



Vehicle Exterior and Add-On Parts Paint Appearance Requirements

1 Scope

1.1 Material Description. This standard describes the surface appearance and quality requirements for GM assembly plant painted vehicle exterior body panels, supplier painted body panels, and supplier painted fascias and exterior add-on parts, and primed parts. The requirements are described in terms of appearance attributes and surface blemishes for each zone that a body panel, fascia, or add-on part is located on a vehicle.

1.1.1 The purpose of these requirements is to ensure that the level of final finish on GM vehicles meets or exceeds the level expected by our customers. This standard applies to primed and/or finished parts topcoated in GM assembly plants or produced and topcoated by suppliers. The standard also includes requirements for paint suppliers.

1.2 Symbols. Not applicable.

1.3 Applicability. Painted car bodies, fascias, and exterior add-on parts painted by or supplied to GM, as well as primed exterior parts supplied to GM.

1.4 Remarks. Implementation of this standard applies to all GM assembly plant painted exterior body panels and fascia effective Model Year (MY) 2017 and forward.

1.4.1 Supplier provided painted fascias and add-on parts for programs with Initial Design Release (IDR) dates after August 1, 2016 will be required to meet the requirements of this version of GMW15777 and/or Statement of Requirements (SOR) documents referenced at the time supplier contracts awarded.

1.4.2 Programs with IDR between June 1, 2011 and September 1, 2016 will be required to meet the requirements of the August 2011 version of GMW15777 and/or SOR documents referenced at the time suppliers were awarded contracts.

1.4.3 Programs with IDR prior to June 1, 2011 will be required to meet the requirements of the February 2009 version of GMW15777 and/or SOR documents referenced at the time suppliers were awarded contracts.

1.4.4 Individual vehicle program teams may move to implement this updated specification on current programs, but they must consult with Assembly Plants, Supplier Quality, Suppliers, Purchasing and others, as required, to assess cost and other ramifications.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ASTM E1499	ISO 2808	VDA 16	VDA 280
DIN 6175-2	SAE J361		

2.2 GM Standards/Specifications.

GMW2	GMW3399	GMW15420	GMW17405
GMW3005	GMW14270	GMW15850	GMW17407
GMW3032	GMW14797	GMW16382	GMW17434
GMW3059	GMW15192	GMW17138	

2.3 Additional References.

- Add-On Part Suppliers; Approved Color Source List
- Assembly Plant; plant-specific Bill of Material (BOM) charts by color.
- BYK-Gardner Technical Specifications (www.byk.com)

- BYKmac-i meters Technical Specifications
- Certified Standard (Physical Panel)
- Digital Master Color Standard (MCS) Library available through GM SupplyPower (www.gmsupplypower.com)
- Dimensional Control Systems (DCS) File Log in the Math Data
- Elcometer Technical Specifications (www.elcometer.com)
- F10 Material Specification Sheet
- Factor tolerances documented on the color data sheet, which is available through GM SupplyPower (www.gmsupplypower.com)
- Farnsworth-Munsell 100 Hue Color Vision Test
- Global Customer Audit (GCA 2016) Worldwide Audit Procedure
- Global Exterior Harmony Review Report
- GM Approved Color Standard (Physical Panel) and Primer Standard (Physical Panel) available from the regional engineering center or Thierry Corporation (www.thierry-corp.com)
- GM Approved Gloss Standard (Physical Plaque)
- GM Approved Orange Peel Visual Plaque available through ACT Laboratories (www.acttestpanels.com)
- GM Working Standard (Physical Panel)
- GTR34920: Enclosures and Decks Technical Specification
- Math Data Files
- Statement of Requirement (SOR)
- Vehicle Technical Specification (VTS)
- Wavescan Meters Technical Specifications available through BYK-Gardner (www.byk.com)

3 Requirements

3.1 Part Zones. Exterior body parts are divided into different appearance zones to set the quality of each zone separately (see Appendix A, Table A1 – Global Customer Audit (GCA) Appearance Zones for Vehicles and Add-On Parts).

3.1.1 Detailed zone definitions of each body panel, fascia or add-on part are common with GCA 2016 definitions. A definition summary is included in Appendix A, Table A1 and Appendix A, Figure A1. Any concerns related to part zone definitions should be resolved with direction from GM Manufacturing Quality or the Design Release engineer (DRE).

3.1.2 Additional zoning guidelines for add-on parts are provided in Appendix A, Table A2 and in Appendix A, Figure A2. Note that the information provided in Appendix A, Table A2 and Appendix A, Figure A2 represents add-on part zoning guidelines. If individual parts have surfaces that fall outside of these guidelines, then the DRE must be contacted to supply and verify actual part zoning.

3.2 General Inspection Requirements.

3.2.1 Completed Vehicle or Painted Part Inspection. For vehicle and part audits, all painted parts should be inspected in approximate vehicle position and at an approximate (arm's length) distance of 0.6 m (~2 ft) from the observer, with viewing procedures as specified in VDA 16: Decorative Surfaces of Attachment and Functional Parts for Automobile Exteriors and Interiors or in SAE J361: Surface Vehicle Recommended Practice - Procedure for Visual Evaluation of Interior and Exterior Automotive Trim.

3.2.2 Manufacturing Facility Quality Inspection Stations for Paint Appearance Defect Identification. Manufacturing facility paint quality inspection stations should be designed to support consistent identification of appearance defects. Assembly facility inspection station construction and lighting requirements for paint defect identification are detailed in GTR34920: Enclosures and Decks Technical Specification.

3.2.2.1 It is recommended that supplier facility inspection areas be designed with similar characteristics to provide a consistent environment for identification of specified defects in Appendix A, Table A3 and quality metrics in Appendix A, Table A4, Table A5, Table A6 and Table A7 prior to shipping supplied parts to GM facilities.

3.2.3 Light Booth Evaluation for Component to Color Standard Color Match. For component to color standard color evaluation, a controlled lighting environment should be utilized and must conform to VDA 16 and VDA 280: Colorimetry for Motor Vehicles, Visual Color Matching and Color Assessment specifications or SAE J361.

3.2.3.1 All shipments of add-on parts under contract or purchase order, and manufactured to this specification, shall be equivalent to their Appearance Approval Report (AAR) approved samples signed by Design Quality.

3.2.3.2 AAR approved samples are to be retained by the Tier 1 supplier for the life of the program. AAR approved samples must have their instrumental color data uploaded into Supplier Quality Management Systems (SQMS) included with their AAR paperwork.

3.2.4 Outdoor Inspection for Vehicle Color Match. Outdoor visual comparison to the GM Working Standard (physical panel) is the method to be used for approval of exterior color match of vehicle bodies and add-on parts. It is required that outdoor visual reviews be supplemented with instrumental measurement for body and fascia according to 3.4.2.8, Steady State Color Harmony Assessment at Assembly Plants.

3.2.4.1 For visual evaluation of paint surface finish, quality and overall vehicle harmony, it is required that completed vehicles be reviewed outdoors in natural daylight (under sunny and/or cloudy conditions). Color harmony events should be scheduled between 10:00 a.m. and 2:00 p.m. under conditions per SAE J361.

3.2.4.2 Color harmony evaluation conditions, including the time of day and weather conditions, must be documented. Color harmony evaluations should be conducted using the GM Working Standard, as defined in GMW16382: Definition and Identification of the Master Certified Standard and the Color Data for Color Process Control.

3.3 Paint Quality Measurement Tools.

- Devices that are not Gage Repeatability and Reproducibility (R and R) approved by GM Vehicle Systems Global Paint should not be used.
- Alternative devices not specified here may be acceptable for use in data trending, but must be approved, in writing, by GM Supplier Quality and GM Vehicle Systems Global Paint prior to contract award.
- All measurement equipment should be maintained and recertified per manufacturer's recommendation.
- Paint and parts suppliers will be responsible to incorporate and maintain certification to the GM Approved Color standard (minimum of once per year) using approved measurement systems within their manufacturing process.

3.3.1 Orange Peel and Structure Balance.

3.3.1.1 Orange Peel and Structure Balance Instrumentation. The required method for orange peel and structure balance characterization of all points is with the BYK Wavescan class of meters. Where possible, based on body panel, fascia, or add-on part size and geometry, instrumentation should be used for orange peel measurement.

3.3.1.1.1 Surfaces that cannot be measured with instrumentation due to part curvature (part radius less than 30 cm) or less than minimum required surface area (sample size less than 25 mm x 40 mm) may be evaluated for orange peel with orange peel visual plaques.

3.3.1.1.2 Surface appearance is characterized by both orange peel R-Value and structure balance B-Value. The approved GM Vehicle Systems Global Paint Gage R and R meters that are approved for surface appearance measurement are:

- BYK Gardner Wavescan Dual (Model 4840): Appearance control of medium to high gloss flat and curved surfaces with radius $r > 0.5$ m.
- BYK Gardner Wavescan Micro (Model 4824): Appearance control of medium to high gloss flat and curved surfaces with radius $r > 0.3$ m.

3.3.1.1.3 Wavescan Meters and Wavescan Meters Technical Specifications are available from BYK-Gardner (www.byk.com). Technical specifications for the equipment, including wheelbase footprint and scan length, are available at this same web site. Annual recertification by the supplier is recommended.

3.3.1.2 Orange Peel Visual Plaques. For parts that cannot be measured by the BYK Wavescan Dual or BYK Wavescan Micro meters due to size or geometry (part radius < 30 cm and sample size less than 25 mm x 40 mm), orange peel visual plaques may be used. Note that orange peel visual plaques are only for the assessment of orange peel R-Value. These orange peel visual plaques are not for the assessment of structure balance B-Value, which must be quantified instrumentally.

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3.3.1.2.1 GM Approved Orange Peel Visual Plaques can be obtained from ACT Laboratories (www.acttestpanels.com). Purchase and use only GM Approved Orange Peel Visual Plaques from ACT Laboratories.

3.3.1.2.2 When using GM orange peel visual plaques, as opposed to the BYK Wavescan Dual or BYK Wavescan Micro meters, 0.5 R-Value units should be added to the published BYK Wavescan standard values outlined in Appendix A, Table A4. Note that specification levels are based on vehicle segment, region of sale, and body panel/add-on part orientation.

3.3.2 Color.

3.3.2.1 GM Approved Color Standard (Physical Panel). GM approved color standard (physical panel) and primer standard (physical panel) for visual color reference can be obtained from the regional engineering center or Thierry Corporation (www.thierry-corp.com).

3.3.2.2 Instrumental Color Measurement Equipment. The GM Vehicle Systems Global Paint Gage R and R approved multi-angle instruments approved for color measurement are:

- BYK-Gardner BYKmac-i Meter (Model 7030): 23 mm diameter aperture for measurement of body panels with radius $r > 0.5$ m.
- BYK-Gardner BYKmac-i Meter (Model 7034): 12 mm diameter aperture for measurement of small parts with radius $r > 0.5$ m.
- As of December 2014, the 23 mm aperture BYKmac-i Model 7030 replaces BYKmac Model 6362, which is no longer manufactured and supplied by BYK-Gardner. Additionally, as of December 2014, the 12 mm aperture BYKmac-i Model 7034 replaces BYKmac Model 6397, which is no longer manufactured and supplied by BYK-Gardner.

BYKmac-i meters are available from BYK-Gardner (www.byk.com). BYKmac-i meters Technical Specifications for equipment are available at the same web site. Annual recertification by the supplier is recommended.

3.3.2.3 Fluorescence and Its Impact on Master Certified Standards (MCS). BYK-Gardner BYKmac-i meters (Model 7030 and Model 7034) have color and effect characterization capability, along with the ability to quantify fluorescence through the allocation of fluorescent light to the emission range. For this reason, all MCS digital standards for MY2016 and forward have been developed with the BYKmac-i class of meters only. Refer to 3.4.2.2, Digital Color Standards and the MCS, for information on virtual color standards.

3.3.2.3.1 To indicate that the GM approved color standard (physical panel) or painted body panel, fascia, or add-on part has a measureable level of fluorescence during measurement, BYKmac-i meter Models 7030 and 7034 notify the user with a visual orange Light Emitting Diode (LED) flash and an audible beep. Fluorescence is quantified in the BYK smart-chart software by the Intensity Emission Index ($Int_{Emission}$).

3.3.2.3.2 BYKmac meters (Model 6362 and 6397) have capability to import MCS digital standards for MY2015 and back and have capability to measure colors with and without fluorescence for these colors. However, for MY2015 MCS digital standards and back, fluorescence cannot be quantified with these older models.

3.3.2.3.3 For MY2016 and forward, MCS digital standards without fluorescence can be imported to the BYKmac meters (Model 6362 and 6397). However, for MY2016 and forward, MCS digital standards with fluorescence cannot be imported to the BYKmac meters (Model 6362 and 6397). For this reason, Models 6362 and 6397 not already upgraded to BYKmac-i capability must be upgraded.

3.3.3 Paint Film Thickness. Only methods approved to ISO 2808: Paints and Varnishes Determination of Film Thickness as indicated in GMW14797: Painted Plastic Parts Performance Requirements should be used for film thickness evaluation. The following meters (see 3.3.3 a thru 3.3.3 g) represent approved examples for measurement of film thickness. Meters can be accessed through the posted web sites.

- a. Automation USA QNix 7500 (www.coating-thickness.com)
- b. BYK Gardner Byko Test Model MPOR (www.byk.com)
- c. Elcometer 355 and 456 (www.elcometer.com)
- d. ElektroPhysik MiniTest 700 Series (www.elektrophysik.com)
- e. Fischer Technology Dualscope FMP100/FMP150, Isoscope MP30e (www.fischer-technology.com)
- f. Imaginant (formerly JSR Ultrasonics) Multi-Layer PELT Gage (<http://www.jsrultrasonics.com/>)
- g. Oxford Instruments CMI233 (www.oxford-instruments.com)

3.3.3.1 Use of microscopes for film build analysis of materials that cannot be measured with film thickness meters requires that the sample provide enough discrimination to measure all individual coating layers. For parts, use of microscopes for film build analysis is the preferred method (refer to GMW17138: Determination of Film Thickness).

3.3.3.2 Selected equipment must be properly calibrated to support accurate measurement on the vehicle or component substrate and paint layering system. Annual recertification by the supplier is recommended.

3.3.3.3 Specifications for maximum paint layering system film thicknesses for plastic parts are detailed in GMW14797.

3.3.3.4 Specifications for minimum paint layering system film thickness for plastic parts are defined in one of these three following locations:

- Dimensional Control Systems (DCS) File Log in the Math Data
- SOR
- F10 Material Specification Sheet.

3.3.3.5 See specifications for minimum performance, compatibility, and processing requirements for all exterior topcoats in GMW3005: Topcoat, Generic Qualification and GM Approved Materials Source List. Painted bodies and add-on parts must meet the requirements of these specifications and one of the following:

- Assembly Plant; plant-specific Bill of Material (BOM) charts by color.
- Add-On Part Suppliers; Approved Color Source List available from each supplier according to GMW17434: Pigment Evaluation.

3.3.4 Gloss.

3.3.4.1 Instrumental Gloss Measurement Equipment. The GM Vehicle Systems Global Paint Gage R and R approved gloss meters approved for gloss measurement are;

- BYK-Gardner MicroTRI Gloss Meter (Model 4446): 20 degree, 60 degree, and 85 degree single angle, and 20/60/85 degree tri-gloss capability. This meter, along with BYK-Gardner Technical Specifications, is available from BYK-Gardner (www.byk.com).
- Elcometer 406 Mini Novo-Gloss: 60 degree single angle and 20/60 degree dual angle capability. This meter, along with Elcometer Technical Specifications, is available from Elcometer (www.elcometer.com).

3.3.4.2 Gloss Measurement. If the requirement for gloss is greater than 60 gloss units, use the 20 degree meter setting on the meter. If the requirement for gloss is less than 60 gloss units, use the 60 degree meter setting for measurements. Gloss requirements for exterior painted surfaces and primed parts are shown in Appendix A, Table A3.

3.3.4.2.1 Add-on parts such as door handles that cannot be successfully measured with the approved gloss meters due to high curvature or small surface area (minimum 10 mm x 10 mm for 20 degree meter settings, minimum 9 mm x 15 mm for 60 degree settings, and minimum 5 mm x 38 mm for 85 degree settings), must be visually approved by a qualified visual evaluator to the GM Approved Gloss Standard (physical plaque). The approved AAR sample may also be used as a reference.

3.4 Paint Quality Requirements. Before any evaluation or measurement is conducted, all inspection surfaces should be clean and free from fingerprints, dirt or dust. No liquids, other than water, should be used for surface cleaning. The use of chemical-based cleaners can cause a change of color values. The best steps for cleaning car bodies and painted parts is to use a clean damp cotton cloth or chamois, followed by drying with a micro-fiber cloth.

3.4.1 Orange Peel and Structure Balance.

3.4.1.1 Orange Peel and Structure Balance Performance Levels. Orange peel is the rough or wavy appearance of a painted surface that is a function of shortwave and longwave measurements; the measurements include the structure spectrum wavelengths of W_b , W_c and W_d . The metric used to quantify orange peel is the R-Value, which can range from R=1 (rough, structured surface appearance) to R=10.5 (smooth, glasslike surface appearance).

3.4.1.1.1 Structure balance is an enhanced surface appearance metric that quantifies the waviness of a surface finish. The metric used to quantify structure spectrum is the B-Value, which is a function of discrete structure spectrum wavelengths W_b and W_d . A structure balance B-Value that is negative represents a longwave dominant or wavy surface appearance. A structure balance B-Value that is positive represents a shortwave dominant or pinchy surface appearance.

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3.4.1.1.2 Both orange peel R-Value and structure balance B-Value are measured with the BYK Wavescan class of meters. See Appendix A, Table A4 for applicable orange peel R-Value levels and Appendix A, Table A5 for applicable structure balance B-Values by vehicle segment, region of sale, and body panel orientation

3.4.1.2 Scaled Vehicle Segments for Body Panels. The vehicle segments for body panels, which correspond to low, medium, and high scaled topcoat classes outlined in GMW3005 include:

- Premium/Luxury
- Non-Premium
- Emerging Market
- Commercial One (1)
- Commercial Two (2)

3.4.1.2.1 For fascias and add-on parts, premium and non-premium segment specification information is provided in Appendix A, Table A4 for orange peel R-Value. Structure Spectrum B-Value specification information is provided in Appendix A, Table A5 and Table A6. Note that fascias and add-on parts do not have structure spectrum B-Value requirements. Note, as well, that fascia average represents the average of left fascia wing, center fascia, and right fascia wing readings. For add-on parts, the average represents the average of part or body panel readings.

3.4.1.2.2 In order of preference, and based on body panel, fascia, or add-on part size and geometry, as indicated, the following methods for orange peel evaluation are approved:

- BYK-Gardner Wavescan Dual Model AW-4840 (topcoat and medium to high gloss primer with part radius > 50 cm).
- BYK-Gardner WaveScan Micro Model AW-4824 (topcoat and medium to high gloss primer with part radius > 30 cm and sample size greater than 25 mm x 40 mm).
- Orange peel visual plaques for body panel and/or fascia and/or add-on part areas where size and geometry (part radius < 30 cm and sample size less than 25 mm x 40 mm) prevent instrumental measurement. Orange peel visual plaques may also be used, as needed, during visual color harmony events and individual appearance part approvals.

3.4.1.3 Orange Peel and Structure Balance Specifications and Tolerance Bands. For full Production Part Approval Process (PPAP) approval, individual specified checkpoints (using an average of three (3) BYK Wavescan readings) must meet the applicable Premium/Luxury, Non-Premium, Emerging Market, Commercial One (1) or Commercial Two (2) vehicle segment performance levels specified in Appendix A, Table A4.

3.4.1.3.1 Note that the orange peel R-Value requirements outlined in Appendix A, Table A4, and structure balance B-Value requirements outlined in Appendix A, Table A5 and Table A6, for surfaces categorized as Zone B in Appendix A, Table A1 and Figure A1, are only for exterior surfaces. Openings and inners categorized as Zone B surfaces in Appendix A, Table A1 do not have orange peel R-Value and structure balance B-Value requirements. Tolerance bands for orange peel R-Value readings and structure balance B-Value readings include ranges bounded by the Best in Segment Target, Competitive, and Competitive Minimum.

- **Best in Segment Target (Green):** Orange peel R-values and structure balance B-Values in the top quartile (above the 75th percentile) of industry data, as measured during the GM Vehicle Systems Global Paint Annual Exterior Appearance Survey, represent values in the Best in Segment Target (Green) Tolerance Band.
- **Competitive (Yellow):** Orange peel R-values above and structure balance B-Values outside of the minimum target but below or outside of the Best in Segment Target, fall within the Competitive (Yellow) tolerance band. The competitive tolerance band is between the 50th percentile and 75th percentile of industry data, as measured during the GM Vehicle Systems Global Paint Annual Exterior Appearance Survey.
- **Non-Competitive (Red):** The 50th percentile of industry data, as measured during the GM Vehicle Systems Global Paint Appearance Survey, represents the competitive minimum for orange peel R-Value and structure balance B-Value readings. Orange peel R-Value readings below and structure spectrum B-Value readings outside of the 50th percentile of industry data are in the Non-Competitive (Red) tolerance band.

3.4.1.3.2 Additional specific orange peel R-Value and structure balance B-Value requirements may be detailed in the SOR, Vehicle Technical Specification (VTS) documents or Math Data Files for Components and may include requirements for orange peel R-value, structure balance B-Value, as well as structure spectrum values W_b , W_c , and W_d .

3.4.1.4 Wavescan Measurement.

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3.4.1.4.1 Wavescan Roll Lengths. Standard measuring lengths of 5 cm, 10 cm, and 20 cm can be used with BYK Wavescan measuring devices. The length used to determine orange peel R-Values and/or structure balance B-Values may be specified in the Math Data Files or should be agreed to by the Supplier, Supplier Quality, and GCA. Use a standard roll length of 10 cm for all checkpoints on body panels and fascias for the BYK Wavescan Dual and a standard roll length of 5 cm for all add-on parts, such as mirror shells, spoilers, moldings, and fuel filler doors, for the BYK Wavescan Micro.

3.4.1.4.2 Wavescan Measurement Procedure. Proper measurement with the BYK Wavescan Dual and BYK Wavescan Micro requires that the measurement surface be clean and dry and that all four (4) wheels of the meter be in contact with the surface of the part or body panel being measured at all times during measurement.

3.4.1.4.2.1 Orange peel R-Values and structure spectrum B-Value should be an equipment-calculated average of three (3) scans at each measurement location. Measurement locations for assembly plant process control are as specified in Appendix B, Figure B2, Figure B3, Figure B4 and Figure B5.

3.4.1.4.2.2 At the specified checkpoints, all parts must meet the most stringent of the specifications given in Appendix A, Table A4 and Appendix A, Table A5 and Table A6, the SOR, or the VTS documents. If using orange peel visual plaques, as opposed to BYK Wavescan meters, for evaluation of orange peel R-Value, add 0.5 units to the published BYK-Gardner Wavescan standard values in Appendix A, Table A4.

3.4.1.4.3 Wavescan Measurement Direction and Measurement Locations. Painted body panel and fascia measurements should be conducted at a distance of at least 25 mm (~1.0 in) from the edge of the body panel. For smaller add-on parts, measurements should be conducted at a distance of at least 15 mm (~0.5 in) from the edge of the add-on part.

3.4.1.4.3.1 For Wavescan measurement of vertical body panels, the center front fascia, and the center rear fascia, it is recommended that the instrument be rolled parallel to the ground. For vertical body panels, the meter should be rolled from front to back along the length of the vehicle. For the center front fascia and the center rear fascia, the meter should be rolled from left to right along the length of the fascia.

3.4.1.4.3.2 For Wavescan measurement of horizontal body panels, it is recommended that the Wavescan meter be rolled from front to back along the length of the vehicle.

3.4.1.4.3.3 Measurement of body to fascia interfaces to quantify uniformity should be conducted so that the meter is rolled in a parallel direction to the fender or quarter cut-line approximately 40 mm (~1.5 in) from the interface while maintaining four (4) wheel contact. It is acceptable to deviate from this direction where the body panel shape prevents four (4) wheel contact.

3.4.1.5 Wavescan Measurement of Add-on Parts with Highly Curved or Small Surfaces. When measuring orange peel R-Value and structure balance B-Value of highly curved surfaces, it is critical that each reading be qualified. Errant measures can be recorded if proper four (4) wheel contact is not maintained on curved surfaces.

3.4.1.5.1 Add-on parts, such as door handles and moldings, that cannot be successfully measured with the BYK Wavescan Micro due to curvature (part radius less than 30 cm) or small surface area (sample size less than 25 mm x 40 mm), must be visually approved by a qualified visual evaluator to GM Approved Orange Peel Visual Plaque. The approved AAR sample may also be used as a reference.

3.4.1.6 Orange Peel Measurement of Primed Parts. For primed parts that are subsequently painted at a GM plant, and where the parts have a greater than 50 unit gloss when read using a 20 degree meter, use of the BYK-Gardner Wavescan Dual or the BYK-Gardner Wavescan Micro is recommended for orange peel measurement. Refer to Appendix A, Table A4, for minimum instrumental orange peel requirements.

3.4.1.6.1 For primed parts that are subsequently painted at a GM plant, and where the parts have less than 50 unit gloss when read using a 20 degree meter, use of orange peel visual plaques is recommended. Refer to Appendix A, Table A4, for minimum visual orange peel requirements for primed parts.

3.4.1.7 Orange Peel Uniformity. The intent of this specification is for uniformity of all appearance attributes over the entire vehicle, including body panels, fascias and add-on parts.

3.4.1.7.1 Maximum targeted variations within body panels, fascias, or add-on parts or between adjacent body panels, fascias, and add-on parts for orange peel R-Value uniformity are outlined in Appendix A, Table A4.

3.4.1.7.2 For orange peel, uniformity specifications are to be applied at the measurement checkpoints outlined in Appendix B, Figure B2, Figure B3, Figure B4 and Figure B5 for vehicle body panels and fascias.

Note: A measurement that does not meet the specification for orange peel R-Value uniformity should only be called in GCA when the condition arises where one or more adjacent surfaces (body panel, fascia, or add-on part) does not meet the competitive minimum orange peel R-Value outlined in Appendix A, Table A4.

3.4.1.7.3 A Problem Report and Resolution (PRR) should not be written for out of specification orange peel R-Value uniformity if the fascia or add-on part meets the orange peel R-Value specification, but does not meet the uniformity requirement to an adjacent body panel, fascia or add-on part.

3.4.2 Color Data Management.

3.4.2.1 Qualification for Visual Evaluation of Color. Visual evaluators of color match must have proven capability as determined by methods, including the Farnsworth-Munsell 100 Hue Color Vision Test (refer to ASTM E1499: Standard Guide for Selection, Evaluation and Training of Observers and SAE J361. The minimum Farnsworth-Munsell score requirement for visual evaluation qualification 16 or less (Superior Discrimination).

3.4.2.1.1 Qualification of evaluators should be repeated every two (2) years, at minimum, to verify that required color acuity scores are maintained.

3.4.2.2 Digital Color Standards and the Master Certified Standard (MCS). The primary reference for objective instrumental color difference calculation is the digital GM MCS for each color. The MCS for a given color represents the digital file created through the measurement of the physical panel representing the mathematical mean of the population of Certified Standards of that color, as defined in GMW16382.

3.4.2.2.1 Physical color standards and primer standards should be stored in their envelopes when not in use and placed in a clean, dry location. Physical color standards and primer standards can be cleaned to remove fingerprints and dirt by wiping with a clean, laundered, 100% cotton cloth and a 1:2 part solution of water and naphtha or alcohol. Physical color standards and primer standards should not be cleaned with any other solvents.

3.4.2.2.2 The Digital MCS Library is currently stored on the GM SupplyPower website (www.gmsupplypower.com). Users with access to Socrates can access GM SupplyPower directly to download the digital MCS files. Users without access to Socrates will need to register to obtain a User Identification (ID) and password at the site before digital files can be downloaded.

3.4.2.3 Color Measurement.

3.4.2.3.1 BYKmac-i Measurement Direction and Measurement Locations for Standards. When measuring color standards, a minimum of five (5) measurements should be taken to record an average value for a given color. During these measurements, the BYKmac-i meter should be oriented with the LED to the top of the standard (as defined on the standard label).

3.4.2.3.2 BYKmac-i Measurement Direction and Measurement Locations for Vehicles. For body panel, fascia, and add-on part measurement of completed vehicles, at least three (3) single measurements should be taken to produce a calculated average reading for each measurement location. The color measurement tool should be indexed slightly (minimum of several millimeters) between the readings for each body panel location.

3.4.2.3.3 Color measurement of body panels, fascias, and add-on parts should be completed with the equipment held in a consistent orientation, as detailed in standardized work documented in Appendix B, Figure B1. The equipment source of illumination should be coincident with the observing direction and sun angle (illumination source at approximately +45 degree angle to the horizontal plane to match the sun's angle).

3.4.2.3.4 For vertically oriented body panels, measurement should be conducted with the LED facing up and the tool body perpendicular to the ground.

3.4.2.3.5 For body to fascia color harmony measurement, the fascia data should be taken at the same orientation as the fender or quarter body panel. The recommended orientation for hood and other horizontal body panel measurement is to measure with the meter parallel to the length of the vehicle body and the light source illuminating surface from the passenger compartment toward the front of the vehicle. The minimum measurement program requirement for process control includes body panel locations defined in Appendix B, Figure B2, Figure B3, Figure B4 and Figure B5. Additional color measurement locations can be added to address specific concerns.

3.4.2.3.6 Locations with the biggest bending radii on the body or part should be selected to prevent measuring error and to preserve correlation to visual impression. If necessary, alternative measurement locations from those shown in Appendix B, Figure B2, Figure B3, Figure B4 and Figure B5, should be arranged with the GM Vehicle Systems Global Paint or Regional Engineering Center and/or the specific GM Assembly Plant. Care should be taken to ensure that all four (4) of the meter's measurement pins are depressed during measurement. Should an error in measurement occur, the LED will blink red and an audible signal will be emitted. For measurement in bright ambient light, the use of a foam insert provided with the equipment may be required to allow for an accurate reading and full depression of all four (4) measurement pins.

3.4.2.4 Color Specifications and Color Measurement Algorithm. The color system for automotive exterior application utilizes color differences weighted for measurement geometry (y), application parameter (g), and color (S) according to the DIN 6175-2 algorithm, which incorporates equations that consider whether a color is non-chromatic and chromatic.

- The DIN 6175-2 algorithm for Pass/Fail process control for total color impression is represented by the sum of the squares of the individual parameters at each measurement geometry.
- For non-metallic colors, the total color impression is characterized by the total color difference ($dE_{t,p}$ GM) calculated according to the DIN 6175-2 algorithm, where the subscript "p" refers to production color difference. These straight shade colors include a single angle measurement (45 degree).
- For metallic and effect colors, the total color impression includes the total color difference ($dE_{t,p}$ GM) and the total effect difference ($dS_{t,p}$ GM). A metallic color includes five (5) measurement angles (15 degree, 25 degree, 45 degree, 75 degree, and 110 degree), and a color with effect pigment includes six (6) measurement angles (-15 degree, 15 degree, 25 degree, 45 degree, 75 degree, and 110 degree). The total effect difference for metallic and effect color includes sparkle parameters at each measurement geometry (15 degree, 45 degree, and 75 degree) and graininess, which is angle independent.
- Refer to Appendix A, Table A7, for a graphical description (Appendix A, Figure A3) of the color parameters $dE_{t,p}$ GM and $dS_{t,p}$ GM. Note that the composite parameter $dSE_{t,p}$ GM, which combines both the color difference and the effect difference into a single value, is no longer used to quantify color difference.

3.4.2.4.1 Color match of painted bodies, fascias, exterior add-on parts painted by or supplied to GM, and primed exterior parts supplied to GM must meet the requirements shown in Appendix A, Table A7. Overall vehicle color harmony assessments completed by a qualified visual evaluator will override process control instrumental color data for situations where discrepancies between instrumental and visual harmony exist.

3.4.2.4.2 Allowable production part and/or vehicle body color variation from the GM-approved MCS and/or mating top-coated parts, as defined by the DIN 6175-2 algorithm, includes:

- Total Color Difference ($dE_{t,p}$ GM) difference of 1.0 or less (PASS), difference between 1.0 and 1.7 (WARN), and difference > 1.7 (FAIL).
- Total Effect Difference ($dS_{t,p}$ GM) difference of 1.0 or less (PASS) and difference of > 1.0 (FAIL).

3.4.2.4.3 The total color difference ($dE_{t,p}$ GM) and total effect difference ($dS_{t,p}$ GM) versus the MCS digital file should be measured at locations specified in Appendix B, Figure B2, Figure B3, Figure B4 and Figure B5, and should deviate no more than the allowable tolerance limits defined in Appendix A, Table A7.

3.4.2.4.4 BYK-Gardner smart-chart, version 4.0, or later, must be used for color data management, color harmony review data collection, and process control.

3.4.2.4.5 Note that the BYK-Gardner Autochart software is no longer supported by BYK-Gardner as of December 2013. In addition, digital MCS files are not supported by BYK-Gardner Autochart. Users should upgrade to BYK smart-chart software.

3.4.2.5 Steady State Fascia and Add-On Part Supplier Color Process Control. Process control should be implemented at fascia and add-on parts suppliers, as defined within this standard, and should utilize color data collection and analysis in dE_p GM DIN 6175-2 format.

3.4.2.5.1 Fascia and add-on part suppliers should measure color position relative to the MCS for each color and part to insure process control and measurements that are within tolerance against the MCS. Measurement should be at locations specified in Appendix B, Figure B2, Figure B3, Figure B4 and Figure B5 or at locations agreed upon by GM Vehicle Systems Global Paint. Frequency of measurement should be weekly, at minimum, for each part and color.

3.4.2.5.2 For fascias, BYK smart-chart electronic data files for these measurements should be distributed, on a weekly basis, to the plant Quality Engineering Manager (QEM). The QEM will trend both the body and fascia color data at critical match points to monitor color position movement away from the MCS target. Ideally, the body to fascia color difference should be less than 1.0 for color metrics dE_p GM and dS_p at each measurement angle, as well as for dG_w , which is angle independent.

3.4.2.5.3 Electronic files should include both the BYK smart-chart "Scorecard Detail Table" and the "Scorecard Detail Scatter x/y Charts for Color and Effect" for each part and color (see examples in Appendix B, Figure B8 and Figure B9). The Scorecard Detail Table files can be exported to Microsoft Excel directly from BYK smart-

chart for ease of distribution, and BYK smart-chart screen shots can be used to capture the Scorecard Detail Scatter x/y Charts for Color and Effect.

3.4.2.5.4 The fascia and add-on part supplier should maintain internal process control trend charts using BYK smart-chart for all parts and colors to verify that color position relative to the MCS is maintained over time.

3.4.2.5.5 BYK smart-chart out of tolerance triggers (PASS = green, WARN = yellow, or FAIL = red) for measurement of add-on part color difference versus the MCS digital file must include both Total Color Difference ($dE_{t,p}$ GM) and Total Effect Difference ($dS_{t,p}$ GM).

3.4.2.5.6 Add-on parts such as door handles that cannot be successfully measured with the BYKmac-i due to radius or surface area constraints, must be visually approved by a qualified visual evaluator to the GM Approved Color Standard. The approved AAR sample may also be used as a reference.

3.4.2.6 Assembly Plant Paint Supplier Batch Approval. Visual and instrumental color difference from the MCS is used to evaluate and accept batch paint prior to shipment to assembly plant and/or supplier facilities.

3.4.2.6.1 Assembly plant paint suppliers should spray test panels, perform visual evaluations, collect color data and provide batch panel color data to their GM assembly plant supplier facility representatives for evaluation with a GM representative and acceptance by GM prior to batch shipment to GM.

3.4.2.6.2 Batch panels should accompany the shipment of totes to the GM assembly plant to support visual evaluation and color measurement prior to load to a GM assembly plant paint mix system.

3.4.2.6.3 Color process control should utilize color data collection and analysis methods using BYK smart-chart and the dE_c DIN 6175-2 format. Measurement attributes for batch approval will include:

- Total Color Difference ($dE_{t,c}$ GM) - all paint types (non-metallic, metallic, and effect paints) with pre-defined measurement geometries for batch panels.
- Total Effect Difference ($dS_{t,c}$ GM) - metallic and effect paints for batch panels.

3.4.2.6.4 Batch paint color position trending and visual comparison in controlled lighting environments should be practiced to ensure consistency of batch. Prior to batch shipment, the paint supplier should communicate color position information and notify GM of deviation from:

- Historical color position, as documented by BYK smart-chart trend charts, that has been shown to achieve vehicle and add-on part match to the MCS, and
- Factor tolerance changes as defined in GMW16382 and factor tolerances documented on the color data sheet, which is available through GM SupplyPower.

3.4.2.7 Steady State Vehicle Body Paint Shop Color Process Control. Process control should be implemented within the paint shop, as defined within this standard, and should utilize color data collection using BYK smart-chart and analysis in Delta- E_p DIN 6175-2 format.

3.4.2.7.1 Paint shops should measure color position relative to the MCS for each color to insure process control and measurements that are within tolerance against the MCS. Measurement should be at locations specified in Appendix B, Figure B2, Figure B3, Figure B4 and Figure B5. Frequency of measurement should be, at minimum, at the same frequency as the Tier 1 fascia supplier and per the individual paint shop process control plan.

3.4.2.7.2 BYK smart-chart electronic data files for these measurements should be distributed, on a weekly basis, to the plant QEM, to monitor color position movement away from the MCS. Ideally, the body to fascia color difference should be less than 1.0 for dE_p , as well as dS , and dG_w , at all relevant measurement angle.

3.4.2.7.3 Electronic files should include both the BYK smart-chart "Scorecard Detail Table" and the "Scorecard Detail Scatter x/y Charts for Color and Effect" for each part and color (see examples, which show body and fascia match to the MCS and body to fascia harmony in Appendix B, Figure B6 and Figure B7). The Scorecard Detail Table files can be exported to Microsoft Excel directly from BYK smart-chart for ease of distribution, and BYK smart-chart screen shots can be used to capture the Scorecard Detail Scatter x/y Charts for Color and Effect.

3.4.2.7.4 In addition, the paint shop should maintain internal process control trend charts using BYK smart-chart for all colors and body styles to verify that the drift of any components of color position relative to the MCS does not occur over time.

3.4.2.7.5 BYK smart-chart out of tolerance triggers (PASS = green, WARN = yellow, or FAIL = red) for measurement of body panel color measurement versus the MCS digital file must include both Total Color Difference ($dE_{t,p}$ GM) and Total Effect Difference ($dS_{t,p}$ GM).

3.4.2.8 Steady State Color Harmony Assessment at Assembly Plants. Exterior vehicle color harmony assessments in steady state production are targeted to be performed, at minimum, once per month per color. Problematic colors should be assessed on a weekly basis. The assembly plant QEM is responsible for scheduling and conducting harmony assessments. Suppliers may be required to support these reviews per QEM direction. The plant QEM, or designate, works in conjunction with Design Quality representatives to define corrective actions.

3.4.2.8.1 Steady state color harmony assessments to evaluate overall vehicle harmony are required to be reviewed outdoors in natural daylight (under sunny and/or cloudy conditions). Color harmony events should be scheduled between 10:00 a.m. and 2:00 p.m. under conditions per SAE J361.

3.4.2.8.2 In addition to visual reviews, instrumental BYKmac-i data should be collected for all vehicles reviewed at steady state color harmony assessments.

3.4.2.8.3 Discrepancies between visual harmony and instrumental color data should be addressed through an evaluation of the area that is not in agreement (body panel visual assessment versus instrumental color data, supplied part visual assessment versus instrumental color data, or visual harmony versus instrumental color data). Visual evaluation of vehicle color harmony at steady state color harmony assessments shall override instrumental color data of a discrepant area.

3.5 Additional Requirements.

3.5.1 Substrate Surface Finish. Surface finish of substrates to be top-coated must not impact painted appearance performance of vehicle body or add-on parts to minimum (Appendix A, Table A3) or product-specific appearance specifications (SOR, VTS, Math Data Files).

3.5.1.1 In the event that final appearance of painted bodies, fascias, or add-on parts is negatively impacted by substrate surface finish, GM reserves the right to demand substrate and/or processing changes as required to meet specifications for painted part appearance as listed in Appendix A, Table A3 and/or SOR documents and/or VTS documents.

3.5.1.2 GM Supplier Quality, working with Vehicle Systems Global Paint, will arrange for measurement of substrates for any identified concerns per specifications referenced herein. Measurements will be made prior to application of any elements of the paint layering system. Reference the following global specifications for additional clarification of steel, aluminum, and polymer substrate quality measurements:

- GMW2: Low Carbon Sheet Steel
- GMW3032: High Strength Sheet Steel 180 MPa through 700 MPa Yield Strengths
- GMW3399: Multi-Phase and Ultra-High Strength Sheet Steel
- GMW15192: Aluminum Sheet for Body and Closure Panel Applications
- GMW15420: Global Qualification Process for Aluminum Sheet
- GMW15850: Injection Mold Tool Standards

3.5.2 Primed Part Inspection and Rejection. All shipments of materials or parts under contract or purchase order, and manufactured to this specification, shall be equivalent in every respect to the initial samples approved by engineering.

3.5.2.1 There shall be no changes in either formulation or manufacturing process permitted without prior notification and approval by engineering. Lack of notification by the supplier constitutes grounds for rejection of any shipment.

3.5.2.2 While samples may be taken from incoming shipments and checked for conformance to this specification, the supplier shall accept responsibility for incoming shipments meeting this specification without dependence upon purchaser's inspection. In addition, the supplier shall submit a Certificate of Analysis with each batch of material arriving at a plant. This document shall be prepared and provide data in accordance with GMW17405: Incoming Paint and Sealer Material Documentation Requirements.

3.5.3 Appearance Attributes and Supplier Capability. Appearance attributes must meet requirements as specified in Appendix A, Table A2 and Appendix A, Table A4, Table A5, Table A6 and Table A7 over the entire vehicle, inclusive of all primed parts and top-coated fascias and add-on parts. Note that the Appendix A, Table A3 specifications for orange peel R-Value, structure balance B-Value, and color are evaluated using the checkpoints outlined in Appendix B, Figure B2, Figure B3, Figure B4 and Figure B5, during the annual GM Vehicle Systems Global Paint Competitive Benchmarking Field Survey.

3.5.3.1 The supplier is responsible at time of technical review to submit any color-specific capability concerns that may impact supplier ability to achieve specified appearance attributes.

3.5.3.2 For situations where a supplier is not capable of achieving the specified appearance attributes in Appendix A, Table A3 and/or Appendix A, Table A4, Table A5, Table A6 and Table A7, located in Appendix A of GMW17407: Vehicle Exterior Painted Plastic Add-On Parts Process Requirements must be approved by the specified stakeholders.

4 Manufacturing Process

4.1 Steady State Production Process Capability and Continuous Improvement. Paint and part suppliers must provide current manufacturing process capability at the technical review process and must develop and maintain paint quality data as an integrated element of a daily/shift production quality feedback processes.

At a minimum, each supplier must implement process control plans that track performance levels while driving variation reduction for the listed paint attributes.

4.1.1 Orange Peel R-Value and Structure Balance B-Value. The paint and part supplier shall develop and maintain appearance position data sets, including trend charts per color, model, build line and part. Reference specification targets in Appendix A, Table A4 for orange peel R-Value and Appendix A, Table A5 and Table A6 for structure balance B-Value.

4.1.2 Color. The paint supplier and add-on part supplier should develop equipment-based color data sets to create trend charts to track color parameters over time. Trend charts should be maintained by color, model, build line, and/or part. The primary reference for color difference calculation is the MCS.

4.1.2.1 The paint supplier and add-on part supplier should also utilize equipment-based color measurement to identify variation in paint batch color position as defined in 3.4.2 Color Data Management and communicate color position through the sharing of BYK smart-chart data downloads.

4.1.2.2 Internal trends charts maintained by the paint supplier, the paint shop, and the part supplier should be used as a tool to minimize color variation. Charts should utilize measured color attributes, including dL^* , da^* , db^* , dC^* , dh^* , dE_c^* , dE_p^* , at all relevant angles, as well as total color difference ($dE_{t,p}$ GM), and total effect difference (dSt_p GM) by color, model, build line, and/or part. Note that the subscript "c" in dE_c^* represents a batch color difference.

4.1.2.3 BYK smart-chart off color triggers (PASS, WARN, or FAIL) against the MCS reference should include both Total Color Difference ($dE_{t,p}$ GM) and Total Effect Difference (dSt_p GM). Reference specification targets in Appendix A, Table A7.

4.1.3 Film Thickness. The supplier should collect paint layering system film thickness measurements by color, part location, and unique layer. This data will be utilized to ensure uniformity of add-on parts and the painted body and to maintain minimum paint film thickness for durability.

4.2 Measurement Locations. Standardized body and add-on part locations for data collection are defined in Appendix B, Figure B2, Figure B3, Figure B4 and Figure B5. Where not defined and/or where part geometry requires more specific definition, the supplier/plant and GM Supplier Quality Engineer (SQE) will identify part and model-specific check locations. These locations will be determined prior to Start of Regular Production (SORP) and will be clearly defined using a graphic or marked-up part which will be retained for reference and be accessible through GM Supplier Quality.

4.3 Part Zoning. For each fascia or add-on part style, suppliers should retain and display a zoned part per the zoning definition developed and communicated by the DRE, as indicated in 3.1 Part Zones.

4.4 Timing for Initiation of Data Collection. Appearance measurements at the assembly plant and supplier sites shall be targeted to commence with Pre-Production Validation (PPV) builds (Week -32 of the GM Global Vehicle Development Process (GVDP)), but will not be formalized until Overall Harmony Approval by Design Quality is achieved for the product program (as documented on the Global Exterior Harmony Review Report).

4.4.1 Add-on part suppliers and the assembly plant should strive to satisfy all appearance requirements of this specification with supporting data prior to submitting to Design Quality and/or the appropriate SQE for AAR.

4.5 Data Submission Requirements. Each supplier and the assembly plant will be able to provide data upon request of the assembly plant or SQE, as required to assess paint performance. Shared information will be used to assess and improve paint system appearance per the requirements of this specification.