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20090504 245

June 1967

OFFICE OF AVIATION MEDICINE
DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION



AD-660202

AM 67-13

A FUNCTIONAL COMPARISON OF BASIC
RESTRAINT SYSTEMS

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FEDERAL AIR SURGEON

June 1967

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ACKNOWLEDGEMENT

The personal assistance of John J. Swearingen and the technical support of this laboratory is gratefully acknowledged. The author also wishes to express his sincere appreciation to Sheila M. Mueller who, under a difficult situation of arranging work schedules and timely deadlines, was responsible for the design and production of these excellent illustrations.

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I. Introduction.

Concern for the inherent safety problems in public and private transportation systems is supported and well documented by the increasing numbers and rate of serious injuries. Although essential efforts have been and are being made to study the nature of these problems, the available information necessary to provide realistic solutions for reducing personal injuries is incomplete and inadequate.

It would appear unlikely, if not impossible, to eliminate the cause of injury situations when the primary contributing factors of the accident are considered: human error and/or mechanical failure. The problem of reduction or possible elimination of personal injuries must then be approached from the standpoint of providing some means of effective protection for the occupant throughout the duration of the accident event. Realistically, any feasible solution to these problems is a matter of selecting the best available method to reduce at least the degree of injury.

It is a well noted circumstance that, among all possible types of injury occurring in potentially survivable accidents, those most frequently occurring result from the partially restrained or wholly unrestrained occupant's striking surrounding structures. Potentially survivable accidents are defined as those occurring under conditions in which the vehicle structure surrounding the occupant remains intact and human tolerance levels are not exceeded. A great number of serious fatal injuries occur specifically when upper body areas (head, neck and chest) impact, or are penetrated by, rigid, uneven structural surfaces. These observations leave no doubt that, in order to achieve the safest environment possible, the occupant must be adequately restrained during accident impact, thus preventing or reducing the chances of interaction with the structure.

It is the purpose of this study to define and compare, in part, the functional (dynamic) characteristics of basic restraint configurations to assist further safety design efforts.

II. Methods.

Valid comparisons of the functional characteristics of restraint systems necessarily involve a comparison of each complete system (seat belt and shoulder harness) assembled from all possible combinations and arrangements of component parts and methods of attachment.

Two basic shoulder harness configurations were selected for this study and are typical of those now in use: the single diagonal belt and the double parallel belts. A total of eight complete restraint systems based on various combinations of the two shoulder harness configurations was used, with three primary methods of harness attachments. Each system is identified by the following criteria: (1) the harness configuration, (2) upper harness attachment, (3) lower end harness attachment. The upper attachment methods include a direct *fixed* (independent) tie-down that is locked in place with a snap ring, or, indirectly, as an integral part of a *self-adjusting* inertia reel system. Lower attachments were limited either to the *fixed* tie-down that was not functionally integrated with a sea belt, or to the *continuous*, functioning part of the seat belt. For single diagonal systems, the lower end of the chest belt is *continuous* as one half of the seat belt sliding freely through a D-ring. Similarly, in the double parallel system, both ends, threaded through dual D-rings, unite to form the complete seat belt. Tests, in which the occupant was restrained only by a seat belt with typical seat attachments, were conducted to provide a basic comparison.

The eight complete systems selected for testing are listed below by figure numbers (all figures, 1 through 12, are in the Appendix) as they

appear in this report. The italicized words above are used to designate attachment methods.

Figure Number	Type of Shoulder Harness	Methods of Attachment	
		Upper End	Lower End
5	Single diagonal	Fixed	Fixed
6	Single diagonal	Fixed	Continuous
7	Single diagonal	Self-adjusting	Fixed
8	Single diagonal	Self-adjusting	Continuous
9	Double parallel	Fixed	Fixed
10	Double parallel	Fixed	Continuous
11	Double parallel	Self-adjusting	Fixed
12	Double parallel	Self-adjusting	Continuous

In addition to this series of tests for complete systems, three other tests were conducted using a seat belt as the only restraint. For each test the seat belt was attached along the platform (floor) surface at points (1) intersecting a vertically projected seat back plane (Figure 2), (2) eight inches forward of the seat back plane (Figure 1), and (3) twelve inches aft of the seat back plane (Figure 3).

These tests were included to demonstrate the significant differences in the effectiveness of restraining characteristics of different types of seat belts. Their function is, in part, dependent on the angle formed by the seat belt as determined by the location of its attachment points.

Facilities provided for these dynamic tests included an indoor acceleration track and vehicle. The vehicle platform had a surface area 4 feet wide and 10½ feet long, to which the seat was secured for the dummy subject. The 180-pound dummy subject had a sitting height of 38 inches, representative of the Air Force 95th percentile. Recording instrumentation for the tests included an electric timer to record platform velocity prior to impact, platform and dummy mounted accelerometers to record the magnitude of deceleration loads, and high speed photography (3000 frames/second) to record the dummy kinematics. The velocities of the acceleration platform prior to impact ranged from 40.6 to 41.3 ft/sec for all tests.

III. Discussion and Conclusions.

In Figures 1 through 12 the patterns of head kinematics are graphically recorded to relate dimensionally the head-face position and orientation to a seat reference point. The numbers along the figure grid lines, vertical and hori-

zontal, are in inches. The seat reference point is established by the intersecting planes that represent the inferior surface of the legs and buttocks (sitting surface) and the posterior surface of the dummy back.

Patterns shown in the figure illustrations represent a composite average of at least three duplicate test runs for each restraint combination. Certain restraint systems in this test series demonstrated, as expected, that significant differences between kinematic patterns can result in any system from variations in restraint-body-seat relationships and restraint adjustments. Examples of the undesirable "submarining" action by the restrained subject were specifically noted in those configurations (arrangements) using (1) fixed upper and lower attachments and (2) a fixed upper attachment with the lower end continuous as a part of the seat belt. These same configurations have, however, produced "non-submarining" patterns (Figures 5, 9, and 6, 10) that may be considered as potentially acceptable systems.

Although these variations do exist, some valid generalizations concerning the restraining qualities of the tested systems are offered for consideration. *First*, it has been established that the double parallel shoulder harness system, properly used, can provide a better restraint function than the single diagonal system for at least two reasons: (1) the distribution of applied loads to two belts is greater than the same loads applied to a single belt, therefore, less belt stretch results in a greater restriction of forward movement, and (2) certain combinations of omni-directional forces have a tendency to cause a body torquing action with a single diagonal restraint that may result in a less efficient restraint function. In all composite patterns the greatest restraining function (considering both the vertical and horizontal displacement) is achieved by the four double parallel systems, although a single diagonal system in some instances presents a better restraint function in one direction.

Second, the relative position of a seat belt tie-down which ultimately establishes the seat belt angle, is a significant factor in achieving effective restraint. In Figures 1, 2, and 3 a comparison can be made to establish the fact that a greater forward location of a tie-down decreases

the restraint function of a seat belt and can seriously compromise the entire restraint system.

Third, and most important, there is a significant difference between the complete restraint system (shoulder harness and seat belts) and a system restraining only with a seat belt. These differences can be recognized easily by comparing the head kinematic patterns in Figure 4 with those shown in Figures 5 through 12.

In conclusion, these tests have clearly demonstrated and reaffirmed the fact that the protective function provided by a complete restraint system is significantly superior to the incomplete system restraining only with a seat belt. It is the opinion of this investigator that restraint selection criteria should not be based exclusively on (1) a particular configuration simply because

it may present more desirable features or (2) a superior configuration, which, in actual usage, could result in a severely compromised restraint function. Although some differences are indicated in the restraining characteristics between the eight tested systems, these differences for certain specific applications may not impair the primary function of achieving adequate body restraint. Therefore, restraint selection should result in a complete system that can best be accommodated by the particular vehicle design to assure a proper restraint function. Additional studies of this type and other various experimental designs should be undertaken to test other restraint configurations and provide the designer with more complete data to evaluate design concepts.

APPENDIX

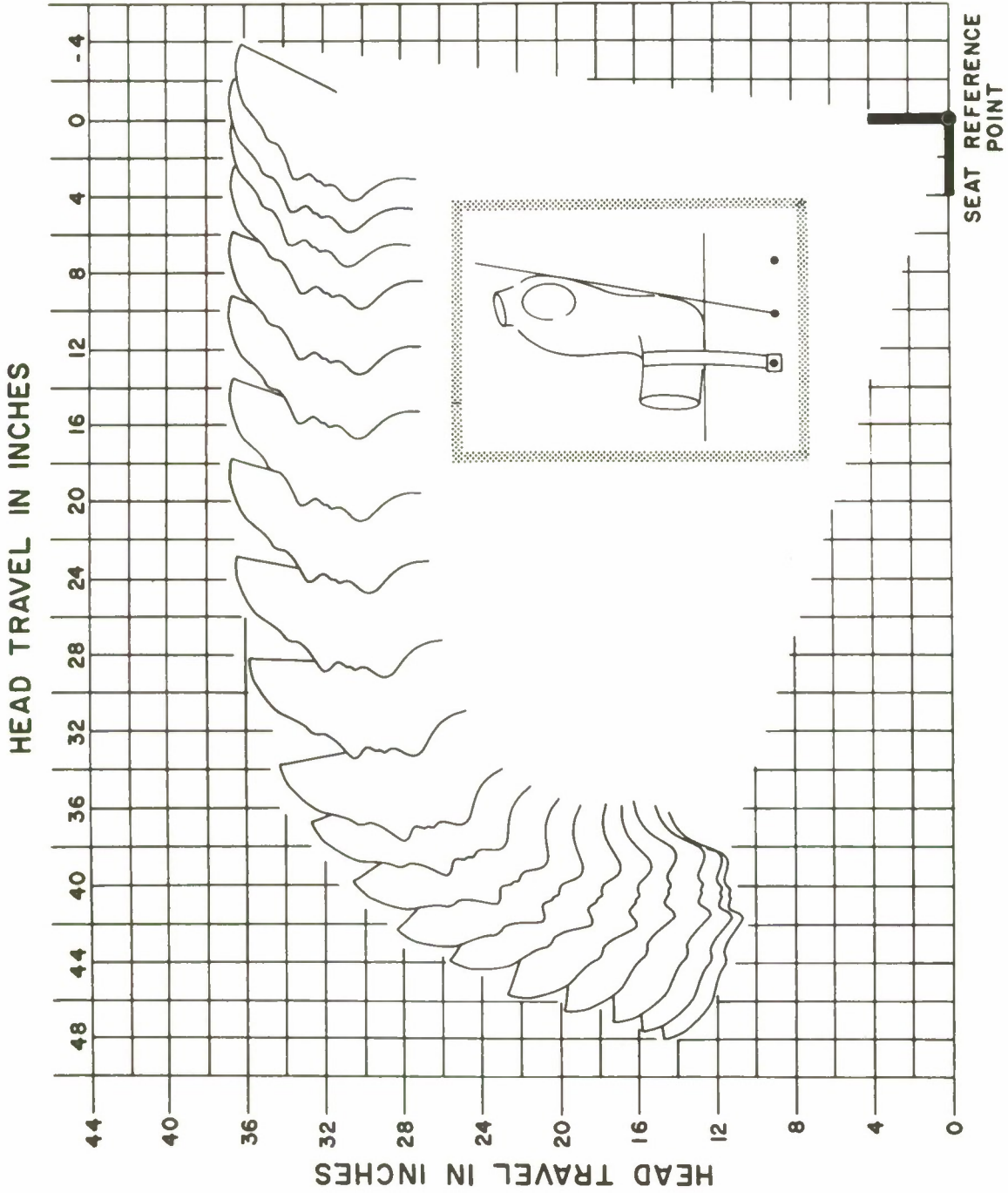


Figure 1: Restraint System: Seat Belt Only
Lower Attachments: Positioned Forward of Seat Back Plane

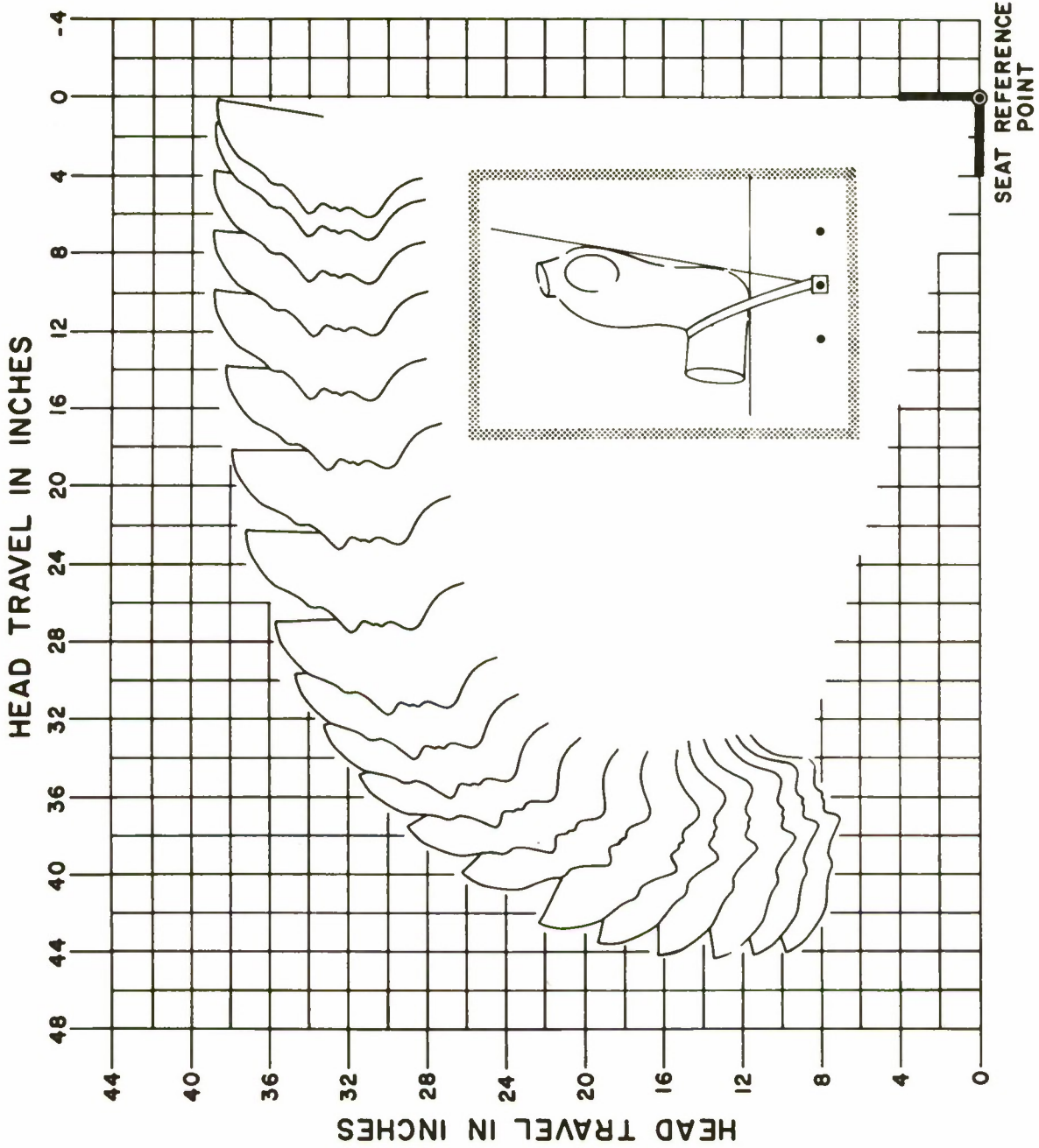


Figure 2: Restraint System: Seat Belt Only
 Lower Attachments: Positioned at Seat Back Plane

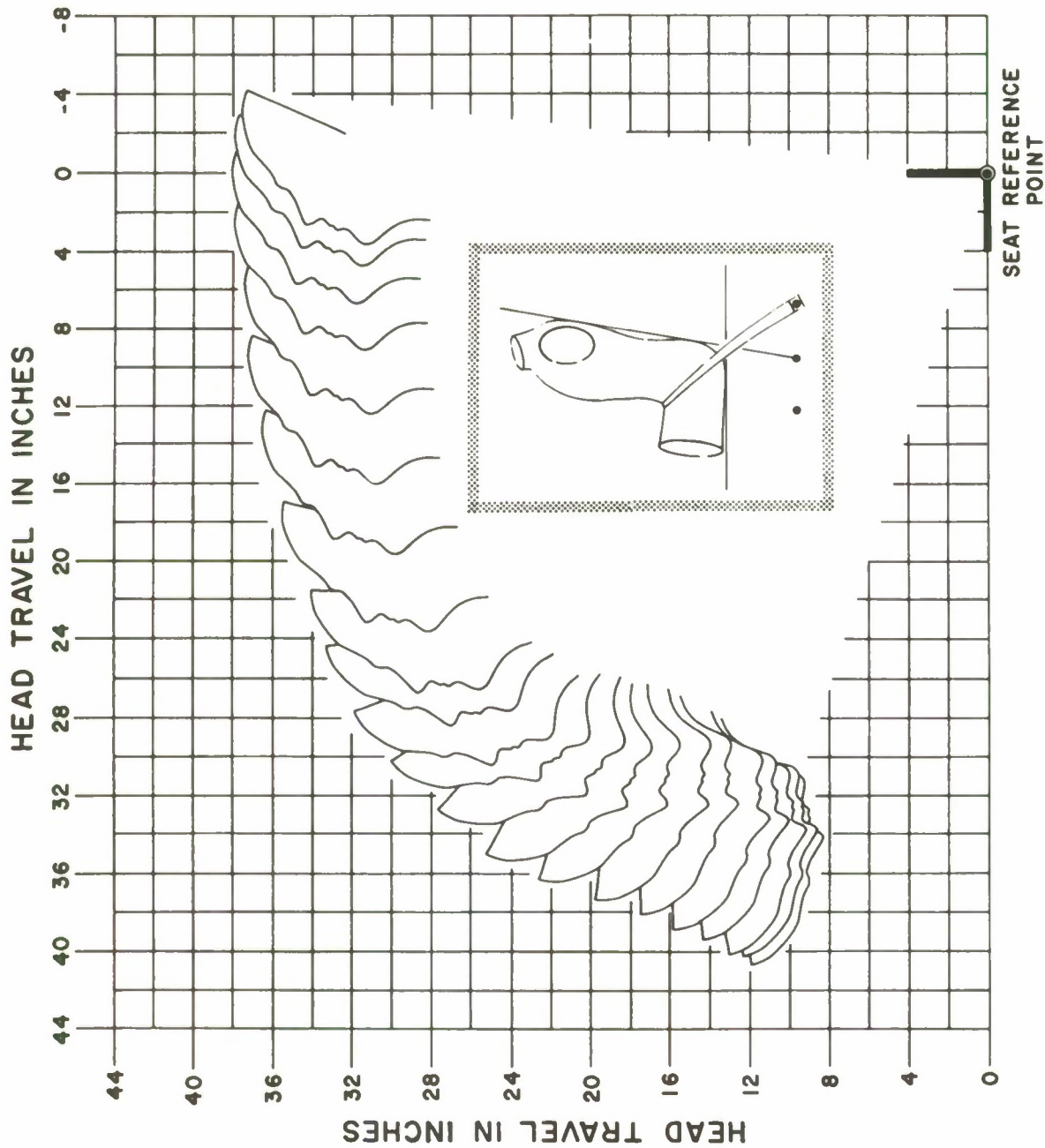


Figure 3: Restraint System: Seat Belt Only
 Lower Attachments: Positioned Aft of Seat Back Plane

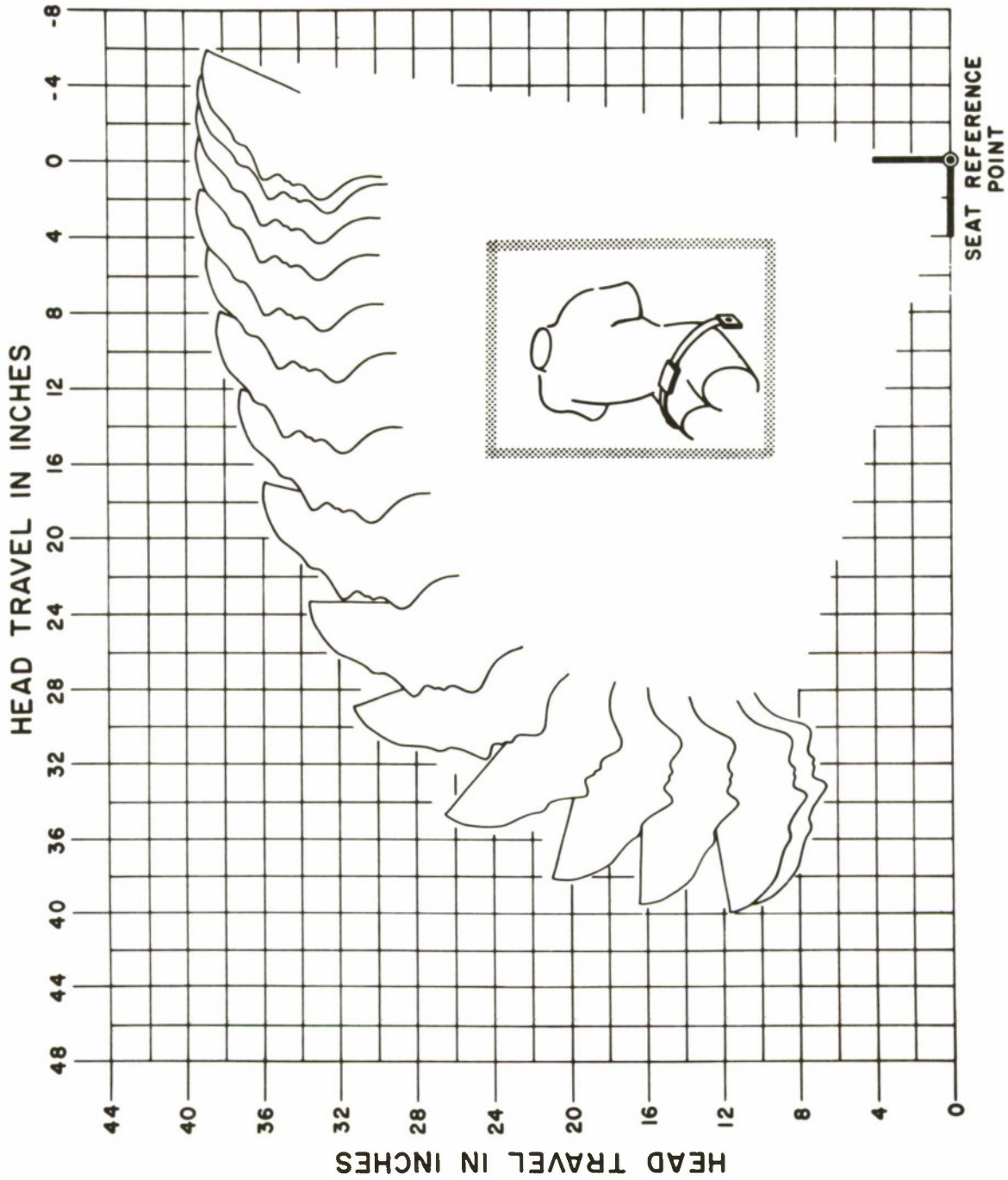


Figure 4: Restraint System: Seat Belt Only
 Upper Attachments:
 Lower Attachments: Fixed at Sides

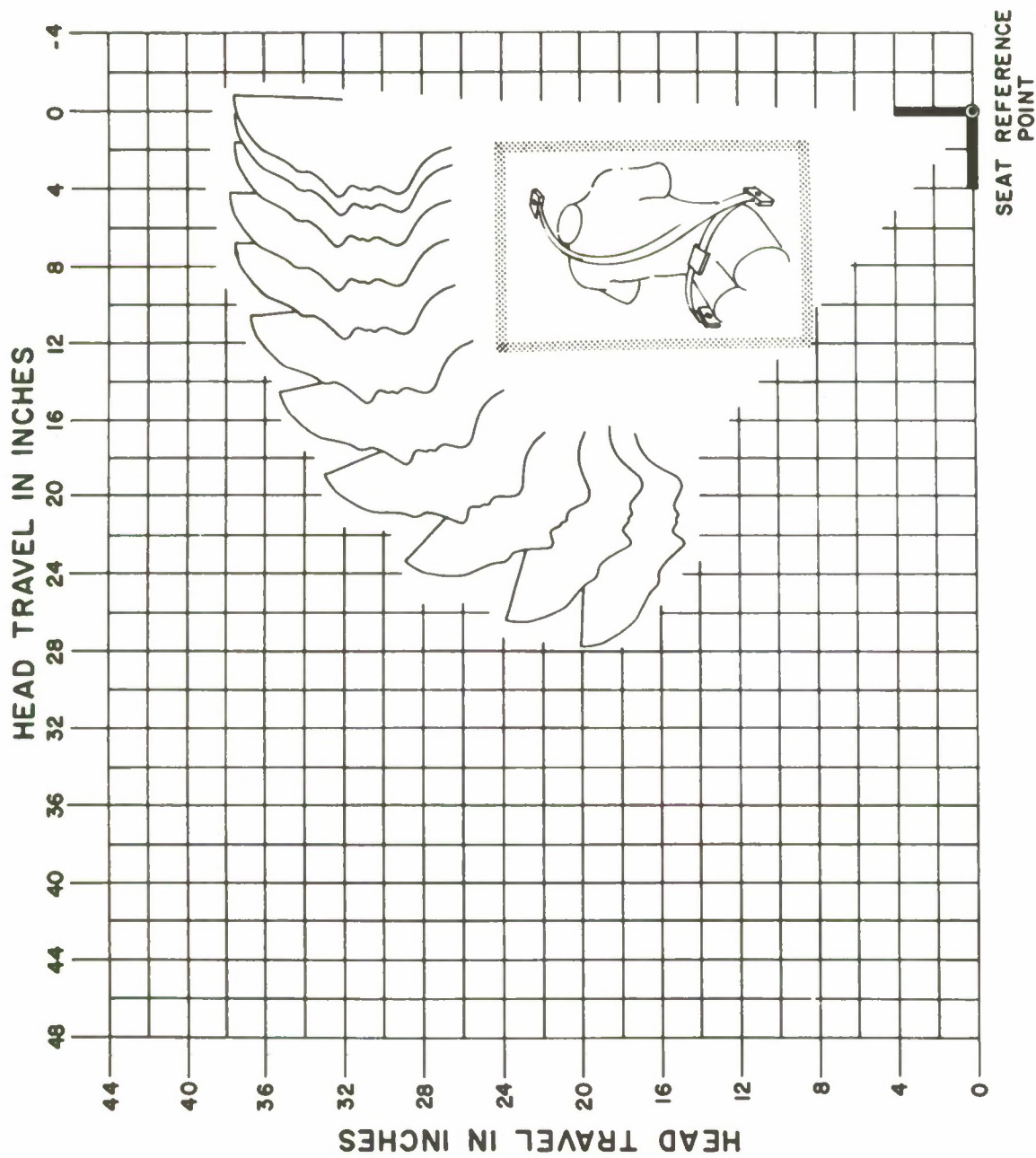


Figure 5: Restraint System: Complete Single Diagonal
 Upper Attachment: Fixed at Side
 Lower Attachment: Fixed at Side

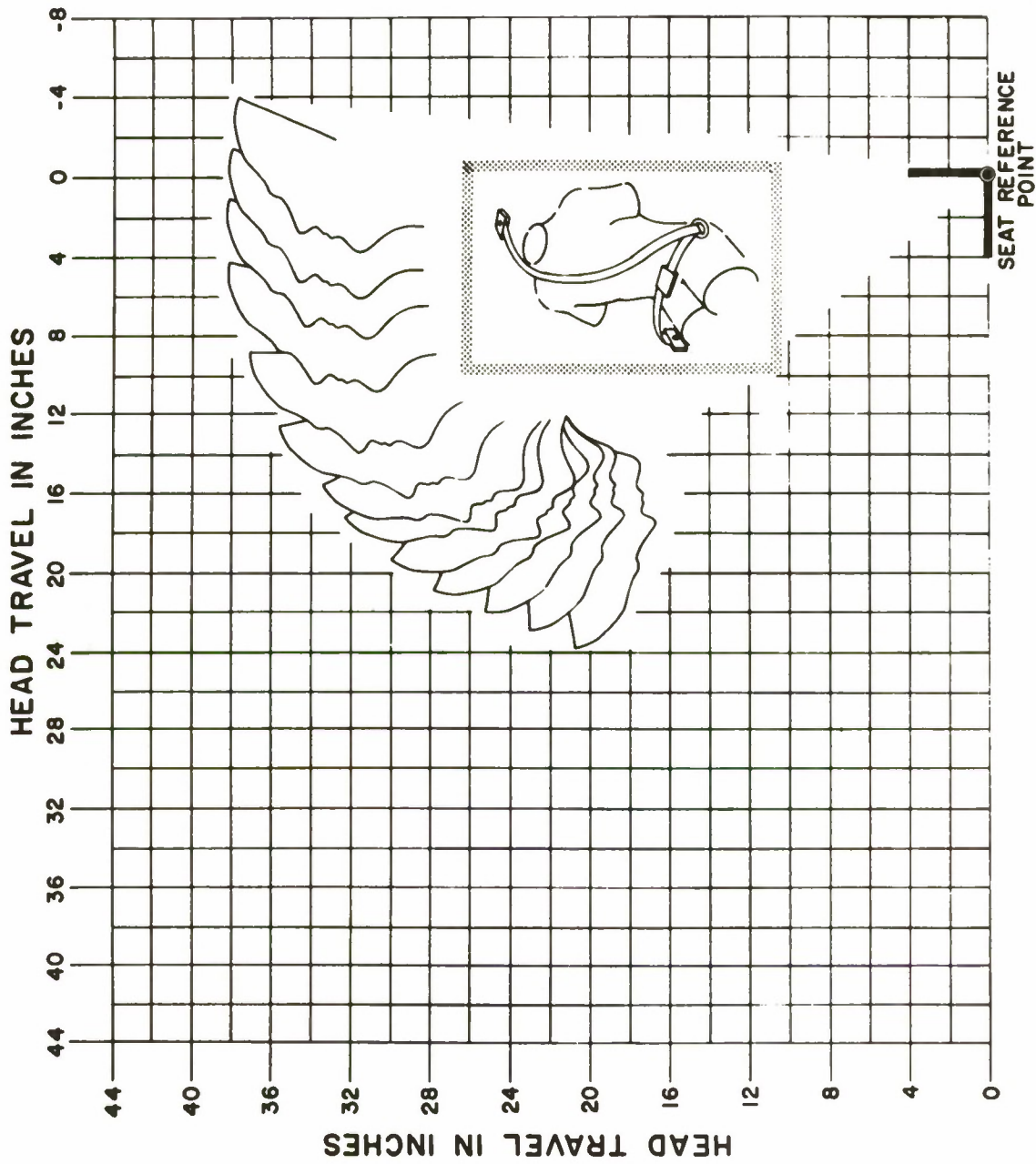


Figure 6: Restraint System: Complete Single Diagonal
 Upper Attachment: Fixed at Side
 Lower Attachment: Continuous with Seat Belt

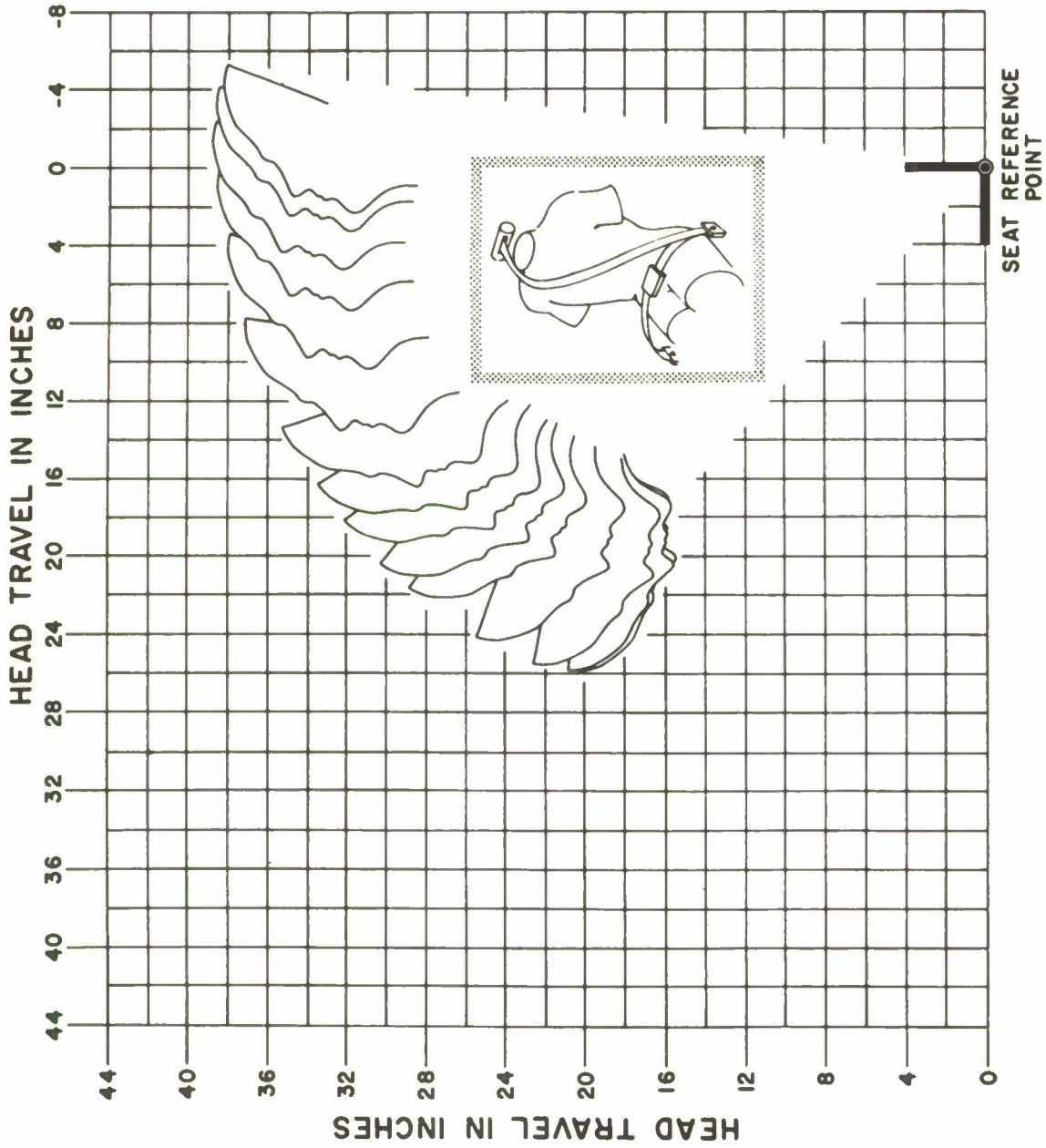
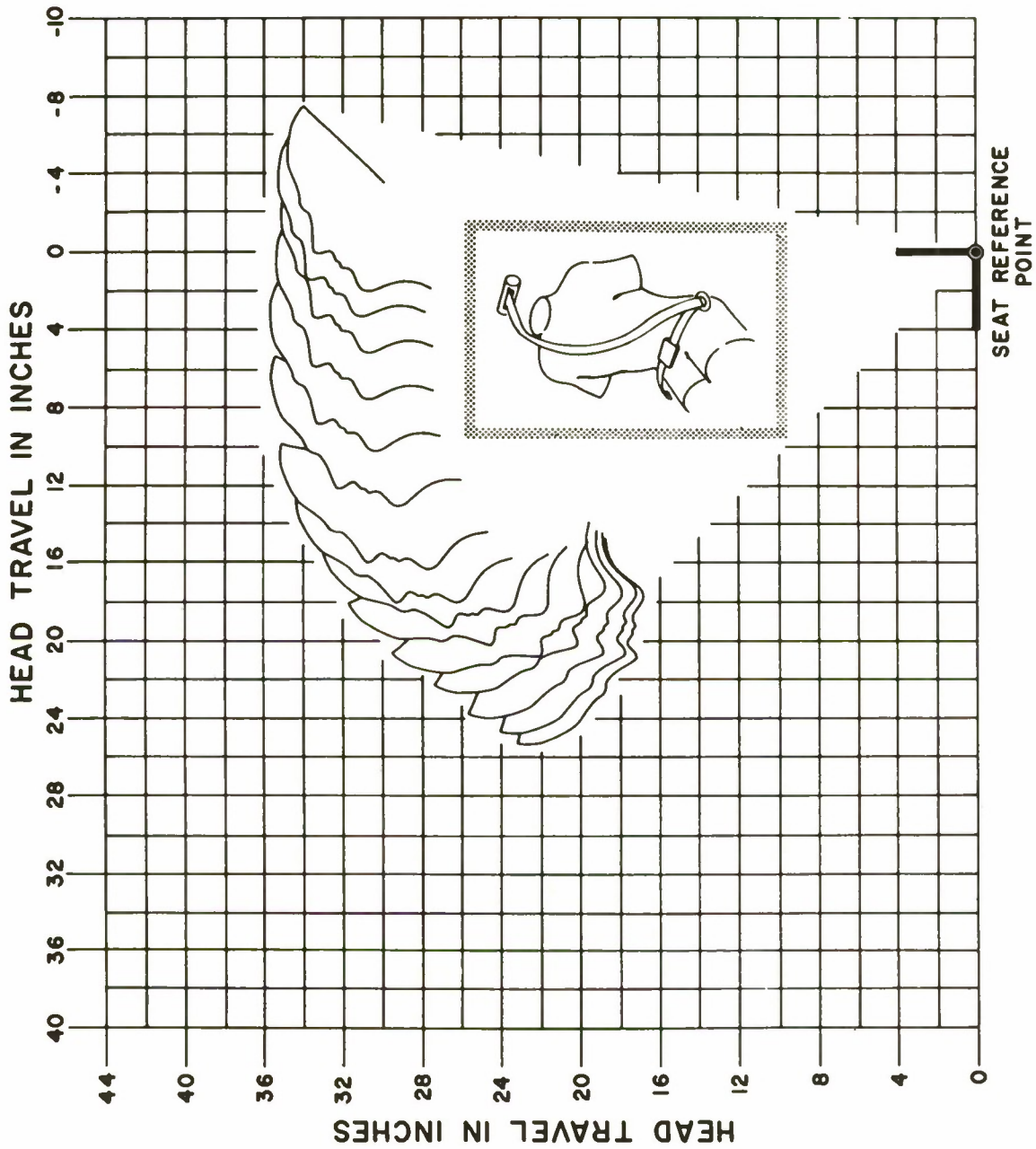


Figure 7: Restraint System: Complete Single Diagonal
 Upper Attachment: Inertia Reel at Side
 Lower Attachments: Fixed at Side



**Figure 8: Restraint System: Complete Single Diagonal
 Upper Attachment: Inertia Reel at Side
 Lower Attachment: Continuous with Seat Belt**

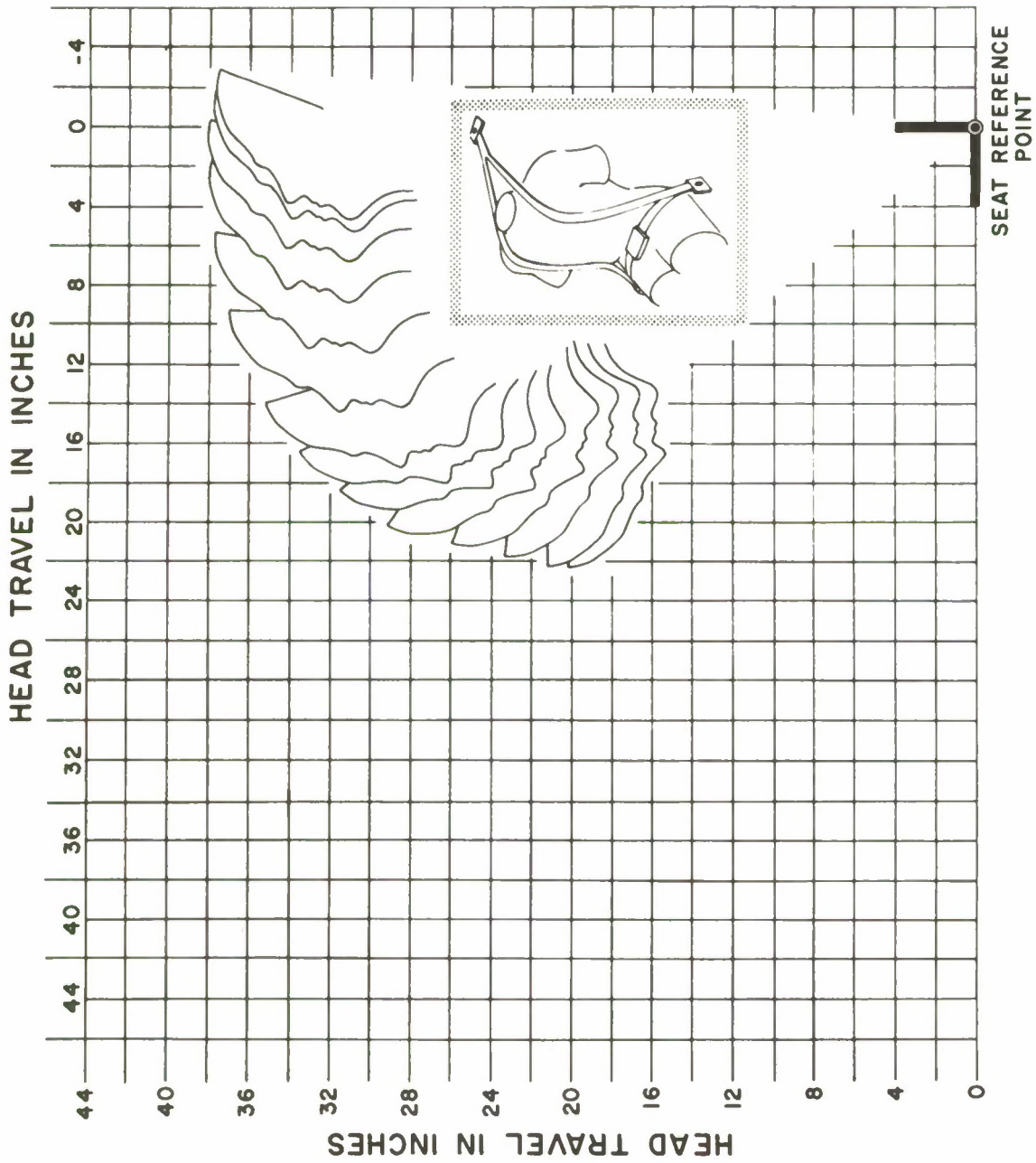


Figure 9: Restraint System: Complete Double Parallel
 Upper Attachment: Fixed at Midline
 Lower Attachments: Fixed at Sides

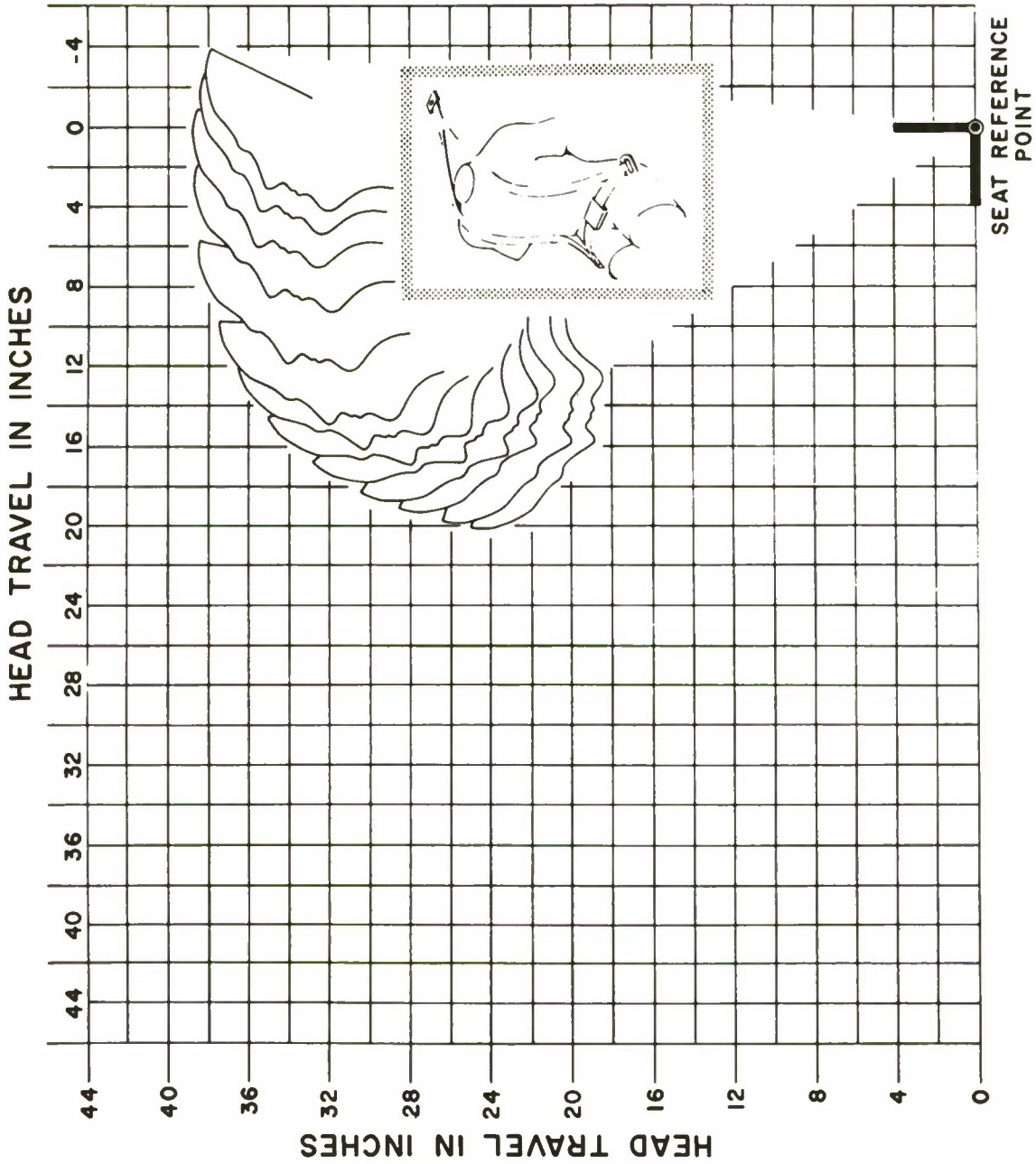


Figure 10: Restraint System: Complete Double Parallel
 Upper Attachment: Fixed at Midline
 Lower Attachments: Continuous as Seat Belt

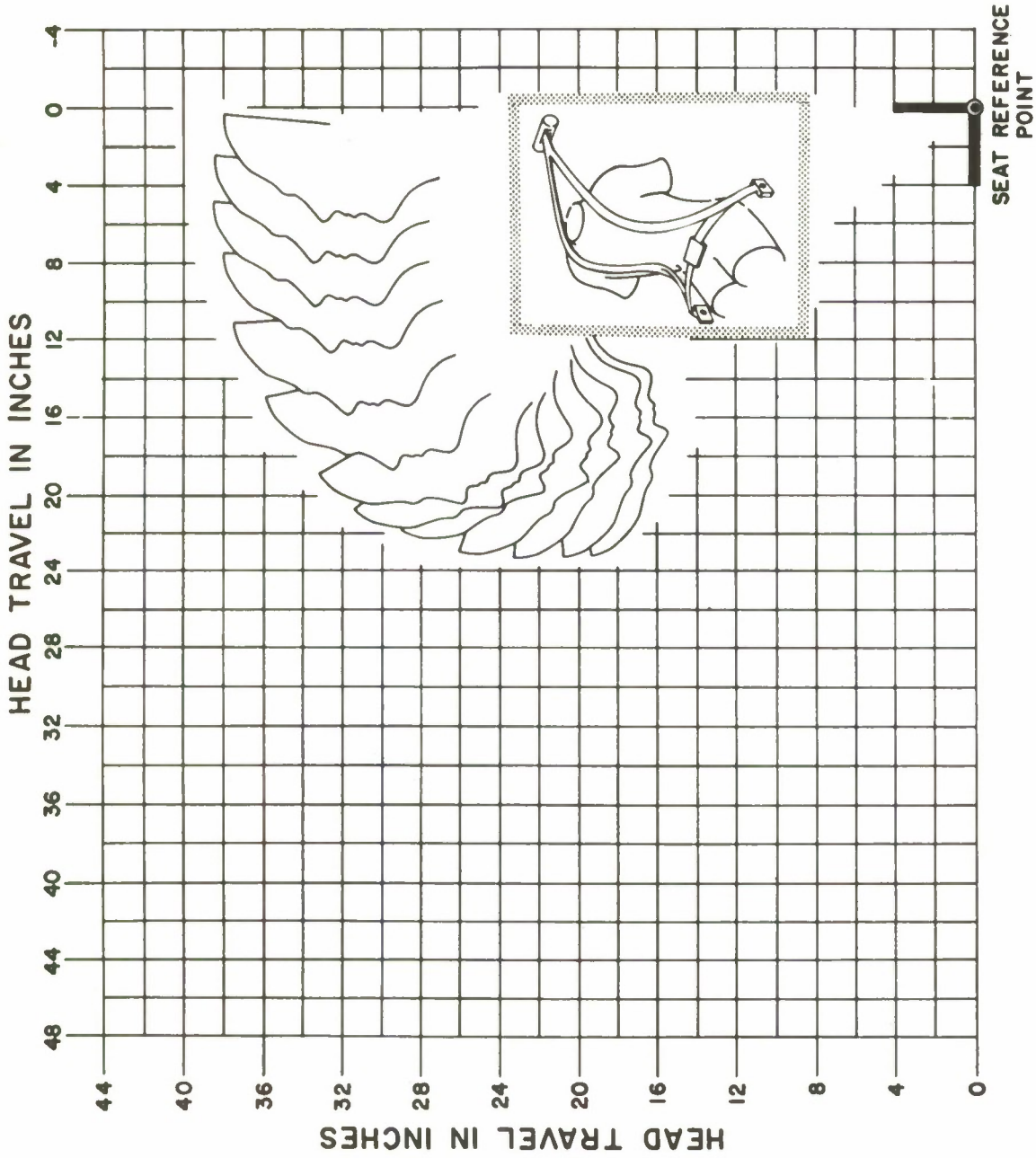


Figure II: Restraint System: Complete Double Parallel
 Upper Attachment: Inertia Reel at Midline
 Lower Attachments: Fixed at Sides

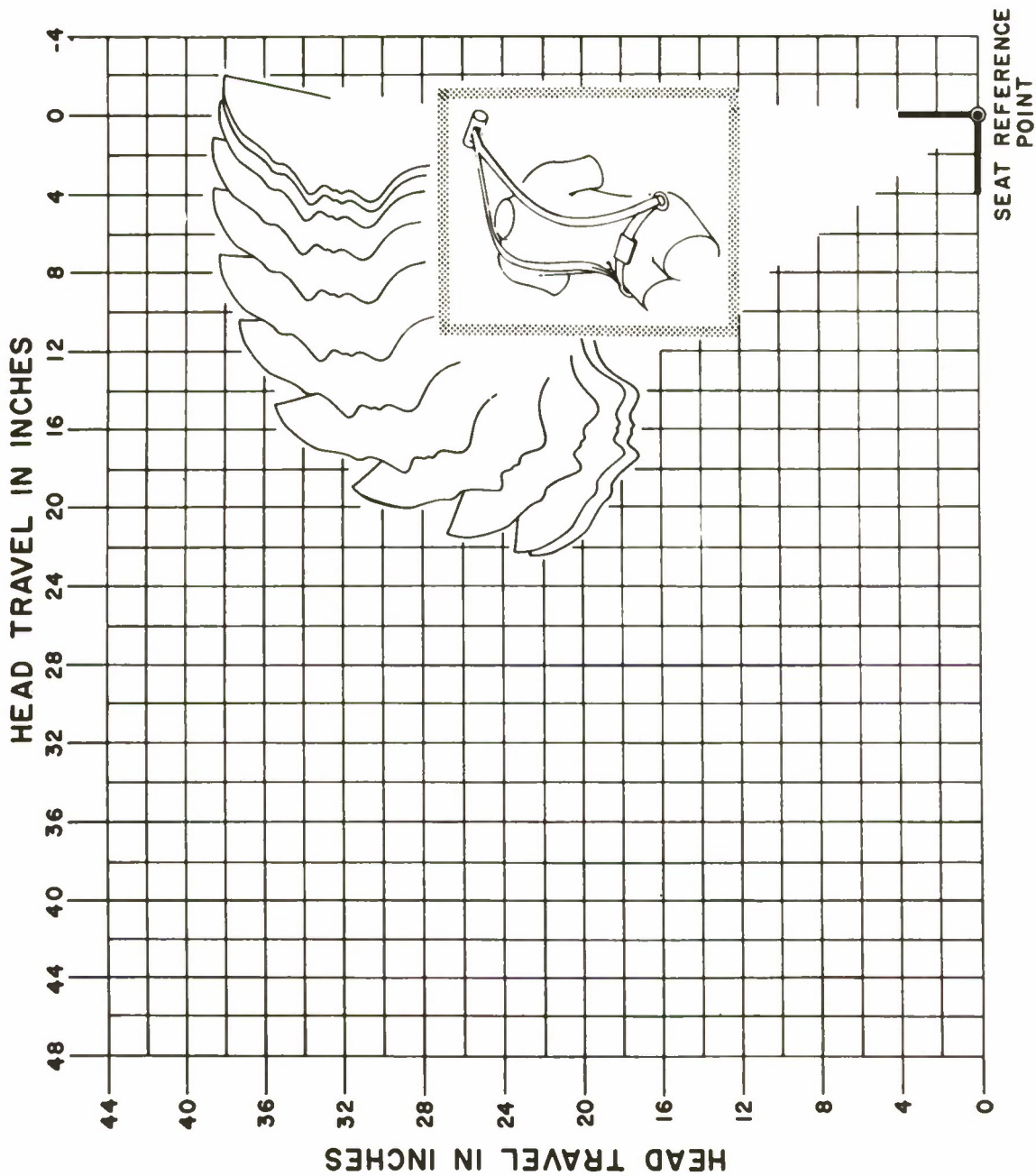


Figure 12: Restraint System: Complete Double Parallel
 Upper Attachment: Inertia Reel at Midline
 Lower Attachments: Continuous as Seat Belt

Federal Aviation Administration, Office of Aviation Medicine, Civil Aeromedical Institute, Oklahoma City, Oklahoma. **A FUNCTIONAL COMPARISON OF BASIC RESTRAINT SYSTEMS** by Joseph W. Young, June 1967, 16 pp., Report No. AM 67-13.

The availability of information necessary to provide realistic solutions for personal safety problems in public and private transportation systems is found to be inadequate and incomplete. The problem of body restraint during the accident event is pursued, in part by this study. Since the greatest frequency of serious injuries occurs from upper body components (head, neck and chest) impacting or being penetrated by rigid, uneven surfaces, it is desirable and essential to restrain the body and prevent interaction with the surrounding structures.

The functional characteristics of eight complete (seat belt and shoulder harness) restraint systems and a typical incomplete (seat belt only) system are presented graphically for comparison in a series of figures based on kinematic head patterns. An additional series compares the relative differences in restraining qualities that result from varying the attachment locations of an incomplete (seat belt only) system.

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