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SAE Instrumented Arm
User's Manual

RATIONALE

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INTRODUCTION

The Instrumented Arm project began late in 1995 with interest in studying arm injuries incurred in vehicle accidents involving driver's-side airbags. According to studies available at the time, injuries to the arm had increased in conjunction with the addition of driver's side airbags in new model vehicles. At the same time, there was also a strong interest in assessing potential frontal arm injury from side airbags.

According to S.M. Kuppa, *et al*, in their 1997 research paper for the SAE International (SAE), *RAID – An Investigation Tool to Study Air Bag/Upper Extremity Interactions,* arm injuries before the introduction of driver's side airbags into the mainstream automotive market accounted for about 1% of the injuries incurred. However, since their introduction, arm injury has increased to about 4%, with female drivers receiving injuries more frequently than males.

The apparent reason for this increase in injury occurrence is the interaction of the arm with the airbag. Through vehicle crash testing with human cadavers and surrogates (crash dummies) researchers have reported injuries to the upper arm, lower arm and hand caused by airbag deployment. Research has shown that arm injuries typically occur in one of two ways: 1) the arm is propelled by the deploying airbag into a pillar or beam or the occupant's head, or 2) "primary contact injuries," which occur when the driver's arm is directly in front of, or on top of, the airbag when it deploys.

The fact that the occurrence of these injuries is seen more often in women may be due to three factors: 1) women are typically shorter than men so as to cause them to be closer to the airbag module, 2) bone density in women commonly decreases with age, 3) women have smaller bones and subsequently lower bone strength.

In October of 1995 the Mechanical Human Simulation Subcommittee of the SAE International (SAE) Human Biomechanics and Simulation Standards Committee (HBSSC) formed the Arm-Airbag Interaction Task Group. The Task Group was formed to investigate and develop a practical measuring device for the study of arm injuries caused by airbags. In the Task Group's initial meeting it was agreed that the primary focus of the group should be arm interaction with current driver-passenger airbags, and future side impact airbags. This focus would entail: the review of highway data, and the development of an instrumented mechanical arm surrogate with appropriate testing procedures. Since 1995 the group, together with *Robert A. Denton, Inc.*, has worked diligently to produce a device that answers the performance criteria determined to be necessary to effectively measure injury in the given area of interest.

The current arm configuration combines many of the original ideas and concepts of the Task Group. While some of the initial ideas have not yet been incorporated, either due to compromise, impracticality or time constraints, the current arm is a usable and highly effective tool for measuring arm injury. Further details regarding use of the Instrumented Arm can be found in: ISO Technical Report (TR) number 15827. Future modifications will include: a low-profile elbow potentiometer to reduce metal-to-metal contact in rigid wall testing and an improved SID-IIs upper arm flesh to better fit at the shoulder joint attachment.

The complete arm is currently used on the SID-IIs side-impact dummy and the Hybrid III 5th percentile Small Female (HIII-5F) dummy. It can be used on either the left or right side making this arm a viable product in nearly any crash situation, anywhere in the world, where arm injury measurement is desired.

1. SCOPE

This user's manual covers the instrumented arm for the Hybrid III 5th Percentile Small Female dummy as well as the SID – IIs dummy. It is intended for technicians and engineers who have an interest in assessing arm injury from the use of frontal and side impact airbags. It covers the construction, disassembly and reassembly, available instrumentation, and segment masses.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

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2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

General Specifications

Kuppa, S., Olson, M., Yeiser, C., Taylor, L. et al., "RAID - An Investigative Tool to Study Air Bag/Upper Extremity Interactions," SAE Technical Paper 970399, 1997, https://doi.org/10.4271/970399.

SAE J211-1 Instrumentation for Impact Test - Part 1 - Electronic Instrumentation

SAE J1733 Sign Convention for Vehicle Crash Testing

SAE J2862 User's Manual for the Small Adult Female Hybrid III Test Dummy

2.1.2 ISO Publications

ISO Technical Report (TR) number 15827, Road vehicles — Test procedures — Evaluating small female dummy arm and forearm interactions with driver frontal airbags and side airbags

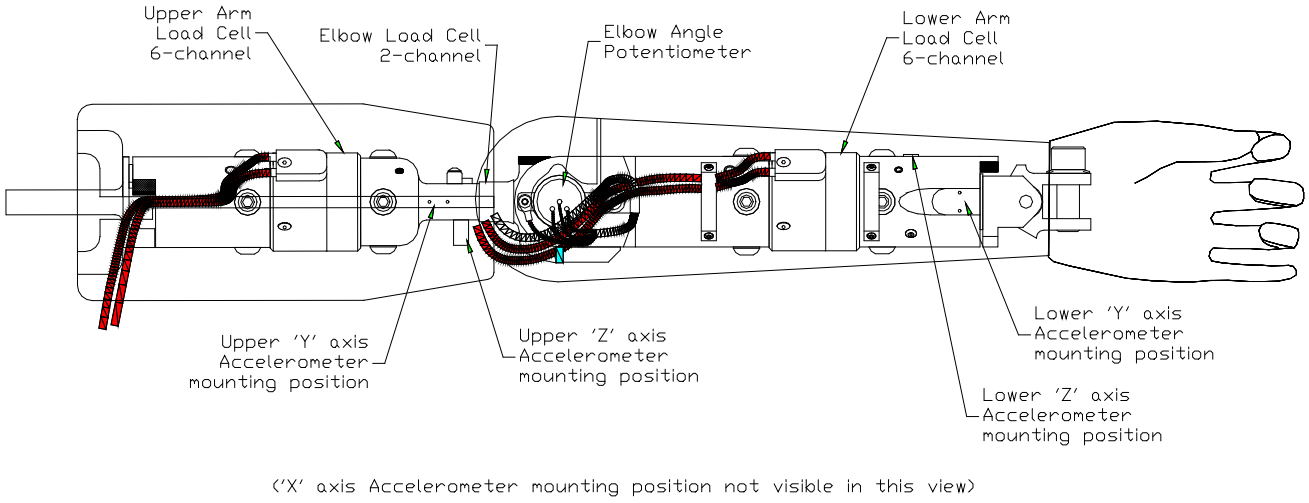


Figure 1 - Air bag interaction arm (HIII-5F left arm shown)

2.2 Instrumentation

The Instrumented Arm supports the use of:

Two (2)	Model 3780	Six-channel Load Cells; measuring: Fx, Fy, Fz, Mx, My, Mz in the Upper and Lower arm sections.
One (1)	Model 3781	Two-channel Load Cells; measuring: Mx, My at the Elbow Joint.
One (1)	Model 4077	Rotary Potentiometer; measuring Elbow rotation.
Six (6)		Uniaxial Accelerometers; **measuring X, Y, and Z at the Elbow and Wrist joints. (SA572-S4 accelerometers)
		****Accelerometers not included with Arm.**
Twenty-one (21)		Total possible data acquisition channels.

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2.3 Weights

The Arm weights: (including flesh components)

Table 1 - Arm masses

	H3-5F	SID-II s
Upper Arm	1.30 kg (2.87 pounds)	1.26 kg (2.78 pounds)
Lower Arm	1.21 kg (2.67 pounds)	
Hand	0.31 kg (0.68 pounds)	
Total	2.82 kg (6.21 pounds)	2.78 kg (6.13 pounds)

The difference between the weight of the Hybrid III 5th Small Female (HIII-5F) arm and the SID-IIs is in the shoulder joint. The SID-IIs uses a lighter weight Z - Pivot (*left: 3985-1; right: 3985-2*) than the HIII-5F (*left: 3993-1; right: 3993-2*). Other than the Pivot and the Upper Arm Flesh, the Arm can be used on either dummy type.

2.4 Range of Motion

The design limits for the Range of Motion:

Table 2 - Range of motion limits

	Bumper Contact	Forced Range	Metal-to-Metal (w/o Bumper)
Shoulder Lateral Rotation	37°	43°	53°
Shoulder Medial Rotation	111°	117°	127°
Elbow Flexion	135°	141°	147°
Elbow Extension	-4.5°**	0°	3.5°
Wrist Supination	100°	105°	108°
Wrist Pronation	100°	105°	108°
Wrist Flexion	27°	31°	34°
Wrist Extension	31°	61°	64°

** Negative number for Elbow Extension Bumper Contact means that the Arm is actually flexed 4.5° when it contacts the Extension Bumper.

2.5 About the Manual

This manual has been put together to help the technician use and maintain the Instrumented Arm package. While all instructions are set forth in a “step-by-step” manner, it is also an excellent reference guide to order parts and recall key information about specific areas of the Arm’s assembly/disassembly and operation.

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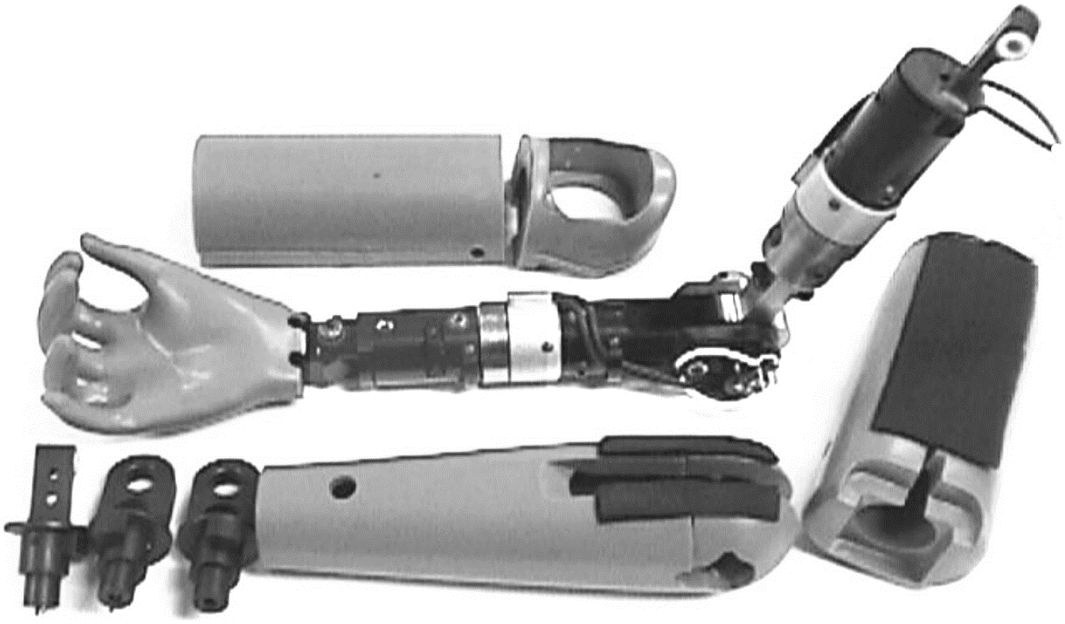


Figure 2 - Model J3525 air bag interactive arm assembly

3. DISASSEMBLY OF ARM – REMOVAL FROM ATD

The only tools necessary to completely disassemble the Arm is a full set of hex wrenches; sizes 0.050” through 7/32” and a small tipped Phillips screwdriver.

To begin the procedure the Arm must first be removed from the dummy (see Figure 3). To remove the Arm from the HIII-5F takeout the 3/8 x 1” SHSS (see Appendix A for screw head style abbreviations) pivot bolt located at the shoulder-arm joint. With the pivot bolt removed the arm can be pulled away from the assembly. Watch for the pivot and compression washers and the pivot nut, they often fall out of the joint when the arm is removed. To remove the Arm from the SID-IIs takeout the 1/4 x 1-1/4 SHSS from the shoulder-arm joint.

NOTE: During re-assembly of the SID-IIs Arm the user may notice interference between the Bushings and the Shoulder Clevis. This may cause some difficulty in assembly, however the user should be able to insert the Arm.

While the shoulder-arm joint is disassembled be sure to inspect the components. The washers are frequently damaged from improper installation. If the washers are damaged the friction adjustment for this joint may be affected. Replace all damaged parts.

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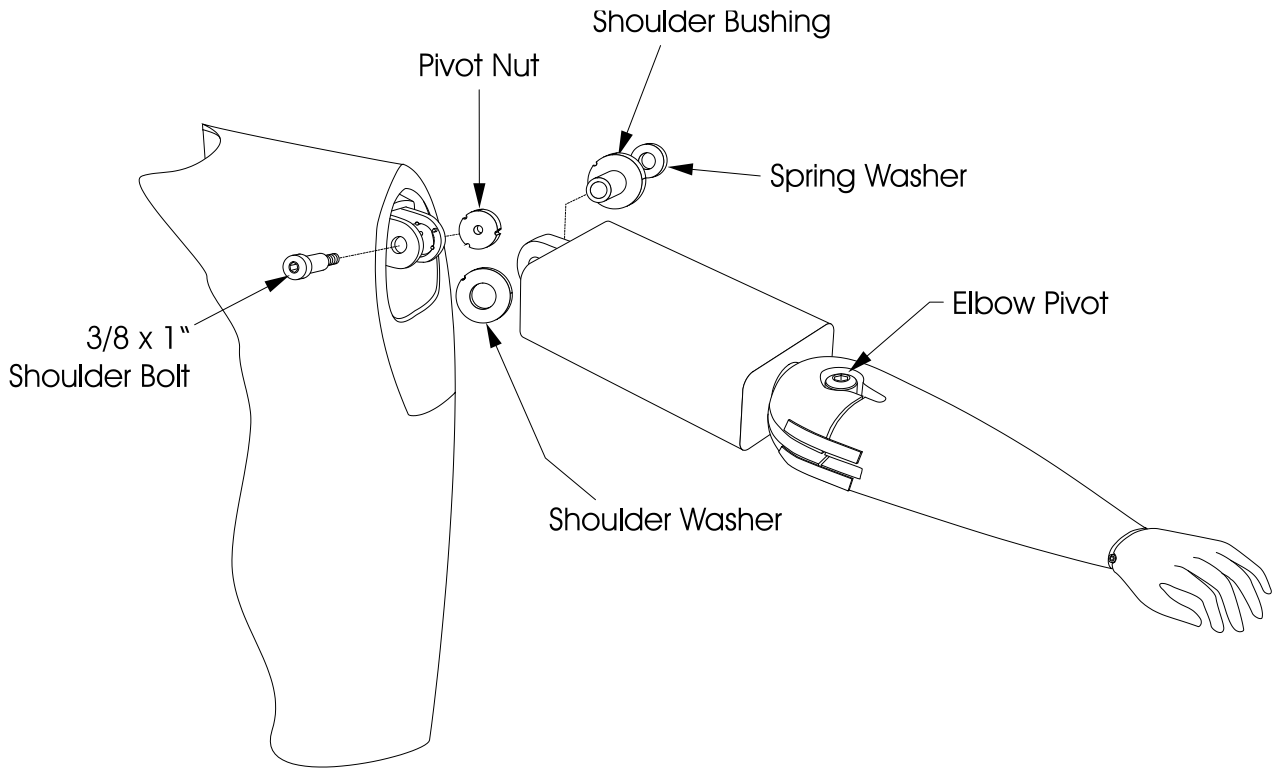


Figure 3 - Arm removal

3.1 Instrumentation Cables

Due to the large number of transducers in a relatively small area, cable paths and strain relief are an important issue. The Arm flesh, both Upper and Lower Arm, has cable guide channels to ensure that the cables are protected in each section of the Arm. Before completing the positioning of all the transducer cables, it is a good idea to mark each cable, connector end, so as to be able to easily determine which cable belongs to each transducer.

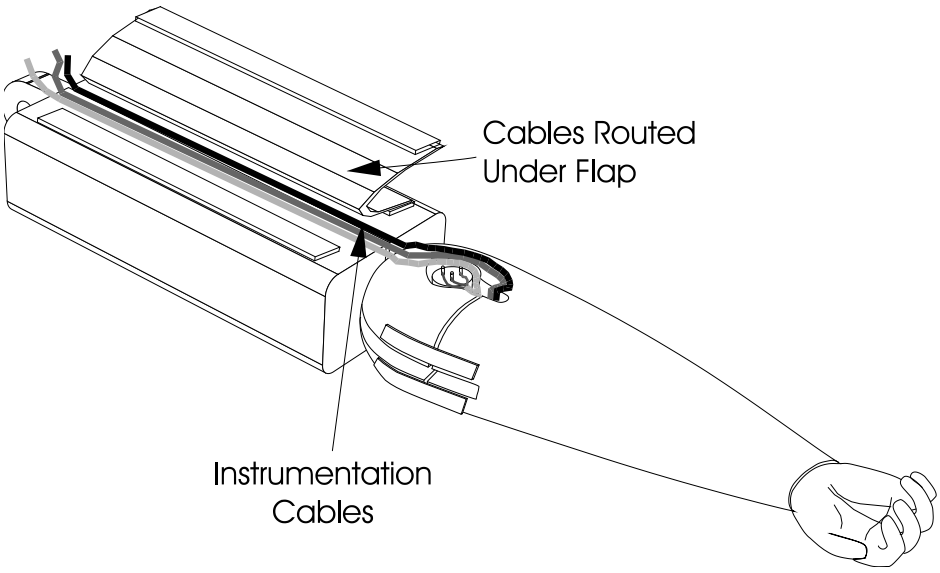


Figure 4 - Cable Routing

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As shown in the Assembly drawings, included at the end the manual, all three of the accelerometer cables are routed through the cable guide located just below the Lower Arm load cell. These cables are then run through the Lower Arm flesh along the load cell toward the Elbow. On the Elbow Clevis there is a second cable guide to collect together the load cell and accelerometer cables. All five of these cables are then routed toward the Elbow and out of the Arm assembly through the cable access hole at the Elbow. The cables should be brought out of the Arm toward the inboard, the side closest to the Upper Torso, of the Arm assembly. All the Lower Arm cables, including the Potentiometer cable, are then secured under the vinyl flap on the inside surface of the Upper Arm.

The three-accelerometer cables for the Upper Arm are passed along the Upper Arm load cell toward the Upper Arm Pivot. All cables must be positioned toward the inside of the Arm.

Once all the cables are properly routed along the inside of the Arm, toward the Upper Torso, and brought together at the top of the Arm Pivot they can be “bundled” together. With all the cables bundled in one group it is easier to manage their connection to the data acquisition system.

As a final check, be sure that the cables are free to move with the Arm. If improperly positioned the cables can hinder Arm motion or be damaged during testing. Leave enough “slack” cable to ensure good, free, movement of the Arm but not enough to allow the cable to be pinched or snagged.

3.2 Disassembly of Arm-Elbow

To begin disassembly of the Arm, first detach the Lower Arm and Hand from the Upper Arm. Start this procedure by removing the potentiometer from the Arm assembly. Take out the two (2) #4-40 x 1/4” BHCS that secure the Potentiometer Body Retainers in position (shown in Figure 6). Then remove the cable strain relief and slide the assembly out of the Elbow joint.

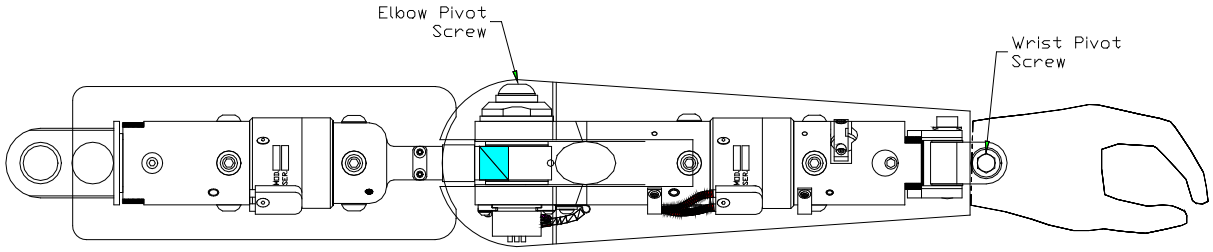


Figure 5 - Arm pivots

Remove the Elbow Pivot screw shown in Figures 5 and 6. When the Pivot screw is removed the Elbow washers will be free to be removed from the assembly.

While the Elbow Pivot washers are out of the assembly, inspect the condition of the washers. The washer immediately under the Pivot screw head is the Spring Washer. The Spring Washer is a flexible material that can be damaged from over-compression. The next washer is the Elbow Washer. This washer only requires inspection for burrs and cleaning with isopropyl alcohol. The third washer is fiberglass. This component should be checked for any damage that will affect the smooth operation of the Elbow, such as; burrs, dirt, etc. Do not apply any oil based lubricants to this joint. Oil has the tendency to attract and collect dirt. If a lubricant is deemed necessary, it generally is not, use a dry (i.e., graphite) type lubricant.

Next, rotate the Upper Arm section (see Figure 7) so that the Locking Screw, on the inside of Elbow joint, is visible. The Locking Screw is a 1/4-28 x 1/4” SSDP. Remove the Locking Screw and pull the Elbow Shaft Assembly out of the Elbow joint. Once the Elbow Pivot is removed the Upper and Lower Arm sections can be pulled apart.

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