REPORT NUMBER 216a-MGA-21-003

SAFETY COMPLIANCE TESTING FOR FMVSS 216a
"Roof Crush Resistance"

****

HYUNDAI ELANTRA
NHTSA No. C20214202

VIN No. 5NPLS4AG4MH005012

Prepared By:
MGA RESEARCH CORPORATION
446 Executive Drive
Troy, Michigan 48083

,

Test Date: May 25-27, 2021
Report Date: June 4, 2021

PRELIMINARY REPORT

PREPARED FOR:

U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
ENFORCEMENT
OFFICE OF VEHICLE SAFETY COMPLIANCE
1200 New Jersey Avenue, SE
WASHINGTON, D.C. 20590

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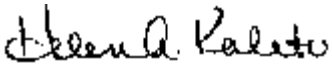
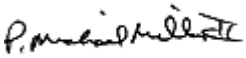
Prepared By: _____
Fern Gorman, Project Leader



_____
Helen A. Kaleto, Laboratory Manager



Approved By: _____
P. Michael Miller II, Vice President

Approval Date: June 4, 2021

PRELIMINARY REPORT ACCEPTANCE BY OVSC:

Accepted By: JAMES A JONES

Digitally signed by JAMES A JONES
Date: 2021.06.09 13:39:26 -04'00'

Acceptance Date:

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<tr><td colspan="4">16. Abstract
Compliance tests were conducted on roof from a Hyundai Elantra, NHTSA No. C20214202, in accordance with the specifications of the Office of Vehicle Safety Compliance Test Procedure No. TP-216a-00 for the determination of FMVSS 216a compliance. The testing was conducted at MGA Research Corporation in Troy, Michigan on May 25-27, 2021. Test failures identified were as follows:
None</td></tr>
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</table>

TABLE OF CONTENTS

1.0 Purpose of Compliance Test and Test Procedure

Purpose: The tests performed are part of the safety compliance program for the National Highway Traffic Safety Administration (NHTSA) by MGA Research Corporation under Contract No. DTNH22-16-D-00028. The purpose of the testing is to determine whether the subject vehicle, Hyundai ELANTRA meets certain performance requirements of FMVSS 216a, "Roof Crush Resistance". The compliance test was conducted in accordance with OVSC Laboratory Test Procedure No. TP-216a-00 dated May 6, 2009.

Test Procedures: The "MGA Research Corporation Testing Procedure for FMVSS 216a", submitted to and approved by the National Highway Traffic Safety Administration, contains the specific procedures used to conduct testing.

This procedure shall not be interpreted to conflict with any portion of NHTSA TP-216a-00, FMVSS 216a nor any amendment thereof within the applicable contract.

2.0 Compliance Test Data Summary

The roof of a Hyundai Elantra was required to sustain a maximum load of 36,956 N (3 x UVW) on both the right and left sides of the vehicle with platen displacement of 127 mm or less. The left side sustained a maximum load of 36,709 N at 31.0 mm of platen travel. The right side sustained a load of 36,875 N at 31.0 mm of platen travel. No head contact was observed.

3.0 Test Data and Results

Data Sheet 1

GENERAL TEST AND VEHICLE PARAMETER DATA

NHTSA No.: C20214202 Test Date: 05/27/2021 Side Tested: Driver
Laboratory: MGA Research Corporation Test Technician(s): Jacob Briskey, Kyle Goodrich

TEST VEHICLE INFORMATION:
Year/Make/Model/Body Style: Hyundai Elantra
Body Color: Black VIN: 5NPLS4AG4MH005012
Build Date: 10/21/2020 Odometer Reading: 696 miles
Engine Data: 4 Cylinders CID 2.0 Liter cc
Engine Placement: Longitudinal or X Lateral
Transmission: Speed Manual X Automatic Overdrive
Drive: Rear Wheel Drive X Front Wheel Drive Four Wheel Drive
Safety Restraints: seat belts and airbags

DATA FROM TIRE SIDEWALL:
Size of the tires on test vehicle: 205/55 R16 Manufacturer: Kumho
Tire Pressure for Max. Load Carrying Capacity: 300 kPa Front 300 kPa Rear
Treadwear: 500 Traction: A Temperature: A

DATA RECORDED FROM VEHICLE PLACARD OR TIRE LABEL:
Recommended Tire Size: 205/55 R16
Recommended Cold Tire Pressure: 235 kPa Front 215 kPa Rear

VEHICLE CAPACITY DATA:
Number of Occupants 2 Front 3 Rear 5 Total
Type of Front Seats X Buckets Bench Split Bench
Type of Front Seatback Fixed X Adjustable with X Lever or Knob

List of Components Removed: Seats, carpet, and exterior trim

UNLOADED VEHICLE WEIGHT:

Right Front	382.0 kg	Right Rear	241.0 kg
Left Front	395.5 kg	Left Rear	238.5 kg
Total Front	777.5 kg	Total Rear	479.5 kg

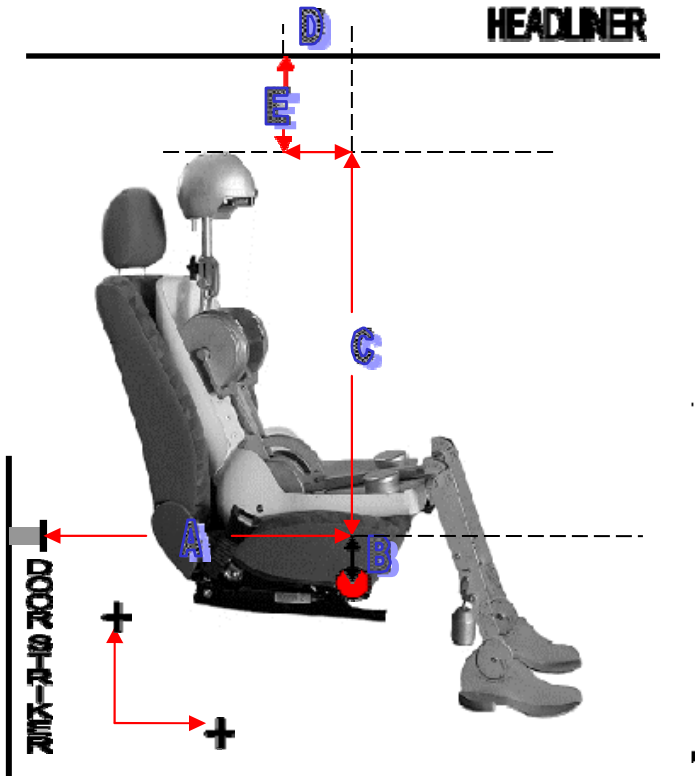
Total Weight: 1,257.0 kg % of Total weight in Front: 62.0 % of Total weight in Rear: 38.0

TEST VEHICLE ATTITUDE:
Pitch Attitude: (Nose Down (ND), Nose Up (NU))
Initial: Right Door Sill Angle 0.1° (NU) Left Door Sill Angle 0.1° (NU)
Preliminary: Right Door Sill Angle 0.1° (NU) Left Door Sill Angle 0.1°
Roll Attitude:
Initial: Left-side 220 Right-side 222
Preliminary: Left-side 416 Right-side 418

Jacob Briskey 05/27/2021
Technician Signature Date

Data Sheet 2

NHTSA No.: C20214202 Test Date: 05/27/2021 Side Tested: Driver
Laboratory: MGA Research Corporation Test Technician(s): Jacob Briskey, Kyle Goodrich



H-Point Data (mm)

		J826 Only	After HRMD Installed
HRMD	**Torso Angle**	18.4°	18.6°
	X (=A) – fore/aft of striker	184.5	185.2
	Z (=B) – Above/below striker below	265.8	266.1

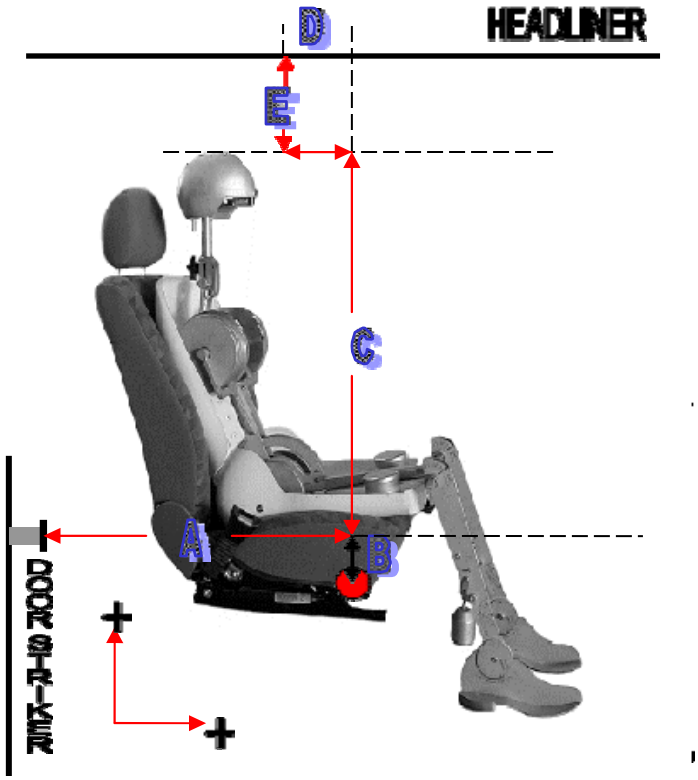
Positioning Data (mm)

C	508.4
D	251.1
E	97.6

986
A – Horizontally from the door striker to the H-point
B – Vertically from the H-point to the door striker
C – Vertically from the door striker to the top of the head
D – Horizontally from the center of the head to the H point
E – Vertically from the top center of the head to the headliner

Data Sheet 3

NHTSA No.: C20214202 Test Date: 05/27/2021 Side Tested: Passenger
Laboratory: MGA Research Corporation Test Technician(s): Jacob Briskey, Kyle Goodrich



H-Point Data (mm)

		J826 Only	After HRMD Installed
HRMD	**Torso Angle**	18.4°	18.2°
	X (=A) – fore/aft of striker	197.4	197.0
	Z (=B) – Above/below striker below	270.8	270.9

Positioning Data (mm)

C	505.2
D	280.5
E	99.5

A – Horizontally from the door striker to the H-point
B – Vertically from the H-point to the door striker
C – Vertically from the door striker to the top of the head
D – Horizontally from the center of the head to the H point
E – Vertically from the top center of the head to the headliner

Data Sheet 4

Test Information – First Tested Side

NHTSA No.: C20214202 Test Date: 05/27/2021 Side Tested: Driver
Laboratory: MGA Research Corporation Test Technician(s): Jacob Briskey, Kyle Goodrich

A. Driver Side Pre-Test Data

Levelness of the Tie-Down Surface/Platform (0 +/- 0.5°): 0.1° Platen
Platen Angles: Pitch Angle: 5° Roll Angle: 25°
Platen Alignment at Vehicle Longitudinal Centerline: 748 mm
Max. Applied Force for Vehicles w/GVWR ≤ 2722 kg = UVW 1,257.0 x 9.8 x **3.0** = 36,956 N
Max. Applied Force for Vehicles w/GVWR > 2722 kg = UVW N/A x 9.8 x **1.5** = N/A N
1. Any convertible top, movable or removable roof structure in their closed positions: Yes
2. Close all windows, close and lock all doors: No ____ Yes X
3. The test device will initially contact the roof at 156 mm aft of windshield.
4. HRMD Top Center of Head Position (Driver): X: -65.8 Y: 409.2 Z: 508.5
5. HPF 201 Head form Top Center of Head Position (Driver): X: -65.9 Y: 409.5 Z: 508.4
HPF device properly aligned: Yes

B. Post Test Data

Maximum load achieved = 36,709 N at 31.0 mm of displacement.
Did the maximum load achieved reach the maximum applied force (0,-250N)? ___ No-Fail X Yes-Pass
Did head contact occur? No X Yes ____ at ____ mm of displacement
Was a 222 N head resultant force attained? No-Pass X Yes-Fail ___ at ___ mm of displacement.
Did the platen travel exceed 127 mm? No-Pass X Yes-Fail ___
Did the windshield break? No X Yes ___ at ___ mm of displacement.
Did the sun roof panel(s) break? No X Yes ____ N/A X

Description of damage and deformation that occurred during the test:

Permanent deformation along driver side roof line.

Data Sheet 4 Continued

Test Information – First Tested Side

Did the second HPF shift from its original position? No X Yes ___ Distance 0 mm

Indicate in the picture below where the second HPF center is located versus the original position (center).
NOTE: The distance between each concentric circle is 2 mm.

Data Sheet 5

Test Information – Second Tested Side

NHTSA No.: C20214202 Test Date: 05/27/2021 Side Tested: Passenger
Laboratory: MGA Research Corporation Test Technician(s): Jacob Briskey, Kyle Goodrich

A. Passenger Side Pre-Test Data

Levelness of the Tie-Down Surface/Platform (0 +/- 0.5º): 0.1° Platen
Platen Angles: Pitch Angle: 5° Roll Angle: 25°
Platen Alignment at Vehicle Longitudinal Centerline: 761 mm
Max. Applied Force for Vehicles w/GVWR ≤ 2722 kg = UVW 1,257.0 x 9.8 x **3.0** = 36,956 N
Max. Applied Force for Vehicles w/GVWR > 2722 kg = UVW N/A x 9.8 x **1.5** = N/A N
1. Any convertible top, movable or removable roof structure in their closed positions: Yes
2. Close all windows, close and lock all doors: No ____ Yes X
3. The test device will initially contact the roof at 161 mm aft of windshield.
4. HRMD Top Center of Head Position (Passenger): X: -89.3 Y: -427.7 Z: 505.2
5. HPF 201 Head form Top Center of Head Position (Passenger): X: -89.5 Y: -427.7 Z: 505.2
HPF device properly aligned: Yes

B. Post Test Data

Maximum load achieved = 36,875 N at 31.0 mm of displacement.
Did the maximum load achieved reach the maximum applied force (0,-250N)? ___ No-Fail X Yes-Pass
Did head contact occur? No X Yes ____ at ____ mm of displacement
Was a 222 N head resultant force attained? No-Pass X Yes-Fail ___ at ___ mm of displacement.
Did the platen travel exceed 127 mm? No-Pass X Yes-Fail ___
Did the windshield break? No X Yes ___ at ___ mm of displacement.
Did the sun roof panel(s) break? No ____ Yes ____ N/A X

Description of damage and deformation that occurred during the test:

Permanent deformation along passenger roof line.

4.0 TEST EQUIPMENT LIST AND CALIBRATION INFORMATION

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ITEM	MFR	MODEL	S/N	CALIB. PERIOD	DATE OF LAST CALIB.	ACCURACY
LVDT 1	MTS	G-Series	LVDT 1	12 Months	10/27/2020	0.164%
LVDT 2	MTS	G-Series	LVDT 2	12 Months	10/27/2020	0.164%
LVDT 3	MTS	G-Series	LVDT 3	12 Months	10/27/2020	0.164%
LVDT 4	MTS	G-Series	LVDT 4	12 Months	10/27/2020	0.164%
Load Cell 1	Interface	1220AF-50K	305372	12 Months	12/18/2020	0.93%
Load Cell 2	Interface	1220AF-50K	568559	12 Months	12/18/2020	0.93%
Load Cell 3	Interface	1220AF-50K	281953	12 Months	12/18/2020	0.93%
Load Cell 4	Interface	1220ACK-50K	557637	12 Months	12/18/2020	0.93%
Load Cell 5	Interface	1220ACK-50K	1019124	12 Months	12/18/2020	0.93%
Load Cell 6	Interface	1220AF-50K	305366	12 Months	12/18/2020	0.93%
Load Cell 7	Interface	1220AF-50K	305386	12 Months	12/18/2020	0.93%
HPF Load Cell	Humanetics	9555TF	DH9302	12 Months	10/27/2020	0.20%
HPF Load Cell	Humanetics	9555TF	EH3439	12 Months	09/29/2020	0.20%
Inclinometer	MIT	Pro 360	MGA00173	12 Months	03/31/2021	0.062° + 0.6R
CMM	FARO	N/A	R10-02-13-11437	12 Months	05/04/2020	±0.345 mm
Tape Measure	Stanley	33-215	TPM007-32	12 Months	09/29/2020	1 mm
Temperature/ Humidity Gauge	Extech	RHM15	MI0225	12 Months	01/31/2021	7.1e-001 %RH 8.5e-002 °C

MICHIGAN OPERATIONS
DATE: 03/18/2019
SUPERCEDES: MGTPLVDT.4

DOC. NO.: MGATP_LVDT_CAL
REVISION NO.: 5
PAGE 4 OF 4

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Linear Voltage Displacement Transducer (LVDT)
Verification for the MAST/Hydraulic Cylinders

Sensor Information		Reference Sensor Information	
Name:	LVDT-1	**Name:**	Tape Measure
Model:	MTS	**Model:**	Stanley
S/N	216-LVDT-1	**S/N:**	MGA 00681
Range	24"	**Capacity:**	12'
Calibration Date	10/27/2020	**Calibration Date:**	12/19/2019
Calibration DueDate	10/27/2021	**Calibrated By:**	NovaStar

Measured Values		Reproduced from Calculated Slope	
Distance (in)	Measured Distance (in)	% Error *	Scale factor Best Fit Line (mm/V)
0.00	0.00	0.00	1.00
2.50	2.48	0.008	Intercept
5.00	5.04	0.008	
7.50	7.52	0.003	
10.00	9.99	0.001	
12.50	12.52	0.002	
15.00	15.04	0.003	
17.50	17.56	0.003	
20.00	20.04	0.002	
22.50	22.56	0.003	Maximum Error
24.00	23.98	0.0008	0.008
: percent Error calculated by 100(Measured - Calculated) / Measured Range			

Calibrated thermometer (ID# MI0095) used to monitor temperate and Relative Humidity.

Temperature	% Relative Humidity
68.2	34

Performed By: [signature]

Approved By: [signature]

All calibrations are traceable to the National Institute of Standards and Technology. Estimated uncertainty of the measurement is ±0.7%. All certification data and equipment are on file for inspection at your request. Best uncertainties represent expanded uncertainties expressed at approximately the 95% confidence level using a coverage factor k=2.

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SUPERCEDES: MGTPLVDT.4

DOC. NO.: MGATP_LVDT_CAL
REVISION NO.: 5
PAGE 4 OF 4

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Linear Voltage Displacement Transducer (LVDT)
Verification for the MAST/Hydraulic Cylinders

Sensor Information		Reference Sensor Information	
Name:	LVDT-2	**Name:**	Tape Measure
Model:	MTS	**Model:**	Stanley
S/N	216-LVDT-2	**S/N:**	MLA00681
Range	24"	**Capacity:**	12'
Calibration Date	10/27/2020	**Calibration Date:**	12/19/2019
Calibration DueDate	10/27/2021	**Calibrated By:**	NovaStar

Measured Values		Reproduced from Calculated Slope	
Distance (in)	Measured Distance (in)	% Error *	Scale factor Best Fit Line (mm/V)
0.00	0.00	0.00	1.00
2.50	2.48	0.008	Intercept
5.00	5.00	0	
7.50	7.48	0.003	
10.00	9.96	0.004	
12.50	12.48	0.002	
15.00	15.00	0	
17.50	17.48	0.001	
20.00	20.00	0	
22.50	22.52	0.0009	Maximum Error
24.00	24.02	0.0008	0.008

: percent Error calculated by 100(Measured - Calculated) / Measured Range

Calibrated thermometer (ID# MI0095) used to monitor temperate and Relative Humidity.

Temperature	% Relative Humidity
68.2	34

Performed By: [signature]

Approved By: [signature]

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DOC. NO.: MGATP_LVDT_CAL
REVISION NO.: 5
PAGE 4 OF 4

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Linear Voltage Displacement Transducer (LVDT)
Verification for the MAST/Hydraulic Cylinders

Sensor Information		Reference Sensor Information	
Name:	LVDT-3	**Name:**	Tape Measure
Model:	MTS	**Model:**	Stanley
S/N	216-LVDT-3	**S/N:**	MGA 00681
Range	24"	**Capacity:**	12'
Calibration Date	10/27/2020	**Calibration Date:**	12/19/2019
Calibration DueDate	10/27/2021	**Calibrated By:**	NovaStar

Measured Values		Reproduced from Calculated Slope	
Distance (in)	Measured Distance (in)	% Error *	Scale factor Best Fit Line (mm/V)
0.00	0.00	0.00	1.00
2.50	2.48	0.008	Intercept
5.00	5.00	0	
7.50	7.52	0.003	
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: percent Error calculated by 100(Measured - Calculated) / Measured Range

Calibrated thermometer (ID# MI0095) used to monitor temperate and Relative Humidity.

Temperature	% Relative Humidity
68.2	34

Performed By: [signature]   Approved By: [signature]

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Linear Voltage Displacement Transducer (LVDT)
Verification for the MAST/Hydraulic Cylinders

Sensor Information		Reference Sensor Information	
Name:	LVDT-4	**Name:**	Tape Measure
Model:	MTS	**Model:**	Stanley
S/N	216-LVDT-4	**S/N:**	MGA00681
Range	24"	**Capacity:**	12'
Calibration Date	10/27/2020	**Calibration Date:**	12/18/2019
Calibration DueDate	10/27/2021	**Calibrated By:**	Nova Star

Measured Values		Reproduced from Calculated Slope	
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Calibrated thermometer (ID# MI0095) used to monitor temperate and Relative Humidity.

Temperature	% Relative Humidity
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Performed By: Approved By:

All calibrations are traceable to the National Institute of Standards and Technology. Estimated uncertainty of the measurement is ±0.7%. All certification data and equipment are on file for inspection at your request. Best uncertainties represent expanded uncertainties expressed at approximately the 95% confidence level using a coverage factor k=2.

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ACCREDITED CALIBRATION CERTIFICATE 1991.01

interface
FORCE MEASUREMENT SOLUTIONS

LOAD CELL CALIBRATION CERTIFICATION

CUSTOMER : MGA RESEARCH CORP
ADDRESS : TROY, MI
CONDITION: AS FOUND & FINAL S.O. #: 205581 P.O. #: MI24081
MODEL: 1220AF-50K SERIAL: 305372 BRIDGE: A CAPACITY: 50 Klbf
PROCEDURE: C-1257 Mounting Per Interface Installation Instruction 15-5

ZERO BALANCE: 0.232 %RO

TEST CONDITIONS

TEMPERATURE: 73 °F HUMIDITY: 23% EXCITATION: 10 VDC

TRACEABILITY

FORCE STANDARD:	STD-10	NIST #:	STD-10B2820	DUE: 15-MAY-2022
STANDARD INDICATOR:	BRD1	NIST #:	EVL645567	
TEST INDICATOR:	BRD4	NIST #:	EVL645567	

SHUNT CALIBRATION

	Shunt (+/- .01%)	Output	Straight Line Conversion	Connections*
TENSION	30.0 KOhm	2.90240 mV/V	35.081 Klbf	-Out to -Exc
COMPRESSION	30.0 KOhm	-2.90403 mV/V	35.088 Klbf	-Out to +Exc

Shunt calibration resistor connections for tension and compression respectively are (-Exc to -Out) and (+Exc to -Out) for connector models; (-Sense to -Out Shuntcal) and (+Sense to -Out Shuntcal) for 7 wire models.

PERFORMANCE

	Rated Output	SEB Output	Nonlinearity	Hysteresis	SEB
TENSION	4.13736 mV/V	4.13675 mV/V	-0.029 %FS	0.037 %FS	± 0.020 %FS
COMPRESSION	-4.13845 mV/V	-4.13815 mV/V	-0.021 %FS	0.036 %FS	± 0.018 %FS

STATIC ERROR BAND (SEB): The band of maximum deviations of the ascending and descending calibration points from a best fit straight line through zero OUTPUT. It includes the effects of NONLINEARITY, HYSTERESIS, and nonreturn to MINIMUM LOAD.

TEST LOAD APPLIED (Klbf)	RECORDED READINGS (mV/V) Tension	Compression
0	.00000	.00000
10	.82679	-.82714
20	1.65400	-1.65451
30	2.48123	-2.48229
40	3.30893	-3.30999
50	4.13736	-4.13845
20	1.65552	-1.65601
0	.00008	-.00025

Interface Inc. certifies that force measurements are traceable to primary standards at NIST. Calibration performed per Interface QA program and the requirements of ISO/IEC 17025, MIL-STD-45662A & ANSI/NCSL Z540-1-1994. Estimated measurement uncertainty is 0.040% RDG. expressed as the expanded uncertainty at 95% confidence level using a coverage factor of k=2. Results relate to load cell serial 305372 only.
DO NOT REPRODUCE THIS REPORT except in full or with Interface Inc. written approval.

TECHNICIAN : CRATTY, RICHARD C.

CALIBRATION DATE : 18-DEC-2020
ISSUED DATE: 18-DEC-2020

APPROVED : Sean Malone - Service Mgr.

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ACCREDITED CALIBRATION CERTIFICATE 1991.01

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FORCE MEASUREMENT SOLUTIONS

LOAD CELL CALIBRATION CERTIFICATION

CUSTOMER : MGA RESEARCH CORP
ADDRESS : TROY, MI
CONDITION: AS FOUND & FINAL S.O. #: 205581 P.O. #: MI24081
MODEL: 1220AF-50K SERIAL: 568559 BRIDGE: A CAPACITY: 50 Klbf
PROCEDURE: C-1257 Mounting Per Interface Installation Instruction 15-5
ZERO BALANCE: 0.033 %RO

TEST CONDITIONS
TEMPERATURE: 73 °F HUMIDITY: 23% EXCITATION: 10 VDC

TRACEABILITY
FORCE STANDARD: STD-10 NIST #: STD-10B2820 DUE: 15-MAY-2022
STANDARD INDICATOR: BRD1 NIST #: EVL645567
TEST INDICATOR: BRD4 NIST #: EVL645567

SHUNT CALIBRATION

	Shunt (+/- .01%)	Output	Straight Line Conversion	Connections*
TENSION	30.0 KOhm	2.90224 mV/V	34.373 Klbf	-Out to -Exc
COMPRESSION	30.0 KOhm	-2.90705 mV/V	34.403 Klbf	-Out to +Exc

Shunt calibration resistor connections for tension and compression respectively are (-Exc to -Out) and (+Exc to -Out) for connector models; (-Sense to -Out Shuntcal) and (+Sense to -Out Shuntcal) for 7 wire models.

PERFORMANCE

	Rated Output	SEB Output	Nonlinearity	Hysteresis	SEB
TENSION	4.22188 mV/V	4.22170 mV/V	-0.008 %FS	0.000 %FS	± 0.007 %FS
COMPRESSION	-4.22551 mV/V	-4.22494 mV/V	-0.019 %FS	0.016 %FS	± 0.014 %FS

STATIC ERROR BAND (SEB): The band of maximum deviations of the ascending and descending calibration points from a best fit straight line through zero OUTPUT. It includes the effects of NONLINEARITY, HYSTERESIS, and nonreturn to MINIMUM LOAD.

TEST LOAD APPLIED (Klbf)	RECORDED READINGS (mV/V) Tension	Compression
0	.00000	.00000
10	.84404	-.84451
20	1.68853	-1.68940
30	2.53332	-2.53461
40	3.37758	-3.38008
50	4.22188	-4.22551
20	1.68853	-1.69009
0	-.00004	-.00001

Interface Inc. certifies that force measurements are traceable to primary standards at NIST. Calibration performed per Interface QA program and the requirements of ISO/IEC 17025, MIL-STD-45662A & ANSI/NCSL Z540-1-1994 . Estimated measurement uncertainty is 0.040% RDG. expressed as the expanded uncertainty at 95% confidence level using a coverage factor of k=2. Results relate to load cell serial 568559 only.
DO NOT REPRODUCE THIS REPORT except in full or with Interface Inc. written approval.

TECHNICIAN : CRATTY, RICHARD C.
CALIBRATION DATE : 18-DEC-2020
ISSUED DATE: 18-DEC-2020

APPROVED : Sean Malone - Service Mgr.

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LOAD CELL CALIBRATION CERTIFICATION

CUSTOMER : MGA RESEARCH CORP
ADDRESS : TROY, MI
CONDITION: AS FOUND & FINAL S.O. #: 205581 P.O. #: MI24081
MODEL: 1220AF-50K SERIAL: 281953 BRIDGE: A CAPACITY: 50 Klbf
PROCEDURE: C-1257 Mounting Per Interface Installation Instruction 15-5
ZERO BALANCE: 0.060 %RO

TEST CONDITIONS
TEMPERATURE: 73 °F HUMIDITY: 21% EXCITATION: 10 VDC

TRACEABILITY
FORCE STANDARD: STD-10 NIST #: STD-10B2820 DUE: 15-MAY-2022
STANDARD INDICATOR: BRD1 NIST #: EVL645567
TEST INDICATOR: BRD4 NIST #: EVL645567

SHUNT CALIBRATION

	Shunt (+/- .01%)	Output	Straight Line Conversion	Connections*
TENSION	30.0 KOhm	2.90282 mV/V	35.062 Klbf	-Out to -Exc
COMPRESSION	30.0 KOhm	-2.89801 mV/V	34.995 Klbf	-Out to +Exc

Shunt calibration resistor connections for tension and compression respectively are (-Exc to -Out) and (+Exc to -Out) for connector models; (-Sense to -Out Shuntcal) and (+Sense to -Out Shuntcal) for 7 wire models.

PERFORMANCE

	Rated Output	SEB Output	Nonlinearity	Hysteresis	SEB
TENSION	4.14061 mV/V	4.13954 mV/V	-0.041 %FS	0.052 %FS	± 0.026 %FS
COMPRESSION	-4.14082 mV/V	-4.14064 mV/V	-0.023 %FS	0.039 %FS	± 0.020 %FS

STATIC ERROR BAND (SEB) The band of maximum deviations of the ascending and descending calibration points from a best fit straight line through zero OUTPUT. It includes the effects of NONLINEARITY, HYSTERESIS, and nonreturn to MINIMUM LOAD.

TEST LOAD APPLIED (Klbf)	RECORDED READINGS (mV/V) Tension	Compression
0	.00000	.00000
10	.82703	- .82761
20	1.65474	-1.65545
30	2.48267	-2.48356
40	3.31150	-3.31185
50	4.14061	-4.14082
20	1.65689	-1.65708
0	.00003	- .00017

Interface Inc. certifies that force measurements are traceable to primary standards at NIST. Calibration performed per Interface QA program and the requirements of ISO/IEC 17025, MIL-STD-45662A & ANSI/NCSL Z540-1-1994 . Estimated measurement uncertainty is 0.040% RDG. expressed as the expanded uncertainty at 95% confidence level using a coverage factor of k=2. Results relate to load cell serial 281953 only.
DO NOT REPRODUCE THIS REPORT except in full or with Interface Inc. written approval.

TECHNICIAN : CRATTY, RICHARD C.
CALIBRATION DATE : 18-DEC-2020
ISSUED DATE: 18-DEC-2020

APPROVED : _____

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LOAD CELL CALIBRATION CERTIFICATION

CUSTOMER : MGA RESEARCH CORP
ADDRESS : TROY, MI
CONDITION: AS FOUND & FINAL S.O. #: 205581 P.O. #: MI24081
MODEL: 1220ACK-50K SERIAL: 557637 BRIDGE: A CAPACITY: 50 Klbf
PROCEDURE: C-1257 Mounting Per Interface Installation Instruction 15-5
ZERO BALANCE: 0.072 %RO

TEST CONDITIONS

TEMPERATURE: 73 °F HUMIDITY: 21% EXCITATION: 10 VDC

TRACEABILITY

FORCE STANDARD: STD-10 NIST #: STD-10B2820 DUE: 15-MAY-2022
STANDARD INDICATOR: BRD1 NIST #: EVL645567
TEST INDICATOR: BRD4 NIST #: EVL645567

SHUNT CALIBRATION

	Shunt (+/- .01%)	Output	Straight Line Conversion	Connections*
TENSION	30.0 KOhm	2.90189 mV/V	34.782 Klbf	-Out to -Exc
COMPRESSION	30.0 KOhm	-2.90915 mV/V	34.818 Klbf	-Out to +Exc

Shunt calibration resistor connections for tension and compression respectively are (-Exc to -Out) and (+Exc to -Out) for connector models; (-Sense to -Out Shuntcal) and (+Sense to -Out Shuntcal) for 7 wire models.

PERFORMANCE

	Rated Output	SEB Output	Nonlinearity	Hysteresis	SEB
TENSION	4.17065 mV/V	4.17149 mV/V	0.032 %FS	-0.028 %FS	± 0.020 %FS
COMPRESSION	-4.17820 mV/V	-4.17771 mV/V	-0.018 %FS	0.016 %FS	± 0.012 %FS

STATIC ERROR BAND (SEB): The band of maximum deviations of the ascending and descending calibration points from a best fit straight line through zero OUTPUT. It includes the effects of NONLINEARITY, HYSTERESIS, and nonreturn to MINIMUM LOAD.

TEST LOAD APPLIED (Klbf)	RECORDED READINGS (mV/V) Tension	Compression
0	.00000	.00000
10	.83484	-.83517
20	1.66938	-1.67060
30	2.50373	-2.50618
40	3.33731	-3.34203
50	4.17065	-4.17820
20	1.66820	-1.67127
0	-.00007	-.00007

Interface Inc. certifies that force measurements are traceable to primary standards at NIST. Calibration performed per Interface QA program and the requirements of ISO/IEC 17025, MIL-STD-45662A & ANSI/NCSL Z540-1-1994 . Estimated measurement uncertainty is 0.040% RDG, expressed as the expanded uncertainty at 95% confidence level using a coverage factor of k=2. Results relate to load cell serial 557637 only.
DO NOT REPRODUCE THIS REPORT except in full or with Interface Inc. written approval.

TECHNICIAN : CRATTY, RICHARD C.

CALIBRATION DATE : 18-DEC-2020
ISSUED DATE: 18-DEC-2020

APPROVED : Sean Malone - Service Mgr.

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LOAD CELL CALIBRATION CERTIFICATION

CUSTOMER : MGA RESEARCH CORP
ADDRESS : TROY, MI
CONDITION: AS FOUND & FINAL S.O. #: 205581 P.O. #: MI24081
MODEL: 1220ACK-50K SERIAL: 1019124 BRIDGE: A CAPACITY: 50 Klbf
PROCEDURE: C-1257 Mounting Per Interface Installation Instruction 15-5

ZERO BALANCE: 0.240 %RO

TEST CONDITIONS

TEMPERATURE: 73 °F HUMIDITY: 23% EXCITATION: 10 VDC

TRACEABILITY

FORCE STANDARD:	STD-10	NIST #:	STD-10B2820	DUE: 15-MAY-2022
STANDARD INDICATOR:	BRD1	NIST #:	EVL645567	
TEST INDICATOR:	BRD4	NIST #:	EVL645567	

SHUNT CALIBRATION

	Shunt (+/- .01%)	Output	Straight Line Conversion	Connections*
TENSION	30.0 KOhm	2.90588 mV/V	34.814 Klbf	-Out to -Exc
COMPRESSION	30.0 KOhm	-2.91010 mV/V	34.827 Klbf	-Out to +Exc

Shunt calibration resistor connections for tension and compression respectively are (-Exc to -Out) and (+Exc to -Out) for connector models; (-Sense to -Out Shuntcal) and (+Sense to -Out Shuntcal) for 7 wire models.

PERFORMANCE

	Rated Output	SEB Output	Nonlinearity	Hysteresis	SEB
TENSION	4.17292 mV/V	4.17340 mV/V	0.018 %FS	-0.013 %FS	± 0.011 %FS
COMPRESSION	-4.17872 mV/V	-4.17797 mV/V	-0.025 %FS	0.020 %FS	± 0.018 %FS

STATIC ERROR BAND (SEB): The band of maximum deviations of the ascending and descending calibration points from a best fit straight line through zero OUTPUT. It includes the effects of NONLINEARITY, HYSTERESIS, and nonreturn to MINIMUM LOAD.

TEST LOAD APPLIED (Klbf)	RECORDED READINGS (mV/V) Tension	Compression
0	.00000	.00000
10	.83459	-.83498
20	1.66952	-1.67044
30	2.50452	-2.50637
40	3.33886	-3.34241
50	4.17292	-4.17872
20	1.66898	-1.67128
0	.00001	.00027

Interface Inc. certifies that force measurements are traceable to primary standards at NIST. Calibration performed per Interface QA program and the requirements of ISO/IEC 17025, MIL-STD-45662A & ANSI/NCSL Z540-1-1994 . Estimated measurement uncertainty is 0.040% RDG. expressed as the expanded uncertainty at 95% confidence level using a coverage factor of k=2. Results relate to load cell serial 1019124 only.
DO NOT REPRODUCE THIS REPORT except in full or with Interface Inc. written approval.

TECHNICIAN : CRATTY, RICHARD C.

CALIBRATION DATE : 18-DEC-2020
ISSUED DATE: 18-DEC-2020

APPROVED : Sean Malone - Service Mgr.

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LOAD CELL CALIBRATION CERTIFICATION

CUSTOMER : MGA RESEARCH CORP
ADDRESS : TROY, MI
CONDITION: AS FOUND & FINAL S.O. #: 205581 P.O. #: MI24081
MODEL: 1220AF-50K SERIAL: 305366 BRIDGE: A CAPACITY: 50 Klbf
PROCEDURE: C-1257 Mounting Per Interface Installation Instruction 15-5
ZERO BALANCE: 0.111 %RO

TEST CONDITIONS
TEMPERATURE: 73 °F HUMIDITY: 21% EXCITATION: 10 VDC

TRACEABILITY
FORCE STANDARD: STD-10 NIST #: STD-10B2820 DUE: 15-MAY-2022
STANDARD INDICATOR: BRD1 NIST #: EVL645567
TEST INDICATOR: BRD4 NIST #: EVL645567

SHUNT CALIBRATION

	Shunt (+/- .01%)	Output	Straight Line Conversion	Connections*
TENSION	30.0 KOhm	2.90424 mV/V	35.051 Klbf	-Out to -Exc
COMPRESSION	30.0 KOhm	-2.90494 mV/V	35.051 Klbf	-Out to +Exc

Shunt calibration resistor connections for tension and compression respectively are (-Exc to -Out) and (+Exc to -Out) for connector models; (-Sense to -Out Shuntcal) and (+Sense to -Out Shuntcal) for 7 wire models.

PERFORMANCE

	Rated Output	SEB Output	Nonlinearity	Hysteresis	SEB
TENSION	4.14376 mV/V	4.14291 mV/V	-0.029 %FS	0.041 %FS	± 0.020 %FS
COMPRESSION	-4.14460 mV/V	-4.14389 mV/V	-0.025 %FS	0.031 %FS	± 0.017 %FS

STATIC ERROR BAND (SEB): The band of maximum deviations of the ascending and descending calibration points from a best fit straight line through zero OUTPUT. It includes the effects of NONLINEARITY, HYSTERESIS, and nonreturn to MINIMUM LOAD.

TEST LOAD APPLIED (Klbf)	RECORDED READINGS (mV/V) Tension	Compression
0	.00000	.00000
10	.82802	-.82823
20	1.65632	-1.65685
30	2.48504	-2.48574
40	3.31430	-3.31507
50	4.14376	-4.14460
20	1.65800	-1.65813
0	.00010	-.00020

Interface Inc. certifies that force measurements are traceable to primary standards at NIST. Calibration performed per Interface QA program and the requirements of ISO/IEC 17025, MIL-STD-45662A & ANSI/NCSL Z540-1-1994. Estimated measurement uncertainty is 0.040% RDG. expressed as the expanded uncertainty at 95% confidence level using a coverage factor of k=2. Results relate to load cell serial 305366 only.
DO NOT REPRODUCE THIS REPORT except in full or with Interface Inc. written approval.

TECHNICIAN : CRATTY, RICHARD C.
CALIBRATION DATE : 18-DEC-2020
ISSUED DATE: 18-DEC-2020

APPROVED : Sean Malone - Service Mgr.

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FORCE MEASUREMENT SOLUTIONS

LOAD CELL CALIBRATION CERTIFICATION

CUSTOMER : MGA RESEARCH CORP
ADDRESS : TROY, MI
CONDITION: AS FOUND & FINAL S.O. #: 205581 P.O. #: MI24081
MODEL: 1220AF-50K SERIAL: 305386 BRIDGE: A CAPACITY: 50 Klbf
PROCEDURE: C-1257 Mounting Per Interface Installation Instruction 15-5
ZERO BALANCE: 0.058 %RO

TEST CONDITIONS

TEMPERATURE: 73 °F HUMIDITY: 23% EXCITATION: 10 VDC

TRACEABILITY

FORCE STANDARD: STD-10 NIST #: STD-10B2820 DUE: 15-MAY-2022
STANDARD INDICATOR: BRD1 NIST #: EVL645567
TEST INDICATOR: BRD4 NIST #: EVL645567

SHUNT CALIBRATION

	Shunt (+/- .01%)	Output	Straight Line Conversion	Connections*
TENSION	30.0 KOhm	2.90823 mV/V	35.144 Klbf	-Out to -Exc
COMPRESSION	30.0 KOhm	-2.90502 mV/V	35.085 Klbf	-Out to +Exc

Shunt calibration resistor connections for tension and compression respectively are (-Exc to -Out) and (+Exc to -Out) for connector models; (-Sense to -Out Shuntcal) and (+Sense to -Out Shuntcal) for 7 wire models.

PERFORMANCE

	Rated Output	SEB Output	Nonlinearity	Hysteresis	SEB
TENSION	4.13838 mV/V	4.13759 mV/V	-0.027 %FS	0.028 %FS	± 0.019 %FS
COMPRESSION	-4.14075 mV/V	-4.14004 mV/V	-0.028 %FS	0.042 %FS	± 0.021 %FS

STATIC ERROR BAND (SEB): The band of maximum deviations of the ascending and descending calibration points from a best fit straight line through zero OUTPUT. It includes the effects of NONLINEARITY, HYSTERESIS, and nonreturn to MINIMUM LOAD.

TEST LOAD APPLIED (Klbf)	RECORDED READINGS (mV/V) Tension	Compression
0	.00000	.00000
10	.82684	- .82737
20	1.65425	-1.65515
30	2.48217	-2.48329
40	3.31035	-3.31189
50	4.13838	-4.14075
20	1.65542	-1.65688
0	.00005	- .00019

Interface Inc. certifies that force measurements are traceable to primary standards at NIST. Calibration performed per Interface QA program and the requirements of ISO/IEC 17025, MIL-STD-45662A & ANSI/NCSL Z540-1-1994. Estimated measurement uncertainty is 0.040% RDG. expressed as the expanded uncertainty at 95% confidence level using a coverage factor of k=2. Results relate to load cell serial 305386 only.
DO NOT REPRODUCE THIS REPORT except in full or with Interface Inc. written approval.

TECHNICIAN : CRATTY, RICHARD C.
CALIBRATION DATE : 18-DEC-2020
ISSUED DATE: 18-DEC-2020

APPROVED : Sean Malone - Service Mgr.

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HUMANETICS
Innovative Solutions
23300 Haggerty Rd. Farmington Hills, MI 48335
Tel: 248-778-2000 Fax: 248-778-2001
email: info@humaneticsatd.com
website: www.humaneticsatd.com

Report Summary

Automated Load Cell Calibration System

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ACCREDITED
Calibration
Cert # 2421.03

Customer Name:	MGA RESEARCH CORPORATION ATTN: SCOTT ARSEN 446 EXECUTIVE DRIVE TROY MI 48083	Identification No.:	AF2010270705
		Date[4]:	10/27/2020

Manufacturer: Humanetics
Model Number: 9555TF
Serial Number: DH9302

As Received Condition		As Shipped Condition		Action Taken	
In Tolerance[6]	☑	In Tolerance[6]	☑	Repair	☐
Out of Tolerance[6]	☐	Out of Tolerance[6]	☐	Full Calibration	☑
Operational	☐	Operational	☐	Special Calibration	☐
Not Operational	☐	Not Operational	☐	Returned "As Is"	☐
Damaged	☐	Damaged	☐		
N/A	☐	N/A	☐		

Received Notes
n/a

As Shipped Notes
n/a

Action Notes
n/a

Technical Notes:

Calibration A2LA Accredited: ☑ Yes ☐ No

1) Unless otherwise noted all calibrations conform to ISO 17025:2005.

Standard ID	Report No.	Serial No.	Due Date	CMC(8) Uncertainty (Force)	CMC(8) Uncertainty (Moment)
2K-CL-D2K-1	2020004272	571308	6/24/2021	0.20% F.S.	0.50% F.S.

2) Calibration Standards Used: Standards used in the calibration of this transducer are traceable to NIST (National Institute of Standards and Technology). With exception of the measurements reported on the Load Cell Bridge Impedance Measurement Summary, which are for verification only.

3) Laboratory Scope: Humanetics Innovative Solution, Inc.'s calibration program is accredited to ISO/IEC 17025:2005 ANSI/NCSL Z-540-1-1994.

4) "Date" indicates confirmation of calibration data and should be used to increment calibration intervals.

5) Calibration Methods: The Calibration Methods used in this calibration are defined in the Calibration Method for Single and Multi-Axis Load Cells (CL-WI-00002P). Procedure Number: CL-PR-00001P/CL-PR-00002P.

6) This document applies only to the calibration of the item described above and the specific calibration performed by the Humanetics Innovative Solutions, Inc. calibration laboratory. When declaring in Tolerance or Out of Tolerance conditions(s), the calibration laboratory utilizes a Shared Risk Method** as the decision rule. The stability of the UUT over time depends on many factors outside our control. It is the responsibility of those using the item described above to quantify their measurement of uncertainty and evaluate the adequacy of their measurement process to demonstrate that measurement traceability is credibly maintained.

7) This report shall not be reproduced, except in full, without the written consent of the Humanetics Innovative Solutions, Inc.'s calibration laboratory.

8) Calibration and Measurement Capabilities (CMC) represent expanded uncertainties expressed at approximately the 95% level of confidence, coverage factor of k = 2.

**The Humanetics Innovative Solutions, Inc. calibration laboratory does not expand the provided measured value(s) by the associated uncertainty of the measurement. When parameter(s) are certified to be within specified tolerance(s), the unexpanded measured value(s) shall fall within the appropriate specification limit. With written agreement from the customer, other decision rules may be used. Please visit the company website at www.humaneticsatd.com for a copy of the Scope and Certificate. A copy of the scope and certificate is also available upon request.

HUMANETICS
Innovative Solutions
23300 Haggerty Rd. Farmington Hills, MI 48335
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website: www.humaneticsatd.com

Calibration Report
Uni-Directional Calibration

Automated Load Cell Calibration System
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Applied Excitation (VDC)	10.000	Date			10/27/2020
Calibration No.	AF2010270705	6 Mo. From Cal	4/27/2021	12 Mo. From Cal	10/27/2021
Model No.	9555TF	Serial No.			DH9302
Technician	BURCHI	Temp (°C)	22.8		Hum. (%) 27.2
Customer	MGA RESEARCH CORPORATION	Last Calibrated			10/8/2019
Description	3-Channel Load Cell	Customer Tag Number			

Voltage Calibration

Bridge	Capacity	Zero Offset	Nonlinearity	Hysteresis	Output @ Capacity	% Change
FX	2224.1 N	-0.0032 mV/V	0.02 % FS	0.15 % FS	1.7100 mV/V	-0.27 % FS
FY	2224.1 N	0.0053 mV/V	0.04 % FS	0.21 % FS	1.7152 mV/V	-0.18 % FS
FZ	4448.2 N	0.0197 mV/V	0.04 % FS	0.18 % FS	-1.2391 mV/V	-0.18 % FS

Calculated Sensitivity Matrix

			Using Sensor @ 10 V Excitation		Using Sensor @ 5V Excitation		Using Sensor @ 2V Excitation	
Bridge	Capacity		Output mV @ Capacity	Output mV/EU	Output mV @ Capacity	Output mV/EU	Output mV @ Capacity	Output mV/EU
FX	2224.1	N	17.0998	0.00768837	8.5499	0.00384419	3.4200	0.00153767
FY	2224.1	N	17.1517	0.00771173	8.5759	0.00385586	3.4303	0.00154235
FZ	4448.2	N	-12.3905	-0.00278550	-6.1953	-0.00139275	-2.4781	-0.00055710

Shunt

Bridge	Shunt Value	Equivalent Load	Bridge Resistance (nom)
FX	150.0 K Ohms	1532.0 N	700.0 Ohms
FY	150.0 K Ohms	1529.0 N	700.0 Ohms
FZ	200.0 K Ohms	3166.0 N	700.0 Ohms

Note: Positive shunt is between +Exc_+Sig Negative shunt is between -Exc_+Sig

Wire Color Codes

FX		FY		FZ	
Brn	+ Exc	Red Stp	+ Exc	Grn	+ Exc
Red	+ Sig	Blk	+ Sig	Blu	+ Sig
N/A	+ Teds	N/A	+ Teds	N/A	+ Teds
Org	- Exc	Wht	- Exc	Vio	- Exc
Yel	- Sig	Blk Stp	- Sig	Gry	- Sig
N/A	- Teds	N/A	- Teds	N/A	- Teds

Reference Load Cell

Standard ID	Manufacturer	Model No.	Serial No.	Report No.	Calibration Due Date
2K-CL-D2K-1	Interface, Inc.	1610FMQ-2K-T	571308	2020004272	6/24/2021

Calibrated by: _____
Humanetics Innovative Solutions, Inc. Authorized Representative

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HUMANETICS
Innovative Solutions
23300 Haggerty Rd. Farmington Hills, MI 48335
Tel: 248-778-2000 Fax: 248-778-2001
email: info@humaneticsatd.com
website: www.humaneticsatd.com

Loading Sequence Summary
Uni-Directional Calibration

Automated Load Cell Calibration System
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Calibration Number	AF2010270705	Date			10/27/2020
Model Number	9555TF	6 Mo. From Cal	4/27/2021	12 Mo. From Cal	10/27/2021
Serial Number	DH9302	Last Calibrated			10/8/2019
Description	3-Channel Load Cell	Temp (°C)	22.8		Hum. (%) 27.2
Customer	MGA RESEARCH CORPORATION	Customer Tag Number			

Loading Sequence

Axis	FS Load EU	FS Output mV/V	Sensitivity mV/V/EU	Nonlinearity % FS	Hysteresis % FS	Moment Arm EU
FX	2224.1 N	1.709979	0.00076884	0.02	0.15	0
FY	2224.1 N	1.715173	0.00077117	0.04	0.21	0
FZ	4448.2 N	-1.239052	-0.00027855	0.04	0.18	0

Bridge Unbalance

FX Axis	0.0002 mV/V
FY Axis	0.0009 mV/V
FZ Axis	0.0005 mV/V

Linearization

Force (	FX	)	=	-0.34	+	1300.80	*	Output (mV/V)
Force (	FY	)	=	-0.37	+	1296.75	*	Output (mV/V)
Force (	FZ	)	=	-0.57	+	-3589.64	*	Output (mV/V)

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website: www.humaneticsatd.com

Crosstalk Summary
Uni-Directional Calibration

Automated Load Cell Calibration System
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Calibration Number	AF2010270705	Date			10/27/2020
Model Number	9555TF	6 Mo. From Cal	4/27/2021	12 Mo. From Cal	10/27/2021
Serial Number	DH9302	Last Calibrated			10/8/2019
Description	3-Channel Load Cell	Temp (°C)	22.8		Hum. (%) 27.2
Customer	MGA RESEARCH CORPORATION	Customer Tag Number			

Crosstalk Data (mV/V)

Bridge	Applied Load	FX	FY	FZ			
FX	2224.1 N	1.709979	-0.004081	0.002473	0.000000	0.000000	0.000000
FY	2224.1 N	0.009471	1.715173	-0.002059	0.000000	0.000000	0.000000
FZ	4448.2 N	0.001255	0.001090	-1.239052	0.000000	0.000000	0.000000

% FS Crosstalk *

Bridge	Applied Load	FX	FY	FZ			
FX	2224.1 N	0.0000%	-0.2379%	-0.1996%	0.0000%	0.0000%	0.0000%
FY	2224.1 N	0.5539%	0.0000%	0.1661%	0.0000%	0.0000%	0.0000%
FZ	4448.2 N	0.0734%	0.0635%	0.0000%	0.0000%	0.0000%	0.0000%

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* Percentage crosstalk for force channels applying moments are corrected for the applied force

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Measurement Report

Load Cell Bridge Impedance Measurement Summary

Automated Load Cell Calibration System

Copyright (c)1987-2017 Humanetics Innovative Solutions Inc.

Calibration Number	AF2010270705	Date			10/27/2020
Model Number	9555TF	6 Mo. From Cal	4/27/2021	12 Mo. From Cal	10/27/2021
Serial Number	DH9302	Last Calibrated			10/8/2019
Description	3-Channel Load Cell	Temp (°C)	22.8		Hum. (%) 27.2
Customer	MGA RESEARCH CORPORATION	Customer Tag			

Bridge Impedance Measurements*

Axis	Input Impedance	Output Impedance	
Channel 1 FX	706.3	705.9	Ohms
Channel 2 FY	704.3	706.0	Ohms
Channel 3 FZ	706.2	704.3	Ohms

Bridge High Short Measurement**

Axis	Bridge to Transducer Body
Channel 1 FX	>=2.00G Ohms (10^9 Ohms)
Channel 2 FY	>=2.00G Ohms (10^9 Ohms)
Channel 3 FZ	>=2.00G Ohms (10^9 Ohms)

Measurement Equipment	Measurement Accuracy
National Instruments PXI-4071 Multimeter	±((0.0048 x <reading>) + 0.05 Ohms)/2 Years @ 18 to 28°C
Keysight B2985A Electrometer/High Resistance Meter	±((0.45 x <reading>) + 10^4 Ohms)/Year @ 23°C ±5°C

*NOTE: Input impedance measurements taken between ±excitation, output impedance measurements taken between ±signal.
**NOTE: High short measurements are taken between ±excitation and the transducer body. Measurements are made at +50.0 VDC.
The measurements reported on this page are for verification purposes only and are not A2LA accredited.

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Report Summary

Automated Load Cell Calibration System

Copyright (c)1987-2017 Humanetics Innovative Solutions, Inc.

A2LA ACCREDITED
Calibration Cert # 2421.03

Customer Name:	MGA RESEARCH CORPORATION 446 EXECUTIVE DRIVE TROY, MI 48083	Identification No.:	AF2009281318
		Date[4]:	9/28/2020

Manufacturer: Humanetics
Model Number: 9555LN2
Serial Number: EH3439

As Received Condition		As Shipped Condition		Action Taken	
In Tolerance[6]	☑	In Tolerance[6]	☑	Repair	☐
Out of Tolerance[6]	☐	Out of Tolerance[6]	☐	Full Calibration	☑
Operational	☐	Operational	☐	Special Calibration	☐
Not Operational	☐	Not Operational	☐	Returned "As Is"	☐
Damaged	☐	Damaged	☐		
N/A	☐	N/A	☐		

Received Notes
n/a

As Shipped Notes
n/a

Action Notes
n/a

Technical Notes:

Calibration A2LA Accredited: ☑ Yes ☐ No

1) Unless otherwise noted all calibrations conform to ISO 17025:2005.

Standard ID	Report No.	Serial No.	Due Date	CMC(8) Uncertainty (Force)	CMC(8) Uncertainty (Moment)
2K-CL-A2K-1	2020000065	574018	1/15/2021	0.20% F.S.	0.50% F.S.

2) Calibration Standards Used: Standards used in the calibration of this transducer are traceable to NIST (National Institute of Standards and Technology). With exception of the measurements reported on the Load Cell Bridge Impedance Measurement Summary, which are for verification only.

3) Laboratory Scope: Humanetics Innovative Solution, Inc.'s calibration program is accredited to ISO/IEC 17025:2005 ANSI/NCSL Z-540-1-1994.

4) "Date" indicates confirmation of calibration data and should be used to increment calibration intervals.

5) Calibration Methods: The Calibration Methods used in this calibration are defined in the Calibration Method for Single and Multi-Axis Load Cells (CL-WI-00002P). Procedure Number: CL-PR-00001P/CL-PR-00002P.

6) This document applies only to the calibration of the item described above and the specific calibration performed by the Humanetics Innovative Solutions, Inc. calibration laboratory. When declaring In Tolerance or Out of Tolerance conditions(s), the calibration laboratory utilizes a Shared Risk Method** as the decision rule. The stability of the UUT over time depends on many factors outside our control. It is the responsibility of those using the item described above to quantify their measurement of uncertainty and evaluate the adequacy of their measurement process to demonstrate that measurement traceability is credibly maintained.

7) This report shall not be reproduced, except in full, without the written consent of the Humanetics Innovative Solutions, Inc.'s calibration laboratory.

8) Calibration and Measurement Capabilities (CMC) represent expanded uncertainties expressed at approximately the 95% level of confidence, coverage factor of k = 2.

**The Humanetics Innovative Solutions, Inc. calibration laboratory does not expand the provided measured value(s) by the associated uncertainty of the measurement. When parameter(s) are certified to be within specified tolerance(s), the unexpanded measured value(s) shall fall within the appropriate specification limit. With written agreement from the customer, other decision rules may be used. Please visit the company website at www.humaneticsatd.com for a copy of the Scope and Certificate. A copy of the scope and certificate is also available upon request.

10/15/2020

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Calibration Report
Uni-Directional Calibration

Automated Load Cell Calibration System
Copyright (c)1987-2017 Humanetics Innovative Solutions, Inc.

Applied Excitation (VDC)	10.000	Date			9/28/2020
Calibration No.	AF2009281318	6 Mo. From Cal	3/28/2021	12 Mo. From Cal	9/28/2021
Model No.	9555LN2	Serial No.			EH3439
Technician	BURCHI	Temp (°C)	23.9		Hum. (%) 49.6
Customer	MGA RESEARCH CORPORATION	Last Calibrated			6/12/2019
Description	3-Channel Load Cell	Customer Tag Number			

Voltage Calibration

Bridge	Capacity	Zero Offset	Nonlinearity	Hysteresis	Output @ Capacity	% Change
FX	2224.1 N	-0.0222 mV/V	0.04 % FS	0.08 % FS	1.7636 mV/V	0.22 % FS
FY	2224.1 N	0.0037 mV/V	0.05 % FS	0.13 % FS	1.7649 mV/V	0.14 % FS
FZ	4448.2 N	-0.0190 mV/V	0.09 % FS	0.05 % FS	-1.2516 mV/V	0.14 % FS

Calculated Sensitivity Matrix

			Using Sensor @ 10 V Excitation		Using Sensor @ 5V Excitation		Using Sensor @ 2V Excitation	
Bridge	Capacity		Output mV @ Capacity	Output mV/EU	Output mV @ Capacity	Output mV/EU	Output mV @ Capacity	Output mV/EU
FX	2224.1	N	17.6358	0.00792939	8.8179	0.00396469	3.5272	0.00158588
FY	2224.1	N	17.6486	0.00793511	8.8243	0.00396756	3.5297	0.00158702
FZ	4448.2	N	-12.5165	-0.00281382	-6.2582	-0.00140691	-2.5033	-0.00056276

Shunt

Bridge	Shunt Value	Equivalent Load	Bridge Resistance (nom)
FX	150.0 K Ohms	1487.0 N	700.0 Ohms
FY	150.0 K Ohms	1486.0 N	700.0 Ohms
FZ	200.0 K Ohms	3139.0 N	700.0 Ohms

Note: Positive shunt is between +Exc_+Sig Negative shunt is between -Exc_+Sig

Wire Color Codes

FX		FY		FZ	
Red	+ Exc	Red Wht	+ Exc	Red Vio	+ Exc
Yel	+ Sig	Yel Wht	+ Sig	Yel Vio	+ Sig
N/A	+ Teds	N/A	+ Teds	N/A	+ Teds
Blk	- Exc	Blk Wht	- Exc	Blk Vio	- Exc
Blu	- Sig	Blu Wht	- Sig	Blu Vio	- Sig
N/A	- Teds	N/A	- Teds	N/A	- Teds

Reference Load Cell

Standard ID	Manufacturer	Model No.	Serial No.	Report No.	Calibration Due Date
2K-CL-A2K-1	Interface, Inc.	1610FMQ-2K-T	574018	2020000065	1/15/2021

Calibrated by: _____
Humanetics Innovative Solutions, Inc. Authorized Representative

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Loading Sequence Summary
Uni-Directional Calibration

Automated Load Cell Calibration System
Copyright (c)1987-2017 Humanetics Innovative Solutions, Inc.

Calibration Number	AF2009281318	Date			9/28/2020
Model Number	9555LN2	6 Mo. From Cal	3/28/2021	12 Mo. From Cal	9/28/2021
Serial Number	EH3439	Last Calibrated			6/12/2019
Description	3-Channel Load Cell	Temp (°C)	23.9		Hum. (%) 49.6
Customer	MGA RESEARCH CORPORATION	Customer Tag Number			

Loading Sequence

Axis	FS Load EU	FS Output mV/V	Sensitivity mV/V/EU	Nonlinearity % FS	Hysteresis % FS	Moment Arm EU
FX	2224.1 N	1.763583	0.00079294	0.04	0.08	0
FY	2224.1 N	1.764856	0.00079351	0.05	0.13	0
FZ	4448.2 N	-1.251649	-0.00028138	0.09	0.05	0

Bridge Unbalance

FX Axis	0.0000 mV/V
FY Axis	0.0011 mV/V
FZ Axis	0.0001 mV/V

Linearization

Force (	FX	)	=	-0.45	+	1261.36	*	Output (mV/V)
Force (	FY	)	=	-0.69	+	1260.50	*	Output (mV/V)
Force (	FZ	)	=	-1.90	+	-3553.80	*	Output (mV/V)

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Crosstalk Summary
Uni-Directional Calibration

Automated Load Cell Calibration System
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Calibration Number	AF2009281318	Date			9/28/2020
Model Number	9555LN2	6 Mo. From Cal	3/28/2021	12 Mo. From Cal	9/28/2021
Serial Number	EH3439	Last Calibrated			6/12/2019
Description	3-Channel Load Cell	Temp (°C)	23.9		Hum. (%) 49.6
Customer	MGA RESEARCH CORPORATION	Customer Tag Number			

Crosstalk Data (mV/V)

		FX	FY	FZ			
Bridge	**Applied Load**						
FX	2224.1 N	1.763583	-0.009235	-0.002096	0.000000	0.000000	0.000000
FY	2224.1 N	0.010399	1.764856	-0.005875	0.000000	0.000000	0.000000
FZ	4448.2 N	-0.004741	0.003745	-1.251649	0.000000	0.000000	0.000000

% FS Crosstalk *

		FX	FY	FZ			
Bridge	**Applied Load**						
FX	2224.1 N	0.0000%	-0.5232%	0.1674%	0.0000%	0.0000%	0.0000%
FY	2224.1 N	0.5896%	0.0000%	0.4694%	0.0000%	0.0000%	0.0000%
FZ	4448.2 N	-0.2688%	0.2122%	0.0000%	0.0000%	0.0000%	0.0000%

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* Percentage crosstalk for force channels applying moments are corrected for the applied force

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Measurement Report
Load Cell Bridge Impedance Measurement Summary

Automated Load Cell Calibration System

Copyright (c)1987-2017 Humanetics Innovative Solutions Inc.

Calibration Number	AF2009281318	Date			9/28/2020
Model Number	9555LN2	6 Mo. From Cal	3/28/2021	12 Mo. From Cal	9/28/2021
Serial Number	EH3439	Last Calibrated			6/12/2019
Description	3-Channel Load Cell	Temp (°C)	23.9		Hum. (%) 49.6
Customer	MGA RESEARCH CORPORATION	Customer Tag			

Bridge Impedance Measurements*

Axis	Input Impedance	Output Impedance	
Channel 1 FX	706.5	706.1	Ohms
Channel 2 FY	706.2	706.1	Ohms
Channel 3 FZ	704.5	704.4	Ohms

Bridge High Short Measurement**

Axis	Bridge to Transducer Body
Channel 1 FX	>=2.00G Ohms (10^9 Ohms)
Channel 2 FY	>=2.00G Ohms (10^9 Ohms)
Channel 3 FZ	>=2.00G Ohms (10^9 Ohms)

Measurement Equipment	Measurement Accuracy
National Instruments PXI-4071 Multimeter	±((0.0048 x <reading>) + 0.05 Ohms)/2 Years @ 18 to 28°C
Keysight B2985A Electrometer/High Resistance Meter	±((0.45 x <reading>) + 10^4 Ohms)/Year @ 23°C ±5°C

*NOTE: Input impedance measurements taken between ±excitation, output impedance measurements taken between ±signal.
**NOTE: High short measurements are taken between ±excitation and the transducer body. Measurements are made at +50.0 VDC.
The measurements reported on this page are for verification purposes only and are not A2LA accredited.

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NovaStar SOLUTIONS
Metrology Management Services

Calibration Certificate

ACCREDITED Calibration #1277.01

35200 Plymouth Rd. / Livonia, MI 48150 / 734.453.8003

Certificate # Z63778:373378

PRO 360 - GENERIC - DIGITAL PROTRACTOR

SERIAL NUMBER:	N/A	WORK ORDER:	373378
ASSET NUMBER:	Z63778	TEST RESULT:	PASS
CUST ASSET NUMBER:	MGA00173	PERFORMED ON:	03/31/21
PROCEDURE NAME:	MIT - PRO 360 - MMC	CAL DUE DATE:	03/31/22
PROCEDURE REV:	1.1	DATA TYPE:	FOUND-LEFT
CALIBRATED BY:	WILLIAM FRENCH	TEMPERATURE:	24 °C
CUSTOMER:	MGA RESEARCH - STATIC LAB 33653 DEQUINDRE TROY, MI 48083	HUMIDITY:	32 %
PRIMARY CONTACT:	Takisha Doss		

This instrument has been processed and calibrated in accordance with the NovaStar Solutions Quality System Manual. All calibrations are traceable to the International System of Units (SI) through a National Metrology Institute (NMI) such as NIST, acceptable intrinsic standards of measurement, or derived by the ration type of self-calibration techniques. The NovaStar Solutions quality system is accredited ISO/IEC 17025 and ANSI/NCSL Z540-1-1994.

The results reported herein apply only to the calibration of the item described above. No sampling plan was used for this calibration.

Where statements of compliance are made, the measurement uncertainty is not factored in unless otherwise noted. Expanded uncertainties are expressed at the approximate 95% level of confidence using a k=2. Due to any number of factors, the recommended due date on the item does not imply continuing conformance to specifications during the recommended interval. Unless otherwise stated the unit under test meets or exceeds manufacturer specifications.

For range and best measurement capability specifications for the standards used to perform this calibration, see the most recent calibration report maintained by this calibration laboratory (available upon request).

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AS RECEIVED CONDITION:	In Tolerance	REMARKS:	N/A
AS RETURNED CONDITION:	In Tolerance		
ACTION TAKEN:	FULL CALIBRATION		

Standards Used

Asset #	Cert #	Description	Cal Date	Due Date
2116	2116:1455281491	42280 - EXTECH - DATA LOGGER	03/05/2021	03/05/2022
2222	2222:1494506043	550-050 - YUASA - ROTARY TABLE	05/11/2017	05/11/2022

QA Signature: 

Date: 3/31/2021 12:20:59 PM

NovaStar SOLUTIONS
Metrology Management Services

Report Of Calibration

ACCREDITED
Calibration #1277.01

35200 Plymouth Rd. / Livonia, MI 48150 / 734.453.8003

PRO 360 - GENERIC - DIGITAL PROTRACTOR

SERIAL NUMBER:	N/A	WORK ORDER:	373378
ASSET NUMBER:	Z63778	TEST RESULT:	PASS
CUST ASSET NUMBER:	MGA00173	PERFORMED ON:	03/31/21
PROCEDURE NAME:	MIT - PRO 360 - MMC	CAL DUE DATE:	03/31/22
PROCEDURE REV:	1.1	DATA TYPE:	FOUND-LEFT
CALIBRATED BY:	WILLIAM FRENCH	TEMPERATURE:	24 °C
CUSTOMER:	MGA RESEARCH - STATIC LAB 33653 DEQUINDRE TROY, MI 48083	HUMIDITY:	32 %
PRIMARY CONTACT:	Takisha Doss		

This instrument has been processed and calibrated in accordance with the NovaStar Solutions Quality System Manual. All calibrations are traceable to the International System of Units (SI) through a National Metrology Institute (NMI) such as NIST, acceptable intrinsic standards of measurement, or derived by the ration type of self-calibration techniques. The NovaStar Solutions quality system is accredited ISO/IEC 17025 and ANSI/NCSL Z540-1-1994.

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Expanded uncertainties are expressed at the approximate 95% level of confidence using a k=2. Due to any number of factors, the recommended due date on the item does not imply continuing conformance to specifications during the recommended interval. Unless otherwise stated the unit under test meets or exceeds manufacturer specifications.

For range and best measurement capability specifications for the standards used to perform this calibration, see the most recent calibration report maintained by this calibration laboratory (available upon request).

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REMARKS: N/A

Standards Used

Asset #	Cert #	Description	Cal Date	Due Date
2116	2116:1455281491	42280 - EXTECH - DATA LOGGER	03/05/2021	03/05/2022
2222	2222:1494506043	550-050 - YUASA - ROTARY TABLE	05/11/2017	05/11/2022

Test Procedure Results

Test results for calibration with work order : 373378

Test Description	Nominal	Test Result	Limit (Lower)	Limit (Upper)	Units	Uncertainty	Pass/Fail
LINEARITY CHECK							
0° REFERENCE	0.0	0.0	-0.1	0.1	°		Pass
5°	5.0	5.0	4.9	5.1	°	0.062° + 0.6R	Pass
30°	30.0	30.0	29.8	30.2	°	0.062° + 0.6R	Pass
60°	60.0	60.1	59.8	60.2	°	0.062° + 0.6R	Pass
90°	90.0	89.9	89.9	90.1	°	0.062° + 0.6R	Pass
60°	60.0	60.1	59.8	60.2	°	0.062° + 0.6R	Pass
30°	30.0	30.1	29.8	30.2	°	0.062° + 0.6R	Pass
5°	5.0	5.0	4.9	5.1	°	0.062° + 0.6R	Pass
0°	0.0	0.0	-0.1	0.1	°		Pass
5°	5.0	5.0	4.9	5.1	°	0.062° + 0.6R	Pass
30°	30.0	29.9	29.8	30.2	°	0.062° + 0.6R	Pass
60°	60.0	59.8	59.8	60.2	°	0.062° + 0.6R	Pass
90°	90.0	89.9	89.9	90.1	°	0.062° + 0.6R	Pass
60°	60.0	59.9	59.8	60.2	°	0.062° + 0.6R	Pass
30°	30.0	29.9	29.8	30.2	°	0.062° + 0.6R	Pass
5°	5.0	5.0	4.9	5.1	°	0.062° + 0.6R	Pass
0°	0.0	0.0	-0.1	0.1	°		Pass
ABSOLUTE ZERO ANGLE	0.0	0.0	-0.1	0.1	°		Pass

- END OF REPORT -

NovaStar SOLUTIONS
Metrology Management Services

Calibration Certificate

ACCREDITED Calibration #1277.01

35200 Plymouth Rd. / Livonia, MI 48150 / 734.453.8003

Certificate # Z162870:356761

RHM15 - EXTECH - HYGRO/THERMOMETER MONITOR

SERIAL NUMBER:	0519	WORK ORDER:	356761
ASSET NUMBER:	Z162870	TEST RESULT:	PASS
CUST ASSET NUMBER:	MI0225	PERFORMED ON:	01/31/21
PROCEDURE NAME:	HUMIDITY	CAL DUE DATE:	01/31/22
PROCEDURE REV:	1.0	DATA TYPE:	FOUND-LEFT
CALIBRATED BY:	James Johnson	TEMPERATURE:	22 °C
CUSTOMER:	MGA RESEARCH 446 EXECUTIVE DRIVE TROY, MI 48083	HUMIDITY:	28 %
PRIMARY CONTACT:	SCOTT ARSEN		

This instrument has been processed and calibrated in accordance with the NovaStar Solutions Quality System Manual. All calibrations are traceable to the National Institute of Standards and Technology (NIST) or to another National Metrology Institute to the International System of Units (SI units), acceptable intrinsic standards of measurement, or derived by the ratio type of self-calibration techniques. The NovaStar Solutions quality system is accredited ISO/IEC 17025 and ANSI/NCSL Z540-1-1994.

The results reported herein apply only to the calibration of the item described above. No sampling plan was used for this calibration.

Where statements of compliance are made, the measurement uncertainty is not factored in unless otherwise noted. Expanded uncertainties are expressed at the approximate 95% level of confidence using a K=2. Due to any number of factors, the recommended due date on the item does not imply continuing conformance to specifications during the recommended interval. Unless otherwise stated the unit under test meets or exceeds manufacturer specifications.

For range and best measurement capability specifications for the standards used to perform this calibration, see the most recent calibration report maintained by this calibration laboratory (available upon request).

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AS RECEIVED CONDITION:	In Tolerance	REMARKS:	N/A
AS RETURNED CONDITION:	In Tolerance		
ACTION TAKEN:	FULL CALIBRATION		

Standards Used

Asset #	Cert #	Description	Cal Date	Due Date
1504	1504:1193650836	1502A - HART SCIENTIFIC - THERMOMETER READOUT	09/03/2020	09/03/2021
2998	529030000004453	42280 - EXTECH - DATA LOGGER	05/08/2020	05/08/2021
3051	529030000011107	2500 - THUNDER SCIENTIFIC CORPORATION - HUMIDITY GENERATOR	12/04/2020	12/04/2021
3119	529030000032436	5608 - FLUKE - PRT	03/23/2020	03/23/2021

QA Signature: John McBurnett Date: 2/1/2021 4:40:17 AM

2/10/2021

NovaStar SOLUTIONS
Metrology Management Services
35200 Plymouth Rd. / Livonia, MI 48150 / 734.453.8003

Report Of Calibration

ACCREDITED
Calibration #1277.01

RHM15 - EXTECH - HYGRO/THERMOMETER MONITOR

SERIAL NUMBER:	0519	WORK ORDER:	356761
ASSET NUMBER:	Z162870	TEST RESULT:	PASS
CUST ASSET NUMBER:	MI0225	PERFORMED ON:	01/31/21
PROCEDURE NAME:	HUMIDITY	CAL DUE DATE:	01/31/22
PROCEDURE REV:	1.0	DATA TYPE:	FOUND-LEFT
CALIBRATED BY:	James Johnson	TEMPERATURE:	22 °C
CUSTOMER:	MGA RESEARCH 446 EXECUTIVE DRIVE TROY, MI 48083	HUMIDITY:	28 %
PRIMARY CONTACT:	SCOTT ARSEN		

This instrument has been processed and calibrated in accordance with the NovaStar Solutions Quality System Manual. All calibrations are traceable to the National Institute of Standards and Technology (NIST) or to another National Metrology Institute to the International System of Units (SI units), acceptable intrinsic standards of measurement, or derived by the ratio type of self-calibration techniques. The NovaStar Solutions quality system is accredited ISO/IEC 17025 and ANSI/NCSL Z540-1-1994.

The results reported herein apply only to the calibration of the item described above. No sampling plan was used for this calibration.

Expanded uncertainties are expressed at the approximate 95% level of confidence using a K=2. Due to any number of factors, the recommended due date on the item does not imply continuing conformance to specifications during the recommended interval. Unless otherwise stated the unit under test meets or exceeds manufacturer specifications.

For range and best measurement capability specifications for the standards used to perform this calibration, see the most recent calibration report maintained by this calibration laboratory (available upon request).

This report may not be reproduced, except in full, without written approval from NovaStar Solutions.

REMARKS: N/A

Standards Used

Asset #	Cert #	Description	Cal Date	Due Date
1504	1504:1193650836	1502A - HART SCIENTIFIC - THERMOMETER READOUT	09/03/2020	09/03/2021
2998	529030000004453	42280 - EXTECH - DATA LOGGER	05/08/2020	05/08/2021
3051	529030000011107	2500 - THUNDER SCIENTIFIC CORPORATION - HUMIDITY GENERATOR	12/04/2020	12/04/2021
3119	529030000032436	5608 - FLUKE - PRT	03/23/2020	03/23/2021

Test Procedure Results

Test results for calibration with work order : 356761

Test Description	Nominal	Test Result	Limit (Lower)	Limit (Upper)	Units	Uncertainty	Pass/Fail
Humidity							
30 %RH	30.00	31.0	25.0	35.0	%RH	7.1e-001	Pass
50 %RH	50.00	48.0	45.0	55.0	%RH	7.1e-001	Pass
70 %RH	70.00	66.0	65.0	75.0	%RH	7.1e-001	Pass
Temperature							
9.984 °C	9.98	10.5	8.0	12.0	°C	8.5e-002	Pass
23.01 °C	23.01	23.3	21.0	25.0	°C	8.5e-002	Pass
32.014 °C	32.01	32.8	30.0	34.0	°C	8.5e-002	Pass

- END OF REPORT -

mga research corporation

MGA RESEARCH CORPORATION

LABORATORY TEST PROCEDURE

FOR

TAPE MEASURE VERIFICATION/CALIBRATION

Procedure Approved By: P. Michael Miller II, Director of Laboratory Operations

Procedure Approved By: Helen Kaleto, Quality Manager

446 executive drive • troy, mi 48083
248 / 577-5001 • fax 248 / 577-5025

Date: 9/29/2020

Description of Test Procedure: This test procedure is used to conduct tape measure verification/calibrations. Tape measures must be verified/calibrated every twelve months.

Equipment:

- Reference Steel Rule Fixture
- Subject Tape Measure

Verification Procedure

- Mount the subject Tape Measure to the Reference Steel Rule Fixture. This is done by simply inserting the blade end into the slot.
- Verify that the blade is pulled tightly against the edge.
- Unfurl the tape measure at least 31 inches (775 mm) and secure the opposite end using tape or clamps.
- Check the pull portion of the tape measure.
- Once attached to the fixture, record all measurements on the data sheet on Page 3. If the tape measure is new, assign an MGA Serial Number and add this to the Peripheral Items Calibration List.
- Verify the blade is pushed tightly against the opposite edge.
- Check the push portion of the tape measure.
- Once attached to the fixture, record all measurements on the data sheet on Page 3. If the tape measure is new, assign an MGA Serial Number and add this to the Peripheral Items Calibration List.
- If all measurements are within 1/32 of an inch (1 mm), the Subject Tape Measure is acceptable for use. If this tolerance is not met, the tape measure should be repaired or thrown out. Typically, the tape measures are not repairable once the blade end is damaged.
- The tape measure has now been checked in both directions.
- Once completed, fill out a new calibration sticker and place it on the Subject Tape Measure.
- Calibration Certificates must be completed and signed and placed in the Calibration File.
- Before placing the procedure in the Calibration File, scan the Certificate page into Word. Save the file on the Network under Peripheral Items with the filename TPMXXX (Date).doc (XXX = Serial Number; Date = Date of Cal (MMDDYYYY).

Calibration Procedure completed by: Scott Arsen

MICHIGAN OPERATIONS
DATE: 04/18/2019
SUPERCEDES: MGATPTMC.10

DOC. NO.: MGATP_TMC
REVISION NO.: 11
PAGE 3 OF 3

Tape Measure Calibration Certificate

Reference Steel Rule

Brand: Swanson
S/N: MGA00798
Calibration Date: 11/06/2019

Subject Tape Measure

Brand: Stanley
S/N: TPM007-32
Calibration Date: 09/29/2020

Reference in (mm)	Subject Tape Measure		Difference	
	Pull	Push	Pull	Push
0 (0)	0	0	0	0
4 (100)	100	99	0	-1
8 (200)	200	199	0	-1
12 (300)	300	299	0	-1
16 (400)	400	399	0	-1
20 (500)	500	499	0	-1
24 (600)	600	599	0	-1
28 (700)	700	699	0	-1
32 (800)	800	799	0	-1
35 (875)	875	874	0	-1

If all differences are ± 1/32 of an inch (1 mm), then the tape measure is acceptable.

Pass * Fail _____ Maximum Difference = 1mm

Date: 9/29/2020 Performed By: Scott Arsen

All calibrations are traceable to the National Institute of Standards and Technology. Estimated uncertainty of the measurement is ± 0.164%. All certification data and equipment are on file for inspection at your request. Best uncertainties represent expanded uncertainties expressed at approximately the 95% confidence level using a coverage factor k=2.

Calibration Certificate

Model: Prime

Calibration Date: 2020-05-14 (YYYY-MM-DD)

Certificate #: R10021311437-20200514-309P

Serial #: R10-02-13-11437

Measurement Standards Traceability

Kinematic Scale Bar- Short	Asset Number: 4308	Calibration Due Date: 8/29/2020	*SI Traceability: 00062977-67be-2191-b308-00955b2da136
Kinematic Scale Bar- Long	Asset Number: 4307	Calibration Due Date: 8/29/2020	*SI Traceability: 00062977-67be-2191-d66e-00955b243692
Thermometer	Asset Number: 4274	Calibration Due Date: 9/6/2020	*SI Traceability: IELC-617134
Calibration Probe	Asset Number: 3736	Calibration Due Date: 7/10/2020	*SI Traceability: 1844900442
Reference Sphere	Asset Number: 3693	Calibration Due Date: 10/17/2020	*SI Traceability: 18-449-000543

The artifacts above have been calibrated with a device traceable to the International System of Units (SI) through a National Metrological Institute (NMI) or through an ISO17025 Accredited Laboratory.
See attached data for measurement results.

Calibration Results*

		Specification	Measurement	Result (Pass/Fail)
3 Single Point Articulation Tests at <=20%, 20%-80% and >=80% range	mm	0.042	0.024	PASSED
1 Effective diameter sphere test	mm	0.021	0.005	PASSED
20 Volumetric ball bar tests in 4 quadrants and 2 orientations	mm	+/-0.059	0.039	PASSED

Instrument condition as received (AS FOUND):
Not within specification

Instrument condition outgoing (AS LEFT):
Within specifications

This certificate invalidates all other certificates generated before: 2020-05-14 11:19:59 AM
This certificate shall not be reproduced, except in full, without permission of FARO Technologies, Inc.
The results of this certificate relate only to the items calibrated or tested.
Calibration Standard Used: ASME B89.4.22-2004.

Approved by Technician: Jundee Apalsorn
Date: 2020-05-14

FARO Technologies Inc
PH1:1-800-736-2771
PH2:407-333-9911
FAX:407-333-8056
125 Technology Park
Lake Mary, FL 32746
USA

FARO®

Cert # L-1147-1 Calibration

ANAB ACCREDITED ISO/IEC 17025 CALIBRATION LABORATORY

MAR 5/20/2020

Page 1 of 3

f:\control\records\05manufa\partspec\XH08-0495.eps Rev6 RevDate: 02/20/18

5.0 Photographs

Hyundai Elantra
NHTSA No. C20214202

Front view of vehicle
Before testing

FMVSS No. 216a

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

3/4 right front view of vehicle
Before testing

020 Audi Elantra
NHTSA No. C20214202
FMVSS No. 216a

Right view of vehicle
Before testing

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Right side interior front seating area
Before testing

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

3/4 right rear view of vehicle
Before testing

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Rear view of vehicle
Before testing

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

3/4 left rear view of vehicle
Before testing

Hyundai Elantra
NHTSA No. C20214202

Left view of vehicle
Before testing

FMVSS No. 216a

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Left side interior front seating area
Before testing

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

3/4 left front view of vehicle
Before testing

Hyundai Elantra
NHTSA No. C20214202

Driver Side Oscar Photograph No. 1

FMVSS No. 216a

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

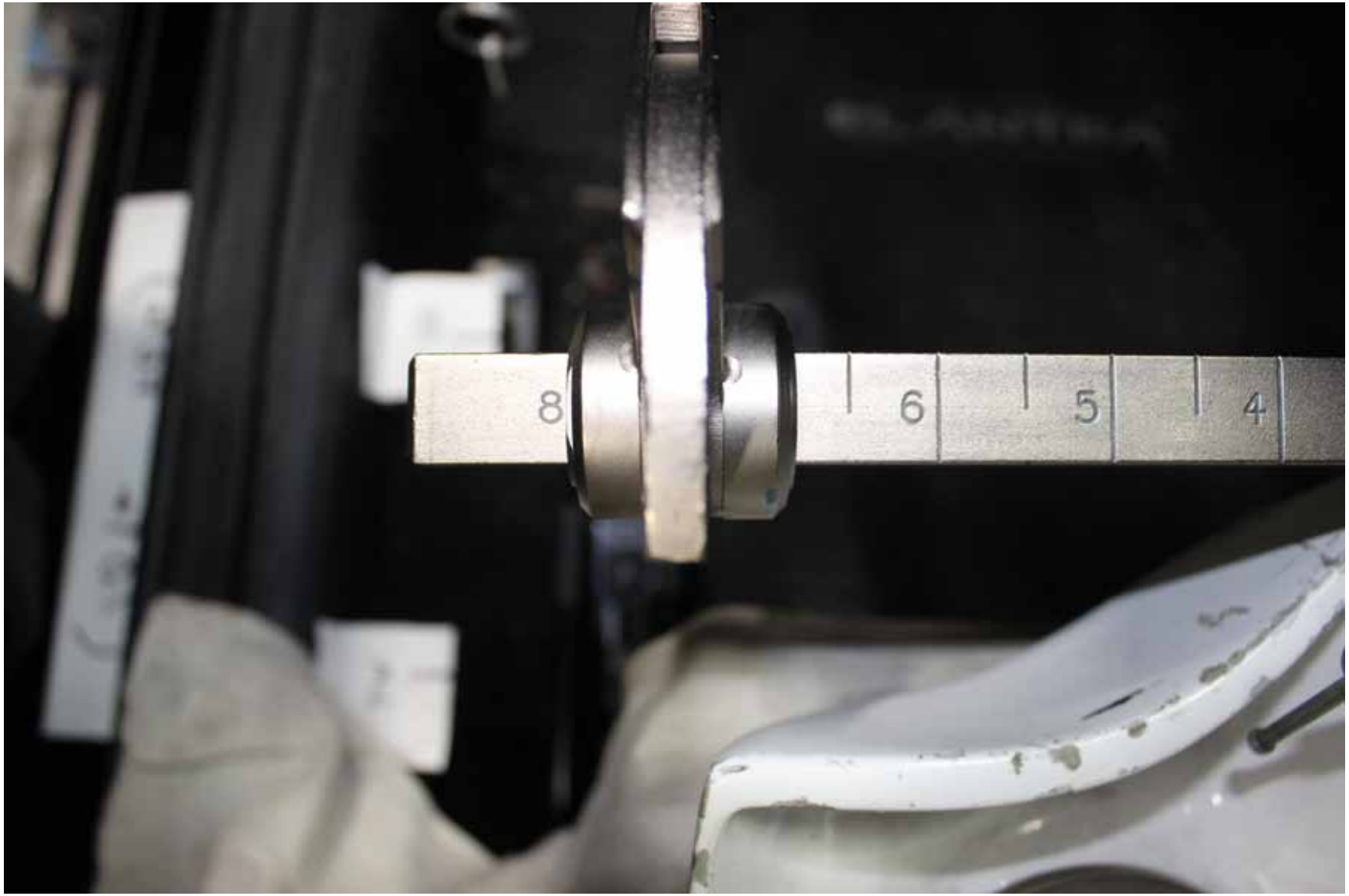
Driver Side Oscar Photograph No. 2

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Driver Side Oscar Photograph No. 3

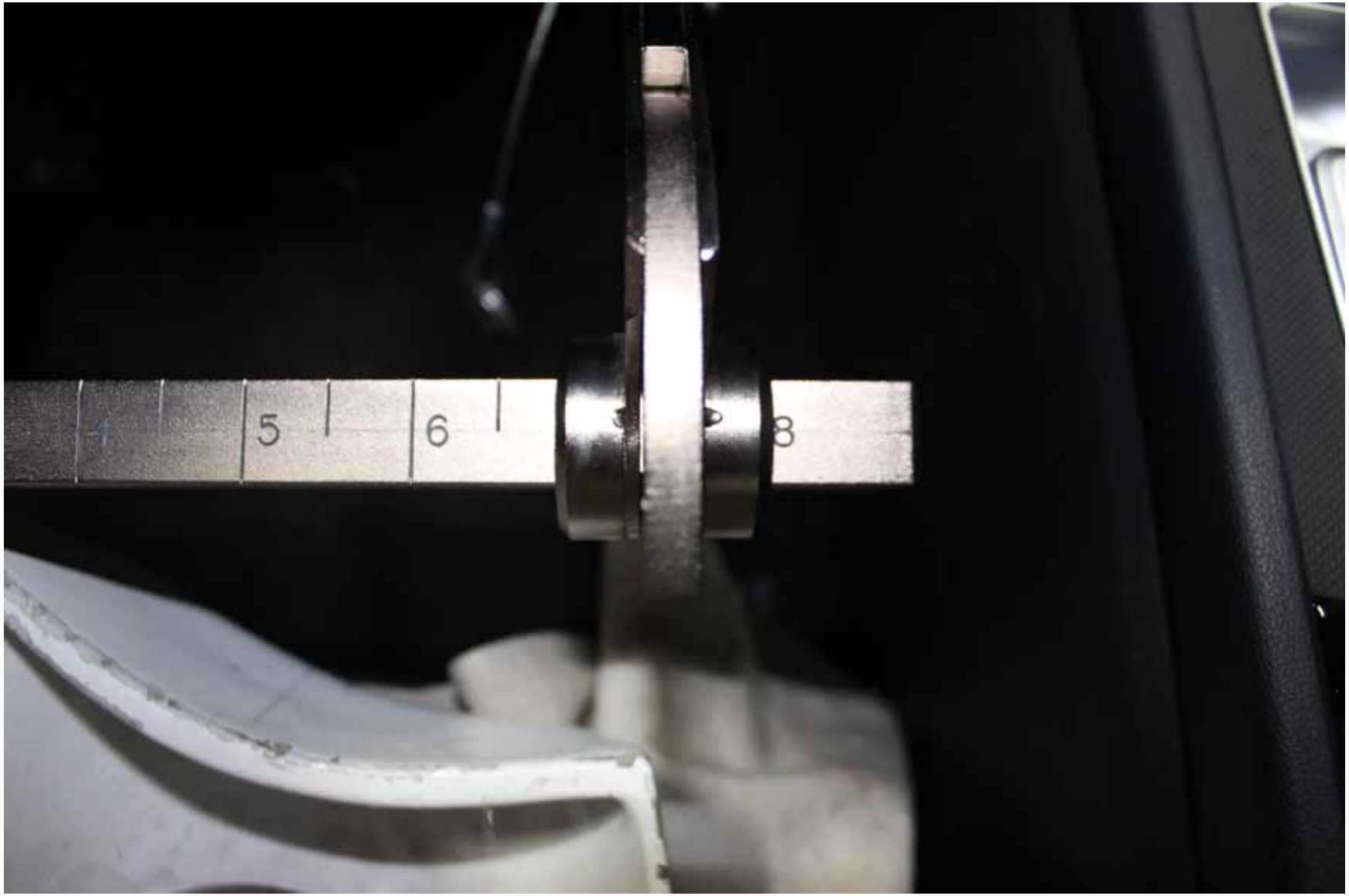
Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Driver Side Oscar Photograph No. 4



Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Driver Side Oscar Photograph No. 5



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FMVSS No. 216a

Driver Side Oscar Photograph No. 6

Hyundai Elantra
NHTSA No. C20214202
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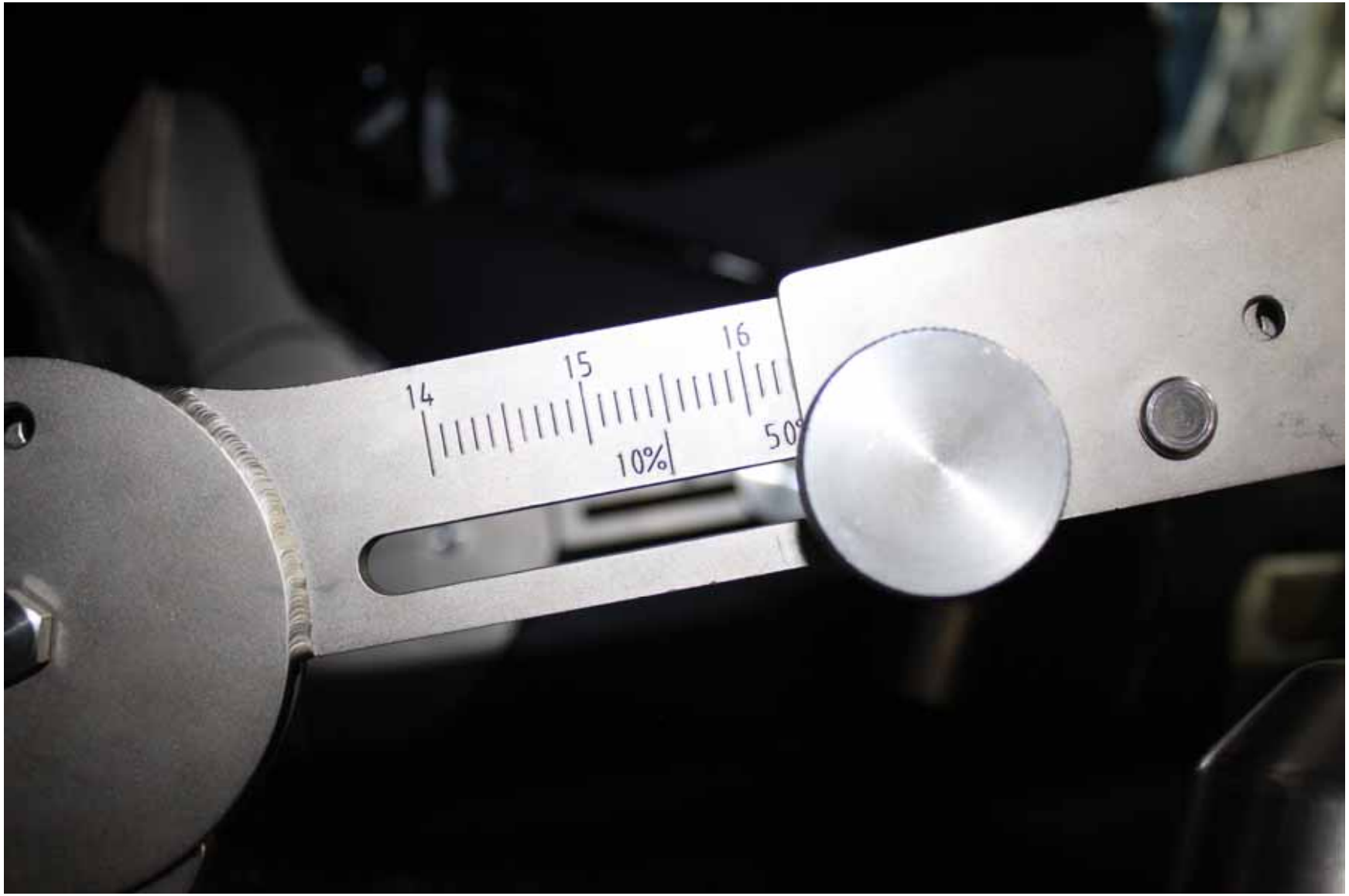
Driver Side Oscar Photograph No. 7

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Driver Side Oscar Photograph No. 8



Hyundai Elantra
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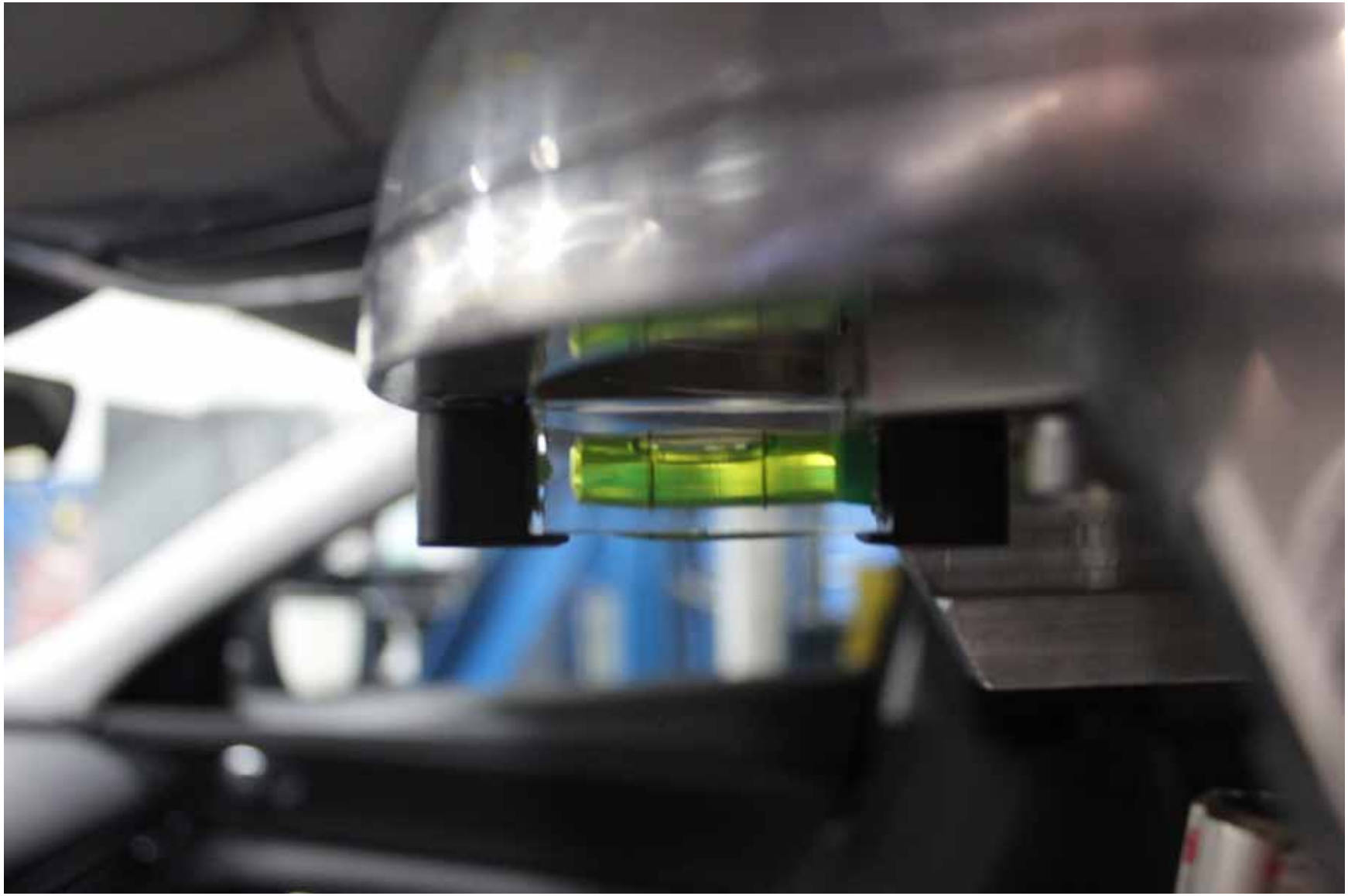
FMVSS No. 216a

Driver Side Oscar Photograph No. 9

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Driver Side Oscar Photograph No. 10



Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Driver Side Oscar Photograph No. 11

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Passenger Side Oscar Photograph No. 1

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

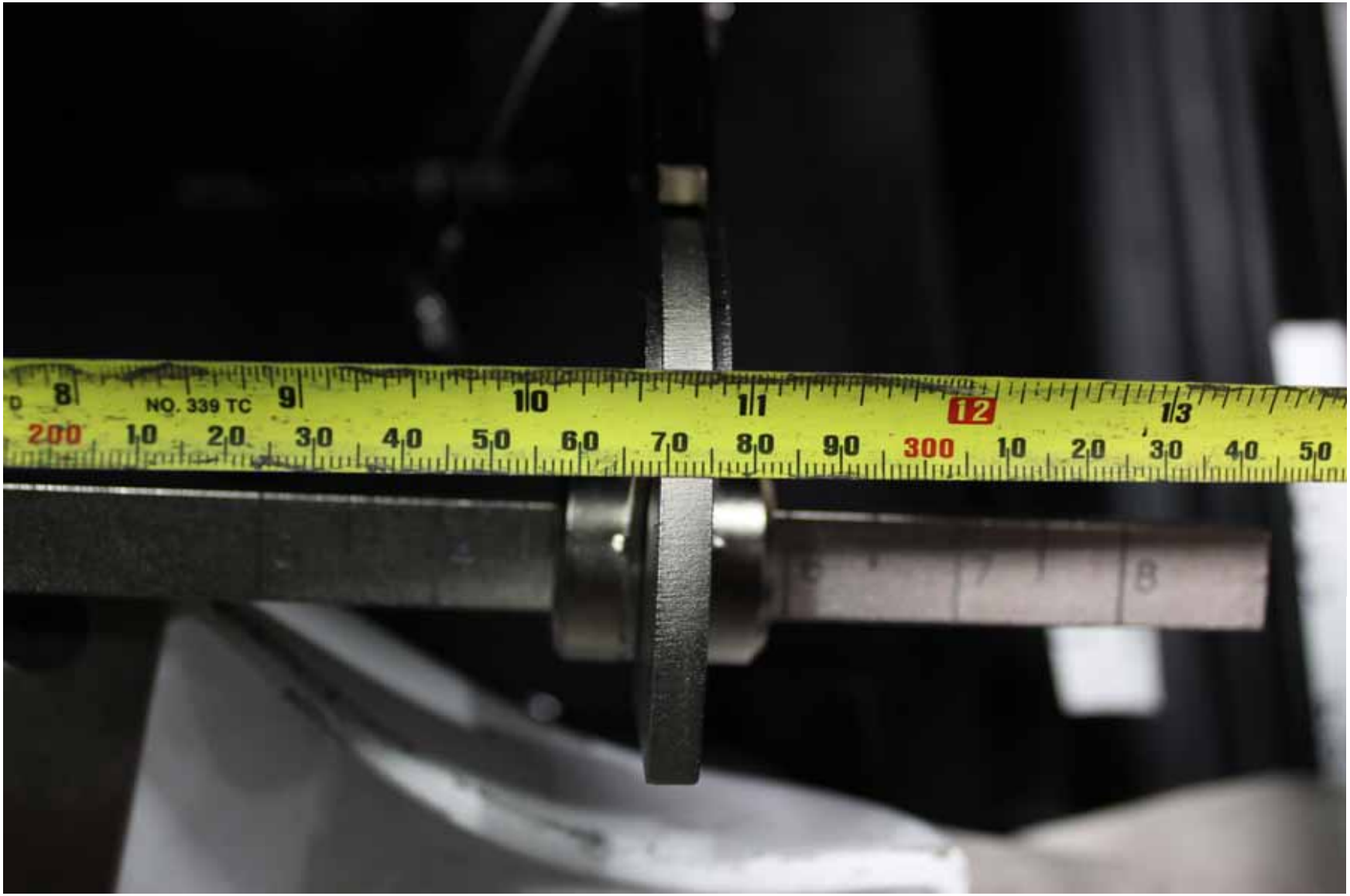
Passenger Side Oscar Photograph No. 2

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Passenger Side Oscar Photograph No. 3

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Passenger Side Oscar Photograph No. 4



Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Passenger Side Oscar Photograph No. 5

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

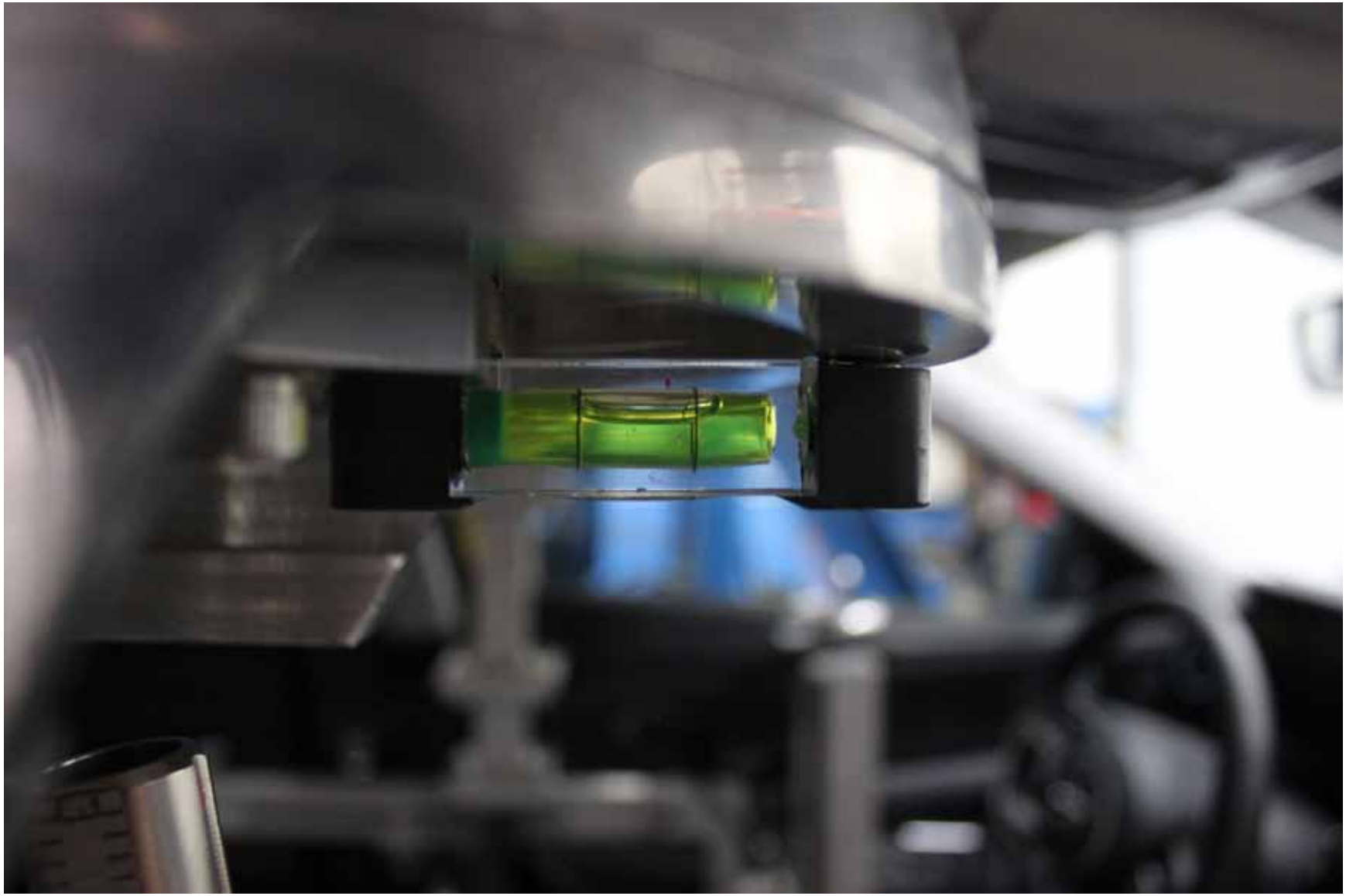
Passenger Side Oscar Photograph No. 6

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Passenger Side Oscar Photograph No. 7

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Passenger Side Oscar Photograph No. 8

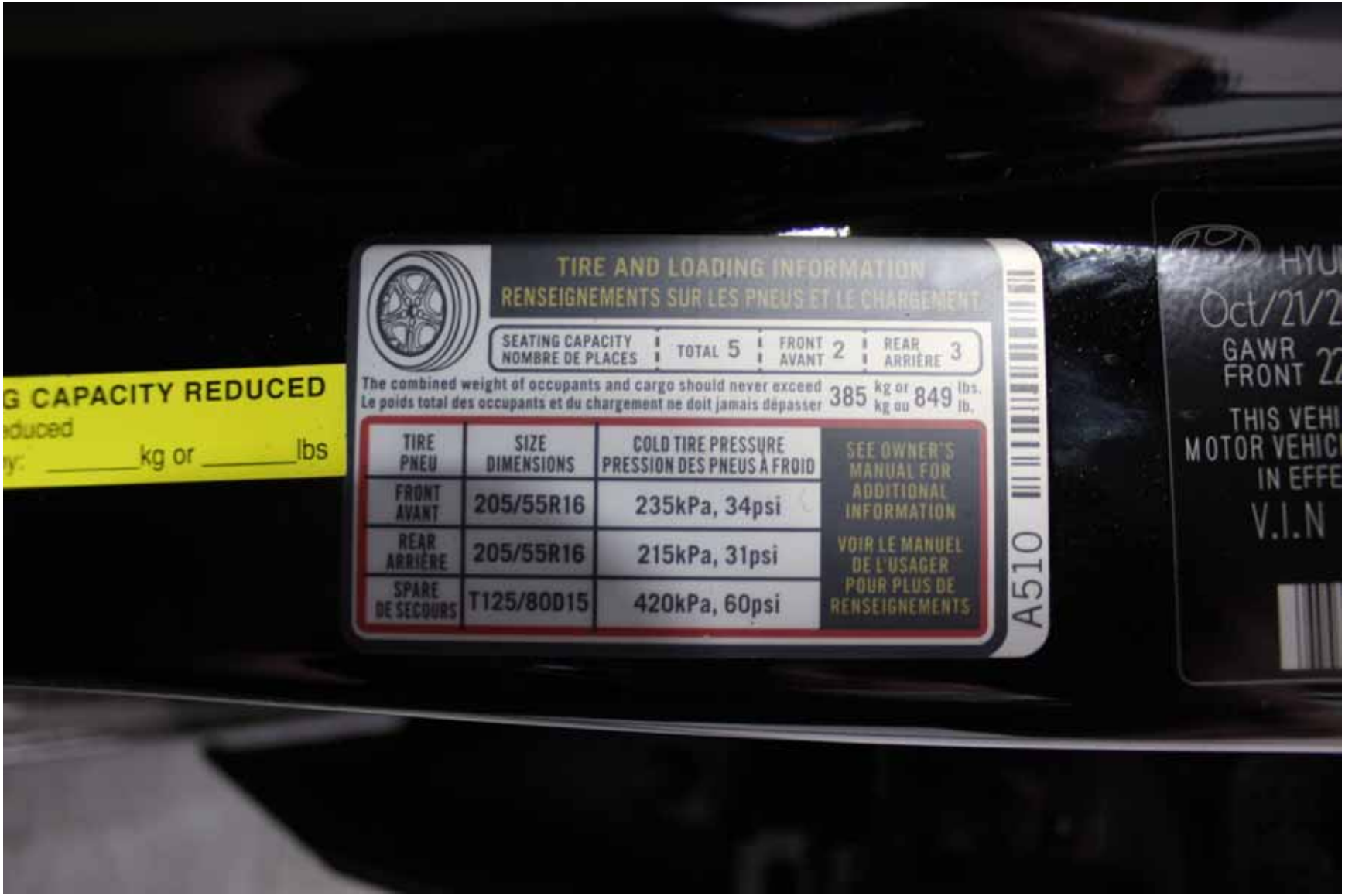


Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Passenger Side Oscar Photograph No. 9

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

VIN Label Photograph No. 1



Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Tire Information Label Photograph No. 1

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph N. 1 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 2 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 3 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 4 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 5 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 6 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

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FMVSS No. 216a

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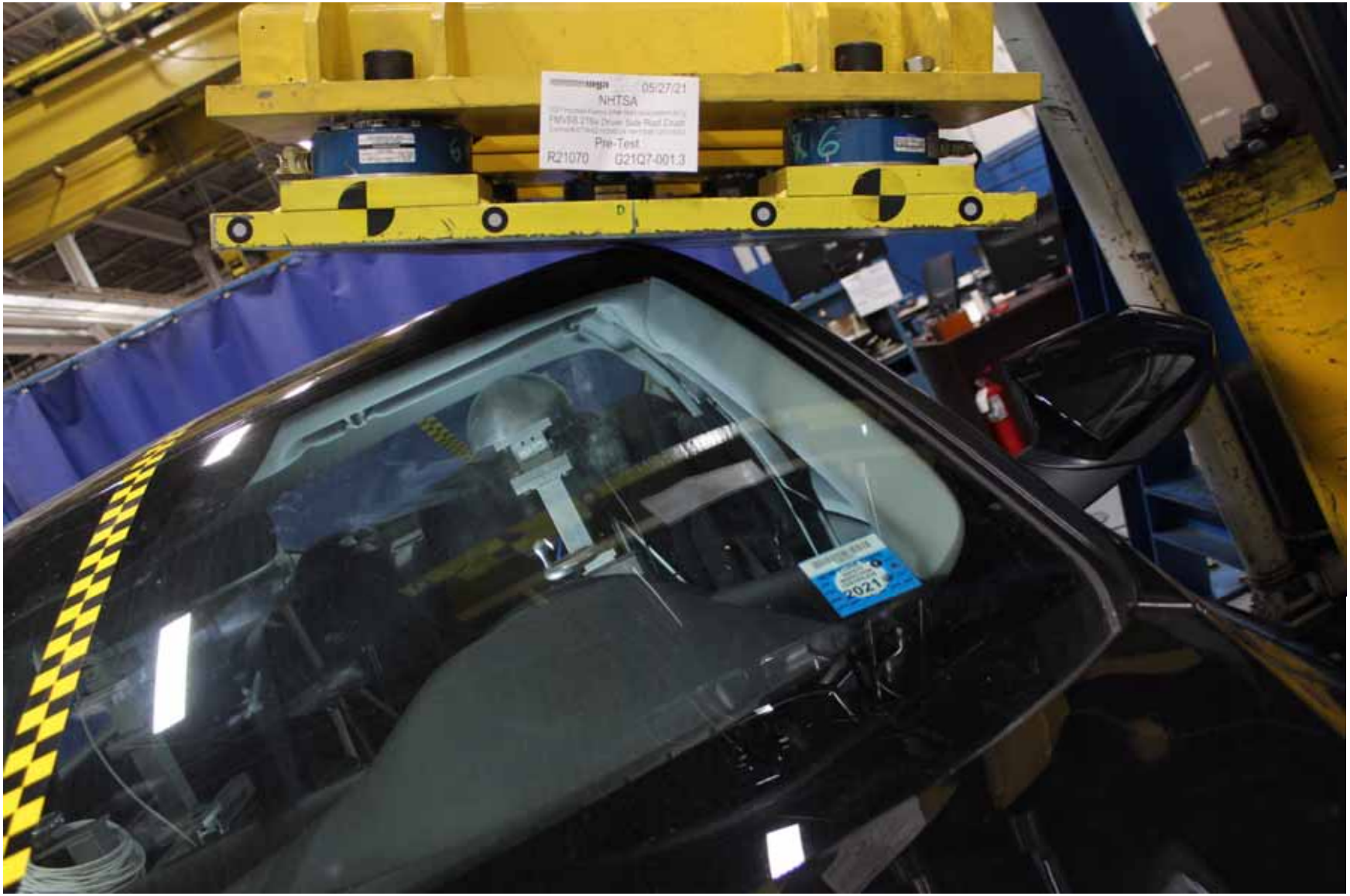

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NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 9 of Test R21070

Hyundai Elantra
NHTSA No. C20214202

Pre-Test Photograph No. 10 of Test R21070

FMVSS No. 216a

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 11 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 12 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 13 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 14 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 15 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 16 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 17 of Test R21070

Hyundai Elantra
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Pre-Test Photograph No. 18 of Test R21070

Hyundai Elantra
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FMVSS No. 216a

Pre-Test Photograph No. 19 of Test R21070

Hyundai Elantra
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FMVSS No. 216a

Pre-Test Photograph No. 20 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 21 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 22 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 23 of Test R21070


05/27/21
NHTSA
2021 Hyundai Elantra VIN# 5NPLS4AG4MH005012
FMVSS 216a Driver Side Roof Crush
Contract# DTNH2216D00028 / NHTSA# C20214202
Pre-Test
R21070
G21Q7-001.3

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 24 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 25 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 26 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 27 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 28 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 29 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

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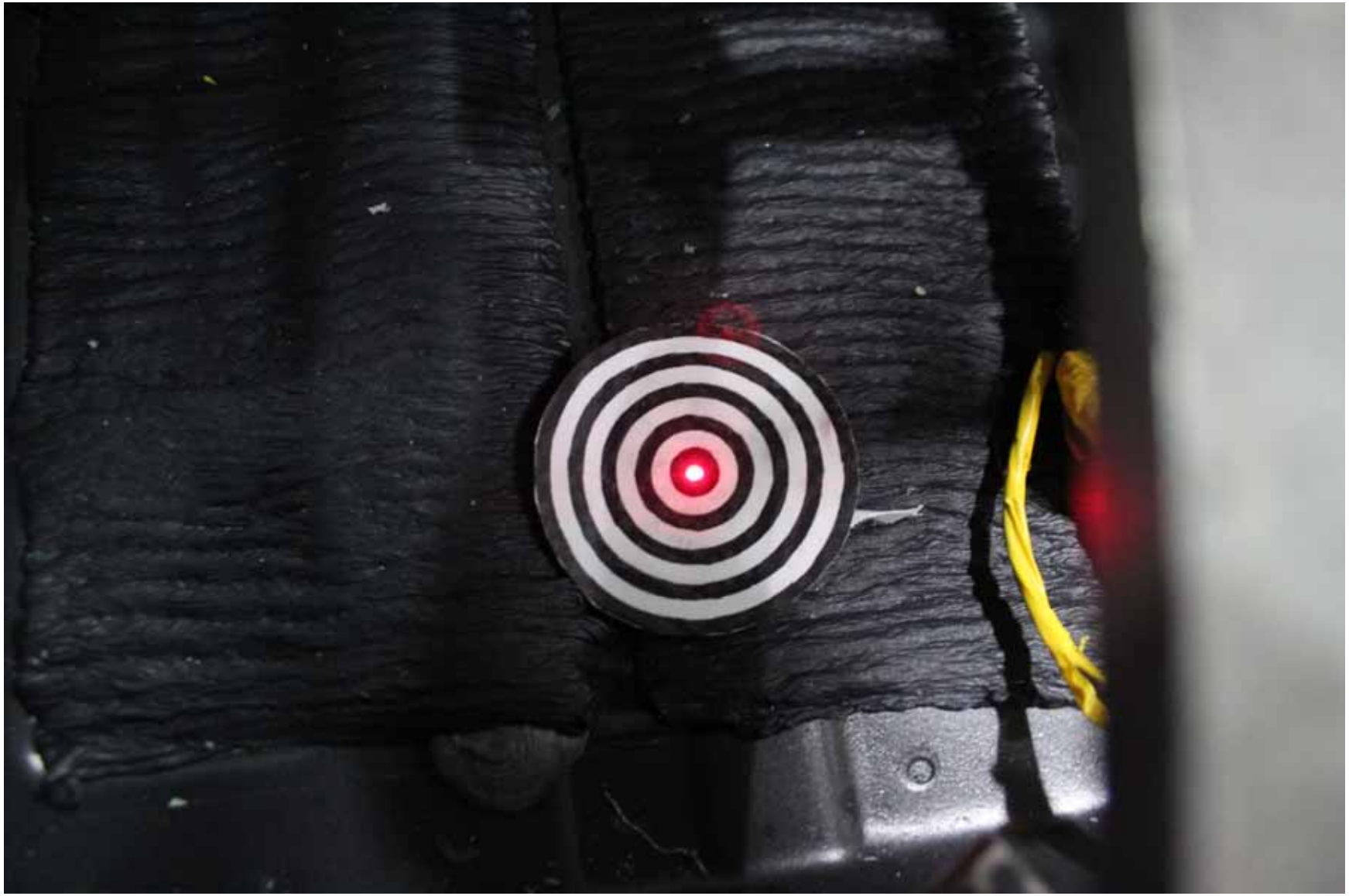

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FMVSS No. 216a

Pre-Test Photograph No. 31 of Test R21070

Hyundai Elantra
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FMVSS No. 216a

Pre-Test Photograph No. 32 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

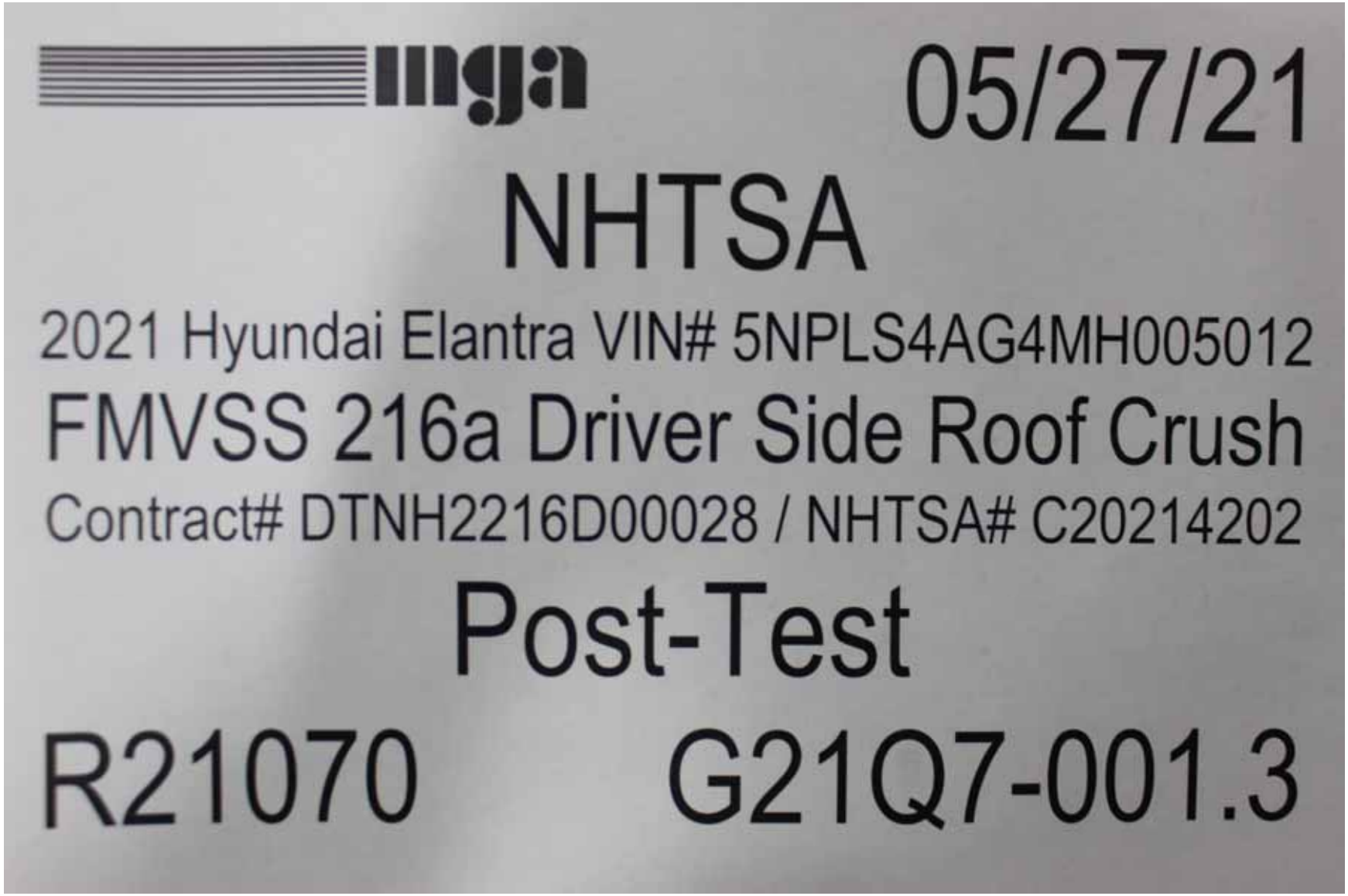
Pre-Test Photograph No. 33 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 34 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 35 of Test R21070



Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 1 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 2 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 3 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 4 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 5 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 6 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 7 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 8 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 9 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 10 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 11 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 12 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 13 of Test R21070

Hyundai Elantra
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FMVSS No. 216a

Post-Test Photograph No. 14 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 15 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 16 of Test R21070

Hyundai Elantra
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FMVSS No. 216a

Post-Test Photograph No. 17 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
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Post-Test Photograph No. 18 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

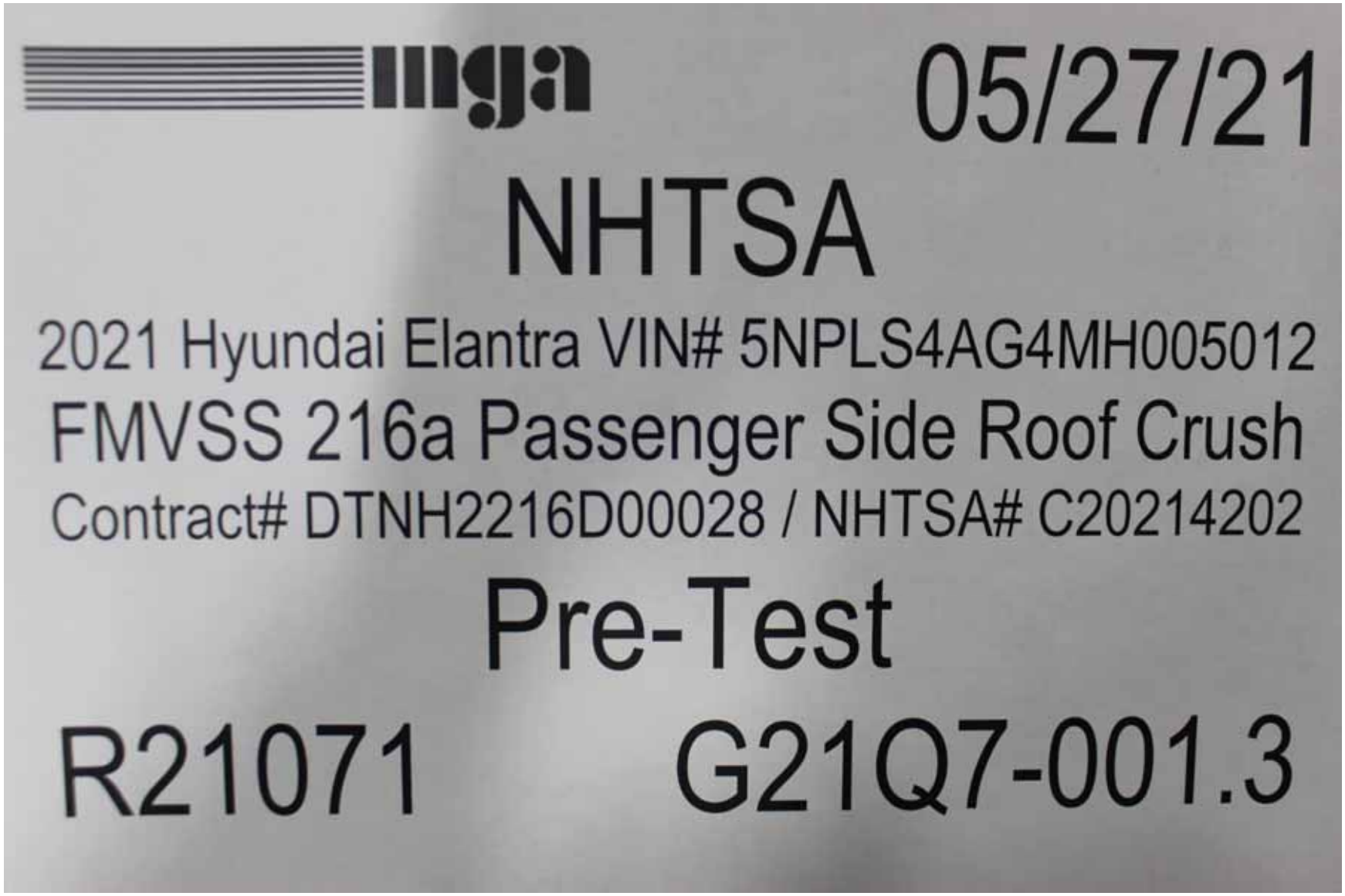
Post-Test Photograph No. 19 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 20 of Test R21070

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 21 of Test R21070



Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 1 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 2 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

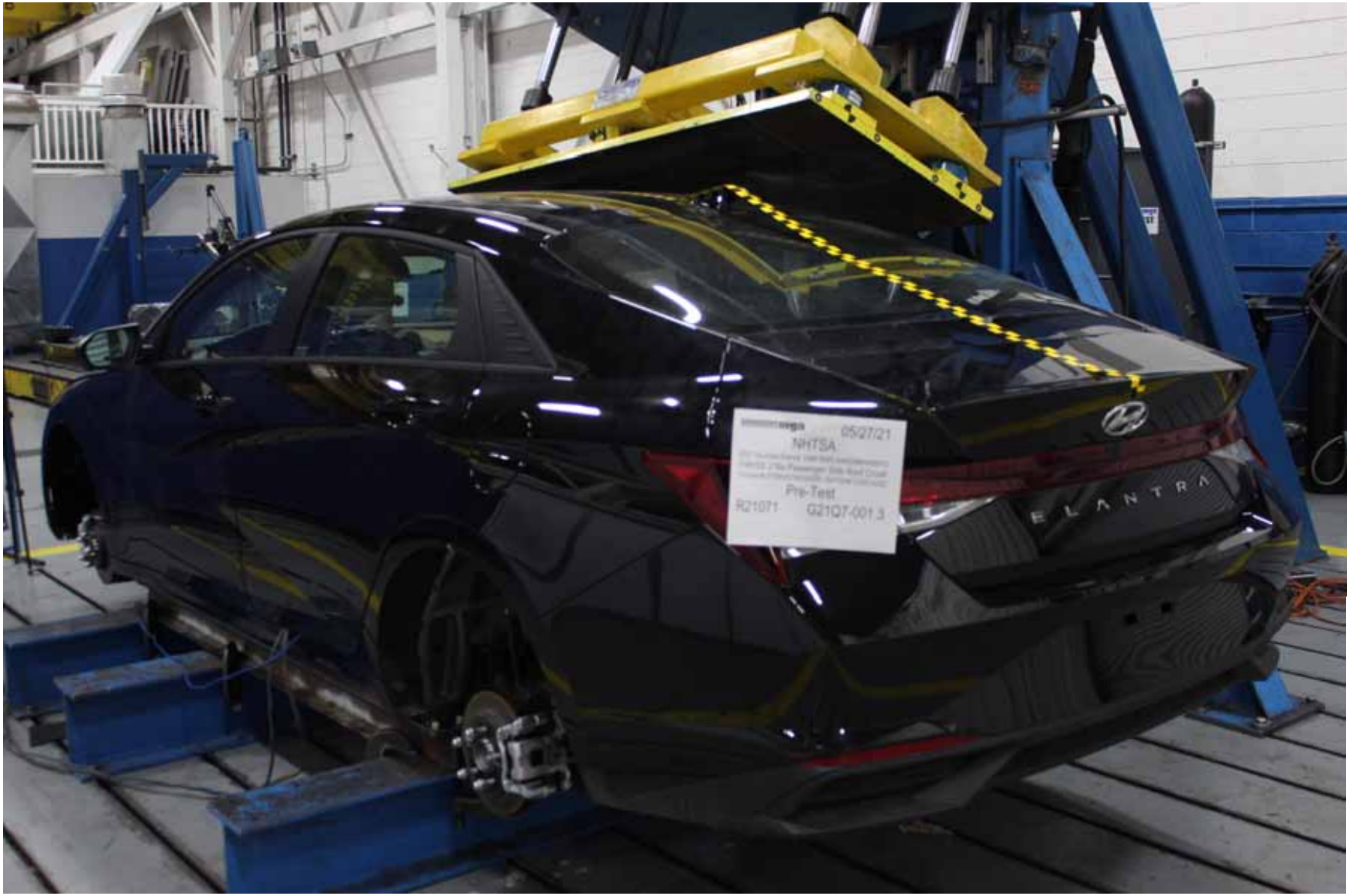
Pre-Test Photograph No. 3 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 4 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 5 of Test R21071



Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 6 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 7 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 8 of Test R21071

Hyundai Elantra
NHTSA No. C20214202

Pre-Test Photograph No. 9 of Test R21071

FMVSS No. 216a

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 10 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 11 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 12 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 13 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 14 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 15 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 16 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 17 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 18 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 19 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 20 Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 21 of Test R21071

020 Audi Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 22 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 23 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 24 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 25 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 26 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

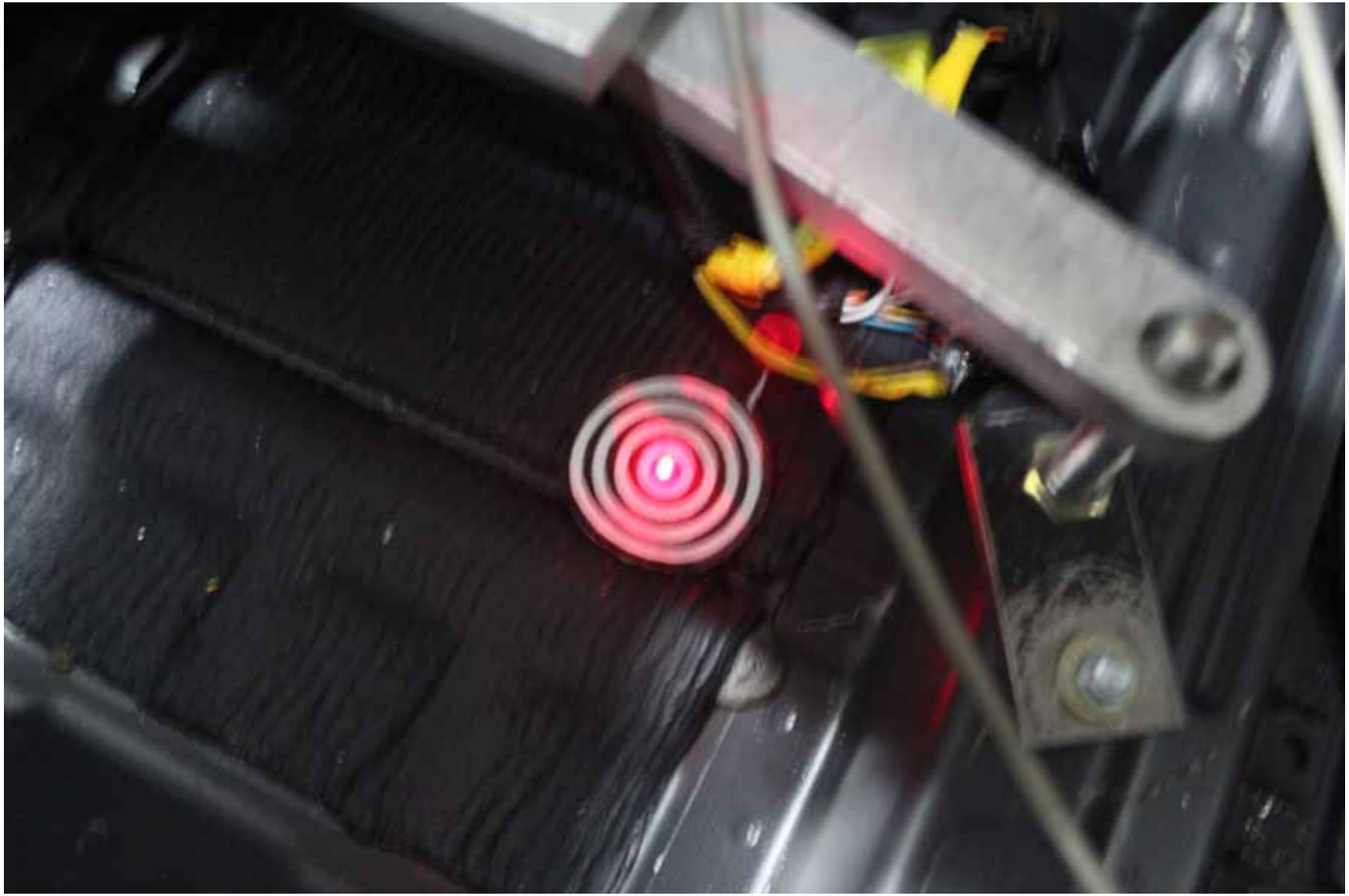
Pre-Test Photograph No. 27 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 28 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 29 of Test R21071



Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 30 of Test R21071

Hyundai Elantra
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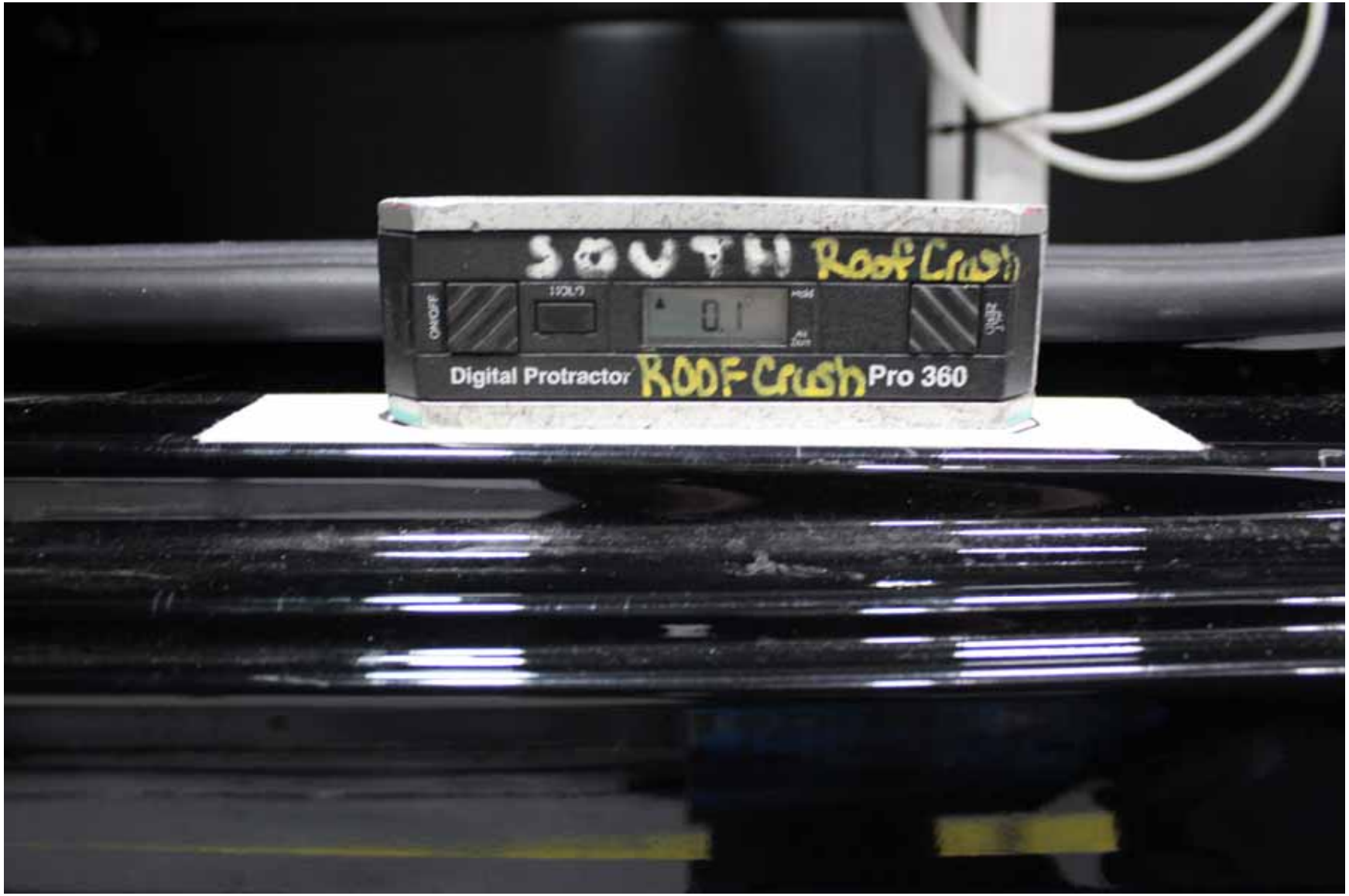
FMVSS No. 216a

Pre-Test Photograph No. 31 of Test R21071



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NHTSA No. C20214202
FMVSS No. 216a

Pre-Test Photograph No. 32 of Test R21071

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FMVSS No. 216a

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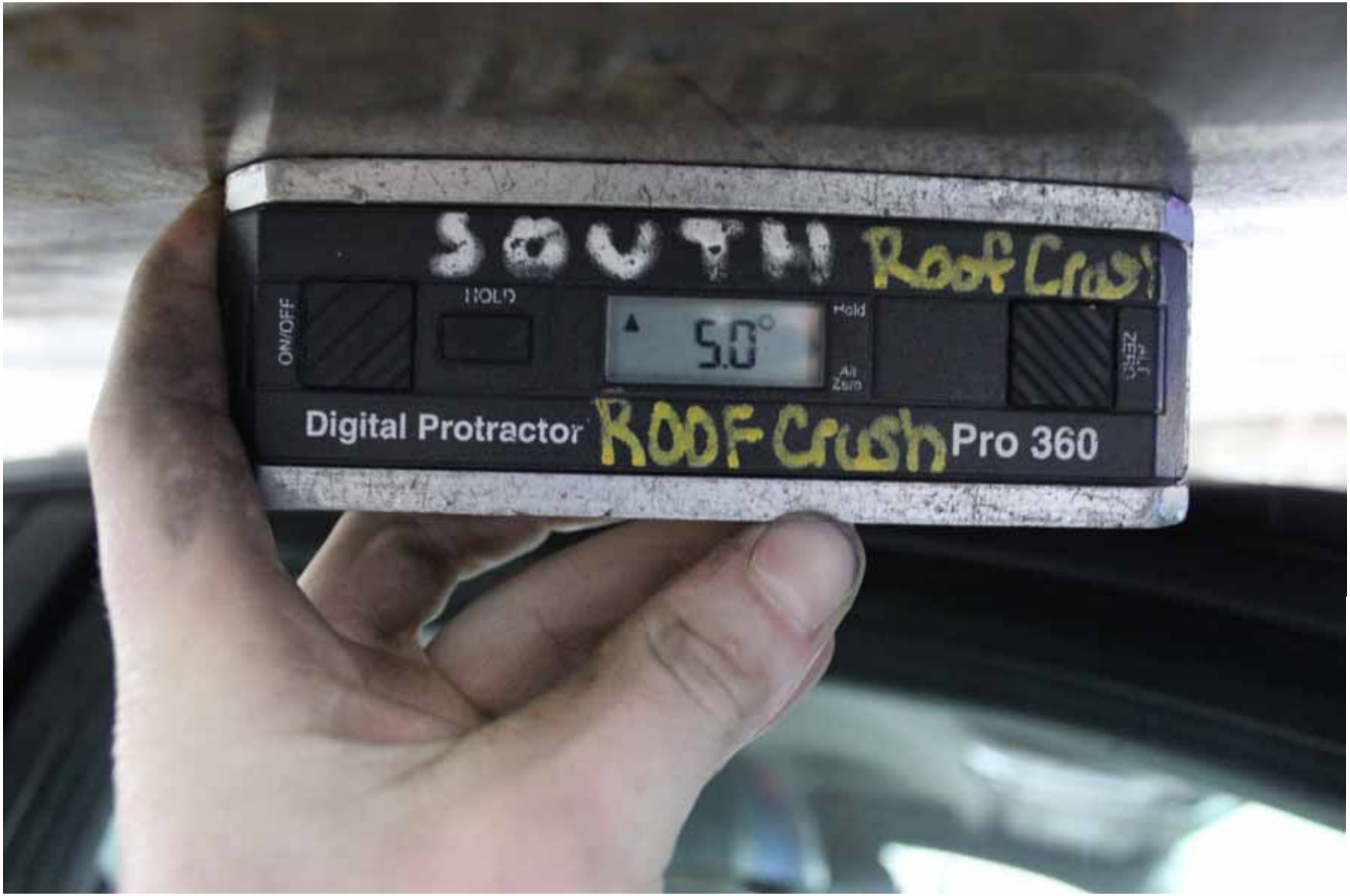

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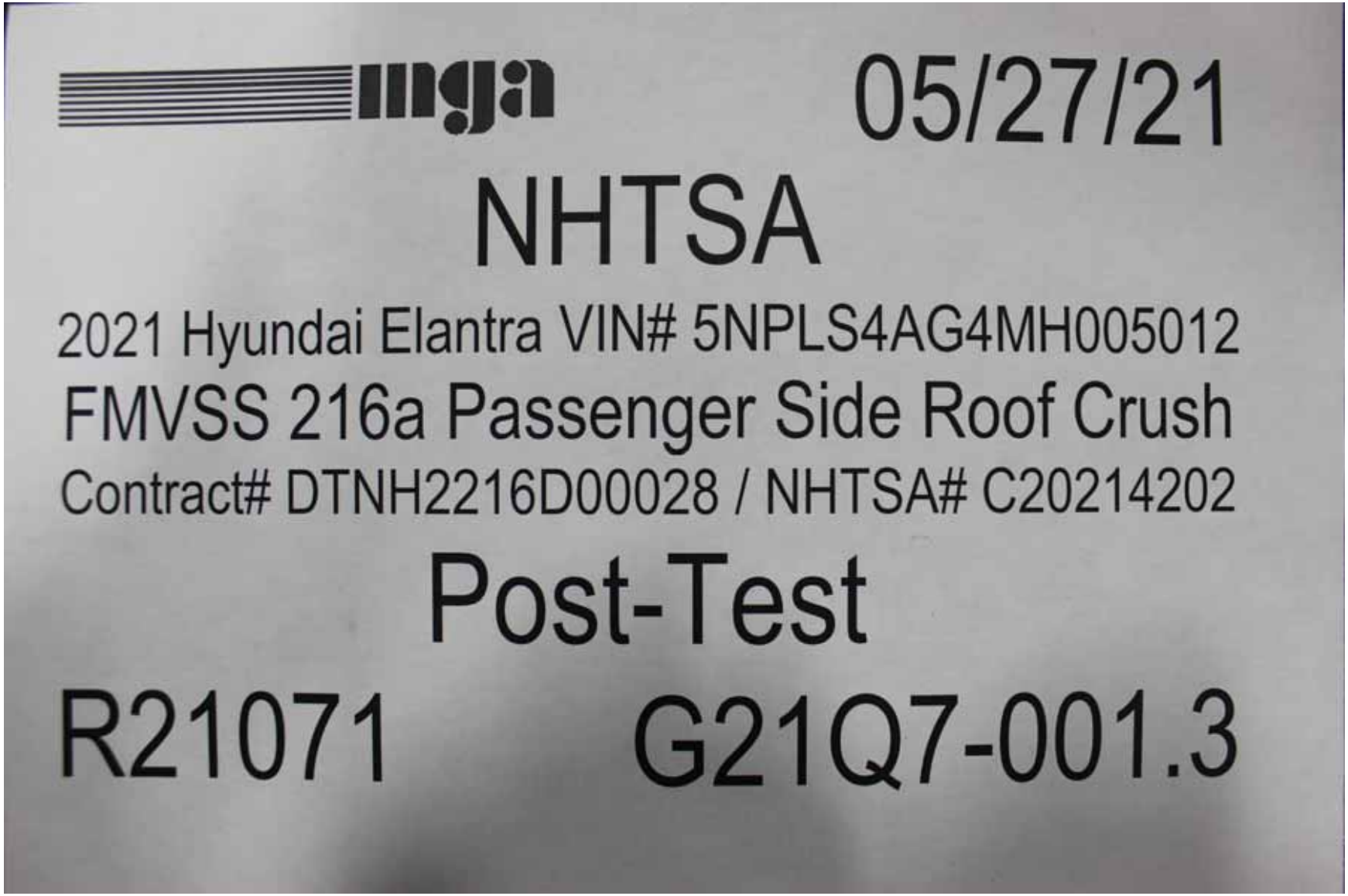

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 1 of Test R21071

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FMVSS No. 216a

Post-Test Photograph No. 2 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 3 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 4 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 5 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 6 of Test R21071

Hyundai Elantra
NHTSA No. C20214202

Post-Test Photograph No. 7 of Test R21071

FMVSS No. 216a

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 8 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 9 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 10 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 11 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 12 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 13 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 14 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 15 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 16 of Test R21071

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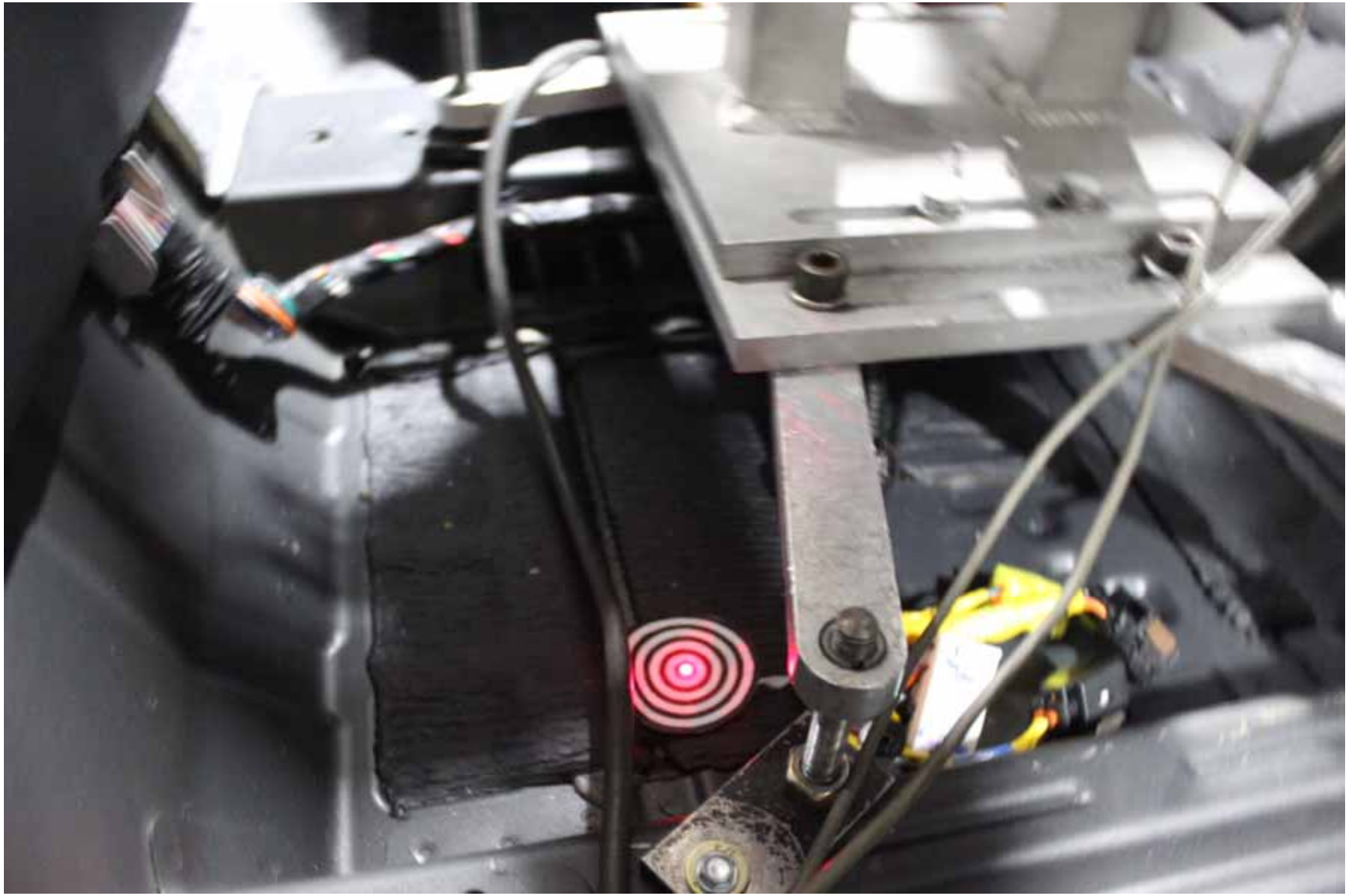
FMVSS No. 216a

Post-Test Photograph No. 17 of Test R21071



Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 18 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 19 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 20 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 21 of Test R21071

Hyundai Elantra
NHTSA No. C20214202
FMVSS No. 216a

Post-Test Photograph No. 22 of Test R21071

6.0 Test Data Plots