COLTS Laboratories Test Glossary

Real Life Simulation- This test is actually five tests in one and is an attempt to simulate actual wear conditions for an AR coated lens. Haze and luminous transmittance are measured throughout the test program and represent two (or eight if all the repeats are counted) of the five tests that are completed. AR Cloth Rub, Tumble Test and Cycle Humidity Oven/Crosshatch Adhesion (CHOCA) are the other three tests and are executed in the order given.

The rub test is designed to replicate the cleaning over the life of the average prescription lens. Measurements were taken using multiple subjects to obtain the finger pressure between the thumb and forefinger during the cleaning process. Also computed were the number of wipes to get the lens clean and the number of times the lens would have to be cleaned during each day of wear over the course of three years. The five lenses would then go on to the Tumble Test, again with appropriate transmittance and haze measurements before and after the test.

The Tumble test is an abrasion test that was created based on actual clinical study data of normal wear for glass, uncoated plastic lenses and coated plastic lenses. It is used by most lens manufacturers in the US and Europe and has repeatedly exhibited good correlation to actual wear experience.

Finally the five lenses are subjected to the CHOCA test with final transmittance and haze measurements after the test. This test has also been correlated to actual wear. There are three meaningful pieces of information that the test will provide. First is the propensity for crazing (A Effects), second is spontaneous delamination (B Effects and finally the crosshatch tape pull or delamination (D Effects).

Results from each of these tests done individually, without the preceding tests were found to yield more favorable numbers than found in the consecutive manner the Real Life Simulation is done. This was a valuable piece of information since the lenses will experience all of the environmental experiences as represented by the Real Life Simulation test.

The ranking of the test is a weighted composite of the individual tests. Crazing is given a higher weight than is delamination. The reason is that the consumer, while upset and complaining about the prescription that delaminates will at least see the open and obvious problem and do something to get it fixed. The issue with crazing is that it is not usually seen until it is in its final stages of deterioration and therefore can be more serious to the wearer. This is mainly due to the fact that crazing has shown to cause “Flare” in oncoming headlights when driving at night causing momentary blindness of the driver. This presents not only a hazard to the driver and others but creates more serious liability for the seller and maker of the product.

In the end the weighted portions were reduced to one number, which is call the COLTS Index and it exists for both the front and the backsides of the lens, depending on which one the customer is interested in obtaining. Most important is that after over 170

different products tested, there has been some confirmation that the results match what has been found in the field in complaints and returns at Cole Vision. At least from an anecdotal point of view if a product can achieve a COLTS Index of 3.25 or better the potential is very small for a return of the product by the customer. Cole Vision's 2,000 stores has shown this over a 3-year period.

Bayer Abrasion- The original ASTM Bayer test was altered slightly to allow for use in the optical field. The test consists of a small pan, that has the footprint of the average telephone, that is shaken back and forth a distance of 4 inches, at 150 cycles per minute for 4 minutes.

The media, originally natural sand, then Alundum ® by Norton (Saint Gobian) of Canada has been changed to Kryptonite B available exclusively from COLTS Laboratories. This material has significantly reduced the standard deviation of the test results. The Bayer test has the smallest deviation of all of the recognized abrasion tests, making this test ideal for daily production use for quality auditing of products.

Holes that have been placed across the center section of the pan allow the lenses to protrude up through the center of each hole, allowing the abrasion to take place without loss of media. The lens farthest away from the operator is always the Standard Lens, which is an uncoated CR-39 ® lens that has been produced in tightly controlled conditions to reduce deviation in cure. Nearest to the operator is the test lens.

Following the test, the two lenses are compared. Each had a hazemeter measurement completed prior to abrasion and another following abrasion. The resulting haze gain of the test lens is divided into the resulting haze of the Reference Lens to establish a ratio of how many more times abrasion resistant the test lens is compared to the Standard Lens. The Standard Lens is used as the basis for comparing all lens materials and coatings.

This test is the most popular abrasion test completed at COLTS Laboratories.

Tumble Abrasion- This test is the second most popular test at COLTS Laboratories. The Tumble test is an abrasion test that was created based on actual clinical study data of normal wear for glass, uncoated plastic lenses and coated plastic lenses. It equates to about one year of normal wear. It is used by most lens manufacturers in the US and Europe and has repeatedly exhibited good correlation to actual wear experience.

The Tumble Test is based on abrasion by a number of different types of media in a barrel that is mixed with a natural sawdust-type material. As lenses fall repeatedly in the barrel a natural wear type of abrasion is imparted. The length of the test for the front surface of the lens is 20 minutes. Important also is that the ISO Reference Lens, which is an uncoated CR-39® lens that has been produced in tightly controlled conditions to reduce deviation in cure, is used as the control lens. 3 are used in each test.

Following the test the three lenses are compared. Each had a hazemeter measurement completed prior to abrasion and another following abrasion. The resulting haze gain of the test lens is divided into the resulting haze of the ISO Reference lens to establish a ration of how many more times abrasion resistant the test lens is compared to the ISO Reference lens or uncoated hard resin lens. The ISO lens is used as the standard for all lens materials and coatings upon which to base results.

Steel Wool Abrasion- This test has been a popular test for many years largely because steel wool is easy to find and use in demonstrations by sales people and retail dispensers. The test is a simple mechanism that slides a piece of steel wool back and forth, at a slow speed, against the surface of the lens for a specific length of time. This test has the highest deviation due to the high variability of the steel wool.

The ISO Reference Lens, which is an uncoated CR-39® lens that has been produced in tightly controlled conditions to reduce deviation in cure, is used as the control lens. 3 are used in each test.

Following the test the lenses are compared. Each had a hazemeter measurement completed prior to abrasion and another following abrasion. The resulting haze gain of the test lens is divided into the resulting haze of the ISO Reference lens to establish a ration of how many more times abrasion resistant the test lens is compared to the ISO Reference lens or uncoated hard resin lens. The ISO lens is used as the standard for all lens materials and coatings upon which to base results.

Eraser Abrasion- This test is most popular in Japan and Germany. Although those tests differ slightly from the US MIL Spec version that we use with the exception that we have mechanized the test to bring repeatability and reliability to results.

What appears to be a common pencil eraser, but which has standard specifications, is attached to a weighted arm that is slid back and forth across the lens surface to abrade it. An ISO Reference Lens is used for comparison. This Reference Lens, which is an uncoated CR-39® lens that has been produced in tightly controlled conditions to reduce deviation in cure, is used as the control lens. 1 lens is used in each test.

Due to the narrow band of abrasion that is created by the eraser and the difficulty achieving reliable and repeatable numbers using the hazemeter, the results are subjective.

Abbe Value - This value is the inverse of the dispersion value (constringence value - British) and represents the amount of chromatic aberration in a lens material. An Abbe Refractometer is used for this measurement, where the refractive index of the material is measured three times, each time with a different illuminant source. The three measurements are then entered into a formula, the result of which is the Abbe Value.

Air Assist, (air cannon) Impact Test - This device allows for much greater equivalent heights (or energy). An air cannon, which has been used by many in the industry for 20 years or more, fires the ball downward (replicating FDA) to the lens and impact energy is computed via two photo cells (speed trap) just prior to impact. Using the Bruceton technique, the residual strength (that strength over and above what the FDA requires) of the lens can be determined. Fifty-five lenses will provide a 95% confidence level for rendering the mean value of the strength of the lens.

Anti-Fog- This test is designed to replicate moving from cold to warm areas while wearing lenses. Test lenses are subjected to ambient conditions for a period of time and then moved over 50° water vapor conditions in which there is a controlled environment. Laser light source energy is used in combination with a photometer to measure flux as light passes through the lens. The time for the lens to fog to 80% of the original value is the criterion for passing this test (EN and ASTM).

Boiling Saltwater - This is an environmental test to assess the robustness of a lens coating. The lens is boiled in de-ionized saltwater for a period of time and inspected for flaws.

Boiling Water - This test is to simulate tinting a lens. The lens is boiled in de-ionized water for a period of 15 minutes and inspected for flaws.

Chemical Resistance - The average dresswear lens may see chemicals common to the household. The tests offered include acetone, alcohol, hair spray, Windex®, bleach, Salt water, methanol, Formula 409® and ammonia but is not limited to those if other products are desired. The surface of the lens is subjected to the chemical for a period of 24 hours (ASTM).

Cloth, Dry Abrasion - Dry cleaning cloths typically used to clean AR coated lenses are subjected to a dry 4000 cycle mechanical rubbing to replicate the typical action seen in normal use. This is done on the surface of an uncoated standard control lens. Haze is measured before and after the test to determine abrasion characteristics. It is best to perform several tests to compare results. Three standard control lenses are used to determine an average in each case.

Cloth, Dry for Cleaning Oil - Dry cleaning cloths typically used to clean AR coated lenses are subjected to 20 cycles of mechanical rubbing to replicate the typical action seen in normal use. This is done on the surface of an uncoated standard control lens with a measured amount of oil applied to the surface. Haze is measured before and after the test to determine cleaning capability. It is best to perform several tests to compare results. Three standard control lenses are used to determine an average in each case.

Cloth, Dry Cleaning for cleaning Oil and Dirt - Dry cleaning cloths typically used to clean AR coated lenses are subjected to 20 cycles of mechanical rubbing to replicate the typical action seen in normal use. This is done on the surface of an uncoated standard control lens with a measured amount of oil applied to the surface as well as a precise mix of ingredients that replicate “dirt”. Haze is measured before and after the test to determine cleaning capability as well as possible abrasion to the lens. It is best to perform several tests to compare results. Three standard control lenses are used to determine an average in each case.

Cloth/Liquid Cleaning for cleaning Oil - Cleaning cloths used with liquid cleaners, liquid cleaners, and moist towelettes typically used to clean non-AR coated lenses and AR coated lenses are subjected to 20 cycles of mechanical rubbing to replicate the typical action seen in normal use. This is done on the surface of an uncoated standard control lens with a measured amount of oil applied to the surface. Haze is measured before and after the test to determine cleaning capability. It is best to perform several tests to compare results. Three standard control lenses are used to determine an average in each case.

Cloth/Liquid Cleaning for cleaning Oil and Dirt - Cleaning cloths used with liquid cleaners, liquid cleaners, and moist towelettes typically used to clean non-AR coated lenses and AR coated lenses are subjected to 20 cycles of mechanical rubbing to replicate the typical action seen in normal use. This is done on the surface of an uncoated standard control lens with a measured amount of oil applied to the surface as well as a precise mix of ingredients that replicate “dirt”. Haze is measured before and after the test to determine cleaning capability as well as possible abrasion to the lens. It is best to perform several tests to compare results. Three standard control lenses are used to determine an average in each case.

Coating Thickness – This test will determine the thickness of a coating on a lens. Measurement of both AR and abrasion resistant coating thickness’ are available through the use of a spectrophotometer. All samples are to be plano but “absolute” measurement requires an additional sample of the same substrate without the coating. The index of the coating must also be supplied for absolute measurements.

Contour Mapping – A Rotlex Class 1 automated instrument measures the lens power through a lens. Two and three dimensional topographical displays are produced for spherical power error, and unwanted astigmatism for progressive and aspheric lenses (ISO).

Cosmetic Inspection - A complete inspection of lenses using common industrial and laboratory techniques are used to report findings regarding: Pits,

scratches, bubbles, flow lines, stress, unidentified particulate, edge cracks, etc. Findings relate to both the coating and the lens underneath the coating or substrate.
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Crosshatch Adhesion- This is a quick test to roughly find out whether there is good adhesion of a coating to the surface of a lens. A tool is used that holds 5 razor blades. It is dragged across the lens surface so as to leave penetrating slices into the lens surface. This is done again at 90 degrees from the first marks and directly across them leaving 25 tiny squares. Tape is pressed onto the surface of the lens and pulled at a 180° after a timed interval. The amount of coating that comes off within the crosshatched area determines a number from 0 to 5, where 5 is pristine.

This test can be combined with other tests e.g., the Cycle Humidity Oven Crosshatch Adhesion Test and the Boiling Water Test.

Cycle Humidity Oven/Crosshatch Adhesion (CHOCA)- Lenses are placed in sealed desiccators, which maintain 95% relative humidity. The oven maintains 65°C for a period of 8 hours then the lenses are removed and inspected for crazing, delamination and then tape is placed on the crosshatched area and pulled (done three times in succession) to evaluate this more severe delamination test.

All lenses are left in ambient laboratory conditions (72°F; 50% RH) for 16 hours and then the steps are repeated twice more. Typical effects seen from this test are crazing and delamination of the coating.

This test has been correlated to actual wear through clinical studies. If effects are seen at the end of the first cycle (day) there is a very high probability that the same effects will be seen during the first 6 to 10 months of normal wear. Effects seen during the second cycle have a very high probability of being seen in one to two years of normal wear. The third cycle illustrates effects that may be seen after two years.

Cycle Humidity / QUV Accelerated Weathering - In this environmental test, lens samples are placed in the QUV instrument for period, alternating from between 340nm UVA, heat, and then a period of condensation. The lens sample is then inspected for damage including crazing and delamination of coating.

Deionized Water Soak (AR) - This is an environmental test to assess the robustness of a lens coating. The lens is soaked in de-ionized water for a period and then inspected for flaws.

Dry Heat - In this environmental test samples are submitted to three days at 8 hours of 180-degree F dry heat. This test is an attempt to simulate dashboard conditions.

Environmental Durability (AR) - The environmental test subjects the lenses to alternate humidity and UVA/heat cycles for a period of 20 hours and includes a specified 'wet cloth rubbing' prior to the cycling in the QUV Accelerated Weathering chamber and then inspected for flaws.

FDA 50" Impact Resistance - This will be the standard go, no-go test that has been in use for over 30 years in the eyewear industry. Sample sizes of 55 lenses will allow for statistical confidence of 95% in the results. Reference: FDA, ANSI Z80.

Frame/lens Strain - This environmental test attempts to duplicate the effects of a lens in a metal frame in various climatic conditions. A slightly oversized lens is mounted in a metal frame to create a stress situation and subjected to a three-day cycle humidity test. The lens is inspected each day for possible crazing and delamination of the coating.

Haze - This optical test will determine the percent of haze in a lens that may cause a decrease in visibility to the wearer. The lens is placed in a hazemeter through which the dispersion of light caused by haze can be measured (ASTM).

Heat/Cold – In the natural environment changes in temperature are normal. This test is an attempt to replicate that environmental condition. Samples are exposed to hot "dashboard" conditions and then slowly allowed to change to frigid conditions all in a dry environment.

Index of Refraction - Index of refraction is computed using standard refractometer equipment and specially prepared samples.

Mechanical Inspection - A complete inspection of lenses using common industrial and laboratory techniques are used to report findings regarding: sphere power, front surface power, cylinder power, prism power, diameter, center thickness, edge thickness, location of PAL fitting marks, etc. Findings are based on ANSI Z80 recommendations and on what is now being used in the industry.

Oven Heat (AR) – An AR coated lens is placed in an oven for an hour to determine if the lens coating will craze or delaminate. The test is an attempt to replicate high heat conditions that may be encountered in a car or on the dash of a car,

Reflection Color (AR) - A spectrophotometer is used to accurately measure this AR coating characteristic of a lens with an AR coating. The X, Y, Z tristimulus values shall be used to calculate the Y, x and y Chromaticity Coordinates. Calculation follows that standard specified by the International Commission on Illumination (CIE) established in 1931.
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Salt Water Soak (AR) - In this environmental test sample lenses are submersed in a salt-water solution for 100 hours and inspected for effects. All effects are recorded by digital photography.

Spectral, Luminous and Mean Reflectance Curve (AR) - A spectrophotometer is used to accurately measure these AR reflective characteristics of a lens with AR coating. The X, Y, Z tristimulus values shall be used to calculate the Y, x and y chromaticity coordinates. Calculation follows that standard specified by the International Commission on Illumination (CIE) established in 1931.

Spectral Analysis- This spectrophotometer test for sunglass products will yield nearly all information typically required to meet transmittance requirements in standards such as ANSI Z80.3, ISO - 8980-3, CEN 94 and the Australian standards. Information is provided for minimum traffic light recognition requirements as well as luminous transmittance information for illuminants C (Photopic), C (Scotopic), A, D65, Average Blue Light, UVA and UVB. X, Y, Z tristimulus values and the x and y chromiticity coordinates are also given as well as the spectral graph and the table of measured values from 290nm to 800nm.

Thermal Shock - This environmental test attempts to simulate dropping a warm pair of spectacles into the snow. Sample lenses are placed in an oven at 180° F for a specific period of time and then into a freezer at 0° F for the same period. Lenses are then cosmetically inspected for damage.

Tint Color Hue (color shift)- Black dye is used to determine if the lens will absorb dye in a manner that will make the color hue in the lens inconsistent across the surface of the lens. A control lens is always included for comparison purposes.

Tint Consistency – Black dye is used to determine if the lens will absorb dye in a manner that will make the transmittance in the lens inconsistent across the surface of the lens. This is a subjective test to determine what is more commonly referred too as 'blotching' or “Streaking”. A control lens is always included for comparison purposes.

Tint Rate - This test allows specific dye to be absorbed for a fixed amount of time. The transmittance is then measured and compared to the control lens. This test is primarily used for determining the hardness of a hard resin lens.

Tint/Color Fade/ QUV Accelerated Weathering - In this environmental test, lens samples are placed in the QUV instrument for a 20 hour period, alternating from between UV, heat, and then a period of moisture. The lens sample is then inspected for change in color or fade in color due to UV. This is a COLTS Laboratories SOP based on what is now being used in the industry: a copy of which can be sent to you by request. Six plano lenses with a 5.50D to a 6.50D base curve for each lens type must be supplied in any lens edge configuration.

Tumble - In this abrasion test that was created based on actual clinical study data of normal wear for glass, uncoated plastic lenses and coated plastic lenses. It is used by most lens manufacturers in the US and Europe and has repeatedly exhibited good correlation to actual wear experience. Sample lenses are placed into a barrel approximately 9" (28cm) wide and 18" (44cm) in diameter. Media in is placed in the barrel, which will abrade the lenses.

UV Resistance - The QUV Accelerated Weathering Tester is recognized in ASTM, ISO, ANSI, SAE, DIN, JIS, BS and other standards groups. This device attempts to replicate out door weathering conditions on an accelerated basis using lighting that closely simulates sunlight. Resistance to UV is one of the tests offered on this device. This is a COLTS Laboratories SOP based on what is now being used in the industry: a copy of which can be sent to you by request. Five plano lenses with a 5.50D to a 6.50D base curve for each lens type must be supplied in any lens edge configuration.

UV Transmittance - A spectrophotometer is used to accurately measure the ultraviolet transmittance of a lens. This is a COLTS Laboratories SOP based on what is now being used in the industry: a copy of which can be sent to you by request. Three plano lenses with a 5.50D to a 6.50D base curve for each lens type must be supplied in any lens edge configuration.

UV Dye, UV Transmittance and Block - This test is designed to replicate the normal use of a lens when worn outdoors in sunlight by the use of a QUV Accelerated Weathering device. The objective is to determine if the UV absorption properties of the lens created by the UV dye will change over time. Dye, sent to COLTS Laboratories will be applied as specified in the dye manufacturer’s product instructions. Initial measurements will be conducted on a spectrophotometer used to accurately measure the ultraviolet transmittance of a lens. The difference found will be reported as well as UV block in nanometers.

Variable Height Impact Resistance - This test is an extension of the FDA test. The equipment used has the capability of releasing a ball at up to 200 inches to impact the lens. Using the Bruceton technique, the residual strength (that strength over and above what the FDA requires) of the lens can be determined. This is a COLTS Laboratories SOP based on what is now being used in the industry: a copy of which can

be sent to you by request. Fifty-five or 11 lenses must be supplied, depending on which test is selected. The lenses must be -2.00D sphere power, at a consistent thickness within +0.2mm, -0.1mm and edged to 54mm, S10 shape, with a safety bevel. This can be done at COLTS for an additional charge.

Yellowness Index, YI - A spectrophotometer is used to accurately measure the yellow color in a lens and is based on calculating the degree where hue leaves white or achromatic color and moves toward yellow. As a positive value, it moves in the yellow direction. This occurs in some lenses over time and in some cases is found even in newly manufactured lenses. The value of 2.60 has been shown to be the maximum level possible before the yellow color becomes disagreeable to the wearer.

Photosensitive Aging – This test is an attempt to determine the life expectancy of a photosensitive lens. The test **is not repeatable,** due to the use of natural sunlight for measurement of transmittance in the activated state. Measurements are also determined in the inactivated state daily for ten days. This test is a best an indication and results are not statistically significant. A video of the lenses with the control lenses is taken digitally at the beginning, at five days and at the end of the test. It must be remembered that the spectral curve of the UVA lamps in the QUV, used in this test are not the same as natural solar transmittance and most likely will not yield accurate color change over the course of the test. Daily temperature is also recorded due to the effect of temperature on photosensitive lenses. Since the test is not repeatable, a minimum of two sample sets of 4 lenses each is required and priced at that minimum. There is a charge of $25 for each additional sample lens. Lenses should not exceed 2.00 diopters in plus or minus power.

Determine Work of Adhesion – This test is one of a series of tests designed to help determine the cleanability of a lens. A piece of tape is attached to a clean lens and then removed with a force gauge to determine the force necessary to remove the tape. Plano lenses are used for this test and the test may also be used on uncoated and hard coated lenses. There is as yet no base line for comparison for this test so it is suggested that a known lens type be submitted with the test lenses to allow comparative information. Plano lenses should be supplied, having a base curve of from 5.00 to 7.00 diopters. This test is a COLTS SOP that follows the ARCA draft standard written under this title.

Determine lifetime Properties – This test is one of a series of tests designed to help determine the long term lifetime of a lens surface. Abrasion is caused by subjecting the lens surface to a series of strokes of a standardized linear wiping action. Measurement is accomplished by use of affixing a tape to the surface after a number of cycles and determining the force required to remove the tape from the surface. There is as yet no base line for comparison for this test so it is suggested that a known lens type be submitted with the test lenses to allow comparative information. Plano lenses should be supplied, having a base curve of from 5.00 to 7.00 diopters. This test is a COLTS SOP that follows the ARCA draft standard written under this title.

Salt Water Soak – Same as that written in current price list. Include: This test is a COLTS SOP that follows the ARCA draft standard written under this title.

Deionized Salt Water Soak – Same as that written in current price list. Include: This test is a COLTS SOP that follows the ARCA draft standard written under this title.

Determining the Ease of Cleaning – This test is one of a series of tests designed to help determine the cleanability of a lens. Using abrasion caused by subjecting a lens surface to 5 cycles of a linear wiping action, cleanability is measured by applying a piece of tape to the lens surface in a prescribed manner and determining the force required to remove the tape from the lens. There is as yet no base line for comparison for this test so it is suggested that a known lens type be submitted with the test lenses to allow comparative information. Plano lenses should be supplied, having a base curve of from 5.00 to 7.00 diopters. This test is a COLTS SOP that follows the ARCA draft standard written under this title.

Determining Anti-Static Properties – This test attempts to replicate the measure of the ability of a lens to build-up static on the surface of a lens. An Electrostatic meter is used to determine the electrostatic field on a lens. The lens is then rubbed for 20 cycles and measured again for electrostatic field. The result is a measurement of the relative anti-static property of the lens. There is as yet no base line for comparison for this test so it is suggested that a known lens type be submitted with the test lenses to allow comparative information. Plano lenses should be supplied, having a base curve of from 5.00 to 7.00 diopters. This test is a COLTS SOP that follows the ARCA draft standard written under this title

Resistance to Fade – This test is an attempt at replicating tint fade through normal wear of a dyed lens. Standard Control lenses are used in this process. Dye supplied by the dye manufacturer is used as directed and the dyed Standard Control lenses are placed into the QUV Accelerated Weathering device to determine the affects of UVA over time.