IMAGING™ GAUGE Quality Test System

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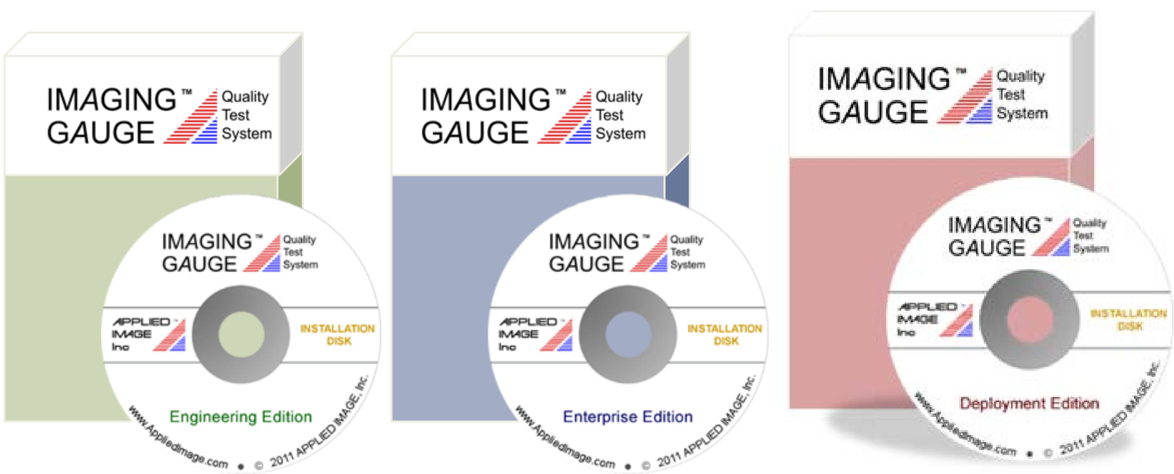
Theory Guide



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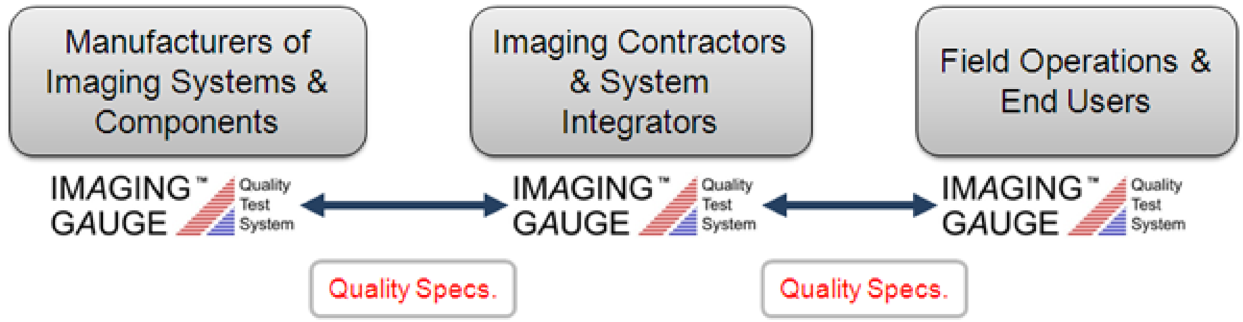
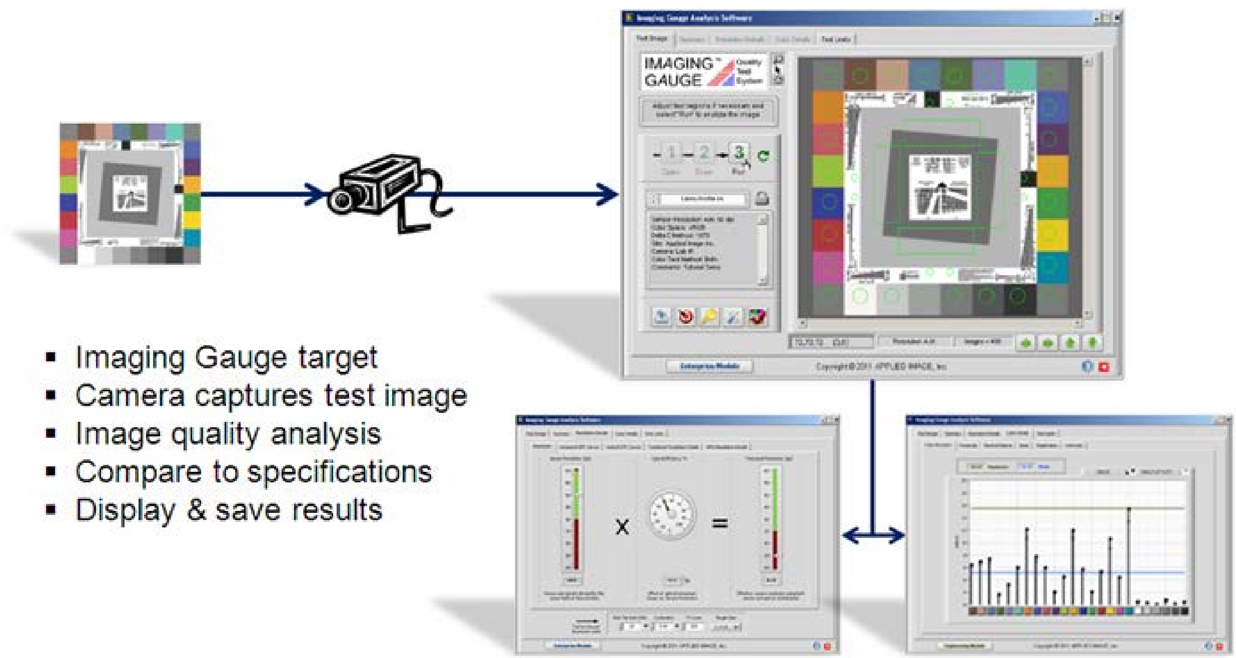
Imaging Gauge™ System Overview



The Imaging Gauge™ system was developed to standardize the assessment of image quality of camera systems. The tool is designed to be utilized throughout the life-cycle of an imaging system: from component manufacturing to system integration and deployment to quality control in the field.

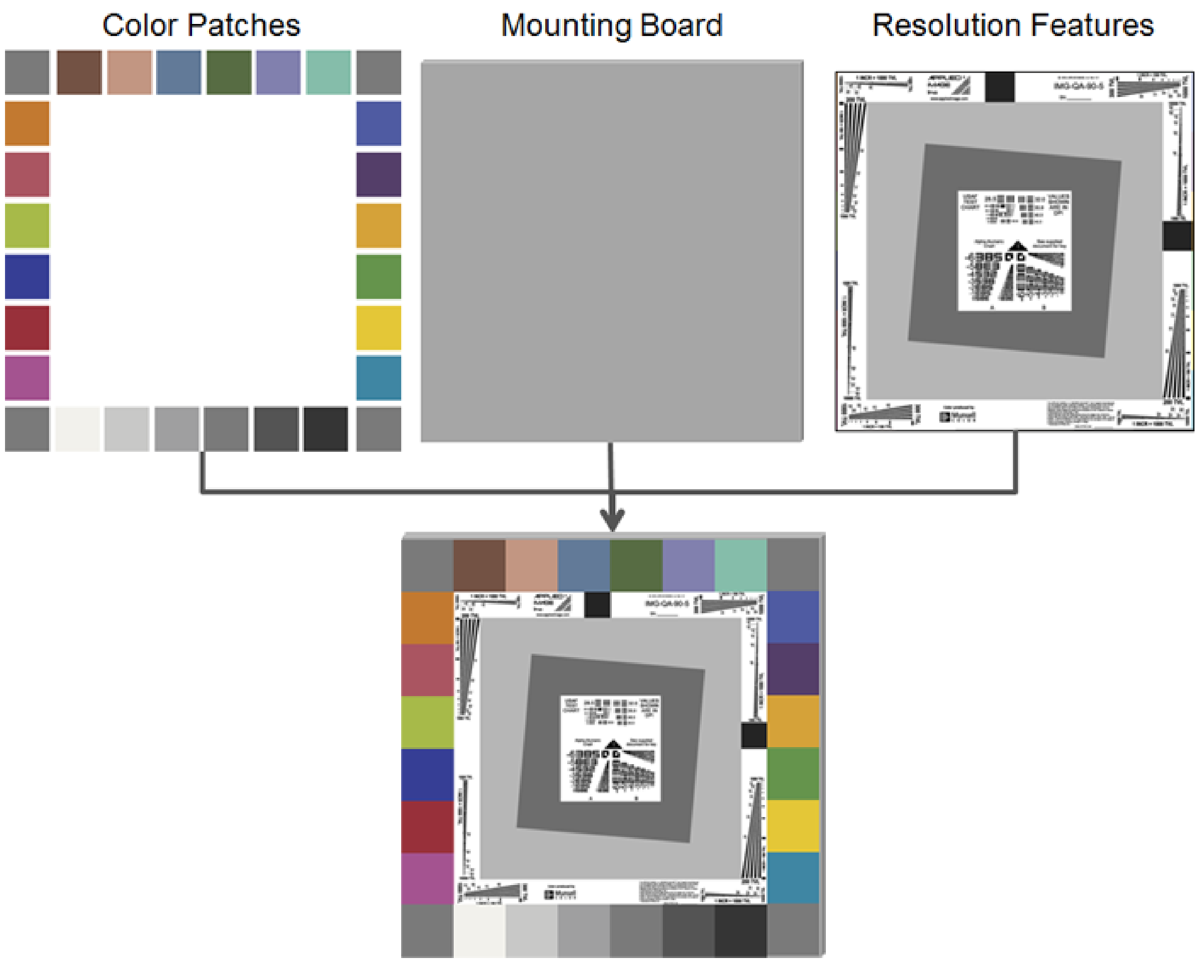


Imaging Gauge™ software analyzes a camera's image quality (IQ) using the QA-90 precision test chart. IQ metrics include color accuracy, resolution, registration, noise, neutral color balance, uniformity and tonescale. Targets are constructed with high-resolution silver-halide paper and Munsell color patches for accuracy and durability. The software is powerful but requires no specialized knowledge to get started.

Target Design & Construction

Targets have three major components: color accuracy patches, the mounting board and the resolution test feature.

Color Patches: Pigment-based color patches using the gamut of the X-Rite ColorChecker® .	**Mounting Board:** Lightweight, 6mm. rigid board of expanded closed-cell polyvinyl chloride (PVC)	**Resolution:** High-resolution silver halide target includes visual and automatic analysis features

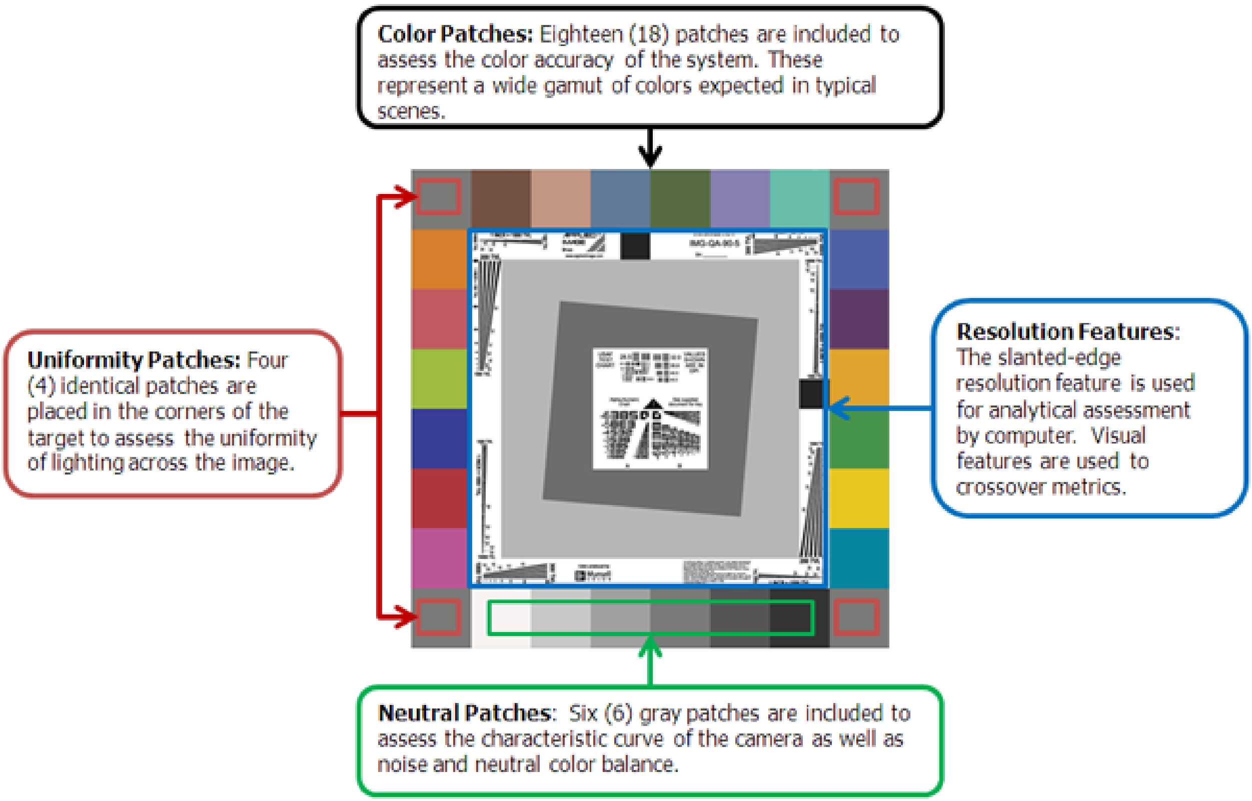


Components are 100% inspected using NIST traceable measurement equipment and assembled with high quality adhesives. Industrial Velcro is attached to the back of the mounting board to enable easy and secure placement of the targets onto the stand mounting brackets.

Target Design Overview

Imaging Gauge™ targets are designed to assess two principle image quality metrics: color accuracy and resolution. Target features are based on well-established image analysis techniques including CIE Color Accuracy methods and ISO 12233. The pigment-based color patches and silver-halide photographic media are also utilized to calculate metrics including registration, noise, neutral color balance, uniformity and tonescale.

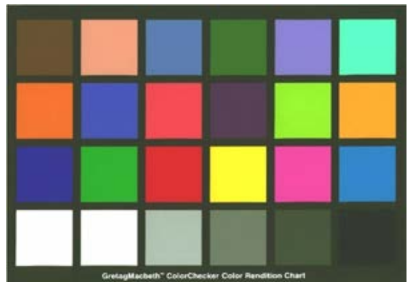
The chart below shows the image quality metrics extracted from each area of the target.



Color Patches

The color set included on Imaging Gauge™ targets is identical to those of the X-Rite ColorChecker® Classic target. These colors are a widely accepted standard in the industry. The pigment-based sheets are inspected, cut and assembled individually onto Imaging Gauge™ targets to ensure the most accurate targets possible.

Color palette definition is identical to the X-Rite ColorChecker® Classic target

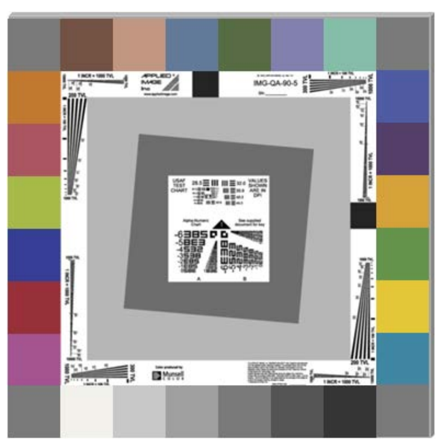


Munsell color sheets are purchased from X-Rite and cut to size

Munsell COLOR

Color sheets are 100% inspected with NIST-traceable instrumentation

Patches are assembled into targets



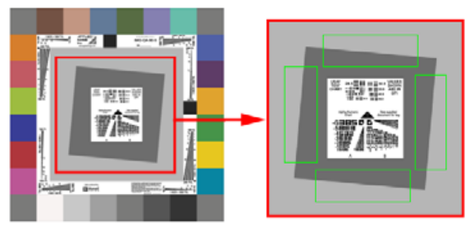
CIELab values are linked to Imaging Gauge™ Software
Note: X-Rite nominal values are shown below. Actual values used by Imaging Gauge™ may be slightly different.

Color	Name	L*	a*	b*
3 YR	Dark Flesh	39.12	13.24	15.07
2.2 YR	Light Flesh	65.43	18.11	18.72
4.3 PB	Blue Sky	49.87	-4.34	-22.29
6.7 GY	Foliage	44.26	-13.8	22.85
9.7 PB	Blue Flower	55.56	9.82	-24.49
2.5 BG	Bluish Green	70.82	-33.43	-0.35
5 YR	Orange	63.51	34.26	59.6
7.5 PB	Purplish-Blue	39.92	11.81	-46.07
2.5 R	Moderate Red	52.24	48.55	18.51
5P	Purple	31.41	20.98	-19.43
5 GY	Yellow-Green	72.46	-24.45	55.93
10 YR	Orange-Yellow	72.95	16.83	68.8
7.5 PB	Blue	29.37	13.06	-49.49
0.25 G	Green	54.91	-38.91	30.77
5R	Red	43.96	52	30.01
5Y	Yellow	82.74	3.45	81.29
2.5 RP	Magenta	52.79	50.88	-12.72
5B	Cyan	50.87	-27.17	-29.46
N9.5	White	95.37	-0.64	2.58
N8	Neutral 8	80.98	-0.03	0.27
N6.5	Neutral 6.5	66.24	-0.10	0.05
N5	Neutral 5	51.24	-0.04	0.66
N3.5	Neutral 3.5	35.37	-0.11	-0.14
N2	Black	20.52	0.35	-0.20

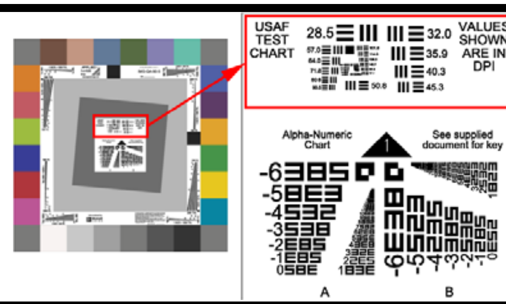
Resolution Features

Imaging Gauge™ targets incorporate three (3) human-readable features and one (1) machine-readable resolution feature to enable the correlation of automatic measurements to real-world image evaluations. The human-readable features include: an alpha-numeric feature, USAF 1951 feature and TV Lines. The machine-readable, slanted-edge feature is based on ISO 12233. All features are printed on high-quality silver-halide paper for durability and consistency.

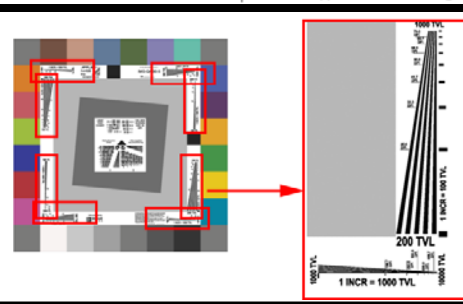
Slanted-Edge feature is based on Applied Image QA-72 test target. The I3A/ISO Camera Resolution Chart conforms to the ISO-12233 standard, "Photography- Electronic still picture cameras - Resolution measurements".



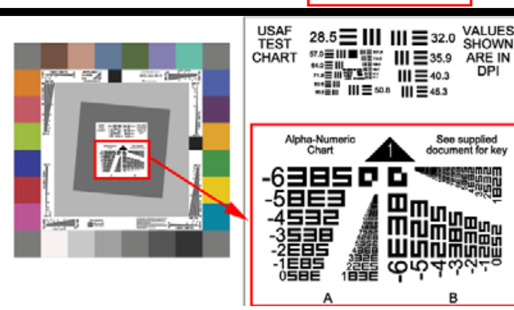
The **USAF 1951** feature is based on the Applied Image T-21 target and conforms to MIL-STD-150A for resolving power tests.



TV-Lines feature is based on the EIA-1956 Resolution Video Test Chart QA-70. For units conversion information, see the page on converting TVL to dpi and cycles/mm.



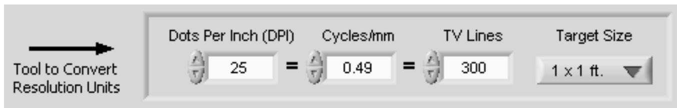
The **Alpha-Numeric feature** is based on the Applied Image T-30 target. See the table below to translate group numbers to resolution.



Group	(left) A	(right) B	cycles/mm	DPI
-12	5E2	E2E	0.250	12.7
-11	3E5	328	0.280	14.2
-10	235	E32	0.310	15.7
-9	E28	235	0.350	17.8
-8	283	538	0.400	20.3
-7	SE2	E85	0.450	22.9
-6	385	E38	0.500	25.4
-5	8E3	523	0.560	28.4
-4	532	235	0.630	32.0
-3	538	385	0.710	36.1
-2	E85	538	0.790	40.1
-1	E85	285	0.890	45.2
0	58E	E52	1.000	50.8
1	83E	823	1.120	56.9
2	2E5	532	1.260	64.0
3	32E	253	1.410	71.6
4	3E8	E82	1.590	80.8
5	35E	8E5	1.780	90.4
6	2E8	E38	2.000	101.6
7	582	235	2.240	113.8
8	832	8E5	2.520	128.0
9	3E8	83E	2.830	143.8
10	5E2	832	3.170	161.0
11	832	523	3.560	180.8
12	532	35E	4.000	203.2
13	583	32E	4.490	228.1
14	5E2	E2E	5.040	256.0
15	3E5	328	5.657	287.4
16	235	E32	6.350	322.6
17	E28	235	7.127	362.1
18	283	538	8.000	406.4
19	SE2	E85	8.980	456.2
20	385	3E8	10.080	512.0
21	8E3	523	11.314	574.8
22	532	235	12.700	645.1
23	538	385	14.255	724.1

Resolution Units Conversion

Imaging Gauge™ software automatically reports resolution measurements in dots per inch (dpi). This unit was chosen as the most widely-used and most appropriate scale for the Imaging Gauge™ target sizes. A conversion function is built in to the program to convert between dpi and two other popular units: cycles per mm and TV Lines. The conversion to TV Lines is defined for each of the three targets. The table below shows a range of these conversions.



DPI	Cy/mm	QA-90-5 TVL (12")	QA-90-6 TVL (24")	QA-90-7 TVL (48")
5	0.10	60	120	240
10	0.20	120	240	480
20	0.39	240	480	960
30	0.59	360	720	1440
40	0.79	480	960	1920
50	0.98	600	1200	2400
60	1.18	720	1440	2880
70	1.38	840	1680	3360
80	1.57	960	1920	3840
90	1.77	1080	2160	4320
100	1.97	1200	2400	4800
110	2.17	1320	2640	5280
120	2.36	1440	2880	5760
130	2.56	1560	3120	6240
140	2.76	1680	3360	6720
150	2.95	1800	3600	7200
160	3.15	1920	3840	7680
170	3.35	2040	4080	8160
180	3.54	2160	4320	8640
190	3.74	2280	4560	9120
200	3.94	2400	4800	9600
210	4.13	2520	5040	10080
220	4.33	2640	5280	10560
230	4.53	2760	5520	11040
240	4.72	2880	5760	11520
250	4.92	3000	6000	12000
260	5.12	3120	6240	12480

270	5.31	3240	6480	12960
280	5.51	3360	6720	13440
290	5.71	3480	6960	13920
300	5.91	3600	7200	14400
310	6.10	3720	7440	14880
320	6.30	3840	7680	15360
330	6.50	3960	7920	15840
340	6.69	4080	8160	16320
350	6.89	4200	8400	16800
360	7.09	4320	8640	17280
370	7.28	4440	8880	17760
380	7.48	4560	9120	18240
390	7.68	4680	9360	18720
400	7.87	4800	9600	19200
410	8.07	4920	9840	19680
420	8.27	5040	10080	20160
430	8.46	5160	10320	20640
440	8.66	5280	10560	21120
450	8.86	5400	10800	21600
460	9.06	5520	11040	22080
470	9.25	5640	11280	22560
480	9.45	5760	11520	23040
490	9.65	5880	11760	23520
500	9.84	6000	12000	24000
600	11.81	7200	14400	28800
650	12.80	7800	15600	31200
700	13.78	8400	16800	33600
750	14.76	9000	18000	36000
800	15.75	9600	19200	38400
850	16.73	10200	20400	40800
900	17.72	10800	21600	43200
950	18.70	11400	22800	45600
1000	19.69	12000	24000	48000
1050	20.67	12600	25200	50400
1100	21.65	13200	26400	52800
1150	22.64	13800	27600	55200
1200	23.62	14400	28800	57600

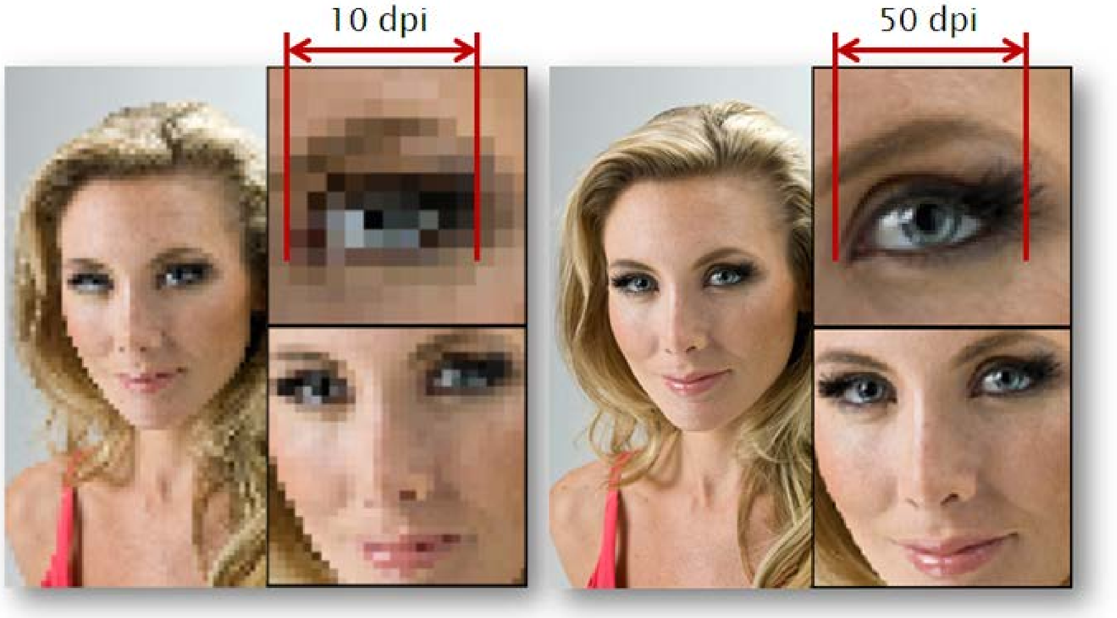
1250	24.61	15000	30000	60000
1300	25.59	15600	31200	62400
1350	26.57	16200	32400	64800

Image Quality Metrics Table

IQ Metric	Performance Assessment	Specification Units
Sensor Resolution	Ability of the imaging system to capture detail in the image	Dots per Inch
Functional Resolution	Ability of the imaging system to capture detail in the image	Dots per Inch
Color Accuracy	Ability to reproduce colors accurately for specific color spaces (sRGB, Adobe RGB, ProPhoto and ECI)	Delta E
Tonescale	Light sensitivity of the camera & correct exposure	Digital code values
Neutral Balance	Assess color shifts in the gray patches	Difference of digital code values
Noise	Granular non-uniformity of the neutral patches	Standard Deviation of Digital Values
Uniformity	Lighting and camera sensor uniformity across the camera's Field-of-View (FOV)	Delta E between gray patches
Registration	Spatial registration of the three camera color planes (red, green and blue)	Number of pixels mis-registered
Target Position	Location of the target within the Field-of-View (FOV) of the camera.	% of FOV

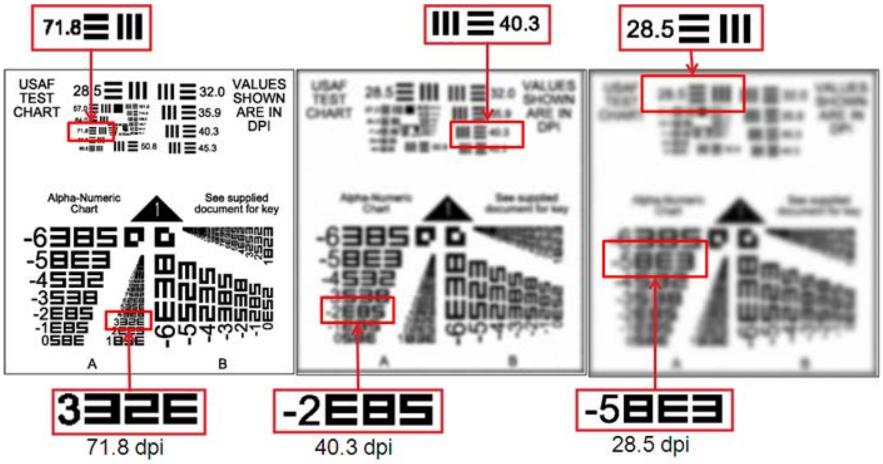
Resolution Metric Overview

The ***Resolution*** of a camera system describes its ability to resolve detail in a scene. The diagrams below illustrate the improved detail quality of the image captured at 50 dots per inch (dpi).



Visual Evaluation:

Traditionally, resolution has been evaluated visually using targets such as the USAF 1951 or Alpha-Numeric features as shown below.

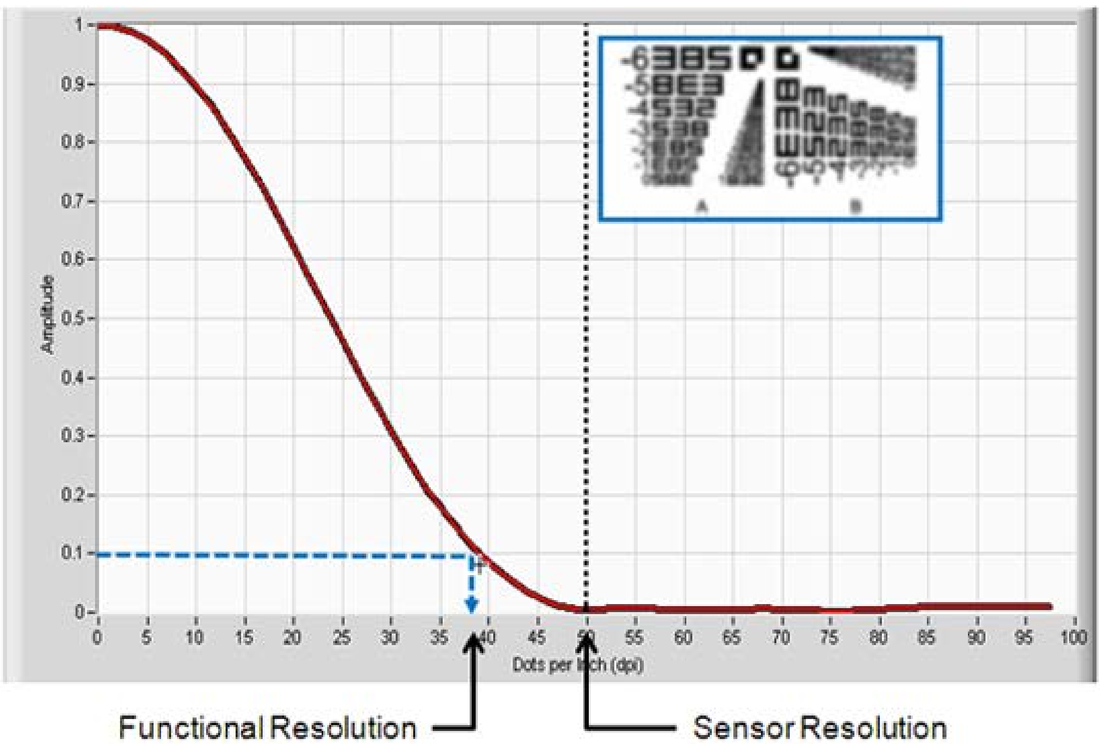


Visual evaluation has a number of disadvantages, including:

- Requires trained evaluators
- Selection of “visible” level is subjective
- Selection varies depending on evaluators personal eyesight
- Repeatability problems for each evaluator
- Measurements are quantized
- Measurements need to be recorded manually
- Measurements don’t distinguish between sensor and optical components

Automatic Resolution Measurement:

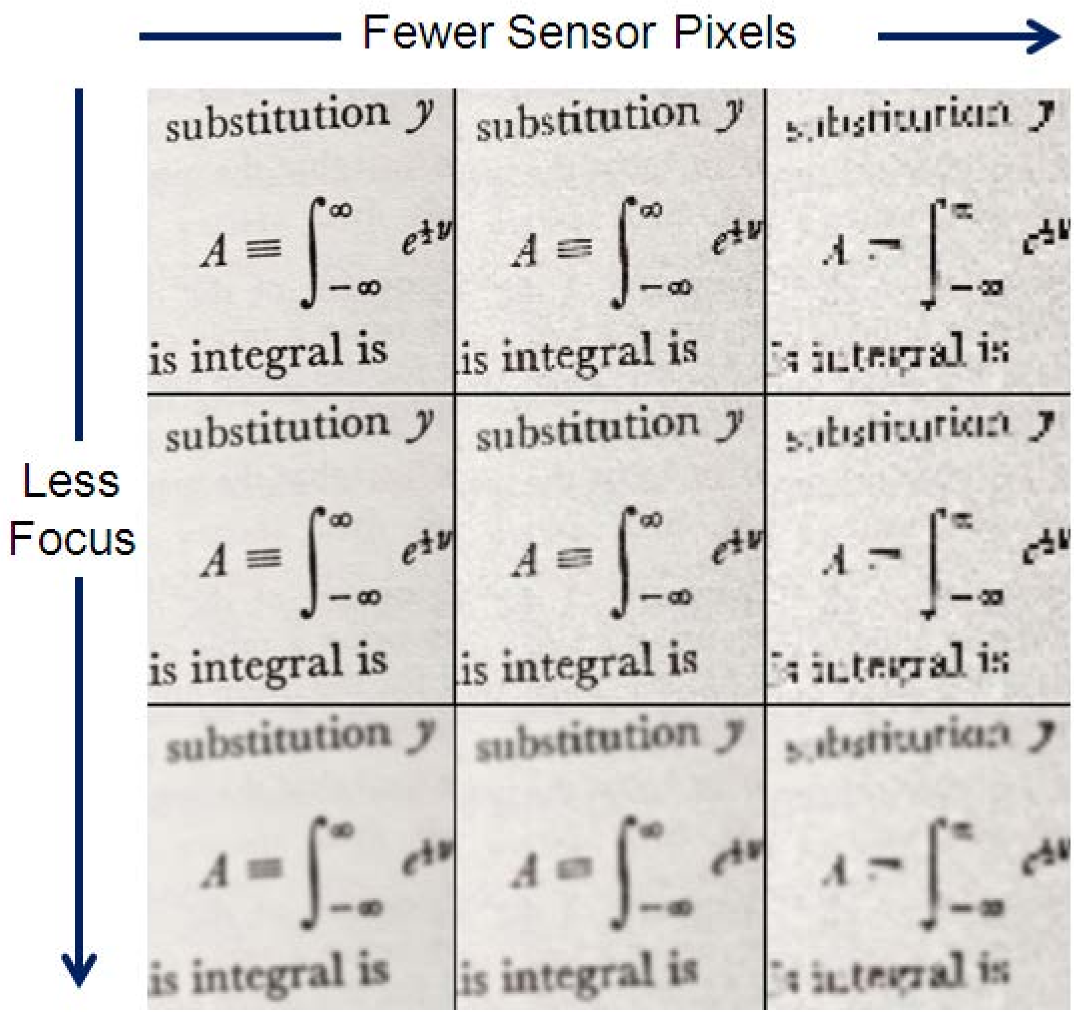
Imaging Gauge™ utilizes the “slanted-edge” technique described in ISO 12233 to allow computer-based evaluation of camera resolution. The program first calculates the Spatial Frequency Response (SFR) of the system, and then extracts the Functional Resolution based on a specified discernment limit. The SFR curve calculates the amount of detail, expressed by the spatial frequency that is captured by an imaging system. The amount of detail is expressed on the y-axis as a ratio of input to output amplitude of a signal. If detail is fully captured by the system for a given frequency, the SFR amplitude is 1. If no detail is captured (at very high frequencies), the SFR amplitude is zero.



$$Optical\ Efficiency = \frac{Functional\ Resolution\ (dpi)}{Sensor\ Resolution\ (dpi)} = \frac{40\ dpi}{50\ dpi} = 80\%$$

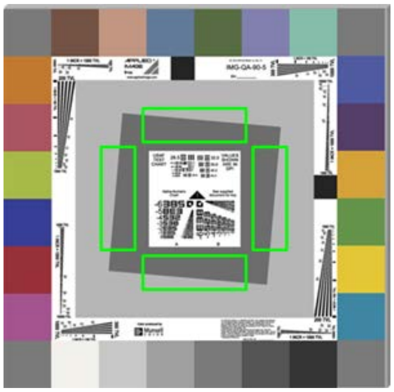
There are two main factors of the resolution performance of a camera system: sensor resolution and the efficiency of the optical components. Sensor resolution provides the maximum possible resolution that can be achieved while the quality of the optical components determines how much of that potential is retained when an actual image is captured.

The chart below shows the effect of both factors. Lower sensor resolution results in fewer pixels defining the text in the image. In the chart, image sizes have been normalized to show the "pixelation" effect for low sensor resolutions. Lower optical efficiency results in less focused, "blurry" images. Each column in the chart indicates a constant sensor resolution. Both components ultimately have the effect of lowering the functional resolution of the system.


Fewer Sensor Pixels
Less Focus
substitution
is integral is

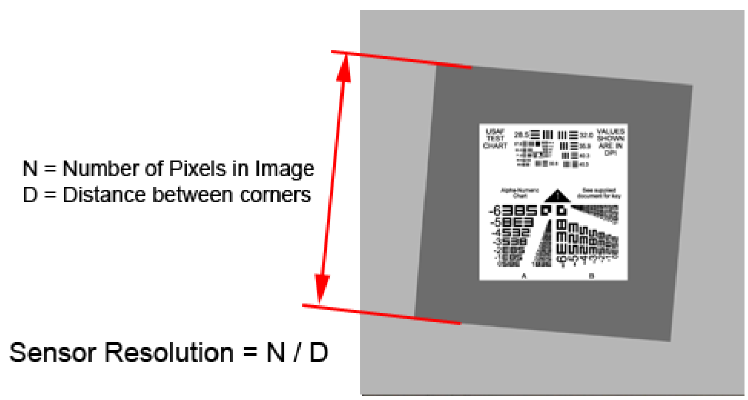
Sensor Resolution

Target Area:



Sensor resolution is the number of pixels in the camera sensor divided by the physical size of an object in the Field-of-View (FOV) of the scene. Imaging Gauge™ divides the number of pixels between corners of the SFR feature by the physical size of the SFR feature to calculate the Sensor Resolution.

Measurement Details:

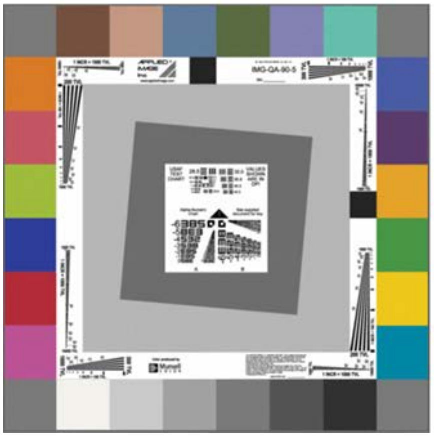


For example, if an image is captured with N = 500 pixels between corners of the slanted-edge feature, the following Sensor Resolution measurements would be reported, depending on the physical target size.

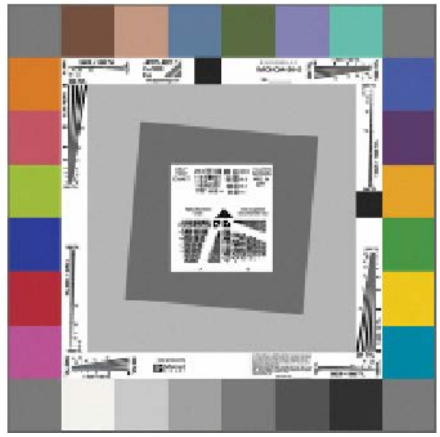
Target	Feature Size	E.g. Sensor Resolution for 500 pixels length
QA-90-5	5 inches	100 dpi
QA-90-6	10 inches	50 dpi
QA-90-7	20 inches	25 dpi

Examples:

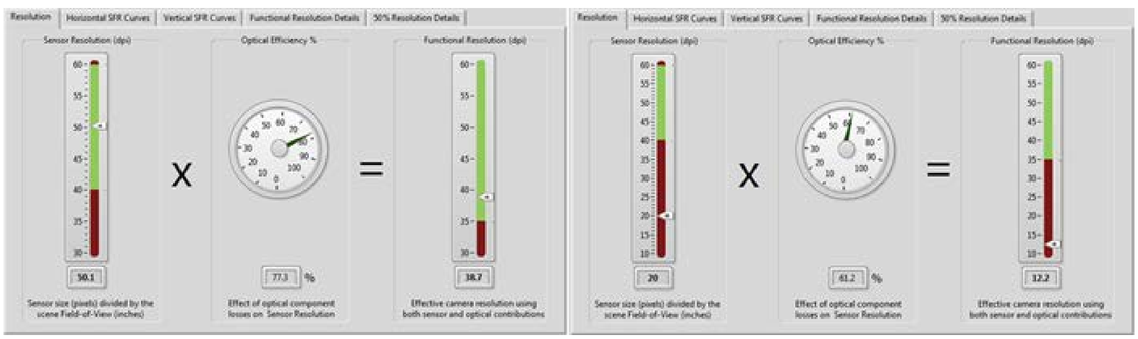
Acceptable Sensor Resolution



Low Sensor Resolution

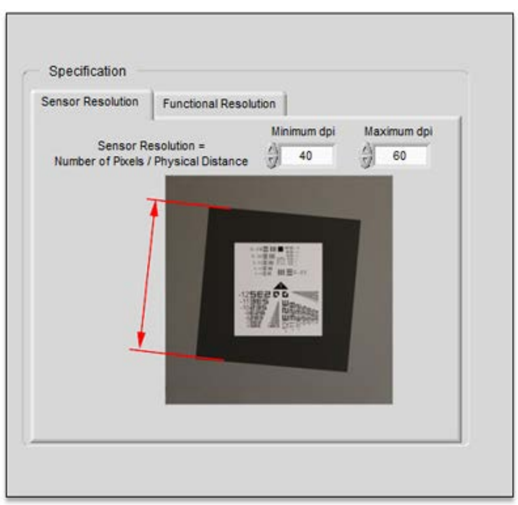


The image on the left was captured at 50 dpi while the unacceptable image on the right was captured at 20 dpi.



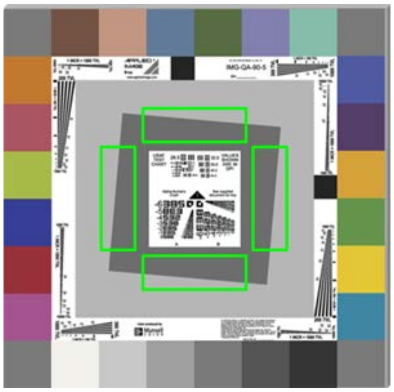
Specification Limits:

The Sensor Resolution upper and lower specification limits can be set in the **Sensor Resolution** tab. An upper limit on Sensor Resolution is intended to limit file size, if necessary.



Functional Resolution

Target Area:

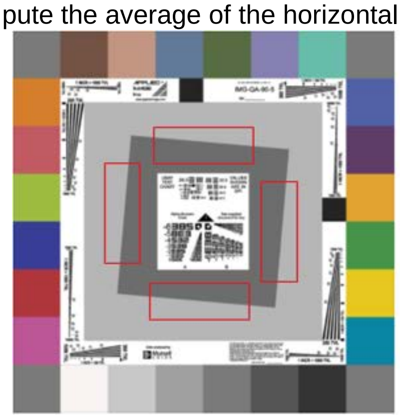


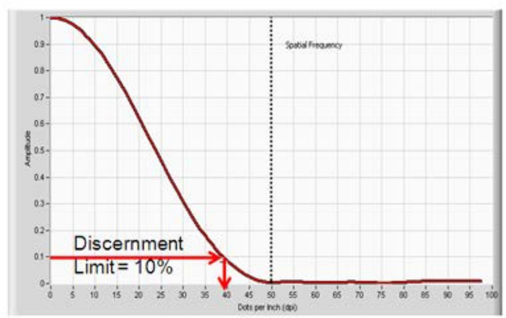
The Functional Resolution is the ***frequency*** at which the SFR amplitude equals the Discernment Limit (typically 10%). Detail in an image that has a higher frequency than this "limiting frequency" is not easily distinguished by the average human observer.

Measurement Details:

The Functional Resolution is computed using these steps:

1. Calculate the horizontal and vertical SFR curves
2. Determine where the SFR amplitude for the Visual curve equals the Discernment Limit.
3. Compute the average of the horizontal and vertical frequencies.

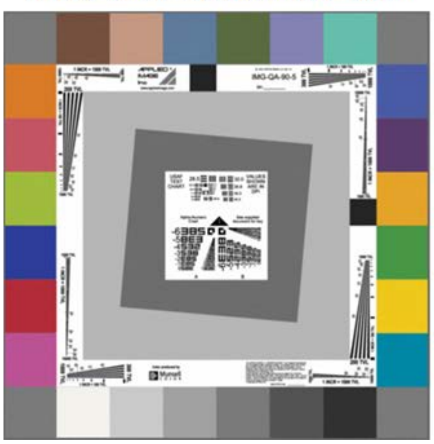




40 dpi = Functional Resolution

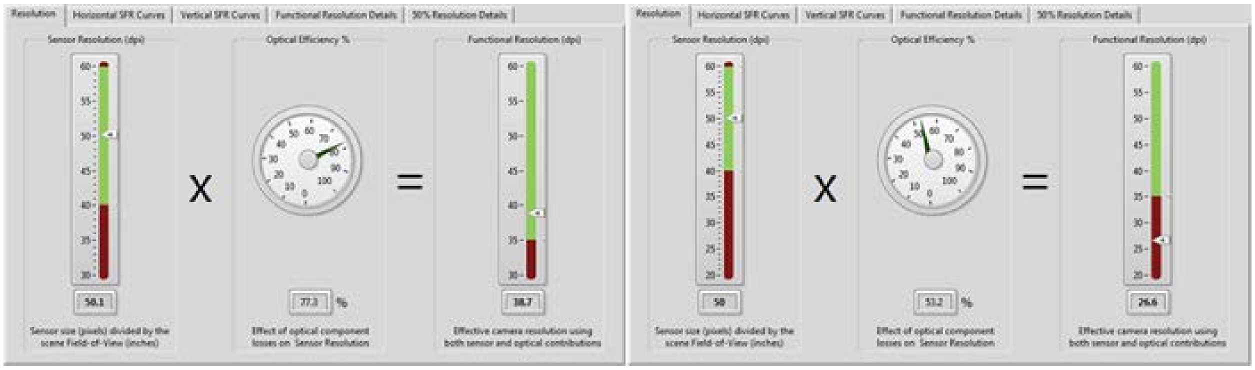
Examples:

Acceptable Functional Resolution



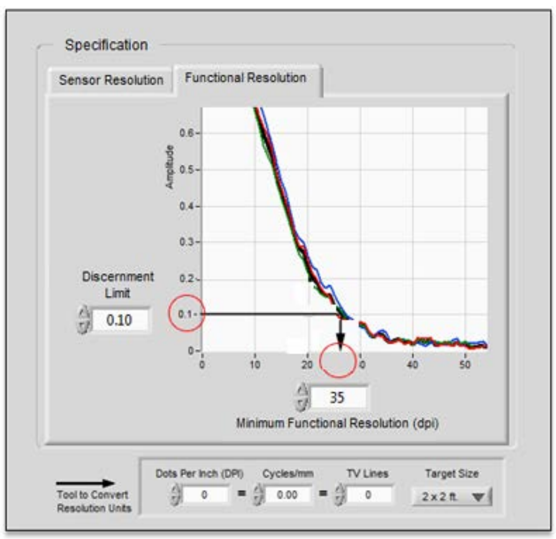
Unacceptable Functional Resolution

The unacceptable functional resolution image has equal sensor resolution (50 dpi) as the acceptable image but much lower optical efficiency (50%). The resulting functional frequency (27 dpi) is below specification (35 dpi).



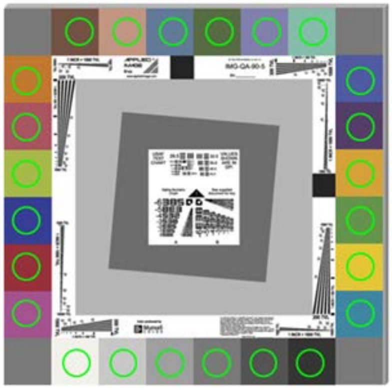
Specification Limits:

Both the discernment limit and minimum functional resolution are required to specify functional resolution. These are accessible in the Functional Resolution tab. A conversion tool is available to calculate resolution units from dpi.



Color Accuracy

Target Area:

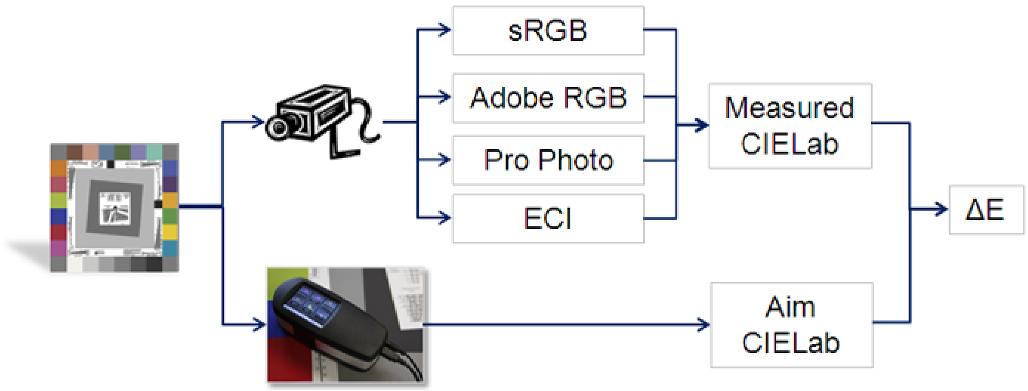


Color Accuracy is measured for each of the 24 color patches on the target. The Color Accuracy of the camera system is calculated by converting the RGB digital code values of the camera to CIELab values, then comparing them to the software CIELab aim values. The conversion of camera RGB code values to CIELab is defined by a camera's color space setting in which the images were captured. Imaging Gauge™ performs this conversion for the four most common color spaces used in cameras: sRGB, Adobe RGB, ProPhoto and ECI.

The comparison of camera CIELab values to the known aim values is accomplished using the "Delta E" calculation recommended by the International Commission on Illumination (CIE). The metric has evolved over time, with three versions available as part of Imaging Gauge™ software (1976, 1994 and 2000). The simplest of these is the earliest and a sample calculation for the dark brown color patch is shown below. For images where the calculated CIELab values are identical to the aim, the Delta E is zero. Delta E values further from zero indicate the degree to which the colors are inaccurate.

Measurement Details:

Imaging Gauge™ employs a Delta E comparison to determine the Color Accuracy of a color patch. Each color included in the Imaging Gauge™ target has a known set of CIELab values (L*, a* and b*). These values are set by the manufacturer of the patches (X-Rite, Inc.), verified by APPLIED IMAGE using a NIST traceable spectrophotometer and stored in the **CIELab Values.txt** file located in the **Support Files** folder.



$$\Delta E_{1976} = \sqrt{\Delta L^* + \Delta a^* + \ \Delta b^*}$$

$$\Delta L^* = L^*_{\text{aim}} - L^*_{\text{measured}}$$

$$\Delta a^* = a^*_{\text{aim}} - a^*_{\text{measured}}$$

$$\Delta b^* = b^*_{\text{aim}} - b^*_{\text{measured}}$$

The maximum and mean Delta E values are calculated for all twenty-four color patches. Theoretically, two colors that measure $\Delta E < 1$ are indistinguishable by the human eye.

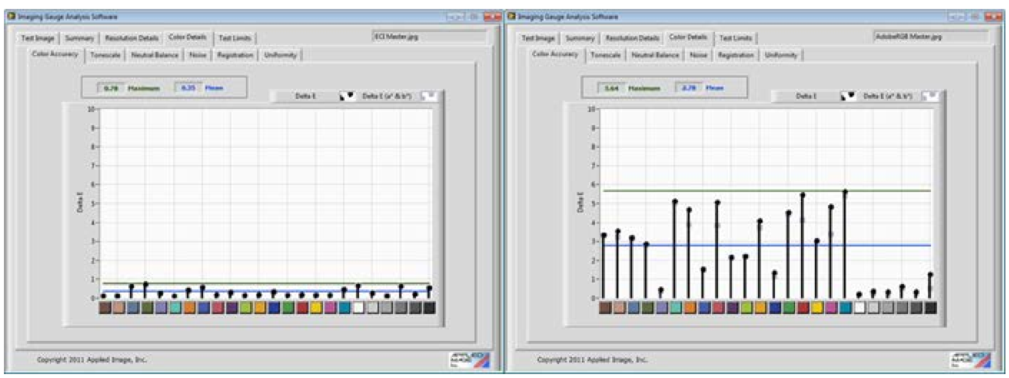
Examples:

Example Calculation	L*	a*	b*	Delta E
Aim Value	39.12	13.24	15.07	8.73
Measured Value	46.21	10.11	19.09	

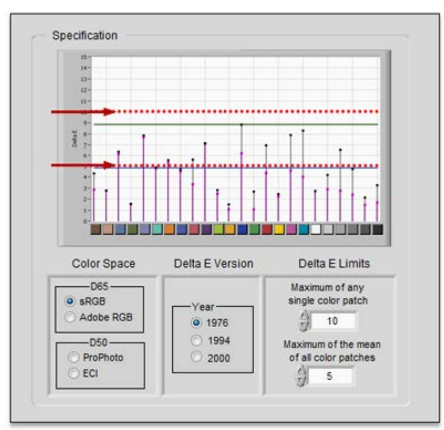
Acceptable Color Accuracy

Unacceptable Color Accuracy

The unacceptable image was created by shifting the hue angle of the captured image. This results in changes to the chromatic patches while leaving the neutral patches relatively unchanged.



Setting Specification Limits:

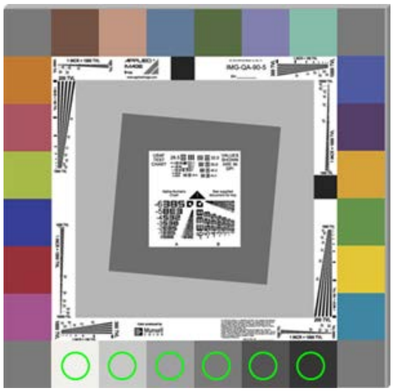


Color Accuracy has two specification limits for the Delta E metric:

Maximum is the highest allowable Delta E value for *any single* color patch.
Mean is the highest allowable value for the mean of *all twenty-four* color patches.

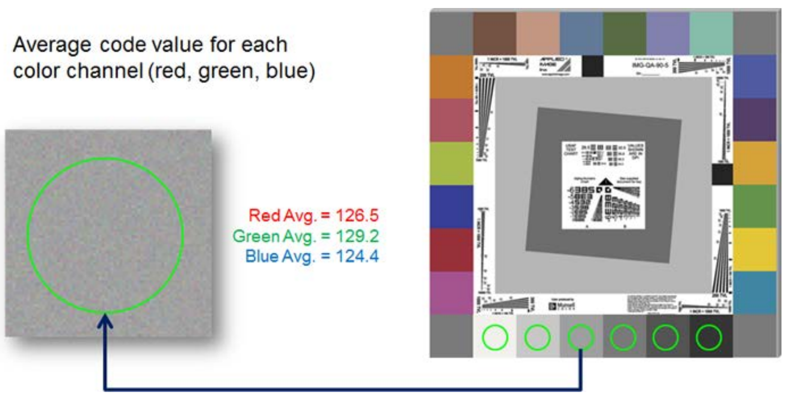
Tonescale Code Values

Target Area:



The average digital code values for the six (6) neutral patches are used to determine the tonescale of the image. Code values are plotted against the neutral density values of the target to determine brightness and contrast of the image. The aim curve is defined for each color space and can be customized for a particular camera system.

Measurement Details:



Examples:

- 20% Darker

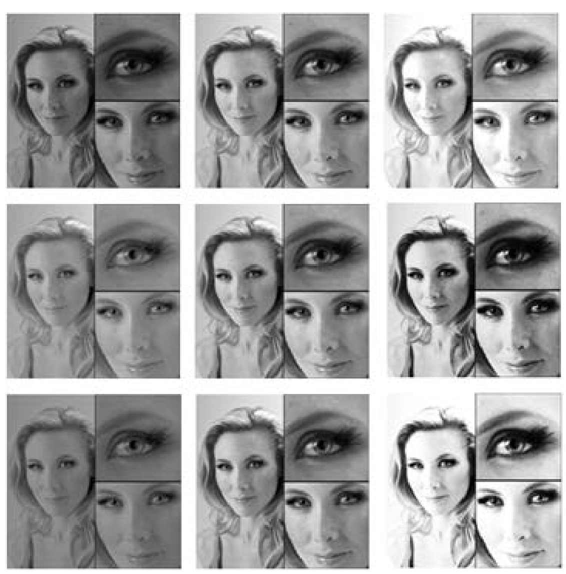
+ 20% Brighter

- 40% Contrast

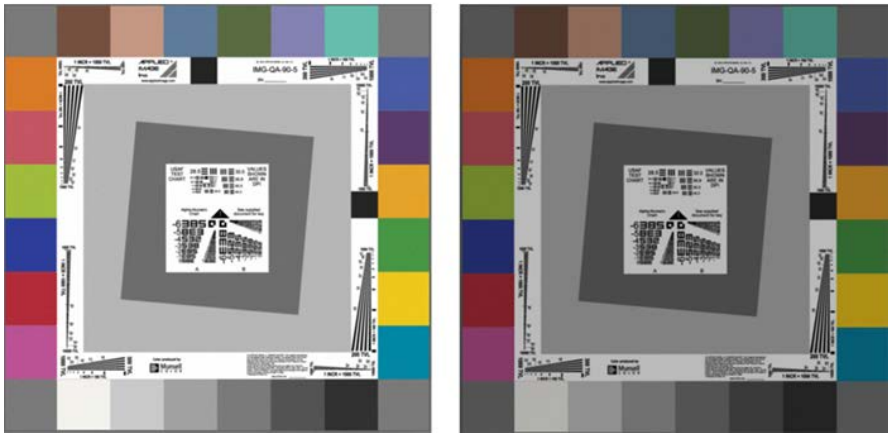
+ 40% Contrast

- 20% Brighter
- 40% Contrast

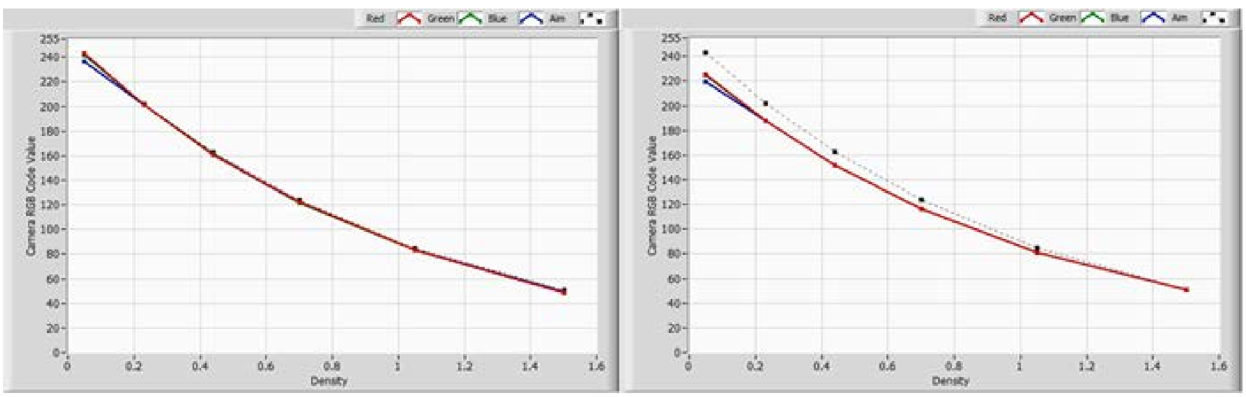
+ 20% Brighter
+ 40% Contrast



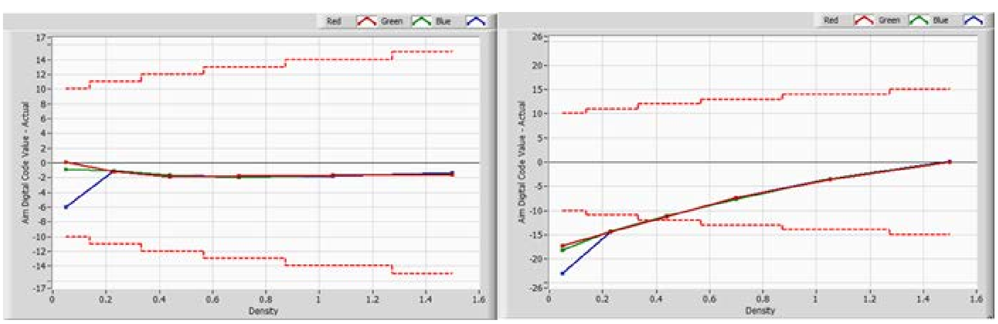
Acceptable Tonescale   *Unacceptable* Tonescale



The darker image on the right has lower digital code values for each of the density patches than the aim except for the highest density (black) patch.



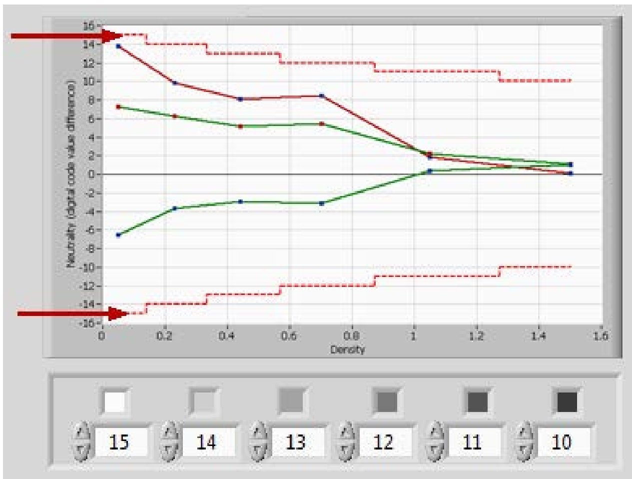
The Delta from Aim chart shows that the two lightest patches are lower than specification.



Specification Limits:

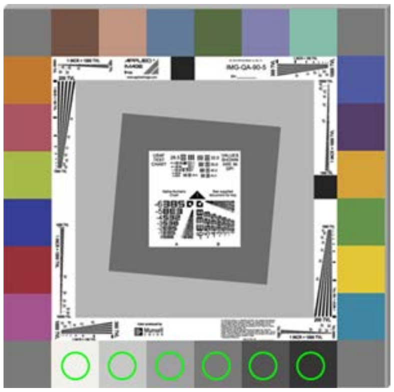
> The tonescale aim curve is dependent on the Color Test Method. When the Color Test Method is set to "Tonescale Only", the aim is defined **(1)** by entering values for each patch directly or **(2)** selecting a gamma, gain, and offset. When Color Test Method is set to either "**Color Profiles**" or "**Both**", the aim is defined by the Color Space (sRGB, Adobe RGB, ProPhoto, ECI) .

Upper and lower specification limits are established by adding and subtracting the limit from the aim value for each density patch.



Neutral Color Balance

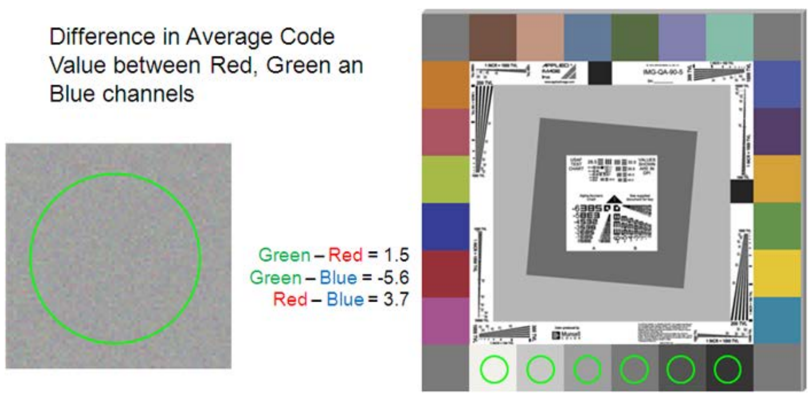
Target Area:



The average digital code values for the six (6) neutral patches are used to calculate color balance for these patches. Neutral color balance assesses the difference between the average values of the three color channels within each neutral patch.

Measurement Details:

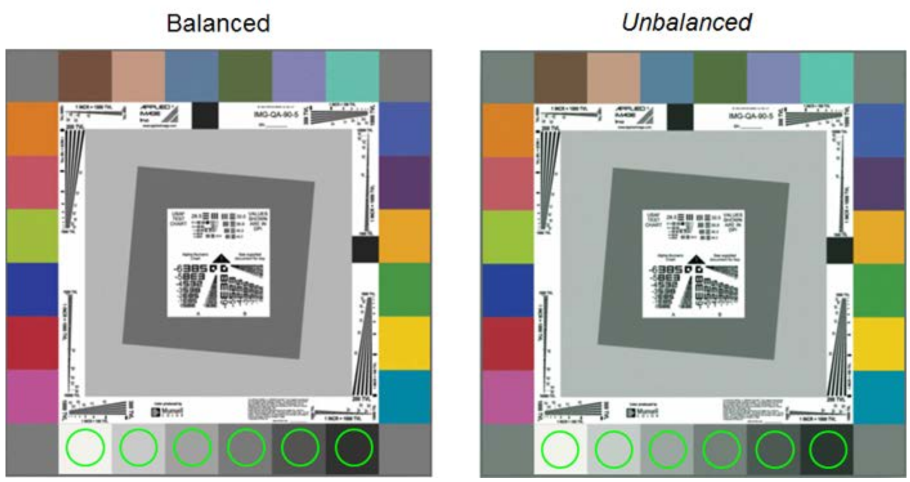
The difference between the average digital value for each of the three color planes is calculated as follows:



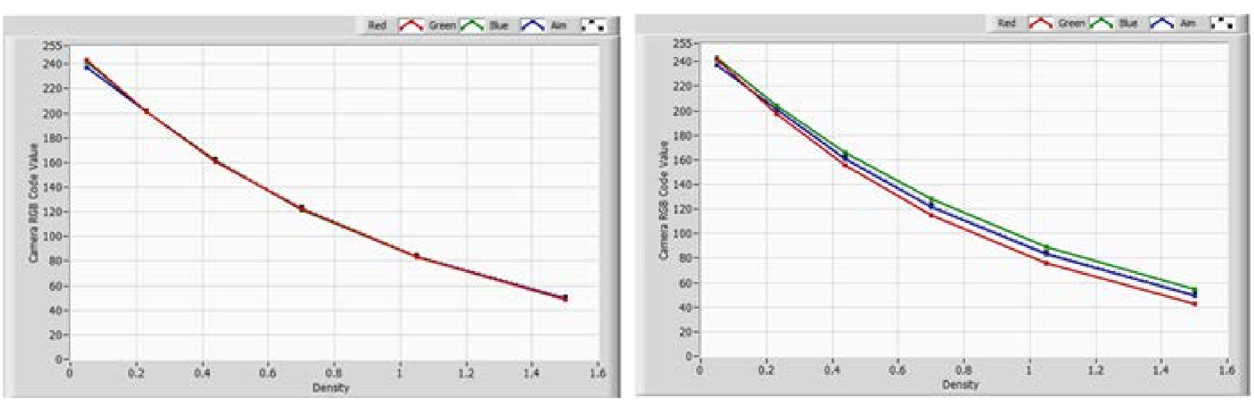
Examples:
The following example demonstrates how neutral balance is calculated for a single patch:

Average **Red** Digital Code Value = 205
Average **Green** Digital Code Value = 210
Average **Blue** Digital Code Value = 215

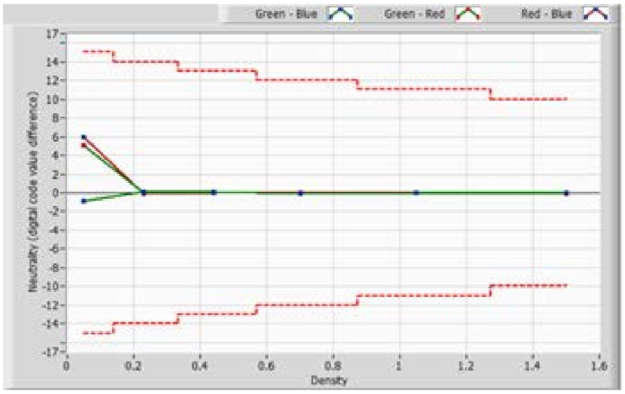
Neutral Balance Calculations:
Green - **Red** = 210 - 205 = 5
Green - **Blue** = 210 - 215 = -5
Red - **Blue** = 205 - 215 = -10

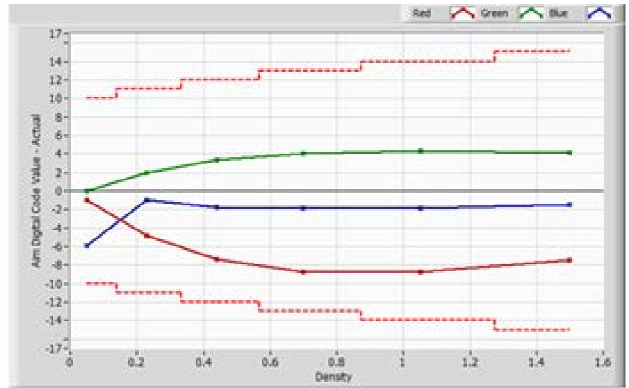


The red, green and blue tonescale lines on the unacceptable image follow the aim tonescale but diverge from each other at higher densities.

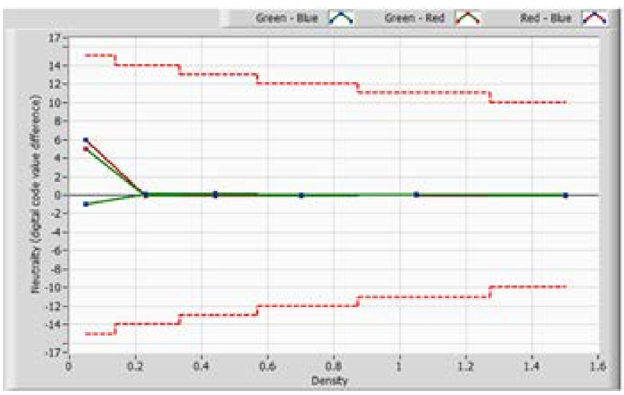


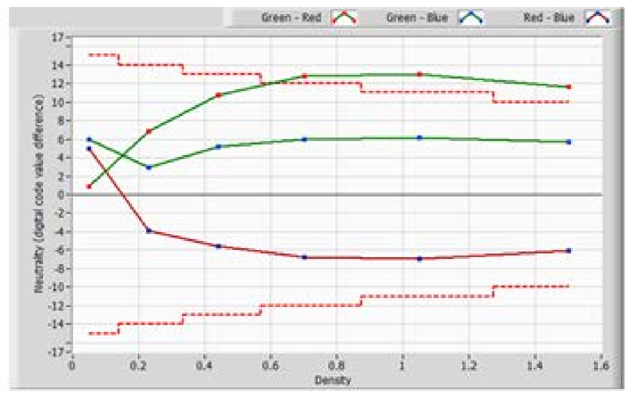
The absolute tonescale deviations from aim are within specification for both images.





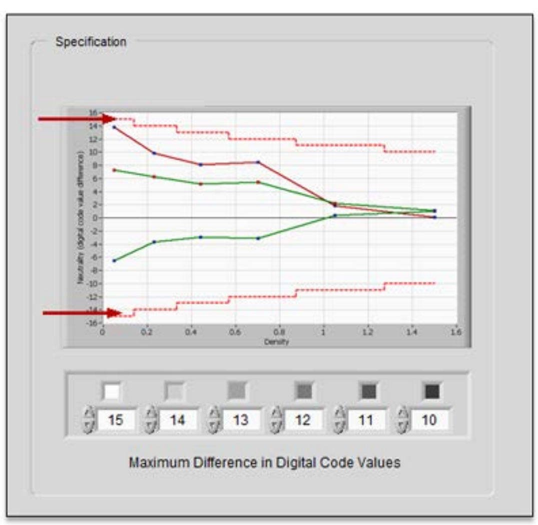
But the Green-Red values on the unacceptable image are outside of the neutral balance specification at higher densities.





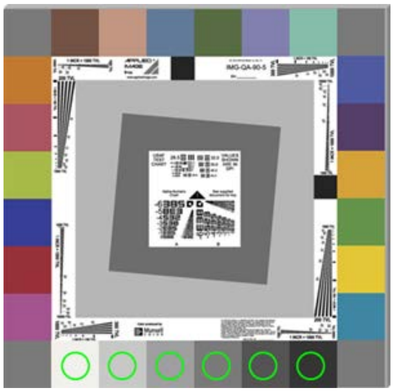
Specification Limits:

The three (3) color balance measurements are displayed with tolerance values around zero. Tolerance levels are not displayed when the Color Test Method is set to "Color Profiles" since this method only assesses color using the Delta E method. Since the neutral balance can be positive or negative the limits are added and subtracted from zero to set limits.



Noise

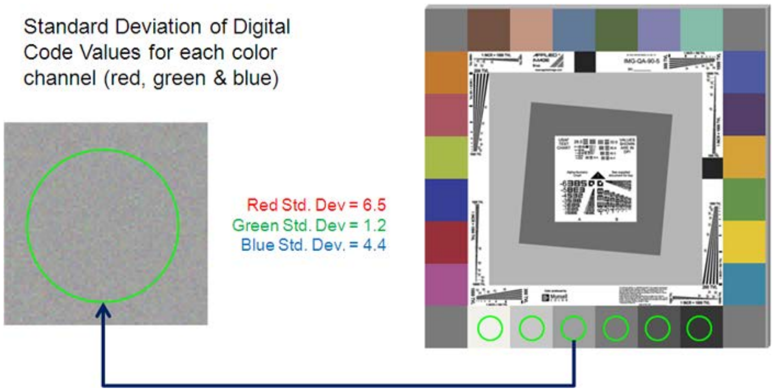
Target Area:



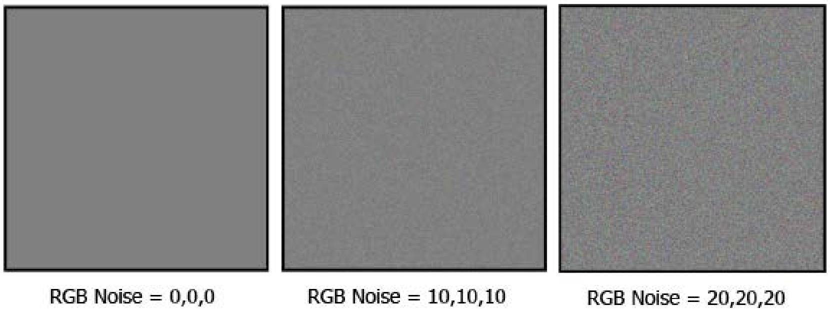
Noise is typically a function of camera settings and sensor quality. It can also be affected by the camera imaging algorithms for sharpening or noise suppression.

Measurement Details:

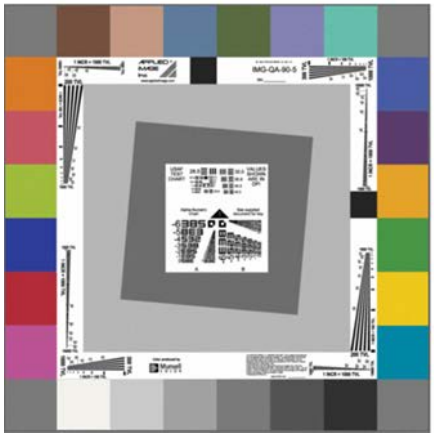
Noise is calculated for the six (6) neutral patches shown below. The calculation is the standard deviation of the red, green and blue digital code values inside the Region-of-Interest (ROI) of each patch.



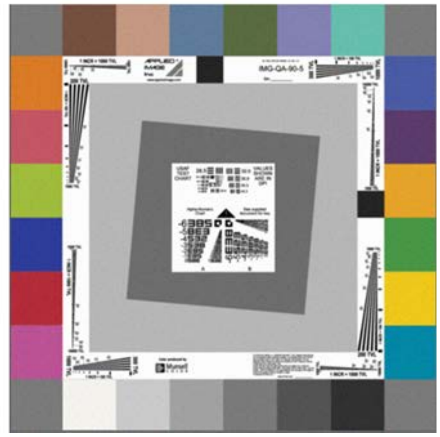
Examples:



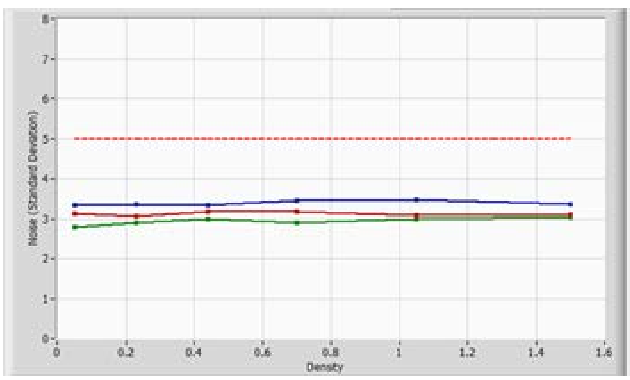
Acceptable Noise

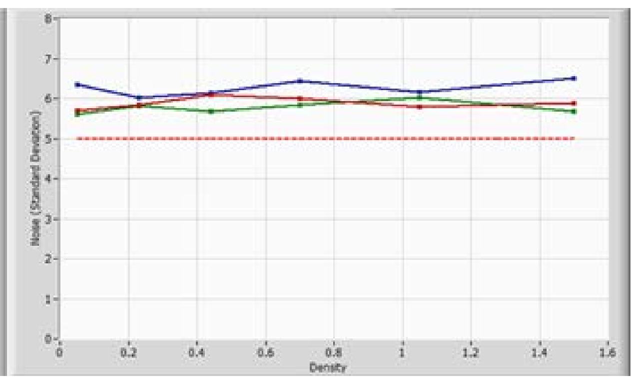


Unacceptable Noise



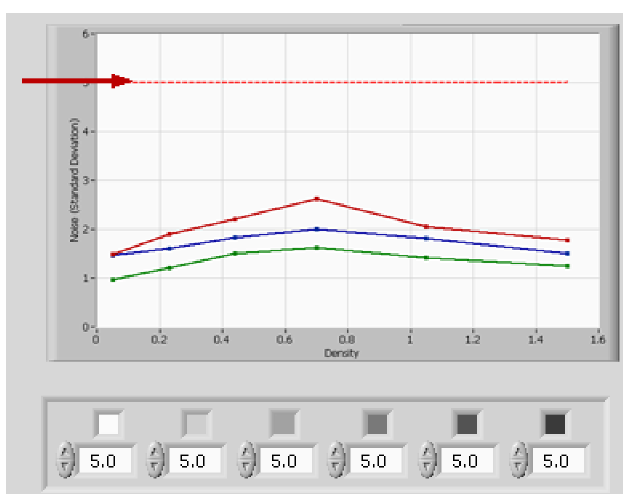
The unacceptable image shows a uniform standard deviation of approximately six digital code values in each of the neutral patches.





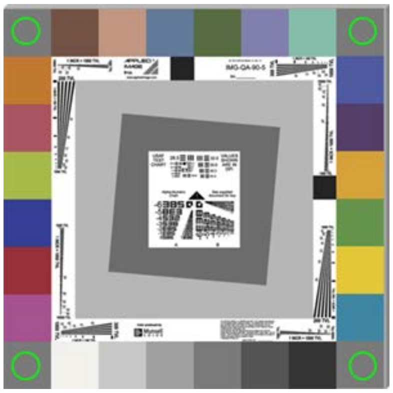
Specification Limits:

The upper specification for noise can be set separately for each of the six (6) neutral patches. The specification at each density is used for noise measured in each of the three color channels: red, green, and blue.



Uniformity

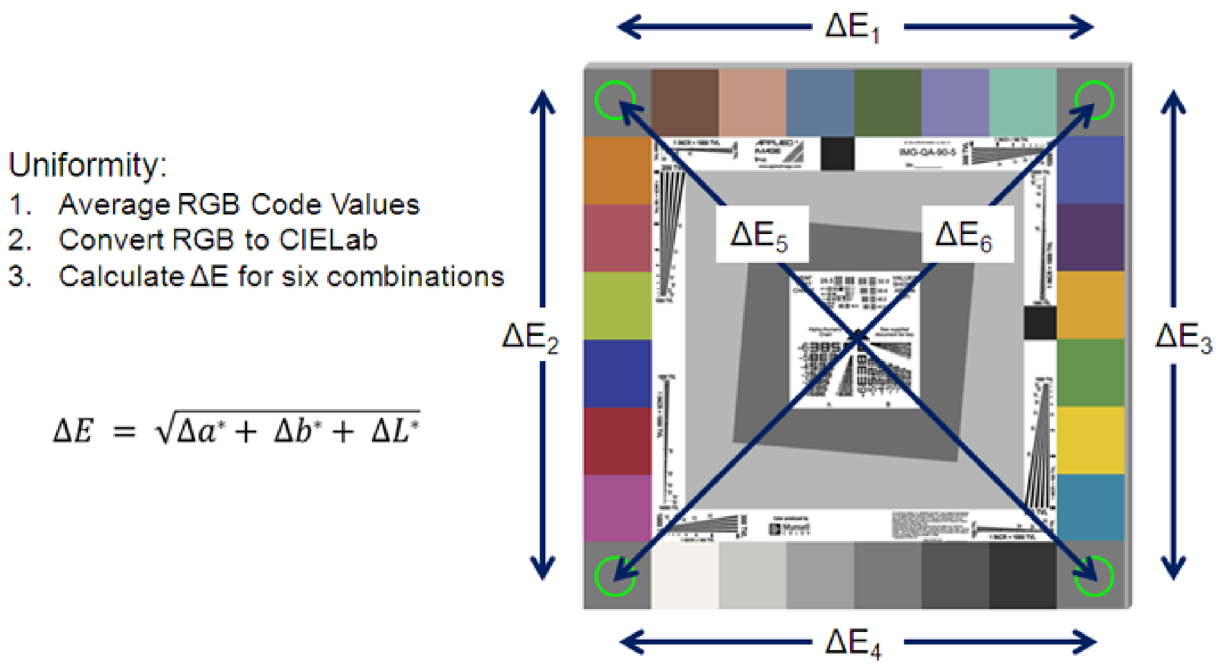
Target Area:



Identical gray patches Munsell #N5 (0.7 neutral density) are placed in the corners of the target to allow the maximum distance to be used to measure uniformity. Uniformity is measured using a *relative* Delta E metric between these four patches.

Measurement Details:

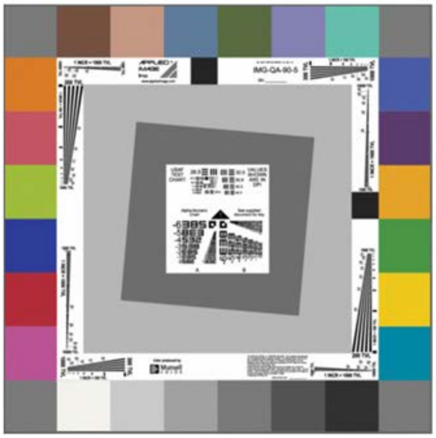
The uniformity is measured using the following steps:



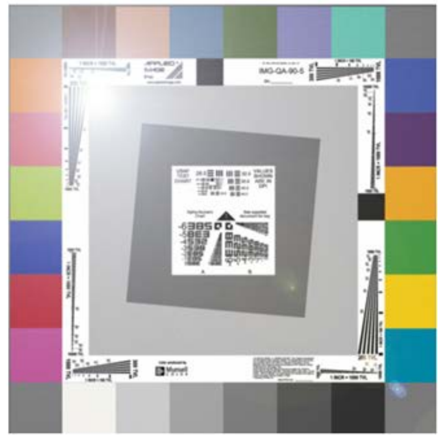
Delta E calculations are made between six (6) patch combinations

Examples:

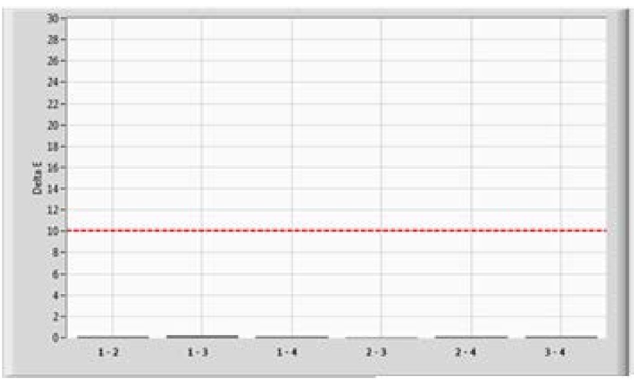
Correct Lighting

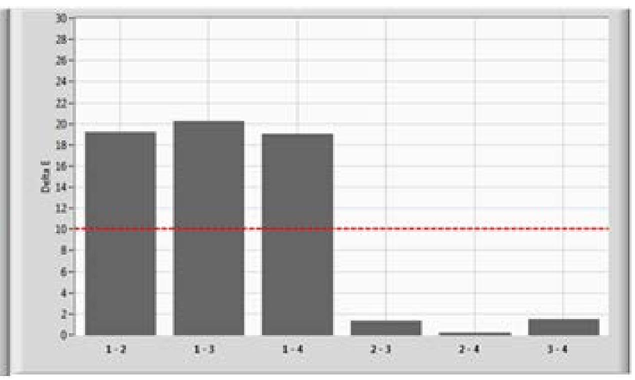


Incorrect Lighting



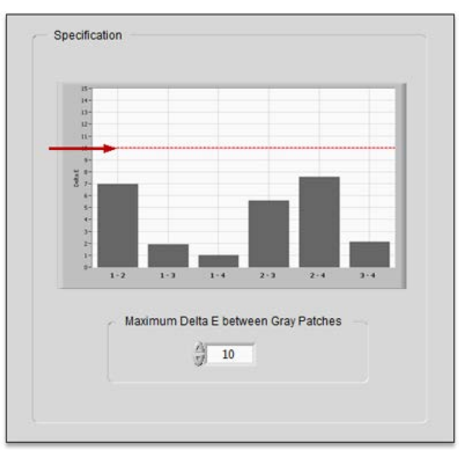
The upper left patch is significantly lighter on the unacceptable image due to a specular lighting pattern. The Delta E between this patch and the other three patches are all above specification. Uniformity between the other three patches is acceptable (below 10).





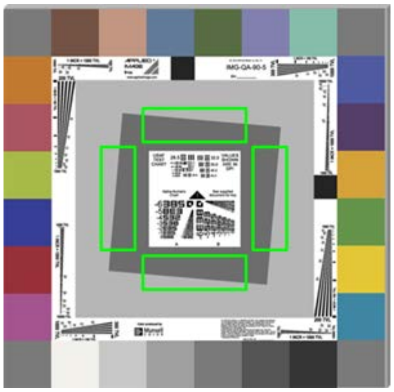
1: Upper Left 2: Upper Right
3: Lower Left 4: Lower Right

Specification Limits:
A single value is entered for the uniformity metric. This value is used as the limit for all six combinations.



Registration

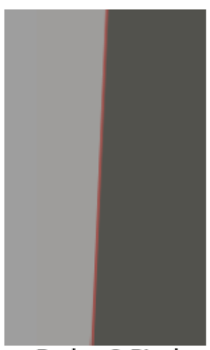
Target Area:



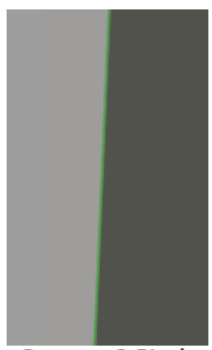
Color plane registration calculates the physical (spatial) difference in color plane location between the three color planes: red, green and blue. When color planes are not registered properly, color shifts occur at the boundaries of objects as shown below.

Measurement Details:

Registration is measured at the four (4) edges of the slanted edge SFR feature. The edges in the SFR feature all have light gray to dark neutral transitions which result in visible (and measurable) color shifts in the image. The horizontal and vertical positions of these color plane transitions are used to calculate the registration metrics for the image. Registration is the difference in pixels between each combination of colors (red to green, red to blue and green to blue).

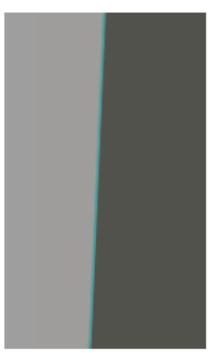


Red + 2 Pixels

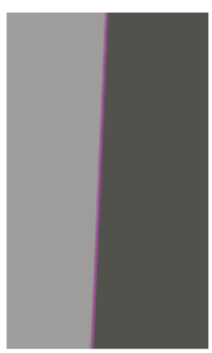


Green + 2 Pixels

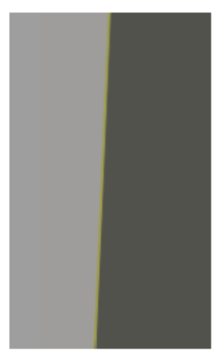
Blue + 2 Pixels



Red - 2 Pixels



Green - 2 Pixels



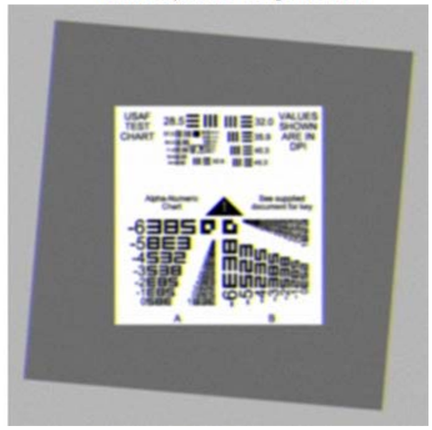
Blue - 2 Pixels

Examples:

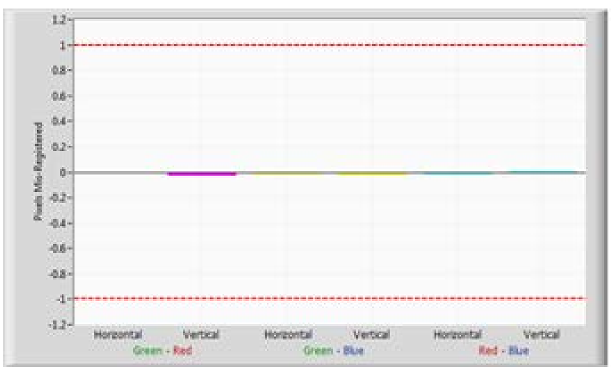
The unacceptable image below had the blue channel mis-registered by two pixels. This is visible as blue along the left edge of the slanted-edge feature an yellow along the right side of the feature.

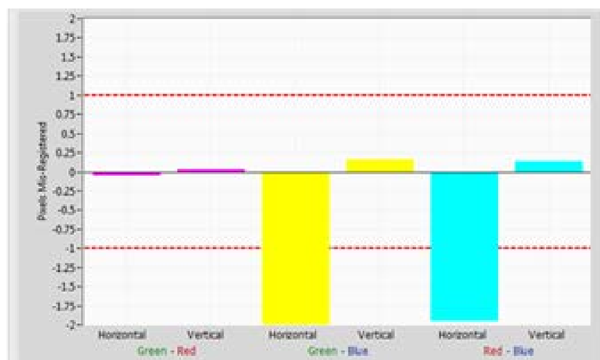
Acceptable Registration

Unacceptable Registration



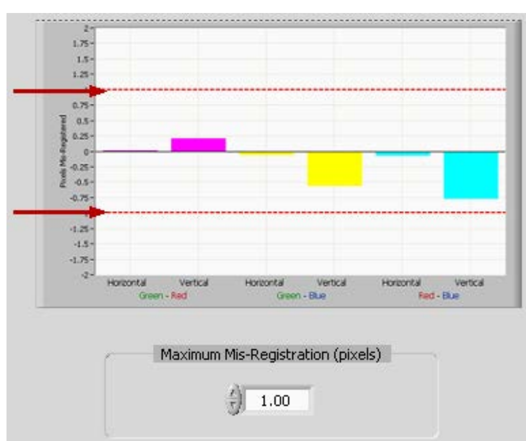
As shown in the chart on the right, the blue channel is mis-registered against both the green and red channels.





Specification Limits:

The aim for registration is set to zero. The limit entered for maximum mis-registration is used for all color combinations and has both positive and negative polarity.



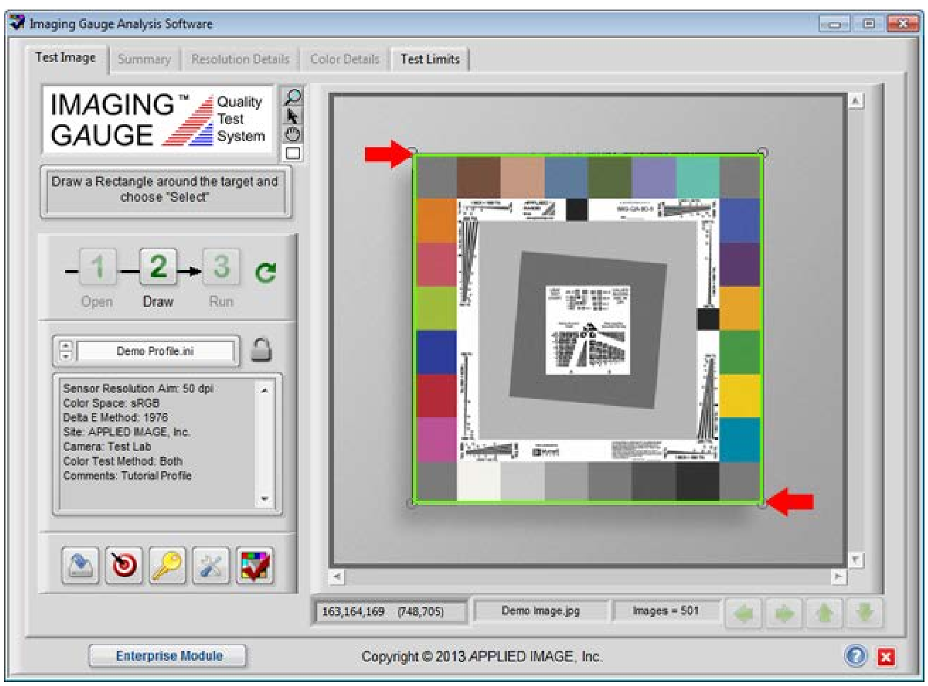
Target Position

Target Area:

The position of the center of the target is measured as a percentage of the height and width of the Field-of-View of the image from the upper left corner of the image.

Measurement Details:

The center-point of the target is the center of the square that is drawn around the target during the analysis process. The horizontal and vertical positions are then calculated as a percentage of the height and width of the overall image:



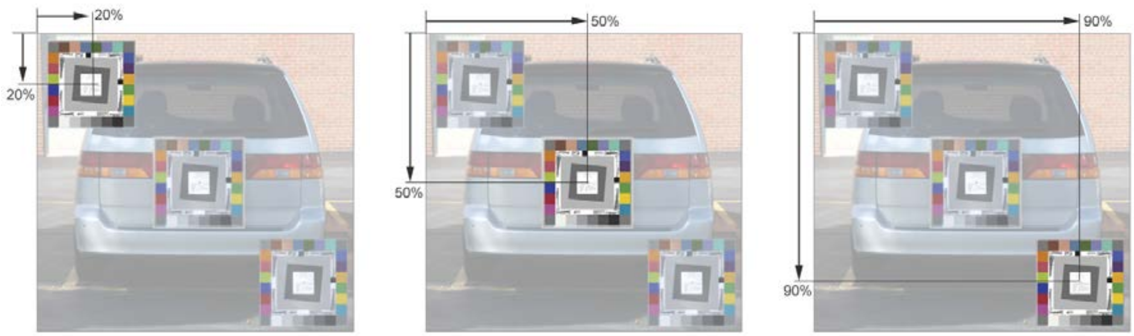
$$\text{Horizontal Position, \%} = \frac{\text{Horizontal Target Centerpoint (pixels)}}{\text{Horizontal Image Width (pixels)}}$$

$$\text{Vertical Position, \%} = \frac{\text{Vertical Target Centerpoint (pixels)}}{\text{Vertical Image Width (pixels)}}$$

Examples:

A perfectly centered target would measure 50% horizontal and 50% vertical. In the example shown below, three (3) target locations are shown:

Location	Horizontal Position	Vertical Position
1	20%	20%
2	50%	50%
3	90%	90%

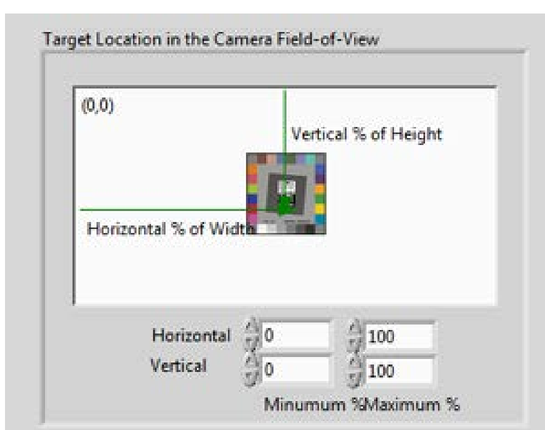


Results are displayed in the Summary Tree along with the upper and lower limits in both directions.

Measurement	Pass / Fail ?	Lower Limit	Value	Upper Limit
Target Position	PASS			
Horizontal Position, %	PASS	45.0	50.0	55.0
Vertical Position, %	PASS	45.0	50.0	55.0

Specification Limits:

The minimum and maximum position limits are set in both directions (horizontal and vertical) to completely specify the acceptable boundaries. If the target position is not required to be checked, 0% minimum and 100% maximum should be used.



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