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APPLICATION OF THE FIAT METHODOLOGY TO VEHICLE SIDE IMPACT

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L. M. Shaw
R. E. Knight
A. C. Trudgen

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16. Abstract

The Fiat methodology for evaluating vehicle compatibility is applied to the vehicle front-to-side impact environment. The data from a previously conducted impact of a Fiat test tool into the front of a Fiat 132 vehicle is analyzed and predictive results presented. The data from a previously conducted impact of a Fiat test tool into the side of Fiat 132 vehicle is analyzed and predictive results presented. A crash test of the impact of the front of a Fiat 132 vehicle into the side of a Fiat 132 vehicle was conducted. The analytical models produced from the results of the two Fiat test tool to Fiat vehicle tests are used to predict the results of impacting the front of a Fiat 132 vehicle into the side of Fiat 132 vehicle, and these results are then compared with the test results. Recommendations for future applications of, and improvements to, the Fiat methodology as applied to side impact are made.

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1.0 INTRODUCTION

Under Contract No. DOT-HS-8-01933, "The Development of a Test Device and Test Procedures to Assess Vehicle Side Structures," with NHTSA, Dynamic Science developed methodology for analyzing and predicting vehicle performance in front-to-side collisions. Over the past several years, Dynamic Science has, under contract with the Fiat Auto S.p.A., developed a methodology for evaluating vehicle compatibility with an ultimate goal of providing compatibility characterization in frontal, side, and rear impact environments. The front-to-front vehicle impact methodology has absorbed most of the research to date. The results of this research have been extremely encouraging, providing accurate prediction capability and justification of the approach methodology. With the present emphasis on the vehicle side impact environment, it becomes imperative that future development of the Fiat methodology be concerned with the front-to-side vehicle environment. The development and use of the Fiat methodology for side impact characterization under a modification of the NHTSA Contract No. DOT-HS-8-01993 could be significant in the development of plans and procedures for NHTSA's future requirements and assessment of vehicle side structures.

The objective of this program modification was to start the development of side impact analysis using the work previously completed under Fiat funding. To meet this objective, the following work tasks were accomplished:

Task 1 - FIAT TEST TOOL-TO-FIAT 132 FRONT IMPACT
Provide previously obtained data from a Fiat test tool impacted into the front of a Fiat 132 vehicle and present predictive results utilizing this test as input.

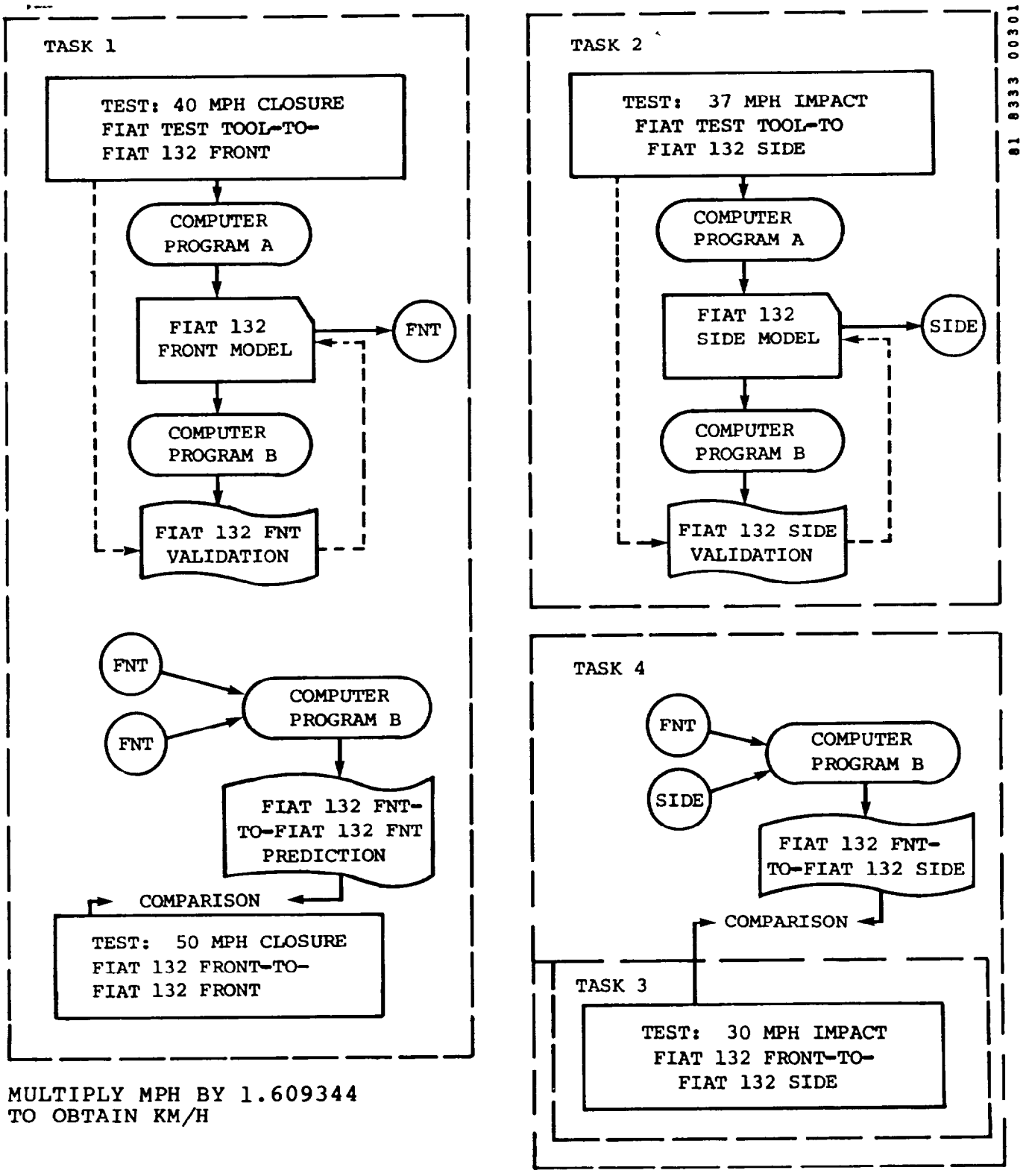
Task 2 - FIAT TEST TOOL-TO-FIAT 132 SIDE IMPACT
Provide previously obtained data from a Fiat test tool impacted into the side of a Fiat 132 vehicle and present predictive results utilizing this test as input.

Task 3 - FIAT 132 FRONT-TO-FIAT 132 SIDE IMPACT
Conduct and present the data for a Fiat 132 front-to-Fiat 132 side crash test.

Task 4 - SIDE IMPACT PREDICTIVE ANALYSIS
Utilizing the analytical models generated in Tasks 1 and 2 predict the side impact response for the test conditions accompanying Task 3.

The effort for each of the above tasks is illustrated in Figure 1 along with the interrelationship between tasks. The end product of Task 1 was to provide an analytical model of the Fiat 132 frontal structure configuration using full-scale crash test data. Task 2 provides an analytical model of the Fiat 132 side structure configuration using full-scale crash test data. For Task 4, the analytical models generated in Tasks 1 and 2 were combined to predict the crash responses for the crash test conditions accompanying the Task 3 full-scale test. A more detailed description of each task and their associated results are presented in the accompanying sections of this report.

A great deal of the work reported herein involved methodologies and upgraded computer programs which are presently under development for Fiat Auto S.p.A, and thus are Fiat proprietary. Therefore, only the results of these analyses can be presented in this report. It was found in generating side impact model representations that considerably more detail and capabilities, over and above the capabilities of the NHTSA Fiat methodology computer programs, were required to provide side impact characterization. As a result, and to provide front-to-side compatibility, the frontal model characterization also required similar changes. To



MULTIPLY MPH BY 1.609344
TO OBTAIN KM/H

FIGURE 1. PROGRAM WORK FLOW.

accommodate this more extensive but improved analysis capability, the models were quite dependent upon the accuracy of the test data input. The proposed test involving the Fiat test tool and Fiat 132 front was conducted many years ago using the first generation test tool. As a result, the data from this test contained errors which could not be corrected for the new model requirements. Thus, a similar test, void of data errors, conducted at a lower impact velocity was substituted for the Task 1 analyses. A similar situation existed for the proposed test tool to Fiat 132 Side Impact Test. Following this test, improved vehicle instrumentation techniques were developed which significantly improved door data quality. As a result, for the Task 2 analyses, the proposed test was replaced by a later one conducted under identical conditions except for a higher impact velocity.

The results presented in this report are quite impressive, particularly when considering the present capabilities of data accuracies in side impact testing. It should be kept in mind that it has been our experience that the development of such predictive technology is evolutionary in nature. The predictive representation of present frontal impact capability has undergone several generations of model characterization approach to provide an accurate predictive methodology. This has resulted from continued improvements in capabilities and technology utilized as efforts have proceeded. The side model characterization used, and the predicted results presented herein, represent an initial effort in this technology and can undergo a similar evolutionary process.

2.0 TASK 1 - FIAT TEST TOOL-TO-FIAT 132 FRONT IMPACT

The objective of this task was to: 1) obtain from Fiat Auto S.p.A. the results from a test between the Fiat test tool and a Fiat 132 passenger car in a frontal head-on impact, 2) exercise computer Program "A," with the test data as input, to define the analytical frontal characterization model for the Fiat 132 vehicle, and 3) to provide, through exercising computer Program "B" with the Fiat 132 frontal model as input, a validation prediction of the Fiat test tool-to-Fiat 132 front crash. The details and test results for the Fiat test tool-to-Fiat 132 frontal head-on crash test at a closure speed of 50 mph (80 km/h) were forwarded to the NHTSA under separate cover (Reference 1).

The Fiat test tool-to-Fiat 132 front characterization test used in the Task 1 analysis was identical to that reported in Reference 1 except for an impact closure speed of 39.18 mph (63 km/h). The data accompanying the first generation test tool test reported in Reference 1 resulted in partial loss of measured loads which could not be corrected for the more sophisticated frontal model required to comply with the side model requirements. The data accompanying the 39.18 mph (63 km/h) test was void of these data errors.

The data from the Fiat test tool-to-Fiat 132 frontal characterization test was entered, along with the Fiat 132 geometric model representation, into computer Program "A." The output of Program "A" provided definition of the interconnecting spring characteristics in the Fiat 132 frontal model. The model, along with the interconnecting spring characteristics, was input into

computer Program "B" together with an analytical model of the Fiat test tool, and exercised under the impact conditions accompanying the characterization test. This procedure provides a method to validate the vehicles analytical model by direct comparison between predicted and test results. This also provides the opportunity to fine tune the model to improve its characterization if necessary.

As a control, and to assist in completing the front-to-side analysis (Section 5.0), the Fiat 132 front characterization model was input into computer Program "B" to predict the crash response accompanying a head-on Fiat 132 front-to-front, 50 mph (80 km/h) closure speed crash test. The Fiat 132 front-to-front test results were obtained from Fiat S.p.A. from a test conducted previously. The review, evaluation, and test results from this test were forwarded to NHTSA under separate cover (Reference 2).

Validation Results - Frontal Model

The results of the Fiat 132 frontal model validation for the above effort are summarized in Table 1. Figure 2 shows the Fiat 132's predicted compartment response compared to the actual test data. Similarly, Figure 3 shows the resulting test tool vehicle's predicted response compared to the actual test data. Of particular interest in frontal simulation is the ability to characterize the vehicle's component dynamic as well as structural responses. Figures 4 and 5 show the Fiat 132's engine and left suspension predicted response, respectively, compared to the actual test results. The right suspension responses (not shown) were essentially

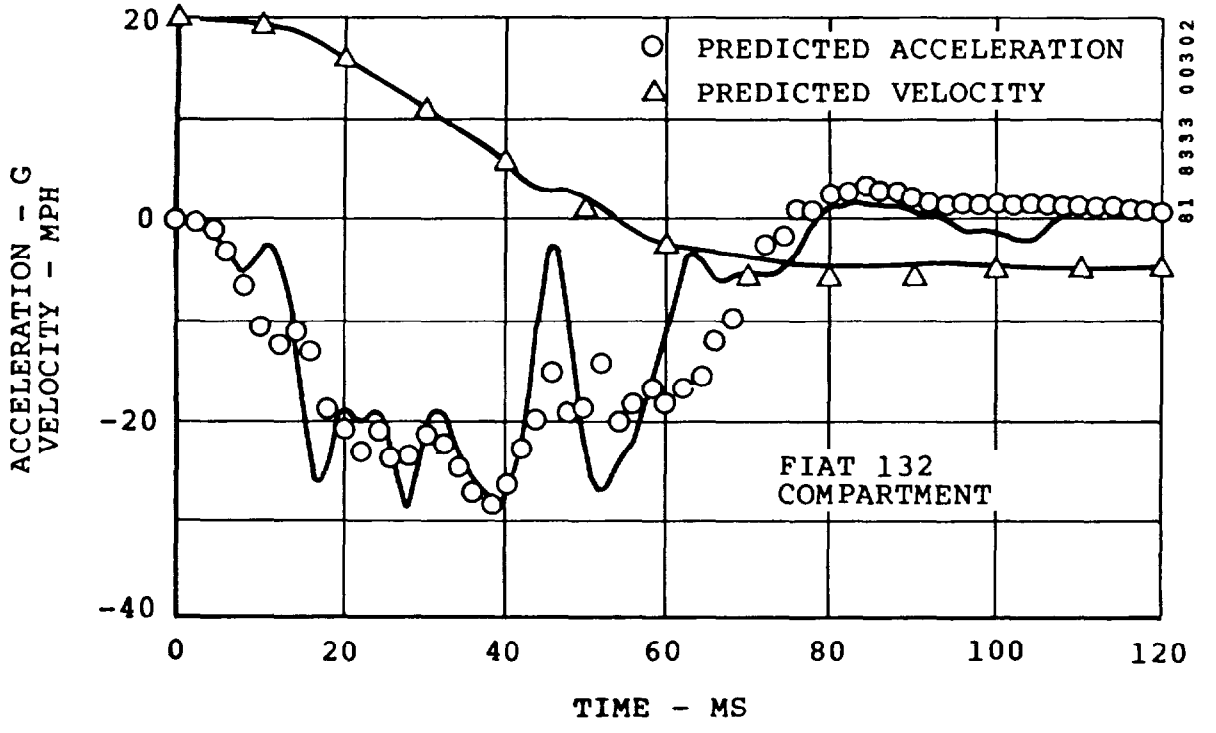


FIGURE 2. COMPARISON BETWEEN PREDICTED AND TEST RESULTS FOR THE FIAT 132 COMPARTMENT - FIAT 132 FRONTAL VALIDATION.

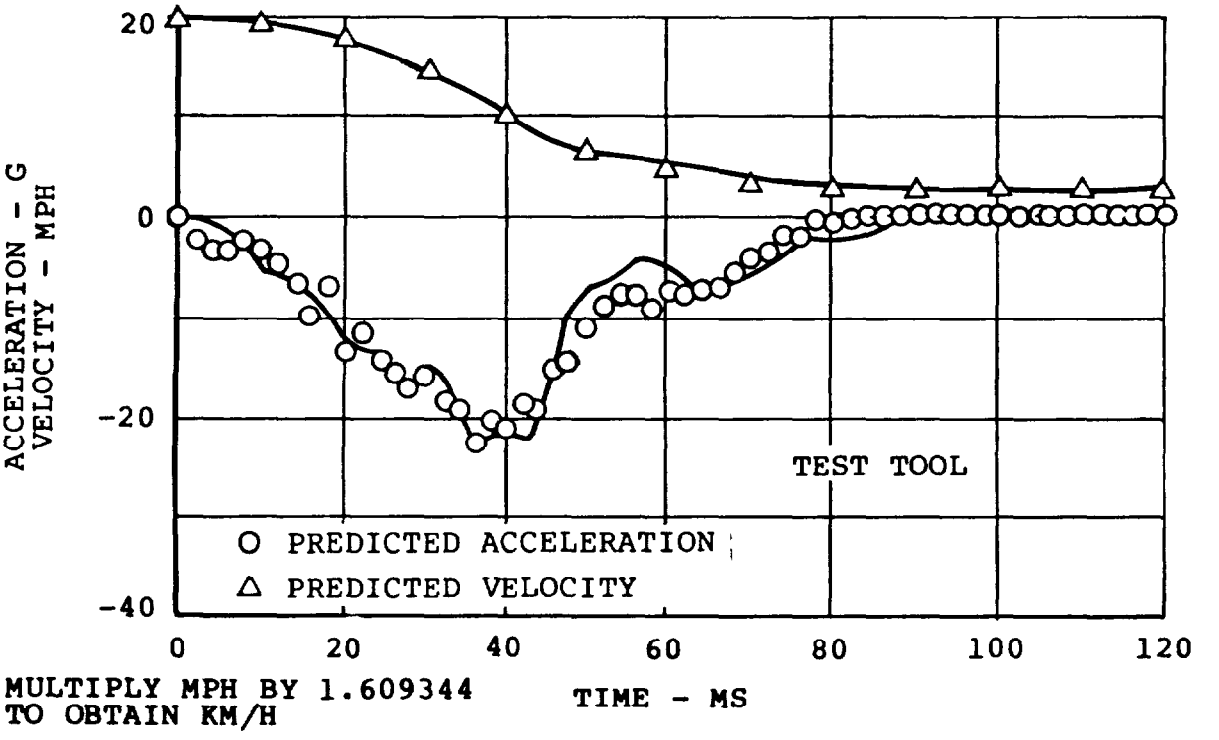


FIGURE 3. COMPARISON BETWEEN PREDICTED AND TEST RESULTS FOR THE FIAT TEST TOOL VEHICLE - FIAT 132 FRONTAL VALIDATION.

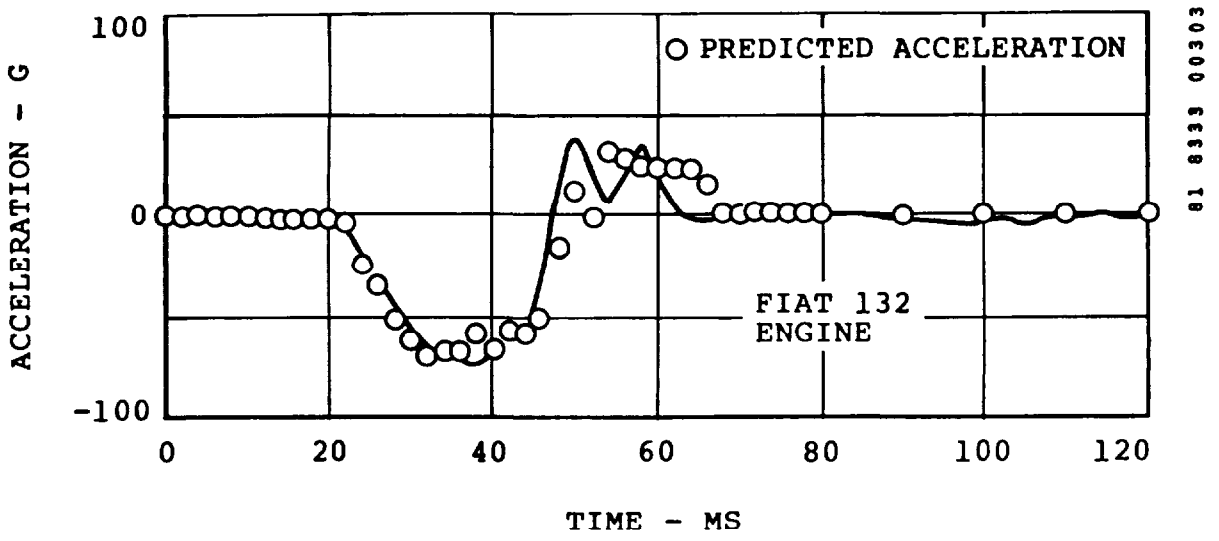


FIGURE 4. COMPARISON BETWEEN PREDICTED AND TEST RESULTS FOR THE FIAT 132 ENGINE - FIAT 132 FRONTAL VALIDATION.

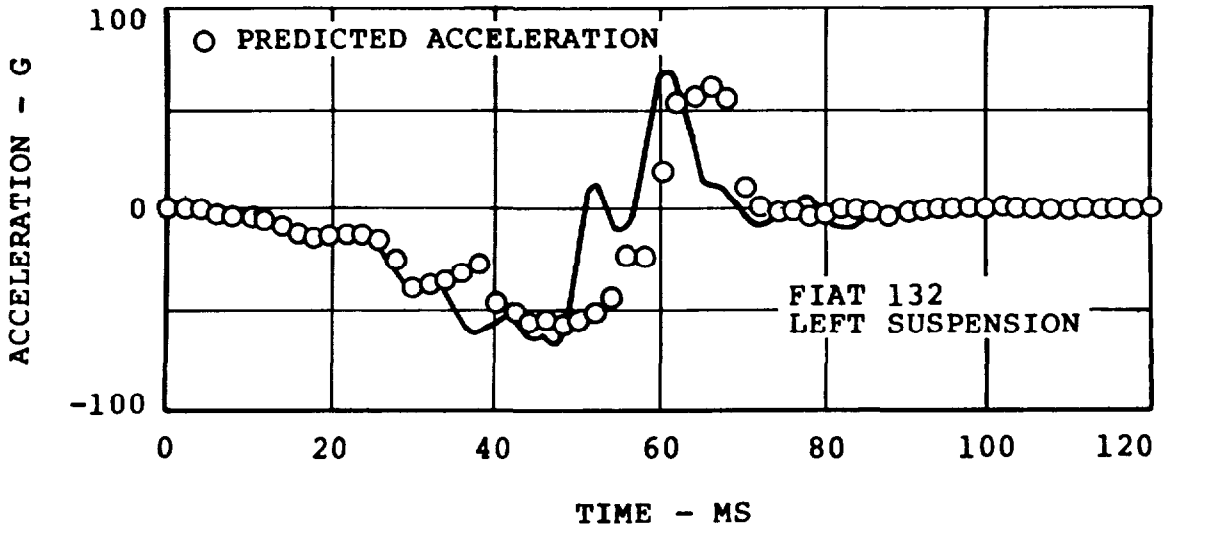


FIGURE 5. COMPARISON BETWEEN PREDICTED AND TEST RESULTS FOR THE FIAT 132 LEFT SUSPENSION - FIAT 132 FRONTAL VALIDATION.

TABLE 1. FIAT 132 FRONTAL MODEL VALIDATION RESULTS SUMMARY

Parameter	Test Data	Simulation
Closure Velocity (mph)	39.18 (63 km/h)	39.18 (63 km/h)
Fiat 132 Weight (lb)	2798 (1269 kg mass)	2798 (1269 kg mass)
Test Tool Weight (lb)	4040 (1833 kg mass)	4040 (1833 kg mass)
Fiat 132 Velocity Change (mph)	24.53 (39.48 km/h)	26.16 (42.10 km/h)
Test Tool Velocity Change (mph)	17.44 (28.07 km/h)	17.41 (28.02 km/h)
Maximum Dynamic Mutual Crush (in)	24.58 (39.56 km/h)	24.31 (39.12 km/h)
Fiat 132 Average Dynamic Crush (in)	21.00 (33.80 km/h)	20.59 (33.14 km/h)

the same as those shown in Figure 5. The results shown indicate excellent representation of the vehicles actual crash response by the analytical model generated. The computer Program "B" input providing these results consisted of a Fiat 132 frontal model and test tool model totaling forty-one (41) degrees of freedom.

Fiat 132 Front-to-Front Results

The validated Fiat 132 frontal model was duplicated and both model sets were input into computer Program "B" along with the initial crash conditions associated with the Fiat 132 front-to-front head-on crash test presented in Reference 2. The resulting simulation provided forty-six (46) degrees of freedom, including both vehicle representations. Table 2 presents a summary of the predicted results compared to the actual test data. It should be

TABLE 2. FIAT 132 FRONT-TO-FRONT PREDICTED CRASH RESULTS SUMMARY

Parameter	Simulation	Test Data
Bullet Vehicle Weight (lb)	2798 (1269 kg mass)	2820 (1279 kg mass)
Target Vehicle Weight (lb)	2798 (1269 kg mass)	2826 (1282 kg mass)
Bullet Vehicle Velocity (mph)	24.36 (39.20 km/h)	24.36 (39.20 km/h)
Target Vehicle Velocity (mph)	24.36 (39.20 km/h)	24.36 (39.20 km/h)
Maximum Dynamic Mutual Crush		
• Integrated Acc. (in)	34.97 (88.82 cm)	37.00 (93.98 cm)
• Photograph (in)	N/A	34.00 (86.36 cm)
Velocity Change at 100 ms (From Accel. Data)		
• Bullet Vehicle (mph)	26.13 (42.05 km/h)	26.06 (41.94 km/h)
• Target Vehicle (mph)	26.13 (42.05 km/h)	26.97 (43.40 km/h)

understood that the vehicle models were identical, therefore, producing exactly the same responses. The crash test, however, presents two identical vehicle models with corresponding responses representative of real-world manufacturing and data acquisition tolerances. The Fiat 132 frontal model configuration used was identical to that used in the validation analysis without slight adjustment of vehicle mass differences.

Figure 6 presents the predicted Fiat 132 compartment response compared to the responses accompanying each of the Fiat 132 test vehicles. Figure 7 presents the predicted Fiat 132 engine response compared to the responses measured on each of the test

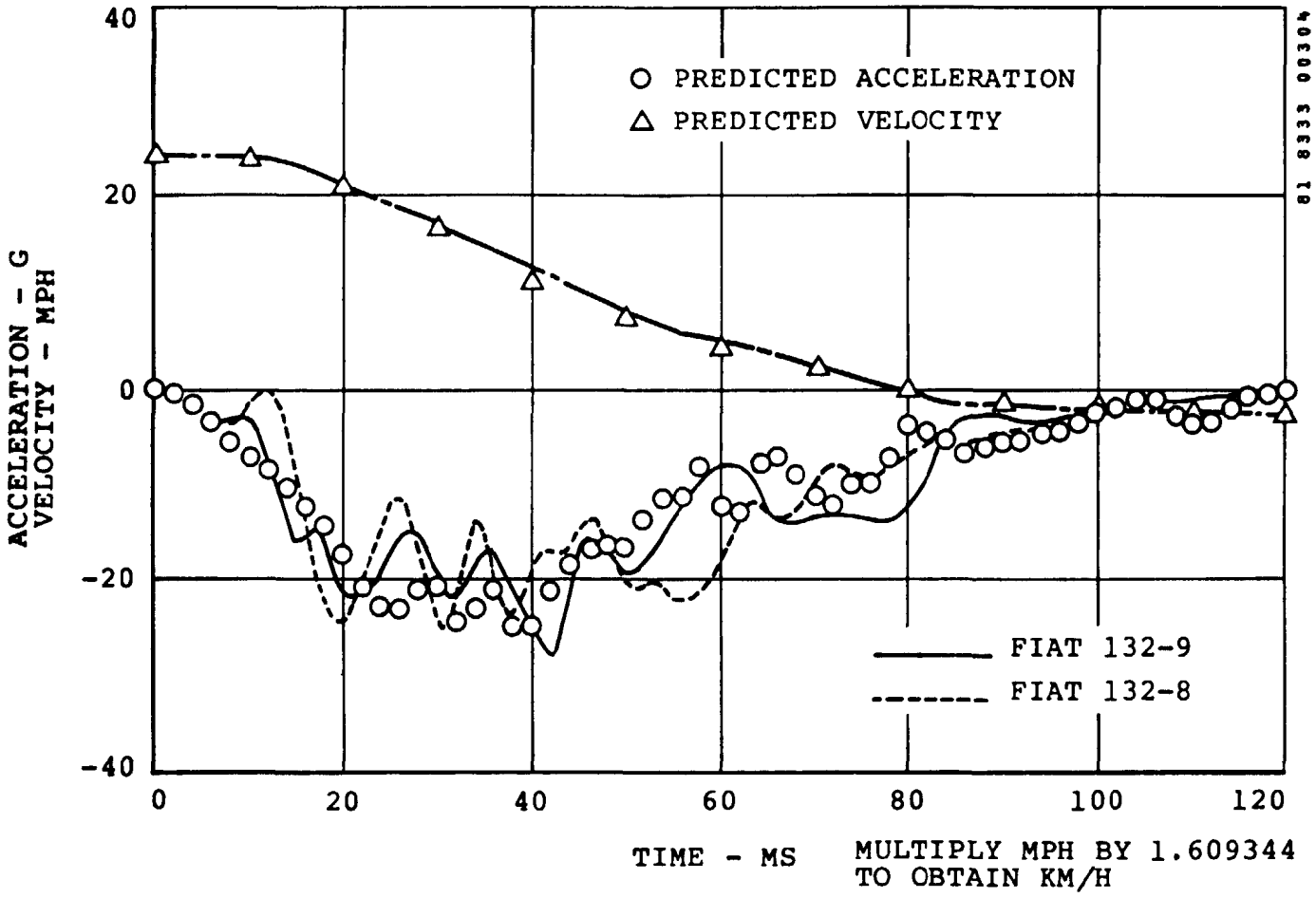


FIGURE 6. COMPARISON BETWEEN PREDICTED AND TEST RESULTS FOR THE FIAT 132 COMPARTMENT.

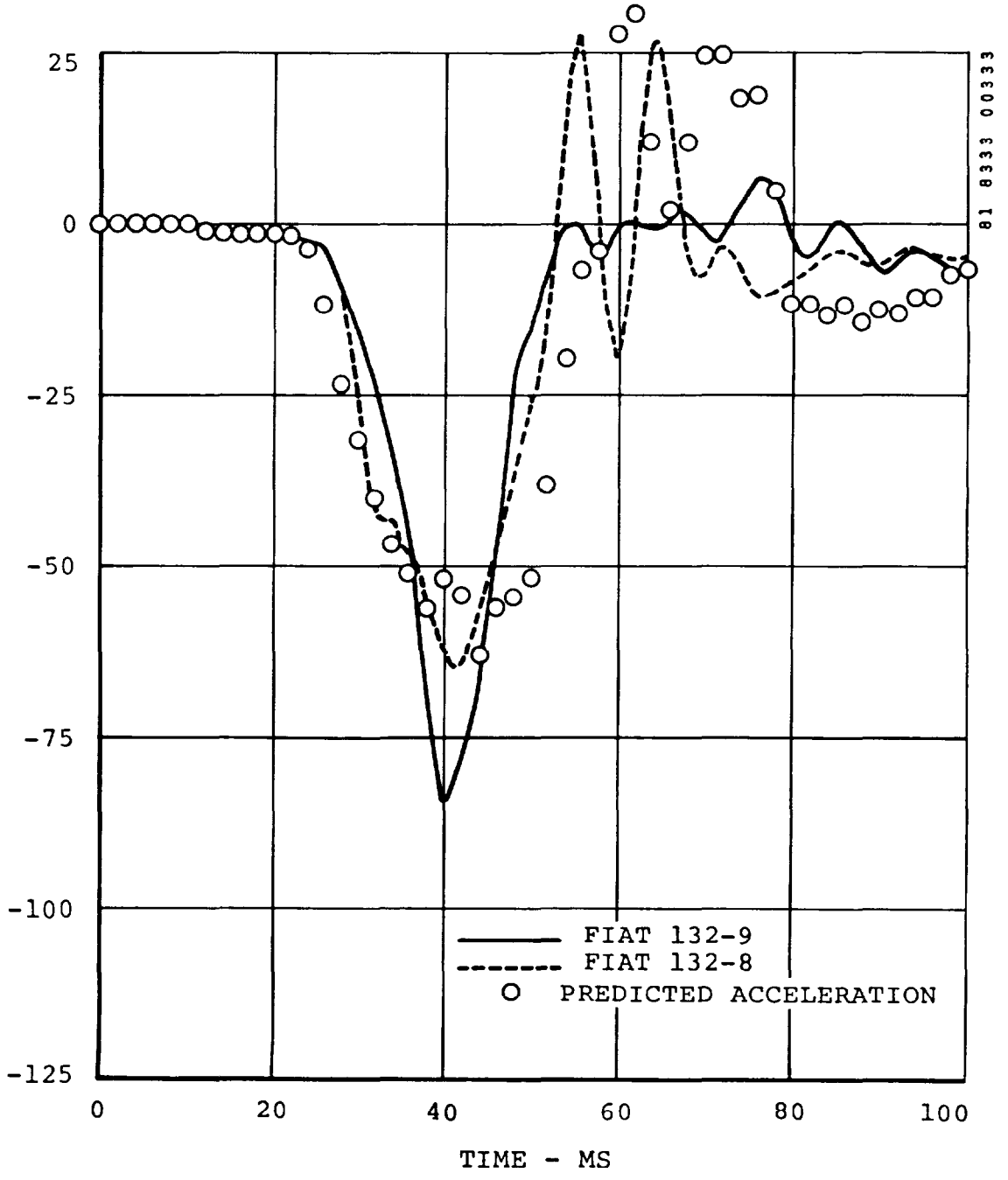


FIGURE 7. COMPARISON BETWEEN PREDICTED AND TEST RESULTS FOR THE FIAT 132 ENGINE.

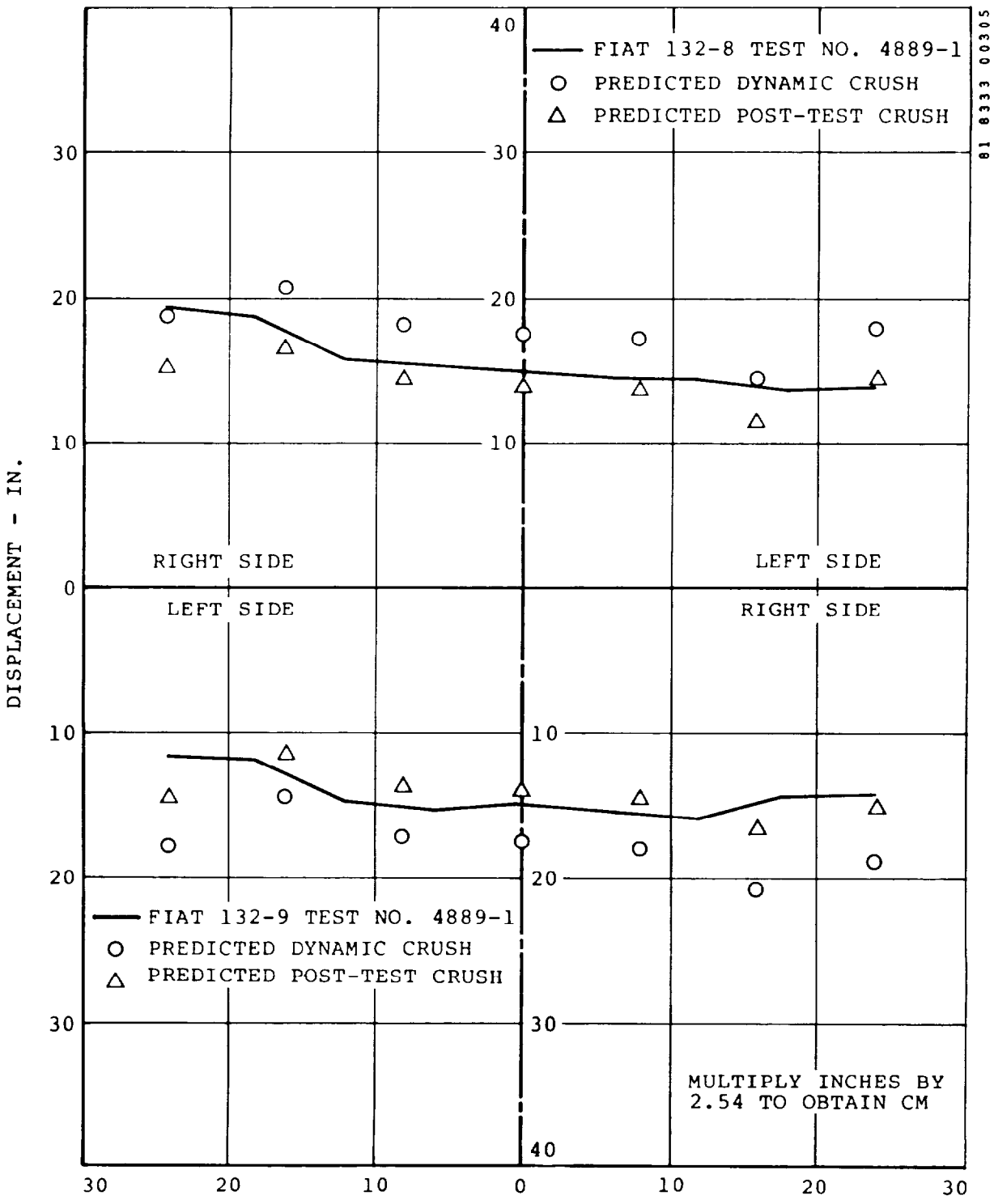


FIGURE 8. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 EXTERIOR CRUSH 17.5 INCHES ABOVE GROUND.

vehicles. Figure 8 presents the predicted dynamic and residual crush of the Fiat 132 models compared to the actual measured post-test crush for the test vehicles.

The results presented in the above figures illustrate the capability of the Fiat methodology for frontal impacts. The predicted results in this analysis were well within the variations present in the responses of the real-world vehicles and their instrumentation when tested under identical conditions. The following sections describe the use of the Fiat methodology for a much more difficult problem, namely the side impact environment.

3.0 TASK 2 - FIAT TEST TOOL-TO-FIAT 132 SIDE IMPACT

The objective of this task was to: 1) obtain from Fiat Auto S.p.A. the results from a test between the Fiat test tool and a Fiat 132 passenger car in a ninety (90) degree side impact, 2) exercise computer Program "A," with the test data as input, to define the analytical side characterization model for the Fiat 132 vehicle, and 3) to provide through exercising computer Program "B," with the Fiat 132 side model as input, a validation prediction of the Fiat test tool-to-Fiat 132 side crash. The details and test results for the Fiat test tool-to-Fiat 132 side test were forwarded to NHTSA under separate cover (Reference 3). To summarize this test, the test involved a 30 mph (48 km/h), ninety (90) degree side impact with the lateral center of test tool face aligned with the Fiat 132's front seat "H" point (vehicle seating reference).

During the evaluation of the side impact characterization test described in Reference 3, it was found that the data describing the interior door motions were of insufficient accuracy to enable development of a model. Thus, a second test conducted under a on-going program involving an identical vehicle and impact configuration, but at an impact speed of 37.49 mph (60.33 km/h), was used.

The data from the 37.49 mph (60.33 km/h) Fiat test tool-to-Fiat 132 side characterization test was entered, along with the Fiat 132 geometric model representation, into computer Program "A."

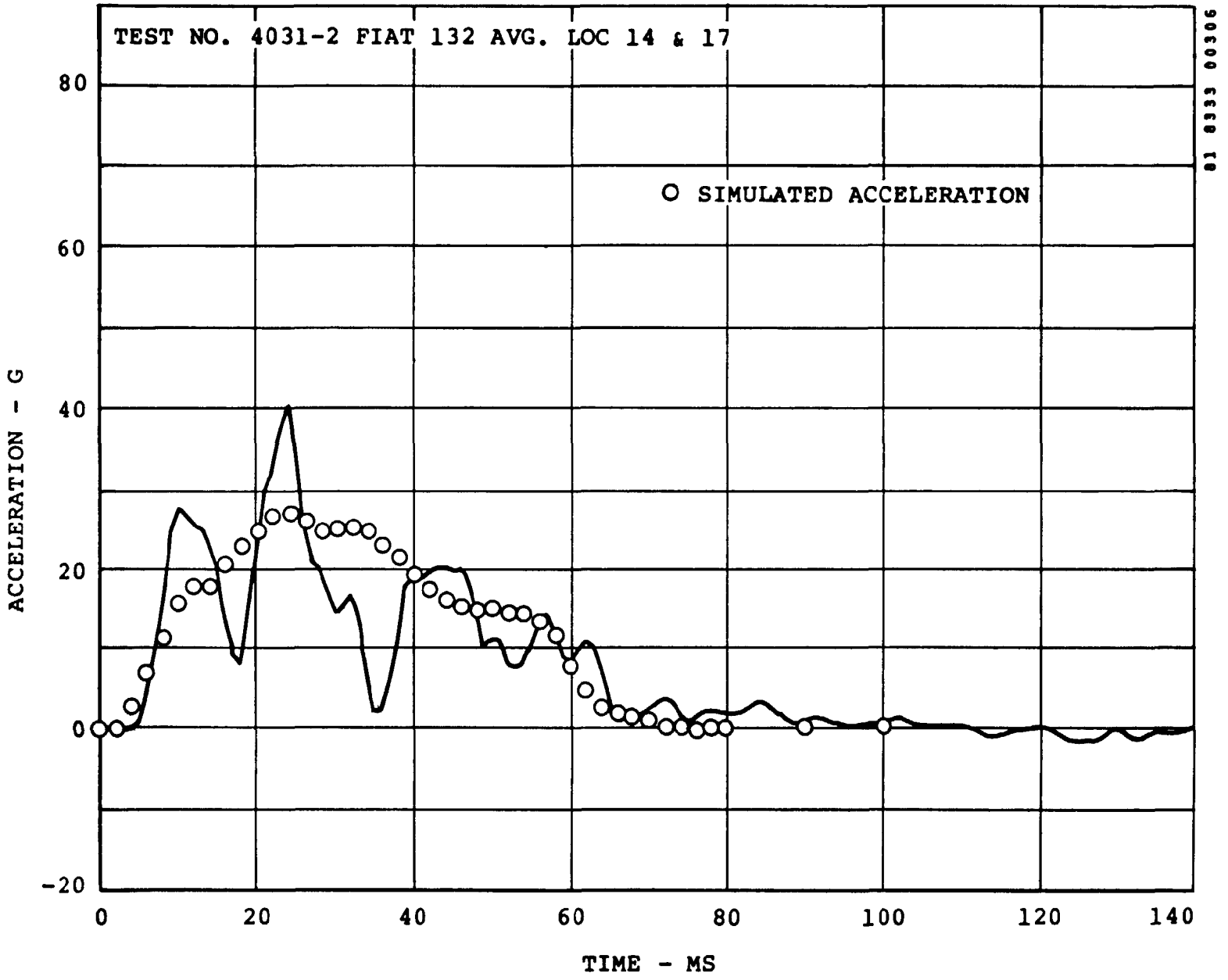


FIGURE 9. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 COMPARTMENT.

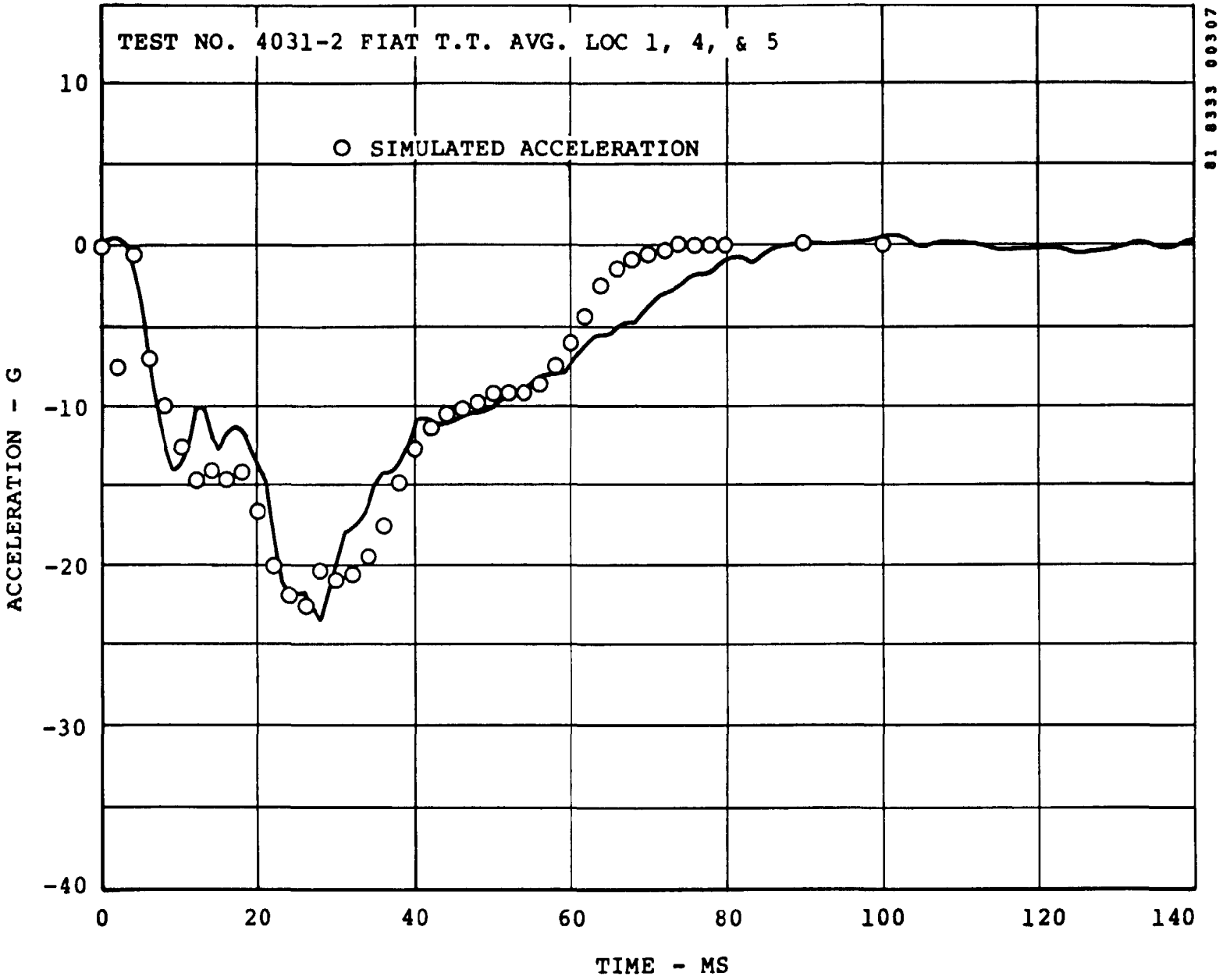


FIGURE 10. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE TEST TOOL.

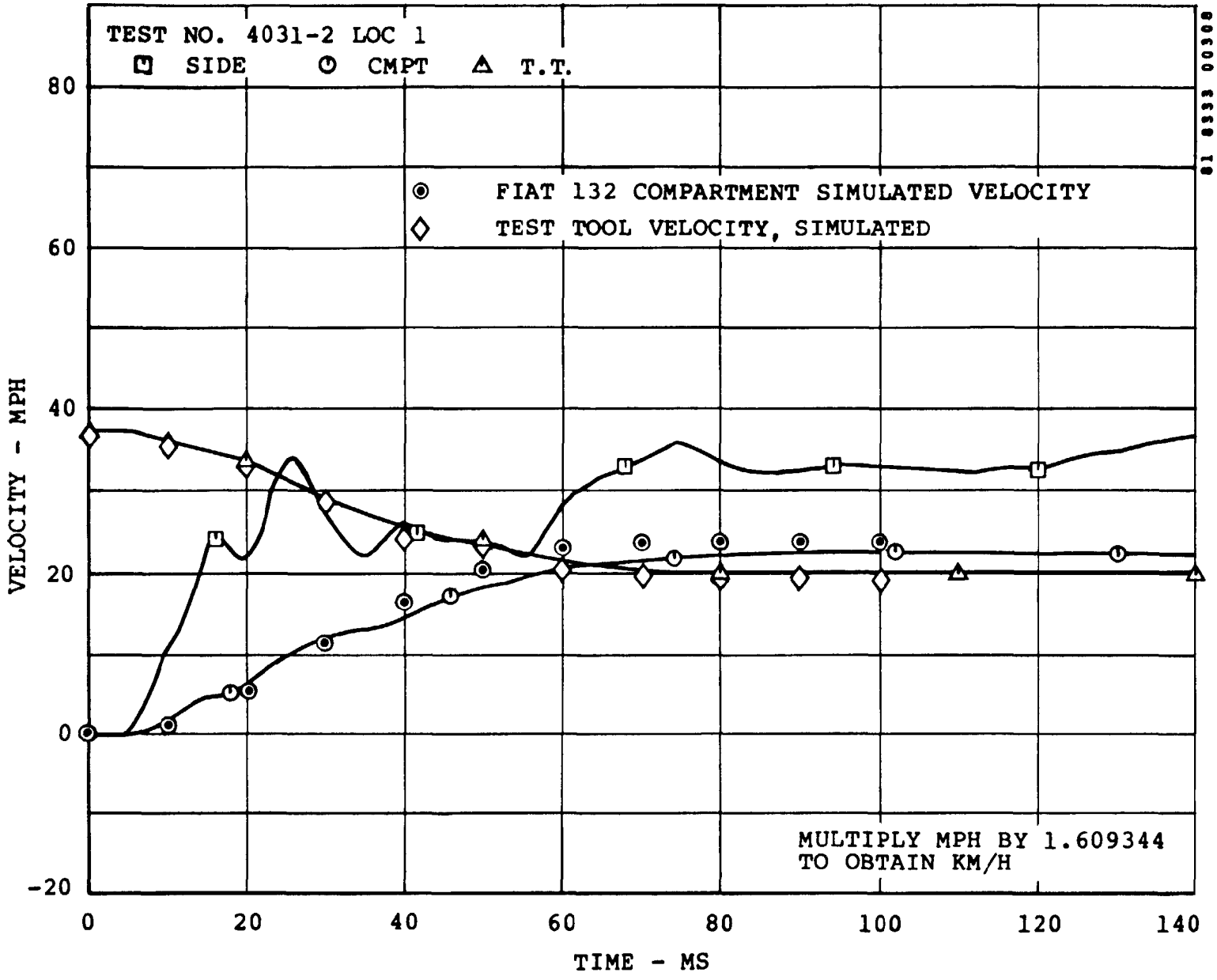


FIGURE 11. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 COMPARTMENT AND TEST TOOL.

This step was finally accomplished under the present model configuration after much initial effort in defining the most optimum model configuration and approach. This work is part of an initial effort to study the use of the Fiat methodology for side impact crashes. The output of Program "A" provided definition of the interconnecting spring characterics in the Fiat 132 side model. The model, along with the interconnecting spring characteristics was input into computer Program "B" along with an analytical model of the Fiat test tool, and exercised under the impact conditions accompanying the characterization test.

Validation Results - Side Model

The results of the Fiat 132 side model validation for the above effort are summarized in Table 3. Figure 9 shows the Fiat 132's predicted lateral compartment acceleration compared to the actual test data. Figure 10 presents the corresponding predicted Fiat test tool acceleration response. Figure 11 shows the Fiat 132 compartment and Fiat test tool predicted velocity profiles compared to the test results.

The difficulty of measuring interior door response during side impacts has been established in several side impact programs, including on-going NHTSA programs. This is particularly true with ninety (90) degree impacts. Present accelerometer devices and acquisition systems have been found to measure incorrect acceleration

TABLE 3. FIAT 132 SIDE MODEL VALIDATION RESULTS SUMMARY

Parameter	Simulation	Test Data
Bullet Vehicle Weight (lb), Test Tool	3995 (1812 kg mass)	3995 (1812 kg mass)
Target Vehicle Weight (lb), Fiat 132 Side	2911 (1320 kg mass)	2933 (1330 kg mass)
Bullet Vehicle Velocity (mph)	37.49 (60.33 km/h)	37.47 (60.33 km/h)
Target Vehicle Velocity (mph)	0.0 (0.0 km/h)	0.0 (0.0 km/h)
Maximum Dynamic Mutual Crush (in)		
• Integrated Acc. (in)	18.80 (47.75 cm)	19.80 (50.29 cm)

response without the aid of deflection tubes. Even with the incorporation of deflection tubes, door response measurement is not always successful. Therefore, the present generation of side impact models required some correction of data. Direct comparison between predicted and actual data must be viewed with this present situation in mind, and with common sense with regard to door dynamic requirements.

Figure 12 presents the predicted velocity profile for the Fiat 132 upper rear door panel compared to that measured in the characterization test near the center of the panel. Figure 13 shows the predicted intrusion history for the same location compared to the corresponding deflection tube data. The predicted velocity profile for the upper front door, adjacent to the driver thorax is shown in Figure 14, along with the test data just forward of the driver chest. Figure 15 presents the corresponding predicted intrusion history for this upper front door panel compared to deflection tube data.

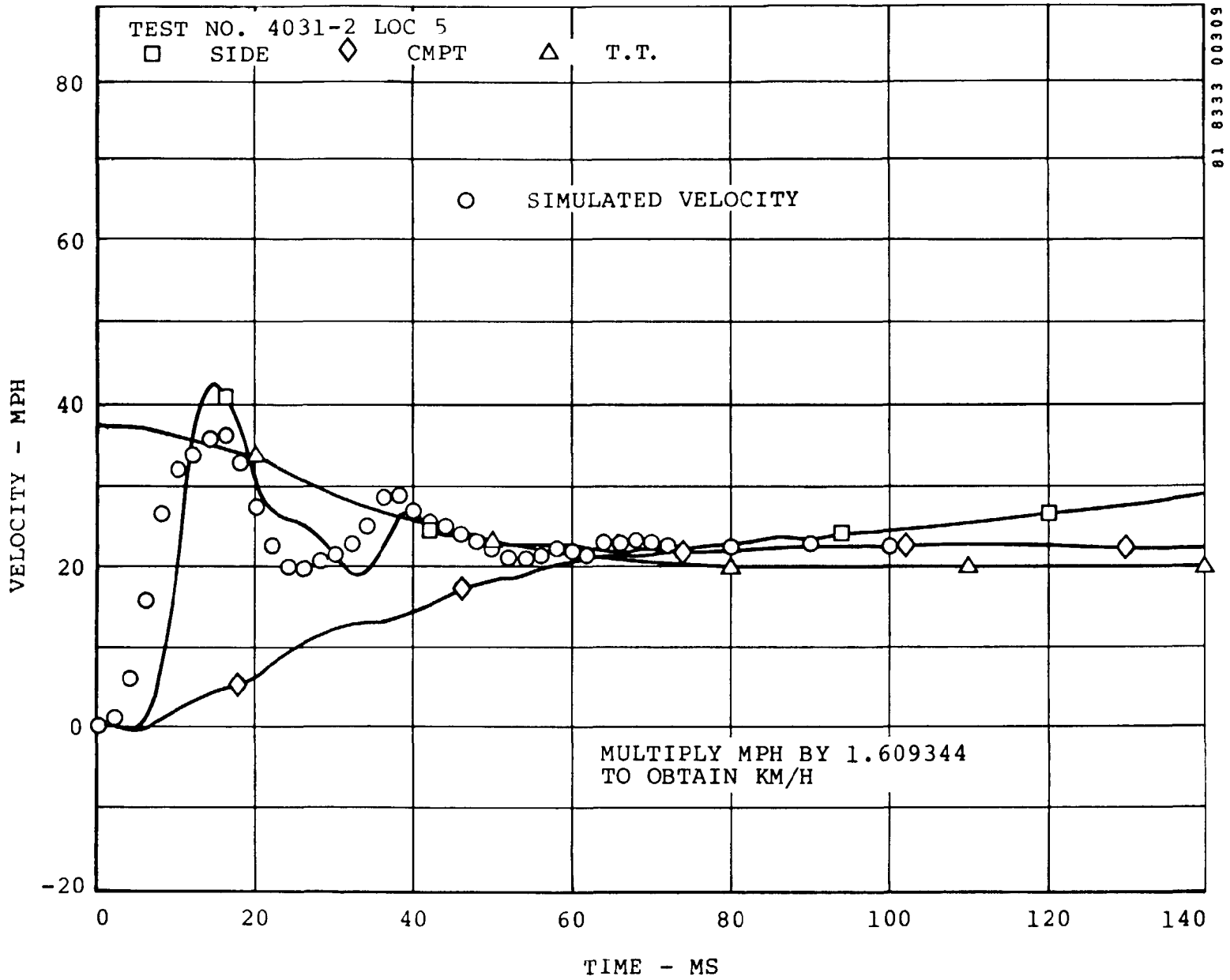


FIGURE 12. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 UPPER REAR DOOR.

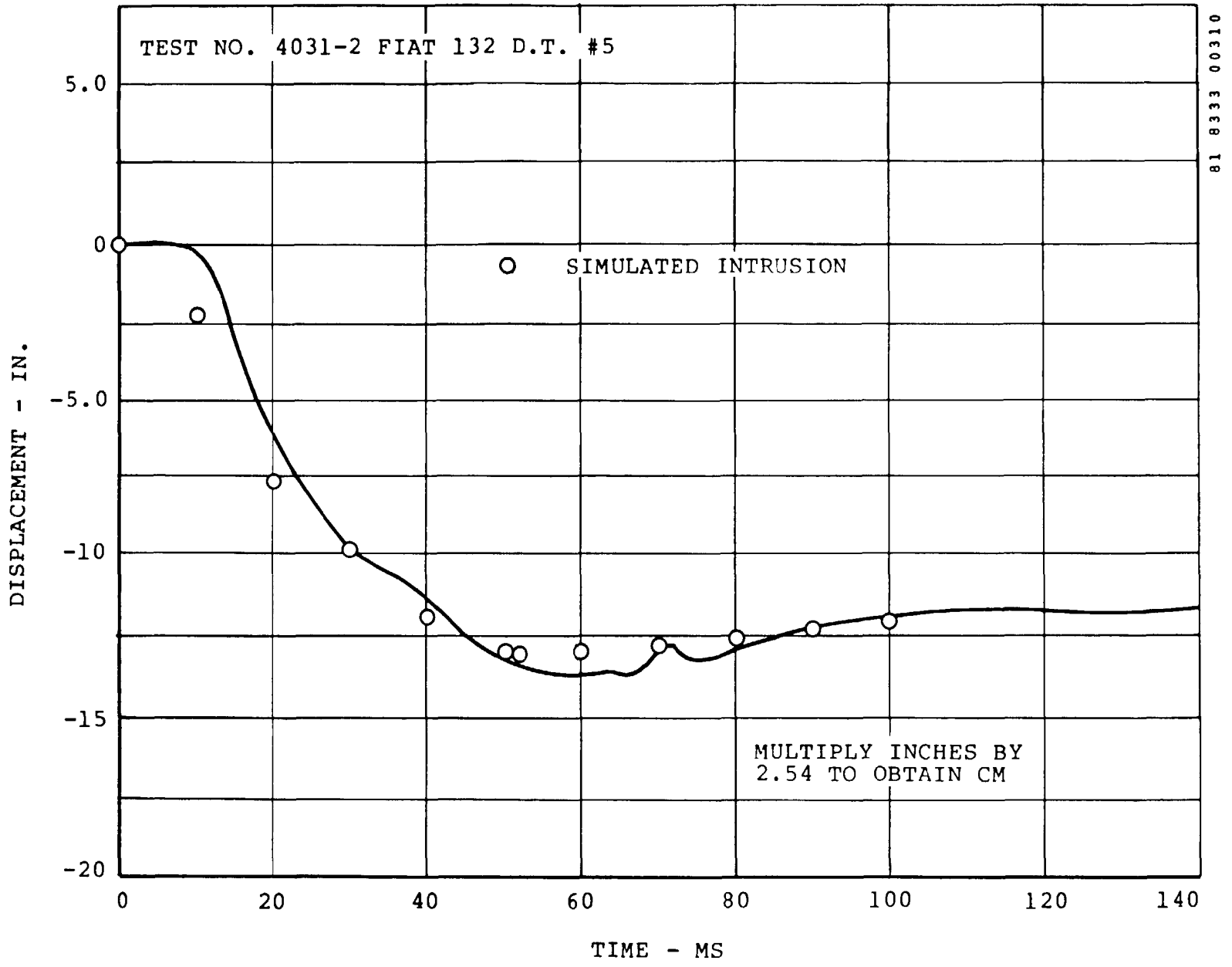


FIGURE 13. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 UPPER REAR DOOR.

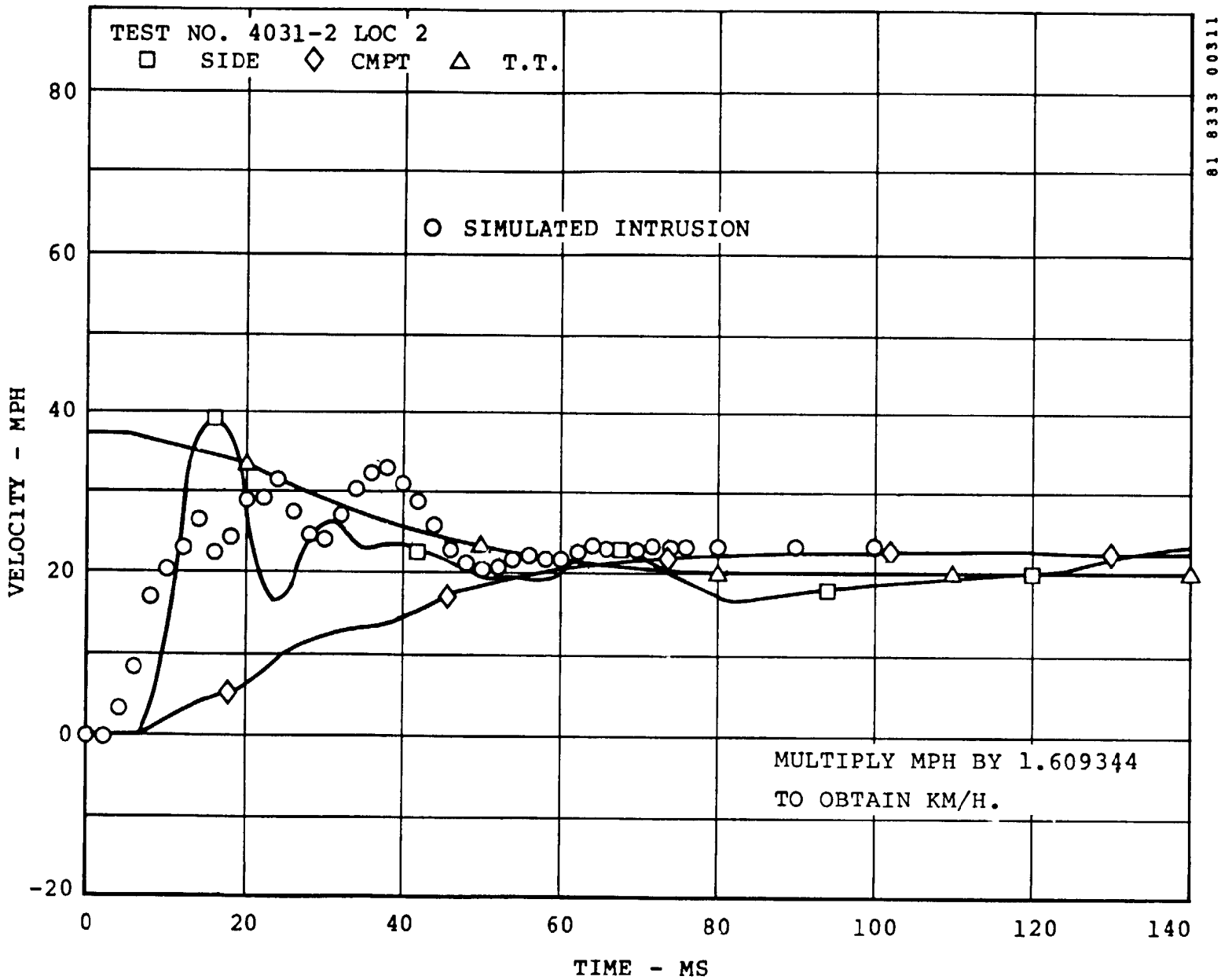


FIGURE 14. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 AFT UPPER FRONT DOOR.

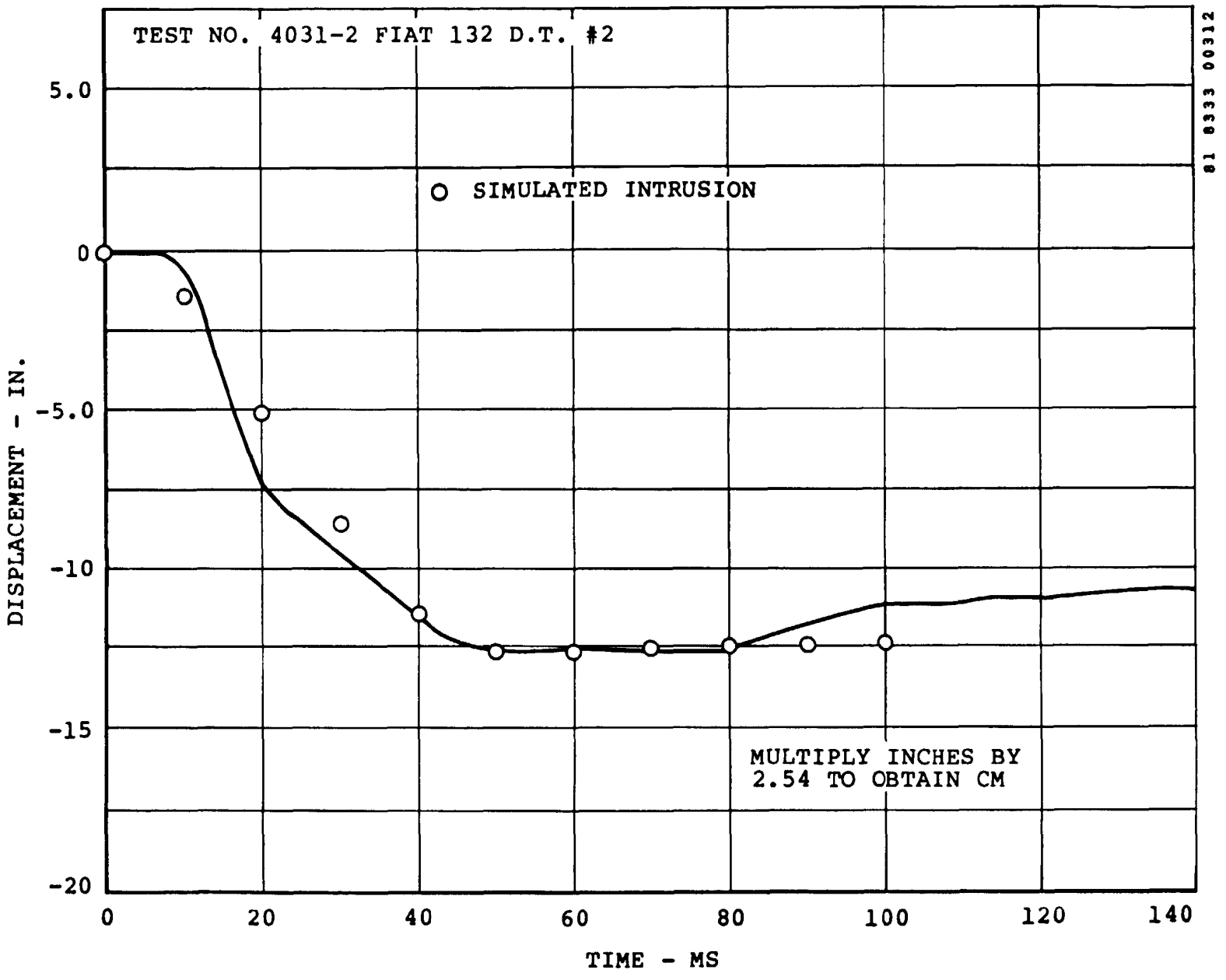


FIGURE 15. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 AFT UPPER FRONT DOOR.

The predicted velocity and intrusion profiles for the Fiat 132's lower rear door are shown in Figure 16 and 17, respectively, compared to their corresponding test data. Similarly, Figures 18 and 19 present the predicted lower front door velocity and intrusion histories, adjacent to the driver pelvis, compared to test data.

The predicted maximum dynamic exterior crush profile of the Fiat 132 during simulation of the test tool-to-Fiat 132 side characterization test is shown at three different vertical stations in Figures 20, 21, and 22. The actual post-test measured crush at locations near each of the predicted locations are shown in each of these figures for comparison.

The analytical model to obtain these results from Program "B" consisted of fifty-eight (58) degrees of freedom, including both the Fiat 132 side and Fiat test-tool models. The results shown indicate quite respectable simulation accuracy, particulary when considering the need to improve interior door, full-scale test, data quality.

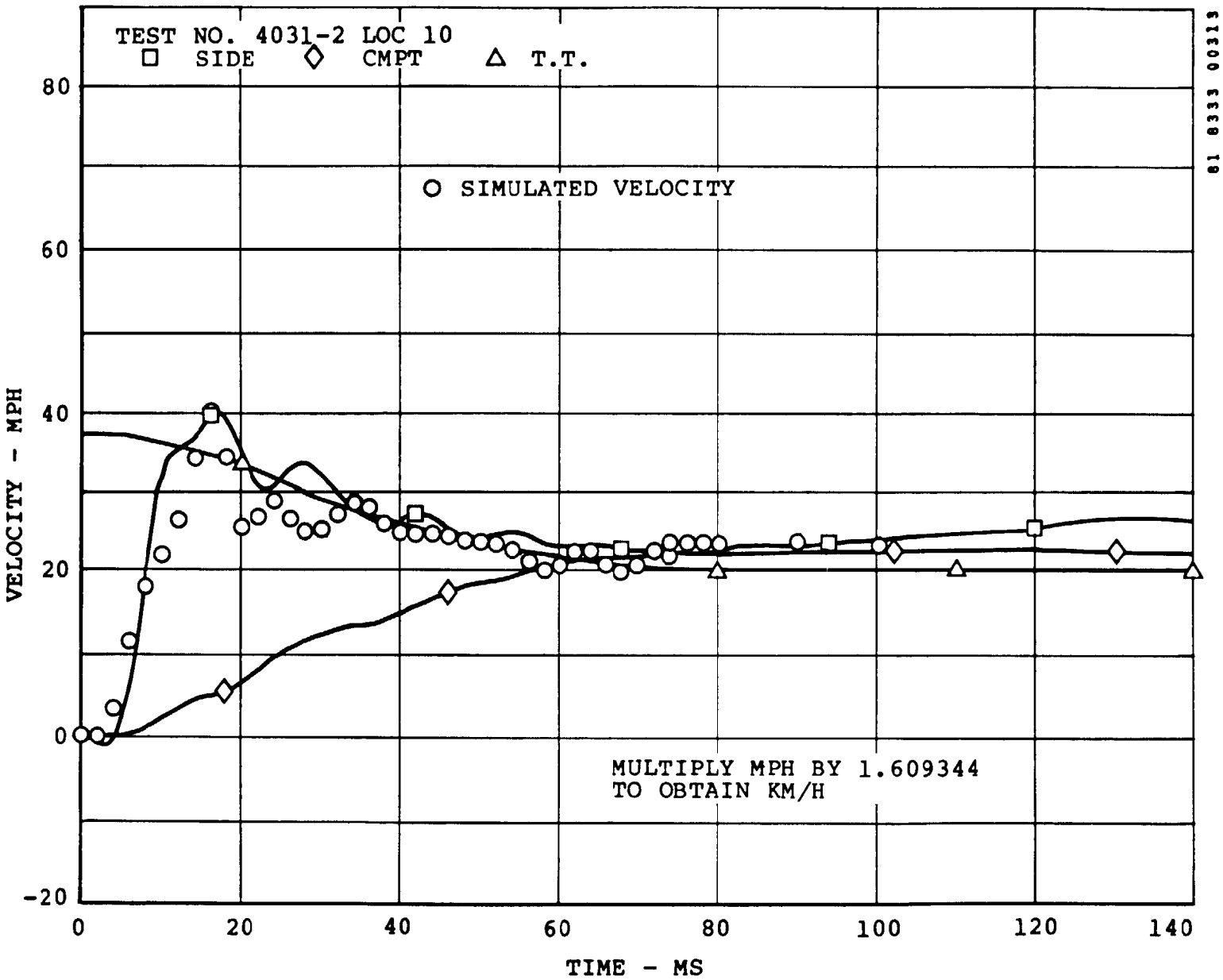


FIGURE 16. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 LOWER REAR DOOR.

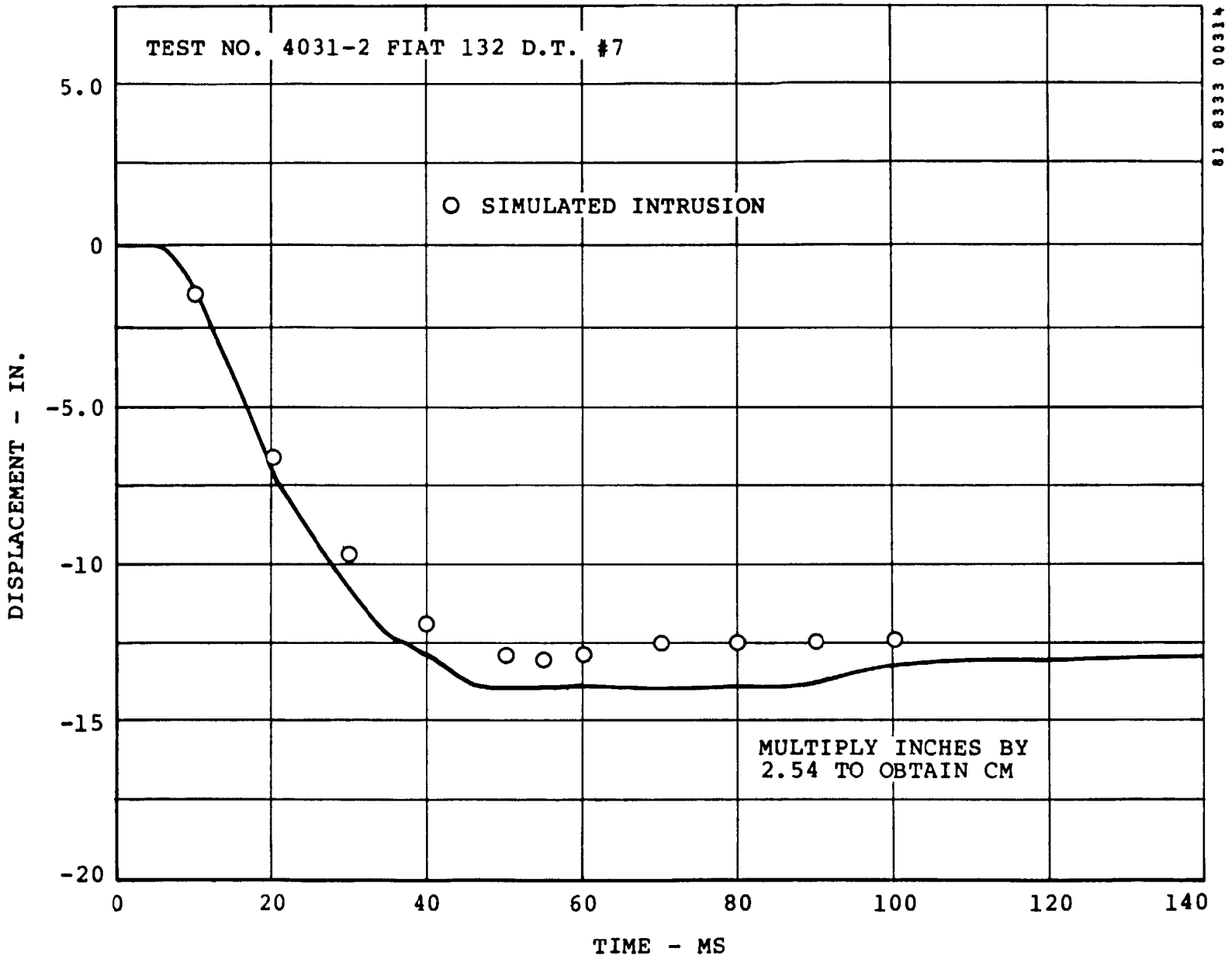


FIGURE 17. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 LOWER REAR DOOR.

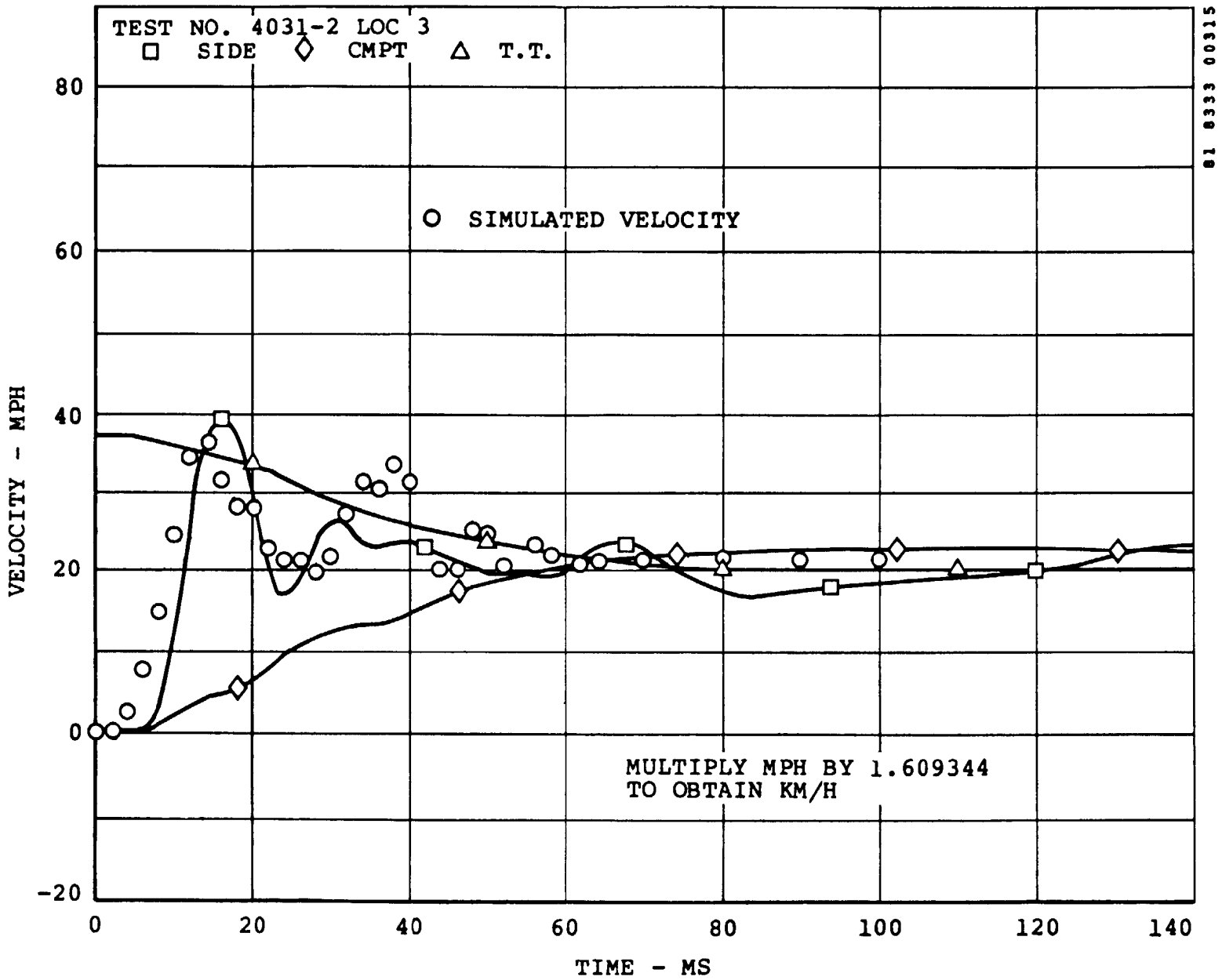


FIGURE 18. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 AFT LOWER FRONT DOOR.

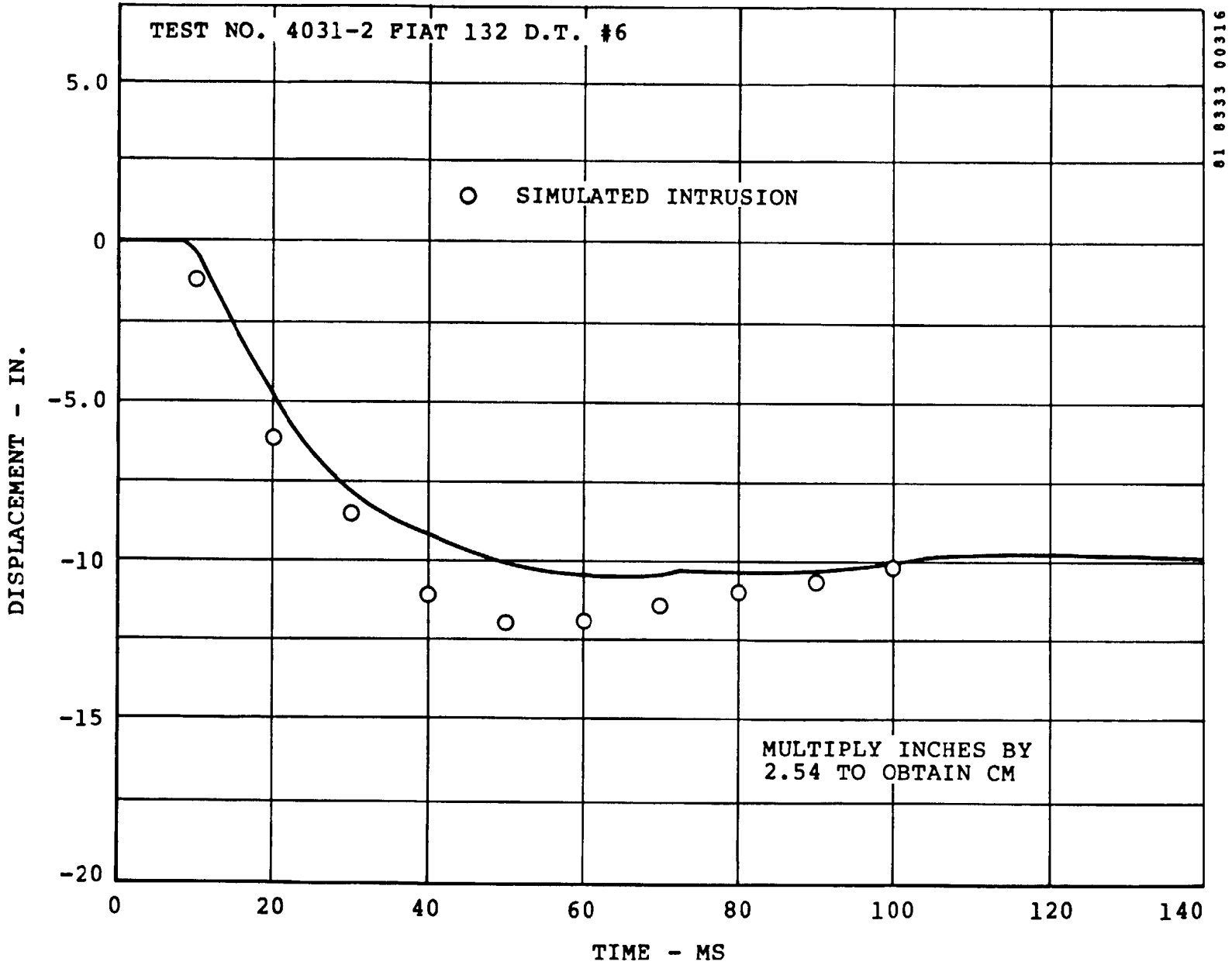


FIGURE 19. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 AFT LOWER FRONT DOOR.

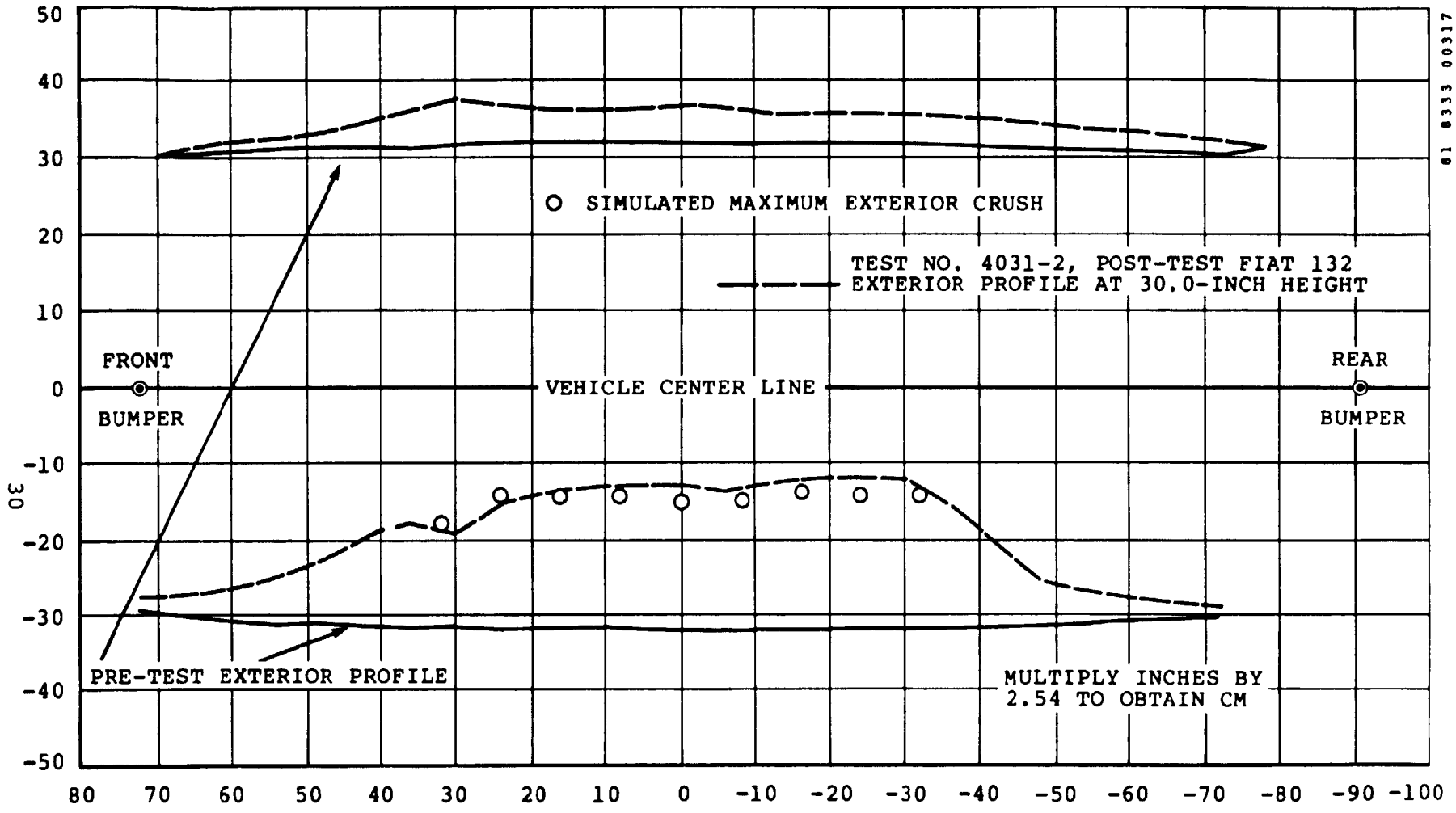


FIGURE 20. COMPARISON BETWEEN SIMULATED MAXIMUM DYNAMIC EXTERIOR CRUSH 28.0 INCHES ABOVE GROUND AND POST-TEST MEASUREMENTS FOR THE FIAT 132.

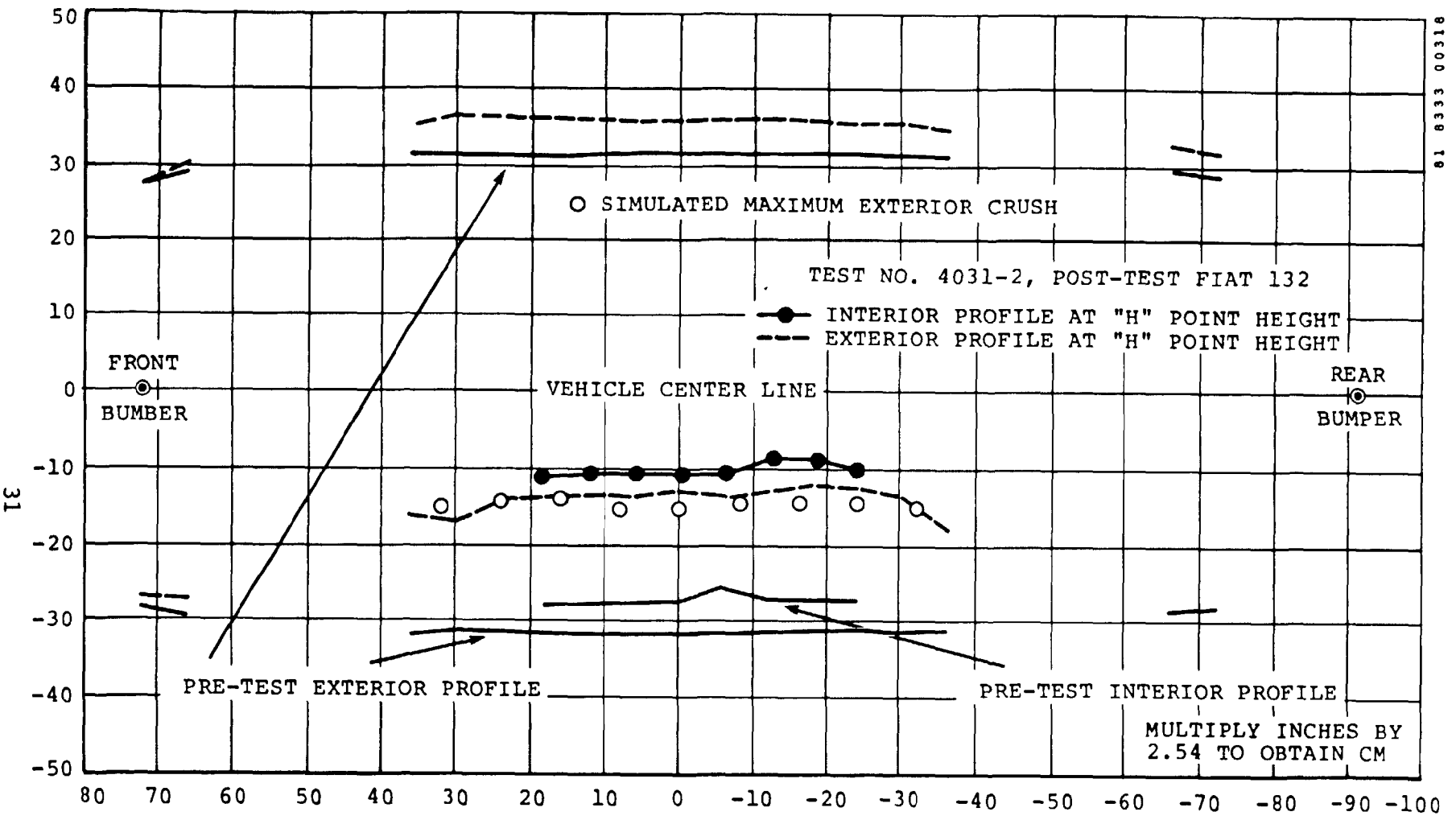


FIGURE 21. COMPARISON BETWEEN SIMULATED MAXIMUM DYNAMIC EXTERIOR CRUSH 17.5 INCHES ABOVE GROUND AND POST-TEST MEASUREMENTS FOR THE FIAT 132.

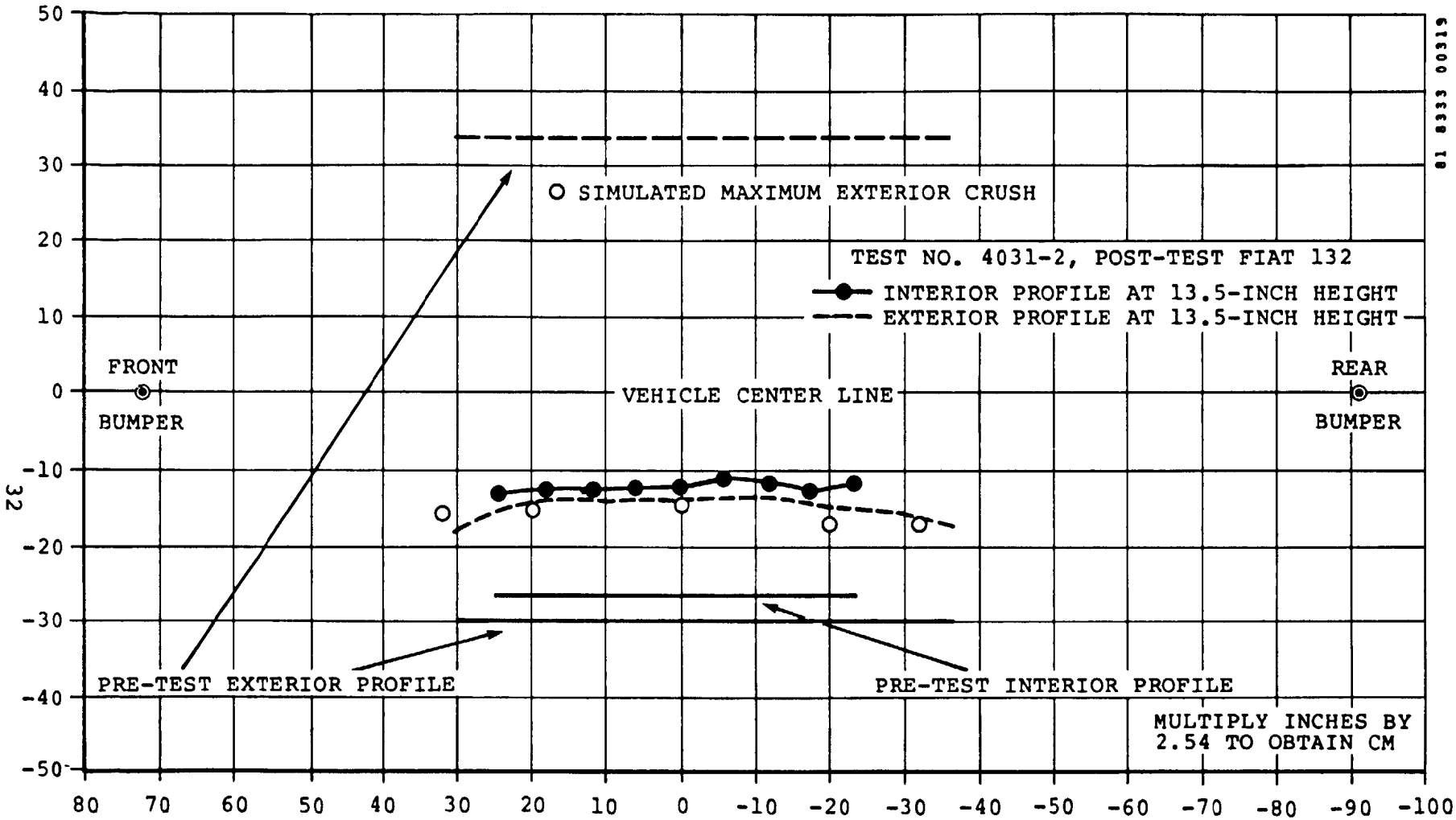


FIGURE 22. COMPARISON BETWEEN SIMULATED MAXIMUM DYNAMIC EXTERIOR CRUSH 10.5 INCHES ABOVE GROUND AND POST-TEST MEASUREMENTS FOR THE FIAT 132.

4.0 TASK 3 - FIAT 132 FRONT-TO-FIAT 132 SIDE IMPACT

The objective of this task was to conduct a full-scale crash test involving a Fiat 132 front into a Fiat 132 side. The following test conditions were to be obtained:

Impact Angle = Ninety (90) Degree

Impact Location = Center of Bullet Vehicle Aligned with Target Vehicle "H" Point on Left Side

Impact Speed

- Bullet Vehicle (Fiat 132 Front) = 30 mph (48 km/h)
- Target Vehicle (Fiat 132 Side) = 0 mph (0 km/h)

Occupants

- Driver (both vehicles)
- Left Rear Passenger (target vehicle)
- Right Front Passenger (bullet vehicle)

The details and results of this test were forwarded under separate cover (Reference 4). The actual impact location of this test was centered six (6) inches (15 cm) forward of the vehicles "H" point. As a result, two simulations in Task 4 (reported in the following Section) were conducted; one with the impact centered on the Fiat 132 vehicle's "H" point, and the second centered eight (8) inches (20.3 cm) forward of the vehicle's "H" point.

5.0 TASK 4 - SIDE IMPACT PREDICTIVE ANALYSIS

The objective of Task 4 was to predict the crash responses for the full-scale test conducted in Task 3 using the analytical models generated in Tasks 1 and 2. The first simulation of this crash condition, involving the Fiat 132 front into the Fiat 132 side, was set up with the center of impact located at the Fiat 132 side longitudinal "H" point. As has been pointed out, the test was conducted with the initial impact centered approximately six (6) inches (15 cm) forward of the "H" point location. As a result, a second simulation was conducted with an eight (8) inch (20.3 cm) shift in the relationship between the front and side models (because of the eight (8) inches (20.3 cm) modularity associated with the test tool this could be done without changing the models), which provided a second representation of the Task 3 test condition.

For each of the simulations, the validated Fiat 132 frontal model and Fiat 132 side model were input into computer Program "B" along with the initial conditions associated with the Task 3 test. The resulting simulation provided fifty-seven (57) degrees of freedom including both vehicle representations. Table 4 presents a summary of the predicted results compared to the actual test data.

Figure 23 presents the predicted target Fiat 132 (side model) lateral compartment response compared to the actual test data. The shaded data points in this figure, and throughout this

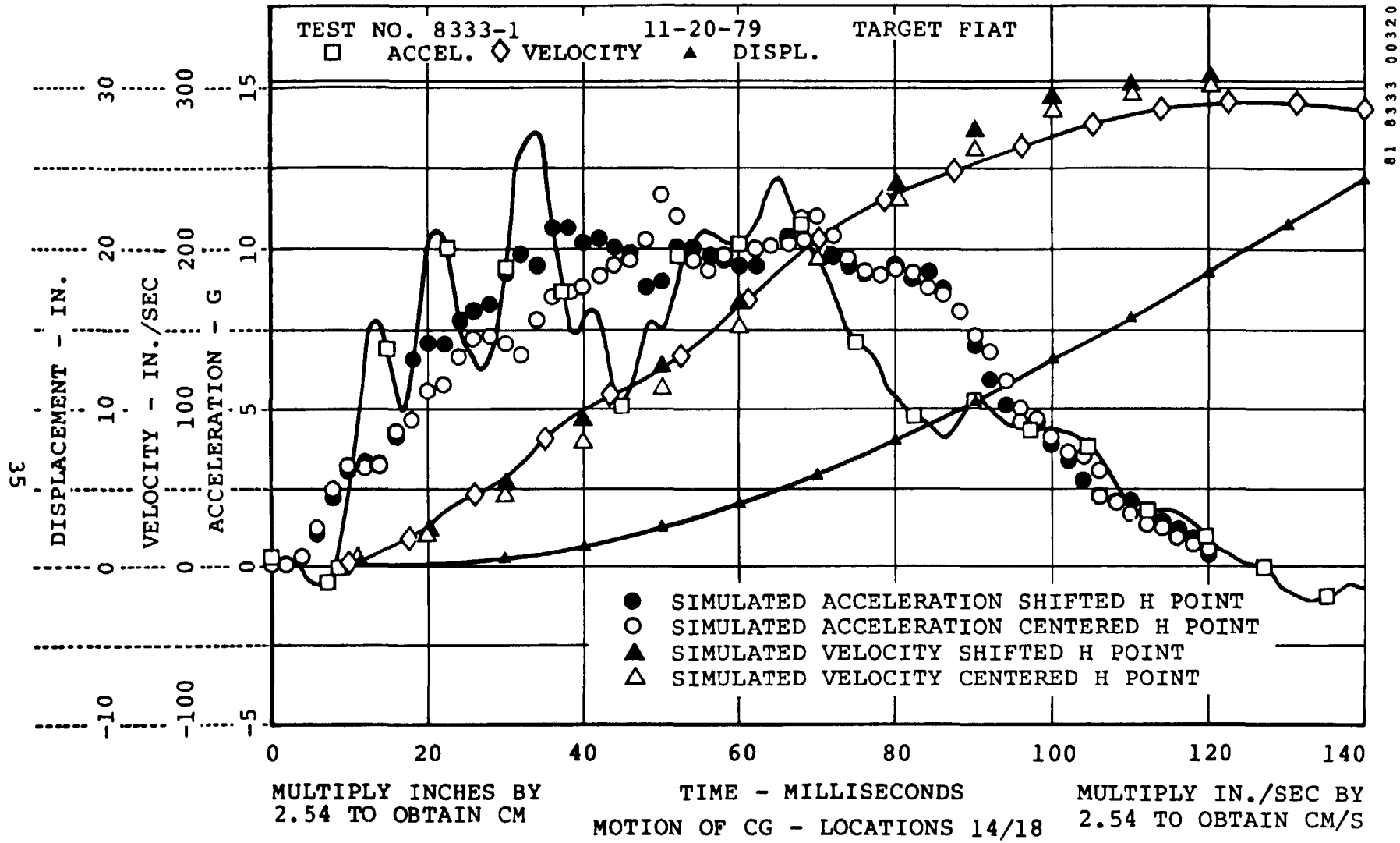


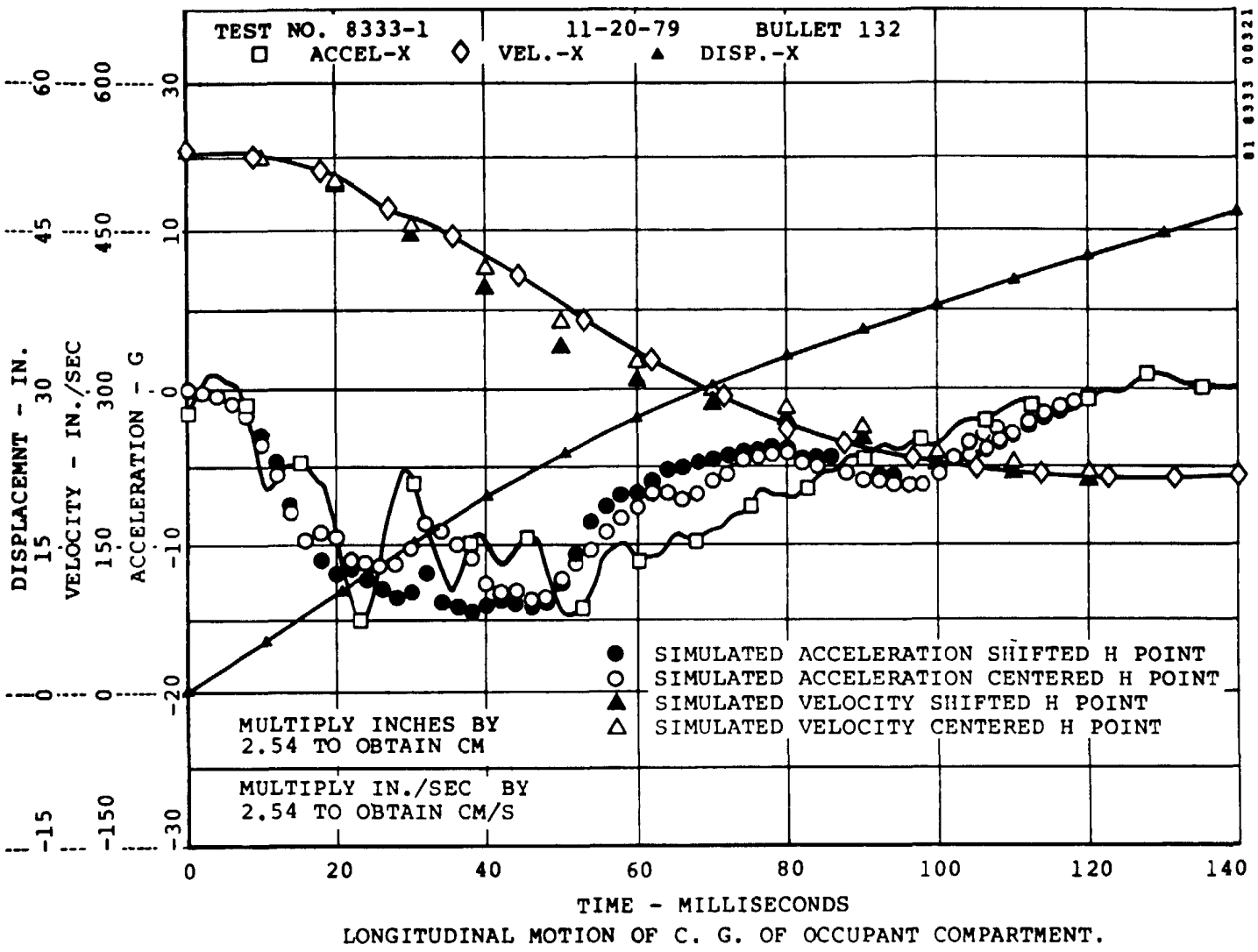
FIGURE 23. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE TARGET FIAT 132 COMPARTMENT.

TABLE 4. FIAT 132 FRONT-TO-FIAT 132 SIDE PREDICTED CRASH RESULTS SUMMARY

Parameter	Simulation	Test Data
Bullet Vehicle Weight (lb), Fiat 132 Front	2798	2823
Target Vehicle Weight (lb), Fiat 132 Side	2912	2920
Bullet Vehicle Velocity (mph)	30.10	30.10
Target Vehicle Velocity (mph)	0.0	0.0
Maximum Dynamic Mutual Crush		
• Integrated Acc. (in)	26.05 (24.35)*	25.3
Velocity Change at 120 ms (From Accel. Data)		
• Bullet Vehicle (mph)	17.59 (18.07)*	17.91
• Target Vehicle (mph)	17.06 (17.48)*	16.46

*Bracketed terms represent values obtained with impact shifted six (6) inches (15 cm) forward of "H" point.
Multiply lb by 0.4535924 to obtain kg
Mulitply mph by 1.609344 to obtain km/h
Mulitply in. by 2.54 to obtain cm

section, represent the results obtained with the simulated impact point shifted six (6) inches (15 cm) forward of the vehicles "H" point. Figure 24 presents the bullet Fiat 132 (frontal model) longitudinal compartment response compared to the actual test data. The predicted upper rear door interior velocity response is shown in Figure 25 compared with two measured test locations within the represented interior panel. The predicted interior intrusion history for this same location is shown in Figure 26 compared to a deflection tube located within the simulated panel. The predictions for the upper front door corresponding to that area adjacent to the driver thorax are shown in Figure 27 along with corresponding measured data just forward of the driver chest. Figure 28 presents the corresponding intrusion history for the upper front door. The measured intrusion profile is questionable as the post-test intrusion for this area is larger than the measurement indicated.



LONGITUDINAL MOTION OF C. G. OF OCCUPANT COMPARTMENT.

FIGURE 24. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE BULLET FIAT 132 COMPARTMENT.

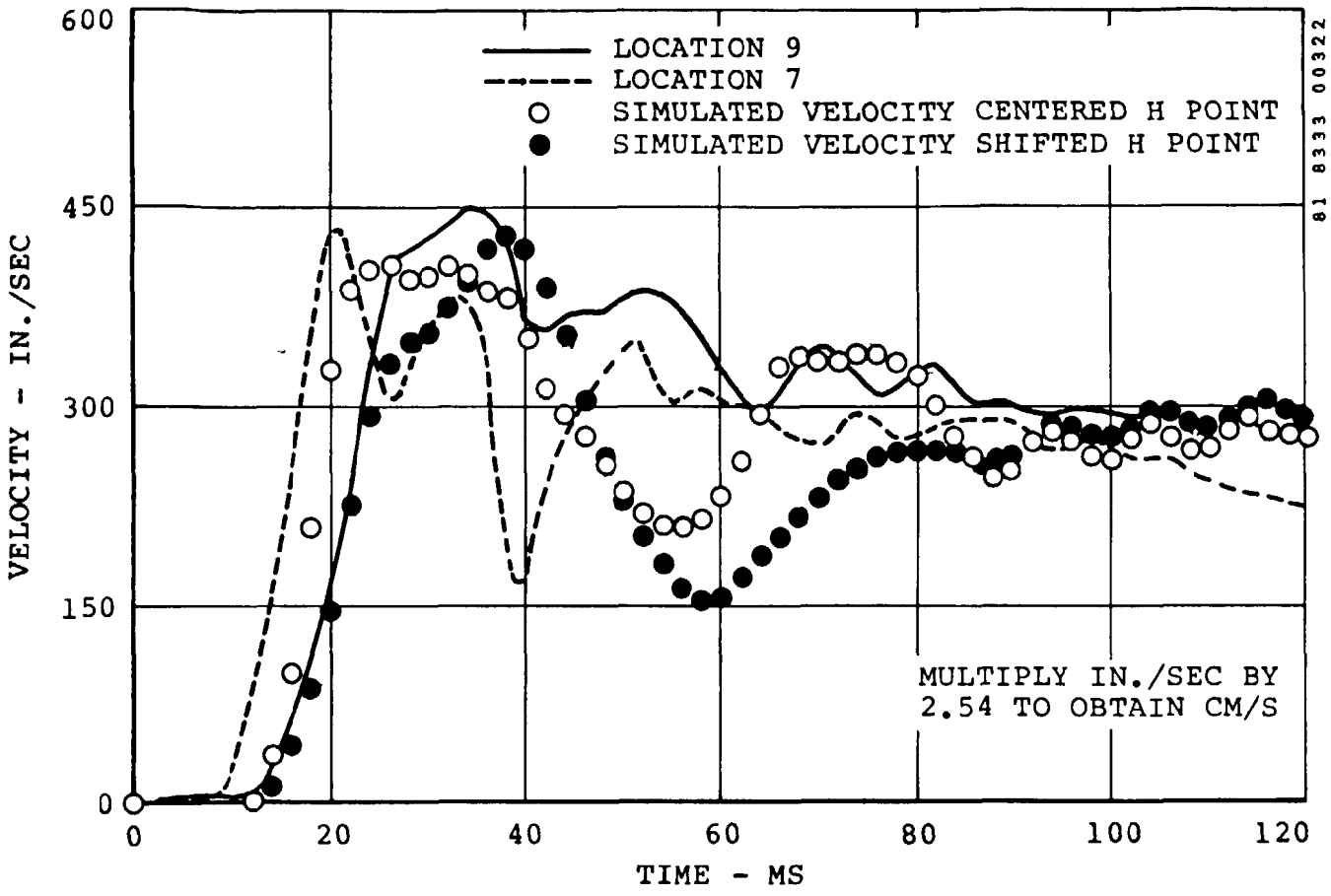
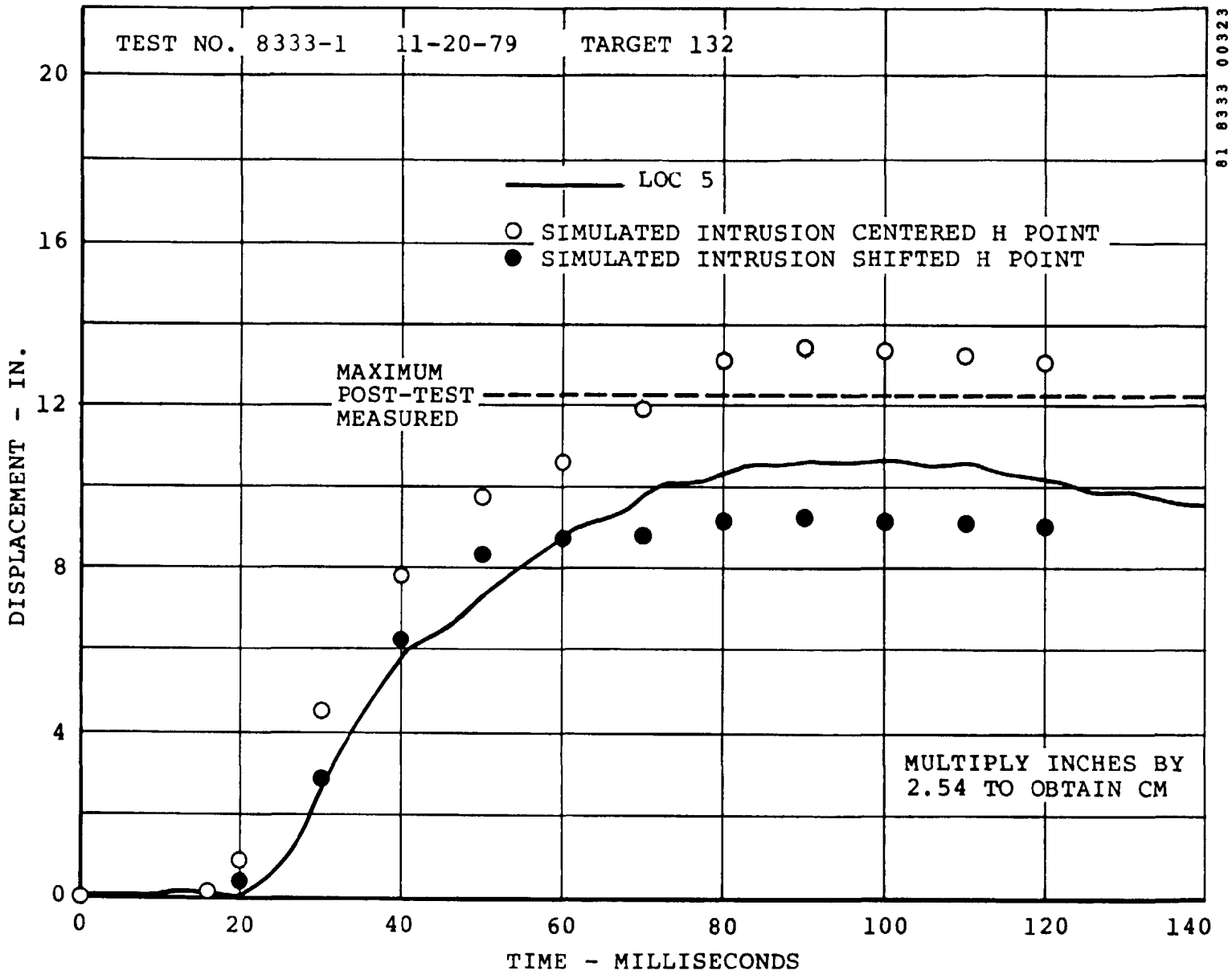


FIGURE 25. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 UPPER REAR DOOR.



RELATIVE DISPLACEMENT OF LEFT REAR DOOR AT PASSENGER CHEST.

FIGURE 26. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 UPPER REAR DOOR.

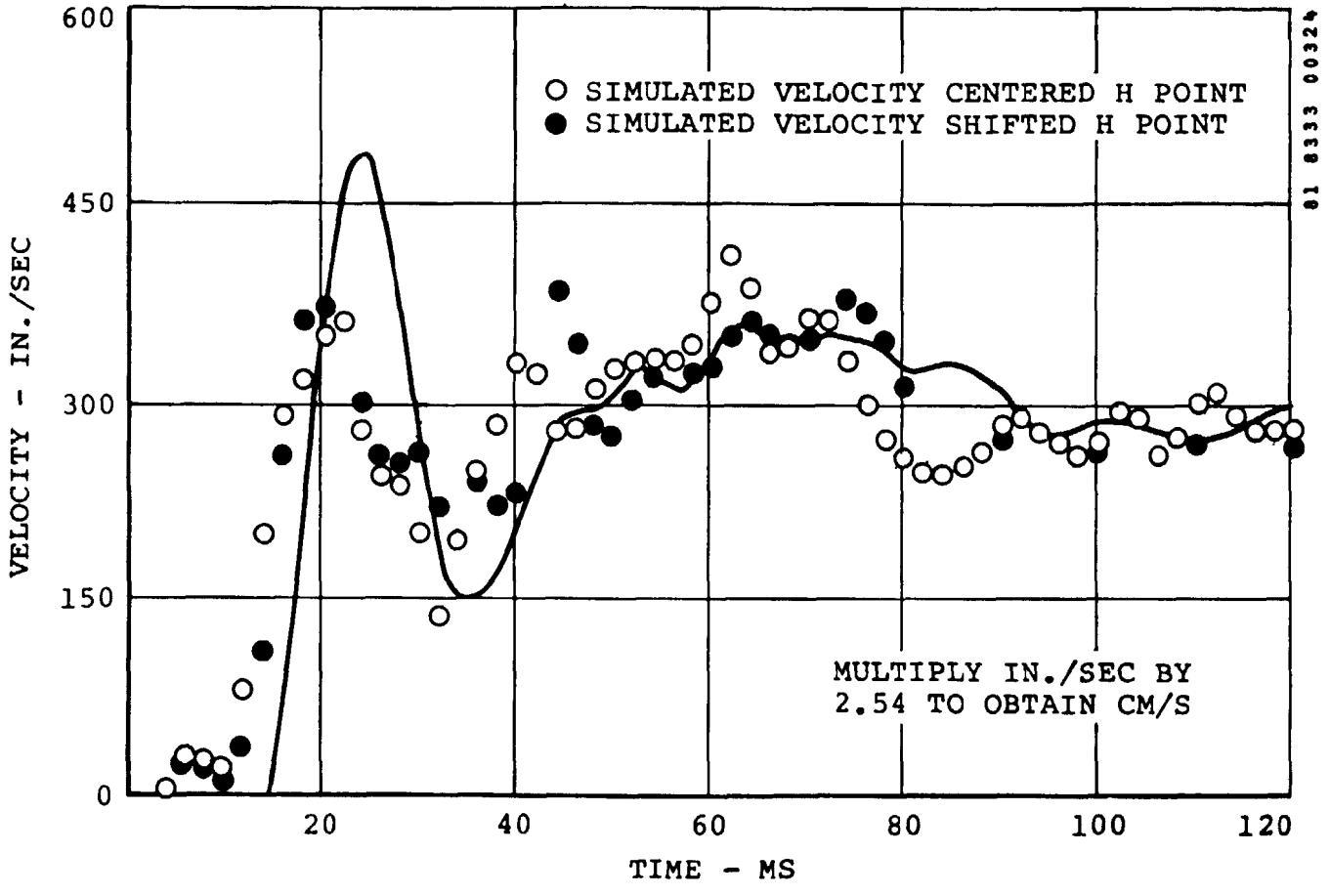
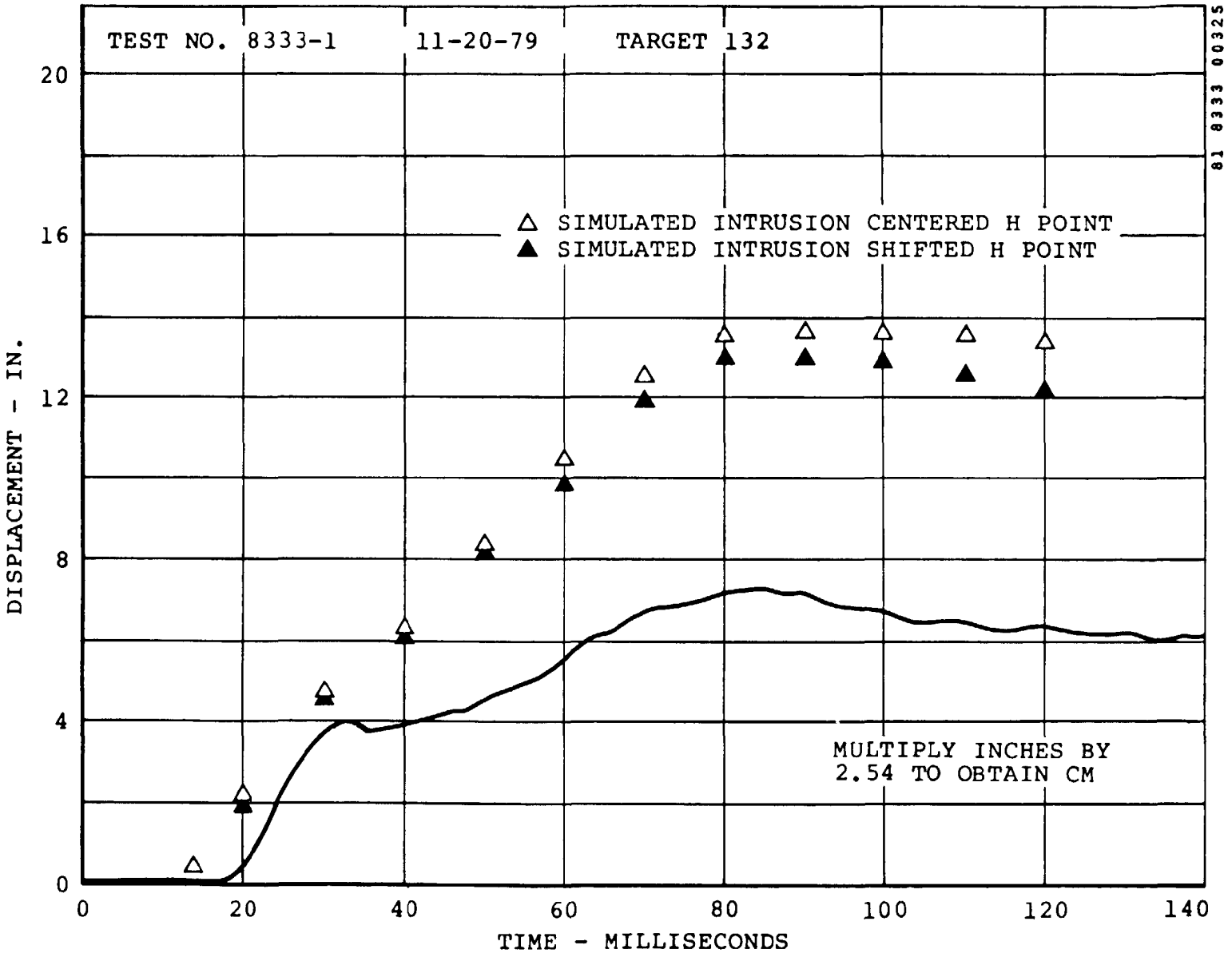


FIGURE 27. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 AFT UPPER FRONT DOOR.



RELATIVE DISPLACEMENT OF LEFT FRONT DOOR AT DRIVERS CHEST.

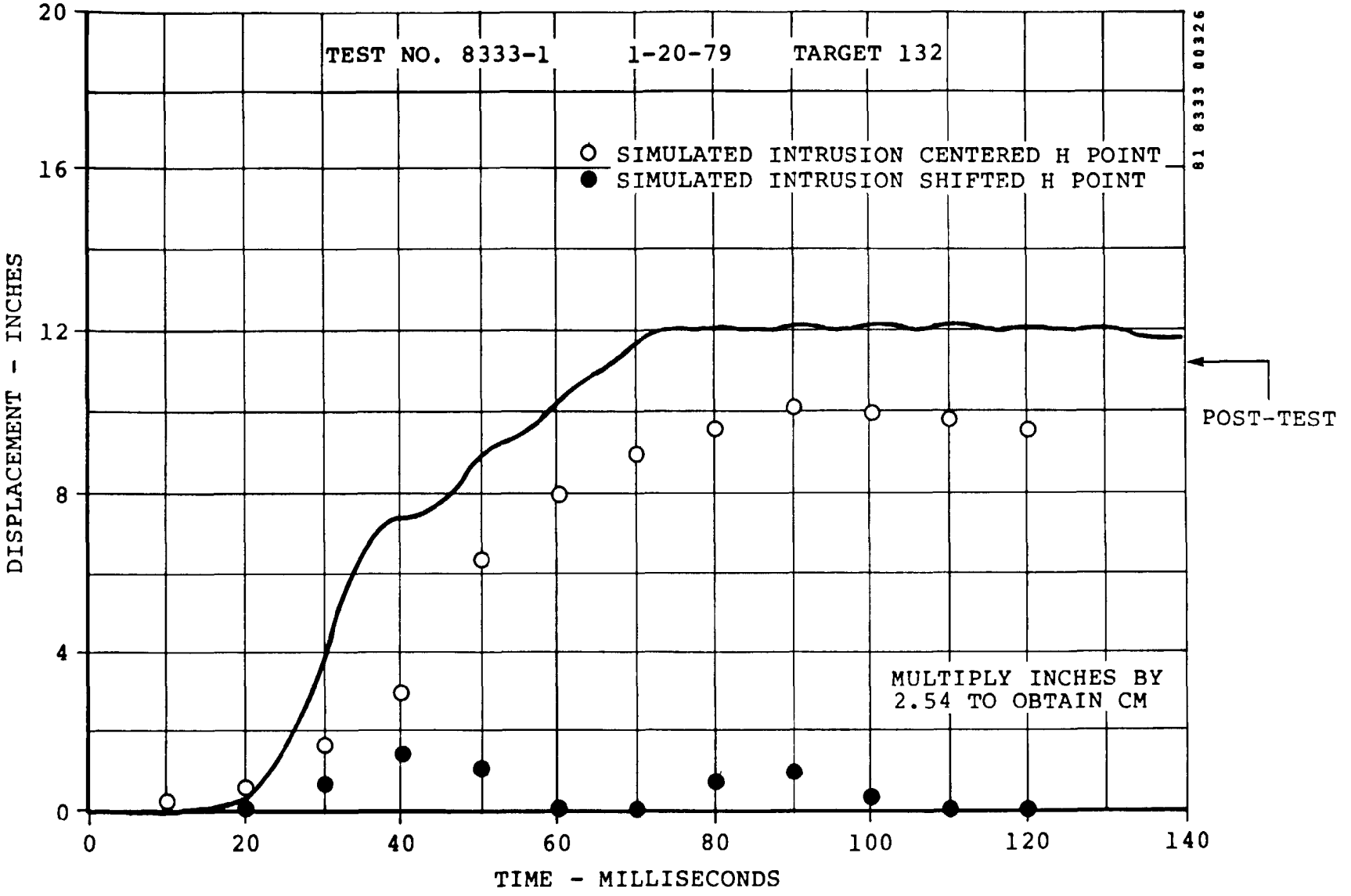
FIGURE 28. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 AFT UPPER FRONT DOOR.

The predicted lower rear door response is illustrated as intrusion history in Figure 29 compared to deflection tube data which was very near the "B" pillar. The prediction associated with a forward impact shift shows very little intrusion as the rear door was not fully engaged by the Fiat 132 front for this shift. Figure 30 presents the predicted lower front door (adjacent to the driver pelvis) velocity histories compared to the measured response of this panel location. The simulation associated with an impact shift (which is closer to the test condition) shows improvement over the initial simulation.

Figures 31, 32 and 33 present the predicted maximum dynamic exterior side crush profiles for the three different vertical locations on the Fiat 132 target vehicle compared to post-test measured deformations. Figures 34 and 35 show the predicted Fiat 132 bullet vehicle maximum dynamic exterior crush for bumper and hood/grill levels, respectively.

In presenting and comparing the predicted results with the Task 3 test results, test measurement locations and simulation panel locations did not coincide perfectly. Thus, comparisons are based on those data most nearly representative of the simulated location. This difference was due to the continuing programs of improvement in instrumenting side interiors.

The simulated results shown in the above analyses are felt to be extremely encouraging. Both the generation of the models from test data and the comparison of predicted results to test data are highly dependent upon our ability to obtain and accurately measure



RELATIVE DISPLACEMENT OF LEFT REAR DOOR AT PASSENGER KNEE.

FIGURE 29. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 LOWER REAR DOOR.

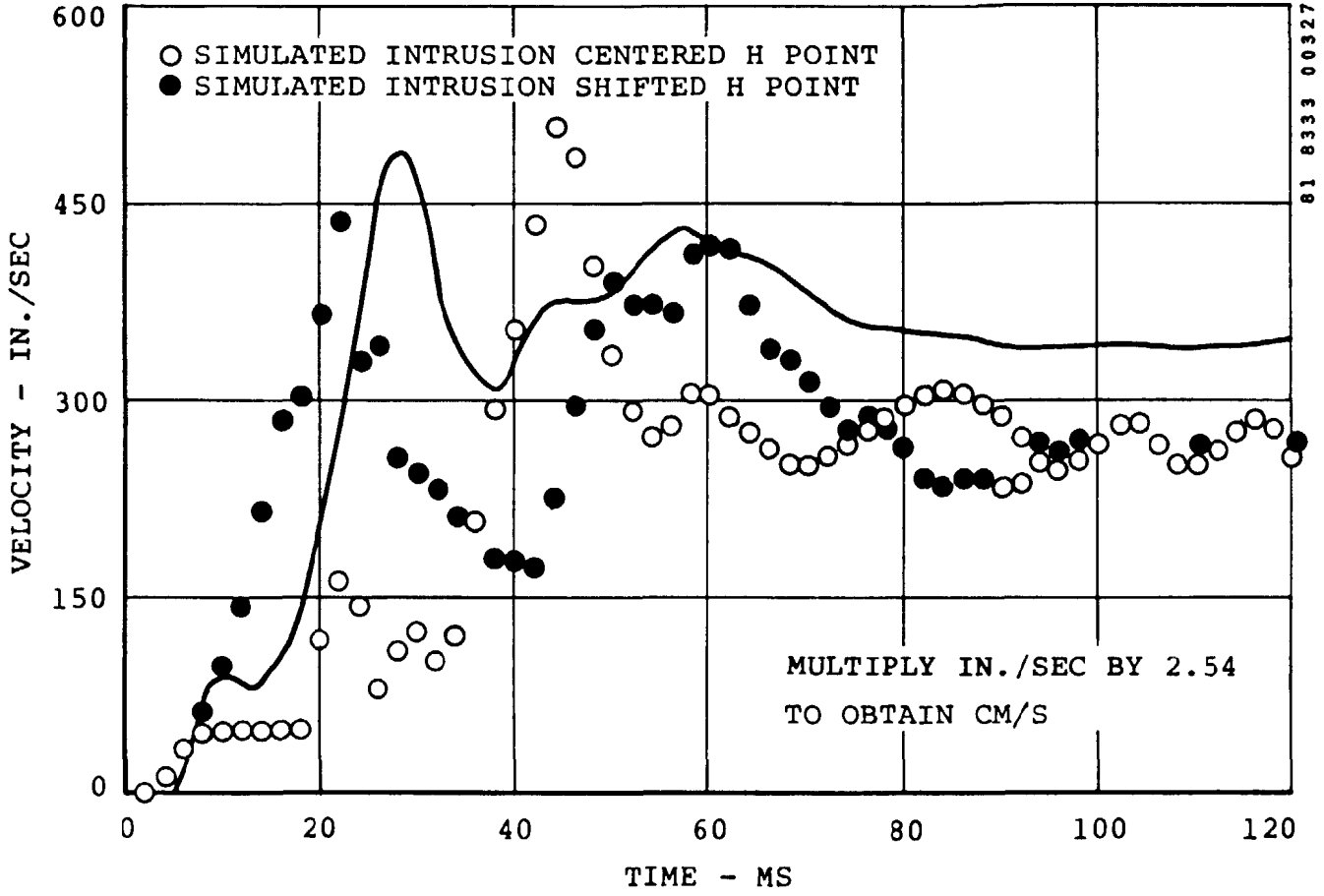


FIGURE 30. COMPARISON BETWEEN SIMULATED AND TEST RESULTS FOR THE FIAT 132 AFT LOWER FRONT DOOR.

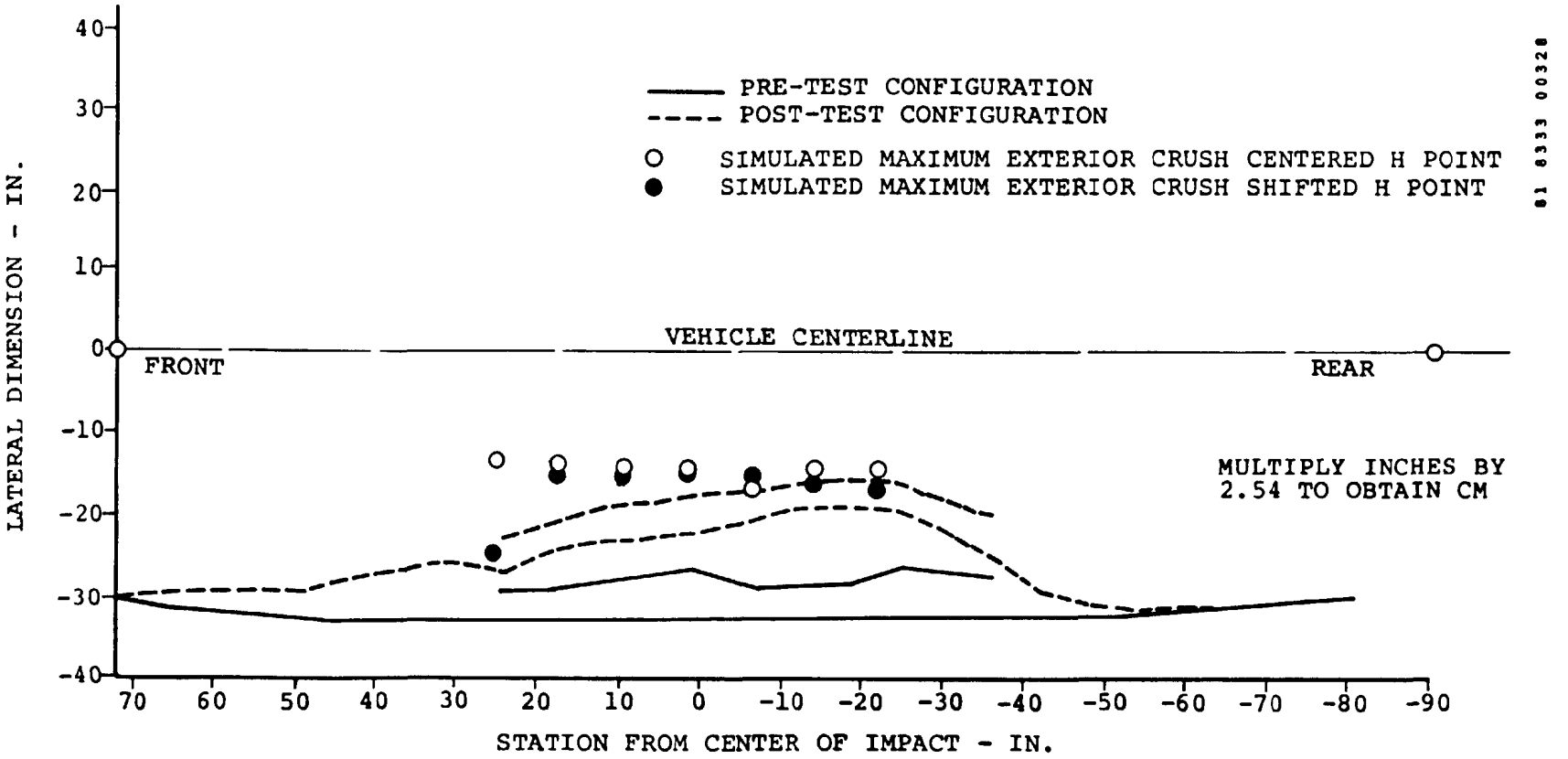


FIGURE 31. COMPARISON BETWEEN SIMULATED MAXIMUM DYNAMIC EXTERIOR CRUSH 28.0 INCHES ABOVE GROUND AND POST-TEST MEASUREMENTS FOR THE FIAT 132.

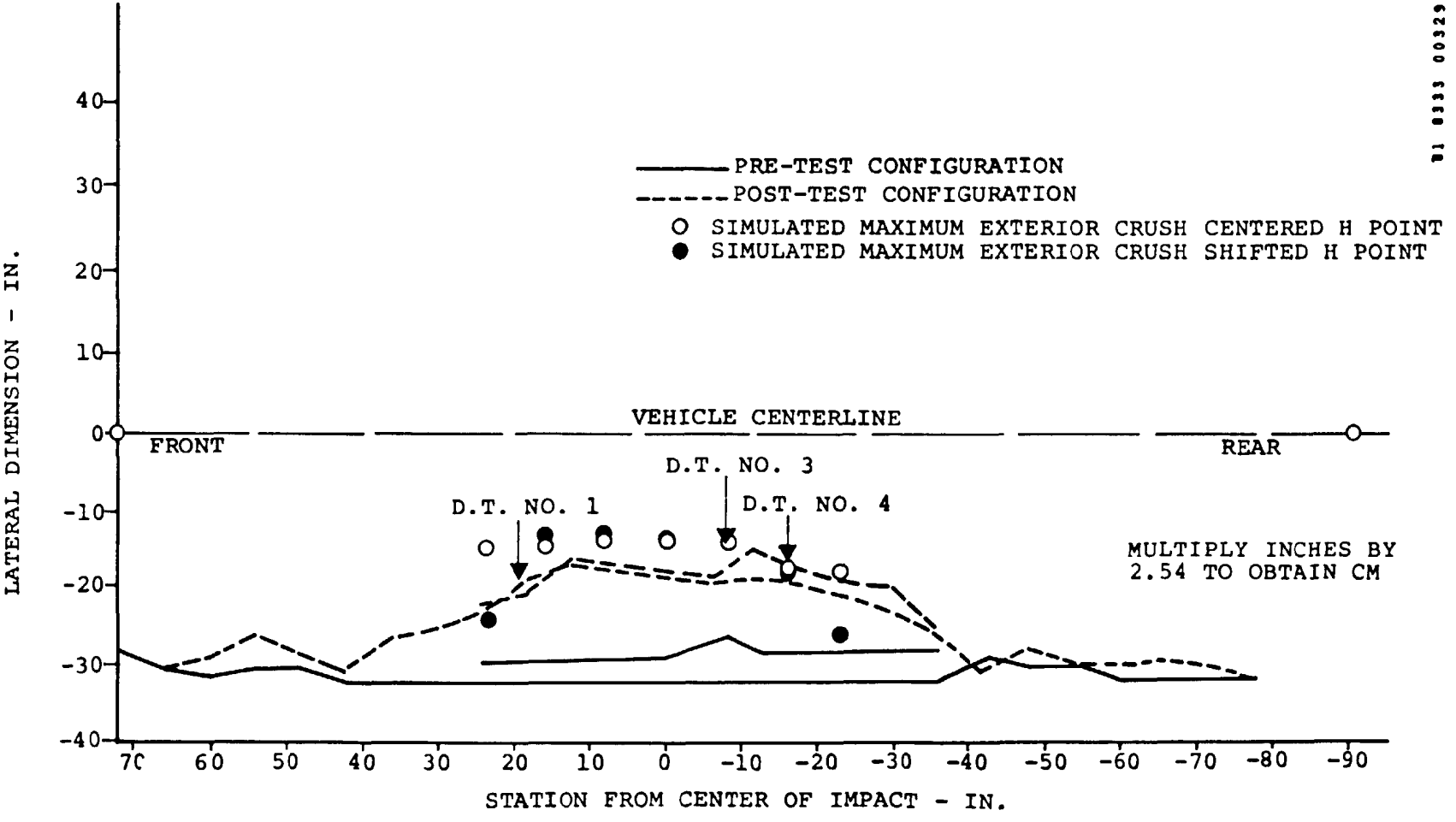


FIGURE 32. COMPARISON BETWEEN SIMULATED MAXIMUM DYNAMIC EXTERIOR CRUSH 17.5 INCHES ABOVE GROUND AND POST-TEST MEASUREMENTS FOR THE FIAT 132.

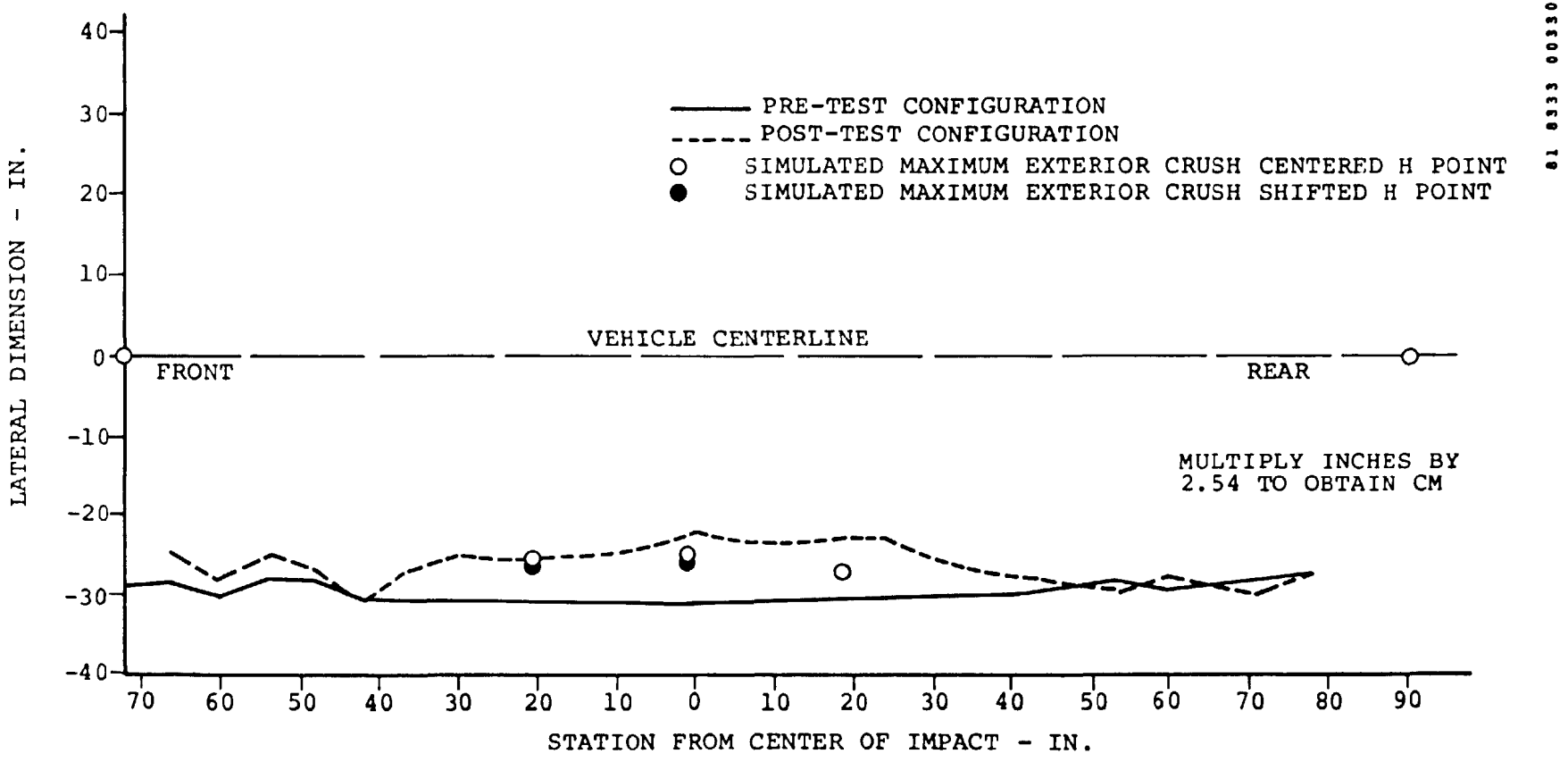


FIGURE 33. COMPARISON BETWEEN SIMULATED MAXIMUM DYNAMIC EXTERIOR CRUSH 10.5 INCHES ABOVE GROUND AND POST-TEST MEASUREMENTS FOR THE FIAT 132.

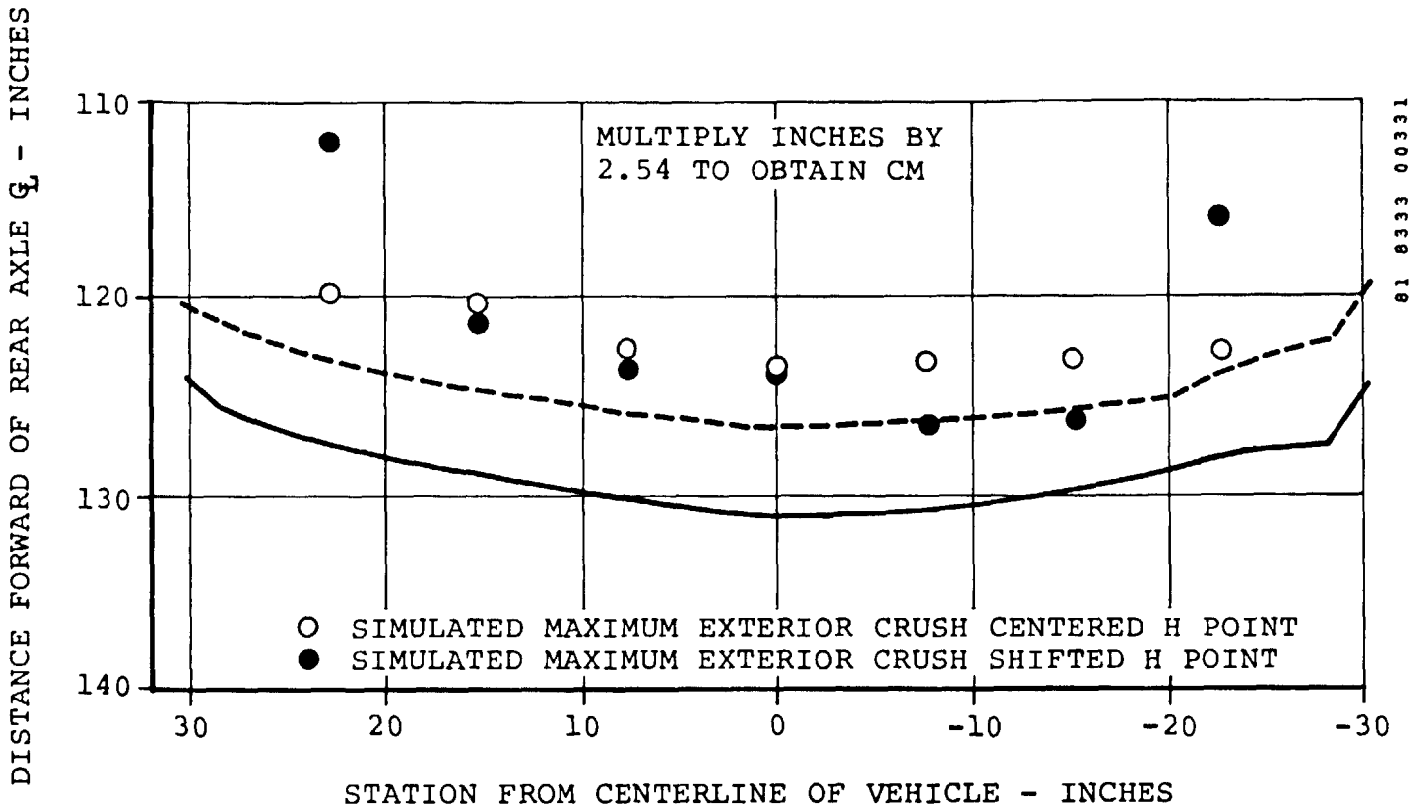


FIGURE 34. FIAT 132 EXTERIOR FRONT CRUSH PROFILE FOR A HEIGHT OF 17.5 INCHES ABOVE GROUND LEVEL ON BULLET VEHICLE.

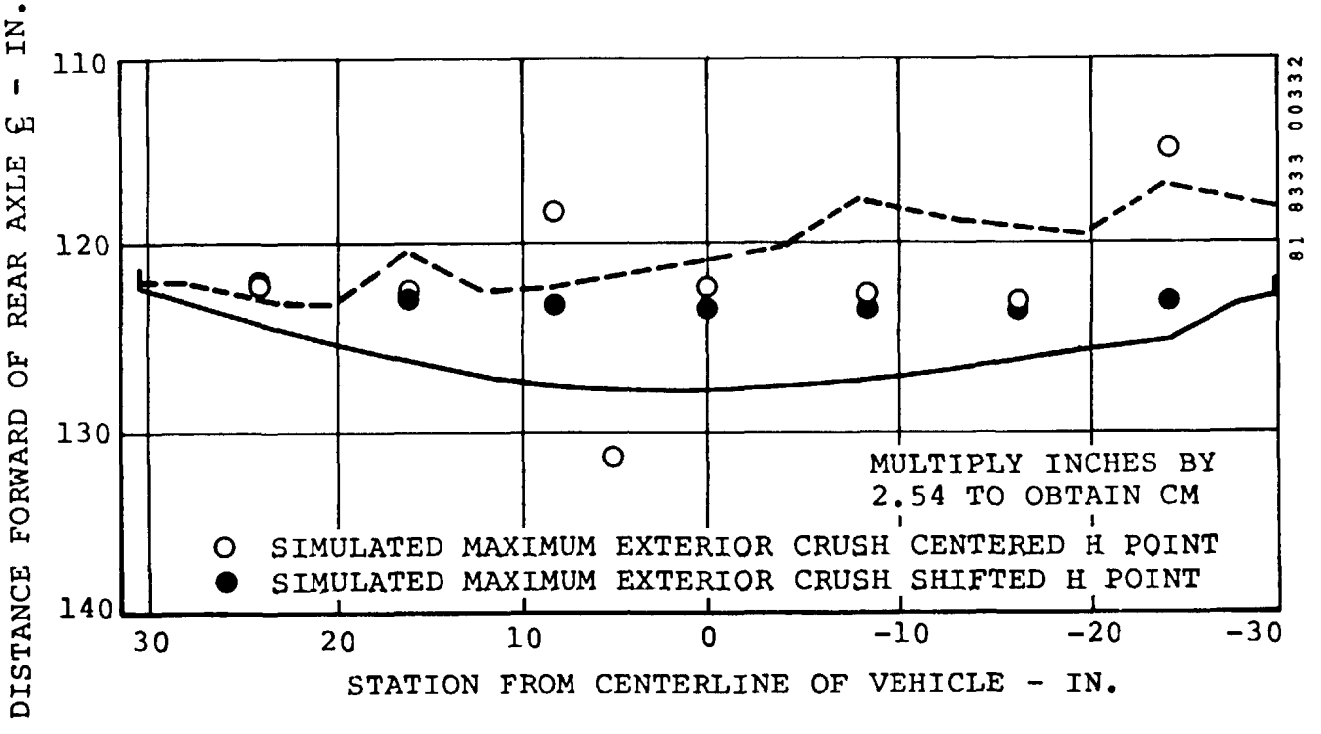


FIGURE 35. FIAT 132 EXTERIOR FRONT CRUSH PROFILE FOR A HEIGHT OF 28.0 INCHES ABOVE GROUND LEVEL ON BULLET VEHICLE.

interior door responses. The ability to shift the impact location without changing the original target and bullet models was demonstrated and improved the initial results by providing a simulated condition which was more closely representative of the actual full-scale test.

The side impact model approach, although considered early in its development, produced extremely good response for those areas provided with accurate initial test data. This is particularly encouraging, showing the general ability of the Fiat methodology for side impact simulation.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Previous research conducted on the Fiat methodology had concentrated on the characterization and predictive capabilities associated with front-to-front collisions. The success of this prior work was demonstrated in the results presented in Task 1, Section 2.0. The predictions for both the test tool-to-Fiat 132 front validation simulation and the Fiat 132 front-to-front simulation were well within the accuracies obtainable for present State-of-the-Art deviations in test data and manufacturing tolerances.

The work reported in Tasks 2 (Section 3.0) through Task 4 (Section 5.0) initiated an investigation into the side impact problem utilizing the Fiat methodology, test tool, and computer analysis procedures. Although the side impact problems, from a structural point of view, are much more difficult to define than the frontal characteristics, the results obtained from the Fiat methodology for side impact simulation were quite impressive. This was particularly true when considering the relatively short period for it's development compared to frontal efforts. The most difficult problem faced in the development of the side structures model concerned the utilization and application of the full-scale side impact test data. Due to the present difficulties in instrumentation and acquisition of interior door data (on the impacted side), the accuracy and reliability of this data is compromised. This often required correction of door data to correlate with the laws of structural mechanics and physics which can be somewhat

subjective. Since this data is the basis by which the vehicles structural characterization is defined, the accuracy of the side model presented herein is somewhat impaired by these problems.

During the conduct of previous Fiat compatibility research, it was found that the development of the Fiat methodology's predictive technology was evolutionary in nature. That is, the generation of a level of model sophistication forged the way for improved modeling and characterization techniques. The side impact characterization results presented in this report represents the initial effort at applying the Fiat methodology to the side impact crash response problem. Continued work should provide means to improve data acquisition techniques as well as structural model representation.

In conclusion, the present State-of-the-Art in accurate side impact characterization is primarily data limited. It was observed in the work presented in this report that for those areas of characterization where the test data were well representative of actual responses the simulated responses of these areas compared favorably with actual responses. This does not mean to imply that the analytical representation of the side impact model cannot or should not be improved. However, improvement could be obtained more readily through the availability of improved test data.

It is recommended for future efforts that a high priority be given initially to improving the instruments, data acquisition, and instrumentation procedures for obtaining the interior door

response of side impacted vehicles. Many approaches have been attempted in the past including installation of accelerometers on mechanical filters and utilization of various types and brands of accelerometer devices. The most successful approach to data has been the installation of the accelerometer on a deflection tube which is also instrumented for measuring deflection. This provides measurement of door response in the lateral direction only, as well as permitting a way of obtaining a realistic interior door acceleration profile, while at the same time providing a deflection measurement which can be used to validate and/or correct the acceleration data.

The objective of the Fiat methodology is to provide a means by which vehicle response interactions can be determined with minimal testing requirements. The ability of the Fiat methodology to accomplish this goal in the future for the side impact environment was clearly demonstrated. The problems identified in this analysis are felt to be quite solvable and within present State-of-the- Art in electronic measurement technology.

REFERENCES

1. Data submittal report entitled, "Excerpts From an Existing Fiat Auto S.p.A. Report of Test Tool-to-Fiat 132 Head-on Impact, Test Data for Task 1," Contract No. DOT-HS-8-01933, Modification No. 4.

2. Data submittal report entitled, "Excerpts From an Existing Fiat Auto S.p.A. Report of Fiat 132 Front-to-Front Head-on Impact, Test Data for Task 1," Contract No. DOT-HS-8-01933, Modification No. 4.

3. Shaw, L.M. and R.E. Knight, "Fiat Compatibility Program: Second Generation Test Tool Six-Inch-Thick Honeycomb Test," Dynamic Science, Inc. Report No. 4993-79-78, May 1979.

4. Shaw, L.M., R.E. Knight, and M. Rodack, "Report of Test 8333-1; Fiat 132 Front-to-Fiat 132 Side Impact," as Required Under Task 3 of Contract No. DOT-HS-8-01933, Modification No. 4, "Fiat Methodology," Dynamic Science, Inc. Report No. 8333-80-073, March 1980.