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SIMULATION ANALYSIS OF HEAD/NECK IMPACT RESPONSE FOR HELMETED AND UNHELMETED MOTORCYCLISTS

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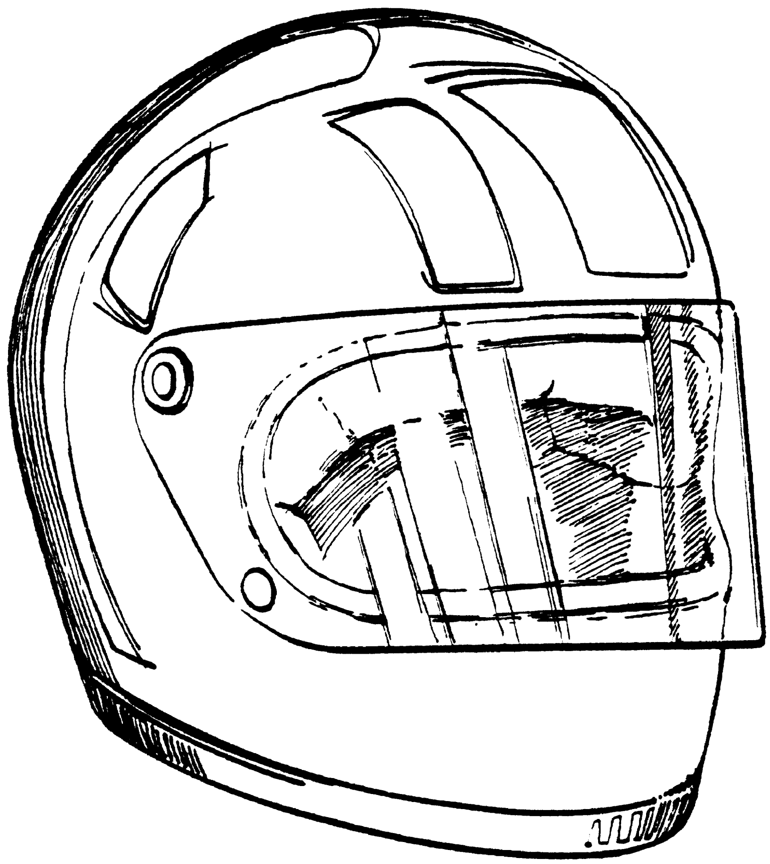

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16. Abstract

The purpose of this study was to determine by use of computer simulations both quantitative and qualitative measures of the effectiveness of motorcycle helmets in reducing head and neck injuries in motorcyclist impacts. The computer model used was the MVMA Two-Dimensional Crash Victim Simulation. The study investigated a wide variety of impact conditions in order to establish a broad overall view of the effectiveness of helmet use. The potential of the helmet to both beneficially and detrimentally affect head and neck response was examined. It was found that helmet use invariably lessens the exposure levels of dynamic responses which have a role in producing head injury. In addition, the study finds helmet use to almost always reduce the severity of neck response as well and for no simulation configuration or condition to greatly increase the likelihood of neck injury. Thus, in the spectrum of real-world motorcyclist impacts, helmet use is predicted to significantly reduce the overall likelihood and severity of both head and neck injuries.

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The opinions, findings, and conclusions expressed in this report are those of the authors and do not necessarily reflect the views of the Insurance Institute for Highway Safety.

1.0 INTRODUCTION AND BACKGROUND

1.1 Introduction

Motorcycle crash investigation data from many countries show that the use of helmets results in fewer head injuries and fatalities. Few would disagree that helmets reduce the likelihood and severity of sharp and blunt trauma to the head resulting from head impacts. The effect of helmet use on neck response, however, is not well understood. Many studies have indicated that the wearing of helmets does not increase the probability of sustaining neck injuries, but controversy on this point exists. Of those concerned with the effectiveness of helmet use many from the engineering and medical professions and from the lay public believe that the mass of the helmet might cause severe loading of the neck structure during a crash event. Another view is simply that, apart from mass effects, if the head is protected, then greater energy must be absorbed by the neck. These views cannot be countered by epidemiological data at the present time because of both the difficulty in diagnosing neck injury in those cases where the cyclist is not killed and lack of a well-defined neck autopsy protocol in those cases where the cyclist is killed.

In the past few years, opponents of mandatory helmet laws have used the unsubstantiated claim of an adverse role of helmets in neck injury causation as partial justification for having the laws repealed. As there is much public demand and legislative support in many states for the repeal of helmet laws, the burden of proof may lie with proponents of the helmet laws, i.e., to show that helmets do not play this adverse role. In a review article, Versace (1977) states that "while the evidence does not support the theory that the helmet is a causal factor in the incidence of neck injury, the state-of-the-art does not provide sufficient data at this time which would indicate that the helmet does not increase the incidence of neck injury." It is the purpose of the current study to expand the state-of-the-art so that this question and others pertaining to helmet use can be answered.

1.2 Background and Methodology

Because there is a lack of sufficient epidemiological data to answer many pertinent questions and because many questions pertaining to the performance of protective headgear cannot be approached from within an epidemiological framework, an alternative approach was taken in this study -- that of mathematical modeling.

An exhaustive search of the literature has shown that very few studies have used computer simulation of dynamic response of the head and neck to investigate helmet performance. Further, those few studies have all used simple mathematical models of limited ability to investigate the many aspects of impact response of the helmeted head and neck. Bishop (1976a, 1976b) has evaluated ice hockey helmet design by using a model which considers only one angular and one linear degree of freedom for a single, combined head/neck mass. The helmet liner is represented by a simple spring-dashpot element. Metz and Ruhl (1973) investigated the influence of crash helmets on whiplash neck torques. No direct head impacts were investigated in that study. Metz and Ruhl used a model with a single torso mass, a two-link neck, and a single head/helmet mass. McElhaney, et al. (1971) studied helmet performance with a one-dimensional model which represented the head by a spring and dashpot and two masses, one representing bone and scalp adjacent to the impact impulse and one representing the remainder of the head mass. A helmet mass was coupled with the head by a spring and a dashpot which represented the liner. McElhaney's simulations did not model the neck or torso. Khalil, et al. (1974) and Liu and Chandran (1975) have predicted strains and pressures in the brain resulting from impact of the helmeted head. Their models are for impacts of idealized fluid-filled containers and neither considers whole body motions or includes representation of the neck or torso.

The current study uses a fourteen degree of freedom, whole-body motion model which emphasizes accurate representation of the human body as a biomechanical system -- the MVMA Two-Dimensional Crash Victim Simulation model (Bowman, et al.,1974, 1977, 1979). This model has been used with great success in a number of studies over the past six years. These include studies which concentrated on head/neck response (Schneider, et al., 1976; Alem, et al., 1977, 1978). In a recent study (Snyder, Foust, and Bowman, 1977) the model was used for simulation of impact events of much the same type as those investigated in the current study. Included in the study by Snyder, et al., were (unhelmeted) head impacts of human free-fall victims against unyielding "ground" surfaces. In that study, the ability of the model to predict accurately the dynamic response for impacts of this type was demonstrated by simulation of drop tests of instrumented anthropomorphic dummies.

The research described in the following report had several goals: 1) to answer previously unaddressed questions regarding neck response for helmeted and unhelmeted head impacts; 2) to model a range of cyclist impact situations accurately enough to provide useful quantitative measures of both head and neck responses; 3) to provide a basis for limited statements relating to helmet design; and finally, 4) to establish a broad overall view of the effectiveness of helmet use by investigating the potential of the helmet to both beneficially and detrimentally affect head and neck response.

2.0 COMPUTER SIMULATION METHODS

Section 3 of this report describes the types of motorcyclist impact configurations simulated in this study and also the specific crash conditions and parameter variations investigated. Results are presented in Section 5. This section explains some of the more important aspects of the computer simulation techniques used.

2.1 The MVMA Two-Dimensional Crash Victim Simulation Model

Computer simulations of motorcycle driver horizontal and vertical surface impacts were made with the MVMA Two-Dimensional Crash Victim Simulator, developed at the University of Michigan Highway Safety Research Institute. This model includes the following features in its representation of the human body:

1. A nine-mass, ten-segment body linkage;
2. An extensible, two-joint neck and a realistically flexible shoulder complex;
3. Energy-absorbing joints;
4. Time-dependent muscle activity level;
5. Contact-sensing ellipses of arbitrary size, position, and number which define the body profile; and,
6. General and arbitrarily definable nonlinear materials with energy-absorbing capability for all parts of the body.

The MVMA 2-D CVS model has found wide application by researchers in the fields of biomechanics, automotive safety design, and highway safety research in general. One particular study in which the model was used, "Study of Impact Tolerance Through Free-Fall Investigation," sponsored by the Insurance Institute for Highway Safety, provided the basis for much of the modeling required in the current study (Snyder, et al., 1977; Foust, et al., 1977; Mohan, et al., 1979). The first reference, Snyder, et al., 1977, in particular, details the development of biomechanical and anthropometric data required for modeling the human body in these simulations.

The MVMA 2-D model is completely documented in the three-volume report, "MVMA Two-Dimensional Crash Victim Simulation, Version 4" (Bowman, et al., 1979). It is described in less detail in "The MVMA Two-Dimensional Crash Victim Simulation," (Robbins, et al., 1974).

2.1.1 The Body Linkage. The MVMA 2-D model body linkage is illustrated in Figure 2-1. Ten physical links are represented. The spinal column of a human being is more or less continuously flexible since it is composed of thirty-three vertebrae and intervening fibrocartilaginous discs. The model simulates flexibility of the combined thoracic and lumbar spines by two articulations, which connect three torso links. These are joints 3 and 4 in the figure. Flexibility of the cervical spine is accounted for by two articulations, one at the occipital condyles and one at the seventh-cervical/first-thoracic juncture (C7-T1), joints 1 and 2, respectively.

Nine masses are associated with the ten links. The neck link L_n is extensible and compressible and has non-zero mass, while the shoulder link (9-7) has no mass but is included in the model to account for

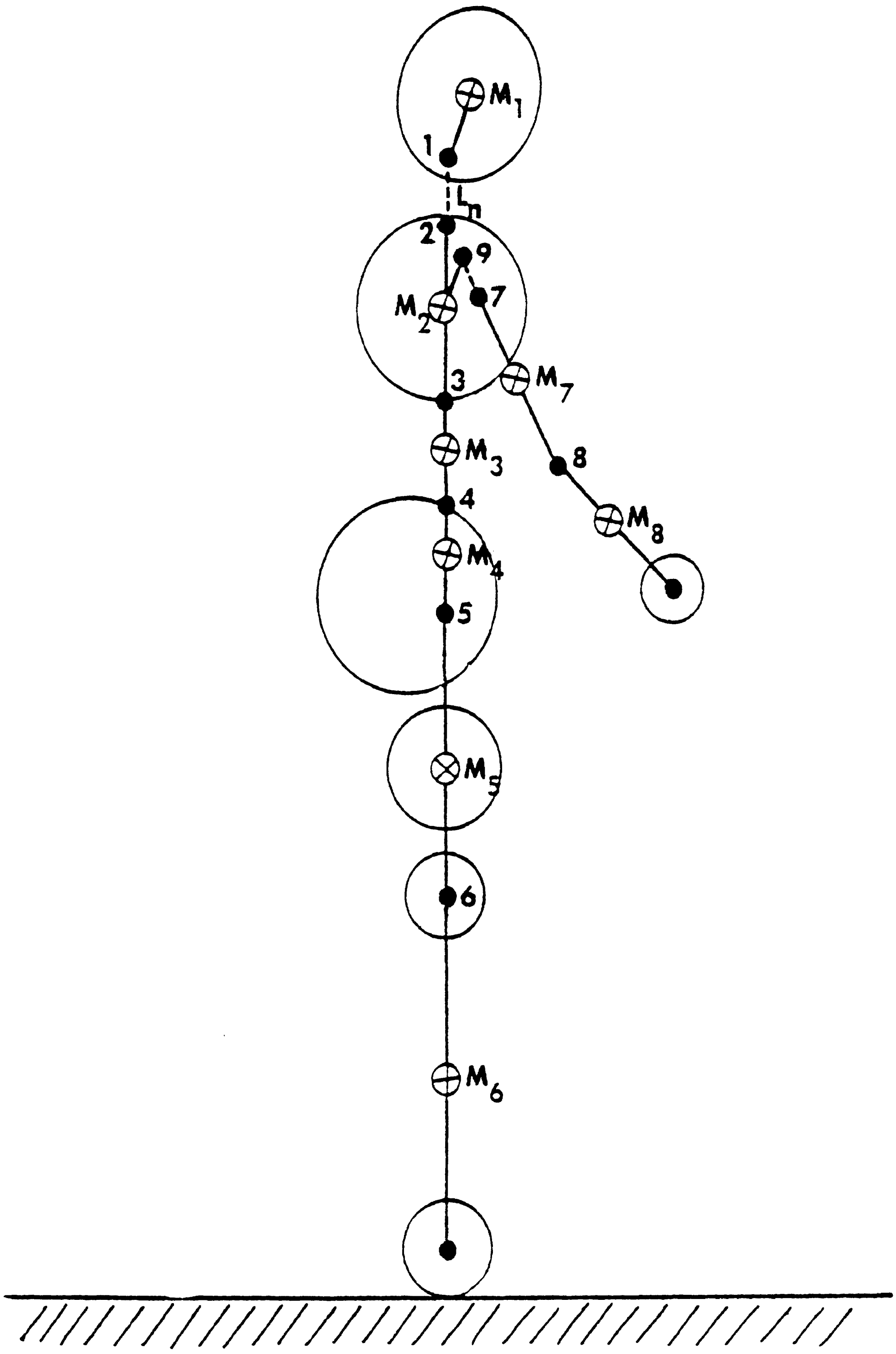


Figure 2-1. MVMA 2-D CVS Body Linkage

sagittal-plane claviscapular shrugging motions. All other links are inextensible and articulate at the joint positions illustrated.

Figure 2-2 illustrates most of the anthropometric measures used in development of an MVMA 2-D linkage data set for the 5 foot 10 inch, 170 pound adult male of the motorcycle driver impact simulations. The measures indicated (and others such as link masses and moments of inertia) were available from various anthropometric studies. Their use in the construction of data sets for the MVMA 2-D CVS model is described in the previously mentioned free-fall study report, Snyder, et al., 1977.

2.1.2 The Joint Model. Resistance to motion between adjacent body links is present in joint structures of the human body. There are passive resistances that result from deformation of both soft and hard connective tissues, and resistance to motion increases when musculature acting about the joint is contracted. Viscoelastic joint elements for both types of resistance are represented in the MVMA 2-D model.

The MVMA 2-D joint model is explained fully by Bowman, et al.(1977,1979). The passive elements are represented in a very general manner so that experimentally determined loading and unloading characteristics of joint structures can be properly modeled. The muscle elements are series combinations of spring and damper components, where the spring and damping coefficients are both functions of the time-dependent level of muscle activation. In this study, it was felt that muscle activity about joints other than the neck would not be a significant factor.

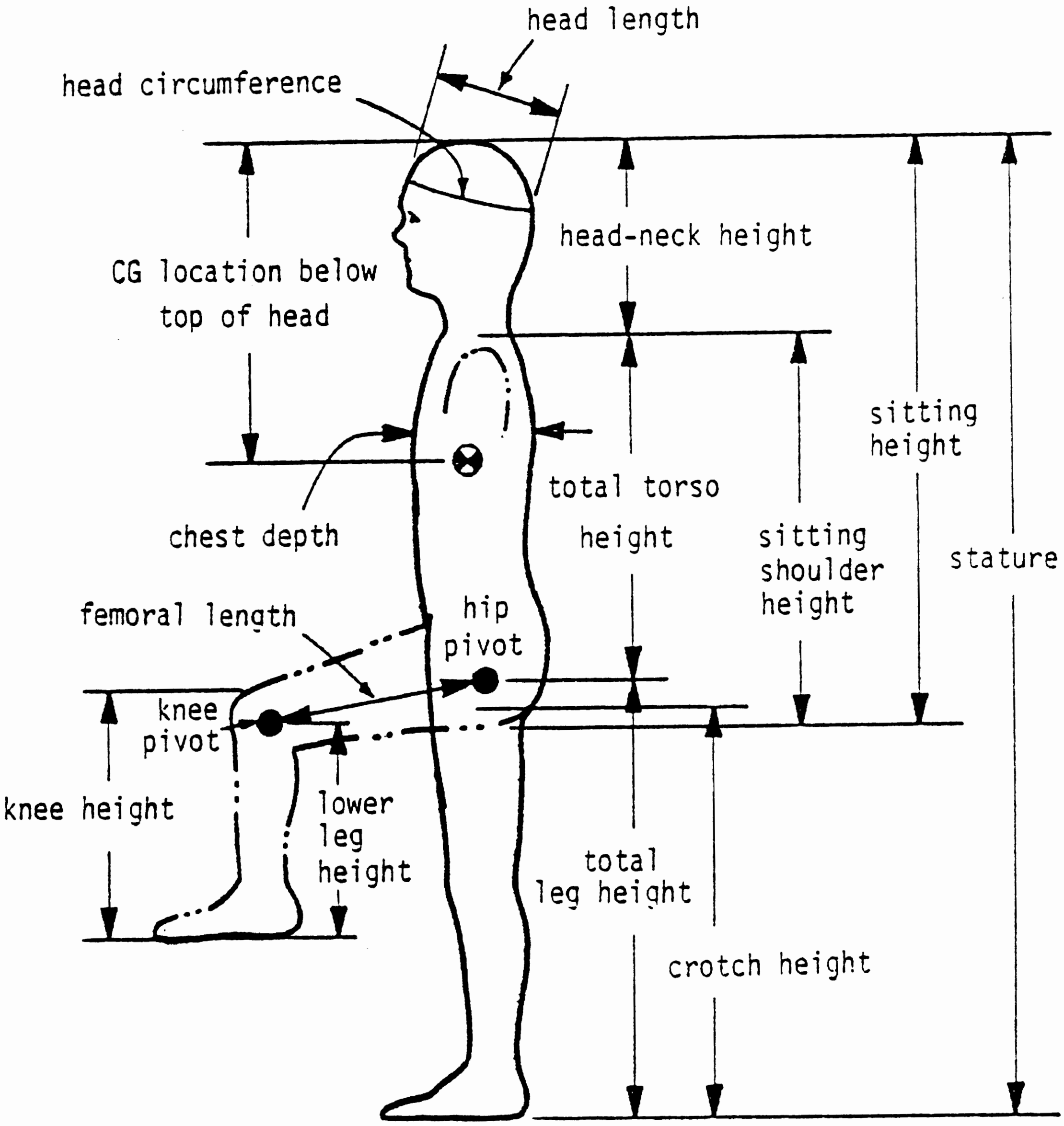


Figure 2-2. Anthropometric Dimensions

The neck joints were, therefore, the only ones for which these elements were represented.

2.1.3 The Body Profile and The Crash Environment. In order that the computer model be able to predict force-producing interactions between the simulated human and his environment, sets of potentially-interacting, geometrical profiles must be defined along with the other input data. For the motorcycle driver simulations, the environment consists either of straight-line segments representing the back of a truck, primary impact being against a vertical surface, or a single, horizontal line representing a road surface. (The four types of impacts simulated in this study are illustrated in Section 3.)

The contact-sensing body profile in the MVMA Two-Dimensional CVS is a set of ellipses of arbitrary number and dimensions, fixed to body links at arbitrary positions. Material properties may be assigned for each ellipse, or any ellipse can be specified as rigid. For the motorcycle driver model, the profile of ellipses was defined so as to: 1) approximate the body dimensions and 2) provide reasonably accurate compliances for the different body parts.

2.1.4 Material Properties. Material properties are prescribed for each of the body contact ellipses and for each straight-line segment describing the crash environment. The MVMA 2-D model does not use defined constitutive properties, but instead requires load-deflection characteristics and information relating to hysteretic energy loss and permanent deformation upon unloading.

2.2 Biomechanical and Helmet Simulation Constants

Development of data suitable for describing the human subject in an MVMA 2-D CVS simulation is fully described in Snyder, et al., 1977. Several aspects of the biomechanical model that are of particular importance in the current study will be described here in some detail. All simulations in this study involve head or chest impacts so loading and unloading characteristics of head and chest will be discussed. Also, since dynamic head and neck response are of primary interest, neck properties will be discussed. The helmet model is described in Section 2.2.4.

2.2.1 Head Properties: Adults. McElhaney, et al., 1973 (and in King et al., 1973) have reported A-P and L-R static load-deflection curves measured by Messerer (1880). The A-P curves for twelve fresh, intact cadaver heads (all adults) are shown in Figure 2-3 and were used in this study as the basis for modeling skull stiffness. Also shown in the figure is a two-segment "best fit" to the twelve curves. The portion of the curves for deflections less than 0.04 inches is unimportant since its energy content is negligible.

Both the anterior and posterior hemispheres of the skull deform significantly in a static test since the skull is subjected to external forces on both sides. Thus, in a static test, the skull behaves like two (nonlinear) springs in series, as illustrated in Figure 2-4. The effective stiffness for such a system is less than for either component. For example, if each component is linear, then

$$k_{eff} = \frac{K_1 \; K_2}{K_1 + K_2} = \frac{K_1}{1 + \frac{K_1}{K_2}} = \frac{K_2}{1 + \frac{K_2}{K_1}} \; .$$

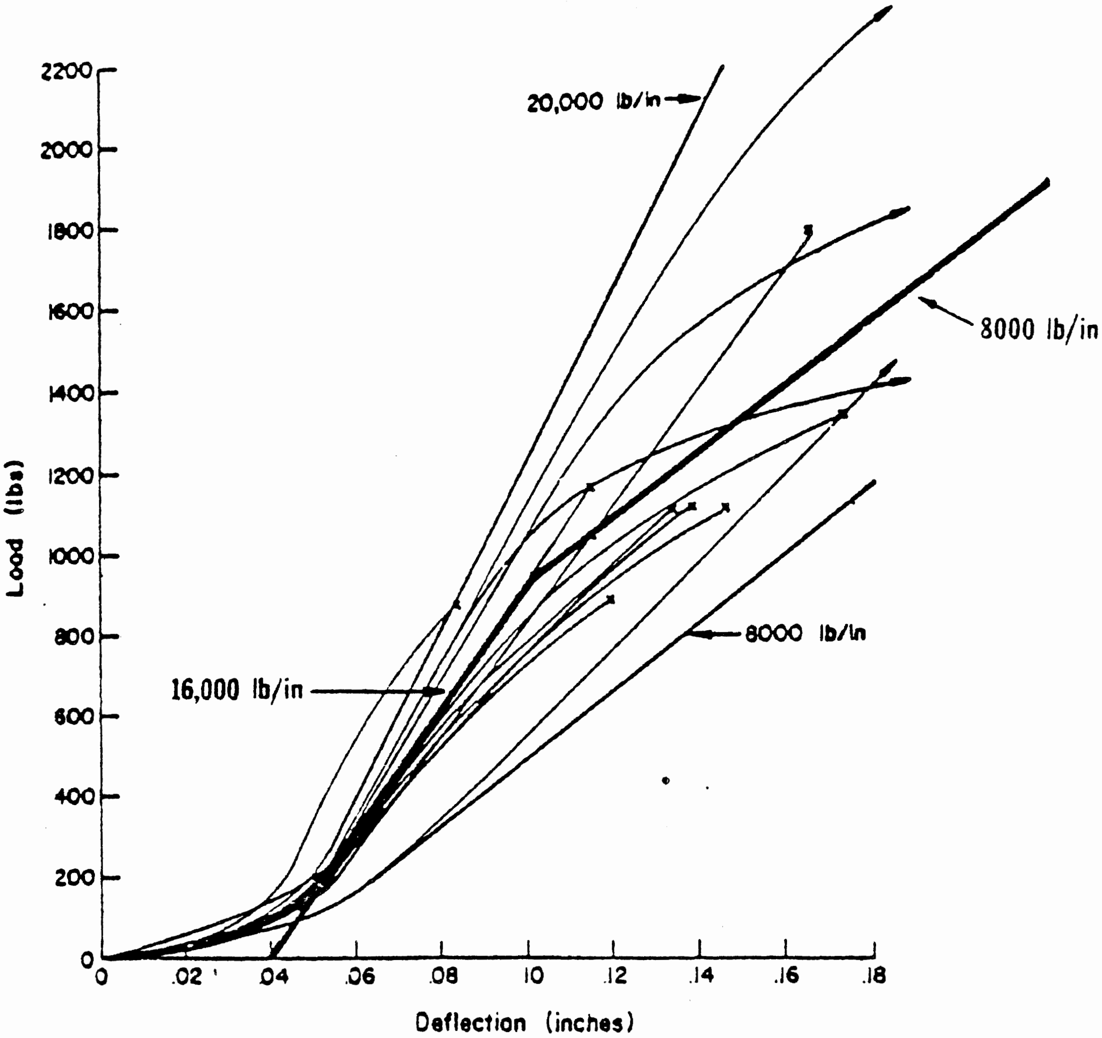


Figure 2-3. A-P Static Force-Deflection Curves for the Adult Head

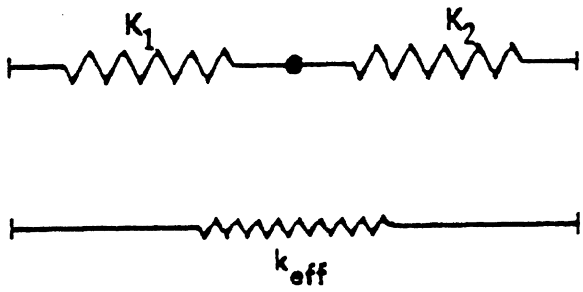
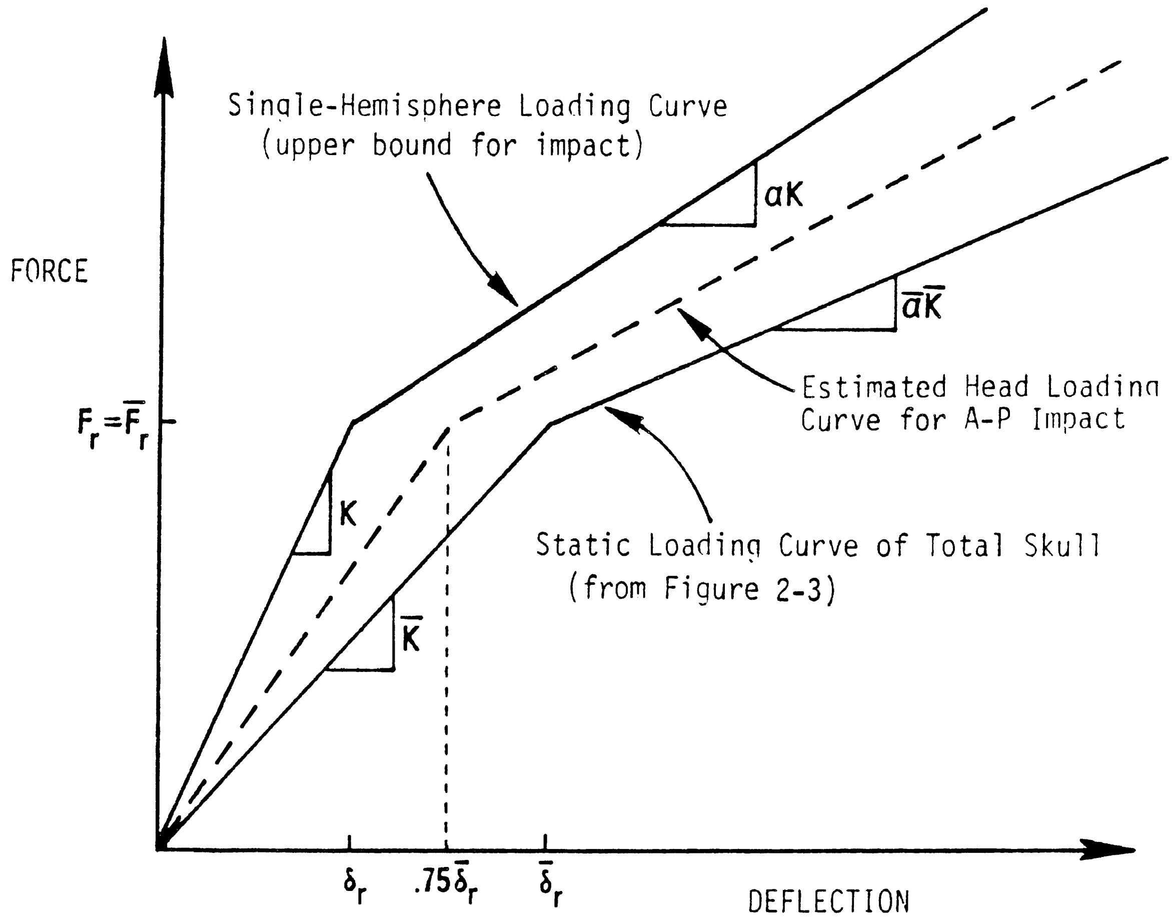


Figure 2-4. Effective Stiffness of Springs in Series

This is clearly less than both K_1 and K_2. If K_1 and K_2 are equal, which is probably approximately true for the anterior and posterior hemispheres of the skull, then $k_{eff} = K_1/2$.

Since the curves in Figure 2-3 were obtained for static loading, the two-segment fit is not completely appropriate for use in simulation of an impact event. During impact loading, the absence of an external force on one side of the skull limits deformations primarily to one hemisphere. In terms of the simple model shown in Figure 2-4, the impact stiffness is K_1 or K_2, both of which are greater than k_{eff} from a static test.

For the purpose of developing a force-deflection curve for head impact, it was assumed that the stiffnesses of the two skull hemispheres are equal. It is necessary, then, to determine the characteristics of identical single-hemisphere, nonlinear components of a series element which has the two-segment (nonlinear), best-fit, static curve of Figure 2-3 as a loading curve. The derivation of the component curves will not be presented here, but results are shown in Figure 2-5.



$K = 2\overline{K}$	$F_r = \overline{F}_r$
$\overline{\alpha} = \alpha$	$\delta_r = \overline{\delta}_r/2$

$\overline{K}$ = slope of first segment, total skull

K = slope of first segment, single hemisphere

$\overline{\alpha}$ = ratio of slope of second segment to slope of first segment, total skull

α = ratio of slope of second segment to slope of first segment, single hemisphere

$\overline{\delta}_r$ = deflection at end of first segment, total skull

δ_r = deflection at end of first segment, single hemisphere

$\overline{F}_r$ = force at end of first segment, total skull

F_r = force at end of first segment, single hemisphere

Figure 2-5. A-P Load-Deflection Curves for Human Head

The derived single-hemisphere loading curve illustrated in this figure would be appropriate as the head loading curve for A-P impact if the opposite hemisphere did not undergo deformation. However, while most of the total deformation can be expected to be in the impacted hemisphere, some must be associated with flexure of the opposite hemisphere. Therefore, the true impact loading curve lies within an envelope bounded above by the single-hemisphere curve and below by the total-skull curve. As no means could be determined for placing the curve within this envelope, the dashed mid-line curve was taken as the head loading curve for impact of the adult skull. The parameters of the two-segment curve are $K' = 1.5\bar{K}$, $\alpha' = \bar{\alpha}$, and $\delta'_r = .75\ \bar{\delta}_r$. As values $\bar{K}$ = 16000 lb/in, $\bar{\alpha} = .5$, and $\bar{\delta}_r = .06$ may be taken from Figure 2-3, the slopes of the two segments of the impact loading curve are K' = 24000 lb/in and $\alpha'K'$ = 12000 lb/in, with the first segment ending at δ'_r = .0457 in.*

Figure 2-6 shows the complete impact loading curve derived for the simulations in this study. The curve consists of the two straight-line segments discussed above and a portion for deflections greater than 0.4126 inches and loads greater than 5500 lb, where skull fracture is represented. The parameters of the fracture section of this curve resulted from personal communication with a researcher at HSRI who has carried out impact testing of adult human cadaver skulls (Nusholtz, pers.comm., 1978). That testing did not result in skull fracture for impact loads less than 5500 lb to any part of the skull. Skull fracture was not attained in any of the computer simulations in this study.

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* The stiffness of 24000 lb/in compares with Stalnaker's (1970) value of 26000 lb/in determined for small deflections by driving point impedance testing of a single cadaver skull.

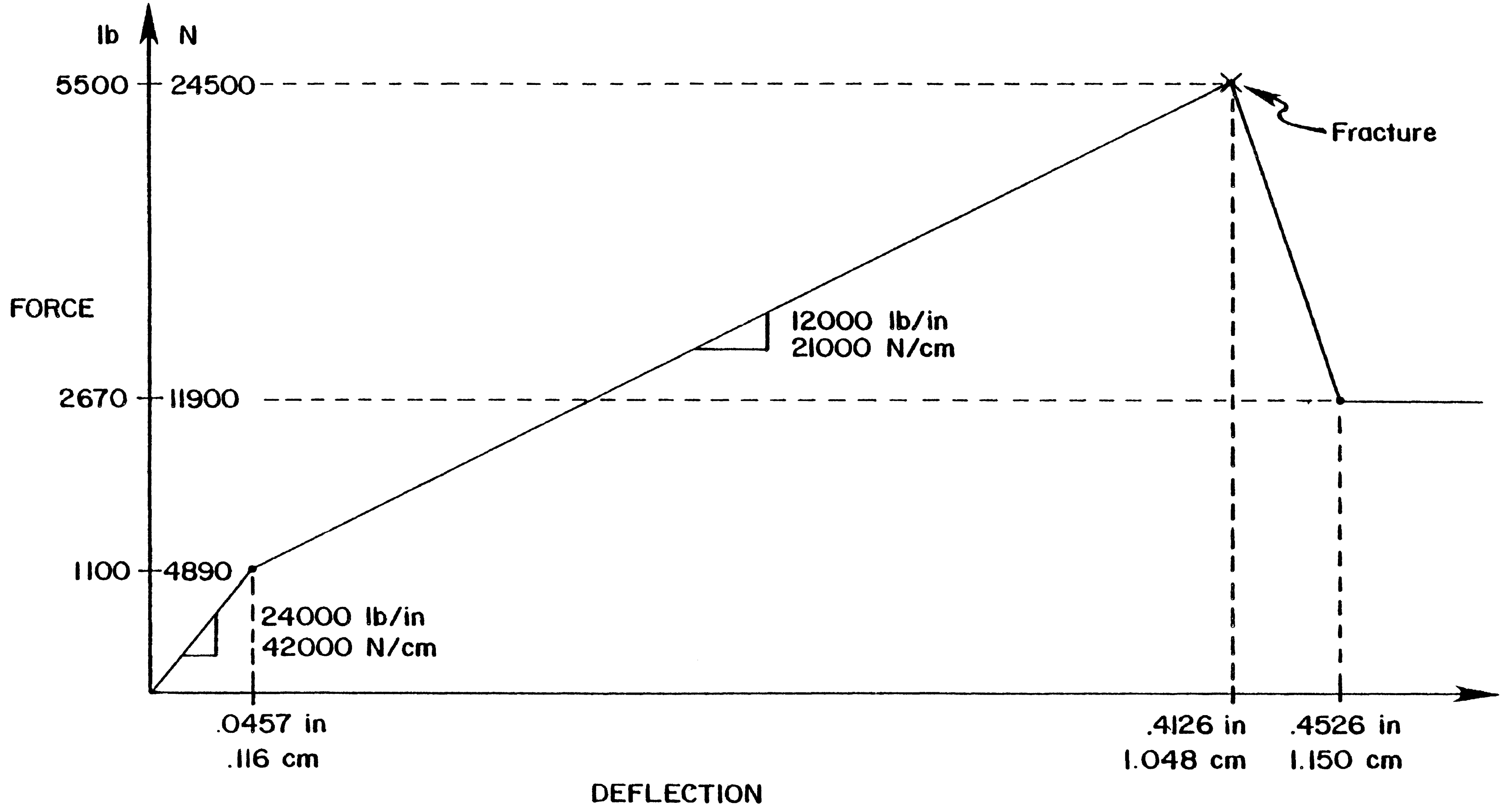

Figure 2-6. Head Loading Curve for A-P Impact

Unloading is not illustrated in Figure 2-6, but the MVMA 2-D CVS model allows specification of characteristics for a general hysteretic unloading with energy absorption and permanent deformation. It is known that the human skull is very elastic until fracture occurs so the simulations assumed 20% energy absorption at the non-fracture limit deflection (0.4126 inches) and proportionately less for maximum deflections that are smaller, the skull being completely elastic in the limit as maximum deflection approaches zero. With regard to permanent deformation, it is assumed that none occurs for deflections less than the fracture deflection. For greater deflections, energy absorption and permanent deformation vary linearly with maximum (or "turnaround") deflections to 85% and 70% respectively at 0.4526 inches. It should be mentioned that the primary impact responses predicted in the MVMA 2-D model simulations are not affected by the accuracy of the unloading parameters since peak accelerations and peak forces occur during loading, not during rebound.

2.2.2 Chest Properties. Lobdell, et al. (1973) report blunt impact force-deflection response of the chest for male and female, embalmed and unembalmed cadavers. Figure 2-7 shows the average force-deflection curve for eight unembalmed, adult cadavers for 16-mph impacts with a 51 lb. striker.* Standard test procedures were used with a striker of six-inch diameter. Six of the cadavers were male and two were female, but there were no significant differences in peak dynamic loads (13%, max-to-min).

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* Lobdell, et al., adjusted their original data by a constant 150 lb. to account for maximal muscle tensing.

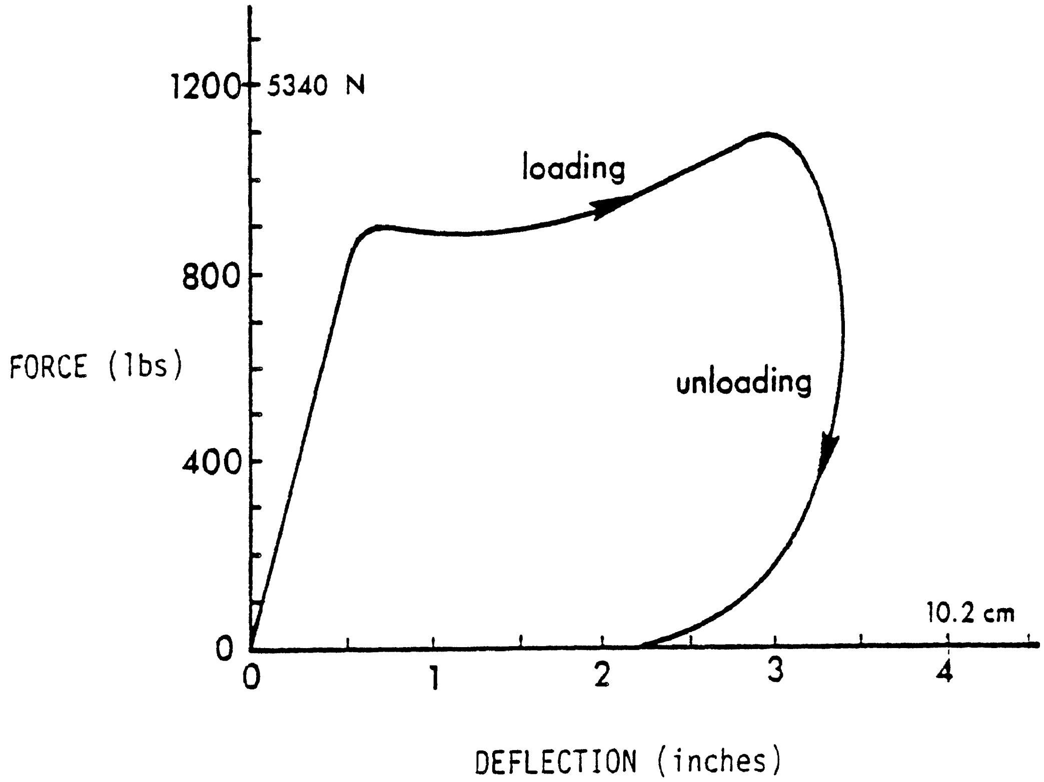

Figure 2-7. Average dynamic force-deflection characteristics of the chest for unembalmed cadavers using 51 lb (23.1 kg) striker at 16 mph (25.7 kph).

The curve in Figure 2-7 was judged to be appropriate as a baseline for an average adult male.* This curve was parameterized and represented by a piecewise linear form for loading. Figure 2-8 illustrates the parameterized curve. The loading curve becomes very steep when the chest deflection reaches about fifty percent of chest depth (Melvin, pers. comm., 1978).

Unloading curves determined by the MVMA 2-D model are quadratic in form and are similar to the experimental chest unloading curve shown in Figure 2-7. For the chest as well as for the head, the unloading curve parameters -- energy absorption and permanent deformation -- were specified as functions of the deflection at which unloading begins, i.e., the "maximum" or "turnaround" deflection. For the chest, elastic unloading is assumed through 0.5 inches of deflection (the first segment of the curve in Figure 2-8). The energy restitution coefficient decreases linearly for maximum deflections greater than 0.5 inches to a value of 0.5 at 2 inches and then 0.25 at 4.5 inches and 0.125 at 9.5 inches. The ratio of permanent deformation to maximum deformation increases from 0. at 0.5 inches to 0.2 at 2 inches, 0.6 at 4.5 inches, and 0.9 at 9.5 inches. These values approximate experimental results.

2.2.3 Neck Joint Properties. Mertz and Patrick (1971) reported on a study of the strength and dynamic response of the human neck. Their study included 90 static neck strength tests on ten volunteers, a series

* Lobdell, et al., suggest that their skeletal deflection curves differ from total thoracic deflection by 1/2 to 3/4 inch. The total thoracic deflection shown includes 1/2 inch of soft-tissue deformation.

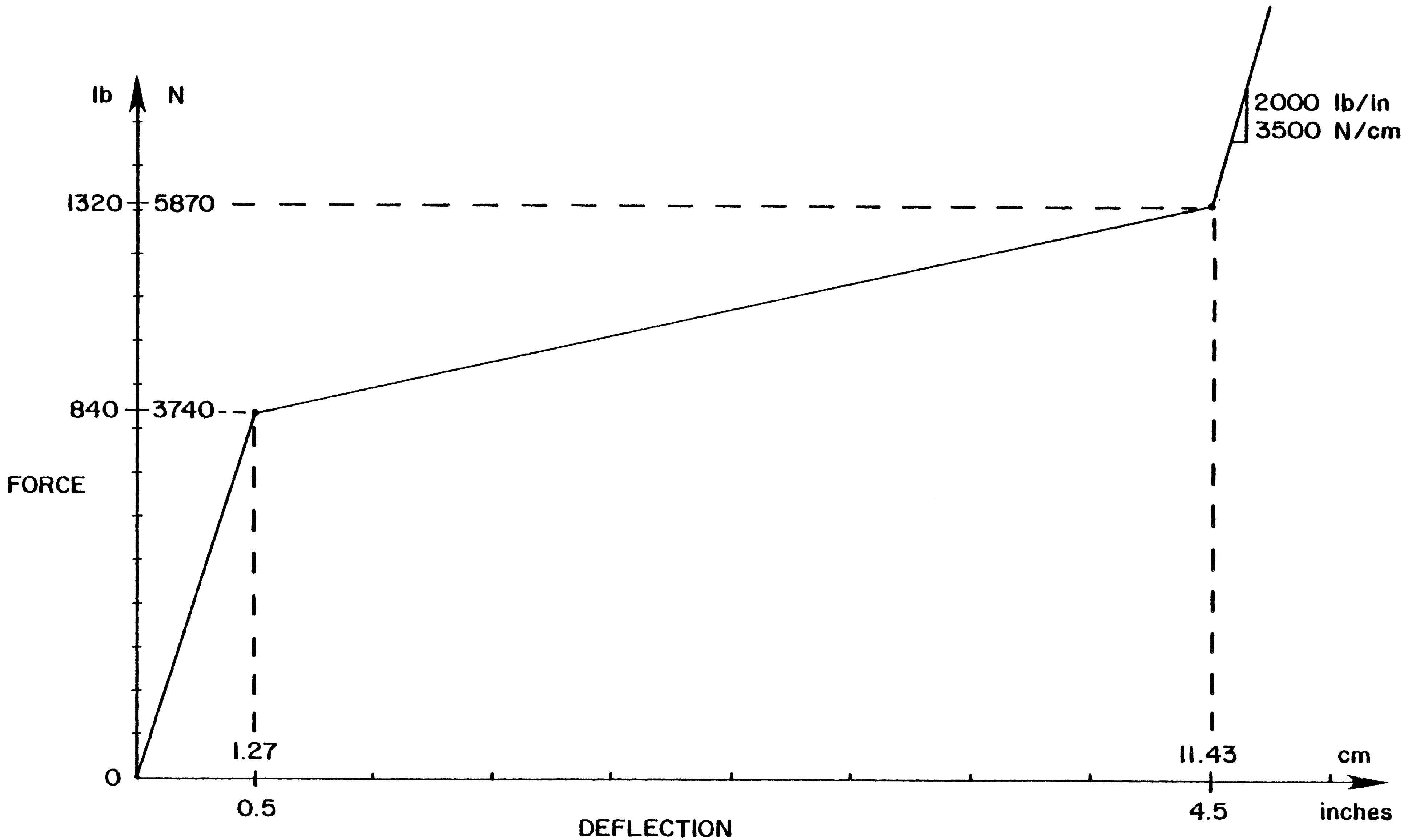

Figure 2-8. Parameterized Loading Curve for Chest Deflections

of dynamic hyperflexion tests with an impact sled which included 132 tests of four cadavers, and a less extensive series of dynamic hyperextension tests of cadavers and a volunteer subject. From analysis of the angular and translational acceleration responses of the head, Mertz and Patrick determined the equivalent moment and neck shear and axial forces at the occipital condyles.* They established loading and unloading curves which relate the equivalent moment at the condyles to the relative angle of rotation of the head with respect to the torso. Their recommended "baseline" curve for this moment for 50th percentile males is shown in Figure 2-9. The illustrated loading curves were used for the neck in the MVMA 2-D CVS simulations of the current study.

Mertz and Patrick also present data pertaining to the relationship between hysteretic energy absorption and head-torso angle from which the piecewise-linear approximation in Figure 2-10 has been derived. This curve expresses the energy restitution coefficient at the occipital condyles as a function of maximum condyle angle. The Mertz-Patrick data support use of the same curve for both flexion and extension. In the simulations, a constant value of 0.46 was used for the flexion restitution coefficient and 0.36 was used for extension. These are reasonably near to values from the curve for the amounts of head-neck angulation occurring in computer simulations. Figure 2-11 relates maximum condyle angle and the ratio maximum condyle angle over "permanent deformation" (i.e., joint angle offset upon complete unloading).

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* The "equivalent" moment about the condyles combines the joint moment component and a component from chin-chest contact, should such contact occur.

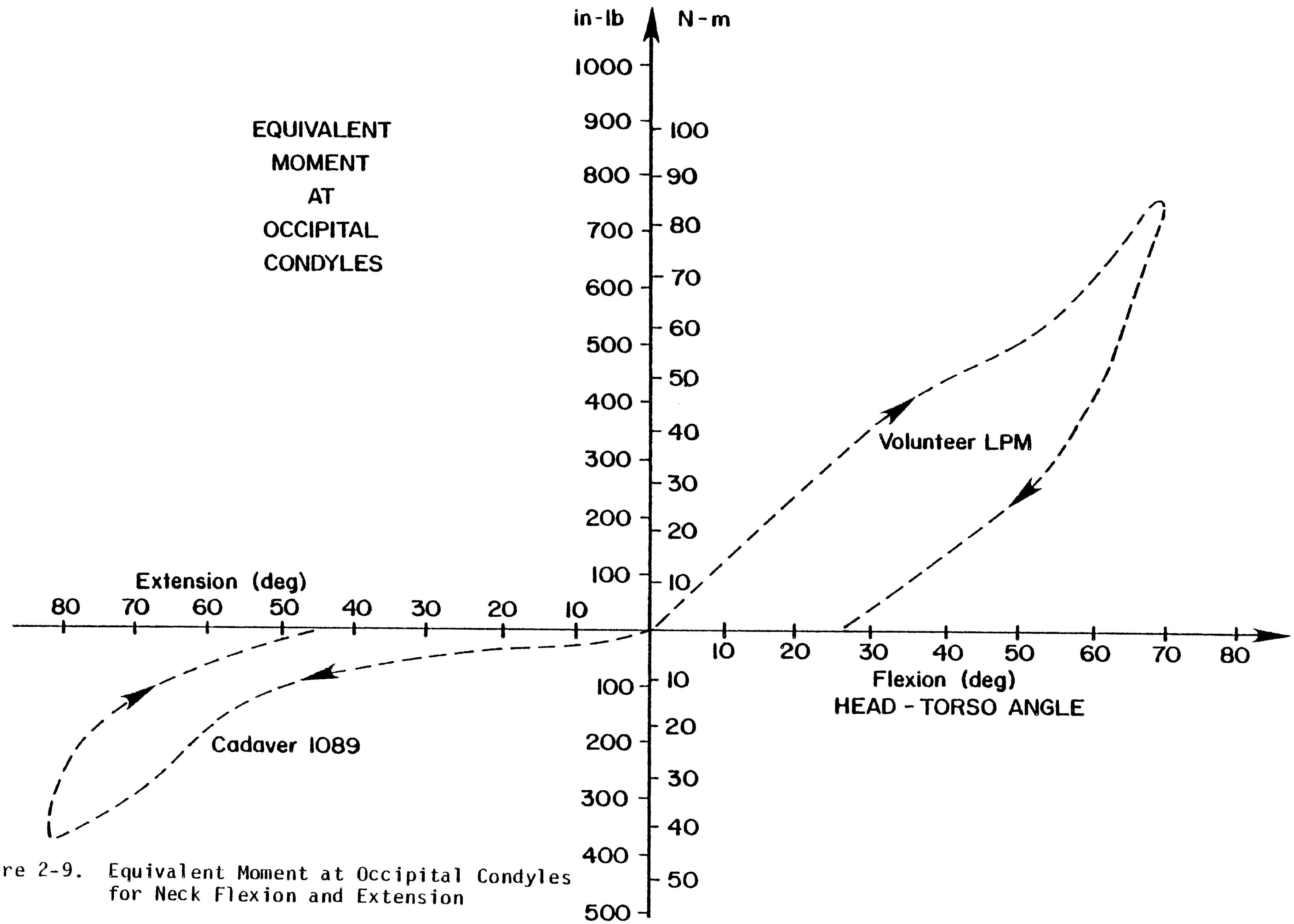

Figure 2-9. Equivalent Moment at Occipital Condyles for Neck Flexion and Extension

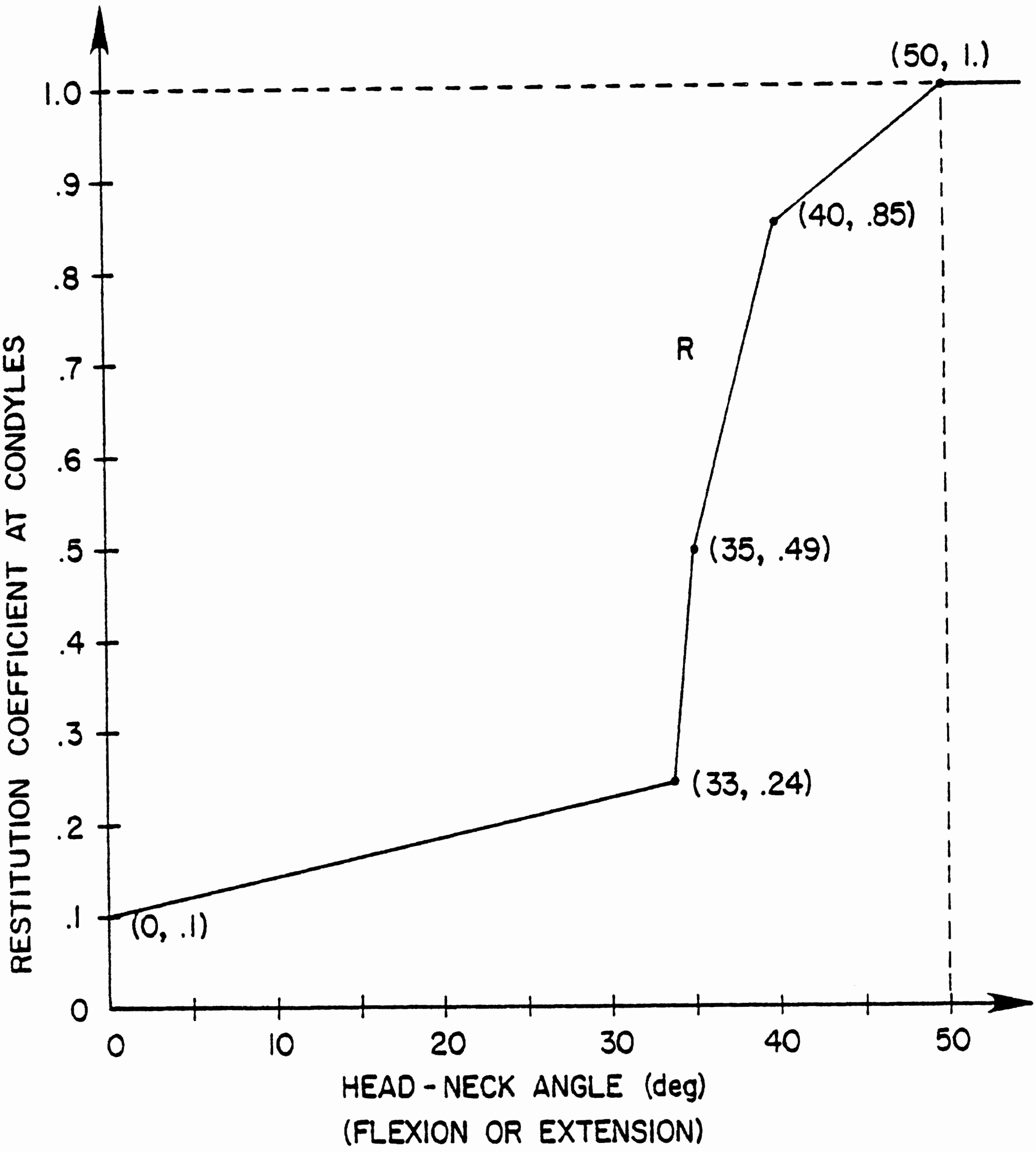

Figure 2-10. Restitution Coefficient at Condyles as a Function of Condyle Angle

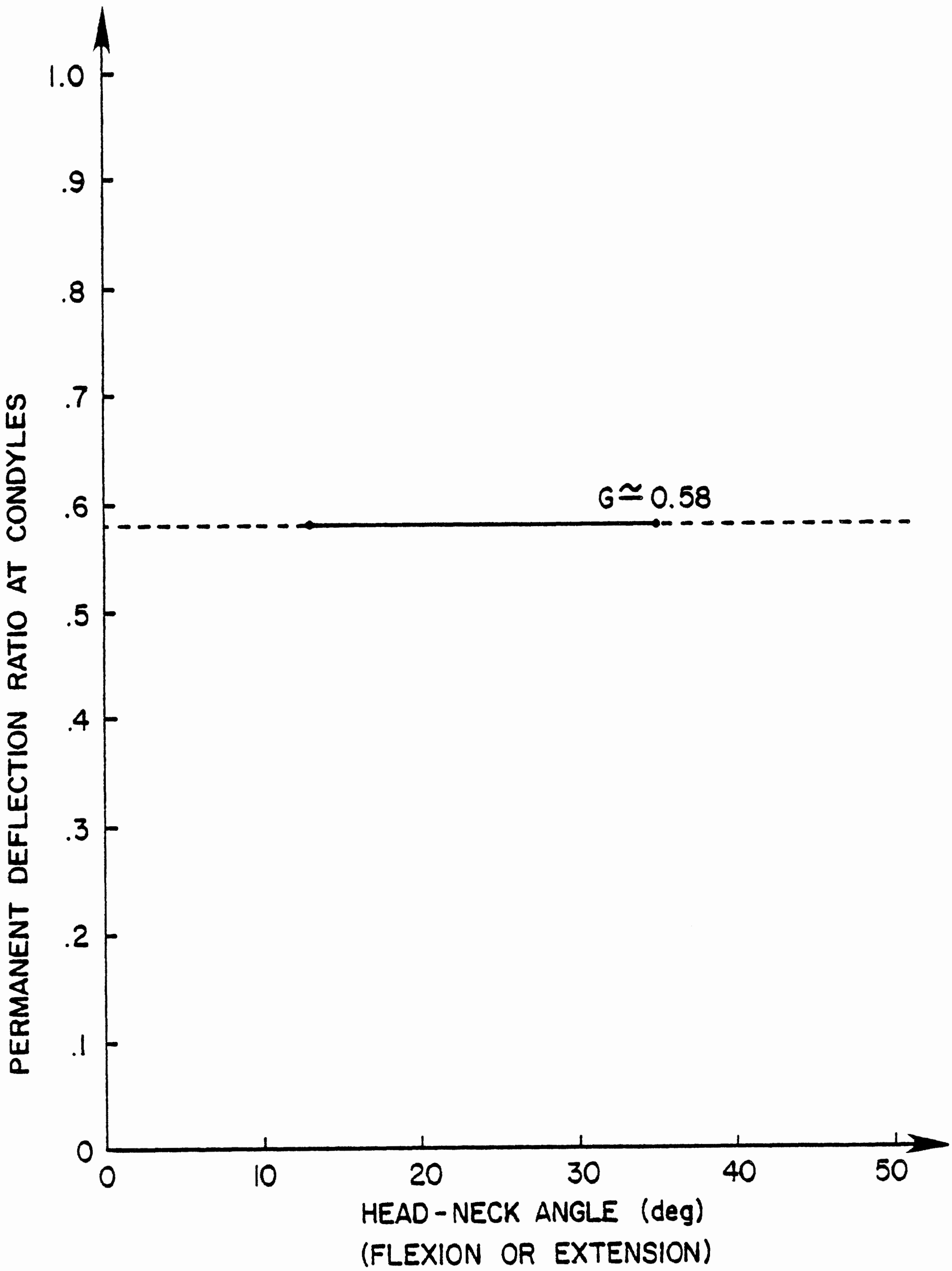

Figure 2-11. Permanent Deflection Ratio as a Function of Condyle Angle

The dashed lines extend the solid line results derived directly from Mertz-Patrick data. The permanent deflection ratio is found to be nearly constant at 0.58 with a root-mean-square deviation of 0.005. The constant value zero was used in the simulations, which does not agree closely with 0.58. However, it is worth noting again that the response parameters of primary interest, peak loads and peak accelerations, occur during loading, not during rebound, so restitution coefficients and permanent deflection ratios are not important input data for simulations in this study.

The MVMA 2-D CVS models a two-joint, one-link neck. In preparing data for simulation it is usually assumed that the two joints, at the occipital condyles and at C_7-T_1, are of equal stiffness and will contribute equally to the total head-torso angle in hyperflexion and in hyperextension. This approach has been used in successful studies in the past. With regard to the unloading parameter curves in Figures 2-10 and 2-11, this means that the abscissa -- head-neck angle, or condyles angle -- is appropriately taken as one half the experimental head-torso angle. An identical curve is appropriate for the C_7-T_1 joint. With regard to Figure 2-9, neck stiffness properties are distributed to the two joints in a manner consistent with the same assumptions. Since the two joints are essentially torsional series elements, the moments at the joints may be assumed equal to each other and equal to a composite, total neck moment. Then, with the assumptions of equal stiffnesses and equal contributions to total head-torso angulation, it can be shown that linear components of the loading curves for the separate joints should be taken as twice the linear component of the total neck (head-torso) curve shown in Figure 2-9. Similarly, quadratic and cubic coefficients are 4 and 8 times as large as those of the total neck curve.

2.2.4 The Helmet Model. The helmet model used in this study was simple but adequate for investigating the primary questions of the study, viz., the effects of adding mass and moment of inertia to the head, and the effects of basic helmet parameters such as lining stiffness, shell smoothness, and overall helmet dimensions.

A standard size fullface Bell helmet was modeled by effectively increasing the dimensions of the motorcyclist's head. The helmet was given an elliptical shape. No distinction was made in the model between the face area and the part of the elliptical profile which properly represents shell surface. It was unnecessary to make any such distinction since all initial body orientations in the simulation matrix (Section 3) were to be for shell surface impact. Possible slipping between the motorcyclist's head and the liner was not considered because helmets normally fit very snugly and because the integrated friction force (torque) for the head/liner interface is much greater than that for the shell/impacted surface interface.

The mass of the head link of the motorcyclist model was increased by the mass of the helmet, the location of the center of gravity was adjusted to account for the helmet, and the head/helmet moment of inertia about the adjusted center of gravity location was determined by analytically combining the inertia parameters of the separate elements. Table 2-1 gives the combined head/helmet inertia parameter values and the separate head and helmet values from which they were derived. Head

TABLE 2-1

HEAD AND HELMET INERTIA PARAMETERS

	HEAD	HELMET	HEAD/HELMET
Mass, lb (kg)	8.65 (3.92)	4.05 (1.84)	12.70 (5.76)
Moment of Inertia, $lb\text{-}sec^2\text{-}in$ ($kg\text{-}m^2$)	0.136 (0.0154)	0.238 (0.0269)	0.395 (0.0446)
Superior Location of CG w.r.t. Condyles, in (cm)	1.660 (4.22)	2.840 (7.21)	2.037 (5.17)
Anterior Location of CG w.r.t. Condyles, in (cm)	0.988 (2.51)	-0.252 (-0.640)	0.592 (1.50)

values used were determined in previous studies. Ewing and Thomas (1972) determined average location of head center of gravity relative to tragion. In another study average location of head CG relative to condyles was determined (Schneider, et al., 1976; Schneider and Bowman, 1978). In the current study measurements for helmet inertia parameters were made in HSRI's biomaterials laboratory using a standard Bell helmet. The helmet CG location was determined and its position relative to tragion with the helmet as normally worn was measured. Determined center of gravity locations for the head and helmet separately and combined are illustrated in Figure 2-12.

The helmet model assumed a rigid shell but represented a one-inch thick liner by a material with loading and unloading properties measured by Kingsbury (1979) using an aluminum head form inside a helmet. Kingsbury (1978, 1979) finds that the loading stiffness of polystyrene helmet liners is only slightly sensitive to rate of loading. The quasi-static loading curve used in the simulations is shown in Figure 2-13. The curve in the figure approximates loading for a Bell Star helmet liner and is representative of liners used by other manufacturers. Unloading characteristics were estimated from Kingsbury data. As previously described for other unloading curves, the restitution coefficient and permanent deformation ratio were defined as piecewise-linear functions of maximum deflection. The restitution coefficient is 1.0 in the limit for maximum deflection equal to zero and decreases to 0.1 at 0.2 inches of deflection. The permanent deformation ratio is zero for zero deflection and becomes level at 0.5 for deflections greater than 0.2 inches.

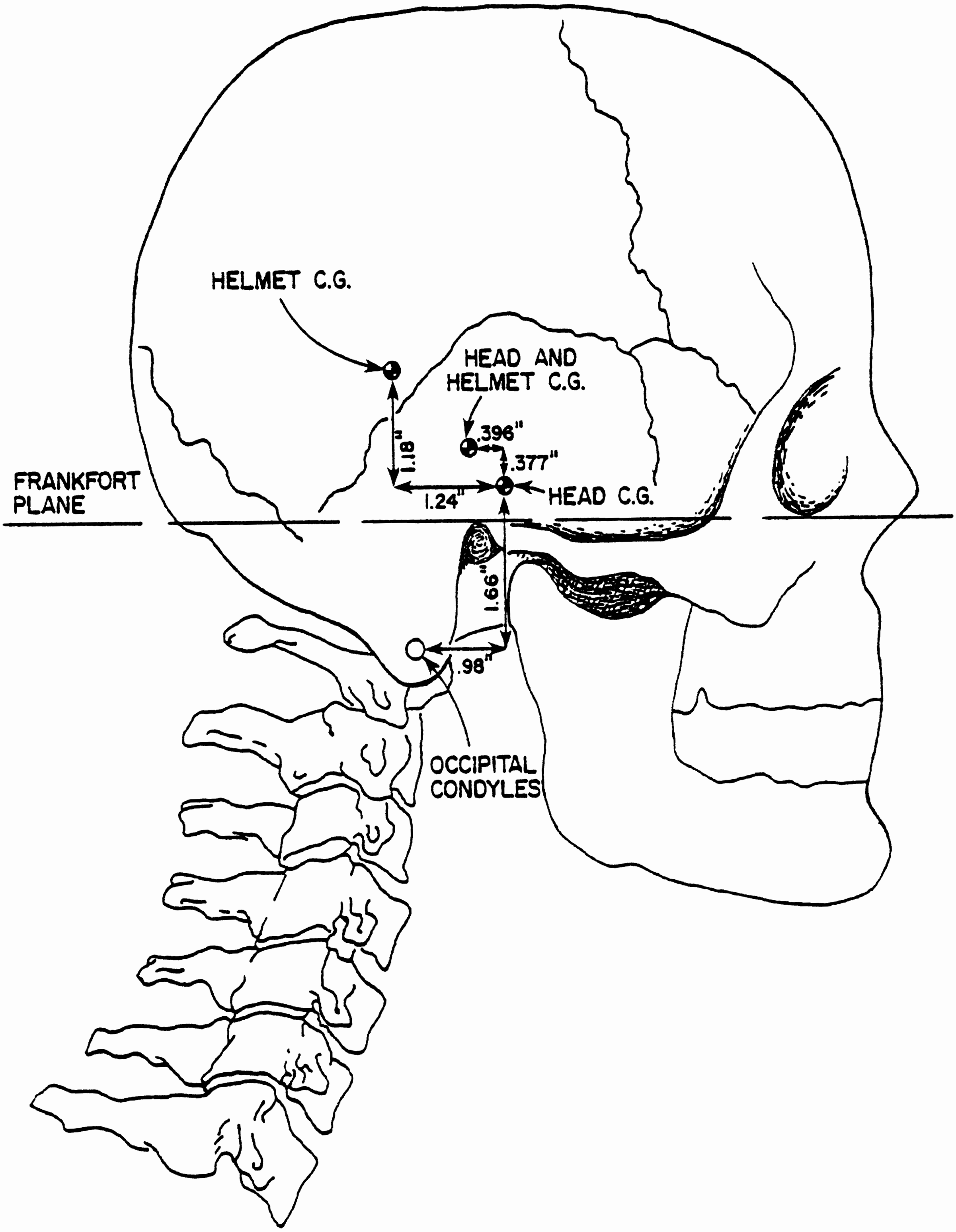

Figure 2-12. Head and Helmet Center of Mass Locations

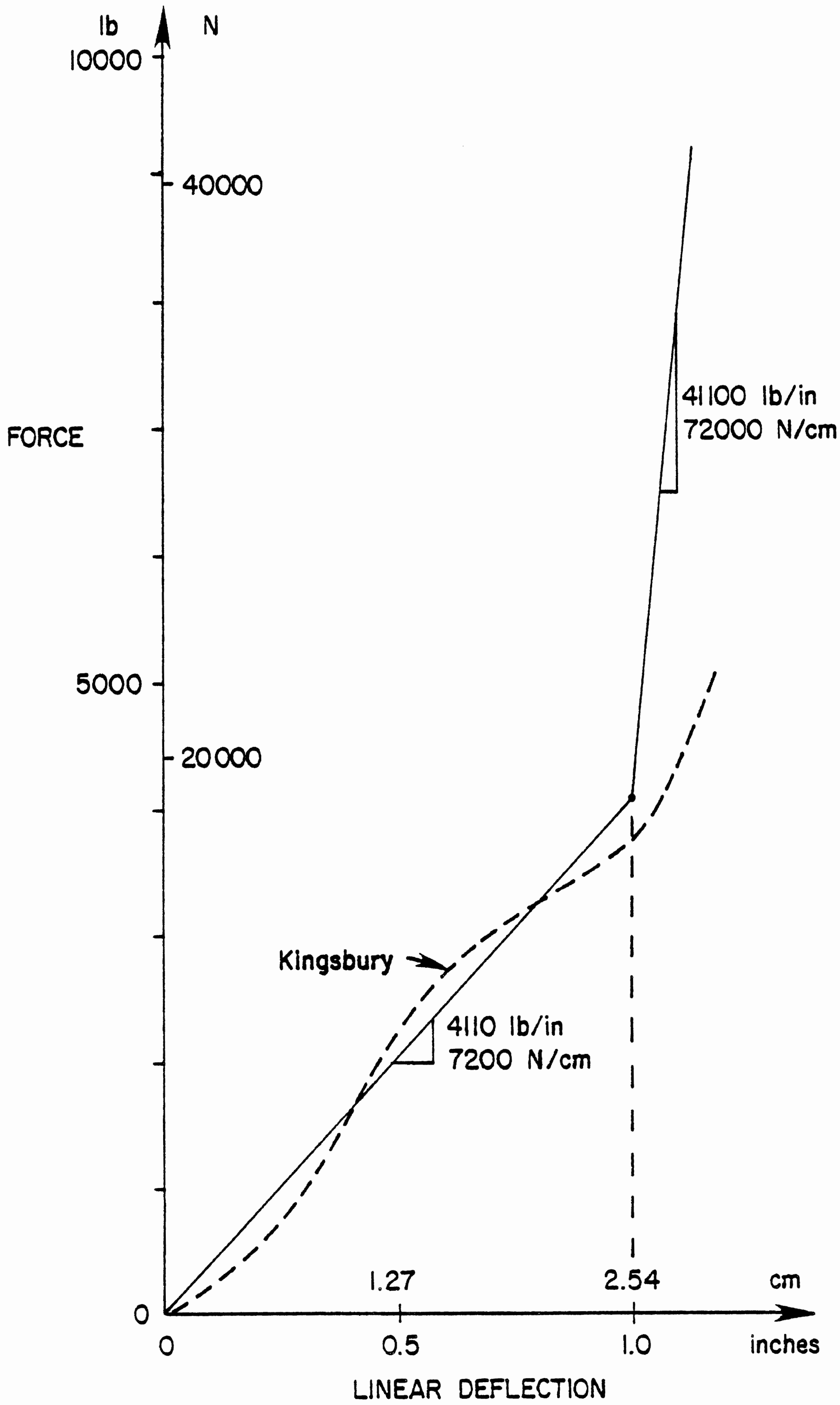

Figure 2-13. Load vs. Displacement for Bell Helmet Liner

Even though, as previously explained, the helmet shape and inertia properties were modeled by simply enlarging the head, it is possible to account for the separate influences of skull and liner loading curves in the MVMA 2-D model. Distinct skull and liner deflections were determined in the simulations.

3.0 MATRIX OF SIMULATIONS

3.1 Basic Simulation Configurations

It is recognized that there are an infinite number of ways in which a motorcyclist may impact with the environment as a result of a crash or accident. In this study we have selected four basic, idealized situations for simulation to provide an understanding of how the head and neck would respond for the helmeted and unhelmeted cases.

Figures 3-1 to 3-4 illustrate these four different model configurations -- A, B, C, and D. In A, the cyclist is moving horizontally in a seated position, and the head impacts a vertical rigid surface simulating the back of a truck. In B, the cyclist is also in the seated position moving with a horizontal velocity and impacts the rigid vertical surface with the chest so that the head and neck are inertially loaded. In both of these cases a secondary impacting surface which angles off from the lower edge of the primary surface has been modeled to prevent other parts of the body from wrapping around the primary impact surface. For the basic run configuration for these two cases the head and neck are initially oriented so that the neck is flexed forward 30 degrees from the vertical torso line at the C_7-T_1 joint and the head is extended back 10 degrees from the neck line at the condyles joint.* This results in the head being oriented at a 70 degree angle to the horizontal just prior to impact.

In C and D, the cyclist strikes a horizontal rigid "road" surface while moving with both horizontal and vertical velocities. In C, the torso of the cyclist is at an angle of 30 degrees to the road; the angle

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* The head line is a line perpendicular to the Frankfort plane.

is 70 degrees for configuration D. For both configurations the lower neck joint (C_7-T_1) is flexed forward 20 degrees and the upper neck joint is extended backward 20 degrees. This results in the initial head angle relative to the road being the same as the torso angle relative to the road -- 30 degrees for configuration C and 70 degrees for D.

3.2 Matrix of Computer Simulations

3.2.1 Basic Run Matrix. Table 3-1 illustrates the basic run matrix utilizing these four impact configurations for helmeted and unhelmeted impacts. All impacts for this basic set were for horizontal velocities of 20 mph (29.3 ft/sec). The two road impact runs also had vertical impact velocities of 19.6 ft/sec, corresponding to a fall height of six feet. Also in this basic run matrix for the road impacts, the cyclist was given a rotational velocity of 100 deg/sec for all body segments, a value estimated as typical for cyclist-road impacts of the type simulated. For chest impacts the coefficient of friction between the chest and truck surface was constant at .35 for all runs. For the head impacts against the truck surface the coefficients of friction were set to .3 and .1, respectively, for unhelmeted and helmeted simulations. For road impacts in this basic matrix the coefficients of friction between the head and road were set to .6 and .2 for unhelmeted and helmeted impacts, respectively. Neck muscle tension for these basic runs was constant at 50 percent of maximum effort in isometric exertion.

3.2.2 Expanded Run Matrix. It must be recognized that some of the parameter values for the basic run matrix simulations were somewhat arbitrarily selected, e.g., the impact velocities and head/neck initial positions. For others, such as coefficients of friction, the values are simply estimates for real world cases. Therefore, additional

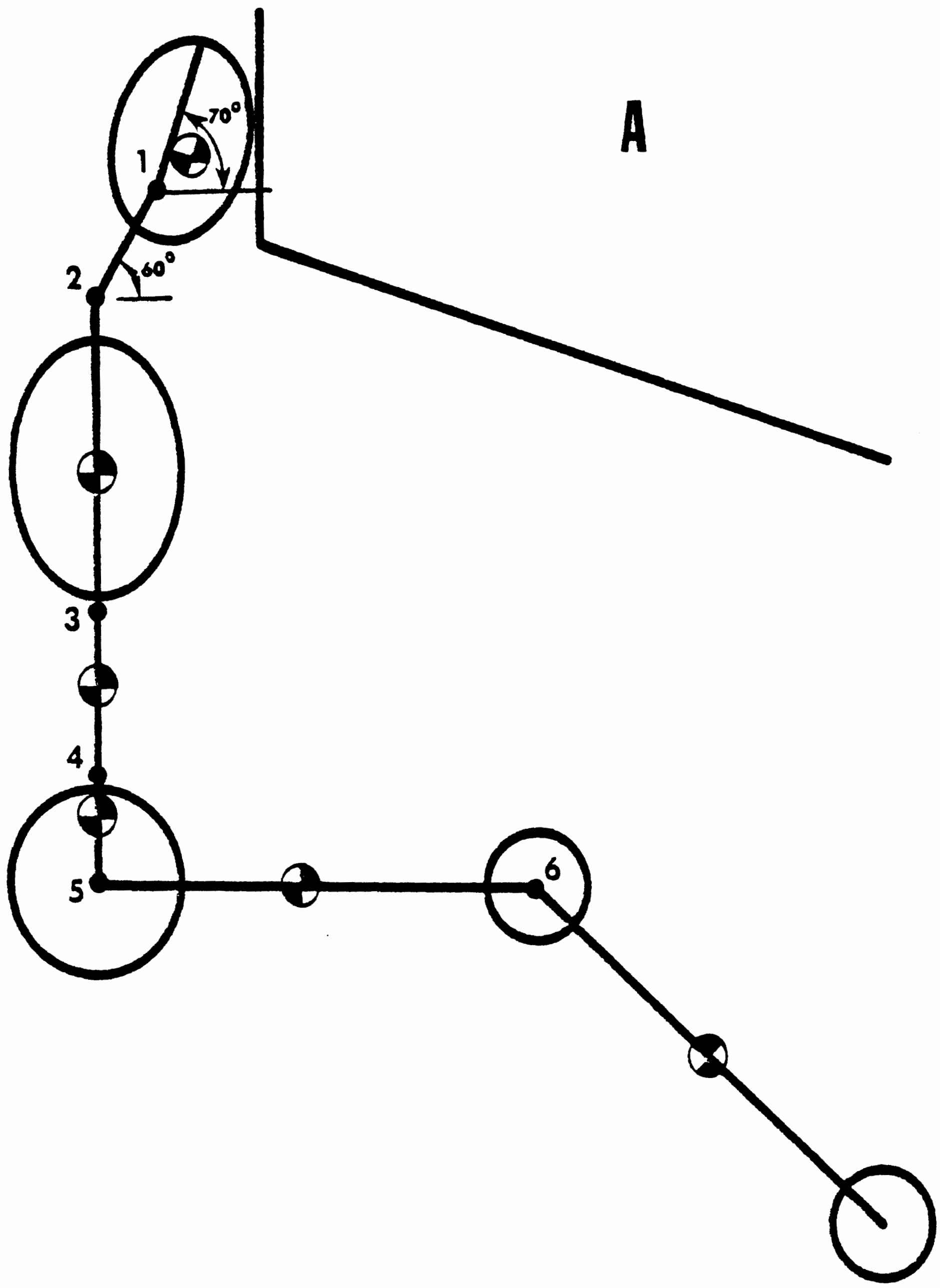

Figure 3-1. Basic Configuration for Head-Truck Impacts

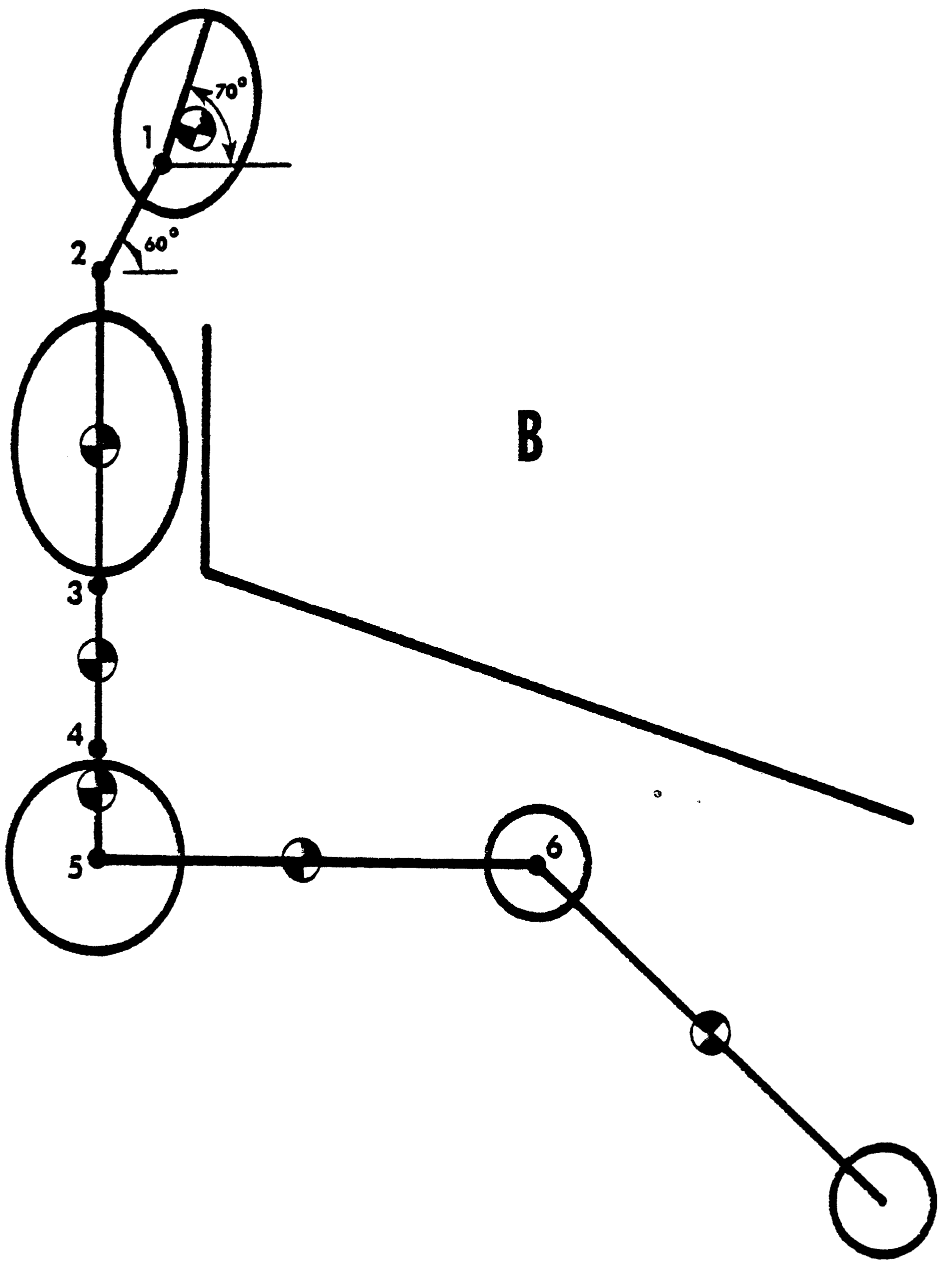

Figure 3-2. Basic Configuration for Chest-Truck Impacts

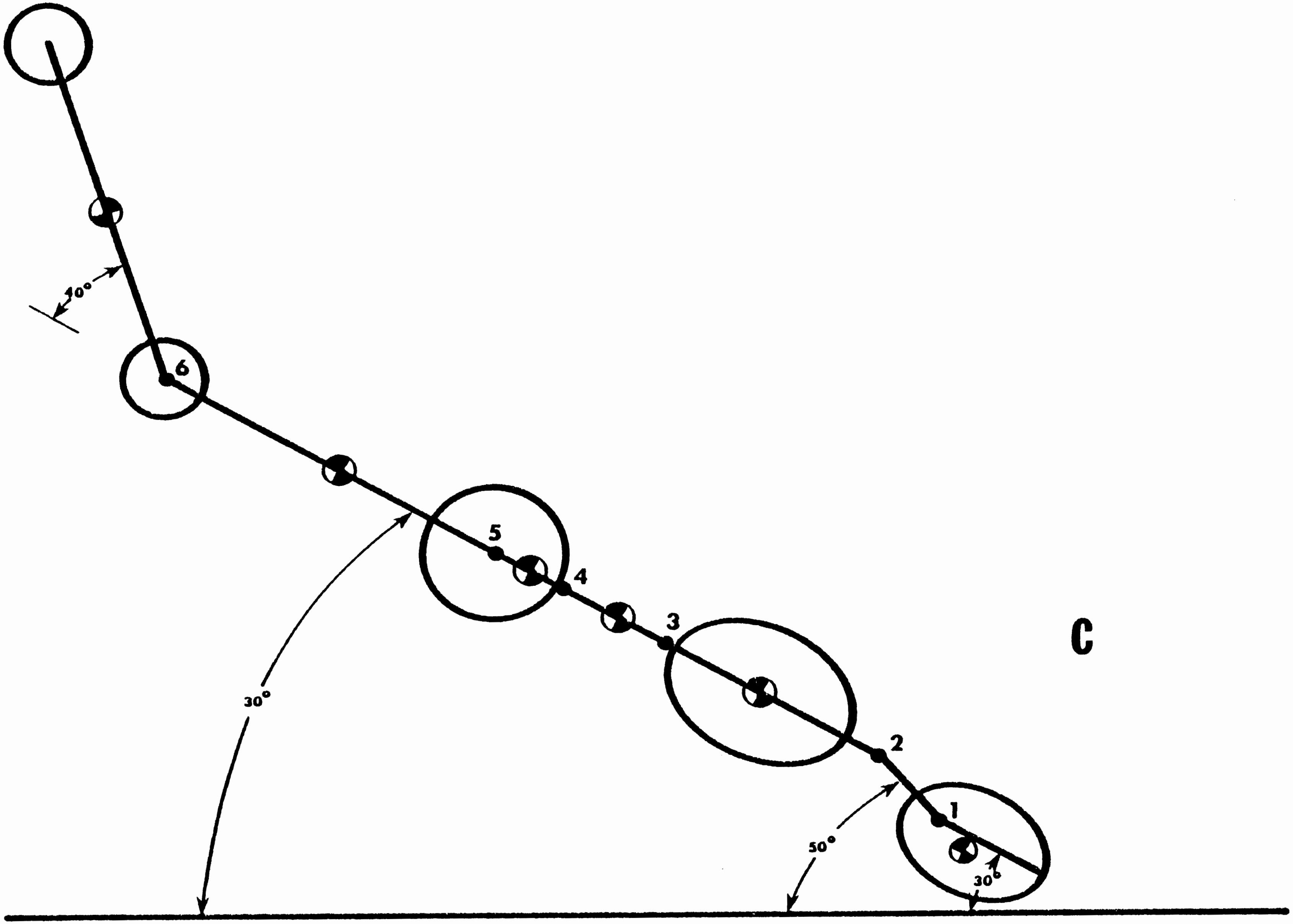

Figure 3-3. Basic Configuration for 30° Road Impacts

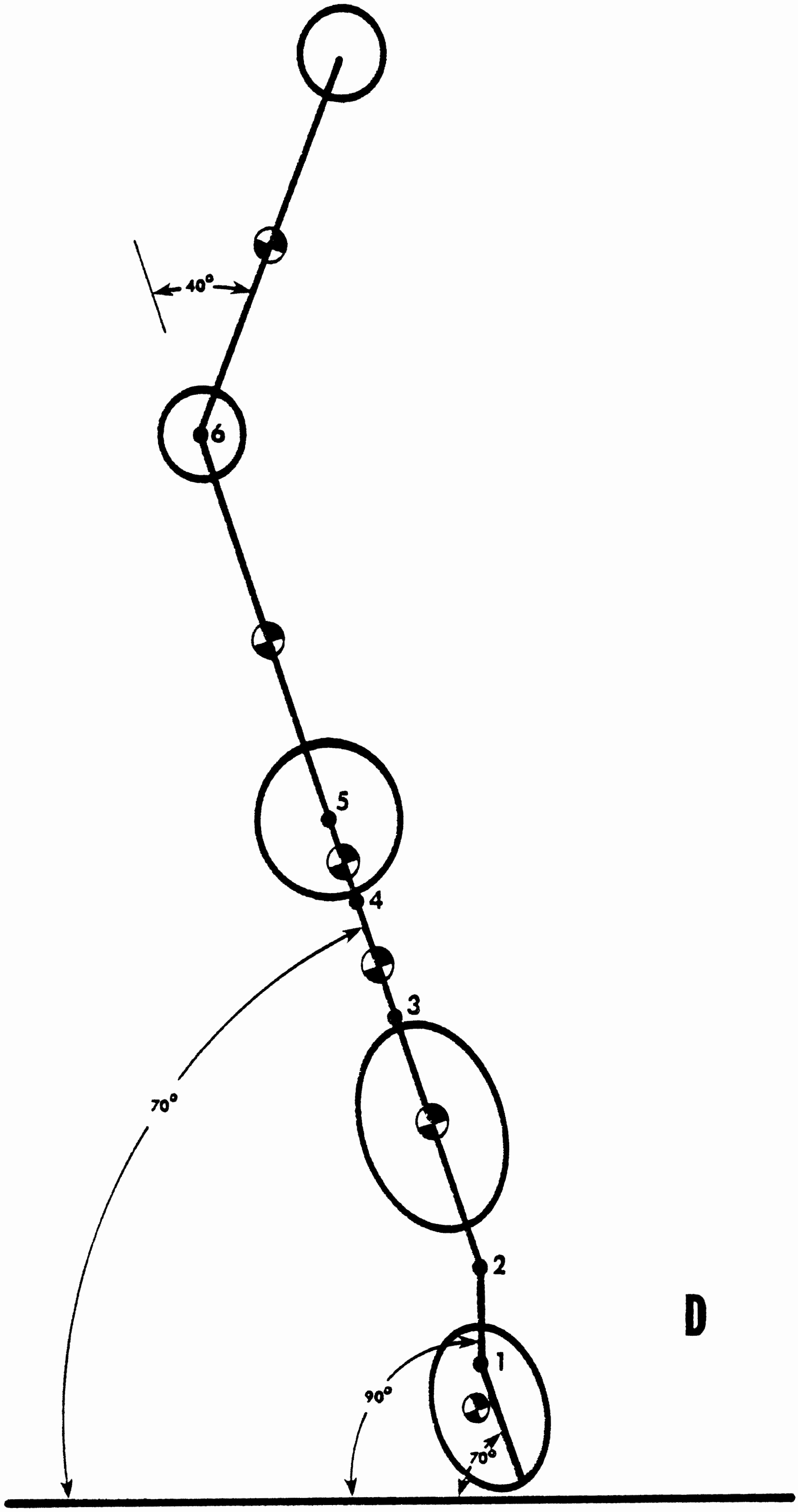

Figure 3-4. Basic Configuration for 70° Road Impacts

TABLE 3-1

BASIC RUN MATRIX

Cyclist Orientation	Impact Condition	Helmet/ No Helmet	Horizontal Velocity (mph)	Vertical Velocity (ft/sec)	% MT	Angular Velocity (deg/sec)	Coeff. of Friction	Condyles[1] Angle(deg)	C7-T1[1] Angle(deg)
Seated	Head w. Truck	no helmet	20	0	50	0	.3	+10	-30
		helmet	20	0	50	0	.1	+10	-30
Seated	Chest w. Truck	no helmet	20	0	50	0	.35	+10	-30
		helmet	20	0	50	0	.35	+10	-30
30° to Road	Head w. Road	no helmet	20	19.6[2]	50	100	.6	+20	-20
		helmet	20	19.6	50	100	.2	+20	-20
70° to Road	Head w. Road	no helmet	20	19.6	50	100	.6	+20	-20
		helmet	20	19.6	50	100	.2	+20	-20

(1) + for extension
- for flexion

(2) Corresponds to a fall height of 6 feet.

simulations were made in which these basic run conditions were individually varied. These additional runs not only provide a measure of parameter sensitivity necessary for meaningful interpretation of the findings but also provide results for a greater range of possible real world conditions.

Table 3-2 is a summary of the parameter variations for these additional runs. For the seated head impact with a truck, helmet and no-helmet runs were made for independent variations of velocity and muscle tension to 10 mph and 10% respectively. For the no-helmet case a run was made for a modified initial position, illustrated in Figure 3-5, where the neck is flexed forward 50 degrees from the torso line (at C_7-T_1 joint) and the head is in line with the neck (condyles angle = 0). For the seated chest impact with a truck eight additional runs were made and include helmet and no-helmet impacts with independent variations to 10 mph and 10% muscle tension, and two different initial positions illustrated in Figures 3-6 and 3-7. In one initial position the neck is flexed forward (at C_7-T_1) 50 degrees and the head is in line with the neck. In the second initial position variation, the neck and torso are in line (C_7-T_1 angle = 0) and the head is extended back 10 degrees from the neck line.

For the road impacts similar sets of additional runs were made for both 30 and 70 degree impacts. As previously mentioned, the coefficients of friction used for the basic helmet and no-helmet runs (.2 and .6) were estimates and represent a simplification of the real world situation where this parameter varies between road surfaces and is also dependent on the contact force,which may produce scraping and gouging of the head or helmet. Thus in order to obtain some measure of the impor-

TABLE 3-2

EXPANDED RUN MATRIX

Cyclist Orientation	Impact Condition	Helmet/ No Helmet[1]	Horiz.Vel. (mph)	Vert.Vel. (ft/sec)	% Muscle Tension	Ang. Vel. (deg/sec)	Coeff.[2] of Friction	Condyles[3] Angle(deg)	C7-T1[3] Angle(deg)
Seated	Head with Truck	both	10	19.6	50	0	.1 .3	10	-30
		both	20	19.6	10	0	.1 .3	10	-30
		helmet	20	19.6	50	0	.3	0	-50
		no helmet	10	19.6	10	0	.1	10	-30
Seated	Chest with Truck	both	10	19.6	50	0	.35	10	-30
		both	20	19.6	10	0	.35	10	-30
		both	20	19.6	50	0	.35	0	-50
		both	20	19.6	50	0	.35	+10	0
		helmet	10	19.6	10	0	.1	10	-30
30 Degrees to Road	Head with Road	no helmet	20	19.6	50	100	0.2	20	-20
		helmet	20	19.6	50	100	0.6	20	-20
		both	20	19.6	50	100	0.0	20	-20
		helmet	20	19.6	50	100	0.1	20	-20
		helmet	20	19.6	50	100	0.3	20	-20
		both	20	19.6	50	100	1.0	20	-20
		both	10	19.6	50	100	.2 .6	20	-20
		both	20	19.6	10	100	.2 .6	20	-20
		both	20	19.6	50	100	.2 .6	-5	-25
		both	20	13.9[4]	50	100	.2 .6	+20	-20
		both	20	19.6	50	0	.2 .6	+20	-20
70 Degrees to Road	Head with Road	no helmet	20	19.6	50	100	0.2	20	-20
		helmet	20	19.6	50	100	0.6	20	-20
		helmet	20	19.6	50	100	0.4	20	-20
		helmet	20	19.6	50	100	0.8	20	-20
		both	20	19.6	50	100	0.0	20	-20
		both	20	19.6	50	100	1.0	20	-20
		both	10	19.6	50	100	.2 .6	20	-20
		both	20	19.6	10	100	.2 .6	20	-20
		both	20	19.6	50	100	.2 .6	0	-20
		both	20	13.9[4]	50	100	.2 .6	20	-20
		helmet	20	19.6	50	0	.2	20	-20

(1) For some combinations of parameter values both helmet and no helmet simulations were made. For others, only a helmet simulation or only a no helmet simulation was made.

(2) If two values are given for coefficient of friction, the first is for the "helmet" simulation and the second is for the "no helmet" simulation.

(3) + for extension
- for flexion

(4) Corresponds to a fall height of three feet.

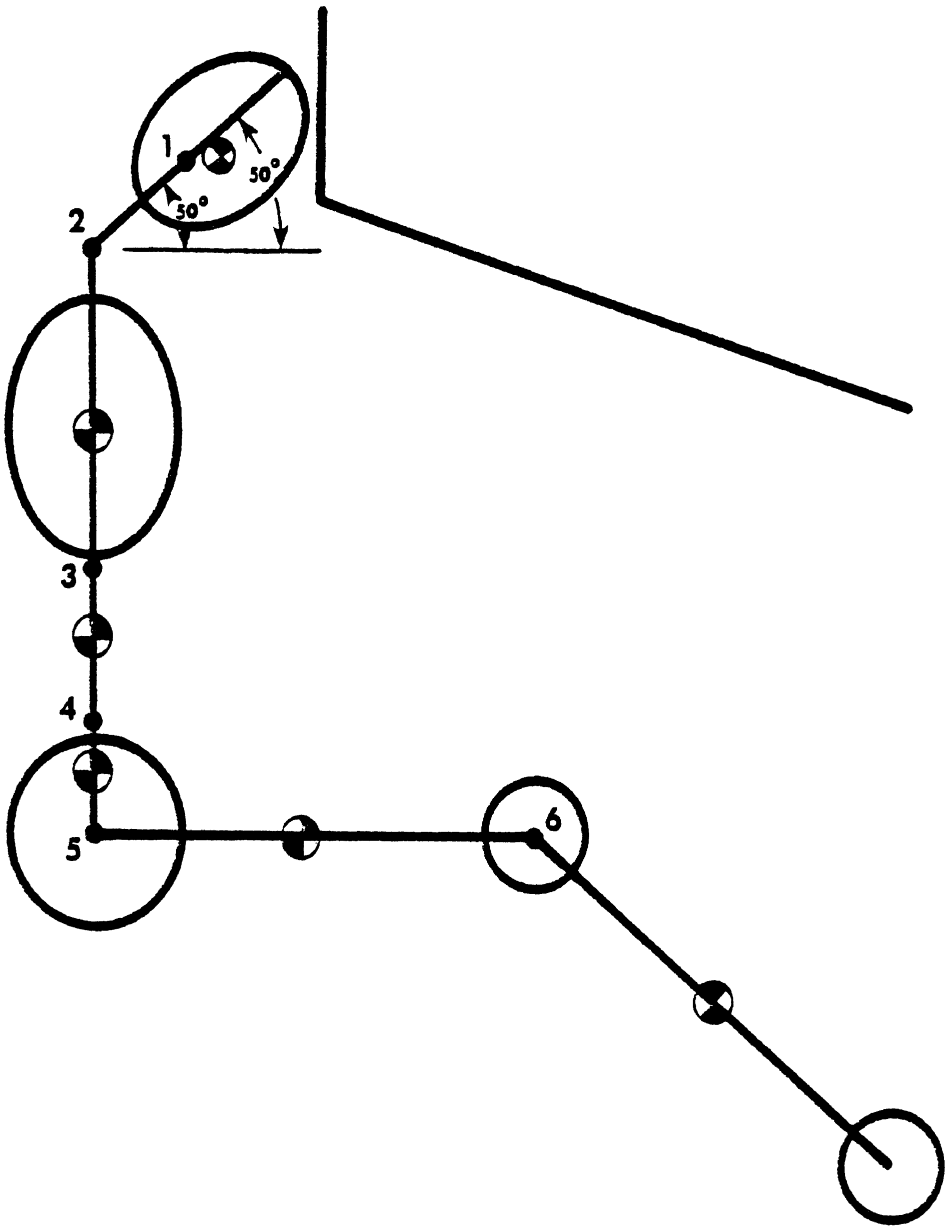

Figure 3-5. Configuration for Head-Truck Impact with Increased Neck Flexion

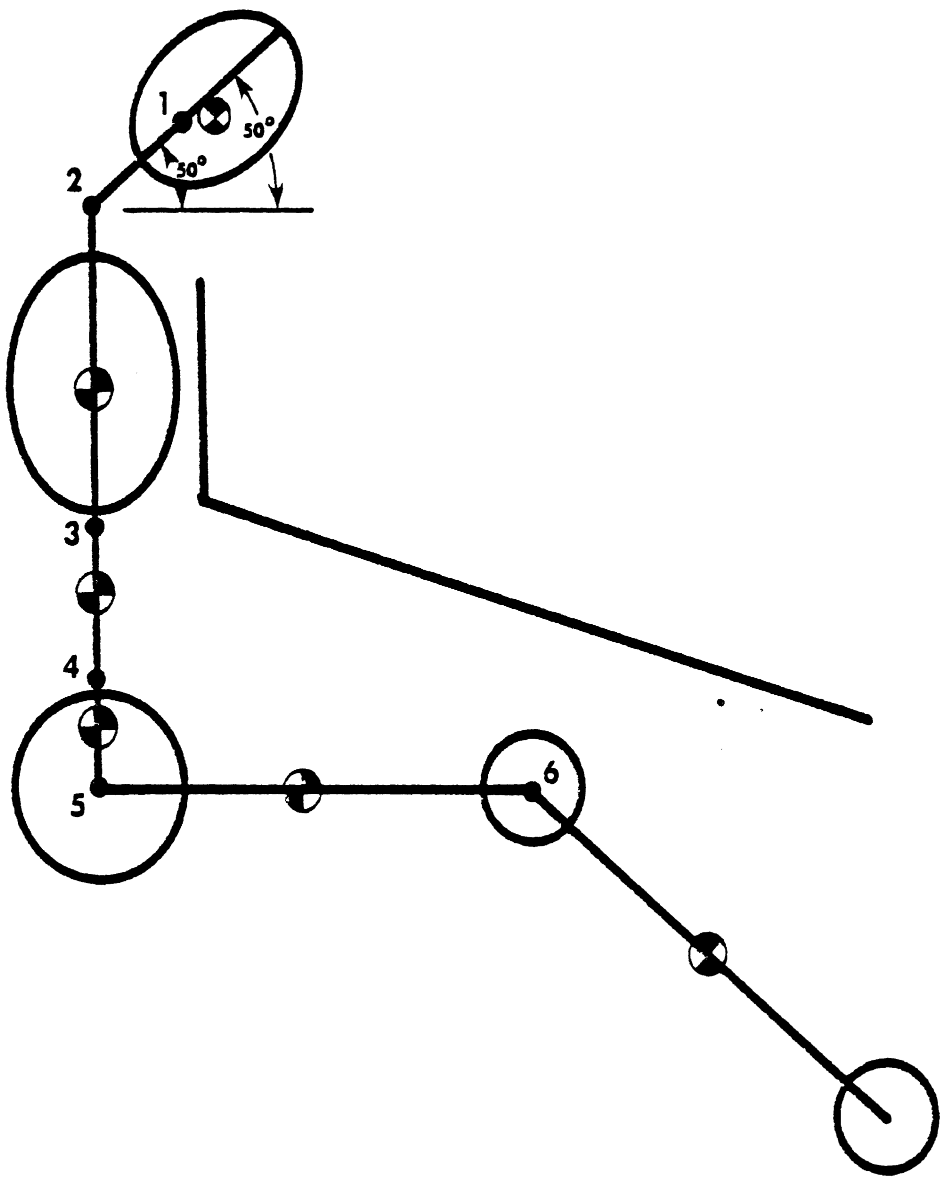

Figure 3-6. Configuration for Chest-Truck Impact with Increased Neck Flexion

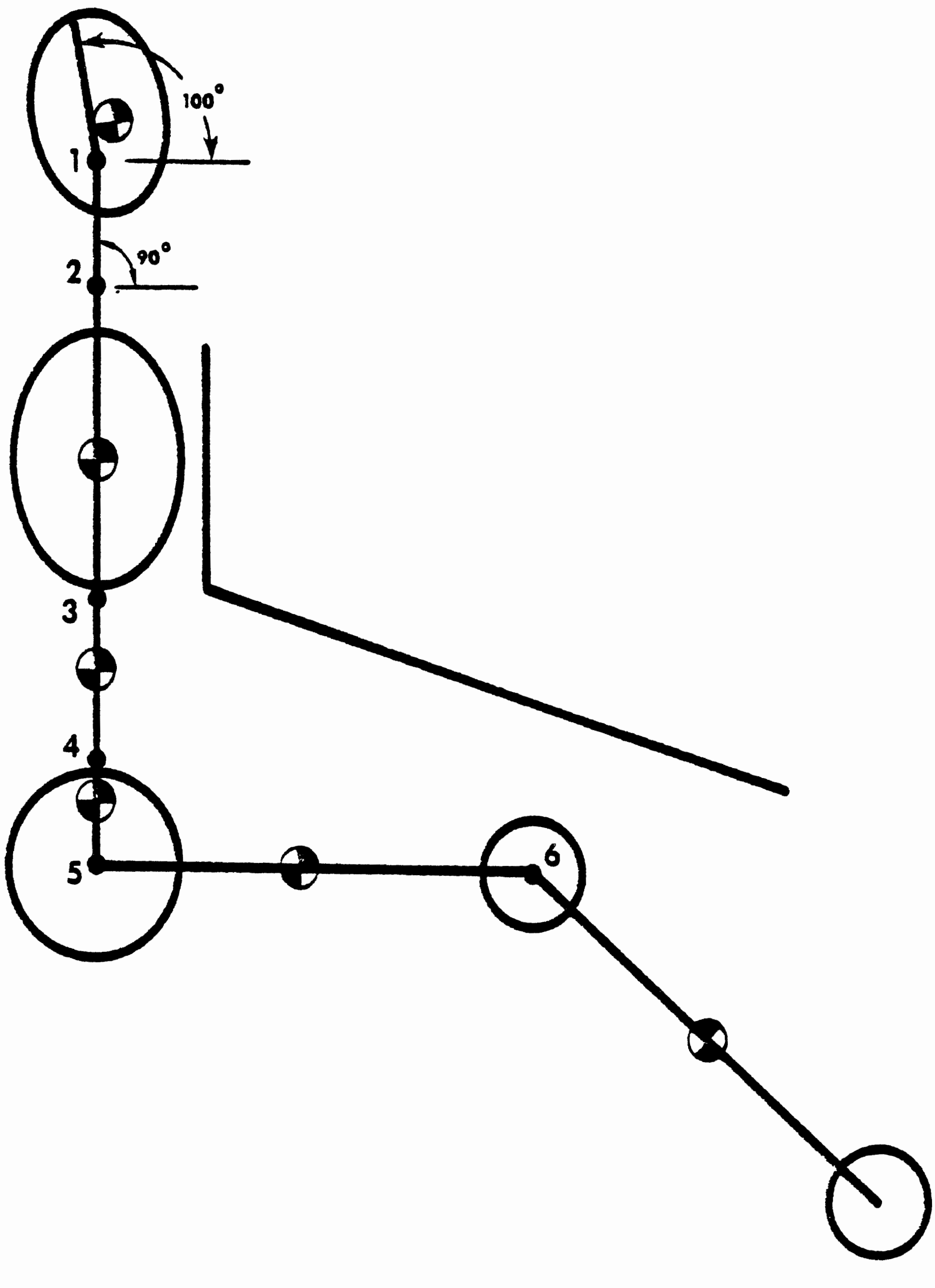

Figure 3-7. Configuration for Chest-Truck Impact with Initial Neck Extension

tance of the values selected on the response differences for helmet and no-helmet runs, and to obtain a more complete picture of how large variations in this parameter affect results, runs were made for coefficients of friction of 0.0 and 1.0 for both helmet and no-helmet conditions. In addition, the values of .2 and .6 were used for no-helmet and helmet runs respectively so that for each head condition, runs for the four coefficients of friction of 0.0, .2, .6, and 1.0 were made. Also, in an attempt to search for an optimum coefficient of friction, 30 degree road impact simulations were made for coefficients of friction of .1 and .3 and 70 degree road simulations were made for coefficients of .4 and .8. Other road impact simulations include helmet and no-helmet impacts for 10 mph and 10% muscle tension, modified initial head/neck positions, and a vertical velocity of 13.9 ft/sec, which corresponds to a fall height of three feet instead of the six-foot height used for the basic runs.

Figures 3-8 and 3-9 illustrate the modified head and neck positions for the 30 and 70 degree impacts respectively. At 30 degrees, the neck is flexed forward 25 degrees from the torso line and the head is flexed forward 5 degrees from the neck line so that the head line makes an angle of 60 degrees with the road. At 70 degrees, the neck is flexed forward 20 degrees as in the basic run but the head is in line with the neck so that the head line makes an angle of 90 degrees with the road surface. In addition to these runs, helmet impacts were made for the case of angular velocity equal to zero.

3.2.3 Miscellaneous Runs. In addition to the computer simulations described above and summarized in Tables 3-1 and 3-2, two additional types of runs were made. These are summarized in Table 3-3. One of

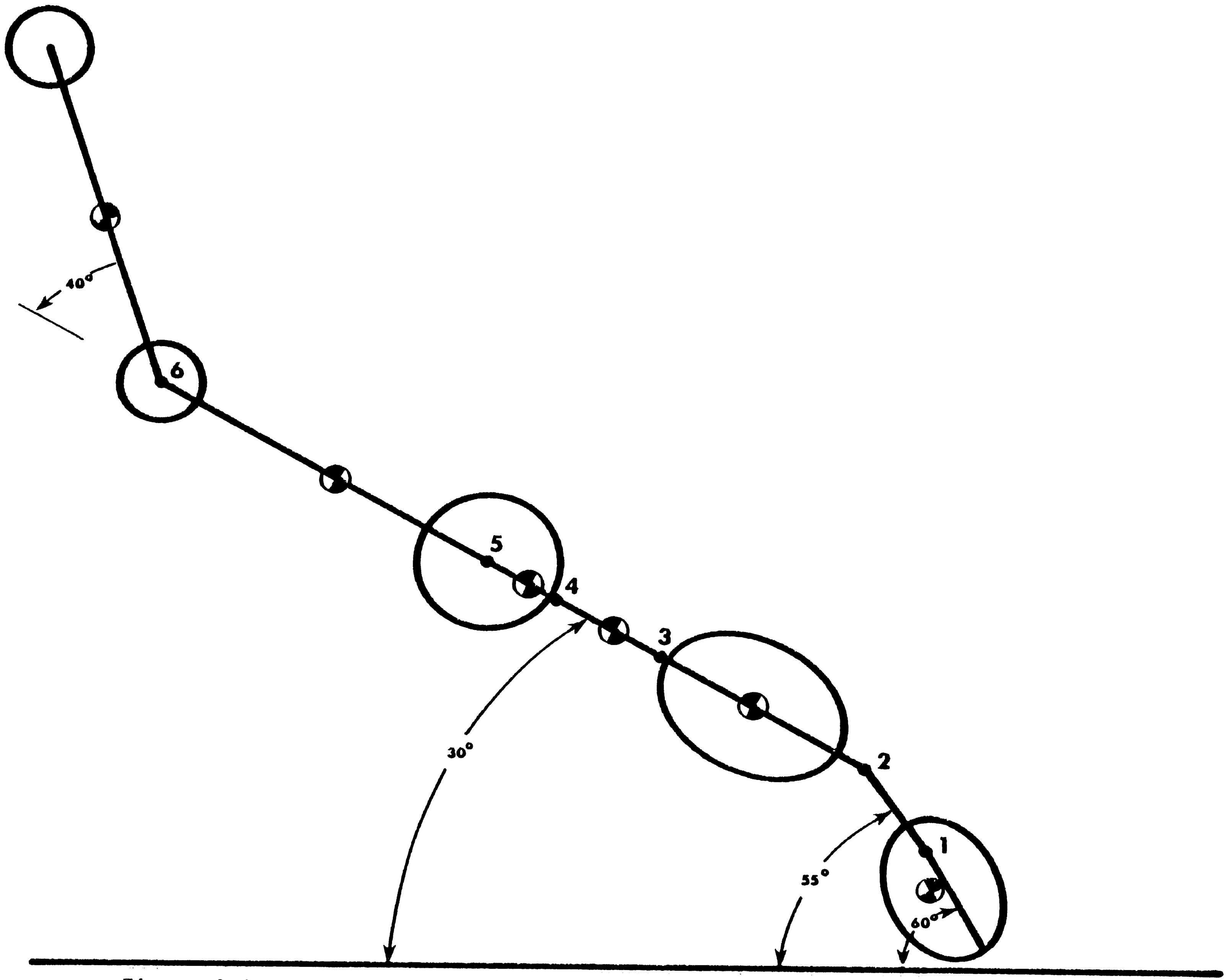

Figure 3-8. Configuration for 30° Road Impact with Neck in Flexion

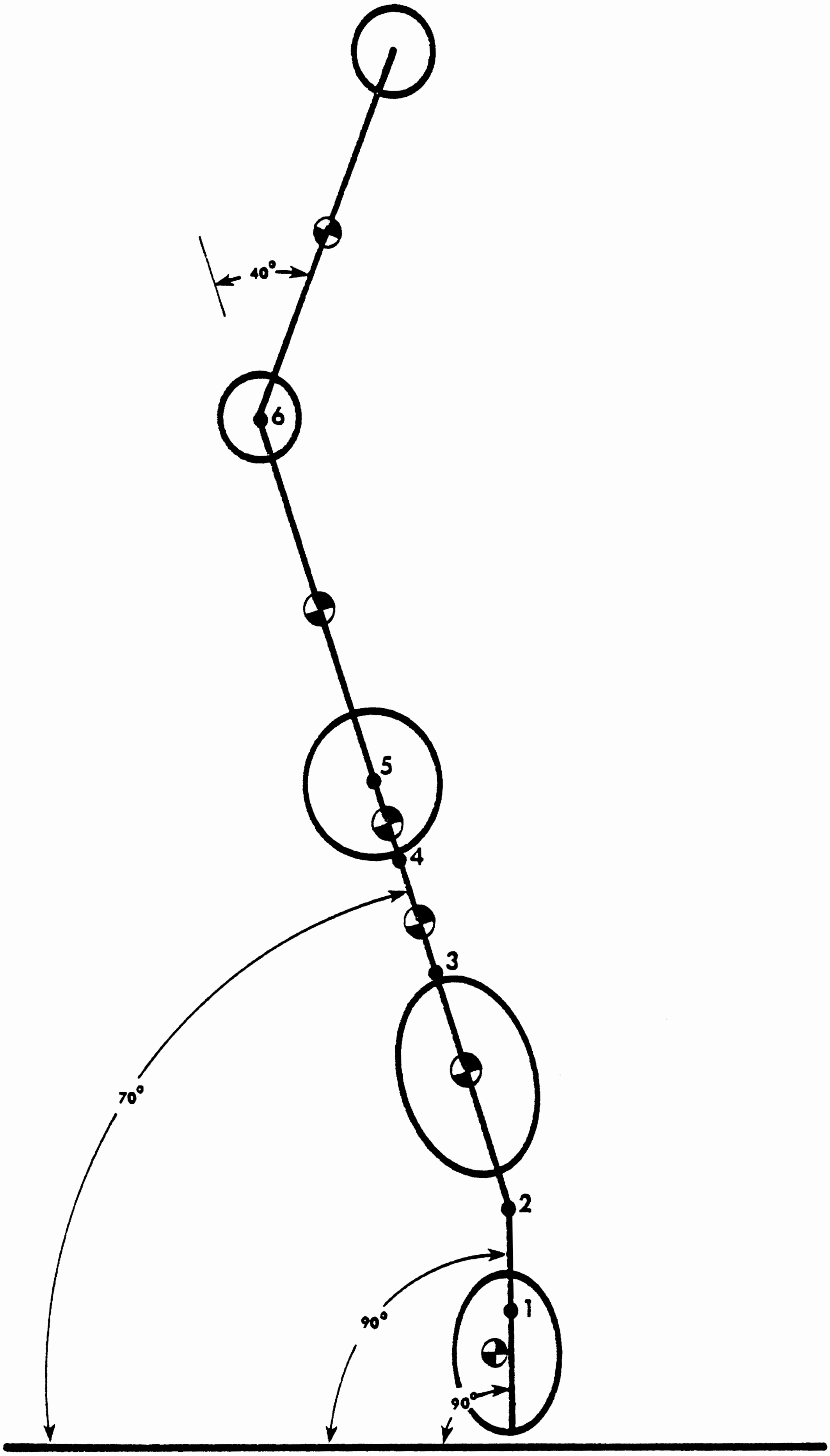

Figure 3-9. Configuration for 70° Road Impact with Neck in Flexion

TABLE 3-3

MATRIX OF MISCELLANEOUS RUNS

Cyclist Orientation	Impact Condition	Helmet/ No Helmet	Variation From Basic Run Conditions
seated	head w. truck	helmet	combined head and helmet mass reduced to head mass only
30° to road	head w. road	no helmet helmet	body mass ≃ 0 body mass ≃ 0
70° to road	head w. road	no helmet helmet	body mass ≃ 0 body mass ≃ 0
30° to road	head w. road	helmet	combined head and helmet mass reduced to head mass only
70° to road	head w. road	helmet	combined head and helmet mass reduced to head mass only

these had to do with determining the importance of body mass on the neck loading for 30 and 70 degree road impacts. In order to examine this factor, additional runs were made for helmet and no helmet, 30 and 70 degree road impacts for the parameter conditions of the basic run matrix except that the masses of the torso and leg segments were reduced to approximately zero.

The second type of run was for a head impact with the truck. In all helmeted simulations of this study, the head and helmet inertias act together (see Section 2). For head impacts in the real world, however, it is only the head mass which generates forces on the helmet liner. Thus it could be important for the head and helmet masses to be separate during impact but combined during rebound. Since this was not possible with the MVMA 2-D model, the three helmeted head impact runs from the basic run matrix were made with the head plus helmet mass was reduced to that of the head mass only. Comparison of these results with those for the basic helmeted head impact runs provide an indication of the error introduced by this modeling inaccuracy.

In all a total of 65 impact simulations comprise the results of this report. All simulations are for 100 msec duration. For the type of impacts investigated, all important dynamic response events occur within this time frame.

4.0 HUMAN INJURY TOLERANCE

While comparisons of simulation results for impacts with and without helmets can, by themselves, provide a good understanding of the relative benefits and detriments of wearing helmets, statements on the absolute benefits or detriments of helmets or on the absolute significance of helmet design parameters and impact conditions cannot be made unless human injury tolerance measures are considered. Comparison of predicted dynamic responses from the simulations with values for human injury tolerance limits allows, to some extent, an assessment of the likelihood and/or degree of injury that would result for the situation simulated.

Injury tolerance measures pertinent to this study are ones which relate to dynamic response of the head and neck. Dynamic responses described in Section 5, which discusses the results of the simulations, include HIC and peak magnitudes for head center of gravity resultant acceleration, head angular acceleration, impact force on the head, neck compression force, and positive and negative shear forces and flexion and extension torques on the neck at the head and at the top of the thoracic spine. These are all included either in the discussion or in tables because all have *a priori* potential of correlating with degree or likelihood of injury. Unfortunately, there is not yet universal agreement among researchers as to which measures are good injury predictors. For those measures for which there is some agreement, the data substantiating tolerance limits are minimal and conflicting. The following discussion draws upon the limited available data in order to establish injury tolerance levels for use in this study for those dynamic response quantities generally agreed to be useful injury indicators.

4.1 Head Injury Tolerance

Brain damage rather than skull fracture is the head injury to which tolerance definition is generally keyed. Neither head load nor skull fracture itself has been found to be a good indicator of cerebral damage. There is a general relationship between disruption of the skull and cerebral damage, but a great number of severely brain-damaged victims have no skull fracture (Smith, 1979). Further, most patients with fractured skulls have relatively mild and recoverable cerebral injuries (Harwood-Nash, et al., 1971; Roberts and Shopfner, 1972). In a study of two thousand cases of head injury, Kalyanaraman, et al. (1970) found that concussion was associated with fracture only 21 percent of the time.

The most accurate indicator of cerebral damage may be intracranial pressure, but there is no consensus. Studies have found good correlation between intracranial pressures and cerebral arteriolar or capillary ruptures (Nahum, et al., 1977; Smith, 1979). On the otherhand, shear strain of the brain stem is suggested by other researchers as the best single indicator of brain injury (Got, el al., 1978; Hodgson and Thomas, 1979). Neither intracranial pressures nor brain stem shear strain, however, can be predicted by a whole body motion model such as the

MVMA 2-D CVS so it is necessary to examine alternative brain injury indicators. Indeed, the difficulties in determining intracranial pressures and brain stem shear strain both by experiment and by modeling have led researchers to seek gross motion measures which correlate well with brain injury. Gross motion measures, such as head accelerations, are easier to determine both experimentally and with model simulations.

4.1.1 Head Injury Criterion (HIC). The Head Injury Criterion, or HIC, is an integrated measure of exposure to linear acceleration; i.e., its value is determined by considering magnitude of the acceleration, shape of the acceleration-time profile, and duration of exposure. HIC has found wide acceptance as the quantity related to whole body dynamics which best predicts degree and likelihood of brain damage.*

Many studies have indicated, however, that there is considerable scatter of the HIC value which will produce experimental vascular ruptures (Got, et al., 1978; Hodgson and Thomas, 1979; Nahum, et al., 1977; Smith, 1979). Got, et al. (1978), using fresh, unembalmed, perfused cadavers, have also investigated correlation between HIC and head AIS, an index of the severity of injury (AAAM, 1976). The AIS, or Abbreviated Injury Scaling, system associates an integer from 1 to 6 with each injury in accordance with Table 4-1.

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* The Head Injury Criterion is generally regarded as having significance primarily for high acceleration exposures which result from an impact. HIC is defined in Appendix A. Also, see: Code of Federal Regulations, Title 49, Part 572, Section 208, U.S. Government Printing Office, Washington, D.C., 1977.

TABLE 4-1

ABBREVIATED INJURY SCALING SYSTEM

AIS Code	Injury Severity
1	Minor
2	Moderate
3	Severe (not life-threatening)
4	Serious (life-threatening, survival probable)
5	Critical (survival uncertain)
6	Maximum (currently untreatable)

In that study, much scatter was observed also in the relationship of AIS to HIC. Among seven free-fall, frontal (forehead) impacts, there were two subjects that displayed severe injuries (AIS=3) and had HIC values of only 700 and 1000. At the other extreme, there was no detected brain injury for a subject that had a HIC greater than 2500. For similar impacts, Nahum, et al. (1977) report a cadaver HIC of 3765 with only moderate injury (AIS=2) and Got, et al. (1978) determine from the data of Stalnaker, et al. (1977) a case with a HIC of 3200 and an AIS of 2. Got, et al., note that one of the two subjects for which AIS 3 injuries occurred at low HIC values had a much thinner than average skull and that medical prognosis was difficult in the second.

Got, et al., feel that the observed scatter of the relationship of HIC to measures of injury severity is not of a nature to cast doubt on value of the use of HIC. Their findings strengthen the prevailing views that HIC is probably the most useful of the gross motion measures that have been considered to date for prediction of brain damage. They note that in the frontal impacts in their study there were no medium-skulled cadaver subjects for which there was both an injury of degree AIS greater than 2 and a HIC of less than 1500. They note also that the brain of a living person can be expected to be more tolerant to HIC exposure than that of a cadaver. Thus, Got, et al., conclude that with regard to frontal impact of the adult skull without fractures, the HIC tolerance limit for brain injury of severity no greater than "moderate" (AIS=2) is in excess of 1500.*

For the current study, a HIC injury tolerance limit of 1500 will be used for analyzing results of the motorcyclist impact simulations.

4.1.2 Peak Head Resultant Acceleration. The integrated acceleration exposure index HIC has largely replaced other gross motion measures for use in prediction of brain injury. Peak head angular acceleration has been suggested by Ommaya, et al. (1967 and 1971) but has found little support (e.g., Hodgson and Thomas, 1979; Mucciardi, et al., 1977). Mucciardi, et al. (1977) used nonlinear Adaptive Learning Network modeling methodology to identify various other dynamic response measures as being useful in predicting Overall AIS in head impacts.** The response data of that study were from 26 tests involving monkeys, and sensitivity of injury to 34 dynamic response measures was investigated. (HIC was not among the 34.) The response parameters which best modeled

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* A HIC injury tolerance level of 1000 was set by NHTSA in June 1972 by Department of Transportation NHTSA Docket Number 69-7, Notice 19, Occupant Crash Protection Head Injury Criterion S6.2 of MVSS 208. In addition to the study by Got, et al., other studies since 1972 indicate that this tolerance level is probably somewhat low. There is further discussion in Appendix A. The general findings of the current study would not be affected by assuming a tolerance level of 1000 instead of 1500.

** Overall AIS was calculated as $[\Sigma (AIS_i)^3]^{\frac{1}{3}}$ with the summation over all observed impact injuries.

Overall AIS were root-mean-square (RMS) resultant linear velocity of head center of gravity, maximum resultant velocity, and the reciprocal of the RMS resultant acceleration.* Data are not available which would allow the results of Mucciardi, et al., to be used for defining an injury-predicting function for human head impacts and the tolerance value which should be associated with AIS 2 level injury. The results of the study lend strong support, however, to the use of first and second time derivatives of the translational position in predicting brain injury resulting from blunt impacts of the head.

In the current study maximum head resultant acceleration is considered along with HIC in the assessment of likelihood of injury in the situations simulated even though, as has been previously noted, the integrated measure of acceleration exposure is currently considered more pertinent by most researchers in the area of human impact injury tolerance. Also, as would be expected, tolerance to head resultant acceleration has been less accurately defined in the literature. Ranges rather than distinct values are normally given. In addition a wide range of test conditions have been used in the reported studies (e.g., impact, inertial loading, fracture, no fracture, short duration acceleration, long duration acceleration).

It is felt that the head resultant acceleration tolerance value most useful for this study is one derived by combining simulation

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* Unconsciousness AIS was most sensitive to RMS resultant velocity, maximum resultant velocity, and an integrated measure of angular acceleration exposure. Time of unconsciousness was most sensitive to RMS resultant velocity, maximum resultant jerk ($\dddot{x}$), and a ratio parameter including both maximum angular acceleration and maximum resultant acceleration.

results and the previously defined HIC tolerance limit (1500). Simulations (17 total) which produced HIC values in the range 900 to 2100 (i.e., bracketing HIC=1500) were used to obtain a linear regression of maximum resultant acceleration on HIC. The result is the regression line $\ddot{x}(g's) = HIC/21.9 + 81.1$, with a correlation coefficient of 0.58.*

The seventeen acceleration-HIC coordinate pairs from which this result was obtained and also data for all other direct head impact simulations are plotted in Figure 4-1. Chest-truck simulations are omitted because HIC is generally regarded as having significance only for acceleration exposures which result from direct head impact. Simulations for which maximum HIC was evaluated over a duration of greater than 20 msec (up to about 90 msec) are marked by triangles.** These cases were all road impacts where the motorcyclist's body followed the head in such a way that there were up to four primary peaks of the force-time response for head contact, i.e., there was a closely-spaced "pulsing." Resultant acceleration as a function of time exhibited less definite cycling over the time range of HIC calculation for these simulations. It can be seen that without the longer duration impacts, there would be much less scatter in the HIC-acceleration relationship.***

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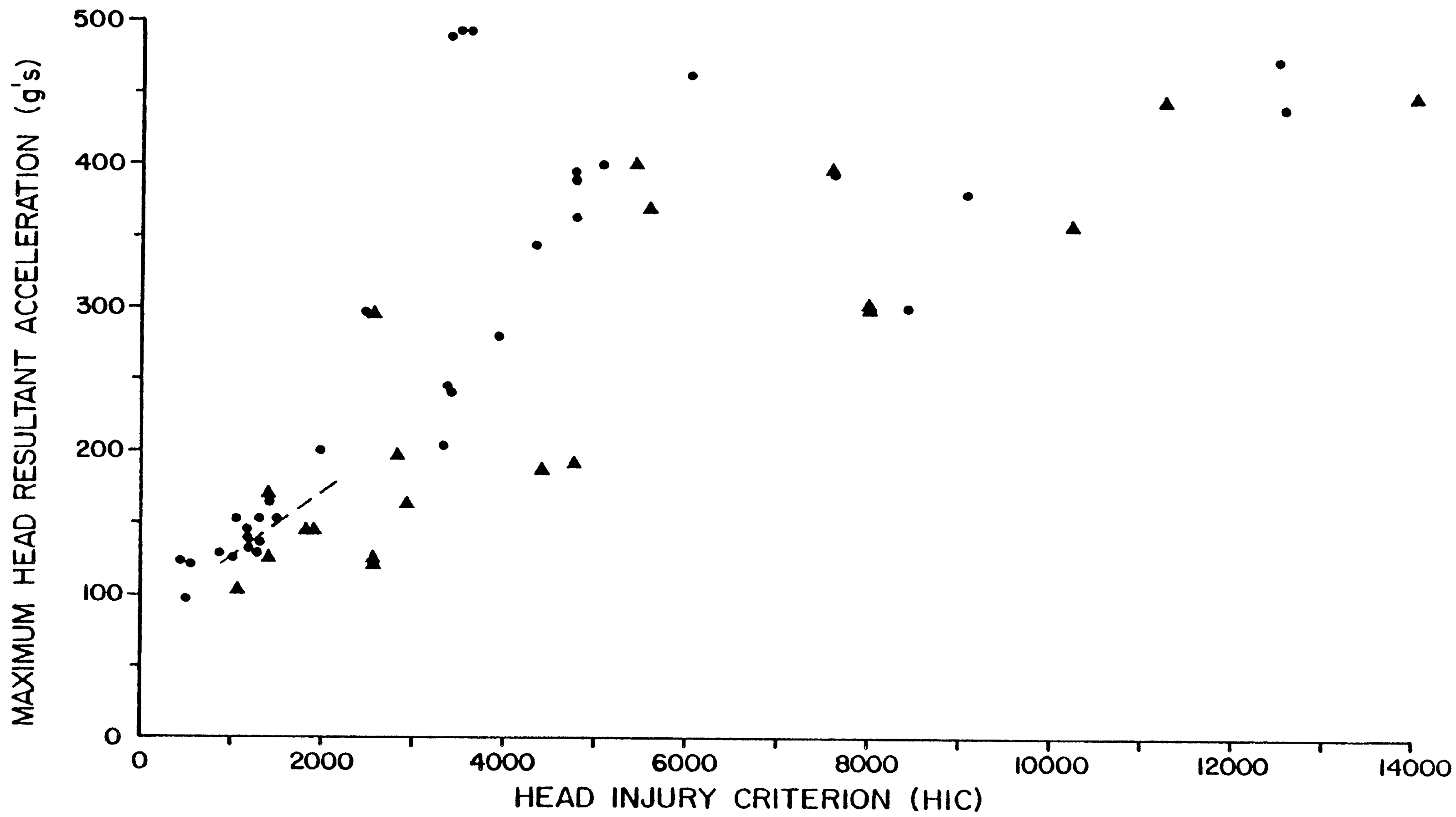
* The amount of scatter in simulation results of Figure 12 is typical of HIC scatter from experimental tests.

** Appendix B includes a table giving HIC value and interval of HIC evaluation for all simulations.

*** A correlation coefficient of 0.83 results if the four longer duration HIC's in the range (900, 2100) are disregarded. The regression line is $\ddot{X} = HIC/12.9 + 46.6$.



NOTE: SEE APPENDIX B FOR DATA.

Figure 4-1. Maximum Head Resultant Acceleration as a Function of HIC from Simulations

The regression analysis of the MVMA 2-D CVS simulation data establishes a maximum head resultant acceleration tolerance that can at the same time be used in assessing the likelihood of injury in impact situations simulated in this current study and can also be applied more broadly to situations and considerations outside of the current study. The regression line shown in Figure 4-1, derived from all impact simulations with HIC in the range 900 to 2100, gives a head resultant acceleration of 150 g's for HIC equal to 1500.

Thus, with regard to frontal and crown (apex) impact of the adult skull without fractures, the maximum head resultant acceleration tolerance limit for brain injury of severity no greater than "moderate" (AIS=2) is established as 150 g's.

4.2 Neck Injury Tolerance

The neck injury tolerance data which will be used for interpreting simulation results come from a study by Mertz and Patrick (1971). Their work included 90 static neck strength tests on ten volunteers, a series of dynamic hyperflexion tests with an impact sled which included 132 tests of four cadavers, and a less extensive series of dynamic hyperextension tests of cadavers and a volunteer subject.

Mertz and Patrick instrumented the head of each subject in the impact sled tests in order to establish time histories for the translational and rotational acceleration responses of the head. Additionally, data were obtained for each subject for the head mass, head mass moment of inertia, and location of the head center of mass with respect to the occipital condyles. With corrections to the inertia parameters in order to account for instrumentation and added weight on the head, it was then possible to calculate, as functions of time, neck torque and shear and axial forces acting at the occipital condyles. After testing, x-ray examination of the cadavers determined the presence or absence of injury of the neck structure.

4.2.1 Condyles Flexion Torque Tolerance.* None of the cadavers exposed to sled tests resulting in hyperflexion of the neck had any observable ligamentous, disc, or bone damage as noted from the analysis of x-rays. The maximum equivalent condyles flexion moment resulting from any test was 1680 in-lb. Mertz and Patrick suggest this value as in injury tolerance limit for a 50th percentile adult male.

For this study, then, a condyles flexion torque injury tolerance limit of 1680 in-lb will be used in the analysis of motorcyclist impact simulations. This should be considered a conservative lower bound since in the living human tensing of the neck musculature will assist the passive tissues (soft and hard) in resisting torsional load while it did not in the Mertz/Patrick cadaver tests.

4.2.2 Condyles Extension Torque Tolerance. In hyperextension tests, Mertz and Patrick were able to obtain ligamentous damage. On the basis of a test in which a cadaver suffered minor ligamentous damage, they suggest 504 in-lb as the associated injury tolerance level for a 50th percentile adult male.

* The condyles flexion torque determined by Mertz and Patrick was an "equivalent moment" which included any contribution from chin contact against the chest (normally absent). This was accounted for in the simulations since the Mertz/Patrick torque-deflection curve was used (Section 2.2.3).

For analysis of simulation results of the current study, the condyles extension torque injury tolerance limit will be taken as 504 in-lb.

4.2.3 Lower Neck Torque Tolerance. No data have been found in the literature which can be used to establish torque tolerance of the lower part of the neck structure, either for flexion or extension. Thus, while torques at the seventh-cervical/first-thoracic vertebral level of the spinal column are reported in Section 5, they cannot be discussed in relation to C7-T1 injury tolerance limits.

4.2.4 Neck Shear and Axial Forces. Mertz and Patrick determined in their study that shear and axial forces at the occipital condyles do not correlate with degree of trauma. They therefore do not define injury tolerance levels for these forces.

4.3 Summary of Injury Tolerance Levels

The values that have been established in this section for injury tolerances are summarized in Table 4-2.

TABLE 4-2

INJURY TOLERANCE LEVELS

Injury Predictor	Injury Tolerance Level
Head Injury Criterion (HIC)	1500 (AIS $\leq$ 2)
Maximum Head Resultant Acceleration	150 g's (AIS $\leq$ 2)
Condyles Flexion Torque	>1680 in-lb (ligamentous injury)
Condyles Extension Torque	504 in-lb (ligamentous injury)

5.0 RESULTS

5.1 Introduction

It would not be either feasible or of value to discuss in great detail the large amount of data generated by this study. All of the data have been reviewed, however, and the important results are discussed in some depth in Sections 5.2 and 5.3, which follow. The reader who is more interested in a summary of the important findings is directed to Section 5.4, which presents tabular and graphical comparisons of "helmet" and "no helmet" simulations, and to Section 6 (Discussion and Conclusions).

5.1.1 Simulations. A total of 65 simulations, or "runs", were made in this study. The configuration and conditions for each simulation are described in the run matrices, Tables 3-1, 3-2, and 3-3 of Section 3. The runs are described further by three tables which follow. Tables 5-1a and 5-1b define a "key" used for assigning a name to each run. Run names are used in several tables in this section and in appendices of the report. Table 5-2 gives the "run number" and "run name" for each simulation and briefly describes the primary variation from standard run conditions. This table also lists plot and comparison reference numbers pertinent to each simulation; these numbers will be discussed in Section 5.1.2. Table 5-3 divides the 65 simulations into the four basic types discussed in Section 3: 1) seated orientation impacts with the head striking a vertical surface (truck); 2) seated orientation impacts with the chest striking a vertical surface; 3) impacts of the head against a road surface for a road-torso angle of 30°; and 4) head-road impacts for a road-torso angle of 70°.

TABLE 5-1a

KEY TO RUN NAMES FOR
HEAD AND CHEST SEATED POSITION IMPACTS

AANNBBK.LCC = typical run name

AA = run type (HR, CR)

NN = horizontal impact velocity in mph (10, 20)

BB = helmet/no helmet (H, NH, HM)

K = muscle activity level (percentage of isometric maximum) x 1/10 (1, 5)

L = head, helmet, or chest coefficient of friction with struck surface x 10 (1, 3)

CC = additional descriptor (F, I2, I3)

AA: HR = head (or helmet) impact against rigid truck
CR = chest impact against rigid truck

NN: 10 = 10 mph
20 = 20 mph

BB: H = helmet
NH = no helmet
HM = helmet but with head mass only

K: 1 = 10% muscle activity level
5 = 50% muscle activity level

L: 1 = 0.1 coefficient of friction (helmet vs. truck)
3 = 0.35 coefficient of friction (chest vs. truck)
3 = 0.3 coefficient of friction (head vs. truck)

CC: F = no additional descriptor
I2 = increased neck flexion
I3 = neck in extension

TABLE 5-1b

KEY TO RUN NAMES FOR
ROAD IMPACTS

AABBNNDK.LCCC = typical run name

AA = run type (R)

BB = helmet/no helmet (H, NH, HM)

NN = horizontal impact velocity in mph (10, 20)

D = body orientation to road (H, V)

K = muscle activity level (percentage of isometric maximum) x 1/10 (1, 5)

L = head, helmet, or chest coefficient of friction with struck surface x 10 (0, 1, 2, 4, 6, 8, 10)

CCC = additional descriptor (F, I2, NR, NM, F-3)

AA: R = road impact by head (or helmet)

BB: H = helmet
NH = no helmet
HM = helmet but with head mass only

NN: 10 = 10 mph
20 = 20 mph

D: H = 30° to road
V = 70° to road

K: 1 = 10% muscle activity level
5 = 50% muscle activity level

L: 0 = 0.0 coefficient of friction
1 = 0.1 coefficient of friction
2 = 0.2 coefficient of friction
4 = 0.4 coefficient of friction
6 = 0.6 coefficient of friction
8 = 0.8 coefficient of friction
10 = 1.0 coefficient of friction

CCC: F = no additional descriptor
I2 = increased neck flexion
NR = no rotational velocity for impact conditions
NM = no mass (≈ 0) for body (helmet and head mass only)
F-3 = 3-foot fall height

TABLE 5-2

COMPUTER SIMULATIONS (Page 1 of 2)

Run No.	Run Name	Run Conditions*	Plot and Comparison Reference Numbers
1	HR20NH5.3F	20mph, 50%MT, Head/Truck angle = 20°	2,3
2	HR20H5.1F		2,32,42,51
3	HR20HN5.3I2	Head/Truck angle = 40°	3
4	HR10H5.1F	10mph	29,32,58
5	HR10NH5.3F		29
6	HR20H1.1F	10%MT	36,51
7	HR20NH1.3F		36
8	HR20HM5.1F	Helmet run with head mass	42
9	CR20NH5.3	20mph, 50%MT, Head 20° from vertical	1
10	CR20H5.3		1,33,45,46,52
11	CR10H5.3	10mph	28,33,59
12	CR10NH5.3		28
13	CR20H1.3	10%MT	37,52
14	CR20NH1.3		37
15	CR20H5.3I2	Head 40° from vertical, neck in flexion	43,45,53
16	CR20NH5.3I2		43
17	CR20H5.3I3	Head back 10° from vertical, neck in extension	44,46,53
18	CR20NH5.3I3		44
19	RH20H5.2F	20mph, 50%MT, Head/road angle = 30°, CFH=.2, CFNH=.6	4,5,8,9,13,34,40,47,49,57,60,64, 65,66,70
20	RNH20H5.6F		4,6,7,10,14,17,61
21	RH20H5.6F	CFH=.6, CFNH=.2	7,8
22	RNH20H5.2		5,6
23	RH10H5.2F	10mph	30,34
24	RNH10H5.6F		30
25	RH20H1.2F	10%MT	38,49
26	RNH20H1.6F		17,38
27	RH20H5.10F	CF = 1.0	40
28	RNH20H5.10F		-
29	RH20H5.2I2	Head/road angle = 60°, neck in flexion	13,15
30	RNH20H5.6I2		14,15
31	RH20H5.2NM	Body mass ≃ 0	47
32	RNH20H5.6NM		-
33	RH20H5.2NR	No initial angular velocity	9,12

TABLE 5-2. COMPUTER SIMULATIONS (Page 2 of 2)

34	RH20V5.2F	20mph, 50%MT, Head/road angle = 70°, CFH = .2, CFNH = .6	18,20,22,26,35,41,48,50,55,60,67,68, 69,71,72
35	RNH20V5.6		18,19,21,23,27,61
36	RH20V5.6F	CFH = .6, CFNH = .2	20,21
37	RNH20V5.2F		19,22
38	RH10V5.2F	10mph	31,35
39	RNH10V5.6F		31
40	RH20V1.2F	10%MT	39,50
41	RNH20V1.0F		27,39
42	RH20V5.10F	CF = 1.0	41
43	RNH20V5.10F		-
44	RH20V5.2I2	Head/road angle = 90°, neck in flexion	25,69
45	RNH20V5.6I2		23,25
46	RH20V5.2NM	Body mass ≃ 0	48
47	RNH20V5.6NM		-
48	RH20V5.2NR	No initial angular velocity	26
49	RNH20H5.6NR	No initial angular velocity	10,12
50	RNH20V5.6F-3	3-foot fall height	54,63
51	RH20V5.2F-3		54,55,62
52	RNH20H5.6F-3		56,63
53	RH20H5.2F-3		56,57,62
54	HR10H1.1F	10%MT	58
55	CR10H1.3		59
56	RH20H5.1F	CFH = 0.1	64
57	RH20H5.3F	CFH = 0.3	65
58	RH20H5.0F	CFH = 0.	66
59	RH20V5.0F	CFH = 0.	72
60	RNH20H5.0F	CFNH = 0.	-
61	RNH20V5.0F	CFNH = 0.	-
62	RH20V5.4F	CFH = 0.4	67
63	RH20V5.8F	CFH = 0.8	68
64	RHM20H5.2F	Helmet run with head mass	70
65	RHM20V5.2F	Helmet run with head mass	71

* MT = muscle tension
CF = coefficient of friction
CFH = coefficient of friction, helmet
CFNH = coefficient of friction, no helmet

TABLE 5-3. COMPUTER SIMULATIONS BY TYPE (Page 1 of 2)

Type	Run No.	Run Name	Plot and Comparison Reference Numbers
Head-Truck	1	HR20NH5.3F	2,3
	2	HR20H5.1F	2,32,42,51
	3	HR20NH5.3I2	3
	4	HR10H5.1F	29,32,58
	5	HR10NH5.3F	29
	6	HR20H1.1F	36,51
	7	HR20NH1.3F	36
	8	HR20HM5.1F	42
	54	HR10H1.1F	58
Chest-Truck	9	CR20NH5.3	1
	10	CR20H5.3	1,33,45,46,52
	11	CR10H5.3	28,33,59
	12	CR10NH5.3	28
	13	CR20H1.3	37,52
	14	CR20NH1.2	37
	15	CR20H5.3I2	43,45,53
	16	CR20NH5.3I2	43
	17	CR20H5.3I3	44,46,53
	18	CR20NH5.3I3	44
	55	CR10H1.3	59
Head-Road Horizontal (30° from Road)	19	RH20H5.2F	4,5,8,9,13,34,40,47,49,57,60, 64,65 66,70
	20	RNH20H5.6F	4,6,7,10,14,17,61
	21	RH20H5.6F	7,8
	22	RNH20H5.2F	5,6
	23	RH10H5.2F	30,34
	24	RNH10H5.6F	30
	25	RH20H1.2F	38,49
	26	RNH20H1.6F	17,38
	27	RH20H5.10F	40
	28	RNH20H5.10F	-
	29	RH20H5.2I2	13,15
	30	RNH20H5.6I2	14,15
	31	RH20H5.2NM	47
	32	RNH20H5.6NM	-
	33	RH20H5.2NR	9,12
	49	RNH20H5.6NR	10,12
	52	RNH20H5.6F-3	56,63
	53	RH20H5.2F-3	56,57,62
	56	RH20H5.1F	64
	57	RH20H5.3F	65
	58	RH20H5.0F	66
	60	RNH20H5.0F	-
	64	RHM20H5.2F	70

TABLE 5-3. COMPUTER SIMULATIONS BY TYPE (Page 2 of 2)

Type	Run No.	Run Name	Plot and Comparison Reference Numbers
Head-Road Vertical (70° from Road)	34	RH20V5.2F	18,20,22,26,35,41,48,50,55,60, 67,68,69, 71,72
	35	RNH20V5.0F	18,19,21,23,27,61
	36	RH20V5.6F	20,21
	37	RNH20V5.2F	19,22
	38	RH10V5.2F	31,35
	39	RNH10V5.6F	31
	40	RH20V1.2F	39,50
	41	RNH20V1.0F	27,39
	42	RH20V5.10F	41
	43	RNH20V5.10F	-
	44	RH20V5.2I2	25,69
	45	RNH20V5.6I2	23,25
	46	RH20V5.2NM	48
	47	RNH20V5.6NM	-
	48	RH20V5.2NR	26
	50	RNH20V5.6F-3	54,63
	51	RH20V5.2F-3	54,55,62
	59	RH20V5.0F	72
	61	RNH20V5.0F	-
	62	RH20V5.4F	67
	63	RH20V5.8F	68
	65	RHM20V5.2F	71

5.1.2 Tables, Comparisons and Plots. In order to facilitate studying the effects of varying parameter values and run conditions, three types of computer-generated output were obtained to supplement the standard printout of tabular time histories for dynamic response variables. Appendix B contains a table from each computer run which summarizes the positive and negative peak response values along with times of occurrence for each of the seventeen dynamic response variables described in Table 5-7. Values are also printed for the Head Injury Criterion (HIC)* and average head and chest resultant accelerations over a 3-msec wide range centered at the time of peak response as illustrated in the example in Table 5-4. The second type of supplementary output is contained in Appendix C, which consists of 69 pages of tables comparing the peak positive and negative magnitudes for dynamic responses for 69 pairs of contrasted runs. An example page is shown here as Table 5-5. Finally, plots were obtained for each of the seventeen response variables described in Table 5-7 and for each of 63 pairs of contrasted runs. (Plots were not made for comparisons 64, 65, 66, 67,68, and 72). The 1071 plots comprise Appendix D.

The 69 pairs of runs which were compared in this study are identified and described in Table 5-6. The numbers in the first column are the plot or comparison reference numbers mentioned above and included in Tables 5-2 and 5-3. The largest number assigned for plots and peak magnitude comparisons is 72 since three reference numbers were not used either for plots or tabular comparisons. Within the text, a number enclosed within brackets [ ] is the plot/comparison reference number for the pair of simulations being contrasted.

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* HIC is defined in Appendix A and discussed in Section 4.1.

TABLE 5-4. PEAK MAGNITUDES OF DYNAMIC RESPONSES: EXAMPLE PAGE FROM APPENDIX B

21

RH20H5.6F

HIC= 1403. BETWEEN 2. AND 50.MSEC
3-MSEC AVG. FOR HEAD= 121. AT 4. MSEC
3-MSEC AVG. FOR CHEST= 47. AT 11. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.3	3.	80.5	82.
2-HEAD ANG. VELOCITY	-825.9	96.	3165.9	18.
3-HEAD ANG. ACCEL.	-5284.2	21.	6424.1	13.
4-HEAD RESUL. ACCEL.	1.0	0.	125.2	4.
5-UPPER NECK STOP TORQUE	-385.0	47.	888.1	24.
6-LOWER NECK STOP TORQUE	-1056.9	23.	440.9	49.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3489.9	14.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	2094.0	14.
9-CONDYLE JOINT ANGLE	1.9	47.	72.9	24.
10-C7-T1 JOINT ANGLE	-60.1	23.	21.9	49.
11-FORCE ALONG NECK	-1157.1	39.	4821.3	11.
12-SHEAR FORCE AT CONDYLES	-435.1	48.	732.4	23.
13-COMP. FORCE AT CONDYLES	-1045.2	39.	4715.2	11.
14-SHEAR FORCE AT C7-T1	-421.9	49.	749.6	23.
15-COMP. FORCE AT C7-T1	-1135.8	39.	4593.4	11.
16-CONDYLE TOTAL TORQUE	-601.7	47.	1288.5	24.
17-C7-T1 TOTAL TORQUE	-1998.0	23.	1553.1	48.

22

RNH20H5.2F

HIC= 4787. BETWEEN 0. AND 7.MSEC
3-MSEC AVG. FOR HEAD= 310. AT 2. MSEC
3-MSEC AVG. FOR CHEST= 26. AT 73. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.1	1.	59.6	58.
2-HEAD ANG. VELOCITY	-2676.1	77.	3299.9	18.
3-HEAD ANG. ACCEL.	-4365.0	30.	17203.4	3.
4-HEAD RESUL. ACCEL.	1.0	0.	367.7	2.
5-UPPER NECK STOP TORQUE	-302.9	88.	372.8	31.
6-LOWER NECK STOP TORQUE	-305.6	100.	329.1	49.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4770.0	3.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	954.0	3.
9-CONDYLE JOINT ANGLE	7.4	88.	59.6	31.
10-C7-T1 JOINT ANGLE	-32.7	100.	18.0	49.
11-FORCE ALONG NECK	-644.8	12.	2882.2	5.
12-SHEAR FORCE AT CONDYLES	-314.3	45.	134.0	99.
13-COMP. FORCE AT CONDYLES	-571.7	12.	2839.3	4.
14-SHEAR FORCE AT C7-T1	-133.0	38.	121.2	100.
15-COMP. FORCE AT C7-T1	-635.6	12.	2789.4	5.
16-CONDYLE TOTAL TORQUE	-517.6	88.	659.2	31.
17-C7-T1 TOTAL TORQUE	-869.7	99.	1003.5	49.

TABLE 5-5. COMPARISON OF PEAK MAGNITUDES FROM RUNS A AND B: EXAMPLE PAGE FROM APPENDIX C

COMPARISON # 36

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= HR20NH1.3F AND B= HR20H1.1F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	218	243	0.897	1.115	10.3% LESS	11.5% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
2-HEAD ANG. VELOC.	6050	4741	1.276	0.784	27.6% GREATER	21.6% LESS	-1452	-1044	1.391	0.719	39.1% GREATER	28.1% LESS
3-HEAD ANG. ACCEL.	14804	8710	1.700	0.588	70.0% GREATER	41.2% LESS	-12671	-4416	2.869	0.349	186.9% GREATER	65.1% LESS
4-HEAD RES. ACCEL.	492	248	1.986	0.504	98.6% GREATER	49.6% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	1209	1125	1.074	0.931	7.4% GREATER	6.9% LESS	-347	-1703	0.204	4.905	79.6% LESS	390.5% GREATER
6-C7-T1 STOP TORQ.	1863	1667	1.117	0.895	11.7% GREATER	10.5% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
7-Z HEAD FORCE	398	118	3.350	0.298	235.0% GREATER	70.2% LESS	-766	-388	1.973	0.507	97.3% GREATER	49.3% LESS
8-X HEAD FORCE	5035	3885	1.296	0.772	29.6% GREATER	22.8% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	68	67	1.021	0.980	2.1% GREATER	2.0% LESS	-5	-38	0.146	6.857	85.4% LESS	585.7% GREATER
10-C7-T1 ANGLE	37	35	1.068	0.936	6.8% GREATER	6.4% LESS	-30	-30	1.000	1.000	0.0% LESS	0.0% GREATER
11-FORCE ALONG NECK	1259	988	1.273	0.785	27.3% GREATER	21.5% LESS	-1238	-944	1.312	0.762	31.2% GREATER	23.8% LESS
12-SHEAR AT CONDYLE	27	28	0.975	1.022	2.1% LESS	2.2% GREATER	-511	-529	0.965	1.036	3.5% LESS	3.6% GREATER
13-COMP. AT CONDYLE	1322	1067	1.239	0.808	23.8% GREATER	19.2% LESS	-1242	-813	1.527	0.655	52.7% GREATER	34.5% LESS
14-SHEAR AT C7-T1	154	64	2.407	0.416	140.7% GREATER	58.4% LESS	-322	-507	0.635	1.574	36.5% LESS	57.4% GREATER
15-COMP. AT C7-T1	1194	937	1.274	0.785	27.4% GREATER	21.5% LESS	-1169	-898	1.301	0.769	30.1% GREATER	23.1% LESS
16-COND. TOTAL TORQ	1320	1210	1.091	0.917	9.1% GREATER	8.3% LESS	-376	-1792	0.210	4.757	79.0% LESS	375.7% GREATER
17-C7-T1 TOTAL TORQ	2160	1924	1.123	0.891	12.3% GREATER	10.9% LESS	-15	0	0.0	0.0	0.0% GREATER	100.0% LESS
HIC	3511	3388	1.036	0.965	3.6% GREATER	3.5% LESS						
HEAD 3-MSEC AVG.	292	236	1.237	0.808	23.7% GREATER	19.2% LESS						
CHEST 3-MSEC AVG	30	22	1.364	0.733	36.4% GREATER	26.7% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

TABLE 5-6

PLOTS AND COMPARISONS (Page 1 of 4)

Plot or Comparison Number**	Comparison	Run Nos.	Parameter Variation/Run Conditions+
1*	CR20NH5.3	9	no helmet (chest-truck baseline)
	CR20H5.3	10	helmet (chest-truck baseline)
2*	HR20NH5.3F	1	no helmet (head-truck baseline)
	HR20H5.1F	2	helmet (head-truck baseline)
3	HR20NH5.3F	1	head-truck angle = 20° (no helmet)
	HR20NH5.3I2	3	head-truck angle = 40° (no helmet)
4*	RNH20H5.6F	20	no helmet (30° road baseline)
	RH20H5.2F	19	helmet (30° road baseline)
5	RNH20H5.2F	22	no helmet (CFNH = .2)
	RH20H5.2F	19	helmet (CFH = .2)
6	RNH20H5.6F	20	CFNH = .6 (no helmet)
	RNH20H5.2F	22	CFNH = .2 (no helmet)
7	RNH20H5.6F	20	no helmet (CFNH = .6)
	RH20H5.6F	21	helmet (CFH = .6)
8	RH20H5.2F	19	CFH = .2 (helmet)
	RH20H5.6F	21	CFH = .6 (helmet)
9	RH20H5.2F	19	100 deg/sec (helmet)
	RH20H5.2NR	33	0 deg/sec (helmet)
10	RNH20H5.6F	20	100 deg/sec (no helmet)
	RNH20H5.6NR	49	0 deg/sec (no helmet)
11-	- - - -		
12	RNH20H5.6NR	44	no helmet (0 deg/sec)
	RH20H5.2NR	33	helmet (0 deg/sec)
13	RH20H5.2F	19	head-road angle = 30° (helmet)
	RH20H5.2I2	29	head-road angle = 60° (helmet)
14	RNH20H5.6F	20	head-road angle = 30° (no helmet)
	RNH20H5.6I2	30	head-road angle = 60° (no helmet)
15	RNH20H5.6I2	30	no helmet (head-road angle = 60°)
	RH20H5.2I2	29	helmet (head-road angle = 60°)
16-	- - - -		
17	RNH20H5.6F	20	50% MT (no helmet)
	RNH20H1.6F	26	10% MT (no helmet)
18*	RNH20V5.6F	35	no helmet (70° road baseline)
	RH20V5.2F	34	helmet (70° road baseline)
19	RNH20V5.6F	35	CFNH = .6 (no helmet)
	RNH20V5.2F	37	CFNH = .2 (no helmet)

Plot or Comparison Number**	Comparison	Run Nos.	Parameter Variation/Run Conditions+
20	RH20V5.2F	34	CFH = .2 (helmet)
	RH20V5.6F	36	CFH = .6 (helmet)
21	RNH20V5.6F	35	no helmet (CFNH = .6)
	RH20V5.6F	36	helmet (CFH = .6)
22	RNH20V5.2F	37	no helmet (CFNH = .2)
	RH20V5.2F	34	helmet (CFH = .2)
23	RNH20V5.6F	35	head-road angle = 70° (no helmet)
	RNH20V5.6I2	45	head-road angle = 90° (no helmet)
24-	- - - -		
25	RNH20V5.6I2	45	no helmet (head-road angle = 90°)
	RH20V5.2I2	44	helmet (head-road angle = 90°)
26	RH20V5.2F	34	100 deg/sec (helmet)
	RH20V5.2NR	48	0 deg/sec (helmet)
27	RNH20V5.6F	35	50% MT (no helmet)
	RNH20V1.6F	41	10% MT (no helmet)
28	CR10NH5.3	12	no helmet (10 mph)
	CR10H5.3	11	helmet (10 mph)
29	HR10NH5.3F	5	no helmet (10 mph)
	HR10H5.1F	4	helmet (10 mph)
30	RNH10H5.6F	24	no helmet (10 mph)
	RH10H5.2F	23	helmet (10 mph)
31	RNH10V5.6F	39	no helmet (10 mph)
	RH10V5.2F	38	helmet (10 mph)
32	HR20H5.1F	2	20 mph (helmet)
	HR10H5.1F	4	10 mph (helmet)
33	CR20H5.3	10	20 mph (helmet)
	CR10H5.3	11	10 mph (helmet)
34	RH20H5.2F	19	20 mph (helmet)
	RH10H5.2F	23	10 mph (helmet)
35	RH20V5.2F	34	20 mph (helmet)
	RH10V5.2F	38	10 mph (helmet)
36	HR20NH1.3F	7	no helmet (10% MT)
	HR20H1.1F	6	helmet (10% MT)
37	CR20NH1.3	14	no helmet (10% MT)
	CR20H1.3	13	helmet (10% MT)
38	RNH20H1.6F	26	no helmet (10% MT)
	RH20H1.2F	25	helmet (10% MT)
39	RNH20V1.6F	41	no helmet (10% MT)
	RH20V1.2F	40	helmet (10% MT)

Plot or Comparison Number**	Comparison	Run Nos.	Parameter Variation/Run Conditions+
40	RH20H5.2F	19	CFH = .2 (helmet)
	RH20H5.10F	27	CFH = 1.0 (helmet)
41	RH20V5.2F	34	CFH = .2 (helmet)
	RH20V5.10F	42	CFH = 1.0 (helmet)
42	HR20H5.1F	2	helmet has helmet mass
	HR20HM5.1F	8	helmet has no mass
43	CR20NH5.3I2	16	no helmet (head-truck angle = 40°)
	CR20H5.3I2	15	helmet (head-truck angle = 40°)
44	CR20NH5.3I3	18	no helmet (head back 10°)
	CR20H5.3I3	17	helmet (head back 10°)
45	CR20H5.3	10	head forward 20° (helmet)
	CR20H5.3I2	15	head forward 40° (helmet)
46	CR20H5.3	10	head forward 20° (helmet)
	CR20H5.3I3	17	head back 10° (helmet)
47	RH20H5.2F	19	standard body mass (helmet, horizontal)
	RH20H5.2NM	31	body mass ≈ 0 (helmet, horizontal)
48	RH20V5.2F	34	standard body mass (helmet, vertical)
	RH20V5.2NM	46	body mass ≈ 0 (helmet, vertical)
49	RH20H5.2F	19	50% MT (helmet)
	RH20H1.2F	25	10% MT (helmet)
50	RH20V5.2F	34	50% MT (helmet)
	RH20V1.2F	40	10% MT (helmet)
51	HR20H5.1F	2	50% MT (helmet)
	HR20H1.1F	6	10% MT (helmet)
52	CR20H5.3	10	50% MT (helmet)
	CR20H1.3	13	10% MT (helmet)
53	CR20H5.3I2	15	head forward 40° (helmet)
	CR20H5.3I3	17	head back 10° (helmet)
54	RNH20V5.6F-3	50	no helmet (70° road, 3-ft drop)
	RH20V5.2F-3	51	helmet (70° road, 3-ft drop)
55	RH20V5.2F	34	6-ft drop (helmet, 70° road)
	RH20V5.2F-3	51	3-ft drop (helmet, 70° road)
56	RNH20H5.6F-3	52	no helmet (30° road, 3-ft drop)
	RH20H5.2F-3	53	helmet (30° road, 3-ft drop)
57	RH20H5.2F	19	6-ft drop (helmet, 30° road)
	RH20H5.2F-3	53	3-ft drop (helmet, 30° road)
58	HR10H5.1F	4	50% MT (10 mph)
	HR10H1.1F	54	10% (10 mph)
59	CR10H5.3	11	50% MT (10 mph)
	CR10H1.3	55	10% MT (10 mph)

Plot or Comparison Number**	Comparison	Run. Nos.	Parameter Variation/Run Conditions+
60	RH20H5.2F	19	30° road (helmet, 6-ft drop)
	RH20V5.2F	34	70° road (helmet, 6-ft drop)
61	RNH20H5.6F	20	30° road (no helmet, 6-ft drop)
	RNH20V5.6F	35	70° road (no helmet, 6-ft drop)
62	RH20H5.2F-3	53	30° road (helmet, 3-ft drop)
	RH20V5.2F-3	51	70° road (helmet, 3-ft drop)
63	RNH20H5.6F-3	52	30° road (no helmet, 3-ft drop)
	RNH20V5.6F-3	50	70° road (no helmet, 3-ft drop)
64#	RH20H5.2F	19	CFH = .2 (helmet, 30° road)
	RH20H5.1F	56	CFH = .1 (helmet, 30° road)
65#	RH20H5.2F	19	CFH = .2 (helmet, 30° road)
	RH20H5.3F	57	CFH = .3 (helmet, 30° road)
66#	RH20H5.2F	19	CFH = .2 (helmet, 30° road)
	RH20H5.0F	58	CFH = 0. (helmet, 30° road)
67#	RH20V5.2F	34	CFH = .2 (helmet, 70° road)
	RH20V5.4F	62	CFH = .4 (helmet, 70° road)
68#	RH20V5.2F	34	CFH = .2 (helmet, 70° road)
	RH20V5.8F	63	CFH = .8 (helmet, 70° road)
69	RH20V5.2F	34	head-road angle = 70° (helmet)
	RH20V5.2I2	44	head-road angle = 90° (helmet)
70	RH20H5.2F	19	helmet has helmet mass
	RHM20H5.2F	64	helmet has no mass
71	RH20V5.2F	34	helmet has helmet mass
	RHM20V5.2F	65	helmet has no mass
72#	RH20V5.2F	34	CFH = .2 (helmet, 70° road)
	RH20V5.0F	59	CFH = 0. (helmet, 70° road)

NOTES:

* Helmet/no helmet comparisons for the four baseline configurations of the basic run matrix are made in plots 1, 2, 4, and 18.

+ CFH = coefficient of friction for helmet, CFNH = coefficient of friction for no helmet ; MT = muscle tension.

- Reference numbers 11, 16, and 24 were not used.

A-B tabulations for peak values were made for reference numbers 64 through 68 and 72, but there are no plots.

** Tabular comparisons (A-B tabulations) are found in Appendix C and plots are in Appendix D. Comparison/Plot numbers referenced in the text are bracketed [ ].

5.1.3 Definitions. The dynamic response variables discussed in the following sections are described in Table 5-7. Most of the seventeen responses included in the table are ones which have *a priori* potential of indicating likelihood or degree of injury to the head (brain) or neck. Although most quantities and terms used in the table are adequately defined there and in Section 4, several points are worthy of special comment.

The terms "upper neck joint" and "occipital condyles" (or simply "condyles") are used interchangeably throughout this report. Similarly, the terms "lower neck joint" and "C7-T1" (seventh-cervical/first-thoracic vertebral level) are used interchangeably. It should be understood, however, that the human neck has not two but eight primary articulations between the skull, the seven cervical vertebrae, and the top of the thoracic spine. It has been demonstrated by various studies using the MVMA 2-D CVS model and other crash victim simulation models that a two-joint representation of the human neck is adequate for accurate prediction of head/neck dynamics, including head translational and rotational accelerations and neck bending moments, shear loadings, and compression/elongation force levels. The "upper neck joint" defined for a simulation is normally located at or near the uppermost articulation of the anatomical structure; this is the occipital condyles, where the skull pivots with the uppermost cervical vertebra (C_1), the "atlas." Similarly, the "lower neck joint" is normally positioned at or near the intervertebral disc at the C_7-T_1 level.

The terms "flexion" and "extension" are used throughout this report to indicate the sense of sagittal-plane bending of the neck. "Flexion"

TABLE 5-7

DYNAMIC RESPONSE VARIABLES IN PLOTS AND COMPARISONS

No.	Variable (units)	Sign Convention
1	Head Angular Position (deg)	counterclockwise for increase
2	Head Angular Velocity (deg/sec)	counterclockwise if positive
3	Head Angular Acceleration (rad/sec^2)	counterclockwise if positive
4	Head Resultant Acceleration (g's)	magnitude at CG
5	Upper Neck Torque (w/o muscle)(in-lb)	positive for extension, negative for flexion
6	Lower Neck Torque (w/o muscle)(in-lb)	positive for extension, negative for flexion
7	Vertical Component of Head (Chest) Contact Force (lb)	friction force for truck, normal force for road
8	Horizontal Component of Head (Chest) Contact Force (lb)	friction force for road, normal force for truck
9	Condyles Joint Angle (deg)	positive for extension, negative for flexion
10	C7-T1 Joint Angle (deg)	positive for extension, negative for flexion
11	Force Along Neck (lb)	positive for compression, negative for elongation
12	Neck Shear Force at Condyles (lb)	positive forward, normal to neck line
13	Neck Compression Force at Condyles (lb)	positive toward torso, along neck line
14	Neck Shear Force at C7-T1 (lb)	positive rearward, normal to neck line
15	Neck Compression Force at C7-T1 (lb)	positive toward head, along neck line
16	Total Upper Neck Torque (includes muscle)(in-lb)	positive for extension, negative for flexion
17	Total Lower Neck Torque (includes muscle)(in-lb)	positive for extension, negative for flexion

NOTE: upper neck joint = condyles
lower neck joint = C7-T1

is the term used for forward bending, and it may be applied to either the upper neck joint or the lower neck joint -- or to the neck as a whole. Similarly, "extension" indicates rearward angulation of the head and/or neck. Neck torques (moments) discussed in the text, given in tables, and illustrated by plots are negative for flexion and positive for extension.

Shear loads on the neck are components of the constraint forces at the two neck joints. They are the components resolved normal to the neck line (the line between the two joints). Positive neck shear loads are those primary loads which would result from a chest impact causing a forward motion of the head and neck, i.e., positive shear loads on the neck are "forward" at the condyles and "rearward" at C7-T1. Along the line of the neck, positive loads indicate "compression" and negative loads indicate "elongation" (or "tension").

Several points should be made with regard to head motion. First, "head resultant acceleration" (always given in g's) is the magnitude of the vector sum of the x- and z-components of head center-of-gravity acceleration. (Out-of-plane, "y-" components of motion are not simulated by the MVMA 2-D CVS model.) Angular responses -- velocity or acceleration -- are positive if counterclockwise, i.e., toward head/neck extension. With regard to angular positions, the inertial (absolute) head angle is zero when the inferior-superior head axis is horizontal, i.e., when the head is pitched so that the eyes are "down" and the top of the head is "forward" (toward positive x). This orientation may be visualized easily with the aid of Figure 2-1. Relative angles between the head and neck at the condyles and between the neck and the thorax at C7-T1 are zero for in-line orientation of head axis and neck line or neck line and thorax line. At each joint, a positive relative angle is for extension.

5.2 General Description of No-Helmet vs. Helmet Baseline Simulation Results

In Sections 5.2.2 through 5.2.5, which follow, all baseline simulations are discussed. The no-helmet simulations for the head-truck, chest-truck, 30° road, and 70° road impacts (20 mph) are numbers 1, 9, 20, and 35, respectively. The four corresponding helmet simulations are numbers 2, 10, 19, and 34. The reference numbers for the four sets of tabular comparisons (in Appendix C) and plots (in Appendix D) are [2], [1], [4], and [18], respectively.

The discussion of comparisons of helmet and no-helmet simulations in these sections is somewhat detailed. Tabular and graphical summaries of these results may be found in Section 5.4.

5.2.1 Effect of Head/Helmet Mass on Helmet Simulations. As mentioned in Section 3.2.3 the MVMA 2-D CVS helmet impact simulations of necessity modeled the head and helmet with one combined mass constant. In the real impact situation, however, the head and helmet masses would not act together -- the head mass alone would impact against the liner material. In order to investigate the seriousness of this compromise, three additional helmet runs were made, one for each baseline head impact condition, with the combined head/helmet mass reduced to that of the head mass alone. All other helmet parameters were maintained as in the helmet baseline runs. In these new simulations, the head mass is more appropriate during impact but less appropriate after unloading (when it should be head plus helmet). Plot/comparison numbers [42], [70], and [71] compare the results of these runs with those of the respective baseline runs for head-truck, 30° road, and 70° road impacts.

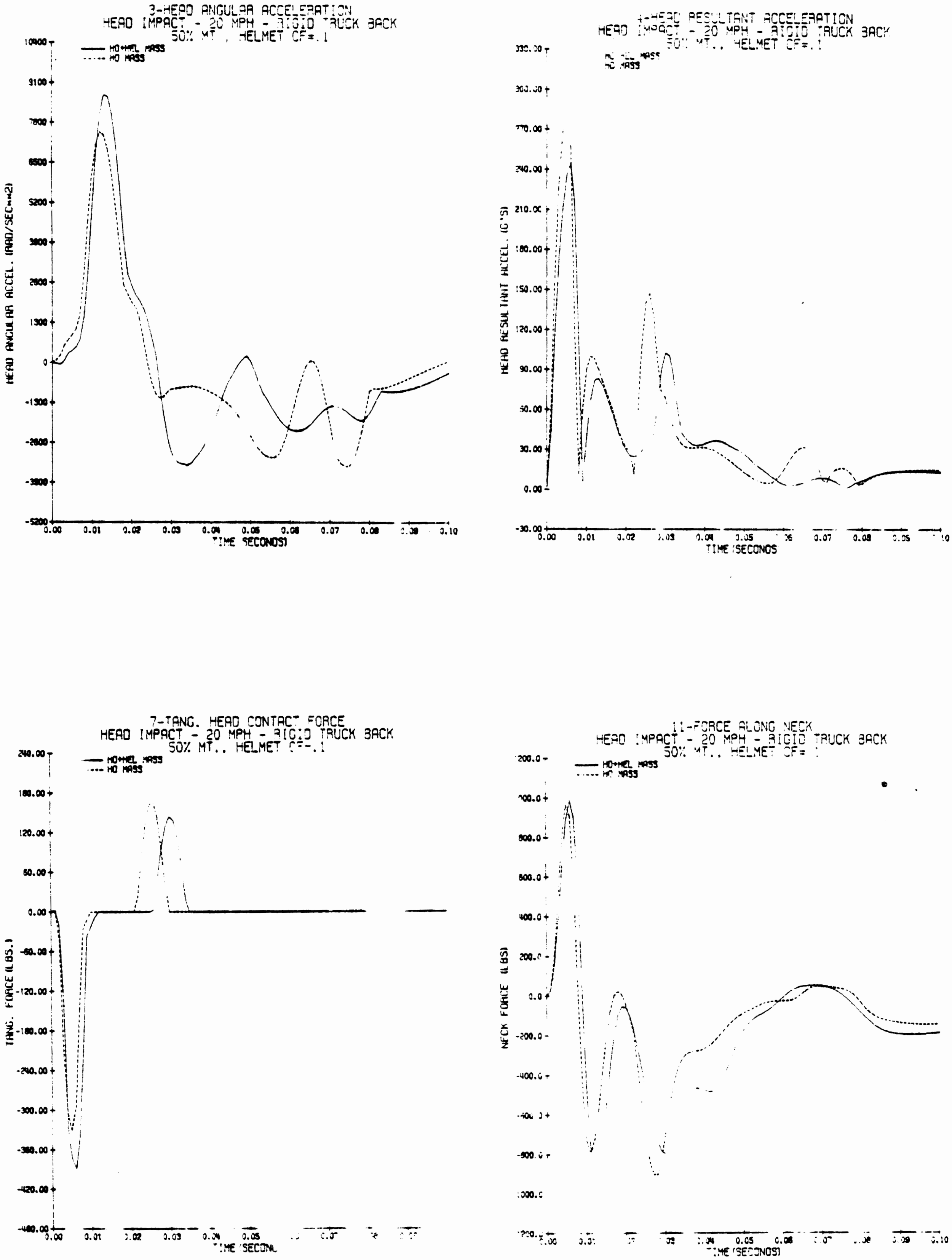

Figure 5-1. Selected Plots from Comparison [42] (Page 1 of 2)

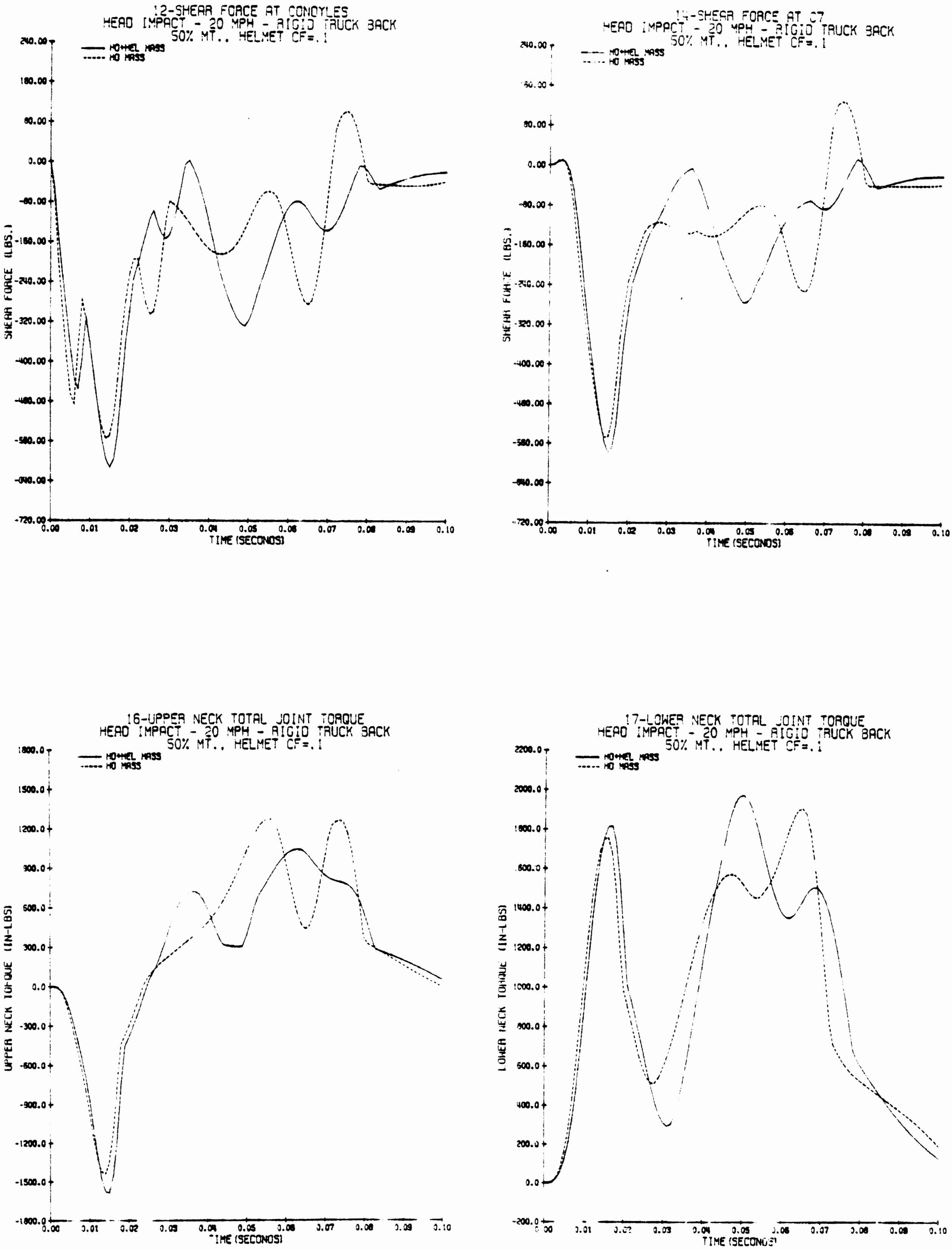

Figure 5-1. Selected Plots from Comparison [42] (Page 2 of 2)

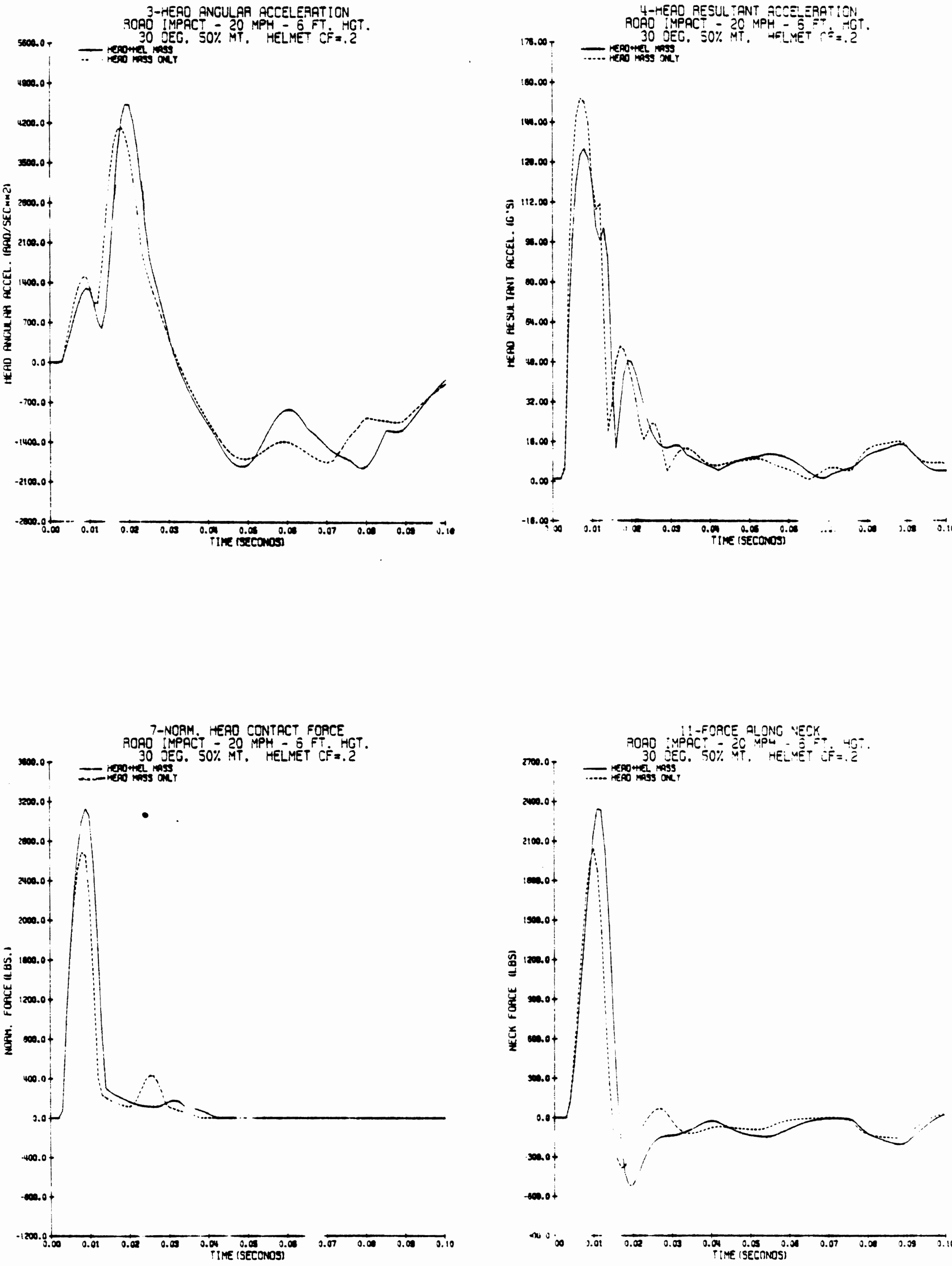

Figure 5-2. Selected Plots from Comparison [70] (Page 1 of 2)

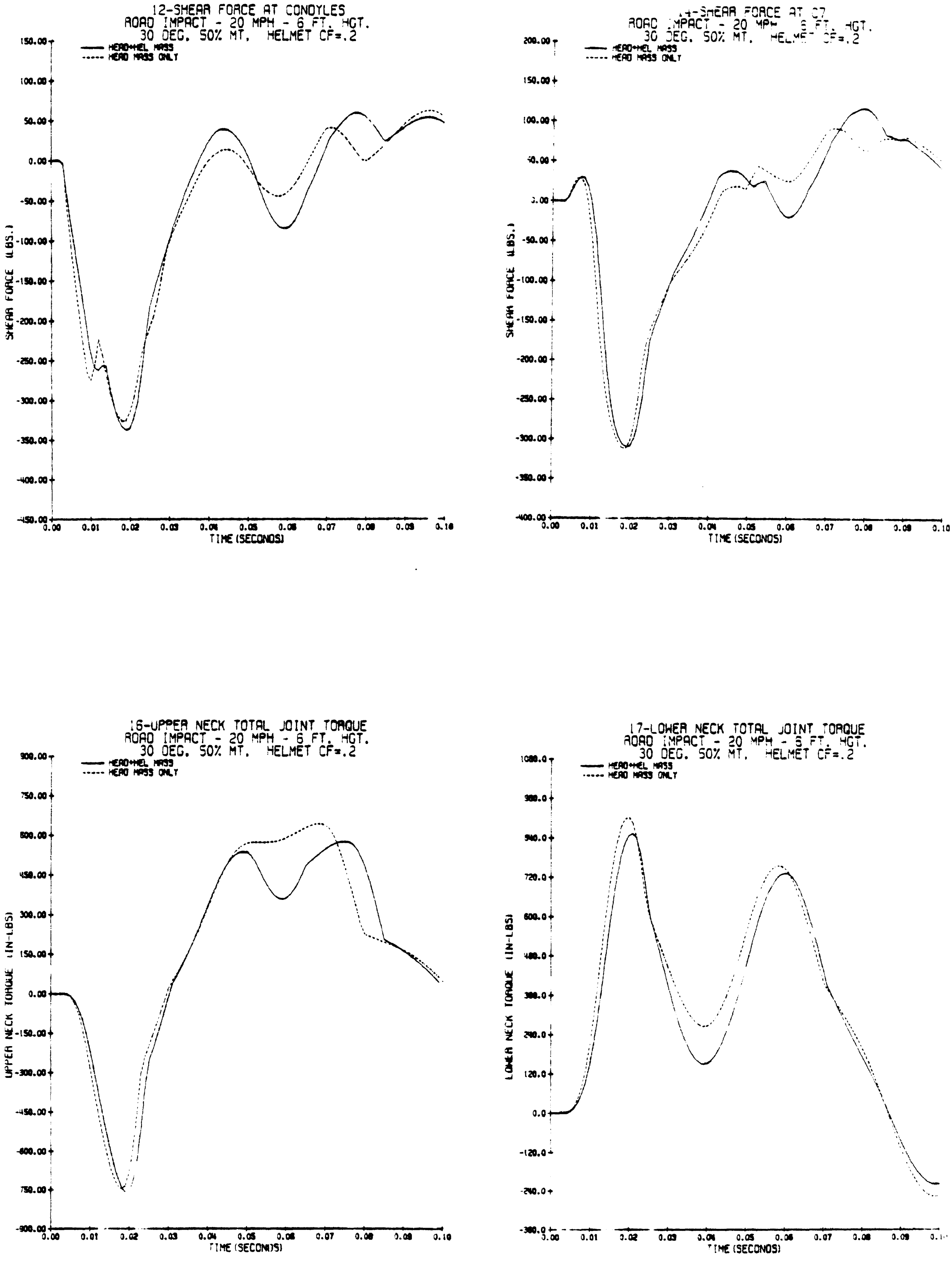

Figure 5-2. Selected Plots from Comparison [70] (Page 2 of 2)

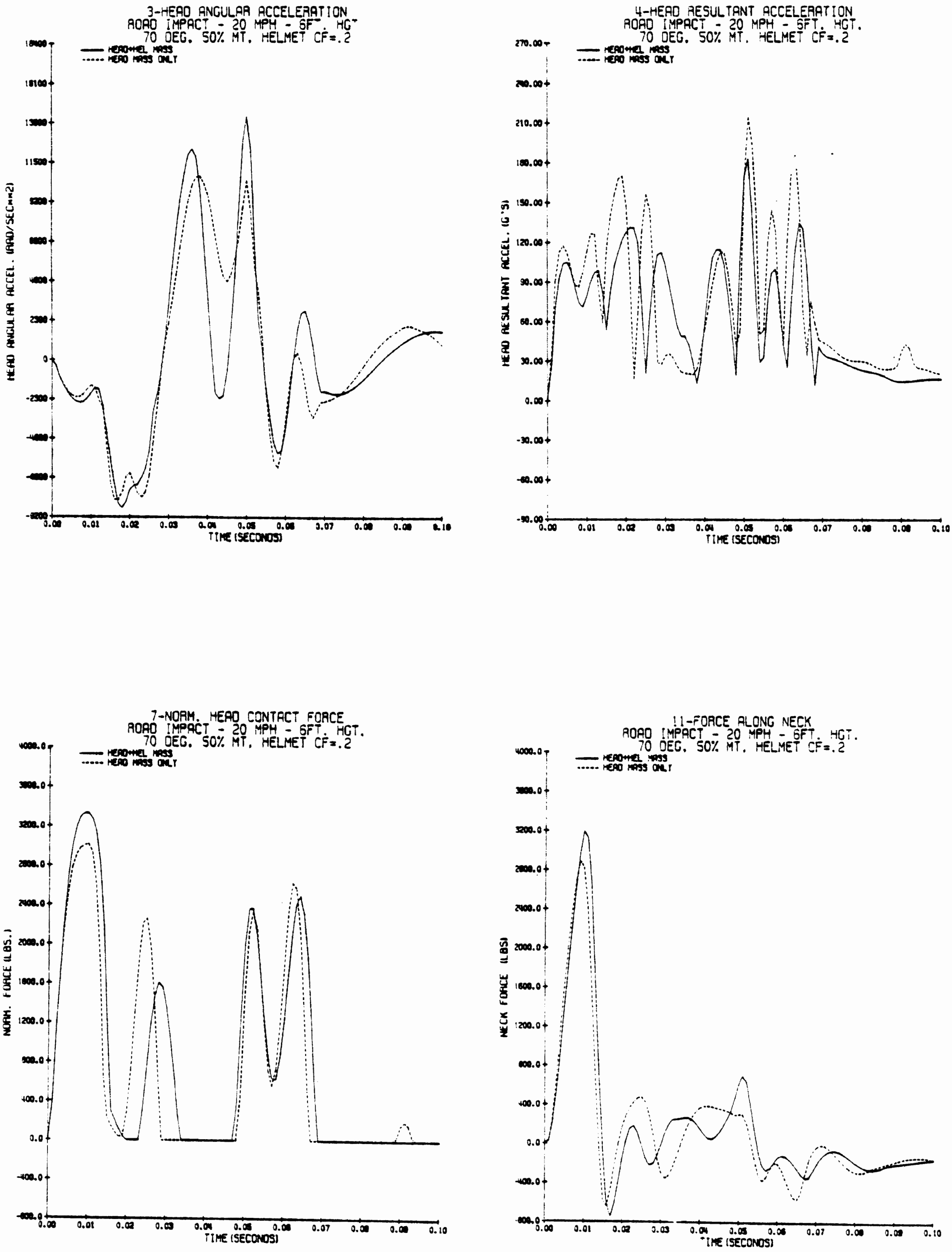

Figure 5-3. Selected Plots from Comparison [71] (Page 1 of 2)

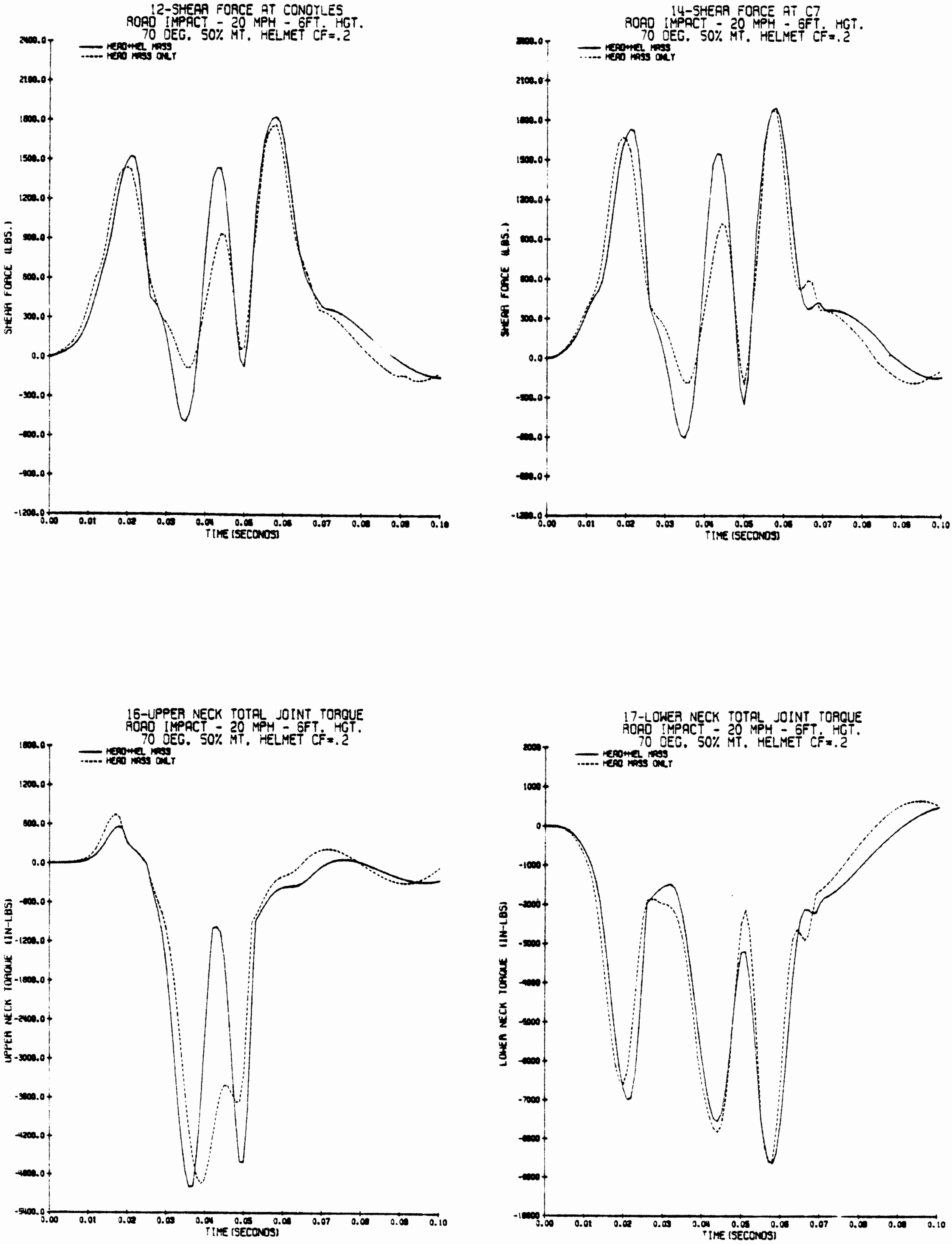

Figure 5-3. Selected Plots from Comparison [71] (Page 2 of 2)

The plots of Figures 5-1, 5-2, and 5-3 illustrate some of the most basic response variables for the head-plus-helmet mass runs and for the head-mass-only helmet impacts. It will be noted that the responses are quite similar overall.

The simulation comparisons made during this study and discussed in the following sections can be separated into two distinct groups. One group compares helmet and no-helmet results (Sections 5.2 and 5.4). The other group compares simulations that are both for no-helmet impacts or both for helmet impacts (Section 5.3). With regard to the latter comparisons, the head/helmet mass compromise is of little consequence and no concern since the purpose of those comparisons is to establish the relative effects of varying impact conditions other than the helmet/no-helmet condition (e.g., friction, fall height, impact angles, etc.). With regard to the results for helmet vs. no-helmet comparisons, however, it is important to establish that the differences between the results for the two types of helmet simulations are small, or otherwise unimportant, in relation to the differences between helmet and no-helmet responses.

Tables 5-8 and 5-9 summarize the percentage increases for peak response values for no-helmet runs relative to values for the two types of helmet runs. These tables give results for baseline conditions for all three types of head impacts investigated in this study, and the response variables included in the tables are those most predictive of injury potential. Table 5-8 is for the baseline helmet/no-helmet comparisons ([2], [4], and [18]) and includes some of the results discussed in later sections of this report. Table 5-9 gives parallel results for no-helmet impacts relative to head-mass-only helmet impacts. There are no Appendix C comparisons or Appendix D plots for the comparisons made for Table 5-9; the numbers there are established by comparing peak responses from runs 2 and 42, 4 and 70, and 18 and 71 for the head-truck, 30°-road, and 70°-road configurations, respectively.

If Tables 5-8 and 5-9 are compared entry for entry, it will be seen that there are three basic types of relationships between the numbers. For those marked by "L", the relative benefit of the helmet is large for both types of helmet simulations so that in the discussions of baseline comparisons in the remainder of Section 5, qualitative statements made regarding helmet benefits will be true regardless of differences between results from the two types of helmet simulations, and any questions regarding the accuracy of quantitative statements are of little importance. For those marked with "C", the magnitudes in Table 5-9 are larger than in Table 5-8 so that any statements relating to helmet benefit, if not completely accurate, must at least be conservative. Finally, for all table entries marked with "S", values are similar for the two types of comparisons, indicating responses for which it does not matter which head/helmet mass is used. Since all entries of these tables can reasonably be placed in at least one of these three groups, the conclusion is reached that the usefulness of helmet vs. no-helmet baseline comparisons is not significantly affected by the head/helmet mass compromise.*

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* The two responses of greatest uncertainty are HIC and neck compression force for the head-truck impact. These responses can be expected to be less sensitive to the head/helmet mass for slightly different run conditions, e.g., for different impact velocity or different initial head/neck orientation.

TABLE 5-8. NO-HELMET IMPACT RESPONSES RELATIVE TO HELMET IMPACT RESPONSES (BASELINE)

Impact Type	HIC	Head Resultant Accel.	Head Angular Accel.	Contact Force	Neck Compression Force	Condyles Extension Torque	Condyles Flexion Torque
Head-Truck	+ 5% S	+101% L	+ 69% C	+29% C	+27% S	+ 19% S	-74% S
30°-Road	+502% L	+199% LS	+434% LCS	+54% C	+80% C	+748% L	- 1% S
70°-Road	+216% LC	+145% L	+107% C	+48% C	+ 4% C	+120% L	-20% S

TABLE 5-9. NO-HELMET IMPACT RESPONSES RELATIVE TO HELMET IMPACT RESPONSES (HEAD MASS ONLY)

Impact Type	HIC	Head Resultant Accel.	Head Angular Accel.	Contact Force	Neck Compression Force	Condyles Extension Torque	Condyles Flexion Torque
Head-Truck	- 12% S	+ 71% L	+ 98% C	+52% C	+ 29% S	- 3% S	-72% S
30°-Road	+400% L	+160% LS	+489% LSC	+78% C	+109% C	+661% L	+ 1% S
70°-Road	+317% LC	+109% L	+174% C	+63% C	+ 15% C	+ 65% L	-19% S

5.2.2 Head-Truck Baseline Impacts. The stick figure drawings in Figure 5-4 illustrate the general motion of the cyclist's body and head and neck during head-truck impacts. The plots in Figure 5-6 compare some of the dynamic response variables for the helmet and no-helmet head-truck baseline impacts at 20 mph [2]. It is seen that the helmet reduces peak values of head angular acceleration and center of gravity resultant acceleration by significant amounts, 41% and 50%, respectively. Most significant is the head resultant acceleration reduction, from nearly 500 g's to less than 250 g's. Peak impact force to the head is reduced from over 5000 lbs to about 3900 lbs. HIC, however, is reduced only slightly, from 3475 to 3317. The reduction of HIC caused by the helmet is much less than might be expected a priori -- and it is much less than the typical reduction seen for other simulations that will be discussed in the following sections -- but the plots for head resultant acceleration make it clear that HIC for the helmet impact (3317) will be relatively large. While the peak head acceleration for this 20 mph impact is reduced by about half by the helmet, the duration of the acceleration pulse is doubled. Since duration is an element of the definition of the Head Injury Criterion, the effect of the smaller peak is nearly balanced by the effect of the broader pulse. For lower impact velocities, the beneficial effect of the helmet on HIC is much greater for the head-truck impact configuration.

Since the impact causes head and neck to rotate backward, the primary torques at the lower neck joint are extension torques for both helmet and no-helmet conditions. Peak torque is 13% greater for the no-helmet condition (2240 in-lbs to 1980 in-lbs). At the upper neck joint the torques peak initially in flexion as the body and neck continue

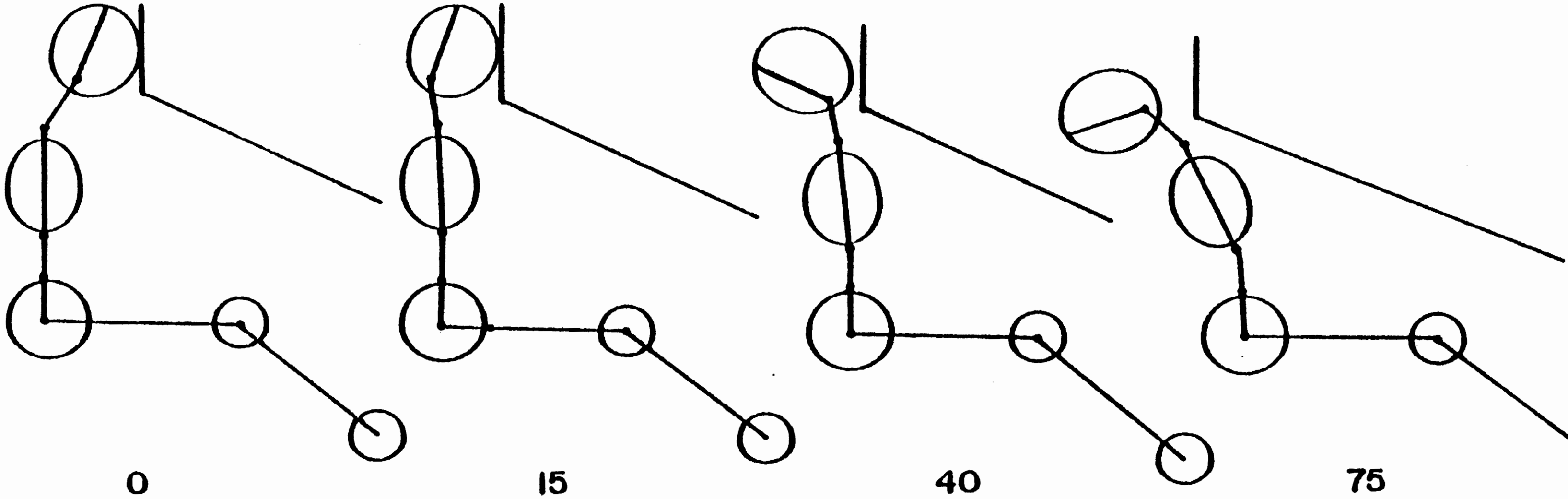


Figure 5-4. HEAD-TRUCK IMPACT - 20 MPH - WITH HELMET

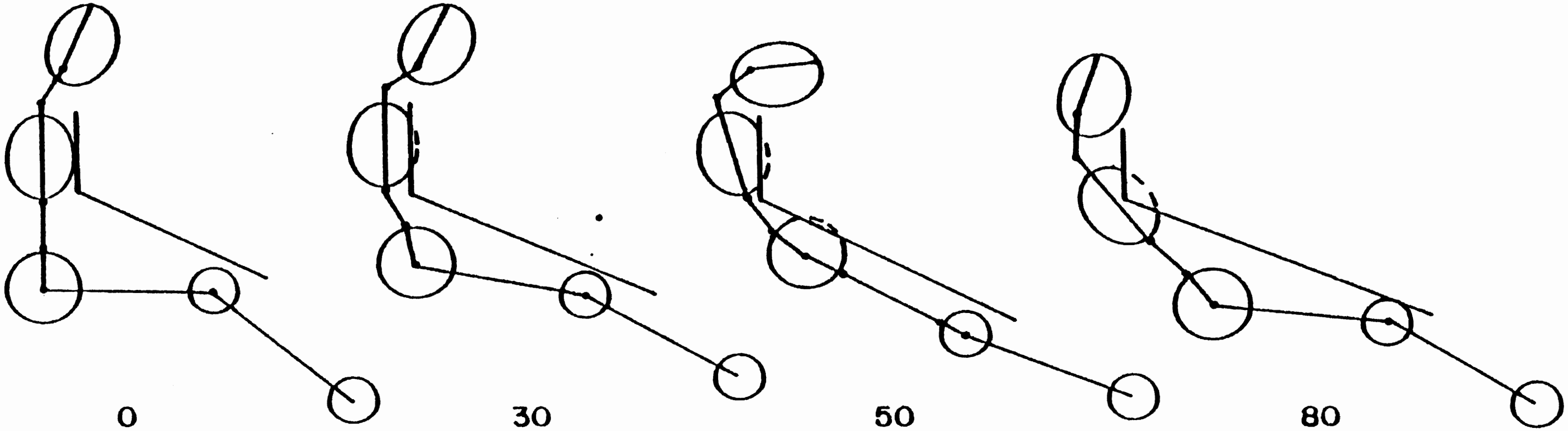


Figure 5-5. CHEST-TRUCK IMPACT - 20 MPH - NO HELMET

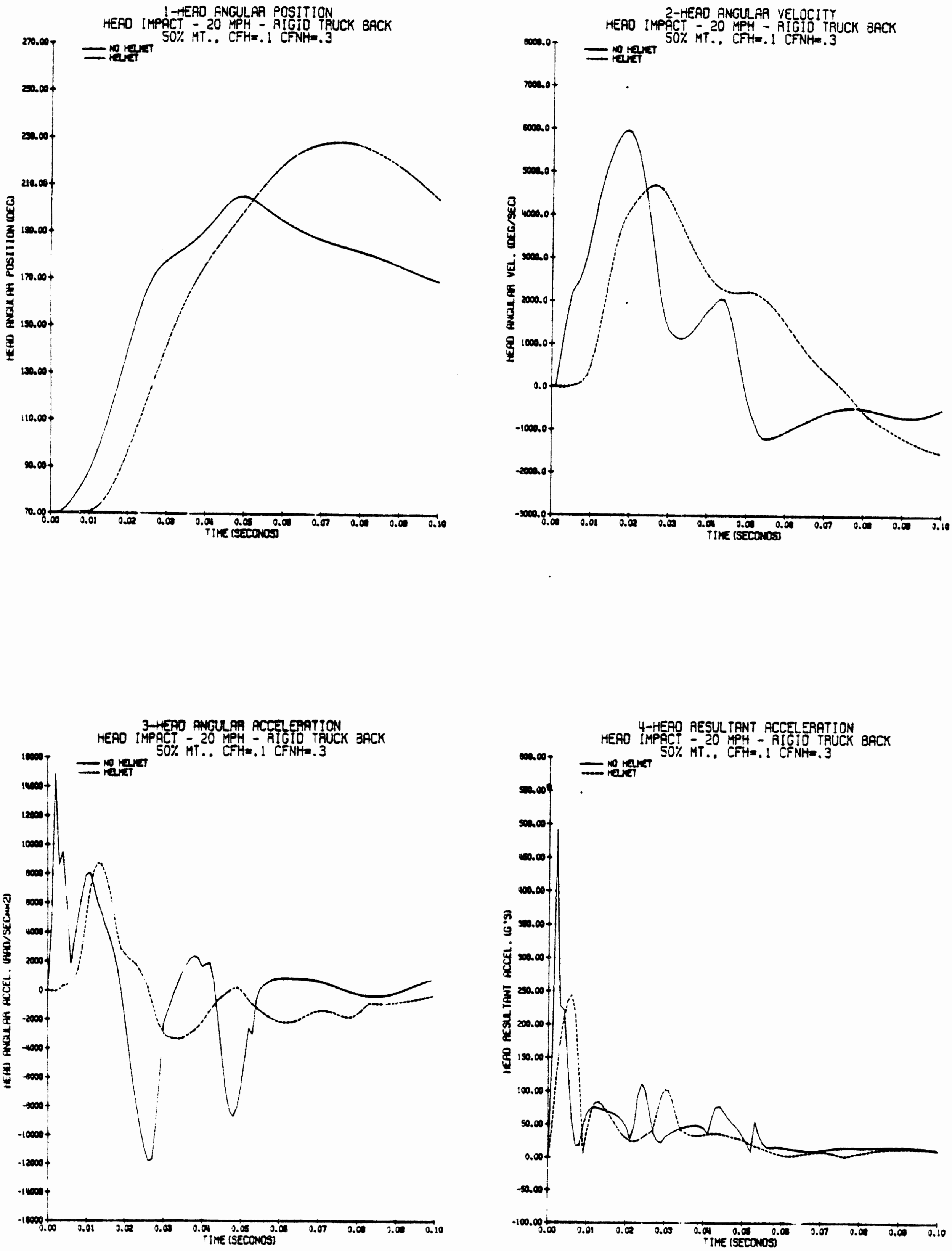


Figure 5-6. Selected Plots from Comparison [2] (Page 1 of 3)

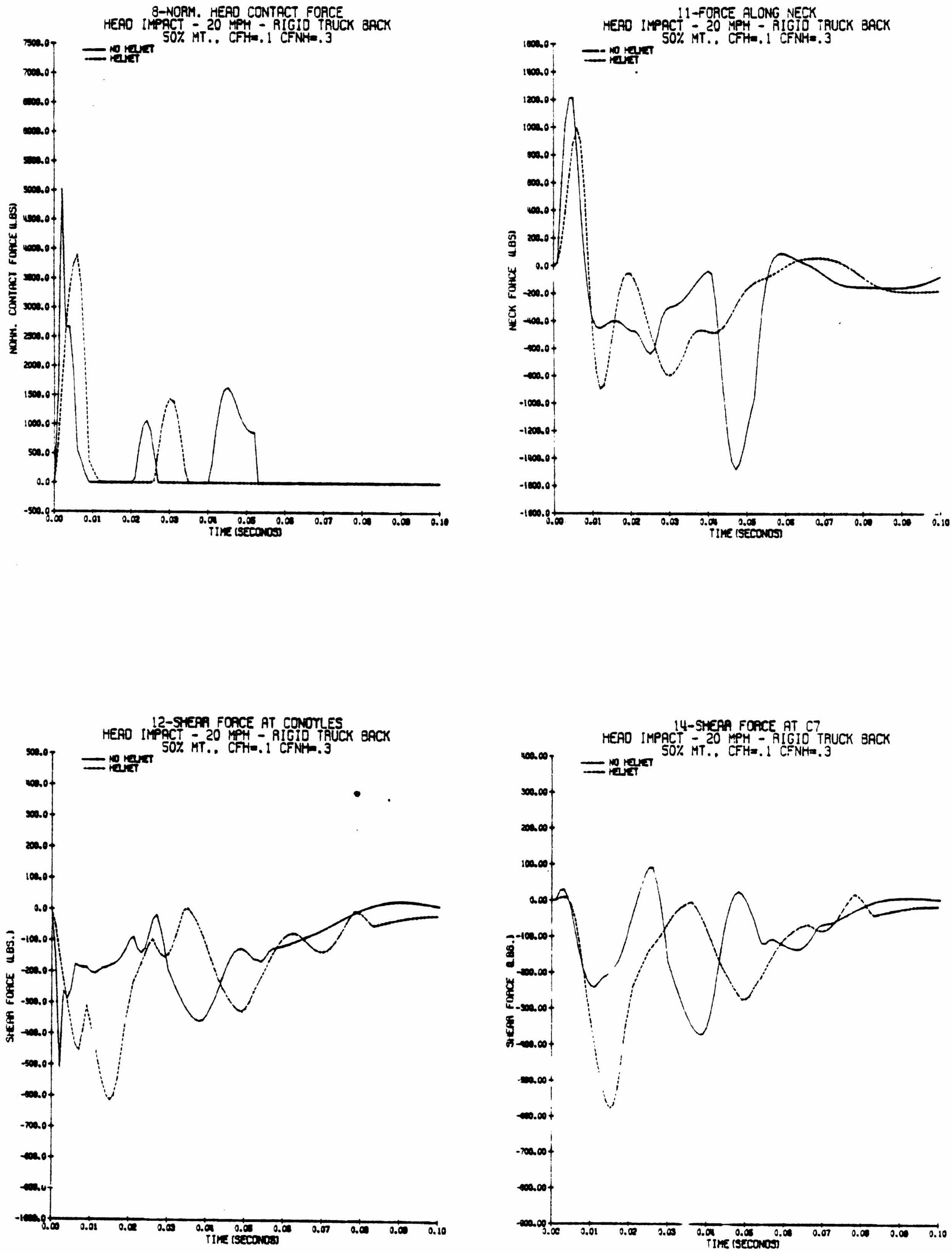
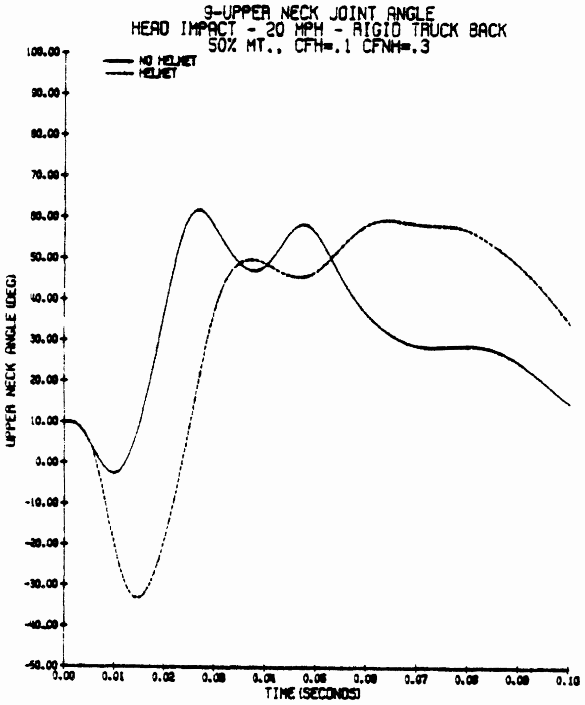
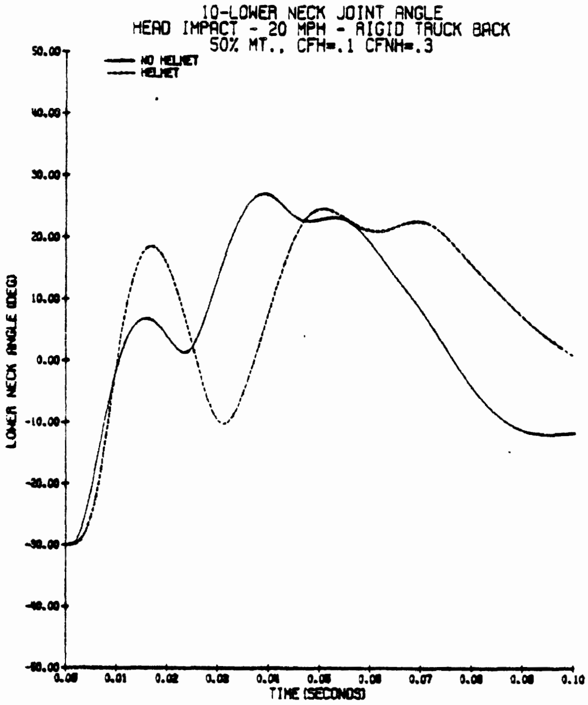
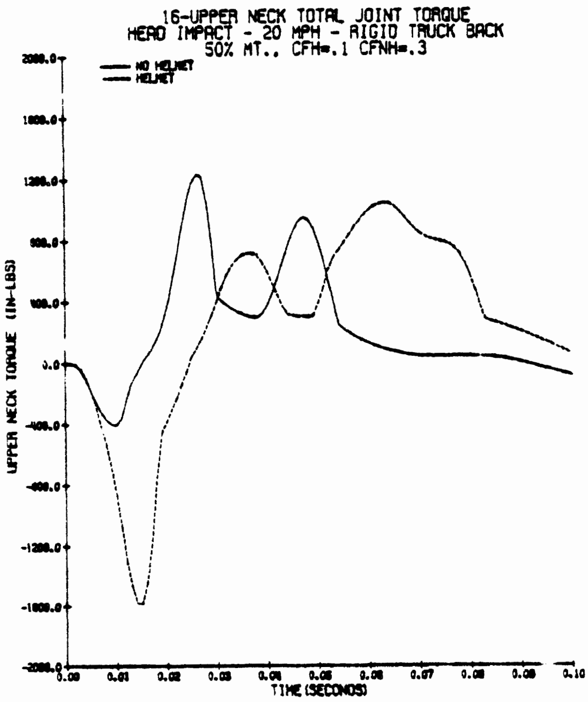


Figure 5-6. Selected Plots from Comparison [2] (Page 2 of 3)







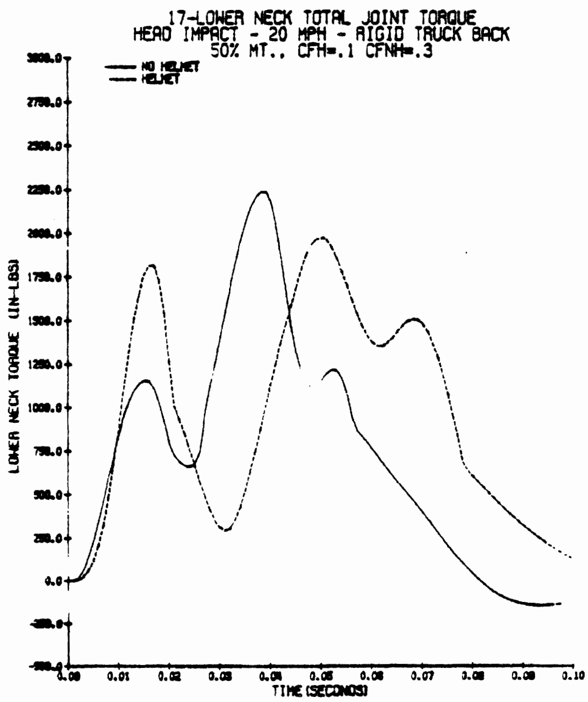


Figure 5-6. Selected Plots from Comparison [2] (Page 3 of 3)

to move forward prior to any significant rotation of the head. The peak values for the helmet condition are nearly four times greater than for the no-helmet condition, -1600 in-lbs to -400 in-lbs, but still less than the injury tolerance limit for flexion at the occipital condyles, (-) 1680 in-lbs. For both helmet and no-helmet conditions, these upper neck torques are later reversed to extension torques, with the no-helmet condition having the greater peak value (1240 in-lbs to 1040 in-lbs). The extension torque for both conditions is much greater than the injury tolerance limit, 504 in-lbs. Forces along the neck are initially compressive but then become neck elongation forces.

The compressive force for the no-helmet run has the higher peak value by almost 25% (1300 lbs to 1050 lbs). The peak elongation force is also larger for the no-helmet condition, nearly twice that for the helmet condition (-1440 lbs to -790 lbs). Peak shear forces are higher for the helmet run at both the upper (614 to 512 lbs) and lower (578 to 373 lbs) neck joints.

Beneficial effects of helmets for protecting the head are evident from these results for the 20 mph impact simulations. With regard to neck torques, the helmet runs consistently show lower values for extension torques, which are likely to be the most significant neck injury mechanism in this type of impact. Flexion torques are higher for the helmet runs but these peak values in all cases are below injury tolerance levels. Compressive and elongation forces on the neck are also significantly lower for the helmet runs. Because of the shape of the head resultant acceleration profiles, HIC is reduced only slightly by the helmet in the 20 mph simulations despite significant reduction of the peak acceleration, and both are much greater than the estimated injury tolerance level, 1500.

The helmet/no-helmet comparison for 10 mph impacts (Comparison/ Plot [29] in Appendices C and D) shows more clearly the benefits of the helmet. Peak head resultant acceleration is reduced by 60%, from nearly 300 g's to 120 g's, and HIC is reduced from 2573, much greater than the injury tolerance level, to 564 -- much less. Peak upper neck extension torques are greater than the injury tolerance level for this typs of impact even at 10 mph, but they exceed the tolerance level by 26% less for the helmet case.

5.2.3 Chest-Truck Baseline Impacts. The stick figure drawings in Figure 5-5 illustrate the general motion of the cyclist's body and head and neck during chest-truck impacts. Figure 5-7 compares some of the dynamic responses for the helmet and no-helmet baseline impacts at 20 mph [1]. It is seen that the initial motion of the head is quite similar for helmet and no-helmet runs. Angulation of the lower neck proceeds in flexion immediately after impact and plateaus at about 40 degrees of flexion from the initial position. For the helmet case a second increase of another 10 degrees flexion occurs at about 70 milliseconds. At this time the angulation of the lower neck joint begins to differ substantially for the two cases as the no-helmet run shows earlier tendencies toward rebound hyperextension. As a consequence of this neck/torso flexion and the fact that the head does not rotate by any significant amount for about 30 msec after impact, the upper neck joint rotation begins with extension from the initial angle for the no-helmet and helmet runs of 8 and 10 degrees, respectively. At about 40 msec, the upper neck joint is beginning to go into flexion for both cases and reaches flexion peaks of 46 and 55 degrees from the initial angle for

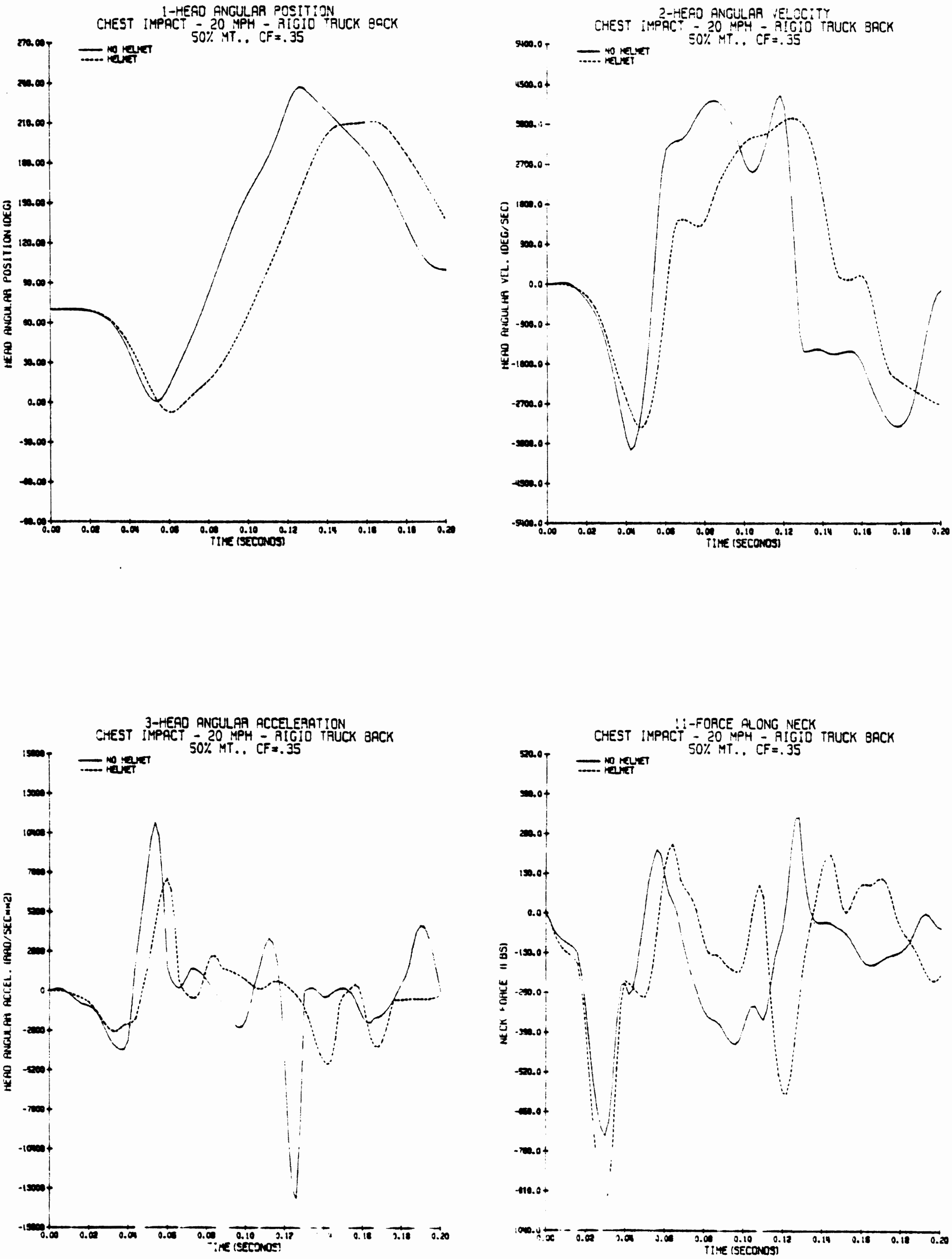


Figure 5-7. Selected Plots from Comparison [1] (Page 1 of 3)

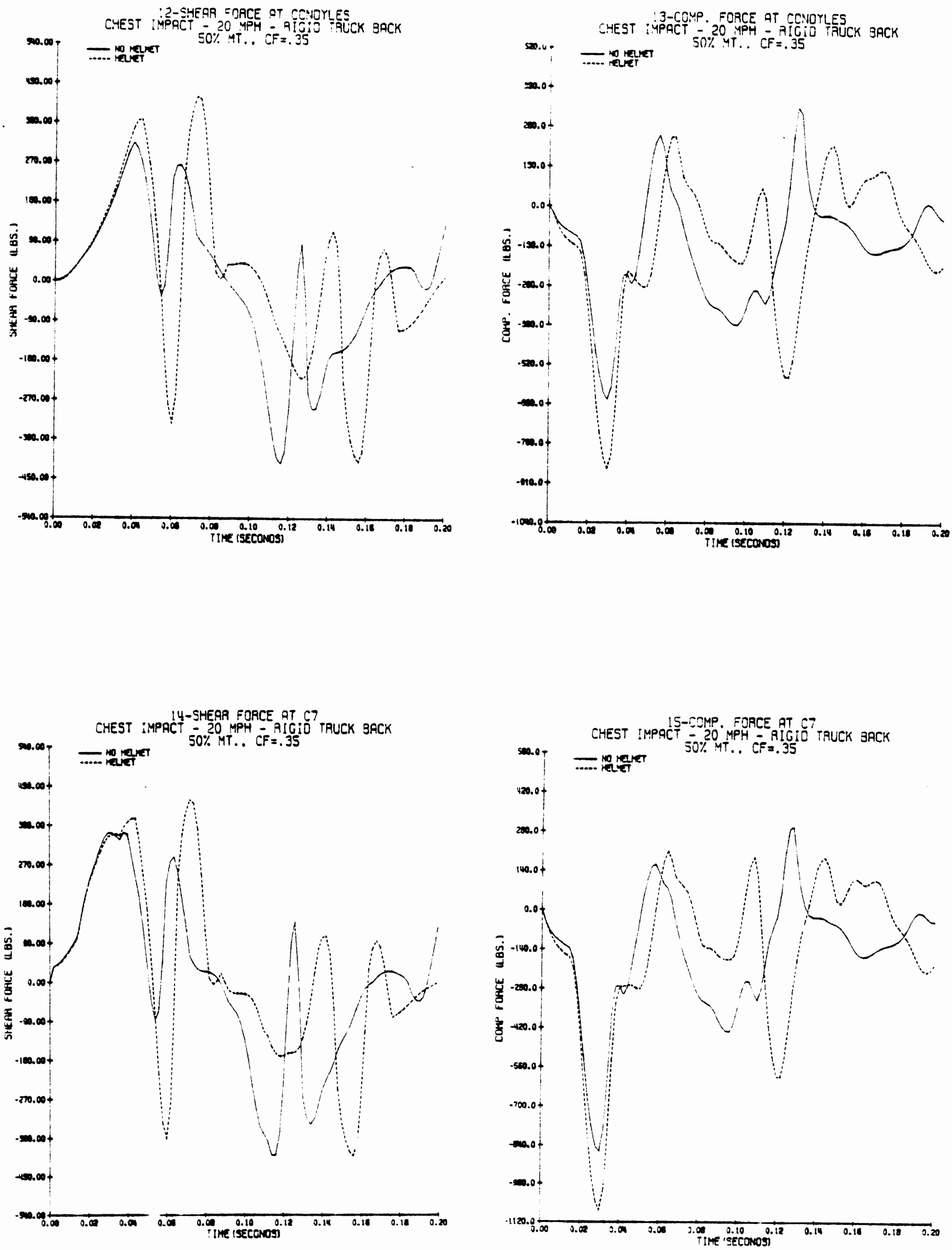


Figure 5-7. Selected Plots from Comparison [1] (Page 2 of 3)

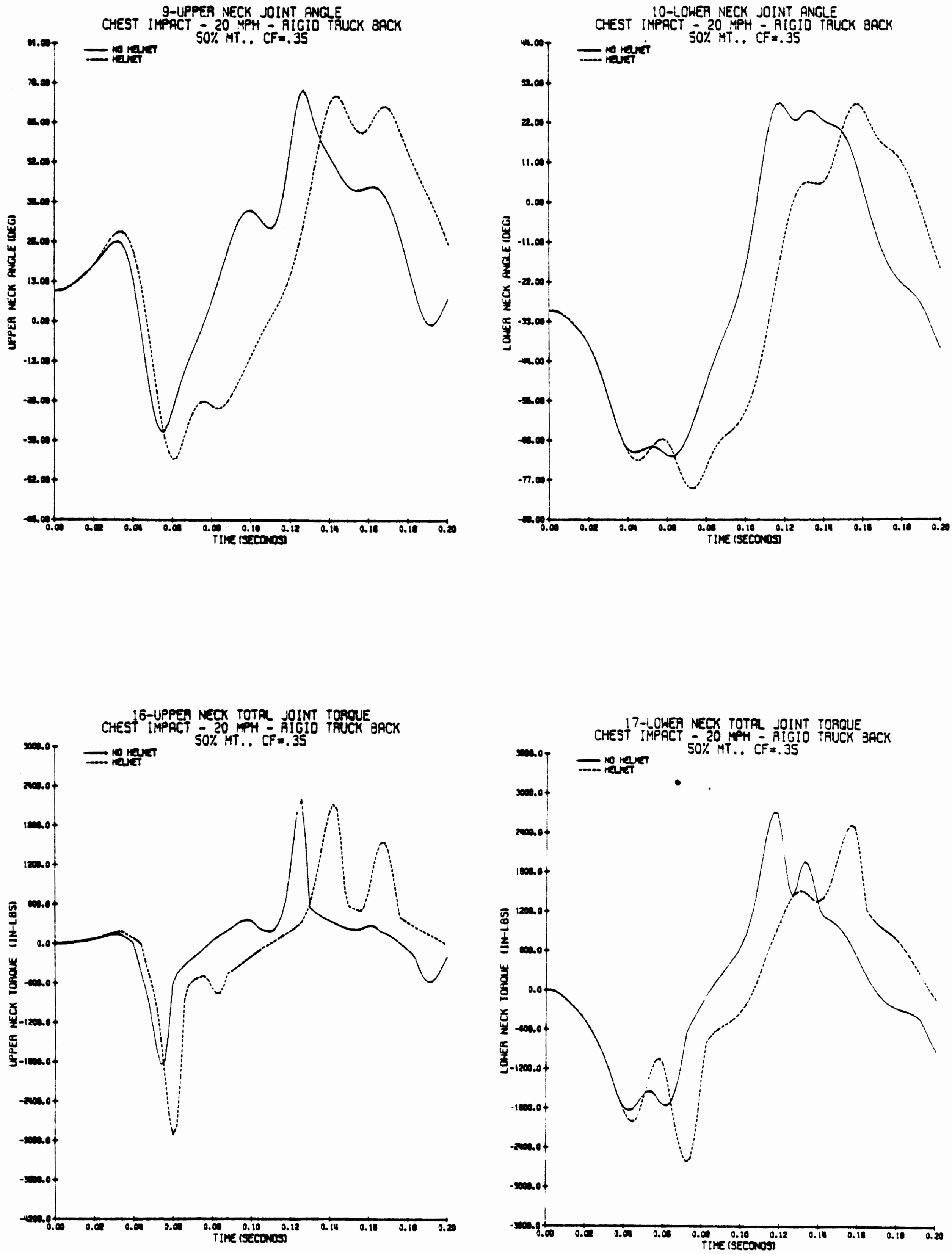


Figure 5-7. Selected Plots from Comparison [1] (Page 3 of 3)

the no-helmet and helmet cases, respectively. As with the lower neck joint, the upper neck angulations begin to differ more after peak flexion, with the no-helmet case again showing earlier tendencies to rebound extension.

Corresponding to the initial extension of the upper neck joint the torques are quite low (less than 200 in-lbs) and similar in magnitude with and without helmet. The flexion torques which follow are substantial, however, and are considerably greater for the helmeted condition: 2936 in-lbs to 1869 in-lbs. Both are greater than the estimated tolerance level for ligamentous tearing (1680 in-lbs), by 75% and 11%, respectively. At the lower neck, peak torques in flexion of 2615 and 1832 in-lbs are reached for helmet and no-helmet runs, respectively. Because of the helmet vs. no-helmet differences at the end of the 100 msec simulations, these simulations were rerun to 200 msec in order to examine the entire rebound phase of the motion. The peak rebound extension angles and torques were significant and nearly equal for the helmet and no-helmet conditions. At the upper neck joint both peak extension torques were about 2200 in-lbs, which is well above the tolerance limit of 504 in-lbs. At the lower neck joint, peak rebound extension torque was 2550 for the helmet case and 2740 for the no-helmet case.

The largest axial forces on the neck are elongation forces with peak values of 956 and 730 lbs for helmet and no-helmet runs. Compressive forces occurring at about 60 msec are 227 lbs and 711 lbs for helmet and no-helmet, respectively. Shear forces are of relatively small magnitude. At the upper neck, forward (positive) shear forces on the neck reach peaks of 422 lbs and 317 lbs and rearward (negative) shear forces reach peaks of 326 and 77 lbs, respectively, for helmet and no-helmet runs. At the lower neck, rearward (positive) shear forces reach peaks of 420 lbs and 347 lbs and forward (negative) shear forces reach peaks of 363 and 129 lbs for helmet and no-helmet, respectively.

Head motion responses are small for these chest-truck runs compared to direct head impact cases, and brain injury is unlikely in this type of situation. Nevertheless, it is worth noting that the helmet runs for 20 mph impacts show reduced peak head angular acceleration (7400 compared with 11100) and reduced HIC value (419 against 566). There is increased likelihood of hyperflexion neck injury for the helmet case, but the greatest potential for neck injury for this type of impact is probably in rebound hyperextension, where the maximum torque levels are equal for the helmet and no-helmet cases.

Chest-truck impact at 10 mph is not at all severe for either the helmet or no-helmet case [28]. No dynamic response variable exceeds its injury tolerance level for either case.

5.2.4 Head-Road Baseline Impacts for 30° Body Orientation. Figure 5-9 shows some of the plot comparisons for no-helmet and helmet 30° road baseline simulations [4]. The helmet run has dramatic and significant reductions in all response parameters. The helmet reduces HIC from 7621, which is far in excess of the estimated injury tolerance level (1500), to 1266. Peak head angular acceleration is reduced from over 24000 rad/sec^2 to 4559 rad/sec^2. Peak head resultant is also reduced to below estimated brain injury tolerance (150 G's) from 398 G's to 133 G's, and peak normal contact force is reduced from 4827 lbs to 3139 lbs.

As a result of the coefficient of friction differences, the head and neck angular motions are considerably different for the helmet and no-helmet conditions as illustrated in the stick figure drawings of Figure 5-8. Without a helmet, the coefficient of friction is .6. This results in a relatively high frictional force which simultaneously drives the lower neck joint angle into flexion and the upper neck joint into extension in the first 10-15 msec after impact. At 25-30 msecs these reverse, with the lower neck going into extension and the upper neck going into mild flexion. In contrast, for the helmet run, where the coefficient of friction is .2, the frictional force is not as significant and the upward contact force dominates, driving the lower neck into initial extension. As a consequence of this and the delay in any rotation of the head itself, the upper neck joint goes into initial flexion. The lower neck remains in extension (though varying) and the upper neck reverses from flexion to extension at about 22 msec. Thus, the torques associated with these angulations are nearly opposite in direction for the helmet and no-helmet runs. Even so, it is significant that the peak torques are much greater for the unhelmeted condition. At the upper joint peak extension torques are 578 and 4908 in-lbs for helmet and no-helmet runs, respectively, and peak flexion torques are 761 and 757, respectively. These flexion torques are far less than the injury tolerance level (1680 in-lbs), but the upper neck extension torques exceed the tolerance level for ligamentous tearing. Significantly, however, the extension torque is only 15% greater than the tolerance level (504 in-lbs) for the helmet case but <u>10 times</u> the tolerance level for the no-helmet case, where severe injury would surely occur. At the lower joint, peak extension torques are 854 and 2418 lbs, and peak

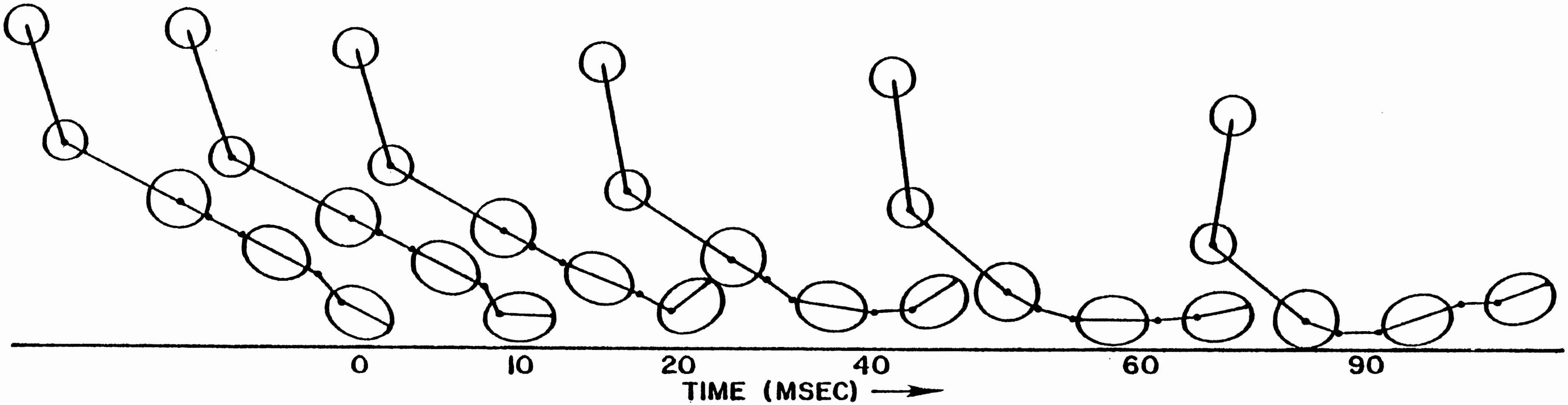


Figure 5-8a. 30° ROAD IMPACT - NO HELMET - C.F. = .6

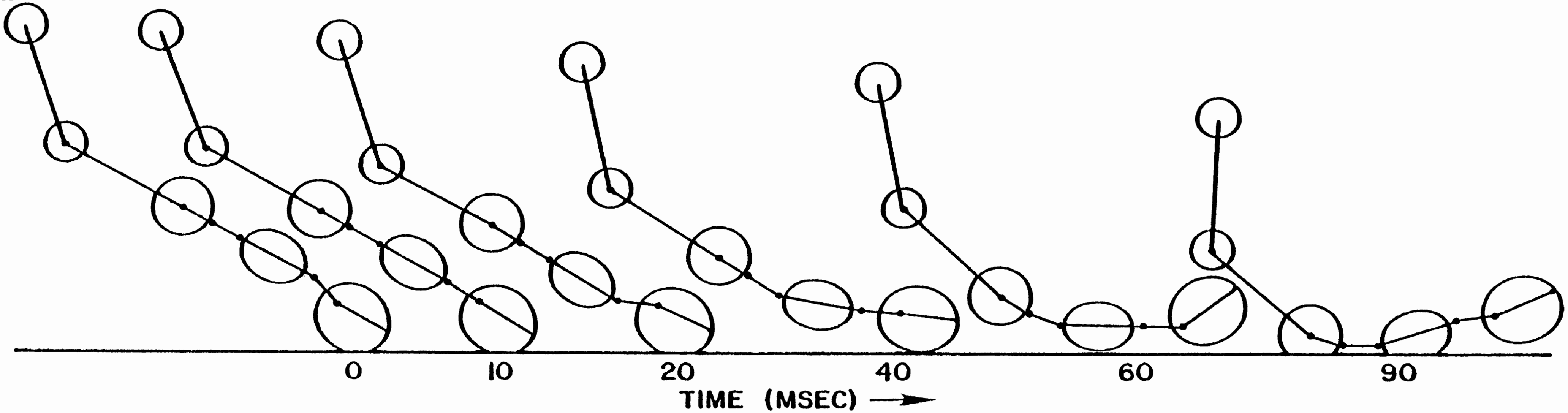


Figure 5-8b. 30° ROAD IMPACT - WITH HELMET - C.F. = .2

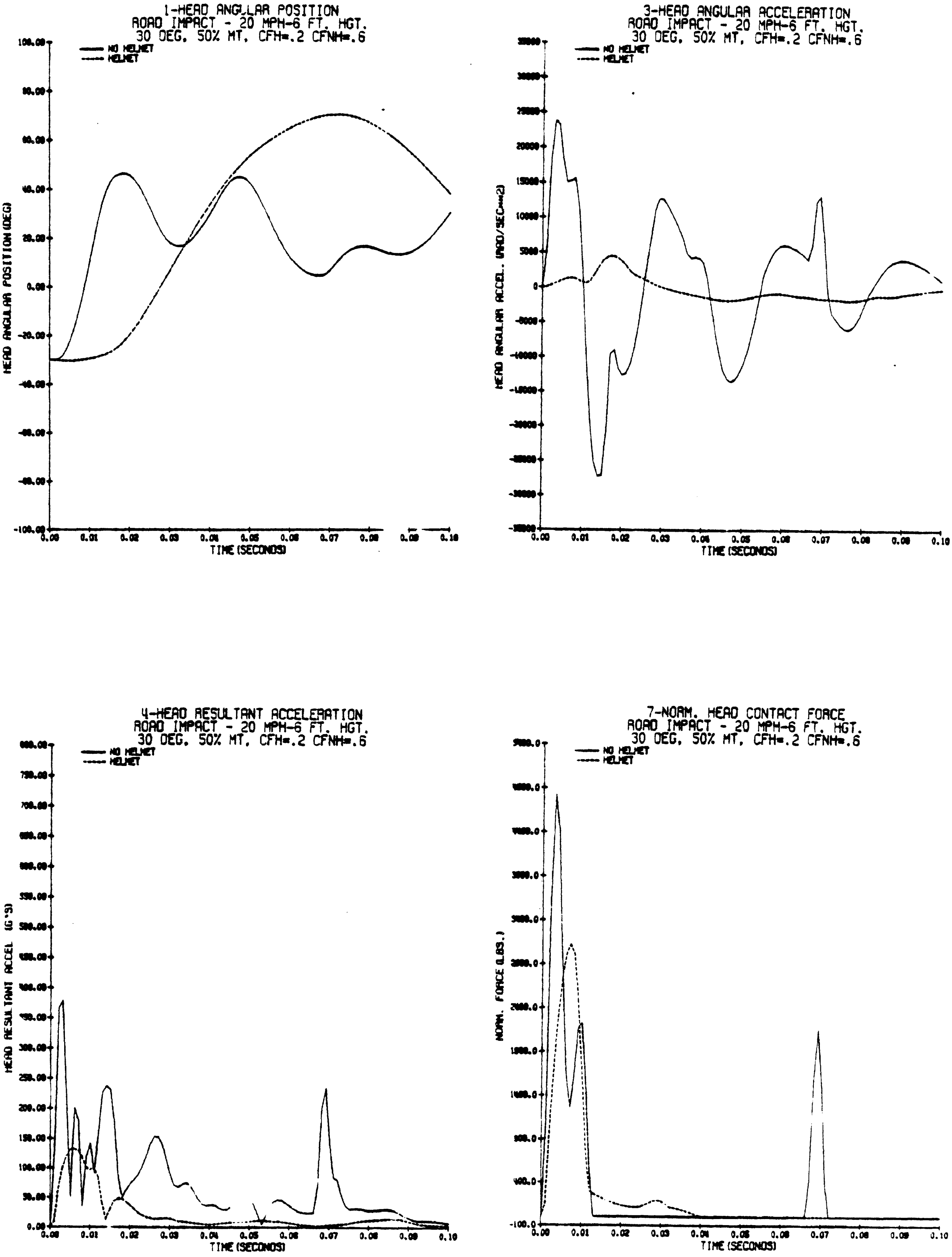


Figure 5-9. Selected Plots from Comparison [4] (Page 1 of 3)

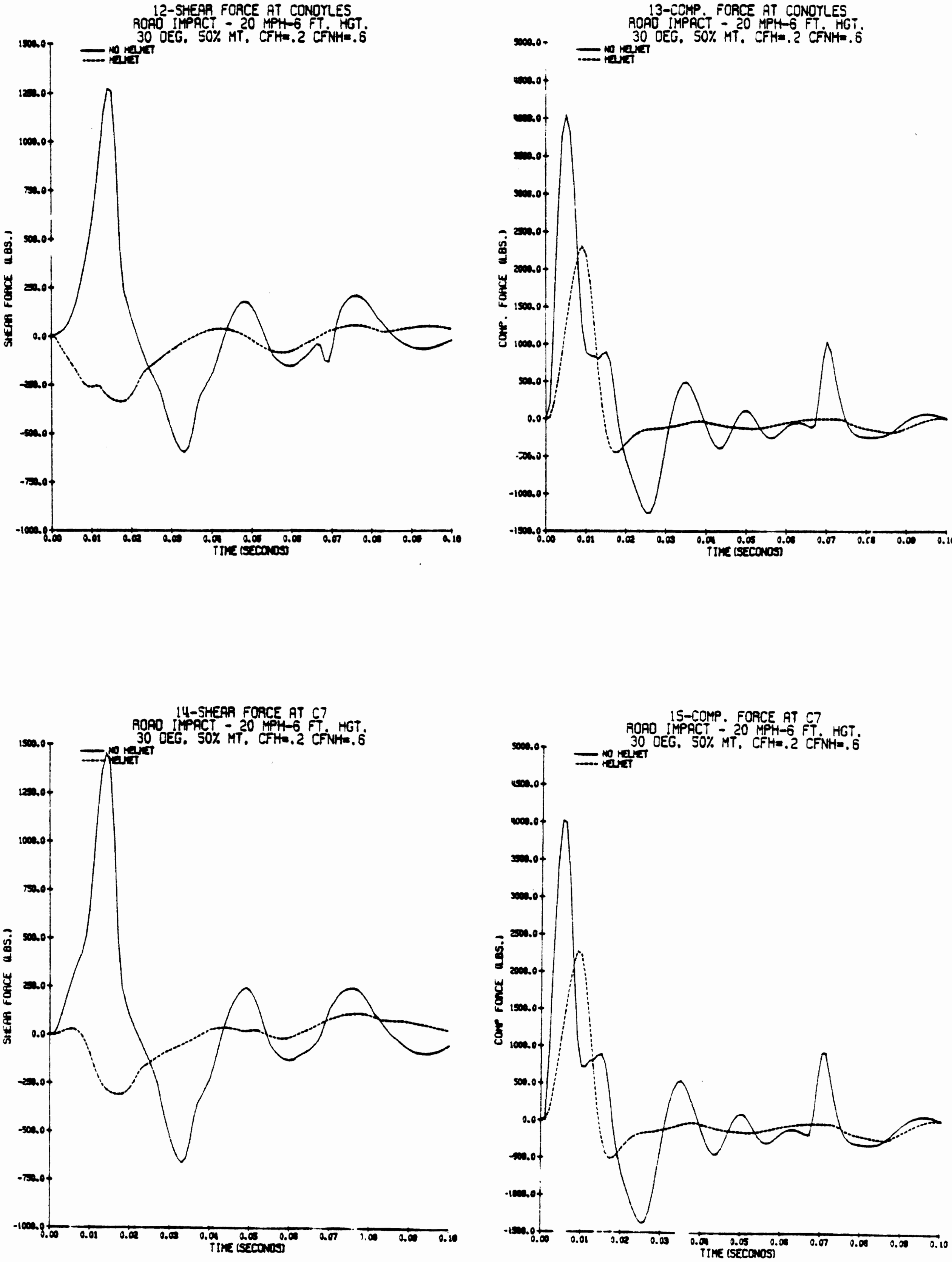


Figure 5-9. Selected Plots from Comparison [4] (Page 2 of 3)

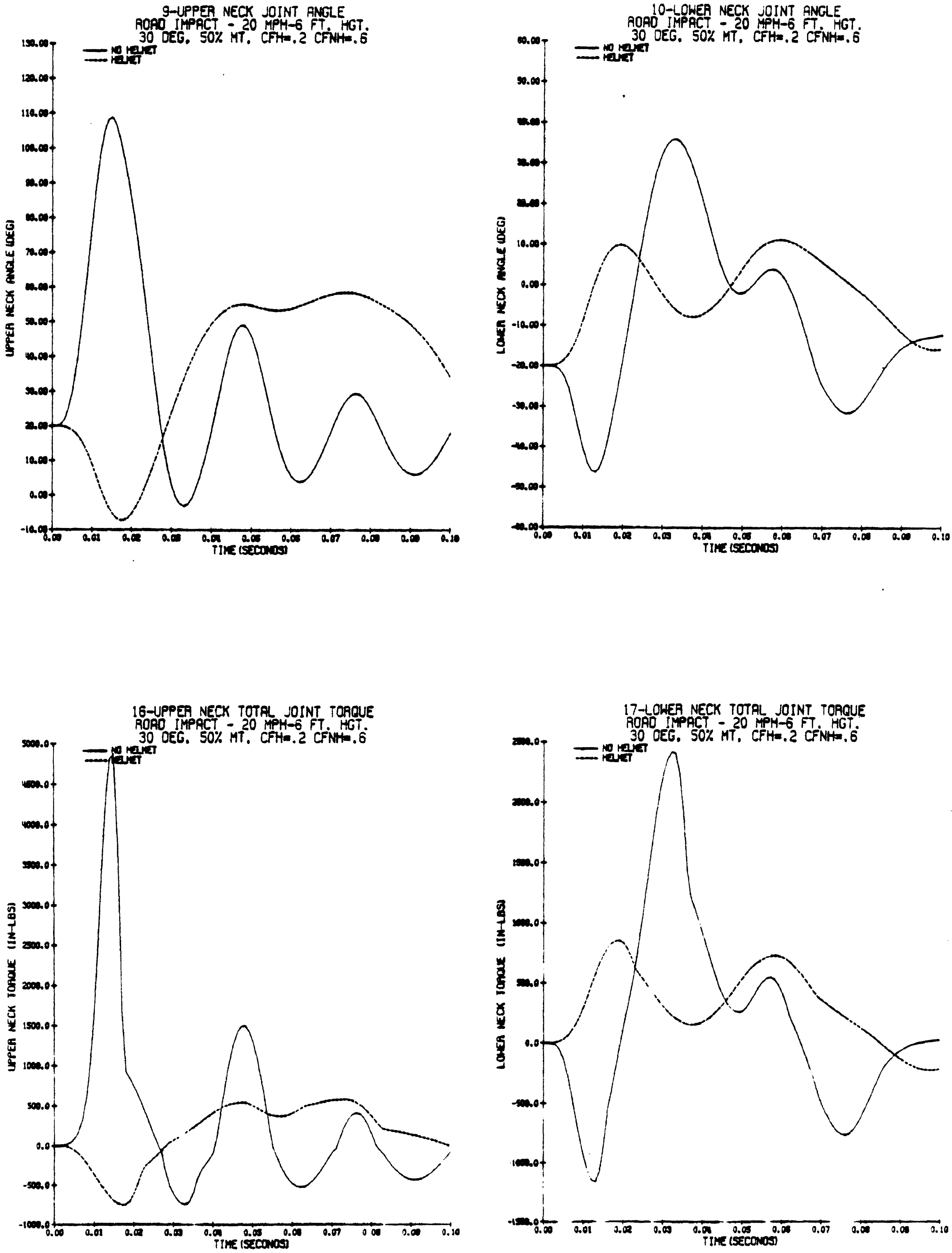


Figure 5-9. Selected Plots from Comparison [4] (Page 3 of 3)

flexion torques are 220 and 1165 lbs, respectively, for helmet and no-helmet runs. Peak compressive, elongation, and shear forces are similarly much greater without a helmet (see Plot [4] of Appendix D).

It is clear, then, that in terms of protection from both head and neck injury, the motorcyclist impacting the road at a low angle and with some horizontal velocity, is benefited greatly by wearing a helmet. The liner and added helmet mass cause the peak values of head injury parameters to be decreased dramatically (e.g., HIC, resultant acceleration, angular acceleration and head contact force). Peak values of neck injury parameters are reduced by the helmet primarily because of the lower coefficient of friction for the helmet-road contact. This point is further clarified by examining Plots [5], [6], [7], and [8] of Appendix D, where the coefficients of friction for helmeted and unhelmeted cases have been reversed and plotted in various combinations. From these comparisons it is seen that the torques and forces in the helmeted case are increased by increasing the coefficient to .6. Thus, it is primarily the coefficient of friction which drives up the neck forces and torques by providing the necessary resistance to translational head motion to allow the body to drive into the neck.

5.2.5 Head-Road Baseline Impacts for 70° Body Orientation. Figure 5-11 shows some of the plot comparisons for helmet and no-helmet 70° road baseline simulations [18]. As with the 30° road impact, the helmet produces large decreases in those response variables related to head and brain injury. HIC is reduced from 14000 to 4440, head resultant acceleration from 448 to 182 G's, head angular acceleration from 29400 to 14200 rad/sec^2, and peak head impact normal force from 4921 to 3335 lbs.

At this higher angle of impact, the overall angular motions at the neck joints are similar with and without a helmet in spite of the coefficient of friction differences. Figure 5-10 illustrates the two cases with stick figure drawings. The action is essentially a tumbling over on the head because of the horizontal velocity at the time of impact. For the helmet case, with smaller coefficient of friction (0.2), the lower neck flexes immediately and remains flexed throughout the first 100 milliseconds. The upper neck joint does into initial extension of about 40° from the initial position due to the initial impact force on the head, which is primarily upward. The downward motion of the body causes immediate flexion of the lower neck joint. At about 20-25 msec the upper neck also goes into flexion as the body rotates over. The net result is a relatively slow forward rotation of the head upon impact followed by a faster forward rotation beginning at about 20 msec. For the unhelmeted case, where the coefficient of friction is 0.6, the lower neck goes into flexion more quickly because of the larger component of frictional force and reaches a larger peak angulation, at about 38 msec. The upper neck joint initially extends a very small amount (about 4° compared to 37° for helmeted case) and then goes into flexion similar to the helmet case but about 10 msec sooner. At 90 to 100 msec the upper neck extension has become quite large (40°) for the unhelmeted case.

Corresponding to these motions, the upper neck torque initially reaches about 500 in-lbs in extension for the helmet case compared to near zero for the unhelmeted case. In flexion, the upper neck torque reaches a peak of 5000 in-lbs for the helmet case and close to 4000

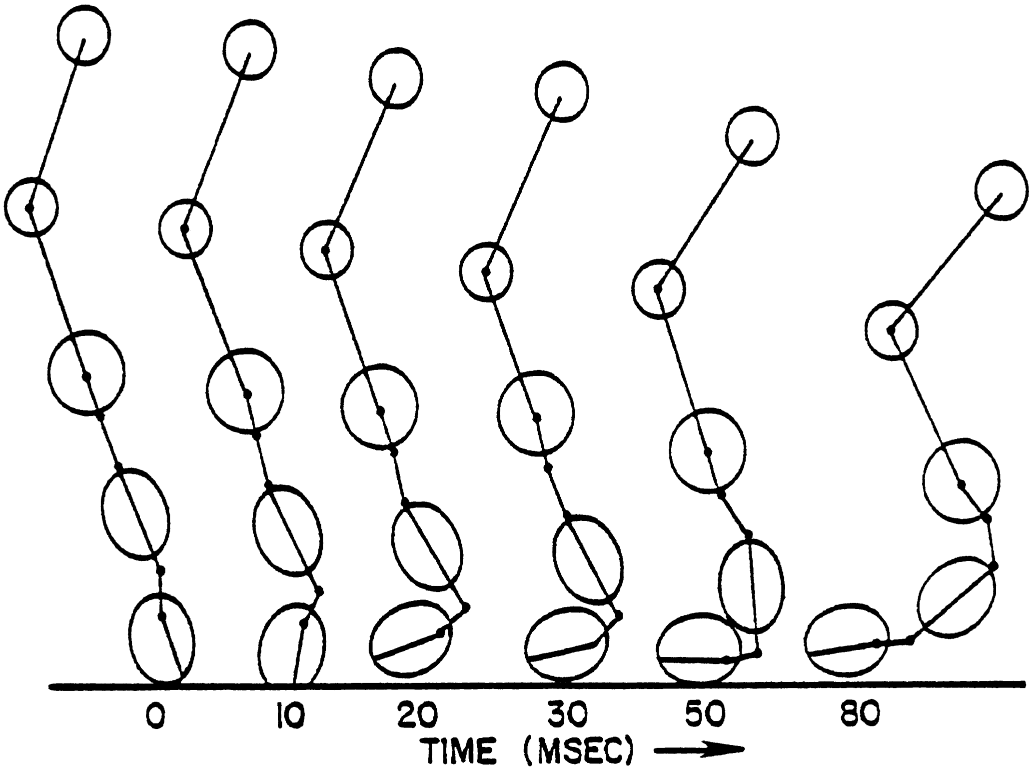


Figure 5-10a. 70° ROAD IMPACT - NO HELMET - C.F. = .6

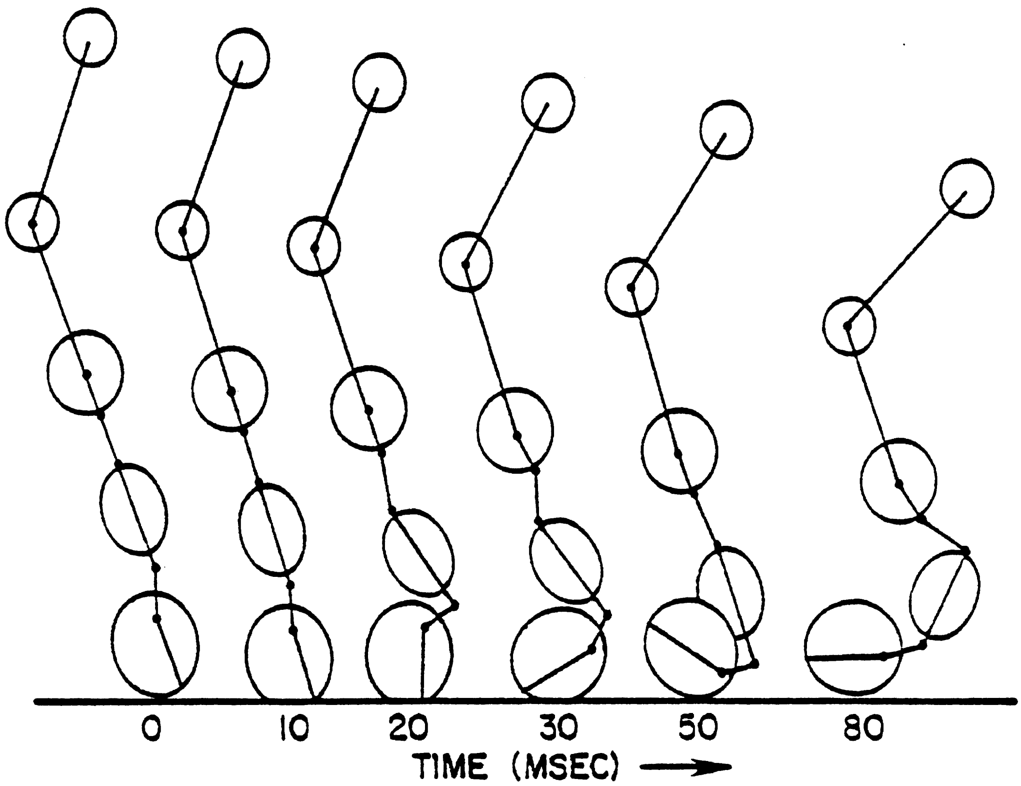


Figure 5-10b. 70° ROAD IMPACT - WITH HELMET - C.F. = .2

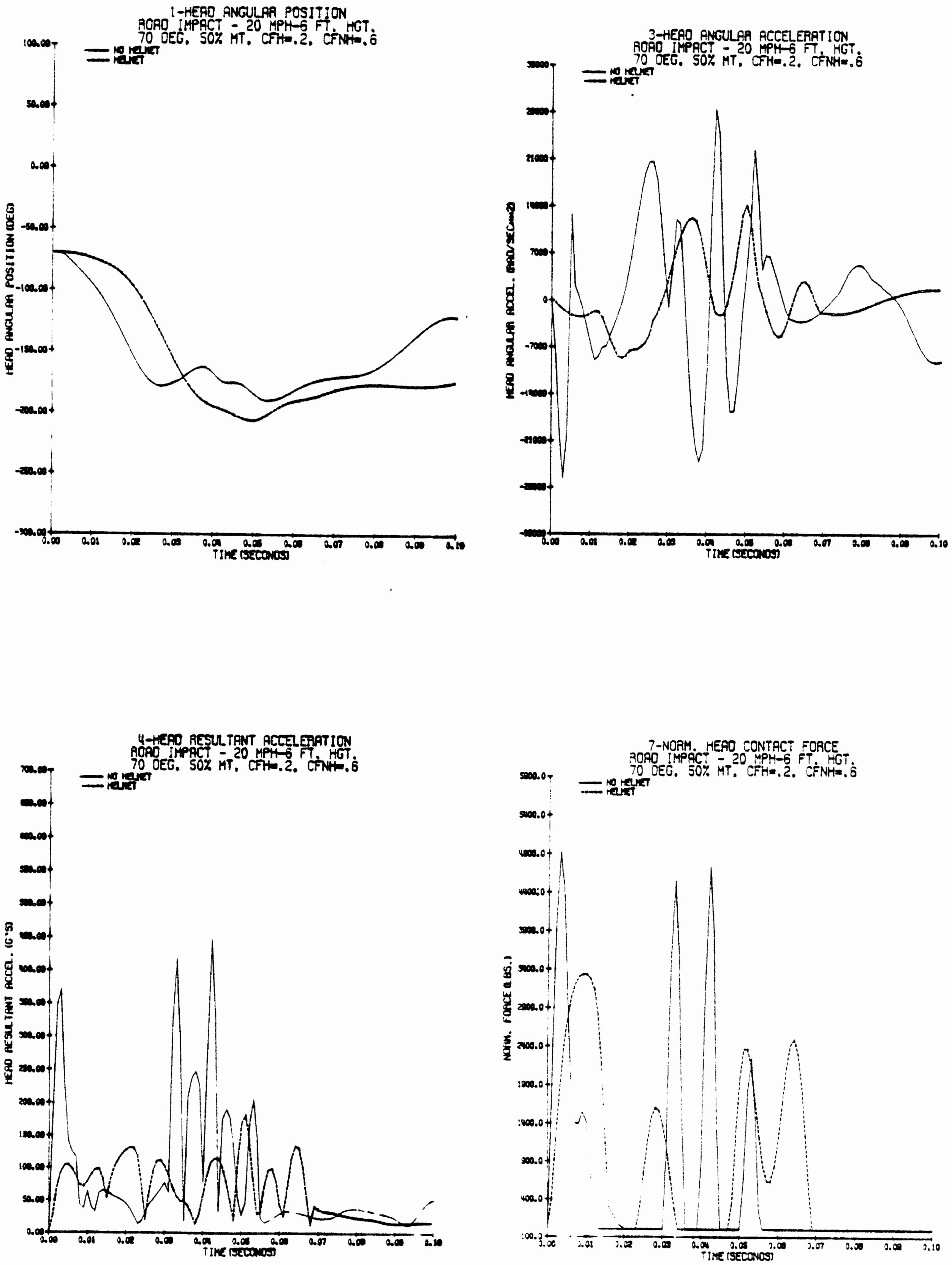


Figure 5-11. Selected Plots from Comparison [18] (Page 1 of 3)

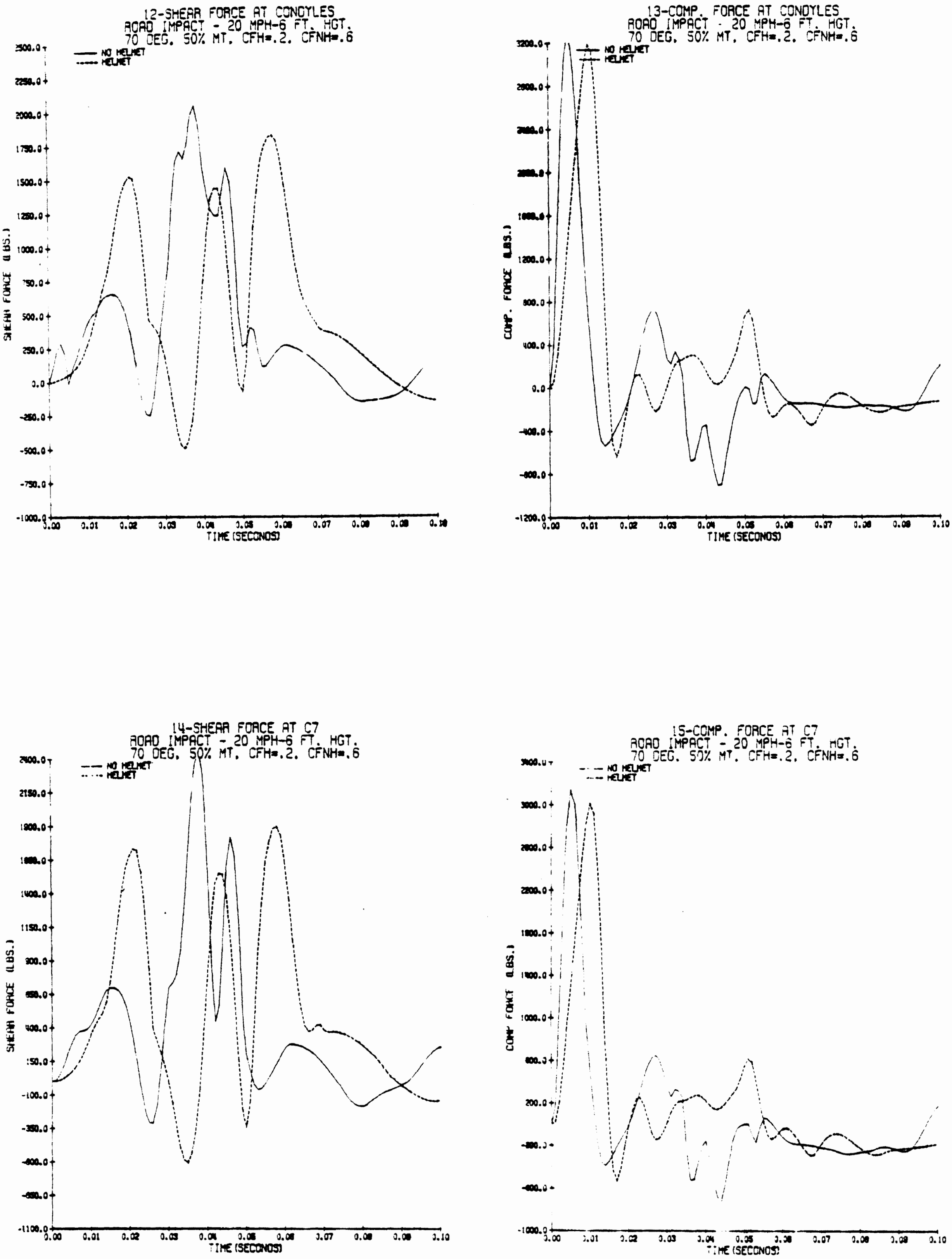


Figure 5-11. Selected Plots from Comparison [18] (Page 2 of 3)

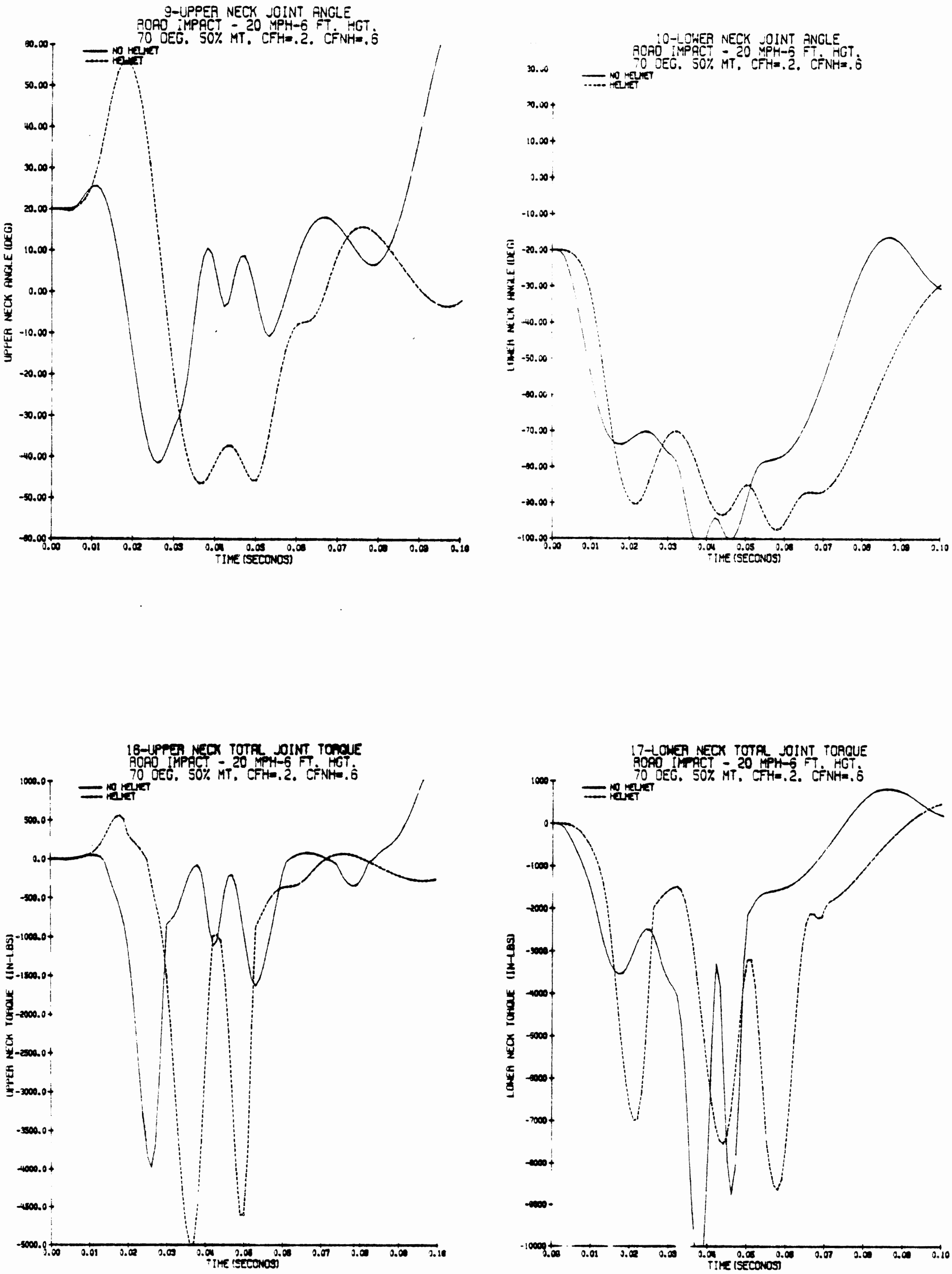


Figure 5-11. Selected Plots from Comparison [18] (Page 3 of 3)

in-lbs for the unhelmeted case. It may be significant that the upper neck torque in extension is close to 1000 in-lbs and increasing rapidly for the no-helmet run at 100 msec but appears to have leveled off near zero for the helmet run. At the lower neck, the torques are primarily in flexion, with the peak value for the no-helmet run being greater than for the helmet run by 25% (10800 in-lbs to 8650 in-lbs). At 100 msec, the end of the run, the torques are in extension for both cases, with the peak for the unhelmeted case again greater than for the helmeted case (818 in-lbs to 489 in-lbs).

As one might expect for this type of impact, the primary loading of the neck is in compression. The peak levels are comparable for unhelmeted and helmeted cases, 3310 lbs for no helmet and 3207 lbs with helmet. For both the helmet run and the no-helmet run, maximum shear loading of the neck at the condyles is forward while at C7-T1 it is rearward.* At the condyles, peak forward shear forces are 1826 lbs and 2051 lbs and peak rearward shear forces are -492 and -255 lbs for helmet and no-helmet runs, respectively. At the lower neck joint, peak rearward (positive) shear forces on the neck are 1905 and 2468 lbs and peak forward (negative) shear forces are -321 and -305 for helmeted and unhelmeted conditions, respectively. For the larger forces at each joint (forward at upper, rearward at lower) the helmet run has the lower peak values.

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* Positive shear forces are forward on the neck at the upper joint (condyles) and rearward on the neck at the lower joint (C7-T1).

As with the 30° road impact, additional simulations were made to examine the effects of coefficient of friction differences. Plots [19], [20], [21], [22], and [41] in Appendix D compare results for various helmet and no-helmet runs with these different coefficients of friction. For the helmet case, increasing the coefficient of friction from .2 to .6 has little effect on the peak values of head angular velocity and angular and resultant accelerations although it reduces HIC significantly, from 4440 to 1437, less than the estimated brain injury tolerance level. Peak normal contact force remains about the same but decreases in duration. Neck torques and forces show consistent decreases when the coefficient of friction is increased to .6. For the unhelmeted case, decreasing the coefficient of friction from .6 to .2 has little effect on head acceleration peak values although it causes considerable bouncing and spiking in these parameters. HIC decreases slightly from 14000 to 12600. Torques and forces on the neck tend to remain the same or increase slightly for decreased coefficient of friction.

It is clear from these results and from examination of plots and tabular comparisons for 30° road impacts ([5] - [8]) and 70° road impacts ([19]- [22]) and [41]) that the coefficient of friction is not as critical a factor at higher angles of impact. It is also clear that values near .6 are more desirable than values near .2 at higher angles. The roll-over, tumbling action caused by the horizontal velocity together with the head-road friction force is assisted by larger values of the friction coefficient, and this reduces loading of the neck by the body. With low friction forces, the body tends more to drive into the head and neck causing higher torques and forces much as would be the case if there were little horizontal velocity to produce the rollover action. Effects of the coefficient of friction between the head or helmet and the road are discussed further in Section 5.3.1, but one additional point should be made here. Simulation 59, with a friction coefficient of zero, shows that the roll-over motion illustrated by Figure 5-10 for 70° impacts occurs only if the head-road friction force is non-zero. In the similar helmet impact simulation (number 34) having a coefficient of friction of .2, the typical rollover occurs. For some friction coefficient near to zero, but probably smaller than realistic for any helmet, rollover will occur for slightly greater values and rollover will not occur for slightly lesser values. (See Plots and Comparison [41]. Note head angle position.*)

Finally, it should be noted that the head-road impact for the more vertical (70°) body orientation is very clearly much more severe than for the more horizontal (30°) orientation for both helmeted and unhelmeted motorcyclists. Dynamic response variable peak values for 70° are consistently much higher than for 30° (in the preceding section). (30° and 70° road impacts are compared directly in Section 5.3.2.) HIC response and upper neck flexion torque response are particularly severe for a vertical body orientation at impact. While the no-helmet HIC of 14000 is reduced by 68% to 4440 for the helmet impact, the HIC value is still much larger than the injury tolerance limit. Upper neck flexion torques, about 5000 and 4000 in-lbs, respectively, for the helmet and

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* The basically different nature of the response for the zero friction case was noted from time-sequenced stick-figure "printer plots" generated by the MVMA 2-D CVS model.

no-helmet cases are 3.0 and 2.4 times the injury tolerance level (1680 in-lbs). In addition, a peak upper neck extension torque greater than twice the extension tolerance level results for the unhelmeted cyclist.

5.3 Results from Additional Simulations

The primary goal of this study was to determine what advantages or disadvantages a helmeted motorcyclist has relative to an unhelmeted motorcyclist in an impact situation. As such, the comparisons of the baseline helmet and no-helmet simulations in the preceding section, together with the summary of helmet vs. no-helmet results in Section 5.4, probably yield the most important findings of the study. The baseline simulations cannot be assessed properly, however, without giving special consideration to several aspects of the simulations not related to whether a helmet condition or a no-helmet condition is modeled. Sections 5.3.1 through 5.3.7 discuss the effects of varying baseline conditions for: 1) coefficient of friction for the head/helmet contact with truck or road; 2) overall body orientation for road impacts; 3) head and neck initial positions; 4) neck muscle tension level; 5) horizontal velocity at impact; 6) fall height for road impacts, i.e., maximum trajectory height; and 7) initial overall body rotational velocity. Simulations for these conditions are important for two reasons. First, they determine whether general statements regarding the effectiveness of helmet use can be made on the basis of the specific, idealized baseline simulations discussed in Section 5.2. Secondly, they make clear the mechanisms for various aspects of head/neck injury and dynamic response resulting for different impact conditions.

Most of the simulations discussed in this section relate to the Expanded Run Matrix of Section 3.2.2, Table 3-2.

5.3.1 Effects of Coefficient of Friction. For the head-truck and chest-truck simulations, only baseline values were used for coefficient of friction between the truck surface and the head, helmet, or chest. The effects of varying coefficient of friction for these simulations could not be of significance since there is no initial component of momentum parallel to the truck surface. For 30° and 70° road impacts, however, friction was varied, and there were found to be significant differences in dynamic responses resulting for the different friction coefficients. This was not unexpected since for all such simulations the initial horizonal momentum (for 10 and 20 mph velocities) was of the same order of magnitude as the vertical momentum at impact.

Because of the significance of frictional force for the road impacts, there has already been some discussion of this subject in Sections 5.2.4 and 5.2.5. The importance of the frictional force is perhaps made most clear by the fact that reducing it to zero completely changes the overall character of the response for the 70° body orientation impact from rollover (Figure 5-10) to dropping down into a prone body impact more like the typical overall response in a 30° impact (Figure 5-8). For realistic helmet-road friction coefficients, however, rollover always occurs for 70° impacts, and the prone body impact always occurs for the more horizontal, 30° initial body orientations. (For the latter case, a helmet-road coefficient of friction much greater than 1.0 would be necessary to cause rollover.)

Since, within limits, the smoothness and hardness of the helmet shell can be modified by use of different material and/or manufacturing methods, it is of interest to establish what values of helmet-road friction coefficient minimize injury-indicating dynamic responses for the 30° road and 70° road impacts. For any given helmet shell, the effective friction coefficient is, of course, a function of the road surface, but it would not be unreasonable to optimize with respect to a concrete or asphalt surface specifically.

For both 30° and 70° helmet-road impact simulations, results from the baseline runs (coefficient of friction value, 0.2) were compared against results from simulations for a range of coefficient of friction values. Comparison numbers for the 30° road impacts are [66], [64], [65], [8], and [40] for friction coefficients of 0., 0.1, 0.3, 0.6, and 1.0, respectively. For 70° road impacts, the comparison numbers are [72], [67], [20], [68], and [41] for values 0.0, 0.4, 0.6, 0.8, and 1.0, respectively.* The plots in Figures 5-12 and 5-13 illustrate the effect on some of the response variables of changing the coefficient of friction from 0.2 to 0.6 for helmet impacts. Figure 5-12 is for the 30°-road simulations and Figure 5-13 is for the 70°-road simulations.

Analysis of Comparisons [8], [40], [64], [65], and [66] shows that for low angle (30°) impacts, a low coefficient of friction for the road-helmet interface is in general advantageous. There is little significant difference between values in the range 0 to 0.3, but the value 0 is not optimal. HIC is minimized at 0.1 and head accelerations and condyles extension and flexion torques are minimized at 0.3. Responses are worsened considerably by a coefficient of friction of 0.6,

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* Appendix C includes tabular comparisons for all of these, but Appendix D plots were not made for [64] through [68] and [72].

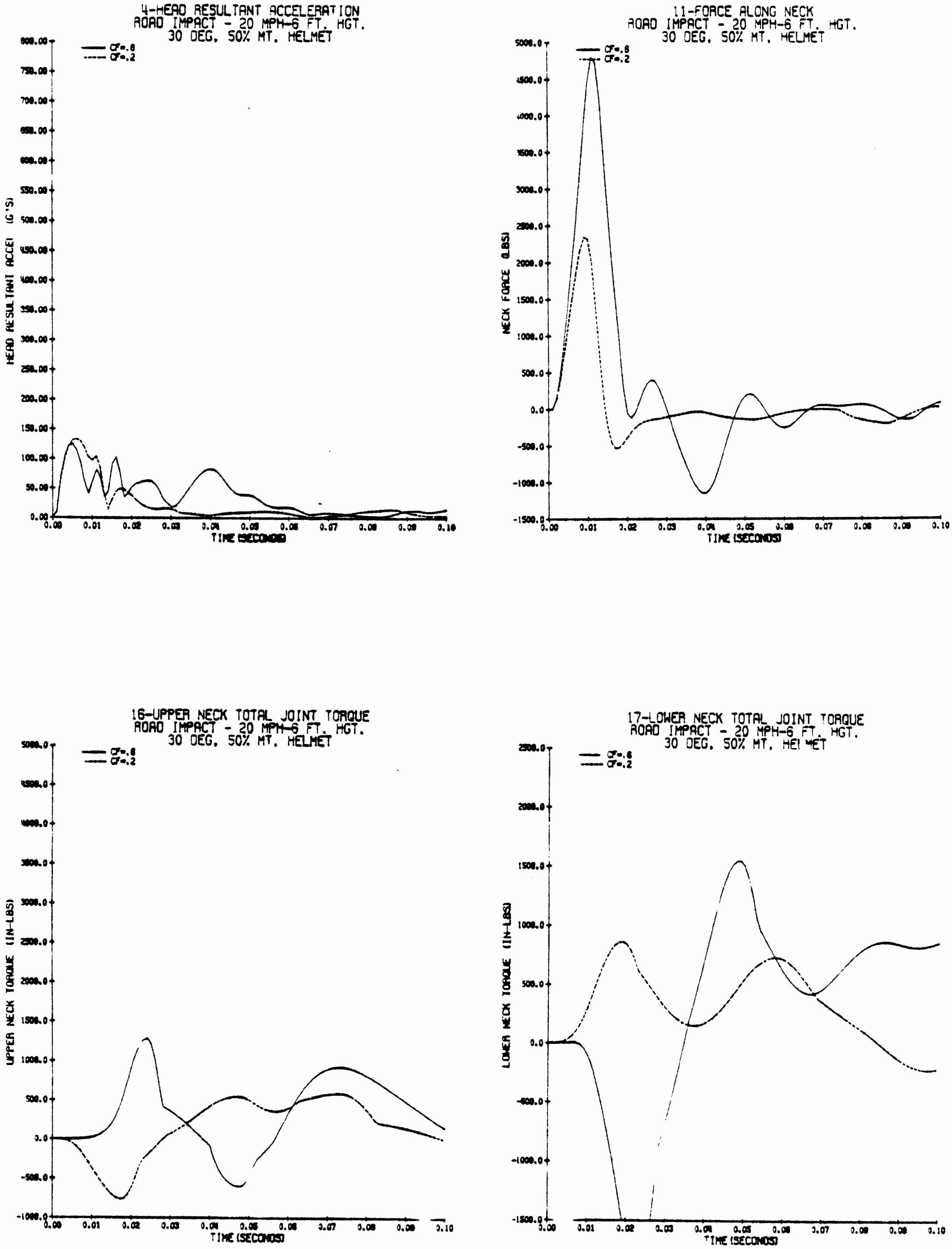

Figure 5-12. Selected Plots from Comparison [8]

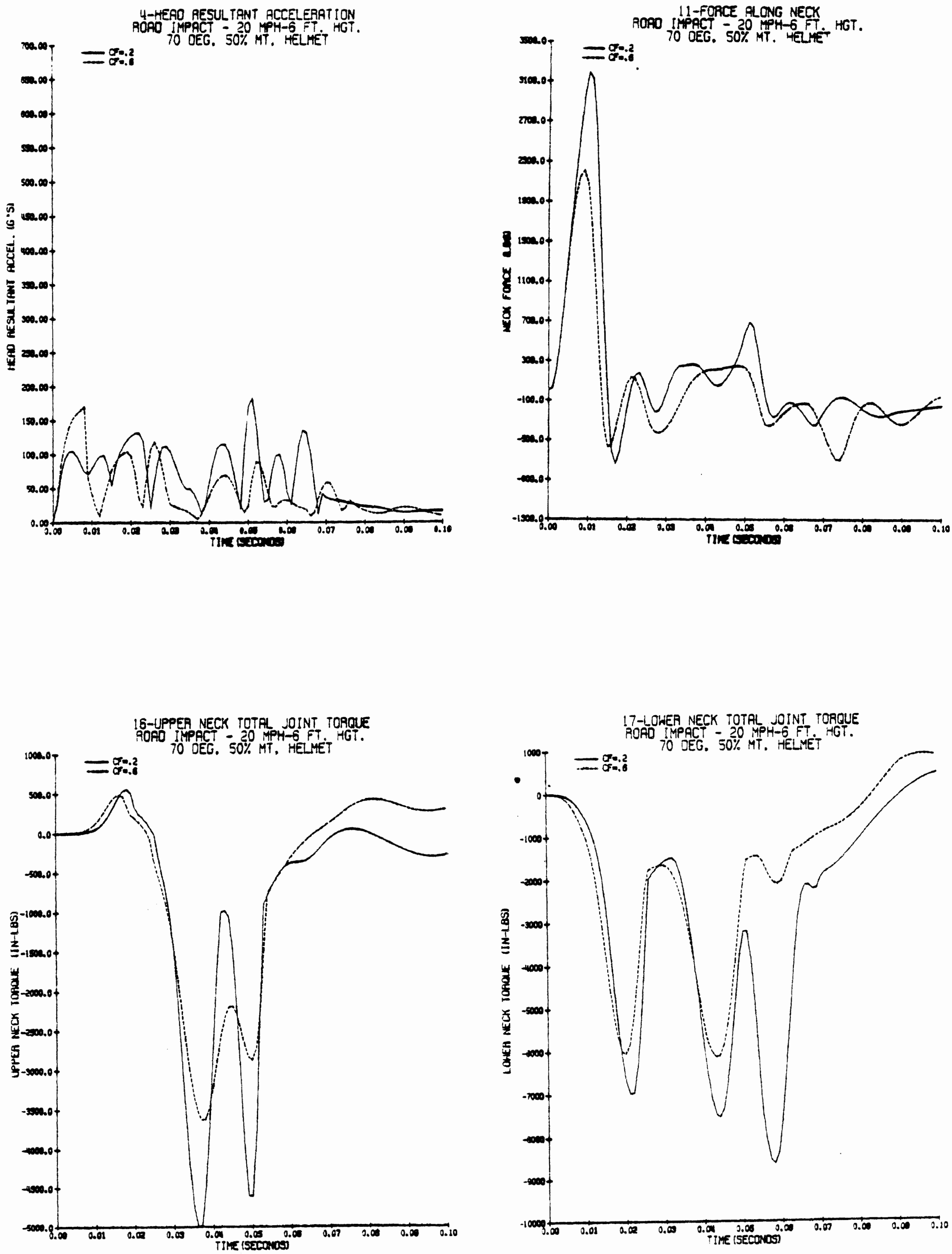

Figure 5-13. Selected Plots from Comparison [20]

HIC increasing relative to its value at 0.2 by 11%, head angular acceleration by 41%, and condyles extension torque by 122%. A coefficient of friction of 1.0 is far worse still, increasing peaks relative to 0.2 by 570% for HIC, 130% for head resultant acceleration, 170% for head angular acceleration, and for condyles extension torque by 780% to ten times the tolerance level.

Comparisons [20], [41], [67], [68], and [72] indicate clearly that the optimal coefficient of friction for the road-helmet interface for a 70° impact orientation is greater than that for a 30° orientation. Again, however, there is a fairly broad range of friction coefficient values for which there are no significant differences in peak values of response variables that have the potential of indicating injury. HIC and condyles extension torque are minimized at a coefficient value of 0.6. Head angular acceleration and condyles flexion torque are minimized at 0.8 and 1.0, respectively. Head resultant acceleration is minimized at 0. but is not much greater at 0.4. Response variables are consistently low for a friction coefficient value of 0.4, and overall results for values in the range 0.4 to 0.8 are similar.

A helmet-road coefficient of friction in the range 0. to 0.3 has been found to be optimal for a 30° impact orientation. Since the range 0.4 to 0.8 is optimal for a 70° orientation, the range 0.3 to 0.4 is suggested as being optimal overall since impact angles are not, of course, limited to any one value in real-world accidents.

5.3.2 30° Vs. 70° Road Impacts. Comparisons [60] and [61] were made to examine in greater detail the differences between 30 and 70 degree road impact responses. Comparison [60] is for helmet impacts (small coefficient of friction), and Comparison [61] is for no-helmet impacts (larger coefficient of friction). Except for magnitude differences, these comparisons for 6-foot fall heights are very similar to those for 3-foot fall heights ([62] and [63]). The plots in Figure 5-14 illustrate some of the results of these comparisons.

Head/neck dynamic responses for the helmet and no-helmet conditions have been previously described in Sections 5.2.4 and 5.2.5 for the 30° road and 70° road baseline simulations. For low angle impacts the overall body action is one of sliding while at higher angles the action is one of tumbling (see Figures 5-8 and 5-10). These general differences cause neck response to be very different for the two impact orientations. Frictional forces have a significant effect on sliding and tumbling and on the resultant neck responses. For low angle impacts, larger coefficients of friction are <u>detrimental</u> since they result in a greater resistance to sliding and thereby allow the body mass to have a greater effect by driving into the neck. At higher angles, the larger coefficients of friction assist the tumbling action, which is <u>beneficial</u> since it reduces the impact of body mass on the neck. The opposite effects of friction in low angle and high angle impacts is made evident by examination of the compressive forces on the neck. The neck compression forces of an unhelmeted cyclist [61] are greater for the 30 degree impact than for the 70 degree impact, while neck compression of a helmeted cyclist [60] is greater for the 70 degree impact.*

* The role of the body mass in generating neck forces and torques is also clearly demonstrated in Plots [47] and [48] of Appendix D, which show that without the effect of body mass, torques and forces on the neck are markedly reduced even though the reductions in peak head contact forces are relatively small.

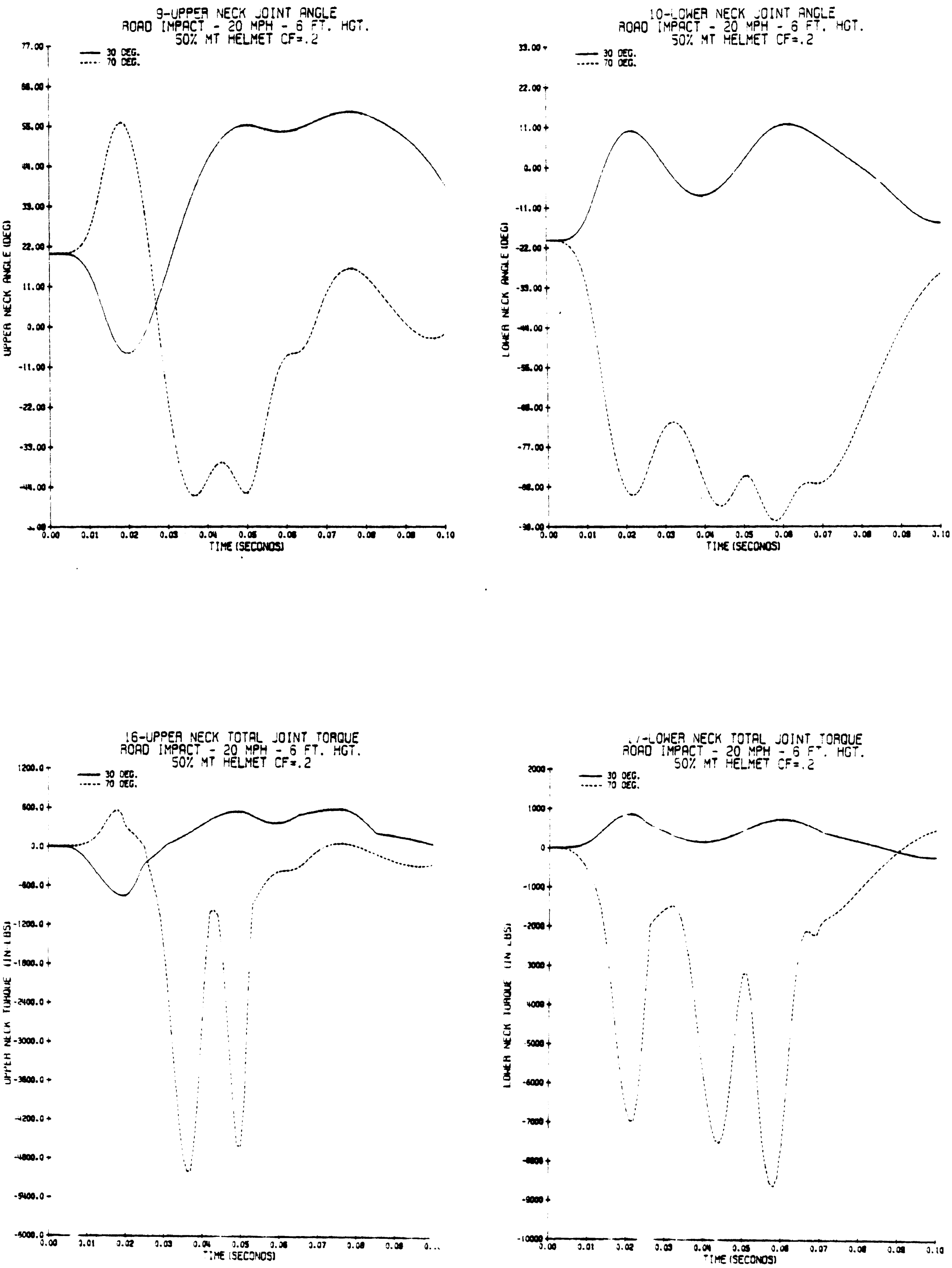

Figure 5-14a. Selected Plots from Comparison [60] (Page 1 of 2)

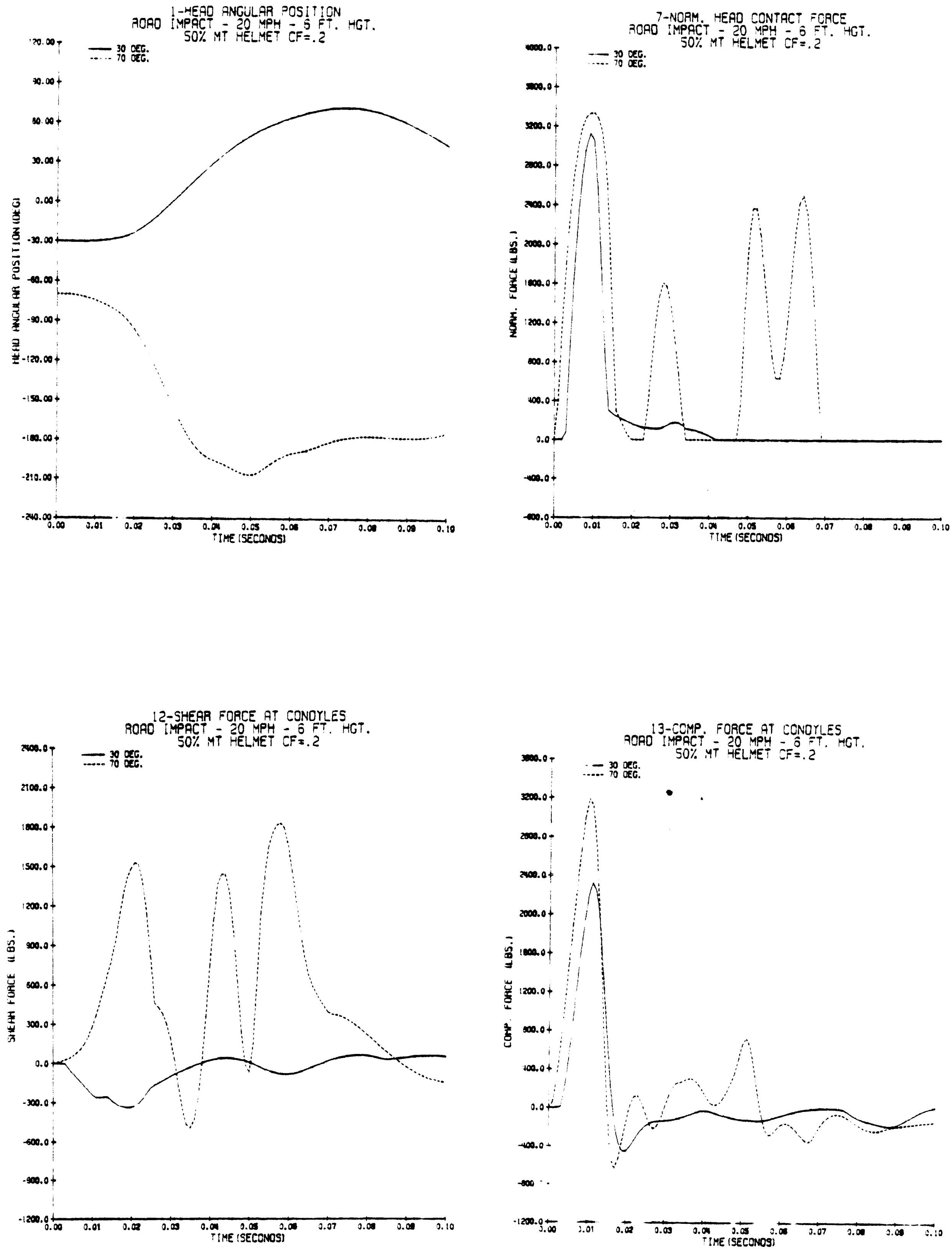

Figure 5-14a. Selected Plots from Comparison [60] (Page 2 of 2)

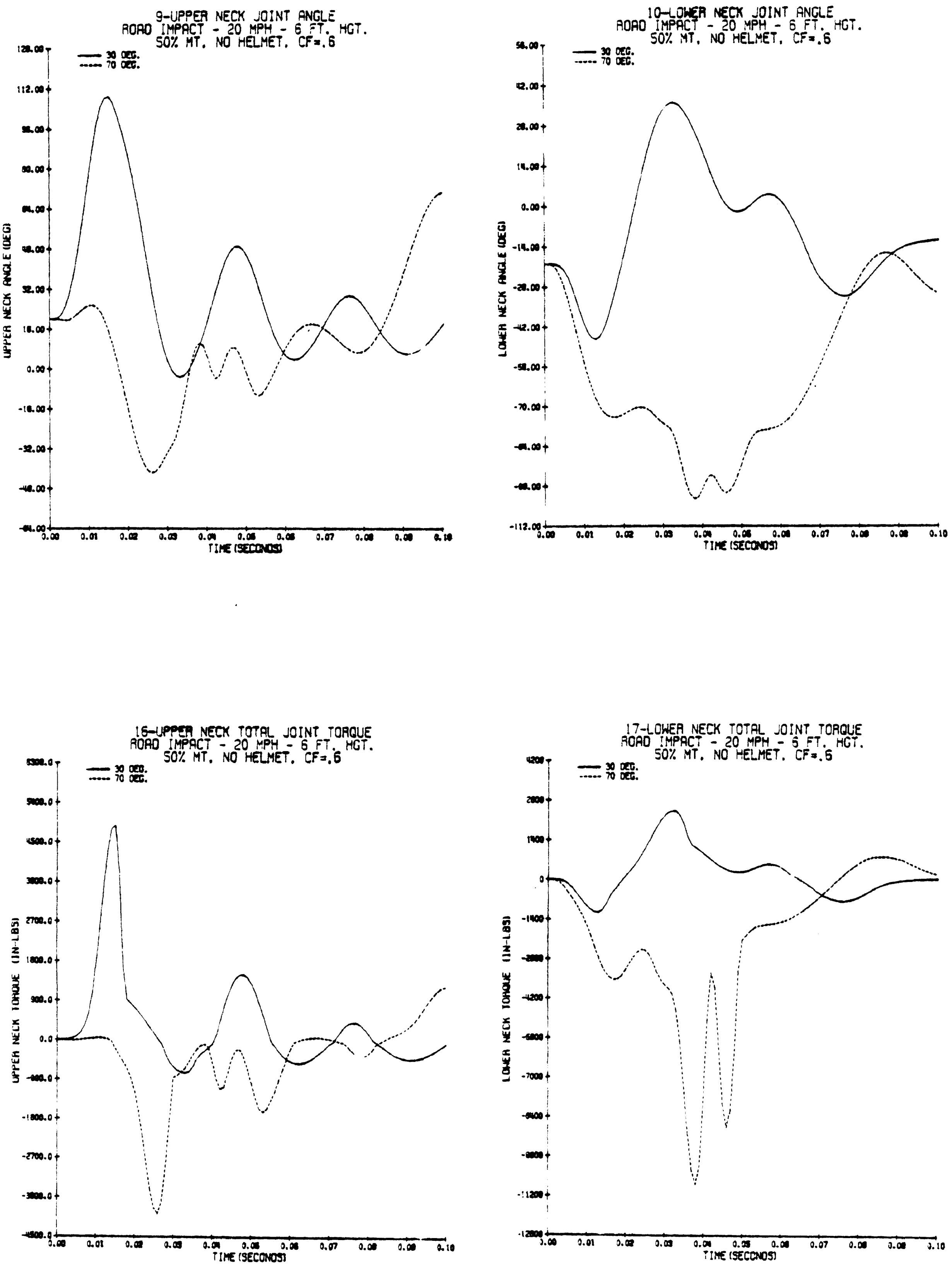

Figure 5-14b. Selected Plots from Comparison [61] (Page 1 of 2)

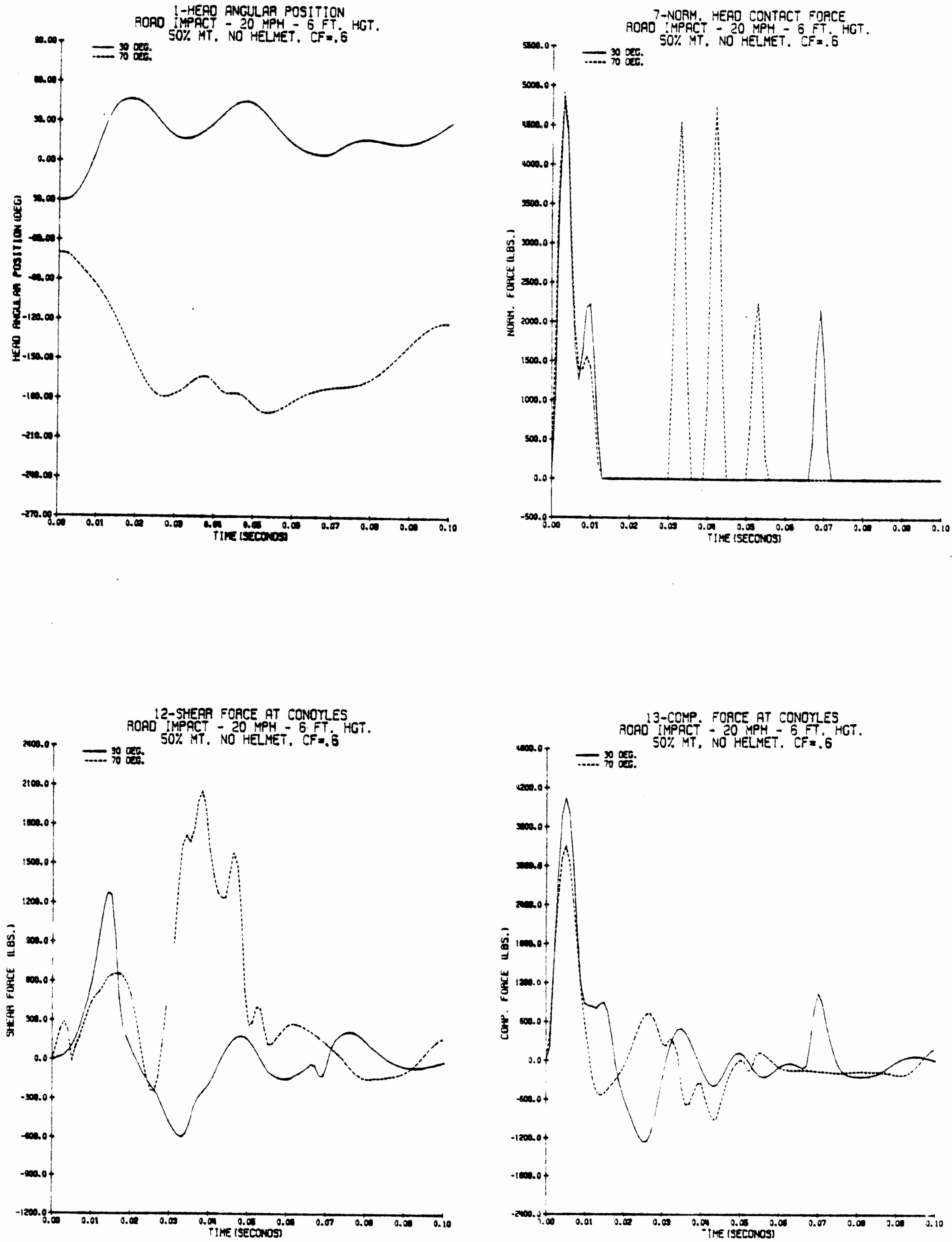

Figure 5-14b. Selected Plots from Comparison [61] (Page 2 of 2)

For the unhelmeted cyclist, the 30 degree impact is also found to be more serious with respect to upper and lower neck injury than the 70 degree impact. While condyles flexion torque is decreased to a safe level at 30° from a value 2.4 times the tolerance level at 70°, the effect of impact orientation angle on the condyles extension torque is of overriding importance, for it is nearly ten times the tolerance level at 30° while only 2.4 times the tolerance at 70°. For the helmeted cyclist, however, the 70 degree impact is found to be the more severe if upper (or lower) neck torques are used as criteria. Peak condyles extension torques are nearly equal for the 30 and 70 degree impacts and only 15% and 11% greater than the injury tolerance level, but the condyles flexion torque is three times the tolerance level for the 70 degree impact while less than half for the 30 degree impact.

With regard to HIC response, the more vertical impact is more severe for both the helmeted and unhelmeted motorcyclists. For helmet impacts, HIC is 3.5 times as large at 70° as at 30°, and for unhelmeted head impacts against the road, HIC is 1.8 times as large at the 70° body orientation.

It is interesting to note, however, that the peak magnitudes of normal head contact force are about the same for 30° and 70° impacts. This is further indication that the magnitude of the impact force itself is primarily dictated by the head mass the head or helmet material characteristics. The duration of the contact force may, however, be influenced by the body mass as indicated by the comparison of 30° and 70° impacts for the helmet condition [60].

5.3.3 Effects of Head and Neck Initial Position on Simulation Results

5.3.3.1 Road Impacts: General. For the road impact simulations, and especially the low angle (30°) road impacts, the response of the head and neck were found to be dependent on the head/helmet-road coefficient of friction as discussed in Section 5.3.1 and in Sections 5.2.4 and 5.2.5. A part of this dependency has to do with the orientation of the force vector on the head (i.e., the vector sum of normal and frictional forces) relative to the positions of the head center of gravity and upper and lower neck joints. Since the initial orientations of the head and neck also bear on these geometric relations, an additional computer run was made for both the low angle and high angle road impacts in which the head and neck orientations at impact were changed. In both these cases the upper and/or lower neck joints were flexed further forward so that the head/road angle was increased relative to the baseline runs. These positions have been previously described and are illustrated in Figures 3-8 and 3-9.

5.3.3.2 70° Road Impacts. In Appendices C and D, comparison [25] gives the results for the helmet and no-helmet 70° road impacts with increased neck flexion. Comparisons [23] and [69] show more clearly the effects of initial neck flexion by comparing results from increased neck flexion with results from baseline head/neck orientation for unhelmeted and helmeted cases, respectively. Figures 5-15 and 5-16 show some of the plots.

For the no-helmet case this new initial position results in little significant change in normal head contact force, head resultant acceleration, HIC or total head rotation, but the initial spike in head

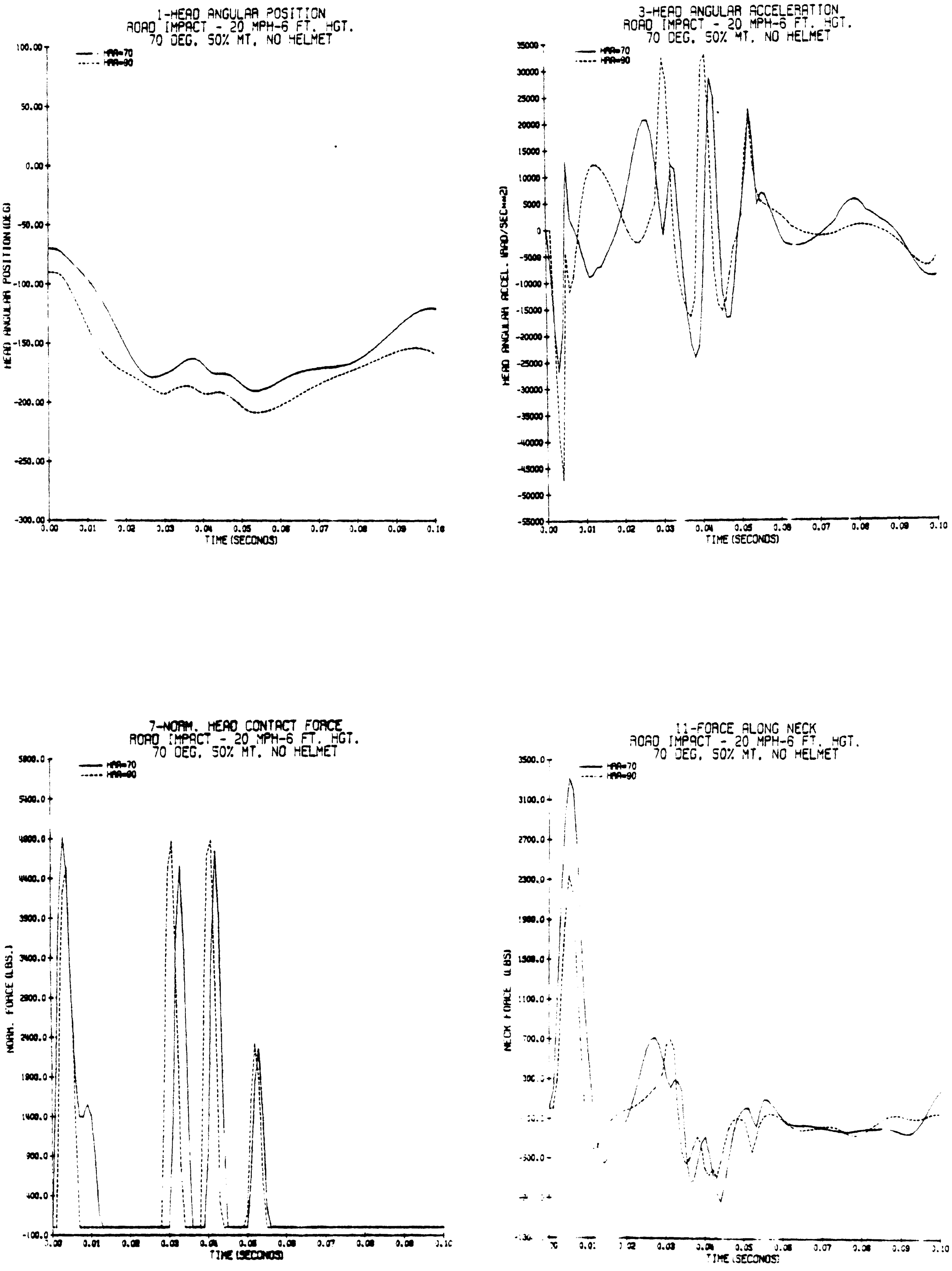

Figure 5-15. Selected Plots from Comparison [23] (Page 1 of 2)

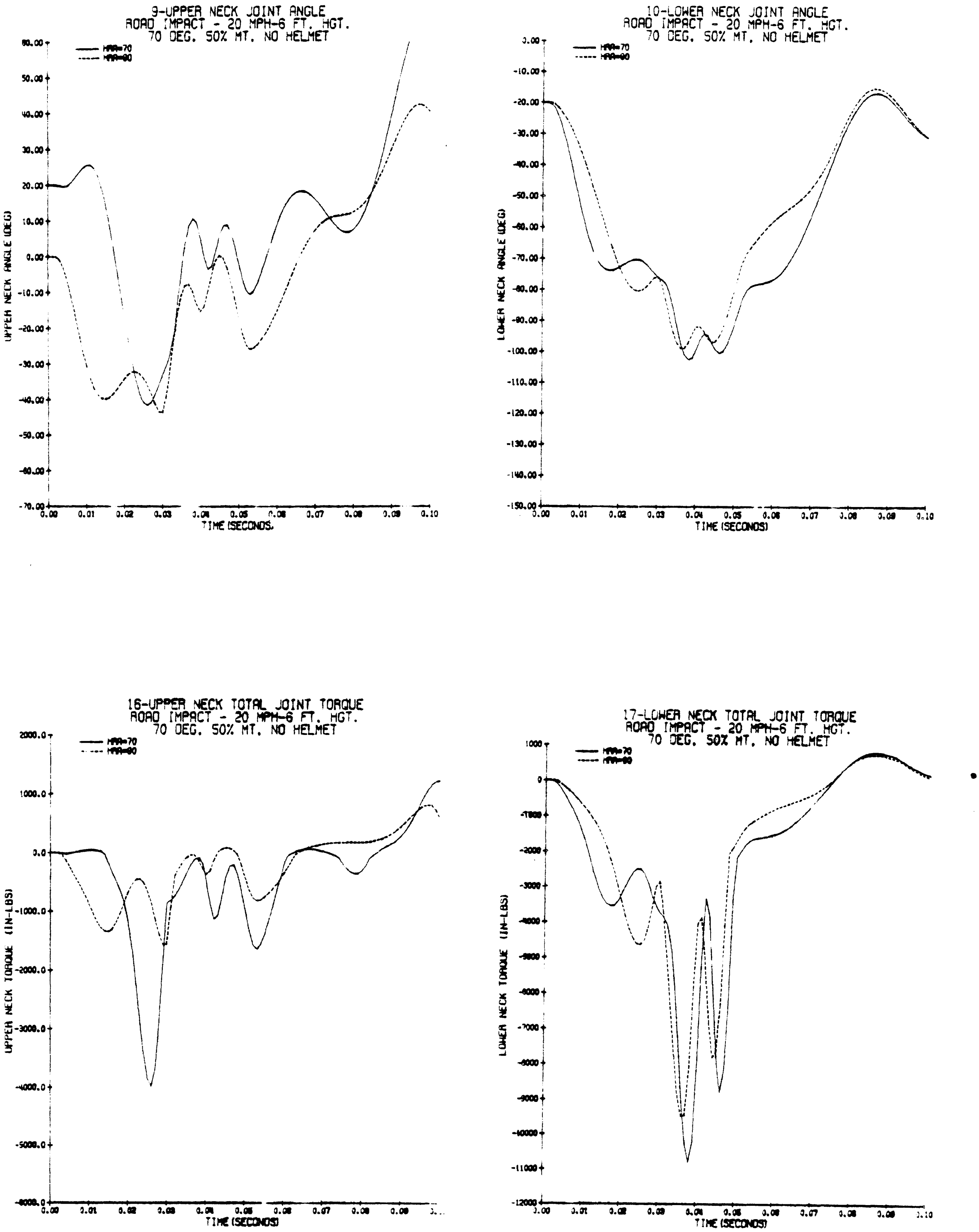

Figure 5-15. Selected Plots from Comparison [23] (Page 2 of 2)

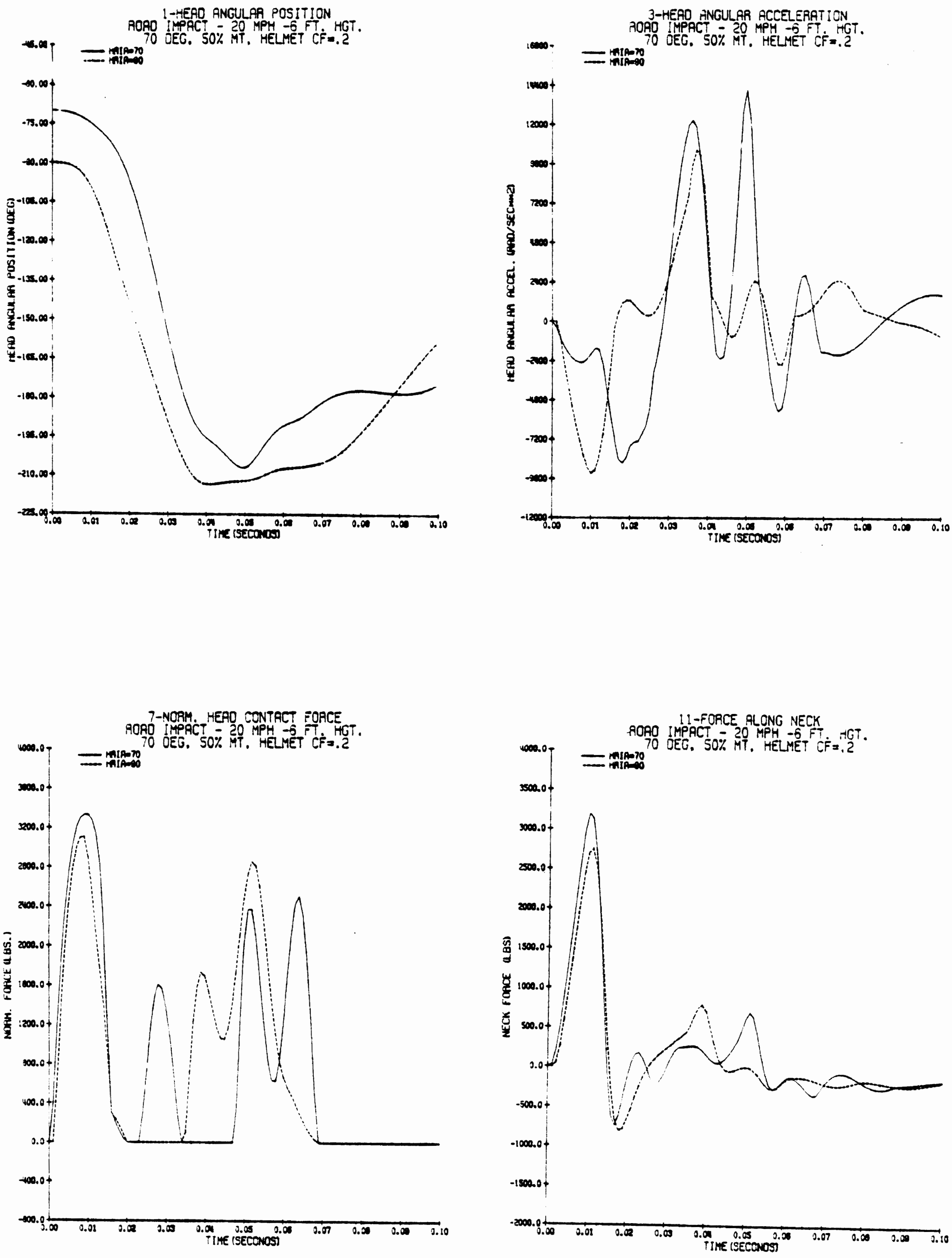

Figure 5-16. Selected Plots from Comparison [69] (Page 1 of 2)

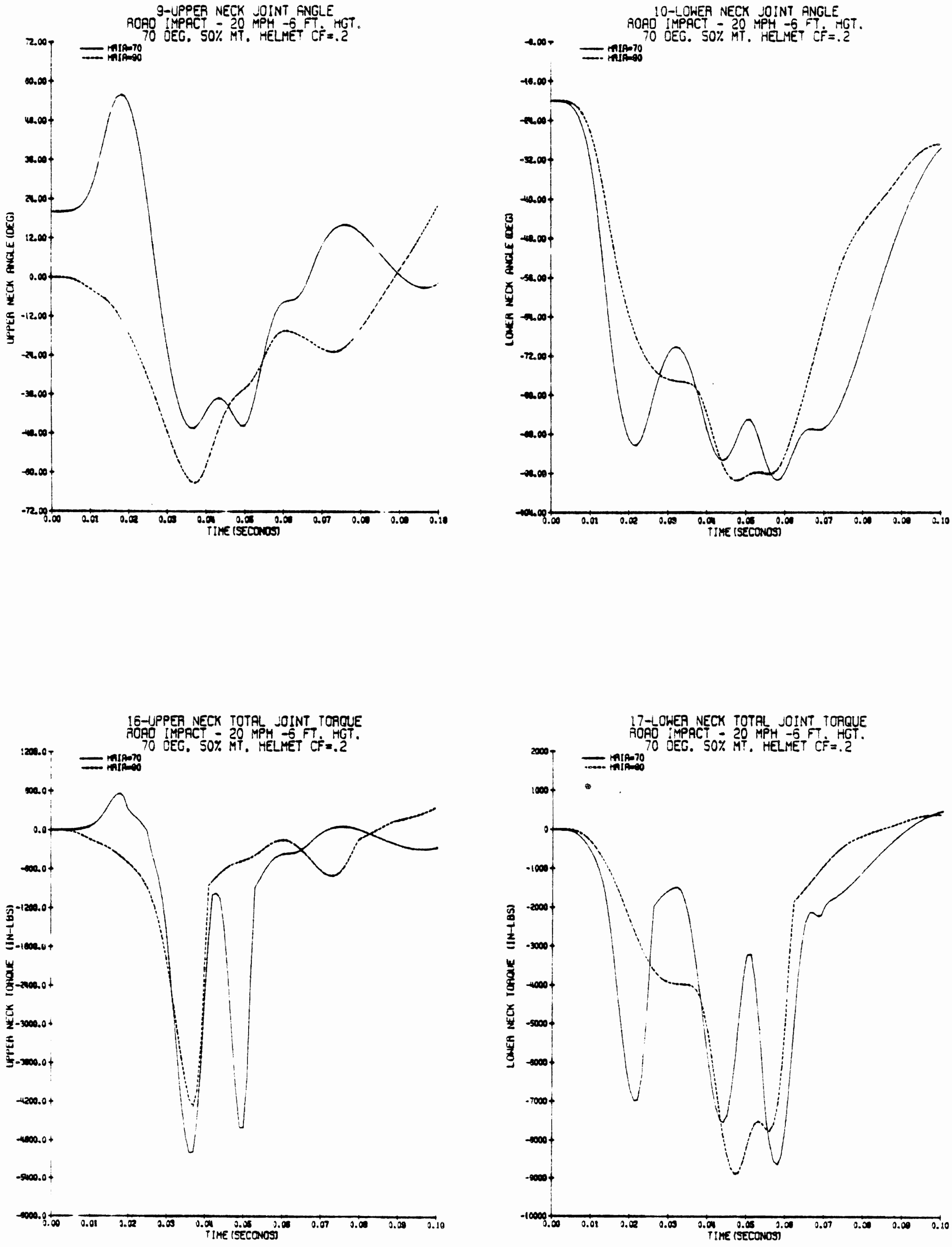

Figure 5-16. Selected Plots from Comparison [69] (Page 2 of 2)

angular acceleration is nearly doubled (-29000 rad/sec^2 to -47000 rad/sec^2). More significantly, the more flexed position significantly reduces the total flexion excursion at this joint.* The major effect is a marked reduction in upper neck joint peak flexion torque from over 3900 in-lbs to a value very near the tolerance limit -- about 1600 in-lbs. Motion of the lower neck joint is affected to a much less degree and results in a reduction of flexion torque from about 10800 in-lbs to about 9500 in-lbs. Compressive and shear forces on the neck show similar reductions for the more flexed initial position.

For the helmet case, HIC is reduced, by a factor of four, because of significant overall reduction of the head resultant acceleration time history. In this new orientation the tendency toward initial upper neck joint hyperextension is removed and the upper neck joint goes into immediate flexion. This is reflected in the head angular acceleration curve by a much earlier peak of comparable magnitude to the baseline run. This has the desirable effect of completely removing the upper neck initial extension torques, which were in excess of tolerance limits, and also results in reduced flexion forques (5000 in-lbs to 4300 in-lbs) since the total excursion from the initial orientation is also reduced. Motion at the lower neck joint is similar but somewhat less severe than for the baseline run, and peak flexion torques are about the same. Compressive forces at the neck are reduced 15 to 20 percent; peak values of shear forces are changed little in the positive direction and reduced significantly in the negative direction.

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* It should be pointed out that the joint torques were always set to zero at initial upper and lower neck joint angles.

In terms of neck injury, then, the major effect of the increased-flexion orientation for 70° road impact is to reduce the likelihood of injury at the upper neck joint by reducing both extension torque and flexion torque. Flexion torque for the no-helmet case is reduced much more significantly than for the helmet case, i.e., the helmet has relatively less positive effect on likelihood of upper neck injury for this orientation. In terms of head injury, however, the relative benefits of the helmet are increased for increased initial neck flexion.

5.3.3.3 30° Road Impacts. Comparison [15] in Appendices C and D contrasts helmet and no-helmet results for the 30° road impact with increased initial neck flexion, and comparisons [13] and [14] contrast the increased initial flexion results for helmet and no helmet, respectively, with baseline results. Figures 5-17 and 5-18 show some of these results. For the helmet case, peak head resultant acceleration is reduced by 5 percent, HIC is reduced by about 25 percent and peak positive and negative values of head angular acceleration are increased dramatically. Head rotation shows an immediate flexion of about 20 degrees primarily as a result of increased initial flexion at the upper neck joint; this response is not present in the baseline run. This results in a significant increase in peak upper neck flexion torque (from 761 to 2727 in-lbs). The lower neck goes into initial extension as it does in the baseline run but returns much earlier (at about 20 msec) to flexion. This causes a small peak lower neck joint flexion torque of 481 lbs which did not occur for the baseline run. Compressive forces on the neck showed little change while negative shear forces increased from about 300 lbs to about 700 lbs.

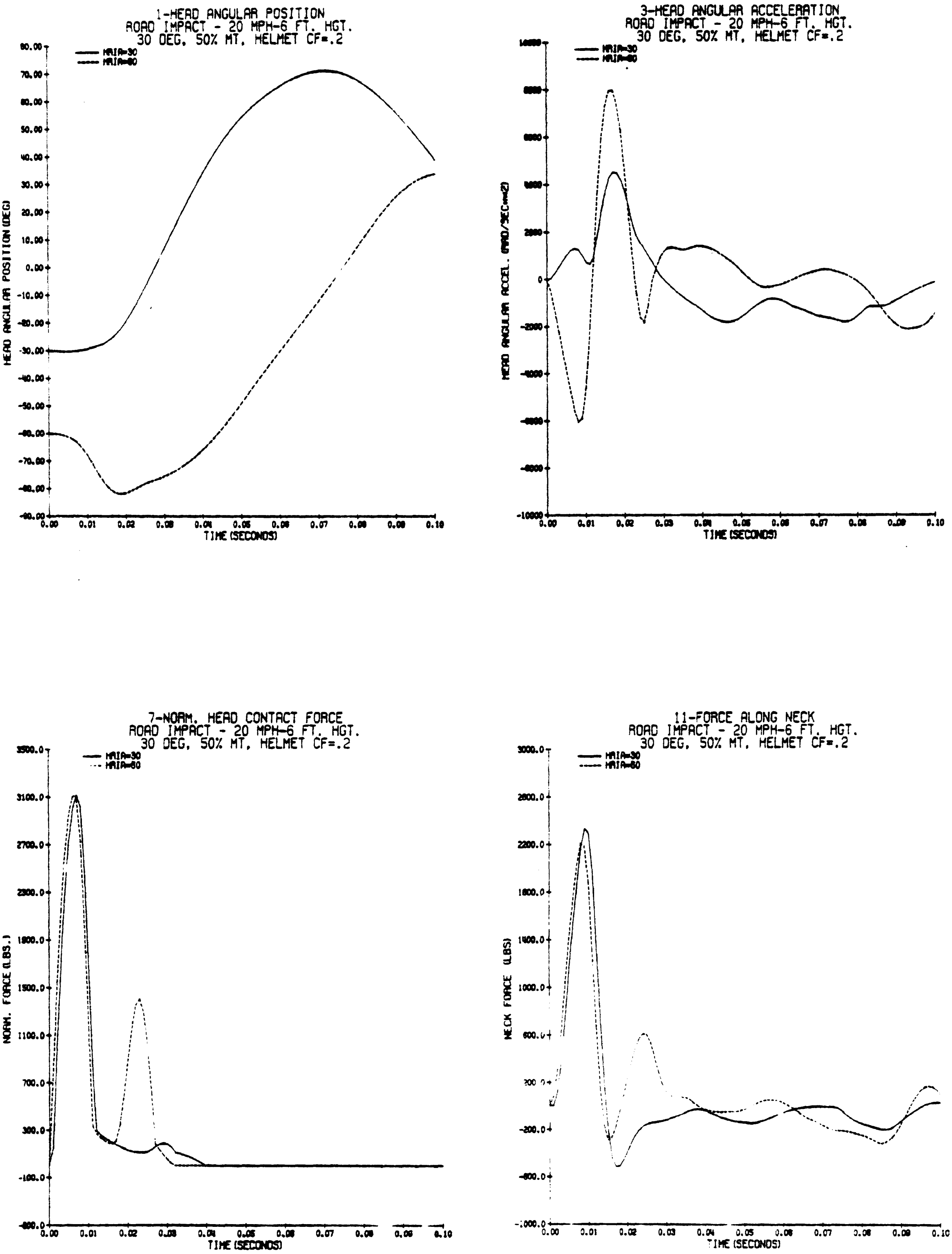

Figure 5-17. Selected Plots from Comparison [13] (Page 1 of 2)

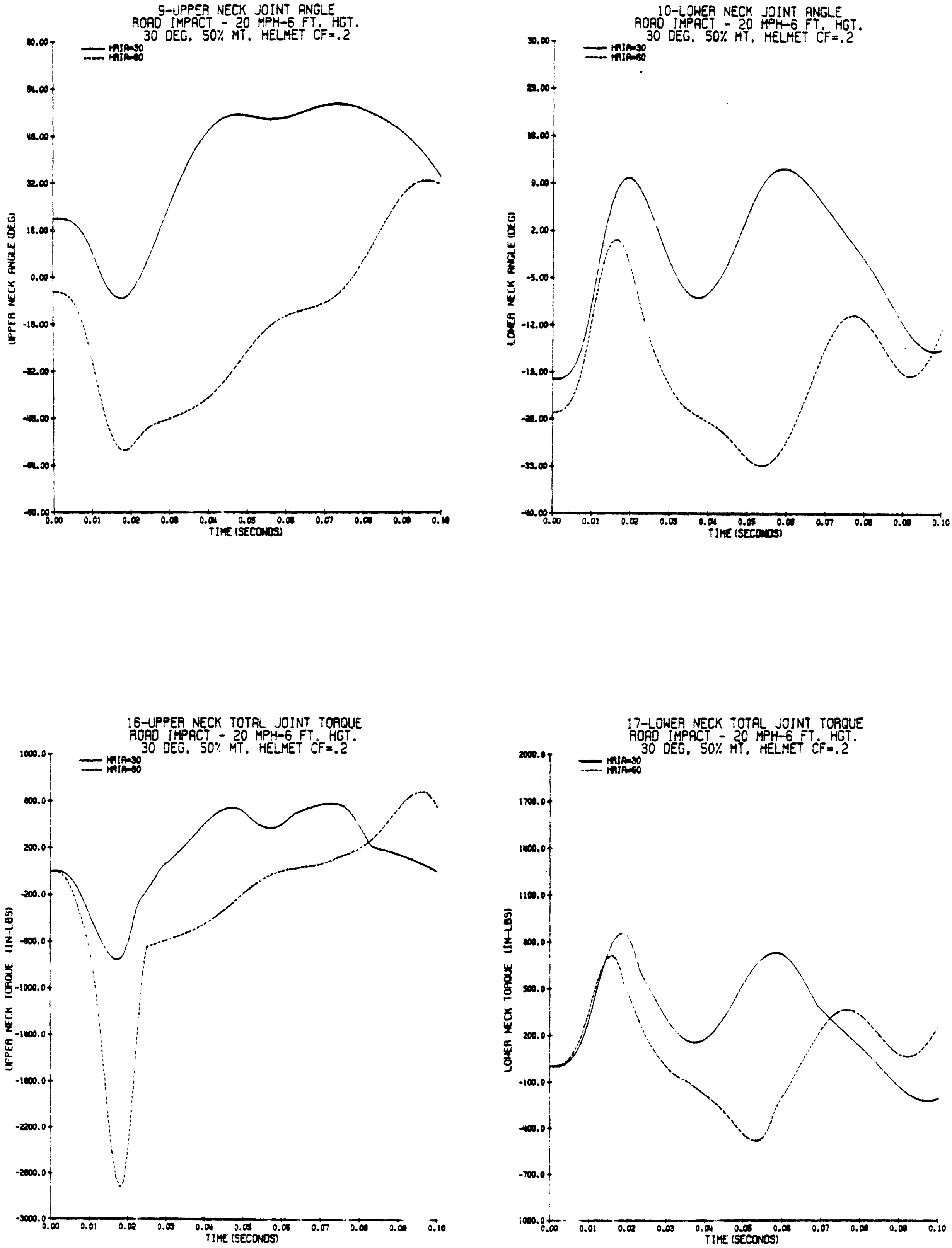

Figure 5-17. Selected Plots from Comparison [13] (Page 2 of 2)

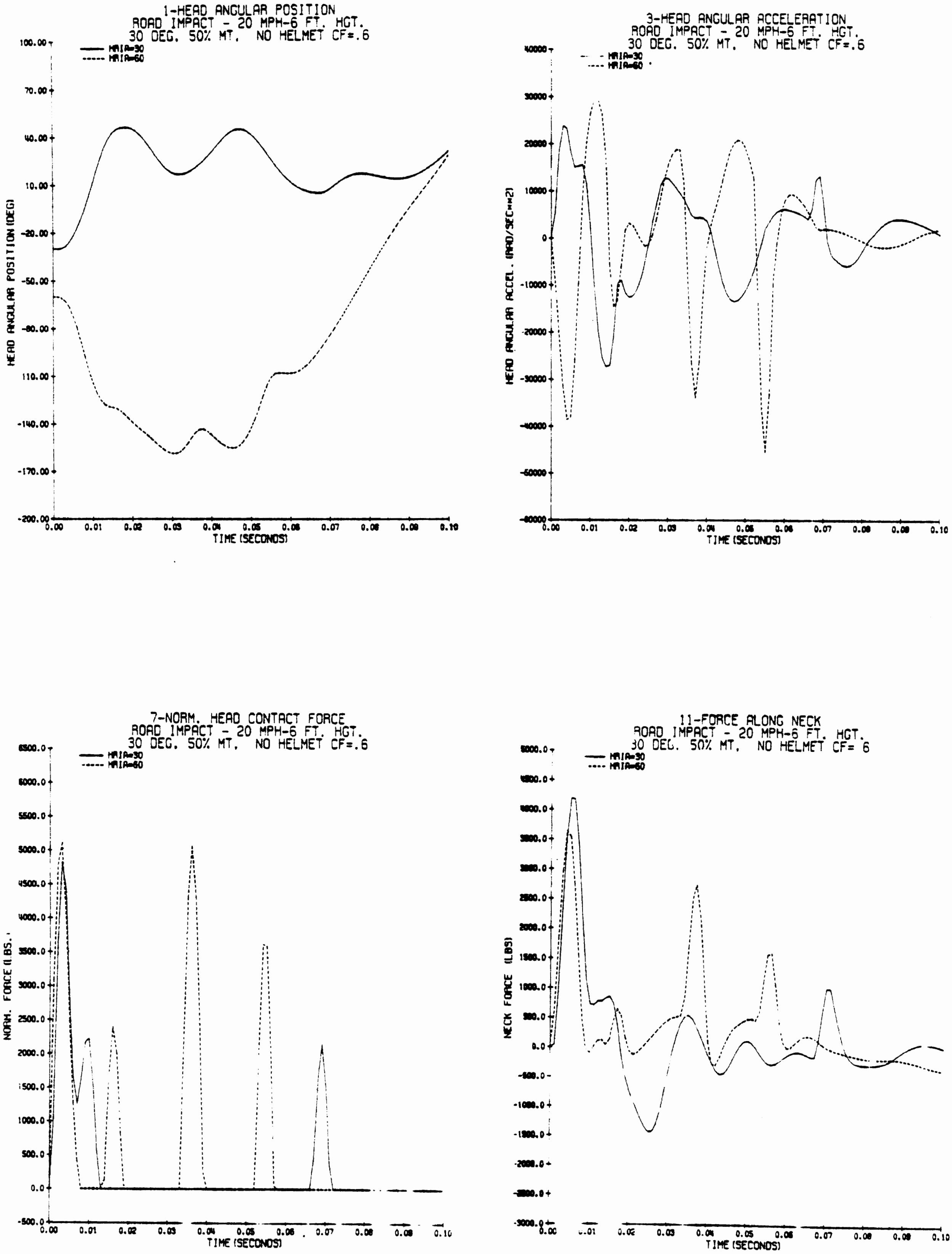

Figure 5-18. Selected Plots from Comparison [14] (Page 1 of 2)

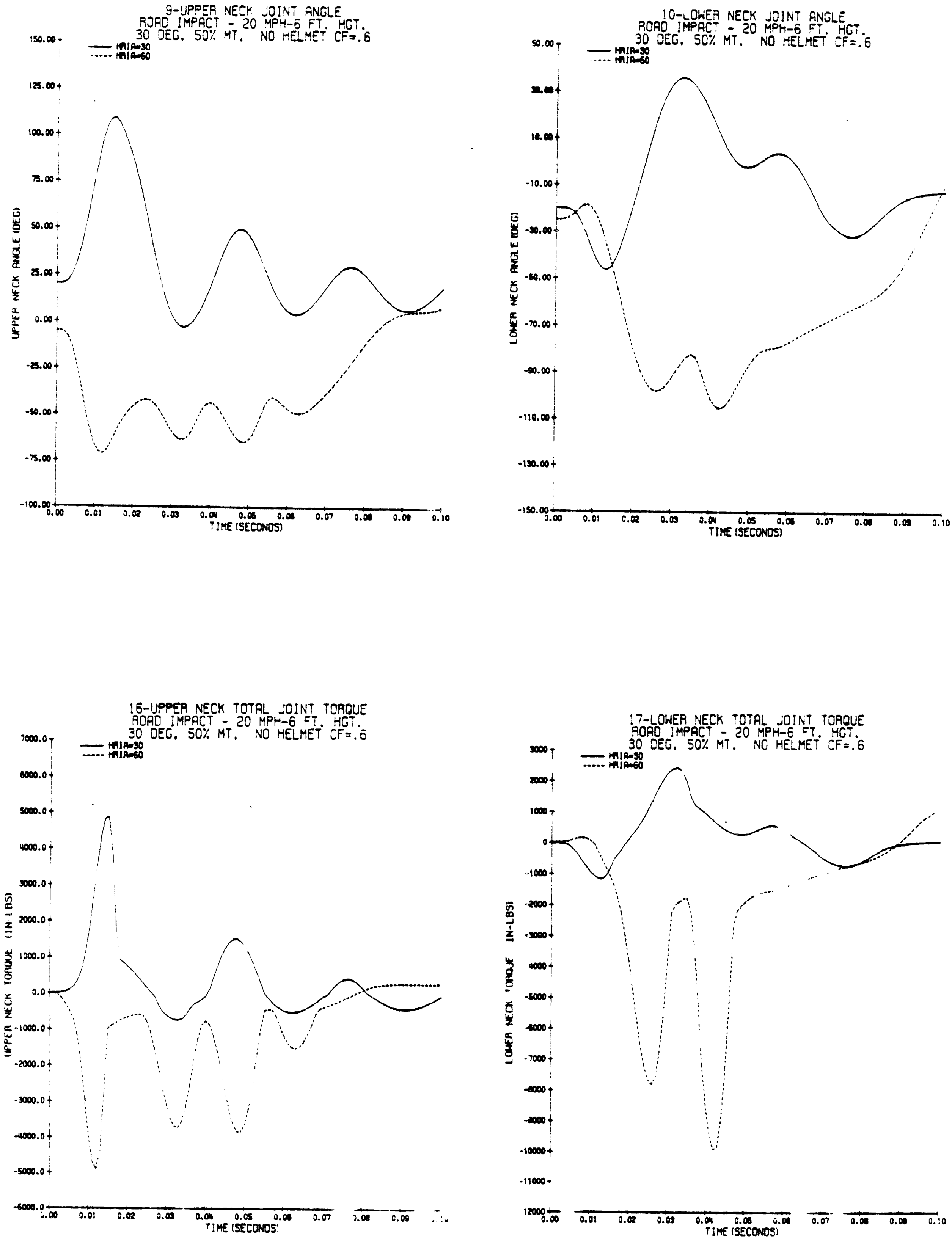

Figure 5-18. Selected Plots from Comparison [14] (Page 2 of 2)

For the no-helmet case, the changes were more significant and dramatic. The more flexed initial orientation results in a complete reversal of head rotation at both the upper and lower neck joints so that, in spite of the higher coefficient of friction, the motion is similar to that for the helmeted condition. HIC increases from 7600 to 11300, peak head resultant acceleration increases from 398 to 444 G's and head angular acceleration reverses its initial direction and nearly doubles in magnitude. The reversals in joint motion result in reversals at the upper neck joint from extension torques to flexion torques of comparable magnitudes (about 5000 in-lbs) and reversals at the lower joint from primarily extension torque to primarily flexion torque of significantly increased magnitude (2400 in-lbs peak extension torque to 9900 in-lbs peak flexion torque).

For 30° road impacts, relative to the unhelmeted conditions, the helmeted condition is perhaps even more beneficial for the increased flexion case than for the baseline case for 30° road impact -- for both head and neck injury. HIC is 92 percent less (for helmet simulations [13]), resultant acceleration is 71 percent less, and peak head angular acceleration is 76 percent less. Neck joint torques are significant only in flexion and are 44 percent less at the upper joint (2727 vs. 4907 in-lbs) and 95 percent less (482 vs. 9911 in-lbs) at the lower joint.

5.3.3.4 Head-Truck and Chest-Truck Impacts. For the head-truck impact condition one additional run was made for the no-helmet case at a new initial position in which the head and neck are flexed further forward (see Figure 3-5). Comparisons of the results of this run with those from the baseline head-truck impact are given in Appendices

C and D by comparison [3]. Figure 5-19 shows some of the graphical results. In general the results for these two initial positions are quite similar, the major changes being offsets in time and angular position. Changes in peak values are relatively minor and it can be expected that the relations between helmet and no-helmet baseline runs described in Section 5.2.2 would not be strongly affected by this change in initial position.

For the chest-truck impacts, two additional initial positions were chosen for both helmet and no-helmet baseline simulations. Comparison [43] contrasts helmet and no-helmet results for impact with the head and neck flexed further forward as shown in Figure 3-6. Comparison [44] gives the results for impact with the head and neck extended backward as illustrated in Figure 3-7. Comparisons [45], [46], and [53] contrast the helmeted run results for the various combinations of the three different initial positions. Figure 5-20 shows some of the comparisons between the head-forward and head-back initial positions. In general, the magnitudes of peak neck torques and elongation forces increase with head/neck extension and decrease with head/neck flexion. Positive shear forces, on the other hand, show significant increases for initial extension relative to initial flexion. Torque increases are most dramatic at the lower neck, where the peak extension torque was 143 percent greater for the head-back initial condition than for initial flexion (-1706 in-lbs to -4146 in-lbs). At the upper neck joint the increase was 40 percent, from -2346 in-lbs to -3440 in-lbs.

Comparison of the response curves of Plots [44] and [45] with those for the baseline chest impact, Plot [1], confirms that the response

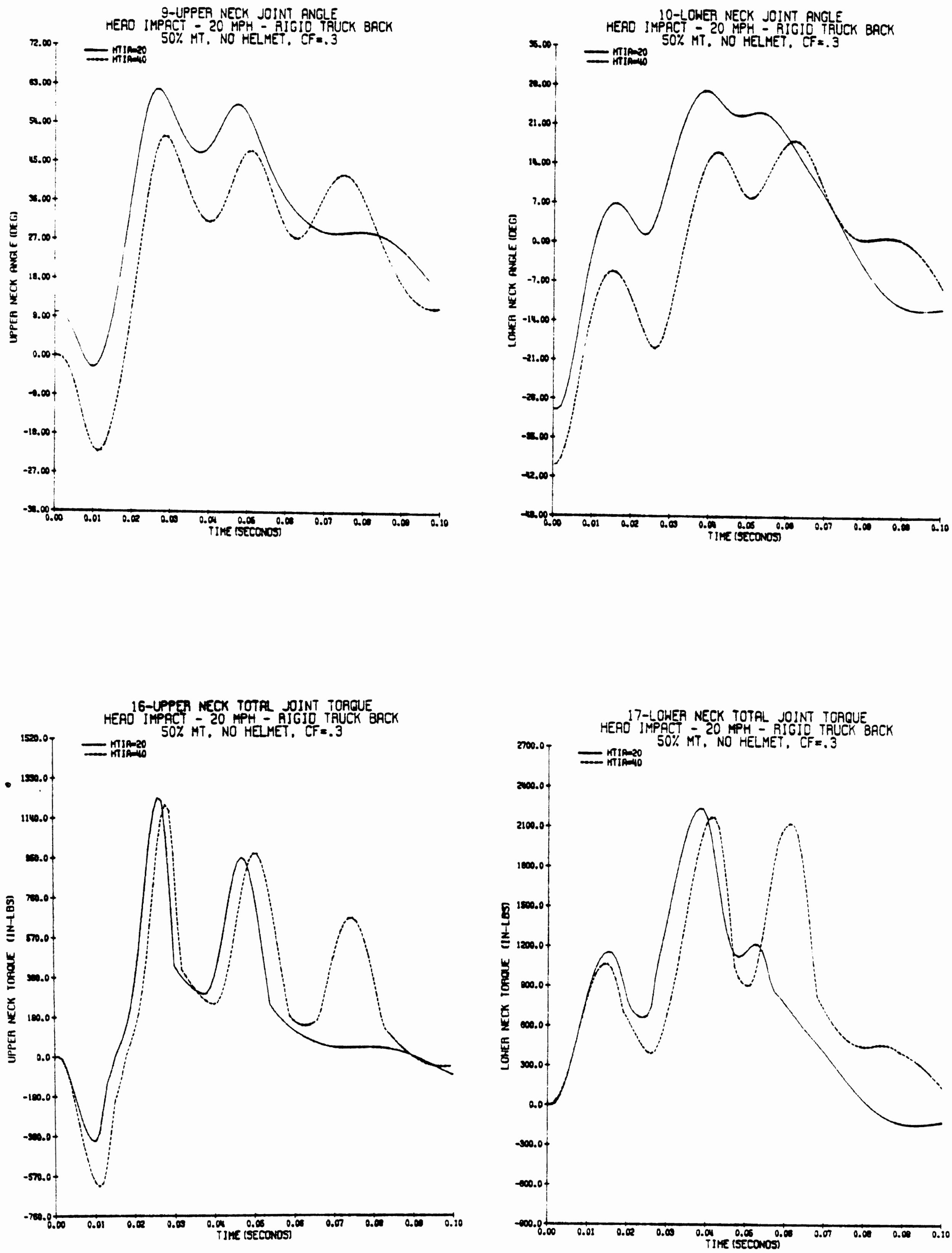

Figure 5-19. Selected Plots from Comparison [3]

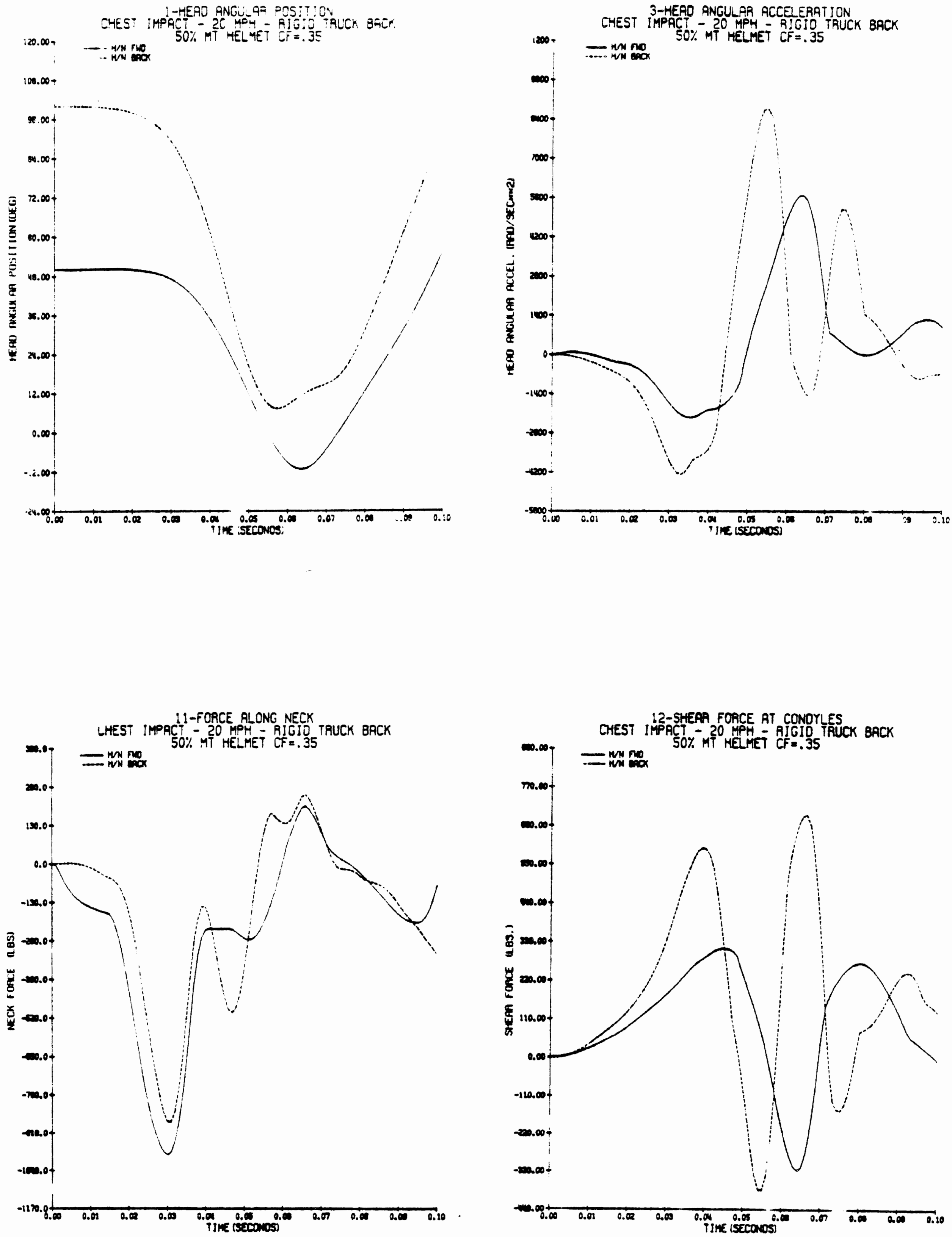

Figure 5-20. Selected Plots from Comparison [53] (Page 1 of 2)

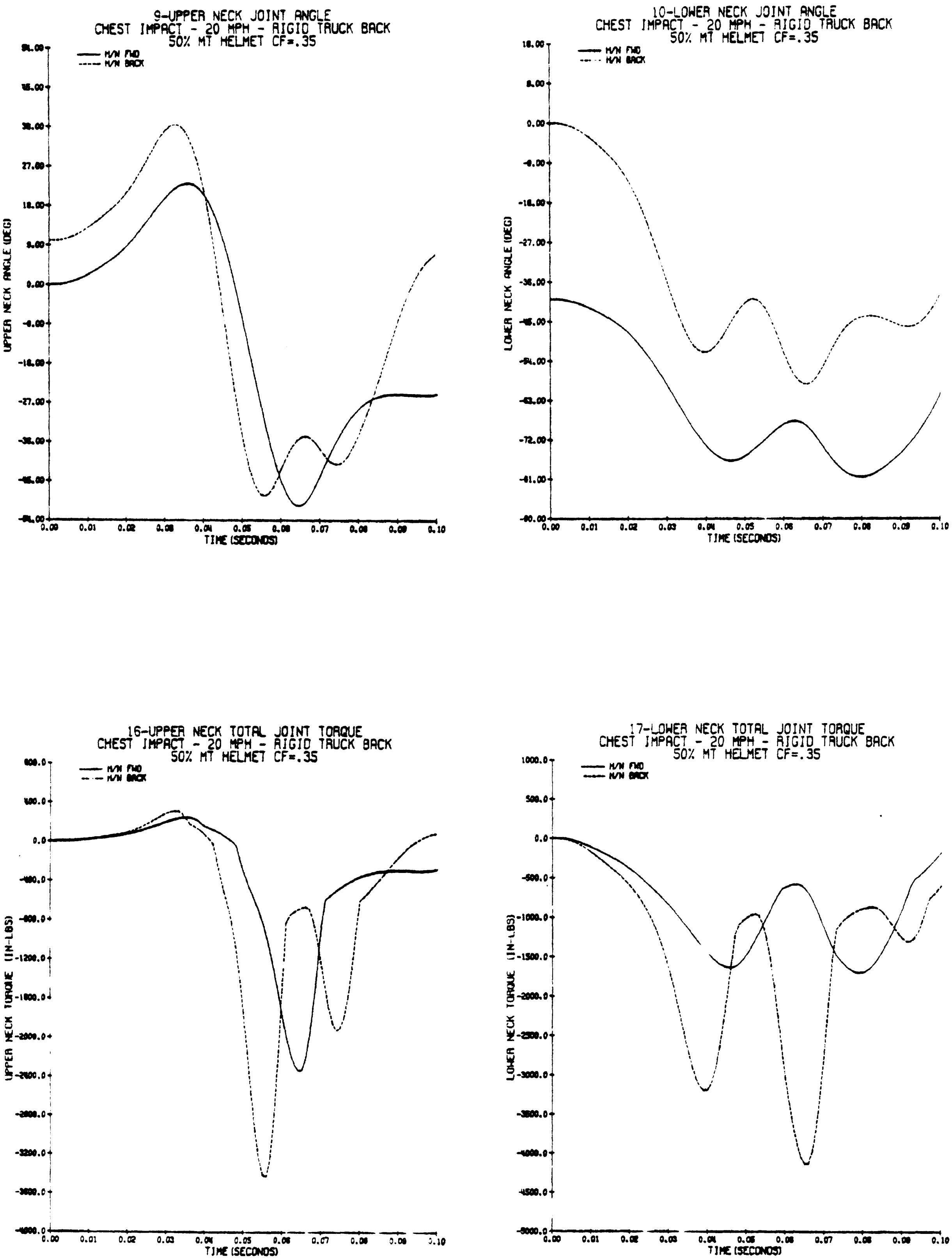

Figure 5-20. Selected Plots from Comparison [53] (Page 2 of 2)

differences between helmet and no-helmet runs in all of these initial positions are essentially the same. Thus the results described in Section 5.2.3 are true regardless of the initial position. It should be noted, however, that for initial neck extension, the detrimental effects of the helmet relative to the no-helmet case for upper neck joint torque are substantially reduced ([1], [44]).

5.3.4 Effects of Muscle Tension Level. All baseline runs were for neck muscle model parameters set to values for a typical young male adult with muscles activated to 50% of maximum potential. The importance of this somewhat arbitrary modeling of muscle was evaluated by making simulations with these parameters altered to represent muscle activation at 10% of maximum for 10 and 20 mph head-truck and chest-truck impacts and 20 mph road impacts for a 6-foot fall height. Run numbers and comparisons numbers for these results can be found in Tables 5-2 and 5-3.

Varying muscle activation level from 50% to 10% is found to have no significant effect for 20 mph impacts, except for the 70° road impact case. Examination of plots and tabular comparisons shows the effects of this variation to be even smaller for 10 mph impacts. (All comparisons discussed below are for 20 mph, helmet impacts.) For 20 mph head-truck impacts, HIC changes by only 2%, peak head resultant acceleration by 1%, and peak neck compression force by only two pounds out of 990 lbs [51]. The most significant differences for this type of impact are for upper neck flexion and extension torques, which are 12% and 16% greater, respectively, for the 10% muscle activation simulation. Differences for the 20 mph chest impact simulations are hardly more significant [52].

Neck compression force is greater by 11% for the lower muscle tension level, for example, while upper neck torques are different by less than 12%. HIC is 29% greater for the 10% muscle activation level, but the HIC values for these two chest impact simulations are small, so a 29% difference is not important. The plots in Figure 5-21 for the 20 mph chest impacts are illustrative of the types of differences which occur for variation of the muscle activation from 50% of maximum isometric potential to 10%.

Differences for 30° road impact simulations are no more significant than those for the seated-orientation impacts [49]. HIC values, for example, differ by 2% while peak neck compression forces are almost identical. The most important differences are for extension torques at the upper and lower neck joints. For the 10% muscle activation level, these torques are 36% greater and 39% less, respectively. The most significant differences occur for the 70° body orientation for road impacts [50]. While peak values for most of the response variables are not affected significantly by varying the muscle activation level, HIC is 34% less for 10% activation -- 2933 as compared with 4440. Neck compression force differs by 2% and upper neck flexion and extension torques decrease by 11% and 18%, respectively.

Examination of the helmet versus no-helmet plots and tabular comparisons for both the 10% and 50% muscle tension runs for the four simulation conditions [36,37,38,39(10%); 2,1,4,18(50%)] shows that this change in muscle tension mostly has no significant effect on the relationships of response parameters for the helmet and no-helmet conditions. For example, the difference between helmet-induced reduction of peak

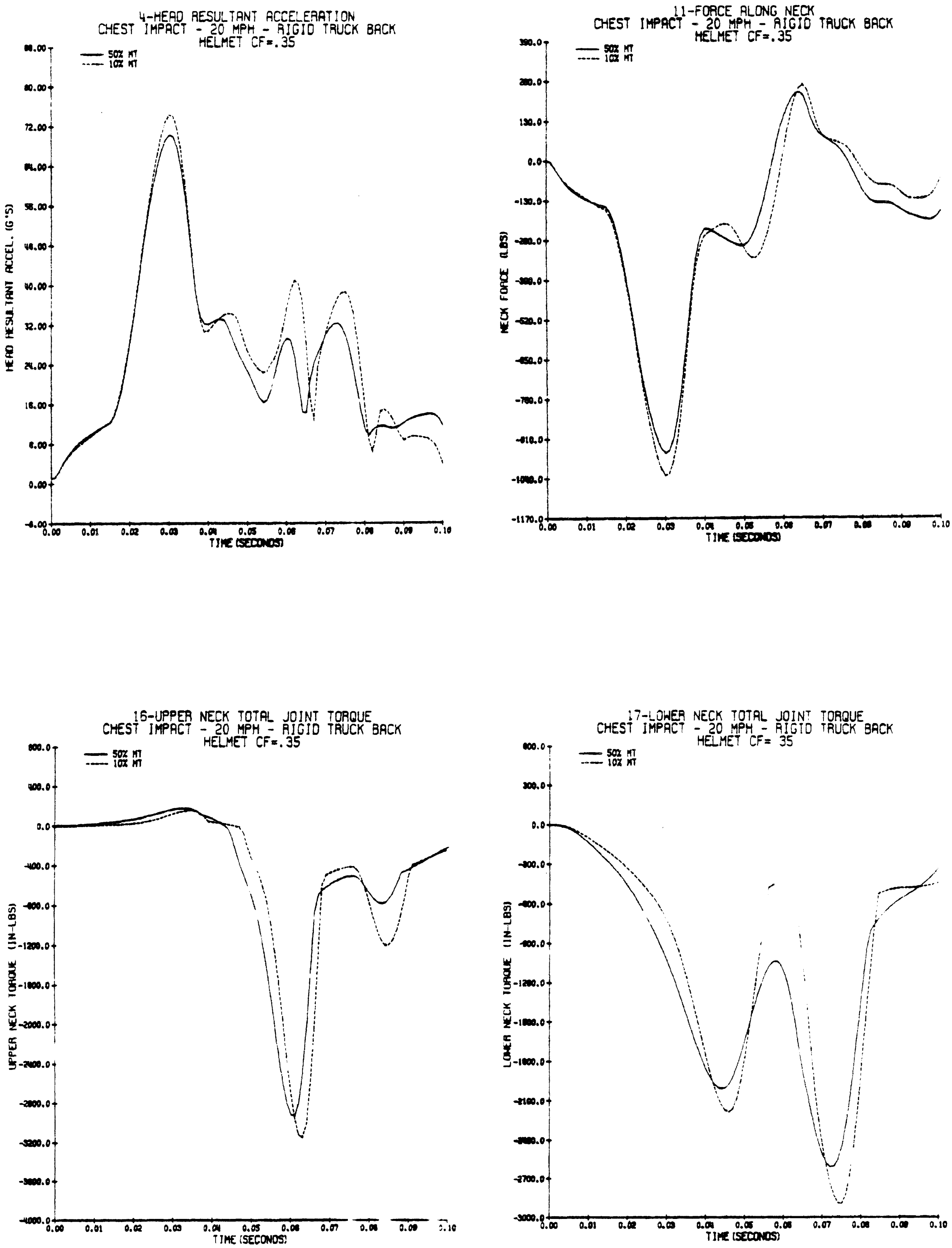

Figure 5-21. Selected Plots from Comparison [52]

head resultant acceleration for the 10% and 50% muscle tension runs is not greater than two percent of the no-helmet response for any of the four baseline configurations. The only difference of significance is for the upper neck torque for the 70° road impact. At 50% muscle tension the peak extension torque for the helmet conditions was less than for the no-helmet condition by about 50% while at 10% muscle tension the peak torques are nearly equal. Peak torques for the two helmet simulations are about the same (560 and 497 in-lbs), however, the percentage reductions being different primarily because of the differences between the no-helmet simulation torques.

5.3.5 10 vs. 20 mph Horizontal Velocity. The baseline horizontal velocity for simulations in this study was selected after some preliminary runs were made for 10, 20 and 30 mph velocities. It was decided to use 20 mph for the majority of simulations since 20 mph is a moderate and typical velocity which, on the basis of the investigatory simulations, seemed to be near the upper limit of survivable impacts. In order to examine the effect of horizontal velocity on simulation results, however, 10 mph runs were also made for each of the baseline helmet and no-helmet impacts. For road impacts of equal fall height and impact orientation, it is clear that there can be no differences between responses for horizontal velocities of 10 and 20 mph except for differences caused by a dependence of sliding friction force on sliding speed. Except for sliding speeds near zero, however, a sliding friction force (Coulomb friction) is independent of sliding speed, being simply the product of the coefficient of friction and the normal component of the contact force. Thus, it is not surprising that there is virtually no difference between the simulation responses for 10 and 20 mph velocity, 30° road impacts for a helmeted cyclist [34]; through 100 msec, the relative velocities between the road and all parts of the cyclist's body in contact with the road remain, for the most part, sufficently greater than zero ($\geq$ 10 in/sec for simulations) even for the 10 mph horizontal impact velocity that the dependence on sliding speed is not a factor.

For the 70° road impacts, however, differences do result for 10 and 20 mph horizontal velocities (see Comparison [35] of Appendix C), and they cannot be totally neglected. The 20 mph simulation shows a more severe response, although the only response variables for which the differences are significant are HIC, which is 56 percent greater (4440 vs. 2842), and peak lower neck extension torque, moderate for 20 mph at 489 in-lbs as compared with zero for 10 mph. Despite the lack of difference between 10 and 20 mph results for 30° road impacts, these differences for the 70° orientation were not completely unanticipated. It has already been seen in Sections 5.2.4, 5.2.5, and 5.3.1 that response for road impacts is more sensitive to friction for the 70° orientation than for 30°. The 10 and 20 mph results for 70° differ because the relative velocity between the helmet and the road reaches values near zero for the 10 mph simulation. This happens at 70° while not at 30° because the head angular motions (velocities) are opposite in direction for the two orientations. Nonetheless, horizontal velocity at impact can probably be considered a minor factor for road impacts.

Differences of much greater magnitude result between 10 and 20 mph impacts for both the head-truck and chest-truck configurations. Plot/Comparison [32] contrasts 10 and 20 mph head-truck helmet simulations. Figure 5-22 illustrates some of these results. The

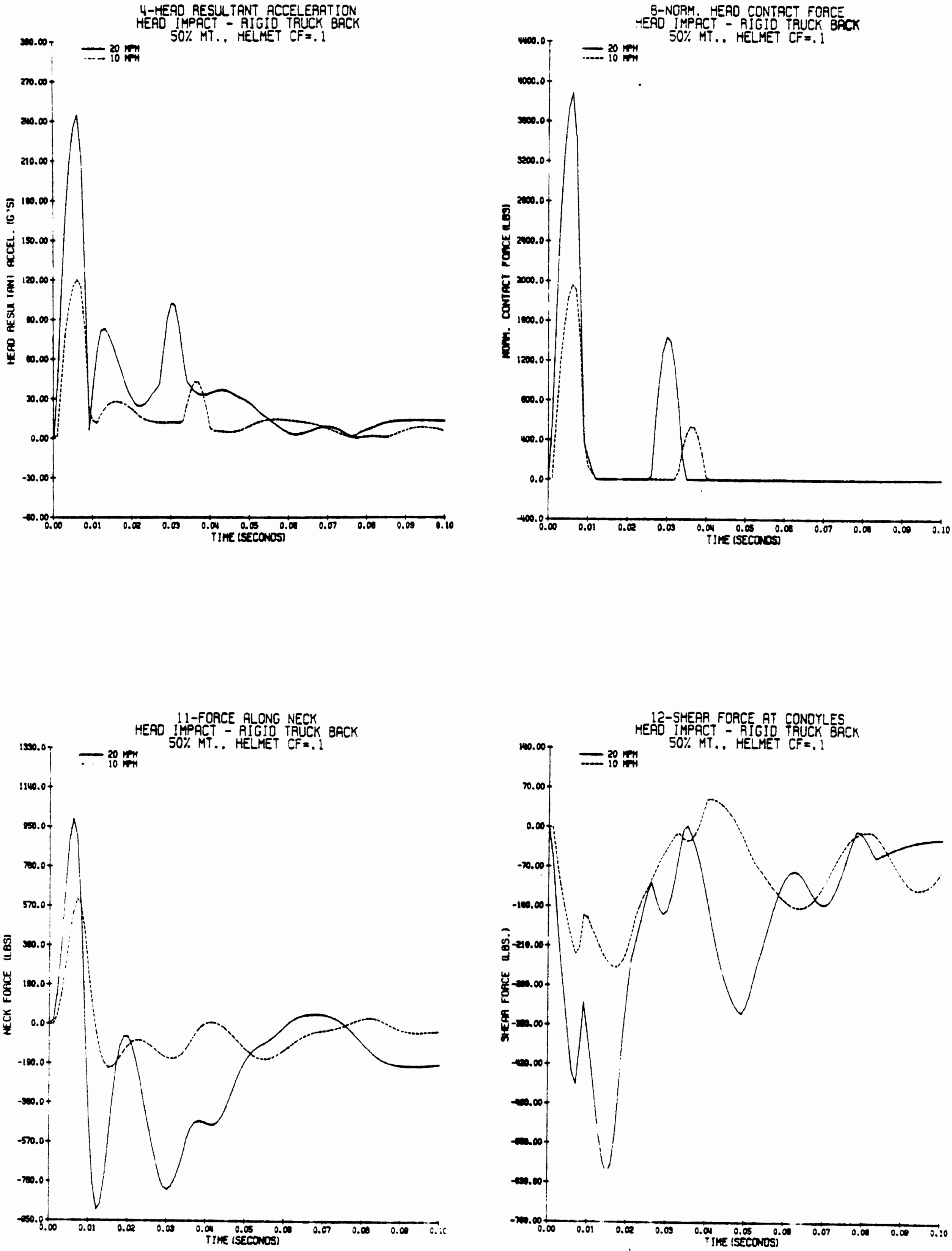

Figure 5-22. Selected Plots from Comparison [32]

reductions in peak values for all injury-related parameters for 10 mph are dramatic. Ten mph peak values are smaller than 20 mph peak values by about 40 to 80%. Head resultant acceleration, contact force, and HIC are less by 51%, 49%, and 83%, respectively, HIC being only 564 in comparison with 3317 for the 20 mph impact. Peak head angular acceleration and upper neck torque are 63% and 58% less, respectively, at 10 mph.

Even greater reductions in response magnitudes result at 10 mph for chest-truck impacts for the helmeted cyclist [33]. Some of the responses for 10 and 20 mph chest-truck impacts are illustrated in Figure 5-23. Ten mph peak values are smaller than 20 mph peaks by 50 to 90% for all responses. The peak chest load at 10 mph is only 1179 lbs in comparison with 5540 lbs at 20 mph, the 10 mph impact energy being insufficient to load the chest into the stiff region of the static loading curve shown in Section 2.2.2 (Figure 2-8). In terms of lessening the likelihood of injury, the most significant reductions of peak responses at 10 mph are for upper neck flexion and extension torques, which are lower by about 70%. HIC is 90% less, but its value even at 20 mph is small (419).

Figures 5-24 and 5-25 illustrate some of the response curves for helmet/no-helmet comparisons for 10 mph impacts, i.e., except for the lower impact velocity, these comparisons are like the helmet/no-helmet comparisons discussed in Sections 5.1.2 and 5.1.3 for head-truck and chest-truck baselines. Head-truck results for 10 mph [29] (Figure 5-24) show even more clearly than 20 mph results the benefits of the helmet. Peak head resultant acceleration is reduced by 60% to 120 g's from nearly 300 g's for the unhelmeted cyclist. HIC is dramatically reduced,

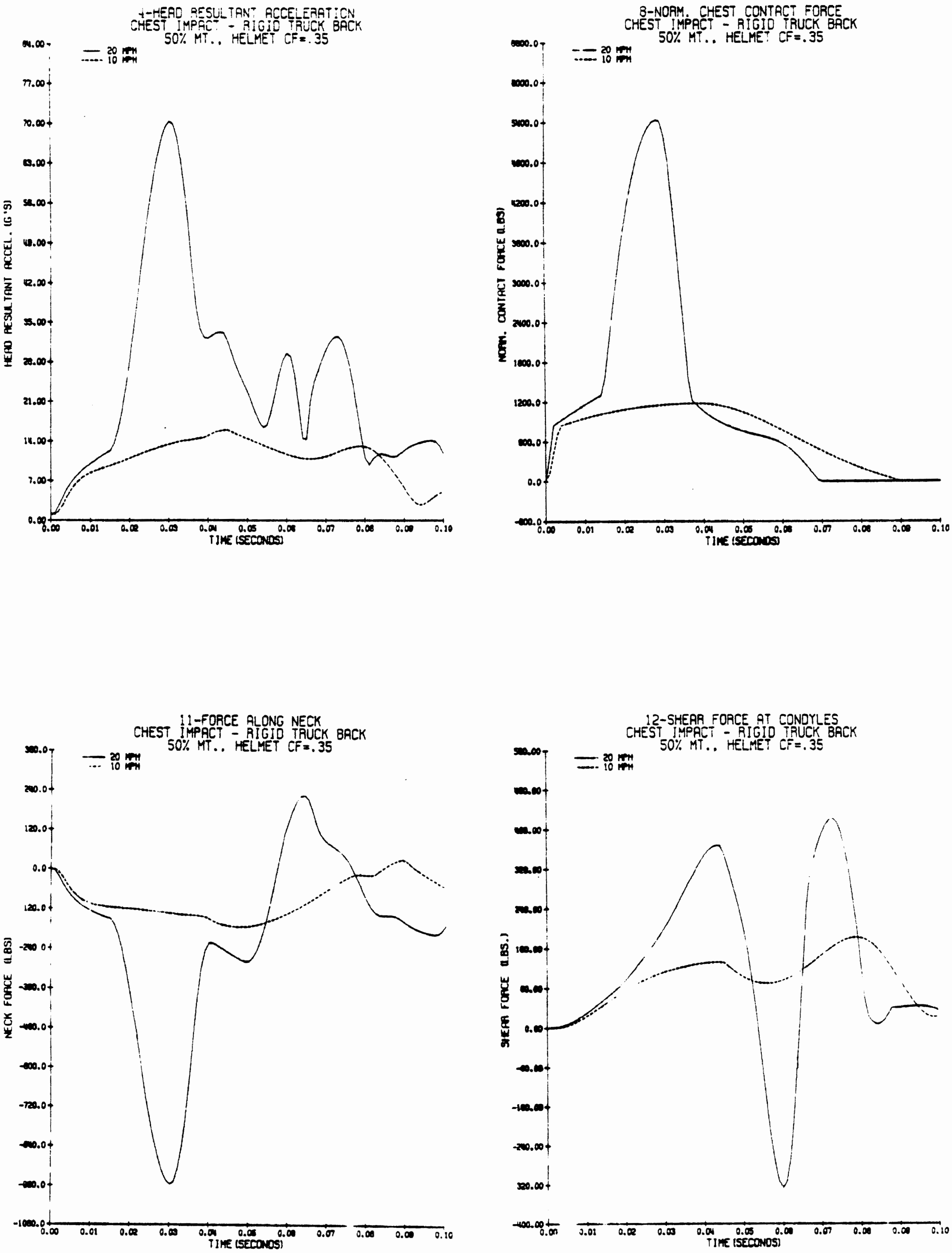

Figure 5-23. Selected Plots from Comparison [33] (Page 1 of 2)

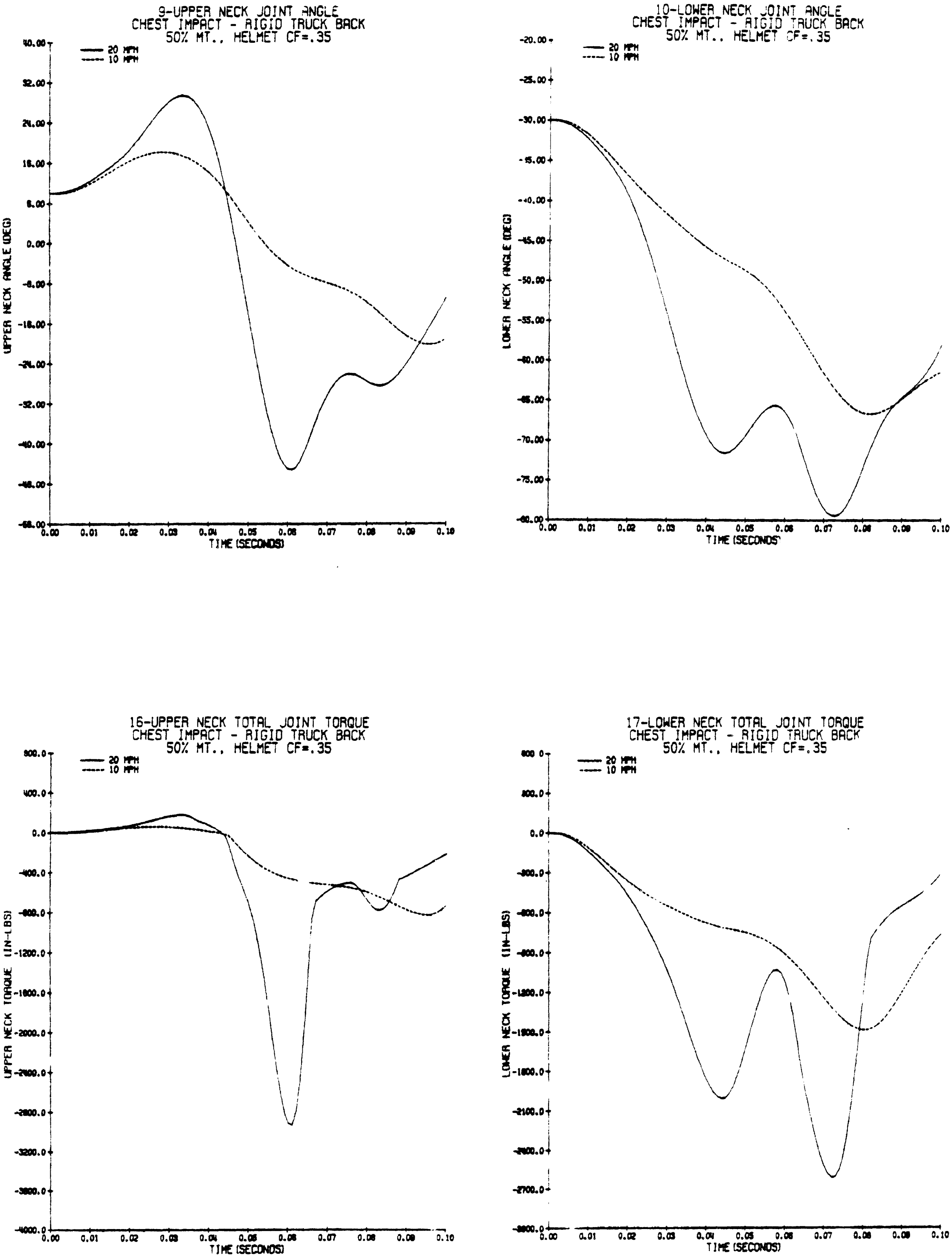

Figure 5-23. Selected Plots from Comparison [33] (Page 2 of 2)

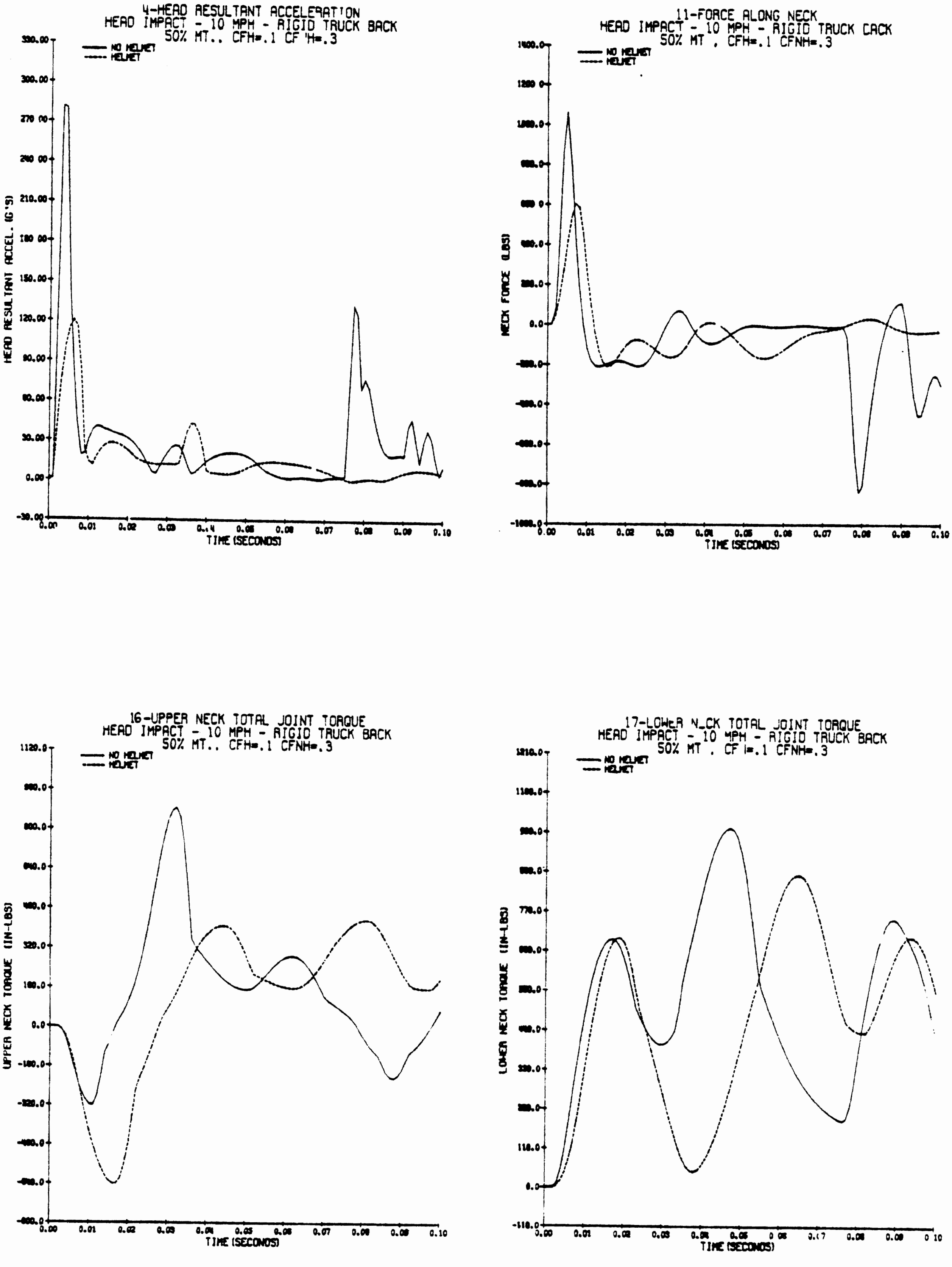

Figure 5-24. Selected Plots from Comparison [29]

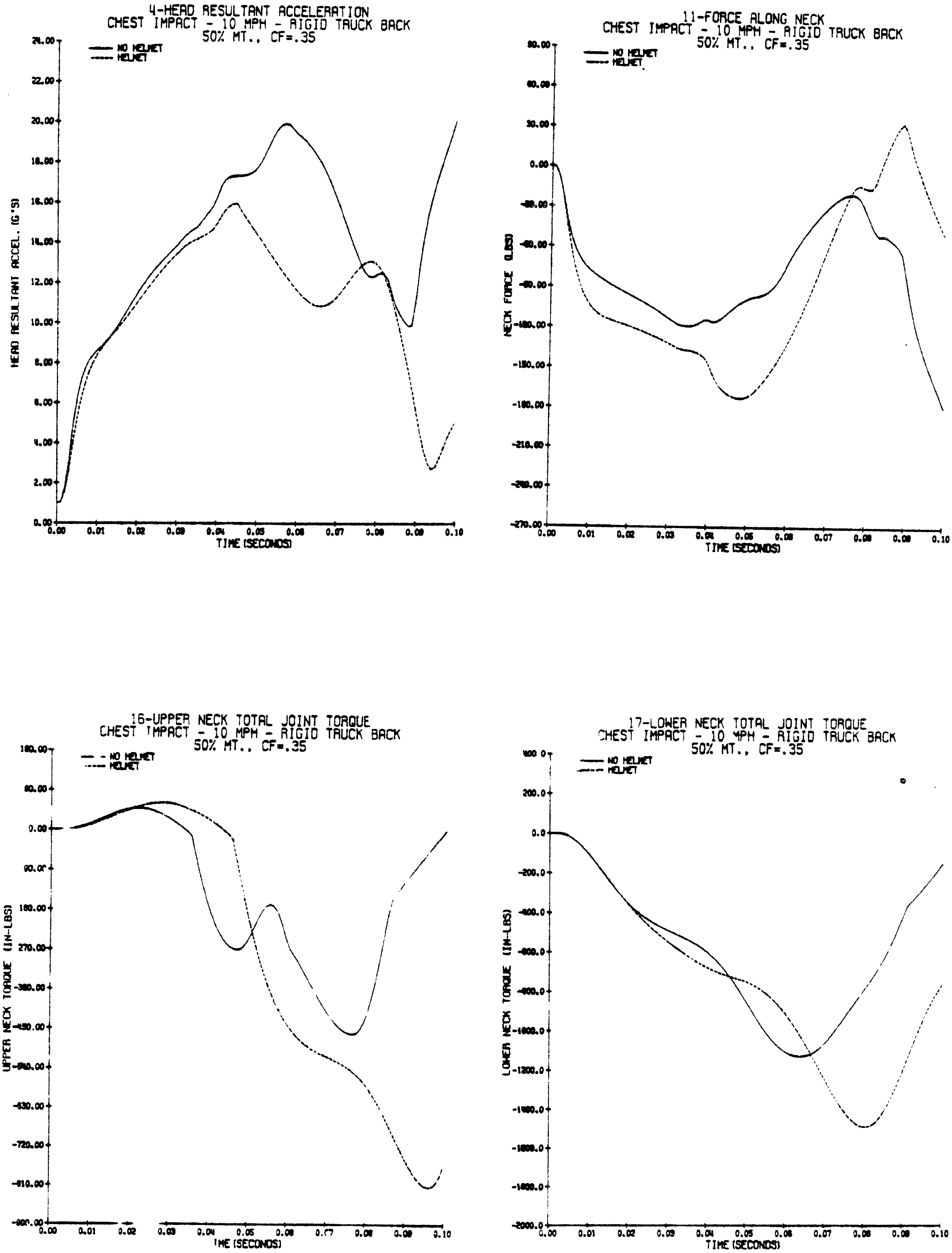

Figure 5-25. Selected Plots from Comparison [28]

from 2573 to 564. For 10 mph chest-truck simulations [28] (Figure 5-25), the relations between helmet and no-helmet responses are, in general, similar to those at 20 mph, with the helmet case having higher peak values in flexion for the neck injury parameters and lower peak values for head angular and resultant accelerations. In all cases, however, the peak values are well below injury tolerance levels and therefore indicate small likelihood of neck injury at 10 mph for either the no-helmet or helmet condition.

5.3.6 <u>3-Foot Vs. 6-Foot Fall Height</u>. For the road impacts, a fall height of six feet was chosen for all the baseline and most of the expanded matrix simulations. This was considered to be a typical trajectory height that a motorcyclist might achieve during ejection, and it results in a vertical impact velocity of 19.6 ft/sec. In order to examine the effect of fall height (i.e., vertical impact velocity) and to expand the interpretation of these road impact simulation results, helmet and no-helmet runs were also made for baseline conditions with the vertical impact velocity reduced to 13.9 ft/sec, corresponding to a fall height of three feet.

Comparison [55] contrasts three-foot and six-foot fall height results for helmet, 70°-road impacts. Some of the response curve comparisons are shown in Figure 5-26. Examination of tabular comparison [55] shows that peak neck torques, shear forces, and compression/elongation forces, and also head accelerations, are roughly 1.5 times as large for a six-foot fall height as for a three-foot height. The factors for nearly all of these responses lie within the range 1.3 to 1.7. HIC is more sensitive, being 2.4 times as large for six feet as for three. The response curves have generally similar shapes.

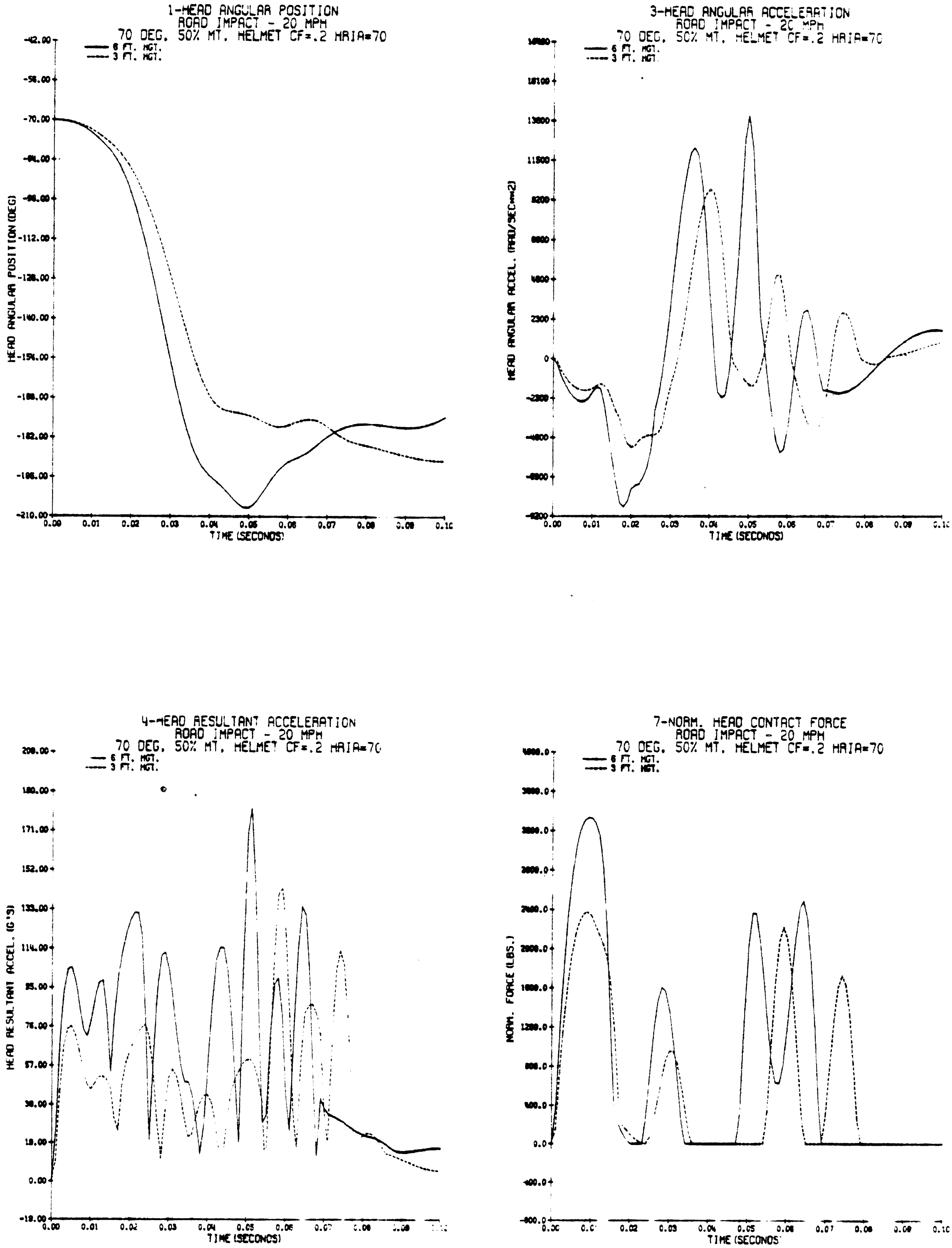

Figure 5-26. Selected Plots from Comparison [55] (Page 1 of 2)

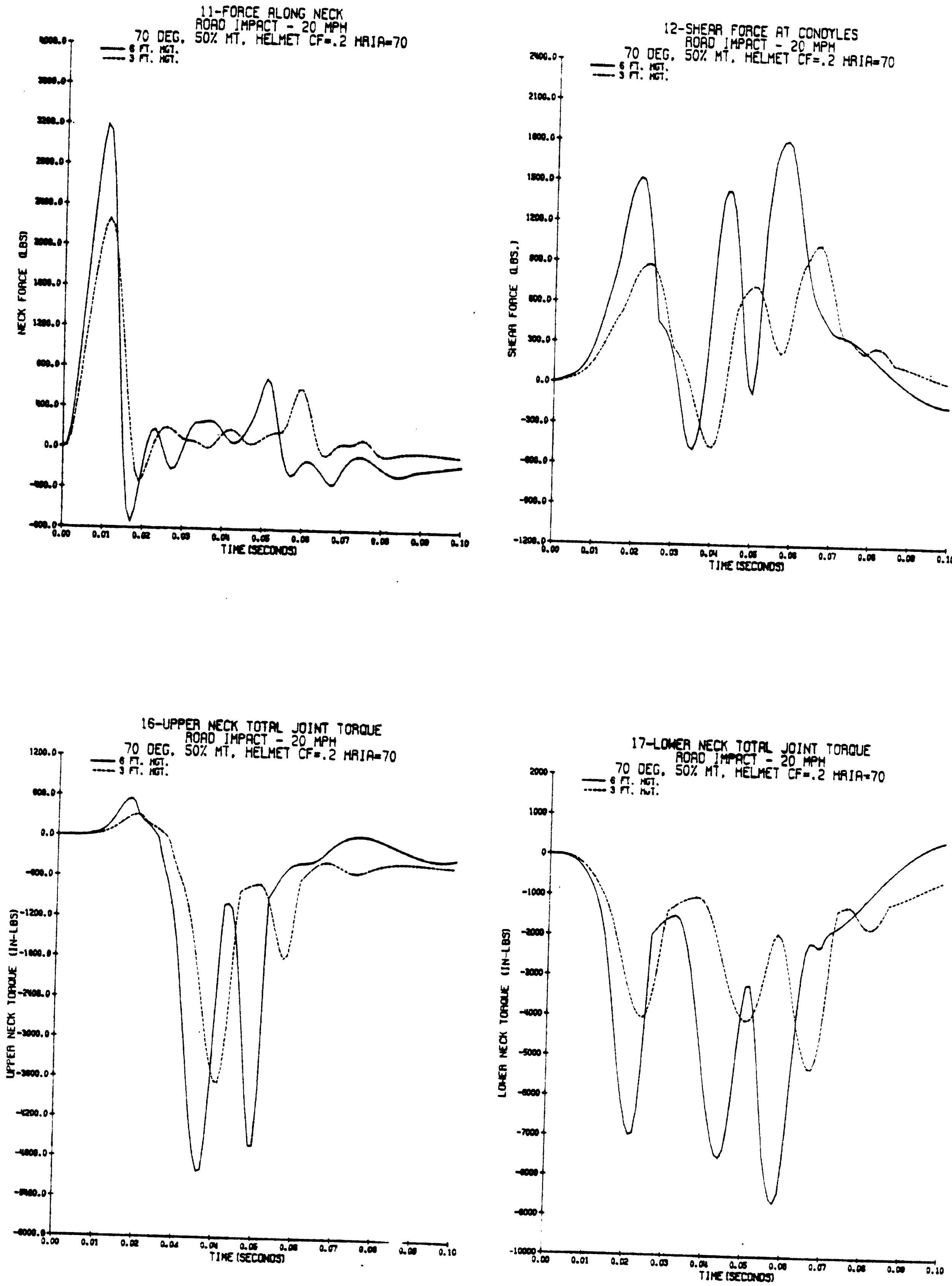

Figure 5-26. Selected Plots from Comparison [55] (Page 2 of 2)

Comparison [54] gives helmet vs. no-helmet results for 70 degree road impacts from three feet. The plots in Figure 5-27 illustrate some of the responses. If the plots and tabular comparisons for the three-foot fall height, helmet/no-helmet results are compared with the baseline (six feet) comparisons [18] (Section 5.2.5), it is found that, in general, the shapes and relative magnitudes of the helmet and no-helmet response curves are about the same for the two heights. For most responses, however, the lower fall height gives reductions of peak values for no-helmet impacts that are relatively larger than for helmet impacts so that there is slightly less relative benefit from the helmet in the three-foot falls than in six-foot falls. At the three-foot fall height, the helmet reduces HIC by 58 percent from 4385 to 1835. This is similar to the percentage reduction at six feet (68%; 14009 to 4440) but may be more significant since the reduced value is not markedly greater than the tolerance level.

Comparisons [57] and [56] in Appendices C and D are for the 30 degree road impact response curves for three-foot vs. six-foot fall height helmet simulations [57] and helmet vs. no-helmet results for a three-foot fall height [56]. Figures 5-28 and 5-29 show some of the curve comparisons. Examination of tabular comparison [57] shows peak head accelerations and neck torques, shear forces, and compression/elongation forces to be on the order of 1.3 times as large for the six-foot fall height as for three. The factors for almost all of these responses are in the range 1.1 to 1.6. As was found for the 70 degree body orientation impacts, HIC is the response parameter most sensitive to variation of fall height, being 2.2 times as large for the six-foot height as for three (for helmet impacts).

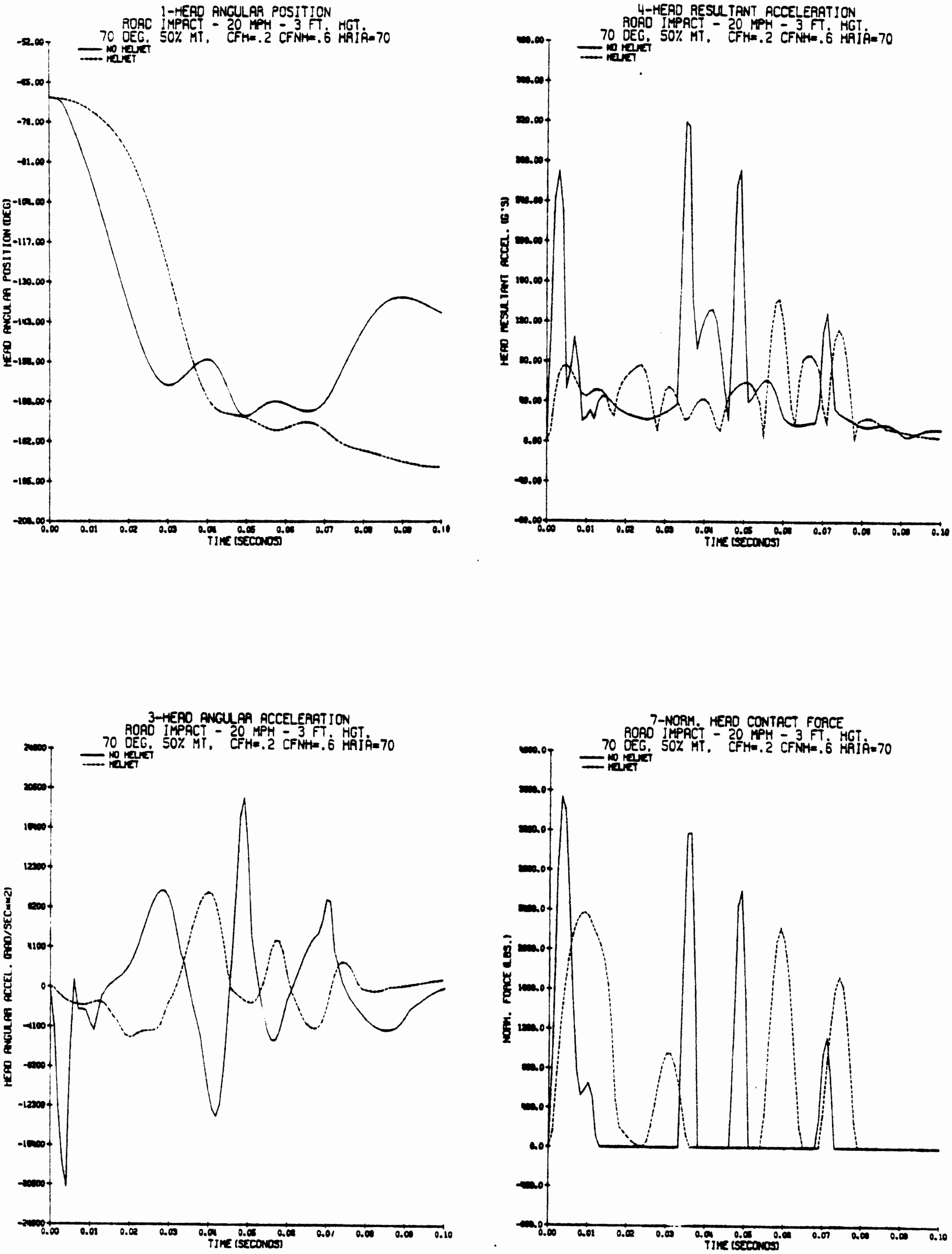

Figure 5-27. Selected Plots from Comparison [54] (Page 1 of 2)

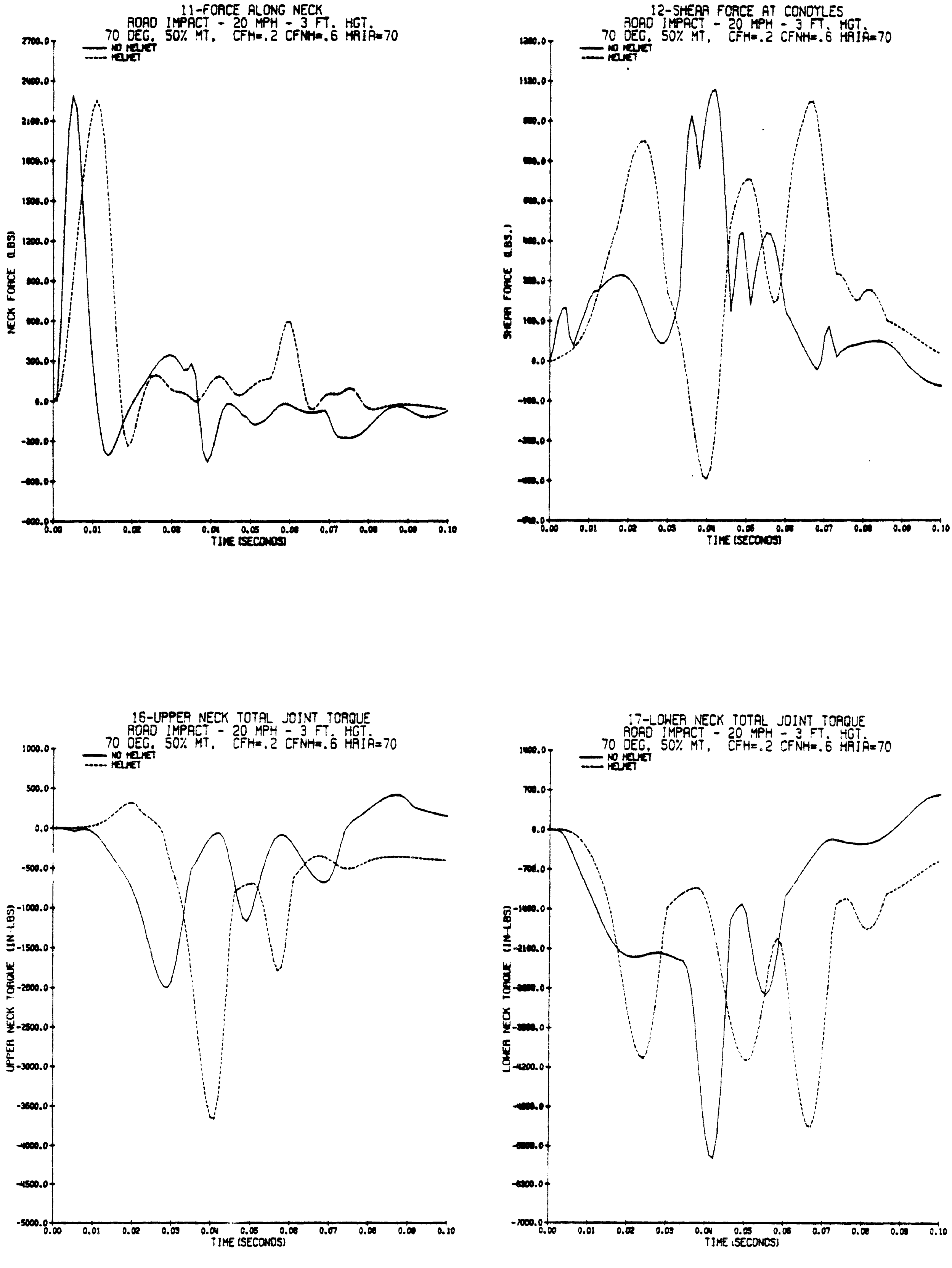

Figure 5-27. Selected Plots from Comparison [54] (Page 2 of 2)

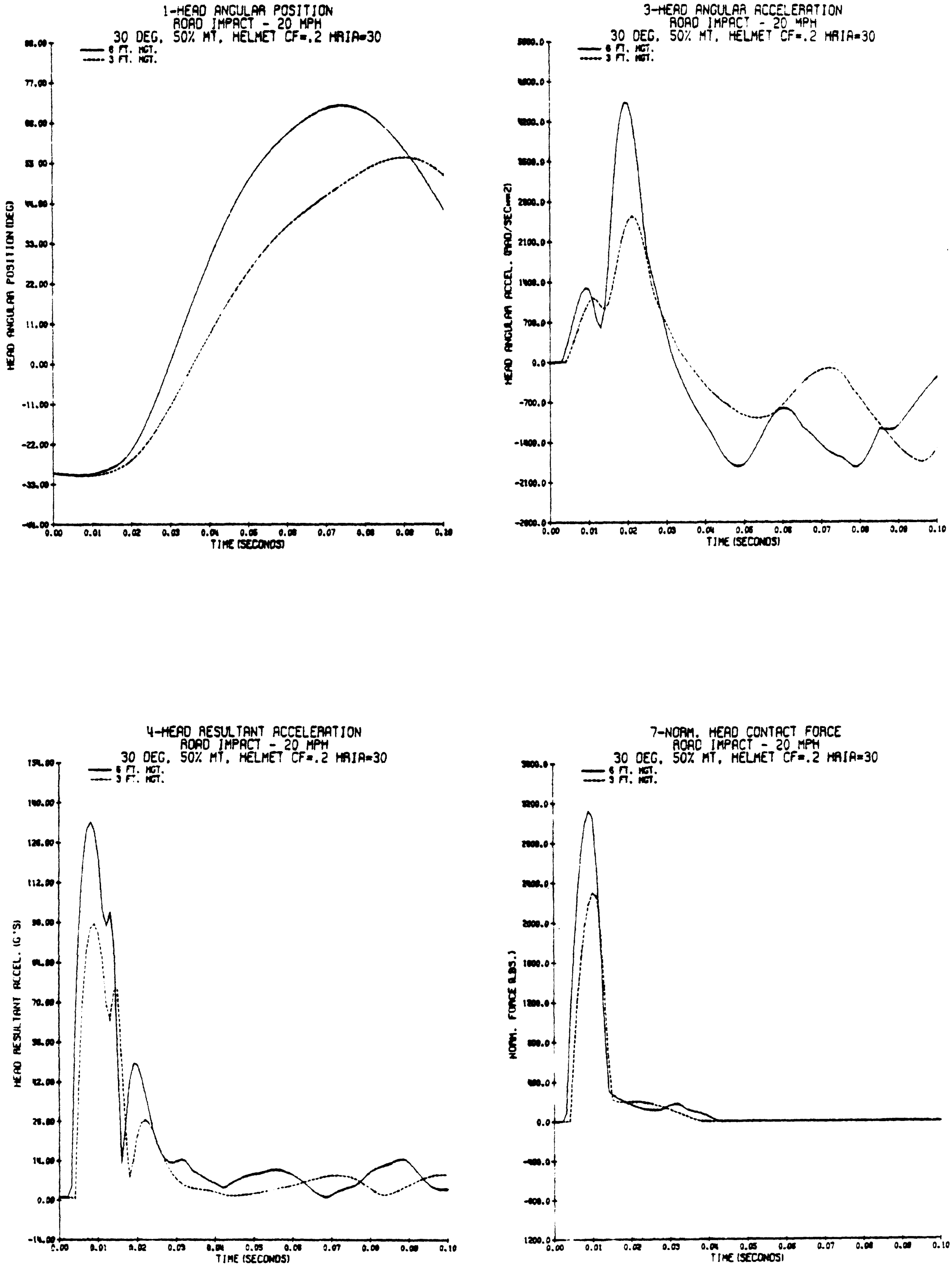

Figure 5-28. Selected Plots from Comparison [57] (Page 1 of 2)

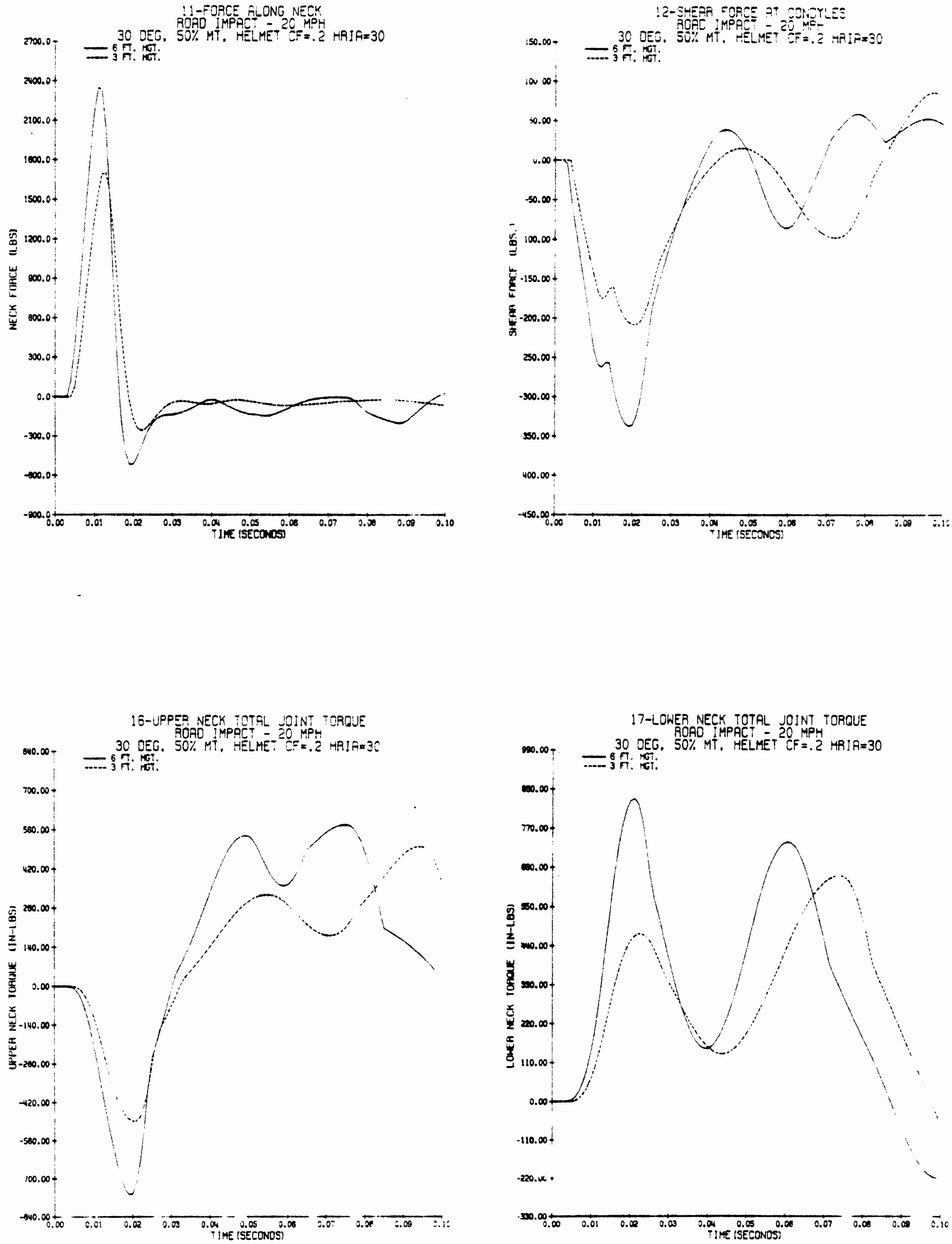

Figure 5-28. Selected Plots from Comparison [57] (Page 2 of 2)

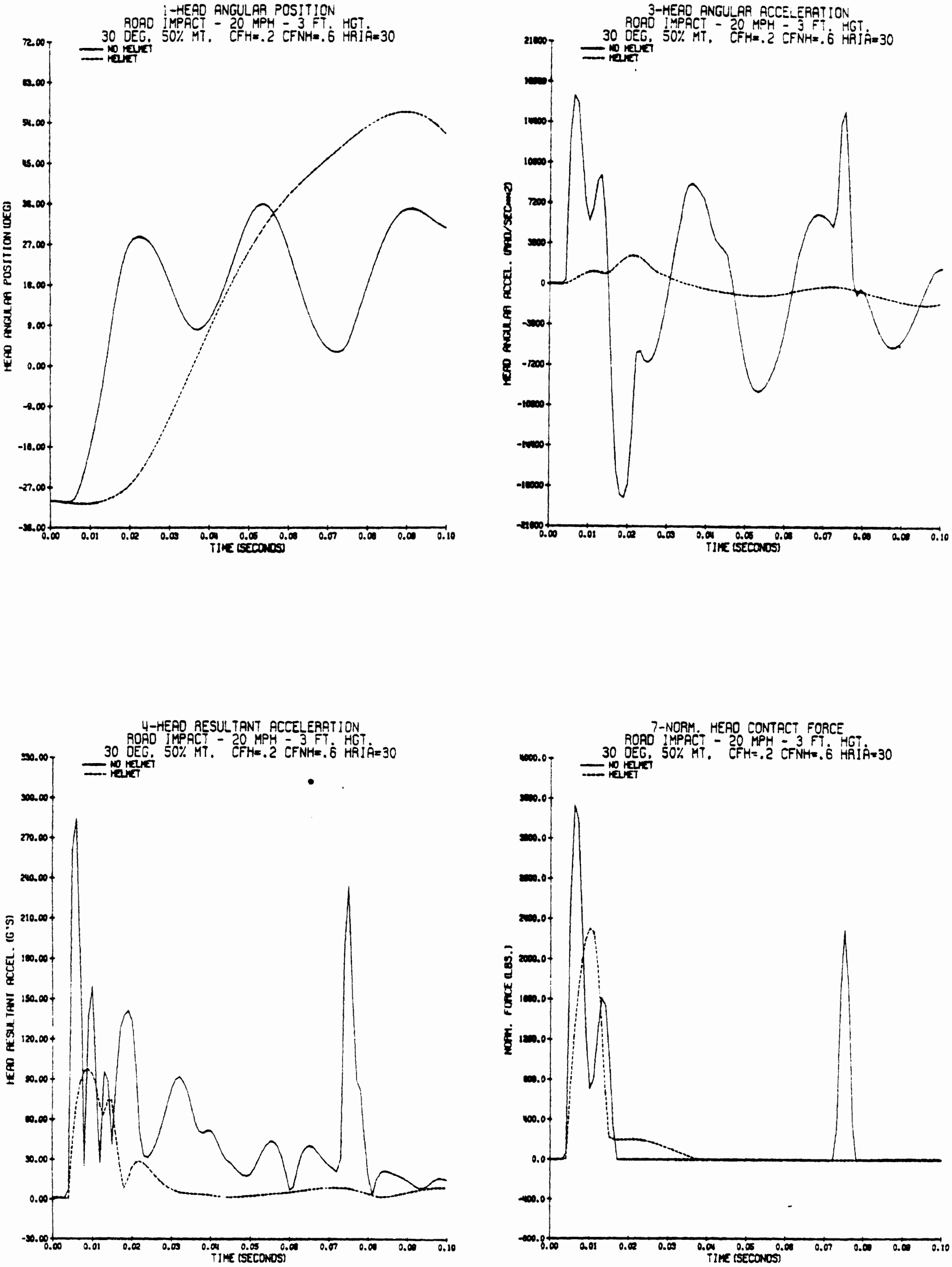

Figure 5-29. Selected Plots from Comparison [56] (Page 1 of 2)

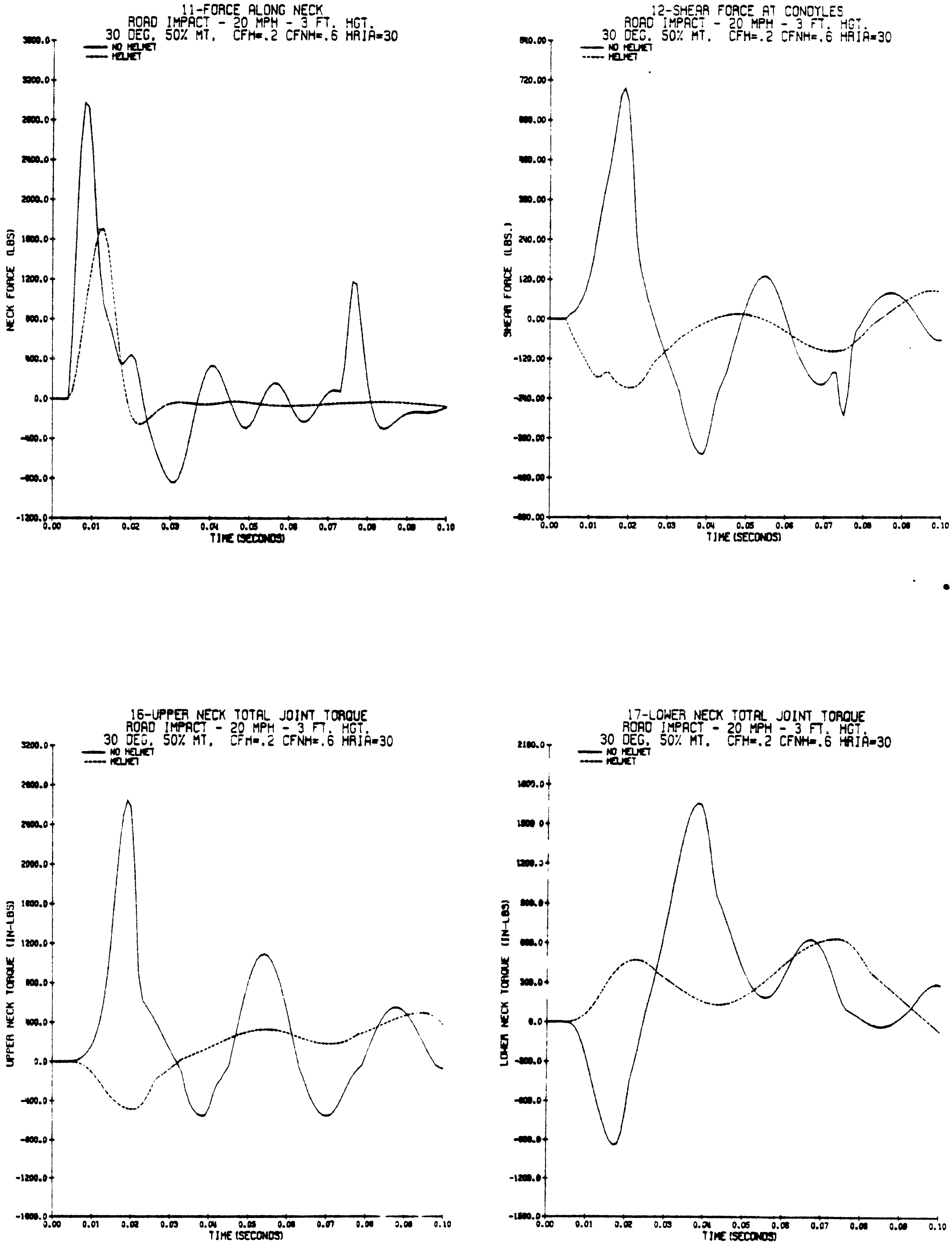

Figure 5-29. Selected Plots from Comparison [56] (Page 2 of 2)

The shapes of the helmet and no-helmet response curves and the relationships between their magnitudes are very similar for the 30° road, three-foot fall height simulations [56] and the six-foot fall, baseline runs [4] (Section 5.2.4). Since the percentage reductions of peak values effected by the helmet are very nearly the same for three-foot and six-foot fall heights, the relative benefits of the helmet may be considered to be independent of fall height in the three to six foot range for 30° road impacts. The response for which the relative benefit of the helmet differs most for the two fall heights is HIC, which is decreased by the helmet from 2686 to 579 (78%) for the three-foot height and from 7621 to 1266 (83%) for the six-foot height. The HIC reduction in each instance is significant, particularly the reduction for the three-foot height to a value substantially below the injury tolerance limit.

5.3.7 <u>Effects of Initial Angular Velocity</u>. Baseline conditions for simulated road impacts include a forward rotational velocity for the motorcyclist at the instant of impact. This is appropriate since a motorcyclist initially oriented in an upright seated position must undergo a forward rotation during the time of the ejection and fall in order to reach an orientation for head impact with road. The baseline value of 100 degrees per second was derived as an estimate of a typical angular velocity. In order to assess the significance of this factor, additional road impact runs were made for baseline conditions but with the angular velocity reduced to zero. Comparisons [9] and [10] contrast 30° road impact results for initial angular velocities of 0 and 100 deg/sec, Comparison [9] for helmet impacts and Comparison [10] for no-helmet impacts. A similar comparison is made for helmet impacts for the 70° road configuration [26].

The 30 degree road impacts with no initial angular velocity [9,10] show slight reductions in peak values of most response parameters. In general the reductions are on the order of ten percent from results of the 100 deg/sec simulations. The reductions are nearly the same for both helmet and no-helmet cases, i.e., there is no differential dependence on initial angular velocity for the helmet and no-helmet cases. This may be seen also from the similarity of Comparisons [4] and [12]; these are the helmet/no-helmet comparisons for 30° road impacts with 100 deg/sec and 0 deg/sec angular velocities, respectively.

For the 70 degree road impact, the effect of reducing the initial angular velocity is generally even less than for 30 degree road impacts [26]. The small differences that do result are slight increases for most parameter peak values. This is opposite to that seen at 30 degrees and is due to the difference between tumbling (70°), where forward angular velocity is beneficial, and sliding (30°), where forward angular velocity is detrimental. The only significant difference is in the peak lower neck flexion torque, where an increase of 22 percent occurred for the case of zero angular velocity. While no zero angular velocity runs were made for 70° road impacts for the no-helmet case, it might be expected that the increase would be at least as great for that case. (Since the coefficient of friction is higher for the no-helmet case, the angular velocity is probably more beneficial). Thus, the comparisons between helmet and no-helmet simulations for the case of no angular velocity would at least be similar to baseline 70°-road, helmet/no-helmet comparisons (e.g., [18]), if not more favorable to the helmet.

5.3.8 Effects of Parameter Variations on Overall Relative Benefit of Helmet Use. In no case do simulation results from any of the parameter variations discussed in the foregoing sections, 5.3.1 through 5.3.7, lead to significant alterations in conclusions regarding the general effectiveness of the helmet as determined from results of baseline simulations. The degree of overall benefit of helmet use relative to nonuse does vary, however, with change of impact conditions. Because the sensitivities to variations are normally small, no quantitative measure of the overall effect on the ratios of no-helmet to helmet injury-related dynamic response quantities will be defined. It is of interest, however, to note whether a parameter variation has a positive or negative effect with respect to relative advantage of the helmet. The procedure for determining the effect of varying impact parameters on the degree of "overall benefit" of helmet use relative to nonuse is described below. "Overall benefit" is assessed from relative magnitudes only, no consideration being given to tolerance limits.

Consider, as an example, the baseline head-truck impacts for helmeted and unhelmeted cyclists. The percentages by which peak helmet impact response magnitudes are less (or greater) than the peak no-helmet response magnitudes are given in tabular comparison [2]. Comparison [2] shows, for example, that "HIC" is 4.5% less for the helmet impact and that peak "condyles total torque" (for extension) is 15.7% less. In order to determine the effect on these relative benefits of varying some impact condition, these percentages from Comparison [2] must be compared with percentages from a different comparison of helmet and no-helmet simulations for which only that impact condition has been varied. Consider the effect of varying horizontal impact velocity for the head-truck simulations from the 20 mph baseline condition to 10 mph. The helmet/no-helmet comparisons of peak response magnitudes are given by Comparison [29]. It shows that, at 10 mph, "HIC" is 78.1% less for the helmeted cyclist and that peak "condyles total torque" (extension) is 50.9% less. With respect to these two responses, at least, it is clear that the helmet has greater relative benefit for a 10 mph horizontal velocity than for 20 mph in head-truck impacts. The "overall" effect of the parameter variation is assessed by comparing the percentages for all of the important injury-related response variables.

Column 4 of Table 5-10 summarizes the results of applying this procedure to the variations in impact conditions used in this study. The parameter value column (column 3) gives the two parameter values or conditions which were used in the two helmet vs. no-helmet comparisons referenced in column 5.

TABLE 5-10. EFFECTS OF PARAMETER VARIATIONS ON OVERALL RELATIVE BENEFIT OF HELMET USE

Parameter Varied	Impact Type	Parameter Values		Parameter Value for Greater Relative Helmet Benefit	Helmet/No-Helmet Comparison Reference Nos.	
coefficient of friction	30° road	.2	.6	.6	5	7
	70° road	.2	.6	.6	21	22
impact angle	road	30°	70°	30°	4	18
head/neck orientation	chest-truck	baseline	flex.	baseline	1	43
		baseline	ext.	extension	1	44
	30° road	baseline	flex.	flexion	4	15
	70° road	baseline	flex.	flexion	18	25
muscle tension	head-truck	10%	50%	equal	36	2
	chest-truck	10%	50%	equal	37	1
	30° road	10%	50%	equal	38	4
	70° road	10%	50%	equal	39	18
horizontal velocity	head-truck	10mph	20mph	10mph*	29	2
	chest-truck	10mph	20mph	10mph	28	1
	30° road	10mph	20mph	equal	30	4
	70° road	10mph	20mph	equal	31	18
fall height	30° road	3ft	6ft	equal	56	4
	70° road	3ft	6ft	6ft	54	18
rotational velocity	30° road	0	100deg/sec.	equal	12	4

* Relative helmet benefit is much greater at 10mph than at 20mph.

5.4 Summary of Helmet vs. No-Helmet Results

Section 5.2 discusses in some detail the helmet vs. no-helmet comparisons for baseline conditions. Section 5.3 describes the effects of using other than baseline values for parameters such as coefficient of friction, horizonal velocity, fall height, muscle tension level, and initial head/neck orientation. Although effects of the variations of baseline conditions were described by comparing results from either two helmet simulations or two no-helmet simulations, for many impact conditions both helmet and no-helmet runs were made. Therefore, in assessing the effectiveness of the use of helmets, we may examine helmet vs. no-helmet comparisons not only for the baseline conditions but also for many different variations about baseline conditions.

Results for 22 different comparisons of helmet and no-helmet simulations are presented graphically in Figures 5-30 through 5-38. These figures include information for all four of the basic impact configurations studied, and each separate figure compares the peak values for a different response variable that has the potential for indicating likelihood or degree of head or neck injury.* Vertical dashed lines on three of the figures indicate the injury tolerance limits defined in Section 4. It should be noted that the findings of this study regarding the relative benefits of helmet use would be unaffected by use of different values for the injury tolerance limits. It should be noted also that while explicit helmet/no-helmet comparisons are included in these figures for head-truck and chest-truck baseline conditions,

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* Dynamic response variables are described by Table 5-7.

the helmet/no-helmet comparisons for the 30°-road and 70°-road baseline conditions are implicit -- i.e., each 30° ROAD and 70° ROAD section of each figure contains implicitly the one additional primary comparison between the adjacent baseline helmet and no-helmet bars (each marked by an asterisk). The helmet/no-helmet baseline plot/comparison reference numbers for 30° and 70° road simulations are [4] and [18], respectively.* Numerical values for the peak responses illustrated in the figures are given in Table 5-11; for each response variable and for each helmet/no-helmet comparison, the larger peak response is shaded.

5.4.1 Head-Truck Impacts. There is high probability of serious brain injury for the 20 mph head impact of a seated motorcyclist against a vertical, rigid "truck" surface. The HIC responses (Figure 5-30) indicate this to be equally true for helmeted and unhelmeted motorcyclists despite the fact that peak head resultant accelerations are reduced by about one-half by the helmet. At 10 mph, however, the benefit of the helmet with respect to reducing HIC exposure is definite: HIC is reduced by 78 percent from a potentially dangerous level to a non-injurious level.

The other responses (Figures 5-31 through 5-38) also show generally greater relative benefits for the helmet at 10 mph than at 20 mph, although the differences are not as dramatic as for HIC. Overall, for 10 and 20 mph head-truck impacts, head resultant accelerations and angular accelerations are reduced by one-third to two-thirds. Peak head contact force is reduced approximately 1100 to 1200 lbs regardless of impact

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* Run numbers and greater description of the simulation conditions than given in Figures 5-30 through 5-38 are given in Table 5-6.

conditions. Neck compression/elongation forces are consistently smaller for the helmet impacts, particularly at 10 mph, but the maximum force levels for this impact configuration are not large compared with forces from road impacts even for the unhelmeted cyclist. There is little difference between shear forces at the upper neck for the helmeted and unhelmeted cyclists, but at the lower neck shear force levels are greater for the helmeted cyclist, although not significantly so. The most significant neck torques resulting from this type of impact are for extension at the upper neck, where magnitudes exceed the injury tolerance level even at 10 mph for the unhelmeted cyclist, but not for the helmeted cyclist. At 20 mph, peak extension torques are greater (double) than the injury tolerance level for the helmeted cyclist also, but for all conditions the peak torque is reduced by the helmet. Peak flexion torques at the upper neck, on the other hand, are significantly greater for the helmeted cyclist, although magnitudes only just reach the injury tolerance level. At the lower neck, torques are in extension only and are comparable for helmet and no-helmet conditions.

5.4.2 Chest-Truck Impacts. In chest impacts of the seated, helmeted motorcyclist, where direct impact of the head does not occur, dynamic response does not, of course, depend on helmet liner properties. For impacts of this type only the mass and rotational inertia of the helmet cause the head and neck response to be different from that for an unhelmeted cyclist.

For the various conditions simulated, acceleration-related responses are decreased by the helmet. In particular, peak head angular accelerations are approximately one-third smaller for the helmeted cyclist and although there is virtually no effect on peak head resultant accelerations, HIC values are reduced by up to 26 percent for 20 mph impacts. (HIC responses are not illustrated in Figure 5-30 since values are not large for this type of impact (400 to 600 for 20 mph) and since HIC is usually not considered a meaningful index for long-duration accelerations not resulting from direct head impact.)

Peak values for most other response variables are moderately increased by the mass and rotational inertia of the helmet, but in general, magnitudes for both helmeted and unhelmeted cyclists are considerably smaller for this type of impact than for the other types simulated -- particularly the road impacts. When the chest strikes the vertical "truck" surface, the head continues to move forward and the neck goes into flexion. Resulting neck elongation forces are about 30 percent greater for the helmeted cyclist, and, as would be expected, shear forces at the upper and lower neck are also greater, typically by 200 lbs and by from 30 to 200 percent. The only types of injuries of significant likelihood for this type of impact are neck injuries associated with excessive neck torque levels. For upper neck flexion torques, the estimated tolerance level for ligamentous tearing is exceeded by from 75 to 100 percent in 20 mph helmeted-cyclist impact simulations and by from 0 to 65 percent in unhelmeted-cyclist simulations. Although the torque levels in flexion are somewhat increased by the helmet, it is the upper neck extension torques which result after rebound from forward head motion and neck flexion that are most serious for this type of impact. In Figure 5-37, peak upper neck extension torques do not exceed the injury tolerance limit because the simulations summarized in these figures were terminated at 100 msec -- prior to rebound hyperextension.

For the direct head impact configurations it was unnecessary to simulate response beyond 100 msec since peak magnitudes for responses occur relatively early. In 200 msec simulations for the 20 mph chest impacts, however, peak extension torques were found to occur at about 140 msec for the helmet case and at about 125 msec for the no-helmet case. The peak extension torque levels for the helmet and no-helmet cases were nearly identical at about 2200 in-lbs, more than five times the injury tolerance.

5.4.3 30° Road Impacts. The benefits of helmet use are graphically illustrated by the simulations for the low-angle (30°) road impacts. Figures 5-30 through 5-38 show that peak values for all injury-related dynamic responses are reduced dramatically by helmet attenuation of impact forces. Most dramatic is the reduction of HIC levels; HIC greatly exceeds the 1500 tolerance level for brain injury (AIS $\leq$ 2) for all conditions simulated for unhelmeted motorcyclists but is reduced to below the 1500 tolerance level in all simulations for helmeted motorcyclists. Percentage decreases of peak dynamic responses are remarkably consistent for the conditions simulated for low-angle road impacts. In comparison with impact of the unprotected head, the helmet liner effects reductions of 75-85% in HIC, 65-70% in head resultant acceleration, and 75-85% in head angular acceleration. Head contact force is typically reduced by about 1600 lbs, or 30-35%. Except for the case where the head and neck are in a pre-flexed orientation, there is typically a 75-90% reduction of upper neck extension torque. The effect of the helmet on peak upper neck flexion torque is more sensitive to conditions, varying from reduction by 44 percent to increase by 47 percent. If the head and neck are pre-flexed, the helmet increases upper neck extension torque by 148 percent but decreases the extension torque by 44 percent, in each case to a value slightly greater than the ligamentous injury tolerance limit.

The helmet liner and helmet mass are primarily responsible for the reduction in peak values of head injury parameters (HIC, head resultant acceleration, head angular acceleration, head contact force). The low coefficient of friction between a helmet and the road and the attenuation of the contact force by the helmet together cause reductions in peak values of neck injury parameters, however. For this impact orientation a helmet/road friction coefficient of 0 to 0.3 is optimal overall and minimizes neck compression force, neck shear forces, and neck torques by reducing the degree to which the body can drive into the neck following head impact.

5.4.4 70° Road Impacts. There are many similarities in dynamic responses for the low-angle (30°) and high-angle (70°) road impacts, and also many distinct differences. (Figures 5-30 through 5-33 show similar magnitudes at 30-degree and 70-degree impact angles for responses related to prediction of head or brain injury.) Further, for these responses, the relative benefits of helmet attenuation of impact forces are similar for the two body orientations; at 70° the helmet causes reductions in comparison with impacts of the unhelmeted head of 60-90% in HIC, 50-80% in head resultant acceleration, and 50-70% in head angular acceleration. These ranges are broader, extending to somewhat lower values (less relative helmet benefit), than those previously given for 30° road impacts. Head contact force is reduced by amounts in the range 1200 to 2000 lbs, always by about 35 percent.

Peak magnitudes of most neck response variables for the 30° and 70° impact angles are quite dissimilar, and also the effect of the helmet on neck responses is very different for the two impact angles. While neck compression force magnitudes are not greatly different for 30° and 70° impacts and while the helmet does have a clear beneficial effect at 70°, the relative benefit of the helmet is not nearly as great as for 30° impacts; i.e., the compression force magnitudes from helmet and no-helmet simulations are more nearly equal at 70°. There is little difference overall at 70° between neck shear forces for the helmeted and unhelmeted cyclists, while at 30° neck shear forces are reduced markedly for the helmeted cyclist. Figures 5-37 and 5-38 show that a helmet causes little overall improvement in neck torque levels for high-angle impacts. As rollover on the head occurs following initial impact, neck flexion torques increase markedly for both the helmeted and unhelmeted cyclists, typically to about twice the injury tolerance limit. Flexion torques are made slightly worse at the upper neck and improved somewhat at the lower neck by the helmet. Peak extension torques at the upper neck occur prior to flexion peaks for helmet impacts and after the flexion peaks for no-helmet impacts; the helmet causes overall reduction of these torques.

As for the 30° road impacts, simulations for 70° road impacts show that there is a range of optimal values for helmet/road friction coefficient for minimizing neck compression force, torques, and shear forces. Values from 0.4 to 0.8 yield similar results overall for the high angle impact.

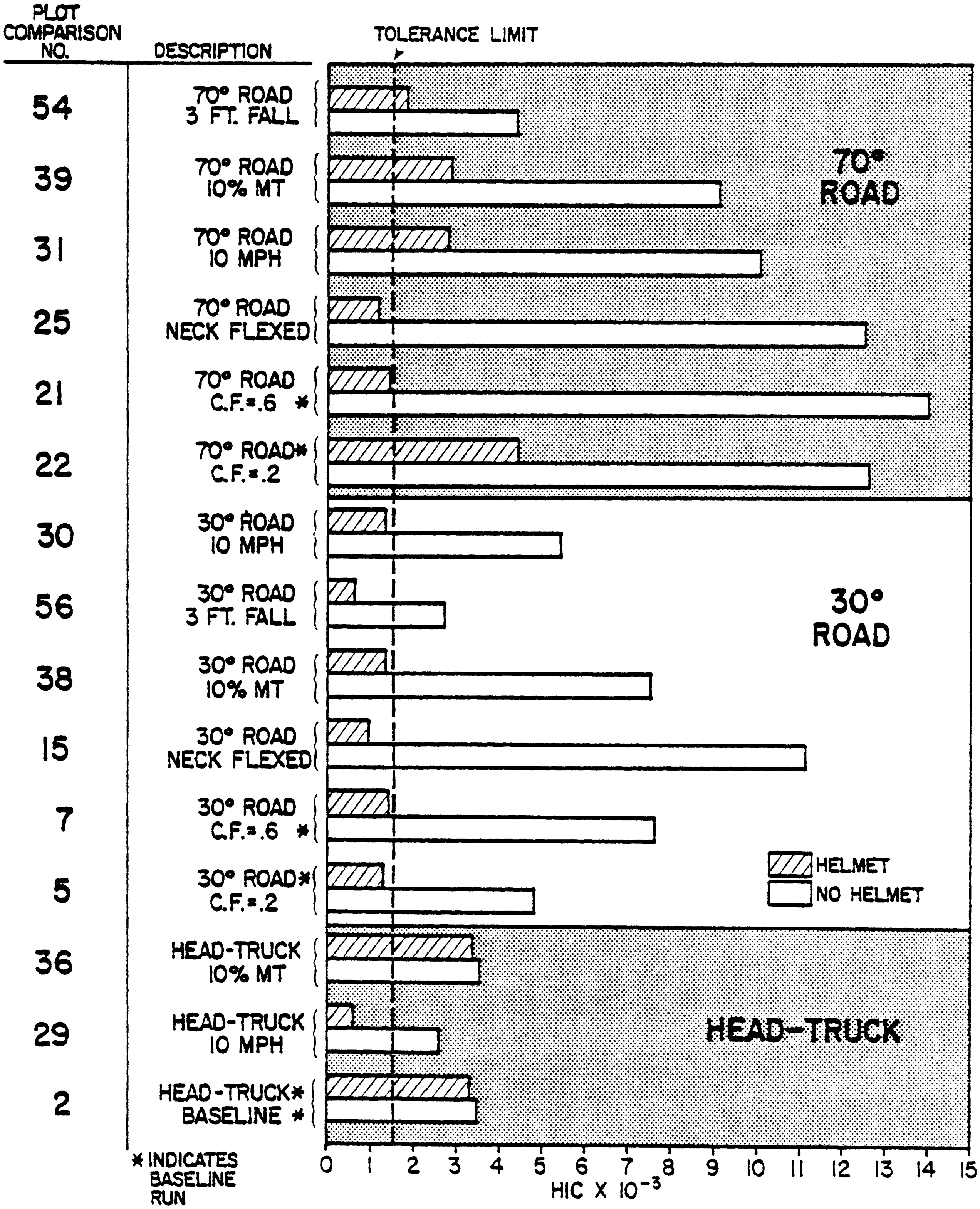

Figure 5-30. HIC Response for Helmet vs. No Helmet Comparisons

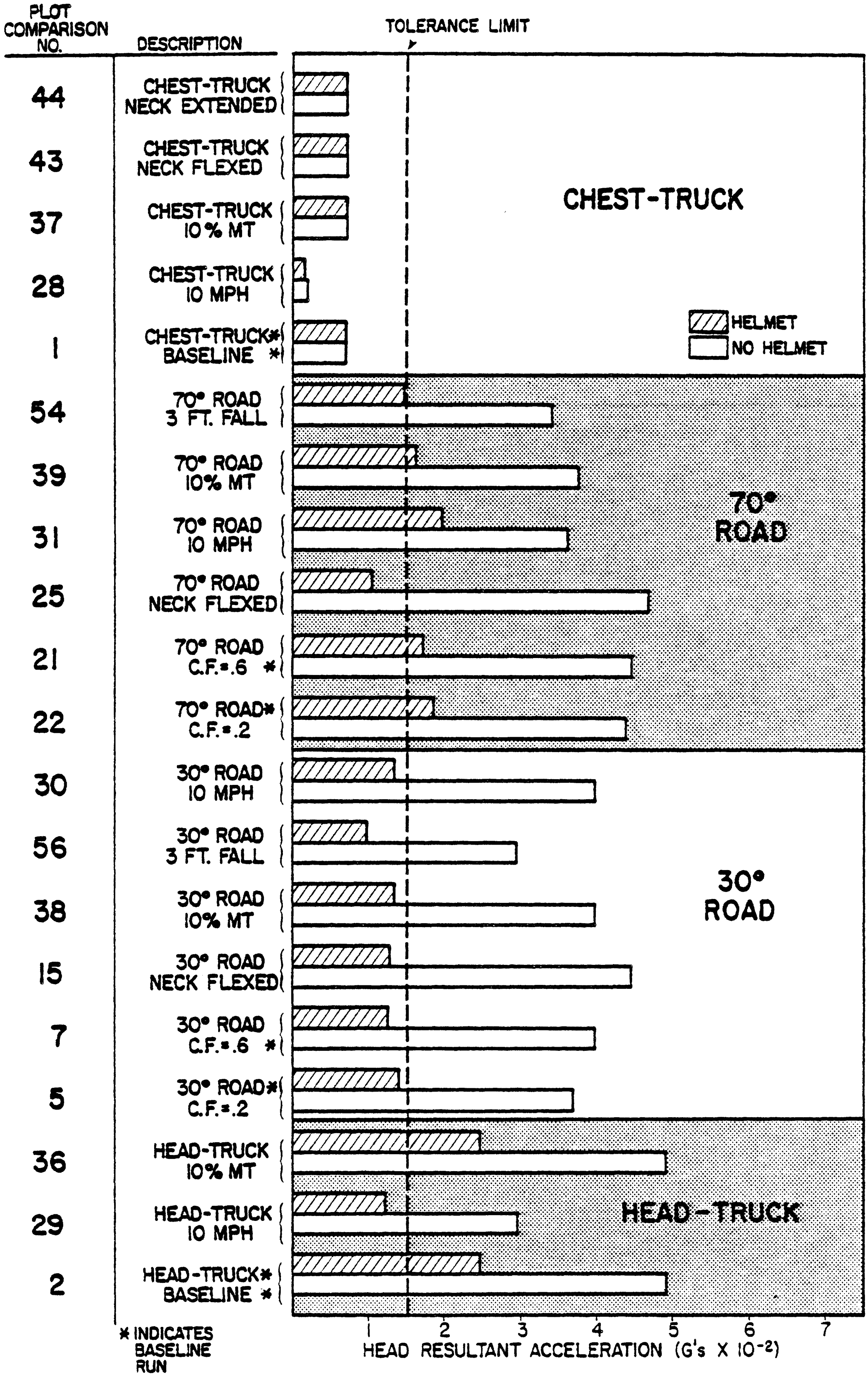

Figure 5-31. Peak Head Resultant Acceleration for Helmet vs. No Helmet Comparisons

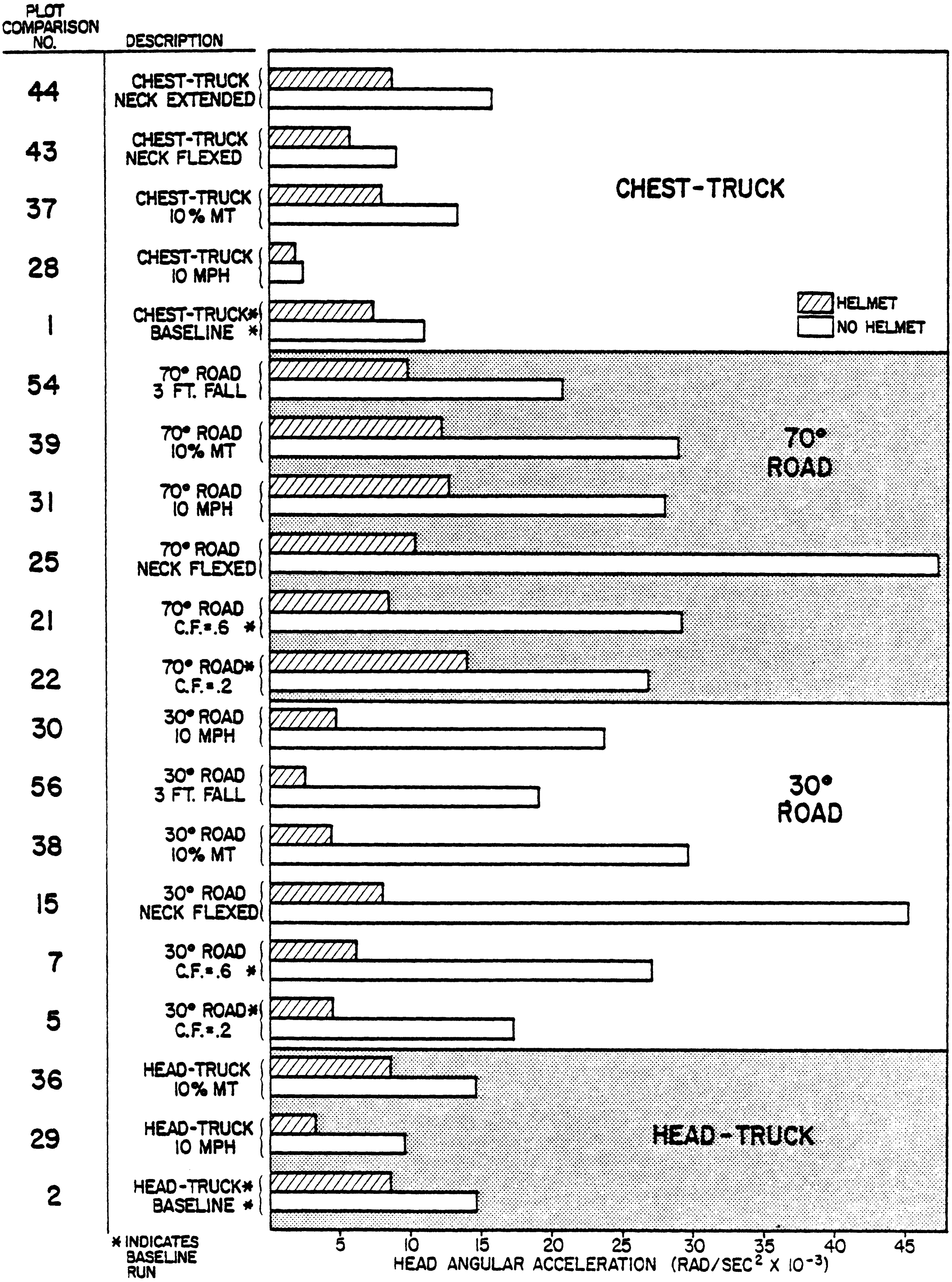

Figure 5-32. Peak Head Angular Acceleration for Helmet vs. No Helmet Comparisons

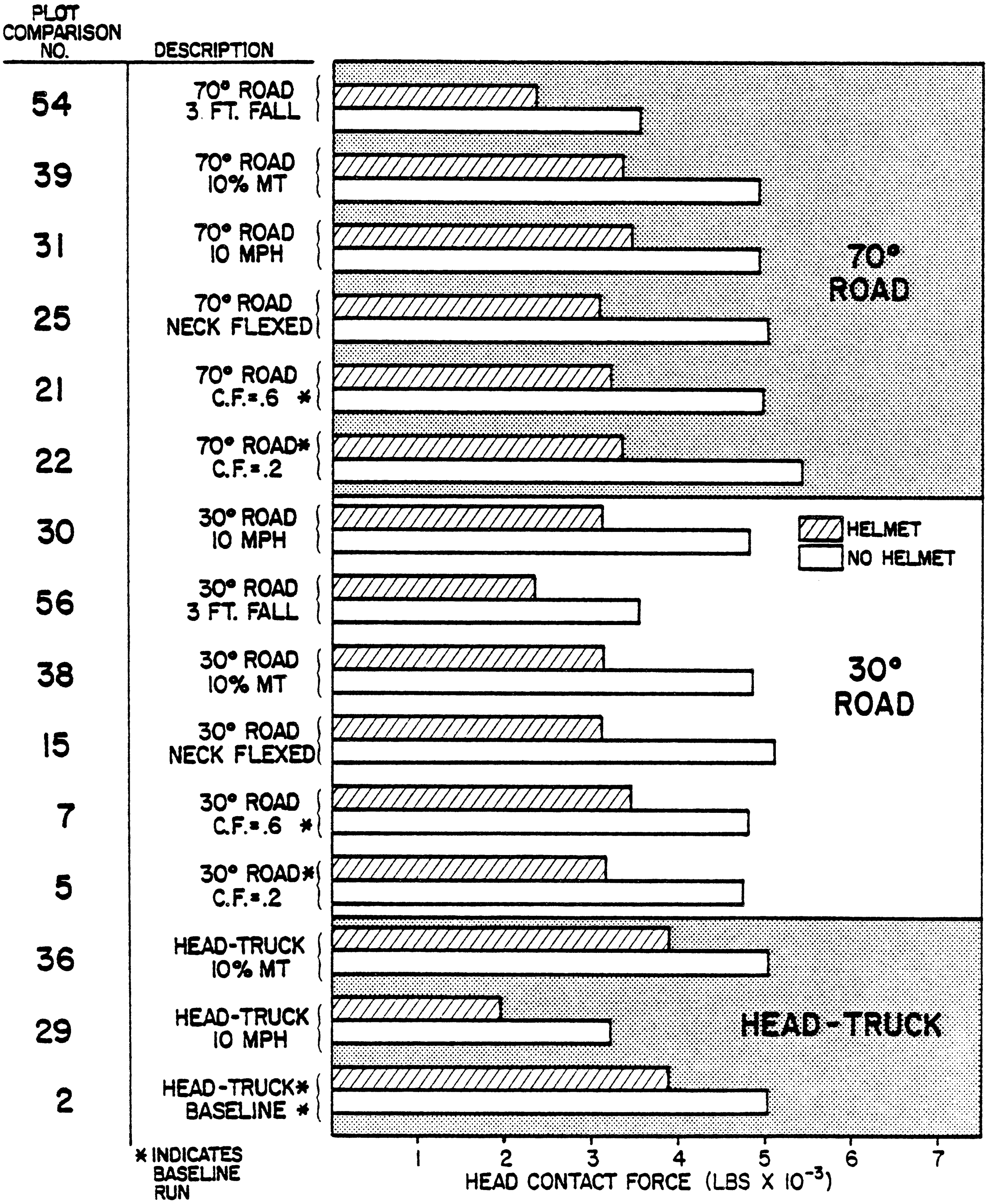

Figure 5-33. Peak Head Contact Force for Helmet vs. No Helmet Comparisons

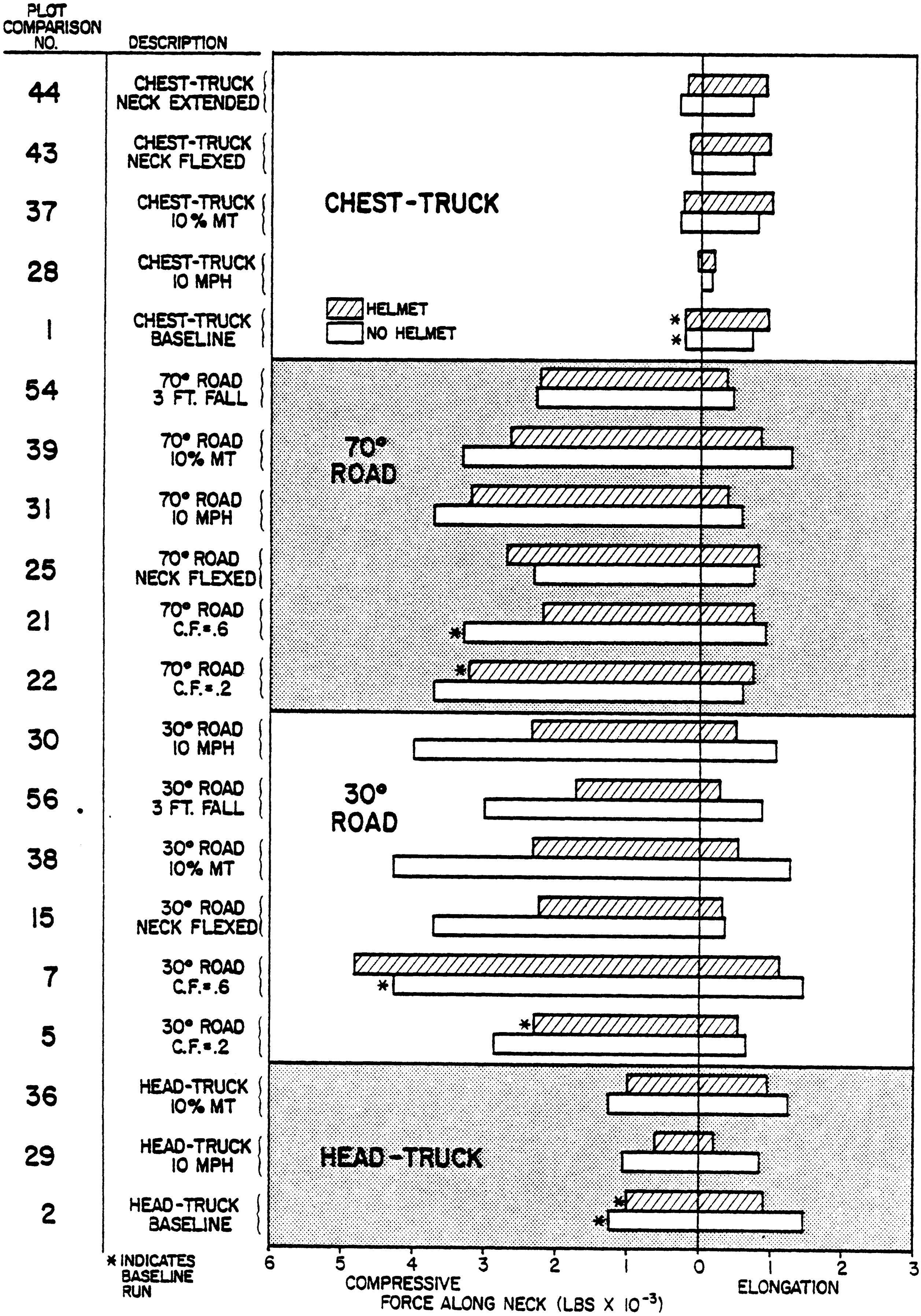

Figure 5-34. Peak Neck Compression/Elongation Forces for Helmet vs. No Helmet Comparisons

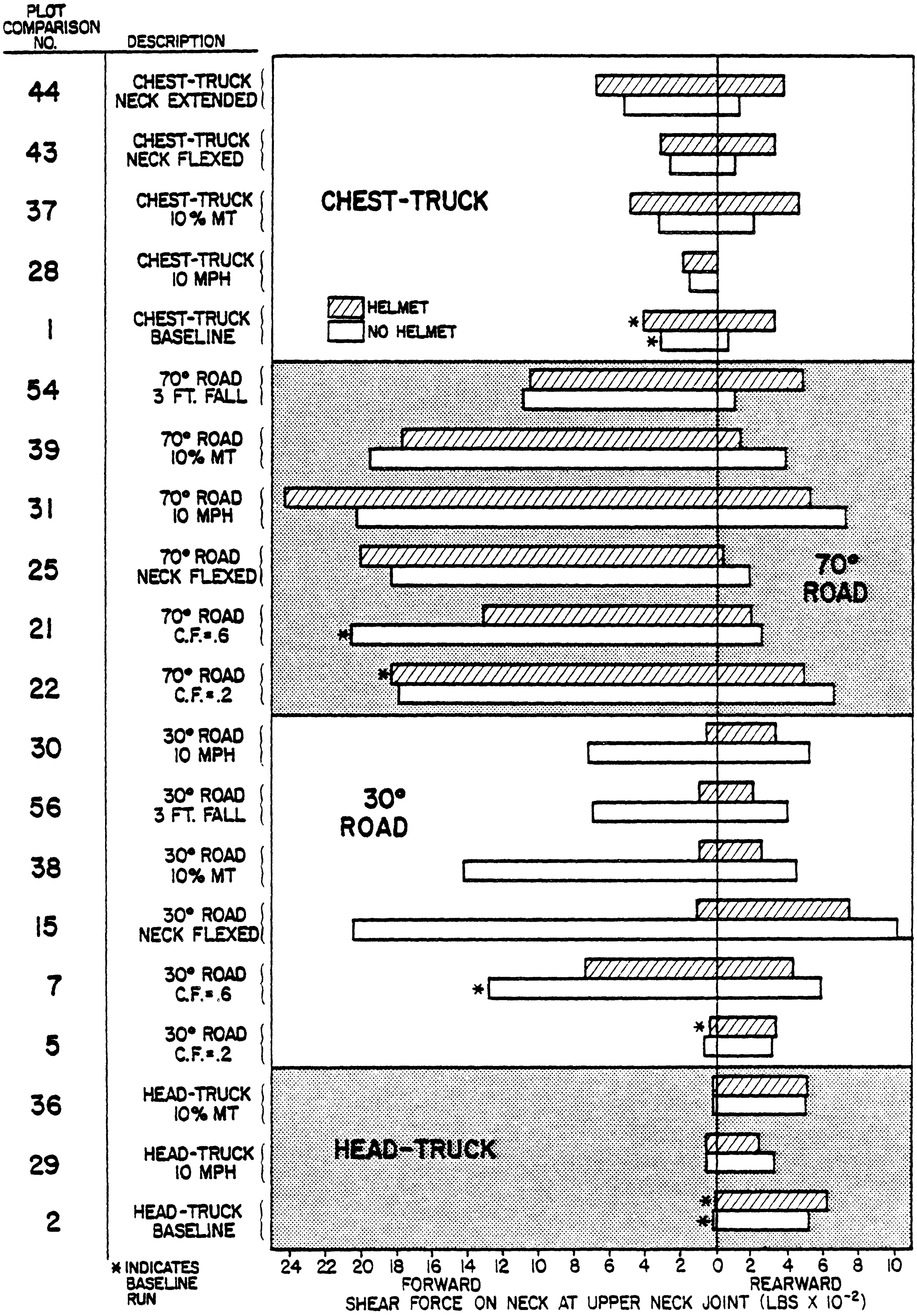

Figure 5-35. Peak Upper Neck Shear Forces for Helmet vs. No Helmet Comparisons

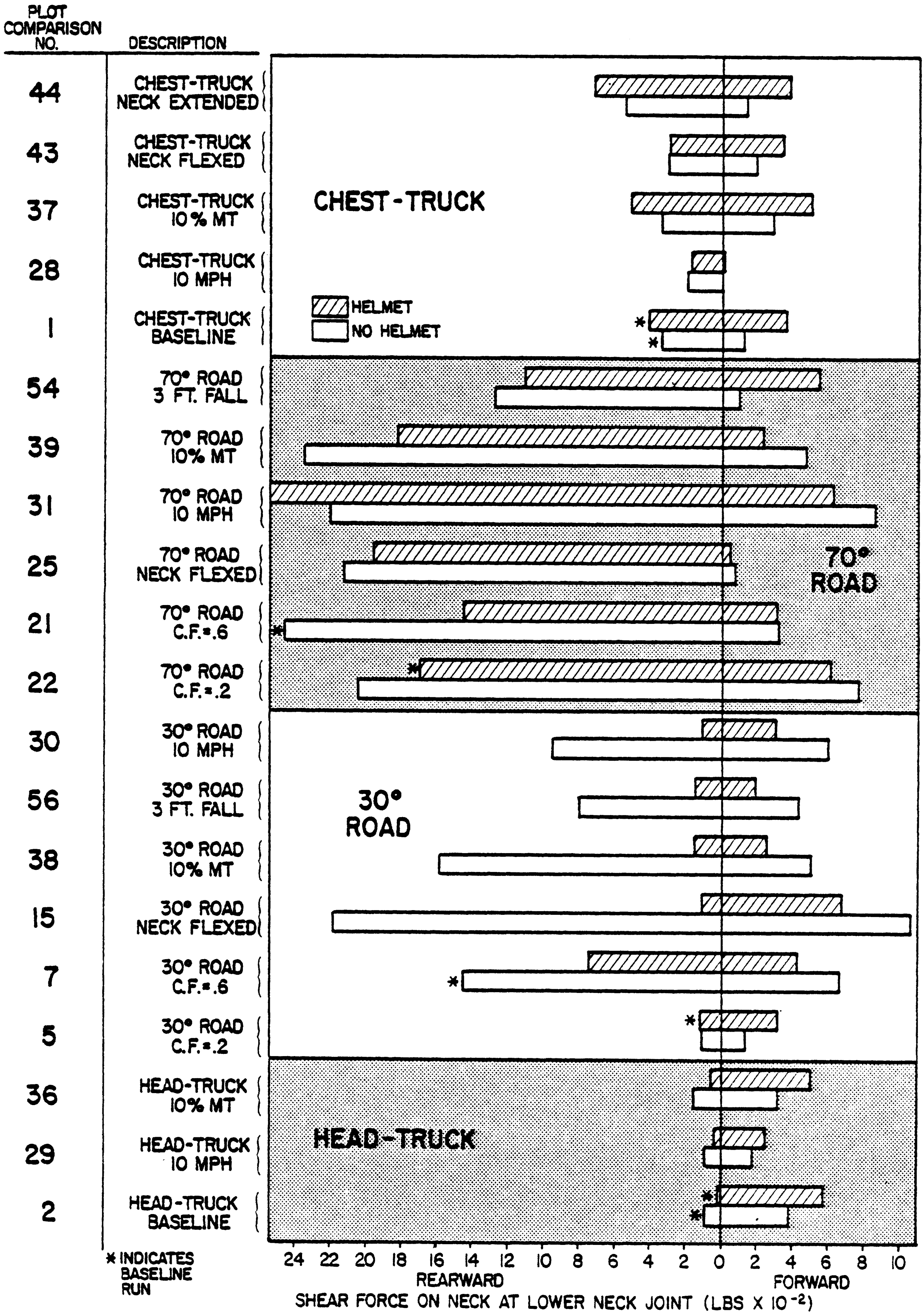

Figure 5-36. Peak Lower Neck Shear Forces for Helmet vs. No Helmet Comparisons

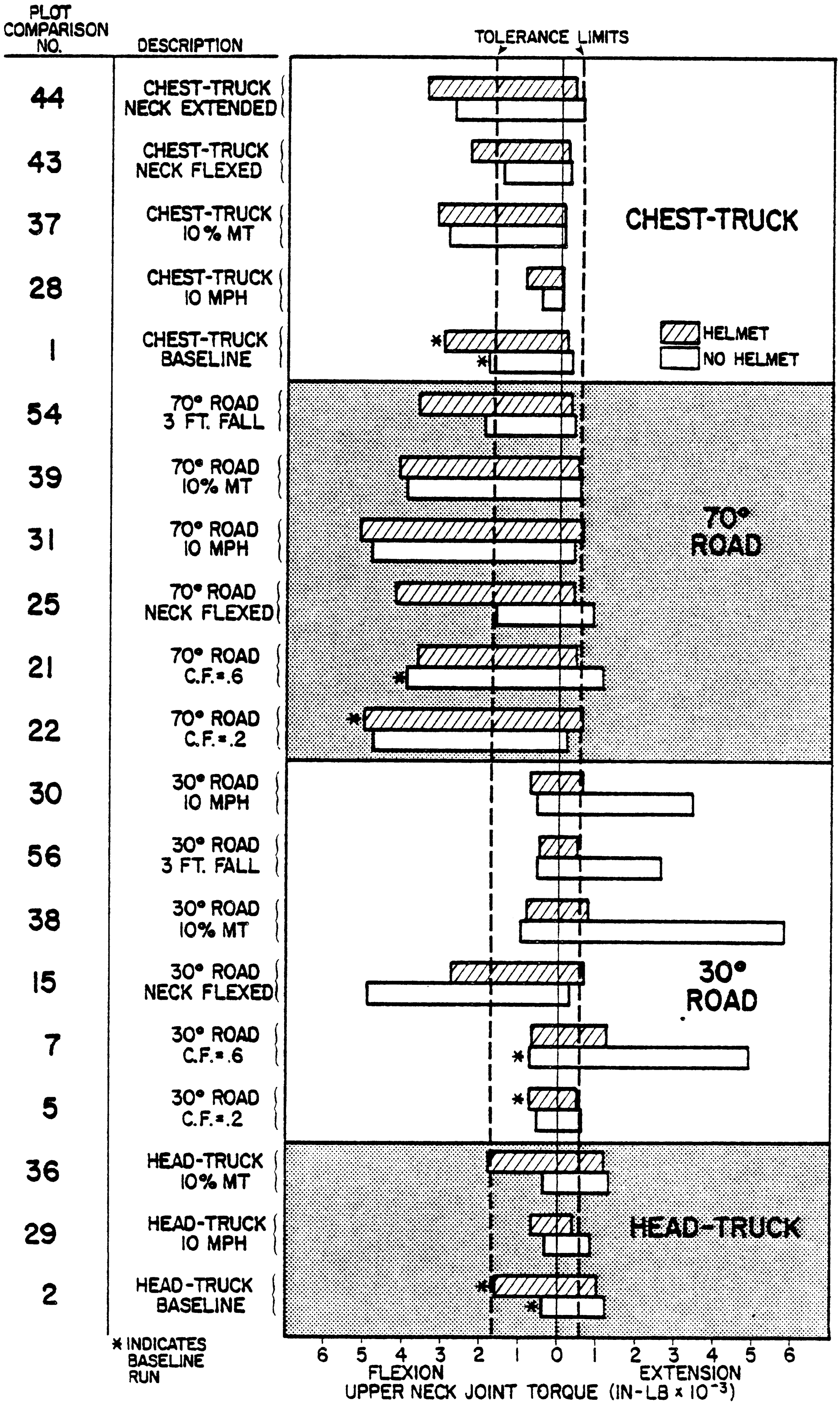

Figure 5-37. Peak Upper Neck Torques for Helmet vs. No Helmet Comparisons

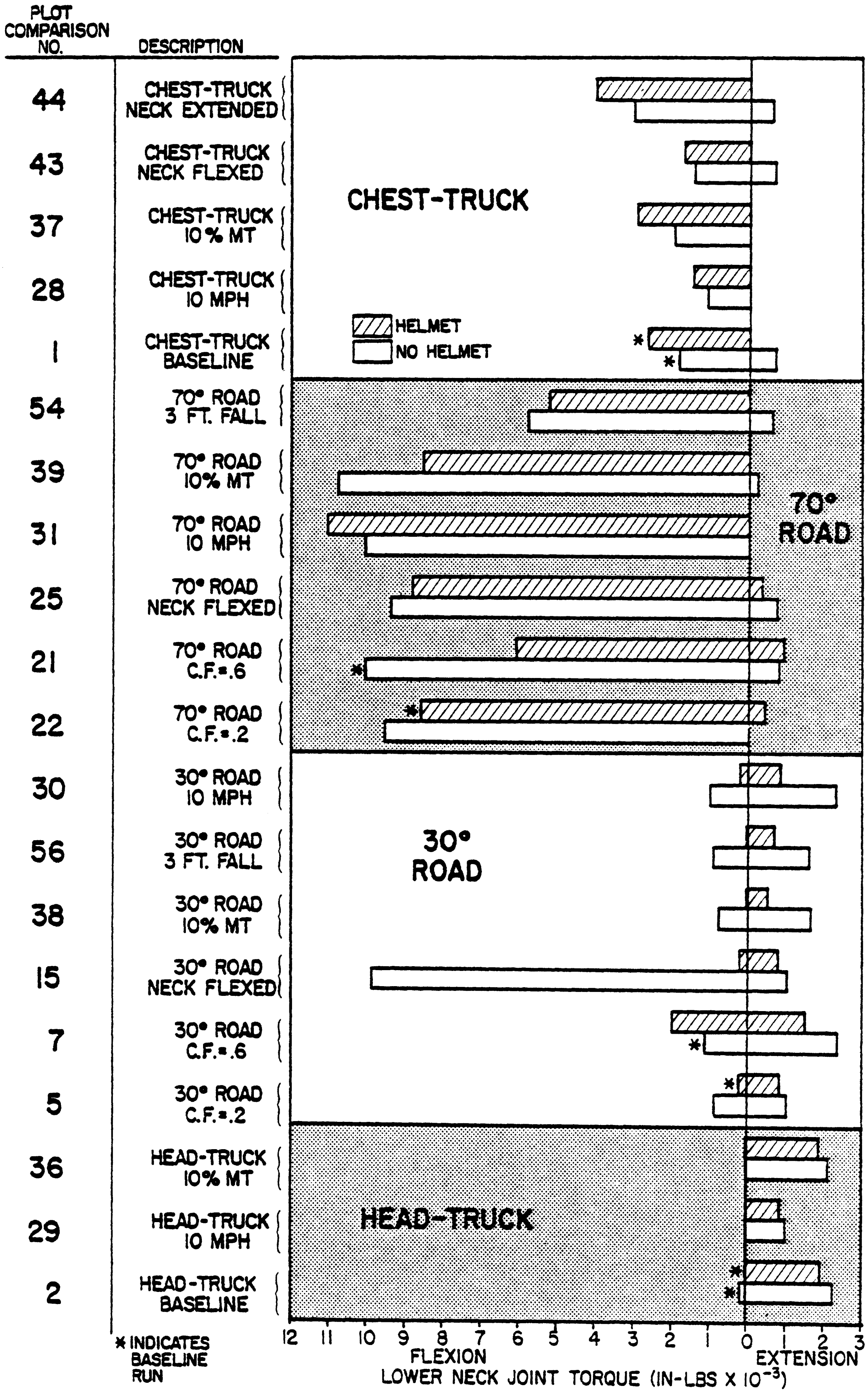

Figure 5-38. Peak Lower Neck Torques for Helmet vs. No Helmet Comparisons

TABLE 5-11a. SUMMARY OF IMPORTANT PEAK DYNAMIC RESPONSES FOR HELMET VS. NO HELMET COMPARISONS

Comparison Reference No.	Run Nos.	Run Names	Description of Runs	*HIC		Head Resultant Acceleration(G's)		Head Angular Acceleration (rad/sec²)	
				No Helmet	Helmet	No Helmet	Helmet	No Helmet	Helmet
1	9 10	CR20NH5.3 CR20H5.3	chest-truck baseline	(566)	(419)	70	70	11107	7391
2	1 2	HR20NH5.3F HR20H5.1F	head-truck baseline	3475	3317	491	245	14807	8740
4	20 19	RNH20H5.6F RH20H5.2F	30° road baseline	7621	1266	398	133	27463	4559
5	22 19	RNH20H5.2F RH20H5.2F	30° road, coefficient of friction = .2	4787	1266	367	133	17203	4559
7	20 21	RNH20H5.6F RH20H5.6F	30° road, coefficient of friction = .6	7621	1403	398	125	27463	6424
12	49 33	RNH20H5.6NR RH20H5.2NR	30° road, 0 deg/sec initial rotation	5618	1069	368	124	24510	3991
15	30 29	RNH20H5.6I2 RH20H5.2I2	30° road, increased neck flexion (head-road angle = 60°)	11276	931	444	126	45497	8049
18	35 34	RNH20V5.6F RH20V5.2F	70° road baseline	14009	4440	448	182	29383	14170
21	35 36	RNH20V5.6F RH20V5.6F	70° road, coefficient of friction = .6	14009	1437	448	171	29383	8589
22	37 34	RNH20V5.2F RH20V5.2F	70° road, coefficient of friction = .2	12624	4440	439	182	26748	14170
25	45 44	RNH20V5.6I2 RH20V5.2I2	70° road, increased neck flexion (head-road angle = 90°)	12535	1175	473	105	47221	10509
28	12 11	CR10NH5.3 CR10H5.3	chest-truck, 10 mph	(77)	(43)	20	16	2413	1989
29	5 4	HR10NH5.3F HR10H5.1F	head-truck, 10 mph	2573	564	298	120	9669	3231
30	24 23	RNH10H5.6F RH10H5.2F	30° road, 10 mph	5486	1305	398	133	23944	4543
31	39 38	RNH10V5.6F RH10V5.2F	70° road, 10 mph	10190	2842	362	197	28217	12984
36	7 6	HR20NH1.3F HR20H1.1F	head-truck, 10% muscle tension	3511	3388	492	248	14804	8710
37	14 13	CR20NH1.3 CR20H1.3	chest-truck, 10% muscle tension	(534)	(542)	73	74	13670	8005
38	26 25	RNH20H1.6F RH20H1.2F	30° road, 10% muscle tension	7603	1288	398	134	29872	4382
39	41 40	RNH20V1.6F RH20V1.2F	70° road, 10% muscle tension	9108	2933	377	162	29043	12094
43	16 15	CR20NH5.3I2 CR20H5.3I2	chest-truck, increased neck flexion	(439)	(424)	72	71	9156	5729
44	18 17	CR20NH5.3I3 CR20H5.3I3	chest-truck, neck in extension	(644)	(611)	68	70	15702	8836
54	50 51	RNH20V5.6F-3 RH20V5.2F-3	70° road, 3-foot fall	4385	1835	340	145	20770	9844
56	52 53	RNH20H5.6F-3 RH20H5.2F-3	30° road, 3-foot fall	2686	579	292	97	19118	2546

* There is no head contact for chest-truck simulations. For these simulations, peak response for neck elongation force rather than compression force is given. HIC values for these simulations probably have little significance since HIC is usually meaningful only over the duration of a direct head impact.

TABLE 5-11b. SUMMARY OF IMPORTANT PEAK DYNAMIC RESPONSES FOR HELMET VS. NO HELMET COMPARISONS

Comparison Reference No.	Run Nos.	Run Names	Description of Runs	*Head Contact Force (lb)		*Neck Compression Force (lb)	
				No Helmet	Helmet	No Helmet	Helmet
1	9 10	CR20NH5.3 CR20H5.3	chest-truck baseline	-	-	-730	-956
2	1 2	HR20NH5.3F HR20H5.1F	head-truck baseline	5026	3890	1253	990
4	20 19	RNH20H5.3F RH20H5.2F	30° road baseline	4827	3139	4271	2371
5	22 19	RNH20H5.2F RH20H5.2F	30° road, coefficient of friction = .2	4770	3139	2882	2371
7	20 21	RNH20H5.6F RH20H5.6F	30° road, coefficient of friction = .6	4827	3489	4271	4821
12	49 33	RNH20H5.6NR RH20H5.2NR	30° road, 0 deg/sec initial rotation	4455	2898	3887	2102
15	30 29	RNH20H5.6I2 RH20H5.2I2	30° road, increased neck flexion (head-road angle = 60°)	5108	3131	3702	2229
18	35 34	RNH20V5.6F RH20V5.2F	70° road baseline	4921	3335	3318	3207
21	35 36	RNH20V5.6F RH20V5.6F	70° road, coefficient of friction = .6	4921	3223	3318	2211
22	37 34	RNH20V5.2F RH20V5.2F	70° road, coefficient of friction = .2	5405	3335	3743	3207
25	45 44	RNH20V5.6I2 RH20V5.2I2	70° road, increased neck flexion (head-road angle = 90°)	5044	3115	2344	2753
28	12 11	CR10NH5.3 CR10H5.3	chest-truck, 10 mph	-	-	-179	-173
29	5 4	HR10NH5.3F HR10H5.1F	head-truck, 10 mph	3196	1976	1061	607
30	24 23	RNH10H5.6F RH10H5.2F	30° road, 10 mph	4827	3127	4030	2348
31	39 38	RNH10V5.6F RH10V5.2F	70° road, 10 mph	4911	3335	3722	3261
36	7 6	HR20NH1.3F HR20H1.1F	head-truck, 10% muscle tension	5035	3885	1258	988
37	14 13	CR20NH1.3 CR20H1.3	chest-truck, 10% muscle tension	-	-	-781	-1029
38	26 25	RNH20H1.6F RH20H1.2F	30° road, 10% muscle tension	4828	3136	4263	2356
39	41 40	RNH20V1.6F RH20V1.2F	70° road, 10% muscle tension	4921	3332	3311	3155
43	16 15	CR20NH5.3I2 CR20H5.3I2	chest-truck, increased neck flexion	-	-	-744	-987
44	18 17	CR20NH5.3I3 CR20H5.3I3	chest-truck, neck in extension	-	-	-690	-875
54	50 51	RNH20V5.6F-3 RH20V5.2F-3	70° road, 3-foot fall	3540	2374	2290	2257
56	52 53	RNH20H5.6F-3 RH20H5.2F-3	30° road, 3-foot fall	3529	2315	3010	1716

* There is no head contact for chest-truck simulations. For these simulations, peak response for neck elongation force rather than compression force is given. HIC values for these simulations probably have little significance since HIC is usually meaningful only over the duration of a direct head impact.

TABLE 5-11c. SUMMARY OF IMPORTANT PEAK DYNAMIC RESPONSES FOR HELMET VS. NO HELMET COMPARISONS

Comparison Reference Number	Run Nos.	Run Names	Description of Runs	Neck Shear Force (pos.) at Condyles (lb)		Neck Shear Force (neg.) at Condyles (lb)		Neck Shear Force (pos.) at C7-T1 (lb)		Neck Shear Force (neg.) at C7-T1 (lb)	
				No Helmet	Helmet	No Helmet	Helmet	No Helmet	Helmet	No Helmet	Helmet
1	9 / 10	CR20NH5.3 / CR20H5.3	chest-truck baseline	317	422	-76	-326	347	419	-129	-362
2	1 / 2	HR20NH5.3F / HR20H5.1F	head-truck baseline	25	9	-512	-614	94	18	-373	-578
4	20 / 19	RNH20H5.3F / RH20H5.2F	30° road baseline	1283	60	-598	-337	1453	118	-662	-310
5	22 / 19	RNH20H5.2F / RH20H5.2F	30° road, coefficient of friction = .2	134	60	-314	-337	121	118	-133	-310
7	20 / 21	RNH20H5.6F / RH20H5.6F	30° road, coefficient of friction = .6	1283	732	-598	-435	1453	749	-662	-421
12	49 / 33	RNH20H5.6NR / RH20H5.2NR	30° road, 0 deg/sec initial rotation	1002	51	-534	-297	1151	93	-587	-276
15	30 / 29	RNH20H5.6I2 / RH20H5.2I2	30° road, increased neck flexion (head-road angle = 60°)	1943	109	-1035	-751	2189	117	-1064	-685
18	35 / 34	RNH20V5.6F / RH20V5.2F	70° road baseline	2051	1826	-255	-492	2468	1904	-321	-608
21	35 / 36	RNH20V5.6F / RH20V5.6F	70° road, coefficient of friction = .6	2051	1311	-255	-187	2468	1468	-321	-305
22	37 / 34	RNH20V5.2F / RH20V5.2F	70° road, coefficient of friction = .2	1795	1826	-668	-492	2052	1904	-771	-608
25	45 / 44	RNH20V5.6I2 / RH20V5.2I2	70° road, increased neck flexion (head-road angle = 90°)	1837	2002	-193	-37	2132	1966	-73	-56
28	12 / 11	CR10NH5.3 / CR10H5.3	chest-truck, 10 mph	162	182	0	0	192	181	0	-5
29	5 / 4	HR10NH5.3F / HR10H5.1F	head-truck, 10 mph	53	52	-323	-248	87	42	-178	-245
30	24 / 23	RNH10H5.6F / RH10H5.2F	30° road, 10 mph	821	59	-541	-336	951	116	-600	-309
31	39 / 38	RNH10V5.6F / RH10V5.2F	70° road, 10 mph	2046	2434	-738	-533	2204	2564	-867	-641
36	7 / 6	HR20NH1.3F / HR20H1.1F	head-truck, 10% muscle tension	27	28	-511	-529	154	64	-322	-507
37	14 / 13	CR20NH1.3 / CR20H1.3	chest-truck, 10% muscle tension	324	497	-215	-475	354	504	-288	-507
38	26 / 25	RNH20H1.6F / RH20H1.2F	30° road, 10% muscle tension	1425	91	-460	-253	1592	145	-519	-242
39	41 / 40	RNH20V1.6F / RH20V1.2F	70° road, 10% muscle tension	1951	1764	-393	-133	2352	1824	-484	-234
43	16 / 15	CR20NH5.3I2 / CR20H5.3I2	chest-truck, increased neck flexion	260	311	-100	-327	315	317	-179	-336
44	18 / 17	CR20NH5.3I3 / CR20H5.3I3	chest-truck, neck in extension	508	692	-131	-389	553	730	-139	-390
54	50 / 51	RNH20V5.6F-3 / RH20V5.2F-3	70° road, 3-foot fall	1093	1048	-98	-474	1272	1127	-90	-551
56	52 / 53	RNH20H5.6F-3 / RH20H5.2F-3	30° road, 3-foot fall	699	38	-409	-208	811	149	-445	-194

There is no head contact for chest-truck simulations. For these simulations, peak response for neck elongation force rather than compression force is given. HIC values for these simulations probably have little significance since HIC is usually meaningful only over the duration of a direct head impact.

TABLE 5-11d. SUMMARY OF IMPORTANT PEAK DYNAMIC RESPONSES FOR HELMET VS. NO HELMET COMPARISONS

Comparison Reference Number	Run Nos.	Run Names	Description of Runs	Condyles Flexion Torque (in-lb)		Condyles Extension Torque (in-lb)		C7-T1 Flexion Torque (in-lb)		C7-T1 Extension Torque (in-lb)	
				No Helmet	Helmet	No Helmet	Helmet	No Helmet	Helmet	No Helmet	Helmet
1	9 10	CR20NH5.3 CR20H5.3	chest-truck baseline	-1869	-2936	357	182	-1832	-2615	698	0
2	1 2	HR20NH5.3F HR20H5.1F	head-truck baseline	-404	-1596	1240	1045	-143	0	2239	1976
4	20 19	RNH20H5.3F RH20H5.2F	30° road baseline	-751	-761	4908	578	-1165	-220	2418	854
5	22 19	RNH20H5.2F RH20H5.2F	30° road, coefficient of friction = .2	-517	-761	659	578	-869	-220	1003	854
7	20 21	RNH20H5.6F RH20H5.6F	30° road, coefficient of friction = .6	-751	-601	4908	1288	-1165	-1998	2418	1553
12	49 33	RNH20H5.6NR RH20H5.2NR	30° road, 0 deg/sec initial rotation	-681	-618	3954	504	-1175	-68	2244	756
15	30 29	RNH20H5.6I2 RH20H5.2I2	30° road, increased neck flexion (head-road angle = 60°)	-4907	-2727	273	677	-9911	-482	1110	710
18	35 34	RNH20V5.6F RH20V5.2F	70° road baseline	-3983	-5001	1229	560	-10802	-8647	818	489
21	35 36	RNH20V5.6F RH20V5.6F	70° road, coefficient of friction = .6	-3983	-3639	1229	491	-10802	-6133	818	931
22	37 34	RNH20V5.2F RH20V5.2F	70° road, coefficient of friction = .2	-4864	-5001	189	560	-9557	-8647	0	489
25	45 44	RNH20V5.6I2 RH20V5.2I2	70° road, increased neck flexion (head-road angle = 90°)	-1611	-4277	815	359	-9463	-8891	751	389
28	12 11	CR10NH5.3 CR10H5.3	chest-truck, 10 mph	-460	-812	49	62	-1129	-1489	0	0
29	5 4	HR10NH5.3F HR10H5.1F	head-truck, 10 mph	-320	-641	887	435	0	0	1003	874
30	24 23	RNH10H5.6F RH10H5.2F	30° road, 10 mph	-609	-759	3457	575	-1017	-218	2448	854
31	39 38	RNH10V5.6F RH10V5.2F	70° road, 10 mph	-4862	-5135	378	612	-10011	-11009	0	0
36	7 6	HR20NH1.3F HR20H1.1F	head-truck, 10% muscle tension	-376	-1792	1320	1210	-15	0	2160	1924
37	14 13	CR20NH1.3 CR20H1.3	chest-truck, 10% muscle tension	-2287	-3153	184	161	-1909	-2900	61	0
38	26 25	RNH20H1.6F RH20H1.2F	30° road, 10% muscle tension	-960	-826	5852	789	-801	-67	1697	520
39	41 40	RNH20V1.6F RH20V1.2F	70° road, 10% muscle tension	-3930	-4110	518	497	-10828	-8581	271	0
43	16 15	CR20NH5.3I2 CR20H5.3I2	chest-truck, increased neck flexion	-1486	-2346	234	233	-1433	-1706	704	0
44	18 17	CR20NH5.3I3 CR20H5.3I3	chest-truck, neck in extension	-2757	-3440	575	300	-3021	-4146	645	0
54	50 51	RNH20V5.6F-3 RH20V5.2F-3	70° road, 3-foot fall	-1999	-3671	433	320	-5846	-5271	666	0
56	52 53	RNH20H5.6F-3 RH20H5.2F-3	30° road, 3-foot fall	-557	-488	2651	501	-945	-68	1663	639

There is no head contact for chest-truck simulations. For these simulations, peak response for neck elongation force rather than compression force is given. HIC values for these simulations probably have little significance since HIC is usually meaningful only over the duration of a direct head impact.

6.0 SUMMARY AND CONCLUSIONS

The simulation results illustrated and discussed in the foregoing sections show clearly that helmet use in general causes marked decreases in dynamic response peak magnitudes for typical motorcyclist impacts. With few exceptions, exposure levels are either reduced for the helmeted cyclist or unchanged. Only for direct chest impacts resulting in inertial loading of the head and neck do neck injury responses for the helmeted cyclist generally exceed those for the unhelmeted cyclist, and then not by significant amounts. Attenuation of responses is in most instances great enough that there is significant reduction of the likelihood that head or neck injury will occur, or that, if injury does occur, it will be much less severe.

6.1 Summary

The MVMA Two-Dimensional Crash Victim Simulation computer model was used to study four types of impact configurations for both helmeted and unhelmeted cyclists. These are:

1) head impact against a vertical, rigid "truck" surface, cyclist in seated orientation;
2) chest impact against a vertical, rigid "truck" surface, cyclist in seated orientation;
3) head impact against a rigid road surface, 30° angle between road and body line;
4) head impact against a rigid road surface, 70° angle between road and body line.

A 20 mph horizontal velocity was used for the baseline condition for each configuration. For the road impact simulations, a six-foot trajectory height baseline was used for the ejected cyclist.

The major findings from helmet/no-helmet comparisons for these impact configurations are listed below:

Head-Truck Impacts

1. Serious brain injury is very likely for direct 20 mph head-truck impact for either the helmeted or unhelmeted cyclist. A helmet reduces peak head resultant acceleration by one-half, but HIC is only slightly reduced, from 3500 to 3300.

2. With regard to reducing HIC exposure, a helmet is most effective at lower impact velocities. At 10 mph, it reduces HIC by almost 80 percent from a dangerous level, 2600, to a non-injurious level, less than 600.

3. Peak head contact force is less by 1100 to 1200 lbs for the helmeted cyclist regardless of impact conditions.

4. Peak upper neck flexion torques are markedly greater for the helmeted cyclist but less than the injury tolerance limit even for 20 mph impacts.

5. At 10 mph, peak upper neck extension torque for the unhelmeted cyclist is about 75 percent in excess of the injury tolerance limit. A helmet reduces the torque to about 15 percent less than the injury tolerance limit. At 20 mph, large extension torques indicate high likelihood of neck injury for both the helmeted and unhelmeted cyclists, but the injury tolerance level is exceeded by much less for the helmeted cyclist -- 100 percent as against 150 percent.

Chest-Truck Impacts

1. In chest-truck impacts, acceleration-related responses are decreased by the helmet. Levels are not dangerously high, however, even for the unhelmeted cyclist at 20 mph.

2. Neck response variables are moderately increased by the helmet, but levels for helmeted and unhelmeted cyclists are mostly smaller for chest-truck impacts than for the other types of impacts simulated.

3. Upper neck flexion torques exceed the injury tolerance level by up to 100 percent for the helmeted cyclist and by up to 65 percent for the unhelmeted cyclist.

4. The most likely injury from this type of impact results from rebound hyperextension of the upper neck, where torque levels are equal for the helmeted and unhelmeted cyclists at about five times the injury tolerance level.

30° Road Impacts

1. For low-angle road impacts, peak values for all injury-related dynamic responses are reduced dramatically by helmet attenuation of impact forces.

2. HIC greatly exceeds 1500, indicating high likelihood of serious brain injury, for all conditions simulated for unhelmeted motorcyclists. Typical values are 5000 to 8000. HIC is reduced to below 1500 in all simulations for helmeted motorcyclists, typically to 1200 to 1300. For conditions simulated, the helmet effects reductions of 75-85% in HIC.

3. The helmet reduces head resultant acceleration by 65-70% and head angular acceleration by 75-85%.

4. Head contact force is typically reduced by about 1600 lbs, or 30-35%.

5. Peak upper neck flexion torque is sometimes decreased and sometimes increased by the helmet, but torque levels, in general, are considerably less than the injury tolerance limit for both the helmeted and unhelmeted cyclists.

6. For most conditions peak upper neck extension torque is 10 times the injury tolerance limit for the unhelmeted cyclist but is reduced by a helmet to levels only slightly exceeding the tolerance limit. Reductions are typically 75-90%.

7. The relatively low coefficient of friction between a helmet and the road is partly responsible for the reductions in peak values of neck injury parameters. For the 30 degree impact orientation, a friction coefficient of 0 to 0.3 is optimal overall.

70° Road Impacts

1. High-angle road impacts are more severe than low-angle impacts with respect to nearly all injury-related dynamic responses, particularly neck injury parameters. The benefits of the helmet are marked but not as great as for a low-angle road impact.

2. The helmet reduces HIC by 60-90%, typically from 10000-15000 to 2000-4000.

3. The helmet reduces head resultant acceleration by 50-80% and head angular acceleration by 50-70%.

4. Head contact force is reduced by amounts in the range 1200 to 2000, always by about 35 percent.

5. Neck hyperflexion injury is likely for this type of impact. Peak torque levels at the upper neck are typically about twice the injury tolerance limit for both helmeted and unhelmeted cyclists. Upper neck flexion torque is normally somewhat increased by a helmet. At the lower neck, flexion torques are even greater but are consistently smaller for the helmeted cyclist.

6. Peak upper neck extension torques are normally less than the injury tolerance limit and normally smaller for the helmeted cyclist. For some conditions the helmet prevents probable hyperextension injury. Lower neck extension torques are less than the upper neck torques.

7. For the 70 degree impact orientation, peak neck compression force, torques, and shear forces decrease as helmet/road coefficient of friction is increased (within limits). A friction coefficient larger than that for a typical helmet is found to be optimal overall for 70° impacts, the best values lying in the range 0.4 to 0.8.

The effects of varying input parameter values away from baseline conditions were studied in order to establish sensitivity of dynamic responses to varied conditions in real-world motorcyclist impacts. In no case did the simulation results from any of these parameter variations lead to significant alterations in conclusions regarding the general effectiveness of the helmet derived from results of the baseline simulations. The degree of overall benefit of helmet use relative to non-use does vary, however, with change of impact conditions. The major findings from variation of parameters for impact conditions are listed below:

Head/Helmet-Road Friction Coefficient

1. Even a small coefficient of friction is sufficient to cause rollover on the head and shoulders (tumbling) for 70° road impacts. Prone body impacts always result for a 30° impact orientation unless the coefficient of friction is unrealistically far in excess of 1.0.

2. A helmet-road surface coefficient of friction of 0.3 to 0.4 is suggested as optimal overall for minimizing exposure levels in real-world accidents. Lower values are better for low-angle impacts and higher values are better for high-angle impacts.

3. For both 30° and 70° road impact angles, the overall benefit of helmet use relative to nonuse increases for larger coefficients of friction.

Road Impact Angle: 30° vs. 70°

1. Overall dynamic response is much different for low and high body angles at impact. Tumbling occurs for high-angle impact but not for low-angle impact.

2. Neck responses are very different for the two impact orientations. With regard to neck trauma, the 30 degree impact is the more severe for an unhelmeted cyclist, while the 70 degree impact is the more severe for a helmeted cyclist.

3. With regard to brain injury, the 70 degree impact is the more severe for both helmeted and unhelmeted cyclists. HIC is about 3.5 times as large at 70° as at 30° for the helmeted cyclist and 1.8 times as large for the unhelmeted cyclist.

4. The relative benefits of helmet use increase overall for the lower (30°) impact angle.

Head/Neck Initial Orientation

1. For head-truck impacts, only minor differences result in dynamic response peak magnitudes if the neck is initially flexed in comparison with the baseline head/neck orientation.

2. For chest-truck impacts, peak neck flexion and extension torques increase, in general, with initial neck extension and decrease with increased initial neck flexion. Detriments of helmet use relative to nonuse are smaller if the neck is initially in extension.

3. For 30° road impacts, initial neck flexion relative to the baseline head/neck orientation causes significant increases of upper and lower neck peak flexion torques while reducing peak extension torques -- markedly for the unhelmeted cyclist. The overall benefit of helmet use relative to nonuse is greater for the flexed initial orientation than for the baseline orientation.

4. For 70° road impacts, initial neck flexion causes reduction of upper and lower neck peak flexion and extension torques for both helmeted and unhelmeted cyclists. For the helmeted cyclist, initial neck flexion causes HIC to be reduced to one-fourth of the baseline value. Only a small reduction in HIC results for the unhelmeted cyclist. The overall benefit of helmet use relative to nonuse is greater for the flexed initial head/neck orientation.

Muscle Tension

1. For the 10 mph head-truck and chest-truck impacts, varying muscle activity level from 50 percent of maximum isometric potential to 10 percent has negligible effect on dynamic response peak magnitudes.

2. At 20 mph effects of varying muscle tension are slightly larger but still insignificant except for the 70° road impact, where HIC is decreased by 34 percent for the lower muscle tension level.

3. The relative benefits of helmet use are essentially the same for 10 percent and 50 percent muscle activity levels.

Horizontal Velocity: 10 mph vs. 20 mph

1. Head-truck impacts at 10 mph produce peak magnitudes of injury-related dynamic response variables that are 40 to 80 percent less than at 20 mph. For a helmeted cyclist, HIC is less than 600 at 10 mph -- 83 percent lower than the HIC at 20 mph. Helmet use as against nonuse has much greater relative benefit for a 10 mph horizontal velocity than for 20 mph.

2. For chest-truck impacts, dynamic response peak magnitudes are 50 to 90 percent smaller for 10 mph impacts than for 20 mph. Most significantly, upper neck torques are reduced by about 70 percent. For 10 mph impacts, exposure levels for all dynamic response variables are below injury tolerance limits for both helmeted and unhelmeted cyclists.

3. Horizontal velocity is a minor factor for road impacts, particularly low-angle impacts. There is little difference in the relative benefits of helmet use as opposed to nonuse for the 10 mph and 20 mph velocities investigated.

Fall Height: 3 ft. vs. 6 ft.

1. The dynamic responses for road impacts for three-foot and six-foot trajectory heights are quite similar in character, the major differences being in peak magnitudes.

2. For 30°-road helmet impacts, peak magnitudes of most accelerations, forces, and torques are roughly 1.3 times as large for a six-foot trajectory height as for a three-foot height. HIC is 2.2 times as large.

3. For 70°-road helmet impacts, dynamic response peak magnitudes are roughly 1.5 times as large for a six-foot fall height as for three feet. HIC is 2.4 times as large.

4. For 30° impacts, the relative benefits of helmet use are very little different for three-foot and six-foot fall heights. For 70° impacts, there is increased relative benefit of helmet use at the six-foot fall height.

Initial Rotational Velocity

1. Only small effects on dynamic response are seen from varying initial rotational velocity between 0 and 100 deg/sec for 30° road impacts. Effects are even smaller for 70° road impacts.

2. The benefits of helmet use relative to nonuse are the same for the initial rotational velocities investigated.

6.2 Conclusions

Through computer simulation of the dynamic impact response of helmeted and unhelmeted motorcyclists for a wide variety of impact conditions, this study has established a broad overall view of the effectiveness of helmet use. The potential of the helmet to both beneficially and detrimentally affect head and neck response has been investigated. The analysis of simulation results indicates that a helmet will invariably lessen the exposure levels of dynamic responses which have a role in producing head injury. In addition, the study finds helmet use to almost always reduce the severity of neck response as well and for no simulation configuration or condition to greatly increase the likelihood of neck injury. Thus, for the spectrum of real-world motorcyclist impacts, helmet use is predicted to significantly reduce the overall likelihood and severity of both head and neck injuries.

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APPENDIX A

HEAD INJURY CRITERION

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HEAD INJURY CRITERION

A.1 Definition of HIC

Head Injury Criterion (HIC)* is a measure of the acceleration exposure of a head during impact:

$$HIC = \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a \, dt \right]^{2.5} (t_2 - t_1)$$

where "a" is the resultant acceleration in g's at the center of gravity of the head and t_1 and t_2 are the time values (in seconds) from the acceleration-time curve which cause the expression on the right-hand side of the equation to be maximized.

A.2 HIC Injury Tolerance Level

A concussion injury tolerance level of HIC = 1000 was set by NHTSA in June 1972 by Department of Transportation NHTSA Docket Number 69-7, Notice 19, Occupant Crash Protection Head Injury Criterion S6.2 of MVSS 208. NHTSA had previously rescinded the use of the SAE Severity Index (Gadd, 1966; SAE Information Report, 1966), a similar integrated measure of acceleration exposure, in Notice 9 of MVSS 208. The original Severity Index tolerance limit of 1000 was intended to model the Wayne State Tolerance Curve for closed head injury (Patrick, et al., 1963). Versace, in a critical review of the Severity Index (1971), proposed

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* Code of Federal Regulations, Title 49, Part 572, Section 208, U.S. Government Printing Office, Washington, D.C., 1977.

the definition above -- later named the Head Injury Criterion index -- as a functional form which follows more consistently from the Wayne State data. Versace notes, however, that certain judgmental and arbitrary selections of analytical parameter values must be made in obtaining the recommended functional form. Further, he points out that values for the tolerance level both larger and smaller than 1000 will model the Wayne State data just as well for either the original Severity Index or for logical extensions of it such as the Head Injury Criterion index. Indeed, Versace does not recommend any specific value for the HIC tolerance limit as best for modeling the Wayne State data. Others have also noted that, while more consistent than the Severity Index, HIC has various weaknesses relating primarily to two points: 1) arbitrary selection of function parameters in its derivation, and 2) the fact that experimental data is from greatly differing types of tests and that only A-P (anterior-posterior) tests of human cadaver heads are represented. In addition, Newman (1975) notes that the original data upon which HIC is founded in no way supports the idea that HIC should be defined as the maximum value of the HIC function over all time intervals. This is an arbitrary element of the HIC definition.

Despite these various criticisms, and others, which can be made of HIC, it is generally accepted as the best whole-body motion index yet proposed for predicting concussion injury. In addition, the tolerance limit of 1000 for the original Severity Index has been retained for HIC in NHTSA Docket Number 69-7, Notice 19, MVSS 208.

Evidence has accumulated since 1972, however, which would support the use of a larger tolerance level for HIC. The findings of Got, et al. (1978) have been described in Section 4. On the basis of their tests, they suggest a HIC limit of 1500 although they recommend additional testing to confirm their results. Newman (1975) points out that, in light of Gadd's revised Severity Index tolerance limit of 1500 for impacts of duration greater than 5 msec (Gadd, 1972; also, see Gadd, 1971), a HIC limit of 1500 might be more reasonable. Hodgson and Thomas (1972) note that if a head impact does not contain a critical HIC interval (HIC $\geq$ 1000) of less than 15 msec, it should be considered safe as far as cerebral concussion is concerned. Thus, at least for intervals longer than 15 msec, Hodgson and Thomas support a tolerance level of greater than 1000. Like the results of Got, et al., cadaver test results of Nahum, et al. (1977) would seem to support a HIC tolerance level (AIS $\leq$ 2) of greater than 1000. One of their tests, an AIS 2 injury with a HIC of 3765, was mentioned in Section 4. Of their other tests, none had HIC's exceeding 1000 but neither were there injuries of severity greater than AIS 2. There were two with HIC's greater than 800 and no discernible brain injury whatsoever (AIS 0), one with HIC equal to 923 and AIS 1, and one with a HIC of 980 and AIS 2. These numbers imply that AIS 2 injuries would occur for HIC's through values greater than 1000 (though perhaps not 1500). The only result from Nahum, et al., counter to this is a case with AIS 2 for HIC of 551.

The free-fall study reported by Snyder, et al. (1977) and Foust, et al. (1977) lends some support to the use of a HIC tolerance limit greater than 1000. In that study, results of MVMA 2-D CVS computer simulations of free-fall impacts were correlated with AIS codes derived from hospital records. No results were obtained for adult head impacts, but for children, a HIC tolerance limit (AIS $\leq$ 2) was determined to be in the range 1700 to 2800. (Adult values can be expected to be less.)

Finally, in a review of the currently existing data base for assessing impact head injury, Robbins (1980) finds that "No numerical criterion for injury can be given more than a limited recommendation at this time due to the shortcomings in both the data base on head injury and in construction of the various criteria." While not endorsing use of a HIC tolerance limit greater than 1000, Robbins finds that neither use of the Head Injury Criterion nor an injury tolerance level of 1000 are on firm ground. Further, Robbins finds that limiting allowable injuries to AIS 2 may be unnecessarily conservative; from examination of the AIS ratings associated with various brain and skull injuries, Robbins concludes "that cerebral concussion at the level AIS = 3 is a logical candidate for use as an upper limit in the construction of injury criteria for the head." This would allow, of course, use of greater tolerance levels than those defined for injuries with an AIS upper limit of 2.

In summary, there is considerable evidence that a HIC tolerance limit of 1500 is justified. Although it is by no means certain that the value 1000 is too conservative, there seems to be better evidence that it is, than that it is not. While 1500 has been used in the current study for the purpose of making specific statements relating to likelihood of head injury, the general conclusions of the study relating to the differences between helmeted and unhelmeted impacts are unaffected.

APPENDIX B

PEAK MAGNITUDES FOR
DYNAMIC RESPONSE VARIABLES

TABLE B-1. HIC SUMMARY

Simulation Type	Run No.	HIC	HIC Duration (msec)	Simulation Type	Run No.	HIC	HIC Duration (msec)
Head-Truck	1	3475	5	Head-Road (30°) (continued)	32	6032	5
	2	3317	5		33	1069	10
	3	3673	5		49	5618	30
	4	564	5		52	2686	35
	5	2573	3		53	579	10
	6	3388	5		56	1244	7
	7	3511	5		57	1301	10
	8	3927	5		58	1336	7
	54	574	5		60	4714	5
					64	1523	7
Chest-Truck	9	566	83				
	10	419	60	Head-Road (70°)	34	4440	65
	11	43	80		35	14009	65
	12	77	88		36	1437	8
	13	542	63		37	12624	17
	14	534	85		38	2842	63
	15	424	17		39	10190	65
	16	439	33		40	2933	30
	17	611	48		41	9108	18
	18	644	78		42	2671	82
	55	42	93		43	8063	25
					44	1175	58
Head-Road (30°)	19	1266	10		45	12535	18
	20	7621	30		46	1099	5
	21	1403	48		47	5138	5
	22	4787	7		48	4749	65
	23	1305	10		50	4385	18
	24	5486	30		51	1835	75
	25	1288	10		59	2671	82
	26	7603	17		61	8063	25
	27	8480	20		62	1992	30
	28	4714	5		63	2011	5
	29	931	12		65	3362	25
	30	11276	55				
	31	1411	5				

1

HR20NH5.3F

HIC= 3475. BETWEEN 0. AND 5.MSEC
3-MSEC AVG. FOR HEAD= 290. AT 2. MSEC
3-MSEC AVG. FOR CHEST= 22. AT 46. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	70.0	0.	204.8	49.
2-HEAD ANG. VELOCITY	-1196.6	55.	5964.9	19.
3-HEAD ANG. ACCEL.	-11989.6	27.	14807.9	2.
4-HEAD RESUL. ACCEL.	1.0	8.	491.4	2.
5-UPPER NECK STOP TORQUE	-304.1	10.	834.0	27.
6-LOWER NECK STOP TORQUE	-0.0	0.	1115.3	38.
7-Z DIR. HEAD CONT. FORCE	-746.3	4.	490.6	45.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	5026.9	2.
9-CONDYLE JOINT ANGLE	-2.7	10.	61.8	27.
10-C7-T1 JOINT ANGLE	-30.0	0.	27.1	39.
11-FORCE ALONG NECK	-1480.4	47.	1253.7	5.
12-SHEAR FORCE AT CONDYLES	-512.5	2.	25.5	90.
13-COMP. FORCE AT CONDYLES	-1444.3	47.	1320.3	5.
14-SHEAR FORCE AT C7-T1	-373.1	38.	94.4	25.
15-COMP. FORCE AT C7-T1	-1435.1	47.	1186.8	5.
16-CONDYLE TOTAL TORQUE	-404.5	10.	1240.7	27.
17-C7-T1 TOTAL TORQUE	-143.8	93.	2239.9	38.

2

HR20H5.1F

HIC= 3317. BETWEEN 2. AND 7.MSEC
3-MSEC AVG. FOR HEAD= 233. AT 5. MSEC
3-MSEC AVG. FOR CHEST= 18. AT 61. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	70.0	3.	228.1	74.
2-HEAD ANG. VELOCITY	-1527.3	100.	4699.9	26.
3-HEAD ANG. ACCEL.	-3361.6	34.	8740.5	13.
4-HEAD RESUL. ACCEL.	1.0	0.	245.0	6.
5-UPPER NECK STOP TORQUE	-1261.7	14.	722.2	63.
6-LOWER NECK STOP TORQUE	-0.0	0.	978.1	50.
7-Z DIR. HEAD CONT. FORCE	-389.1	6.	144.0	30.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	3890.9	6.
9-CONDYLE JOINT ANGLE	-33.2	14.	59.4	63.
10-C7-T1 JOINT ANGLE	-30.0	0.	24.7	50.
11-FORCE ALONG NECK	-899.0	12.	990.0	6.
12-SHEAR FORCE AT CONDYLES	-614.3	15.	9.3	34.
13-COMP. FORCE AT CONDYLES	-796.7	30.	1070.3	6.
14-SHEAR FORCE AT C7-T1	-578.5	15.	18.0	78.
15-COMP. FORCE AT C7-T1	-858.7	12.	935.7	6.
16-CONDYLE TOTAL TORQUE	-1596.6	14.	1045.5	63.
17-C7-T1 TOTAL TORQUE	-0.0	0.	1976.7	50.

3

HR20NH5.312

HIC= 3673. BETWEEN 0. AND 5.MSEC
3-MSEC AVG. FOR HEAD= 270. AT 1. MSEC
3-MSEC AVG. FOR CHEST= 23. AT 4. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	50.0	0.	193.8	74.
2-HEAD ANG. VELOCITY	-1568.1	83.	5748.2	21.
3-HEAD ANG. ACCEL.	-11652.4	27.	13920.8	1.
4-HEAD RESUL. ACCEL.	0.7	71.	489.8	1.
5-UPPER NECK STOP TORQUE	-446.9	11.	788.7	28.
6-LOWER NECK STOP TORQUE	-0.0	0.	1184.4	61.
7-Z DIR. HEAD CONT. FORCE	-800.1	2.	490.6	50.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	5288.1	1.
9-CONDYLE JOINT ANGLE	-22.1	11.	50.9	28.
10-C7-T1 JOINT ANGLE	-40.0	0.	18.2	61.
11-FORCE ALONG NECK	-1417.3	52.	1702.1	4.
12-SHEAR FORCE AT CONDYLES	-435.0	1.	48.6	29.
13-COMP. FORCE AT CONDYLES	-1373.1	52.	1752.4	4.
14-SHEAR FORCE AT C7-T1	-391.5	62.	100.6	27.
15-COMP. FORCE AT C7-T1	-1382.9	52.	1579.1	4.
16-CONDYLE TOTAL TORQUE	-621.3	11.	1201.7	28.
17-C7-T1 TOTAL TORQUE	-0.0	0.	2176.0	41.

4

HR10H5.1F

HIC= 564. BETWEEN 2. AND 7.MSEC
3-MSEC AVG. FOR HEAD= 116. AT 5. MSEC
3-MSEC AVG. FOR CHEST= 8. AT 7. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	70.0	4.	172.2	100.
2-HEAD ANG. VELOCITY	-4.1	3.	2371.6	30.
3-HEAD ANG. ACCEL.	-1533.0	37.	3231.0	16.
4-HEAD RESUL. ACCEL.	0.3	77.	120.4	6.
5-UPPER NECK STOP TORQUE	-464.8	16.	239.4	81.
6-LOWER NECK STOP TORQUE	-0.0	0.	251.3	94.
7-Z DIR. HEAD CONT. FORCE	-197.7	6.	54.0	36.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	1976.9	6.
9-CONDYLE JOINT ANGLE	-13.2	17.	44.2	81.
10-C7-T1 JOINT ANGLE	-30.0	0.	4.7	94.
11-FORCE ALONG NECK	-210.0	15.	607.3	7.
12-SHEAR FORCE AT CONDYLES	-248.1	17.	52.2	40.
13-COMP. FORCE AT CONDYLES	-180.9	15.	639.9	7.
14-SHEAR FORCE AT C7-T1	-245.7	17.	42.1	40.
15-COMP. FORCE AT C7-T1	-211.9	15.	570.9	7.
16-CONDYLE TOTAL TORQUE	-641.9	16.	435.5	81.
17-C7-T1 TOTAL TORQUE	-0.0	0.	874.2	64.

5

HR10NH5.3F

HIC= 2573. BETWEEN 2. AND 5.MSEC
3-MSEC AVG. FOR HEAD= 244. AT 3. MSEC
3-MSEC AVG. FOR CHEST= 12. AT 4. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	70.0	0.	156.9	100.
2-HEAD ANG. VELOCITY	-1029.6	78.	3885.2	21.
3-HEAD ANG. ACCEL.	-6890.5	31.	9669.4	4.
4-HEAD RESUL. ACCEL.	1.0	0.	298.3	3.
5-UPPER NECK STOP TORQUE	-246.7	10.	544.9	32.
6-LOWER NECK STOP TORQUE	-0.0	0.	314.1	47.
7-Z DIR. HEAD CONT. FORCE	-534.8	5.	487.9	77.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	3196.5	3.
9-CONDYLE JOINT ANGLE	0.7	11.	55.0	32.
10-C7-T1 JOINT ANGLE	-30.0	0.	7.4	48.
11-FORCE ALONG NECK	-853.5	79.	1061.6	5.
12-SHEAR FORCE AT CONDYLES	-323.5	3.	53.1	31.
13-COMP. FORCE AT CONDYLES	-825.7	79.	1110.6	4.
14-SHEAR FORCE AT C7-T1	-178.7	88.	87.3	31.
15-COMP. FORCE AT C7-T1	-823.5	79.	1001.1	5.
16-CONDYLE TOTAL TORQUE	-320.0	10.	887.2	32.
17-C7-T1 TOTAL TORQUE	-0.0	0.	1003.1	47.

6

HR20H1.1F

HIC= 3388. BETWEEN 2. AND 7.MSEC
3-MSEC AVG. FOR HEAD= 236. AT 5. MSEC
3-MSEC AVG. FOR CHEST= 22. AT 58. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	70.0	3.	243.0	76.
2-HEAD ANG. VELOCITY	-1044.1	100.	4741.4	29.
3-HEAD ANG. ACCEL.	-4416.2	40.	8710.1	14.
4-HEAD RESUL. ACCEL.	1.0	0.	248.0	6.
5-UPPER NECK STOP TORQUE	-1703.1	15.	1125.9	68.
6-LOWER NECK STOP TORQUE	-0.0	0.	1667.6	55.
7-Z DIR. HEAD CONT. FORCE	-388.6	6.	118.8	35.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	3885.6	6.
9-CONDYLE JOINT ANGLE	-38.4	15.	67.3	68.
10-C7-T1 JOINT ANGLE	-30.0	0.	35.3	56.
11-FORCE ALONG NECK	-944.5	12.	988.5	6.
12-SHEAR FORCE AT CONDYLES	-529.5	16.	28.1	40.
13-COMP. FORCE AT CONDYLES	-813.7	12.	1067.7	6.
14-SHEAR FORCE AT C7-T1	-507.7	16.	64.2	39.
15-COMP. FORCE AT C7-T1	-898.4	12.	937.3	6.
16-CONDYLE TOTAL TORQUE	-1792.8	15.	1210.8	68.
17-C7-T1 TOTAL TORQUE	-0.0	0.	1924.7	55.

7

HR20NH1.3F

HIC= 3511. BETWEEN 0. AND 5.MSEC
3-MSEC AVG. FOR HEAD= 292. AT 2. MSEC
3-MSEC AVG. FOR CHEST= 30. AT 46. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	70.0	0.	218.0	50.
2-HEAD ANG. VELOCITY	-1452.5	61.	6050.9	22.
3-HEAD ANG. ACCEL.	-12671.1	50.	14804.2	2.
4-HEAD RESUL. ACCEL.	1.0	0.	492.5	2.
5-UPPER NECK STOP TORQUE	-347.2	10.	1209.4	30.
6-LOWER NECK STOP TORQUE	-0.0	0.	1863.3	42.
7-Z DIR. HEAD CONT. FORCE	-766.9	4.	398.0	44.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	5035.6	2.
9-CONDYLE JOINT ANGLE	-5.6	11.	68.7	30.
10-C7-T1 JOINT ANGLE	-30.0	0.	37.7	43.
11-FORCE ALONG NECK	-1238.9	46.	1258.6	4.
12-SHEAR FORCE AT CONDYLES	-511.0	2.	27.5	51.
13-COMP. FORCE AT CONDYLES	-1242.2	46.	1322.0	4.
14-SHEAR FORCE AT C7-T1	-322.6	41.	154.5	29.
15-COMP. FORCE AT C7-T1	-1169.0	46.	1194.1	4.
16-CONDYLE TOTAL TORQUE	-376.9	10.	1320.4	30.
17-C7-T1 TOTAL TORQUE	-15.5	100.	2160.5	42.

8

HR20HM5.1F

HIC= 3927. BETWEEN 2. AND 7.MSEC
3-MSEC AVG. FOR HEAD= 271. AT 4. MSEC
3-MSEC AVG. FOR CHEST= 19. AT 64. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	70.0	0.	231.3	73.
2-HEAD ANG. VELOCITY	-1588.7	99.	4180.8	24.
3-HEAD ANG. ACCEL.	-3386.6	74.	7490.6	12.
4-HEAD RESUL. ACCEL.	1.0	0.	287.4	5.
5-UPPER NECK STOP TORQUE	-1122.4	13.	950.2	74.
6-LOWER NECK STOP TORQUE	-0.0	0.	1055.3	65.
7-Z DIR. HEAD CONT. FORCE	-330.3	5.	168.0	25.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	3302.6	5.
9-CONDYLE JOINT ANGLE	-31.2	14.	64.1	74.
10-C7-T1 JOINT ANGLE	-30.0	0.	26.0	65.
11-FORCE ALONG NECK	-911.9	27.	970.2	5.
12-SHEAR FORCE AT CONDYLES	-556.2	14.	103.9	75.
13-COMP. FORCE AT CONDYLES	-885.5	27.	1054.5	5.
14-SHEAR FORCE AT C7-T1	-551.6	14.	133.2	74.
15-COMP. FORCE AT C7-T1	-894.8	27.	917.3	5.
16-CONDYLE TOTAL TORQUE	-1442.6	13.	1279.1	56.
17-C7-T1 TOTAL TORQUE	-0.0	0.	1910.9	65.

9

CR20NH5.3

HIC= 566. BETWEEN 17. AND 100.MSEC
3-MSEC AVG. FOR HEAD= 70. AT 30. MSEC
3-MSEC AVG. FOR CHEST= 61. AT 23. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	0.8	53.	157.4	100.
2-HEAD ANG. VELOCITY	-3753.7	42.	4156.8	84.
3-HEAD ANG. ACCEL.	-3919.8	37.	11107.2	54.
4-HEAD RESUL. ACCEL.	1.0	0.	70.6	30.
5-UPPER NECK STOP TORQUE	-1497.2	54.	111.6	98.
6-LOWER NECK STOP TORQUE	-1077.4	61.	10.4	100.
7-Z DIR. HEAD CONT. FORCE	-40.0	20.	955.3	29.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	5366.7	28.
9-CONDYLE JOINT ANGLE	-36.2	55.	36.5	99.
10-C7-T1 JOINT ANGLE	-70.5	62.	-18.0	100.
11-FORCE ALONG NECK	-730.7	30.	211.1	56.
12-SHEAR FORCE AT CONDYLES	-76.9	100.	317.5	40.
13-COMP. FORCE AT CONDYLES	-636.2	30.	233.7	56.
14-SHEAR FORCE AT C7-T1	-129.1	100.	347.3	39.
15-COMP. FORCE AT C7-T1	-867.3	29.	166.1	57.
16-CONDYLE TOTAL TORQUE	-1869.8	54.	357.4	98.
17-C7-T1 TOTAL TORQUE	-1832.8	42.	698.5	100.

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CR20H5.3

HIC= 419. BETWEEN 17. AND 77.MSEC
3-MSEC AVG. FOR HEAD= 70. AT 30. MSEC
3-MSEC AVG. FOR CHEST= 61. AT 23. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-7.5	60.	70.0	5.
2-HEAD ANG. VELOCITY	-3244.8	47.	3207.6	100.
3-HEAD ANG. ACCEL.	-2689.9	33.	7391.0	60.
4-HEAD RESUL. ACCEL.	1.0	0.	70.4	30.
5-UPPER NECK STOP TORQUE	-2497.0	60.	44.2	33.
6-LOWER NECK STOP TORQUE	-1803.6	72.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-96.2	21.	859.7	29.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	5440.0	28.
9-CONDYLE JOINT ANGLE	-45.3	61.	29.5	33.
10-C7-T1 JOINT ANGLE	-79.4	72.	-30.0	0.
11-FORCE ALONG NECK	-956.8	30.	227.3	63.
12-SHEAR FORCE AT CONDYLES	-326.4	60.	422.7	73.
13-COMP. FORCE AT CONDYLES	-863.4	30.	234.8	63.
14-SHEAR FORCE AT C7-T1	-362.6	60.	419.8	72.
15-COMP. FORCE AT C7-T1	-1079.0	30.	213.8	64.
16-CONDYLE TOTAL TORQUE	-2936.4	60.	182.9	33.
17-C7-T1 TOTAL TORQUE	-2615.6	72.	-0.0	0.

11

CR10H5.3

HIC= 43. BETWEEN 7. AND 87.MSEC
3-MSEC AVG. FOR HEAD= 16. AT 44. MSEC
3-MSEC AVG. FOR CHEST= 14. AT 14. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	24.7	82.	70.0	6.
2-HEAD ANG. VELOCITY	-1282.5	48.	1526.6	100.
3-HEAD ANG. ACCEL.	-790.9	32.	1989.4	97.
4-HEAD RESUL. ACCEL.	1.0	0.	16.0	44.
5-UPPER NECK STOP TORQUE	-626.4	95.	3.3	28.
6-LOWER NECK STOP TORQUE	-869.9	81.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	347.4	52.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	1179.6	39.
9-CONDYLE JOINT ANGLE	-20.2	96.	18.2	28.
10-C7-T1 JOINT ANGLE	-66.6	81.	-30.0	0.
11-FORCE ALONG NECK	-173.1	48.	35.1	89.
12-SHEAR FORCE AT CONDYLES	0.0	0.	182.2	79.
13-COMP. FORCE AT CONDYLES	-159.7	48.	36.4	89.
14-SHEAR FORCE AT C7-T1	-5.8	99.	181.3	76.
15-COMP. FORCE AT C7-T1	-198.6	48.	41.2	88.
16-CONDYLE TOTAL TORQUE	-812.7	95.	62.1	27.
17-C7-T1 TOTAL TORQUE	-1489.2	80.	-0.0	0.

12

CR10NH5.3

HIC= 77. BETWEEN 12. AND 100.MSEC
3-MSEC AVG. FOR HEAD= 20. AT 57. MSEC
3-MSEC AVG. FOR CHEST= 14. AT 13. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	38.0	68.	85.5	100.
2-HEAD ANG. VELOCITY	-1222.2	37.	2281.9	100.
3-HEAD ANG. ACCEL.	-1158.4	24.	2413.8	77.
4-HEAD RESUL. ACCEL.	1.0	0.	20.1	100.
5-UPPER NECK STOP TORQUE	-352.0	76.	1.6	22.
6-LOWER NECK STOP TORQUE	-594.3	65.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	342.6	50.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	1172.4	38.
9-CONDYLE JOINT ANGLE	-5.8	76.	16.5	22.
10-C7-T1 JOINT ANGLE	-59.0	66.	-30.0	0.
11-FORCE ALONG NECK	-179.2	100.	0.0	0.
12-SHEAR FORCE AT CONDYLES	-0.0	0.	162.9	57.
13-COMP. FORCE AT CONDYLES	-162.6	100.	-0.0	0.
14-SHEAR FORCE AT C7-T1	-0.0	0.	192.2	56.
15-COMP. FORCE AT C7-T1	-185.1	100.	0.0	0.
16-CONDYLE TOTAL TORQUE	-460.6	76.	49.7	21.
17-C7-T1 TOTAL TORQUE	-1129.5	63.	-0.0	0.

13

CR20H1.3

HIC= 542. BETWEEN 17. AND 80.MSEC
3-MSEC AVG. FOR HEAD= 74. AT 30. MSEC
3-MSEC AVG. FOR CHEST= 61. AT 23. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-13.7	63.	70.0	8.
2-HEAD ANG. VELOCITY	-3497.1	50.	3169.6	100.
3-HEAD ANG. ACCEL.	-2815.5	33.	8005.6	62.
4-HEAD RESUL. ACCEL.	1.0	0.	74.6	30.
5-UPPER NECK STOP TORQUE	-3035.8	62.	116.3	34.
6-LOWER NECK STOP TORQUE	-2698.4	74.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-136.6	21.	798.3	29.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	5403.2	28.
9-CONDYLE JOINT ANGLE	-48.9	63.	36.9	35.
10-C7-T1 JOINT ANGLE	-86.7	75.	-30.0	0.
11-FORCE ALONG NECK	-1029.8	30.	252.0	65.
12-SHEAR FORCE AT CONDYLES	-475.9	62.	497.6	75.
13-COMP. FORCE AT CONDYLES	-926.7	30.	266.0	64.
14-SHEAR FORCE AT C7-T1	-507.0	62.	504.1	75.
15-COMP. FORCE AT C7-T1	-1150.2	30.	213.1	65.
16-CONDYLE TOTAL TORQUE	-3153.3	62.	161.6	34.
17-C7-T1 TOTAL TORQUE	-2900.0	74.	-0.0	0.

14

CR20NH1.3

HIC= 534. BETWEEN 15. AND 100.MSEC
3-MSEC AVG. FOR HEAD= 72. AT 29. MSEC
3-MSEC AVG. FOR CHEST= 62. AT 23. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-8.1	55.	143.9	100.
2-HEAD ANG. VELOCITY	-4354.2	45.	4484.9	90.
3-HEAD ANG. ACCEL.	-4547.0	33.	13670.3	56.
4-HEAD RESUL. ACCEL.	0.6	54.	73.0	29.
5-UPPER NECK STOP TORQUE	-2179.1	56.	118.0	100.
6-LOWER NECK STOP TORQUE	-1733.6	65.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-72.1	20.	919.5	29.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	5333.2	28.
9-CONDYLE JOINT ANGLE	-42.9	56.	37.0	100.
10-C7-T1 JOINT ANGLE	-78.7	65.	-30.0	0.
11-FORCE ALONG NECK	-781.5	30.	297.1	58.
12-SHEAR FORCE AT CONDYLES	-215.5	56.	324.3	43.
13-COMP. FORCE AT CONDYLES	-675.6	30.	323.0	57.
14-SHEAR FORCE AT C7-T1	-288.9	56.	354.4	65.
15-COMP. FORCE AT C7-T1	-921.9	29.	238.0	58.
16-CONDYLE TOTAL TORQUE	-2287.1	56.	184.4	100.
17-C7-T1 TOTAL TORQUE	-1909.9	65.	61.6	100.

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CR20H5.3I2

HIC= 424. BETWEEN 20. AND 37.MSEC
3-MSEC AVG. FOR HEAD= 71. AT 30. MSEC
3-MSEC AVG. FOR CHEST= 60. AT 23. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-11.2	63.	55.2	100.
2-HEAD ANG. VELOCITY	-2637.1	49.	2691.5	100.
3-HEAD ANG. ACCEL.	-2245.3	35.	5729.6	63.
4-HEAD RESUL. ACCEL.	1.0	0.	71.9	30.
5-UPPER NECK STOP TORQUE	-1934.3	64.	72.0	35.
6-LOWER NECK STOP TORQUE	-1083.2	79.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-88.0	20.	941.5	29.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	5532.2	28.
9-CONDYLE JOINT ANGLE	-50.7	64.	22.9	35.
10-C7-T1 JOINT ANGLE	-80.6	79.	-40.0	0.
11-FORCE ALONG NECK	-987.4	30.	196.3	65.
12-SHEAR FORCE AT CONDYLES	-327.6	64.	311.2	44.
13-COMP. FORCE AT CONDYLES	-891.7	30.	210.5	65.
14-SHEAR FORCE AT C7-T1	-336.5	64.	317.1	44.
15-COMP. FORCE AT C7-T1	-1123.1	29.	157.1	65.
16-CONDYLE TOTAL TORQUE	-2346.0	64.	233.5	35.
17-C7-T1 TOTAL TORQUE	-1706.7	79.	-0.0	0.

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CR20NH5.3I2

HIC= 439. BETWEEN 17. AND 50.MSEC
3-MSEC AVG. FOR HEAD= 72. AT 29. MSEC
3-MSEC AVG. FOR CHEST= 61. AT 23. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-2.3	55.	139.8	100.
2-HEAD ANG. VELOCITY	-3205.5	44.	3628.7	72.
3-HEAD ANG. ACCEL.	-3969.5	35.	9156.7	56.
4-HEAD RESUL. ACCEL.	1.0	0.	72.7	29.
5-UPPER NECK STOP TORQUE	-1140.9	57.	71.4	33.
6-LOWER NECK STOP TORQUE	-733.0	42.	16.4	100.
7-Z DIR. HEAD CONT. FORCE	-25.6	20.	1039.9	29.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	5431.2	28.
9-CONDYLE JOINT ANGLE	-41.5	57.	22.9	33.
10-C7-T1 JOINT ANGLE	-73.4	43.	-26.0	100.
11-FORCE ALONG NECK	-744.7	29.	166.1	60.
12-SHEAR FORCE AT CONDYLES	-100.0	57.	260.6	42.
13-COMP. FORCE AT CONDYLES	-646.4	29.	181.9	59.
14-SHEAR FORCE AT C7-T1	-179.5	100.	315.5	31.
15-COMP. FORCE AT C7-T1	-898.1	29.	145.2	61.
16-CONDYLE TOTAL TORQUE	-1486.5	57.	234.3	33.
17-C7-T1 TOTAL TORQUE	-1433.4	42.	704.8	100.

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CR20H5.3I3

HIC= 611. BETWEEN 22. AND 70.MSEC
3-MSEC AVG. FOR HEAD= 70. AT 31. MSEC
3-MSEC AVG. FOR CHEST= 63. AT 23. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	7.4	57.	100.0	0.
2-HEAD ANG. VELOCITY	-4410.4	44.	3139.2	88.
3-HEAD ANG. ACCEL.	-4281.1	33.	8836.2	54.
4-HEAD RESUL. ACCEL.	0.9	3.	70.4	31.
5-UPPER NECK STOP TORQUE	-2961.9	55.	110.2	32.
6-LOWER NECK STOP TORQUE	-3123.9	65.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	725.2	28.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	5228.2	27.
9-CONDYLE JOINT ANGLE	-48.4	55.	36.4	32.
10-C7-T1 JOINT ANGLE	-59.4	65.	0.0	0.
11-FORCE ALONG NECK	-875.6	30.	235.0	66.
12-SHEAR FORCE AT CONDYLES	-389.3	54.	692.9	65.
13-COMP. FORCE AT CONDYLES	-787.9	30.	204.0	66.
14-SHEAR FORCE AT C7-T1	-390.1	54.	730.7	65.
15-COMP. FORCE AT C7-T1	-943.0	30.	292.3	65.
16-CONDYLE TOTAL TORQUE	-3440.5	55.	300.6	32.
17-C7-T1 TOTAL TORQUE	-4146.9	65.	-0.0	0.

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CR20NH5.3I3

HIC= 644. BETWEEN 22. AND 100.MSEC
3-MSEC AVG. FOR HEAD= 68. AT 31. MSEC
3-MSEC AVG. FOR CHEST= 64. AT 23. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	10.2	50.	172.1	100.
2-HEAD ANG. VELOCITY	-5111.0	40.	4968.7	79.
3-HEAD ANG. ACCEL.	-5941.0	36.	15702.5	50.
4-HEAD RESUL. ACCEL.	0.8	3.	68.7	31.
5-UPPER NECK STOP TORQUE	-2324.2	50.	244.4	92.
6-LOWER NECK STOP TORQUE	-2094.0	57.	2.1	100.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	828.8	28.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	5198.1	27.
9-CONDYLE JOINT ANGLE	-43.9	50.	44.4	92.
10-C7-T1 JOINT ANGLE	-52.1	57.	7.0	100.
11-FORCE ALONG NECK	-690.0	31.	349.3	52.
12-SHEAR FORCE AT CONDYLES	-131.9	50.	508.3	38.
13-COMP. FORCE AT CONDYLES	-609.0	31.	382.7	51.
14-SHEAR FORCE AT C7-T1	-139.6	50.	553.2	38.
15-COMP. FORCE AT C7-T1	-762.1	30.	269.7	52.
16-CONDYLE TOTAL TORQUE	-2757.5	50.	575.1	92.
17-C7-T1 TOTAL TORQUE	-3021.4	57.	645.6	100.

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RH20H5.2F

HIC= 1266. BETWEEN 5. AND 15.MSEC
3-MSEC AVG. FOR HEAD= 131. AT 8. MSEC
3-MSEC AVG. FOR CHEST= 23. AT 78. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.5	6.	70.7	74.
2-HEAD ANG. VELOCITY	-1781.3	100.	2875.0	32.
3-HEAD ANG. ACCEL.	-1844.8	78.	4559.9	19.
4-HEAD RESUL. ACCEL.	0.9	2.	133.4	8.
5-UPPER NECK STOP TORQUE	-551.4	19.	347.9	75.
6-LOWER NECK STOP TORQUE	-0.0	0.	186.1	61.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3139.7	9.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	627.9	9.
9-CONDYLE JOINT ANGLE	-7.3	19.	58.7	75.
10-C7-T1 JOINT ANGLE	-20.0	0.	11.4	61.
11-FORCE ALONG NECK	-525.9	19.	2371.9	11.
12-SHEAR FORCE AT CONDYLES	-337.8	19.	60.9	78.
13-COMP. FORCE AT CONDYLES	-458.3	19.	2321.8	11.
14-SHEAR FORCE AT C7-T1	-310.1	19.	118.7	79.
15-COMP. FORCE AT C7-T1	-515.4	19.	2304.7	11.
16-CONDYLE TOTAL TORQUE	-761.4	19.	578.8	74.
17-C7-T1 TOTAL TORQUE	-220.0	99.	854.0	21.

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RNH20H5.6F

HIC= 7621. BETWEEN 0. AND 30.MSEC
3-MSEC AVG. FOR HEAD= 324. AT 2. MSEC
3-MSEC AVG. FOR CHEST= 38. AT 5. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.1	1.	46.5	18.
2-HEAD ANG. VELOCITY	-3666.0	25.	8379.3	10.
3-HEAD ANG. ACCEL.	-27463.1	14.	24337.0	3.
4-HEAD RESUL. ACCEL.	1.0	0.	398.2	2.
5-UPPER NECK STOP TORQUE	-466.0	33.	4218.2	14.
6-LOWER NECK STOP TORQUE	-527.5	12.	1058.0	32.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4827.9	3.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	2896.7	3.
9-CONDYLE JOINT ANGLE	-3.2	33.	108.9	14.
10-C7-T1 JOINT ANGLE	-46.4	13.	36.1	32.
11-FORCE ALONG NECK	-1441.9	25.	4271.5	5.
12-SHEAR FORCE AT CONDYLES	-598.5	33.	1283.9	14.
13-COMP. FORCE AT CONDYLES	-1270.1	25.	4044.8	5.
14-SHEAR FORCE AT C7-T1	-662.7	33.	1453.2	14.
15-COMP. FORCE AT C7-T1	-1385.9	25.	4090.7	5.
16-CONDYLE TOTAL TORQUE	-751.8	33.	4908.5	14.
17-C7-T1 TOTAL TORQUE	-1165.7	12.	2418.2	32.

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RH20H5.6F

HIC= 1403. BETWEEN 2. AND 50.MSEC
3-MSEC AVG. FOR HEAD= 121. AT 4. MSEC
3-MSEC AVG. FCR CHEST= 47. AT 11. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.3	3.	80.5	82.
2-HEAD ANG. VELOCITY	-825.9	96.	3165.9	18.
3-HEAD ANG. ACCEL.	-5284.2	21.	6424.1	13.
4-HEAD RESUL. ACCEL.	1.0	0.	125.2	4.
5-UPPER NECK STOP TORQUE	-385.0	47.	888.1	24.
6-LOWER NECK STOP TORQUE	-1056.9	23.	440.9	49.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3489.9	14.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	2094.0	14.
9-CONDYLE JOINT ANGLE	1.9	47.	72.9	24.
10-C7-T1 JOINT ANGLE	-60.1	23.	21.9	49.
11-FORCE ALONG NECK	-1157.1	39.	4821.3	11.
12-SHEAR FORCE AT CONDYLES	-435.1	48.	732.4	23.
13-COMP. FORCE AT CONDYLES	-1045.2	39.	4715.2	11.
14-SHEAR FORCE AT C7-T1	-421.9	49.	749.6	23.
15-COMP. FORCE AT C7-T1	-1135.8	39.	4593.4	11.
16-CONDYLE TOTAL TORQUE	-601.7	47.	1288.5	24.
17-C7-T1 TOTAL TORQUE	-1998.0	23.	1553.1	48.

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RNH20H5.2F

HIC= 4787. BETWEEN 0. AND 7.MSEC
3-MSEC AVG. FOR HEAD= 310. AT 2. MSEC
3-MSEC AVG. FOR CHEST= 26. AT 73. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.1	1.	59.6	58.
2-HEAD ANG. VELOCITY	-2676.1	77.	3299.9	18.
3-HEAD ANG. ACCEL.	-4365.0	30.	17203.4	3.
4-HEAD RESUL. ACCEL.	1.0	0.	367.7	2.
5-UPPER NECK STOP TORQUE	-302.9	88.	372.8	31.
6-LOWER NECK STOP TORQUE	-305.6	100.	329.1	49.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4770.0	3.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	954.0	3.
9-CONDYLE JOINT ANGLE	7.4	88.	59.6	31.
10-C7-T1 JOINT ANGLE	-32.7	100.	18.0	49.
11-FORCE ALONG NECK	-644.8	12.	2882.2	5.
12-SHEAR FORCE AT CONDYLES	-314.3	45.	134.0	99.
13-COMP. FORCE AT CONDYLES	-571.7	12.	2839.3	4.
14-SHEAR FORCE AT C7-T1	-133.0	38.	121.2	100.
15-COMP. FORCE AT C7-T1	-635.6	12.	2789.4	5.
16-CONDYLE TOTAL TORQUE	-517.6	88.	659.2	31.
17-C7-T1 TOTAL TORQUE	-869.7	99.	1003.5	49.

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RH10H5.2F

HIC= 1305. BETWEEN 2. AND 12.MSEC
3-MSEC AVG. FOR HEAD= 131. AT 5. MSEC
3-MSEC AVG. FOR CHEST= 23. AT 75. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.3	4.	70.6	71.
2-HEAD ANG. VELOCITY	-1796.3	100.	2869.7	30.
3-HEAD ANG. ACCEL.	-1831.7	76.	4543.6	17.
4-HEAD RESUL. ACCEL.	1.0	0.	133.3	6.
5-UPPER NECK STOP TORQUE	-550.2	17.	344.6	73.
6-LOWER NECK STOP TORQUE	-0.0	0.	183.7	58.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3127.3	7.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	625.5	7.
9-CONDYLE JOINT ANGLE	-7.3	17.	58.6	73.
10-C7-T1 JOINT ANGLE	-20.0	0.	11.3	59.
11-FORCE ALONG NECK	-523.3	17.	2348.3	9.
12-SHEAR FORCE AT CONDYLES	-336.7	17.	59.9	75.
13-COMP. FORCE AT CONDYLES	-456.5	17.	2304.8	9.
14-SHEAR FORCE AT C7-T1	-309.3	17.	116.8	77.
15-COMP. FORCE AT C7-T1	-512.7	17.	2282.2	9.
16-CONDYLE TOTAL TORQUE	-759.5	17.	575.2	72.
17-C7-T1 TOTAL TORQUE	-218.5	97.	854.0	18.

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RNH10H5.6F

HIC= 5486. BETWEEN 0. AND 30.MSEC
3-MSEC AVG. FOR HEAD= 329. AT 2. MSEC
3-MSEC AVG. FOR CHEST= 35. AT 5. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.1	1.	53.6	46.
2-HEAD ANG. VELOCITY	-3181.7	54.	7683.0	11.
3-HEAD ANG. ACCEL.	-23142.4	15.	23944.3	3.
4-HEAD RESUL. ACCEL.	1.0	0.	398.2	2.
5-UPPER NECK STOP TORQUE	-401.7	91.	2853.6	15.
6-LOWER NECK STOP TORQUE	-383.2	12.	1101.2	32.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4827.9	3.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	2896.7	3.
9-CONDYLE JOINT ANGLE	0.7	91.	98.1	15.
10-C7-T1 JOINT ANGLE	-38.0	13.	36.8	32.
11-FORCE ALONG NECK	-1116.6	25.	4030.4	5.
12-SHEAR FORCE AT CONDYLES	-541.0	33.	821.0	15.
13-COMP. FORCE AT CONDYLES	-971.2	25.	3823.2	5.
14-SHEAR FORCE AT C7-T1	-600.3	33.	951.0	14.
15-COMP. FORCE AT C7-T1	-1072.5	25.	3867.9	5.
16-CONDYLE TOTAL TORQUE	-609.9	91.	3457.9	15.
17-C7-T1 TOTAL TORQUE	-1017.6	76.	2448.1	32.

25

RH20H1.2F

HIC= 1288. BETWEEN 5. AND 15.MSEC
3-MSEC AVG. FOR HEAD= 132. AT 8. MSEC
3-MSEC AVG. FOR CHEST= 28. AT 80. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.6	7.	86.1	76.
2-HEAD ANG. VELOCITY	-1284.5	100.	2851.5	35.
3-HEAD ANG. ACCEL.	-2146.1	68.	4382.0	20.
4-HEAD RESUL. ACCEL.	0.3	77.	134.1	8.
5-UPPER NECK STOP TORQUE	-763.9	21.	706.8	69.
6-LOWER NECK STOP TORQUE	-0.0	0.	315.5	23.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3136.5	9.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	627.3	9.
9-CONDYLE JOINT ANGLE	-14.2	21.	69.0	69.
10-C7-T1 JOINT ANGLE	-20.0	0.	17.5	24.
11-FORCE ALONG NECK	-513.5	19.	2356.4	11.
12-SHEAR FORCE AT CONDYLES	-253.8	21.	91.4	69.
13-COMP. FORCE AT CONDYLES	-447.4	19.	2311.6	11.
14-SHEAR FORCE AT C7-T1	-242.0	21.	145.7	69.
15-COMP. FORCE AT C7-T1	-495.4	19.	2292.6	11.
16-CONDYLE TOTAL TORQUE	-826.4	21.	789.0	69.
17-C7-T1 TOTAL TORQUE	-67.4	100.	520.2	23.

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RNH20H1.6F

HIC= 7603. BETWEEN 0. AND 17.MSEC
3-MSEC AVG. FOR HEAD= 325. AT 2. MSEC
3-MSEC AVG. FOR CHEST= 39. AT 5. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.1	1.	52.3	56.
2-HEAD ANG. VELOCITY	-3985.4	28.	9005.9	10.
3-HEAD ANG. ACCEL.	-29872.6	14.	24568.2	3.
4-HEAD RESUL. ACCEL.	1.0	0.	398.3	2.
5-UPPER NECK STOP TORQUE	-858.5	37.	5669.6	15.
6-LOWER NECK STOP TORQUE	-624.9	13.	1350.4	38.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4828.0	3.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	2896.8	3.
9-CONDYLE JOINT ANGLE	-16.4	38.	118.1	15.
10-C7-T1 JOINT ANGLE	-50.2	13.	40.8	38.
11-FORCE ALONG NECK	-1276.9	28.	4263.7	5.
12-SHEAR FORCE AT CONDYLES	-460.2	38.	1425.0	15.
13-COMP. FORCE AT CONDYLES	-1129.9	28.	4041.4	5.
14-SHEAR FORCE AT C7-T1	-519.5	38.	1592.0	15.
15-COMP. FORCE AT C7-T1	-1229.5	28.	4080.2	5.
16-CONDYLE TOTAL TORQUE	-960.0	37.	5852.7	15.
17-C7-T1 TOTAL TORQUE	-801.7	13.	1697.2	38.

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RH20H5.10F

HIC= 8480. BETWEEN 5. AND 25.MSEC
3-MSEC AVG. FOR HEAD= 271. AT 14. MSEC
3-MSEC AVG. FOR CHEST= 52. AT 11. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.4	5.	44.6	100.
2-HEAD ANG. VELOCITY	-1334.1	39.	3531.7	61.
3-HEAD ANG. ACCEL.	-10915.8	19.	12299.8	13.
4-HEAD RESUL. ACCEL.	0.9	2.	309.2	15.
5-UPPER NECK STOP TORQUE	-1118.7	49.	4397.5	21.
6-LOWER NECK STOP TORQUE	-8349.8	21.	400.5	86.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4407.7	14.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	4407.7	14.
9-CONDYLE JOINT ANGLE	-21.1	49.	110.2	21.
10-C7-T1 JOINT ANGLE	-100.3	21.	20.6	87.
11-FORCE ALONG NECK	-1234.5	42.	4910.2	11.
12-SHEAR FORCE AT CONDYLES	-520.5	49.	3559.8	21.
13-COMP. FORCE AT CONDYLES	-1108.8	42.	4907.6	11.
14-SHEAR FORCE AT C7-T1	-503.6	50.	3821.9	21.
15-COMP. FORCE AT C7-T1	-1206.8	42.	4596.9	11.
16-CONDYLE TOTAL TORQUE	-1550.4	49.	5090.4	21.
17-C7-T1 TOTAL TORQUE	-10235.9	21.	1473.6	86.

28

RNH20H5.10F

HIC= 4714. BETWEEN 2. AND 7.MSEC
3-MSEC AVG. FOR HEAD= 326. AT 4. MSEC
3-MSEC AVG. FOR CHEST= 30. AT 73. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.3	3.	66.5	51.
2-HEAD ANG. VELOCITY	-2776.9	66.	4840.0	21.
3-HEAD ANG. ACCEL.	-8359.8	30.	14414.0	5.
4-HEAD RESUL. ACCEL.	0.9	2.	386.3	5.
5-UPPER NECK STOP TORQUE	-279.4	77.	786.1	31.
6-LOWER NECK STOP TORQUE	-302.1	93.	508.9	44.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4721.8	5.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	-0.0	0.
9-CONDYLE JOINT ANGLE	8.9	77.	70.8	31.
10-C7-T1 JOINT ANGLE	-32.5	93.	24.0	44.
11-FORCE ALONG NECK	-519.6	14.	2263.8	6.
12-SHEAR FORCE AT CONDYLES	-359.8	5.	172.2	92.
13-COMP. FORCE AT CONDYLES	-459.6	14.	2276.1	6.
14-SHEAR FORCE AT C7-T1	-208.6	13.	181.5	93.
15-COMP. FORCE AT C7-T1	-503.6	14.	2192.3	6.
16-CONDYLE TOTAL TORQUE	-482.9	77.	1175.3	31.
17-C7-T1 TOTAL TORQUE	-954.6	92.	1339.4	44.

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RH20H5.212

HIC= 931. BETWEEN 0. AND 12.MSEC
3-MSEC AVG. FOR HEAD= 124. AT 4. MSEC
3-MSEC AVG. FOR CHEST= 20. AT 93. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-81.9	18.	33.3	100.
2-HEAD ANG. VELOCITY	-2395.5	11.	1993.5	79.
3-HEAD ANG. ACCEL.	-6088.3	8.	8049.4	16.
4-HEAD RESUL. ACCEL.	0.7	62.	126.9	5.
5-UPPER NECK STOP TORQUE	-2317.3	18.	319.2	96.
6-LOWER NECK STOP TORQUE	-220.3	53.	101.7	16.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3131.8	6.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	626.4	6.
9-CONDYLE JOINT ANGLE	-58.9	18.	32.6	96.
10-C7-T1 JOINT ANGLE	-32.9	53.	0.7	16.
11-FORCE ALONG NECK	-318.3	85.	2229.8	8.
12-SHEAR FORCE AT CONDYLES	-751.0	18.	109.1	94.
13-COMP. FORCE AT CONDYLES	-294.4	85.	2199.5	8.
14-SHEAR FORCE AT C7-T1	-685.8	17.	117.9	95.
15-COMP. FORCE AT C7-T1	-358.3	84.	2148.2	8.
16-CONDYLE TOTAL TORQUE	-2727.9	18.	677.0	96.
17-C7-T1 TOTAL TORQUE	-482.4	53.	710.3	16.

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RNH20H5.612

HIC= 11276. BETWEEN 2. AND 57.MSEC
3-MSEC AVG. FOR HEAD= 391. AT 35. MSEC
3-MSEC AVG. FOR CHEST= 39. AT 36. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-158.9	30.	28.1	100.
2-HEAD ANG. VELOCITY	-9315.8	7.	7502.6	52.
3-HEAD ANG. ACCEL.	-45497.5	55.	29727.3	11.
4-HEAD RESUL. ACCEL.	1.0	0.	444.8	35.
5-UPPER NECK STOP TORQUE	-4387.9	11.	13.5	100.
6-LOWER NECK STOP TORQUE	-8320.7	42.	23.3	100.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	5108.8	2.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	3065.3	2.
9-CONDYLE JOINT ANGLE	-71.3	12.	8.1	100.
10-C7-T1 JOINT ANGLE	-105.4	42.	-9.3	100.
11-FORCE ALONG NECK	-366.1	100.	3702.2	4.
12-SHEAR FORCE AT CONDYLES	-1035.6	11.	1943.6	41.
13-COMP. FORCE AT CONDYLES	-333.6	100.	3589.9	4.
14-SHEAR FORCE AT C7-T1	-1064.2	11.	2189.0	41.
15-COMP. FORCE AT C7-T1	-364.1	100.	3539.3	4.
16-CONDYLE TOTAL TORQUE	-4907.7	11.	273.4	100.
17-C7-T1 TOTAL TORQUE	-9911.9	42.	1110.9	100.

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RH20H5.2NM

HIC= 1411. BETWEEN 5. AND 10.MSEC
3-MSEC AVG. FOR HEAD= 165. AT 8. MSEC
3-MSEC AVG, FOR CHEST= 127. AT 8. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.6	7.	11.5	31.
2-HEAD ANG. VELOCITY	-500.7	96.	1323.3	26.
3-HEAD ANG. ACCEL.	-1386.9	38.	1975.9	16.
4-HEAD RESUL. ACCEL.	0.2	93.	172.3	8.
5-UPPER NECK STOP TORQUE	-319.4	16.	132.5	39.
6-LOWER NECK STOP TORQUE	-128.9	38.	51.9	61.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	2919.7	8.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	583.9	8.
9-CONDYLE JOINT ANGLE	6.4	16.	48.1	40.
10-C7-T1 JOINT ANGLE	-24.0	38.	0.5	62.
11-FORCE ALONG NECK	-53.2	15.	626.1	9.
12-SHEAR FORCE AT CONDYLES	-197.8	9.	122.2	38.
13-COMP. FORCE AT CONDYLES	-46.7	15.	806.1	9.
14-SHEAR FORCE AT C7-T1	-61.3	16.	45.5	38.
15-COMP. FORCE AT C7-T1	-23.2	15.	251.6	9.
16-CONDYLE TOTAL TORQUE	-425.5	16.	354.1	39.
17-C7-T1 TOTAL TORQUE	-295.2	38.	471.7	61.

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RNH20H5.6NM

HIC= 6032. BETWEEN 2. AND 7.MSEC
3-MSEC AVG. FOR HEAD= 387. AT 4. MSEC
3-MSEC AVG. FOR CHEST= 300. AT 5. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.3	3.	37.2	41.
2-HEAD ANG. VELOCITY	-1878.2	57.	4350.4	7.
3-HEAD ANG. ACCEL.	-5904.6	16.	24866.0	5.
4-HEAD RESUL. ACCEL.	1.0	2.	461.9	5.
5-UPPER NECK STOP TORQUE	-235.9	92.	409.1	43.
6-LOWER NECK STOP TORQUE	-215.0	89.	246.6	31.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4701.1	5.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	2820.7	5.
9-CONDYLE JOINT ANGLE	11.3	92.	60.9	43.
10-C7-T1 JOINT ANGLE	-27.6	89.	14.6	31.
11-FORCE ALONG NECK	-115.1	11.	1648.6	6.
12-SHEAR FORCE AT CONDYLES	-168.4	30.	88.8	14.
13-COMP. FORCE AT CONDYLES	-119.8	10.	2118.8	5.
14-SHEAR FORCE AT C7-T1	-58.2	30.	49.2	6.
15-COMP. FORCE AT C7-T1	-41.0	11.	660.6	6.
16-CONDYLE TOTAL TORQUE	-387.2	92.	656.0	43.
17-C7-T1 TOTAL TORQUE	-591.7	88.	1042.4	31.

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RH20H5.2NR

HIC= 1069. BETWEEN 2. AND 12.MSEC
3-MSEC AVG. FOR HEAD= 123. AT 6. MSEC
3-MSEC AVG. FOR CHEST= 27. AT 78. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.0	0.	66.7	70.
2-HEAD ANG. VELOCITY	-1435.4	100.	2738.3	30.
3-HEAD ANG. ACCEL.	-1845.9	72.	3991.5	17.
4-HEAD RESUL. ACCEL.	1.0	0.	124.7	6.
5-UPPER NECK STOP TORQUE	-490.3	17.	285.9	71.
6-LOWER NECK STOP TORQUE	-0.0	0.	122.2	19.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	2898.6	7.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	579.7	7.
9-CONDYLE JOINT ANGLE	-4.5	17.	56.3	72.
10-C7-T1 JOINT ANGLE	-20.0	0.	7.3	19.
11-FORCE ALONG NECK	-477.4	18.	2102.0	9.
12-SHEAR FORCE AT CONDYLES	-297.6	17.	51.6	74.
13-COMP. FORCE AT CONDYLES	-420.1	18.	2074.5	9.
14-SHEAR FORCE AT C7-T1	-276.6	17.	93.0	73.
15-COMP. FORCE AT C7-T1	-473.1	18.	2040.3	9.
16-CONDYLE TOTAL TORQUE	-678.2	17.	504.1	71.
17-C7-T1 TOTAL TORQUE	-68.5	98.	756.4	19.

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RH20V5.2F

HIC= 4440. BETWEEN 2. AND 67.MSEC
3-MSEC AVG. FOR HEAD= 166. AT 50. MSEC
3-MSEC AVG. FOR CHEST= 34. AT 10. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-207.0	49.	-70.0	0.
2-HEAD ANG. VELOCITY	-6620.3	28.	2127.1	54.
3-HEAD ANG. ACCEL.	-8665.1	18.	14170.3	50.
4-HEAD RESUL. ACCEL.	1.0	0.	182.9	51.
5-UPPER NECK STOP TORQUE	-4460.6	36.	279.3	18.
6-LOWER NECK STOP TORQUE	-7378.2	57.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3335.1	9.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	667.0	9.
9-CONDYLE JOINT ANGLE	-46.5	36.	56.0	18.
10-C7-T1 JOINT ANGLE	-97.5	58.	-20.0	0.
11-FORCE ALONG NECK	-747.5	17.	3207.1	10.
12-SHEAR FORCE AT CONDYLES	-492.5	35.	1826.0	57.
13-COMP. FORCE AT CONDYLES	-642.0	17.	3192.8	10.
14-SHEAR FORCE AT C7-T1	-608.1	34.	1904.7	57.
15-COMP. FORCE AT C7-T1	-532.4	17.	3012.1	10.
16-CONDYLE TOTAL TORQUE	-5001.6	36.	560.0	18.
17-C7-T1 TOTAL TORQUE	-8647.0	57.	489.3	100.

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RNH20V5.6F

HIC= 14009. BETWEEN 0. AND 65.MSEC
3-MSEC AVG. FOR HEAD= 349. AT 36. MSEC
3-MSEC AVG. FOR CHEST= 36. AT 6. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-190.7	53.	-70.0	0.
2-HEAD ANG. VELOCITY	-6552.5	18.	3013.3	88.
3-HEAD ANG. ACCEL.	-29179.5	3.	29383.4	42.
4-HEAD RESUL. ACCEL.	1.0	0.	448.3	42.
5-UPPER NECK STOP TORQUE	-3508.0	26.	772.0	99.
6-LOWER NECK STOP TORQUE	-9140.0	38.	0.3	86.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4921.9	3.
8-X DIR. HEAD CONT. FORCE	-1847.6	5.	2953.1	3.
9-CONDYLE JOINT ANGLE	-41.6	26.	70.6	100.
10-C7-T1 JOINT ANGLE	-102.5	38.	-16.5	86.
11-FORCE ALONG NECK	-934.8	44.	3318.0	5.
12-SHEAR FORCE AT CONDYLES	-255.4	25.	2051.5	38.
13-COMP. FORCE AT CONDYLES	-939.5	43.	3312.9	5.
14-SHEAR FORCE AT C7-T1	-321.1	25.	2468.0	38.
15-COMP. FORCE AT C7-T1	-735.1	43.	3153.7	5.
16-CONDYLE TOTAL TORQUE	-3983.5	26.	1229.0	99.
17-C7-T1 TOTAL TORQUE	-10802.1	38.	818.2	85.

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RH20V5.6F

HIC= 1437. BETWEEN 2. AND 10.MSEC
3-MSEC AVG. FOR HEAD= 164. AT 6. MSEC
3-MSEC AVG. FOR CHEST= 23. AT 10. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-218.3	49.	-70.0	0.
2-HEAD ANG. VELOCITY	-6667.7	26.	2584.8	58.
3-HEAD ANG. ACCEL.	-7792.6	16.	8589.5	51.
4-HEAD RESUL. ACCEL.	1.0	0.	171.1	8.
5-UPPER NECK STOP TORQUE	-3165.1	37.	229.1	16.
6-LOWER NECK STOP TORQUE	-4907.2	43.	4.2	98.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3223.4	8.
8-X DIR. HEAD CONT. FORCE	-423.8	10.	1934.0	8.
9-CONDYLE JOINT ANGLE	-39.7	37.	53.7	16.
10-C7-T1 JOINT ANGLE	-88.4	43.	-11.1	98.
11-FORCE ALONG NECK	-703.1	73.	2211.7	9.
12-SHEAR FORCE AT CONDYLES	-187.0	50.	1311.9	20.
13-COMP. FORCE AT CONDYLES	-709.7	73.	2280.8	9.
14-SHEAR FORCE AT C7-T1	-305.2	51.	1468.8	19.
15-COMP. FORCE AT C7-T1	-650.3	73.	2075.5	9.
16-CONDYLE TOTAL TORQUE	-3639.8	37.	491.9	16.
17-C7-T1 TOTAL TORQUE	-6133.1	43.	931.8	97.

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RNH20V5.2F

HIC= 12624. BETWEEN 30. AND 47.MSEC
3-MSEC AVG. FOR HEAD= 343. AT 42. MSEC
3-MSEC AVG. FOR CHEST= 33. AT 6. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-196.6	65.	-70.0	0.
2-HEAD ANG. VELOCITY	-8201.0	19.	1420.3	91.
3-HEAD ANG. ACCEL.	-16449.2	37.	26748.6	26.
4-HEAD RESUL. ACCEL.	1.0	0.	439.5	36.
5-UPPER NECK STOP TORQUE	-4336.2	26.	40.0	12.
6-LOWER NECK STOP TORQUE	-8181.3	51.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	5405.5	36.
8-X DIR. HEAD CONT. FORCE	-412.3	9.	1081.1	36.
9-CONDYLE JOINT ANGLE	-46.0	26.	38.8	13.
10-C7-T1 JOINT ANGLE	-99.8	51.	-20.0	0.
11-FORCE ALONG NECK	-582.0	14.	3743.9	5.
12-SHEAR FORCE AT CONDYLES	-668.0	26.	1795.0	51.
13-COMP. FORCE AT CONDYLES	-539.0	14.	3590.8	5.
14-SHEAR FORCE AT C7-T1	-771.6	26.	2052.5	51.
15-COMP. FORCE AT C7-T1	-403.4	14.	3567.2	5.
16-CONDYLE TOTAL TORQUE	-4864.6	26.	189.0	12.
17-C7-T1 TOTAL TORQUE	-9557.2	51.	0.0	0.

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RH10V5.2F

HIC= 2842. BETWEEN 12. AND 75.MSEC
3-MSEC AVG. FOR HEAD= 175. AT 53. MSEC
3-MSEC AVG. FOR CHEST= 36. AT 11. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-207.8	83.	-70.0	0.
2-HEAD ANG. VELOCITY	-6298.5	30.	2256.1	55.
3-HEAD ANG. ACCEL.	-8387.9	61.	12984.6	52.
4-HEAD RESUL. ACCEL.	1.0	0.	197.5	53.
5-UPPER NECK STOP TORQUE	-4588.1	38.	320.4	19.
6-LOWER NECK STOP TORQUE	-9630.7	61.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3335.1	9.
8-X DIR. HEAD CONT. FORCE	-628.7	12.	666.2	9.
9-CONDYLE JOINT ANGLE	-47.1	39.	57.7	19.
10-C7-T1 JOINT ANGLE	-103.9	62.	-20.0	0.
11-FORCE ALONG NECK	-362.9	18.	3261.8	10.
12-SHEAR FORCE AT CONDYLES	-533.0	37.	2434.2	62.
13-COMP. FORCE AT CONDYLES	-288.6	18.	3263.1	10.
14-SHEAR FORCE AT C7-T1	-641.0	37.	2564.9	61.
15-COMP. FORCE AT C7-T1	-204.8	18.	3061.2	10.
16-CONDYLE TOTAL TORQUE	-5135.0	38.	612.2	19.
17-C7-T1 TOTAL TORQUE	-11009.0	61.	0.0	0.

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RNH10V5.6F

HIC= 10190. BETWEEN 2. AND 67.MSEC
3-MSEC AVG. FOR HEAD= 314. AT 2. MSEC
3-MSEC AVG. FOR CHEST= 37. AT 6. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-193.4	70.	-70.0	0.
2-HEAD ANG. VELOCITY	-7465.0	20.	2019.1	30.
3-HEAD ANG. ACCEL.	-28217.3	3.	27321.5	27.
4-HEAD RESUL. ACCEL.	1.0	0.	362.6	3.
5-UPPER NECK STOP TORQUE	-4325.1	28.	147.5	14.
6-LOWER NECK STOP TORQUE	-8629.9	55.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4911.8	3.
8-X DIR. HEAD CONT. FORCE	-2062.5	9.	2947.1	3.
9-CONDYLE JOINT ANGLE	-45.9	28.	49.3	14.
10-C7-T1 JOINT ANGLE	-101.2	55.	-20.0	0.
11-FORCE ALONG NECK	-560.1	22.	3722.4	5.
12-SHEAR FORCE AT CONDYLES	-738.2	28.	2046.6	56.
13-COMP. FORCE AT CONDYLES	-549.3	21.	3597.2	5.
14-SHEAR FORCE AT C7-T1	-867.4	28.	2204.1	55.
15-COMP. FORCE AT C7-T1	-425.7	22.	3540.2	5.
16-CONDYLE TOTAL TORQUE	-4862.1	28.	378.1	14.
17-C7-T1 TOTAL TORQUE	-10011.9	55.	0.0	0.

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RH20V1.2F

HIC= 2933. BETWEEN 2. AND 32.MSEC
3-MSEC AVG. FOR HEAD= 145. AT 54. MSEC
3-MSEC AVG. FOR CHEST= 34. AT 10. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-214.3	51.	-70.0	0.
2-HEAD ANG. VELOCITY	-6384.2	30.	2583.5	57.
3-HEAD ANG. ACCEL.	-7762.2	18.	12094.1	53.
4-HEAD RESUL. ACCEL.	1.0	0.	162.2	54.
5-UPPER NECK STOP TORQUE	-4004.6	52.	420.4	18.
6-LOWER NECK STOP TORQUE	-8309.5	60.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3332.4	9.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	666.5	9.
9-CONDYLE JOINT ANGLE	-44.2	52.	61.2	19.
10-C7-T1 JOINT ANGLE	-100.3	61.	-20.0	0.
11-FORCE ALONG NECK	-824.9	16.	3155.8	10.
12-SHEAR FORCE AT CONDYLES	-133.4	36.	1764.2	60.
13-COMP. FORCE AT CONDYLES	-710.1	16.	3151.8	10.
14-SHEAR FORCE AT C7-T1	-234.0	36.	1824.5	60.
15-COMP. FORCE AT C7-T1	-622.4	16.	2967.8	10.
16-CONDYLE TOTAL TORQUE	-4110.3	52.	497.9	18.
17-C7-T1 TOTAL TORQUE	-8581.7	60.	-0.0	0.

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RNH20V1.6F

HIC= 9108. BETWEEN 32. AND 50.MSEC
3-MSEC AVG. FOR HEAD= 325. AT 2. MSEC
3-MSEC AVG. FOR CHEST= 33. AT 5. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-191.8	54.	-70.0	0.
2-HEAD ANG. VELOCITY	-6797.3	20.	2937.7	35.
3-HEAD ANG. ACCEL.	-29043.2	3.	22811.1	53.
4-HEAD RESUL. ACCEL.	1.0	0.	377.7	43.
5-UPPER NECK STOP TORQUE	-3810.8	27.	420.4	100.
6-LOWER NECK STOP TORQUE	-10437.4	40.	4.8	89.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4921.8	3.
8-X DIR. HEAD CONT. FORCE	-1845.7	5.	2953.1	3.
9-CONDYLE JOINT ANGLE	-43.3	27.	61.2	100.
10-C7-T1 JOINT ANGLE	-105.8	40.	-10.7	89.
11-FORCE ALONG NECK	-1291.6	45.	3311.3	5.
12-SHEAR FORCE AT CONDYLES	-393.6	27.	1951.6	40.
13-COMP. FORCE AT CONDYLES	-1348.8	45.	3307.5	5.
14-SHEAR FORCE AT C7-T1	-484.8	27.	2352.2	40.
15-COMP. FORCE AT C7-T1	-1029.2	45.	3143.4	5.
16-CONDYLE TOTAL TORQUE	-3930.2	27.	518.2	100.
17-C7-T1 TOTAL TORQUE	-10828.1	40.	271.5	89.

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RH20V5.10F

HIC= 2052. BETWEEN 2. AND 7.MSEC
3-MSEC AVG. FOR HEAD= 209. AT 4. MSEC
3-MSEC AVG, FOR CHEST= 20. AT 8. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-221.3	50.	-70.0	0.
2-HEAD ANG. VELOCITY	-6645.7	25.	2990.3	74.
3-HEAD ANG. ACCEL.	-8106.8	6.	7844.5	36.
4-HEAD RESUL. ACCEL.	1.0	0.	237.4	6.
5-UPPER NECK STOP TORQUE	-2717.2	37.	356.8	100.
6-LOWER NECK STOP TORQUE	-4328.9	19.	0.4	100.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3141.1	7.
8-X DIR. HEAD CONT. FORCE	-1342.4	8.	2983.0	6.
9-CONDYLE JOINT ANGLE	-36.8	37.	59.0	100.
10-C7-T1 JOINT ANGLE	-85.9	19.	-15.9	100.
11-FORCE ALONG NECK	-836.5	86.	1930.9	8.
12-SHEAR FORCE AT CONDYLES	-183.5	51.	1269.8	20.
13-COMP. FORCE AT CONDYLES	-821.5	86.	2043.8	8.
14-SHEAR FORCE AT C7-T1	-254.9	51.	1405.6	19.
15-COMP. FORCE AT C7-T1	-832.4	86.	1810.3	8.
16-CONDYLE TOTAL TORQUE	-3169.5	37.	715.7	100.
17-C7-T1 TOTAL TORQUE	-5852.7	19.	730.1	100.

RNH20V5.10F

HIC= 8063. BETWEEN 0. AND 25.MSEC
3-MSEC AVG. FOR HEAD= 247. AT 2. MSEC
3-MSEC AVG. FOR CHEST= 39. AT 6. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-156.8	35.	-55.6	14.
2-HEAD ANG. VELOCITY	-7699.9	26.	3913.3	77.
3-HEAD ANG. ACCEL.	-27481.9	15.	22971.4	34.
4-HEAD RESUL. ACCEL.	1.0	0.	295.5	2.
5-UPPER NECK STOP TORQUE	-3627.4	34.	1561.9	15.
6-LOWER NECK STOP TORQUE	-3934.1	17.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4859.9	3.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	-0.0	0.
9-CONDYLE JOINT ANGLE	-42.3	34.	83.9	15.
10-C7-T1 JOINT ANGLE	-83.9	17.	-20.0	0.
11-FORCE ALONG NECK	-709.0	27.	4050.7	6.
12-SHEAR FORCE AT CONDYLES	-576.5	34.	1485.6	16.
13-COMP. FORCE AT CONDYLES	-684.5	27.	3841.2	6.
14-SHEAR FORCE AT C7-T1	-679.8	34.	1760.4	16.
15-COMP. FORCE AT C7-T1	-506.3	27.	3869.2	6.
16-CONDYLE TOTAL TORQUE	-4171.7	34.	2061.9	15.
17-C7-T1 TOTAL TORQUE	-5450.2	17.	0.0	0.

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RH20V5.2I2

HIC= 1175. BETWEEN 2. AND 60.MSEC
3-MSEC AVG. FOR HEAD= 102. AT 5. MSEC
3-MSEC AVG. FOR CHEST= 27. AT 11. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-213.4	40.	-90.0	0.
2-HEAD ANG. VELOCITY	-4949.2	16.	1831.8	88.
3-HEAD ANG. ACCEL.	-9275.9	10.	10509.7	37.
4-HEAD RESUL. ACCEL.	0.7	63.	105.2	5.
5-UPPER NECK STOP TORQUE	-3825.1	37.	68.0	100.
6-LOWER NECK STOP TORQUE	-7416.5	47.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3115.8	8.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	623.2	8.
9-CONDYLE JOINT ANGLE	-63.3	37.	22.5	100.
10-C7-T1 JOINT ANGLE	-97.5	47.	-20.0	1.
11-FORCE ALONG NECK	-811.1	18.	2753.7	10.
12-SHEAR FORCE AT CONDYLES	-37.5	75.	2002.5	48.
13-COMP. FORCE AT CONDYLES	-760.9	18.	2703.0	10.
14-SHEAR FORCE AT C7-T1	-56.2	36.	1966.7	47.
15-COMP. FORCE AT C7-T1	-663.2	18.	2617.4	10.
16-CONDYLE TOTAL TORQUE	-4277.5	37.	359.4	100.
17-C7-T1 TOTAL TORQUE	-8891.1	47.	389.1	98.

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RNH20V5.6I2

HIC= 12535. BETWEEN 27. AND 45.MSEC
3-MSEC AVG. FOR HEAD= 387. AT 30. MSEC
3-MSEC AVG. FOR CHEST= 28. AT 43. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-209.1	53.	-90.0	0.
2-HEAD ANG. VELOCITY	-7472.4	8.	2031.2	31.
3-HEAD ANG. ACCEL.	-47221.0	4.	35604.8	40.
4-HEAD RESUL. ACCEL.	0.9	1.	473.2	30.
5-UPPER NECK STOP TORQUE	-1318.3	29.	452.9	97.
6-LOWER NECK STOP TORQUE	-7830.5	36.	0.8	86.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	5044.3	40.
8-X DIR. HEAD CONT. FORCE	-1626.5	5.	3026.6	40.
9-CONDYLE JOINT ANGLE	-44.0	29.	42.3	97.
10-C7-T1 JOINT ANGLE	-99.0	36.	-14.9	86.
11-FORCE ALONG NECK	-745.3	40.	2344.4	5.
12-SHEAR FORCE AT CONDYLES	-193.8	5.	1837.3	36.
13-COMP. FORCE AT CONDYLES	-879.3	40.	2410.6	5.
14-SHEAR FORCE AT C7-T1	-73.8	11.	2132.7	36.
15-COMP. FORCE AT C7-T1	-596.2	40.	2244.7	5.
16-CONDYLE TOTAL TORQUE	-1611.4	29.	815.0	97.
17-C7-T1 TOTAL TORQUE	-9463.7	36.	751.2	85.

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RH20V5.2NM

HIC= 1099. BETWEEN 2. AND 7.MSEC
3-MSEC AVG. FOR HEAD= 150. AT 5. MSEC
3-MSEC AVG, FOR CHEST= 145. AT 6. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-97.3	46.	-70.0	0.
2-HEAD ANG. VELOCITY	-1158.7	17.	493.8	66.
3-HEAD ANG. ACCEL.	-2651.3	6.	1335.3	29.
4-HEAD RESUL. ACCEL.	0.4	21.	155.1	6.
5-UPPER NECK STOP TORQUE	-334.8	29.	4.6	100.
6-LOWER NECK STOP TORQUE	-283.2	40.	0.1	97.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	2833.4	6.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	566.7	6.
9-CONDYLE JOINT ANGLE	5.4	29.	29.2	100.
10-C7-T1 JOINT ANGLE	-31.3	40.	-17.4	97.
11-FORCE ALONG NECK	-37.1	13.	715.7	7.
12-SHEAR FORCE AT CONDYLES	-42.5	27.	82.9	13.
13-COMP. FORCE AT CONDYLES	-35.7	13.	910.2	6.
14-SHEAR FORCE AT C7-T1	-22.4	27.	31.2	8.
15-COMP. FORCE AT C7-T1	-9.2	13.	236.7	7.
16-CONDYLE TOTAL TORQUE	-444.4	29.	98.5	100.
17-C7-T1 TOTAL TORQUE	-504.5	39.	142.9	95.

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RNH20V5.6NM

HIC= 5138. BETWEEN 0. AND 5.MSEC
3-MSEC AVG. FCR HEAD= 358. AT 2. MSEC
3-MSEC AVG. FOR CHEST= 241. AT 3. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-128.2	26.	-59.4	75.
2-HEAD ANG. VELCCITY	-3182.3	9.	2131.2	53.
3-HEAD ANG. ACCEL.	-24280.1	3.	5593.3	25.
4-HEAD RESUL. ACCEL.	1.0	0.	407.3	2.
5-UPPER NECK STCP TORQUE	-654.7	25.	133.3	72.
6-LOWER NECK STCP TORQUE	-462.8	30.	23.6	83.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4559.5	2.
8-X DIR. HEAD CCNT. FORCE	-18.8	5.	2735.7	2.
9-CCNDYLE JOINT ANGLE	-11.1	25.	48.1	72.
10-C7-T1 JOINT ANGLE	-43.0	31.	-4.2	83.
11-FORCE ALONG NECK	-131.5	8.	1280.6	4.
12-SHEAR FORCE AT CONDYLES	-61.3	83.	290.2	3.
13-COMP. FORCE AT CCNDYLES	-131.6	8.	1645.3	3.
14-SHEAR FORCE AT C7-T1	-14.5	83.	54.2	4.
15-COMP. FORCE AT C7-T1	-40.7	8.	510.6	4.
16-CONDYLE TOTAL TORQUE	-884.0	25.	388.2	71.
17-C7-T1 TOTAL TORQUE	-980.6	16.	493.4	82.

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RH20V5.2NR

HIC= 4749. BETWEEN 2. AND 67.MSEC
3-MSEC AVG. FOR HEAD= 175. AT 50. MSEC
3-MSEC AVG. FCR CHEST= 34. AT 10. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-199.3	49.	-70.0	0.
2-HEAD ANG. VELOCITY	-6587.9	29.	1934.2	54.
3-HEAD ANG. ACCEL.	-8638.1	18.	13524.0	36.
4-HEAD RESUL. ACCEL.	1.0	0.	193.1	51.
5-UPPER NECK STOP TORQUE	-5005.2	36.	282.8	18.
6-LOWER NECK STCP TORQUE	-9223.6	58.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3296.1	10.
8-X DIR. HEAD CCNT. FORCE	-0.0	0.	659.2	10.
9-CCNDYLE JOINT ANGLE	-48.8	36.	56.2	18.
10-C7-T1 JOINT ANGLE	-102.7	58.	-20.0	0.
11-FORCE ALONG NECK	-674.9	17.	3245.3	10.
12-SHEAR FORCE AT CONDYLES	-633.2	35.	2291.3	58.
13-COMP. FORCE AT CCNDYLES	-573.5	17.	3230.9	10.
14-SHEAR FORCE AT C7-T1	-751.9	35.	2396.4	58.
15-COMP. FORCE AT C7-T1	-473.8	17.	3047.9	10.
16-CONDYLE TOTAL TORQUE	-5563.6	36.	565.5	18.
17-C7-T1 TOTAL TORQUE	-10605.8	58.	-0.0	0.

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RNH20H5.6NR

HIC= 5618. BETWEEN 0. AND 30.MSEC
3-MSEC AVG. FOR HEAD= 302. AT 2. MSEC
3-MSEC AVG. FOR CHEST= 35. AT 5. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.0	0.	49.6	47.
2-HEAD ANG. VELOCITY	-3500.8	55.	7716.2	10.
3-HEAD ANG. ACCEL.	-24510.9	15.	22362.3	3.
4-HEAD RESUL. ACCEL.	1.0	0.	368.8	2.
5-UPPER NECK STOP TORQUE	-458.3	93.	3319.1	15.
6-LOWER NECK STOP TORQUE	-463.4	13.	943.8	33.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4455.5	3.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	2673.3	3.
9-CONDYLE JOINT ANGLE	-2.8	93.	102.1	15.
10-C7-T1 JOINT ANGLE	-43.1	13.	34.0	33.
11-FORCE ALONG NECK	-1247.7	25.	3887.6	5.
12-SHEAR FORCE AT CONDYLES	-534.4	33.	1002.5	15.
13-COMP. FORCE AT CONDYLES	-1092.7	25.	3707.4	5.
14-SHEAR FORCE AT C7-T1	-587.4	33.	1151.6	14.
15-COMP. FORCE AT C7-T1	-1206.1	25.	3726.0	5.
16-CONDYLE TOTAL TORQUE	-681.9	93.	3954.3	15.
17-C7-T1 TOTAL TORQUE	-1175.6	78.	2244.3	33.

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RNH20V5.6F-3

HIC= 4385. BETWEEN 32. AND 50.MSEC
3-MSEC AVG. FOR HEAD= 275. AT 35. MSEC
3-MSEC AVG. FOR CHEST= 21. AT 5. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-173.8	50.	-70.0	0.
2-HEAD ANG. VELOCITY	-4509.7	14.	2672.1	74.
3-HEAD ANG. ACCEL.	-20770.6	4.	19646.2	49.
4-HEAD RESUL. ACCEL.	1.0	0.	340.7	35.
5-UPPER NECK STOP TORQUE	-1645.2	28.	132.4	87.
6-LOWER NECK STOP TORQUE	-4533.6	41.	0.4	100.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3540.1	3.
8-X DIR. HEAD CONT. FORCE	-610.7	5.	2124.1	3.
9-CONDYLE JOINT ANGLE	-27.9	29.	48.1	87.
10-C7-T1 JOINT ANGLE	-86.8	42.	-16.1	100.
11-FORCE ALONG NECK	-458.1	39.	2290.0	5.
12-SHEAR FORCE AT CONDYLES	-98.6	100.	1093.3	41.
13-COMP. FORCE AT CONDYLES	-416.7	39.	2290.8	5.
14-SHEAR FORCE AT C7-T1	-90.8	70.	1272.8	41.
15-COMP. FORCE AT C7-T1	-316.5	14.	2187.8	5.
16-CONDYLE TOTAL TORQUE	-1999.6	28.	433.3	87.
17-C7-T1 TOTAL TORQUE	-5846.1	41.	666.5	100.

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RH20V5.2F-3

HIC= 1835. BETWEEN 2. AND 77.MSEC
3-MSEC AVG. FOR HEAD= 136. AT 58. MSEC
3-MSEC AVG. FOR CHEST= 23. AT 11. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-190.2	99.	-70.0	0.
2-HEAD ANG. VELOCITY	-4926.5	32.	537.4	61.
3-HEAD ANG. ACCEL.	-5156.4	20.	9844.4	40.
4-HEAD RESUL. ACCEL.	1.0	0.	145.3	58.
5-UPPER NECK STOP TORQUE	-3193.4	40.	113.1	19.
6-LOWER NECK STOP TORQUE	-4243.2	66.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	2374.9	9.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	475.0	9.
9-CONDYLE JOINT ANGLE	-39.8	40.	46.7	20.
10-C7-T1 JOINT ANGLE	-85.4	66.	-20.0	1.
11-FORCE ALONG NECK	-338.5	19.	2257.4	11.
12-SHEAR FORCE AT CONDYLES	-474.4	40.	1348.1	66.
13-COMP. FORCE AT CONDYLES	-288.0	19.	2245.5	11.
14-SHEAR FORCE AT C7-T1	-551.7	39.	1127.3	66.
15-COMP. FORCE AT C7-T1	-212.5	19.	2140.1	11.
16-CONDYLE TOTAL TORQUE	-3671.8	40.	320.0	19.
17-C7-T1 TOTAL TORQUE	-5271.8	66.	0.0	1.

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RNH20H5.6F-3

HIC= 2686. BETWEEN 2. AND 37.MSEC
3-MSEC AVG. FOR HEAD= 241. AT 5. MSEC
3-MSEC AVG. FOR CHEST= 26. AT 8. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.4	4.	36.0	53.
2-HEAD ANG. VELOCITY	-2931.1	62.	5893.8	15.
3-HEAD ANG. ACCEL.	-19118.8	18.	16813.4	6.
4-HEAD RESUL. ACCEL.	0.9	3.	292.5	5.
5-UPPER NECK STOP TORQUE	-350.4	70.	2107.1	19.
6-LOWER NECK STOP TORQUE	-434.2	17.	561.1	38.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3529.8	6.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	2117.9	6.
9-CONDYLE JOINT ANGLE	4.3	70.	90.7	19.
10-C7-T1 JOINT ANGLE	-41.3	17.	25.4	38.
11-FORCE ALONG NECK	-845.3	30.	3010.7	8.
12-SHEAR FORCE AT CONDYLES	-409.1	38.	699.0	19.
13-COMP. FORCE AT CONDYLES	-740.0	30.	2924.3	8.
14-SHEAR FORCE AT C7-T1	-445.7	39.	811.2	19.
15-COMP. FORCE AT C7-T1	-823.2	30.	2890.2	8.
16-CONDYLE TOTAL TORQUE	-557.7	38.	2651.2	19.
17-C7-T1 TOTAL TORQUE	-945.7	17.	1663.9	38.

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RH20H5.2F-3

HIC= 579. BETWEEN 5. AND 15.MSEC
3-MSEC AVG. FOR HEAD= 96. AT 8. MSEC
3-MSEC AVG. FOR CHEST= 14. AT 79. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.7	8.	56.4	89.
2-HEAD ANG. VELOCITY	-973.7	100.	1970.0	35.
3-HEAD ANG. ACCEL.	-1752.5	96.	2546.1	21.
4-HEAD RESUL. ACCEL.	0.5	4.	97.5	9.
5-UPPER NECK STOP TORQUE	-362.0	20.	301.6	95.
6-LOWER NECK STOP TORQUE	-0.0	0.	146.3	74.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	2315.1	10.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	463.0	10.
9-CONDYLE JOINT ANGLE	3.5	21.	56.9	95.
10-C7-T1 JOINT ANGLE	-20.0	0.	9.0	75.
11-FORCE ALONG NECK	-258.1	22.	1716.2	12.
12-SHEAR FORCE AT CONDYLES	-208.1	20.	88.8	97.
13-COMP. FORCE AT CONDYLES	-219.7	22.	1687.7	12.
14-SHEAR FORCE AT C7-T1	-194.4	21.	149.2	98.
15-COMP. FORCE AT C7-T1	-260.6	22.	1662.1	12.
16-CONDYLE TOTAL TORQUE	-488.5	20.	501.2	94.
17-C7-T1 TOTAL TORQUE	-68.3	100.	639.9	73.

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HR10H1.1F

HIC= 574. BETWEEN 2. AND 7.MSEC
3-MSEC AVG. FOR HEAD= 117. AT 5. MSEC
3-MSEC AVG. FOR CHEST= 8. AT 7. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	70.0	5.	191.2	100.
2-HEAD ANG. VELOCITY	-5.1	4.	2438.5	37.
3-HEAD ANG. ACCEL.	-1672.1	54.	2886.5	18.
4-HEAD RESUL. ACCEL.	0.7	85.	121.8	6.
5-UPPER NECK STOP TORQUE	-586.2	19.	460.1	89.
6-LOWER NECK STOP TORQUE	-0.0	0.	814.2	100.
7-Z DIR. HEAD CONT. FORCE	-197.4	6.	61.8	90.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	1974.3	6.
9-CONDYLE JOINT ANGLE	-18.7	19.	52.5	89.
10-C7-T1 JOINT ANGLE	-30.0	0.	21.4	100.
11-FORCE ALONG NECK	-390.8	93.	606.5	7.
12-SHEAR FORCE AT CONDYLES	-200.1	7.	62.7	54.
13-COMP. FORCE AT CONDYLES	-382.4	93.	539.5	7.
14-SHEAR FORCE AT C7-T1	-183.6	20.	64.4	53.
15-COMP. FORCE AT C7-T1	-375.9	93.	572.7	7.
16-CONDYLE TOTAL TORQUE	-637.8	19.	512.5	89.
17-C7-T1 TOTAL TORQUE	-0.0	0.	960.5	100.

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CR10H1.3

HIC= 42. BETWEEN 7. AND 100.MSEC
3-MSEC AVG. FOR HEAD= 16. AT 48. MSEC
3-MSEC AVG. FOR CHEST= 14. AT 14. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	12.0	83.	70.0	8.
2-HEAD ANG. VELOCITY	-1657.8	59.	1089.0	100.
3-HEAD ANG. ACCEL.	-852.2	41.	1848.7	81.
4-HEAD RESUL. ACCEL.	1.0	0.	16.3	48.
5-UPPER NECK STOP TORQUE	-786.4	84.	21.1	38.
6-LOWER NECK STOP TORQUE	-1448.0	95.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	361.3	50.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	1174.9	38.
9-CONDYLE JOINT ANGLE	-24.7	84.	25.2	38.
10-C7-T1 JOINT ANGLE	-75.6	95.	-30.0	0.
11-FORCE ALONG NECK	-175.8	44.	66.5	89.
12-SHEAR FORCE AT CONDYLES	0.0	0.	194.4	96.
13-COMP. FORCE AT CONDYLES	-160.2	44.	64.7	89.
14-SHEAR FORCE AT C7-T1	0.0	0.	180.1	95.
15-COMP. FORCE AT C7-T1	-203.5	43.	66.7	89.
16-CONDYLE TOTAL TORQUE	-848.2	84.	45.0	37.
17-C7-T1 TOTAL TORQUE	-1592.9	95.	-0.0	0.

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RH20H5.1F

HIC= 1244. BETWEEN 5. AND 12.MSEC
3-MSEC AVG. FOR HEAD= 141. AT 8. MSEC
3-MSEC AVG, FOR CHEST= 24. AT 76. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.6	7.	75.2	72.
2-HEAD ANG. VELOCITY	-1875.7	100.	3080.2	31.
3-HEAD ANG. ACCEL.	-1961.4	48.	5113.4	19.
4-HEAD RESUL. ACCEL.	0.4	68.	143.0	8.
5-UPPER NECK STOP TORQUE	-656.8	19.	393.4	74.
6-LOWER NECK STOP TORQUE	-0.0	0.	239.1	20.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3091.9	9.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	309.2	9.
9-CONDYLE JOINT ANGLE	-11.2	19.	60.3	74.
10-C7-T1 JOINT ANGLE	-20.0	0.	14.2	21.
11-FORCE ALONG NECK	-467.7	19.	1957.7	11.
12-SHEAR FORCE AT CONDYLES	-387.5	19.	53.5	94.
13-COMP. FORCE AT CONDYLES	-408.6	19.	1947.8	10.
14-SHEAR FORCE AT C7-T1	-363.0	19.	110.2	78.
15-COMP. FORCE AT C7-T1	-448.6	19.	1902.9	11.
16-CONDYLE TOTAL TORQUE	-896.6	19.	636.2	73.
17-C7-T1 TOTAL TORQUE	-207.2	97.	1035.4	20.

RH20H5.3F

HIC= 1301. BETWEEN 5. AND 15.MSEC
3-MSEC AVG. FOR HEAD= 124. AT 7. MSEC
3-MSEC AVG, FOR CHEST= 23. AT 11. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.5	6.	66.1	75.
2-HEAD ANG. VELOCITY	-1772.6	100.	2613.7	33.
3-HEAD ANG. ACCEL.	-1837.9	82.	3834.4	20.
4-HEAD RESUL. ACCEL.	0.9	2.	127.0	7.
5-UPPER NECK STOP TORQUE	-443.9	20.	280.7	79.
6-LOWER NECK STOP TORQUE	-0.0	0.	137.2	64.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3187.4	9.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	956.2	9.
9-CONDYLE JOINT ANGLE	-1.9	20.	56.0	79.
10-C7-T1 JOINT ANGLE	-20.0	0.	8.4	64.
11-FORCE ALONG NECK	-600.9	20.	2888.2	12.
12-SHEAR FORCE AT CONDYLES	-274.7	19.	61.9	97.
13-COMP. FORCE AT CONDYLES	-520.9	20.	2794.4	12.
14-SHEAR FORCE AT C7-T1	-251.6	19.	123.1	82.
15-COMP. FORCE AT C7-T1	-599.0	20.	2803.0	12.
16-CONDYLE TOTAL TORQUE	-612.0	20.	486.9	78.
17-C7-T1 TOTAL TORQUE	-253.0	100.	640.6	21.

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RH20H5.0F

HIC= 1336. BETWEEN 5. AND 12.MSEC
3-MSEC AVG. FOR HEAD= 151. AT 8. MSEC
3-MSEC AVG, FOR CHEST= 24. AT 75. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.6	7.	80.1	72.
2-HEAD ANG. VELOCITY	-1802.3	100.	3235.4	29.
3-HEAD ANG. ACCEL.	-1985.9	75.	5522.0	18.
4-HEAD RESUL. ACCEL.	0.2	67.	154.4	8.
5-UPPER NECK STOP TORQUE	-746.1	18.	451.4	72.
6-LOWER NECK STOP TORQUE	-0.0	0.	308.9	20.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3055.3	9.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	-0.0	0.
9-CONDYLE JOINT ANGLE	-13.7	19.	62.2	73.
10-C7-T1 JOINT ANGLE	-20.0	0.	17.3	20.
11-FORCE ALONG NECK	-439.9	18.	1615.5	10.
12-SHEAR FORCE AT CONDYLES	-426.1	19.	55.0	75.
13-COMP. FORCE AT CONDYLES	-382.4	18.	1532.9	10.
14-SHEAR FORCE AT C7-T1	-404.8	19.	106.3	76.
15-COMP. FORCE AT C7-T1	-413.8	18.	1569.9	10.
16-CONDYLE TOTAL TORQUE	-1006.2	18.	713.5	72.
17-C7-T1 TOTAL TORQUE	-158.2	96.	1178.9	20.

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RH20V5.0F

HIC= 2671. BETWEEN 0. AND 82.MSEC
3-MSEC AVG. FOR HEAD= 122. AT 23. MSEC
3-MSEC AVG, FOR CHEST= 41. AT 12. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-158.1	41.	-70.0	0.
2-HEAD ANG. VELOCITY	-5281.3	32.	2467.3	100.
3-HEAD ANG. ACCEL.	-7197.6	21.	16013.9	39.
4-HEAD RESUL. ACCEL.	1.0	0.	125.4	15.
5-UPPER NECK STOP TORQUE	-5650.7	39.	250.9	20.
6-LOWER NECK STOP TORQUE	-4779.4	24.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3786.3	14.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	-0.0	0.
9-CONDYLE JOINT ANGLE	-51.4	39.	54.8	21.
10-C7-T1 JOINT ANGLE	-87.8	24.	-20.0	1.
11-FORCE ALONG NECK	-246.8	20.	3920.4	11.
12-SHEAR FORCE AT CONDYLES	-1096.4	39.	1453.8	24.
13-COMP. FORCE AT CONDYLES	-183.9	20.	3876.6	11.
14-SHEAR FORCE AT C7-T1	-1195.5	39.	1626.2	24.
15-COMP. FORCE AT C7-T1	-94.1	20.	3701.4	11.
16-CONDYLE TOTAL TORQUE	-6230.4	39.	521.5	20.
17-C7-T1 TOTAL TORQUE	-6347.7	24.	0.0	1.

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RNH20H5.0F

HIC= 4714. BETWEEN 2. AND 7.MSEC
3-MSEC AVG. FOR HEAD= 326. AT 4. MSEC
3-MSEC AVG, FOR CHEST= 30. AT 73. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.3	3.	66.5	51.
2-HEAD ANG. VELOCITY	-2776.9	66.	4840.0	21.
3-HEAD ANG. ACCEL.	-8359.8	30.	14414.0	5.
4-HEAD RESUL. ACCEL.	0.9	2.	386.3	5.
5-UPPER NECK STOP TORQUE	-279.4	77.	786.1	31.
6-LOWER NECK STOP TORQUE	-302.1	93.	508.9	44.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4721.8	5.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	-0.0	0.
9-CONDYLE JOINT ANGLE	8.9	77.	70.8	31.
10-C7-T1 JOINT ANGLE	-32.5	93.	24.0	44.
11-FORCE ALONG NECK	-519.6	14.	2263.8	6.
12-SHEAR FORCE AT CONDYLES	-359.8	5.	172.2	92.
13-COMP. FORCE AT CONDYLES	-459.6	14.	2276.1	6.
14-SHEAR FORCE AT C7-T1	-208.6	13.	181.5	93.
15-COMP. FORCE AT C7-T1	-503.6	14.	2192.3	6.
16-CONDYLE TOTAL TORQUE	-482.9	77.	1175.3	31.
17-C7-T1 TOTAL TORQUE	-954.6	92.	1339.4	44.

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RNH20V5.0F

HIC= 8063. BETWEEN 0. AND 25.MSEC
3-MSEC AVG. FOR HEAD= 247. AT 2. MSEC
3-MSEC AVG, FOR CHEST= 39. AT 6. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-156.8	35.	-55.6	14.
2-HEAD ANG. VELOCITY	-7699.9	26.	3913.3	77.
3-HEAD ANG. ACCEL.	-27481.9	15.	22971.4	34.
4-HEAD RESUL. ACCEL.	1.0	0.	295.5	2.
5-UPPER NECK STOP TORQUE	-3627.4	34.	1561.9	15.
6-LOWER NECK STOP TORQUE	-3934.1	17.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	4859.9	3.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	-0.0	0.
9-CONDYLE JOINT ANGLE	-42.3	34.	83.9	15.
10-C7-T1 JOINT ANGLE	-83.9	17.	-20.0	0.
11-FORCE ALONG NECK	-709.0	27.	4050.7	6.
12-SHEAR FORCE AT CONDYLES	-576.5	34.	1485.6	16.
13-COMP. FORCE AT CONDYLES	-684.5	27.	3841.2	6.
14-SHEAR FORCE AT C7-T1	-679.8	34.	1760.4	16.
15-COMP. FORCE AT C7-T1	-506.3	27.	3869.2	6.
16-CONDYLE TOTAL TORQUE	-4171.7	34.	2061.9	15.
17-C7-T1 TOTAL TORQUE	-5450.2	17.	0.0	0.

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RH20V5.4F

HIC= 1992. BETWEEN 0. AND 30.MSEC
3-MSEC AVG. FOR HEAD= 128. AT 51. MSEC
3-MSEC AVG, FOR CHEST= 27. AT 9. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-215.5	49.	-70.0	0.
2-HEAD ANG. VELOCITY	-6693.8	27.	2541.1	55.
3-HEAD ANG. ACCEL.	-8082.1	17.	11630.0	50.
4-HEAD RESUL. ACCEL.	1.0	0.	143.6	51.
5-UPPER NECK STOP TORQUE	-3496.1	37.	242.4	16.
6-LOWER NECK STOP TORQUE	-5540.9	43.	0.1	96.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3274.4	8.
8-X DIR. HEAD CONT. FORCE	-427.1	11.	1309.8	8.
9-CONDYLE JOINT ANGLE	-41.6	37.	54.4	17.
10-C7-T1 JOINT ANGLE	-91.0	43.	-17.9	96.
11-FORCE ALONG NECK	-657.1	16.	2598.9	9.
12-SHEAR FORCE AT CONDYLES	-137.9	34.	1374.6	20.
13-COMP. FORCE AT CONDYLES	-568.9	16.	2625.1	9.
14-SHEAR FORCE AT C7-T1	-273.5	50.	1552.5	20.
15-COMP. FORCE AT C7-T1	-540.2	89.	2450.6	9.
16-CONDYLE TOTAL TORQUE	-3988.7	37.	510.8	16.
17-C7-T1 TOTAL TORQUE	-6836.9	43.	808.8	95.

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RH20V5.8F

HIC= 2011. BETWEEN 2. AND 7.MSEC
3-MSEC AVG. FOR HEAD= 193. AT 5. MSEC
3-MSEC AVG, FOR CHEST= 22. AT 9. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-220.1	50.	-70.0	0.
2-HEAD ANG. VELOCITY	-6651.8	25.	2700.3	65.
3-HEAD ANG. ACCEL.	-7672.1	16.	8114.0	36.
4-HEAD RESUL. ACCEL.	1.0	0.	208.9	7.
5-UPPER NECK STOP TORQUE	-2913.9	37.	223.1	16.
6-LOWER NECK STOP TORQUE	-4502.1	43.	8.3	100.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3176.4	8.
8-X DIR. HEAD CONT. FORCE	-298.0	11.	2514.7	7.
9-CONDYLE JOINT ANGLE	-38.1	37.	53.4	16.
10-C7-T1 JOINT ANGLE	-86.6	43.	-8.8	100.
11-FORCE ALONG NECK	-828.2	77.	2047.5	9.
12-SHEAR FORCE AT CONDYLES	-205.2	51.	1285.6	20.
13-COMP. FORCE AT CONDYLES	-837.3	77.	2120.6	8.
14-SHEAR FORCE AT C7-T1	-275.1	51.	1430.3	19.
15-COMP. FORCE AT C7-T1	-777.1	78.	1914.2	9.
16-CONDYLE TOTAL TORQUE	-3376.4	37.	515.0	84.
17-C7-T1 TOTAL TORQUE	-5938.7	19.	936.6	98.

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RHM20H5.2F

HIC= 1523. BETWEEN 5. AND 12.MSEC
3-MSEC AVG. FOR HEAD= 151. AT 7. MSEC
3-MSEC AVG, FOR CHEST= 25. AT 77. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-30.5	6.	74.0	70.
2-HEAD ANG. VELOCITY	-1681.6	100.	2998.6	32.
3-HEAD ANG. ACCEL.	-1744.9	70.	4132.8	17.
4-HEAD RESUL. ACCEL.	0.7	65.	153.8	7.
5-UPPER NECK STOP TORQUE	-539.6	18.	390.8	69.
6-LOWER NECK STOP TORQUE	-0.0	0.	207.5	59.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	2710.4	9.
8-X DIR. HEAD CONT. FORCE	-0.0	0.	542.1	8.
9-CONDYLE JOINT ANGLE	-6.8	18.	60.2	69.
10-C7-T1 JOINT ANGLE	-20.0	0.	12.6	59.
11-FORCE ALONG NECK	-335.1	17.	2043.1	10.
12-SHEAR FORCE AT CONDYLES	-327.2	19.	63.3	96.
13-COMP. FORCE AT CONDYLES	-315.2	17.	2022.5	9.
14-SHEAR FORCE AT C7-T1	-313.0	18.	93.3	71.
15-COMP. FORCE AT C7-T1	-374.2	17.	1982.9	10.
16-CONDYLE TOTAL TORQUE	-746.8	18.	645.9	68.
17-C7-T1 TOTAL TORQUE	-257.5	99.	903.1	20.

RHM20V5.2F

HIC= 3362. BETWEEN 2. AND 27.MSEC
3-MSEC AVG. FOR HEAD= 194. AT 51. MSEC
3-MSEC AVG, FOR CHEST= 30. AT 9. MSEC

	MINIMUM	AT MSEC	MAXIMUM	AT MSEC
1-HEAD ANG. POSITION	-211.0	46.	-70.0	0.
2-HEAD ANG. VELOCITY	-6914.1	28.	3026.1	54.
3-HEAD ANG. ACCEL.	-8284.2	16.	10721.0	37.
4-HEAD RESUL. ACCEL.	1.0	0.	214.4	51.
5-UPPER NECK STOP TORQUE	-4412.8	39.	421.7	17.
6-LOWER NECK STOP TORQUE	-7358.1	57.	-0.0	0.
7-Z DIR. HEAD CONT. FORCE	-0.0	0.	3015.1	10.
8-X DIR. HEAD CONT. FORCE	-13.8	13.	603.0	10.
9-CONDYLE JOINT ANGLE	-46.2	39.	61.3	17.
10-C7-T1 JOINT ANGLE	-97.5	57.	-20.0	0.
11-FORCE ALONG NECK	-657.9	15.	2893.2	9.
12-SHEAR FORCE AT CONDYLES	-175.1	94.	1766.1	58.
13-COMP. FORCE AT CONDYLES	-577.5	64.	2881.3	9.
14-SHEAR FORCE AT C7-T1	-200.8	50.	1879.6	57.
15-COMP. FORCE AT C7-T1	-468.3	65.	2729.3	9.
16-CONDYLE TOTAL TORQUE	-4944.8	39.	744.2	17.
17-C7-T1 TOTAL TORQUE	-8598.4	57.	649.5	95.

APPENDIX C

PEAK MAGNITUDE COMPARISONS

COMPARISON #1

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= CR20NH5.3 AND B= CR20H5.3

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	157	70	2.249	0.445	124.9% GREATER	55.5% LESS	0	-7	0.0	0.0	100.0% LESS	0.0% GREATER
2-HEAD ANG. VELOC.	4156	3207	1.296	0.772	29.6% GREATER	22.8% LESS	-3753	-3244	1.157	0.864	15.7% GREATER	13.6% LESS
3-HEAD ANG. ACCEL.	11107	7391	1.503	0.665	50.3% GREATER	33.5% LESS	-3919	-2689	1.457	0.686	45.7% GREATER	31.4% LESS
4-HEAD RES. ACCEL.	70	70	1.003	0.997	0.3% GREATER	0.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	111	44	2.525	0.396	152.5% GREATER	60.4% LESS	-1497	-2497	0.600	1.668	40.0% LESS	66.8% GREATER
6-C7-T1 STOP TORQ.	10	0	0.0	0.0	0.0% GREATER	100.0% LESS	-1077	-1803	0.597	1.674	40.3% LESS	67.4% GREATER
7-Z HEAD FORCE	955	859	1.111	0.900	11.1% GREATER	10.0% LESS	-40	-96	0.416	2.405	58.4% LESS	140.5% GREATER
8-X HEAD FORCE	5366	5440	0.987	1.014	1.3% LESS	1.4% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	36	29	1.237	0.808	23.7% GREATER	19.2% LESS	-36	-45	0.799	1.251	20.1% LESS	25.1% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-70	-79	0.888	1.126	11.2% LESS	12.6% GREATER
11-FORCE ALONG NECK	211	227	0.929	1.077	7.1% LESS	7.7% GREATER	-730	-956	0.764	1.309	23.6% LESS	30.9% GREATER
12-SHEAR AT CONDYLE	317	422	0.751	1.331	24.9% LESS	33.1% GREATER	-76	-326	0.236	4.244	76.4% LESS	324.4% GREATER
13-COMP. AT CONDYLE	233	234	0.995	1.005	0.5% LESS	0.5% GREATER	-636	-863	0.737	1.357	26.3% LESS	35.7% GREATER
14-SHEAR AT C7-T1	347	419	0.827	1.209	17.3% LESS	20.9% GREATER	-129	-362	0.356	2.809	64.4% LESS	180.9% GREATER
15-COMP. AT C7-T1	166	213	0.777	1.287	22.3% LESS	28.7% GREATER	-867	-1079	0.804	1.244	19.6% LESS	24.4% GREATER
16-COND. TOTAL TORQ	357	182	1.954	0.512	95.4% GREATER	48.8% LESS	-1869	-2936	0.637	1.570	36.3% LESS	57.0% GREATER
17-C7-T1 TOTAL TORQ	698	0	0.0	0.0	0.0% GREATER	100.0% LESS	-1832	-2615	0.701	1.427	29.9% LESS	42.7% GREATER
HIC	566	419	1.351	0.740	35.1% GREATER	26.0% LESS						
HEAD 3-MSEC AVG.	70	70	1.000	1.000	0.0% LESS	0.0% GREATER						
CHEST 3-MSEC AVG	61	61	1.000	1.000	0.0% LESS	0.0% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #2

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= HR20NH5.3F AND B= HR20H5.1F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	204	228	0.898	1.114	10.2% LESS	11.4% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
2-HEAD ANG. VELOC.	5964	4699	1.265	0.788	26.9% GREATER	21.2% LESS	-1196	-1527	0.783	1.276	21.7% LESS	27.6% GREATER
3-HEAD ANG. ACCEL.	14807	8740	1.694	0.590	69.4% GREATER	41.0% LESS	-11989	-3361	3.567	0.280	256.7% GREATER	72.0% LESS
4-HEAD RES. ACCEL.	491	245	2.006	0.499	100.6% GREATER	50.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	834	722	1.155	0.866	15.5% GREATER	13.4% LESS	-304	-1261	0.241	4.149	75.9% LESS	314.9% GREATER
6-C7-T1 STOP TORQ.	1115	978	1.140	0.877	14.0% GREATER	12.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
7-Z HEAD FORCE	490	144	3.407	0.294	240.7% GREATER	70.6% LESS	-746	-389	1.918	0.521	91.8% GREATER	47.9% LESS
8-X HEAD FORCE	5026	3890	1.292	0.774	29.2% GREATER	22.6% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	61	59	1.040	0.961	4.0% GREATER	3.9% LESS	-2	-33	0.081	12.296	91.9% LESS	*****% GREATER
10-C7-T1 ANGLE	27	24	1.097	0.911	9.7% GREATER	8.9% LESS	-30	-30	1.000	1.000	0.0% LESS	0.0% GREATER
11-FORCE ALONG NECK	1253	990	1.266	0.790	26.6% GREATER	21.0% LESS	-1480	-899	1.647	0.607	64.7% GREATER	39.3% LESS
12-SHEAR AT CONDYLE	25	9	2.742	0.365	174.2% GREATER	63.5% LESS	-512	-614	0.834	1.199	16.6% LESS	19.9% GREATER
13-COMP. AT CONDYLE	1320	1070	1.234	0.811	23.4% GREATER	18.9% LESS	-1444	-796	1.813	0.552	81.3% GREATER	44.8% LESS
14-SHEAR AT C7-T1	94	18	5.244	0.191	424.4% GREATER	80.9% LESS	-373	-578	0.645	1.551	35.5% LESS	55.1% GREATER
15-COMP. AT C7-T1	1186	935	1.268	0.788	26.8% GREATER	21.2% LESS	-1435	-858	1.671	0.598	67.1% GREATER	40.2% LESS
16-COND. TOTAL TORQ	1240	1045	1.187	0.843	18.7% GREATER	15.7% LESS	-404	-1596	0.253	3.947	74.7% LESS	294.7% GREATER
17-C7-T1 TOTAL TORQ	2239	1976	1.133	0.882	13.3% GREATER	11.8% LESS	-143	0	0.0	0.0	0.0% GREATER	100.0% LESS
HIC	3475	3317	1.048	0.955	4.8% GREATER	4.5% LESS						
HEAD 3-MSEC AVG.	290	233	1.245	0.803	24.5% GREATER	19.7% LESS						
CHEST 3-MSEC AVG	22	18	1.222	0.818	22.2% GREATER	18.2% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #3

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= HR20NH5.3F AND B= HR20NH5.312

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	204	193	1.057	0.946	5.7% GREATER	5.4% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
2-HEAD ANG. VELOC.	5964	5748	1.038	0.964	3.8% GREATER	3.6% LESS	-1196	-1568	0.763	1.310	23.7% LESS	31.0% GREATER
3-HEAD ANG. ACCEL.	14807	13920	1.064	0.940	6.4% GREATER	6.0% LESS	-11989	-11652	1.029	0.972	2.9% GREATER	2.8% LESS
4-HEAD RES. ACCEL.	491	489	1.003	0.997	0.3% GREATER	0.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	834	788	1.057	0.946	5.7% GREATER	5.4% LESS	-304	-446	0.680	1.470	32.0% LESS	47.0% GREATER
6-C7-T1 STOP TORQ.	1115	1184	0.942	1.062	5.8% LESS	6.2% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
7-Z HEAD FORCE	490	490	1.000	1.000	0.0% LESS	0.0% GREATER	-746	-800	0.933	1.072	6.7% LESS	7.2% GREATER
8-X HEAD FORCE	5026	5288	0.951	1.052	4.9% LESS	5.2% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	61	50	1.214	0.824	21.4% GREATER	17.6% LESS	-2	-22	0.122	8.185	87.8% LESS	718.5% GREATER
10-C7-T1 ANGLE	27	18	1.489	0.672	48.9% GREATER	32.8% LESS	-30	-40	0.750	1.333	25.0% LESS	33.3% GREATER
11-FORCE ALONG NECK	1253	1702	0.737	1.358	26.3% LESS	35.8% GREATER	-1480	-1417	1.045	0.957	4.5% GREATER	4.3% LESS
12-SHEAR AT CONDYLE	25	48	0.525	1.906	47.5% LESS	90.6% GREATER	-512	-435	1.178	0.849	17.8% GREATER	15.1% LESS
13-COMP. AT CONDYLE	1320	1752	0.753	1.327	24.7% LESS	32.7% GREATER	-1444	-1373	1.052	0.951	5.2% GREATER	4.9% LESS
14-SHEAR AT C7-T1	94	100	0.938	1.066	6.2% LESS	6.6% GREATER	-373	-391	0.953	1.049	4.7% LESS	4.9% GREATER
15-COMP. AT C7-T1	1186	1579	0.752	1.331	24.8% LESS	33.1% GREATER	-1435	-1382	1.038	0.964	3.8% GREATER	3.6% LESS
16-COND. TOTAL TORQ	1240	1201	1.032	0.969	3.2% GREATER	3.1% LESS	-404	-621	0.651	1.536	34.9% LESS	53.6% GREATER
17-C7-T1 TOTAL TORQ	2239	2176	1.029	0.971	2.9% GREATER	2.9% LESS	-143	0	0.0	0.0	0.0% GREATER	100.0% LESS
HIC	3475	3673	0.946	1.057	5.4% LESS	5.7% GREATER						
HEAD 3-MSEC AVG.	290	270	1.074	0.931	7.4% GREATER	6.9% LESS						
CHEST 3-MSEC AVG	22	23	0.957	1.045	4.3% LESS	4.5% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 4

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20H5.6F AND B= RF20H5.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	46	70	0.658	1.520	34.2% LESS	52.0% GREATER	-30	-30	0.987	1.013	1.3% LESS	1.3% GREATER
2-HEAD ANG. VELOC.	8379	2875	2.915	0.343	191.5% GREATER	65.7% LESS	-3666	-1781	2.058	0.486	105.8% GREATER	51.4% LESS
3-HEAD ANG. ACCEL.	24337	4559	5.337	0.187	433.7% GREATER	81.3% LESS	-27463	-1844	14.887	0.067	*****% GREATER	93.3% LESS
4-HEAD RES. ACCEL.	398	133	2.985	0.335	198.5% GREATER	66.5% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	4218	347	12.125	0.082	*****% GREATER	91.8% LESS	-466	-551	0.845	1.183	15.5% LESS	18.3% GREATER
6-C7-T1 STOP TORQ.	1058	186	5.685	0.176	468.5% GREATER	82.4% LESS	-527	0	0.0	0.0	0.0% GREATER	100.0% LESS
7-Z HEAD FORCE	4827	3139	1.538	0.650	53.8% GREATER	35.0% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2896	627	4.613	0.217	361.3% GREATER	78.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	108	58	1.855	0.539	85.5% GREATER	46.1% LESS	-3	-7	0.438	2.281	56.2% LESS	128.1% GREATER
10-C7-T1 ANGLE	36	11	3.167	0.316	216.7% GREATER	68.4% LESS	-46	-20	2.320	0.431	132.0% GREATER	56.9% LESS
11-FORCE ALONG NECK	4271	2371	1.801	0.555	80.1% GREATER	44.5% LESS	-1441	-525	2.742	0.365	174.2% GREATER	63.5% LESS
12-SHEAR AT CONDYLE	1283	60	21.082	0.047	*****% GREATER	95.3% LESS	-598	-337	1.772	0.564	77.2% GREATER	43.6% LESS
13-COMP. AT CONDYLE	4044	2321	1.742	0.574	74.2% GREATER	42.6% LESS	-1270	-458	2.771	0.361	177.1% GREATER	63.9% LESS
14-SHEAR AT C7-T1	1453	118	12.243	0.082	*****% GREATER	91.8% LESS	-662	-310	2.137	0.468	113.7% GREATER	53.2% LESS
15-COMP. AT C7-T1	4090	2304	1.775	0.563	77.5% GREATER	43.7% LESS	-1385	-515	2.689	0.372	168.9% GREATER	62.8% LESS
16-COND. TOTAL TORQ	4908	578	8.480	0.118	748.0% GREATER	88.2% LESS	-751	-761	0.987	1.013	1.3% LESS	1.3% GREATER
17-C7-T1 TOTAL TORQ	2418	854	2.832	0.353	183.2% GREATER	64.7% LESS	-1165	-220	5.299	0.189	429.9% GREATER	81.1% LESS
HIC	7621	1266	6.020	0.166	502.0% GREATER	83.4% LESS						
HEAD 3-MSEC AVG.	324	131	2.473	0.404	147.3% GREATER	59.6% LESS						
CHEST 3-MSEC AVG	38	23	1.652	0.605	65.2% GREATER	39.5% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #5

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20H5.2F AND B= RH20H5.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	59	70	0.843	1.186	15.7% LESS	18.6% GREATER	-30	-30	0.987	1.013	1.3% LESS	1.3% GREATER
2-HEAD ANG. VELOC.	3299	2875	1.148	0.871	14.8% GREATER	12.9% LESS	-2676	-1781	1.502	0.666	50.2% GREATER	33.4% LESS
3-HEAD ANG. ACCEL.	17203	4559	3.773	0.265	277.3% GREATER	73.5% LESS	-4365	-1844	2.366	0.423	136.6% GREATER	57.7% LESS
4-HEAD RES. ACCEL.	367	133	2.756	0.363	175.6% GREATER	63.7% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	372	347	1.072	0.933	7.2% GREATER	6.7% LESS	-302	-551	0.549	1.820	45.1% LESS	82.0% GREATER
6-C7-T1 STOP TORQ.	329	186	1.768	0.565	76.8% GREATER	43.5% LESS	-305	0	0.0	0.0	0.0% GREATER	100.0% LESS
7-Z HEAD FORCE	4770	3139	1.519	0.658	51.9% GREATER	34.2% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	954	627	1.519	0.658	51.9% GREATER	34.2% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	59	58	1.015	0.985	1.5% GREATER	1.5% LESS	0	-7	0.0	0.0	100.0% LESS	0.0% GREATER
10-C7-T1 ANGLE	18	11	1.579	0.633	57.9% GREATER	36.7% LESS	-32	-20	1.635	0.612	63.5% GREATER	38.8% LESS
11-FORCE ALONG NECK	2892	2371	1.215	0.823	21.5% GREATER	17.7% LESS	-644	-525	1.226	0.816	22.6% GREATER	18.4% LESS
12-SHEAR AT CONDYLE	134	60	2.200	0.454	120.0% GREATER	54.6% LESS	-314	-337	0.930	1.075	7.0% LESS	7.5% GREATER
13-COMP. AT CONDYLE	2839	2321	1.223	0.818	22.3% GREATER	18.2% LESS	-571	-458	1.247	0.802	24.7% GREATER	19.8% LESS
14-SHEAR AT C7-T1	121	118	1.021	0.979	2.1% GREATER	2.1% LESS	-133	-310	0.429	2.332	57.1% LESS	133.2% GREATER
15-COMP. AT C7-T1	2789	2304	1.210	0.826	21.0% GREATER	17.4% LESS	-635	-515	1.233	0.811	23.3% GREATER	18.9% LESS
16-COND. TOTAL TORQ	659	578	1.139	0.878	13.9% GREATER	12.2% LESS	-517	-761	0.680	1.471	32.0% LESS	47.1% GREATER
17-C7-T1 TOTAL TORQ	1003	854	1.175	0.851	17.5% GREATER	14.9% LESS	-869	-220	3.953	0.253	295.3% GREATER	74.7% LESS
HIC	4787	1266	3.781	0.264	278.1% GREATER	73.6% LESS						
HEAD 3-MSEC AVG.	310	131	2.366	0.423	136.6% GREATER	57.7% LESS						
CHEST 3-MSEC AVG	26	23	1.130	0.885	13.0% GREATER	11.5% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #6

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20H5.6F AND B= RNH20H5.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	46	59	0.780	1.282	22.0% LESS	28.2% GREATER	-30	-30	1.000	1.000	0.0% LESS	0.0% GREATER
2-HEAD ANG. VELOC.	8379	3299	2.539	0.394	153.9% GREATER	60.6% LESS	-3666	-2676	1.370	0.730	37.0% GREATER	27.0% LESS
3-HEAD ANG. ACCEL.	24337	17203	1.415	0.707	41.5% GREATER	29.3% LESS	-27463	-4365	6.292	0.159	529.2% GREATER	84.1% LESS
4-HEAD RES. ACCEL.	398	367	1.083	0.923	8.3% GREATER	7.7% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	4218	372	11.315	0.088	*****% GREATER	91.2% LESS	-466	-302	1.538	0.650	53.8% GREATER	35.0% LESS
6-C7-T1 STOP TORQ.	1058	329	3.215	0.311	221.5% GREATER	68.9% LESS	-527	-305	1.726	0.579	72.6% GREATER	42.1% LESS
7-Z HEAD FORCE	4827	4770	1.012	0.988	1.2% GREATER	1.2% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2896	954	3.036	0.329	203.6% GREATER	67.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	108	59	1.827	0.547	82.7% GREATER	45.3% LESS	-3	0	0.0	0.0	0.0% GREATER	100.0% LESS
10-C7-T1 ANGLE	36	18	2.006	0.499	100.6% GREATER	50.1% LESS	-46	-32	1.419	0.705	41.9% GREATER	29.5% LESS
11-FORCE ALONG NECK	4271	2882	1.482	0.675	48.2% GREATER	32.5% LESS	-1441	-644	2.236	0.447	123.6% GREATER	55.3% LESS
12-SHEAR AT CONDYLE	1283	134	9.581	0.104	858.1% GREATER	89.6% LESS	-598	-314	1.904	0.525	90.4% GREATER	47.5% LESS
13-COMP. AT CONDYLE	4044	2839	1.425	0.702	42.5% GREATER	29.8% LESS	-1270	-571	2.222	0.450	122.2% GREATER	55.0% LESS
14-SHEAR AT C7-T1	1453	121	11.990	0.083	*****% GREATER	91.7% LESS	-662	-133	4.983	0.201	398.3% GREATER	79.9% LESS
15-COMP. AT C7-T1	4090	2789	1.467	0.682	46.7% GREATER	31.8% LESS	-1385	-635	2.180	0.459	118.0% GREATER	54.1% LESS
16-COND. TOTAL TORQ	4908	659	7.446	0.134	644.6% GREATER	86.6% LESS	-751	-517	1.452	0.688	45.2% GREATER	31.2% LESS
17-C7-T1 TOTAL TORQ	2418	1003	2.410	0.415	141.0% GREATER	58.5% LESS	-1165	-869	1.340	0.746	34.0% GREATER	25.4% LESS
HIC	7621	4787	1.592	0.628	59.2% GREATER	37.2% LESS						
HEAD 3-MSEC AVG.	324	310	1.045	0.957	4.5% GREATER	4.3% LESS						
CHEST 3-MSEC AVG	38	26	1.462	0.684	46.2% GREATER	31.6% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 7

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20H5.6F AND B= RH20H5.6F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	46	80	0.578	1.731	42.2% LESS	73.1% GREATER	-30	-30	0.993	1.007	0.7% LESS	0.7% GREATER
2-HEAD ANG. VELOC.	8379	3165	2.647	0.378	164.7% GREATER	62.2% LESS	-3666	-825	4.439	0.225	343.9% GREATER	77.5% LESS
3-HEAD ANG. ACCEL.	24337	6424	3.788	0.264	278.8% GREATER	73.6% LESS	-27463	-5284	5.197	0.192	419.7% GREATER	80.8% LESS
4-HEAD RES. ACCEL.	398	125	3.181	0.314	218.1% GREATER	68.6% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	4218	888	4.750	0.211	375.0% GREATER	78.9% LESS	-466	-385	1.210	0.826	21.0% GREATER	17.4% LESS
6-C7-T1 STOP TORQ.	1058	440	2.400	0.417	140.0% GREATER	58.3% LESS	-527	-1056	0.499	2.004	50.1% LESS	100.4% GREATER
7-Z HEAD FORCE	4827	3489	1.383	0.723	38.3% GREATER	27.7% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2896	2094	1.383	0.723	38.3% GREATER	27.7% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	108	72	1.494	0.669	49.4% GREATER	33.1% LESS	-3	0	0.0	0.0	0.0% GREATER	100.0% LESS
10-C7-T1 ANGLE	36	21	1.648	0.607	64.8% GREATER	39.3% LESS	-46	-60	0.772	1.295	22.8% LESS	29.5% GREATER
11-FORCE ALONG NECK	4271	4821	0.886	1.129	11.4% LESS	12.9% GREATER	-1441	-1157	1.246	0.802	24.6% GREATER	19.8% LESS
12-SHEAR AT CONDYLE	1283	732	1.753	0.570	75.3% GREATER	43.0% LESS	-598	-435	1.376	0.727	37.6% GREATER	27.3% LESS
13-COMP. AT CONDYLE	4044	4715	0.858	1.166	14.2% LESS	16.6% GREATER	-1270	-1045	1.215	0.823	21.5% GREATER	17.7% LESS
14-SHEAR AT C7-T1	1453	749	1.939	0.516	93.9% GREATER	48.4% LESS	-662	-421	1.571	0.637	57.1% GREATER	36.3% LESS
15-COMP. AT C7-T1	4090	4593	0.891	1.123	10.9% LESS	12.3% GREATER	-1385	-1135	1.220	0.820	22.0% GREATER	18.0% LESS
16-COND. TOTAL TORQ	4908	1288	3.809	0.263	280.9% GREATER	73.7% LESS	-751	-601	1.249	0.800	24.9% GREATER	20.0% LESS
17-C7-T1 TOTAL TORQ	2418	1553	1.557	0.642	55.7% GREATER	35.8% LESS	-1165	-1998	0.583	1.714	41.7% LESS	71.4% GREATER
HIC	7621	1403	5.432	0.184	443.2% GREATER	81.6% LESS						
HEAD 3-MSEC AVG.	324	121	2.678	0.373	167.8% GREATER	62.7% LESS						
CHEST 3-MSEC AVG	38	47	0.809	1.237	19.1% LESS	23.7% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #8

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20H5.2F AND B= RH20H5.6F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	80	0.878	1.139	12.2% LESS	13.9% GREATER	-30	-30	1.007	0.993	0.7% GREATER	0.7% LESS
2-HEAD ANG. VELOC.	2875	3165	0.908	1.101	9.2% LESS	10.1% GREATER	-1781	-825	2.157	0.464	115.7% GREATER	53.6% LESS
3-HEAD ANG. ACCEL.	4559	6424	0.710	1.409	29.0% LESS	40.9% GREATER	-1844	-5284	0.349	2.864	65.1% LESS	186.4% GREATER
4-HEAD RES. ACCEL.	133	125	1.065	0.939	6.5% GREATER	6.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	347	888	0.392	2.553	60.8% LESS	155.3% GREATER	-551	-385	1.432	0.698	43.2% GREATER	30.2% LESS
6-C7-T1 STOP TORQ.	186	440	0.422	2.369	57.8% LESS	136.9% GREATER	0	-1056	0.0	0.0	100.0% LESS	0.0% GREATER
7-Z HEAD FORCE	3139	3489	0.900	1.112	10.0% LESS	11.2% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	627	2094	0.300	3.335	70.0% LESS	233.5% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	58	72	0.805	1.242	19.5% LESS	24.2% GREATER	-7	0	0.0	0.0	0.0% GREATER	100.0% LESS
10-C7-T1 ANGLE	11	21	0.521	1.921	47.9% LESS	92.1% GREATER	-20	-60	0.333	3.005	66.7% LESS	200.5% GREATER
11-FORCE ALONG NECK	2371	4821	0.492	2.033	50.8% LESS	103.3% GREATER	-525	-1157	0.454	2.200	54.6% LESS	120.0% GREATER
12-SHEAR AT CONDYLE	60	732	0.083	12.026	91.7% LESS	*****% GREATER	-337	-435	0.776	1.288	22.4% LESS	28.8% GREATER
13-COMP. AT CONDYLE	2321	4715	0.492	2.031	50.8% LESS	103.1% GREATER	-458	-1045	0.438	2.281	56.2% LESS	128.1% GREATER
14-SHEAR AT C7-T1	118	749	0.158	6.315	84.2% LESS	531.5% GREATER	-310	-421	0.735	1.361	26.5% LESS	36.1% GREATER
15-COMP. AT C7-T1	2304	4593	0.502	1.993	49.8% LESS	99.3% GREATER	-515	-1135	0.454	2.204	54.6% LESS	120.4% GREATER
16-COND. TOTAL TORQ	578	1288	0.449	2.226	55.1% LESS	122.6% GREATER	-761	-601	1.265	0.790	26.5% GREATER	21.0% LESS
17-C7-T1 TOTAL TORQ	854	1553	0.550	1.819	45.0% LESS	81.9% GREATER	-220	-1998	0.110	9.082	89.0% LESS	808.2% GREATER
HIC	1266	1403	0.902	1.108	9.8% LESS	10.8% GREATER						
HEAD 3-MSEC AVG.	131	121	1.083	0.924	8.3% GREATER	7.6% LESS						
CHEST 3-MSEC AVG	23	47	0.489	2.043	51.1% LESS	104.3% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 9

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20H5.2F AND B= RF20H5.2NR

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	66	1.060	0.943	6.0% GREATER	5.7% LESS	-30	-30	1.017	0.984	1.7% GREATER	1.6% LESS
2-HEAD ANG. VELOC.	2875	2738	1.050	0.952	5.0% GREATER	4.8% LESS	-1781	-1435	1.241	0.806	24.1% GREATER	19.4% LESS
3-HEAD ANG. ACCEL.	4559	3991	1.142	0.875	14.2% GREATER	12.5% LESS	-1844	-1845	0.999	1.001	0.1% LESS	0.1% GREATER
4-HEAD RES. ACCEL.	133	124	1.070	0.935	7.0% GREATER	6.5% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	347	285	1.217	0.822	21.7% GREATER	17.8% LESS	-551	-490	1.125	0.889	12.5% GREATER	11.1% LESS
6-C7-T1 STOP TORQ.	186	122	1.523	0.657	52.3% GREATER	34.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
7-Z HEAD FORCE	3139	2898	1.083	0.923	8.3% GREATER	7.7% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	627	579	1.083	0.923	8.3% GREATER	7.7% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	58	56	1.043	0.959	4.3% GREATER	4.1% LESS	-7	-4	1.622	0.616	62.2% GREATER	38.4% LESS
10-C7-T1 ANGLE	11	7	1.562	0.640	56.2% GREATER	36.0% LESS	-20	-20	1.000	1.000	0.0% LESS	0.0% GREATER
11-FORCE ALONG NECK	2371	2102	1.128	0.886	12.8% GREATER	11.4% LESS	-525	-477	1.102	0.908	10.2% GREATER	9.2% LESS
12-SHEAR AT CONDYLE	60	51	1.180	0.847	18.0% GREATER	15.3% LESS	-337	-297	1.135	0.881	13.5% GREATER	11.9% LESS
13-COMP. AT CONDYLE	2321	2074	1.119	0.893	11.9% GREATER	10.7% LESS	-458	-420	1.091	0.917	9.1% GREATER	8.3% LESS
14-SHEAR AT C7-T1	118	93	1.276	0.783	27.6% GREATER	21.7% LESS	-310	-276	1.121	0.892	12.1% GREATER	10.8% LESS
15-COMP. AT C7-T1	2304	2040	1.130	0.885	13.0% GREATER	11.5% LESS	-515	-473	1.089	0.918	8.9% GREATER	8.2% LESS
16-COND. TOTAL TORQ	578	504	1.148	0.871	14.8% GREATER	12.9% LESS	-761	-678	1.123	0.891	12.3% GREATER	10.9% LESS
17-C7-T1 TOTAL TORQ	854	756	1.129	0.886	12.9% GREATER	11.4% LESS	-220	-68	3.212	0.311	221.2% GREATER	68.9% LESS
HIC	1266	1069	1.184	0.844	18.4% GREATER	15.6% LESS						
HEAD 3-MSEC AVG.	131	123	1.065	0.939	6.5% GREATER	6.1% LESS						
CHEST 3-MSEC AVG	23	27	0.852	1.174	14.8% LESS	17.4% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #10

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20H5.6F AND B= RNH20H5.6NR

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	46	49	0.937	1.067	6.3% LESS	6.7% GREATER	-30	-30	1.003	0.997	0.3% GREATER	0.3% LESS
2-HEAD ANG. VELOC.	8373	7716	1.086	0.921	8.6% GREATER	7.9% LESS	-3666	-3500	1.047	0.955	4.7% GREATER	4.5% LESS
3-HEAD ANG. ACCEL.	24337	22362	1.088	0.919	8.8% GREATER	8.1% LESS	-27463	-24510	1.120	0.893	12.0% GREATER	10.7% LESS
4-HEAD RES. ACCEL.	398	368	1.080	0.926	8.0% GREATER	7.4% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	4218	3319	1.271	0.787	27.1% GREATER	21.3% LESS	-466	-458	1.017	0.983	1.7% GREATER	1.7% LESS
6-C7-T1 STOP TORQ.	1058	943	1.121	0.892	12.1% GREATER	10.8% LESS	-527	-463	1.138	0.878	13.8% GREATER	12.2% LESS
7-Z HEAD FORCE	4827	4455	1.084	0.923	8.4% GREATER	7.7% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2896	2673	1.084	0.923	8.4% GREATER	7.7% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	108	102	1.067	0.938	6.7% GREATER	6.2% LESS	-3	-2	1.143	0.875	14.3% GREATER	12.5% LESS
10-C7-T1 ANGLE	36	34	1.062	0.942	6.2% GREATER	5.8% LESS	-46	-43	1.077	0.929	7.7% GREATER	7.1% LESS
11-FORCE ALONG NECK	4271	3887	1.099	0.910	9.9% GREATER	9.0% LESS	-1441	-1247	1.156	0.865	15.6% GREATER	13.5% LESS
12-SHEAR AT CONDYLE	1283	1002	1.281	0.781	28.1% GREATER	21.9% LESS	-598	-534	1.120	0.893	12.0% GREATER	10.7% LESS
13-COMP. AT CONDYLE	4044	3707	1.091	0.917	9.1% GREATER	8.3% LESS	-1270	-1092	1.162	0.860	16.2% GREATER	14.0% LESS
14-SHEAR AT C7-T1	1453	1151	1.262	0.792	26.2% GREATER	20.8% LESS	-662	-587	1.128	0.886	12.8% GREATER	11.4% LESS
15-COMP. AT C7-T1	4090	3726	1.098	0.911	9.8% GREATER	8.9% LESS	-1385	-1206	1.149	0.870	14.9% GREATER	13.0% LESS
16-COND. TOTAL TORQ	4908	3954	1.241	0.806	24.1% GREATER	19.4% LESS	-751	-681	1.103	0.907	10.3% GREATER	9.3% LESS
17-C7-T1 TOTAL TORQ	2418	2244	1.077	0.928	7.7% GREATER	7.2% LESS	-1165	-1175	0.992	1.008	0.8% LESS	0.8% GREATER
HIC	7621	5618	1.357	0.737	35.7% GREATER	26.3% LESS						
HEAD 3-MSEC AVG.	324	302	1.073	0.932	7.3% GREATER	6.8% LESS						
CHEST 3-MSEC AVG	38	35	1.086	0.921	8.6% GREATER	7.9% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #12

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20H5.6NR AND B= RH20H5.2NR

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	49	66	0.744	1.345	25.6% LESS	34.5% GREATER	-30	-30	1.000	1.000	0.0% LESS	0.0% GREATER
2-HEAD ANG. VELOC.	7716	2738	2.818	0.355	181.8% GREATER	64.5% LESS	-3500	-1435	2.439	0.410	143.9% GREATER	59.0% LESS
3-HEAD ANG. ACCEL.	22362	3991	5.602	0.178	460.2% GREATER	82.2% LESS	-24510	-1845	13.279	0.075	*****% GREATER	92.5% LESS
4-HEAD RES. ACCEL.	368	124	2.957	0.338	195.7% GREATER	66.2% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	3319	285	11.609	0.086	*****% GREATER	91.4% LESS	-458	-490	0.935	1.070	6.5% LESS	7.0% GREATER
6-C7-T1 STOP TORQ.	943	122	7.723	0.129	672.3% GREATER	87.1% LESS	-463	0	0.0	0.0	0.0% GREATER	100.0% LESS
7-Z HEAD FORCE	4455	2898	1.537	0.651	53.7% GREATER	34.9% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2673	579	4.612	0.217	361.2% GREATER	78.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	102	56	1.813	0.551	81.3% GREATER	44.9% LESS	-2	-4	0.622	1.607	37.8% LESS	60.7% GREATER
10-C7-T1 ANGLE	34	7	4.658	0.215	365.8% GREATER	78.5% LESS	-43	-20	2.155	0.464	115.5% GREATER	53.6% LESS
11-FORCE ALONG NECK	3887	2102	1.849	0.541	84.9% GREATER	45.9% LESS	-1247	-477	2.614	0.383	161.4% GREATER	61.7% LESS
12-SHEAR AT CONDYLE	1002	51	19.428	0.051	*****% GREATER	94.9% LESS	-534	-297	1.796	0.557	79.6% GREATER	44.3% LESS
13-COMP. AT CONDYLE	3707	2074	1.787	0.560	78.7% GREATER	44.0% LESS	-1092	-420	2.601	0.384	160.1% GREATER	61.6% LESS
14-SHEAR AT C7-T1	1151	93	12.383	0.081	*****% GREATER	91.9% LESS	-587	-276	2.124	0.471	112.4% GREATER	52.9% LESS
15-COMP. AT C7-T1	3726	2040	1.826	0.548	82.6% GREATER	45.2% LESS	-1206	-473	2.549	0.392	154.9% GREATER	60.8% LESS
16-COND. TOTAL TORQ	3954	504	7.844	0.127	684.4% GREATER	87.3% LESS	-681	-678	1.005	0.995	0.5% GREATER	0.5% LESS
17-C7-T1 TOTAL TORQ	2244	756	2.967	0.337	196.7% GREATER	66.3% LESS	-1175	-68	17.162	0.058	*****% GREATER	94.2% LESS
HIC	5618	1069	5.255	0.190	425.5% GREATER	81.0% LESS						
HEAD 3-MSEC AVG.	302	123	2.455	0.407	145.5% GREATER	59.3% LESS						
CHEST 3-MSEC AVG	35	27	1.296	0.771	29.6% GREATER	22.9% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #13

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20H5.2F AND B= RF20H5.212

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	33	2.123	0.471	112.3% GREATER	52.9% LESS	-30	-81	0.372	2.685	62.8% LESS	168.5% GREATER
2-HEAD ANG. VELOC.	2875	1993	1.442	0.693	44.2% GREATER	30.7% LESS	-1781	-2395	0.744	1.345	25.6% LESS	34.5% GREATER
3-HEAD ANG. ACCEL.	4559	8049	0.566	1.765	43.4% LESS	76.5% GREATER	-1844	-6088	0.303	3.300	69.7% LESS	230.0% GREATER
4-HEAD RES. ACCEL.	133	126	1.051	0.951	5.1% GREATER	4.9% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	347	319	1.090	0.918	9.0% GREATER	8.2% LESS	-551	-2317	0.238	4.203	76.2% LESS	320.3% GREATER
6-C7-T1 STOP TORQ.	186	101	1.830	0.546	83.0% GREATER	45.4% LESS	0	-220	0.0	0.0	100.0% LESS	0.0% GREATER
7-Z HEAD FORCE	3139	3131	1.003	0.997	0.3% GREATER	0.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	627	626	1.002	0.998	0.2% GREATER	0.2% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	58	32	1.801	0.555	80.1% GREATER	44.5% LESS	-7	-58	0.124	8.068	87.6% LESS	706.8% GREATER
10-C7-T1 ANGLE	11	0	16.286	0.061	*****% GREATER	93.9% LESS	-20	-32	0.608	1.645	39.2% LESS	64.5% GREATER
11-FORCE ALONG NECK	2371	2229	1.064	0.940	6.4% GREATER	6.0% LESS	-525	-318	1.652	0.605	65.2% GREATER	39.5% LESS
12-SHEAR AT CONDYLE	60	109	0.558	1.791	44.2% LESS	79.1% GREATER	-337	-751	0.450	2.223	55.0% LESS	122.3% GREATER
13-COMP. AT CONDYLE	2321	2199	1.056	0.947	5.6% GREATER	5.3% LESS	-458	-294	1.557	0.642	55.7% GREATER	35.8% LESS
14-SHEAR AT C7-T1	118	117	1.007	0.993	0.7% GREATER	0.7% LESS	-310	-685	0.452	2.212	54.8% LESS	121.2% GREATER
15-COMP. AT C7-T1	2304	2148	1.073	0.932	7.3% GREATER	6.8% LESS	-515	-358	1.438	0.695	43.8% GREATER	30.5% LESS
16-COND. TOTAL TORQ	578	677	0.855	1.170	14.5% LESS	17.0% GREATER	-761	-2727	0.279	3.583	72.1% LESS	258.3% GREATER
17-C7-T1 TOTAL TORQ	854	710	1.202	0.832	20.2% GREATER	16.8% LESS	-220	-482	0.456	2.193	54.4% LESS	119.3% GREATER
HIC	1266	931	1.360	0.735	36.0% GREATER	26.5% LESS						
HEAD 3-MSEC AVG.	131	124	1.056	0.947	5.6% GREATER	5.3% LESS						
CHEST 3-MSEC AVG	23	20	1.150	0.870	15.0% GREATER	13.0% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #14

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20H5.6F AND B= RNH20H5.612

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	46	28	1.655	0.604	65.5% GREATER	39.6% LESS	-30	-158	0.189	5.279	81.1% LESS	427.9% GREATER
2-HEAD ANG. VELOC.	8379	7502	1.117	0.895	11.7% GREATER	10.5% LESS	-3666	-9315	0.394	2.541	60.6% LESS	154.1% GREATER
3-HEAD ANG. ACCEL.	24337	29727	0.819	1.221	18.1% LESS	22.1% GREATER	-27463	-45497	0.604	1.657	39.6% LESS	65.7% GREATER
4-HEAD RES. ACCEL.	399	444	0.895	1.117	10.5% LESS	11.7% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	4218	13	312.459	0.003	*****% GREATER	99.7% LESS	-466	-4387	0.106	9.416	89.4% LESS	841.6% GREATER
6-C7-T1 STOP TORQ.	1058	23	45.408	0.022	*****% GREATER	97.8% LESS	-527	-8320	0.063	15.774	93.7% LESS	*****% GREATER
7-Z HEAD FORCE	4827	5108	0.945	1.058	5.5% LESS	5.8% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2896	3065	0.945	1.058	5.5% LESS	5.8% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	108	8	13.444	0.074	*****% GREATER	92.6% LESS	-3	-71	0.045	22.281	95.5% LESS	*****% GREATER
10-C7-T1 ANGLE	36	0	0.0	0.0	0.0% GREATER	100.0% LESS	-46	-105	0.440	2.272	56.0% LESS	127.2% GREATER
11-FORCE ALONG NECK	4271	3702	1.154	0.867	15.4% GREATER	13.3% LESS	-1441	-366	3.939	0.254	293.9% GREATER	74.6% LESS
12-SHEAR AT CONDYLE	1283	1943	0.661	1.514	33.9% LESS	51.4% GREATER	-598	-1035	0.578	1.730	42.2% LESS	73.0% GREATER
13-COMP. AT CONDYLE	4044	3589	1.127	0.888	12.7% GREATER	11.2% LESS	-1270	-333	3.807	0.263	280.7% GREATER	73.7% LESS
14-SHEAR AT C7-T1	1453	2189	0.664	1.506	33.6% LESS	50.6% GREATER	-662	-1064	0.623	1.606	37.7% LESS	60.6% GREATER
15-COMP. AT C7-T1	4090	3539	1.156	0.865	15.6% GREATER	13.5% LESS	-1385	-364	3.806	0.263	280.6% GREATER	73.7% LESS
16-COND. TOTAL TORQ	4908	273	17.954	0.056	*****% GREATER	94.4% LESS	-751	-4907	0.153	6.528	84.7% LESS	552.8% GREATER
17-C7-T1 TOTAL TORQ	2418	1110	2.177	0.459	117.7% GREATER	54.1% LESS	-1165	-9911	0.118	8.503	88.2% LESS	750.3% GREATER
HIC	7621	11276	0.676	1.480	32.4% LESS	48.0% GREATER						
HEAD 3-MSEC AVG.	324	391	0.829	1.207	17.1% LESS	20.7% GREATER						
CHEST 3-MSEC AVG	38	39	0.974	1.026	2.6% LESS	2.6% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #15

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20H5.612 AND B= RF20H5.212

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	28	33	0.844	1.185	15.6% LESS	18.5% GREATER	-158	-81	1.940	0.515	94.0% GREATER	48.5% LESS
2-HEAD ANG. VELOC.	7502	1993	3.764	0.266	276.4% GREATER	73.4% LESS	-9315	-2395	3.889	0.257	288.9% GREATER	74.3% LESS
3-HEAD ANG. ACCEL.	29727	8049	3.693	0.271	269.3% GREATER	72.9% LESS	-45497	-6088	7.473	0.134	647.3% GREATER	86.6% LESS
4-HEAD RES. ACCEL.	444	126	3.505	0.285	250.5% GREATER	71.5% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	13	319	0.042	23.644	95.8% LESS	*****% GREATER	-4387	-2317	1.894	0.528	89.4% GREATER	47.2% LESS
6-C7-T1 STOP TORQ.	23	101	0.229	4.365	77.1% LESS	336.5% GREATER	-8320	-220	37.770	0.026	*****% GREATER	97.4% LESS
7-Z HEAD FORCE	5108	3131	1.631	0.613	63.1% GREATER	38.7% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	3065	626	4.894	0.204	389.4% GREATER	79.6% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	8	32	0.248	4.025	75.2% LESS	302.5% GREATER	-71	-58	1.211	0.826	21.1% GREATER	17.4% LESS
10-C7-T1 ANGLE	0	0	0.0	0.0	100.0% LESS	0.0% GREATER	-105	-32	3.204	0.312	220.4% GREATER	68.8% LESS
11-FORCE ALONG NECK	3702	2229	1.660	0.602	66.0% GREATER	39.8% LESS	-366	-318	1.150	0.869	15.0% GREATER	13.1% LESS
12-SHEAR AT CONDYLE	1943	109	17.815	0.056	*****% GREATER	94.4% LESS	-1035	-751	1.379	0.725	37.9% GREATER	27.5% LESS
13-COMP. AT CONDYLE	3589	2199	1.632	0.613	63.2% GREATER	38.7% LESS	-333	-294	1.133	0.882	13.3% GREATER	11.8% LESS
14-SHEAR AT C7-T1	2189	117	18.567	0.054	*****% GREATER	94.6% LESS	-1064	-685	1.552	0.644	55.2% GREATER	35.6% LESS
15-COMP. AT C7-T1	3539	2148	1.648	0.607	64.8% GREATER	39.3% LESS	-364	-358	1.016	0.984	1.6% GREATER	1.6% LESS
16-COND. TOTAL TORQ	273	677	0.404	2.476	59.6% LESS	147.6% GREATER	-4907	-2727	1.799	0.556	79.9% GREATER	44.4% LESS
17-C7-T1 TOTAL TORQ	1110	710	1.564	0.639	56.4% GREATER	36.1% LESS	-9911	-482	20.547	0.049	*****% GREATER	95.1% LESS
HIC	11276	931	12.112	0.083	*****% GREATER	91.7% LESS						
HEAD 3-MSEC AVG.	391	124	3.153	0.317	215.3% GREATER	68.3% LESS						
CHEST 3-MSEC AVG	39	20	1.950	0.513	95.0% GREATER	48.7% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #17

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20H5.6F AND B= RNH20H1.6F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	46	52	0.885	1.125	11.1% LESS	12.5% GREATER	-30	-30	1.000	1.000	0.0% LESS	0.0% GREATER
2-HEAD ANG. VELOC.	8379	9005	0.930	1.075	7.0% LESS	7.5% GREATER	-3666	-3985	0.920	1.087	8.0% LESS	8.7% GREATER
3-HEAD ANG. ACCEL.	24337	24568	0.991	1.009	0.9% LESS	0.9% GREATER	-27463	-29872	0.919	1.088	8.1% LESS	8.8% GREATER
4-HEAD RES. ACCEL.	398	398	1.000	1.000	0.0% LESS	0.0% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	4218	5669	0.744	1.344	25.6% LESS	34.4% GREATER	-466	-858	0.543	1.842	45.7% LESS	84.2% GREATER
6-C7-T1 STOP TORQ.	1058	1350	0.783	1.276	21.7% LESS	27.6% GREATER	-527	-624	0.844	1.185	15.6% LESS	18.5% GREATER
7-Z HEAD FORCE	4827	4828	1.000	1.000	0.0% LESS	0.0% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2896	2896	1.000	1.000	0.0% LESS	0.0% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	108	118	0.922	1.084	7.8% LESS	8.4% GREATER	-3	-16	0.195	5.125	80.5% LESS	412.5% GREATER
10-C7-T1 ANGLE	36	40	0.885	1.130	11.5% LESS	13.0% GREATER	-46	-50	0.924	1.082	7.6% LESS	8.2% GREATER
11-FORCE ALONG NECK	4271	4263	1.002	0.998	0.2% GREATER	0.2% LESS	-1441	-1276	1.129	0.886	12.9% GREATER	11.4% LESS
12-SHEAR AT CONDYLE	1283	1425	0.901	1.110	9.9% LESS	11.0% GREATER	-598	-460	1.301	0.769	30.1% GREATER	23.1% LESS
13-COMP. AT CONDYLE	4044	4041	1.001	0.999	0.1% GREATER	0.1% LESS	-1270	-1129	1.124	0.890	12.4% GREATER	11.0% LESS
14-SHEAR AT C7-T1	1453	1592	0.913	1.096	8.7% LESS	9.6% GREATER	-662	-519	1.276	0.784	27.6% GREATER	21.6% LESS
15-COMP. AT C7-T1	4090	4080	1.003	0.997	0.3% GREATER	0.3% LESS	-1385	-1229	1.127	0.887	12.7% GREATER	11.3% LESS
16-COND. TOTAL TORQ	4909	5852	0.839	1.192	16.1% LESS	19.2% GREATER	-751	-960	0.783	1.277	21.7% LESS	27.7% GREATER
17-C7-T1 TOTAL TORQ	2418	1697	1.425	0.702	42.5% GREATER	29.8% LESS	-1165	-801	1.454	0.688	45.4% GREATER	31.2% LESS
HIC	7621	7603	1.002	0.998	0.2% GREATER	0.2% LESS						
HEAD 3-MSEC AVG.	324	325	0.997	1.003	0.3% LESS	0.3% GREATER						
CHEST 3-MSEC AVG	38	39	0.974	1.026	2.6% LESS	2.6% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #18

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20V5.6F AND B= RF20V5.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-190	-207	0.921	1.085	7.9% LESS	8.5% GREATER
2-HEAD ANG. VELOC.	3013	2127	1.417	0.706	41.7% GREATER	29.4% LESS	-6552	-6620	0.990	1.010	1.0% LESS	1.0% GREATER
3-HEAD ANG. ACCEL.	29383	14170	2.074	0.482	107.4% GREATER	51.8% LESS	-29179	-8665	3.367	0.297	236.7% GREATER	70.3% LESS
4-HEAD RES. ACCEL.	448	182	2.451	0.408	145.1% GREATER	59.2% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	772	279	2.764	0.362	176.4% GREATER	63.8% LESS	-3508	-4460	0.786	1.272	21.4% LESS	27.2% GREATER
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% GREATER	100.0% LESS	-9140	-7378	1.239	0.807	23.9% GREATER	19.3% LESS
7-Z HEAD FORCE	4921	3335	1.476	0.678	47.6% GREATER	32.2% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2953	667	4.427	0.226	342.7% GREATER	77.4% LESS	-1847	0	0.0	0.0	0.0% GREATER	100.0% LESS
9-CONDYLES ANGLE	70	56	1.261	0.793	26.1% GREATER	20.7% LESS	-41	-46	0.895	1.118	10.5% LESS	11.8% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-102	-97	1.051	0.951	5.1% GREATER	4.9% LESS
11-FORCE ALONG NECK	3318	3207	1.035	0.967	3.5% GREATER	3.3% LESS	-934	-747	1.251	0.800	25.1% GREATER	20.0% LESS
12-SHEAR AT CONDYLE	2051	1826	1.123	0.890	12.3% GREATER	11.0% LESS	-255	-492	0.519	1.928	48.1% LESS	92.8% GREATER
13-COMP. AT CONDYLE	3312	3192	1.038	0.964	3.8% GREATER	3.6% LESS	-939	-642	1.463	0.683	46.3% GREATER	31.7% LESS
14-SHEAR AT C7-T1	2463	1904	1.296	0.772	29.6% GREATER	22.8% LESS	-321	-608	0.528	1.894	47.2% LESS	89.4% GREATER
15-COMP. AT C7-T1	3153	3012	1.047	0.955	4.7% GREATER	4.5% LESS	-735	-532	1.381	0.724	38.1% GREATER	27.6% LESS
16-COND. TOTAL TORQ	1229	560	2.195	0.456	119.5% GREATER	54.4% LESS	-3983	-5001	0.796	1.256	20.4% LESS	25.6% GREATER
17-C7-T1 TOTAL TORQ	818	489	1.672	0.598	67.2% GREATER	40.2% LESS	-10802	-8647	1.249	0.800	24.9% GREATER	20.0% LESS
HIC	14009	4440	3.155	0.317	215.5% GREATER	68.3% LESS						
HEAD 3-MSEC AVG.	349	166	2.102	0.476	110.2% GREATER	52.4% LESS						
CHEST 3-MSEC AVG	36	34	1.059	0.944	5.9% GREATER	5.6% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 19

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20V5.6F AND B= RNH20V5.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-190	-196	0.970	1.031	3.0% LESS	3.1% GREATER
2-HEAD ANG. VELOC.	3013	1420	2.122	0.471	112.2% GREATER	52.9% LESS	-6552	-8201	0.799	1.252	20.1% LESS	25.2% GREATER
3-HEAD ANG. ACCEL.	29333	26748	1.095	0.910	9.9% GREATER	9.0% LESS	-29179	-16449	1.774	0.564	77.4% GREATER	43.6% LESS
4-HEAD RES. ACCEL.	448	439	1.020	0.980	2.0% GREATER	2.0% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	772	40	19.300	0.052	*****% GREATER	94.8% LESS	-3508	-4336	0.809	1.236	19.1% LESS	23.6% GREATER
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% GREATER	100.0% LESS	-9140	-8181	1.117	0.895	11.7% GREATER	10.5% LESS
7-Z HEAD FORCE	4921	5405	0.911	1.098	8.9% LESS	9.8% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2953	1081	2.732	0.366	173.2% GREATER	63.4% LESS	-1847	-412	4.481	0.223	348.1% GREATER	77.7% LESS
9-CONDYLES ANGLE	70	38	1.820	0.550	82.0% GREATER	45.0% LESS	-41	-46	0.904	1.106	9.6% LESS	10.6% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-102	-99	1.027	0.974	2.7% GREATER	2.6% LESS
11-FORCE ALONG NECK	3318	3743	0.886	1.128	11.4% LESS	12.8% GREATER	-934	-582	1.606	0.623	60.6% GREATER	37.7% LESS
12-SHEAR AT CONDYLE	2051	1795	1.143	0.875	14.3% GREATER	12.5% LESS	-255	-668	0.382	2.616	61.8% LESS	161.6% GREATER
13-COMP. AT CONDYLE	3312	3590	0.923	1.084	7.7% LESS	8.4% GREATER	-939	-539	1.743	0.574	74.3% GREATER	42.6% LESS
14-SHEAR AT C7-T1	2468	2052	1.202	0.832	20.2% GREATER	16.8% LESS	-321	-771	0.416	2.403	58.4% LESS	140.3% GREATER
15-COMP. AT C7-T1	3153	3567	0.884	1.131	11.6% LESS	13.1% GREATER	-735	-403	1.822	0.549	82.2% GREATER	45.1% LESS
16-COND. TOTAL TORQ	1229	189	6.503	0.154	550.3% GREATER	84.6% LESS	-3983	-4864	0.819	1.221	18.1% LESS	22.1% GREATER
17-C7-T1 TOTAL TORQ	818	0	0.0	0.0	0.0% GREATER	100.0% LESS	-10802	-9557	1.130	0.885	13.0% GREATER	11.5% LESS
HIC	14009	12624	1.110	0.901	11.0% GREATER	9.9% LESS						
HEAD 3-MSEC AVG.	349	343	1.017	0.983	1.7% GREATER	1.7% LESS						
CHEST 3-MSEC AVG	36	33	1.091	0.917	9.1% GREATER	8.3% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #20

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20V5.2F AND B= RF20V5.6F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-207	-218	0.948	1.055	5.2% LESS	5.5% GREATER
2-HEAD ANG. VELOC.	2127	2584	0.823	1.215	17.7% LESS	21.5% GREATER	-6620	-6667	0.993	1.007	0.7% LESS	0.7% GREATER
3-HEAD ANG. ACCEL.	14170	8589	1.650	0.606	65.0% GREATER	39.4% LESS	-8665	-7792	1.112	0.899	11.2% GREATER	10.1% LESS
4-HEAD RES. ACCEL.	182	171	1.065	0.935	6.9% GREATER	6.5% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	279	229	1.219	0.820	21.9% GREATER	18.0% LESS	-4460	-3165	1.409	0.710	40.9% GREATER	29.0% LESS
6-C7-T1 STOP TORQ.	0	4	0.0	0.0	100.0% LESS	0.0% GREATER	-7378	-4907	1.504	0.665	50.4% GREATER	33.5% LESS
7-Z HEAD FORCE	3335	3223	1.035	0.967	3.5% GREATER	3.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	667	1934	0.345	2.900	65.5% LESS	190.0% GREATER	0	-423	0.0	0.0	100.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	56	53	1.043	0.959	4.3% GREATER	4.1% LESS	-46	-39	1.171	0.854	17.1% GREATER	14.6% LESS
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-97	-88	1.103	0.907	10.3% GREATER	9.3% LESS
11-FORCE ALONG NECK	3207	2211	1.450	0.690	45.0% GREATER	31.0% LESS	-747	-703	1.063	0.941	6.3% GREATER	5.9% LESS
12-SHEAR AT CONDYLE	1826	1311	1.392	0.718	39.2% GREATER	28.2% LESS	-492	-187	2.634	0.380	163.4% GREATER	62.0% LESS
13-COMP. AT CONDYLE	3192	2280	1.400	0.714	40.0% GREATER	28.6% LESS	-642	-709	0.905	1.105	9.5% LESS	10.5% GREATER
14-SHEAR AT C7-T1	1904	1468	1.297	0.771	29.7% GREATER	22.9% LESS	-608	-305	1.992	0.502	99.2% GREATER	49.8% LESS
15-COMP. AT C7-T1	3012	2075	1.451	0.689	45.1% GREATER	31.1% LESS	-532	-650	0.819	1.221	18.1% LESS	22.1% GREATER
16-COND. TOTAL TORQ	560	491	1.138	0.878	13.8% GREATER	12.2% LESS	-5001	-3639	1.374	0.728	37.4% GREATER	27.2% LESS
17-C7-T1 TOTAL TORQ	499	931	0.525	1.904	47.5% LESS	90.4% GREATER	-8647	-6133	1.410	0.709	41.0% GREATER	29.1% LESS
HIC	4440	1437	3.090	0.324	209.0% GREATER	67.6% LESS						
HEAD 3-MSEC AVG.	166	164	1.012	0.988	1.2% GREATER	1.2% LESS						
CHEST 3-MSEC AVG	34	23	1.478	0.676	47.8% GREATER	32.4% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 21

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20V5.6F AND B= RH20V5.6F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-190	-218	0.874	1.145	12.6% LESS	14.5% GREATER
2-HEAD ANG. VELOC.	3013	2584	1.166	0.858	16.6% GREATER	14.2% LESS	-6552	-6667	0.983	1.018	1.7% LESS	1.8% GREATER
3-HEAD ANG. ACCEL.	29383	8589	3.421	0.292	242.1% GREATER	70.8% LESS	-29179	-7792	3.745	0.267	274.5% GREATER	73.3% LESS
4-HEAD RES. ACCEL.	448	171	2.620	0.382	162.0% GREATER	61.8% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	772	229	3.370	0.297	237.0% GREATER	70.3% LESS	-3508	-3165	1.108	0.902	10.8% GREATER	9.8% LESS
6-C7-T1 STOP TORQ.	0	4	0.071	14.000	92.9% LESS	*****% GREATER	-9140	-4907	1.863	0.537	86.3% GREATER	46.3% LESS
7-Z HEAD FORCE	4921	3223	1.527	0.655	52.7% GREATER	34.5% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2953	1934	1.527	0.655	52.7% GREATER	34.5% LESS	-1847	-423	4.360	0.229	336.0% GREATER	77.1% LESS
9-CONDYLES ANGLE	70	53	1.315	0.761	31.5% GREATER	23.9% LESS	-41	-39	1.048	0.954	4.8% GREATER	4.6% LESS
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-102	-88	1.160	0.862	16.0% GREATER	13.8% LESS
11-FORCE ALONG NECK	3318	2211	1.500	0.667	50.0% GREATER	33.3% LESS	-934	-703	1.330	0.752	33.0% GREATER	24.8% LESS
12-SHEAR AT CONDYLE	2051	1311	1.564	0.639	56.4% GREATER	36.1% LESS	-255	-187	1.366	0.732	36.6% GREATER	26.8% LESS
13-COMP. AT CONDYLE	3312	2280	1.453	0.688	45.3% GREATER	31.2% LESS	-939	-709	1.324	0.755	32.4% GREATER	24.5% LESS
14-SHEAR AT C7-T1	2468	1468	1.680	0.595	68.0% GREATER	40.5% LESS	-321	-305	1.052	0.950	5.2% GREATER	5.0% LESS
15-COMP. AT C7-T1	3153	2075	1.519	0.658	51.9% GREATER	34.2% LESS	-735	-650	1.130	0.885	13.0% GREATER	11.5% LESS
16-COND. TOTAL TORQ	1229	491	2.498	0.400	149.8% GREATER	60.0% LESS	-3983	-3639	1.094	0.914	9.4% GREATER	8.6% LESS
17-C7-T1 TOTAL TORQ	818	931	0.878	1.139	12.2% LESS	13.9% GREATER	-10802	-6133	1.761	0.568	76.1% GREATER	43.2% LESS
HIC	14009	1437	9.749	0.103	874.9% GREATER	89.7% LESS						
HEAD 3-MSEC AVG.	349	164	2.128	0.470	112.8% GREATER	53.0% LESS						
CHEST 3-MSEC AVG	36	23	1.565	0.639	56.5% GREATER	36.1% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #22

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20V5.2F AND B= RF20V5.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-196	-207	0.950	1.053	5.0% LESS	5.3% GREATER
2-HEAD ANG. VELOC.	1420	2127	0.668	1.498	33.2% LESS	49.8% GREATER	-8201	-6620	1.239	0.807	23.9% GREATER	19.3% LESS
3-HEAD ANG. ACCEL.	26749	14170	1.888	0.530	88.8% GREATER	47.0% LESS	-16449	-8665	1.898	0.527	89.8% GREATER	47.3% LESS
4-HEAD RES. ACCEL.	439	182	2.403	0.416	140.3% GREATER	58.4% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	40	279	0.143	6.983	85.7% LESS	598.3% GREATER	-4336	-4460	0.972	1.029	2.8% LESS	2.9% GREATER
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-8181	-7378	1.109	0.902	10.9% GREATER	9.8% LESS
7-Z HEAD FORCE	5405	3335	1.621	0.617	62.1% GREATER	38.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	1081	667	1.621	0.617	62.1% GREATER	38.3% LESS	-412	0	0.0	0.0	0.0% GREATER	100.0% LESS
9-CONDYLES ANGLE	38	56	0.693	1.443	30.7% LESS	44.3% GREATER	-46	-46	0.989	1.011	1.1% LESS	1.1% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-99	-97	1.024	0.977	2.4% GREATER	2.3% LESS
11-FORCE ALONG NECK	3743	3207	1.167	0.857	16.7% GREATER	14.3% LESS	-582	-747	0.779	1.284	22.1% LESS	28.4% GREATER
12-SHEAR AT CONDYLE	1795	1826	0.983	1.017	1.7% LESS	1.7% GREATER	-668	-492	1.356	0.737	35.6% GREATER	26.3% LESS
13-COMP. AT CONDYLE	3590	3192	1.125	0.889	12.5% GREATER	11.1% LESS	-539	-642	0.840	1.191	16.0% LESS	19.1% GREATER
14-SHEAR AT C7-T1	2052	1904	1.078	0.928	7.8% GREATER	7.2% LESS	-771	-608	1.269	0.788	26.9% GREATER	21.2% LESS
15-COMP. AT C7-T1	3567	3012	1.184	0.844	18.4% GREATER	15.6% LESS	-403	-532	0.758	1.320	24.2% LESS	32.0% GREATER
16-COND. TOTAL TORQ	189	560	0.337	2.963	66.2% LESS	196.3% GREATER	-4864	-5001	0.973	1.028	2.7% LESS	2.8% GREATER
17-C7-T1 TOTAL TORQ	0	485	0.0	0.0	100.0% LESS	0.0% GREATER	-9557	-8647	1.105	0.905	10.5% GREATER	9.5% LESS
HIC	12624	4440	2.843	0.352	184.3% GREATER	64.8% LESS						
HEAD 3-MSEC AVG.	343	166	2.066	0.484	106.6% GREATER	51.6% LESS						
CHEST 3-MSEC AVG	33	34	0.971	1.030	2.9% LESS	3.0% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #23

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20V5.6F AND B= RNH20V5.612

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-190	-209	0.912	1.096	8.8% LESS	9.6% GREATER
2-HEAD ANG. VELOC.	3013	2031	1.484	0.674	48.4% GREATER	32.6% LESS	-6552	-7472	0.877	1.140	12.3% LESS	14.0% GREATER
3-HEAD ANG. ACCEL.	29383	35604	0.825	1.212	17.5% LESS	21.2% GREATER	-29179	-47221	0.618	1.618	38.2% LESS	61.8% GREATER
4-HEAD RES. ACCEL.	448	473	0.947	1.056	5.3% LESS	5.6% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	772	452	1.705	0.587	70.5% GREATER	41.3% LESS	-3508	-1318	2.661	0.376	166.1% GREATER	62.4% LESS
6-C7-T1 STOP TORQ.	0	0	0.375	2.667	62.5% LESS	166.7% GREATER	-9140	-7830	1.167	0.857	16.7% GREATER	14.3% LESS
7-Z HEAD FORCE	4921	5044	0.976	1.025	2.4% LESS	2.5% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2953	3026	0.976	1.025	2.4% LESS	2.5% GREATER	-1847	-1626	1.136	0.880	13.6% GREATER	12.0% LESS
9-CONDYLES ANGLE	70	42	1.665	0.599	66.9% GREATER	40.1% LESS	-41	-44	0.945	1.058	5.5% LESS	5.8% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-102	-99	1.035	0.966	3.5% GREATER	3.4% LESS
11-FORCE ALONG NECK	3318	2344	1.415	0.707	41.5% GREATER	29.3% LESS	-934	-745	1.254	0.797	25.4% GREATER	20.3% LESS
12-SHEAR AT CONDYLE	2051	1837	1.117	0.896	11.7% GREATER	10.4% LESS	-255	-193	1.318	0.759	31.8% GREATER	24.1% LESS
13-COMP. AT CONDYLE	3312	2410	1.374	0.728	37.4% GREATER	27.2% LESS	-939	-879	1.068	0.936	6.8% GREATER	6.4% LESS
14-SHEAR AT C7-T1	2468	2132	1.157	0.864	15.7% GREATER	13.6% LESS	-321	-73	4.351	0.230	335.1% GREATER	77.0% LESS
15-COMP. AT C7-T1	3153	2244	1.405	0.712	40.5% GREATER	28.8% LESS	-735	-596	1.233	0.811	23.3% GREATER	18.9% LESS
16-COND. TOTAL TORQ	1229	815	1.508	0.663	50.8% GREATER	33.7% LESS	-3983	-1611	2.472	0.405	147.2% GREATER	59.5% LESS
17-C7-T1 TOTAL TORQ	818	751	1.089	0.918	8.9% GREATER	8.2% LESS	-10802	-9463	1.141	0.876	14.1% GREATER	12.4% LESS
HIC	14009	12535	1.118	0.895	11.8% GREATER	10.5% LESS						
HEAD 3-MSEC AVG.	349	387	0.902	1.109	9.8% LESS	10.9% GREATER						
CHEST 3-MSEC AVG	36	28	1.286	0.778	28.6% GREATER	22.2% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 25

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20V5.612 AND B= RF20V5.212

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-209	-213	0.980	1.021	2.0% LESS	2.1% GREATER
2-HEAD ANG. VELOC.	2031	1831	1.109	0.902	10.9% GREATER	9.8% LESS	-7472	-4949	1.510	0.662	51.0% GREATER	33.8% LESS
3-HEAD ANG. ACCEL.	35604	10509	3.388	0.295	238.8% GREATER	70.5% LESS	-47221	-9275	5.091	0.196	409.1% GREATER	80.4% LESS
4-HEAD RES. ACCEL.	473	105	4.458	0.222	349.8% GREATER	77.8% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	452	68	6.660	0.150	566.0% GREATER	85.0% LESS	-1318	-3825	0.345	2.902	65.5% LESS	190.2% GREATER
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% GREATER	100.0% LESS	-7830	-7416	1.056	0.947	5.6% GREATER	5.3% LESS
7-Z HEAD FORCE	5044	3115	1.619	0.618	61.9% GREATER	38.2% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	3026	623	4.857	0.206	385.7% GREATER	79.4% LESS	-1626	0	0.0	0.0	0.0% GREATER	100.0% LESS
9-CONDYLES ANGLE	42	22	1.880	0.532	88.0% GREATER	46.8% LESS	-44	-63	0.695	1.439	30.5% LESS	43.9% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-99	-97	1.015	0.985	1.5% GREATER	1.5% LESS
11-FORCE ALONG NECK	2344	2753	0.851	1.175	14.5% LESS	17.5% GREATER	-745	-811	0.919	1.088	8.1% LESS	8.8% GREATER
12-SHEAR AT CONDYLE	1837	2002	0.918	1.090	8.2% LESS	9.0% GREATER	-193	-37	5.168	0.193	416.8% GREATER	80.7% LESS
13-COMP. AT CONDYLE	2410	2703	0.892	1.121	10.8% LESS	12.1% GREATER	-879	-760	1.156	0.865	15.6% GREATER	13.5% LESS
14-SHEAR AT C7-T1	2132	1966	1.084	0.922	8.4% GREATER	7.8% LESS	-73	-56	1.313	0.762	31.3% GREATER	23.8% LESS
15-COMP. AT C7-T1	2244	2617	0.858	1.166	14.2% LESS	16.6% GREATER	-596	-663	0.899	1.112	10.1% LESS	11.2% GREATER
16-COND. TOTAL TORQ	815	359	2.268	0.441	126.8% GREATER	55.9% LESS	-1611	-4277	0.377	2.655	62.3% LESS	165.5% GREATER
17-C7-T1 TOTAL TORQ	751	389	1.931	0.518	93.1% GREATER	48.2% LESS	-9463	-8891	1.064	0.939	6.4% GREATER	6.1% LESS
HIC	12535	1175	10.668	0.094	966.8% GREATER	90.6% LESS						
HEAD 3-MSEC AVG.	387	102	3.794	0.264	279.4% GREATER	73.6% LESS						
CHEST 3-MSEC AVG	28	27	1.037	0.964	3.7% GREATER	3.6% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #26

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20V5.2F AND B= RH20V5.2NR

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-207	-199	1.039	0.963	3.9% GREATER	3.7% LESS
2-HEAD ANG. VELOC.	2127	1934	1.100	0.909	10.0% GREATER	9.1% LESS	-6620	-6587	1.005	0.995	0.5% GREATER	0.5% LESS
3-HEAD ANG. ACCEL.	14170	13524	1.048	0.954	4.8% GREATER	4.6% LESS	-8665	-8638	1.003	0.997	0.3% GREATER	0.3% LESS
4-HEAD RES. ACCEL.	182	193	0.947	1.056	5.3% LESS	5.6% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	279	282	0.988	1.013	1.2% LESS	1.3% GREATER	-4460	-5005	0.891	1.122	10.9% LESS	12.2% GREATER
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-7378	-9223	0.800	1.250	20.0% LESS	25.0% GREATER
7-Z HEAD FORCE	3335	3296	1.012	0.988	1.2% GREATER	1.2% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	667	659	1.012	0.988	1.2% GREATER	1.2% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	56	56	0.996	1.004	0.4% LESS	0.4% GREATER	-46	-48	0.953	1.049	4.7% LESS	4.9% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-97	-102	0.949	1.053	5.1% LESS	5.3% GREATER
11-FORCE ALONG NECK	3207	3245	0.988	1.012	1.2% LESS	1.2% GREATER	-747	-674	1.108	0.903	10.8% GREATER	9.7% LESS
12-SHEAR AT CONDYLE	1826	2291	0.797	1.255	20.3% LESS	25.5% GREATER	-492	-633	0.778	1.286	22.2% LESS	28.6% GREATER
13-COMP. AT CONDYLE	3192	3230	0.988	1.012	1.2% LESS	1.2% GREATER	-642	-573	1.119	0.893	11.9% GREATER	10.7% LESS
14-SHEAR AT C7-T1	1904	2396	0.795	1.258	20.5% LESS	25.8% GREATER	-608	-751	0.809	1.236	19.1% LESS	23.6% GREATER
15-COMP. AT C7-T1	3012	3047	0.988	1.012	1.2% LESS	1.2% GREATER	-532	-473	1.124	0.890	12.4% GREATER	11.0% LESS
16-COND. TOTAL TORQ	560	565	0.990	1.010	1.0% LESS	1.0% GREATER	-5001	-5563	0.899	1.112	10.1% LESS	11.2% GREATER
17-C7-T1 TOTAL TORQ	489	0	0.0	0.0	0.0% GREATER	100.0% LESS	-8647	-10605	0.815	1.227	18.5% LESS	22.7% GREATER
HIC	4440	4749	0.935	1.070	6.5% LESS	7.0% GREATER						
HEAD 3-MSEC AVG.	166	175	0.949	1.054	5.1% LESS	5.4% GREATER						
CHEST 3-MSEC AVG	34	34	1.000	1.000	0.0% LESS	0.0% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #27

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20V5.6F AND B= RNH20V1.6F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-190	-191	0.994	1.006	0.6% LESS	0.6% GREATER
2-HEAD ANG. VELOC.	3013	2937	1.026	0.975	2.6% GREATER	2.5% LESS	-6552	-6797	0.964	1.037	3.6% LESS	3.7% GREATER
3-HEAD ANG. ACCEL.	29383	22811	1.288	0.776	28.8% GREATER	22.4% LESS	-29179	-29043	1.005	0.995	0.5% GREATER	0.5% LESS
4-HEAD RES. ACCEL.	448	377	1.187	0.843	18.7% GREATER	15.7% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	772	420	1.836	0.545	83.6% GREATER	45.5% LESS	-3508	-3810	0.921	1.086	7.9% LESS	8.6% GREATER
6-C7-T1 STOP TORQ.	0	4	0.063	16.000	93.7% LESS	*****% GREATER	-9140	-10437	0.876	1.142	12.4% LESS	14.2% GREATER
7-Z HEAD FORCE	4921	4921	1.000	1.000	0.0% GREATER	0.0% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2953	2953	1.000	1.000	0.0% LESS	0.0% GREATER	-1847	-1845	1.001	0.999	0.1% GREATER	0.1% LESS
9-CONDYLES ANGLE	70	61	1.154	0.867	15.4% GREATER	13.3% LESS	-41	-43	0.961	1.041	3.9% LESS	4.1% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-102	-105	0.969	1.032	3.1% LESS	3.2% GREATER
11-FORCE ALONG NECK	3318	3311	1.002	0.998	0.2% GREATER	0.2% LESS	-934	-1291	0.724	1.382	27.6% LESS	38.2% GREATER
12-SHEAR AT CONDYLE	2051	1951	1.051	0.951	5.1% GREATER	4.9% LESS	-255	-393	0.649	1.541	35.1% LESS	54.1% GREATER
13-COMP. AT CONDYLE	3312	3307	1.002	0.998	0.2% GREATER	0.2% LESS	-939	-1348	0.697	1.436	30.3% LESS	43.6% GREATER
14-SHEAR AT C7-T1	2463	2352	1.049	0.953	4.9% GREATER	4.7% LESS	-321	-484	0.662	1.510	33.8% LESS	51.0% GREATER
15-COMP. AT C7-T1	3153	3143	1.003	0.997	0.3% GREATER	0.3% LESS	-735	-1029	0.714	1.400	28.6% LESS	40.0% GREATER
16-COND. TOTAL TORQ	1229	518	2.372	0.422	137.2% GREATER	57.8% LESS	-3983	-3930	1.014	0.987	1.4% GREATER	1.3% LESS
17-C7-T1 TOTAL TORQ	818	271	3.014	0.332	201.4% GREATER	66.8% LESS	-10802	-10828	0.998	1.002	0.2% LESS	0.2% GREATER
HIC	14009	9108	1.538	0.650	53.8% GREATER	35.0% LESS						
HEAD 3-MSEC AVG.	349	325	1.074	0.931	7.4% GREATER	6.9% LESS						
CHEST 3-MSEC AVG	36	33	1.091	0.917	9.1% GREATER	8.3% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 28

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= CR10NH5.3 AND B= CR10H5.3

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	85	70	1.221	0.819	22.1% GREATER	18.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
2-HEAD ANG. VELOC.	2281	1526	1.495	0.669	49.5% GREATER	33.1% LESS	-1222	-1282	0.953	1.049	4.7% LESS	4.9% GREATER
3-HEAD ANG. ACCEL.	2413	1989	1.213	0.824	21.3% GREATER	17.6% LESS	-1158	-790	1.465	0.683	46.5% GREATER	31.7% LESS
4-HEAD RES. ACCEL.	20	16	1.256	0.796	25.6% GREATER	20.4% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	1	3	0.485	2.062	51.5% LESS	106.2% GREATER	-352	-626	0.562	1.780	43.8% LESS	78.0% GREATER
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-594	-869	0.683	1.464	31.7% LESS	46.4% GREATER
7-Z HEAD FORCE	342	347	0.986	1.014	1.4% LESS	1.4% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	1172	1179	0.994	1.006	0.6% LESS	0.6% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	16	18	0.907	1.103	9.3% LESS	10.3% GREATER	-5	-20	0.287	3.483	71.3% LESS	248.3% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-59	-66	0.886	1.129	11.4% LESS	12.9% GREATER
11-FORCE ALONG NECK	0	35	0.0	0.0	100.0% LESS	0.0% GREATER	-179	-173	1.035	0.966	3.5% GREATER	3.4% LESS
12-SHEAR AT CONDYLE	162	182	0.894	1.118	10.6% LESS	11.8% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
13-COMP. AT CONDYLE	0	36	0.0	0.0	100.0% LESS	0.0% GREATER	-162	-159	1.018	0.982	1.8% GREATER	1.8% LESS
14-SHEAR AT C7-T1	192	181	1.060	0.943	6.0% GREATER	5.7% LESS	0	-5	0.0	0.0	100.0% LESS	0.0% GREATER
15-COMP. AT C7-T1	0	41	0.0	0.0	100.0% LESS	0.0% GREATER	-185	-198	0.932	1.073	6.8% LESS	7.3% GREATER
16-COND. TOTAL TORQ	49	62	0.800	1.249	20.0% LESS	24.9% GREATER	-460	-812	0.567	1.764	43.3% LESS	76.4% GREATER
17-C7-T1 TOTAL TORQ	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-1129	-1489	0.758	1.318	24.2% LESS	31.8% GREATER
HIC	77	43	1.791	0.558	79.1% GREATER	44.2% LESS						
HEAD 3-MSEC AVG.	20	16	1.250	0.800	25.0% GREATER	20.0% LESS						
CHEST 3-MSEC AVG	14	14	1.000	1.000	0.0% LESS	0.0% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #29

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= HR10NH5.3F AND B= HR10H5.1F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	156	172	0.911	1.098	8.9% LESS	9.8% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
2-HEAD ANG. VELOC.	3885	2371	1.638	0.610	63.8% GREATER	39.0% LESS	-1029	-4251	1.122	0.004	*****% GREATER	99.6% LESS
3-HEAD ANG. ACCEL.	9669	3231	2.993	0.334	199.3% GREATER	66.6% LESS	-6890	-1533	4.495	0.222	349.5% GREATER	77.8% LESS
4-HEAD RES. ACCEL.	298	120	2.478	0.404	147.8% GREATER	59.6% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	544	239	2.276	0.439	127.6% GREATER	56.1% LESS	-246	-464	0.531	1.884	46.9% LESS	88.4% GREATER
6-C7-T1 STOP TORQ.	314	251	1.250	0.800	25.0% GREATER	20.0% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
7-Z HEAD FORCE	487	54	9.035	0.111	803.5% GREATER	88.9% LESS	-534	-197	2.705	0.370	170.5% GREATER	63.0% LESS
8-X HEAD FORCE	3196	1976	1.617	0.618	61.7% GREATER	38.2% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	55	44	1.244	0.804	24.4% GREATER	19.6% LESS	0	-13	0.0	0.0	100.0% LESS	0.0% GREATER
10-C7-T1 ANGLE	7	4	1.574	0.635	57.4% GREATER	36.5% LESS	-30	-30	1.000	1.000	0.0% LESS	0.0% GREATER
11-FORCE ALONG NECK	1061	607	1.748	0.572	74.8% GREATER	42.8% LESS	-853	-210	4.064	0.246	306.4% GREATER	75.4% LESS
12-SHEAR AT CONDYLE	53	52	1.017	0.983	1.7% GREATER	1.7% LESS	-323	-248	1.304	0.767	30.4% GREATER	23.3% LESS
13-COMP. AT CONDYLE	1110	639	1.736	0.576	73.6% GREATER	42.4% LESS	-825	-180	4.564	0.219	356.4% GREATER	78.1% LESS
14-SHEAR AT C7-T1	87	42	2.074	0.482	107.4% GREATER	51.8% LESS	-178	-245	0.727	1.375	27.3% LESS	37.5% GREATER
15-COMP. AT C7-T1	1001	570	1.754	0.570	75.4% GREATER	43.0% LESS	-823	-211	3.886	0.257	288.6% GREATER	74.3% LESS
16-COND. TOTAL TORQ	887	435	2.037	0.491	103.7% GREATER	50.9% LESS	-320	-641	0.499	2.006	50.1% LESS	100.6% GREATER
17-C7-T1 TOTAL TORQ	1003	874	1.147	0.871	14.7% GREATER	12.9% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
HIC	2573	564	4.562	0.219	356.2% GREATER	78.1% LESS						
HEAD 3-MSEC AVG.	244	116	2.103	0.475	110.3% GREATER	52.5% LESS						
CHEST 3-MSEC AVG	12	8	1.500	0.667	50.0% GREATER	33.3% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #30

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH10H5.6F AND B= RF10H5.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	53	70	0.759	1.317	24.1% LESS	31.7% GREATER	-30	-30	0.993	1.007	0.7% LESS	0.7% GREATER
2-HEAD ANG. VELOC.	7683	2869	2.677	0.374	167.7% GREATER	62.6% LESS	-3181	-1796	1.771	0.565	77.1% GREATER	43.5% LESS
3-HEAD ANG. ACCEL.	23944	4543	5.270	0.190	427.0% GREATER	81.0% LESS	-23142	-1831	12.634	0.079	*****% GREATER	92.1% LESS
4-HEAD RES. ACCEL.	398	133	2.987	0.335	198.7% GREATER	66.5% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	2853	344	8.281	0.121	728.1% GREATER	87.9% LESS	-401	-550	0.730	1.370	27.0% LESS	37.0% GREATER
6-C7-T1 STOP TORQ.	1101	183	5.995	0.167	499.5% GREATER	83.3% LESS	-383	0	0.0	0.0	0.0% GREATER	100.0% LESS
7-Z HEAD FORCE	4827	3127	1.544	0.648	54.4% GREATER	35.2% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2896	625	4.631	0.216	363.1% GREATER	78.4% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	98	58	1.674	0.597	67.4% GREATER	40.3% LESS	0	-7	0.0	0.0	100.0% LESS	0.0% GREATER
10-C7-T1 ANGLE	36	11	3.257	0.307	225.7% GREATER	69.3% LESS	-38	-20	1.900	0.526	90.0% GREATER	47.4% LESS
11-FORCE ALONG NECK	4030	2348	1.716	0.583	71.6% GREATER	41.7% LESS	-1116	-523	2.134	0.469	113.4% GREATER	53.1% LESS
12-SHEAR AT CONDYLE	821	59	13.706	0.073	*****% GREATER	92.7% LESS	-541	-336	1.607	0.622	60.7% GREATER	37.8% LESS
13-COMP. AT CONDYLE	3823	2304	1.659	0.603	65.9% GREATER	39.7% LESS	-971	-456	2.127	0.470	112.7% GREATER	53.0% LESS
14-SHEAR AT C7-T1	951	116	8.142	0.123	714.2% GREATER	87.7% LESS	-600	-309	1.941	0.515	94.1% GREATER	48.5% LESS
15-COMP. AT C7-T1	3867	2282	1.695	0.590	69.5% GREATER	41.0% LESS	-1072	-512	2.092	0.478	109.2% GREATER	52.2% LESS
16-COND. TOTAL TORQ	3457	575	6.012	0.166	501.2% GREATER	83.4% LESS	-609	-759	0.803	1.245	19.7% LESS	24.5% GREATER
17-C7-T1 TOTAL TORQ	2448	854	2.867	0.349	186.7% GREATER	65.1% LESS	-1017	-218	4.657	0.215	365.7% GREATER	78.5% LESS
HIC	5486	1305	4.204	0.238	320.4% GREATER	76.2% LESS						
HEAD 3-MSEC AVG.	329	131	2.511	0.398	151.1% GREATER	60.2% LESS						
CHEST 3-MSEC AVG	35	23	1.522	0.657	52.2% GREATER	34.3% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #31

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH10V5.6F AND B= RH10V5.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-193	-207	0.931	1.074	6.9% LESS	7.4% GREATER
2-HEAD ANG. VELOC.	2019	2256	0.895	1.117	10.5% LESS	11.7% GREATER	-7465	-5298	1.185	0.844	18.5% GREATER	15.6% LESS
3-HEAD ANG. ACCEL.	27321	12984	2.104	0.475	110.4% GREATER	52.5% LESS	-28217	-8387	3.364	0.297	236.4% GREATER	70.3% LESS
4-HEAD RES. ACCEL.	362	197	1.836	0.545	83.6% GREATER	45.5% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	147	320	0.460	2.172	54.0% LESS	117.2% GREATER	-4325	-4588	0.943	1.061	5.7% LESS	6.1% GREATER
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-8629	-9630	0.896	1.116	10.4% LESS	11.6% GREATER
7-Z HEAD FORCE	4911	3335	1.473	0.679	47.3% GREATER	32.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2947	666	4.424	0.226	342.4% GREATER	77.4% LESS	-2062	-628	3.281	0.305	228.1% GREATER	69.5% LESS
9-CONDYLES ANGLE	49	57	0.854	1.170	14.6% LESS	17.0% GREATER	-45	-47	0.975	1.026	2.5% LESS	2.6% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-101	-103	0.974	1.027	2.6% LESS	2.7% GREATER
11-FORCE ALONG NECK	3722	3261	1.141	0.876	14.1% GREATER	12.4% LESS	-560	-362	1.543	0.648	54.3% GREATER	35.2% LESS
12-SHEAR AT CONDYLE	2046	2434	0.841	1.189	15.9% LESS	18.9% GREATER	-738	-533	1.385	0.722	38.5% GREATER	27.8% LESS
13-COMP. AT CONDYLE	3597	3263	1.102	0.907	10.2% GREATER	9.3% LESS	-549	-288	1.903	0.525	90.3% GREATER	47.5% LESS
14-SHEAR AT C7-T1	2204	2564	0.859	1.164	14.1% LESS	16.4% GREATER	-867	-641	1.353	0.739	35.3% GREATER	26.1% LESS
15-COMP. AT C7-T1	3540	3061	1.156	0.865	15.6% GREATER	13.5% LESS	-425	-204	2.079	0.481	107.9% GREATER	51.9% LESS
16-COND. TOTAL TORQ	378	612	0.618	1.619	38.2% LESS	61.9% GREATER	-4862	-5135	0.947	1.056	5.3% LESS	5.6% GREATER
17-C7-T1 TOTAL TORQ	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-10011	-11009	0.909	1.100	9.1% LESS	10.0% GREATER
HIC	10190	2842	3.586	0.279	258.6% GREATER	72.1% LESS						
HEAD 3-MSEC AVG.	314	175	1.794	0.557	79.4% GREATER	44.3% LESS						
CHEST 3-MSEC AVG	37	36	1.028	0.973	2.8% GREATER	2.7% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #32

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= HR20H5.1F AND B= HR10H5.1F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	228	172	1.325	0.755	32.5% GREATER	24.5% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
2-HEAD ANG. VELOC.	4699	2371	1.982	0.505	98.2% GREATER	49.5% LESS	-1527	-4372.512		0.003	*****% GREATER	99.7% LESS
3-HEAD ANG. ACCEL.	8740	3231	2.705	0.370	170.5% GREATER	63.0% LESS	-3361	-1533	2.193	0.456	119.3% GREATER	54.4% LESS
4-HEAD RES. ACCEL.	245	120	2.035	0.491	103.5% GREATER	50.9% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	722	239	3.017	0.331	201.7% GREATER	66.9% LESS	-1261	-464	2.715	0.368	171.5% GREATER	63.2% LESS
6-C7-T1 STOP TORQ.	978	251	3.892	0.257	289.2% GREATER	74.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
7-Z HEAD FORCE	144	54	2.667	0.375	166.7% GREATER	62.5% LESS	-389	-197	1.968	0.508	96.8% GREATER	49.2% LESS
8-X HEAD FORCE	3890	1976	1.968	0.508	96.8% GREATER	49.2% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	59	44	1.344	0.744	34.4% GREATER	25.6% LESS	-33	-13	2.515	0.398	151.5% GREATER	60.2% LESS
10-C7-T1 ANGLE	24	4	5.255	0.190	425.5% GREATER	81.0% LESS	-30	-30	1.000	1.000	0.0% LESS	0.0% GREATER
11-FORCE ALONG NECK	990	607	1.630	0.613	63.0% GREATER	38.7% LESS	-899	-210	4.281	0.234	328.1% GREATER	76.6% LESS
12-SHEAR AT CONDYLE	9	52	0.178	5.613	82.2% LESS	461.3% GREATER	-614	-248	2.476	0.404	147.6% GREATER	59.6% LESS
13-COMP. AT CONDYLE	1070	639	1.673	0.598	67.3% GREATER	40.2% LESS	-796	-180	4.404	0.227	340.4% GREATER	77.3% LESS
14-SHEAR AT C7-T1	18	42	0.428	2.339	57.2% LESS	133.9% GREATER	-578	-245	2.354	0.425	135.4% GREATER	57.5% LESS
15-COMP. AT C7-T1	935	570	1.639	0.610	63.9% GREATER	39.0% LESS	-858	-211	4.052	0.247	305.2% GREATER	75.3% LESS
16-COND. TOTAL TORQ	1045	435	2.401	0.417	140.1% GREATER	58.3% LESS	-1596	-641	2.487	0.402	148.7% GREATER	59.8% LESS
17-C7-T1 TOTAL TORQ	1976	874	2.261	0.442	126.1% GREATER	55.8% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
HIC	3317	564	5.881	0.170	488.1% GREATER	83.0% LESS						
HEAD 3-MSEC AVG.	233	116	2.009	0.498	100.9% GREATER	50.2% LESS						
CHEST 3-MSEC AVG	18	8	2.250	0.444	125.0% GREATER	55.6% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #33

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= CR20H5.3 AND B= CR10H5.3

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	70	1.000	1.000	0.0% LESS	0.0% GREATER	-7	0	0.0	0.0	0.0% GREATER	100.0% LESS
2-HEAD ANG. VELOC.	3207	1526	2.101	0.476	110.1% GREATER	52.4% LESS	-3244	-1282	2.530	0.395	153.0% GREATER	60.5% LESS
3-HEAD ANG. ACCEL.	7391	1989	3.715	0.269	271.5% GREATER	73.1% LESS	-2689	-790	3.401	0.294	240.1% GREATER	70.6% LESS
4-HEAD RES. ACCEL.	70	16	4.400	0.227	340.0% GREATER	77.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	44	3	13.394	0.075	*****% GREATER	92.5% LESS	-2497	-626	3.986	0.251	298.6% GREATER	74.9% LESS
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-1803	-869	2.073	0.482	107.3% GREATER	51.8% LESS
7-Z HEAD FORCE	859	347	2.475	0.404	147.5% GREATER	59.6% LESS	-96	0	0.0	0.0	0.0% GREATER	100.0% LESS
8-X HEAD FORCE	5440	1179	4.612	0.217	361.2% GREATER	78.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	29	18	1.621	0.617	62.1% GREATER	38.3% LESS	-45	-20	2.243	0.446	124.3% GREATER	55.4% LESS
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-79	-66	1.192	0.839	19.2% GREATER	16.1% LESS
11-FORCE ALONG NECK	227	35	6.476	0.154	547.6% GREATER	84.6% LESS	-956	-173	5.527	0.181	452.7% GREATER	81.9% LESS
12-SHEAR AT CONDYLE	422	182	2.320	0.431	132.0% GREATER	56.9% LESS	-326	0	0.0	0.0	0.0% GREATER	100.0% LESS
13-COMP. AT CONDYLE	234	36	6.451	0.155	545.1% GREATER	84.5% LESS	-863	-159	5.406	0.185	440.6% GREATER	81.5% LESS
14-SHEAR AT C7-T1	419	181	2.315	0.432	131.5% GREATER	56.8% LESS	-362	-5	62.517	0.016	*****% GREATER	98.4% LESS
15-COMP. AT C7-T1	213	41	5.189	0.193	418.9% GREATER	80.7% LESS	-1079	-198	5.433	0.184	443.3% GREATER	81.6% LESS
16-COND. TOTAL TORQ	192	62	2.945	0.340	194.5% GREATER	66.0% LESS	-2936	-812	3.613	0.277	261.3% GREATER	72.3% LESS
17-C7-T1 TOTAL TORQ	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-2615	-1489	1.756	0.569	75.6% GREATER	43.1% LESS
HIC	419	43	9.744	0.103	874.4% GREATER	89.7% LESS						
HEAD 3-MSEC AVG.	70	16	4.375	0.229	337.5% GREATER	77.1% LESS						
CHEST 3-MSEC AVG	61	14	4.357	0.230	335.7% GREATER	77.0% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #34

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20H5.2F AND B= RF10H5.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	70	1.001	0.999	0.1% GREATER	0.1% LESS	-30	-30	1.007	0.993	0.7% GREATER	0.7% LESS
2-HEAD ANG. VELOC.	2975	2869	1.002	0.998	0.2% GREATER	0.2% LESS	-1781	-1796	0.992	1.008	0.8% LESS	0.8% GREATER
3-HEAD ANG. ACCEL.	4559	4543	1.004	0.996	0.4% GREATER	0.4% LESS	-1844	-1831	1.007	0.993	0.7% GREATER	0.7% LESS
4-HEAD RES. ACCEL.	133	133	1.001	0.999	0.1% GREATER	0.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	347	344	1.010	0.991	1.0% GREATER	0.9% LESS	-551	-550	1.002	0.998	0.2% GREATER	0.2% LESS
6-C7-T1 STOP TORQ.	186	183	1.013	0.987	1.3% GREATER	1.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
7-Z HEAD FORCE	3139	3127	1.004	0.996	0.4% GREATER	0.4% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	627	625	1.004	0.996	0.4% GREATER	0.4% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	58	58	1.002	0.998	0.2% GREATER	0.2% LESS	-7	-7	1.000	1.000	0.0% LESS	0.0% GREATER
10-C7-T1 ANGLE	11	11	1.009	0.991	0.9% GREATER	0.9% LESS	-20	-20	1.000	1.000	0.0% LESS	0.0% GREATER
11-FORCE ALONG NECK	2371	2348	1.010	0.990	1.0% GREATER	1.0% LESS	-525	-523	1.005	0.995	0.5% GREATER	0.5% LESS
12-SHEAR AT CONDYLE	60	59	1.017	0.984	1.7% GREATER	1.6% LESS	-337	-336	1.003	0.997	0.3% GREATER	0.3% LESS
13-COMP. AT CONDYLE	2321	2304	1.007	0.993	0.7% GREATER	0.7% LESS	-458	-456	1.004	0.996	0.4% GREATER	0.4% LESS
14-SHEAR AT C7-T1	118	116	1.016	0.984	1.6% GREATER	1.6% LESS	-310	-309	1.003	0.997	0.3% GREATER	0.3% LESS
15-COMP. AT C7-T1	2304	2282	1.010	0.990	1.0% GREATER	1.0% LESS	-515	-512	1.005	0.995	0.5% GREATER	0.5% LESS
16-COND. TOTAL TORQ	578	575	1.006	0.994	0.6% GREATER	0.6% LESS	-761	-759	1.003	0.998	0.3% GREATER	0.2% LESS
17-C7-T1 TOTAL TORQ	854	854	1.000	1.000	0.0% LESS	0.0% GREATER	-220	-218	1.007	0.993	0.7% GREATER	0.7% LESS
HIC	1266	1305	0.970	1.031	3.0% LESS	3.1% GREATER						
HEAD 3-MSEC AVG.	131	131	1.000	1.000	0.0% LESS	0.0% GREATER						
CHEST 3-MSEC AVG	23	23	1.000	1.000	0.0% LESS	0.0% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 35

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20V5.2F AND B= RH10V5.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-207	-207	0.996	1.004	0.4% LESS	0.4% GREATER
2-HEAD ANG. VELOC.	2127	2256	0.943	1.061	5.7% LESS	6.1% GREATER	-6620	-6298	1.051	0.951	5.1% GREATER	4.9% LESS
3-HEAD ANG. ACCEL.	14170	12984	1.091	0.916	9.1% GREATER	8.4% LESS	-8665	-8387	1.033	0.968	3.3% GREATER	3.2% LESS
4-HEAD RES. ACCEL.	182	197	0.926	1.080	7.4% LESS	8.0% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	279	320	0.872	1.147	12.8% LESS	14.7% GREATER	-4460	-4588	0.972	1.029	2.8% LESS	2.9% GREATER
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-7378	-9630	0.766	1.305	23.4% LESS	30.5% GREATER
7-Z HEAD FORCE	3335	3335	1.000	1.000	0.0% LESS	0.0% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	667	666	1.001	0.999	0.1% GREATER	0.1% LESS	0	-628	0.0	0.0	100.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	56	57	0.971	1.030	2.9% LESS	3.0% GREATER	-46	-47	0.987	1.013	1.3% LESS	1.3% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-97	-103	0.938	1.066	6.2% LESS	6.6% GREATER
11-FORCE ALONG NECK	3207	3261	0.983	1.017	1.7% LESS	1.7% GREATER	-747	-362	2.060	0.485	106.0% GREATER	51.5% LESS
12-SHEAR AT CONDYLE	1826	2434	0.750	1.333	25.0% LESS	33.3% GREATER	-492	-533	0.924	1.082	7.6% LESS	8.2% GREATER
13-COMP. AT CONDYLE	3192	3263	0.978	1.022	2.2% LESS	2.2% GREATER	-642	-288	2.225	0.450	122.5% GREATER	55.0% LESS
14-SHEAR AT C7-T1	1904	2564	0.743	1.347	25.7% LESS	34.7% GREATER	-608	-641	0.949	1.054	5.1% LESS	5.4% GREATER
15-COMP. AT C7-T1	3012	3061	0.984	1.016	1.6% LESS	1.6% GREATER	-532	-204	2.600	0.385	160.0% GREATER	61.5% LESS
16-COND. TOTAL TORQ	560	612	0.915	1.093	8.5% LESS	9.3% GREATER	-5001	-5135	0.974	1.027	2.6% LESS	2.7% GREATER
17-C7-T1 TOTAL TORQ	489	0	0.0	0.0	0.0% GREATER	100.0% LESS	-8647	-11009	0.785	1.273	21.5% LESS	27.3% GREATER
HIC	4440	2842	1.562	0.640	56.2% GREATER	36.0% LESS						
HEAD 3-MSEC AVG.	166	175	0.949	1.054	5.1% LESS	5.4% GREATER						
CHEST 3-MSEC AVG	34	36	0.944	1.059	5.6% LESS	5.9% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 36

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= HR2ONH1.3F AND B= HR2OH1.1F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	218	243	0.897	1.115	10.3% LESS	11.5% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
2-HEAD ANG. VELOC.	6050	4741	1.276	0.784	27.6% GREATER	21.6% LESS	-1452	-1044	1.391	0.719	39.1% GREATER	28.1% LESS
3-HEAD ANG. ACCEL.	14804	8710	1.700	0.588	70.0% GREATER	41.2% LESS	-12671	-4416	2.869	0.349	186.9% GREATER	65.1% LESS
4-HEAD RES. ACCEL.	492	248	1.986	0.504	98.6% GREATER	49.6% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	1209	1125	1.074	0.931	7.4% GREATER	6.9% LESS	-347	-1703	0.204	4.905	79.6% LESS	390.5% GREATER
6-C7-T1 STOP TORQ.	1863	1667	1.117	0.895	11.7% GREATER	10.5% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
7-Z HEAD FORCE	398	118	3.350	0.298	235.0% GREATER	70.2% LESS	-766	-388	1.973	0.507	97.3% GREATER	49.3% LESS
8-X HEAD FORCE	5035	3885	1.296	0.772	29.6% GREATER	22.8% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	68	67	1.021	0.980	2.1% GREATER	2.0% LESS	-5	-38	0.146	6.857	85.4% LESS	585.7% GREATER
10-C7-T1 ANGLE	37	35	1.068	0.936	6.8% GREATER	6.4% LESS	-30	-30	1.000	1.000	0.0% LESS	0.0% GREATER
11-FORCE ALONG NECK	1258	988	1.273	0.785	27.3% GREATER	21.5% LESS	-1238	-944	1.312	0.762	31.2% GREATER	23.8% LESS
12-SHEAR AT CONDYLE	27	28	0.975	1.022	2.1% LESS	2.2% GREATER	-511	-529	0.965	1.036	3.5% LESS	3.6% GREATER
13-COMP. AT CONDYLE	1322	1067	1.239	0.808	23.8% GREATER	19.2% LESS	-1242	-813	1.527	0.655	52.7% GREATER	34.5% LESS
14-SHEAR AT C7-T1	154	64	2.407	0.416	140.7% GREATER	58.4% LESS	-322	-507	0.635	1.574	36.5% LESS	57.4% GREATER
15-COMP. AT C7-T1	1194	937	1.274	0.785	27.4% GREATER	21.5% LESS	-1169	-898	1.301	0.769	30.1% GREATER	23.1% LESS
16-COND. TOTAL TORQ	1320	1210	1.091	0.917	9.1% GREATER	8.3% LESS	-376	-1792	0.210	4.757	79.0% LESS	375.7% GREATER
17-C7-T1 TOTAL TORQ	2160	1924	1.123	0.891	12.3% GREATER	10.9% LESS	-15	0	0.0	0.0	0.0% GREATER	100.0% LESS
HIC	3511	3388	1.036	0.965	3.6% GREATER	3.5% LESS						
HEAD 3-MSEC AVG.	292	236	1.237	0.808	23.7% GREATER	19.2% LESS						
CHEST 3-MSEC AVG	30	22	1.364	0.733	36.4% GREATER	26.7% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 37

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= CR2ONH1.3 AND B= CR2OH1.3

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	143	70	2.056	0.486	105.6% GREATER	51.4% LESS	-8	-13	0.591	1.691	40.9% LESS	69.1% GREATER
2-HEAD ANG. VELOC.	4484	3169	1.415	0.707	41.5% GREATER	29.3% LESS	-4354	-3497	1.245	0.803	24.5% GREATER	19.7% LESS
3-HEAD ANG. ACCEL.	13670	8005	1.708	0.586	70.8% GREATER	41.4% LESS	-4547	-2815	1.615	0.619	61.5% GREATER	38.1% LESS
4-HEAD RES. ACCEL.	73	74	0.975	1.022	2.1% LESS	2.2% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	118	116	1.015	0.986	1.5% GREATER	1.4% LESS	-2179	-3035	0.718	1.393	28.2% LESS	39.3% GREATER
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-1733	-2698	0.642	1.557	35.8% LESS	55.7% GREATER
7-Z HEAD FORCE	919	798	1.152	0.868	15.2% GREATER	13.2% LESS	-72	-136	0.528	1.895	47.2% LESS	89.5% GREATER
8-X HEAD FORCE	5333	5403	0.987	1.013	1.3% LESS	1.3% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	37	36	1.003	0.997	0.3% GREATER	0.3% LESS	-42	-48	0.877	1.140	12.3% LESS	14.0% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-78	-86	0.908	1.102	9.2% LESS	10.2% GREATER
11-FORCE ALONG NECK	297	252	1.179	0.848	17.9% GREATER	15.2% LESS	-781	-1029	0.759	1.318	24.1% LESS	31.8% GREATER
12-SHEAR AT CONDYLE	324	497	0.652	1.534	34.8% LESS	53.4% GREATER	-215	-475	0.453	2.208	54.7% LESS	120.8% GREATER
13-COMP. AT CONDYLE	323	266	1.214	0.824	21.4% GREATER	17.6% LESS	-675	-926	0.729	1.372	27.1% LESS	37.2% GREATER
14-SHEAR AT C7-T1	354	504	0.703	1.422	29.7% LESS	42.2% GREATER	-288	-507	0.570	1.755	43.0% LESS	75.5% GREATER
15-COMP. AT C7-T1	238	213	1.117	0.895	11.7% GREATER	10.5% LESS	-921	-1150	0.802	1.248	19.8% LESS	24.8% GREATER
16-COND. TOTAL TORQ	184	161	1.141	0.876	14.1% GREATER	12.4% LESS	-2287	-3153	0.725	1.379	27.5% LESS	37.9% GREATER
17-C7-T1 TOTAL TORQ	61	0	0.0	0.0	0.0% GREATER	100.0% LESS	-1909	-2900	0.659	1.518	34.1% LESS	51.8% GREATER
HIC	534	542	0.985	1.015	1.5% LESS	1.5% GREATER						
HEAD 3-MSEC AVG.	72	74	0.973	1.028	2.7% LESS	2.8% GREATER						
CHEST 3-MSEC AVG	62	61	1.016	0.984	1.6% GREATER	1.6% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 38

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20H1.6F AND B= RH20H1.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	52	86	0.607	1.646	39.3% LESS	64.6% GREATER	-30	-30	0.984	1.017	1.6% LESS	1.7% GREATER
2-HEAD ANG. VELOC.	9005	2851	3.158	0.317	215.8% GREATER	68.3% LESS	-3985	-1284	3.103	0.322	210.3% GREATER	67.8% LESS
3-HEAD ANG. ACCEL.	24568	4382	5.607	0.178	460.7% GREATER	82.2% LESS	-29872	-2146	13.919	0.072	*****% GREATER	92.8% LESS
4-HEAD RES. ACCEL.	398	134	2.970	0.337	197.0% GREATER	66.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	5669	706	8.022	0.125	702.2% GREATER	87.5% LESS	-858	-763	1.124	0.890	12.4% GREATER	11.0% LESS
6-C7-T1 STOP TORQ.	1350	315	4.280	0.234	328.0% GREATER	76.6% LESS	-624	0	0.0	0.0	0.0% GREATER	100.0% LESS
7-Z HEAD FORCE	4828	3136	1.539	0.650	53.9% GREATER	35.0% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2896	627	4.618	0.217	361.8% GREATER	78.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	118	69	1.712	0.584	71.2% GREATER	41.6% LESS	-16	-14	1.155	0.866	15.5% GREATER	13.4% LESS
10-C7-T1 ANGLE	40	17	2.331	0.429	133.1% GREATER	57.1% LESS	-50	-20	2.510	0.398	151.0% GREATER	60.2% LESS
11-FORCE ALONG NECK	4263	2356	1.809	0.553	80.9% GREATER	44.7% LESS	-1276	-513	2.487	0.402	148.7% GREATER	59.8% LESS
12-SHEAR AT CONDYLE	1425	91	15.591	0.064	*****% GREATER	93.6% LESS	-460	-253	1.813	0.551	81.3% GREATER	44.9% LESS
13-COMP. AT CONDYLE	4041	2311	1.748	0.572	74.9% GREATER	42.8% LESS	-1129	-447	2.525	0.396	152.5% GREATER	60.4% LESS
14-SHEAR AT C7-T1	1592	145	10.927	0.092	992.7% GREATER	90.8% LESS	-519	-242	2.147	0.466	114.7% GREATER	53.4% LESS
15-COMP. AT C7-T1	4080	2292	1.780	0.562	78.0% GREATER	43.8% LESS	-1229	-495	2.482	0.403	148.2% GREATER	59.7% LESS
16-COND. TOTAL TORQ	5852	789	7.418	0.135	641.8% GREATER	86.5% LESS	-960	-826	1.162	0.861	16.2% GREATER	13.9% LESS
17-C7-T1 TOTAL TORQ	1697	520	3.263	0.307	226.3% GREATER	69.3% LESS	-801	-67	11.895	0.084	*****% GREATER	91.6% LESS
HIC	7603	1288	5.903	0.169	490.3% GREATER	83.1% LESS						
HEAD 3-MSEC AVG.	325	132	2.462	0.406	146.2% GREATER	59.4% LESS						
CHEST 3-MSEC AVG	39	28	1.393	0.718	39.3% GREATER	28.2% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #39

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20V1.6F AND B= RF20V1.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-191	-214	0.895	1.117	10.5% LESS	11.7% GREATER
2-HEAD ANG. VELOC.	2937	2583	1.137	0.879	13.7% GREATER	12.1% LESS	-6797	-5384	1.065	0.939	6.5% GREATER	6.1% LESS
3-HEAD ANG. ACCEL.	22811	12094	1.886	0.530	88.6% GREATER	47.0% LESS	-29043	-7762	3.742	0.267	274.2% GREATER	73.3% LESS
4-HEAD RES. ACCEL.	377	162	2.329	0.429	132.9% GREATER	57.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	420	420	1.000	1.000	0.0% LESS	0.0% GREATER	-3810	-4004	0.952	1.051	4.8% LESS	5.1% GREATER
6-C7-T1 STOP TORQ.	4	0	0.0	0.0	0.0% GREATER	100.0% LESS	-10437	-8309	1.256	0.796	25.6% GREATER	20.4% LESS
7-Z HEAD FORCE	4921	3332	1.477	0.677	47.7% GREATER	32.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	2953	666	4.431	0.226	343.1% GREATER	77.4% LESS	-1845	0	0.0	0.0	0.0% GREATER	100.0% LESS
9-CONDYLES ANGLE	61	61	1.000	1.000	0.0% LESS	0.0% GREATER	-43	-44	0.980	1.021	2.0% LESS	2.1% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-105	-100	1.055	0.948	5.5% GREATER	5.2% LESS
11-FORCE ALONG NECK	3311	3155	1.049	0.953	4.9% GREATER	4.7% LESS	-1291	-824	1.566	0.639	56.6% GREATER	36.1% LESS
12-SHEAR AT CONDYLE	1951	1764	1.106	0.904	10.6% GREATER	9.6% LESS	-393	-133	2.951	0.339	195.1% GREATER	66.1% LESS
13-COMP. AT CONDYLE	3307	3151	1.049	0.953	4.9% GREATER	4.7% LESS	-1348	-710	1.899	0.526	89.9% GREATER	47.4% LESS
14-SHEAR AT C7-T1	2352	1824	1.289	0.776	28.9% GREATER	22.4% LESS	-484	-234	2.072	0.483	107.2% GREATER	51.7% LESS
15-COMP. AT C7-T1	3143	2967	1.059	0.944	5.9% GREATER	5.6% LESS	-1029	-622	1.654	0.605	65.4% GREATER	39.5% LESS
16-COND. TOTAL TORQ	518	497	1.041	0.961	4.1% GREATER	3.9% LESS	-3930	-4110	0.956	1.046	4.4% LESS	4.6% GREATER
17-C7-T1 TOTAL TORQ	271	0	0.0	0.0	0.0% GREATER	100.0% LESS	-10828	-8581	1.262	0.793	26.2% GREATER	20.7% LESS
HIC	9108	2933	3.105	0.322	210.5% GREATER	67.8% LESS						
HEAD 3-MSEC AVG.	325	145	2.241	0.446	124.1% GREATER	55.4% LESS						
CHEST 3-MSEC AVG	33	34	0.971	1.030	2.9% LESS	3.0% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #40

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20H5.2F AND B= RF20H5.10F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	44	1.585	0.631	58.5% GREATER	36.9% LESS	-30	-30	1.003	0.997	0.3% GREATER	0.3% LESS
2-HEAD ANG. VELOC.	2875	3531	0.814	1.228	18.6% LESS	22.8% GREATER	-1781	-1334	1.335	0.749	33.5% GREATER	25.1% LESS
3-HEAD ANG. ACCEL.	4559	12299	0.371	2.697	62.9% LESS	169.7% GREATER	-1844	-10915	0.169	5.917	83.1% LESS	491.7% GREATER
4-HEAD RES. ACCEL.	133	309	0.431	2.318	56.9% LESS	131.8% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	347	4397	0.079	12.640	92.1% LESS	*****% GREATER	-551	-1118	0.493	2.029	50.7% LESS	102.9% GREATER
6-C7-T1 STOP TORQ.	186	400	0.465	2.152	53.5% LESS	115.2% GREATER	0	-8349	0.0	0.0	100.0% LESS	0.0% GREATER
7-Z HEAD FORCE	3139	4407	0.712	1.404	28.8% LESS	40.4% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	627	4407	0.142	7.020	85.8% LESS	602.0% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	58	110	0.533	1.877	46.7% LESS	87.7% GREATER	-7	-21	0.346	2.890	65.4% LESS	189.0% GREATER
10-C7-T1 ANGLE	11	20	0.553	1.807	44.7% LESS	80.7% GREATER	-20	-100	0.199	5.015	80.1% LESS	401.5% GREATER
11-FORCE ALONG NECK	2371	4910	0.483	2.070	51.7% LESS	107.0% GREATER	-525	-1234	0.426	2.347	57.4% LESS	134.7% GREATER
12-SHEAR AT CONDYLE	60	3559	0.017	58.453	98.3% LESS	*****% GREATER	-337	-520	0.649	1.541	35.1% LESS	54.1% GREATER
13-COMP. AT CONDYLE	2321	4907	0.473	2.114	52.7% LESS	111.4% GREATER	-458	-1108	0.413	2.419	58.7% LESS	141.9% GREATER
14-SHEAR AT C7-T1	118	3821	0.031	32.198	96.9% LESS	*****% GREATER	-310	-503	0.616	1.624	38.4% LESS	62.4% GREATER
15-COMP. AT C7-T1	2304	4596	0.501	1.995	49.9% LESS	99.5% GREATER	-515	-1206	0.427	2.341	57.3% LESS	134.1% GREATER
16-COND. TOTAL TORQ	578	5090	0.114	8.795	88.6% LESS	779.5% GREATER	-761	-1550	0.491	2.036	50.9% LESS	103.6% GREATER
17-C7-T1 TOTAL TORQ	854	1473	0.580	1.726	42.0% LESS	72.6% GREATER	-220	-10235	0.021	46.527	97.9% LESS	*****% GREATER
HIC	1260	8480	0.149	6.698	85.1% LESS	569.8% GREATER						
HEAD 3-MSEC AVG.	131	271	0.483	2.069	51.7% LESS	106.9% GREATER						
CHEST 3-MSEC AVG	23	52	0.442	2.261	55.8% LESS	126.1% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #41

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20V5.2F AND B= RH20V5.10F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-207	-221	0.935	1.069	6.5% LESS	6.9% GREATER
2-HEAD ANG. VELOC.	2127	2990	0.711	1.406	28.9% LESS	40.6% GREATER	-6620	-6645	0.996	1.004	0.4% LESS	0.4% GREATER
3-HEAD ANG. ACCEL.	14170	7844	1.806	0.554	80.6% GREATER	44.6% LESS	-8665	-8106	1.069	0.936	6.9% GREATER	6.4% LESS
4-HEAD RES. ACCEL.	182	237	0.770	1.298	23.0% LESS	29.8% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	279	356	0.783	1.277	21.7% LESS	27.7% GREATER	-4460	-2717	1.642	0.609	64.2% GREATER	39.1% LESS
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	100.0% LESS	0.0% GREATER	-7378	-4328	1.704	0.587	70.4% GREATER	41.3% LESS
7-Z HEAD FORCE	3335	3141	1.062	0.942	6.2% GREATER	5.8% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	667	2983	0.224	4.472	77.6% LESS	347.2% GREATER	0	-1342	0.0	0.0	100.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	56	59	0.949	1.054	5.1% LESS	5.4% GREATER	-46	-36	1.264	0.791	26.4% GREATER	20.9% LESS
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-97	-85	1.135	0.881	13.5% GREATER	11.9% LESS
11-FORCE ALONG NECK	3207	1930	1.661	0.602	66.1% GREATER	39.8% LESS	-747	-836	0.894	1.119	10.6% LESS	11.9% GREATER
12-SHEAR AT CONDYLE	1826	1269	1.438	0.695	43.8% GREATER	30.5% LESS	-492	-183	2.684	0.373	168.4% GREATER	62.7% LESS
13-COMP. AT CONDYLE	3192	2043	1.562	0.640	56.2% GREATER	36.0% LESS	-642	-821	0.781	1.280	21.9% LESS	28.0% GREATER
14-SHEAR AT C7-T1	1904	1405	1.355	0.738	35.5% GREATER	26.2% LESS	-608	-254	2.386	0.419	138.6% GREATER	58.1% LESS
15-COMP. AT C7-T1	3012	1810	1.664	0.601	66.4% GREATER	39.9% LESS	-532	-832	0.640	1.563	36.0% LESS	56.3% GREATER
16-COND. TOTAL TORQ	560	715	0.782	1.278	21.8% LESS	27.8% GREATER	-5001	-3169	1.578	0.634	57.8% GREATER	36.6% LESS
17-C7-T1 TOTAL TORQ	489	730	0.670	1.492	33.0% LESS	49.2% GREATER	-8647	-5852	1.477	0.677	47.7% GREATER	32.3% LESS
HIC	4440	2052	2.164	0.462	116.4% GREATER	53.8% LESS						
HEAD 3-MSEC AVG.	166	209	0.794	1.259	20.6% LESS	25.9% GREATER						
CHEST 3-MSEC AVG	34	20	1.700	0.588	70.0% GREATER	41.2% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 42

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= HR20H5.1F AND B= HR20HM5.1F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	228	231	0.986	1.014	1.4% LESS	1.4% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
2-HEAD ANG. VELOC.	4699	4180	1.124	0.890	12.4% GREATER	11.0% LESS	-1527	-1588	0.961	1.040	3.9% LESS	4.0% GREATER
3-HEAD ANG. ACCEL.	8740	7490	1.167	0.857	16.7% GREATER	14.3% LESS	-3361	-3386	0.993	1.007	0.7% LESS	0.7% GREATER
4-HEAD RES. ACCEL.	245	287	0.852	1.173	14.8% LESS	17.3% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	722	950	0.760	1.316	24.0% LESS	31.6% GREATER	-1261	-1122	1.124	0.890	12.4% GREATER	11.0% LESS
6-C7-T1 STOP TORQ.	978	1055	0.927	1.079	7.3% LESS	7.9% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
7-Z HEAD FORCE	144	168	0.857	1.167	14.3% LESS	16.7% GREATER	-389	-330	1.178	0.849	17.8% GREATER	15.1% LESS
8-X HEAD FORCE	3890	3302	1.178	0.849	17.8% GREATER	15.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	59	64	0.927	1.079	7.3% LESS	7.9% GREATER	-33	-31	1.064	0.940	6.4% GREATER	6.0% LESS
10-C7-T1 ANGLE	24	26	0.950	1.053	5.0% LESS	5.3% GREATER	-30	-30	1.000	1.000	0.0% LESS	0.0% GREATER
11-FORCE ALONG NECK	990	970	1.020	0.980	2.0% GREATER	2.0% LESS	-899	-911	0.986	1.014	1.4% LESS	1.4% GREATER
12-SHEAR AT CONDYLE	9	103	0.090	11.172	91.0% LESS	*****% GREATER	-614	-556	1.104	0.905	10.4% GREATER	9.5% LESS
13-COMP. AT CONDYLE	1070	1054	1.015	0.985	1.5% GREATER	1.5% LESS	-796	-885	0.900	1.111	10.0% LESS	11.1% GREATER
14-SHEAR AT C7-T1	18	133	0.135	7.400	86.5% LESS	640.0% GREATER	-578	-551	1.049	0.954	4.9% GREATER	4.6% LESS
15-COMP. AT C7-T1	935	917	1.020	0.980	2.0% GREATER	2.0% LESS	-858	-894	0.960	1.042	4.0% LESS	4.2% GREATER
16-COND. TOTAL TORQ	1045	1279	0.817	1.223	18.3% LESS	22.3% GREATER	-1596	-1442	1.107	0.904	10.7% GREATER	9.6% LESS
17-C7-T1 TOTAL TORQ	1976	1910	1.034	0.967	3.4% GREATER	3.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
HIC	3317	3927	0.845	1.184	15.5% LESS	18.4% GREATER						
HEAD 3-MSEC AVG.	233	271	0.860	1.163	14.0% LESS	16.3% GREATER						
CHEST 3-MSEC AVG	18	19	0.947	1.056	5.3% LESS	5.6% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #43

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= CR20NH5.312 AND B= CR20H5.312

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	139	55	2.533	0.395	153.3% GREATER	60.5% LESS	-2	-11	0.205	4.870	79.5% LESS	387.0% GREATER
2-HEAD ANG. VELOC.	3628	2691	1.348	0.742	34.8% GREATER	25.8% LESS	-3205	-2637	1.216	0.823	21.6% GREATER	17.7% LESS
3-HEAD ANG. ACCEL.	9156	5729	1.598	0.626	59.8% GREATER	37.4% LESS	-3969	-2245	1.768	0.566	76.8% GREATER	43.4% LESS
4-HEAD RES. ACCEL.	72	71	1.011	0.989	1.1% GREATER	1.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	71	72	0.992	1.008	0.8% LESS	0.8% GREATER	-1140	-1934	0.590	1.695	41.0% LESS	69.5% GREATER
6-C7-T1 STOP TORQ.	16	0	0.0	0.0	0.0% GREATER	100.0% LESS	-733	-1083	0.677	1.478	32.3% LESS	47.8% GREATER
7-Z HEAD FORCE	1039	941	1.105	0.905	10.5% GREATER	9.5% LESS	-25	-88	0.291	3.437	70.9% LESS	243.7% GREATER
8-X HEAD FORCE	5431	5532	0.982	1.019	1.8% LESS	1.9% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	22	22	1.000	1.000	0.0% LESS	0.0% GREATER	-41	-50	0.819	1.222	18.1% LESS	22.2% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-73	-80	0.911	1.098	8.9% LESS	9.8% GREATER
11-FORCE ALONG NECK	166	196	0.846	1.182	15.4% LESS	18.2% GREATER	-744	-987	0.754	1.326	24.6% LESS	32.6% GREATER
12-SHEAR AT CONDYLE	260	311	0.837	1.194	16.3% LESS	19.4% GREATER	-100	-327	0.305	3.276	69.5% LESS	227.6% GREATER
13-COMP. AT CONDYLE	181	210	0.864	1.157	13.6% LESS	15.7% GREATER	-646	-891	0.725	1.379	27.5% LESS	37.9% GREATER
14-SHEAR AT C7-T1	315	317	0.995	1.005	0.5% LESS	0.5% GREATER	-179	-336	0.533	1.875	46.7% LESS	87.5% GREATER
15-COMP. AT C7-T1	145	157	0.924	1.082	7.6% LESS	8.2% GREATER	-898	-1123	0.800	1.251	20.0% LESS	25.1% GREATER
16-COND. TOTAL TORQ	234	233	1.003	0.997	0.3% GREATER	0.3% LESS	-1486	-2346	0.634	1.578	36.6% LESS	57.8% GREATER
17-C7-T1 TOTAL TORQ	704	0	0.0	0.0	0.0% GREATER	100.0% LESS	-1433	-1706	0.840	1.191	16.0% LESS	19.1% GREATER
HIC	439	424	1.035	0.966	3.5% GREATER	3.4% LESS						
HEAD 3-MSEC AVG.	72	71	1.014	0.986	1.4% GREATER	1.4% LESS						
CHEST 3-MSEC AVG	61	60	1.017	0.984	1.7% GREATER	1.6% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #44

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= CR20NH5.313 AND B= CR20H5.313

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	172	100	1.721	0.581	72.1% GREATER	41.9% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
2-HEAD ANG. VELOC.	4968	3139	1.583	0.632	58.3% GREATER	36.8% LESS	-5111	-4410	1.159	0.863	15.9% GREATER	13.7% LESS
3-HEAD ANG. ACCEL.	15702	8836	1.777	0.563	77.7% GREATER	43.7% LESS	-5941	-4281	1.388	0.721	38.8% GREATER	27.9% LESS
4-HEAD RES. ACCEL.	68	70	0.976	1.025	2.4% LESS	2.5% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	244	110	2.218	0.451	121.8% GREATER	54.9% LESS	-2324	-2961	0.785	1.274	21.5% LESS	27.4% GREATER
6-C7-T1 STOP TORQ.	2	0	0.0	0.0	0.0% GREATER	100.0% LESS	-2094	-3123	0.670	1.492	33.0% LESS	49.2% GREATER
7-Z HEAD FORCE	828	725	1.143	0.875	14.3% GREATER	12.5% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	5198	5228	0.994	1.006	0.6% LESS	0.6% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	44	36	1.220	0.820	22.0% GREATER	18.0% LESS	-43	-48	0.907	1.103	9.3% LESS	10.3% GREATER
10-C7-T1 ANGLE	7	0	0.0	0.0	0.0% GREATER	100.0% LESS	-52	-59	0.877	1.140	12.3% LESS	14.0% GREATER
11-FORCE ALONG NECK	349	235	1.486	0.673	48.6% GREATER	32.7% LESS	-690	-875	0.788	1.269	21.2% LESS	26.9% GREATER
12-SHEAR AT CONDYLE	508	692	0.734	1.363	26.6% LESS	36.3% GREATER	-131	-389	0.339	2.951	66.1% LESS	195.1% GREATER
13-COMP. AT CONDYLE	382	204	1.876	0.533	87.6% GREATER	46.7% LESS	-609	-787	0.773	1.294	22.7% LESS	29.4% GREATER
14-SHEAR AT C7-T1	553	730	0.757	1.321	24.3% LESS	32.1% GREATER	-139	-390	0.358	2.794	64.2% LESS	179.4% GREATER
15-COMP. AT C7-T1	269	292	0.923	1.084	7.7% LESS	8.4% GREATER	-762	-943	0.808	1.237	19.2% LESS	23.7% GREATER
16-COND. TOTAL TORQ	575	300	1.913	0.523	91.3% GREATER	47.7% LESS	-2757	-3440	0.801	1.248	19.9% LESS	24.8% GREATER
17-C7-T1 TOTAL TORQ	645	0	0.0	0.0	0.0% GREATER	100.0% LESS	-3021	-4146	0.729	1.373	27.1% LESS	37.3% GREATER
HIC	644	611	1.054	0.949	5.4% GREATER	5.1% LESS						
HEAD 3-MSEC AVG.	68	70	0.971	1.029	2.9% LESS	2.9% GREATER						
CHEST 3-MSEC AVG	64	63	1.016	0.984	1.6% GREATER	1.6% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 45

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= CR20H5.3 AND B= CR20H5.312

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	55	1.268	0.789	26.8% GREATER	21.1% LESS	-7	-11	0.670	1.493	33.0% LESS	49.3% GREATER
2-HEAD ANG. VELOC.	3207	2691	1.192	0.839	19.2% GREATER	16.1% LESS	-3244	-2637	1.230	0.813	23.0% GREATER	18.7% LESS
3-HEAD ANG. ACCEL.	7391	5729	1.290	0.775	29.0% GREATER	22.5% LESS	-2689	-2245	1.198	0.835	19.8% GREATER	16.5% LESS
4-HEAD RES. ACCEL.	70	71	0.979	1.021	2.1% LESS	2.1% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	44	72	0.614	1.629	38.6% LESS	62.9% GREATER	-2497	-1934	1.291	0.775	29.1% GREATER	22.5% LESS
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-1803	-1083	1.665	0.601	66.5% GREATER	39.9% LESS
7-Z HEAD FORCE	859	941	0.913	1.095	8.7% LESS	9.5% GREATER	-96	-88	1.093	0.915	9.3% GREATER	8.5% LESS
8-X HEAD FORCE	5440	5532	0.983	1.017	1.7% LESS	1.7% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	29	22	1.288	0.776	28.8% GREATER	22.4% LESS	-45	-50	0.893	1.119	10.7% LESS	11.9% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-79	-80	0.985	1.015	1.5% LESS	1.5% GREATER
11-FORCE ALONG NECK	227	196	1.158	0.864	15.8% GREATER	13.6% LESS	-956	-987	0.969	1.032	3.1% LESS	3.2% GREATER
12-SHEAR AT CONDYLE	422	311	1.358	0.736	35.8% GREATER	26.4% LESS	-326	-327	0.996	1.004	0.4% LESS	0.4% GREATER
13-COMP. AT CONDYLE	234	210	1.115	0.897	11.5% GREATER	10.3% LESS	-863	-891	0.968	1.033	3.2% LESS	3.3% GREATER
14-SHEAR AT C7-T1	419	317	1.324	0.755	32.4% GREATER	24.5% LESS	-362	-336	1.078	0.928	7.8% GREATER	7.2% LESS
15-COMP. AT C7-T1	213	157	1.361	0.735	36.1% GREATER	26.5% LESS	-1079	-1123	0.961	1.041	3.9% LESS	4.1% GREATER
16-COND. TOTAL TORQ	182	233	0.783	1.277	21.7% LESS	27.7% GREATER	-2936	-2346	1.252	0.799	25.2% GREATER	20.1% LESS
17-C7-T1 TOTAL TORQ	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-2615	-1706	1.533	0.653	53.3% GREATER	34.7% LESS
HIC	419	424	0.988	1.012	1.2% LESS	1.2% GREATER						
HEAD 3-MSEC AVG.	70	71	0.986	1.014	1.4% LESS	1.4% GREATER						
CHEST 3-MSEC AVG	61	60	1.017	0.984	1.7% GREATER	1.6% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 46

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= CR20H5.3 AND B= CR20H5.313

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	100	0.700	1.429	30.0% LESS	42.9% GREATER	-7	0	0.0	0.0	0.0% GREATER	100.0% LESS
2-HEAD ANG. VELOC.	3207	3139	1.022	0.979	2.2% GREATER	2.1% LESS	-3244	-4410	0.736	1.359	26.4% LESS	35.9% GREATE
3-HEAD ANG. ACCEL.	7391	8836	0.836	1.196	16.4% LESS	19.6% GREATER	-2689	-4281	0.628	1.592	37.2% LESS	59.2% GREATE
4-HEAD RES. ACCEL.	70	70	1.000	1.000	0.0% LESS	0.0% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
5-CONDYL STOP TORQ	44	110	0.401	2.493	59.9% LESS	149.3% GREATER	-2497	-2961	0.843	1.186	15.7% LESS	18.6% GREATE
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-1803	-3123	0.577	1.732	42.3% LESS	73.2% GREATE
7-Z HEAD FORCE	859	725	1.185	0.844	18.5% GREATER	15.6% LESS	-96	0	0.0	0.0	0.0% GREATER	100.0% LESS
8-X HEAD FORCE	5440	5228	1.041	0.961	4.1% GREATER	3.9% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
9-CONDYLES ANGLE	29	36	0.810	1.234	19.0% LESS	23.4% GREATER	-45	-48	0.936	1.068	6.4% LESS	6.8% GREATE
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-79	-59	1.337	0.748	33.7% GREATER	25.2% LESS
11-FORCE ALONG NECK	227	235	0.967	1.034	3.3% LESS	3.4% GREATER	-956	-875	1.093	0.915	9.3% GREATER	8.5% LESS
12-SHEAR AT CONDYLE	422	692	0.610	1.639	39.0% LESS	63.9% GREATER	-326	-389	0.838	1.193	16.2% LESS	19.3% GREAT
13-COMP. AT CONDYLE	234	204	1.151	0.869	15.1% GREATER	13.1% LESS	-863	-787	1.096	0.913	9.6% GREATER	8.7% LESS
14-SHEAR AT C7-T1	419	730	0.575	1.741	42.5% LESS	74.1% GREATER	-362	-390	0.930	1.076	7.0% LESS	7.6% GREAT
15-COMP. AT C7-T1	213	292	0.731	1.367	26.9% LESS	36.7% GREATER	-1079	-943	1.144	0.874	14.4% GREATER	12.6% LESS
16-COND. TOTAL TORQ	182	300	0.608	1.644	39.2% LESS	64.4% GREATER	-2936	-3440	0.853	1.172	14.7% LESS	17.2% GREAT
17-C7-T1 TOTAL TORQ	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-2615	-4146	0.631	1.585	36.9% LESS	58.5% GREAT
HIC	419	611	0.686	1.458	31.4% LESS	45.8% GREATER						
HEAD 3-MSEC AVG.	70	70	1.000	1.000	0.0% LESS	0.0% GREATER						
CHEST 3-MSEC AVG	61	63	0.968	1.033	3.2% LESS	3.3% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #47

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH2OH5.2F AND B= RH2OH5.2NM

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	11	6.148	0.163	514.8% GREATER	83.7% LESS	-30	-30	0.997	1.003	0.3% LESS	0.3% GREATER
2-HEAD ANG. VELOC.	2875	1323	2.173	0.460	117.3% GREATER	54.0% LESS	-1781	-500	3.558	0.281	255.8% GREATER	71.9% LESS
3-HEAD ANG. ACCEL.	4559	1975	2.308	0.433	130.8% GREATER	56.7% LESS	-1844	-1386	1.330	0.752	33.0% GREATER	24.8% LESS
4-HEAD RES. ACCEL.	133	172	0.774	1.292	22.6% LESS	29.2% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	347	132	2.626	0.381	162.6% GREATER	61.9% LESS	-551	-319	1.726	0.579	72.6% GREATER	42.1% LESS
6-C7-T1 STOP TORQ.	186	51	3.586	0.279	258.6% GREATER	72.1% LESS	0	-128	0.0	0.0	100.0% LESS	0.0% GREATER
7-Z HEAD FORCE	3139	2919	1.075	0.930	7.5% GREATER	7.0% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	627	583	1.075	0.930	7.5% GREATER	7.0% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	58	48	1.220	0.819	22.0% GREATER	18.1% LESS	-7	0	0.0	0.0	0.0% GREATER	100.0% LESS
10-C7-T1 ANGLE	11	0	22.800	0.044	*****% GREATER	95.6% LESS	-20	-24	0.833	1.200	16.7% LESS	20.0% GREATER
11-FORCE ALONG NECK	2371	626	3.788	0.264	278.8% GREATER	73.6% LESS	-525	-53	9.885	0.101	888.5% GREATER	89.9% LESS
12-SHEAR AT CONDYLE	60	122	0.498	2.007	50.2% LESS	100.7% GREATER	-337	-197	1.708	0.586	70.8% GREATER	41.4% LESS
13-COMP. AT CONDYLE	2321	806	2.880	0.347	188.0% GREATER	65.3% LESS	-458	-46	9.814	0.102	881.4% GREATER	89.8% LESS
14-SHEAR AT C7-T1	118	45	2.609	0.383	160.9% GREATER	61.7% LESS	-310	-61	5.059	0.198	405.9% GREATER	80.2% LESS
15-COMP. AT C7-T1	2304	251	9.160	0.109	816.0% GREATER	89.1% LESS	-515	-23	22.216	0.045	*****% GREATER	95.5% LESS
16-COND. TOTAL TORQ	578	354	1.635	0.612	63.5% GREATER	38.8% LESS	-761	-425	1.789	0.559	78.9% GREATER	44.1% LESS
17-C7-T1 TOTAL TORQ	854	471	1.810	0.552	81.0% GREATER	44.8% LESS	-220	-295	0.745	1.342	25.5% LESS	34.2% GREATER
HIC	1266	1411	0.897	1.115	10.3% LESS	11.5% GREATER						
HEAD 3-MSEC AVG.	131	165	0.794	1.260	20.6% LESS	26.0% GREATER						
CHEST 3-MSEC AVG	23	127	0.181	5.522	81.9% LESS	452.2% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #48

CCMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20V5.2F AND B= RH20V5.2NM

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.C	0.0% LESS	0.0% GREATER	-207	-97	2.127	0.470	112.7% GREATER	53.0% LESS
2-HEAD ANG. VELOC.	2127	493	4.308	0.232	330.8% GREATER	76.8% LESS	-6620	-1158	5.714	0.175	471.4% GREATER	82.5% LESS
3-HEAD ANG. ACCEL.	14170	1335	10.612	0.094	961.2% GREATER	90.6% LESS	-8665	-2651	3.268	0.306	226.8% GREATER	69.4% LESS
4-HEAD RES. ACCEL.	182	155	1.179	0.848	17.9% GREATER	15.2% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	279	4	60.717	0.016	*****% GREATER	98.4% LESS	-4460	-334	13.323	0.075	*****% GREATER	92.5% LESS
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	100.0% LESS	0.0% GREATER	-7378	-283	26.053	0.038	*****% GREATER	96.2% LESS
7-Z HEAD FORCE	3335	2833	1.177	C.850	17.7% GREATER	15.0% LESS	0	0	0.0	0.0	0.0% LESS	C.0% GREATER
8-X HEAD FORCE	667	566	1.177	0.850	17.7% GREATER	15.0% LESS	0	0	0.C	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	56	29	1.918	0.521	91.8% GREATER	47.9% LESS	-46	0	0.0	0.0	0.0% GREATER	100.0% LESS
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-97	-31	3.115	0.321	211.5% GREATER	67.9% LESS
11-FORCE ALONG NECK	3207	715	4.481	0.223	348.1% GREATER	77.7% LESS	-747	-37	20.148	C.050	*****% GREATER	95.0% LESS
12-SHEAR AT CONDYLE	1826	82	22.027	0.045	*****% GREATER	95.5% LESS	-492	-42	11.588	0.086	*****% GREATER	91.4% LESS
13-COMP. AT CONDYLE	3192	910	3.508	0.285	250.8% GREATER	71.5% LESS	-642	-35	17.983	0.056	*****% GREATER	94.4% LESS
14-SHEAR AT C7-T1	1904	31	61.048	0.016	*****% GREATER	98.4% LESS	-608	-22	27.147	0.037	*****% GREATER	96.3% LESS
15-COMP. AT C7-T1	3012	286	10.506	0.095	950.6% GREATER	90.5% LESS	-532	-9	57.870	C.017	*****% GREATER	98.3% LESS
16-COND. TOTAL TORQ	560	98	5.685	0.176	468.5% GREATER	82.4% LESS	-5001	-444	11.255	C.089	*****% GREATER	91.1% LESS
17-C7-T1 TOTAL TORQ	489	142	3.424	0.292	242.4% GREATER	70.8% LESS	-8647	-504	17.140	0.059	*****% GREATER	94.2% LESS
HIC	4440	1099	4.040	0.248	304.0% GREATER	75.2% LESS						
HEAD 3-MSEC AVG.	166	150	1.107	0.904	10.7% GREATER	9.6% LESS						
CHEST 3-MSEC AVG	34	145	0.234	4.265	76.6% LESS	326.5% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #49

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20H5.2F AND B= RF20H1.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	86	0.821	1.218	17.9% LESS	21.8% GREATER	-30	-30	0.997	1.003	0.3% LESS	0.3% GREATE
2-HEAD ANG. VELOC.	2875	2851	1.008	0.992	0.8% GREATER	0.8% LESS	-1781	-1284	1.387	0.721	38.7% GREATER	27.9% LESS
3-HEAD ANG. ACCEL.	4559	4382	1.041	0.961	4.1% GREATER	3.9% LESS	-1844	-2146	0.860	1.163	14.0% LESS	16.3% GREATE
4-HEAD RES. ACCEL.	133	134	0.995	1.005	0.5% LESS	0.5% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
5-CONDYL STOP TORQ	347	706	0.492	2.032	50.8% LESS	103.2% GREATER	-551	-763	0.722	1.385	27.8% LESS	38.5% GREATE
6-C7-T1 STOP TORQ.	186	315	0.590	1.695	41.0% LESS	69.5% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
7-Z HEAD FORCE	3139	3136	1.001	0.999	0.1% GREATER	0.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
8-X HEAD FORCE	627	627	1.001	0.999	0.1% GREATER	0.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
9-CONDYLES ANGLE	58	69	0.851	1.175	14.9% LESS	17.5% GREATER	-7	-14	0.514	1.945	48.6% LESS	94.5% GREATE
10-C7-T1 ANGLE	11	17	0.651	1.535	34.9% LESS	53.5% GREATER	-20	-20	1.000	1.000	0.0% LESS	0.0% GREATE
11-FORCE ALONG NECK	2371	2356	1.007	0.993	0.7% GREATER	0.7% LESS	-525	-513	1.024	0.976	2.4% GREATER	2.4% LESS
12-SHEAR AT CONDYLE	60	91	0.666	1.501	33.4% LESS	50.1% GREATER	-337	-253	1.331	0.751	33.1% GREATER	24.9% LESS
13-COMP. AT CONDYLE	2321	2311	1.004	0.996	0.4% GREATER	0.4% LESS	-458	-447	1.024	0.976	2.4% GREATER	2.4% LESS
14-SHEAR AT C7-T1	118	145	0.815	1.227	18.5% LESS	22.7% GREATER	-310	-242	1.281	0.780	28.1% GREATER	22.0% LESS
15-COMP. AT C7-T1	2304	2292	1.005	0.995	0.5% GREATER	0.5% LESS	-515	-495	1.040	0.961	4.0% GREATER	3.9% LESS
16-COND. TOTAL TORQ	578	789	0.734	1.363	26.6% LESS	36.3% GREATER	-761	-826	0.921	1.085	7.9% LESS	8.5% GREATE
17-C7-T1 TOTAL TORQ	854	520	1.642	0.609	64.2% GREATER	39.1% LESS	-220	-67	3.264	0.306	226.4% GREATER	69.4% LESS
HIC	1266	1288	0.983	1.017	1.7% LESS	1.7% GREATER						
HEAD 3-MSEC AVG.	131	132	0.992	1.008	0.8% LESS	0.8% GREATER						
CHEST 3-MSEC AVG	23	28	0.821	1.217	17.9% LESS	21.7% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #50

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20V5.2F AND B= RH20V1.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-207	-214	0.966	1.035	3.4% LESS	3.5% GREATE
2-HEAD ANG. VELOC.	2127	2583	0.823	1.215	17.7% LESS	21.5% GREATER	-6620	-6384	1.037	0.964	3.7% GREATER	3.6% LESS
3-HEAD ANG. ACCEL.	14170	12094	1.172	0.853	17.2% GREATER	14.7% LESS	-8665	-7762	1.116	0.896	11.6% GREATER	10.4% LESS
4-HEAD RES. ACCEL.	182	162	1.128	0.887	12.8% GREATER	11.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
5-CONDYL STOP TORQ	279	420	0.664	1.505	33.6% LESS	50.5% GREATER	-4460	-4004	1.114	0.898	11.4% GREATER	10.2% LESS
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-7378	-8309	0.888	1.126	11.2% LESS	12.6% GREATE
7-Z HEAD FORCE	3335	3332	1.001	0.999	0.1% GREATER	0.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
8-X HEAD FORCE	667	666	1.001	0.999	0.1% GREATER	0.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
9-CONDYLES ANGLE	56	61	0.915	1.093	8.5% LESS	9.3% GREATER	-46	-44	1.052	0.951	5.2% GREATER	4.9% LESS
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-97	-100	0.972	1.029	2.8% LESS	2.9% GREATE
11-FORCE ALONG NECK	3207	3155	1.016	0.984	1.6% GREATER	1.6% LESS	-747	-824	0.906	1.104	9.4% LESS	10.4% GREATE
12-SHEAR AT CONDYLE	1826	1764	1.035	0.966	3.5% GREATER	3.4% LESS	-492	-133	3.692	0.271	269.2% GREATER	72.9% LESS
13-COMP. AT CONDYLE	3192	3151	1.013	0.987	1.3% GREATER	1.3% LESS	-642	-710	0.904	1.106	9.6% LESS	10.6% GREATE
14-SHEAR AT C7-T1	1904	1824	1.044	0.958	4.4% GREATER	4.2% LESS	-608	-234	2.599	0.385	159.9% GREATER	61.5% LESS
15-COMP. AT C7-T1	3012	2967	1.015	0.985	1.5% GREATER	1.5% LESS	-532	-622	0.855	1.169	14.5% LESS	16.9% GREATE
16-COND. TOTAL TORQ	560	497	1.125	0.889	12.5% GREATER	11.1% LESS	-5001	-4110	1.217	0.822	21.7% GREATER	17.8% LESS
17-C7-T1 TOTAL TORQ	489	0	0.0	0.0	0.0% GREATER	100.0% LESS	-8647	-8581	1.008	0.992	0.8% GREATER	0.8% LESS
HIC	4440	2933	1.514	0.661	51.4% GREATER	33.9% LESS						
HEAD 3-MSEC AVG.	166	145	1.145	0.873	14.5% GREATER	12.7% LESS						
CHEST 3-MSEC AVG	34	34	1.000	1.000	0.0% LESS	0.0% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 51

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= HR20H5.1F AND B= HR20H1.1F

	(+)A	(+)B	A/B	B/A	A IS X%* GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	228	243	0.939	1.065	6.1% LESS	6.5% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
2-HEAD ANG. VELOC.	4699	4741	0.991	1.009	0.9% LESS	0.9% GREATER	-1527	-1044	1.463	0.684	46.3% GREATER	31.6% LESS
3-HEAD ANG. ACCEL.	8740	8710	1.003	0.997	0.3% GREATER	0.3% LESS	-3361	-4416	0.761	1.314	23.9% LESS	31.4% GREAT
4-HEAD RES. ACCEL.	245	248	0.988	1.012	1.2% LESS	1.2% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
5-CONDYL STOP TORQ	722	1125	0.641	1.559	35.9% LESS	55.9% GREATER	-1261	-1703	0.741	1.350	25.9% LESS	35.0% GREAT
6-C7-T1 STOP TORQ.	978	1667	0.597	1.705	41.3% LESS	70.5% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
7-Z HEAD FORCE	144	118	1.212	0.825	21.2% GREATER	17.5% LESS	-389	-388	1.001	0.999	0.1% GREATER	0.1% LESS
8-X HEAD FORCE	3890	3885	1.001	0.999	0.1% GREATER	0.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
9-CONDYLES ANGLE	59	67	0.883	1.133	11.7% LESS	13.3% GREATER	-33	-38	0.865	1.157	13.5% LESS	15.7% GREAT
10-C7-T1 ANGLE	24	35	0.700	1.429	30.0% LESS	42.9% GREATER	-30	-30	1.000	1.000	0.0% LESS	0.0% GREAT
11-FORCE ALONG NECK	990	988	1.002	0.998	0.2% GREATER	0.2% LESS	-899	-944	0.952	1.051	4.8% LESS	5.1% GREAT
12-SHEAR AT CONDYLE	9	28	0.331	3.022	66.9% LESS	202.2% GREATER	-614	-529	1.160	0.862	16.0% GREATER	13.8% LESS
13-COMP. AT CONDYLE	1070	1067	1.002	0.998	0.2% GREATER	0.2% LESS	-796	-813	0.979	1.021	2.1% LESS	2.1% GREAT
14-SHEAR AT C7-T1	18	64	0.280	3.567	72.0% LESS	256.7% GREATER	-578	-507	1.139	0.878	13.9% GREATER	12.2% LESS
15-COMP. AT C7-T1	935	937	0.998	1.002	0.2% LESS	0.2% GREATER	-858	-898	0.956	1.046	4.4% LESS	4.6% GREAT
16-COND. TOTAL TORQ	1045	1210	0.863	1.158	13.7% LESS	15.8% GREATER	-1596	-1792	0.891	1.123	10.9% LESS	12.3% GREAT
17-C7-T1 TOTAL TORQ	1976	1924	1.027	0.974	2.7% GREATER	2.6% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
HIC	3317	3388	0.979	1.021	2.1% LESS	2.1% GREATER						
HEAD 3-MSEC AVG.	233	236	0.987	1.013	1.3% LESS	1.3% GREATER						
CHEST 3-MSEC AVG	18	22	0.818	1.222	18.2% LESS	22.2% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 52

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= CR20H5.3 AND B= CR20H1.3

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	70	1.000	1.000	0.0% LESS	0.0% GREATER	-7	-13	0.547	1.827	45.3% LESS	82.7% GREAT
2-HEAD ANG. VELOC.	3207	3169	1.012	0.988	1.2% GREATER	1.2% LESS	-3244	-3497	0.928	1.078	7.2% LESS	7.8% GREAT
3-HEAD ANG. ACCEL.	7391	8005	0.923	1.083	7.7% LESS	8.3% GREATER	-2689	-2815	0.955	1.047	4.5% LESS	4.7% GREAT
4-HEAD RES. ACCEL.	70	74	0.944	1.060	5.6% LESS	6.0% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
5-CONDYL STOP TORQ	44	116	0.380	2.631	62.0% LESS	163.1% GREATER	-2497	-3035	0.823	1.216	17.7% LESS	21.6% GREAT
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-1803	-2698	0.668	1.496	33.2% LESS	49.6% GREAT
7-Z HEAD FORCE	859	798	1.077	0.929	7.7% GREATER	7.1% LESS	-96	-136	0.704	1.420	29.6% LESS	42.0% GREAT
8-X HEAD FORCE	5440	5403	1.007	0.993	0.7% GREATER	0.7% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
9-CONDYLES ANGLE	29	36	0.799	1.251	20.1% LESS	25.1% GREATER	-45	-48	0.926	1.079	7.4% LESS	7.9% GREAT
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-79	-86	0.916	1.092	8.4% LESS	9.2% GREAT
11-FORCE ALONG NECK	227	252	0.902	1.109	9.8% LESS	10.9% GREATER	-956	-1029	0.929	1.076	7.1% LESS	7.6% GREAT
12-SHEAR AT CONDYLE	422	497	0.849	1.177	15.1% LESS	17.7% GREATER	-326	-475	0.686	1.458	31.4% LESS	45.8% GREAT
13-COMP. AT CONDYLE	234	266	0.883	1.133	11.7% LESS	13.3% GREATER	-863	-926	0.932	1.073	6.8% LESS	7.3% GREAT
14-SHEAR AT C7-T1	419	504	0.833	1.201	16.7% LESS	20.1% GREATER	-362	-507	0.715	1.398	28.5% LESS	39.8% GREAT
15-COMP. AT C7-T1	213	213	1.003	0.997	0.3% GREATER	0.3% LESS	-1079	-1150	0.938	1.066	6.2% LESS	6.6% GREAT
16-COND. TOTAL TORQ	182	161	1.132	0.884	13.2% GREATER	11.6% LESS	-2936	-3153	0.931	1.074	6.9% LESS	7.4% GREAT
17-C7-T1 TOTAL TORQ	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-2615	-2900	0.902	1.109	9.8% LESS	10.9% GREAT
HIC	419	542	0.773	1.294	22.7% LESS	29.4% GREATER						
HEAD 3-MSEC AVG.	70	74	0.946	1.057	5.4% LESS	5.7% GREATER						
CHEST 3-MSEC AVG	61	61	1.000	1.000	0.0% LESS	0.0% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #53

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= CR20H5.312 AND B= CR20H5.313

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	55	100	0.552	1.812	44.8% LESS	81.2% GREATER	-11	0	0.0	0.0	0.0% GREATER	100.0% LESS
2-HEAD ANG. VELOC.	2691	3139	0.857	1.166	14.3% LESS	16.6% GREATER	-2637	-4410	0.598	1.672	40.2% LESS	67.2% GREAT
3-HEAD ANG. ACCEL.	5729	8836	0.648	1.542	35.2% LESS	54.2% GREATER	-2245	-4281	0.524	1.907	47.6% LESS	90.7% GREAT
4-HEAD RES. ACCEL.	71	70	1.021	0.979	2.1% GREATER	2.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
5-CONDYL STOP TORQ	72	110	0.653	1.531	34.7% LESS	53.1% GREATER	-1934	-2961	0.653	1.531	34.7% LESS	53.1% GREAT
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-1083	-3123	0.347	2.884	65.3% LESS	188.4% GREAT
7-Z HEAD FORCE	941	725	1.298	0.770	29.8% GREATER	23.0% LESS	-88	0	0.0	0.0	0.0% GREATER	100.0% LESS
8-X HEAD FORCE	5532	5228	1.058	0.945	5.8% GREATER	5.5% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
9-CONDYLES ANGLE	22	36	0.629	1.590	37.1% LESS	59.0% GREATER	-50	-48	1.048	0.955	4.8% GREATER	4.5% LESS
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-80	-59	1.357	0.737	35.7% GREATER	26.3% LESS
11-FORCE ALONG NECK	196	235	0.835	1.197	16.5% LESS	19.7% GREATER	-987	-875	1.128	0.887	12.8% GREATER	11.3% LESS
12-SHEAR AT CONDYLE	311	692	0.449	2.227	55.1% LESS	122.7% GREATER	-327	-389	0.842	1.188	15.8% LESS	18.8% GREAT
13-COMP. AT CONDYLE	210	204	1.032	0.969	3.2% GREATER	3.1% LESS	-891	-787	1.132	0.884	13.2% GREATER	11.6% LESS
14-SHEAR AT C7-T1	317	730	0.434	2.304	56.6% LESS	130.4% GREATER	-336	-390	0.863	1.159	13.7% LESS	15.9% GREAT
15-COMP. AT C7-T1	157	292	0.537	1.861	46.3% LESS	86.1% GREATER	-1123	-943	1.191	0.840	19.1% GREATER	16.0% LESS
16-COND. TOTAL TORQ	233	300	0.777	1.287	22.3% LESS	28.7% GREATER	-2346	-3440	0.682	1.467	31.8% LESS	46.7% GREAT
17-C7-T1 TOTAL TORQ	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-1706	-4146	0.412	2.430	58.8% LESS	143.0% GREAT
HIC	424	611	0.694	1.441	30.6% LESS	44.1% GREATER						
HEAD 3-MSEC AVG.	71	70	1.014	0.986	1.4% GREATER	1.4% LESS						
CHEST 3-MSEC AVG	60	63	0.952	1.050	4.8% LESS	5.0% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 54

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20V5.6F-3 AND B= RH20V5.2F-3

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LES THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-173	-190	0.914	1.094	8.6% LESS	9.4% GREAT
2-HEAD ANG. VELOC.	2672	537	4.972	0.201	397.2% GREATER	79.9% LESS	-4509	-4926	0.915	1.092	8.5% LESS	9.2% GREAT
3-HEAD ANG. ACCEL.	19646	9844	1.996	0.501	99.6% GREATER	49.9% LESS	-20770	-5156	4.028	0.248	302.8% GREATER	75.2% LESS
4-HEAD RES. ACCEL.	340	145	2.345	0.426	134.5% GREATER	57.4% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
5-CONDYL STOP TORQ	132	113	1.171	0.854	17.1% GREATER	14.6% LESS	-1645	-3193	0.515	1.941	48.5% LESS	94.1% GREAT
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% GREATER	100.0% LESS	-4533	-4243	1.068	0.936	6.8% GREATER	6.4% LESS
7-Z HEAD FORCE	3540	2374	1.491	0.671	49.1% GREATER	32.9% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
8-X HEAD FORCE	2124	475	4.472	0.224	347.2% GREATER	77.6% LESS	-610	0	0.0	0.0	0.0% GREATER	100.0% LESS
9-CONDYLES ANGLE	48	46	1.030	0.971	3.0% GREATER	2.9% LESS	-27	-39	0.701	1.427	29.9% LESS	42.7% GREAT
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-86	-85	1.016	0.984	1.6% GREATER	1.6% LESS
11-FORCE ALONG NECK	2290	2257	1.014	0.986	1.4% GREATER	1.4% LESS	-458	-338	1.353	0.739	35.3% GREATER	26.1% LESS
12-SHEAR AT CONDYLE	1093	1048	1.043	0.959	4.3% GREATER	4.1% LESS	-98	-474	0.208	4.811	79.2% LESS	381.1% GREAT
13-COMP. AT CONDYLE	2290	2245	1.020	0.980	2.0% GREATER	2.0% LESS	-416	-288	1.447	0.691	44.7% GREATER	30.9% LESS
14-SHEAR AT C7-T1	1272	1127	1.129	0.886	12.9% GREATER	11.4% LESS	-90	-551	0.165	6.076	83.5% LESS	507.6% GREAT
15-COMP. AT C7-T1	2187	2140	1.022	0.978	2.2% GREATER	2.2% LESS	-316	-212	1.489	0.671	48.9% GREATER	32.9% LESS
16-COND. TOTAL TORQ	433	320	1.354	0.739	35.4% GREATER	26.1% LESS	-1999	-3671	0.545	1.836	45.5% LESS	83.6% GREAT
17-C7-T1 TOTAL TORQ	666	0	0.0	0.0	0.0% GREATER	100.0% LESS	-5846	-5271	1.109	0.902	10.9% GREATER	9.8% LESS
HIC	4385	1835	2.390	0.418	139.0% GREATER	58.2% LESS						
HEAD 3-MSEC AVG.	275	136	2.022	0.495	102.2% GREATER	50.5% LESS						
CHEST 3-MSEC AVG	21	23	0.913	1.095	8.7% LESS	9.5% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #55

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20V5.2F AND B= RH20V5.2F-3

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-207	-190	1.088	0.919	8.8% GREATER	8.1% LESS
2-HEAD ANG. VELOC.	2127	537	3.958	0.253	295.8% GREATER	74.7% LESS	-6620	-4926	1.344	0.744	34.4% GREATER	25.6% LESS
3-HEAD ANG. ACCEL.	14170	9844	1.439	0.695	43.9% GREATER	30.5% LESS	-8665	-5156	1.680	0.595	68.0% GREATER	40.5% LESS
4-HEAD RES. ACCEL.	182	145	1.259	0.794	25.9% GREATER	20.6% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
5-CONDYL STOP TORQ	279	113	2.469	0.405	146.9% GREATER	59.5% LESS	-4460	-3193	1.397	0.716	39.7% GREATER	28.4% LESS
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-7378	-4243	1.739	0.575	73.9% GREATER	42.5% LESS
7-Z HEAD FORCE	3335	2374	1.404	0.712	40.4% GREATER	28.8% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
8-X HEAD FORCE	667	475	1.404	0.712	40.4% GREATER	28.8% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
9-CONDYLES ANGLE	56	46	1.199	0.834	19.9% GREATER	16.6% LESS	-46	-39	1.168	0.856	16.8% GREATER	14.4% LESS
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-97	-85	1.142	0.876	14.2% GREATER	12.4% LESS
11-FORCE ALONG NECK	3207	2257	1.421	0.704	42.1% GREATER	29.6% LESS	-747	-338	2.208	0.453	120.8% GREATER	54.7% LESS
12-SHEAR AT CONDYLE	1826	1048	1.742	0.574	74.2% GREATER	42.6% LESS	-492	-474	1.038	0.963	3.8% GREATER	3.7% LESS
13-COMP. AT CONDYLE	3192	2245	1.422	0.703	42.2% GREATER	29.7% LESS	-642	-288	2.229	0.449	122.9% GREATER	55.1% LESS
14-SHEAR AT C7-T1	1904	1127	1.690	0.592	69.0% GREATER	40.8% LESS	-608	-551	1.102	0.907	10.2% GREATER	9.3% LESS
15-COMP. AT C7-T1	3012	2140	1.407	0.711	40.7% GREATER	28.9% LESS	-532	-212	2.505	0.399	150.5% GREATER	60.1% LESS
16-COND. TOTAL TORQ	560	320	1.750	0.571	75.0% GREATER	42.9% LESS	-5001	-3671	1.362	0.734	36.2% GREATER	26.6% LESS
17-C7-T1 TOTAL TORQ	489	0	0.0	0.0	0.0% GREATER	100.0% LESS	-8647	-5271	1.640	0.610	64.0% GREATER	39.0% LESS
HIC	4440	1835	2.420	0.413	142.0% GREATER	58.7% LESS						
HEAD 3-MSEC AVG.	166	136	1.221	0.819	22.1% GREATER	18.1% LESS						
CHEST 3-MSEC AVG	34	23	1.478	0.676	47.8% GREATER	32.4% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #56

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20H5.6F-3 AND B= RH20H5.2F-3

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	36	56	0.638	1.567	36.2% LESS	56.7% GREATER	-30	-30	0.990	1.010	1.0% LESS	1.0% GREATE
2-HEAD ANG. VELOC.	5893	1970	2.992	0.334	199.2% GREATER	66.6% LESS	-2931	-973	3.010	0.332	201.0% GREATER	66.8% LESS
3-HEAD ANG. ACCEL.	16813	2546	6.604	0.151	560.4% GREATER	84.9% LESS	-19118	-1752	10.909	0.092	990.9% GREATER	90.8% LESS
4-HEAD RES. ACCEL.	292	97	3.000	0.333	200.0% GREATER	66.7% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
5-CONDYL STOP TORQ	2107	301	6.986	0.143	598.6% GREATER	85.7% LESS	-350	-362	0.968	1.033	3.2% LESS	3.3% GREATE
6-C7-T1 STOP TORQ.	561	146	3.835	0.261	283.5% GREATER	73.9% LESS	-434	0	0.0	0.0	0.0% GREATER	100.0% LESS
7-Z HEAD FORCE	3529	2315	1.525	0.656	52.5% GREATER	34.4% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
8-X HEAD FORCE	2117	463	4.574	0.219	357.4% GREATER	78.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
9-CONDYLES ANGLE	90	56	1.594	0.627	59.4% GREATER	37.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
10-C7-T1 ANGLE	25	9	2.822	0.354	182.2% GREATER	64.6% LESS	-41	-20	2.065	0.484	106.5% GREATER	51.6% LESS
11-FORCE ALONG NECK	3010	1716	1.754	0.570	75.4% GREATER	43.0% LESS	-845	-258	3.275	0.305	227.5% GREATER	69.5% LESS
12-SHEAR AT CONDYLE	699	88	7.872	0.127	687.2% GREATER	87.3% LESS	-409	-208	1.966	0.509	96.6% GREATER	49.1% LESS
13-COMP. AT CONDYLE	2924	1687	1.733	0.577	73.3% GREATER	42.3% LESS	-740	-219	3.368	0.297	236.8% GREATER	70.3% LESS
14-SHEAR AT C7-T1	811	149	5.437	0.184	443.7% GREATER	81.6% LESS	-445	-194	2.293	0.436	129.3% GREATER	56.4% LESS
15-COMP. AT C7-T1	2890	1662	1.739	0.575	73.9% GREATER	42.5% LESS	-823	-260	3.159	0.317	215.9% GREATER	68.3% LESS
16-COND. TOTAL TORQ	2651	501	5.290	0.189	429.0% GREATER	81.1% LESS	-557	-488	1.142	0.876	14.2% GREATER	12.4% LESS
17-C7-T1 TOTAL TORQ	1663	639	2.600	0.385	160.0% GREATER	61.5% LESS	-945	-68	13.846	0.072	*****% GREATER	92.8% LESS
HIC	2686	579	4.639	0.216	363.9% GREATER	78.4% LESS						
HEAD 3-MSEC AVG.	241	96	2.510	0.398	151.0% GREATER	60.2% LESS						
CHEST 3-MSEC AVG	26	14	1.857	0.538	85.7% GREATER	46.2% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #57

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20H5.2F AND B= RH20H5.2F-3

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	56	1.254	0.798	25.4% GREATER	20.2% LESS	-30	-30	0.993	1.007	0.7% LESS	0.7% GREATER
2-HEAD ANG. VELOC.	2875	1970	1.459	0.685	45.9% GREATER	31.5% LESS	-1781	-973	1.829	0.547	82.9% GREATER	45.3% LESS
3-HEAD ANG. ACCEL.	4559	2546	1.791	0.558	79.1% GREATER	44.2% LESS	-1844	-1752	1.053	0.950	5.3% GREATER	5.0% LESS
4-HEAD RES. ACCEL.	133	97	1.368	0.731	36.8% GREATER	26.9% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	347	301	1.154	0.867	15.4% GREATER	13.3% LESS	-551	-362	1.523	0.657	52.3% GREATER	34.3% LESS
6-C7-T1 STOP TORQ.	186	146	1.272	0.786	27.2% GREATER	21.4% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
7-Z HEAD FORCE	3139	2315	1.356	0.737	35.6% GREATER	26.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	627	463	1.356	0.737	35.6% GREATER	26.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	58	56	1.032	0.969	3.2% GREATER	3.1% LESS	-7	0	0.0	0.0	0.0% GREATER	100.0% LESS
10-C7-T1 ANGLE	11	9	1.267	0.789	26.7% GREATER	21.1% LESS	-20	-20	1.000	1.000	0.0% LESS	0.0% GREATER
11-FORCE ALONG NECK	2371	1716	1.382	0.724	38.2% GREATER	27.6% LESS	-525	-258	2.038	0.491	103.8% GREATER	50.9% LESS
12-SHEAR AT CONDYLE	60	88	0.686	1.458	31.4% LESS	45.8% GREATER	-337	-208	1.623	0.616	62.3% GREATER	38.4% LESS
13-COMP. AT CONDYLE	2321	1687	1.376	0.727	37.6% GREATER	27.3% LESS	-458	-219	2.086	0.479	108.6% GREATER	52.1% LESS
14-SHEAR AT C7-T1	118	149	0.796	1.257	20.4% LESS	25.7% GREATER	-310	-194	1.595	0.627	59.5% GREATER	37.3% LESS
15-COMP. AT C7-T1	2304	1662	1.387	0.721	38.7% GREATER	27.9% LESS	-515	-260	1.978	0.506	97.8% GREATER	49.4% LESS
16-COND. TOTAL TORQ	578	501	1.155	0.866	15.5% GREATER	13.4% LESS	-761	-488	1.559	0.642	55.9% GREATER	35.8% LESS
17-C7-T1 TOTAL TORQ	854	639	1.335	0.749	33.5% GREATER	25.1% LESS	-220	-68	3.221	0.310	222.1% GREATER	69.0% LESS
HIC	1266	579	2.187	0.457	118.7% GREATER	54.3% LESS						
HEAD 3-MSEC AVG.	131	96	1.365	0.733	36.5% GREATER	26.7% LESS						
CHEST 3-MSEC AVG	23	14	1.643	0.609	64.3% GREATER	39.1% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 58

CCMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= HR10H5.1F AND B= HR10H1.1F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	172	191	0.901	1.110	9.9% LESS	11.0% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
2-HEAD ANG. VELOC.	2371	2438	0.973	1.028	2.7% LESS	2.8% GREATER	-4	-5	0.804	1.244	19.6% LESS	24.4% GREATE
3-HEAD ANG. ACCEL.	3231	2886	1.119	0.893	11.9% GREATER	10.7% LESS	-1533	-1672	0.917	1.091	8.3% LESS	9.1% GREATE
4-HEAD RES. ACCEL.	120	121	0.989	1.012	1.1% LESS	1.2% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
5-CONDYL STOP TORQ	239	460	0.520	1.922	48.0% LESS	92.2% GREATER	-464	-586	0.793	1.261	20.7% LESS	26.1% GREATE
6-C7-T1 STOP TORQ.	251	814	0.309	3.240	69.1% LESS	224.0% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
7-Z HEAD FORCE	54	61	0.874	1.144	12.6% LESS	14.4% GREATER	-197	-197	1.002	0.998	0.2% GREATER	0.2% LESS
8-X HEAD FORCE	1976	1974	1.001	0.999	0.1% GREATER	0.1% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
9-CONDYLES ANGLE	44	52	0.842	1.188	15.8% LESS	18.8% GREATER	-13	-18	0.706	1.417	29.4% LESS	41.7% GREATE
10-C7-T1 ANGLE	4	21	0.220	4.553	78.0% LESS	355.3% GREATER	-30	-30	1.000	1.000	0.0% LESS	0.0% GREATE
11-FORCE ALONG NECK	607	606	1.001	0.999	0.1% GREATER	0.1% LESS	-210	-390	0.537	1.861	46.3% LESS	86.1% GREATE
12-SHEAR AT CONDYLE	52	62	0.833	1.201	16.7% LESS	20.1% GREATER	-248	-200	1.240	0.807	24.0% GREATER	19.3% LESS
13-COMP. AT CONDYLE	639	639	1.001	0.999	0.1% GREATER	0.1% LESS	-180	-382	0.473	2.114	52.7% LESS	111.4% GREATE
14-SHEAR AT C7-T1	42	64	0.654	1.530	34.6% LESS	53.0% GREATER	-245	-183	1.338	0.747	33.8% GREATER	25.3% LESS
15-COMP. AT C7-T1	570	572	0.997	1.003	0.3% LESS	0.3% GREATER	-211	-375	0.564	1.774	43.6% LESS	77.4% GREATE
16-COND. TOTAL TORQ	435	512	0.850	1.177	15.0% LESS	17.7% GREATER	-641	-637	1.006	0.994	0.6% GREATER	0.6% LESS
17-C7-T1 TOTAL TORQ	874	960	0.910	1.099	9.0% LESS	9.9% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
HIC	564	574	0.983	1.018	1.7% LESS	1.8% GREATER						
HEAD 3-MSEC AVG.	116	117	0.991	1.009	0.9% LESS	0.9% GREATER						
CHEST 3-MSEC AVG	8	8	1.000	1.000	0.0% LESS	0.0% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 59

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= CR10H5.3 AND B= CR10H1.3

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	70	1.000	1.000	0.0% LESS	0.0% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
2-HEAD ANG. VELOC.	1526	1089	1.402	0.713	40.2% GREATER	28.7% LESS	-1282	-1657	0.774	1.293	22.6% LESS	29.3% GREATER
3-HEAD ANG. ACCEL.	1989	1848	1.076	0.929	7.6% GREATER	7.1% LESS	-790	-852	0.928	1.078	7.2% LESS	7.8% GREATER
4-HEAD RES. ACCEL.	16	16	0.992	1.019	1.8% LESS	1.9% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	3	21	0.156	6.394	84.4% LESS	539.4% GREATER	-626	-786	0.797	1.255	20.3% LESS	25.5% GREATER
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-869	-1448	0.601	1.665	39.9% LESS	66.5% GREATER
7-Z HEAD FORCE	347	361	0.962	1.040	3.8% LESS	4.0% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	1179	1174	1.004	0.996	0.4% GREATER	0.4% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	18	25	0.722	1.385	27.8% LESS	38.5% GREATER	-20	-24	0.818	1.223	18.2% LESS	22.3% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-66	-75	0.881	1.135	11.9% LESS	13.5% GREATER
11-FORCE ALONG NECK	35	66	0.528	1.895	47.2% LESS	89.5% GREATER	-173	-175	0.985	1.016	1.5% LESS	1.6% GREATER
12-SHEAR AT CONDYLE	182	194	0.937	1.067	6.3% LESS	6.7% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
13-COMP. AT CONDYLE	36	64	0.563	1.777	43.7% LESS	77.7% GREATER	-159	-160	0.997	1.003	0.3% LESS	0.3% GREATER
14-SHEAR AT C7-T1	181	180	1.007	0.993	0.7% GREATER	0.7% LESS	-5	0	0.0	0.0	0.0% GREATER	100.0% LESS
15-COMP. AT C7-T1	41	66	0.618	1.619	38.2% LESS	61.9% GREATER	-198	-203	0.976	1.025	2.4% LESS	2.5% GREATER
16-COND. TOTAL TORQ	62	45	1.380	0.725	38.0% GREATER	27.5% LESS	-812	-848	0.958	1.044	4.2% LESS	4.4% GREATER
17-C7-T1 TOTAL TORQ	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-1489	-1592	0.935	1.070	6.5% LESS	7.0% GREATER
HIC	43	42	1.024	0.977	2.4% GREATER	2.3% LESS						
HEAD 3-MSEC AVG.	16	16	1.000	1.000	0.0% LESS	0.0% GREATER						
CHEST 3-MSEC AVG	14	14	1.000	1.000	0.0% LESS	0.0% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #60

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20H5.2F AND B= RH20V5.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	0	0.0	0.0	0.0% GREATER	100.0% LESS	-30	-207	0.147	6.787	85.3% LESS	578.7% GREAT
2-HEAD ANG. VELOC.	2875	2127	1.352	0.740	35.2% GREATER	26.0% LESS	-1781	-6620	0.269	3.717	73.1% LESS	271.7% GREAT
3-HEAD ANG. ACCEL.	4559	14170	0.322	3.108	67.8% LESS	210.8% GREATER	-1844	-8665	0.213	4.697	78.7% LESS	369.7% GREAT
4-HEAD RES. ACCEL.	133	182	0.729	1.371	27.1% LESS	37.1% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
5-CONDYL STOP TORQ	347	279	1.246	0.803	24.6% GREATER	19.7% LESS	-551	-4460	0.124	8.090	87.6% LESS	709.0% GREAT
6-C7-T1 STOP TORQ.	186	0	0.0	0.0	0.0% GREATER	100.0% LESS	0	-7378	0.0	0.0	100.0% LESS	0.0% GREAT
7-Z HEAD FORCE	3139	3335	0.941	1.062	5.9% LESS	6.2% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
8-X HEAD FORCE	627	667	0.941	1.062	5.9% LESS	6.2% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
9-CONDYLES ANGLE	59	56	1.048	0.954	4.8% GREATER	4.6% LESS	-7	-46	0.157	6.370	84.3% LESS	537.0% GREAT
10-C7-T1 ANGLE	11	0	0.0	0.0	0.0% GREATER	100.0% LESS	-20	-97	0.205	4.875	79.5% LESS	387.5% GREAT
11-FORCE ALONG NECK	2371	3207	0.740	1.352	26.0% LESS	35.2% GREATER	-525	-747	0.704	1.421	29.6% LESS	42.1% GREAT
12-SHEAR AT CONDYLE	60	1826	0.033	29.984	96.7% LESS	*****% GREATER	-337	-492	0.686	1.458	31.4% LESS	45.8% GREAT
13-COMP. AT CONDYLE	2321	3192	0.727	1.375	27.3% LESS	37.5% GREATER	-458	-642	0.714	1.401	28.6% LESS	40.1% GREAT
14-SHEAR AT C7-T1	118	1904	0.062	16.046	93.8% LESS	*****% GREATER	-310	-608	0.510	1.961	49.0% LESS	96.1% GREAT
15-COMP. AT C7-T1	2304	3012	0.765	1.307	23.5% LESS	30.7% GREATER	-515	-532	0.968	1.033	3.2% LESS	3.3% GREAT
16-COND. TOTAL TORQ	578	560	1.034	0.968	3.4% GREATER	3.2% LESS	-761	-5001	0.152	6.569	84.8% LESS	556.9% GREAT
17-C7-T1 TOTAL TORQ	854	489	1.745	0.573	74.5% GREATER	42.7% LESS	-220	-8647	0.025	39.305	97.5% LESS	*****% GREAT
HIC	1266	4440	0.285	3.507	71.5% LESS	250.7% GREATER						
HEAD 3-MSEC AVG.	131	166	0.789	1.267	21.1% LESS	26.7% GREATER						
CHEST 3-MSEC AVG	23	34	0.676	1.478	32.4% LESS	47.8% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #61

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20H5.6F AND B= RNH20V5.6F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	46	0	0.0	0.0	0.0% GREATER	100.0% LESS	-30	-190	0.158	6.336	84.2% LESS	533.6% GREAT
2-HEAD ANG. VELOC.	8379	3013	2.781	0.360	178.1% GREATER	64.0% LESS	-3666	-6552	0.559	1.787	44.1% LESS	78.7% GREAT
3-HEAD ANG. ACCEL.	24337	29383	0.828	1.207	17.2% LESS	20.7% GREATER	-27463	-29179	0.941	1.062	5.9% LESS	6.2% GREAT
4-HEAD RES. ACCEL.	398	448	0.888	1.126	11.2% LESS	12.6% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
5-CONDYL STOP TORQ	4218	772	5.464	0.183	446.4% GREATER	81.7% LESS	-466	-3508	0.133	7.528	86.7% LESS	652.8% GREAT
6-C7-T1 STOP TORQ.	1058	0	*******	0.000	*****% GREATER	100.0% LESS	-527	-9140	0.058	17.327	94.2% LESS	*****% GREAT
7-Z HEAD FORCE	4827	4921	0.981	1.019	1.9% LESS	1.9% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
8-X HEAD FORCE	2896	2953	0.981	1.019	1.9% LESS	1.9% GREATER	0	-1847	0.0	0.0	100.0% LESS	0.0% GREAT
9-CONDYLES ANGLE	108	70	1.542	0.648	54.2% GREATER	35.2% LESS	-3	-41	0.077	13.000	92.3% LESS	*****% GREAT
10-C7-T1 ANGLE	36	0	0.0	0.0	0.0% GREATER	100.0% LESS	-46	-102	0.453	2.209	54.7% LESS	120.9% GREAT
11-FORCE ALONG NECK	4271	3318	1.287	0.777	28.7% GREATER	22.3% LESS	-1441	-934	1.542	0.648	54.2% GREATER	35.2% LESS
12-SHEAR AT CONDYLE	1283	2051	0.626	1.598	37.4% LESS	59.8% GREATER	-598	-255	2.343	0.427	134.3% GREATER	57.3% LESS
13-COMP. AT CONDYLE	4044	3312	1.221	0.819	22.1% GREATER	18.1% LESS	-1270	-939	1.352	0.740	35.2% GREATER	26.0% LESS
14-SHEAR AT C7-T1	1453	2468	0.589	1.698	41.1% LESS	69.8% GREATER	-662	-321	2.064	0.485	106.4% GREATER	51.5% LESS
15-COMP. AT C7-T1	4090	3153	1.297	0.771	29.7% GREATER	22.9% LESS	-1385	-735	1.885	0.530	88.5% GREATER	47.0% LESS
16-COND. TOTAL TORQ	4908	1229	3.994	0.250	299.4% GREATER	75.0% LESS	-751	-3983	0.189	5.299	81.1% LESS	429.9% GREAT
17-C7-T1 TOTAL TORQ	2418	818	2.956	0.338	195.6% GREATER	66.2% LESS	-1165	-10802	0.108	9.267	89.2% LESS	826.7% GREAT
HIC	7621	14009	0.544	1.838	45.6% LESS	83.8% GREATER						
HEAD 3-MSEC AVG.	324	349	0.928	1.077	7.2% LESS	7.7% GREATER						
CHEST 3-MSEC AVG	38	36	1.056	0.947	5.6% GREATER	5.3% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #62

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20H5.2F-3 AND B= RF20V5.2F-3

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	56	0	0.0	0.0	0.0% GREATER	100.0% LESS	-30	-190	0.161	6.195	83.9% LESS	519.5% GREAT
2-HEAD ANG. VELOC.	1970	537	3.666	0.273	266.6% GREATER	72.7% LESS	-973	-4926	0.198	5.060	80.2% LESS	406.0% GREAT
3-HEAD ANG. ACCEL.	2546	9844	0.259	3.866	74.1% LESS	286.6% GREATER	-1752	-5156	0.340	2.942	66.0% LESS	194.2% GREAT
4-HEAD RES. ACCEL.	97	145	0.671	1.490	32.9% LESS	49.0% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
5-CONDYL STOP TORQ	301	113	2.667	0.375	166.7% GREATER	62.5% LESS	-362	-3193	0.113	8.822	88.7% LESS	782.2% GREAT
6-C7-T1 STOP TORQ.	146	0	0.0	0.0	0.0% GREATER	100.0% LESS	0	-4243	0.0	0.0	100.0% LESS	0.0% GREAT
7-Z HEAD FORCE	2315	2374	0.975	1.026	2.5% LESS	2.6% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
8-X HEAD FORCE	463	475	0.975	1.026	2.5% LESS	2.6% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
9-CONDYLES ANGLE	56	46	1.218	0.821	21.8% GREATER	17.9% LESS	0	-39	0.0	0.0	100.0% LESS	0.0% GREAT
10-C7-T1 ANGLE	9	0	0.0	0.0	0.0% GREATER	100.0% LESS	-20	-85	0.234	4.270	76.6% LESS	327.0% GREAT
11-FORCE ALONG NECK	1716	2257	0.760	1.315	24.0% LESS	31.5% GREATER	-258	-338	0.762	1.312	23.8% LESS	31.2% GREAT
12-SHEAR AT CONDYLE	98	1048	0.085	11.803	91.5% LESS	*****% GREATER	-208	-474	0.439	2.280	56.1% LESS	128.0% GREAT
13-COMP. AT CONDYLE	1687	2245	0.752	1.331	24.8% LESS	33.1% GREATER	-219	-288	0.763	1.311	23.7% LESS	31.1% GREAT
14-SHEAR AT C7-T1	149	1127	0.132	7.556	86.8% LESS	655.6% GREATER	-194	-551	0.352	2.838	64.8% LESS	183.8% GREAT
15-COMP. AT C7-T1	1662	2140	0.777	1.288	22.3% LESS	28.8% GREATER	-260	-212	1.226	0.815	22.6% GREATER	18.5% LESS
16-COND. TOTAL TORQ	501	320	1.566	0.638	56.6% GREATER	36.2% LESS	-488	-3671	0.133	7.516	86.7% LESS	651.6% GREAT
17-C7-T1 TOTAL TORQ	639	0	0.0	0.0	0.0% GREATER	100.0% LESS	-68	-5271	0.013	77.186	98.7% LESS	*****% GREAT
HIC	579	1835	0.316	3.169	68.4% LESS	216.9% GREATER						
HEAD 3-MSEC AVG.	96	136	0.706	1.417	29.4% LESS	41.7% GREATER						
CHEST 3-MSEC AVG	14	23	0.609	1.643	39.1% LESS	64.3% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 63

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RNH20H5.6F-3 AND B= RNH20V5.6F-3

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LE THAN /A/
1-HEAD ANG. POSN.	36	0	0.0	0.0	0.0% GREATER	100.0% LESS	-30	-173	0.175	5.717	82.5% LESS	471.7% GREA
2-HEAD ANG. VELOC.	5893	2672	2.206	0.453	120.6% GREATER	54.7% LESS	-2931	-4509	0.650	1.539	35.0% LESS	53.9% GREA
3-HEAD ANG. ACCEL.	16813	19646	0.856	1.168	14.4% LESS	16.8% GREATER	-19118	-20770	0.920	1.086	8.0% LESS	8.6% GREA
4-HEAD RES. ACCEL.	292	340	0.859	1.165	14.1% LESS	16.5% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREA
5-CONDYL STOP TORQ	2107	132	15.919	0.063	*****% GREATER	93.7% LESS	-350	-1645	0.213	4.695	78.7% LESS	369.5% GREA
6-C7-T1 STOP TORQ.	561	0	*******	0.001	*****% GREATER	99.9% LESS	-434	-4533	0.096	10.441	90.4% LESS	944.1% GREA
7-Z HEAD FORCE	3529	3540	0.997	1.003	0.3% LESS	0.3% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREA
8-X HEAD FORCE	2117	2124	0.997	1.003	0.3% LESS	0.3% GREATER	0	-610	0.0	0.0	100.0% LESS	0.0% GREA
9-CONDYLES ANGLE	90	48	1.886	0.530	88.6% GREATER	47.0% LESS	0	-27	0.0	0.0	100.0% LESS	0.0% GREA
10-C7-T1 ANGLE	25	0	0.0	0.0	0.0% GREATER	100.0% LESS	-41	-86	0.476	2.102	52.4% LESS	110.2% GREA
11-FORCE ALONG NECK	3010	2290	1.315	0.761	31.5% GREATER	23.9% LESS	-845	-458	1.845	0.542	84.5% GREATER	45.8% LESS
12-SHEAR AT CONDYLE	699	1093	0.639	1.564	36.1% LESS	56.4% GREATER	-409	-98	4.149	0.241	314.9% GREATER	75.9% LESS
13-COMP. AT CONDYLE	2924	2290	1.277	0.783	27.7% GREATER	21.7% LESS	-740	-416	1.776	0.563	77.6% GREATER	43.7% LESS
14-SHEAR AT C7-T1	811	1272	0.637	1.569	36.3% LESS	56.9% GREATER	-445	-90	4.909	0.204	390.9% GREATER	79.6% LESS
15-COMP. AT C7-T1	2890	2187	1.321	0.757	32.1% GREATER	24.3% LESS	-823	-316	2.601	0.384	160.1% GREATER	61.6% LESS
16-COND. TOTAL TORQ	2651	433	6.119	0.163	511.9% GREATER	83.7% LESS	-557	-1999	0.279	3.585	72.1% LESS	258.5% GREA
17-C7-T1 TOTAL TORQ	1663	666	2.496	0.401	149.6% GREATER	59.9% LESS	-945	-5846	0.162	6.182	83.8% LESS	518.2% GREA
HIC	2686	4385	0.613	1.633	38.7% LESS	63.3% GREATER						
HEAD 3-MSEC AVG.	241	275	0.876	1.141	12.4% LESS	14.1% GREATER						
CHEST 3-MSEC AVG	26	21	1.238	0.808	23.8% GREATER	19.2% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #64

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20H5.2F AND B= RF20H5.1F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	75	0.940	1.064	6.0% LESS	6.4% GREATER	-30	-30	0.997	1.003	0.3% LESS	0.3% GREAT
2-HEAD ANG. VELOC.	2875	3080	0.933	1.071	6.7% LESS	7.1% GREATER	-1781	-1875	0.950	1.053	5.0% LESS	5.3% GREAT
3-HEAD ANG. ACCEL.	4559	5113	0.892	1.121	10.8% LESS	12.1% GREATER	-1844	-1961	0.941	1.063	5.9% LESS	6.3% GREAT
4-HEAD RES. ACCEL.	133	143	0.933	1.072	6.7% LESS	7.2% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
5-CONDYL STOP TORQ	347	393	0.884	1.131	11.6% LESS	13.1% GREATER	-551	-656	0.840	1.191	16.0% LESS	19.1% GREAT
6-C7-T1 STOP TORQ.	186	239	0.778	1.285	22.2% LESS	28.5% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
7-Z HEAD FORCE	3139	3091	1.015	0.985	1.5% GREATER	1.5% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
8-X HEAD FORCE	627	309	2.031	0.492	103.1% GREATER	50.8% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREAT
9-CONDYLES ANGLE	58	60	0.973	1.027	2.7% LESS	2.7% GREATER	-7	-11	0.652	1.534	34.8% LESS	53.4% GREAT
10-C7-T1 ANGLE	11	14	0.803	1.246	19.7% LESS	24.6% GREATER	-20	-20	1.000	1.000	0.0% LESS	0.0% GREAT
11-FORCE ALONG NECK	2371	1957	1.212	0.825	21.2% GREATER	17.5% LESS	-525	-467	1.124	0.889	12.4% GREATER	11.1% LESS
12-SHEAR AT CONDYLE	60	53	1.138	0.878	13.8% GREATER	12.2% LESS	-337	-387	0.872	1.147	12.8% LESS	14.7% GREAT
13-COMP. AT CONDYLE	2321	1947	1.192	0.839	19.2% GREATER	16.1% LESS	-458	-408	1.122	0.892	12.2% GREATER	10.9% LESS
14-SHEAR AT C7-T1	118	110	1.077	0.928	7.7% GREATER	7.2% LESS	-310	-363	0.854	1.171	14.6% LESS	17.1% GREAT
15-COMP. AT C7-T1	2304	1902	1.211	0.826	21.1% GREATER	17.4% LESS	-515	-448	1.149	0.870	14.9% GREATER	13.0% LESS
16-COND. TOTAL TORQ	578	636	0.910	1.099	9.0% LESS	9.9% GREATER	-761	-896	0.849	1.178	15.1% LESS	17.8% GREAT
17-C7-T1 TOTAL TORQ	854	1035	0.825	1.212	17.5% LESS	21.2% GREATER	-220	-207	1.062	0.942	6.2% GREATER	5.8% LESS
HIC	1266	1244	1.018	0.983	1.8% GREATER	1.7% LESS						
HEAD 3-MSEC AVG.	131	141	0.929	1.076	7.1% LESS	7.6% GREATER						
CHEST 3-MSEC AVG	23	24	0.958	1.043	4.2% LESS	4.3% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #65

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20H5.2F   AND B= RF20H5.3F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	66	1.070	0.935	7.0% GREATER	6.5% LESS	-30	-30	1.000	1.000	0.0% LESS	0.0% GREATI
2-HEAD ANG. VELOC.	2875	2613	1.100	0.909	10.0% GREATER	9.1% LESS	-1781	-1772	1.005	0.995	0.5% GREATER	0.5% LESS
3-HEAD ANG. ACCEL.	4559	3834	1.189	0.841	18.9% GREATER	15.9% LESS	-1844	-1837	1.004	0.996	0.4% GREATER	0.4% LESS
4-HEAD RES. ACCEL.	133	127	1.050	0.952	5.0% GREATER	4.8% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATI
5-CONDYL STOP TORQ	347	280	1.239	0.807	23.9% GREATER	19.3% LESS	-551	-443	1.242	0.805	24.2% GREATER	19.5% LESS
6-C7-T1 STOP TORQ.	186	137	1.356	0.737	35.6% GREATER	26.3% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATI
7-Z HEAD FORCE	3139	3187	0.985	1.015	1.5% LESS	1.5% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATI
8-X HEAD FORCE	627	956	0.657	1.523	34.3% LESS	52.3% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATI
9-CONDYLES ANGLE	58	56	1.048	0.954	4.8% GREATER	4.6% LESS	-7	-1	3.842	0.260	284.2% GREATER	74.0% LESS
10-C7-T1 ANGLE	11	8	1.357	0.737	35.7% GREATER	26.3% LESS	-20	-20	1.000	1.000	0.0% LESS	0.0% GREATE
11-FORCE ALONG NECK	2371	2888	0.821	1.218	17.9% LESS	21.8% GREATER	-525	-600	0.875	1.143	12.5% LESS	14.3% GREATI
12-SHEAR AT CONDYLE	60	61	0.984	1.016	1.6% LESS	1.6% GREATER	-337	-274	1.230	0.813	23.0% GREATER	18.7% LESS
13-COMP. AT CONDYLE	2321	2794	0.831	1.204	16.9% LESS	20.4% GREATER	-458	-520	0.880	1.137	12.0% LESS	13.7% GREATE
14-SHEAR AT C7-T1	118	123	0.964	1.037	3.6% LESS	3.7% GREATER	-310	-251	1.233	0.811	23.3% GREATER	18.9% LESS
15-COMP. AT C7-T1	2304	2803	0.822	1.216	17.8% LESS	21.6% GREATER	-515	-599	0.860	1.162	14.0% LESS	16.2% GREATI
16-COND. TOTAL TORQ	578	486	1.189	0.841	18.9% GREATER	15.9% LESS	-761	-612	1.244	0.804	24.4% GREATER	19.6% LESS
17-C7-T1 TOTAL TORQ	854	640	1.333	0.750	33.3% GREATER	25.0% LESS	-220	-253	0.870	1.150	13.0% LESS	15.0% GREATE
HIC	1266	1301	0.973	1.028	2.7% LESS	2.8% GREATER						
HEAD 3-MSEC AVG.	131	124	1.056	0.947	5.6% GREATER	5.3% LESS						
CHEST 3-MSEC AVG	23	23	1.000	1.000	0.0% LESS	0.0% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #66

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20H5.2F AND B= RH20H5.0F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	80	0.883	1.133	11.7% LESS	13.3% GREATER	-30	-30	0.997	1.003	0.3% LESS	0.3% GREATE
2-HEAD ANG. VELOC.	2875	3235	0.889	1.125	11.1% LESS	12.5% GREATER	-1781	-1802	0.988	1.012	1.2% LESS	1.2% GREATE
3-HEAD ANG. ACCEL.	4559	5522	0.826	1.211	17.4% LESS	21.1% GREATER	-1844	-1985	0.929	1.076	7.1% LESS	7.6% GREATE
4-HEAD RES. ACCEL.	133	154	0.864	1.157	13.6% LESS	15.7% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
5-CONDYL STOP TORQ	347	451	0.771	1.297	22.9% LESS	29.7% GREATER	-551	-746	0.739	1.353	26.1% LESS	35.3% GREATE
6-C7-T1 STOP TORQ.	186	308	0.602	1.660	39.8% LESS	66.0% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
7-Z HEAD FORCE	3139	3055	1.028	0.973	2.8% GREATER	2.7% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
8-X HEAD FORCE	627	0	0.0	0.0	0.0% GREATER	100.0% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATE
9-CONDYLES ANGLE	58	62	0.944	1.060	5.6% LESS	6.0% GREATER	-7	-13	0.533	1.877	46.7% LESS	87.7% GREATE
10-C7-T1 ANGLE	11	17	0.659	1.518	34.1% LESS	51.8% GREATER	-20	-20	1.000	1.000	0.0% LESS	0.0% GREATE
11-FORCE ALONG NECK	2371	1615	1.468	0.681	46.8% GREATER	31.9% LESS	-525	-439	1.195	0.836	19.5% GREATER	16.4% LESS
12-SHEAR AT CONDYLE	60	55	1.107	0.903	10.7% GREATER	9.7% LESS	-337	-426	0.793	1.261	20.7% LESS	26.1% GREATE
13-COMP. AT CONDYLE	2321	1632	1.422	0.703	42.2% GREATER	29.7% LESS	-458	-382	1.198	0.834	19.8% GREATER	16.6% LESS
14-SHEAR AT C7-T1	118	106	1.117	0.896	11.7% GREATER	10.4% LESS	-310	-404	0.766	1.305	23.4% LESS	30.5% GREATE
15-COMP. AT C7-T1	2304	1569	1.468	0.681	46.8% GREATER	31.9% LESS	-515	-413	1.246	0.803	24.6% GREATER	19.7% LESS
16-COND. TOTAL TORQ	578	713	0.811	1.233	18.9% LESS	23.3% GREATER	-761	-1006	0.757	1.322	24.3% LESS	32.2% GREATE
17-C7-T1 TOTAL TORQ	854	1178	0.724	1.380	27.6% LESS	38.0% GREATER	-220	-158	1.391	0.719	39.1% GREATER	28.1% LESS
HIC	1266	1336	0.948	1.055	5.2% LESS	5.5% GREATER						
HEAD 3-MSEC AVG.	131	151	0.868	1.153	13.2% LESS	15.3% GREATER						
CHEST 3-MSEC AVG	23	24	0.958	1.043	4.2% LESS	4.3% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON # 67

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B
A= RH20V5.2F AND B= RH20V5.4F

	(+) A	(+) B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-) A	(-) B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-207	-215	0.961	1.041	3.9% LESS	4.1% GREATER
2-HEAD ANG. VELOC.	2127	2541	0.837	1.195	16.3% LESS	19.5% GREATER	-6620	-6693	0.989	1.011	1.1% LESS	1.1% GREATER
3-HEAD ANG. ACCEL.	14170	11630	1.218	0.821	21.8% GREATER	17.9% LESS	-8665	-8082	1.072	0.933	7.2% GREATER	6.7% LESS
4-HEAD RES. ACCEL.	182	143	1.274	0.785	27.4% GREATER	21.5% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	279	242	1.152	0.868	15.2% GREATER	13.2% LESS	-4460	-3496	1.276	0.784	27.6% GREATER	21.6% LESS
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	100.0% LESS	0.0% GREATER	-7378	-5540	1.332	0.751	33.2% GREATER	24.9% LESS
7-Z HEAD FORCE	3335	3274	1.019	0.982	1.9% GREATER	1.8% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	667	1309	0.509	1.964	49.1% LESS	96.4% GREATER	0	-427	0.0	0.0	100.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	56	54	1.029	0.971	2.9% GREATER	2.9% LESS	-46	-41	1.118	0.895	11.8% GREATER	10.5% LESS
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-97	-91	1.071	0.933	7.1% GREATER	6.7% LESS
11-FORCE ALONG NECK	3207	2598	1.234	0.810	23.4% GREATER	19.0% LESS	-747	-657	1.138	0.879	13.8% GREATER	12.1% LESS
12-SHEAR AT CONDYLE	1826	1374	1.328	0.753	32.8% GREATER	24.7% LESS	-492	-137	3.571	0.280	257.1% GREATER	72.0% LESS
13-COMP. AT CONDYLE	3192	2625	1.216	0.822	21.6% GREATER	17.8% LESS	-642	-568	1.128	0.886	12.8% GREATER	11.4% LESS
14-SHEAR AT C7-T1	1904	1552	1.227	0.815	22.7% GREATER	18.5% LESS	-608	-273	2.223	0.450	122.3% GREATER	55.0% LESS
15-COMP. AT C7-T1	3012	2450	1.229	0.814	22.9% GREATER	18.6% LESS	-532	-540	0.986	1.015	1.4% LESS	1.5% GREATER
16-COND. TOTAL TORQ	560	510	1.096	0.912	9.6% GREATER	8.8% LESS	-5001	-3988	1.254	0.797	25.4% GREATER	20.3% LESS
17-C7-T1 TOTAL TORQ	489	808	0.605	1.653	39.5% LESS	65.3% GREATER	-8647	-6836	1.265	0.791	26.5% GREATER	20.9% LESS
HIC	4440	1992	2.229	0.449	122.9% GREATER	55.1% LESS						
HEAD 3-MSEC AVG.	166	128	1.297	0.771	29.7% GREATER	22.9% LESS						
CHEST 3-MSEC AVG	34	27	1.259	0.794	25.9% GREATER	20.6% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #68

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B
A= RH20V5.2F AND B= RH20V5.8F

	(+) A	(+) B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-) A	(-) B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-207	-220	0.940	1.063	6.0% LESS	6.3% GREATER
2-HEAD ANG. VELOC.	2127	2700	0.788	1.269	21.2% LESS	26.9% GREATER	-6620	-6651	0.995	1.005	0.5% LESS	0.5% GREATER
3-HEAD ANG. ACCEL.	14170	8114	1.746	0.573	74.6% GREATER	42.7% LESS	-8665	-7672	1.129	0.885	12.9% GREATER	11.5% LESS
4-HEAD RES. ACCEL.	182	208	0.876	1.142	12.4% LESS	14.2% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	279	223	1.252	0.799	25.2% GREATER	20.1% LESS	-4460	-2913	1.531	0.653	53.1% GREATER	34.7% LESS
6-C7-T1 STOP TORQ.	0	8	0.0	0.0	100.0% LESS	0.0% GREATER	-7378	-4502	1.639	0.610	63.9% GREATER	39.0% LESS
7-Z HEAD FORCE	3335	3176	1.050	0.952	5.0% GREATER	4.8% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	667	2514	0.265	3.770	73.5% LESS	277.0% GREATER	0	-298	0.0	0.0	100.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	56	53	1.049	0.954	4.9% GREATER	4.6% LESS	-46	-38	1.220	0.819	22.0% GREATER	18.1% LESS
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-97	-86	1.126	0.888	12.6% GREATER	11.2% LESS
11-FORCE ALONG NECK	3207	2047	1.566	0.638	56.6% GREATER	36.2% LESS	-747	-828	0.903	1.108	9.7% LESS	10.8% GREATER
12-SHEAR AT CONDYLE	1826	1285	1.420	0.704	42.0% GREATER	29.6% LESS	-492	-205	2.400	0.417	140.0% GREATER	58.3% LESS
13-COMP. AT CONDYLE	3192	2120	1.506	0.664	50.6% GREATER	33.6% LESS	-642	-837	0.767	1.304	23.3% LESS	30.4% GREATER
14-SHEAR AT C7-T1	1904	1430	1.332	0.751	33.2% GREATER	24.9% LESS	-608	-275	2.210	0.452	121.0% GREATER	54.8% LESS
15-COMP. AT C7-T1	3012	1914	1.574	0.636	57.4% GREATER	36.4% LESS	-532	-777	0.685	1.460	31.5% LESS	46.0% GREATER
16-COND. TOTAL TORQ	560	515	1.087	0.920	8.7% GREATER	8.0% LESS	-5001	-3376	1.481	0.675	48.1% GREATER	32.5% LESS
17-C7-T1 TOTAL TORQ	489	936	0.522	1.914	47.8% LESS	91.4% GREATER	-8647	-5938	1.456	0.687	45.6% GREATER	31.3% LESS
HIC	4440	2011	2.208	0.453	120.8% GREATER	54.7% LESS						
HEAD 3-MSEC AVG.	166	193	0.860	1.163	14.0% LESS	16.3% GREATER						
CHEST 3-MSEC AVG	34	22	1.545	0.647	54.5% GREATER	35.3% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #69

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B
A= RH20V5.2F AND B= RH20V5.2I2

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-207	-213	0.970	1.031	3.0% LESS	3.1% GREATER
2-HEAD ANG. VELOC.	2127	1831	1.161	0.861	16.1% GREATER	13.9% LESS	-6620	-4949	1.338	0.748	33.8% GREATER	25.2% LESS
3-HEAD ANG. ACCEL.	14170	10509	1.348	0.742	34.8% GREATER	25.8% LESS	-8665	-9275	0.934	1.070	6.6% LESS	7.0% GREATER
4-HEAD RES. ACCEL.	182	105	1.739	0.575	73.9% GREATER	42.5% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	279	68	4.107	0.243	310.7% GREATER	75.7% LESS	-4460	-3825	1.166	0.858	16.6% GREATER	14.2% LESS
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-7378	-7416	0.995	1.005	0.5% LESS	0.5% GREATER
7-Z HEAD FORCE	3335	3115	1.070	0.934	7.0% GREATER	6.6% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	667	623	1.070	0.934	7.0% GREATER	6.6% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	56	22	2.489	0.402	148.9% GREATER	59.8% LESS	-46	-63	0.735	1.361	26.5% LESS	36.1% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-97	-97	1.000	1.000	0.0% LESS	0.0% GREATER
11-FORCE ALONG NECK	3207	2753	1.165	0.859	16.5% GREATER	14.1% LESS	-747	-811	0.922	1.085	7.8% LESS	8.5% GREATER
12-SHEAR AT CONDYLE	1826	2002	0.912	1.097	8.8% LESS	9.7% GREATER	-492	-37	13.133	0.076	*****% GREATER	92.4% LESS
13-COMP. AT CONDYLE	3192	2703	1.181	0.847	18.1% GREATER	15.3% LESS	-642	-760	0.844	1.185	15.6% LESS	18.5% GREATER
14-SHEAR AT C7-T1	1904	1966	0.968	1.033	3.2% LESS	3.3% GREATER	-608	-56	10.820	0.092	982.0% GREATER	90.8% LESS
15-COMP. AT C7-T1	3012	2617	1.151	0.869	15.1% GREATER	13.1% LESS	-532	-663	0.803	1.246	19.7% LESS	24.6% GREATER
16-COND. TOTAL TORQ	560	359	1.558	0.642	55.8% GREATER	35.8% LESS	-5001	-4277	1.169	0.855	16.9% GREATER	14.5% LESS
17-C7-T1 TOTAL TORQ	489	389	1.258	0.795	25.8% GREATER	20.5% LESS	-8647	-8891	0.973	1.028	2.7% LESS	2.8% GREATER
HIC	4440	1175	3.779	0.265	277.9% GREATER	73.5% LESS						
HEAD 3-MSEC AVG.	166	102	1.627	0.614	62.7% GREATER	38.6% LESS						
CHEST 3-MSEC AVG	34	27	1.259	0.794	25.9% GREATER	20.6% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #70

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B
A= RH20H5.2F AND B= RFM20H5.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	70	74	0.955	1.047	4.5% LESS	4.7% GREATER	-30	-30	1.000	1.000	0.0% LESS	0.0% GREATER
2-HEAD ANG. VELOC.	2875	2888	0.995	1.005	0.5% LESS	0.5% GREATER	-1781	-1681	1.059	0.944	5.9% GREATER	5.6% LESS
3-HEAD ANG. ACCEL.	4559	4132	1.103	0.906	10.3% GREATER	9.4% LESS	-1844	-1744	1.057	0.946	5.7% GREATER	5.4% LESS
4-HEAD RES. ACCEL.	133	153	0.867	1.153	13.3% LESS	15.3% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	347	390	0.890	1.123	11.0% LESS	12.3% GREATER	-551	-539	1.022	0.979	2.2% GREATER	2.1% LESS
6-C7-T1 STOP TORQ.	186	207	0.897	1.115	10.3% LESS	11.5% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
7-Z HEAD FORCE	3139	2710	1.158	0.863	15.8% GREATER	13.7% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	627	542	1.158	0.863	15.8% GREATER	13.7% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	58	60	0.975	1.026	2.5% LESS	2.6% GREATER	-7	-6	1.074	0.932	7.4% GREATER	6.8% LESS
10-C7-T1 ANGLE	11	12	0.905	1.105	9.5% LESS	10.5% GREATER	-20	-20	1.000	1.000	0.0% LESS	0.0% GREATER
11-FORCE ALONG NECK	2371	2043	1.161	0.861	16.1% GREATER	13.9% LESS	-525	-385	1.366	0.732	36.6% GREATER	26.8% LESS
12-SHEAR AT CONDYLE	60	63	0.962	1.039	3.8% LESS	3.9% GREATER	-337	-327	1.032	0.969	3.2% GREATER	3.1% LESS
13-COMP. AT CONDYLE	2321	2022	1.148	0.871	14.8% GREATER	12.9% LESS	-458	-315	1.454	0.688	45.4% GREATER	31.2% LESS
14-SHEAR AT C7-T1	118	93	1.272	0.786	27.2% GREATER	21.4% LESS	-310	-313	0.991	1.009	0.9% LESS	0.9% GREATER
15-COMP. AT C7-T1	2304	1982	1.162	0.860	16.2% GREATER	14.0% LESS	-515	-374	1.377	0.726	37.7% GREATER	27.4% LESS
16-COND. TOTAL TORQ	578	645	0.896	1.116	10.4% LESS	11.6% GREATER	-761	-746	1.020	0.981	2.0% GREATER	1.9% LESS
17-C7-T1 TOTAL TORQ	854	903	0.946	1.057	5.4% LESS	5.7% GREATER	-220	-257	0.854	1.170	14.6% LESS	17.0% GREATER
HIC	1266	1523	0.831	1.203	16.9% LESS	20.3% GREATER						
HEAD 3-MSEC AVG.	131	151	0.868	1.153	13.2% LESS	15.3% GREATER						
CHEST 3-MSEC AVG	23	25	0.920	1.087	8.0% LESS	8.7% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #71

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20V5.2F AND B= PEM20V5.2F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-207	-211	0.981	1.019	1.9% LESS	1.9% GREATER
2-HEAD ANG. VELOC.	2127	3026	0.703	1.423	29.7% LESS	42.3% GREATER	-6620	-6914	0.958	1.044	4.2% LESS	4.4% GREATER
3-HEAD ANG. ACCEL.	14170	10721	1.322	0.757	32.2% GREATER	24.3% LESS	-8665	-8284	1.046	0.956	4.6% GREATER	4.4% LESS
4-HEAD RES. ACCEL.	182	214	0.853	1.172	14.7% LESS	17.2% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	279	421	0.662	1.510	33.8% LESS	51.0% GREATER	-4460	-4412	1.011	0.989	1.1% GREATER	1.1% LESS
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-7378	-7358	1.003	0.997	0.3% GREATER	0.3% LESS
7-Z HEAD FORCE	3335	3015	1.106	0.904	10.6% GREATER	9.6% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	667	603	1.106	0.904	10.6% GREATER	9.6% LESS	0	-13	0.0	0.0	100.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	56	61	0.914	1.095	8.6% LESS	9.5% GREATER	-46	-46	1.006	0.994	0.6% GREATER	0.6% LESS
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-97	-97	1.000	1.000	0.0% LESS	0.0% GREATER
11-FORCE ALONG NECK	3207	2893	1.108	0.902	10.8% GREATER	9.8% LESS	-747	-657	1.136	0.880	13.6% GREATER	12.0% LESS
12-SHEAR AT CONDYLE	1826	1766	1.034	0.967	3.4% GREATER	3.3% LESS	-492	-175	2.813	0.356	181.3% GREATER	64.4% LESS
13-COMP. AT CONDYLE	3192	2881	1.108	0.902	10.8% GREATER	9.8% LESS	-642	-577	1.112	0.900	11.2% GREATER	10.0% LESS
14-SHEAR AT C7-T1	1904	1879	1.013	0.987	1.3% GREATER	1.3% LESS	-608	-200	3.028	0.330	202.8% GREATER	67.0% LESS
15-COMP. AT C7-T1	3012	2729	1.104	0.906	10.4% GREATER	9.4% LESS	-532	-468	1.137	0.880	13.7% GREATER	12.0% LESS
16-COND. TOTAL TORQ	560	744	0.752	1.329	24.8% LESS	32.9% GREATER	-5001	-4944	1.011	0.989	1.1% GREATER	1.1% LESS
17-C7-T1 TOTAL TORQ	489	649	0.753	1.327	24.7% LESS	32.7% GREATER	-8647	-8598	1.006	0.994	0.6% GREATER	0.6% LESS
HIC	4440	3362	1.321	0.757	32.1% GREATER	24.3% LESS						
HEAD 3-MSEC AVG.	166	194	0.856	1.169	14.4% LESS	16.9% GREATER						
CHEST 3-MSEC AVG	34	30	1.133	0.882	13.3% GREATER	11.8% LESS						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

COMPARISON #72

COMPARISON BETWEEN PEAK MAGNITUDES FOR RUNS A AND B

A= RH20V5.2F AND B= RH20V5.0F

	(+)A	(+)B	A/B	B/A	A IS X% GREATER/LESS THAN B	B IS X% GREATER/LESS THAN A	(-)A	(-)B	A/B	B/A	/A/ IS X% GREATER/LESS THAN /B/	/B/ IS X% GREATER/LESS THAN /A/
1-HEAD ANG. POSN.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-207	-158	1.309	0.764	30.9% GREATER	23.6% LESS
2-HEAD ANG. VELOC.	2127	2467	0.862	1.160	13.8% LESS	16.0% GREATER	-6620	-5281	1.254	0.798	25.4% GREATER	20.2% LESS
3-HEAD ANG. ACCEL.	14170	16013	0.885	1.130	11.5% LESS	13.0% GREATER	-8665	-7197	1.204	0.831	20.4% GREATER	16.9% LESS
4-HEAD RES. ACCEL.	182	125	1.459	0.686	45.9% GREATER	31.4% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
5-CONDYL STOP TORQ	279	250	1.113	0.898	11.3% GREATER	10.2% LESS	-4460	-5650	0.789	1.267	21.1% LESS	26.7% GREATER
6-C7-T1 STOP TORQ.	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-7378	-4779	1.544	0.648	54.4% GREATER	35.2% LESS
7-Z HEAD FORCE	3335	3786	0.881	1.135	11.9% LESS	13.5% GREATER	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
8-X HEAD FORCE	667	0	0.0	0.0	0.0% GREATER	100.0% LESS	0	0	0.0	0.0	0.0% LESS	0.0% GREATER
9-CONDYLES ANGLE	56	54	1.022	0.979	2.2% GREATER	2.1% LESS	-46	-51	0.905	1.105	9.5% LESS	10.5% GREATER
10-C7-T1 ANGLE	0	0	0.0	0.0	0.0% LESS	0.0% GREATER	-97	-87	1.110	0.901	11.0% GREATER	9.9% LESS
11-FORCE ALONG NECK	3207	3920	0.818	1.222	18.2% LESS	22.2% GREATER	-747	-246	3.029	0.330	202.9% GREATER	67.0% LESS
12-SHEAR AT CONDYLE	1826	1453	1.256	0.796	25.6% GREATER	20.4% LESS	-492	-1096	0.449	2.226	55.1% LESS	122.6% GREATER
13-COMP. AT CONDYLE	3192	3876	0.824	1.214	17.6% LESS	21.4% GREATER	-642	-183	3.491	0.286	249.1% GREATER	71.4% LESS
14-SHEAR AT C7-T1	1904	1626	1.171	0.854	17.1% GREATER	14.6% LESS	-608	-1195	0.509	1.966	49.1% LESS	96.6% GREATER
15-COMP. AT C7-T1	3012	3701	0.814	1.229	18.6% LESS	22.9% GREATER	-532	-94	5.658	0.177	465.8% GREATER	82.3% LESS
16-COND. TOTAL TORQ	560	521	1.074	0.931	7.4% GREATER	6.9% LESS	-5001	-6230	0.803	1.246	19.7% LESS	24.6% GREATER
17-C7-T1 TOTAL TORQ	489	0	0.0	0.0	0.0% GREATER	100.0% LESS	-8647	-6347	1.362	0.734	36.2% GREATER	26.6% LESS
HIC	4440	2671	1.662	0.602	66.2% GREATER	39.8% LESS						
HEAD 3-MSEC AVG.	166	122	1.361	0.735	36.1% GREATER	26.5% LESS						
CHEST 3-MSEC AVG	34	41	0.829	1.206	17.1% LESS	20.6% GREATER						

NOTE: Positive neck torques are for extension and negative torques are for flexion.

APPENDIX D

(SUMMARY)

CALCOMP PLOTS OF

SIMULATION RESULTS

APPENDIX D (SUMMARY)

CALCOMP PLOTS OF SIMULATION RESULTS

Sixty-five computer simulations were made in this study. Dynamic responses for different impact situations were contrasted by tabular comparison of the peak magnitudes of seventeen response variables (Appendix C) and by Calcomp plots of the response variables. Since there are 1071 plots total -- 17 response variables for each of 63 comparisons between runs -- the unabridged Appendix D is not an integral part of this report.* Rather, only the plots for helmet/no-helmet comparisons for the four baseline impact configurations are included here. These four sets of plots are as follows:

Plot No.	Parameter Variation/Run Conditions
2	helmet vs. no helmet for head-truck baseline conditions
1	helmet vs. no helmet for chest-truck baseline conditions
4	helmet vs. no helmet for 30° road baseline conditions
18	helmet vs. no helmet for 70° road baseline conditions

Baseline conditions are described in Table 3-1 and the impact orientations for the four baselines are illustrated in Figures 3-1 through 3-4, all of which are included here. Also included here are Tables 5-6 and 5-7 from Section 5. Table 5-7 describes the seventeen dynamic response variables included in each set of plots. Table 5-6 lists and describes all plot- and tabular-comparisons made for pairs of simulations.

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* A copy of Appendix D may be obtained from the authors at the Highway Safety Research Institute, University of Michigan, Ann Arbor, Michigan 48103.

TABLE 3-1

BASIC RUN MATRIX

Cyclist Orientation	Impact Condition	Helmet/ No Helmet	Horizontal Velocity (mph)	Vertical Velocity (ft/sec)	% MT	Angular Velocity (deg/sec)	Coeff. of Friction	Condyles[1] Angle(deg)	C7-T1[1] Angle(deg)
Seated	Head w. Truck	no helmet	20	0	50	0	.3	+10	-30
		helmet	20	0	50	0	.1	+10	-30
Seated	Chest w. Truck	no helmet	20	0	50	0	.35	+10	-30
		helmet	20	0	50	0	.35	+10	-30
30° to Road	Head w. Road	no helmet	20	19.6[2]	50	100	.6	+20	-20
		helmet	20	19.6	50	100	.2	+20	-20
70° to Road	Head w. Road	no helmet	20	19.6	50	100	.6	+20	-20
		helmet	20	19.6	50	100	.2	+20	-20

(1) + for extension
- for flexion

(2) Corresponds to a fall height of 6 feet.

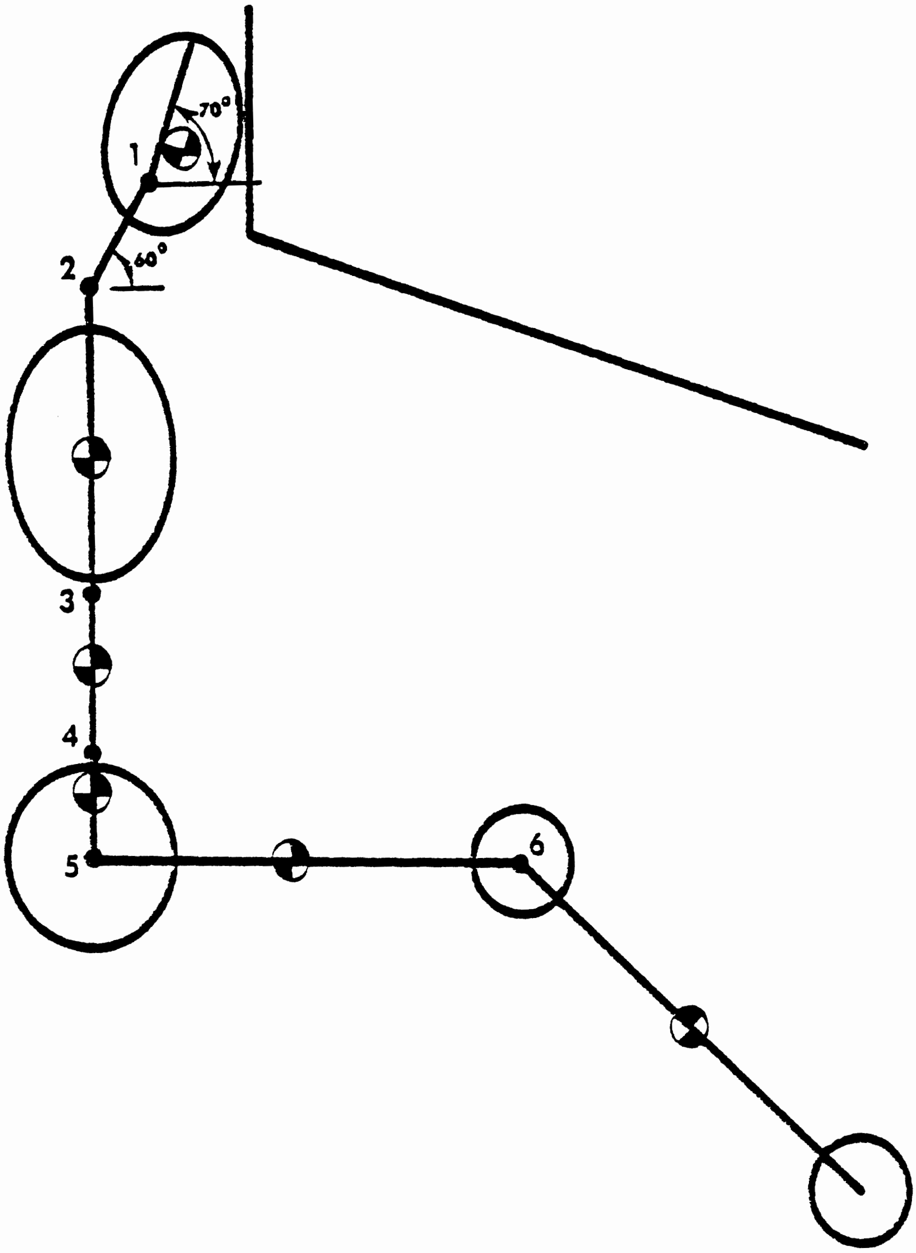


Figure 3-1. Basic Configuration for Head-Truck Impacts

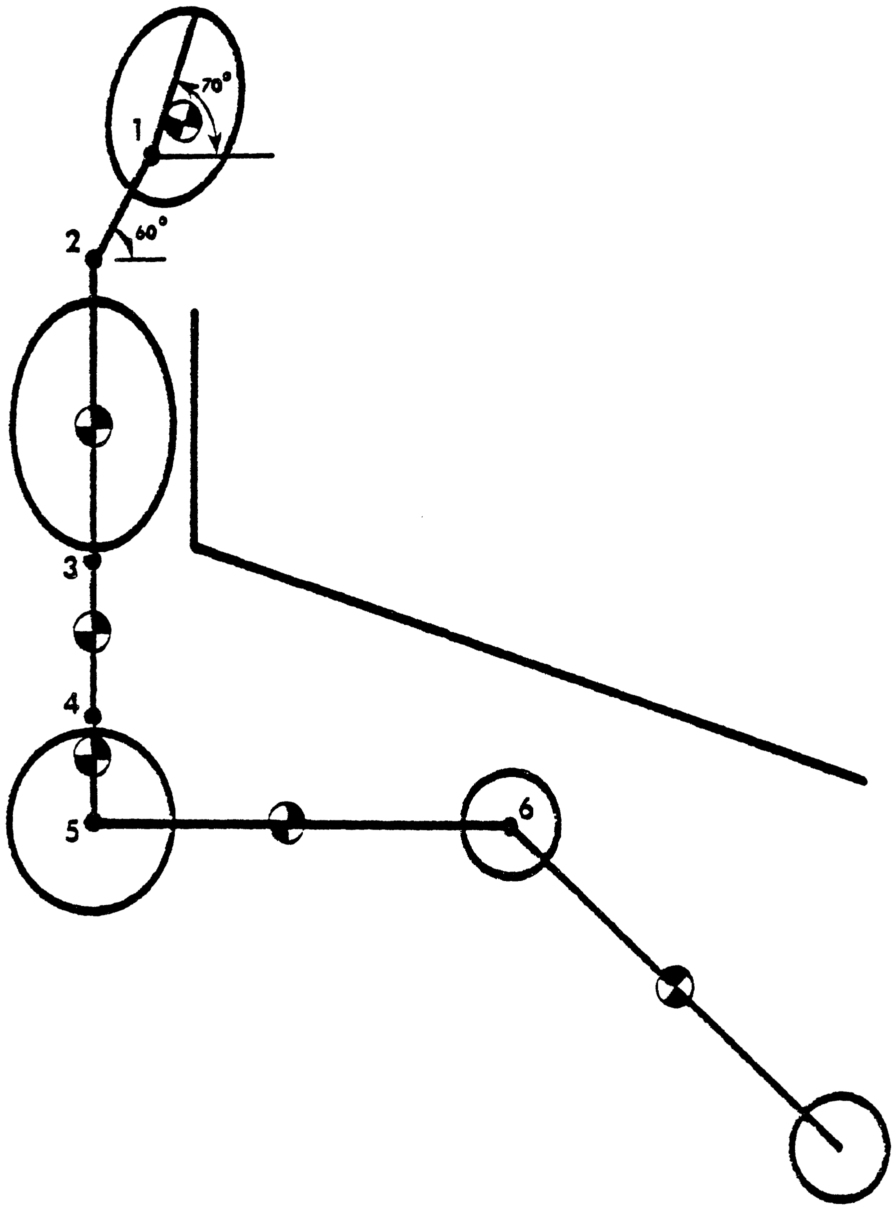


Figure 3-2. Basic Configuration for Chest-Truck Impacts

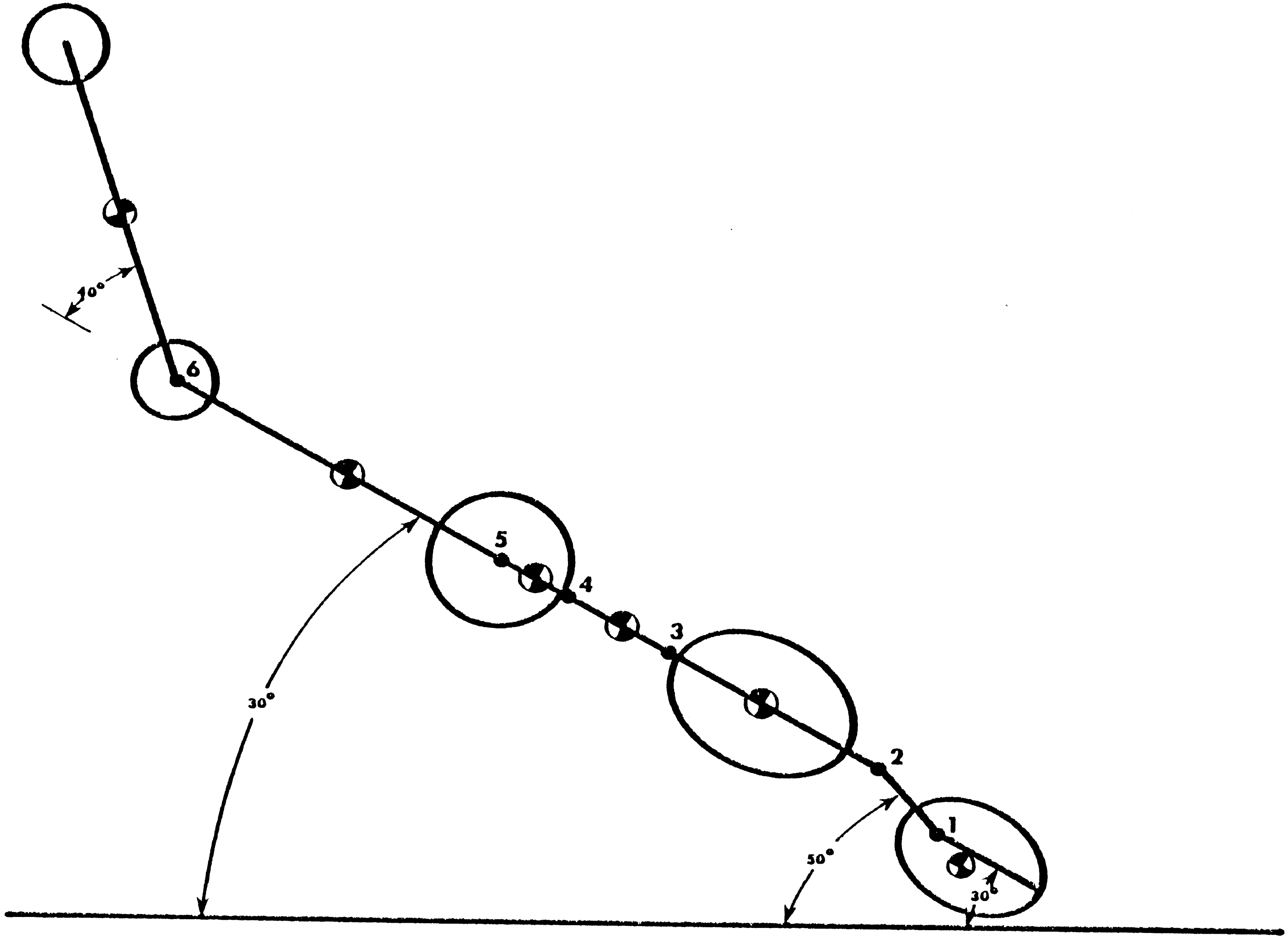


Figure 3-3. Basic Configuration for 30° Road Impacts

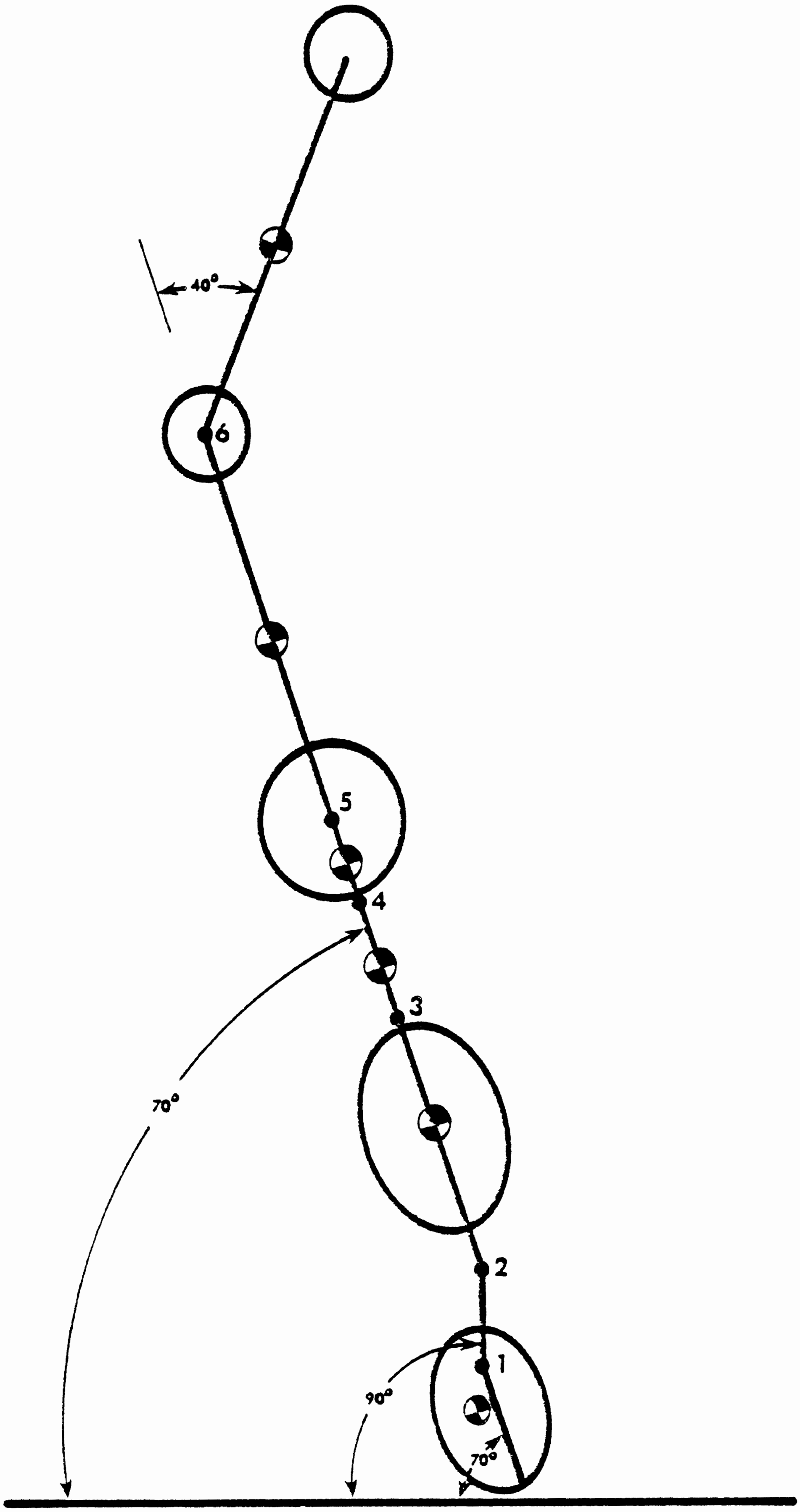


Figure 3-4. Basic Configuration for 70° Road Impacts

TABLE 5-7

DYNAMIC RESPONSE VARIABLES IN PLOTS AND COMPARISONS

No.	Variable (units)	Sign Convention
1	Head Angular Position (deg)	counterclockwise for increase
2	Head Angular Velocity (deg/sec)	counterclockwise if positive
3	Head Angular Acceleration (rad/sec^2)	counterclockwise if positive
4	Head Resultant Acceleration (g's)	magnitude at CG
5	Upper Neck Torque (w/o muscle)(in-lb)	positive for extension, negative for flexion
6	Lower Neck Torque (w/o muscle)(in-lb)	positive for extension, negative for flexion
7	Vertical Component of Head (Chest) Contact Force (lb)	friction force for truck, normal force for road
8	Horizontal Component of Head (Chest) Contact Force (lb)	friction force for road, normal force for truck
9	Condyles Joint Angle (deg)	positive for extension, negative for flexion
10	C7-T1 Joint Angle (deg)	positive for extension, negative for flexion
11	Force Along Neck (lb)	positive for compression, negative for elongation
12	Neck Shear Force at Condyles (lb)	positive forward, normal to neck line
13	Neck Compression Force at Condyles (lb)	positive toward torso, along neck line
14	Neck Shear Force at C7-T1 (lb)	positive rearward, normal to neck line
15	Neck Compression Force at C7-T1 (lb)	positive toward head, along neck line
16	Total Upper Neck Torque (includes muscle)(in-lb)	positive for extension, negative for flexion
17	Total Lower Neck Torque (includes muscle)(in-lb)	positive for extension, negative for flexion

NOTE: upper neck joint = condyles
lower neck joint = C7-T1

TABLE 5-6

PLOTS AND COMPARISONS (Page 1 of 4)

Plot or Comparison Number**	Comparison	Run Nos.	Parameter Variation/Run Conditions+
1*	CR20NH5.3	9	no helmet (chest-truck baseline)
	CR20H5.3	10	helmet (chest-truck baseline)
2*	HR20NH5.3F	1	no helmet (head-truck baseline)
	HR20H5.1F	2	helmet (head-truck baseline)
3	HR20NH5.3F	1	head-truck angle = 20° (no helmet)
	HR20NH5.3I2	3	head-truck angle = 40° (no helmet)
4*	RNH20H5.6F	20	no helmet (30° road baseline)
	RH20H5.2F	19	helmet (30° road baseline)
5	RNH20H5.2F	22	no helmet (CFNH = .2)
	RH20H5.2F	19	helmet (CFH = .2)
6	RNH20H5.6F	20	CFNH = .6 (no helmet)
	RNH20H5.2F	22	CFNH = .2 (no helmet)
7	RNH20H5.6F	20	no helmet (CFNH = .6)
	RH20H5.6F	21	helmet (CFH = .6)
8	RH20H5.2F	19	CFH = .2 (helmet)
	RH20H5.6F	21	CFH = .6 (helmet)
9	RH20H5.2F	19	100 deg/sec (helmet)
	RH20H5.2NR	33	0 deg/sec (helmet)
10	RNH20H5.6F	20	100 deg/sec (no helmet)
	RNH20H5.6NR	49	0 deg/sec (no helmet)
11-	- - - -		
12	RNH20H5.6NR	44	no helmet (0 deg/sec)
	RH20H5.2NR	33	helmet (0 deg/sec)
13	RH20H5.2F	19	head-road angle = 30° (helmet)
	RH20H5.2I2	29	head-road angle = 60° (helmet)
14	RNH20H5.6F	20	head-road angle = 30° (no helmet)
	RNH20H5.6I2	30	head-road angle = 60° (no helmet)
15	RNH20H5.6I2	30	no helmet (head-road angle = 60°)
	RH20H5.2I2	29	helmet (head-road angle = 60°)
16-	- - - -		
17	RNH20H5.6F	20	50% MT (no helmet)
	RNH20H1.6F	26	10% MT (no helmet)
18*	RNH20V5.6F	35	no helmet (70° road baseline)
	RH20V5.2F	34	helmet (70° road baseline)
19	RNH20V5.6F	35	CFNH = .6 (no helmet)
	RNH20V5.2F	37	CFNH = .2 (no helmet)

Plot or Comparison Number**	Comparison	Run Nos.	Parameter Variation/Run Conditions+
20	RH20V5.2F	34	CFH = .2 (helmet)
	RH20V5.6F	36	CFH = .6 (helmet)
21	RNH20V5.6F	35	no helmet (CFNH = .6)
	RH20V5.6F	36	helmet (CFH = .6)
22	RNH20V5.2F	37	no helmet (CFNH = .2)
	RH20V5.2F	34	helmet (CFH = .2)
23	RNH20V5.6F	35	head-road angle = 70° (no helmet)
	RNH20V5.6I2	45	head-road angle = 90° (no helmet)
24-	- - - -		
25	RNH20V5.6I2	45	no helmet (head-road angle = 90°)
	RH20V5.2I2	44	helmet (head-road angle = 90°)
26	RH20V5.2F	34	100 deg/sec (helmet)
	RH20V5.2NR	48	0 deg/sec (helmet)
27	RNH20V5.6F	35	50% MT (no helmet)
	RNH20V1.6F	41	10% MT (no helmet)
28	CR10NH5.3	12	no helmet (10 mph)
	CR10H5.3	11	helmet (10 mph)
29	HR10NH5.3F	5	no helmet (10 mph)
	HR10H5.1F	4	helmet (10 mph)
30	RNH10H5.6F	24	no helmet (10 mph)
	RH10H5.2F	23	helmet (10 mph)
31	RNH10V5.6F	39	no helmet (10 mph)
	RH10V5.2F	38	helmet (10 mph)
32	HR20H5.1F	2	20 mph (helmet)
	HR10H5.1F	4	10 mph (helmet)
33	CR20H5.3	10	20 mph (helmet)
	CR10H5.3	11	10 mph (helmet)
34	RH20H5.2F	19	20 mph (helmet)
	RH10H5.2F	23	10 mph (helmet)
35	RH20V5.2F	34	20 mph (helmet)
	RH10V5.2F	38	10 mph (helmet)
36	HR20NH1.3F	7	no helmet (10% MT)
	HR20H1.1F	6	helmet (10% MT)
37	CR20NH1.3	14	no helmet (10% MT)
	CR20H1.3	13	helmet (10% MT)
38	RNH20H1.6F	26	no helmet (10% MT)
	RH20H1.2F	25	helmet (10% MT)
39	RNH20V1.6F	41	no helmet (10% MT)
	RH20V1.2F	40	helmet (10% MT)

Plot or Comparison Number**	Comparison	Run Nos.	Parameter Variation/Run Conditions+
40	RH20H5.2F	19	CFH = .2 (helmet)
	RH20H5.10F	27	CFH = 1.0 (helmet)
41	RH20V5.2F	34	CFH = .2 (helmet)
	RH20V5.10F	42	CFH = 1.0 (helmet)
42	HR20H5.1F	2	helmet has helmet mass
	HR20HM5.1F	8	helmet has no mass
43	CR20NH5.3I2	16	no helmet (head-truck angle = 40°)
	CR20H5.3I2	15	helmet (head-truck angle = 40°)
44	CR20NH5.3I3	18	no helmet (head back 10°)
	CR20H5.3I3	17	helmet (head back 10°)
45	CR20H5.3	10	head forward 20° (helmet)
	CR20H5.3I2	15	head forward 40° (helmet)
46	CR20H5.3	10	head forward 20° (helmet)
	CR20H5.3I3	17	head back 10° (helmet)
47	RH20H5.2F	19	standard body mass (helmet, horizontal)
	RH20H5.2NM	31	body mass ≈ 0 (helmet, horizontal)
48	RH20V5.2F	34	standard body mass (helmet, vertical)
	RH20V5.2NM	46	body mass ≈ 0 (helmet, vertical)
49	RH20H5.2F	19	50% MT (helmet)
	RH20H1.2F	25	10% MT (helmet)
50	RH20V5.2F	34	50% MT (helmet)
	RH20V1.2F	40	10% MT (helmet)
51	HR20H5.1F	2	50% MT (helmet)
	HR20H1.1F	6	10% MT (helmet)
52	CR20H5.3	10	50% MT (helmet)
	CR20H1.3	13	10% MT (helmet)
53	CR20H5.3I2	15	head forward 40° (helmet)
	CR20H5.3I3	17	head back 10° (helmet)
54	RNH20V5.6F-3	50	no helmet (70° road, 3-ft drop)
	RH20V5.2F-3	51	helmet (70° road, 3-ft drop)
55	RH20V5.2F	34	6-ft drop (helmet, 70° road)
	RH20V5.2F-3	51	3-ft drop (helmet, 70° road)
56	RNH20H5.6F-3	52	no helmet (30° road, 3-ft drop)
	RH20H5.2F-3	53	helmet (30° road, 3-ft drop)
57	RH20H5.2F	19	6-ft drop (helmet, 30° road)
	RH20H5.2F-3	53	3-ft drop (helmet, 30° road)
58	HR10H5.1F	4	50% MT (10 mph)
	HR10H1.1F	54	10% (10 mph)
59	CR10H5.3	11	50% MT (10 mph)
	CR10H1.3	55	10% MT (10 mph)

Plot or Comparison Number**	Comparison	Run. Nos.	Parameter Variation/Run Conditions+
60	RH20H5.2F	19	30° road (helmet, 6-ft drop)
	RH20V5.2F	34	70° road (helmet, 6-ft drop)
61	RNH20H5.6F	20	30° road (no helmet, 6-ft drop)
	RNH20V5.6F	35	70° road (no helmet, 6-ft drop)
62	RH20H5.2F-3	53	30° road (helmet, 3-ft drop)
	RH20V5.2F-3	51	70° road (helmet, 3-ft drop)
63	RNH20H5.6F-3	52	30° road (no helmet, 3-ft drop)
	RNH20V5.6F-3	50	70° road (no helmet, 3-ft drop)
64#	RH20H5.2F	19	CFH = .2 (helmet, 30° road)
	RH20H5.1F	56	CFH = .1 (helmet, 30° road)
65#	RH20H5.2F	19	CFH = .2 (helmet, 30° road)
	RH20H5.3F	57	CFH = .3 (helmet, 30° road)
66#	RH20H5.2F	19	CFH = .2 (helmet, 30° road)
	RH20H5.0F	58	CFH = 0. (helmet, 30° road)
67#	RH20V5.2F	34	CFH = .2 (helmet, 70° road)
	RH20V5.4F	62	CFH = .4 (helmet, 70° road)
68#	RH20V5.2F	34	CFH = .2 (helmet, 70° road)
	RH20V5.8F	63	CFH = .8 (helmet, 70° road)
69	RH20V5.2F	34	head-road angle = 70° (helmet)
	RH20V5.2I2	44	head-road angle = 90° (helmet)
70	RH20H5.2F	19	helmet has helmet mass
	RHM20H5.2F	64	helmet has no mass
71	RH20V5.2F	34	helmet has helmet mass
	RHM20V5.2F	65	helmet has no mass
72#	RH20V5.2F	34	CFH = .2 (helmet, 70° road)
	RH20V5.0F	59	CFH = 0. (helmet, 70° road)

NOTES:

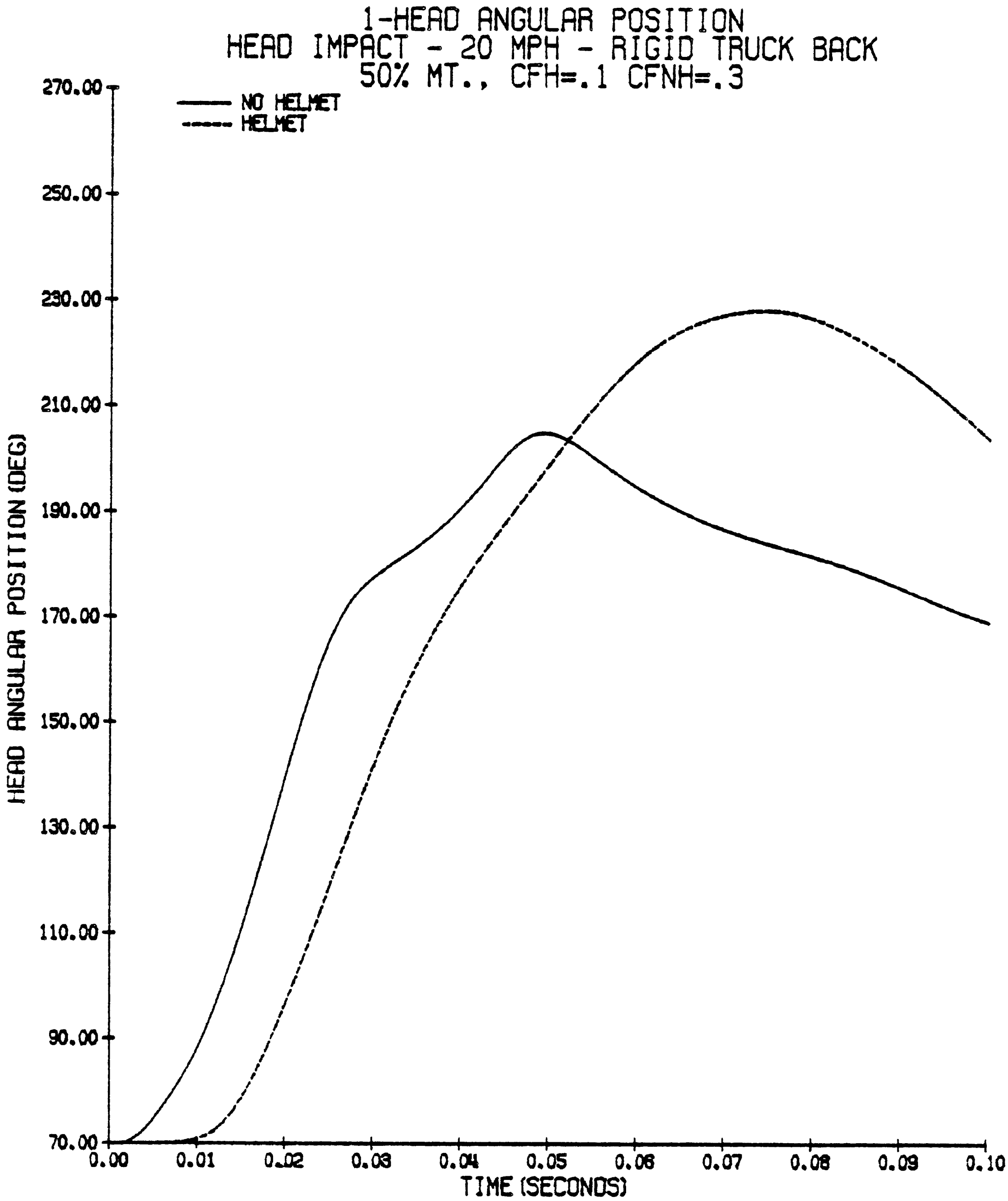
* Helmet/no helmet comparisons for the four baseline configurations of the basic run matrix are made in plots 1, 2, 4, and 18.

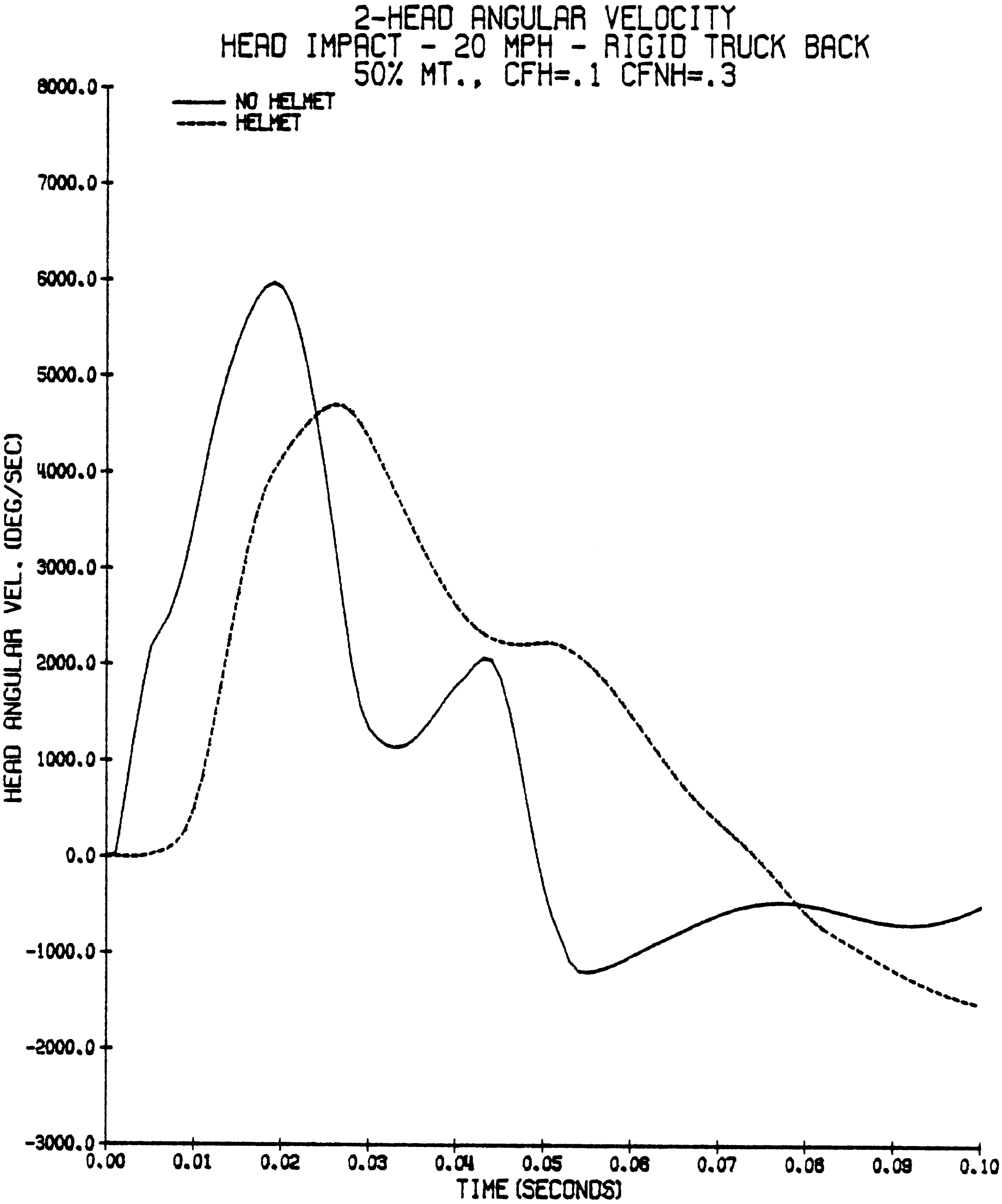
+ CFH = coefficient of friction for helmet, CFNH = coefficient of friction for no helmet ; MT = muscle tension.

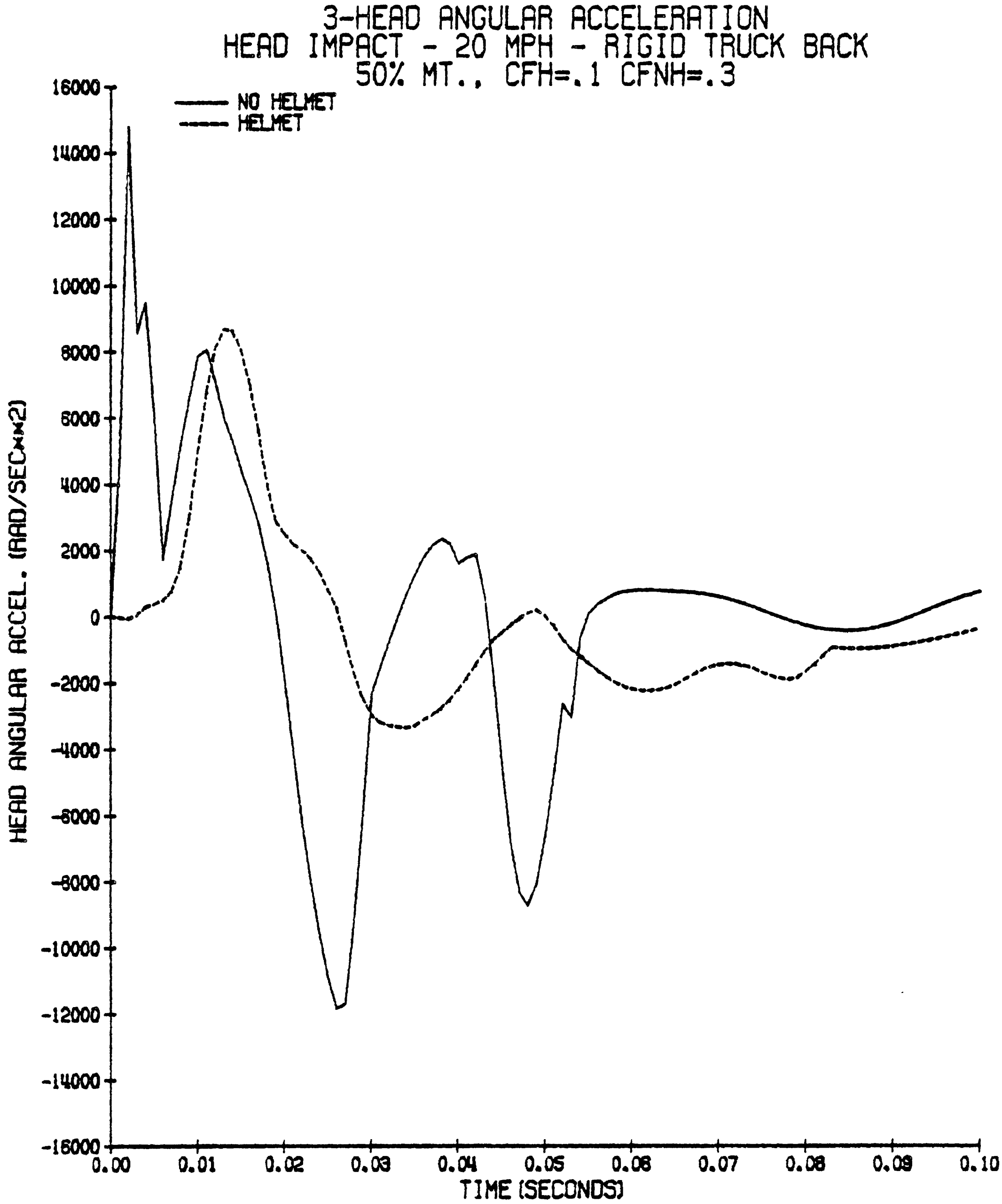
- Reference numbers 11, 16, and 24 were not used.

A-B tabulations for peak values were made for reference numbers 64 through 68 and 72, but there are no plots.

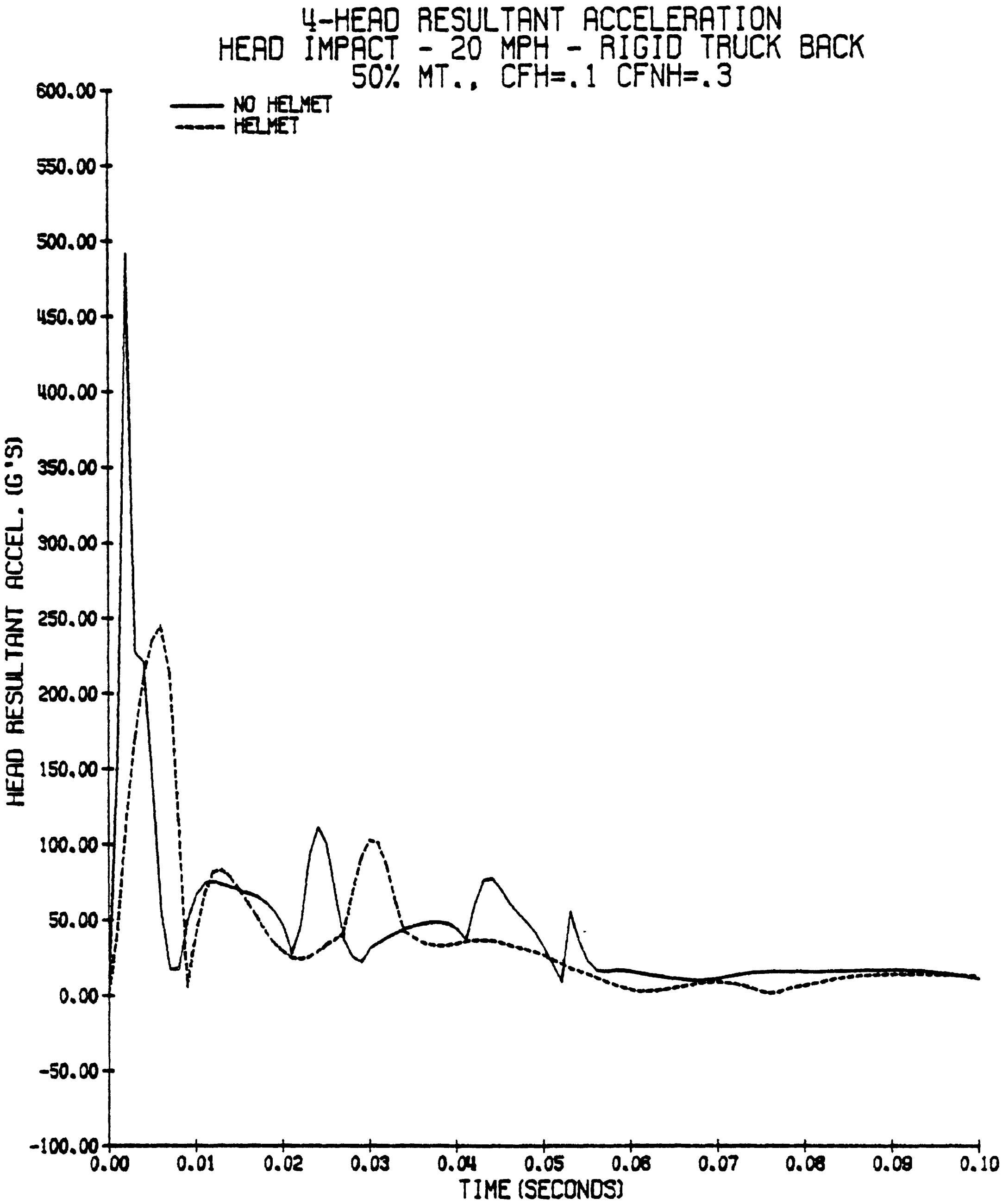
** Tabular comparisons (A-B tabulations) are found in Appendix C and plots are in Appendix D. Comparison/Plot numbers referenced in the text are bracketed [ ].

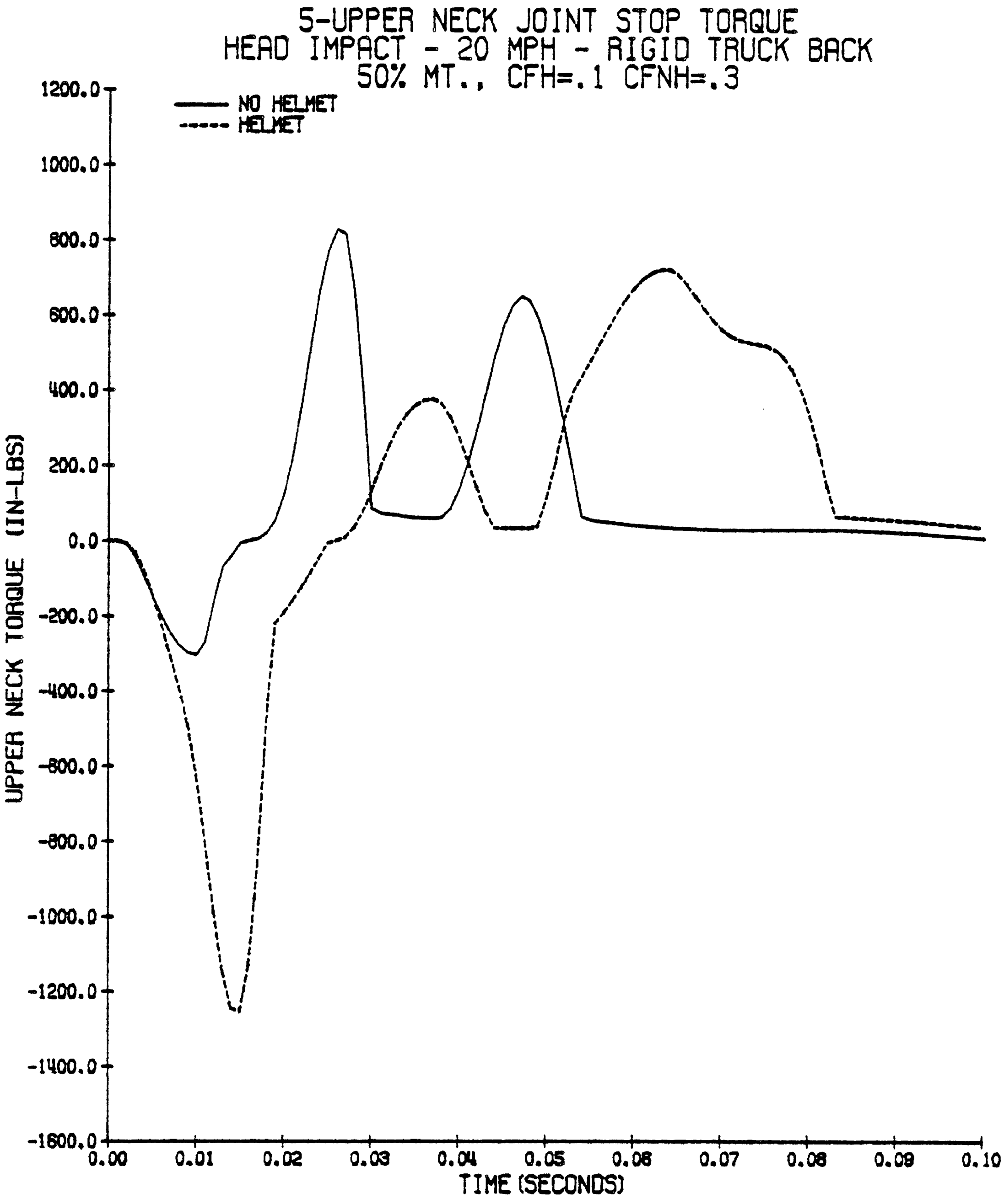

1-HEAD ANGULAR POSITION
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3
NO HELMET
HELMET
HEAD ANGULAR POSITION (DEG)
270.00
250.00
230.00
210.00
190.00
170.00
150.00
130.00
110.00
90.00
70.00
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

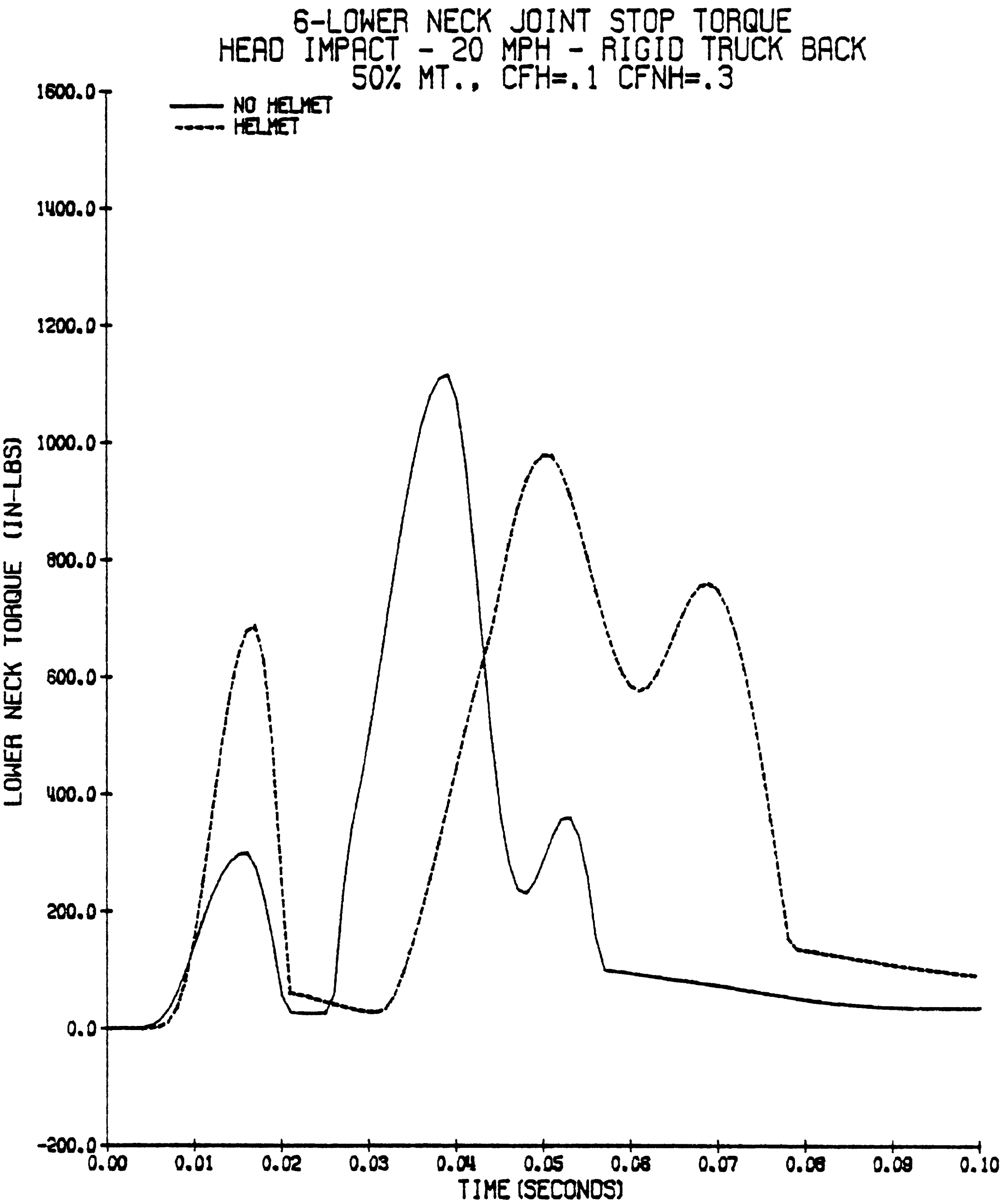

2-HEAD ANGULAR VELOCITY
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3
NO HELMET
HELMET
8000.0
7000.0
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
-1000.0
-2000.0
-3000.0
HEAD ANGULAR VEL. (DEG/SEC)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)



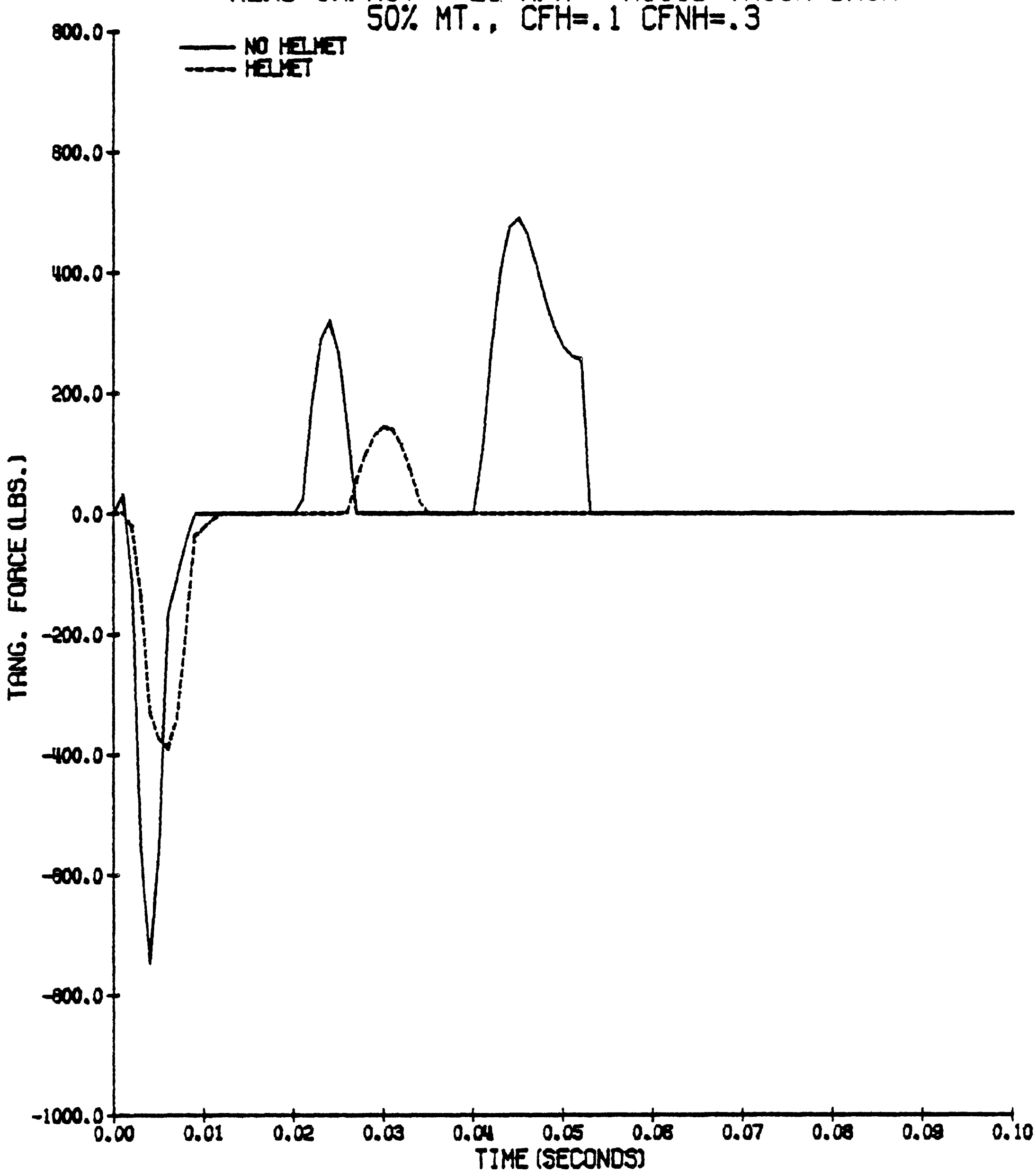
3-HEAD ANGULAR ACCELERATION
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3
NO HELMET
HELMET
HEAD ANGULAR ACCEL. (RAD/SEC**2)
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
-16000
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

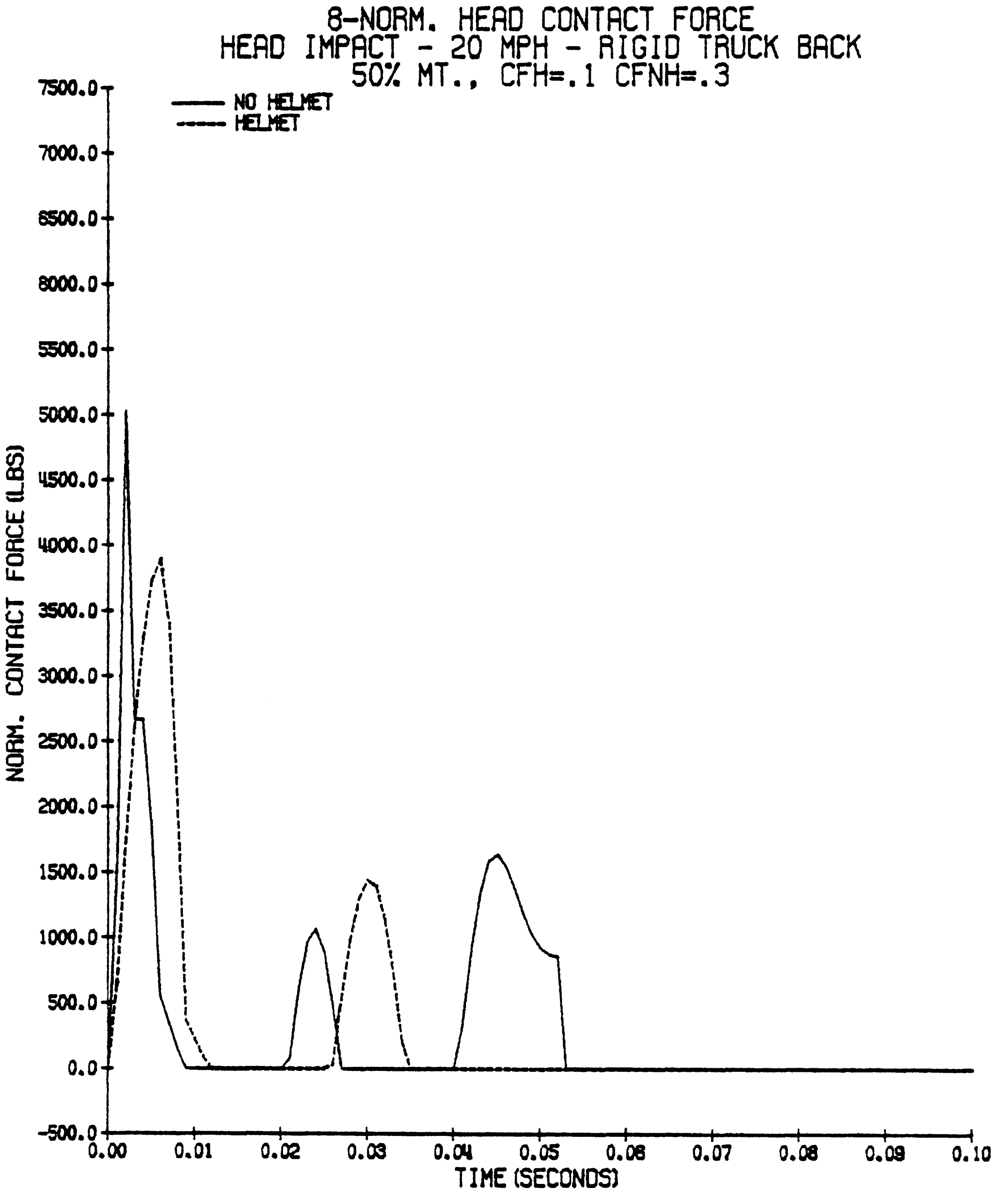

4-HEAD RESULTANT ACCELERATION
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3
NO HELMET
HELMET
HEAD RESULTANT ACCEL. (G'S)
600.00
550.00
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

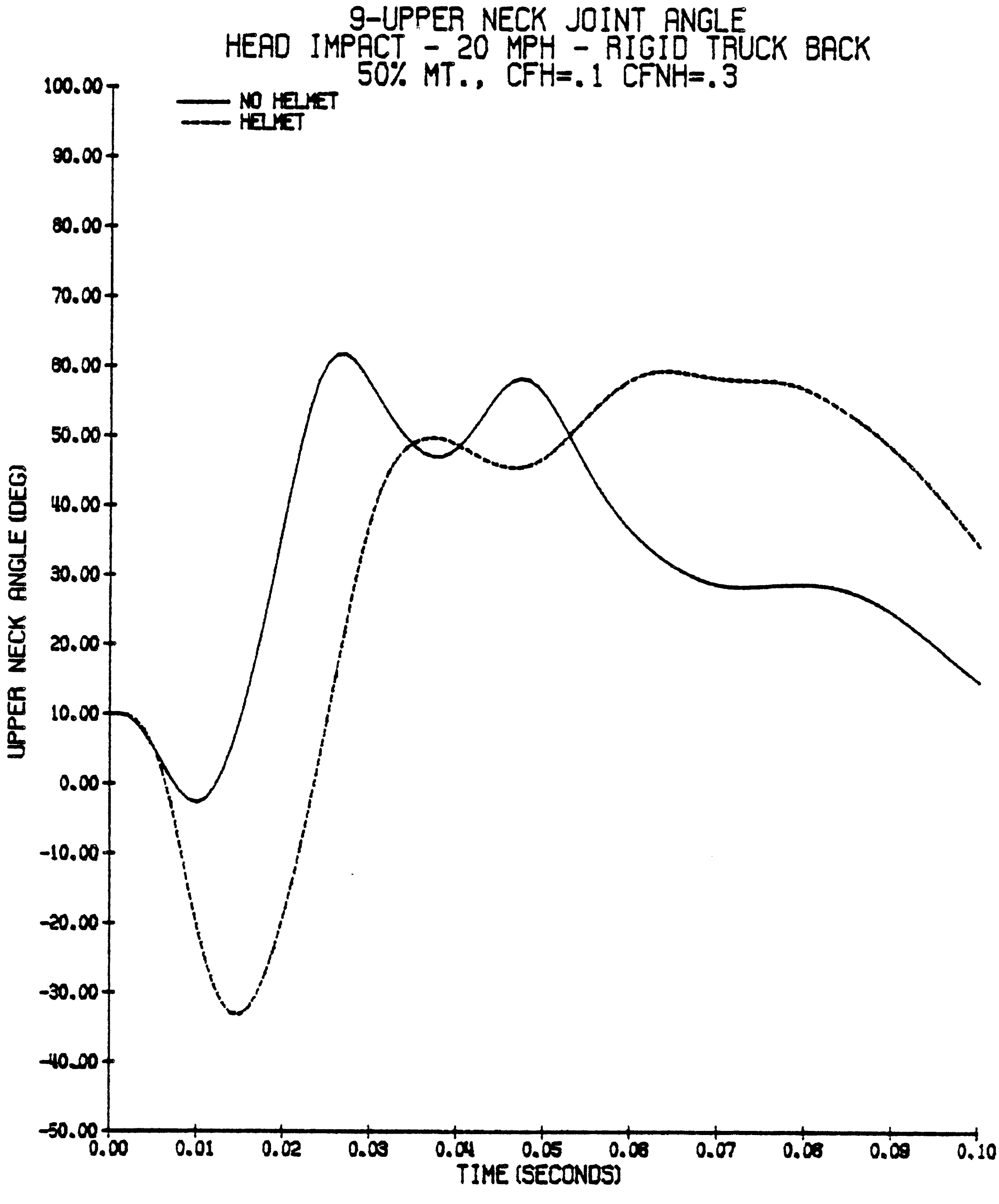

5-UPPER NECK JOINT STOP TORQUE
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3
NO HELMET
HELMET
UPPER NECK TORQUE (IN-LBS)
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
-200.0
-400.0
-600.0
-800.0
-1000.0
-1200.0
-1400.0
-1600.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

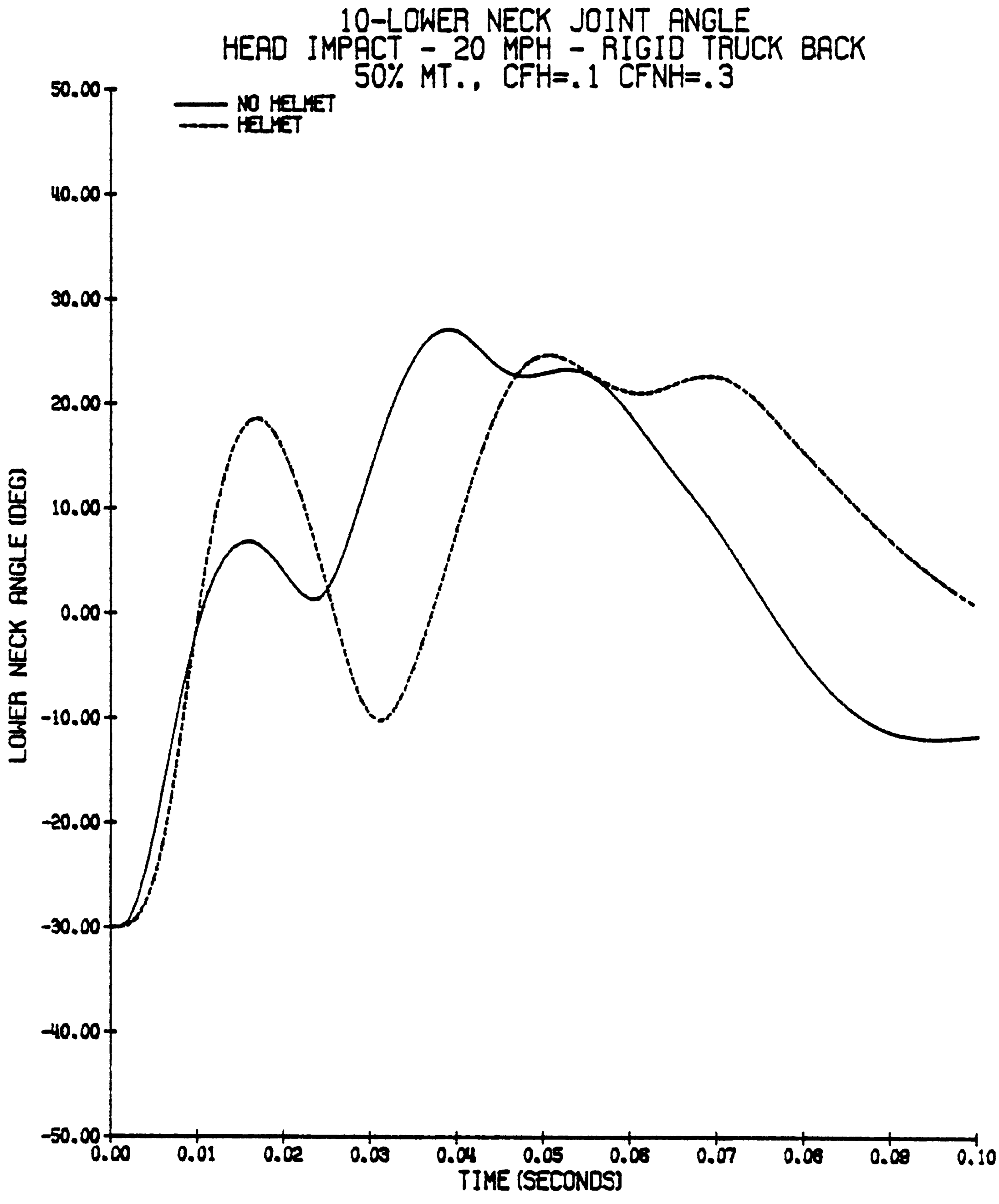

6-LOWER NECK JOINT STOP TORQUE
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3
NO HELMET
HELMET
LOWER NECK TORQUE (IN-LBS)
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
-200.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

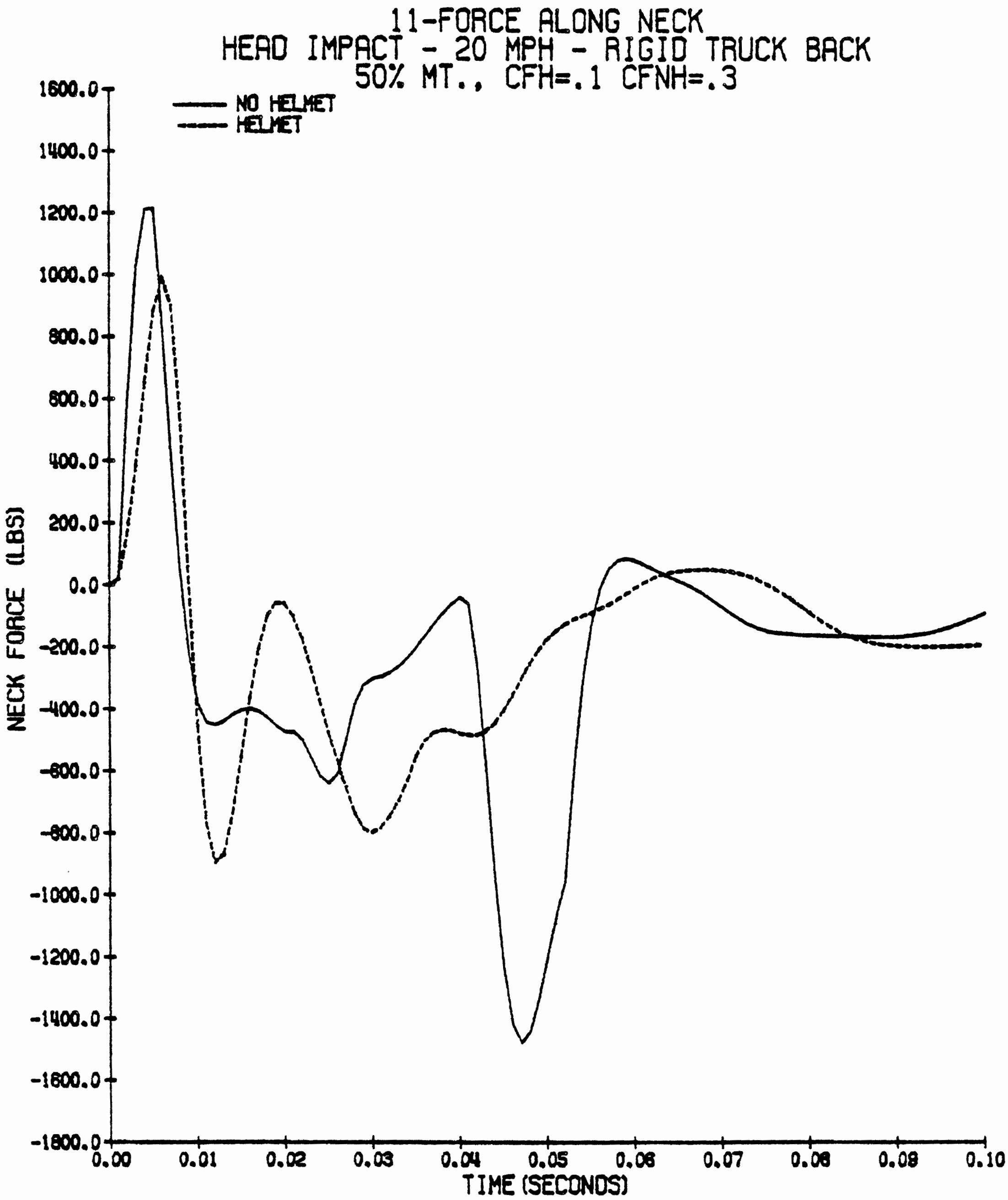
7-TANG. HEAD CONTACT FORCE
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3

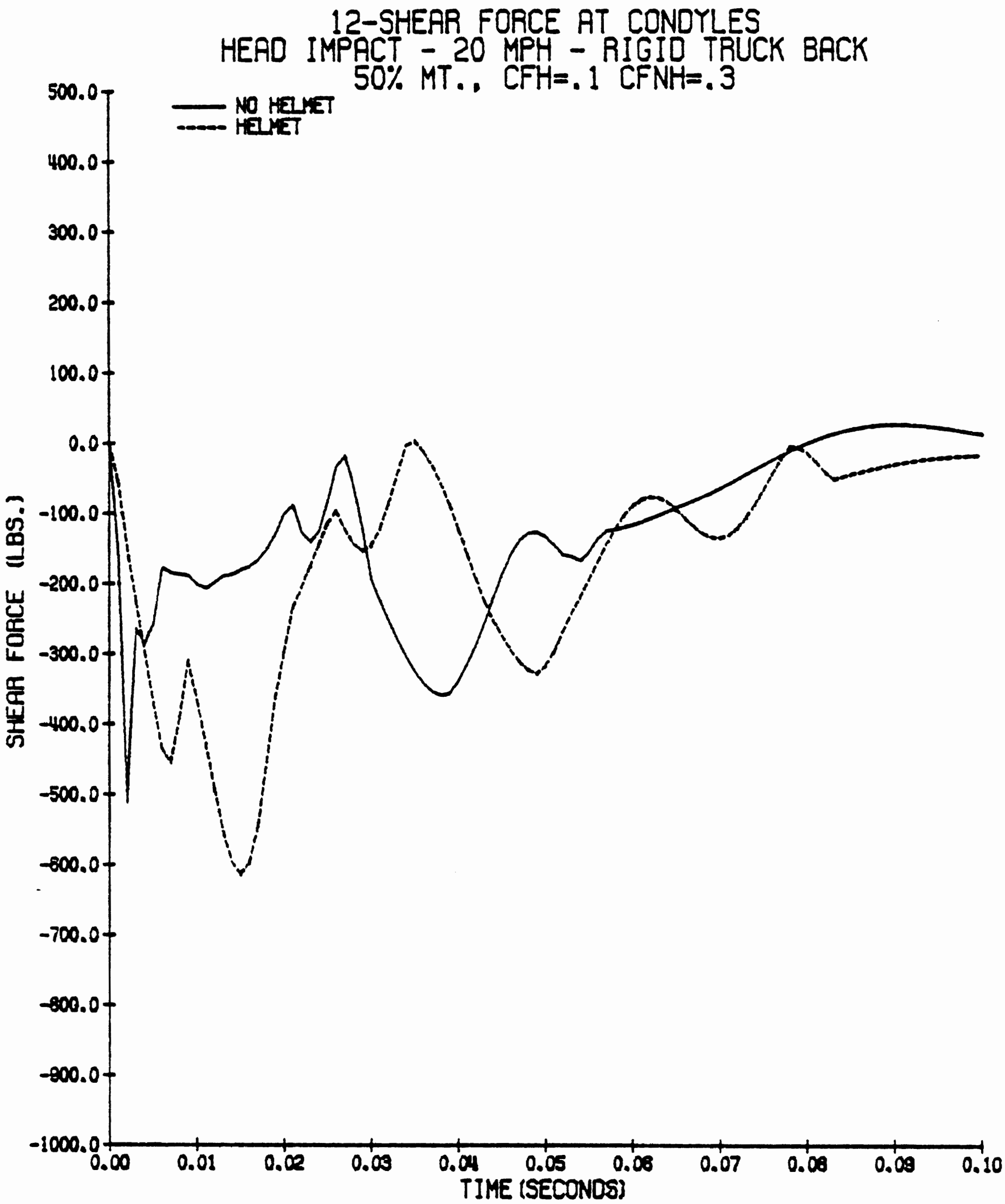


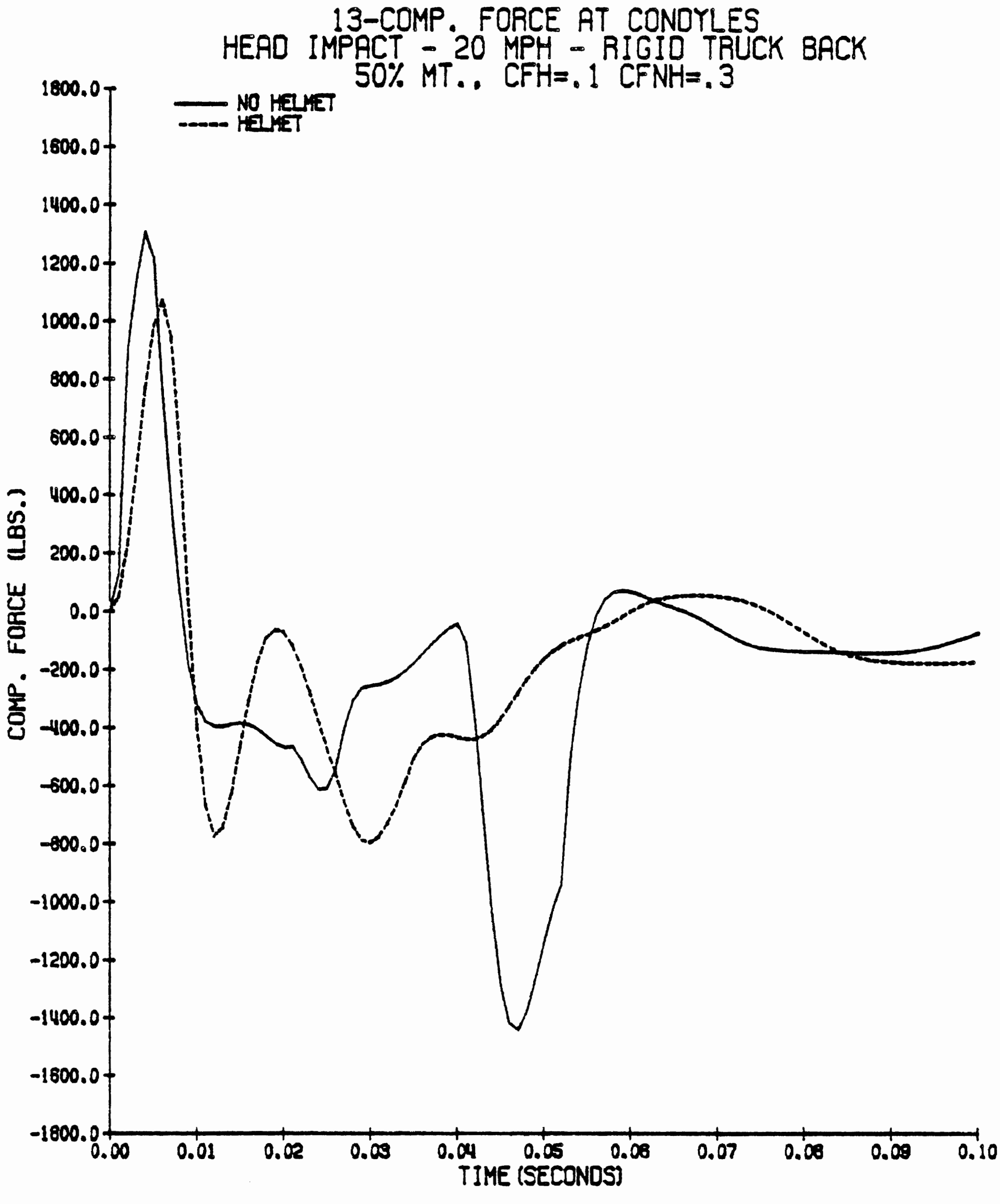

8-NORM. HEAD CONTACT FORCE
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3
NO HELMET
HELMET
NORM. CONTACT FORCE (LBS)
7500.0
7000.0
6500.0
6000.0
5500.0
5000.0
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
-500.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)


9-UPPER NECK JOINT ANGLE
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3
NO HELMET
HELMET
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
UPPER NECK ANGLE (DEG)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

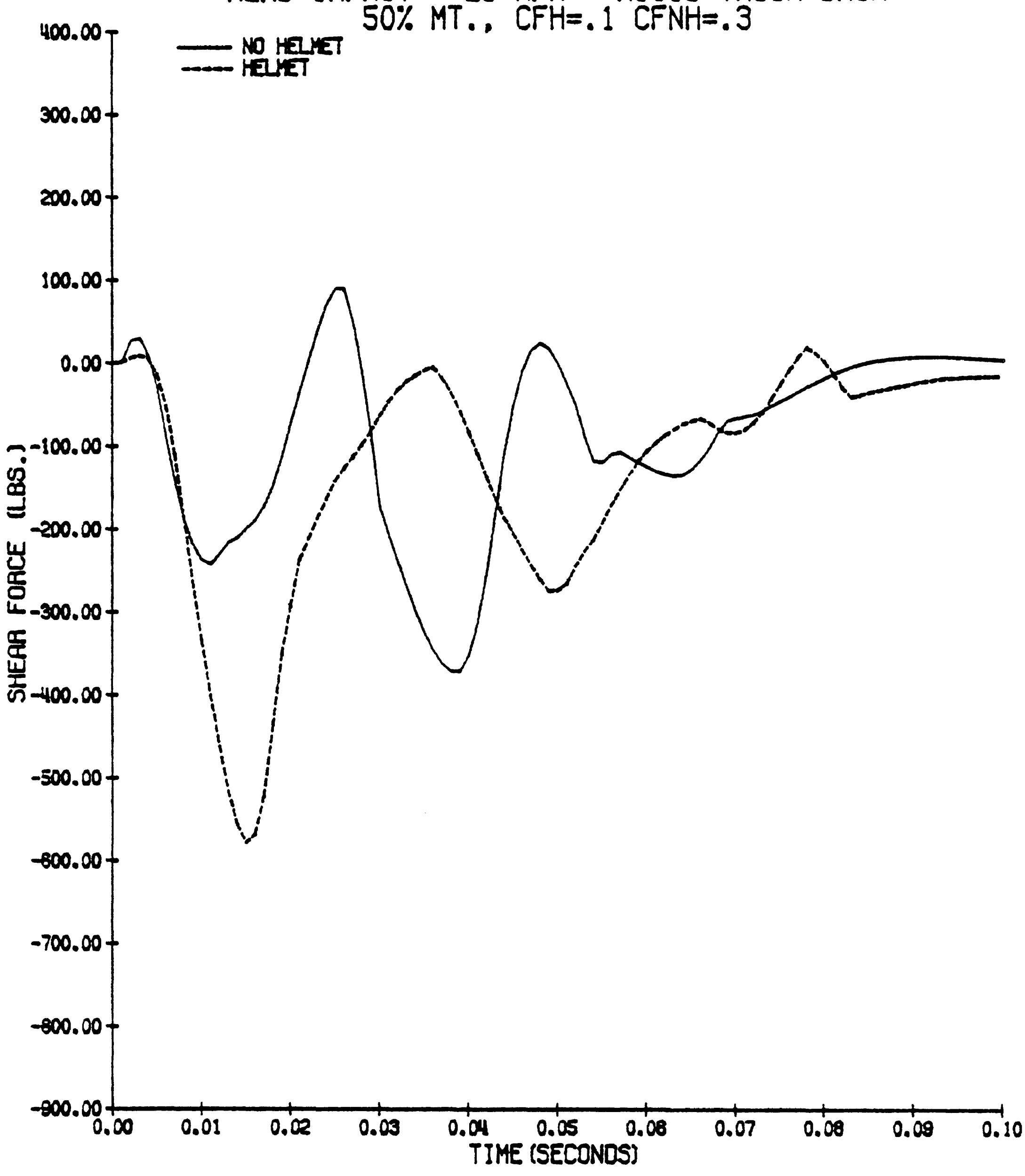

10-LOWER NECK JOINT ANGLE
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3
NO HELMET
HELMET
LOWER NECK ANGLE (DEG)
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

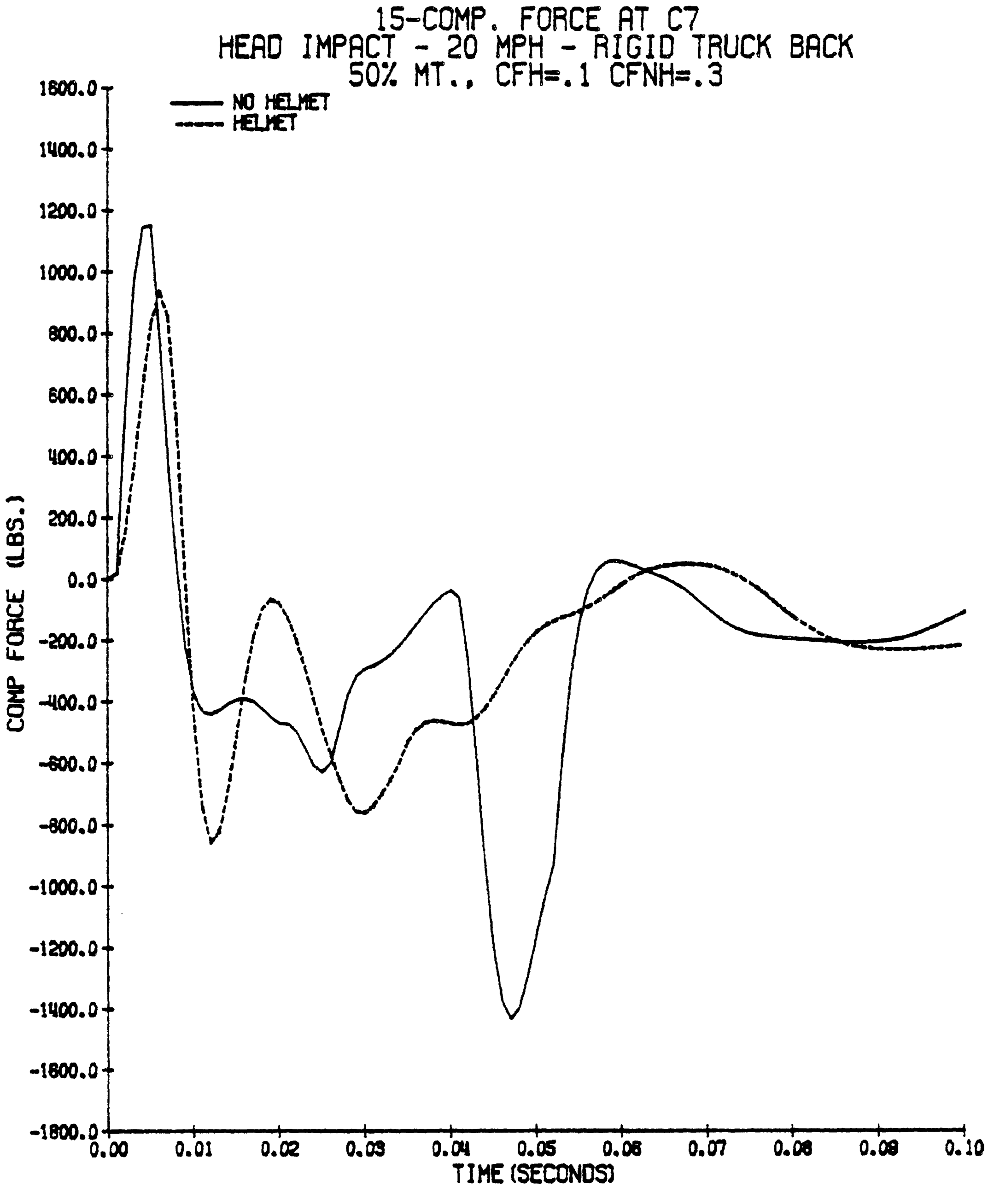

11-FORCE ALONG NECK
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3
NO HELMET
HELMET
NECK FORCE (LBS)
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
-200.0
-400.0
-600.0
-800.0
-1000.0
-1200.0
-1400.0
-1600.0
-1800.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

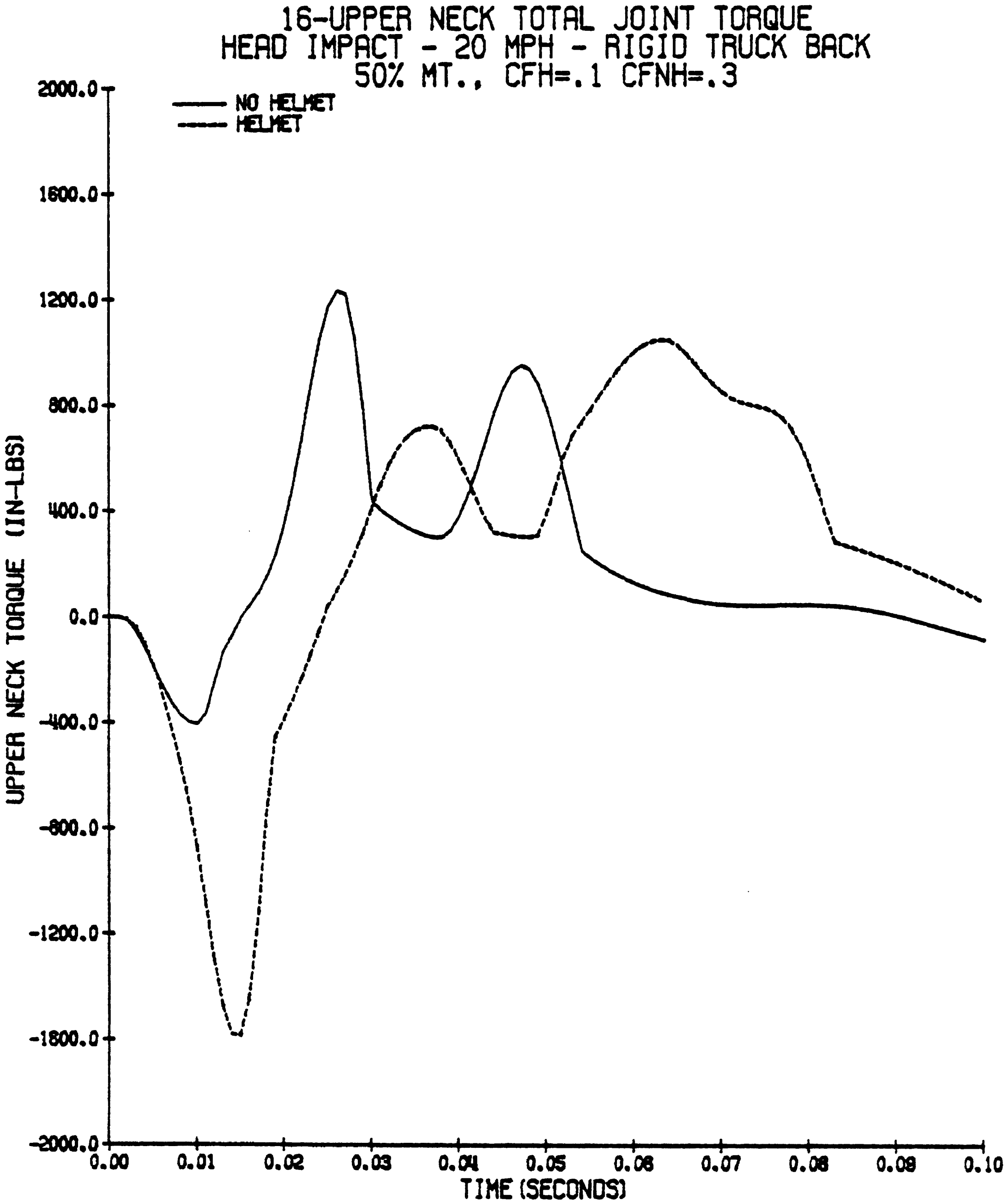

12-SHEAR FORCE AT CONDYLES
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3
NO HELMET
HELMET
SHEAR FORCE (LBS.)
500.0
400.0
300.0
200.0
100.0
0.0
-100.0
-200.0
-300.0
-400.0
-500.0
-600.0
-700.0
-800.0
-900.0
-1000.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)


13-COMP. FORCE AT CONDYLES
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3
NO HELMET
HELMET
1800.0
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
-200.0
-400.0
-600.0
-800.0
-1000.0
-1200.0
-1400.0
-1600.0
-1800.0
COMP. FORCE (LBS.)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

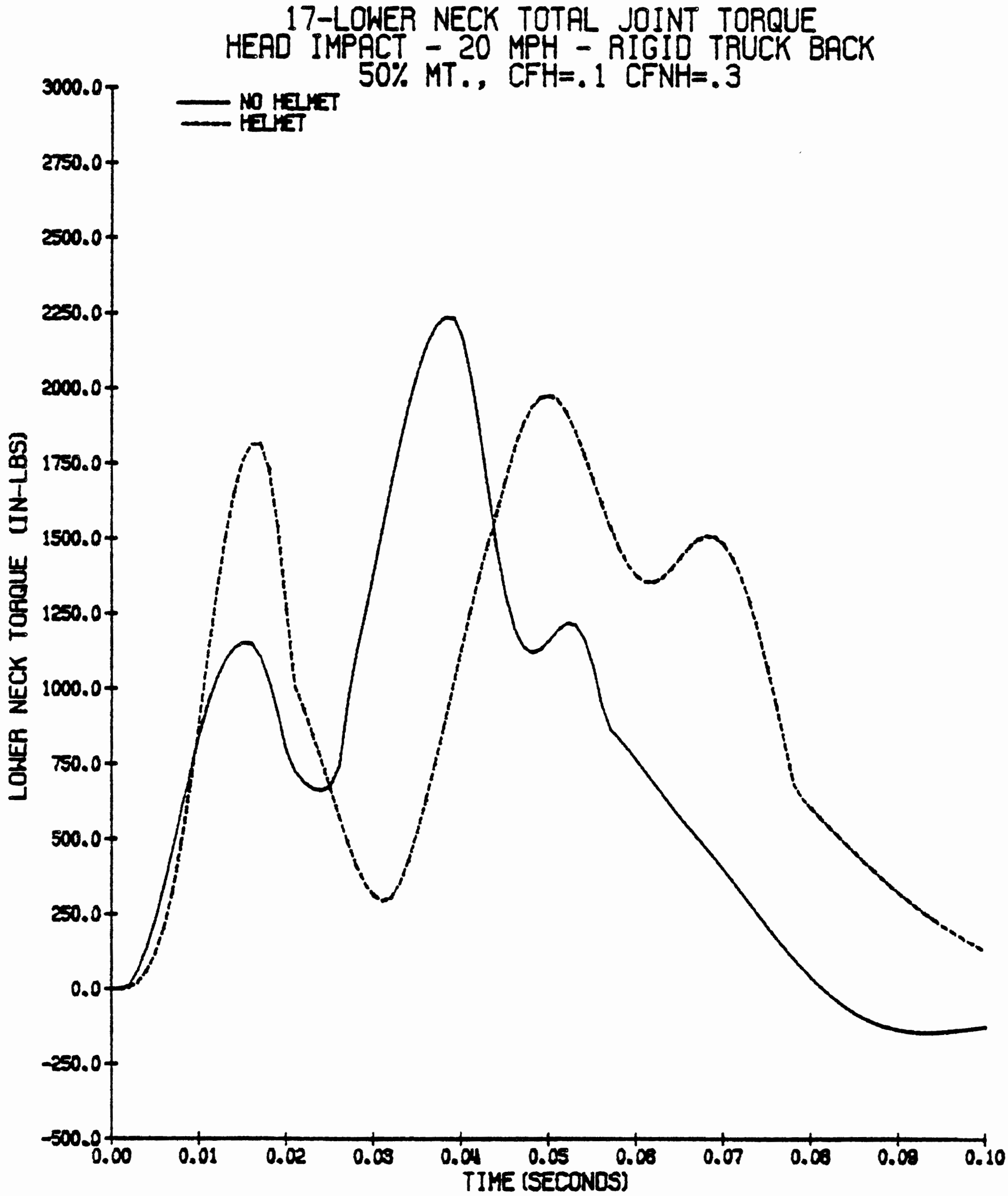
14-SHEAR FORCE AT C7
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3



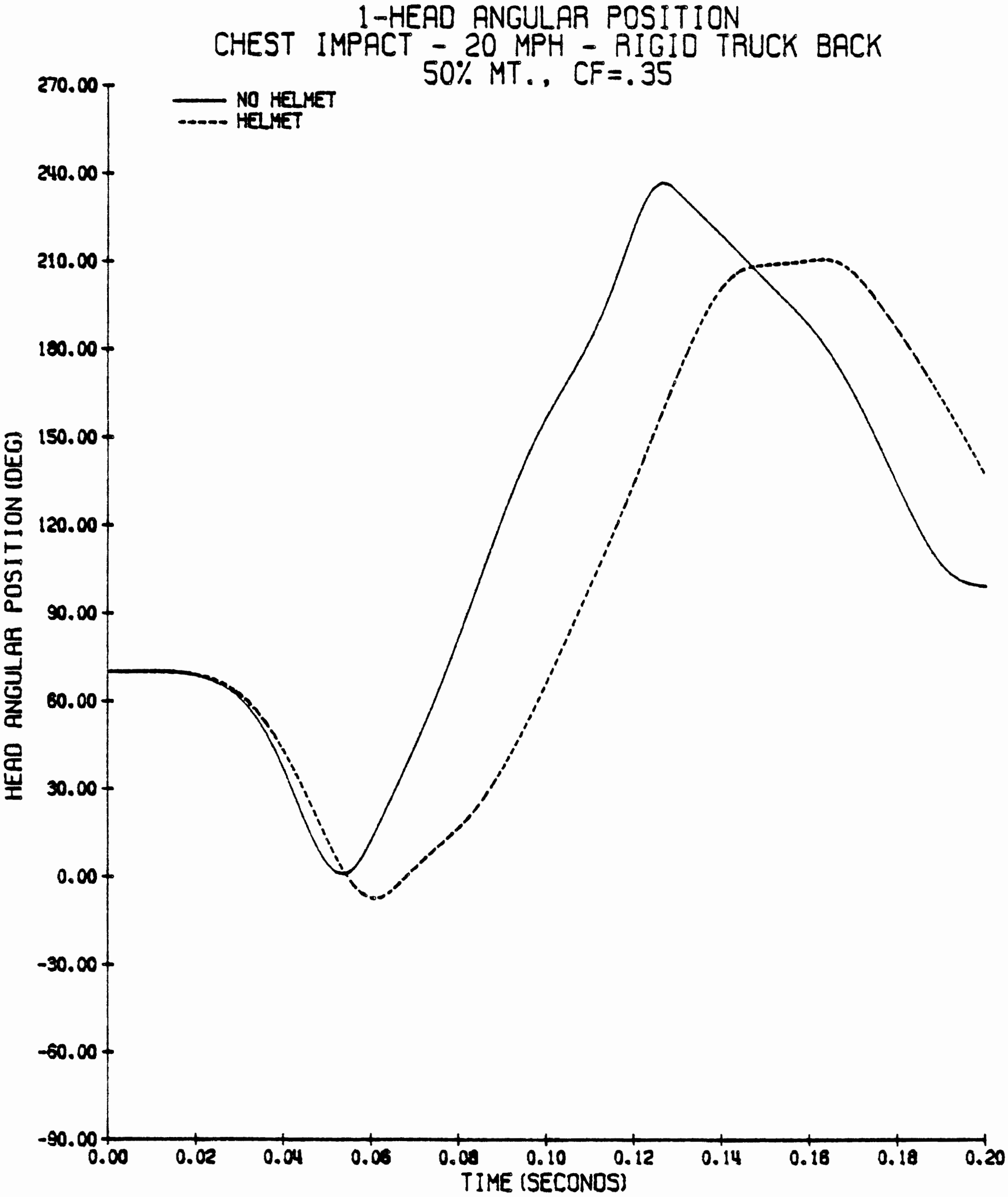

15-COMP. FORCE AT C7
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3
NO HELMET
HELMET
COMP FORCE (LBS.)
TIME (SECONDS)
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
-200.0
-400.0
-600.0
-800.0
-1000.0
-1200.0
-1400.0
-1600.0
-1800.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10


16-UPPER NECK TOTAL JOINT TORQUE
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3
NO HELMET
HELMET
2000.0
1600.0
1200.0
800.0
400.0
0.0
-400.0
-800.0
-1200.0
-1600.0
-2000.0
UPPER NECK TORQUE (IN-LBS)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

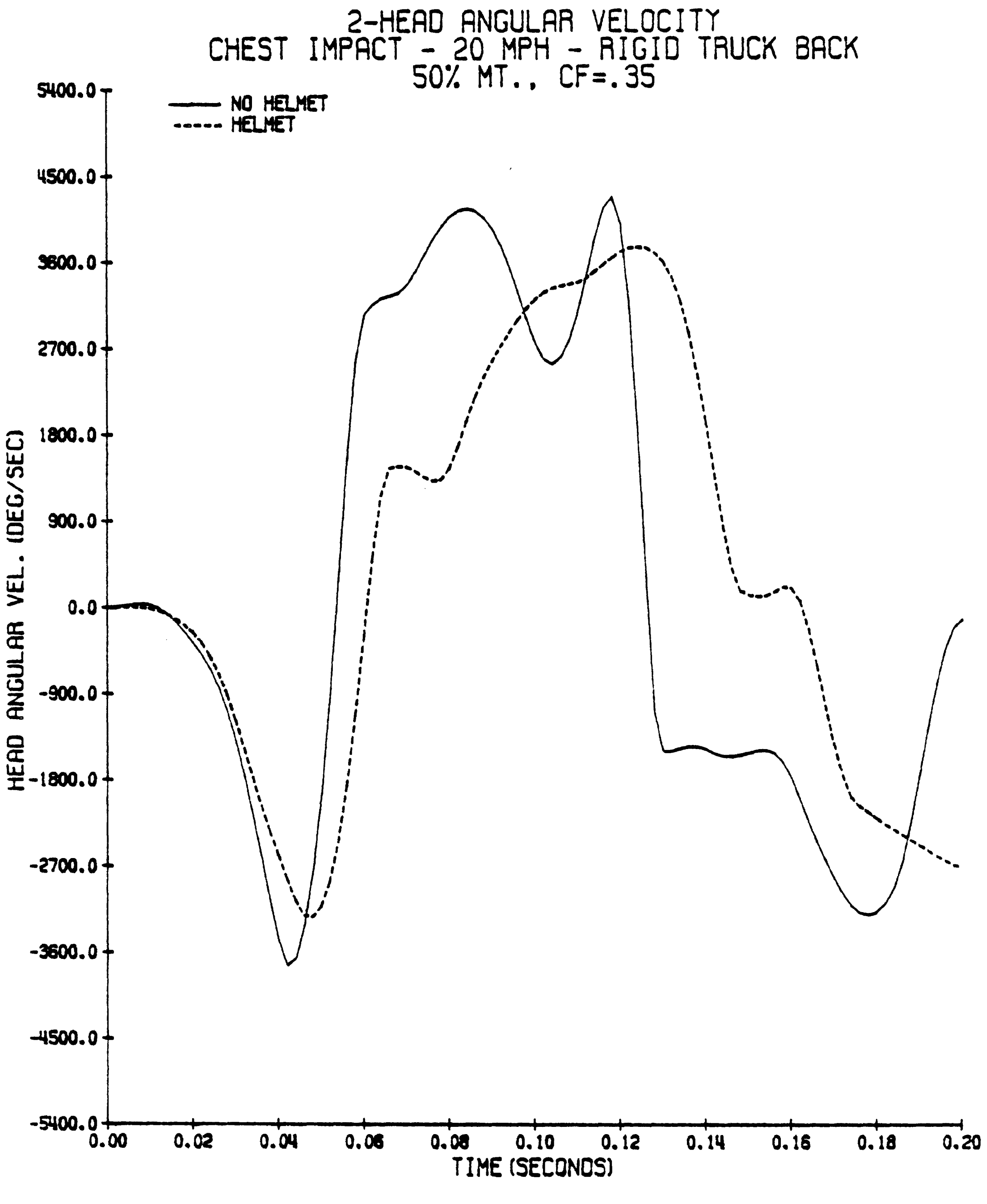
[2]-17

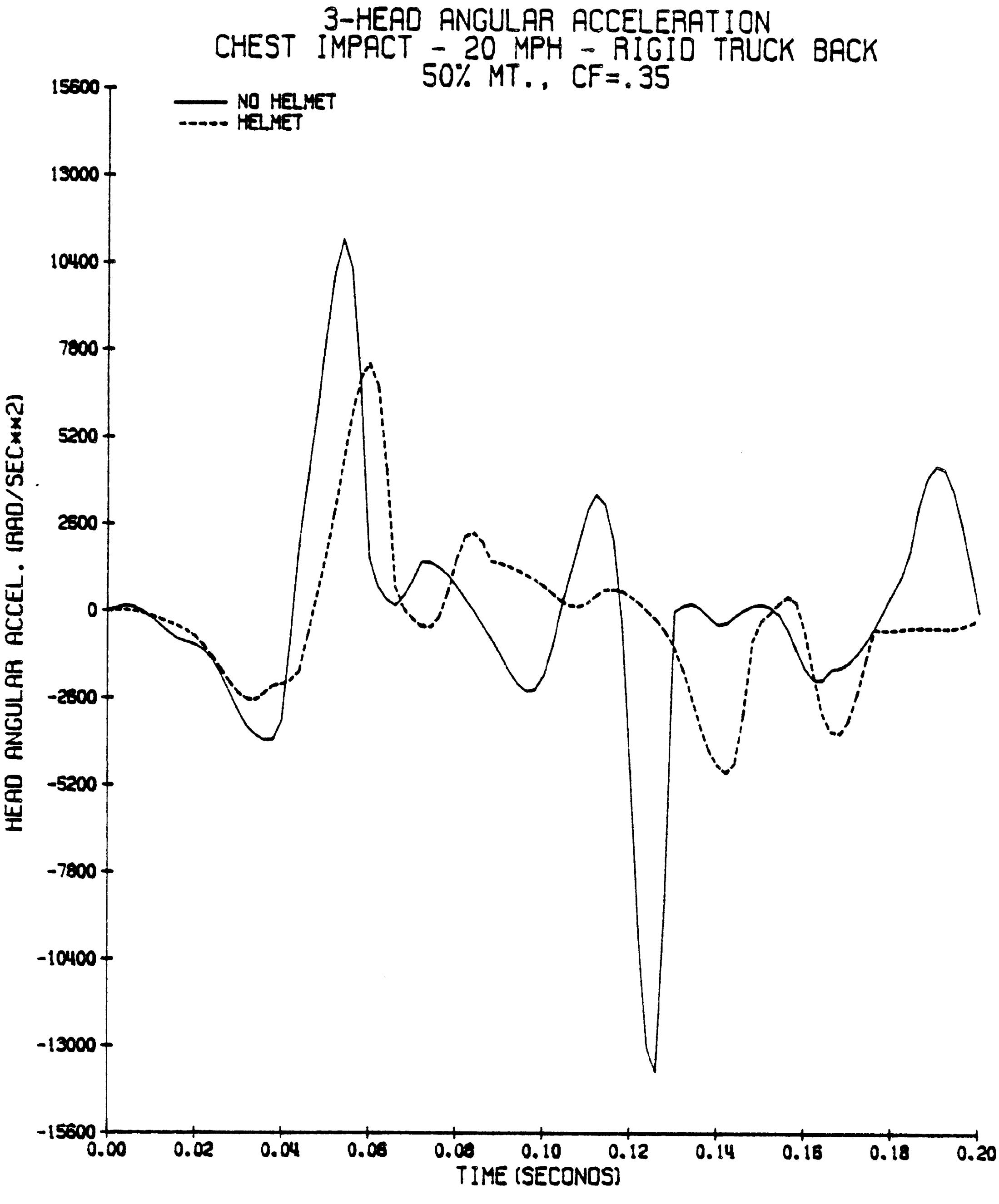

17-LOWER NECK TOTAL JOINT TORQUE
HEAD IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CFH=.1 CFNH=.3
NO HELMET
HELMET
LOWER NECK TORQUE (IN-LBS)
3000.0
2750.0
2500.0
2250.0
2000.0
1750.0
1500.0
1250.0
1000.0
750.0
500.0
250.0
0.0
-250.0
-500.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

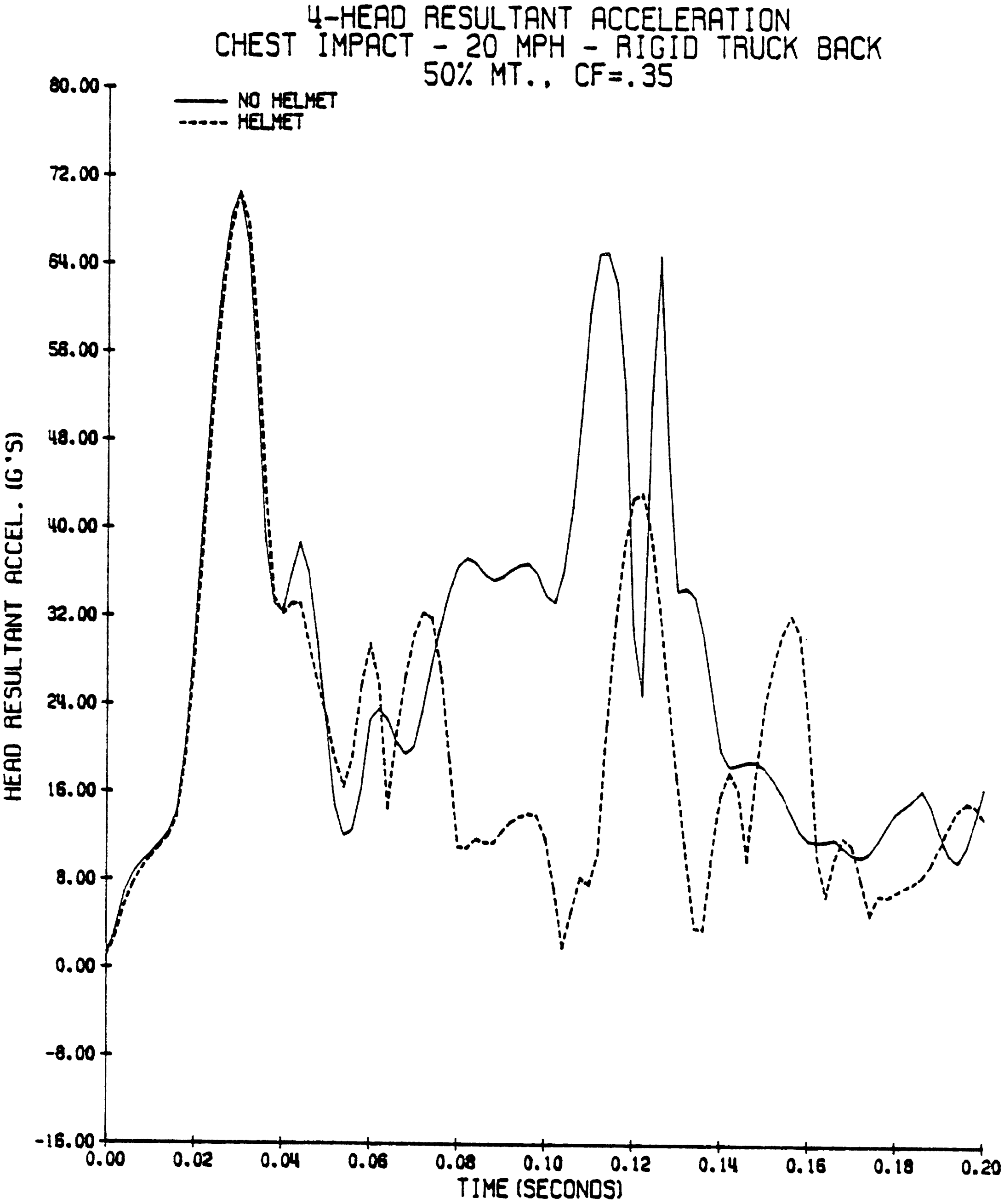
[1]-1

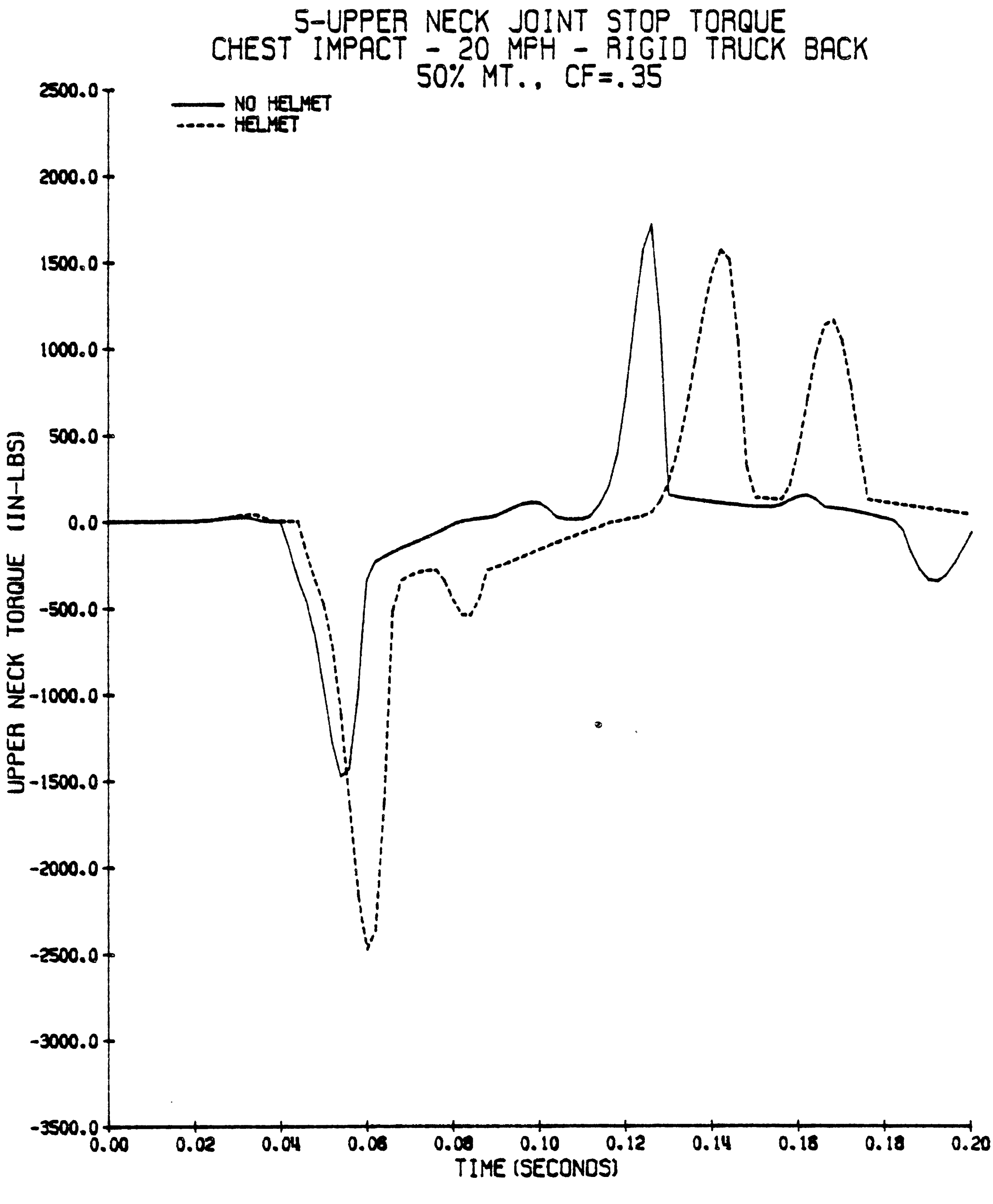


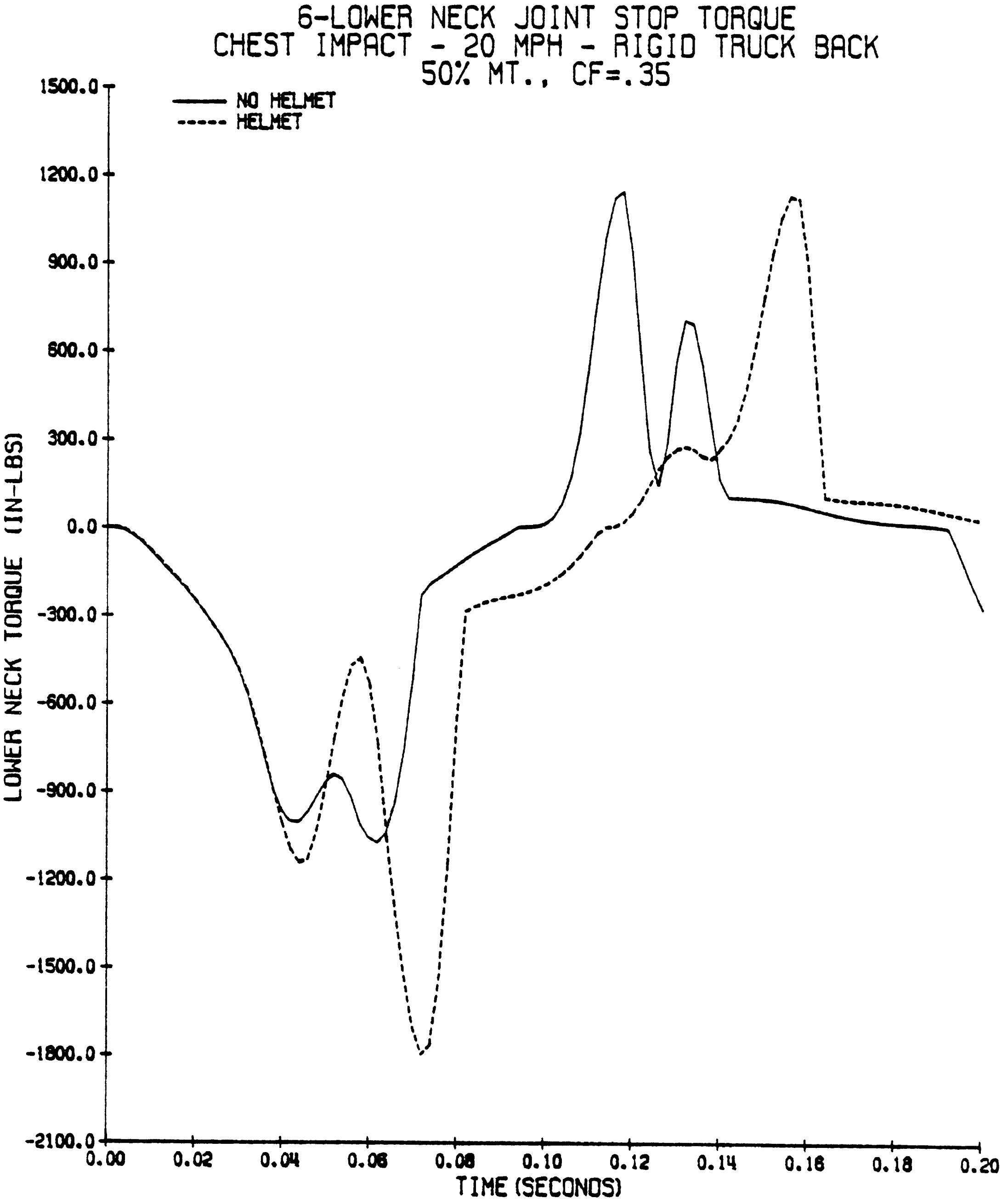
1-HEAD ANGULAR POSITION
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
HEAD ANGULAR POSITION (DEG)
270.00
240.00
210.00
180.00
150.00
120.00
90.00
60.00
30.00
0.00
-30.00
-60.00
-90.00
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)

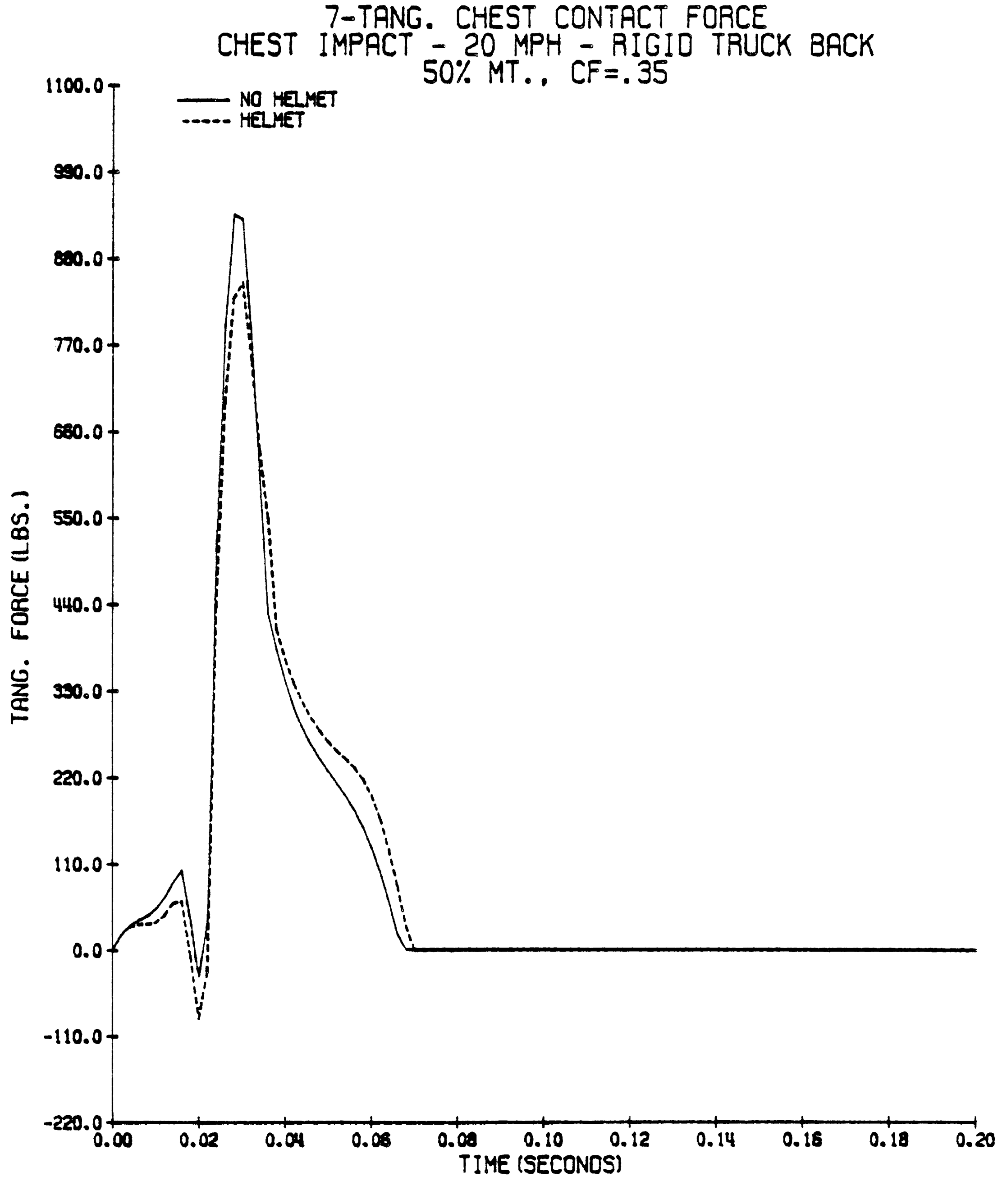

2-HEAD ANGULAR VELOCITY
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
HEAD ANGULAR VEL. (DEG/SEC)
5400.0
4500.0
3600.0
2700.0
1800.0
900.0
0.0
-900.0
-1800.0
-2700.0
-3600.0
-4500.0
-5400.0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)

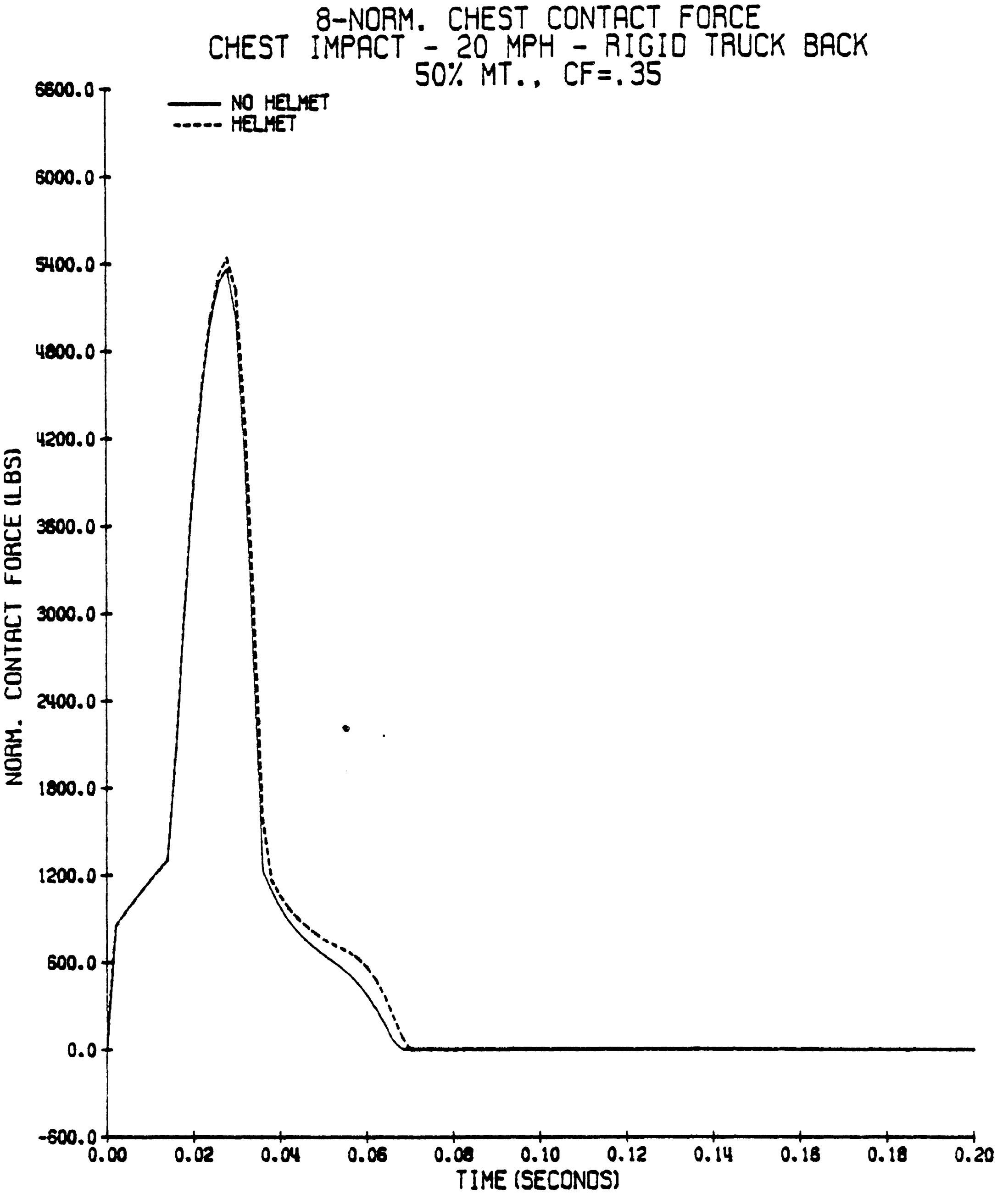

3-HEAD ANGULAR ACCELERATION
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
HEAD ANGULAR ACCEL. (RAD/SEC**2)
15600
13000
10400
7800
5200
2600
0
-2600
-5200
-7800
-10400
-13000
-15600
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)

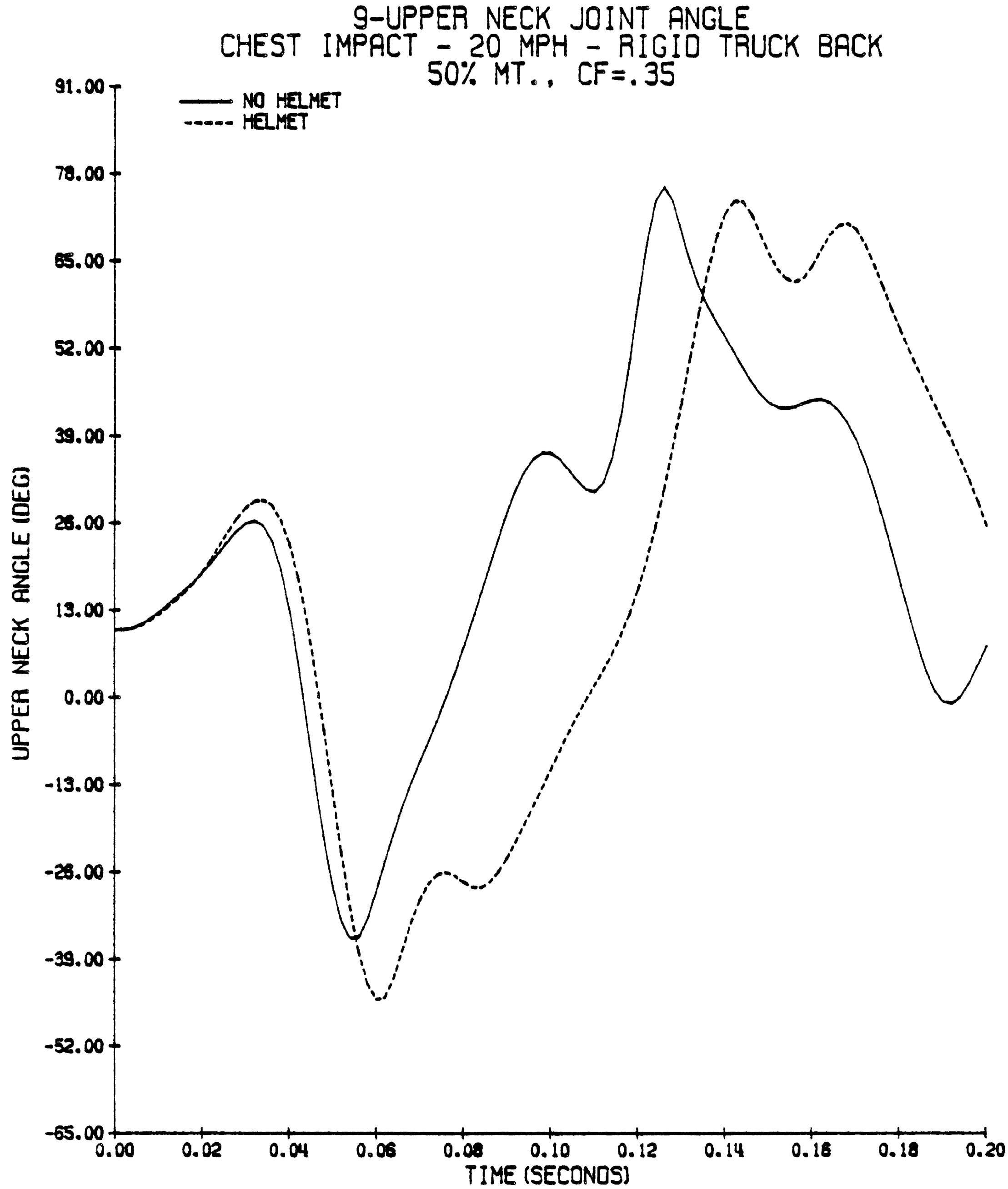

4-HEAD RESULTANT ACCELERATION
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
HEAD RESULTANT ACCEL. (G'S)
80.00
72.00
64.00
56.00
48.00
40.00
32.00
24.00
16.00
8.00
0.00
-8.00
-16.00
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)


5-UPPER NECK JOINT STOP TORQUE
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
UPPER NECK TORQUE (IN-LBS)
2500.0
2000.0
1500.0
1000.0
500.0
0.0
-500.0
-1000.0
-1500.0
-2000.0
-2500.0
-3000.0
-3500.0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)

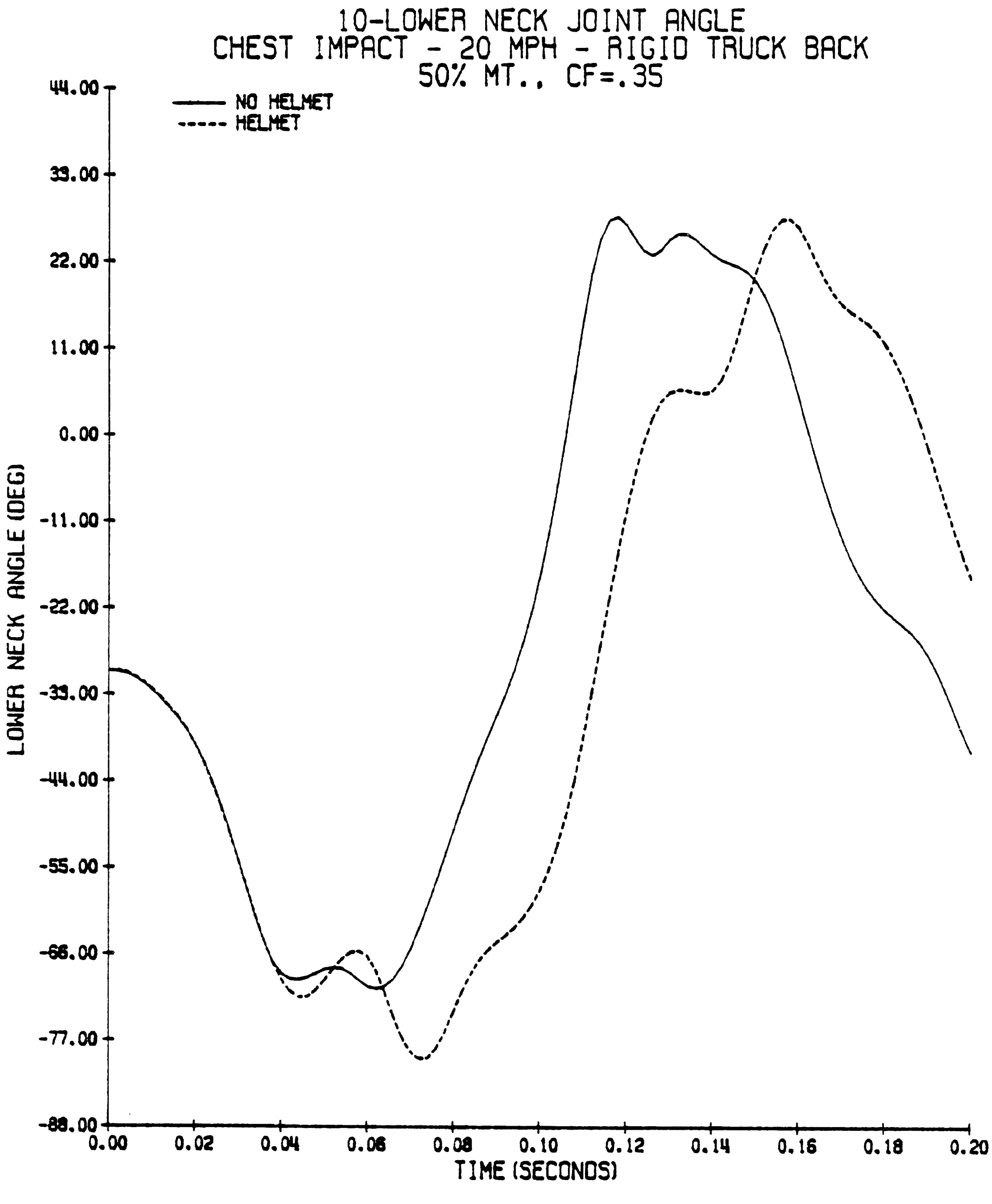

6-LOWER NECK JOINT STOP TORQUE
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
1500.0
1200.0
900.0
600.0
300.0
0.0
-300.0
-600.0
-900.0
-1200.0
-1500.0
-1800.0
-2100.0
LOWER NECK TORQUE (IN-LBS)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)

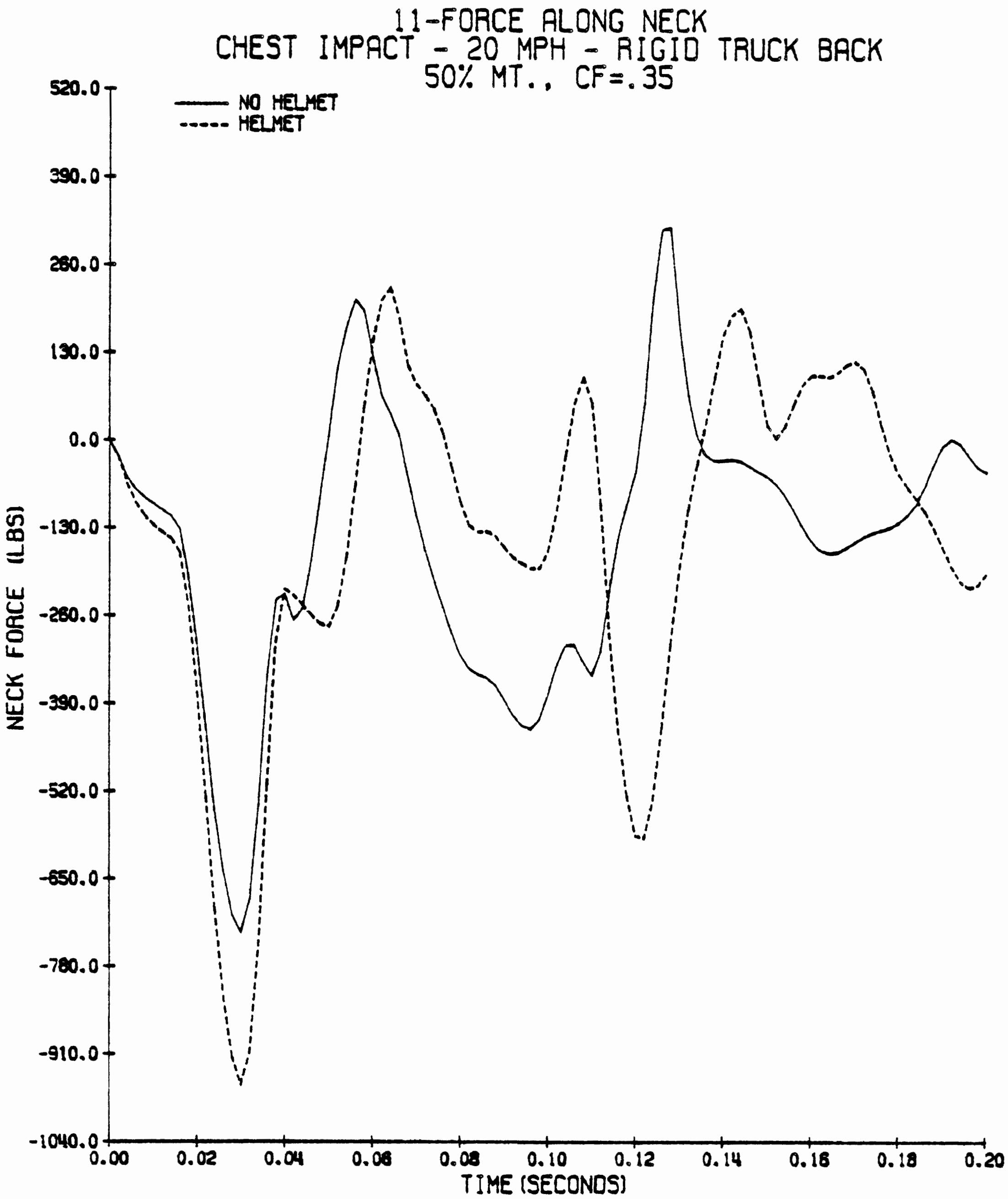

7-TANG. CHEST CONTACT FORCE
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
1100.0
990.0
880.0
770.0
660.0
550.0
440.0
330.0
220.0
110.0
0.0
-110.0
-220.0
TANG. FORCE (LBS.)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)


8-NORM. CHEST CONTACT FORCE
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
NORM. CONTACT FORCE (LBS)
6600.0
6000.0
5400.0
4800.0
4200.0
3600.0
3000.0
2400.0
1800.0
1200.0
600.0
0.0
-600.0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)

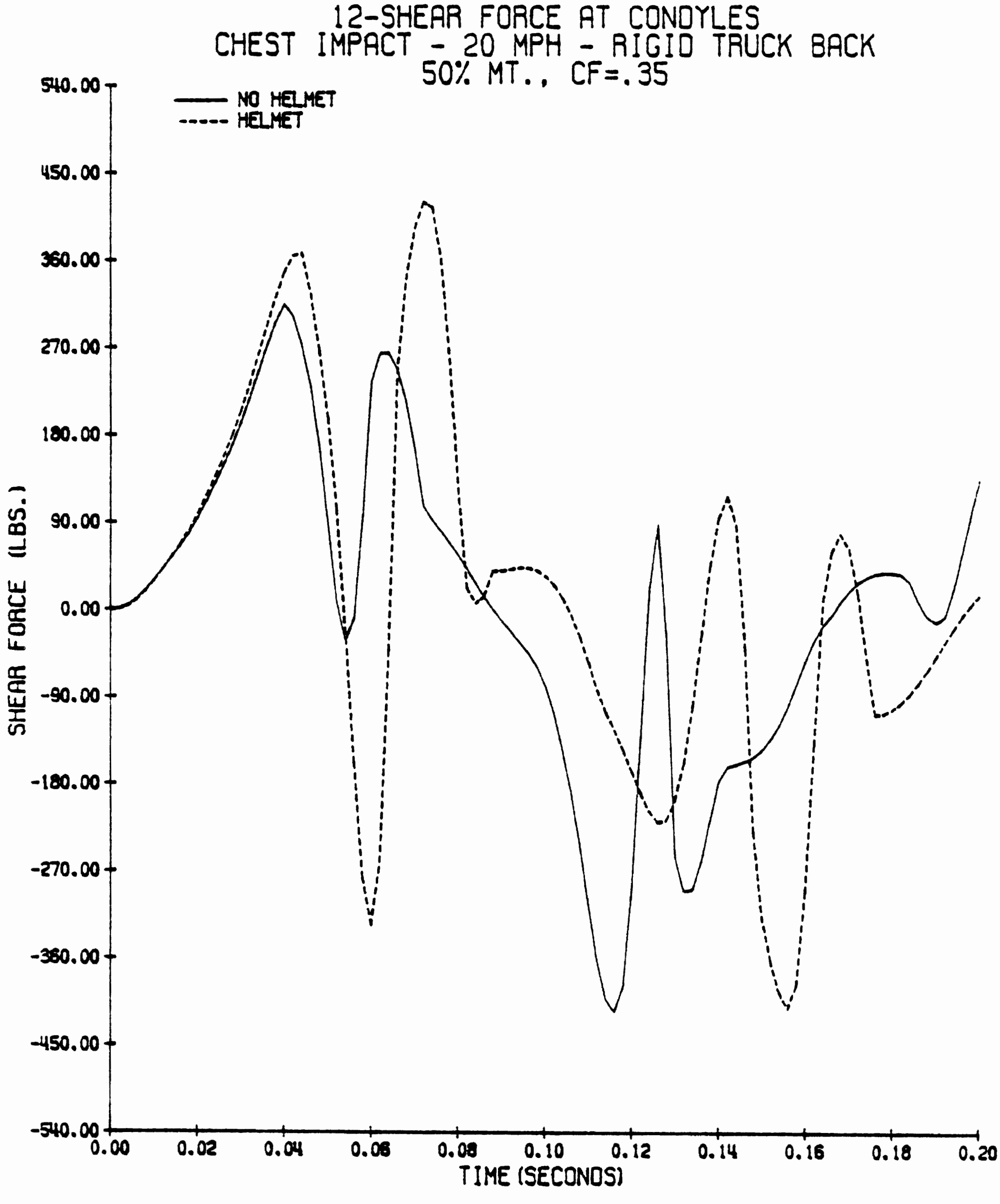


9-UPPER NECK JOINT ANGLE
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
UPPER NECK ANGLE (DEG)
91.00
78.00
65.00
52.00
39.00
26.00
13.00
0.00
-13.00
-26.00
-39.00
-52.00
-65.00
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)


10-LOWER NECK JOINT ANGLE
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
LOWER NECK ANGLE (DEG)
44.00
33.00
22.00
11.00
0.00
-11.00
-22.00
-33.00
-44.00
-55.00
-66.00
-77.00
-88.00
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)

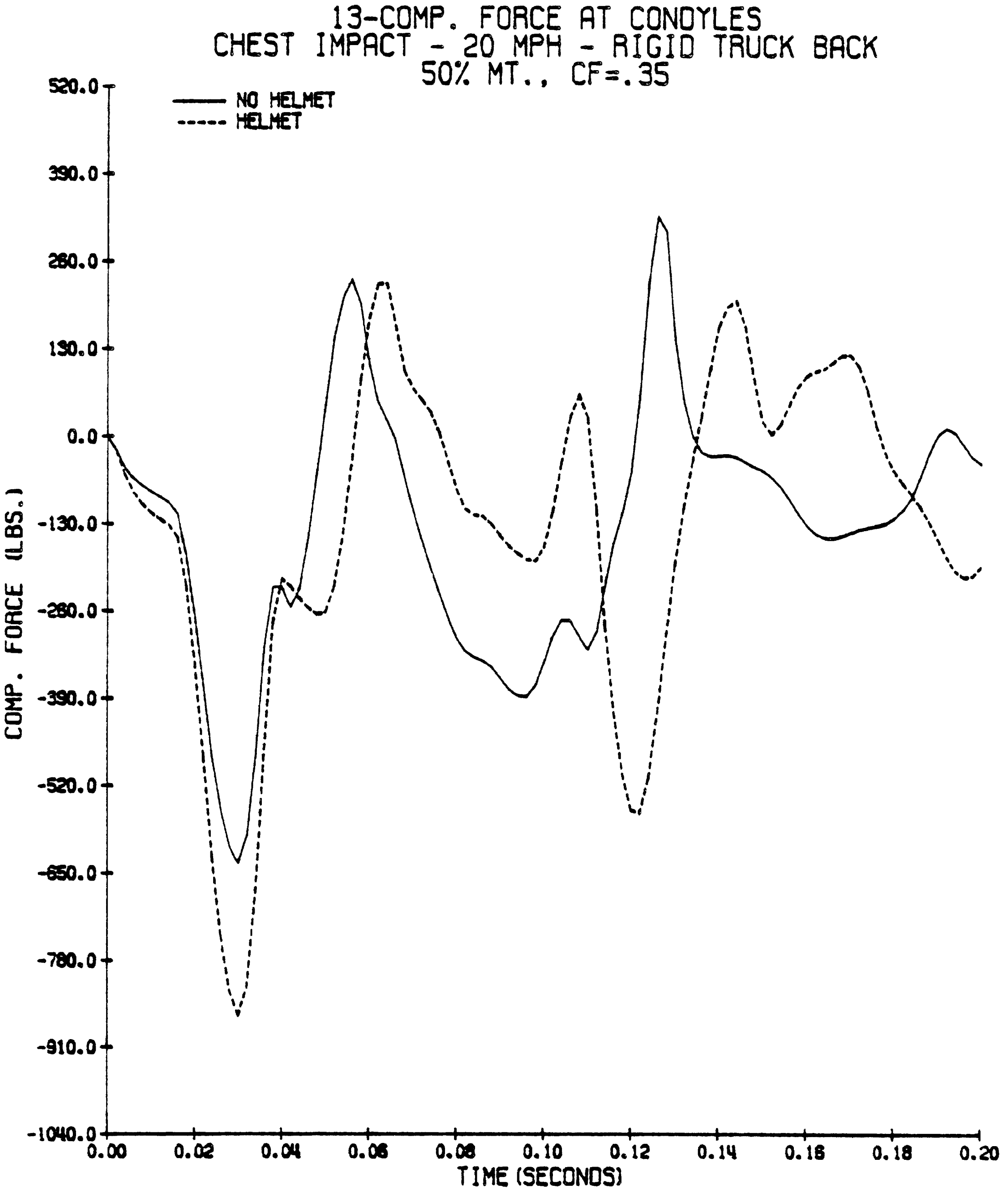


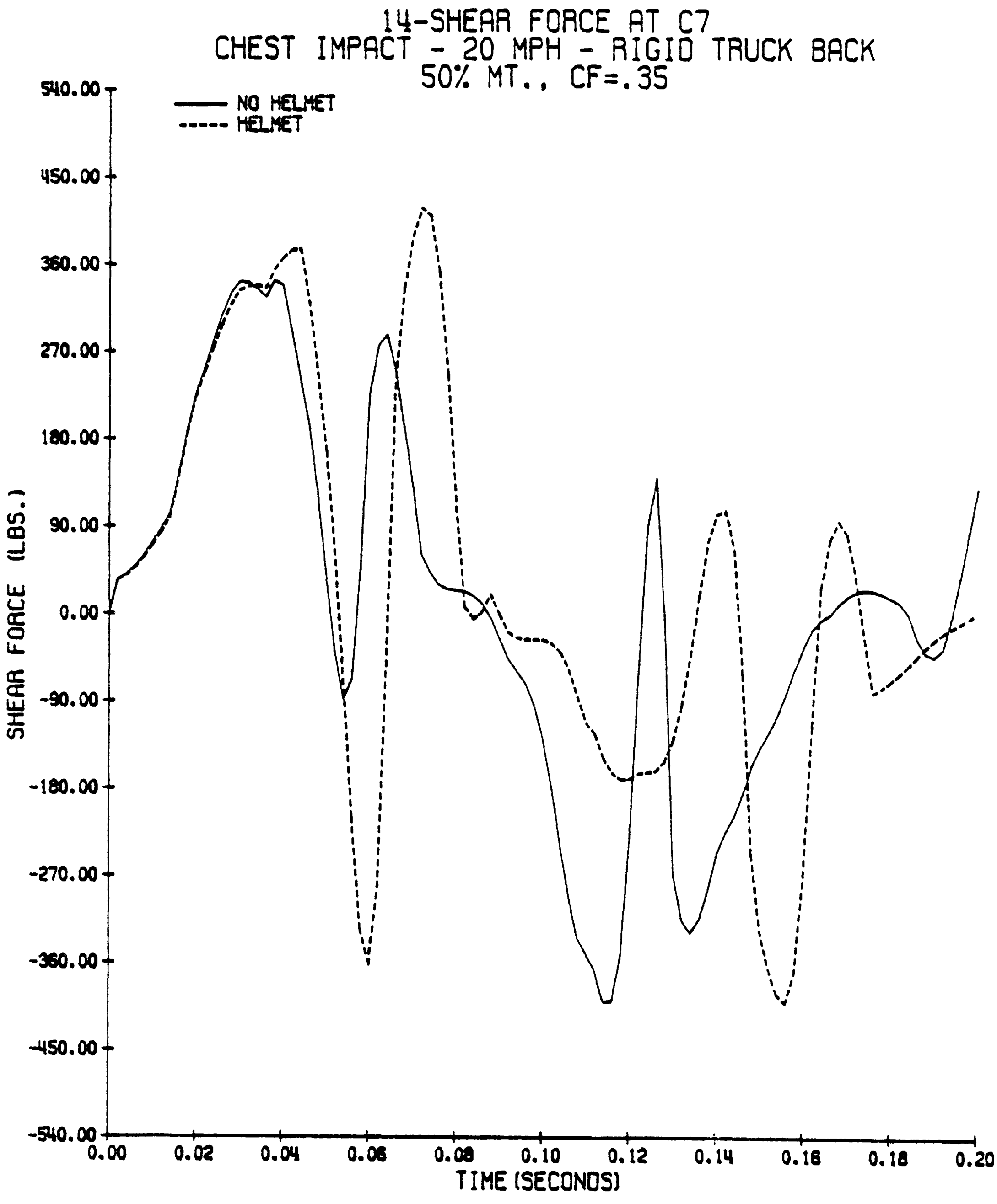
11-FORCE ALONG NECK
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
NECK FORCE (LBS)
520.0
390.0
260.0
130.0
0.0
-130.0
-260.0
-390.0
-520.0
-650.0
-780.0
-910.0
-1040.0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)

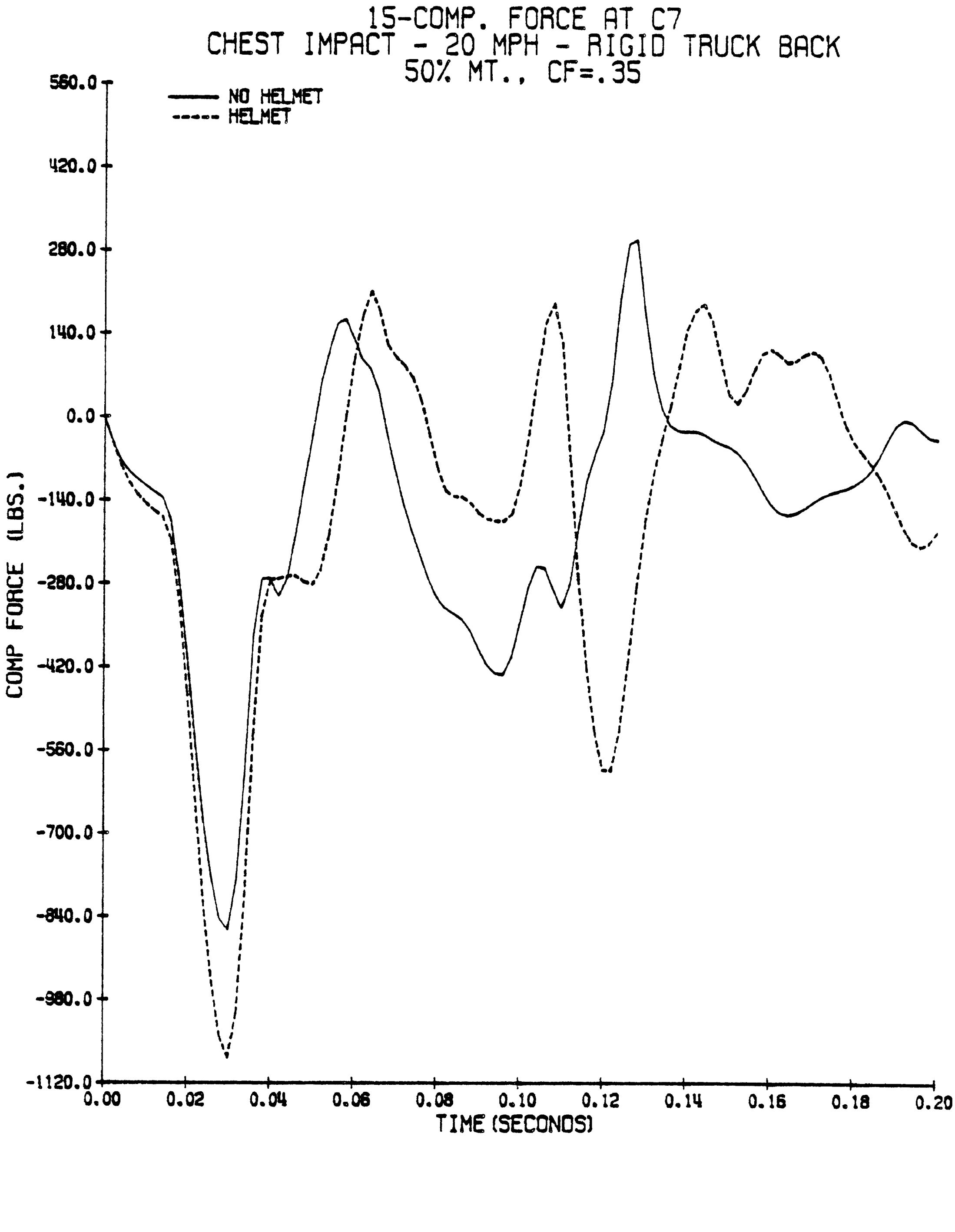


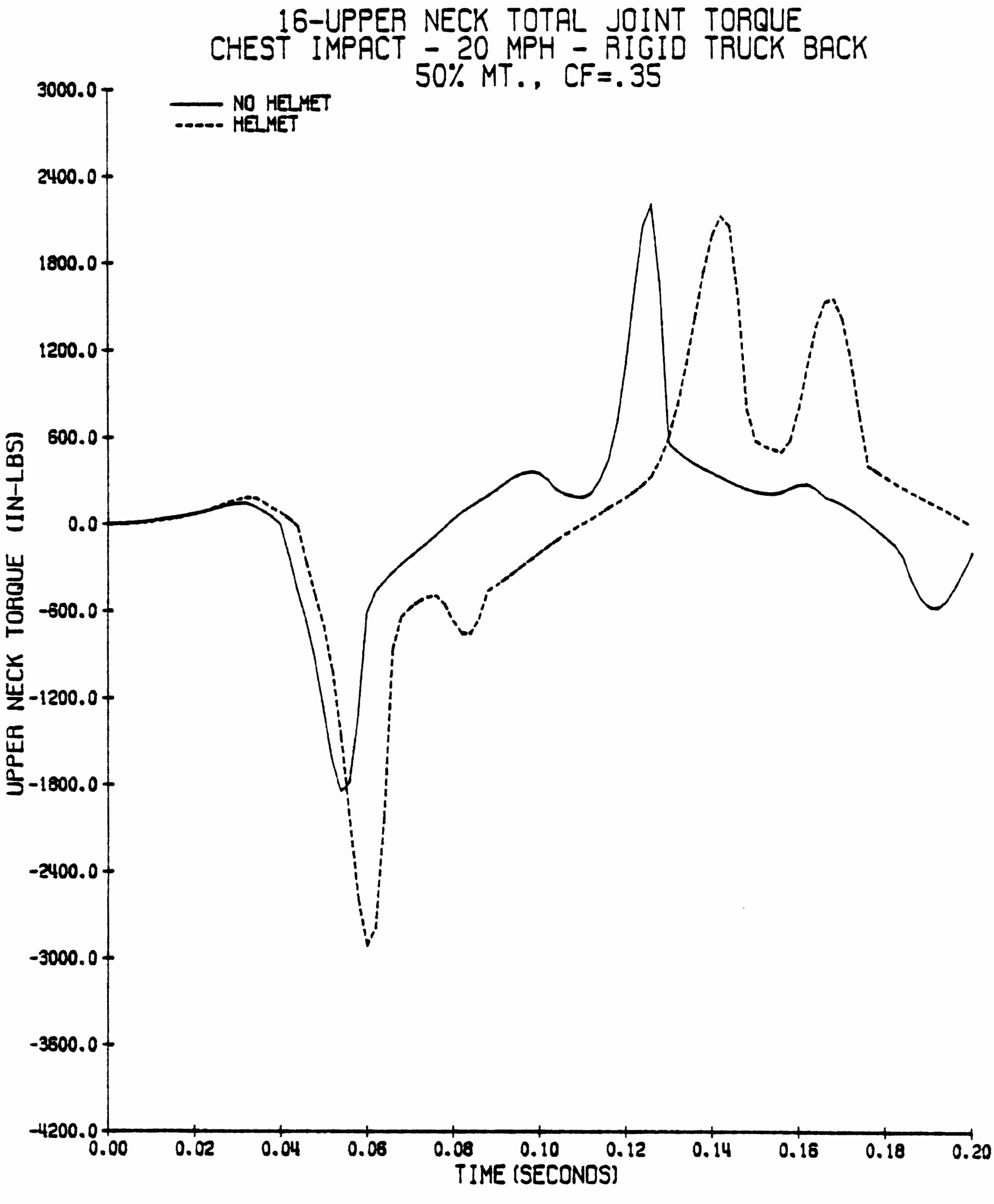
12-SHEAR FORCE AT CONDYLES
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
SHEAR FORCE (LBS.)
540.00
450.00
360.00
270.00
180.00
90.00
0.00
-90.00
-180.00
-270.00
-360.00
-450.00
-540.00
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)

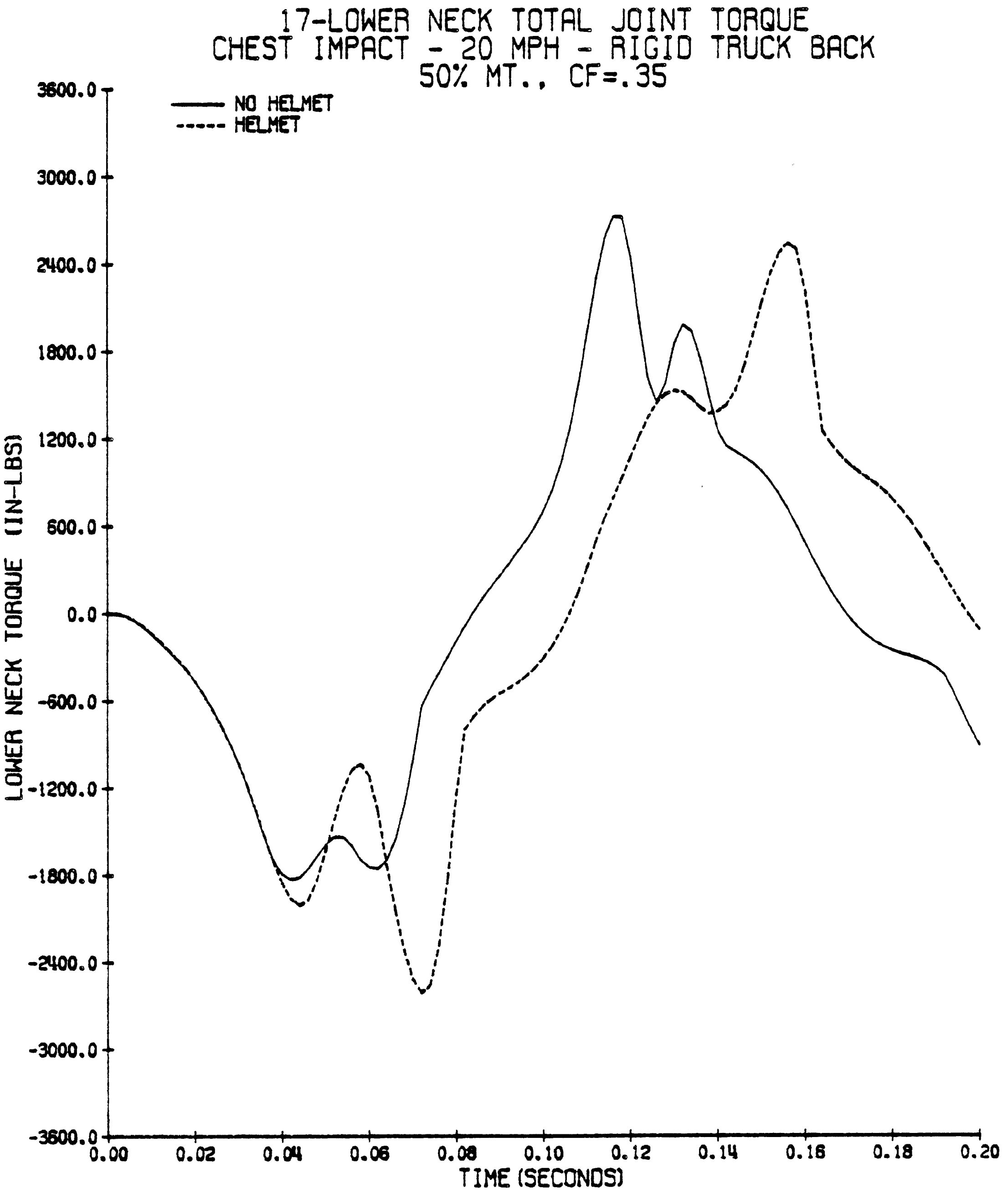
[1]-13

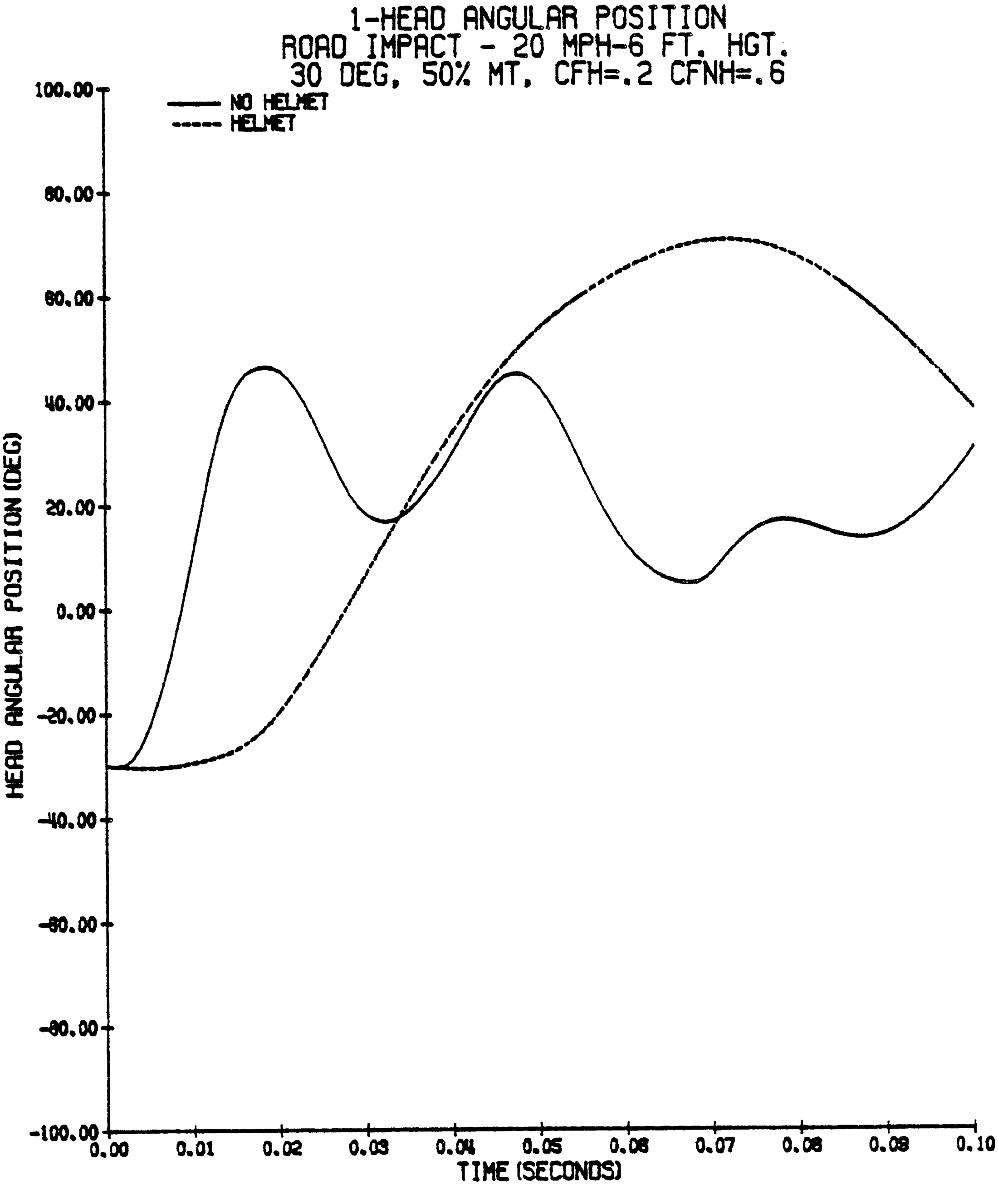

13-COMP. FORCE AT CONDYLES
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
520.0
390.0
260.0
130.0
0.0
-130.0
-260.0
-390.0
-520.0
-650.0
-780.0
-910.0
-1040.0
COMP. FORCE (LBS.)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)

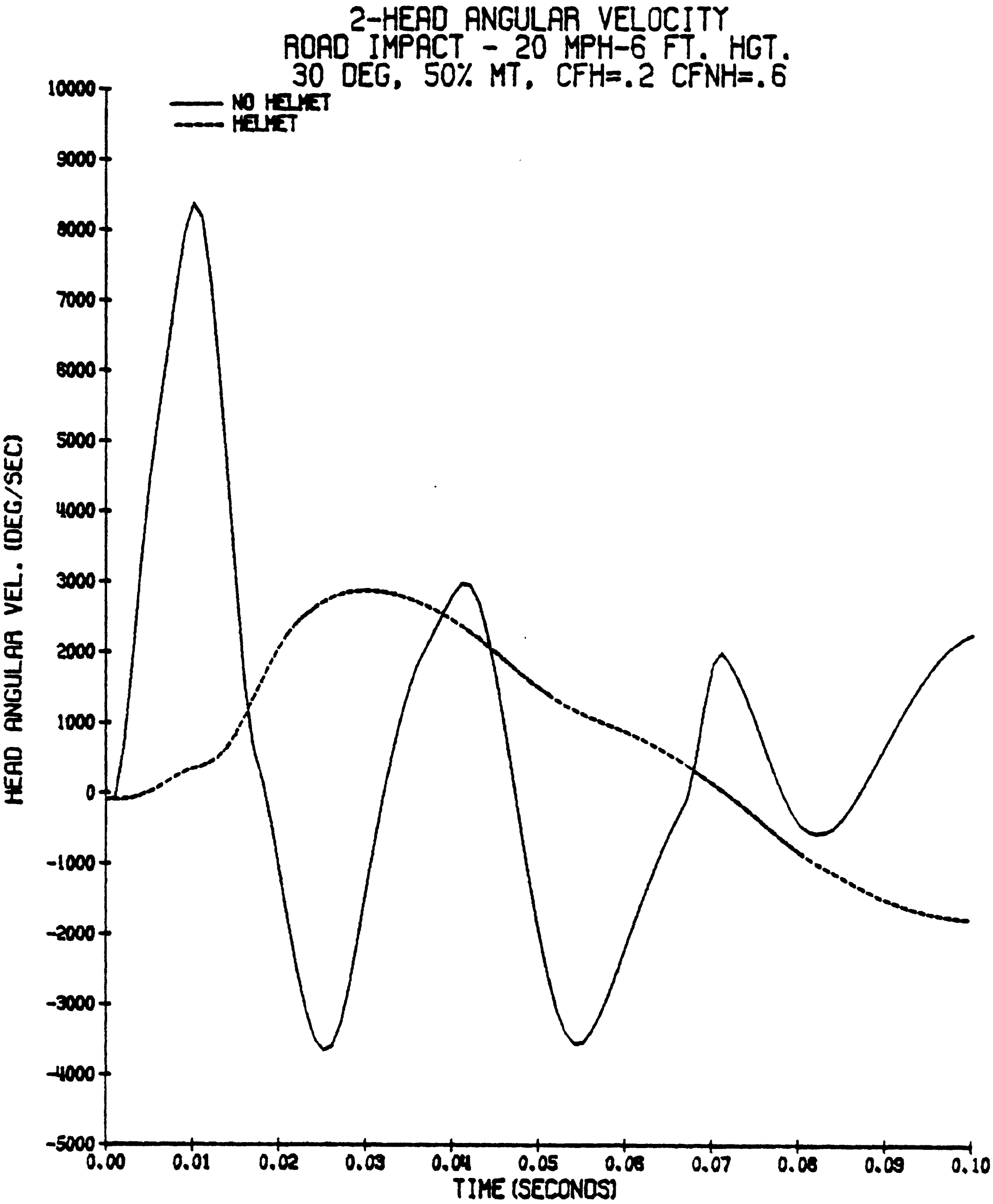

14-SHEAR FORCE AT C7
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
SHEAR FORCE (LBS.)
540.00
450.00
360.00
270.00
180.00
90.00
0.00
-90.00
-180.00
-270.00
-360.00
-450.00
-540.00
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)

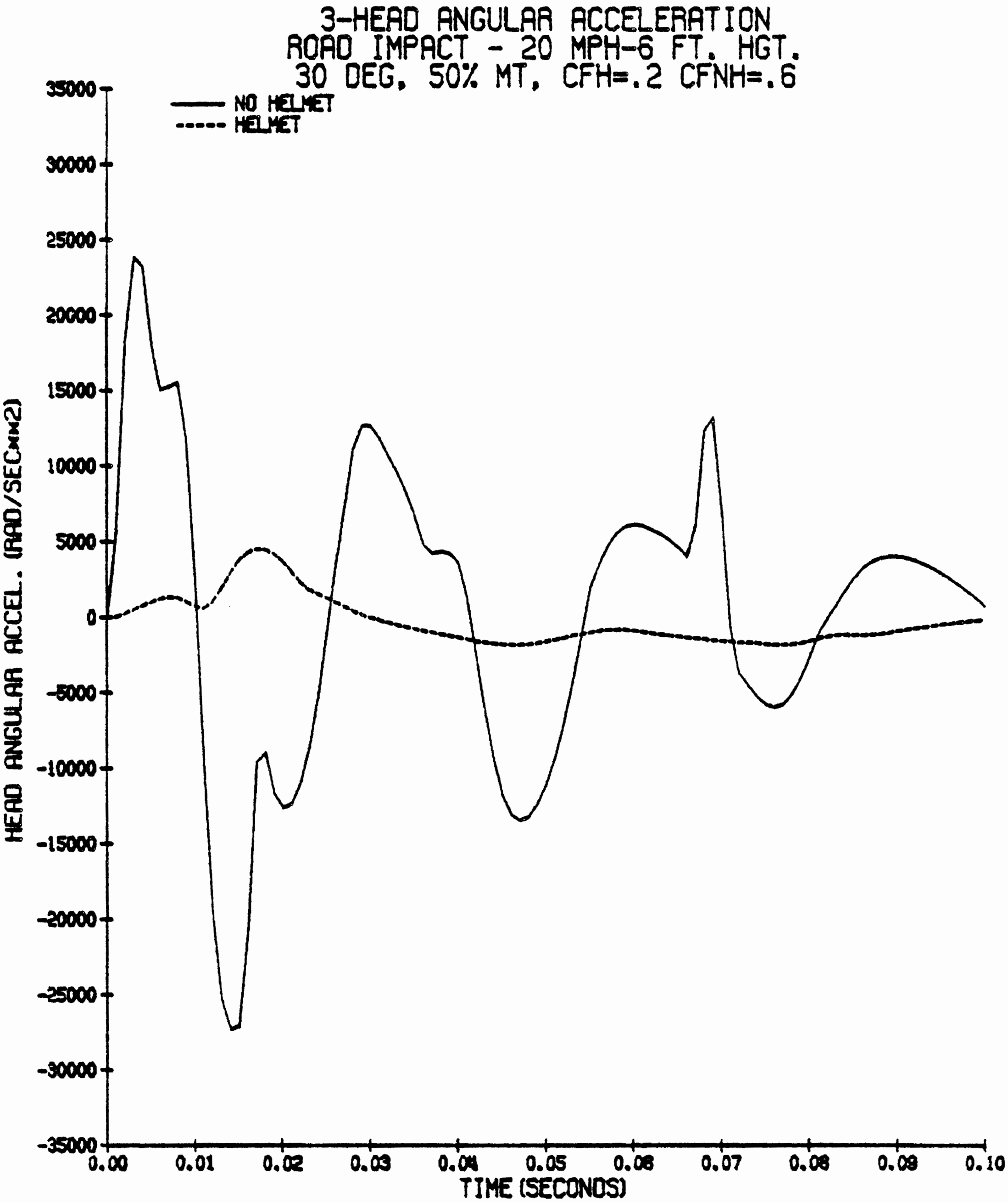

15-COMP. FORCE AT C7
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
560.0
420.0
280.0
140.0
0.0
-140.0
-280.0
-420.0
-560.0
-700.0
-840.0
-980.0
-1120.0
COMP FORCE (LBS.)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)

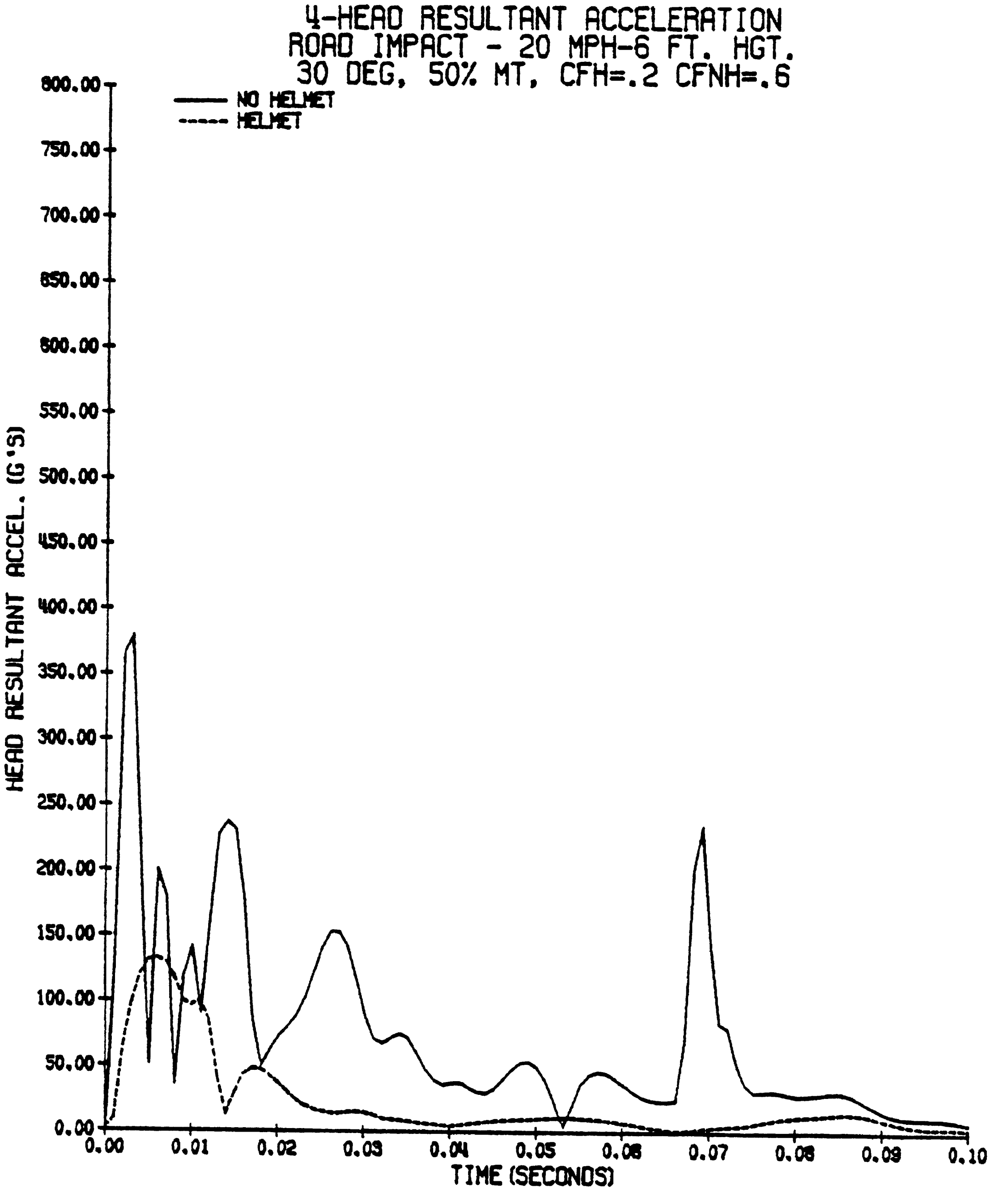

16-UPPER NECK TOTAL JOINT TORQUE
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
UPPER NECK TORQUE (IN-LBS)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
-600.0
-1200.0
-1800.0
-2400.0
-3000.0
-3600.0
-4200.0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)

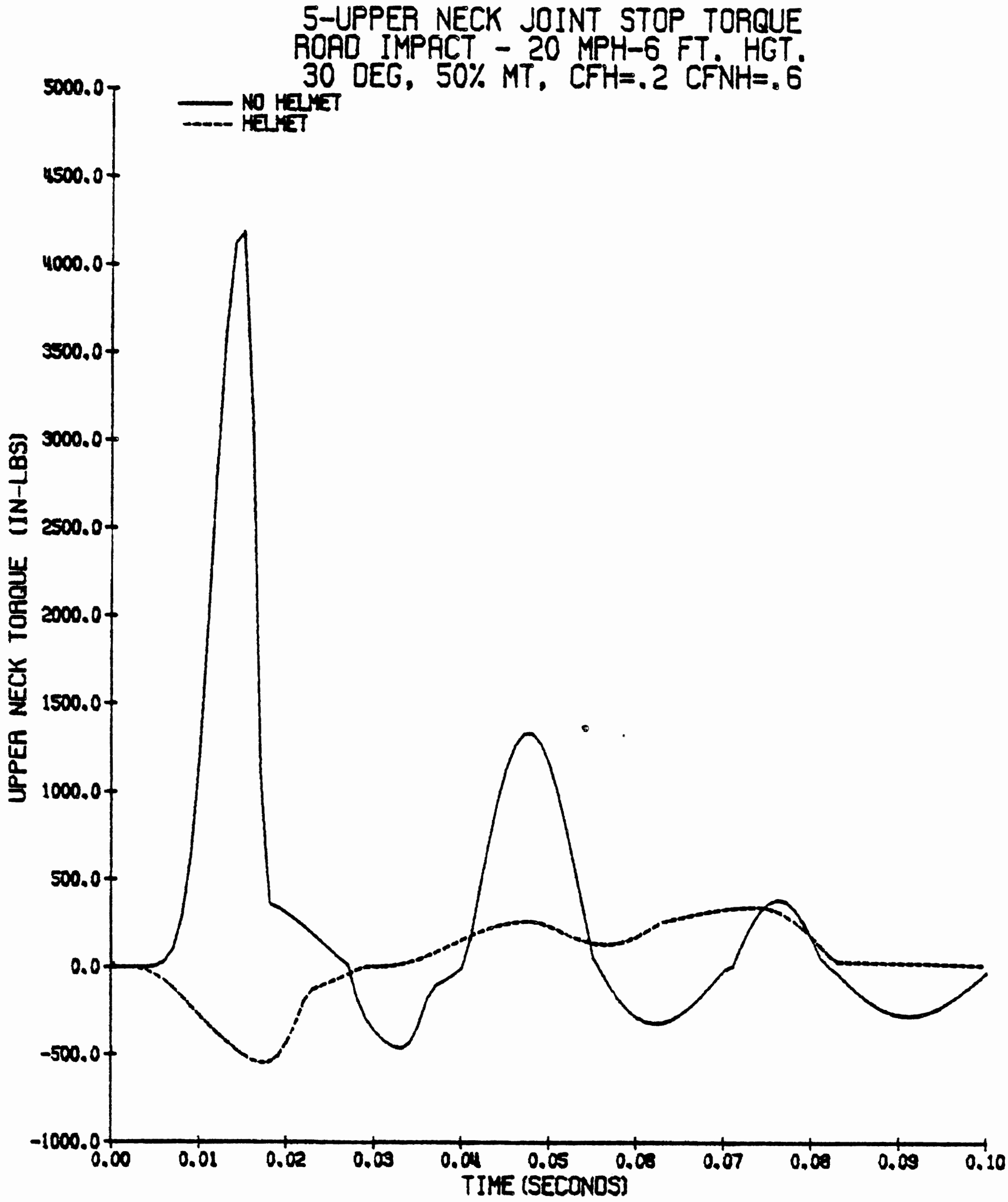

17-LOWER NECK TOTAL JOINT TORQUE
CHEST IMPACT - 20 MPH - RIGID TRUCK BACK
50% MT., CF=.35
NO HELMET
HELMET
3600.0
3000.0
2400.0
1800.0
1200.0
600.0
0.0
-600.0
-1200.0
-1800.0
-2400.0
-3000.0
-3600.0
LOWER NECK TORQUE (IN-LBS)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SECONDS)

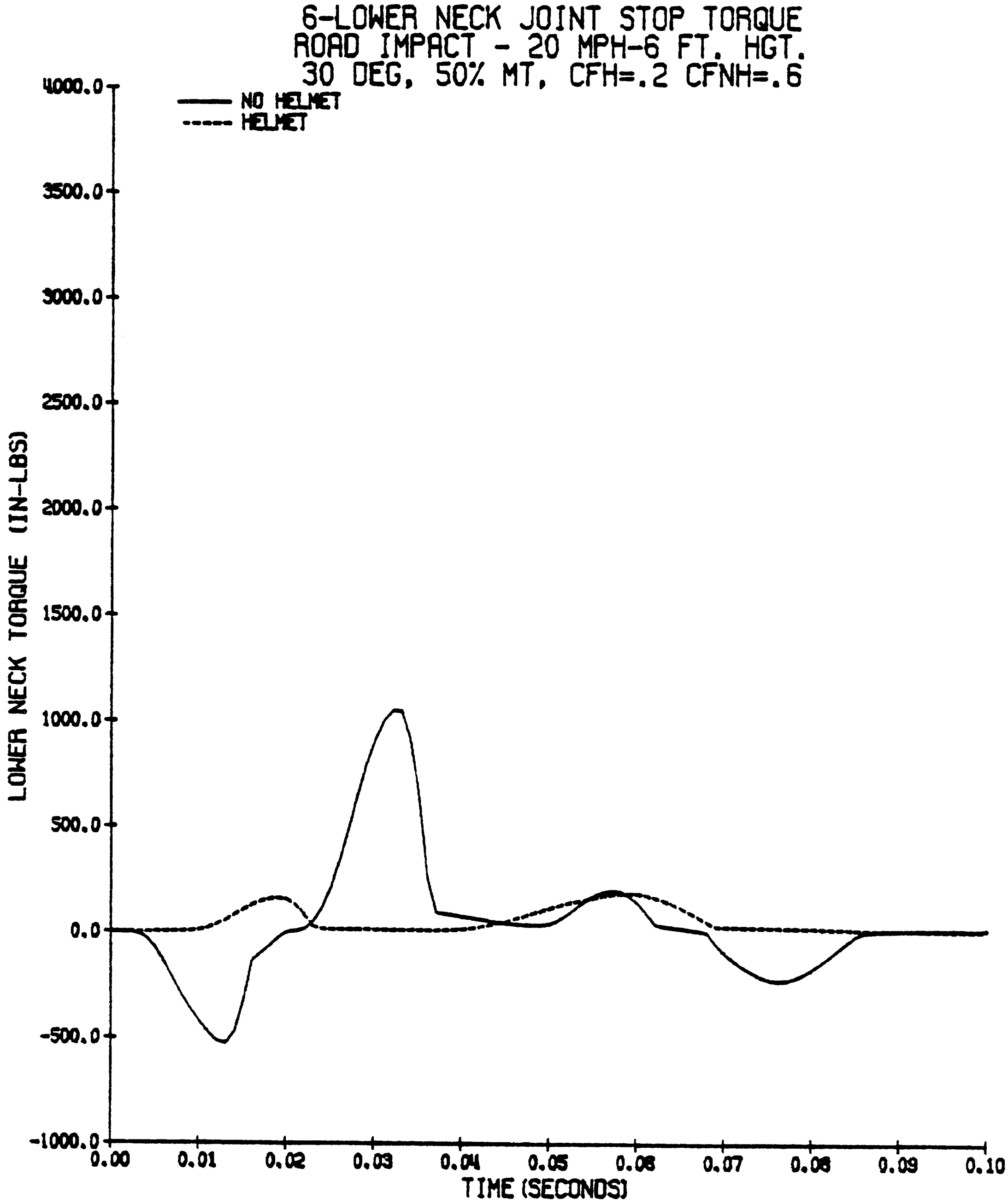

1-HEAD ANGULAR POSITION
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG, 50% MT, CFH=.2 CFNH=.6
NO HELMET
HELMET
HEAD ANGULAR POSITION (DEG)
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
-60.00
-80.00
-100.00
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

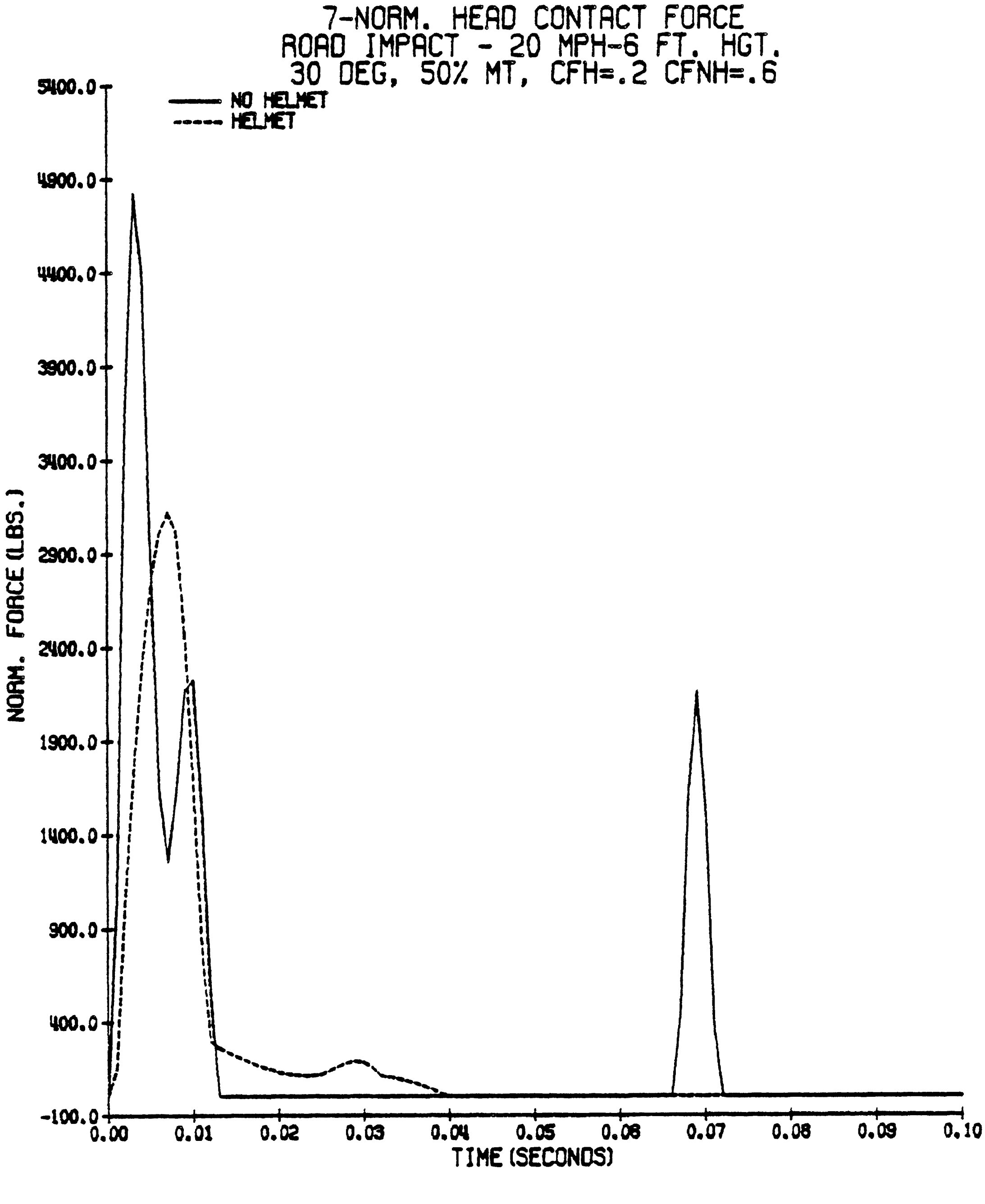

2-HEAD ANGULAR VELOCITY
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG, 50% MT, CFH=.2 CFNH=.6
NO HELMET
HELMET
HEAD ANGULAR VEL. (DEG/SEC)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

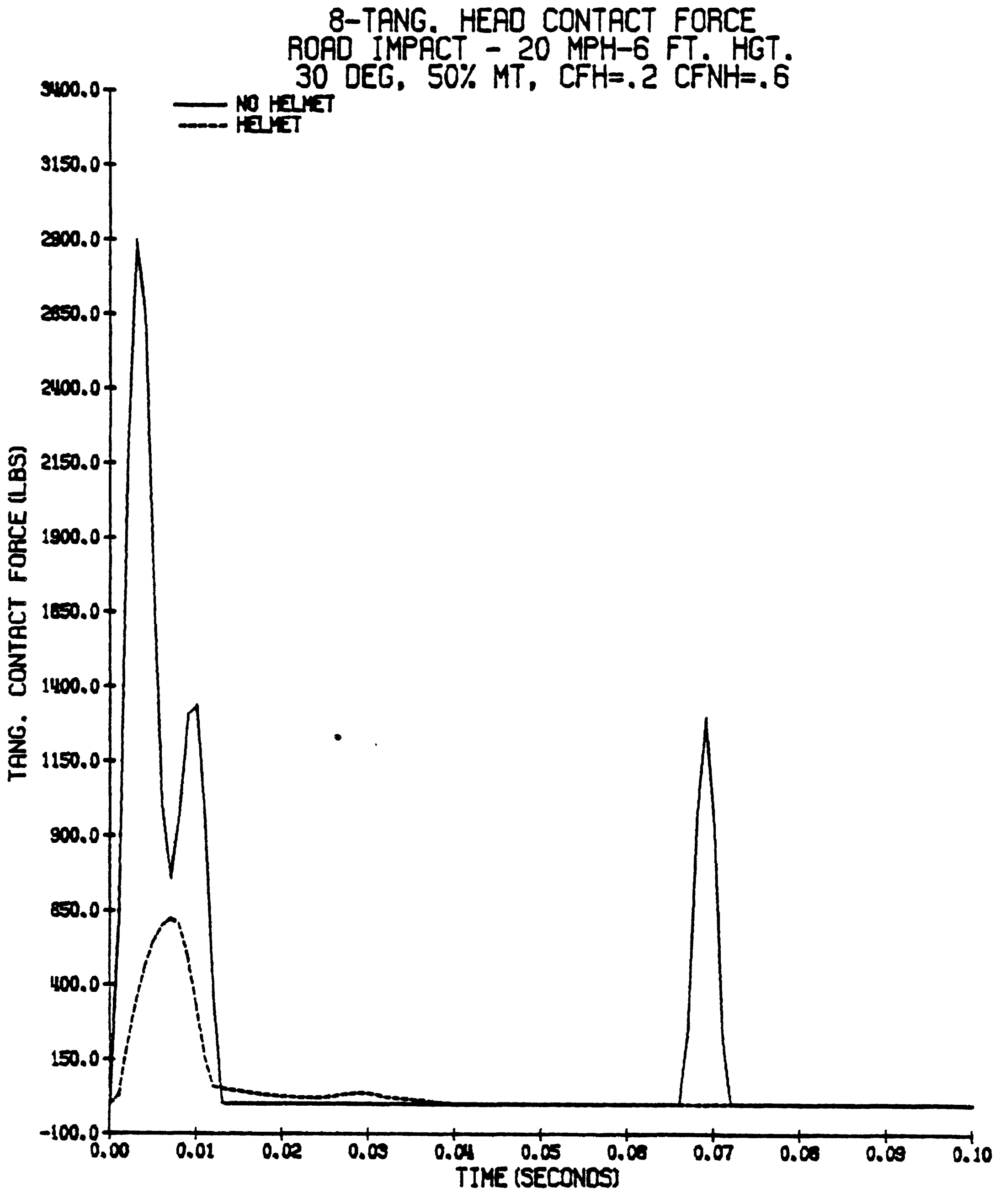

3-HEAD ANGULAR ACCELERATION
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG, 50% MT, CFH=.2 CFNH=.6
NO HELMET
HELMET
HEAD ANGULAR ACCEL. (RAD/SEC**2)
35000
30000
25000
20000
15000
10000
5000
0
-5000
-10000
-15000
-20000
-25000
-30000
-35000
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)


4-HEAD RESULTANT ACCELERATION
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG, 50% MT, CFH=.2 CFNH=.6
NO HELMET
HELMET
HEAD RESULTANT ACCEL. (G'S)
800.00
750.00
700.00
650.00
600.00
550.00
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

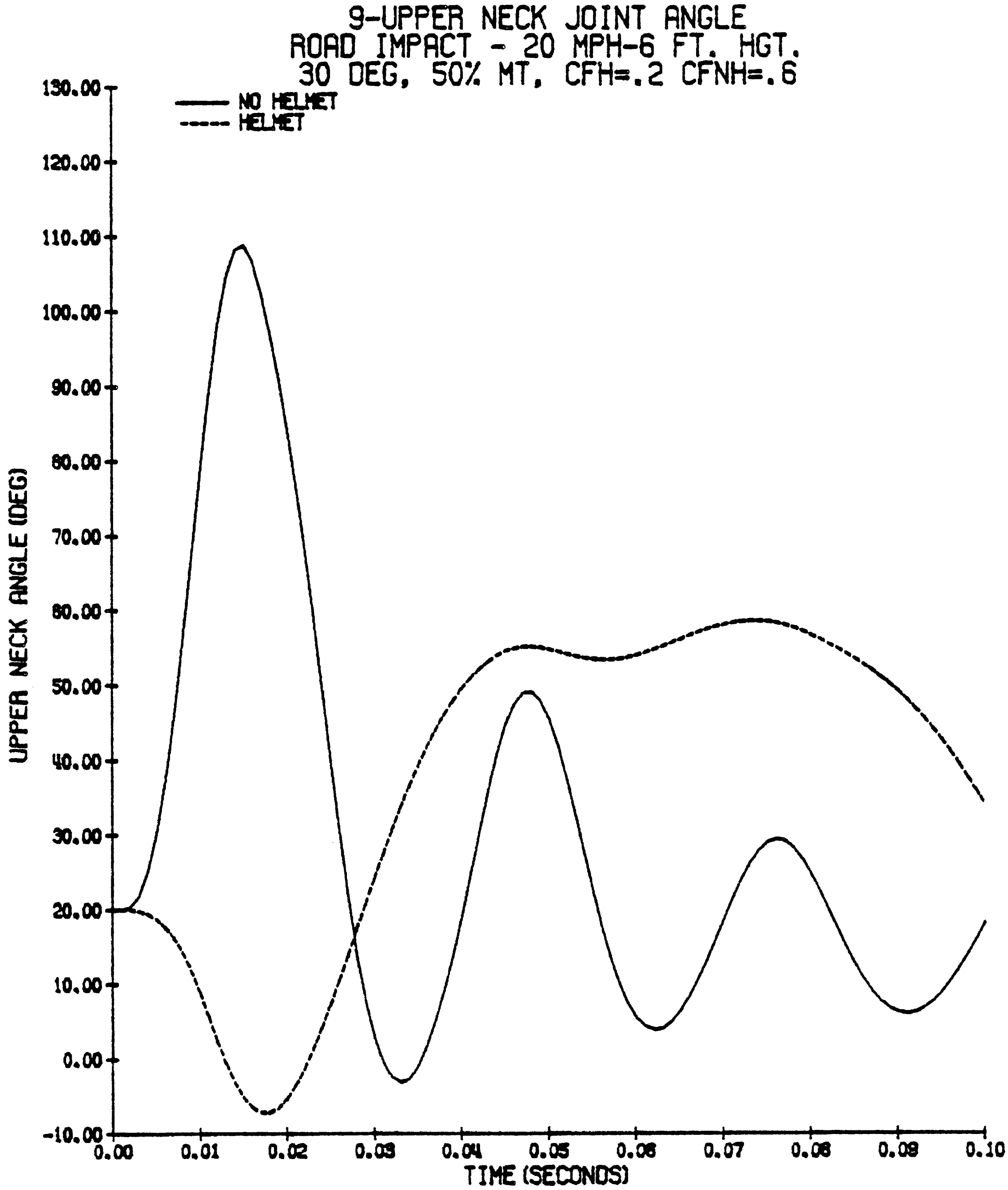

5-UPPER NECK JOINT STOP TORQUE
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG, 50% MT, CFH=.2 CFNH=.6
NO HELMET
HELMET
UPPER NECK TORQUE (IN-LBS)
5000.0
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
-500.0
-1000.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

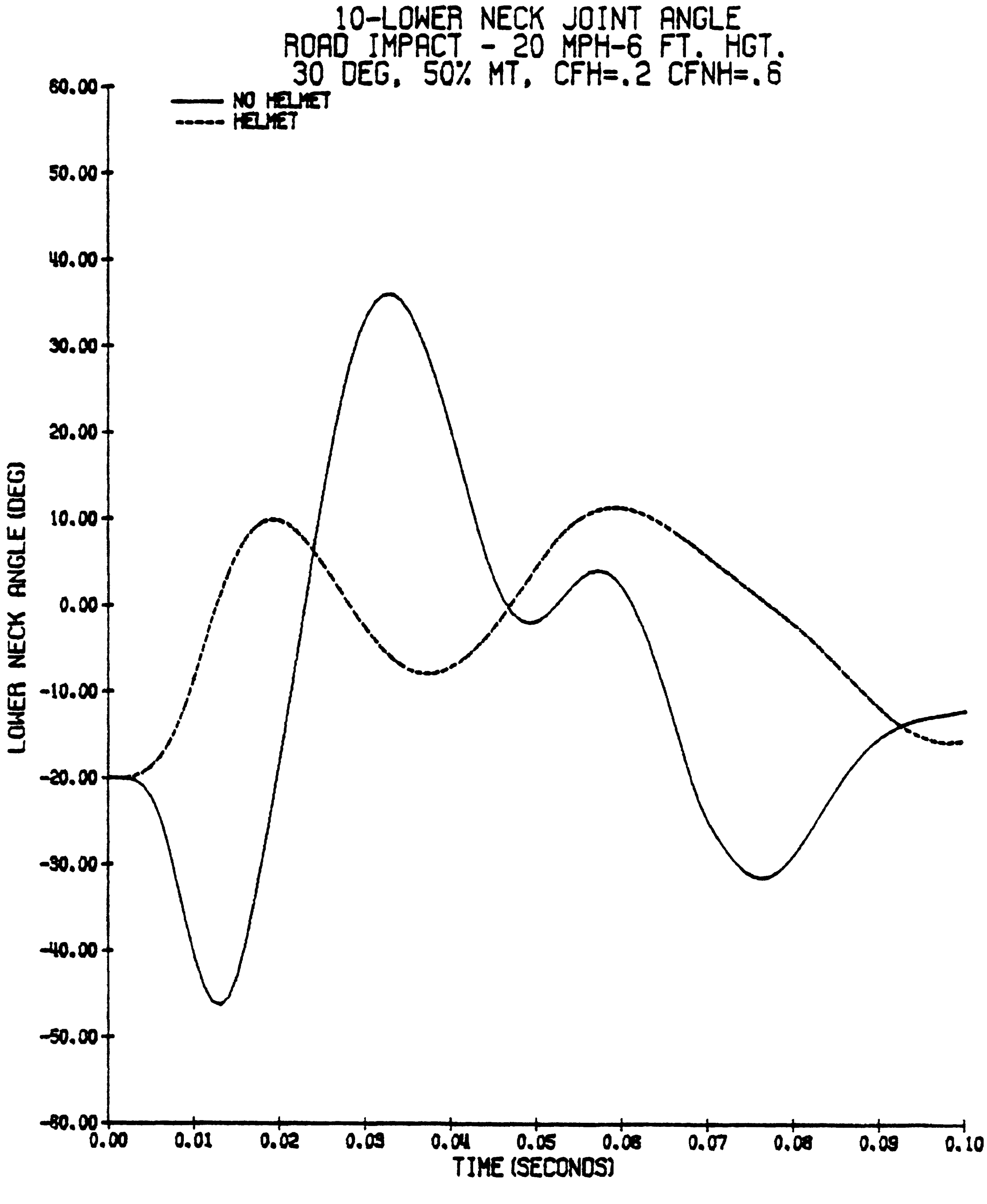

6-LOWER NECK JOINT STOP TORQUE
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG, 50% MT, CFH=.2 CFNH=.6
NO HELMET
HELMET
LOWER NECK TORQUE (IN-LBS)
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
-500.0
-1000.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

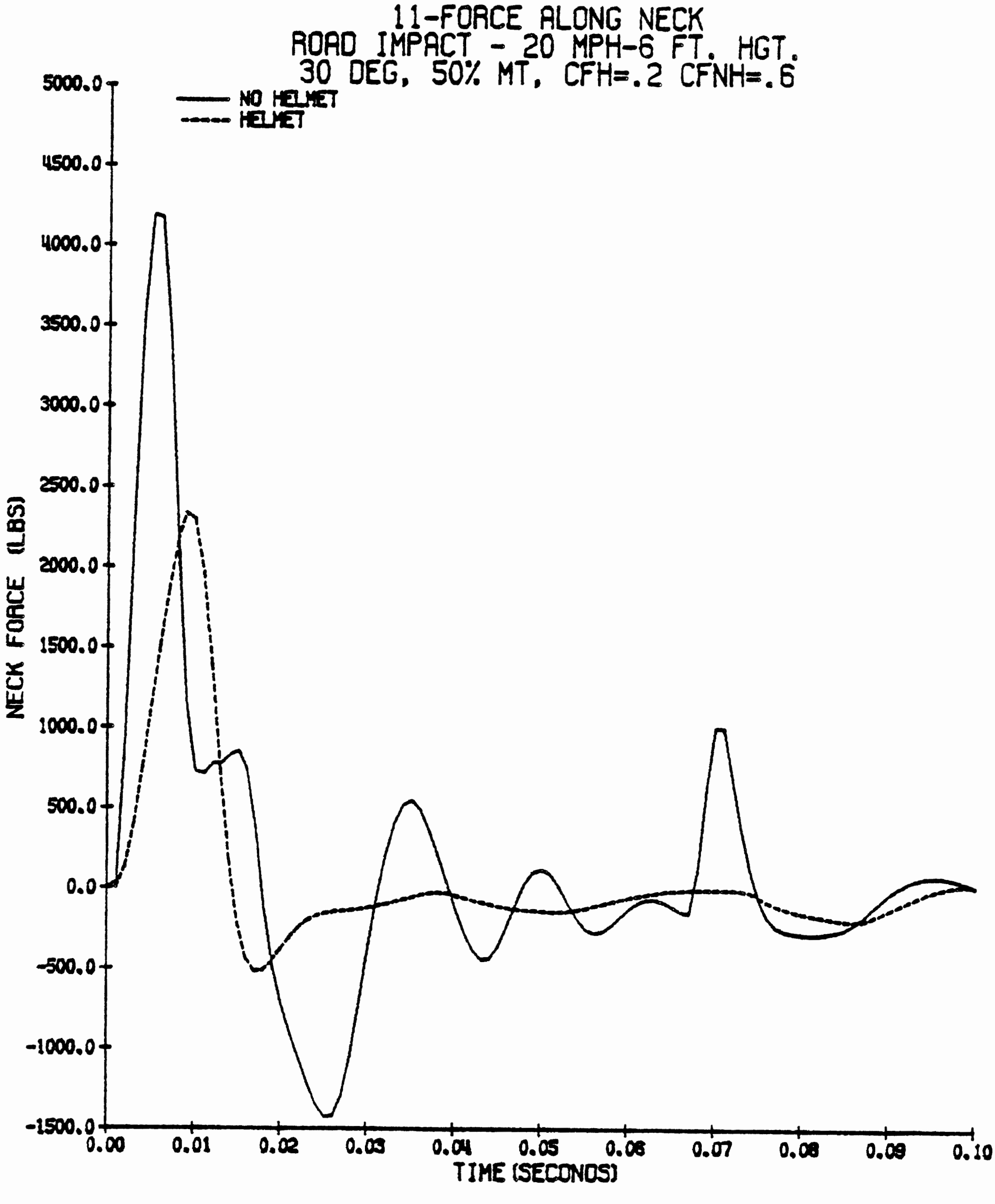

7-NORM. HEAD CONTACT FORCE
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG, 50% MT, CFH=.2 CFNH=.6
NO HELMET
HELMET
NORM. FORCE (LBS.)
5400.0
4900.0
4400.0
3900.0
3400.0
2900.0
2400.0
1900.0
1400.0
900.0
400.0
-100.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

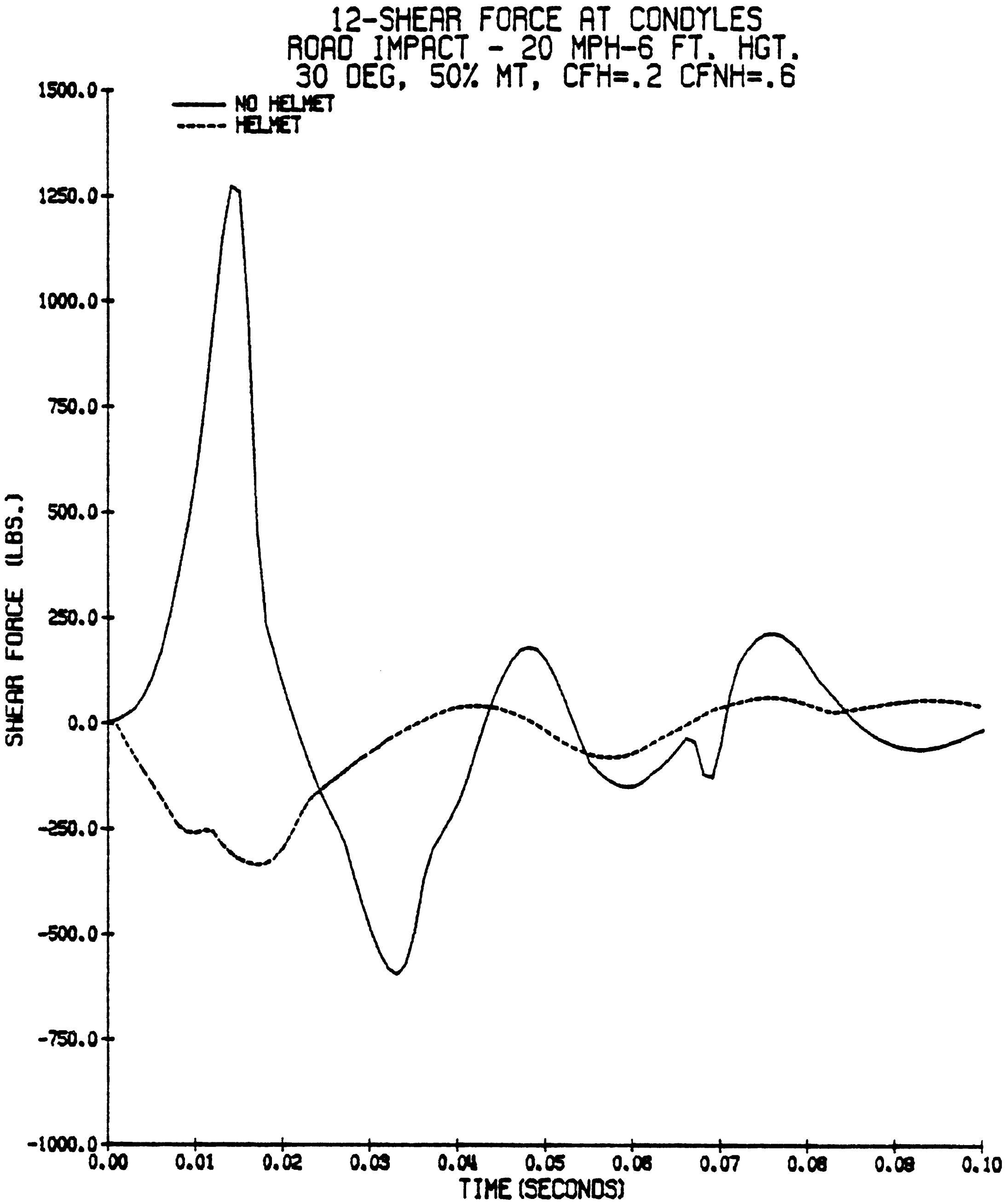


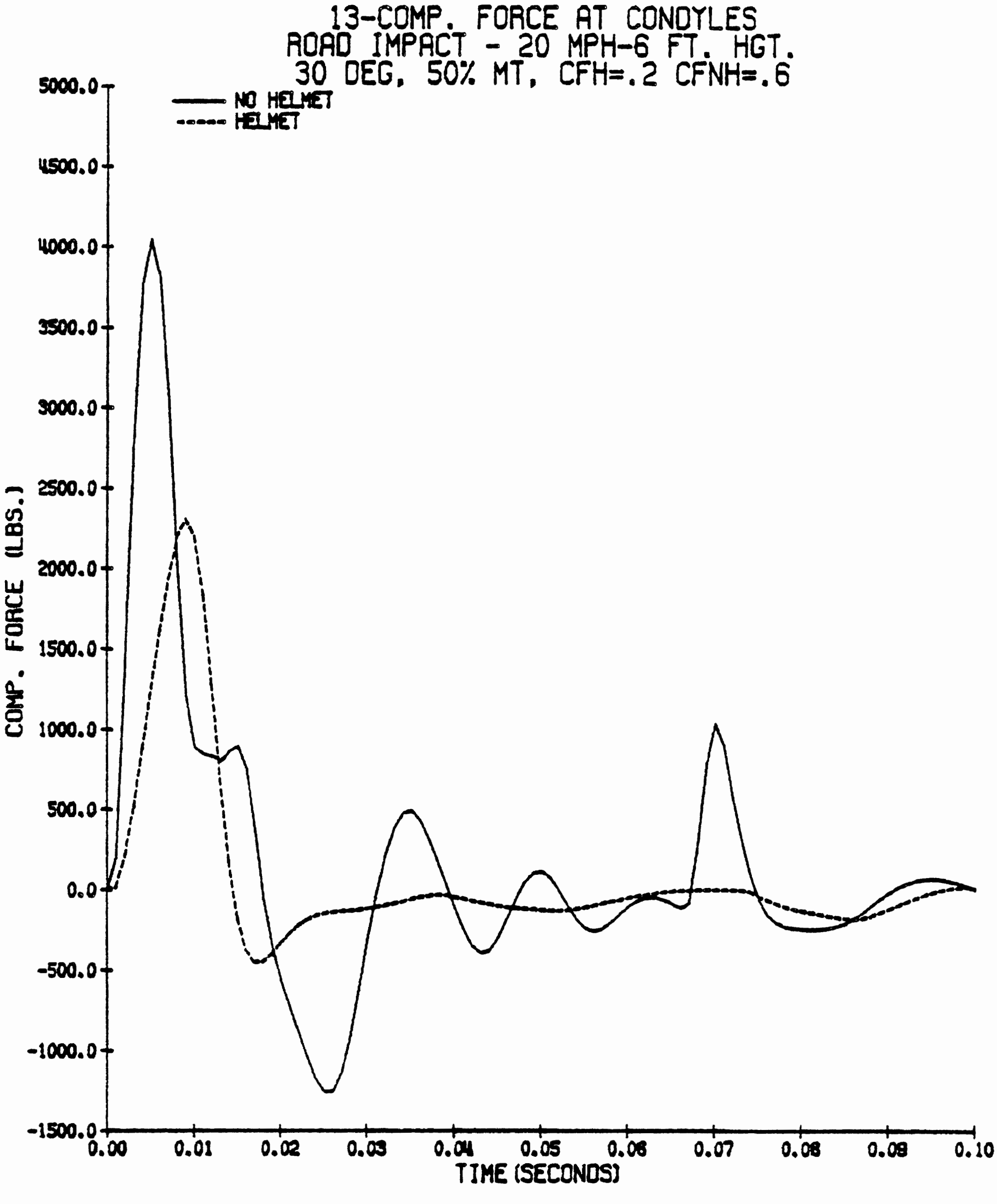
8-TANG. HEAD CONTACT FORCE
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG, 50% MT, CFH=.2 CFNH=.6
NO HELMET
HELMET
TANG. CONTACT FORCE (LBS)
TIME (SECONDS)

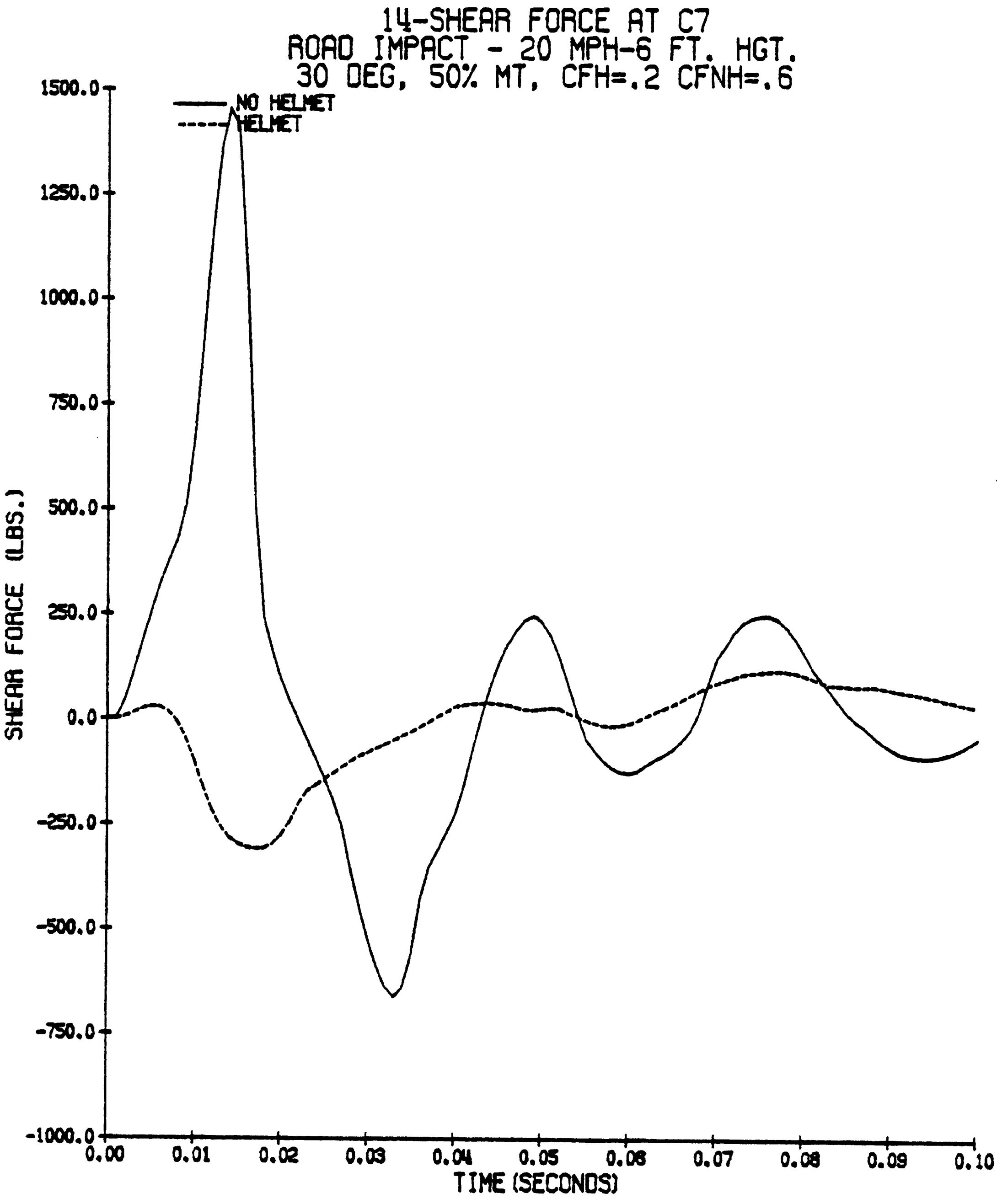

9-UPPER NECK JOINT ANGLE
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG, 50% MT, CFH=.2 CFNH=.6
NO HELMET
HELMET
UPPER NECK ANGLE (DEG)
130.00
120.00
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

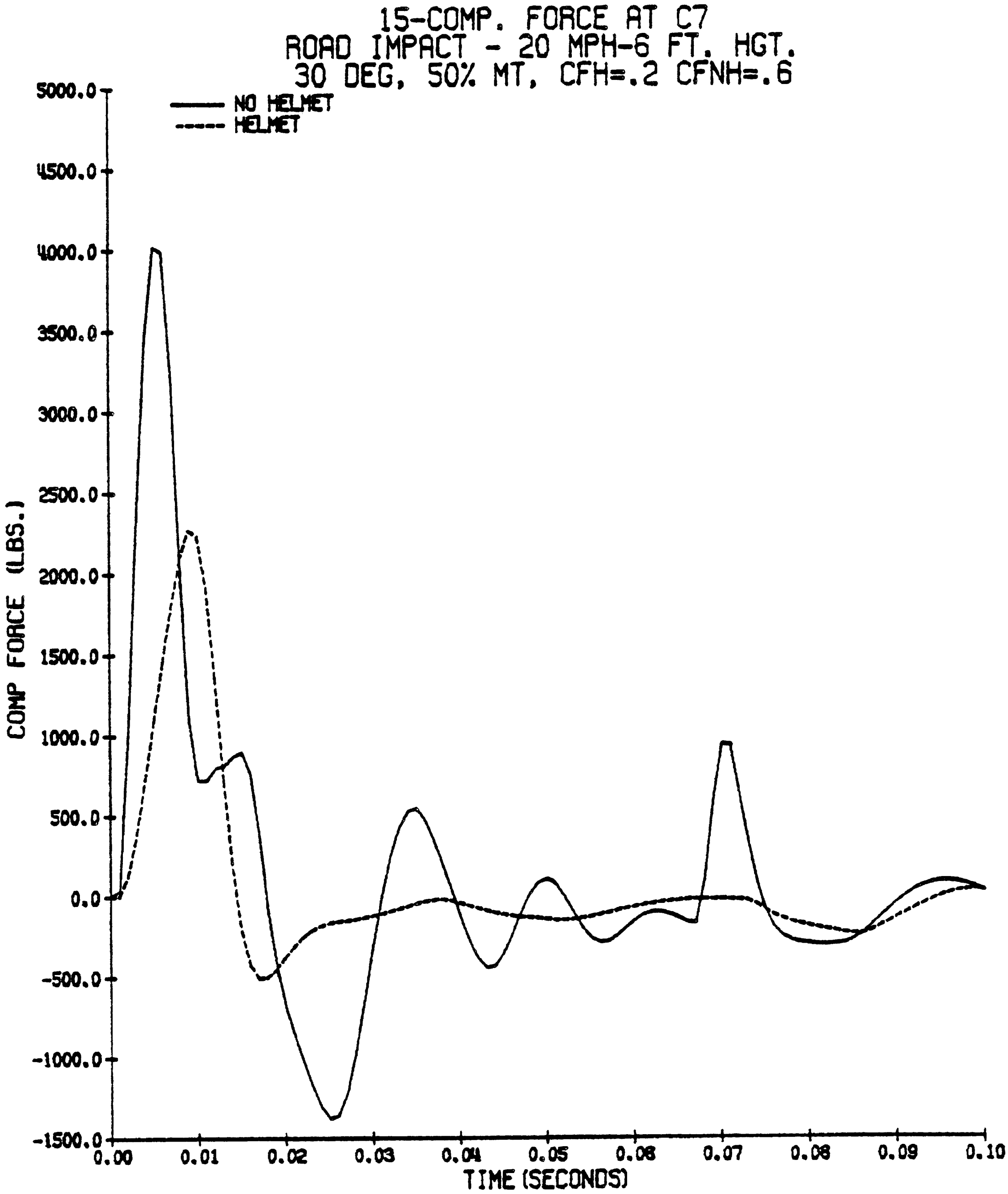

10-LOWER NECK JOINT ANGLE
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG, 50% MT, CFH=.2 CFNH=.6
NO HELMET
HELMET
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
LOWER NECK ANGLE (DEG)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

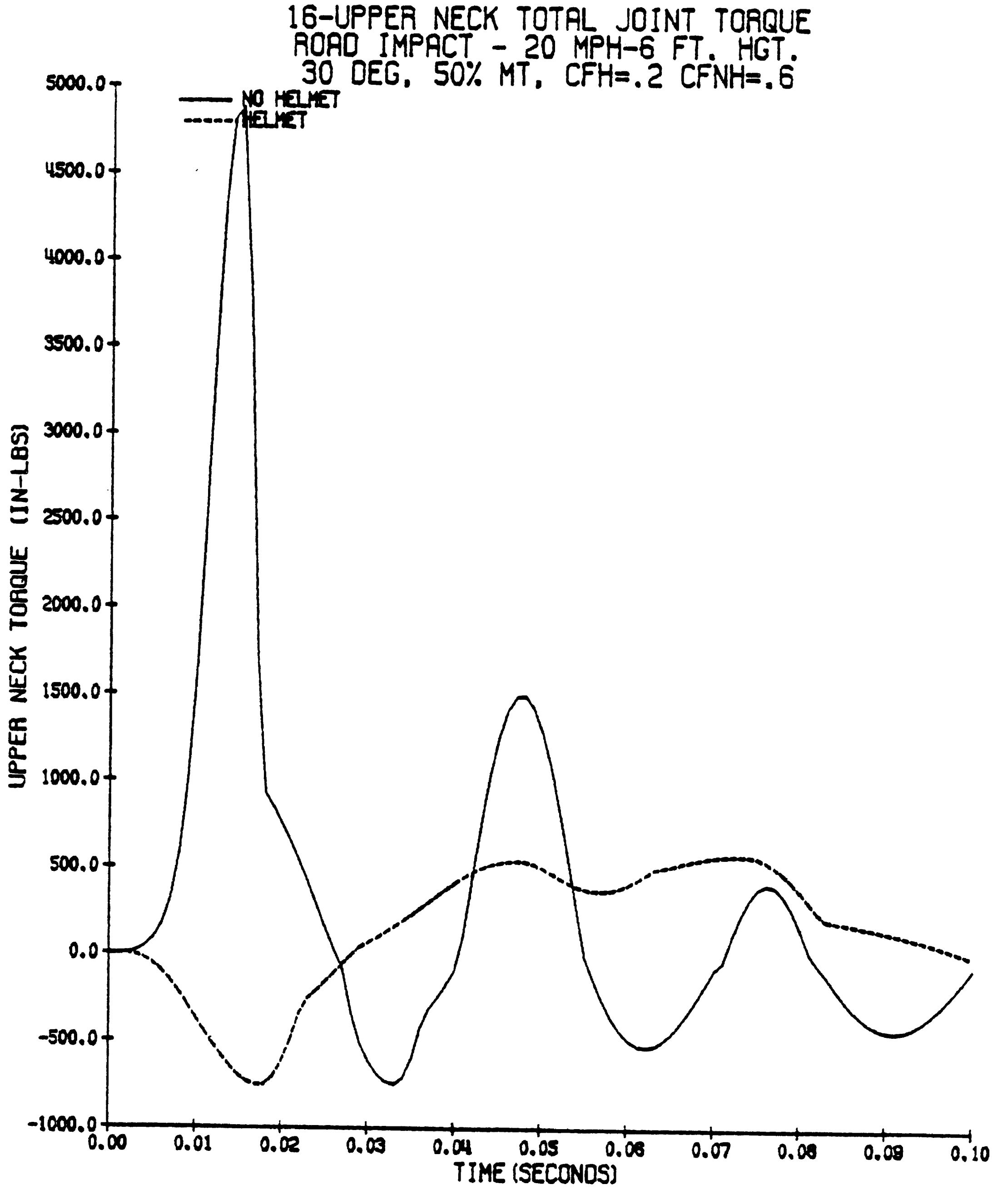

11-FORCE ALONG NECK
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG, 50% MT, CFH=.2 CFNH=.6
NO HELMET
HELMET
NECK FORCE (LBS)
5000.0
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
-500.0
-1000.0
-1500.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

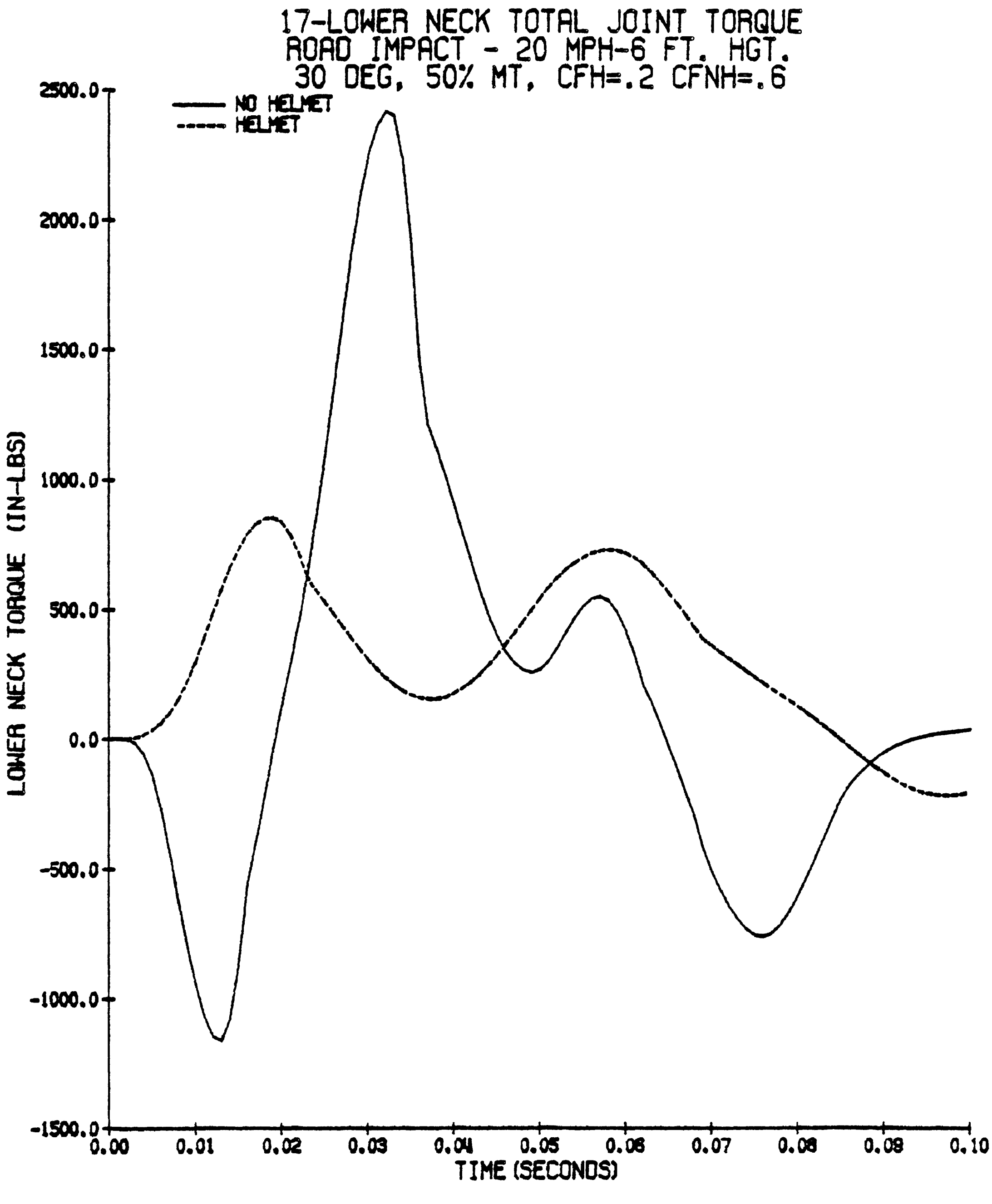

12-SHEAR FORCE AT CONDYLES
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG, 50% MT, CFH=.2 CFNH=.6
NO HELMET
HELMET
SHEAR FORCE (LBS.)
1500.0
1250.0
1000.0
750.0
500.0
250.0
0.0
-250.0
-500.0
-750.0
-1000.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)


13-COMP. FORCE AT CONDYLES
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG. 50% MT. CFH=.2 CFNH=.6
NO HELMET
HELMET
COMP. FORCE (LBS.)
5000.0
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
-500.0
-1000.0
-1500.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

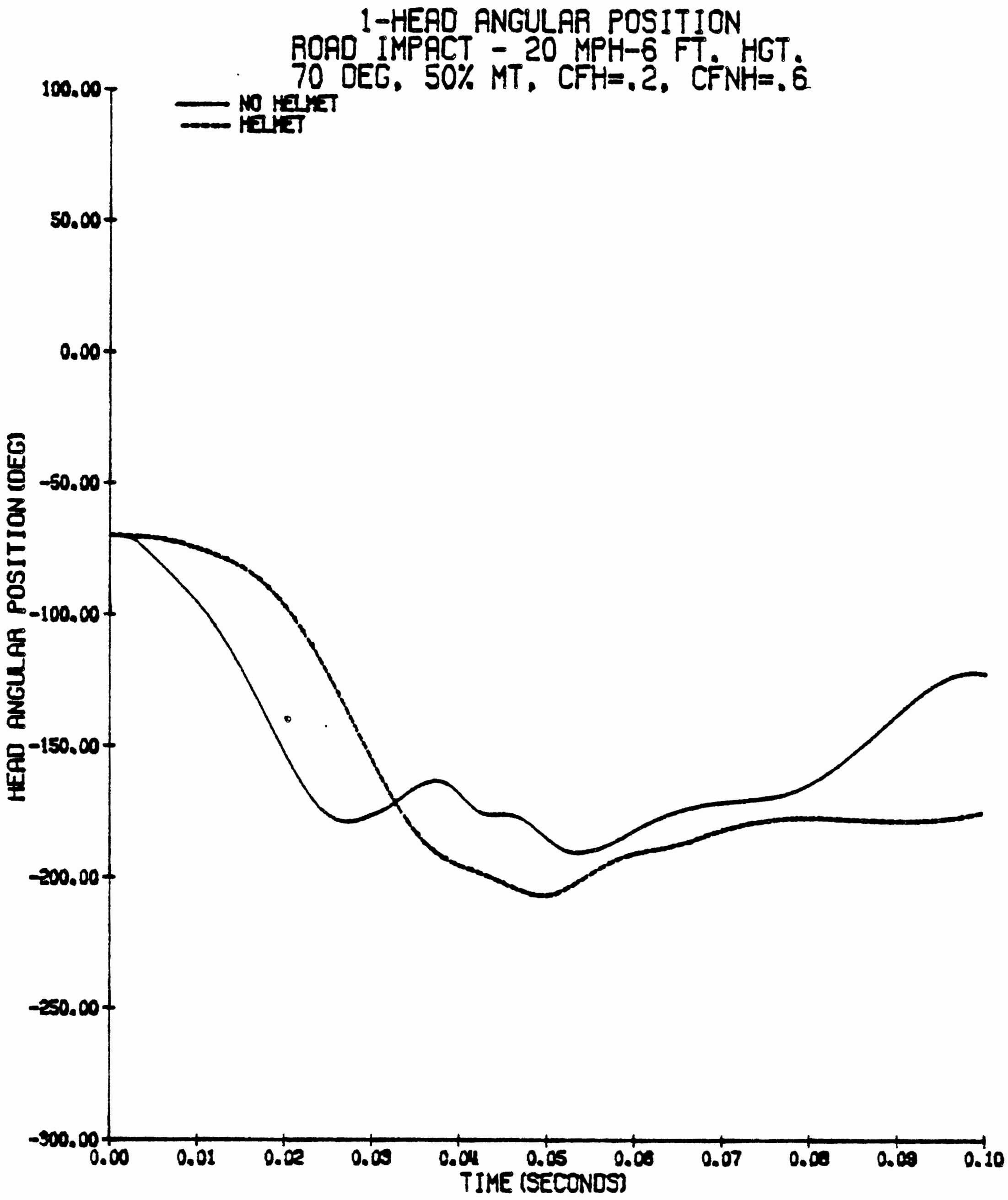

14-SHEAR FORCE AT C7
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG, 50% MT, CFH=.2 CFNH=.6
NO HELMET
HELMET
SHEAR FORCE (LBS.)
1500.0
1250.0
1000.0
750.0
500.0
250.0
0.0
-250.0
-500.0
-750.0
-1000.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

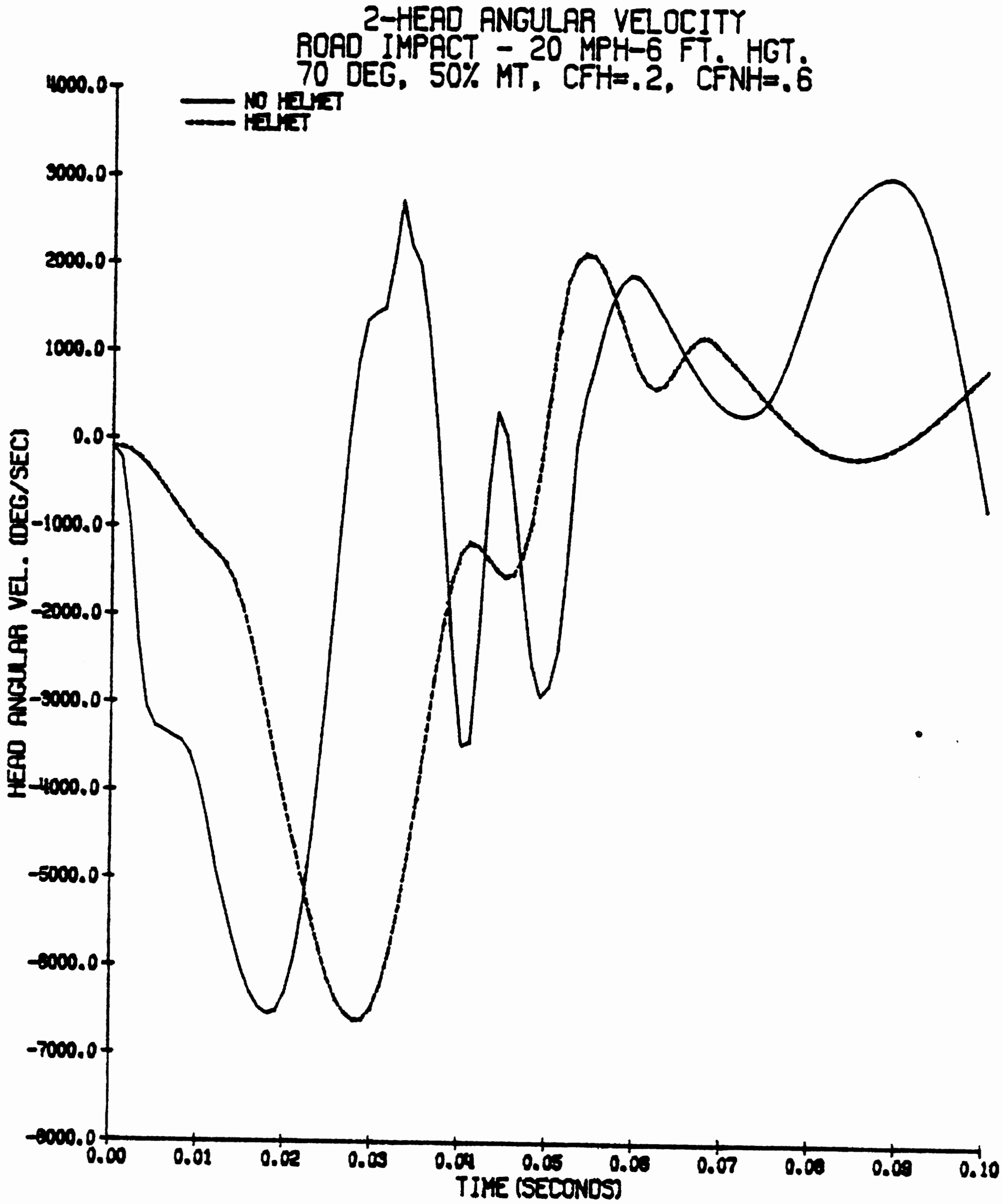

15-COMP. FORCE AT C7
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG, 50% MT, CFH=.2 CFNH=.6
NO HELMET
HELMET
COMP FORCE (LBS.)
5000.0
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
-500.0
-1000.0
-1500.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

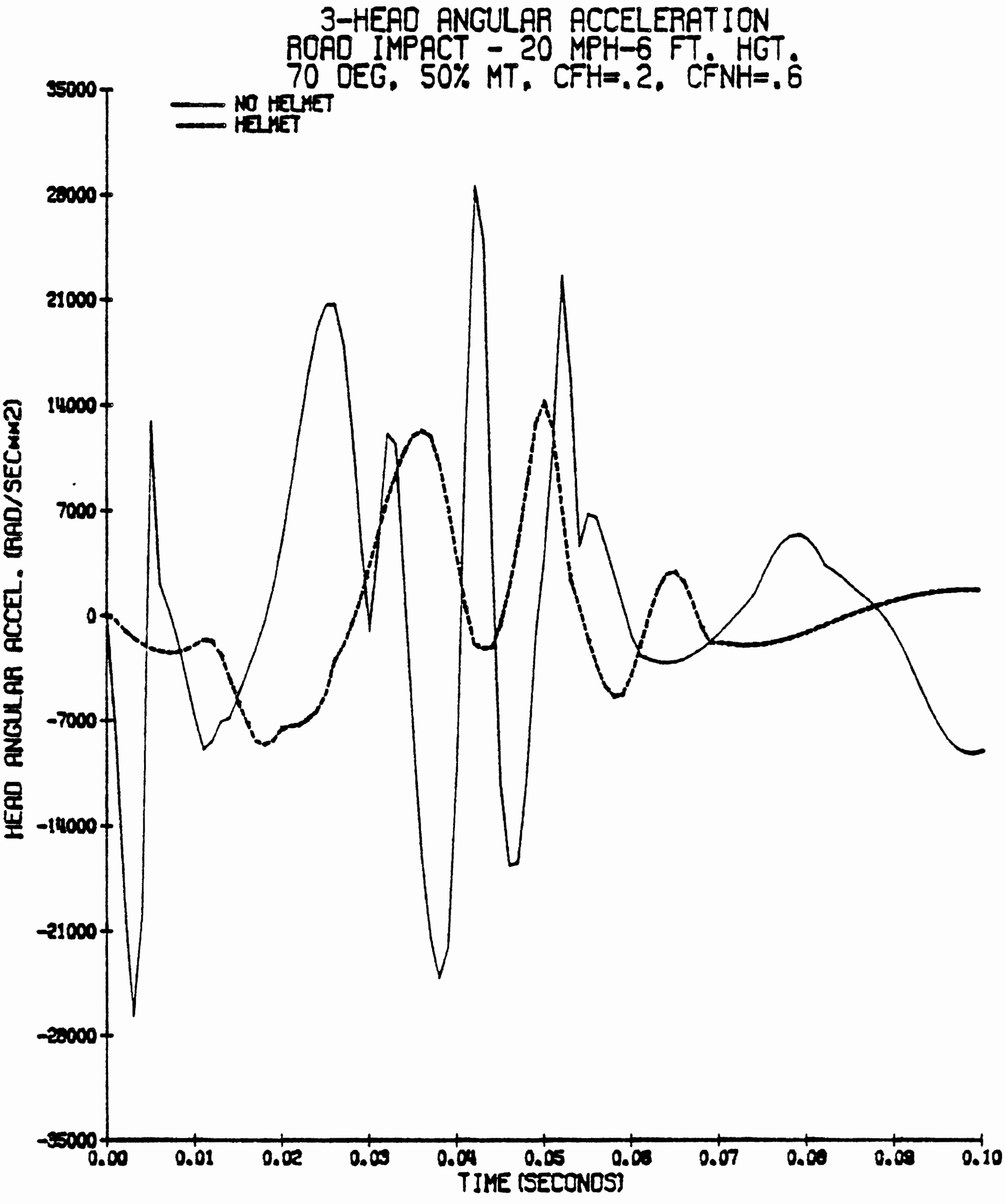

16-UPPER NECK TOTAL JOINT TORQUE
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG. 50% MT. CFH=.2 CFNH=.6
NO HELMET
HELMET
UPPER NECK TORQUE (IN-LBS)
5000.0
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
-500.0
-1000.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

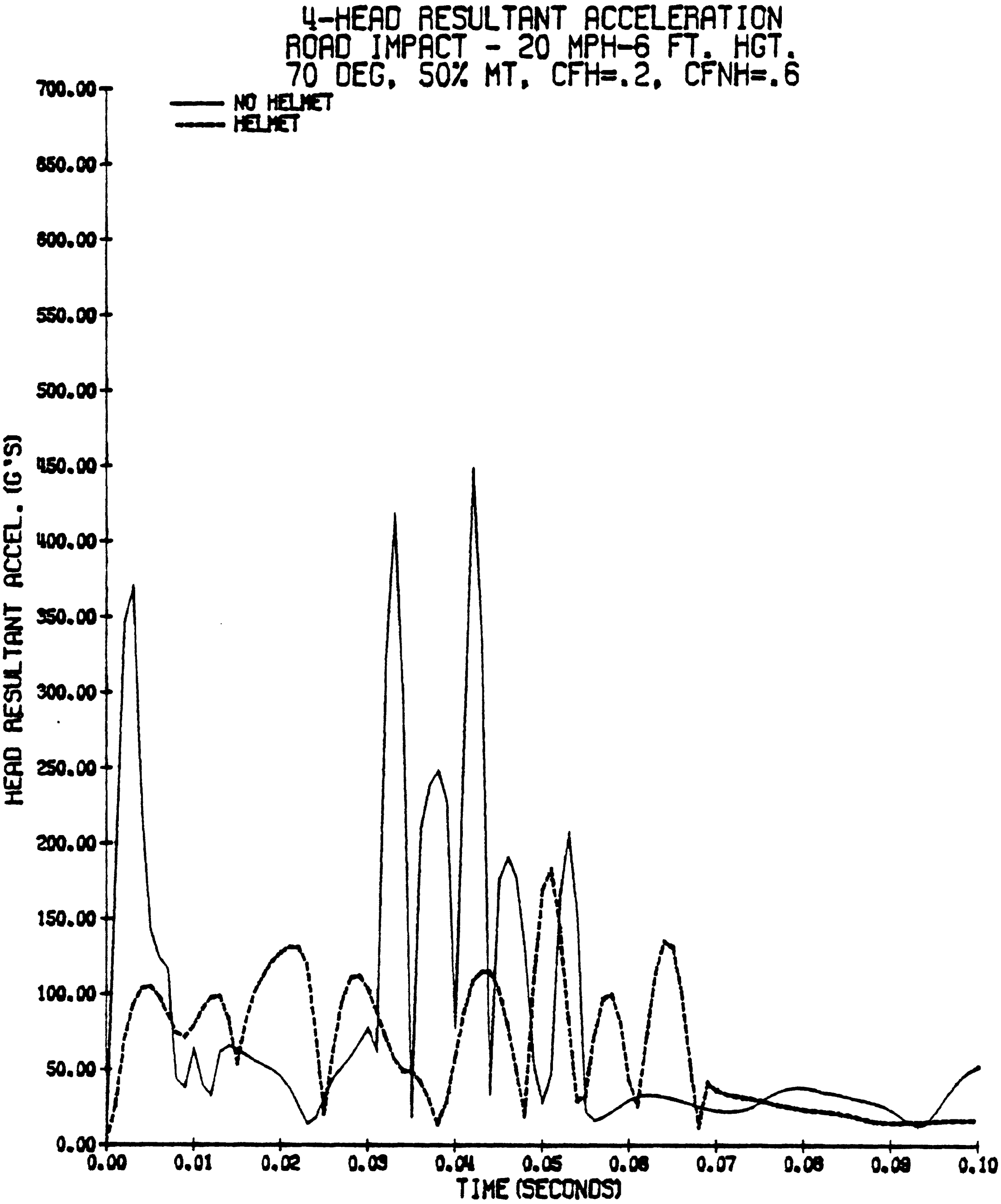


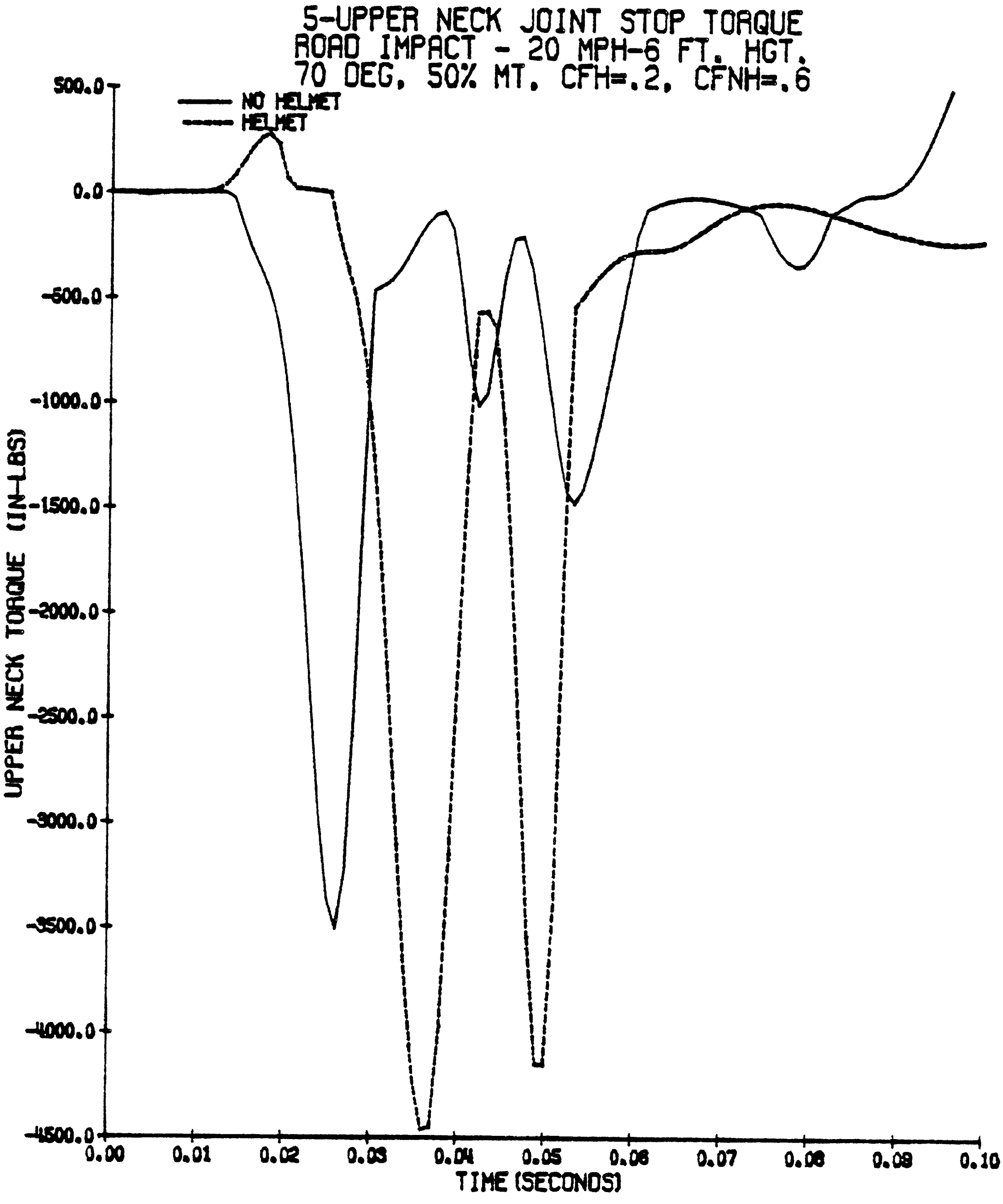
17-LOWER NECK TOTAL JOINT TORQUE
ROAD IMPACT - 20 MPH-6 FT. HGT.
30 DEG, 50% MT, CFH=.2 CFNH=.6
NO HELMET
HELMET
LOWER NECK TORQUE (IN-LBS)
2500.0
2000.0
1500.0
1000.0
500.0
0.0
-500.0
-1000.0
-1500.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

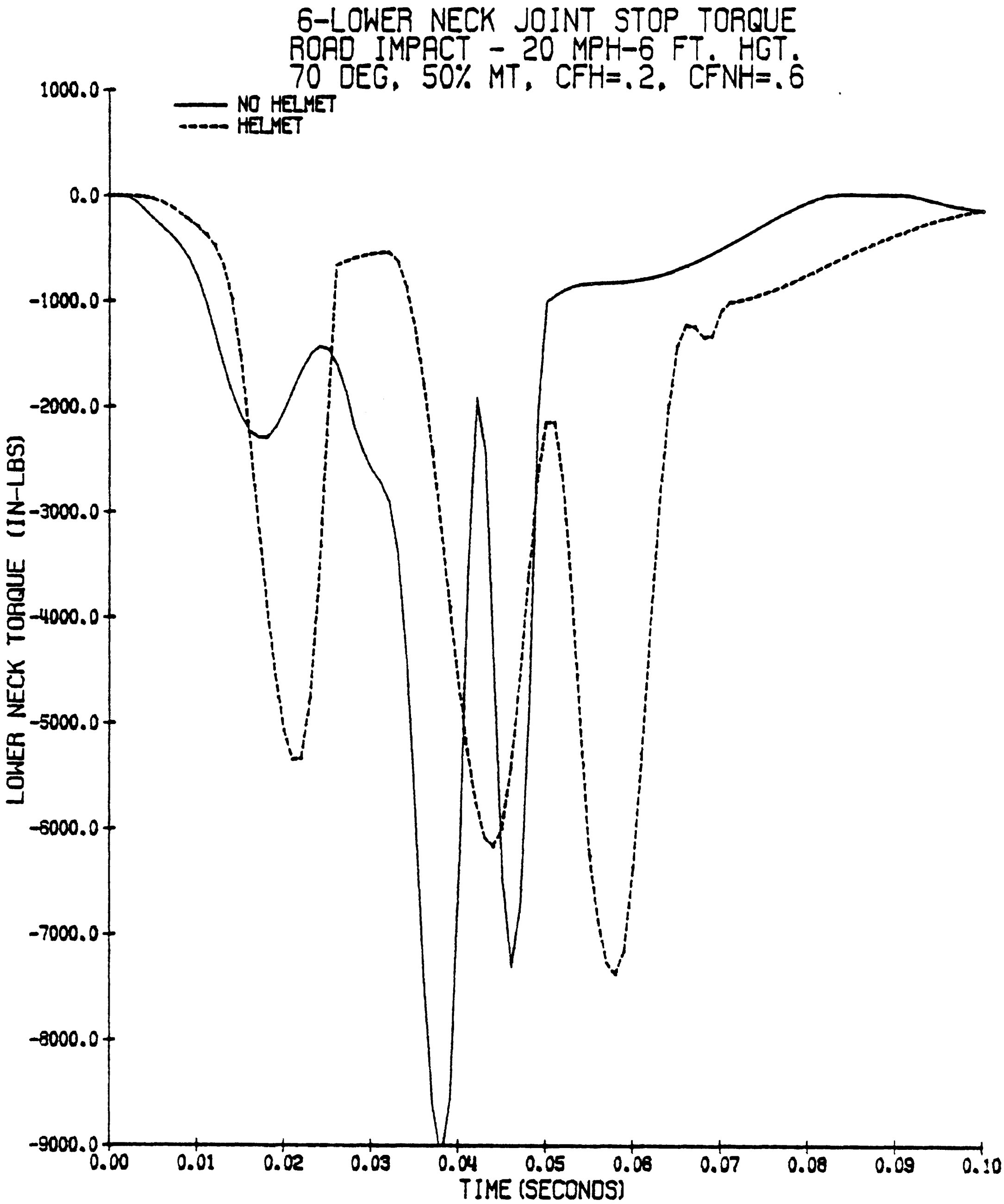

1-HEAD ANGULAR POSITION
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG, 50% MT, CFH=.2, CFNH=.6
NO HELMET
HELMET
HEAD ANGULAR POSITION (DEG)
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

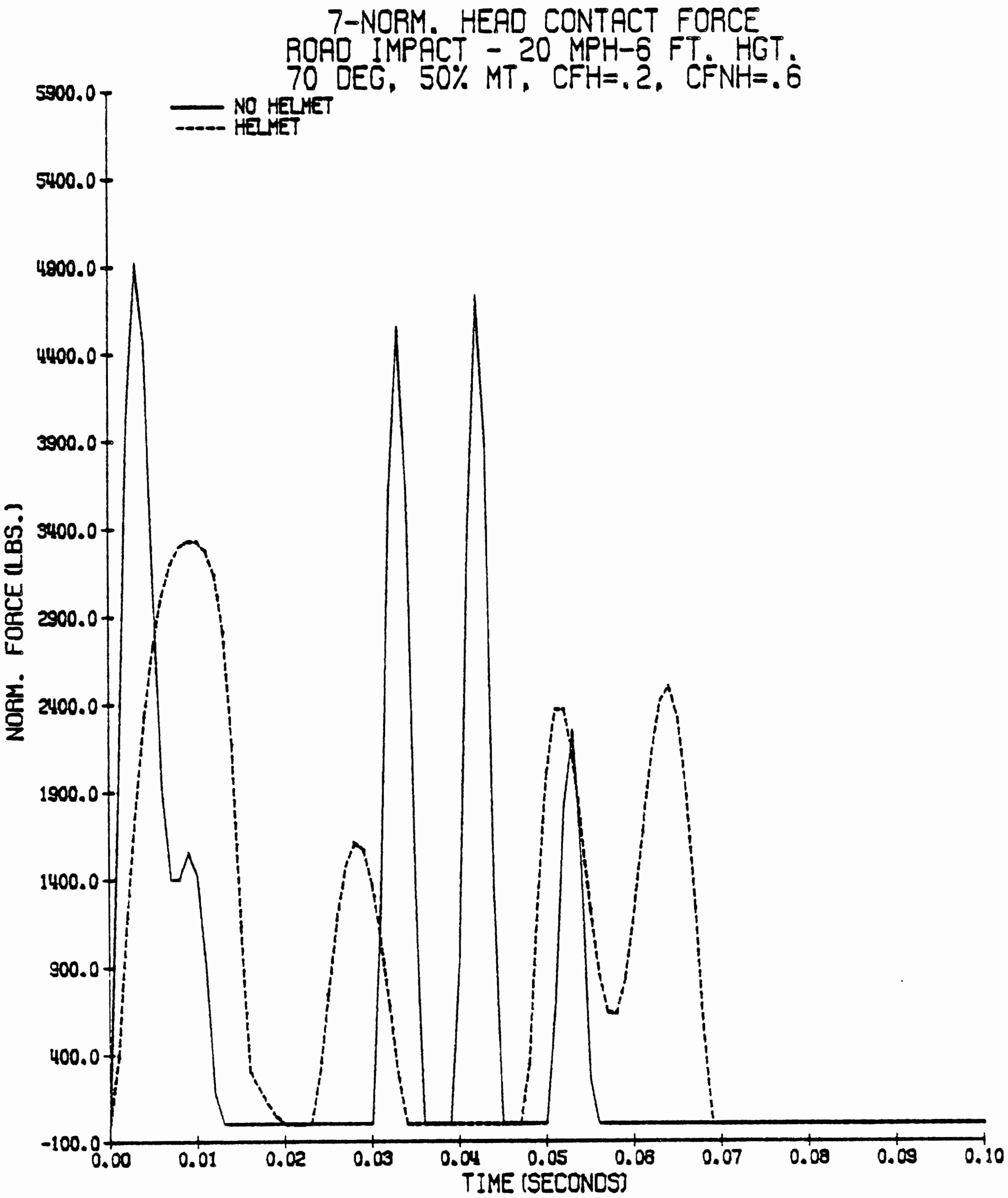

2-HEAD ANGULAR VELOCITY
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG, 50% MT, CFH=.2, CFNH=.6
NO HELMET
HELMET
HEAD ANGULAR VEL. (DEG/SEC)
4000.0
3000.0
2000.0
1000.0
0.0
-1000.0
-2000.0
-3000.0
-4000.0
-5000.0
-6000.0
-7000.0
-8000.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

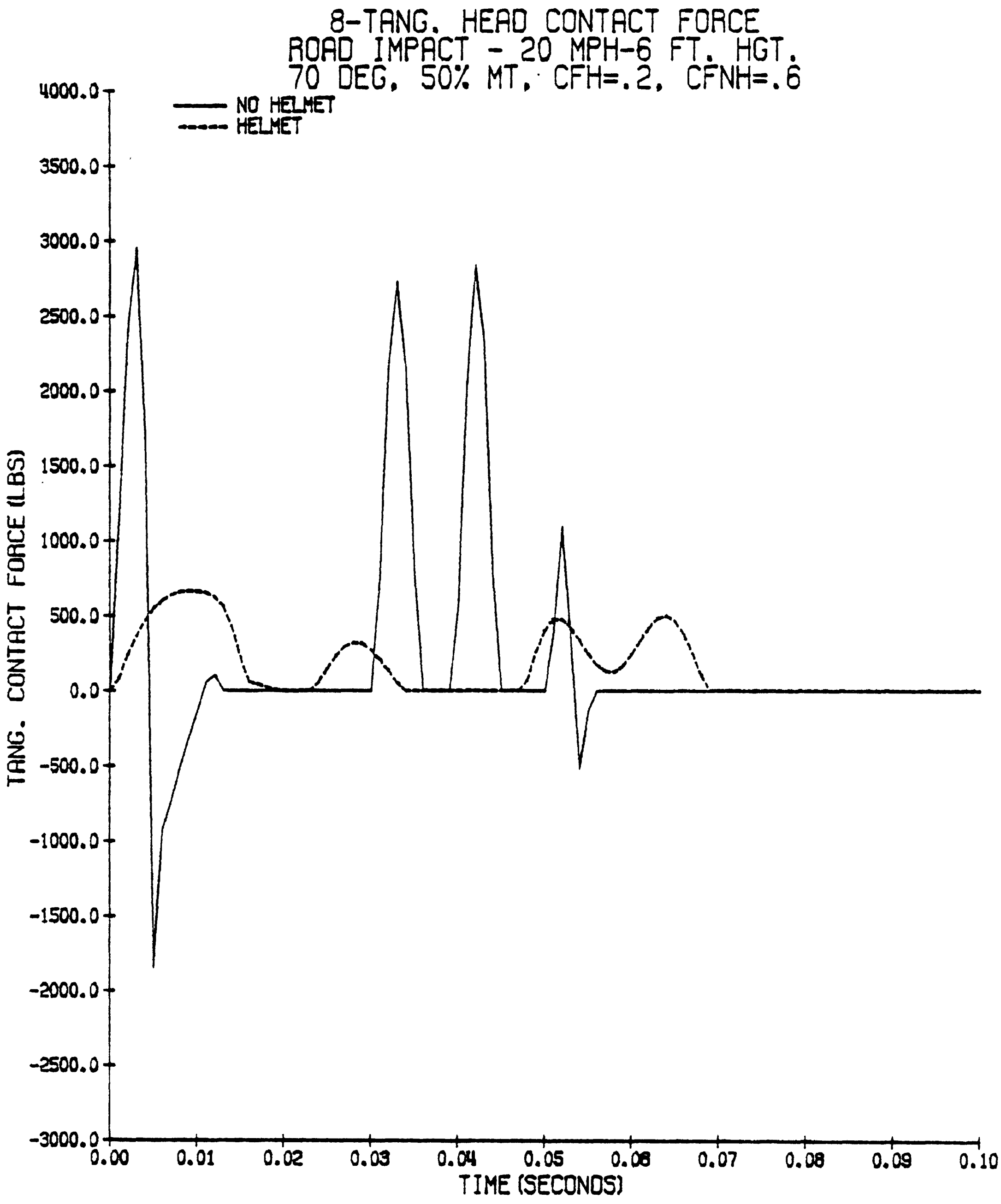

3-HEAD ANGULAR ACCELERATION
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG, 50% MT, CFH=.2, CFNH=.6
NO HELMET
HELMET
HEAD ANGULAR ACCEL. (RAD/SEC**2)
35000
28000
21000
14000
7000
0
-7000
-14000
-21000
-28000
-35000
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

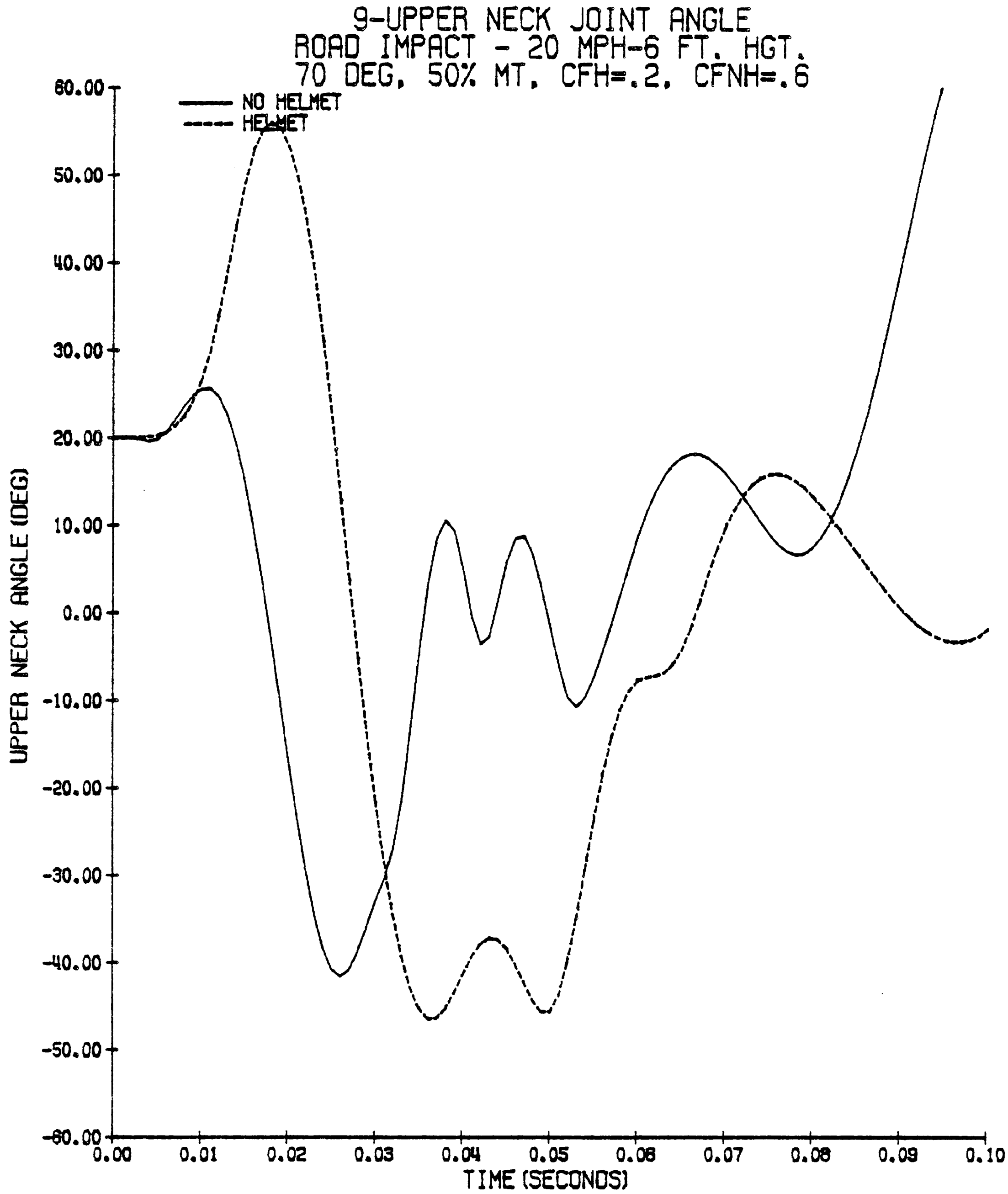

4-HEAD RESULTANT ACCELERATION
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG, 50% MT, CFH=.2, CFNH=.6
NO HELMET
HELMET
HEAD RESULTANT ACCEL. (G'S)
TIME (SECONDS)
700.00
650.00
600.00
550.00
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10

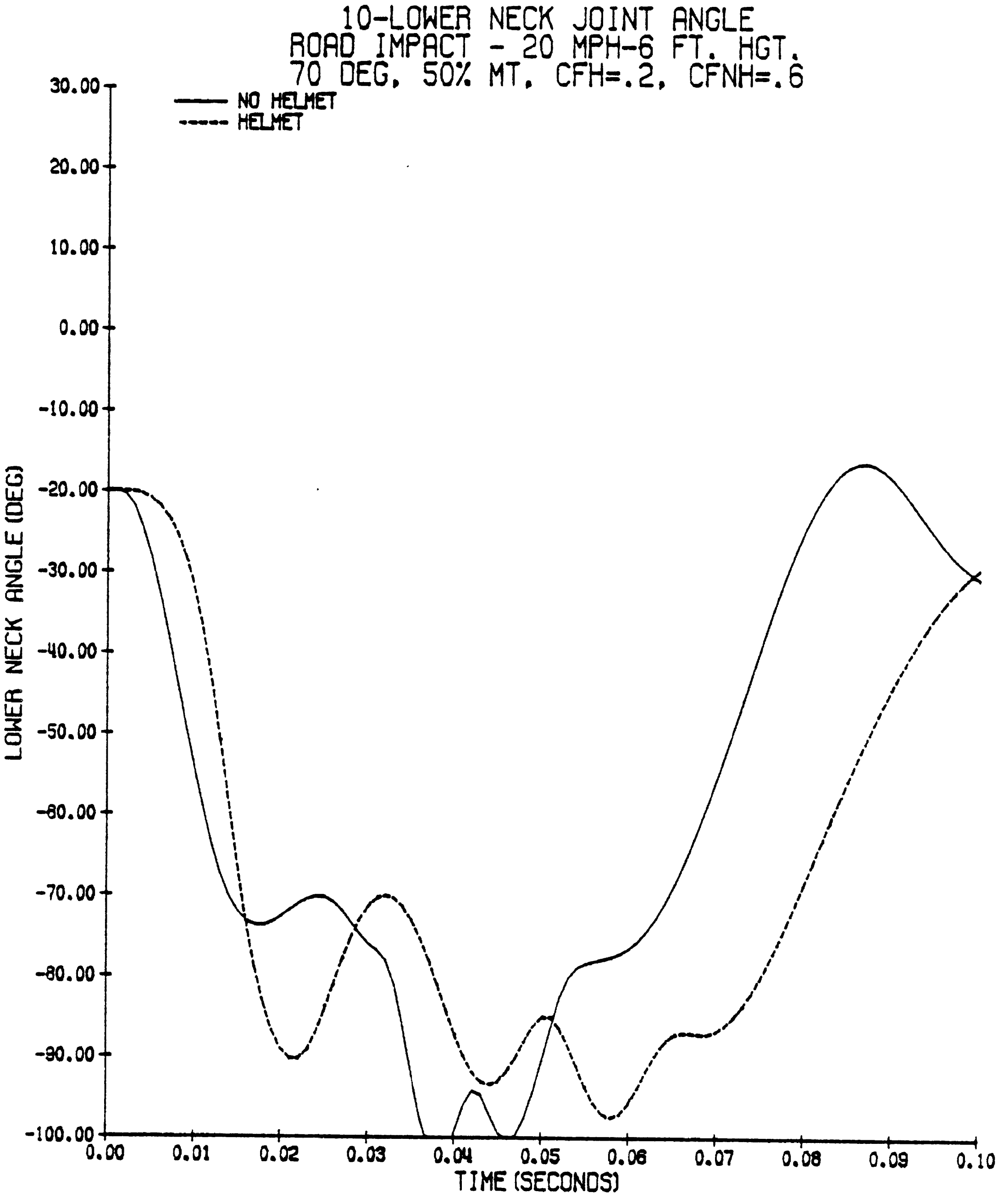

5-UPPER NECK JOINT STOP TORQUE
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG. 50% MT. CFH=.2. CFNH=.6
NO HELMET
HELMET
500.0
0.0
-500.0
-1000.0
-1500.0
-2000.0
-2500.0
-3000.0
-3500.0
-4000.0
-4500.0
UPPER NECK TORQUE (IN-LBS)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)


6-LOWER NECK JOINT STOP TORQUE
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG, 50% MT, CFH=.2, CFNH=.6
NO HELMET
HELMET
LOWER NECK TORQUE (IN-LBS)
1000.0
0.0
-1000.0
-2000.0
-3000.0
-4000.0
-5000.0
-6000.0
-7000.0
-8000.0
-9000.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

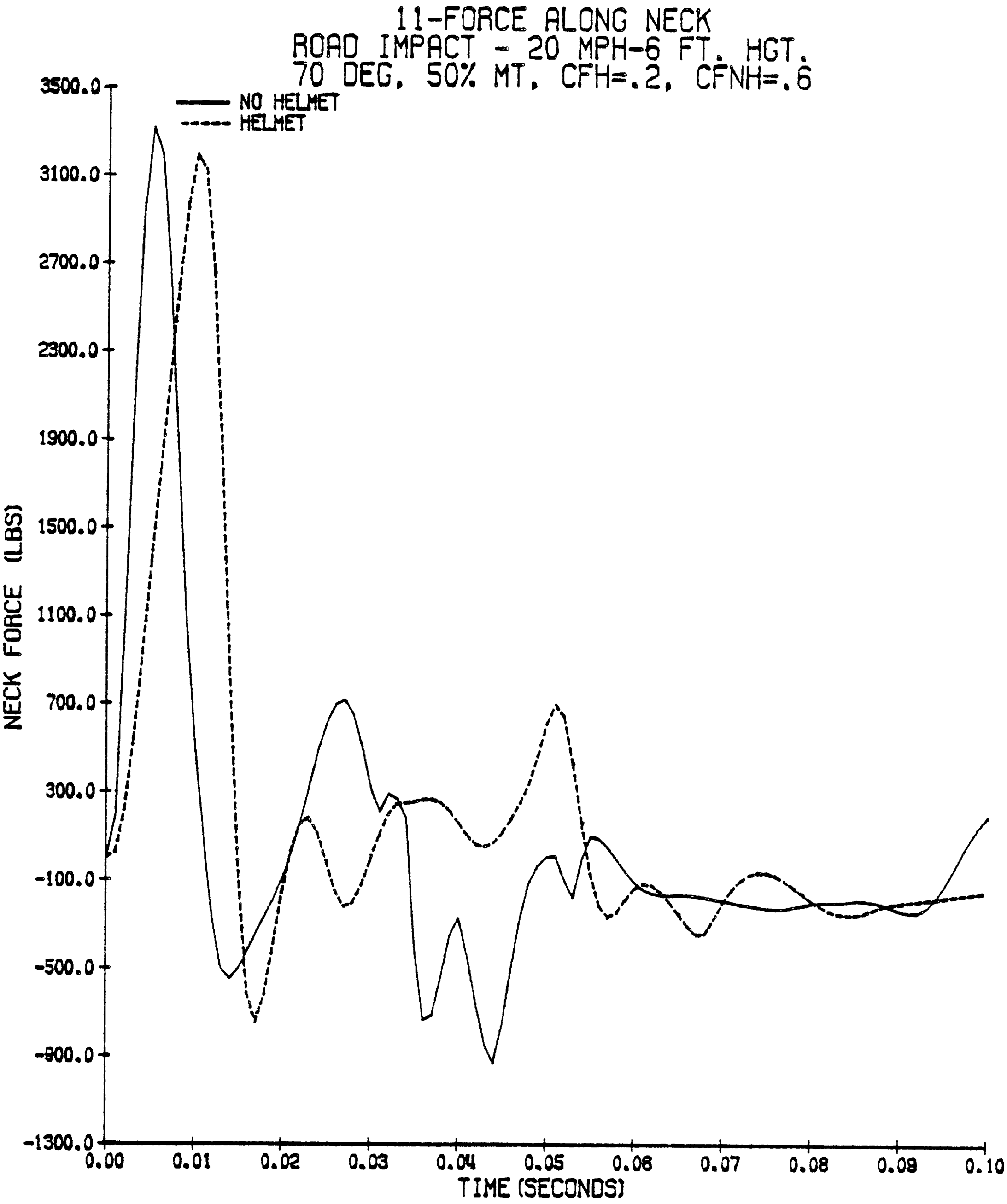

7-NORM. HEAD CONTACT FORCE
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG, 50% MT, CFH=.2, CFNH=.6
NO HELMET
HELMET
NORM. FORCE (LBS.)
5900.0
5400.0
4900.0
4400.0
3900.0
3400.0
2900.0
2400.0
1900.0
1400.0
900.0
400.0
-100.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

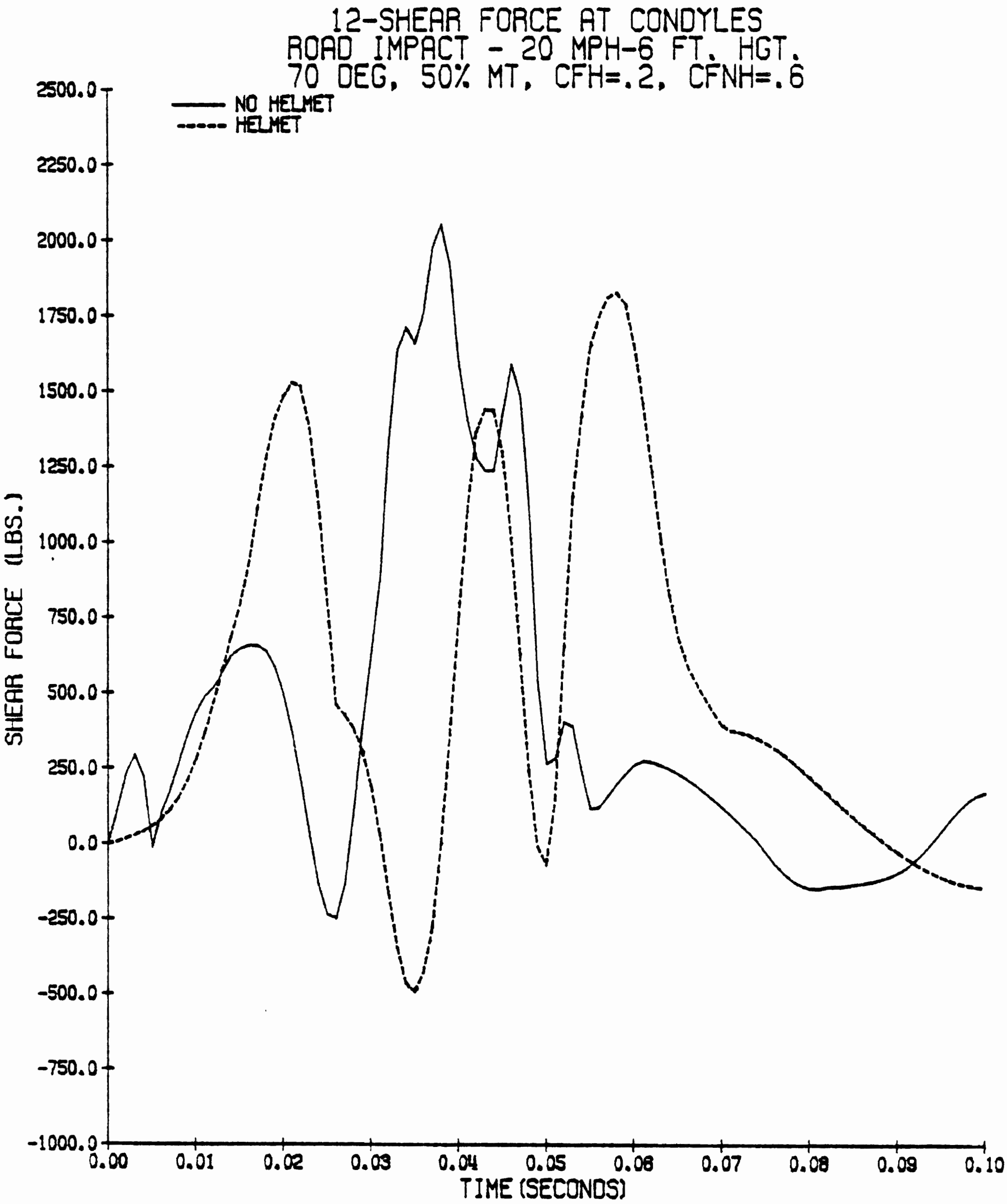

8-TANG. HEAD CONTACT FORCE
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG. 50% MT. CFH=.2, CFNH=.6
NO HELMET
HELMET
TANG. CONTACT FORCE (LBS)
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
-500.0
-1000.0
-1500.0
-2000.0
-2500.0
-3000.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

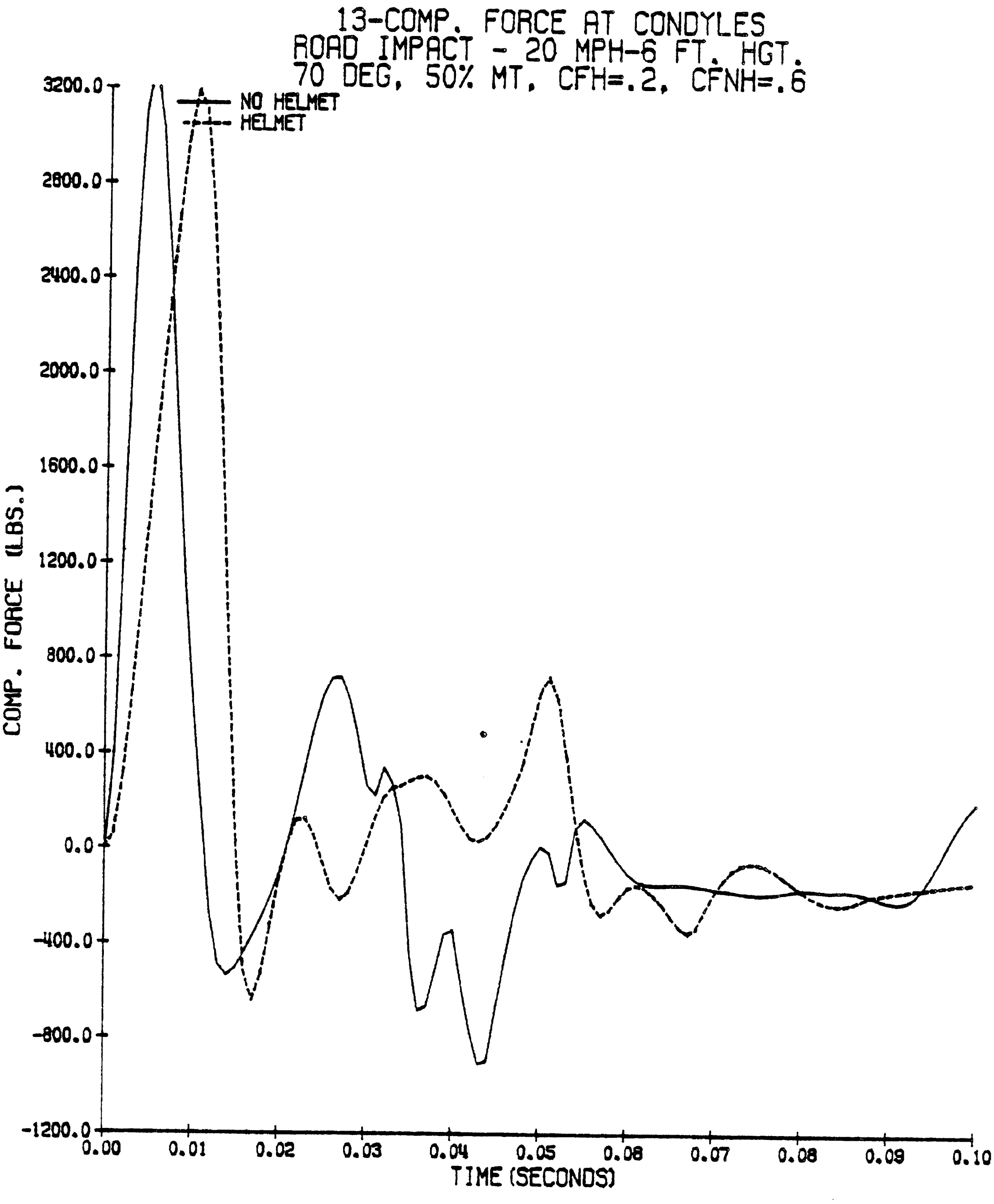

9-UPPER NECK JOINT ANGLE
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG, 50% MT, CFH=.2, CFNH=.6
NO HELMET
HELMET
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
UPPER NECK ANGLE (DEG)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)



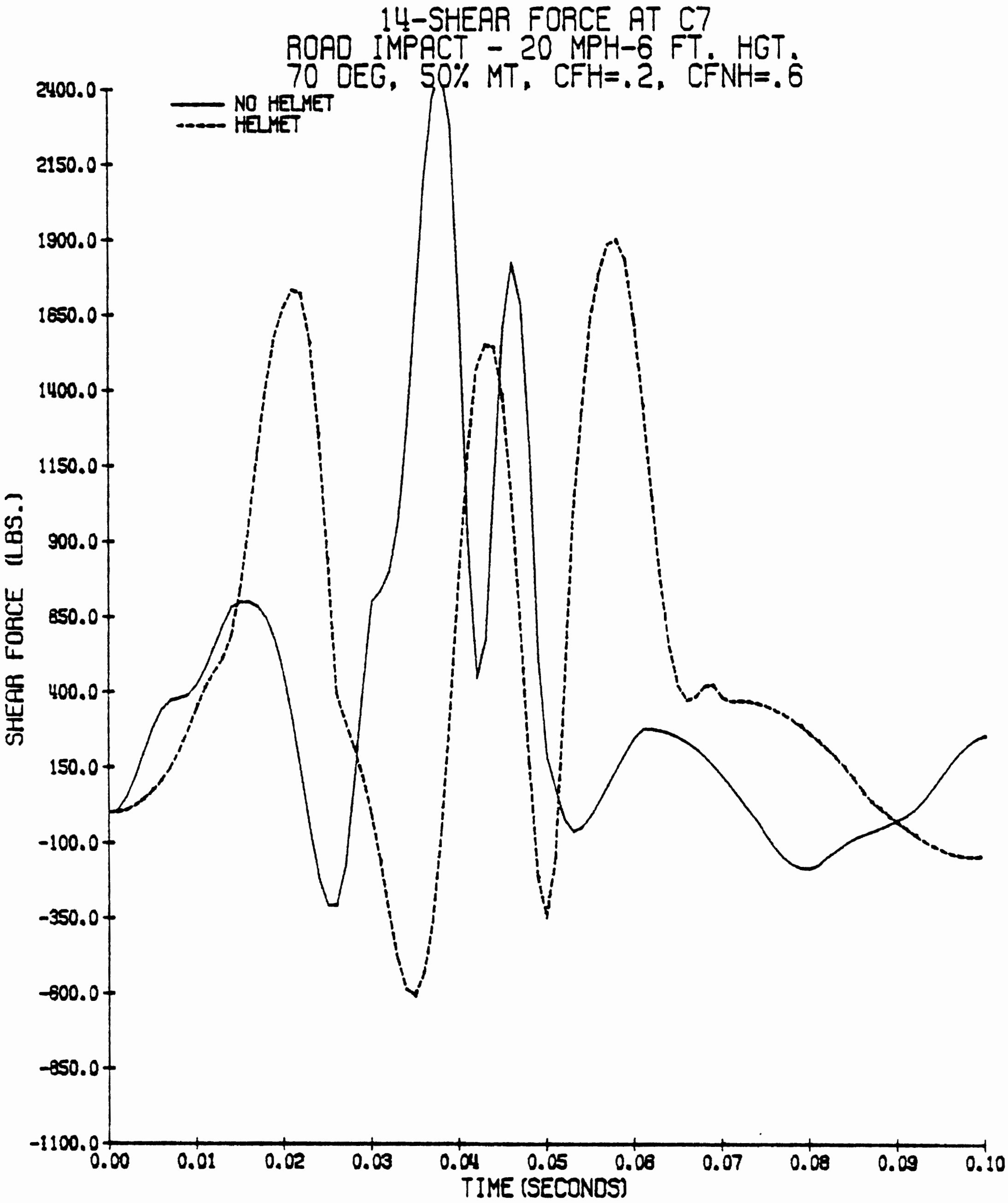
10-LOWER NECK JOINT ANGLE
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG. 50% MT. CFH=.2. CFNH=.6
NO HELMET
HELMET
LOWER NECK ANGLE (DEG)
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
-80.00
-90.00
-100.00
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

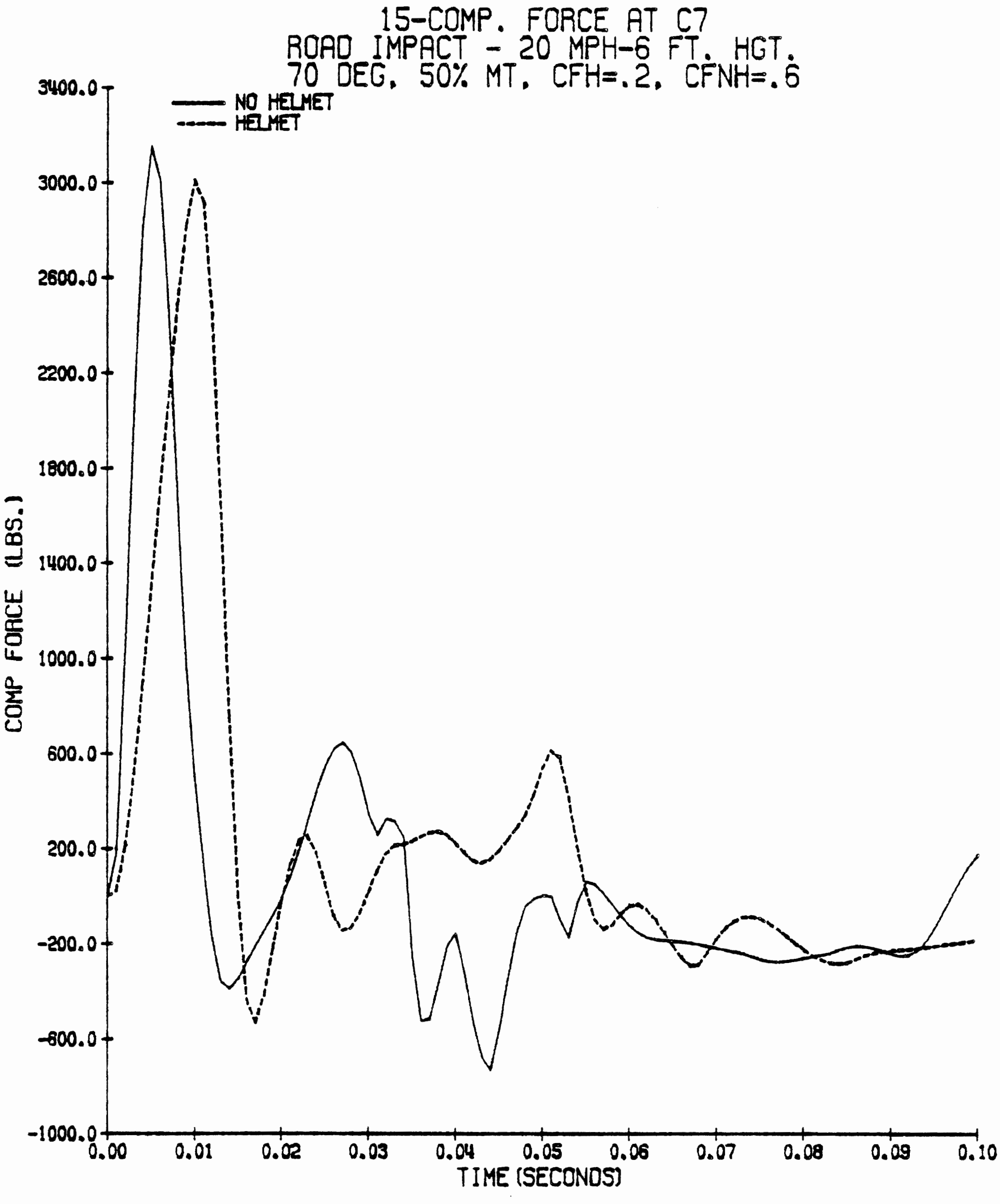

11-FORCE ALONG NECK
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG. 50% MT. CFH=.2. CFNH=.6
NO HELMET
HELMET
3500.0
3100.0
2700.0
2300.0
1900.0
1500.0
1100.0
700.0
300.0
-100.0
-500.0
-900.0
-1300.0
NECK FORCE (LBS)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

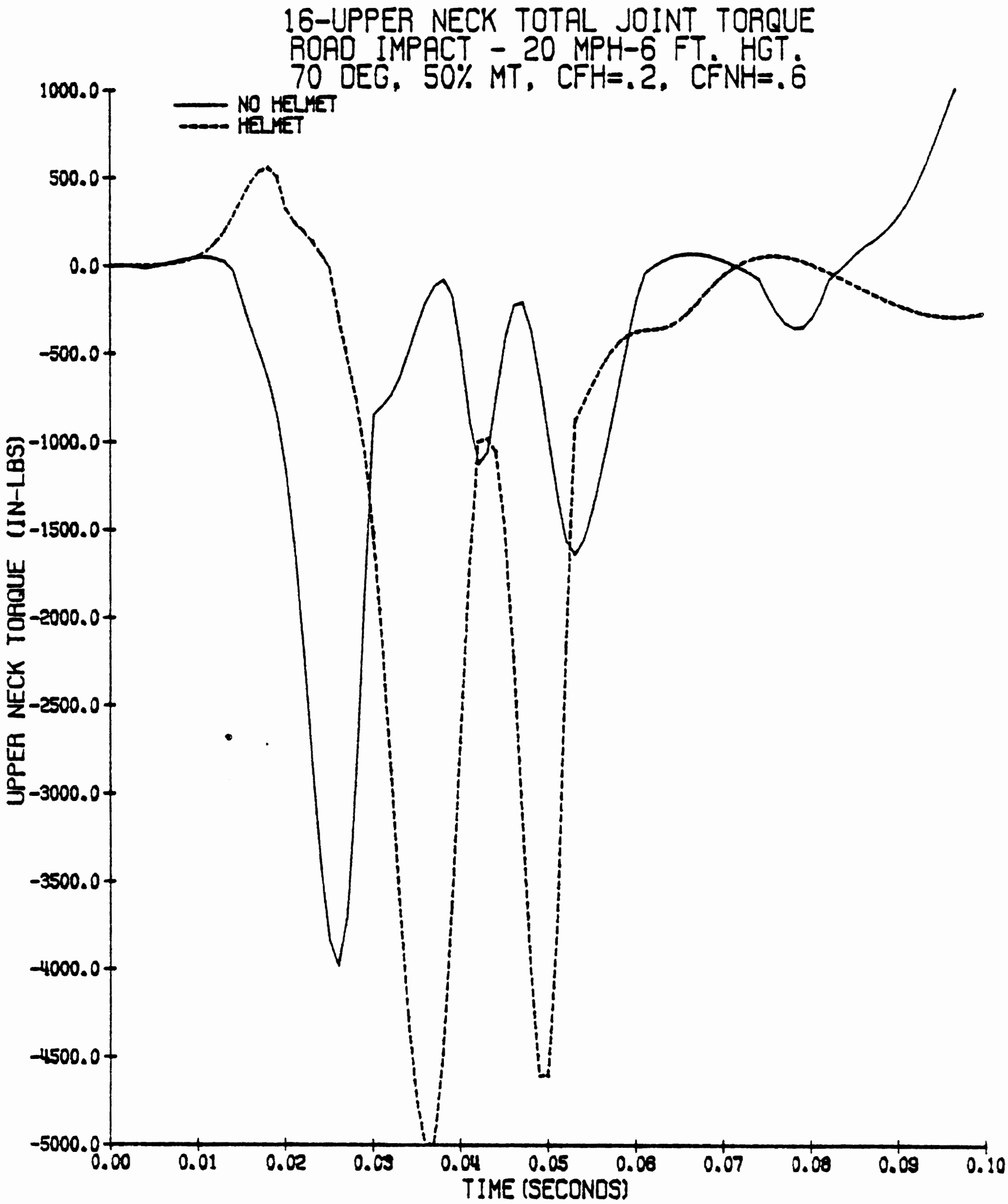

12-SHEAR FORCE AT CONDYLES
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG, 50% MT, CFH=.2, CFNH=.6
NO HELMET
HELMET
SHEAR FORCE (LBS.)
2500.0
2250.0
2000.0
1750.0
1500.0
1250.0
1000.0
750.0
500.0
250.0
0.0
-250.0
-500.0
-750.0
-1000.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)

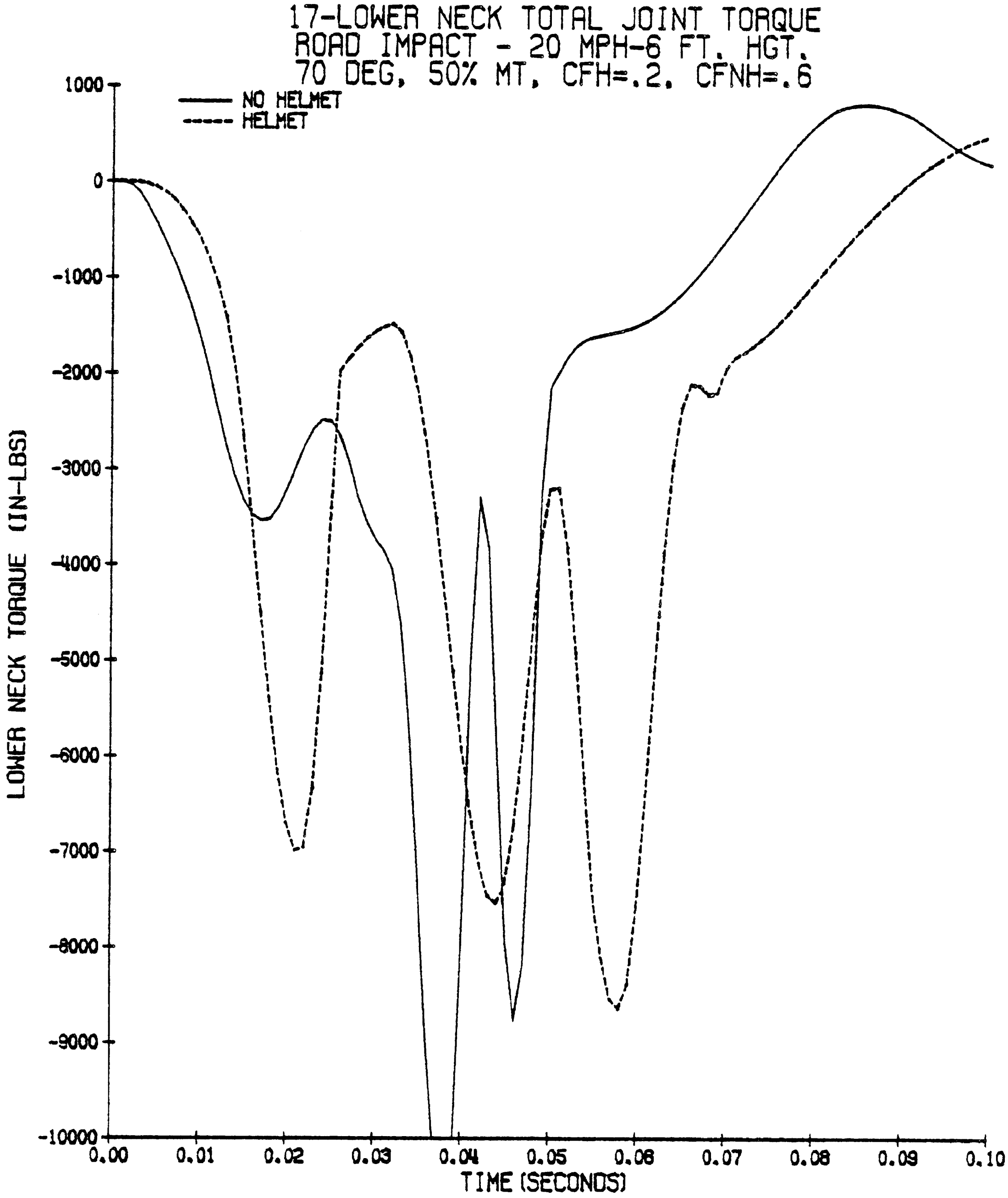


13-COMP. FORCE AT CONDYLES
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG, 50% MT, CFH=.2, CFNH=.6
NO HELMET
HELMET
COMP. FORCE (LBS.)
3200.0
2800.0
2400.0
2000.0
1600.0
1200.0
800.0
400.0
0.0
-400.0
-800.0
-1200.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)


14-SHEAR FORCE AT C7
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG, 50% MT, CFH=.2, CFNH=.6
NO HELMET
HELMET
2400.0
2150.0
1900.0
1650.0
1400.0
1150.0
900.0
650.0
400.0
150.0
-100.0
-350.0
-600.0
-850.0
-1100.0
SHEAR FORCE (LBS.)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)


15-COMP. FORCE AT C7
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG. 50% MT. CFH=.2. CFNH=.6
NO HELMET
HELMET
3400.0
3000.0
2600.0
2200.0
1800.0
1400.0
1000.0
600.0
200.0
-200.0
-600.0
-1000.0
COMP FORCE (LBS.)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)


16-UPPER NECK TOTAL JOINT TORQUE
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG, 50% MT, CFH=.2, CFNH=.6
NO HELMET
HELMET
UPPER NECK TORQUE (IN-LBS)
1000.0
500.0
0.0
-500.0
-1000.0
-1500.0
-2000.0
-2500.0
-3000.0
-3500.0
-4000.0
-4500.0
-5000.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)


17-LOWER NECK TOTAL JOINT TORQUE
ROAD IMPACT - 20 MPH-6 FT. HGT.
70 DEG, 50% MT, CFH=.2, CFNH=.6
NO HELMET
HELMET
LOWER NECK TORQUE (IN-LBS)
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10000
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
TIME (SECONDS)