EVOLUTION OF VEHICLE CRASHWORTHINESS AS INFLUENCED BY THE NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

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The design, development, and production of an automobile is an extremely complicated, difficult, and competitive process. Not only must good judgements about the design, size, cost, market segment, and many other characteristics of a vehicle be made many years in advance of its first public appearance, the many processes that merge the initial decisions and ideas into a viable product must be efficient and functional for a manufacturer to create a marketable product. As the nation's concerns for protecting the environment, conserving natural resources, and improving public safety continue, each of the technologies that direct, develop, and evaluate these various aspects of a vehicle's design should also become more effective, efficient, and timely(1).

One aspect of vehicle design, the safety afforded by the vehicle, provides no exception to the above statement. Reducing the human losses from highway crashes is a complex challenge to both the vehicle manufacturing industry and to the government. Motor vehicle crash injuries result from unfortunate coincidences of many human, technological, and environmental factors. Eliminating injuries and fatalities requires effective and balanced strategies and actions.

The Department of Transportation (DOT) is charged with the responsibility for reducing losses from motor vehicle crashes on U.S. highways. One agency of DOT, the Federal Highway Administration (FHWA), sets standards for highway design; another agency, the National Highway Traffic Safety Administration (NHTSA), sets standards for motor vehicle safety performance; and both agencies implement a variety of highway and traffic safety programs. The Department works in many constructive ways with state and local governments, industry, and other private groups to improve safety on our roads(2).

This paper presents an overview of safety technologies introduced into motor vehicle designs that have been realized as a result of actions taken by the National Highway Traffic Safety Administration in meeting its safety mandate.

SAFETY PROBLEM

Before discussing the technologies that have been introduced into vehicle designs to improve vehicle safety, it is important to understand the magnitude of the safety problem associated with motor vehicle crashes. This section provides that overview.

The historical magnitude of the motor vehicle safety problem may be grasped by comparing the number of deaths that have occurred on U.S. roads (2,766,590) from 1900 to 1989 with the total number of deaths of Americans that have occurred in all U.S. wars since the nation was founded in 1776 (1,186,654) [3]. Each year in this nation, about 40,000 people die as a result of motor vehicle crashes, For example, in 1992, there were 39,235 fatalities (32,869 vehicle occupants, 6,366 nonmotorists) in 34,928 motor vehicle crashes [2]. This is the equivalent to the losses that would be incurred if a major commercial airline were to crash every day, 365 days a year.

In addition to the fatalities suffered in 1992, there were 416,000 persons injured with incapacitating injuries (i.e., an injury, other than a fatal injury, which prevents the injured person from walking, driving, or normally continuing the activities the person was capable of performing before the injury occurred), 863,000 persons injured with nonincapacitating injuries (i.e., an injury, other than a fatal or incapacitating injury, which is evident to observers at the scene of the accident), and 1,790,000 other injuries (i.e., injuries claimed by an individual but not evident to an observer). These add up to 3,070,000 total injuries in 1992. Each year, the years of potential life lost amount to 1.4 million and the related economic losses total $75 billion(3).

SAFETY IMPROVEMENTS

The NHTSA has been very instrumental in introducing safety technologies into vehicle design. Figure 1 provides a summary look at these technologies. Over the years, crashworthiness improvements to passenger cars have been implemented due to standards issued for roof crush resistance, seat belts and automatic protection, head restraints, steering wheel impact protection, padded dash and interior protection, side door impact protection, child safety seats, fuel system integrity, door locks, window glazing, and bumper requirements. The next section provides a summary of the crashworthiness related Federal motor vehicle safety standards. Another agency program, the New Car Assessment Program (NCAP), provided motivation for manufacturers to improve some aspects of safety design beyond that required by the safety standards. This program is summarized as well.

FEDERAL MOTOR VEHICLE SAFETY STANDARDS

In September of 1966, the National Traffic and Motor Vehicle Safety Act was signed into law. The law directs the Secretary of Transportation to issue Federal motor vehicle safety standards (FMVSS) to which motor vehicle manufacturers must conform. The first such standards became effective on all vehicles manufactured on or after January 1, 1968, for sale or use in the United States, with the exception of FMVSS No. 209, which was effective upon issuance on March 1, 1967. Additional standards have been added and others are in the process of being developed and issued. The following provides a brief description of the crashworthiness related standards.

Standard No. 201, Occupant Protection in Interior Impact, specifies requirements for padded instrument panels, seat backs, sun visors, and armrests. Additionally, glove compartment doors are required to remain closed during a crash. Over a wide range of speeds, injuries suffered by occupants are largely determined by how well the structures on the inside of the vehicle cushion the human body striking them.

Standard No. 202, Head Restraints, specifies requirements for head restraints to reduce the frequency and severity of neck injuries in rear end and other collisions.

Standard No. 203, Impact Protection for the Driver from the Steering Control System, specifies requirements for minimizing chest, neck, and facial injuries by providing steering systems that yield forward, cushioning the impact of the driver's chest by absorbing much of the driver's impact energy in frontal crashes. Such systems are highly effective in reducing the likelihood of serious and fatal injuries.

Standard No. 204, Steering Control Rearward Displacement, specifies requirements limiting the rearward displacement of the steering column into the passenger compartment to reduce the likelihood of chest, neck, or head injuries.

Standard No. 205, Glazing Materials, specifies requirements for all glazing materials used in windshields, windows, and interior partitions of motor vehicles. Its purpose is to reduce the likelihood of lacerations and to minimize the possibility of occupants penetrating the windshield in collisions.

Standard No. 206, Door Locks and Door Retention Components, requires locking systems and specifies load requirements for door latches and door hinge systems to minimize the probability of occupants being thrown from the vehicle as a result of impact forces encountered by the vehicle during a crash.

Standard No. 207, Seating Systems, establishes requirements for seats, their attachment assemblies, and their installation to minimize the possibility of failure as a result of forces acting on the seat during a vehicle crash.

Standard No. 208, Occupant Crash Protection, specifies requirements for both active and automatic occupant crash protection systems. The most recent upgrade required that vehicles be equipped with air bag systems. With this requirement, improved knee bolsters were necessary to control occupant kinematics and femur loadings.

Standard No. 209, Seat Belt Assemblies, specifies requirements for seat belt assemblies. The requirements applies to straps, webbing, or similar materials, as well as to all necessary buckles and other fasteners and all hardware designed for installing the assembly in a motor vehicle, and to the installation, usage, and maintenance instructions for the assembly.

Standard No. 210, Seat Belt Assembly Anchorages, specifies requirements for seat belt assembly anchorages to ensure effective occupant restraint and to reduce the likelihood of failure in collisions.

Standard No. 211, Wheel Nuts, Wheel Discs, and Hub Caps, requires that "spinner" hub caps and other winged projections (both functional and nonfunctional) be removed from wheel nuts,wheel discs, and hub caps. Its purpose is to eliminate a potential hazard to pedestrians and cyclists.

Standard No. 212, Windshield Mounting, requires that each windshield mounting must be anchored in place and retain specified percentages of its periphery in a crash situation. The purpose of this standard is to keep vehicle occupants within the confines of the passenger compartment during a crash.

Standard No. 213, Child Seating Systems, specifies requirements for dynamic testing of child seating systems to minimize the likelihood of injury and/or death of children in vehicle crashes or sudden stops. The standard also includes requirements for providing information regarding proper installation and use of the child seats.

Standard No. 214, Side Impact Protection, specifies requirements for crush resistance levels in side doors of passenger cars to minimize the safety hazard caused by intrusion into the passenger compartment in a side impact accident. More recently, the standard has been updated to incorporate occupant protection requirements from a dynamic side impact test procedure. This new requirement is leading to improved door paddings and upgraded vehicle side structures.

Standard No. 216, Roof Crush Strength, sets minimum requirements for roofs to reduce the likelihood of roof collapse in a rollover accident. This standard provides an alternative to conformity with the rollover test requirements of Standard No. 208.

Standard No. 219, Windshield Zone Intrusion, regulates the intrusion of vehicle parts outside the occupant compartment into a defined zone in front of the windshield during a frontal barrier crash test. Its purpose is to reduce crash injuries and fatalities that

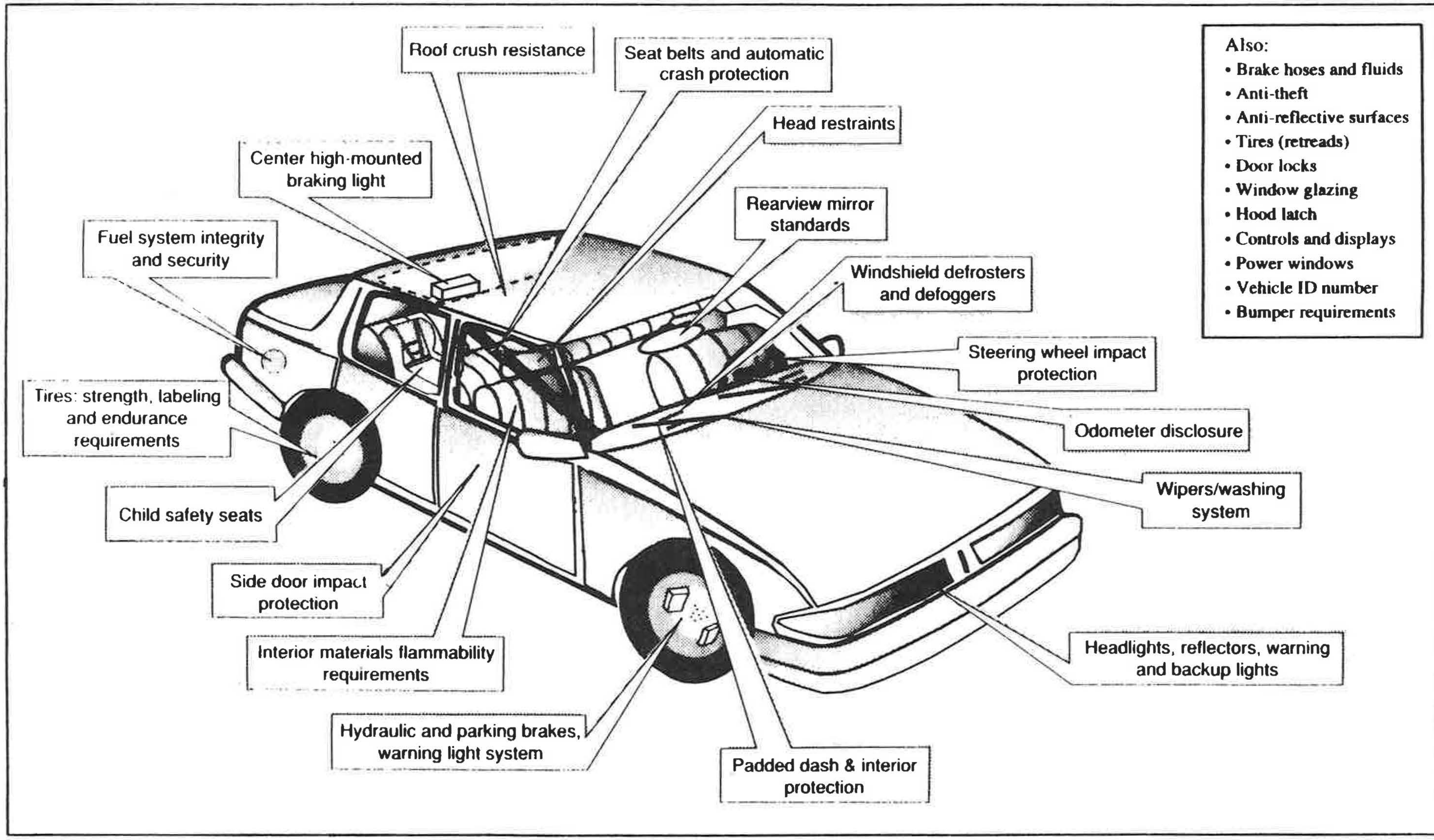

FIGURE 1 NHTSA's motor vehicle safety standards.

result from occupants contacting vehicle components displaced near or through the windshield.

Standard No. 301, Fuel System Integrity, specifies requirements for the integrity of the entire fuel system, including the fuel tanks, fuel pump, carburetor, emission controls, lines, and connections in severe front, rear, or lateral barrier impact crash tests. Manufacturers must also be able to demonstrate that fuel loss will not exceed one ounce per minute in s static rollover test following these barrier crash tests, as well as not exceeding these limits after, and incidental to, the crash tests.

Standard No. 302, Flammability of Interior Materials, specifies burn resistance requirements for materials used in the occupant compartment of motor vehicles in order to reduce deaths and fires causes by vehicle fires.

NHTSA has evaluated several of the crashworthiness safety standards including those pertaining to side door strength, restraint systems, roof crush resistance, and steering assemblies. As part of these evaluations, benefit estimations were developed. These are summarized in Table 1. Note that the benefits are representative only of the year on which the evaluation was based.

Historical and cumulative effects of safety standards can be estimated by adjusting the full fleet estimates in Table 1 for model year safety equipment content and fatality experience(4). Table 2 summarizes such estimates by year for each of the crashworthiness standards evaluated since 1967. Note that in some instances safety equipment was installed on some vehicles prior to the effective date of the standard. Therefore, although these estimates represent savings from the safety equipment that is required to meet safety standards, they do not necessarily correspond with the effective date of the standard.

NEW CAR ASSESSMENT PROGRAM

In 1978, the NHTSA began the crashworthiness assessment of new cars by conducting high speed 35-mph frontal barrier crash tests. The New Car Assessment Program's (NCAP's) primary goals are to provide consumers with a measure of the relative safety potential of automobiles and to establish market forces which encourage vehicle manufacturers to design higher levels of safety into their vehicles. NCAP represents the first program ever initiated to provide relative crashworthiness information to consumers on potential safety performance of passenger vehicles(5).

The test conditions for NCAP are based on years of development work conducted by NHTSA, the automobile industry, and others to develop the test devices and test procedures used in measuring compliance to the passive restraint requirements of FMVSS No. 208. For these requirements, certain injury criteria, as measured by the anthropomorphic dummies, are not to be exceeded in a 30 mph frontal barrier crash. The injury criteria apply to the head (as measured by a composite of acceleration values known as the Head Injury Criterion, or HIC), chest (as measured by chest deceleration, chest Gs), and upper leg (as measured by femur axial compression loads). These criteria are used to evaluate the compliance of vehicles to the safety standard and to assess the performance of the vehicles in the NCAP tests.

The major differences between the NCAP tests and the FMVSS No. 208 tests, which have been conducted for model year (MY) 1987 through 1994 passenger cars, are the nominal speed at which the tests are conducted (i. e., 30 versus 35 mph) and the use of all available restraint systems in the NCAP tests as compared to only the use of the passive restraint systems in the FMVSS No. 208 tests. (Note: The exception to this is the condition in which the vehicle has a driver air bag and a manual safety belt system for the right front passenger. In the FMVSS No. 208 test, the vehicle is then tested with the air bag as the restraint for the driver and the manual system for the passenger)[1]. Other minor variations between the two test conditions include that for the NCAP tests, dummies are not calibrated as often as in the FMVSS No. 208 tests, a load cell barrier is attached to the fixed rigid barrier, and additional instrumentation is used (e.g., load cells on the safety belts).

The NCAP crash tests are conducted at 35 mph in order to provide a level of impact severity sufficiently higher than the 30 mph FMVSS No. 208 test speed so that possible differences in frontal crash safety performance can be observed. As calculated from the kinetic energy, a 35 mph crash is about one-third more severe than a crash at 30 mph.

In these 35 mph crash tests, the vehicle experiences a total change in velocity, including rebound from the barrier, of approximately 40 mph. In a 30 mph crash test, the change in velocity is approximately 33 mph. From examination of the National Accident Sampling System (NASS) files, the fatality and injury rates for restrained front seat occupants are two to three times greater in a crash with a 40 mph change in velocity than in a crash with 33 mph change in velocity. For events in which crash severity is determined, the NASS files also show that more than 40 percent of the life-threatening (AIS 4 and greater) injuries and fatalities of occupants in frontal collisions occur in crashes with a change in velocity greater than 33 mph.

NHTSA has now conducted over 400 NCAP crash tests of different passenger cars, light trucks, and vans. The

TABLE 1 ANNUAL FLEET BENEFITS OF MAJOR CRASHWORTHINESS FEDERAL MOTOR VEHICLE SAFETY STANDARDS[4]

FMVSS	Fatalities	Injuries
201 Interior Impact	Up to 700	
202 Head Restraints		64,000
203,204 Steering Assemblies	1,300	
205,212 Windshield Glazing Installation	105	47,000
206,216 Door Locks & Roof Crush Resistance	510	
207 Seat Back Locks	None	None
213 Child Safety Seats	192	
214 Side Impact	480	9,400

data from the driver and passenger dummies are regularly released as part of NHTSA's Consumer Information Program as required by Title II of the Motor Vehicle Information and Cost Savings Act (15 U. S. C. 1942 et seq.).

With MY 1987 automobiles, the mandatory passive safety requirements of Federal Motor Vehicle Safety Standard (FMVSS) No. 208, "Occupant Crash Protection," were phased in. Prior to 1987, only a few vehicles had been voluntarily produced with passive restraint systems. These included General Motors, Ford, and Mercedes air bags and Volkswagen and Toyota passive belts. Beginning in MY 1987, the manufacturers selected either passive belts (2 or 3 point, non-motorized or motorized) or air bags to meet the FMVSS No. 208 requirements.

There are significant differences in the potential safety performance among passenger cars. Head Injury Criterion (HIC) values range from a low of 185 to a high of 4500. Even in model year (MY) 92 vehicles, these values range from a low of 282 to a high of 2021. This indicates that NCAP tests continue to provide consumers with occupant protection information which may be used in purchasing decisions.

Since 1979, significant measurable improvements have occurred in passenger car safety. The average for HIC has decreased by approximately 30 percent from a high of almost 1300 in 1980 to less than 1000 in 1992.

The percentage of passenger cars which meet FMVSS No. 208 requirements in the NCAP tests increased from less than 25 percent in 1979 to over 60 percent in 1992.

The percentage of passenger cars in the higher risk group (HIC exceeds 1250, and/or chest acceleration exceeds 70 gs, and/or femur loads exceed 3000 lbs.) has significantly declined from the early years of NCAP. In MY 1979, more than 50 percent of the passenger cars were in this higher risk group. In MY 1992, less than 25 percent are in this group. Accident data indicate that passenger cars in the lower risk group may expose restrained occupants to significantly lower fatality rates in frontal collisions.

Positive actions have been taken by the manufacturers to institute significant improvements in passenger car safety performance. Many specific examples of vehicle makes and models which were improved after initial NCAP tests can be cited. In some cases, the manufacturers modified the existing model and in other cases the improved safety was incorporated in a complete redesign of the model. Changes incorporated into specific makes and models by the manufacturers reduced high dummy responses by as much as 75 percent.

In addition to the overall trends which have shown the influence of NCAP in improving vehicle safety performance, many specific examples of vehicle makes and models which were improved after initial NCAP tests can be cited.

Two early examples in the program occurred with Volvo and Mercedes models. Each of these manufacturers have traditionally advertised the safety aspects of their vehicles. In 1979, a Volvo 244 DL and, in 1980, a Mercedes 240D, were tested in NCAP. Surprisingly, both of these vehicles had high driver and passenger HIC values. Examination of the safety belts of these vehicles indicated unsatisfactory belt reel-out from the retractors due to excessive belt lengths. This

TABLE 2 ESTIMATED ANNUAL AND TOTAL FATALITY BENEFITS RESULTING FROM CRASHWORTHINESS SAFETY STANDARDS, 1967-1990[4]

Year	201	203, 204	205, 212	206, 216	208, 209 210, 213	214	Total
1967					520		520
1968	82	140	7		777		1,005
1969	116	198	17	36	1,081	60	1,508
1970	297	506	32	90	1,334	48	2,307
1971	381	649	47	139	1,614	102	2,932
1972	488	830	65	197	2,296	142	4,018
1973	561	955	80	242	2,425	203	4,466
1974	517	868	75	240	2,501	186	4,387
1975	539	903	79	272	2,163	243	4,199
1976	590	980	97	314	1,936	285	4,202
1977	645	1,065	98	359	1,882	334	4,383
1978	726	1,174	110	411	1,445	391	4,257
1979	744	1,202	113	445	1,250	417	4,171
1980	752	1,215	116	465	1,280	439	4,267
1981	742	1,196	115	467	1,297	442	4,259
1982	666	1,059	102	418	1,138	402	3,785
1983	690	1,096	106	423	1,370	423	4,108
1984	698	1,109	111	447	1,696	441	4,502
1985	681	1,080	106	464	2,506	438	5,275
1986	733	1,182	118	508	3,495	482	6,518
1987	738	1,190	119	512	4,234	497	7,290
1988	757	1,223	122	537	4,823	515	7,977
1989	736	1,186	118	527	4,813	500	7,880
1990	710	1,145	114	507	5,000	482	7,958
Total	13,588	22,151	2,067	8,020	52,876	7,472	106,174

condition allowed severe head contacts to occur between the driver dummies and the steering assemblies, and between the passenger dummies and the instrument panels. Both manufacturers made significant design changes to eliminate these safety problems. Results of their models in succeeding years indicate the success of their changes.

Notable examples occurred when initial tests of several apanese models resulted in very high dummy responses. These models included the Honda Civic and Prelude, the Mazda 626 and RX-7, and the Toyota Celica, Corolla, and Cressida. Factors which contributed to the poor performance of these models in these initial tests may have included inadequate energy management of

TABLE 3 NCAP EXAMPLES OF VEHICLE SAFETY IMPROVEMENTS

VEHICLE IDENTIFICATION			DUMMY RESPONSE PARAMETERS							
MAKE	MODEL	MY	HICD	HICP	CGD	CGP	LFEMD	RFEMD	LFEMP	RFEMP
VOLVO	DL	79	1782	1889	52	61	320	900	700	320
VOLVO	DL	82	550	381	45	35	154	1147	892	227
VOLVO	DL (SW)	85	621	262	33	31	100	1005	630	615
VOLVO	DL	85	651	310	36	25	350	1020	590	
MERCEDES	240D	80	1262	1369	54	44	674	1687	666	1449
MERCEDES	300SD	84	890	734	63	44	1410	1150	295	490
MERCEDES	190E	90	800	833	60	58	705	1028	582	331
DODGE	COLT	82	932	1730	72	44	517	782	506	276
DODGE	COLT	85	787	741	42	32	480	460	1090	370
RENAULT	MEDAL.	88	1656	873	57	38	205	617	411	1193
EAGLE	MEDAL.	89	745	589	41	39	1721	1738	1574	1670
FORD	GRANADA	79	1442	1279	61	56	1750	350	390	570
FORD	GRANADA	82	860	1050		52	980	800	460	340
FORD	TAURUS	86	1209	695	53	37	828	1485	566	502
FORD	TAURUS	88	707	359	38	47		775	455	438
FORD	TEMPO	84	2955	1104	63	45	750	480	675	370
FORD	TEMPO	85	1207	932	52	40	870	580	440	310
FORD	TEMPO	88	721	470	47	50	1113	1773	1037	702
HONDA	CIVIC	79	2030	2093	93	46	1080	838	1520	1460
HONDA	CIVIC	80	2626	1506	54	47	1006	3118	418	218
HONDA	CIVIC	81	607	492	41	35	200	500	1100	540
HONDA	CIVIC	84	563	846	37	43	1067	602	1566	1275
HONDA	PRELUDE	80	2904	1759	52	45	445	1057	465	277
HONDA	PRELUDE	84	659	475	43	31	600	510	690	980
HYUNDAI	EXCEL	86	999	2662	73	55	2248	785	1597	520
HYUNDAI	EXCEL	87	757	345	54	46	2408	1794	1187	1006
HYUNDAI	EXCEL	87	716	1003	55	43	790	345	1360	775
HYUNDAI	EXCEL	90	696	419	41	39	1385	1921	1682	964
MAZDA	626	82	969	1693	47	50	575	1215	550	250
MAZDA	626	83	1196	1087	45	56	450	350	260	360
MAZDA	626	87	846	801	52	46	820	1300	1487	1255
MAZDA	RX-7	85	921	1345	40	42	369	476	604	809
MAZDA	RX-7	88	921	614	39	48	186	1135	268	650

TABLE 3 (continued)

VEHICLE IDENTIFICATION			DUMMY RESPONSE PARAMETERS							
MAKE	MODEL	MY	HICD	HICP	CGD	CGP	LFEMD	RFEMD	LFEMP	RFEMP
VOLVO	DL	79	1782	1889	52	61	320	900	700	320
MERCURY	SABLE	86	1237	680	48	44	1039	1780	671	465
MERCURY	SABLE	88	712	410	51	35		1512	862	913
PONTIAC	FIREBIRD	79	965	1297	42	47	582	472	503	717
PONTIAC	FIREBIRD	83	408	376	34	32	900	480	100	125
AAB	9000	86	773	1443	71	46	484		541	421
SAAB	9000	87	584	440	37	35	120	346	435	638
TOYOTA	CELICA	79	849	1862	61	59	2920	435	400	520
TOYOTA	CELICA	82	702	530	36	45	456	448	360	359
TOYOTA	CELICA	86	627	430	42	40	382	721	439	593
TOYOTA	CELICA	90	834	685	50	37	1071	1190	406	609
TOYOTA	COROLLA	80	838	1162	69	92	740	775	200	270
TOYOTA	COROLLA	82	842	828	59	40	1400	1178	888	507
TOYOTA	COROLLA	84	630	611	41	42	1320	730	340	395
TOYOTA	COROLLA	89	994	546	49	45	1101	894	451	681
TOYOTA	COROLLA	84	432	602	37	47	1100	450	580	300
TOYOTA	COROLLA	88	593	397	42	40	719	1162	300	393
TOYOTA	CRESSIDA	81	1980	771	55	50	1710	1982	1644	1807
TOYOTA	CRESSIDA	85	883	914	50	58	1725	1820	1355	1820
TOYOTA	CRESSIDA	89	790	544	51	51	1632	1554	1246	1107
VW	JETTA	81	1210	1272	68	52	1276	1191	1559	1286
VW	JETTA	85	898	1008	50	51	362	396	711	516
AUDI	4000	80	1322	1428	70	45	408	353	1030	527
AUDI	5000	85	2105	557	39	31	362	357	292	326
AUDI	100	89	185	710	35	31	998	571	894	757

the crash forces (i. e., poor structural design), excessive intrusion and inappropriate collapse characteristics of the steering assembly and instrument panels, and inferior safety belt parameters. The data in Table 3 indicate the manufacturers' positive reactions to improve the safety performance of these models. In some cases, the manufacturers modified the existing model, and in other cases the improved safety was incorporated in a complete redesign of the model. Relative to the improvements in potential occupant protection, the results, as shown in the table, were exceptional. HIC values were reduced by as much as 75 percent and chest Gs and femur loads were reduced by 50 percent or more.

Other interesting examples have occurred with the beginning of the New Car Assessment "Optional Test"

Program in 1986. This program gives to the manufacturers the option to request a test or retest of a particular vehicle model, based on design changes to a previously tested model or the introduction of innovative safety features. This optional test is sponsored by the manufacturer but conducted by following the NCAP test procedures under NHTSA control at a NHTSA approved test site.

The Mercury Sable, the Ford Taurus, and the Audi 100 are examples of models which have been tested in this optional program. For the Sable and the Taurus, the manufacturers incorporated design changes after the initial NCAP tests were conducted. The retests indicate the potential for improved occupant protection.

For the Audi 100, the manufacturer requested the optional test because of innovative safety features, which included a driver air bag and unique safety belt pre-tensioning devices. All dummy responses were low in the Audi 100 test with the driver HIC of 185 being the lowest HIC ever recorded in the NCAP 35 mph test. The manufacturer (Audi) has used these data extensively in advertising campaigns to inform consumers of the occupant safety provided by the Audi 100. Data are shown in Table 3 of other Audi models. These data show the inferior NCAP performance of previously tested Audi models. The comparison between the previous Audi models and the new Audi 100 and the use of the Audi 100 NCAP results in the advertising campaigns may represent a change in philosophy by the manufacturer toward NCAP safety performance.

Table 3 contains several other examples from different manufacturers which illustrate the capabilities to introduce improvements in safety performance in particular makes and models.

SUMMARY

Over the years, crashworthiness improvements to passenger cars have been implemented due to standards issued for roof crush resistance, seat belts and automatic protection, head restraints, steering wheel impact protection, padded dash and interior protection, side door impact protection, child safety seats, fuel system integrity, door locks, window glazing, and bumper requirements. Another agency program, the New Car Assessment Program (NCAP), provided motivation for manufacturers to improve some aspects of safety design beyond that required by the safety standards. In responding to NCAP, manufacturers have improved the poorer performance resulting from inadequate energy management of the crash forces (i.e., poor structural design), excessive intrusion and inappropriate collapse characteristics of the steering assembly and instrument panels, and inferior safety belt parameters.

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