripe dimensions. Area multi-focus (AMF) is an optical technique for profiling that offers high speed and significantly more data for accurate 3D characterization.

DEFECTS
Flash or blobs can create shorts which can reduce performance or even render devices inoperative. Because defects can occur anywhere on the device, high densities of edge measurements are needed to identify defects by location.

OVERLAY REGISTRATION
Comparing concentricity of interlayer targets for device registration in multi-layers to tolerances of plus or minus a few microns is also required. Standard optical measurement technique with shallow depth of field is needed for these measurements.

Flexible printed circuit manufacturing is in its early stages, with little or no standardization of the material sizes or form factors. It is highly desirable to choose measurement and inspection equipment which can serve both sub-scale R&D and pilot production today, and be extended to full scale production in the future. VIEW Micro-Metrology offers a full line of measurement platforms, ranging from small benchtop systems to large format systems which can be automated with roll-to-roll material handling. All VIEW Micro-Metrology systems offer the same optics, lighting, cameras and image measurement software, enabling pre-production systems to scale efficiently to full production in the future.

VIEW Micro-Metrology
1711 W 17th Street
Tempe, AZ 85281
www.viewmm.com

Fast, Accurate Metrology for Printed Electronics
VIEW Micro-Metrology produces high accuracy video coordinate measuring systems for process control metrology.
Small in Size, Big on Performance!

OPTI-LUX™ 365 Series
UV-A LED Inspection Flashlights

Designed especially for the discerning NDT professional. These LED flashlights combine a rugged, compact lamp body with a powerful, amazingly uniform beam profile that surpasses those of more expensive inspection lamps. You have to see it to believe it!

- Four models to choose from: high-intensity and standard-intensity versions, each with or without an internal black light filter
- Coverage area up to 2.5 inch (6.3 cm) diameter at 15 inches (38 cm), with a minimum UV-A intensity of 2,000 µW/cm²
- Instant-on operation; lamp reaches full intensity immediately!
- Powered by one rechargeable lithium-ion battery with an extra battery included. Each provides 4 hours of continuous inspection between charges.
- Meets ASTM UV-A intensity and wavelength specifications for FPI and MPI
- Externally mounted black light filter with rubber bumper available as an accessory
- All models come with a certificate of compliance for both output and wavelength measurements

OPTI-LUX™ 365 Series LED flashlights come complete with lanyard, belt holster, two rechargeable batteries, two-position smart charging cradle with AC power cord, UV-absorbing spectacles and a padded carrying case.

<table>
<thead>
<tr>
<th>Model</th>
<th>Nominal steady-state UV-A (365 nm) intensity at 15 in (38 cm)</th>
<th>Visible light measurement</th>
<th>Diameter of UV-A coverage area at 15 in (38 cm)</th>
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<tbody>
<tr>
<td>OLX-365</td>
<td>10,000 µW/cm²</td>
<td>0.8 foot-candles (8.6 lux)</td>
<td>2 inch (5.0 cm)</td>
</tr>
<tr>
<td>OLX-365B</td>
<td>10,000 µW/cm²</td>
<td>0.4 foot-candles (4.3 lux)</td>
<td>2 inch (5.0 cm)</td>
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<tr>
<td>OLX-365FL</td>
<td>4,500 µW/cm² maximum</td>
<td>0.3 foot-candles (3.2 lux)</td>
<td>2.5 inch (6.3 cm)</td>
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<tr>
<td>OLX-365BFL</td>
<td>4,500 µW/cm² maximum</td>
<td>0.2 foot-candles (2.1 lux)</td>
<td>2.5 inch (6.3 cm)</td>
</tr>
</tbody>
</table>

① All UV-A intensity readings were taken with the Spectroline® AccuMAX™ Series meter, and are factory set to the values shown
② To address aerospace industry concerns

To learn more, scan QR code, call 1-800-274-8888 or visit www.spectroline.com