# INVESTIGATION OF NEW SIDE IMPACT TEST PROCEDURES IN JAPAN

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## ABSTRACT

Various countries are independently conducting side impact tests with actual vehicles, resulting in extensive revisions of safety measures for accidents involving side collisions. However, the number of people injured and killed in these collisions remains high, and so more effective overall measures, including those for the vehicle itself, are urgently needed. The IHRA is actively conducting research toward enacting laws to standardize future methods of side impact tests as one way to realize international harmonization projects. This has led to MDB improvements as well as the improvement and development of dummies.

This report is intended to be useful for IHRA research activities. Tests were conducted using the improved dummies (ES-2, ES-2re) and AE- MDB in order to provide research results for comparison with body and dummy responses obtained in conditions complying with current regulations in Japan and Europe, and proposed regulations in the US.

## INTRODUCTION

Japan introduced a side impact regulation in 1998 for occupant protection in side collisions. As a result, the number of fatal and serious injuries in side collisions has reduced. However, there are still many side collision accidents, and further effective countermeasures are needed to reduce fatalities and serious injuries in side impacts. It is known that occupants in cars are inclined to sustain serious injuries when struck by vehicles with high front stiffness and high ground clearance such as SUVs (sport utility vehicles), MPVs and minivans. It is also necessary to consider improving the protection of occupants against side collisions with narrow objects such as trees and poles in single collisions.

In this paper, new side impact test procedures were investigated, which have been discussed in IHRA SIWG (International Harmonized Research Activities Side Impact Working Group), and are proposed by the United States. These tests consist of (1) AE-MDB test in which the current vehicle specifications and front stiffness are taken into consideration and (2) Pole impact.

These test procedures were compared with the current regulation (ECE/R95). In the tests of the present research, new side impact dummies such as ES-2, SID-IIs and ES-2re were used in addition to the EuroSID-1.

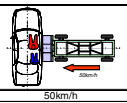
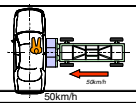
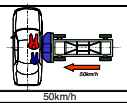
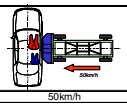
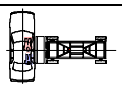
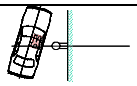
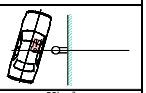
## TEST CONDITIONS

### Test Conditions

Table 1 shows the test configurations and conditions in the present research. In the tests, two types of Japanese bonnet-type 4 door sedans as car A and car B were used. These two cars are representative models of the vehicle fleet in Japan. From Test No.1 to 4, car A was used as the target car. From No.5 to 7, car B was used.

Test No.1, 2, 3, 4 and 5 were conducted on the basis of the ECE/R95 test configuration. In Test No.1, the ECE/R95 moving deformable barrier (MDB) was used, and the EuroSID-1 was placed in a front seat and SID-IIs in a rear seat. In Test No.2, only ES-2 was placed in a front seat. In Test No.3 and 4, the AE-MDB was used as an MDB, and the ES-2 was placed in a front seat and SID-IIs in a rear seat. In Test No.3, the center line of the AE-MDB was in alignment with the front seat reference point (SRP) of the test car. On the other hand, in Test No.4, the center line of the AD-MDB was 250 mm behind the SRP. From Test No.1 to 4, injury criteria of dummies in front and rear seats were compared. In Test No.5, ES-2 was placed in the front seat of car B, and SID-IIs in the rear seat, and the injury criteria of the dummy were compared with the pole test using the same car model (Test No.6 and 7).

**Table 1.**
**Test conditions in full-scale side impact test**

| Test No. | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Test config. | |  |  |  |  |  |  |  |
| Impact velocity | | 50km/h | 50km/h | 50km/h | 50km/h | 50km/h | 32km/h | 32km/h |
| Impact point | | Striking vehicle C/L<br>Front seat SRP of struck vehicle | Striking vehicle C/L<br>Front seat SRP of struck vehicle | Striking vehicle C/L<br>Front seat SRP of struck vehicle | Striking vehicle C/L<br>Front seat SRP+250mm of struck vehicle | Striking vehicle C/L<br>Front seat SRP of struck vehicle | Pole center to<br>Front Dummy Head center | |
| MDB | Type | ECER95 | ECER95 | AE-MDB | AE-MDB | ECER95 | Pole: Size 254mm (10 inch) | |
| | Mass | 950kg | 950kg | 1503kg | 1503kg | 950kg | | |
| | Ground Height | 300mm | 300mm | Barrier:300mm<br>Bumper:350mm | Barrier:300mm<br>Bumper:350mm | 300mm | Pole: Impact angle 75° | |
| Struck Vehicle | Mass | 143[illegible]kg | 1432kg | 1433kg | 1418kg | 1266kg | 1194kg | 1194kg |
| | Front Dummy | EuroSID-1 | ES-2 | ES-2 | ES-2 | ES-2 | ES-2 | ES-2re |
| | Rear Dummy | SID-IIs | [illegible] | SID-IIs | SID-IIs | SID-IIs | - | - |

Test No.6 and 7 are a pole test which was conducted based on the pole test proposed by NHTSA (FMVSS214 Draft). This pole test was conducted according to the proposal by NHTSA in the FMVSS 214 Draft where the impact velocity is 32 km/h, the impact angle is 75° and the pole diameter is 254 mm. In Test No.6 and 7, a curtain airbag was installed in car B. The ES-2 was placed in the front seat in Test No.6, and the ES-2re in Test No.7. In both tests, the center of gravity of the dummy head in a front seat was in alignment with the center of the pole.

### Moving deformable barrier

In ECE/R95 test conditions, the impact velocity of the MDB was 50 km/h and the ground clearance was 300 mm. The front face of the MDB in the tests was a barrier with a progressively changing crush pressure. The AE-MDB is an MDB that was developed based on the car dimensions, mass and front stiffness in the current vehicle fleet (Figure 1). It also considers both-vehicle traveling and loading of the rear seat occupants. The AE-MDB tests were conducted under two conditions: Center line of AE-MDB was in alignment with the front seat SRP (Test No.3), and it was 250 mm behind the front seat SRP (Test No.4).

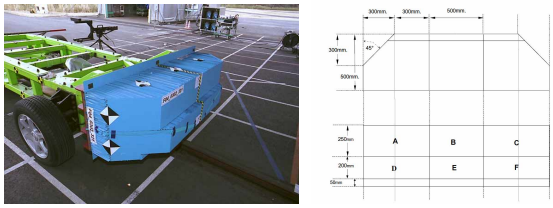



**Figure 1. Dimensions of AE-MDB.**

## TEST RESULTS

### Vehicle and MDB Deformation

The deformations of test car A (outer and inner panel) and MDB in Test No.1, 2, 3 and 4 are presented in Figure 2a and 2b. The deformation of car B and MDB are also presented in Figure 3a and 3b. Velocity-time histories of car A at the side sill and front door, the MDB, and the lower spine of the ES-2 were compared in Test No.2, 3 and 4, and are shown in Figure 4.

The common velocity and its time of MDB and test car A (side sill) are different with various deformations of test car. Especially, there are differences of velocity at the front door among Test No.1, 2, 3 and 4, which can cause different injury criteria of the dummy.

*Exterior*

*Interior*

*MDB*

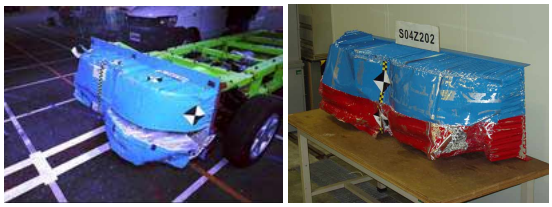
Test No.1 (ECE/R95, EuroSID-1) Test No.2 (ECE/R95, ES-2)

**Figure 2a. Deformation of test car and MDB (Test No.1 and 2).**

*Exterior*

*Interior*

*MDB*




Test No.3 (AE-MDB) Test No.4 (AE-MDB, SRP-250mm)

**Figure 2b. Deformation of test car and MDB (Test No.3 and 4).**

*Exterior* *MDB*

*Interior*

Test No.5 (ECE/R95, ES-2)

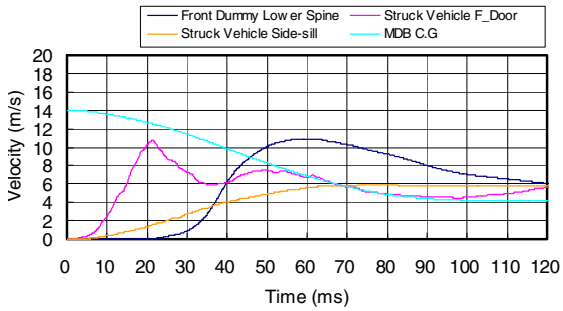
**Figure 3a. Deformation of test car and MDB (Test No.5).**

*Exterior*

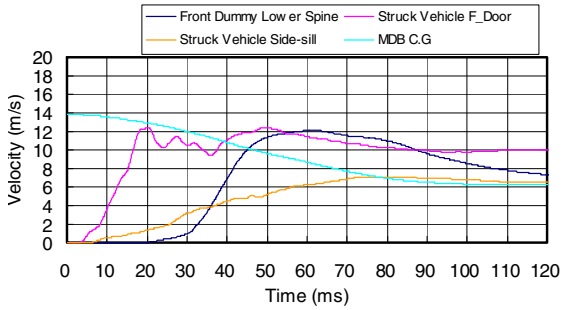
*Interior*

Test No.6 (ES-2) Test No.7 (ES-2re)

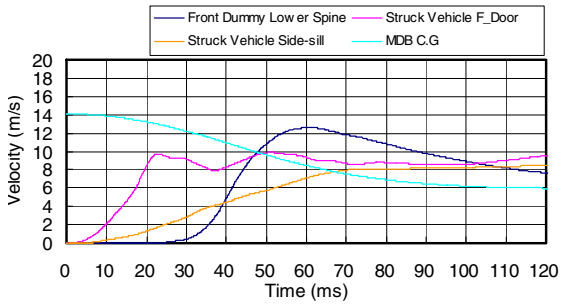
**Figure 3b. Deformation of test car and MDB (Test No.6 and 7).**




(a) Test No.2 (ECE/R95)




(b) Test No.3 (AE-MDB)




(c) Test No.4 (AE-MDB, SRP-250mm)

**Figure 4. Velocity-time histories of car A and MDB.**

## Dummy Injury Criteria in Car A

**Front seat dummy (EuroSID-1, ES-2)** Using the test results of Test No.1, 2, 3 and 4, the injury criteria of EuroSID-1 and ES-2 in car A impacted by AE-MDB were compared with those in the test condition using ECE/R95 MDB (Test No.2).

Injury criteria of the dummy were compared for ECE/R95 MDB and AE-MDB. Figure 5 shows the HPC (head performance criteria) of ES-2 in Test No.2, 3 and 4. The HPC of the dummy were higher in the AE-MDB tests than the ECE/R95 MDB test. In Test No.4 (SRP-250) where the AE-MDB target location was 250 mm behind the SRP, the head of the front seat dummy interacted with the B-pillar and HPC was above 600.

Figure 6 compares thorax upper, middle and lower rib deflections of the ES-2 dummy in Test No.2, 3 and 4. The thorax deflections are in descending order of upper, middle and lower rib, and there are no significant differences of dummy thorax deflection between ECE/R95 MDB and AE-MDB. The thorax deflection was slightly smaller in Test No.3 (AE-MDB center was in alignment with the target car front seat SRP) among the three tests.

The thorax V*C of ES-2 is compared in Figure 7. The V*C in upper, middle and lower rib was highest in the ECE/R95 MDB test (Test No.2), and lowest in the AE-MDB test (Test No.3).

The abdominal force and pubic force of ES-2 are compared in Figure 8. The abdominal force shows similar values among the three tests, whereas the pubic force is higher in the AE-MDB tests (Test No.3 and 4) than the ECE/R95 MDB test (Test No.2). In Test No.3, the abdominal force and pubic force are highest, though the thorax rib deflection and V*C were smallest among the three tests.

Injury criteria of front seat dummies are compared between EuroSID-1 (Test No.1) and ES-2 (Test No.2) in Figure 9. The thorax rib deflection and V*C are higher for ES-2 than EuroSID-1. However, the abdominal force and pubic force are similar between the two dummies. Due to a modification of the back plate of ES-2 from EuroSID-1, interaction between the dummy back and the seat back was changed, which significantly affects the thorax injury criteria.

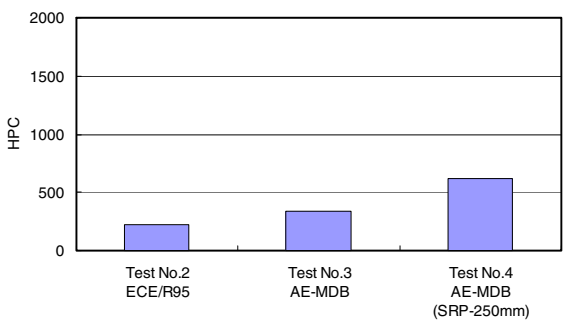



**Figure 5. HPC of ES-2 in car A.**

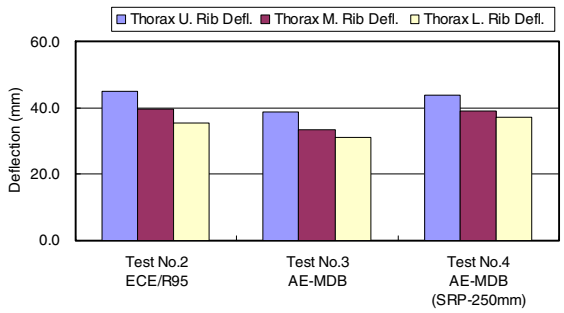



**Figure 6. Thorax rib deflection of ES-2 in car A struck by ECE/R95 MDB or AE-MDB.**

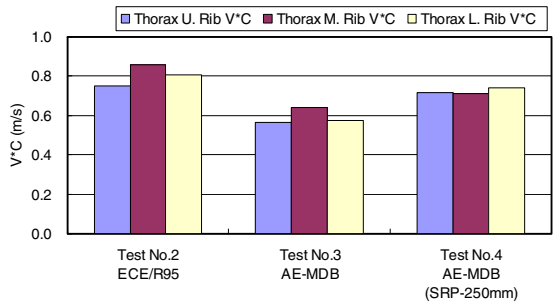



**Figure 7. Thorax Rib V*C of ES-2 in car A struck by ECE/R95 MDB or AE-MDB.**

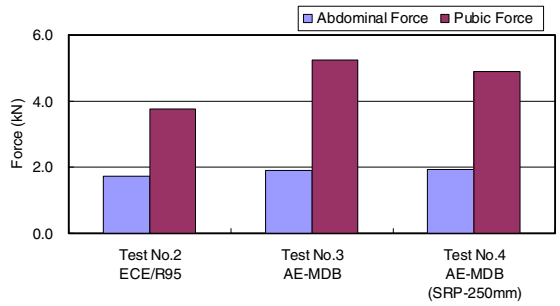
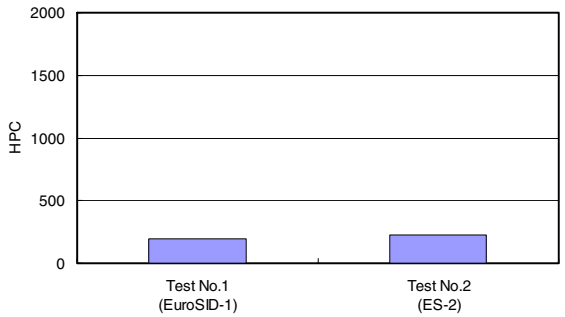
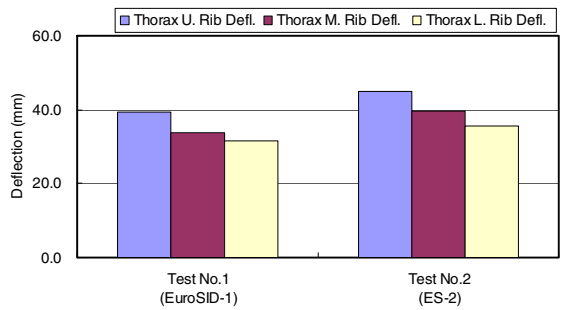


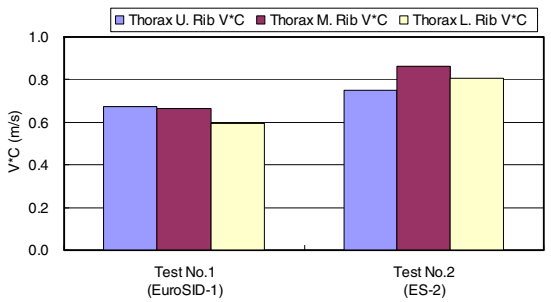

**Figure 8. Abdominal and Pubic Force of ES-2 in car A struck by ECE/R95 MDB or AE-MDB.**



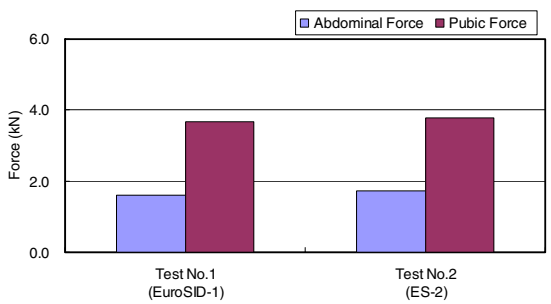

(a) HPC




(b) Thorax rib deflection




(c) Thorax rib V*C




(d) Abdominal force and pubic force

**Figure 9. Comparison of injury criteria between EuroSID-1 and ES-2 in car A struck by ECE/R95 MDB.**

**Rear seat dummy (SID-IIs)** The injury criteria of the rear seat dummy (SID IIs) in car A impacted by ECE/R95 MDB and AE-MDB were compared from the results of Test No.1, 3, and 4.

Figure 10 shows the HPC of SID-IIs. The HPC was inclined to be higher in the AE-MDB test than ECE/R95 MDB. In Test No.4, the head made contact with the C-pillar, which led to high HPC because the AE-MDB impacted toward the rear of the car compared with other tests.

The shoulder rib deflection and thorax rib accelerations of SID-IIs are compared in Figure 11. The shoulder rib deflections are similar among the three tests. The upper and middle rib accelerations are lower in Test No.3, and higher in Test No.4 compared with the ECE/R95 MDB test (No.1). The lower thorax rib accelerations are similar in the two AE-MDB tests, and they are far higher than in the ECE/R95 MDB test.

Figure 12 shows abdominal rib deflections of SID-IIs. Compared with the ECE/R95 test, the abdominal upper rib deflection is small in Test No.3, and is large in Test No.4. The abdominal lower rib deflection in the AE-MDB tests (Test No.3 and 4) is larger than that in the ECE/R95 MDB test (Test No.1).

The pubic force, iliac force and acetabulum force are shown in Figure 13. The pubic force is similar in the three tests. The iliac force is significantly greater in the AE-MDB tests (Test No.3 and 4) than in the ECE/R95 MDB test (Test No.1). On the other hand, the acetabulum force in the AE-MDB test is high in Test No.3 and is low in Test No.4 compared with that in the ECE/R95 MDB test.

In the present research, the impact location of the AE-MDB tests was changed, therefore, the vehicle deformation and door impact velocity became different from that of ECE/R95 MDB, which affected the injury criteria of the dummy in the front seat. In Test No.4, since the vehicle deformation around the rear seat was large and the injury criteria of the rear seat dummy in this test tended to be higher than in the other tests, the effects of MDB were large compared with the front seat dummy.

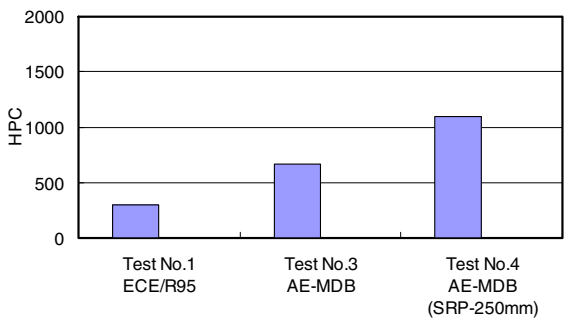



**Figure 10. HPC of rear seat dummy (SID-IIs) in car A struck by ECE/R95 MDB or AE-MDB.**

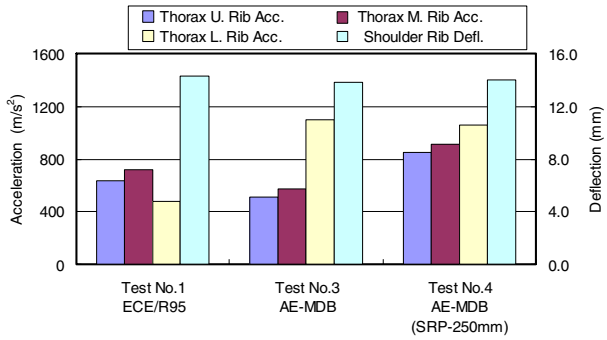



**Figure 11. Shoulder rib deflection and thorax rib accelerations of rear seat dummy (SID-IIs) in car A struck by ECE/R95 MDB or AE-MDB.**

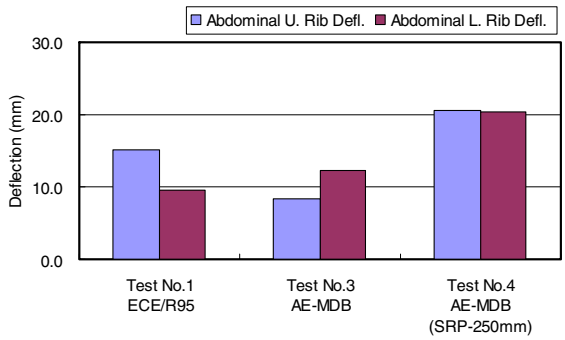



**Figure 12. Abdominal rib deflection of rear seat dummy (SID-IIs) in car A struck by ECE/R95 MDB or AE-MDB.**

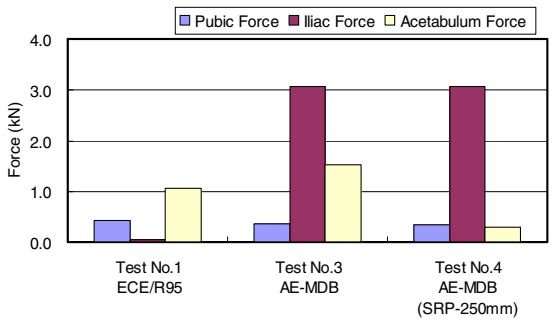



**Figure 13. Pubic, iliac and acetabulum force of rear seat dummy (SID-IIs) in car A struck by ECE/R95 MDB or AE-MDB.**

### Dummy Injury Criteria in Car B

Based on Test No.5, 6 and 7, the injury criteria of the dummy in car B were examined. The car exterior deformations at the ground clearance level of H.P., thorax, and side sill in the pole test (Test No.6 and 7) are shown in Figure 14. The vehicle deformation at each location is similar in these tests. The deformation of car B in Test No.6 is relatively large compared with that in Test No.7.

The injury criteria of the dummy in car B were compared between the ECE/R95 MDB test and pole test. Figure 15 shows the HPC of the dummy.

Although the curtain airbag deployed, the HPC of the dummy was higher in the pole test compared with the ECE/R95 MDB test. The HPC of ES-2 in the pole test was especially large. Thorax rib deflection is compared in Figure 16. The thorax upper, middle and lower rib deflections were larger in the pole test than in the ECE/R95 MDB test because the door intrusion at the thorax was large in the pole test. The thorax upper, middle and lower rib deflections showed similar tendencies between ES-2 and ES-2re. However, in general, the ES-2re showed higher thorax deflections than ES-2. Thorax rib V*C of the dummy in car B is compared in Figure 17. The V*C is higher in the pole test than in the ECE/R95 MDB test. Abdominal force and pubic force of the dummy are shown in Figure 18. The abdominal force is higher in the pole test whereas the pubic force is higher in the ECE/R95 test.

The ES-2 and ES-2re were compared in the pole test (Test No.6 and 7). The thorax upper rib V*C is similar between ES-2 and ES-2re. The thorax middle rib V*C of ES-2re is higher than that of ES-2, and the lower rib V*C of ES-2 is higher than that of ES-2re. Abdominal force and pubic force are similar between ES-2 and ES-2re.

It is difficult to directly compare dummy injury criteria between the pole test proposed by NHTSA and the ECE/R95 test since the test configurations were different. However, the pole test is very severe for the injury criteria of the head and chest of the dummy. In comparing the ES-2re with ES-2, the thorax rib deflection and thorax rib V*C showed higher values in ES-2re since the ES-2re was improved against oblique impacts.

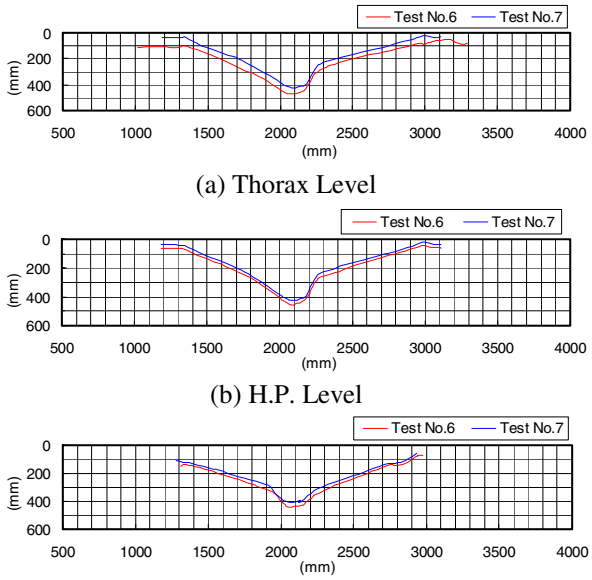



**Figure 14. Deformation of outer panel of car B in the pole test (Test No.6 and 7).**

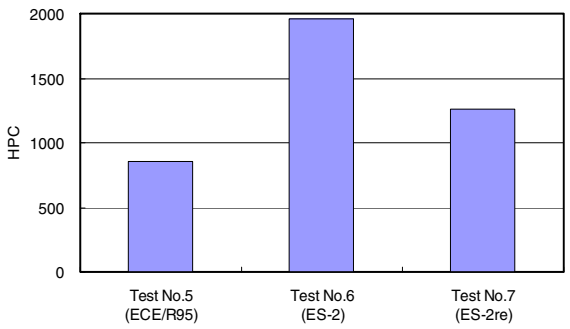



**Figure 15. HPC of ES-2 and ES-2re in car B in the ECE/R95 test and pole test.**

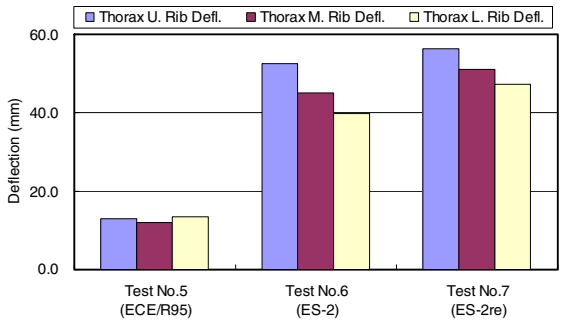



**Figure 16. Thorax rib deflection of ES-2 and ES-2re in car B in the ECE/R95 test and pole test.**

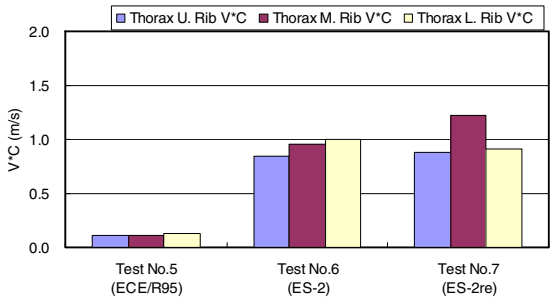



**Figure 17. Thorax rib V*C of ES-2 and ES-2re in car B in the ECE/R95 test and pole test.**

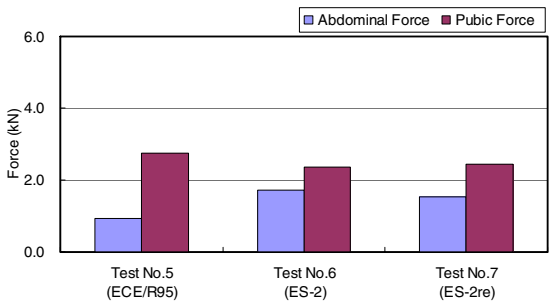



**Figure 18. Abdominal force and pubic force of ES-2 and ES-2re in car B in the ECE/R95 test and pole test.**

## SUMMARY

The test procedures proposed by IHRA or by NHTSA were compared with the present test (ECE/R95) with respect to injury criteria of the dummy and dummy types. The results are summarized as follows.

(1) *AD-MDB*

The tests using AD-MDB, which has been developed to reflect the specifications and stiffness of the present cars, were compared with the ECE/R95 test.

(i) The vehicle deformation and velocity-time histories were different and could affect injury criteria of the front seat dummy, especially for pubic force.

(ii) In the AE-MDB test with rearward target point (SRP-250 mm), the deformation in the rear door was large and affected the rear dummy injury criteria. The head made contact with the C-pillar, which led to high HPC.

(iii) Regarding the injury criteria of EuroSID-1 and ES-2 in the ECE/R95 MDB tests, the thorax deflection and thorax V*C were higher for ES-2 because the back plate of ES-2 was modified from EuroSID-1.

(2) *Pole impact test*

The pole test, which NHTSA is considering introducing in the regulation (FMVSS214 draft), was compared with the ECE/R95 MDB test.

(i) The injury criteria of the head and chest of the dummy in the pole test were far higher than in the ECE/R95 test.

(ii) The HPC of the dummy in the pole test could be higher, even though the curtain air bag deployed, depending on airbag deployment timing.

(iii) ES-2re showed a larger thorax rib deflection and V*C than ES-2 due to the modification of ES-2re against oblique impacts. However, they showed similar HPC, abdominal force and pubic force.

The MDB prescribed in the present regulation (ECE/R95) was determined on the basis of investigations of vehicles in the 1970s. Recently, there are various vehicle types in the fleet, and it is necessary to develop an MDB (AE-MDB) which reflects the vehicle specifications and front stiffness of the current cars.

In the present research, a series of side impact tests was conducted using the AE-MDB that is under development based on the data of each country in IHRA SIWG. Fundamental research is on-going to develop test procedures with a high level of occupant protection. In addition to car-to-car collisions, occupant protection in single-car crashes is also important. In the present research, the pole test

proposed by NHTSA was carried out and the dummy injury criteria were examined. In Japan, basic research on occupant protection in side collisions will be continued, and side impact test procedures will be developed in the near future.

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