SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
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# SURFACE VEHICLE INFORMATION REPORT

SAE J2052

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## TEST DEVICE HEAD CONTACT DURATION ANALYSIS



### FOREWORD

A new technique is established for determining head impact contact duration called the "Force Difference Method." This technique will allow calculation of Head Injury Criterion (HIC) only during head contact.

1. SCOPE:

This methodology can be used for all calculations of HIC, with all test devices having an upper neck triaxial load cell mounted rigidly to the head, and head triaxial accelerometers.

1.1 Purpose:

The purpose of this SAE Information Report is to describe a computer-adaptable technique for determining head engagement and disengagement times for use in the calculation of the HIC without reliance on contact switches or photography.

2. REFERENCES:

2.1 Applicable Documents:

SAE J211 OCT88, Instrumentation for Impact Test

52 Federal Register 36423, September 29, 1987

"Head Contact Duration Analysis," ISO/TC22/SC12/WG3N179

"Code of Federal Regulations...Transportation 49 Parts 400-999" Revised as of October 1, 1985, Sections 571.208, Standard No. 208, Occupant Crash Protection

Fadel, I. E., Shaw, D. S. "Hybrid III Head Contact Duration" presentation for SAE Safety Test Instrumentation Subcommittee, minutes of May 25, 1988

2.2 Definitions:

2.2.1 HIC: The HIC is one of the "injury criteria" prescribed by S6 of the Federal Motor Vehicle Safety Standard (FMVSS) 208. It is the maximum value calculable from the head c.g. resultant acceleration-time profile in accordance with the following equation:

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

Where:

a is the resultant acceleration expressed as multiples of G (the acceleration of gravity), and $t_1$ and $t_2$ are any two points in time during the crash.

NOTE: Although a HIC window of 36 milliseconds maximum was subsequently mandated by NHTSA, it is not utilized with this document.

2.2.2 CONTACT HIC: HIC values calculated only during the periods of each head contact.

2.2.3 $t_e$, $t_d$: The head engagement and disengagement times, $t_e$ and $t_d$ respectively, are determined by the method given in Section 4. These are the starting and ending times, i.e., the windows for the iterative HIC calculations for each head contact.

NOTE: The maximum contact HIC for each $t_e$, $t_d$ interval will have associated with it times $t_1$, $t_2$ which may be equal to, or less than the $t_e$, $t_d$ interval.

2.2.4 ACCELEROMETERS ($a_x$, $a_y$, $a_z$): The triaxial accelerometer(s) in the head of the test device will be referred to as an accelerometer, omitting the triaxial classification as defined in SAE J211; $+a_x$ is forward, $+a_y$ is to the right, and $+a_z$ is downward. These orientations are shown in Figure 1.

2.2.5 LOAD CELL: The triaxial force load cell (attached rigidly to the base of the skull portion of the test device to which the neck is attached) will be referred to as a load cell, omitting the triaxial and upper neck classification. Load cells with additional outputs can also be used.

2.2.6 HEAD MASS (M): The mass of the head including the masses of the head accelerometers and mounting brackets and the mass of the load cell which is rigidly attached to the head.

2.2.7 INERTIAL HEAD FORCES ($Ma_x$, $Ma_y$, $Ma_z$): The inertial head forces are calculated from the triaxial accelerometers which are inside the head of the test device. The accelerations are multiplied by the M of the test device to determine the inertial head forces. The directions of these inertial forces are the same as the directions of their corresponding acceleration vectors.

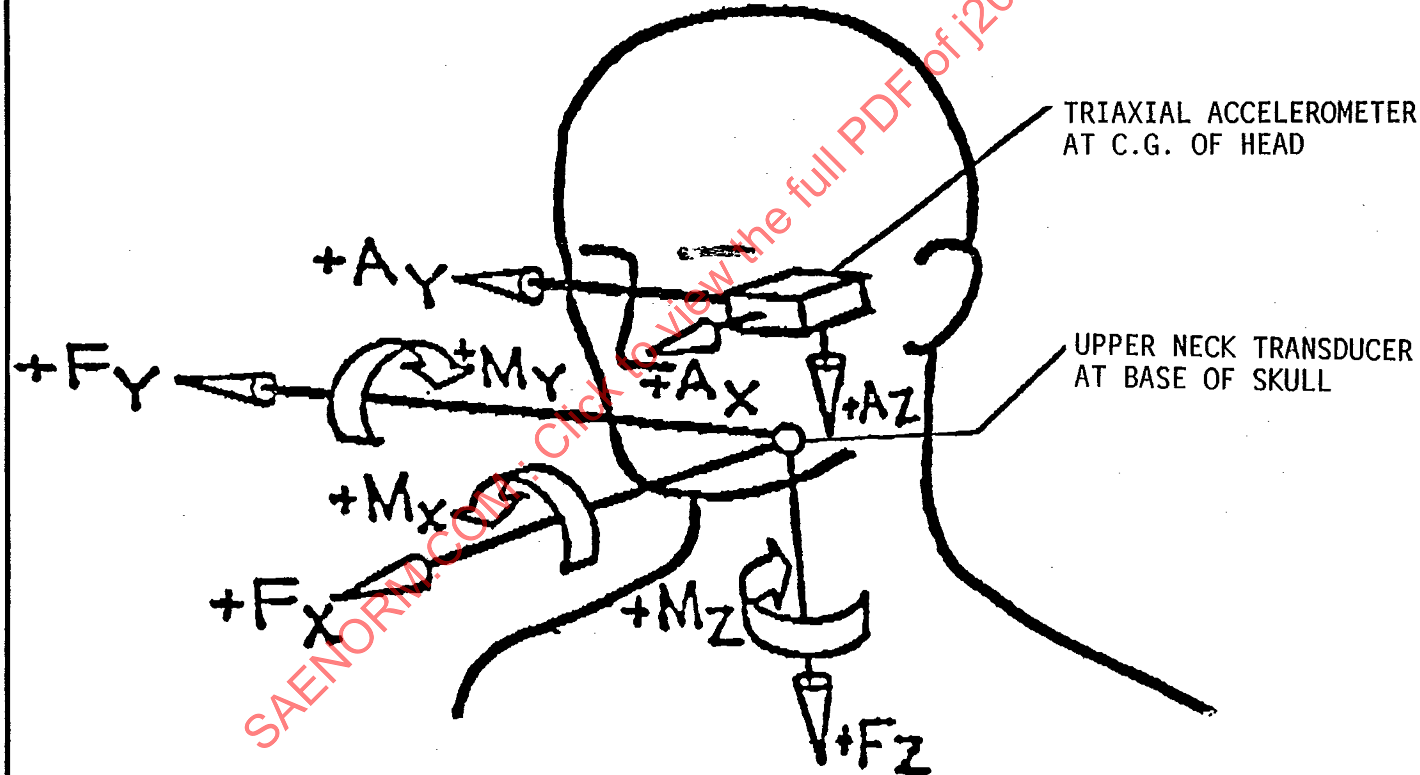


FIGURE 1 - Head Contact Duration Analysis - Acceleration and Force

2.2.8 NECK FORCES ($F_x$, $F_y$, $F_z$): The neck forces are determined directly from the load cell, per 2.2.5, which reads the forces acting on the neck at the location of the load cell (the base of the skull in this case). $F_x$ is longitudinal shear, $F_y$ is lateral shear, and $F_z$ is axial force. Forces ($F_x$, $F_y$, $F_z$) are applied to the neck in this paper (see Figure 1). A positive $F_x$ output from the load cell means head rearward motion relative to neck; positive $F_y$ output is head left motion relative to neck; and positive $F_z$ output is tensile force or head upward motion relative to the neck. Conventions are per SAE J211.

2.2.9 TEST DEVICE: Any full, partial or simulated anthropomorphic dummy equipped with head accelerometers and load cell per 2.2.4 and 2.2.5 is defined as the test device. The 50th percentile male Hybrid III dummy specified in Part 572, subpart E, of FMVSS 208 (3), can be used, as can any derivative of that dummy with proper instrumentation.

3. DATA ACQUISITION AND PROCESSING SYSTEM:

The data acquisition and processing system must be capable of supplying transducer data per SAE J211 which recommends that both head acceleration and neck force utilize channel class 1000, and that any multiple recording devices are time-referenced per 4.4.2 of SAE J211.

4. PROCEDURE FOR DETERMINING HEAD CONTACT DURATION ($t_e$, $t_d$):

The subject method uses the following equation:

$$F = \sqrt{[(Ma_x-F_x)^2 + (Ma_y-F_y)^2 + (Ma_z-F_z)^2]} \qquad \text{(Eq.2)}$$

The acceleration components ($a_x$, $a_y$, $a_z$) of the head are multiplied by the M to produce the components of inertial head force. Each neck force component ($F_x$, $F_y$, $F_z$) is subtracted from the corresponding calculated inertial head force component. The aforementioned subtractions produce three force-differences. The external resultant head force (F) is calculated by taking the root sum square of the force-differences, and is plotted as a function of time. This plot represents the resultant contact force acting on the head.

In order to establish consistent engagement ($t_e$) and disengagement ($t_d$) times for each contact, the following method is established: A contact is assumed to have occurred when the force level has reached 500 N. The $t_e$ for this contact is obtained by tracing backwards in time from the 500 N point on the force versus time curve until 200 N is first reached. The $t_d$ for this contact is determined by tracking forward in time until the curve crosses the 200 N force level.

A subsequent contact is assumed to have occurred when the force level again has reached 500 N after the first time $t_d$. The $t_e$ and $t_d$ for this second contact are determined in the same manner used for determining $t_e$ and $t_d$ in the previous contact. This process is repeated for each subsequent contact, and is illustrated in Figure 2.

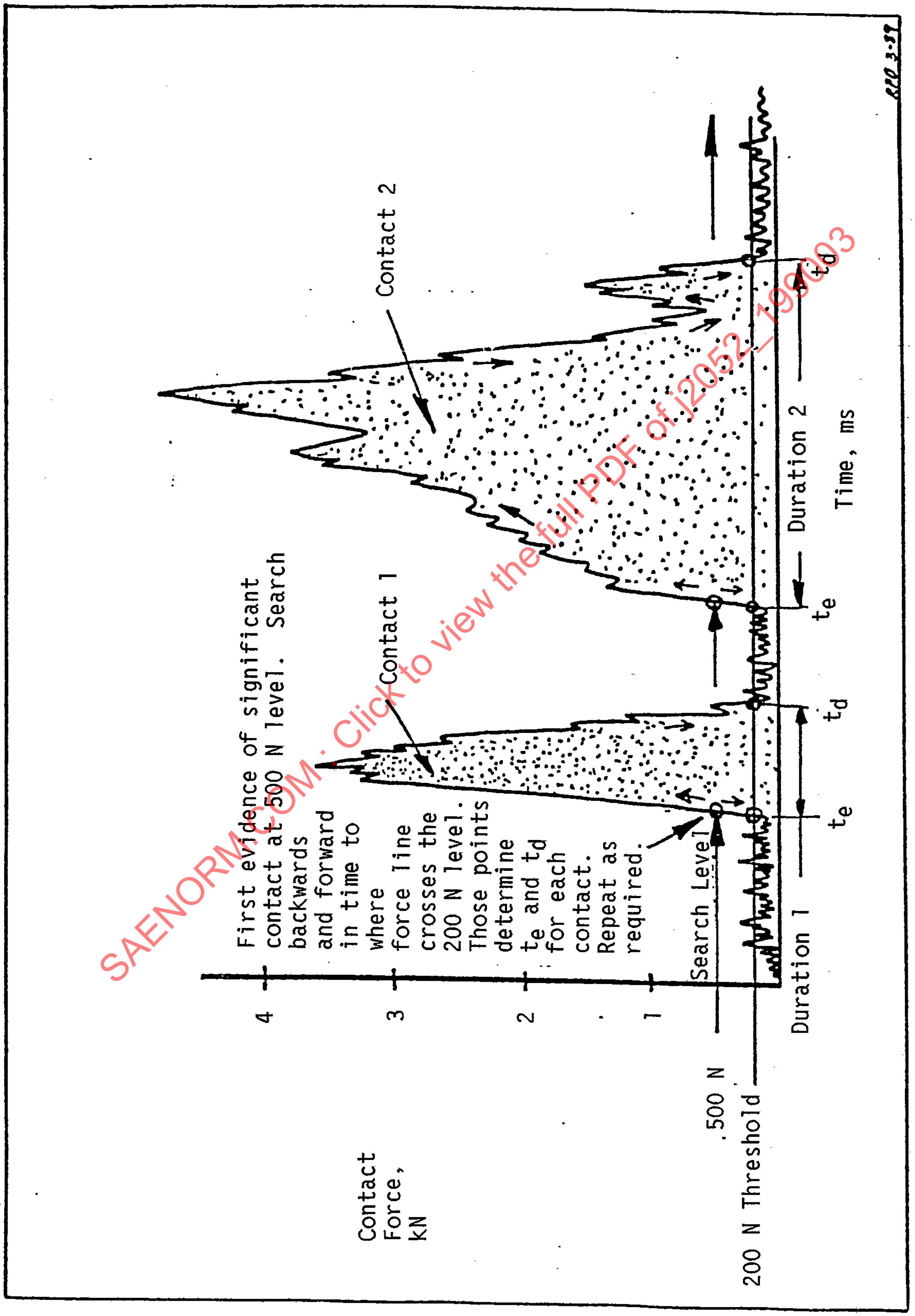


FIGURE 2 - Determination of Contact Durations from Contact Force-Time Curve

## 5. OTHER INFORMATION:

### 5.1 Maximum Contact HIC:

The HIC is calculated for each contact interval determined in Section 3. The HIC $t_1$ and $t_2$ values for each contact interval may be equal to, or within the corresponding $t_e$, $t_d$ interval. The maximum contact HIC is the largest HIC value from all the contacts.

### 5.2 Resultant External Contact Force, F, and Its Direction ($\theta_x$, $\theta_y$, $\theta_z$):

The procedure in Section 4 allows the calculation of the actual contact force (which is the peak force shown in Figure 2). The direction of that force can be obtained by the following equations:

$$\theta_x = \cos^{-1}\left[\frac{Ma_x - F_x}{F}\right] \quad \text{(Eq.3)}$$

$$\theta_y = \cos^{-1}\left[\frac{Ma_y - F_y}{F}\right] \quad \text{(Eq.4)}$$

$$\theta_z = \cos^{-1}\left[\frac{Ma_z - F_z}{F}\right] \quad \text{(Eq.5)}$$

Where:

$\theta_x$, $\theta_y$, and $\theta_z$ are the direction cosine angles of the resultant external contact force, F.