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Development of Crashworthy Passenger Seats for General-Aviation Aircraft

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□ **Airport power supply --- Russian book** GLADYSH, I. S. ANDREEV, P. L. 1979 248 PAGES Moscow, Izdatel'stvo Transport, 1979. 248 p. In Russian.
*AIRPORT PLANNING, *CIRCUIT PROTECTION, *ELECTRIC NETWORKS, *ELECTRIC POWER SUPPLIES, *GROUND SUPPORT EQUIPMENT, *TERMINAL FACILITIES
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*EQUATORIAL ORBITS, *NATIONAL AVIATION SYSTEM, *SPACE LAW CONVENTIONS, EARTH ATMOSPHERE, INTERNATIONAL LAW, OUTER SPACE TREATY, SPACE SHUTTLES, SYNCHRONOUS SATELLITES
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□ **Aeronautical information data subsystems /AIDS/** FISCHER, F. W. AA(Studiengemeinschaft fuer Flugsicherung, Westerngrund, West Germany) SEP. 1979 4 PAGES The Controller, vol. 18, Sept. 1979, p. 30-33.
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C02 N79-31141*#

□ **Rotary balance data for a typical single-engine general aviation design for an angle-of-attack range of 8 deg to 90 deg. 2: High-wing model A** Bihrle Applied Research, Inc., Jericho, N. Y. MULCAY, W. ROSE, R. Washington NASA SEP. 1979 116 PAGES REFS. NASA-CR-3101 AVAIL- NTIS HC A06/MF A01
*AERODYNAMIC CHARACTERISTICS, *GENERAL AVIATION AIRCRAFT, *ROTARY STABILITY, *SPIN TESTS
ANGLE OF ATTACK, BODY-WING AND TAIL CONFIGURATIONS, WIND TUNNEL TESTS
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□ **Development of crashworthy passenger seats for general-aviation aircraft** Boeing Vertol Co., Philadelphia, Pa. REILLY, M. J. TANNER, A. E. AUG. 1979 112 PAGES REFS. NASA-CR-159100 D210-11336-1 AVAIL- NTIS HC A06/MF A01
*GENERAL AVIATION AIRCRAFT, *LIGHT AIRCRAFT, *SAFETY MANAGEMENT, *SEATS
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□ **Airport flammability, full scale fire tests** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex. BRICKER, R. W. In NASA. Ames Res. Center Conf. on Fire Resistant Mater. p 1-1. (SEE N79-31166 22-03) JUL. 1979 11 PAGES AVAIL- NTIS HC A13/MF A01
*AIRCRAFT, *BOEING 737 AIRCRAFT, *FIRES, *FLAMMABILITY
AIRCRAFT COMPARTMENTS, EVACUATING (TRANSPORTATION), FLAME PROPAGATION, FUSELAGES, SMOKE
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□ **Recent advances in materials toxicology** Southwest Foundation for Research and Education, San Antonio, Tex. RUSSO, D. M. In NASA. Ames Res. Center Conf. on Fire Resistant Mater. p 27-43 (SEE N79-31166 22-03) JUL. 1979 17 PAGES AVAIL- NTIS HC A13/MF A01
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FIREBREAKS, FLOORS, FOAMS, GRAPHS (CHARTS), NONFLAMMABLE MATERIALS, TABLES (DATA), THERMAL INSULATION, WALLS
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Development of Crashworthy Passenger Seats for General Aviation Aircraft

by

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ABSTRACT

This report documents the design and analysis effort undertaken in the development of two crashworthy passenger seats. Rationale used in the selection of the concepts is discussed and advantages and disadvantages of each concept are presented.

FOREWORD

This report was prepared by the Boeing Vertol Company for the National Aeronautics and Space Administration, Langley Research Center, under NASA Contract NAS1-14637. E. Alfaro-Bou was NASA technical monitor for this work. The Boeing Vertol Project Engineer was M. J. Reilly.

SUMMARY

The purpose of this program was to design two types of energy absorbing passenger seat concepts suitable for installation in light twin-engine fixed wing aircraft. An existing passenger seat for such an aircraft was used to obtain the envelope constraints. Ceiling suspended and floor supported seat concept designs were developed. A restraint system suitable for both concepts was designed. Energy absorbing hardware for both concepts was fabricated and tension and compression tests were conducted to demonstrate the stroking capability and the force deflection characteristics. Crash impact analysis was made and seat loads developed. The basic seat structures were analyzed to determine the adequacy of their strength under crash impact loading.

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INTRODUCTION

This study was conducted to develop 2 crashworthy passenger seat concepts suitable for use in light twin-engine fixed wing aircraft.

Background

Serious development of crashworthy seats for aircraft was begun approximately 15 years ago, principally for use in military helicopters. Development progressed slowly due to the constraints of low weight and cost and the need for reliable energy attenuating devices. Arrangement of the attenuators such that the crash impact stroking kinematics were not affected by various impact angles presented a formidable challenge. This was complicated by the need to maintain the integrity and function of the seat in a crash environment where its mounting structure and attachments are severely distorted by the impact. Providing an adequate restraint system to limit the occupant's motion relative to the seat, necessitated the development of new materials and configurations.

The lightweight crashworthy seat state-of-the-art has just reached a point where the first practical seats are being designed for production military aircraft. Consideration can now be given to adapting some of these proven principles to crashworthy seating in private and commercial airplanes. The Boeing Vertol Company, who has been a leader in crashworthy development, was awarded a contract by NASA-Langley to design 2 crashworthy passenger seat concepts suitable for light twin-engine airplanes.

Technical Discussion

A crashworthy seat is one that will withstand a specified crash impulse loading and will reduce the crash accelerations on the occupant to within the limits of human tolerance. A crash impulse, produced by the rapid reduction of the aircraft's velocity at impact, consists of a high acceleration for a short duration of time. The resulting peak G can produce serious or fatal injury to the aircraft occupants. The objective then is to reduce the peak G to within the limits of human tolerance and to account for the energy in the pulse by increasing the duration of the lower G pulse until the areas under the curves are equal. An example of this reduction in G level or energy attenuation is shown in Figure 1.

Energy attenuation in a crashworthy seat is accomplished by suspending the seat in a manner so that the seat, with the occupant, can move or stroke, relative to the aircraft, in a direction opposite to the resultant crash force. Load limiting devices or energy attenuators resist motion in the direction of the crash impact at a level which is within force levels that can be tolerated by the occupant. The limiting load of the attenuator is set by multiplying the occupants weight by the tolerable acceleration level or G.

Human tolerance limits vary depending upon the direction in which the forces act on the occupant. Higher forces can be tolerated in the forward and rearward directions than in the vertical direction (Figures 2 and 3). Seats with separate attenuation systems for the various axes require different load settings for each axis so as not to exceed the human tolerance limits.

Load settings for energy attenuators should be set for a light weight occupant at their maximum human tolerance limit. Heavier occupants will experience lower G level accelerations at this load setting because a lower G level multiplied by the heavier occupant weight will equal the load setting of the attenuator. Heavier occupants, however, will stroke a farther distance than the lighter occupant. For this reason stroking requirements are established for the heavier occupant.

Requirements

The design requirements established by NASA were for two seat concepts, one a ceiling suspended seat and the other a floor supported seat. The seats were to be designed for a 75kg (165 lb) occupant. Navajo aircraft crash test data was to be provided by NASA to be used in establishing crash design pulses. However, due to the unavailability of finalized test data, NASA directed that the Crash Survival Design Guide impulse data in TR 71-22 (Reference 1) be used as a guide in establishing the crash pulse for the NASA seat designs. This essentially is a

[1]CRASH SURVIVAL DESIGN GUIDE, Dynamic Science; USAAMRDL Technical Report 71-22, Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia October 1971, AD 733358.

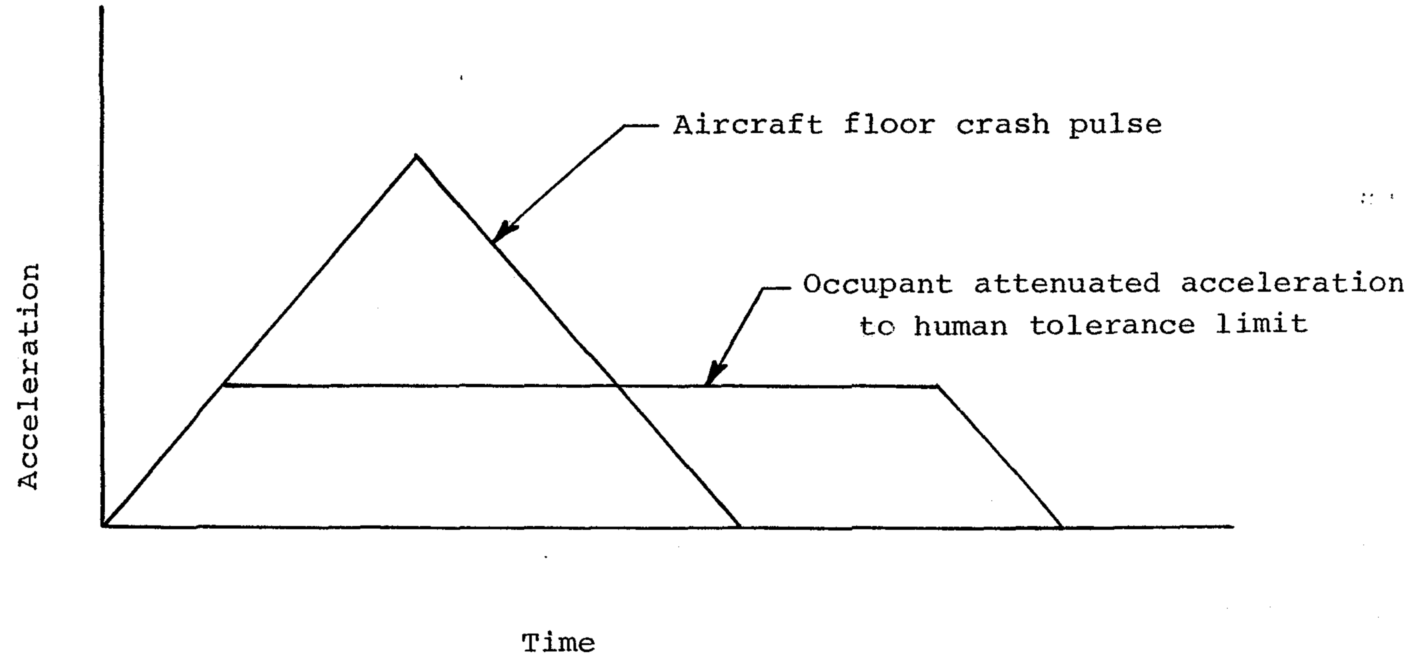


Figure 1. Crash pulse and attenuation curves.

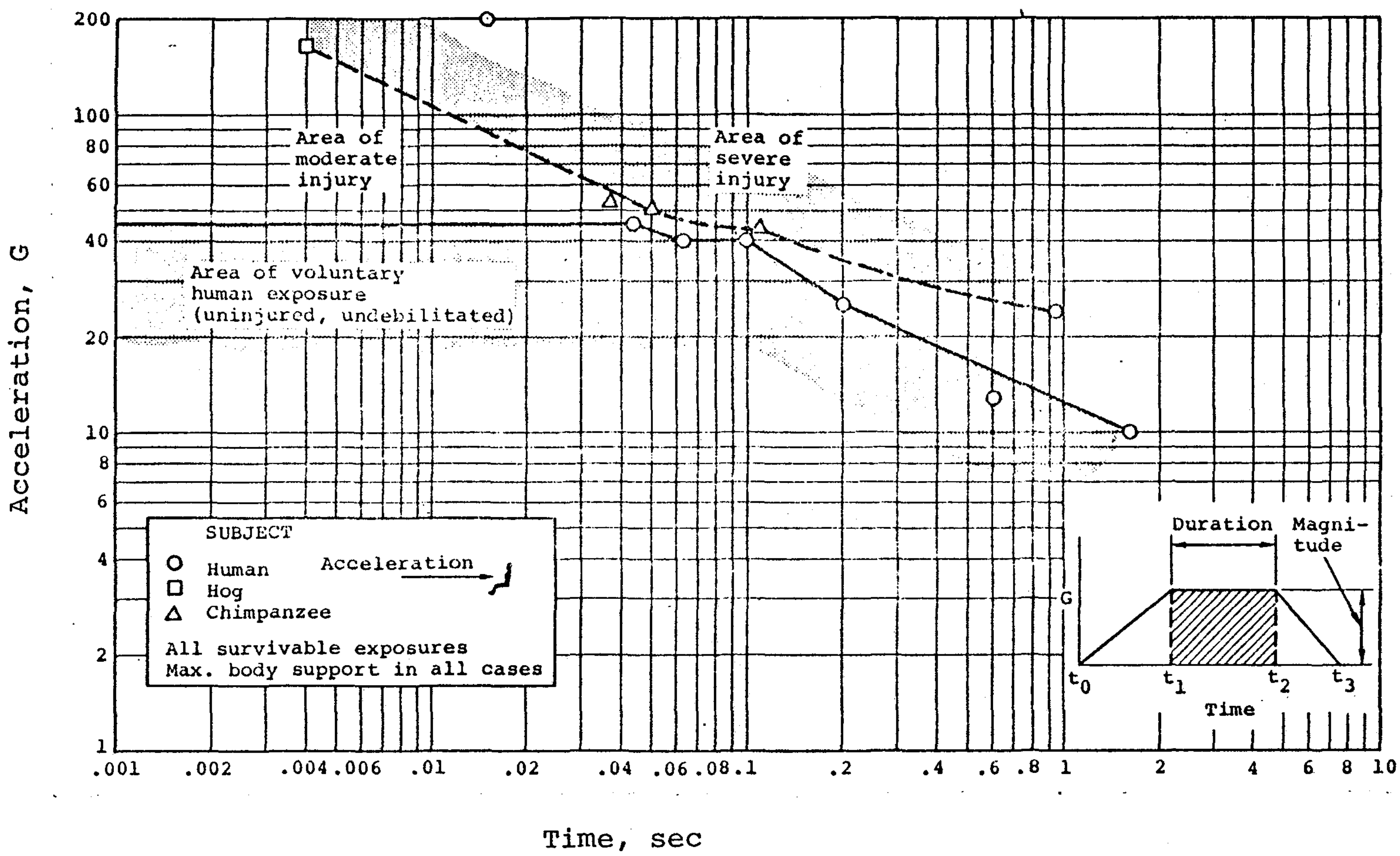


Figure 2. Human tolerance to forward acceleration.

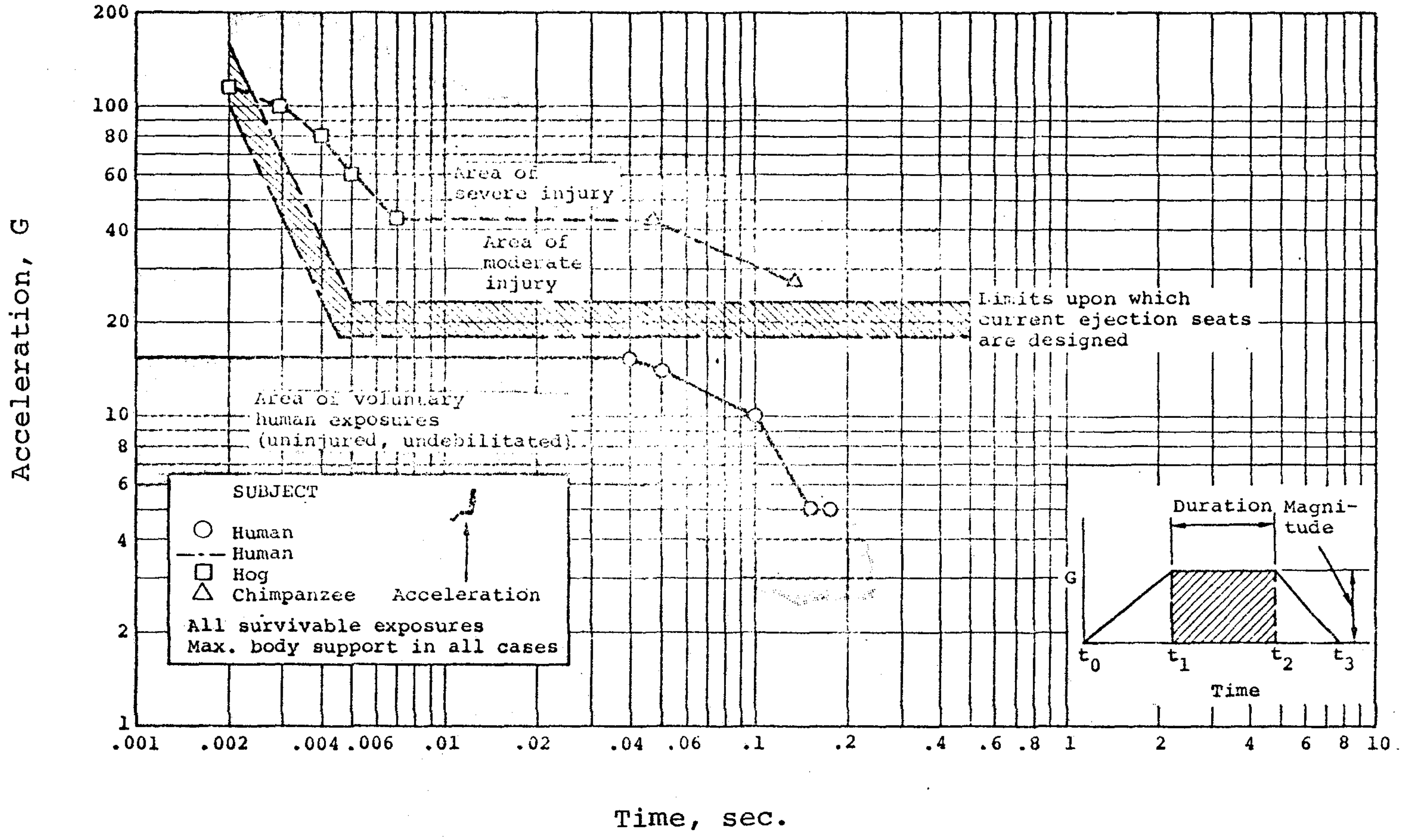


Figure 3. Human tolerance to downward acceleration.

forward impact at 15 m/s (50 fps) and a three-axis vertical impact at 15 m/s (50 fps). Both seats were to be designed within the envelope constraints for installation in the Piper Navajo aircraft. The seats however, could be adapted to any fixed wing aircraft or helicopter. Seat weight was to be approximately the same as that of the Navajo seat which is 10 kg (22 lbm).

GOALS

The following goals were established as the objectives of the crashworthy passenger seat development program.

- Establish energy absorbing seat design criteria
- Develop ceiling supported and floor mounted seat geometries.
- Determine crash loading on seat structure
- Perform stress analysis on basic seat structure
- Develop, fabricate, and test energy attenuating mechanisms
- Prepare detail design drawings

Scope

The crashworthy seat design program was divided into the following tasks:

Task I - Crashworthy ceiling suspended seat design

Task II - Crashworthy floor mounted seat design

Task III - Restraint System Design

Task IV - Energy attenuators development and tests

CRASHWORTHY CEILING SUSPENDED SEAT DESIGN - TASK I

Design Considerations

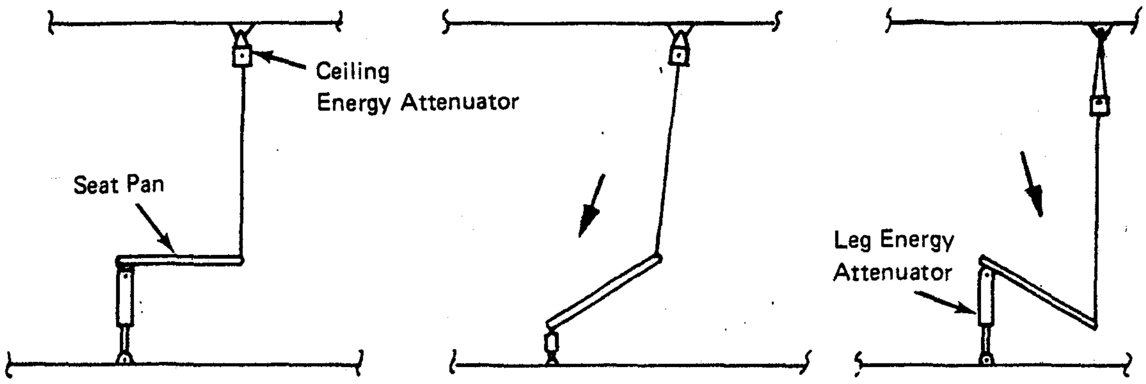
Ceiling suspended seats have been the preferred configuration selected for light weight crashworthy seating in military helicopters. This concept can be designed to be inherently stable during stroking without using guide tubes or tracks generally used on heavier floor mounted crashworthy pilot seats. The energy attenuators of seats suspended from the ceiling tend to be self-aligning with the occupant's center-of-gravity. This feature minimizes the change in moment and results in a near constant loading on the attenuators and a more constant acceleration on the occupant. One disadvantage is the need for adequate ceiling structure from which to suspend the seat.

Ceiling suspended seats must be designed such that they are fully suspended from the ceiling with energy attenuating devices. Supports below the seat pan (such as diagonal braces or cables) should only stabilize the seat and should freely collapse as the seat moves down. Rigid legs, even with deforming or stroking features, should not be used because attenuating devices above and below the seat do not tend to act together. Center-of-gravity shifts due to variations in occupant weight or variations in impact angle cause the load distribution to the attenuators to vary. As the load is shifted toward one or the other attenuator, that attenuator will stroke first, and the threshold stroking load for the second attenuator may not be reached (Figure 4).

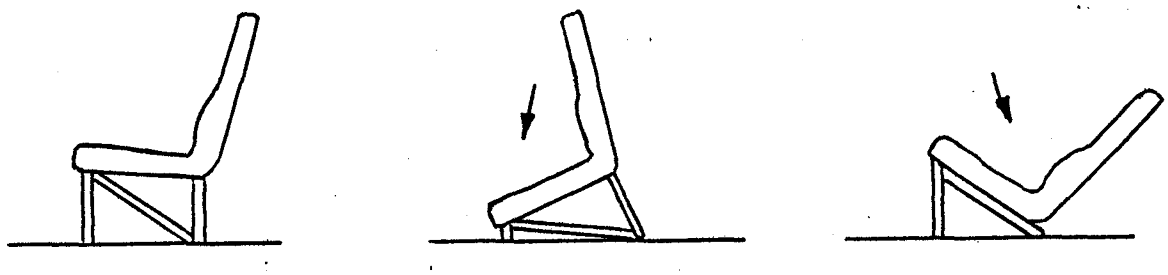
Seat Design

In designing a crashworthy seat which is fully suspended from the ceiling and has no vertical supports from the floor, the seat pan must be stabilized by attachments to the ceiling. This can be accomplished by slinging the seat with straps attached to the four corners of the seat pan (Figure 5a). Although this would provide the lightest weight approach, ingress and egress to the seat would be encumbered by the front straps.

The geometry of a seat which is fully supported from above, yet provides unencumbered freedom to the seat pan, is shown in Figure 5b. In this design a compressive tube member is used at the back of the seat and a tension strap runs from



Ceiling Suspended Seat



Floor Supported Seat

Figure 4. Effects of attenuators in parallel.

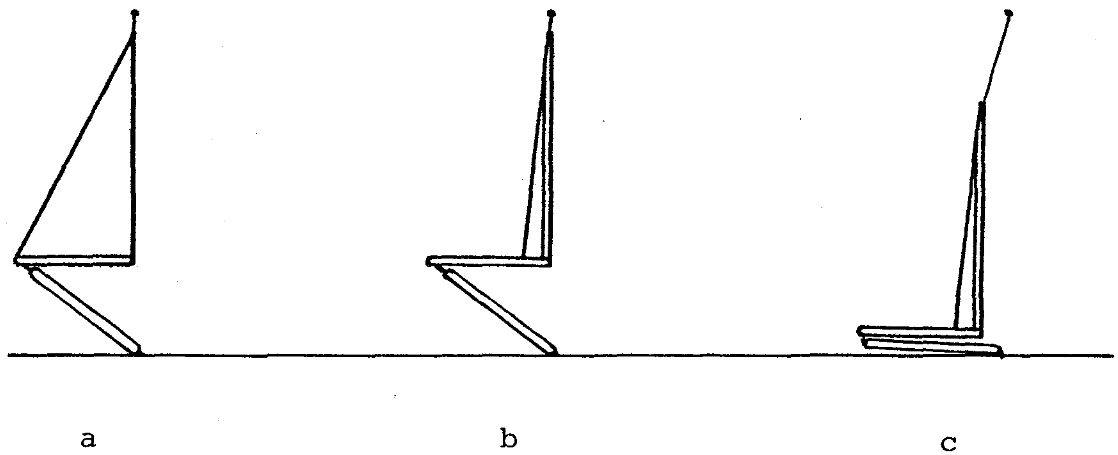


Figure 5. Seat pan suspension and stabilization.

the ceiling attachment to the seat pan, a short distance forward of the back. This provides a truss from which the tubular seat pan is cantilevered.

The seat is stabilized by members under the seat. These members are designed so as not to impede the seat from stroking fully to the floor. Diagonal tubular struts provide seat stability during vertical stroking. The struts rotate downward as the seat moves downward to the floor (Figure 5c). The seat pan is maintained in a level attitude through the action of the struts and the cantilevered suspension system. Energy attenuators are incorporated in the diagonal struts which stroke during predominantly forward crash accelerations.

Two sets of energy attenuators are used in the seat, one set at the ceiling and the other set in the diagonal struts under the seat. The attenuator at the ceiling consists of a hairpin loop of high tensile strength wire and 2 double grooved rollers. Each side of the wire loop is passed over both rollers in a double pass manner, providing a compact arrangement (Figure 6). The ends of the wire extend down into the seat back tubes.

During crash impact, controlled force/deflection is produced by bending and unbending wire as it passes back and forth over the rollers. Force of the occupant against the seat will cause stroking or movement of the wire over the rollers when a predetermined crash force is reached. This stroking force is determined by multiplying the occupant weight by an acceleration within the human tolerance limits. Stroking length of the attenuator is limited only by the length of the wire used. The unit is light in weight, weighing less than 0.06 kg (2 oz). It is highly reliable producing repeatable and flat force/deflection curves and is not affected by environmental factors. The unit is limited to use in tension load applications only.

The diagonal strut wire-bending energy attenuators (Figure 7) consists of telescoping aluminum tubes with fittings at each end for attachment to aircraft structure and the seat structure. Music wire or similar high tensile strength wire is attached to both ends of the inner tube. The wire is passed through 3 rollers on a trolley inside the tube. The trolley is pinned to the outer tube and a slot is provided in the inner tube to allow the trolley to move back or forth relative to the inner tube. This arrangement provides all the advantages of a pure wire-bending attenuator which is highly reliable, producing repeatable and flat force deflection curves and is not affected by environmental factors. It has the additional advantages of being able to stroke under tension or compressive loading and will maintain the rigidity of the seat after stroking.

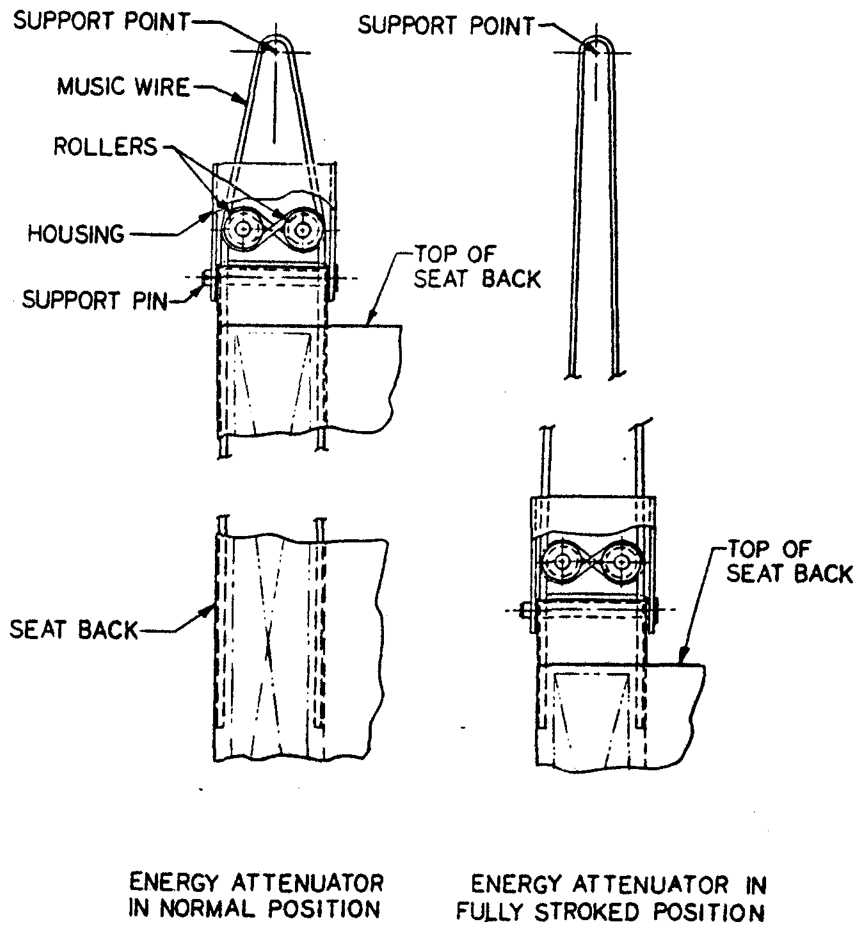


Figure 6. Typical tension wire-bending energy attenuator.

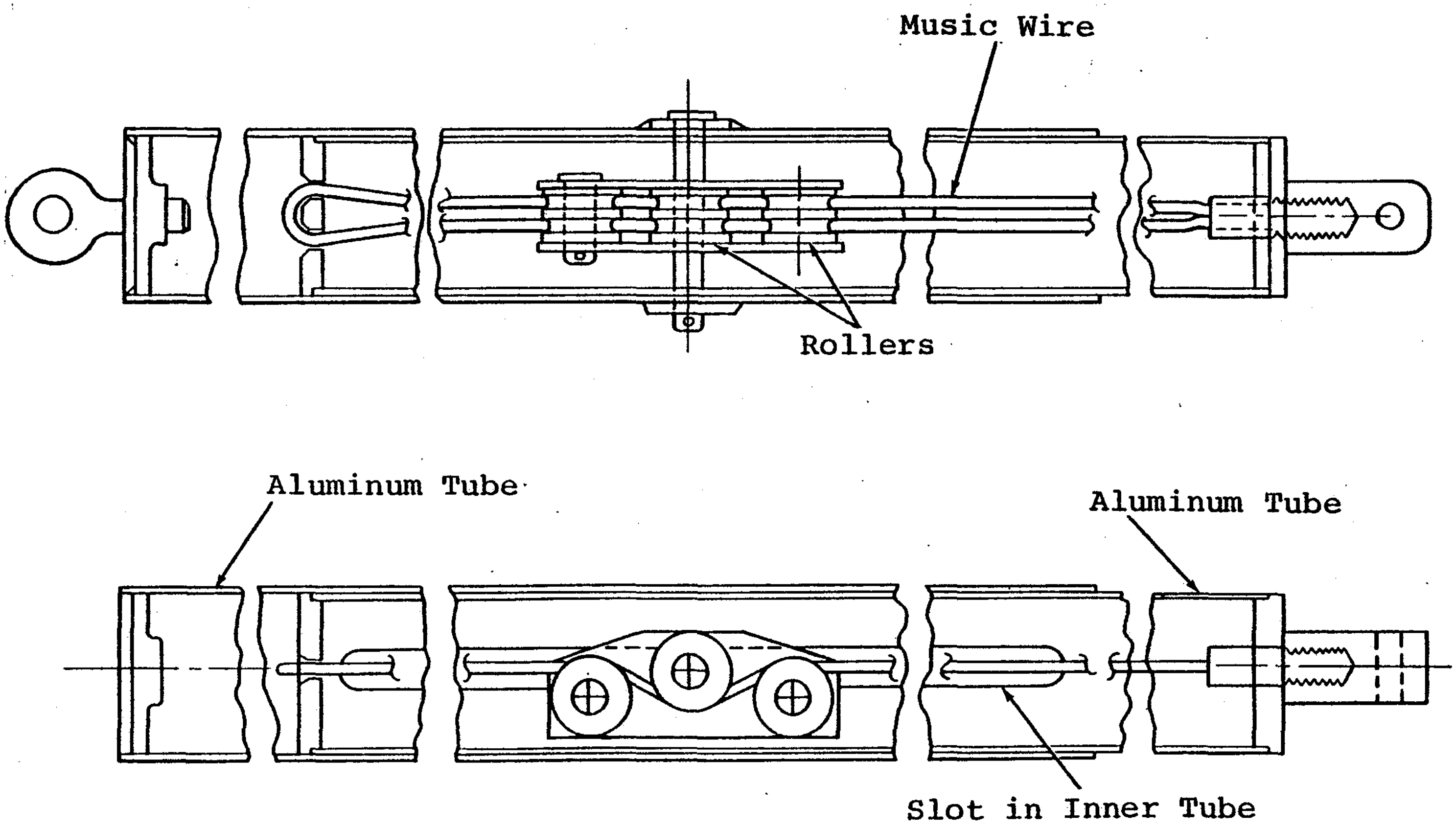


Figure 7. Tubular tension/compression wire-bending energy attenuator.

The diagonal strut attenuator serves as a stabilizing brace during predominantly vertical impact accelerations. It also serves as an energy attenuator and will stroke under predominantly forward impact accelerations. Figure 8 shows the kinematics for the seat in the fully stroked vertical and forward positions.

Energy attenuation is also provided on the seat in the lateral direction. Annealed stainless steel cables are crossed under the seat to provide stability for normal use and also to act as an energy attenuator. In a crash impact having lateral components, the annealed cable will yield at a predetermined load and will limit the lateral acceleration on the occupant. Due to the close proximity of the seat to the side of the aircraft, the seat will stroke laterally only toward the aisle. The seat and occupant would be restrained on the opposite side, by the side of the aircraft.

The seat pan and back are constructed of tubular frames. These frames are covered with low elongation polyester fabric which distribute the occupant load to the frames. Foam seat and back cushions are placed over the fabric covers. The thickness of the seat pan cushion is the maximum recommended for crashworthy seats. Thick cushions are not used because the occupant would be accelerated into a thick cushion during a crash and a high peak G overshoot would occur as the occupant bottoms-out.

The foam cushions are covered with upholstery material and vinyl. A metal skirt is provided around the bottom of the seat pan for aesthetic appearance and is padded with foam and covered with vinyl. The skirt is made of thin aluminum which is designed to crush as the seat pan strokes to the floor, providing the maximum seat stroke.

A foam headrest is provided over the top of the seat back. The vertical energy attenuators and shoulder strap attachments are contained in the headrest. The headrest is covered with the same material as the seat cushions.

Installation of the seat in the aircraft consists of 2 attachments at the ceiling and 4 attachments at the floor. Brackets are provided on the floor at the rear of the seat for attachment of the diagonal struts and vertical hold-down cables. Clips are provided on the floor at the front of the seat for attaching the stabilizing cables.

Attachment to the ceiling is by means of turnbuckles. One end of the turnbuckle is attached to the aircraft structure in the ceiling and the other end is attached to the

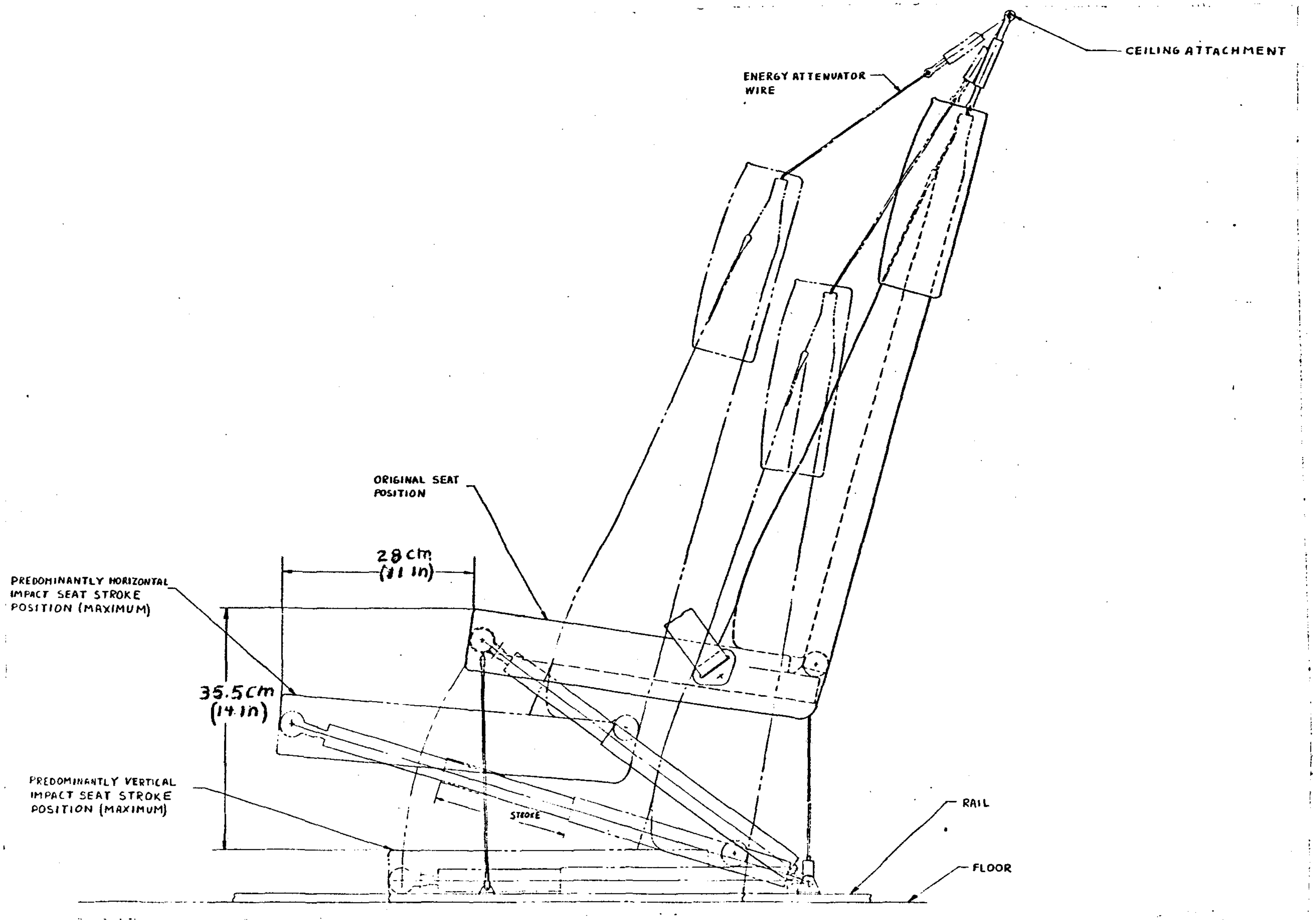


Figure 8. Seat kinematics for vertical and forward stroking.

vertical wire-bending energy attenuator. The tightening of the turnbuckles provides tension on the cables under the seat, producing a rigid seat installation.

The attenuation system is designed for the vertical effective weight of a 75 kg (165 lbm) occupant with a predominantly vertical resultant force impact and for the full 75 kg (165 lbm) occupant weight in a predominantly forward resultant force impact. Vertical effective weight is 80 percent of occupant weight because leg weight is supported by the floor. Ceiling attenuators are sized to limit the 75 kg (165 lbm) occupant acceleration to 12 G so as to minimize ceiling structure loading. Diagonal strut attenuators are sized to limit the forward acceleration of the 75 kg (165 lbm) occupant to 15 G. Crash pulse is as specified in TR 71-22 (Reference 1) and as amended by TR 77-13 (Reference 2). Details on the crash pulse used in the ceiling suspended seat design are shown in Table I (Reference 2). To obtain the crash pulse input to the seat, measured at the floor, it is assumed that some of the crash energy is absorbed by airframe structural deformation or stroke. The energy remaining is absorbed by seat stroking. Table I shows the total system crash energy to be absorbed and the total stroke required to absorb the energy. The energy absorbed by airframe deformation, represented by test sled stroke, plus the energy absorbed by the seat when added together equals the total system energy absorption.

With energy attenuators provided above the seat for vertical stroking, diagonal struts below the seat for forward stroking and crossed cables under the seat for lateral stroking, energy attenuation is accomplished in each of these directions. When acting together, the attenuators provide combined three-axis seat attenuation.

A weight estimate of the ceiling suspended seat shows the weight to be comparable with the weight of the non-crashworthy Navajo seat.

[2]Reilly, M. J., CRASHWORTHY, TROOP SEAT TESTING PROGRAM, Boeing Vertol Company, Philadelphia, Penna.; USAAMRDL Technical Report 77-13, Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, August 1977.

TABLE 1. SEAT STROKE

Test or Impact Condition	TEST PULSE Item *	TEST PULSE Velocity Change, fps	Peak G	Avg G	Calc. Stroke cm (in.) 100% Efficiency	Estimated Efficiency	Required Stroke cm (in.)
3-Axis	System	42	--	10.5	79.5 (31.3)	87%	91.4 (36.0)
Floor	Sled	42	34	17.0	49.1 (19.3)	85%	57.8 (22.8)
Seat	Seat	42	--	10.5	30.4 (12.0)	89%	33.6 (13.2)
Fwd	System	50	--	10.5	112.5 (44.3)	85%	141.1 (55.5)
Floor	Sled	50	24	12.0	98.6 (38.8)	85%	123.2 (48.5)
Seat	Seat	50	--	10.5	14.0 (5.5)	85%	17.7 (7.0)
3-Axis	System	50	--	12.0	98.6 (38.8)	85%	116.0 (45.7)
Ceiling	Sled	50	34	17.0	69.6 (27.4)	85%	82.0 (32.3)
Seat	Seat	50	--	12.0	29.0 (11.4)	85%	34.1 (13.4)
Fwd	System	50	--	10.5	112.5 (44.3)	85%	140.8 (55.5)
Ceiling	Sled	50	24	12.0	98.6 (38.8)	85%	123.4 (48.5)
Seat	Seat	50	--	10.5	14.0 (5.5)	85%	17.7 (7.0)

* System = Total deceleration of test sled plus seat

CRASHWORTHY FLOOR MOUNTED SEAT DESIGN - TASK II

Design Considerations

Design of a lightweight, free-standing, floor mounted seat is more difficult than the design of a ceiling suspended seat. A structural/mechanical system must be provided on the floor to guide and stabilize the floor mounted seat during crash impact stroking. The approach used for crashworthy pilot seats in military aircraft is to provide a structural stand or carriage on which guide tracks or slides are mounted to control the seat during stroking. Such an approach is not practical for a lightweight passenger seat. The structural stand not only would be heavy but would also present a hazard for impact by the occupant seated behind the seat. The attenuation and stabilizing guide system must be integral with and contained within the seat bucket envelope to minimize weight and to avoid impact hazards to other passengers.

A stabilizing guide system which is integral with the seat must move as the seat strokes. Loads on such a system are constantly changing as the center-of-gravity of the seat and occupant change relative to the point that the system is anchored to the floor. As the center-of-gravity shifts relative to the energy attenuators, the load or occupant acceleration required to cause the attenuators to stroke will also vary.

The resultant load on the seat, due to variations in impact attitude, will also have a similar effect on the occupant acceleration required to cause attenuator stroking. A ceiling suspended seat, being free to pivot about its ceiling attenuator, tends to align the attenuators through the point of applied force. This minimizes the change in the moment arm and results in a more constant occupant acceleration. The floor mounted seat, being more affected by the variations in the direction of the applied force, will have more limitations than the ceiling supported seat. The floor mounted seat design loading will have to be optimized for the more probable impact attitudes and conditions.

The floor mounted seat concept presented uses the predominantly vertical impact condition described in the Crash Survival Design Guide (Reference 1) as the optimum condition for which the energy attenuating system is designed. This condition prescribes a resultant force on the seat, acting through the occupant center-of-gravity, at an angle of 0.524 rad (30°) from vertical and with a 0.175 rad (10°) roll. An impact velocity of 15 m/s (50 fps) is prescribed. At this speed the airplane is not flying but is in a stalled condition. Its vertical speed is probably near to or greater than its forward speed. Impact would occur with a predominantly vertical component. Some forward component would most likely be present for a fixed wing aircraft. A pure vertical impact is not as likely for a fixed wing aircraft as it would be for a helicopter. For this reason, the pure vertical condition will not be considered in the optimized design condition.

The requirements of the Crash Survival Design Guide (Reference 1) establishes a 15 m/s (50 fps) velocity change for forward impact. Lateral components are considered by designing for impact with a 0.524 rad (30°) yawed attitude. For this condition the aircraft impacts the ground in a normal landing attitude with landing gear either down or retracted. The aircraft is considered to be flying at the instant of touchdown and has a speed much in excess of the maximum design velocity change of 15 m/s (50 fps). It is considered that the velocity change occurs rapidly but the aircraft does not decelerate completely. A bounce may occur after the first impact deceleration and subsequent decelerations would be more gradual until the aircraft comes to a stop. Another horizontal impact consideration is that the aircraft has landed and runs into an abutment after the aircraft had gradually decelerated; impact occurring at or below 15 m/s (50 fps). Little or no vertical component is present in these horizontal impact conditions. Human tolerance to forward acceleration is considerably higher than for vertical, therefore, energy attenuation in the forward direction is not critical.

Design for impact with resultant forces in the area between horizontal and 0.524 rad (30°) from vertical will be given minimal consideration. The reason is that for the aircraft to develop resultant forces in this quadrant, the aircraft would have to impact the ground in a nose-low attitude. The impact velocity would be greater than 15 m/s (50 fps) and deceleration would be rapid, producing a high peak crash impulse. Velocity changes above 15 m/s (50 fps) are not considered to be potentially survivable, therefore the energy attenuation system design for the floor mounted seat will not be optimized for this region of impact attitudes or resultant forces.

Due to the lower efficiency of the attenuation system of the floor supported seat, as compared to the ceiling suspended seat, the predominantly vertical 15 m/s (50 fps) crash impulse requirement of Reference 1 and 2 could not be met. A 13 m/s (42 fps) impact was used for this condition and is shown in Table 1.

Seat Design

The basic construction of the floor mounted seat structure is similar to that of the ceiling suspended seat structure. A tubular member outlines the seat pan and fabric cover is stretched across the tubular frame supporting the foam cushion. The seat back is also formed of tubular members covered with a fabric membrane. Seat back support is provided by a tubular strut attached to each side of the seat back at the top and to each side of the seat pan. Shoulder harness loads, applied to the top of the seat back, are reacted by a tension load on the vertical back members and a compression load on the diagonal strut members.

The seat pan is supported from the floor by a 4-bar linkage system. The arrangement allows the seat to stroke downward and forward during crash impact while maintaining the seat pan in a level attitude. Figure 9 shows the kinematics of a stroking seat. Parallel links attached to the front and rear of the seat pan are rigid, withstanding tension and compression loading. A third link connected between the top of the rear fixed link and the bottom of the front fixed link is a compressible link or energy attenuator.

The energy attenuator is a wire-bending tubular device similar to the telescoping tube diagonal strut attenuator used under the ceiling suspended seat. The principal difference is the outer telescoping tube which has been shortened and the attachment to the seat is at the trolley pin, rather than at the end of the outer telescoping tube. This arrangement allows a greater stroke-to-length ratio permitting the seat to stroke to the floor. The stroking attenuator is projected into the seat back (Figure 9). During stroking, as well as during normal flight, lateral stability of the seat is maintained by diagonal cables attached in the plane of the fixed links.

The parallel linkage energy attenuation system provides an optimum crash force attenuation for the 0.524 rad (30°) from vertical resultant condition. It also provides energy attenuation up to the 1.571 rad (90°) from vertical resultant or horizontal crash force. The single attenuator, through the action of the parallelogram linkage, provides for the predominantly vertical as well as horizontal impact pulse while separate attenuators are required for the ceiling suspended seat. With the use of diagonal cables for lateral attenuation, the seat provides energy attenuation in all three axes.

A weight estimate of the floor mounted energy attenuating seat shows the weight to be comparable with the weight of the non-crashworthy Navajo seat.

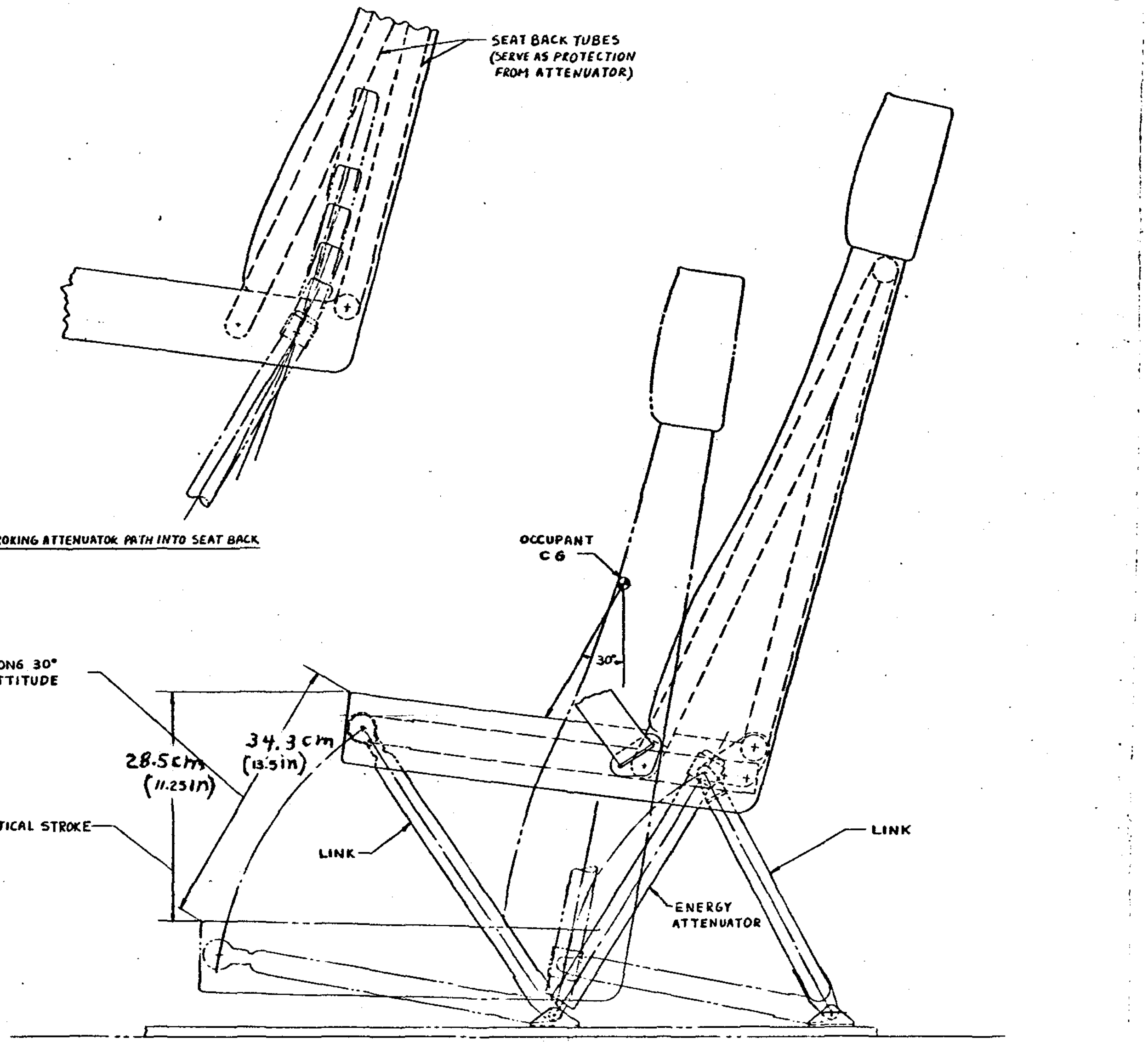


Figure 9. Seat kinematics for combined vertical and forward stroking.

RESTRAINT SYSTEM DESIGN - TASK III

The restraint system proposed for use on ceiling suspended crashworthy passenger seats is unique for aircraft installations. A system for proper crashworthiness requires a lapbelt and double shoulder strap arrangement. The problem is one of designing a system which makes it difficult for the occupant not to use the shoulder strap portion of the system. When a system is provided which employs an individual lapbelt and an individual shoulder harness, only the lapbelt is used in most instances.

The proposed system combines the lapbelt and shoulder strap into a continuous strap such that the shoulder strap must be used in order to properly adjust the lapbelt. The shoulder straps are connected in an inverted Y arrangement to the seat back at the headrest (Figure 10). Conventional lapbelt anchor fittings are provided on each side of the seat pan. The shoulder straps are threaded through the anchor fittings and a lapbelt buckle is attached to one end. The other end is threaded through an adjuster which plugs into the buckle.

Donning the restraint system consists of sitting in the seat and slipping the shoulder straps over the shoulders. The ends of the lapbelt are grasped and the plug-in connection inserted in the buckle. The free end of the strap is pulled through the adjuster until the shoulder straps and lapbelt are snug. Only one adjuster is provided otherwise the lapbelt could be adjusted snugly while the shoulder straps remained stowed against the back of the seat. The position of the lapbelt buckle would be toward the right side of the seat when the system is properly adjusted for a heavy person and toward the left side of the seat for a small person.

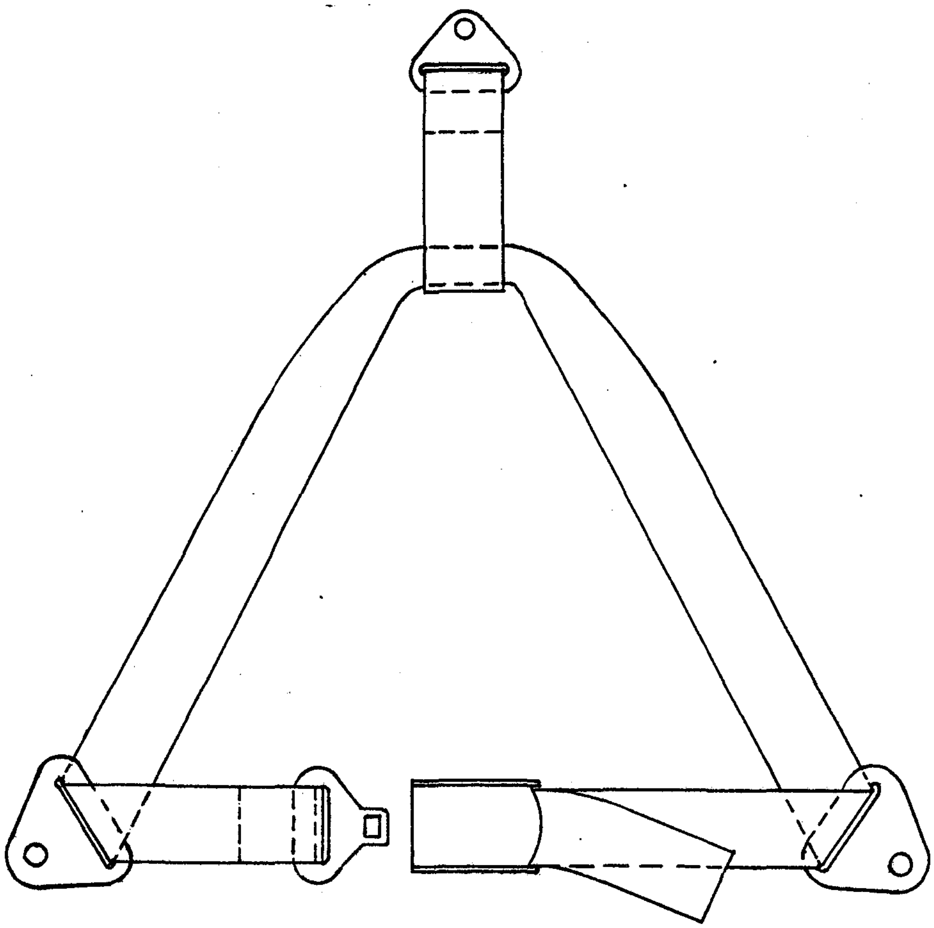


Figure 10. Combined lapbelt shoulder harness restraints system.

ATTENUATION SYSTEM TESTING - TASK IV

Types of energy attenuators tested and the performance of the tests are discussed in this section.

Energy Attenuator Configurations

Attenuators used for the ceiling suspended seat and the floor mounted seat are similar in that they all employ a wire element which bends in passing over rollers during crash load stroking. Two types of attenuators are used for the ceiling suspended seat, a simple tension wire and roller arrangement at the ceiling and telescoping tube tension/compression device under the seat. The floor mounted seat uses only one type attenuator, a modified telescoping tube type, which is supported at the center pin rather than at the end, allowing a shorter couple between support points. The outer telescoping tube is shortened to provide more clearance.

Energy Attenuator Static Testing

Four static tests were conducted on the three types of energy attenuators. The test number will be the same for similar tests; however, a letter suffix designates the repeat of a given test. Tests were conducted in a tension/compression Instron test machine.

<u>Test 1 - Tension Attenuator Ceiling Mounted</u> - The ceiling mounted energy attenuator, consisting of a wire loop passing over 2 rollers in an aluminum housing, was installed in the test machine. The wire loop was 2.54 mm (0.1 in.) diameter music wire. Adapters were used for attaching the test specimen to the lower base plate and to the load cell at the top (Figure 11).

A load was applied and increased until it reached 4804 N (1080 lbf). At this point the attenuator began stroking as the wire moved over the rollers. A characteristic peak force due to starting friction was recorded (Figure 12). The load dropped down to 4448 N (1000 lbf) and ran steadily as the attenuator stroked 0.33 m (13 in.). The test was stopped and then restarted at the 0.33 m (13 in.) point to determine the peaking effect. The load rose to 4671 N (1050 lbf) and dropped

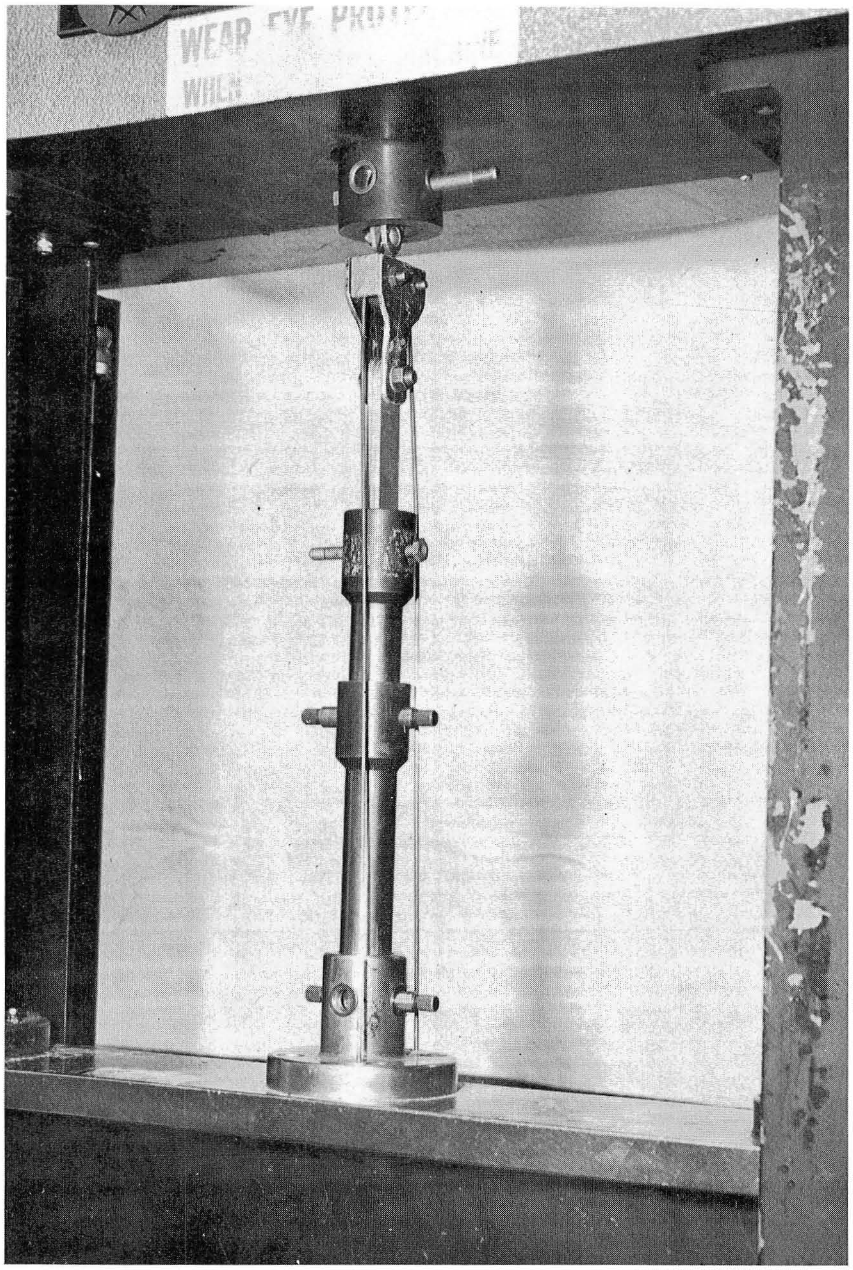


Figure 11. Pre-test 1, tension wire energy attenuator.

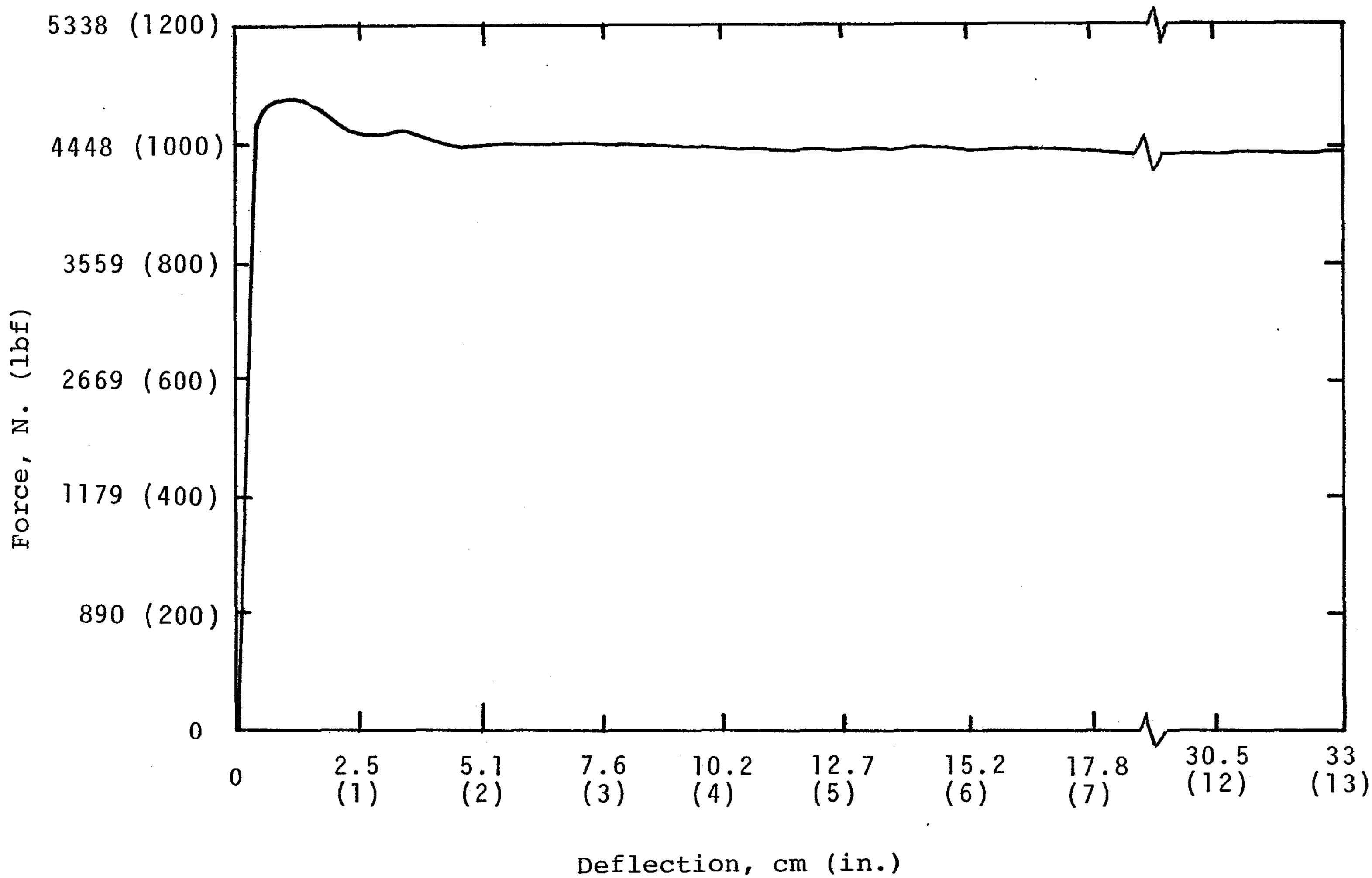


Figure 12. Tension attenuator force/deflection.

back to 4448 N (1000 lbf) during the remainder of the run. A smooth and flat force/deflection curve was produced which is characteristic of wire-bending energy attenuators. Figure 13 shows the attenuator in the stroked condition.

Test 1A - Tension Attenuator Ceiling Mounted - A second test was conducted with a wire-bending tension attenuator using a different configuration wire element. To eliminate the starting peak, shown in Figure 12, a slack loop configuration was used (Figure 14). The wire element was made of 302 stainless steel wire of 2.8 mm (0.11 in.) diameter. Test installation was the same as shown in Figure 11.

A load was applied and stroking began at 4715 N (1060 lbf). The starting peak had been eliminated and the load rose gradually until the steady stroking force of 5516 N (1240 lbf) was reached at 0.05 m (2 in.) of deflection. Stroking continued at this level until test was stopped after 0.33 m (13 in.) of deflection (Figure 15). Elimination of the starting peak is desirable to prevent excessive initial peak accelerations on the occupant in a crash.

Test 2 - Tension/Compression Telescoping Tube Attenuator - A test was conducted on the attenuator used for predominantly forward crash loads and installed diagonally under the ceiling suspended seat. The attenuator consists of a telescoping tube in which a wire element is passed over 3 rollers during stroking (Figure 7). Music wire of 2.54 mm (0.1 in.) diameter was used for the wire element. Adapers were used to install the test specimen in the Instron test machine (Figure 16). Attachment was made to the load cell at the top and base plate at the bottom.

A force was applied to the attenuator and was increased until a load of 4849 (1090) lbf) was reached at which point, stroking began. An initial peak of 5071 N (1140 lbf) was recorded and the load dropped to the continuous stroking load of 3870 N (870 lbf) (Figure 17). Stroking continued until the test was stopped at 0.20 m (8 in.) of deflection.

The initial starting peak was excessive; however, this can be eliminated by providing slack in the wire loop similar to that shown in Figure 14. Figure 18 shows the attenuator in the stroked condition.

Test 3 - Tension/Compression Trunnion Tube Attenuator - A trunnion tube energy attenuator, similar to the telescoping tube attenuator, for forward load attenuation of the ceiling mounted seat, was tested for the floor mounted seat. The trunnion attenuator is mounted by a trunnion connection at the wire bending rollers (Figure 19). The attenuator consists of a tube in which a wire element, anchored to both ends of the tube, is passed over 3 rollers during stroking. Music

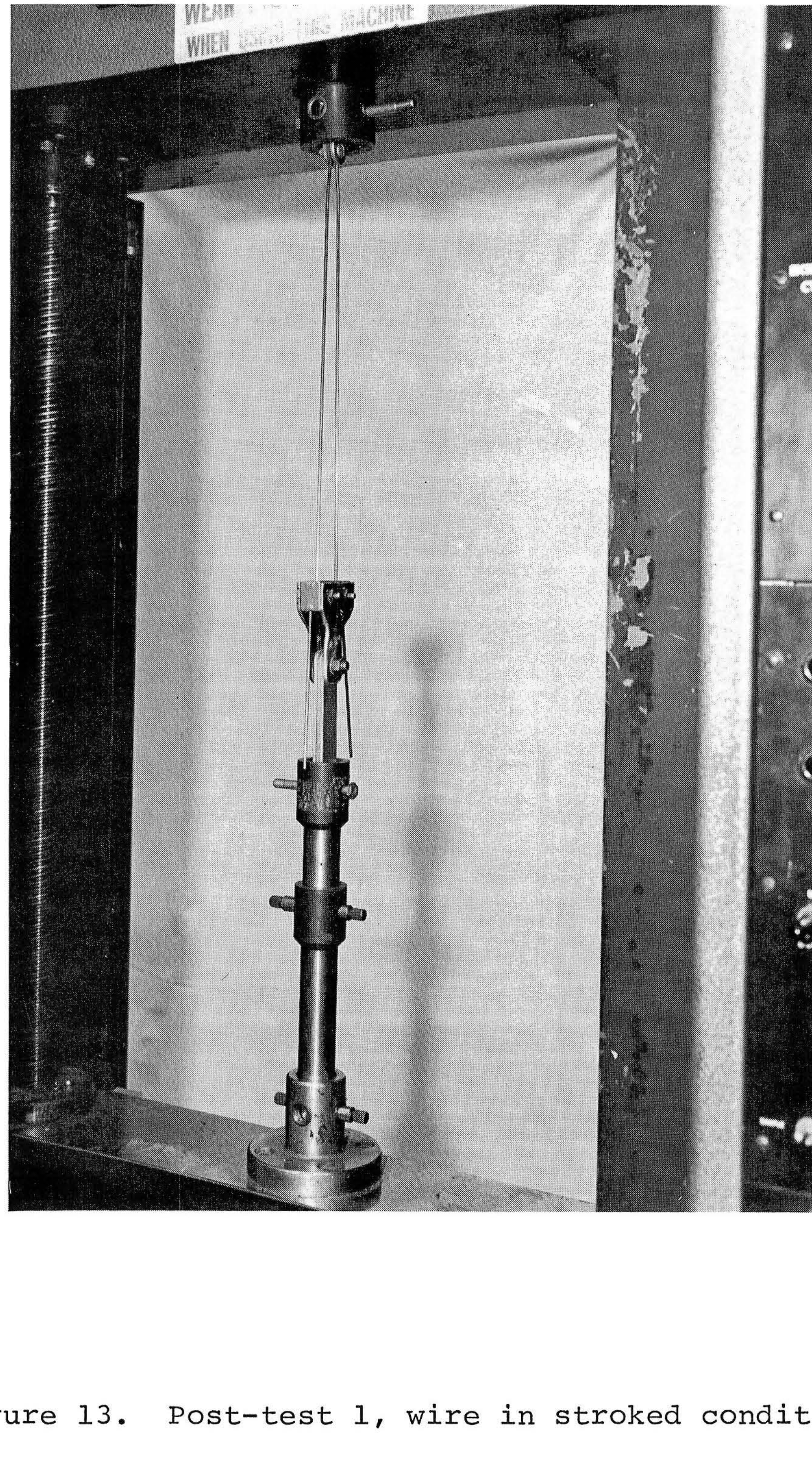


Figure 13. Post-test 1, wire in stroked condition.

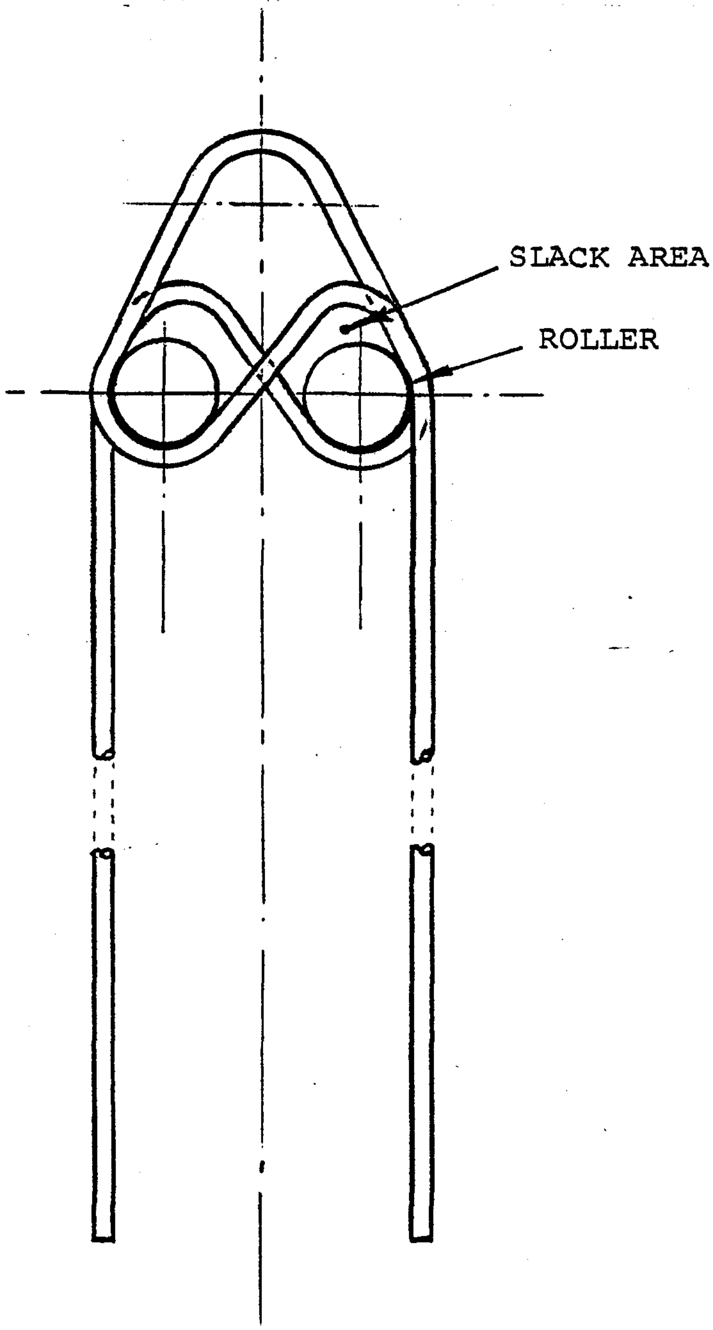


Figure 14. Slack-loop energy attenuator wire.

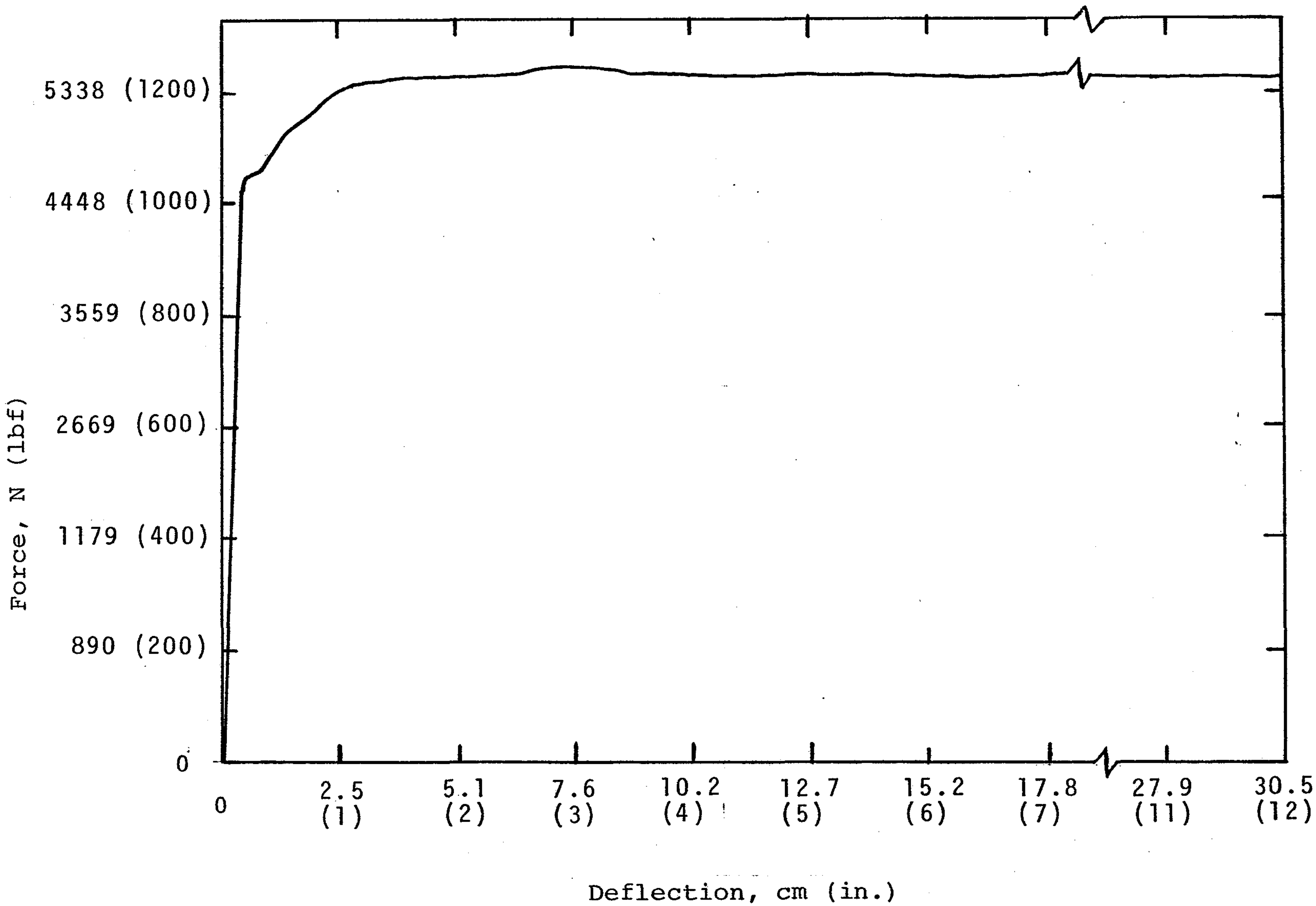


Figure 15. Tension attenuator force/deflection.

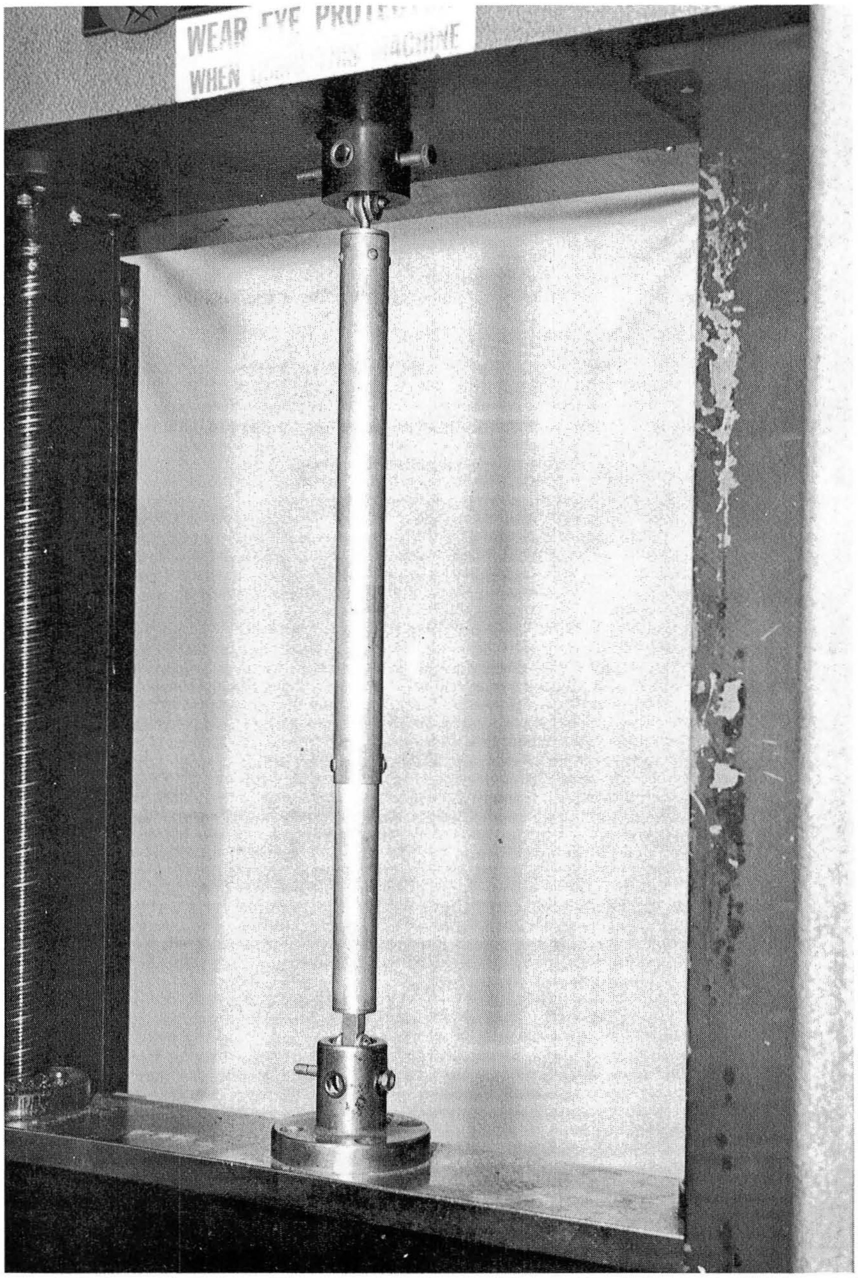


Figure 16. Pre-test 2, telescoping tube energy attenuator.

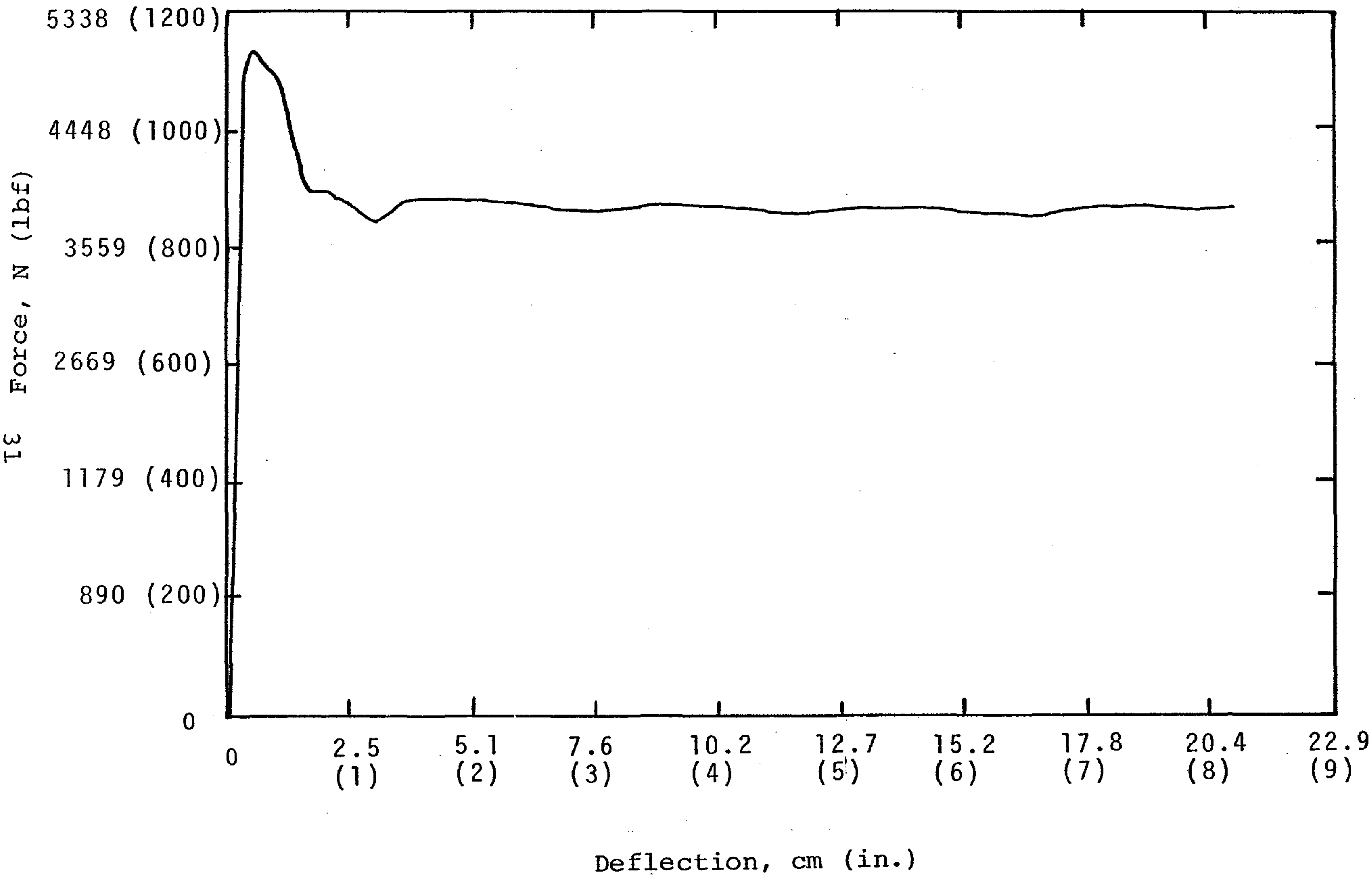


Figure 17. Tubular attenuator force/deflection.

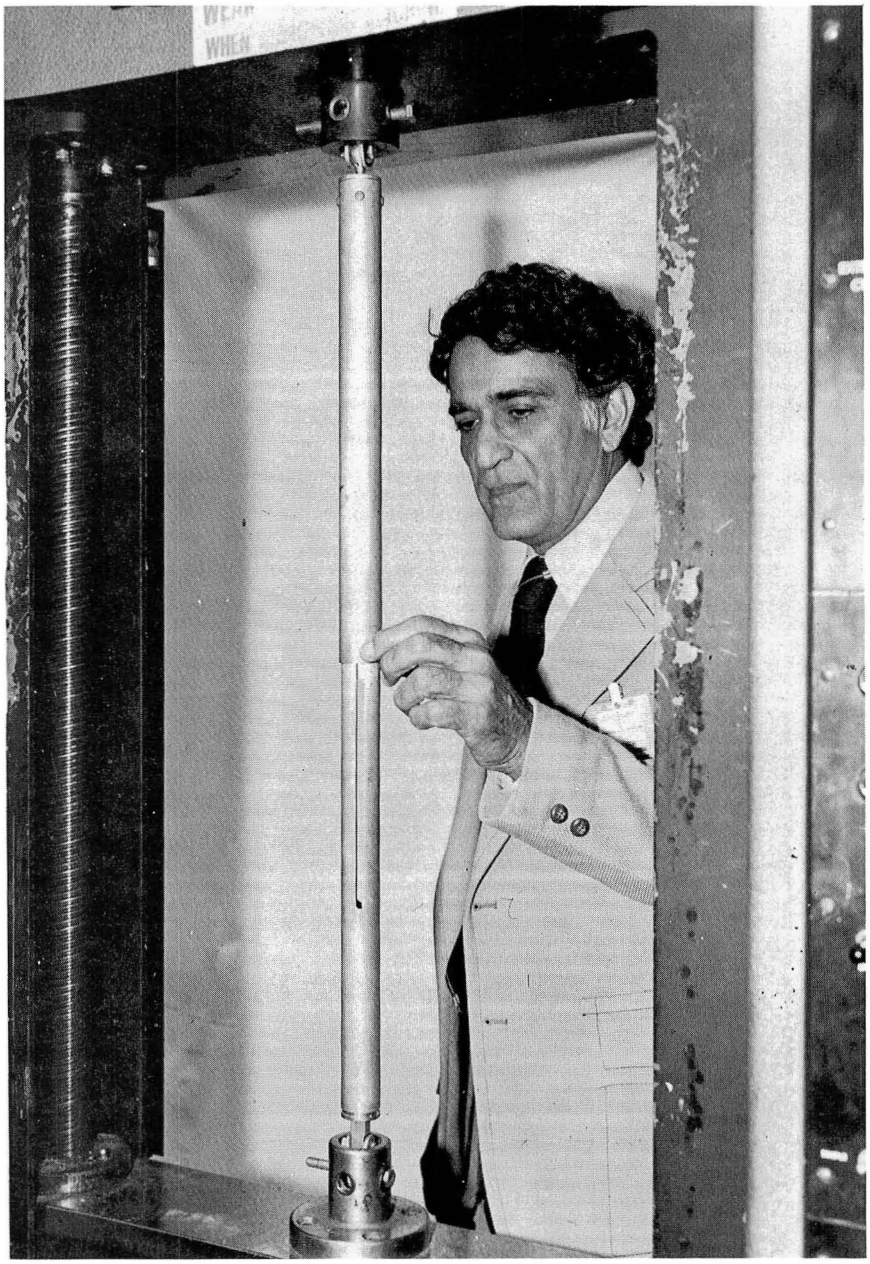


Figure 18. Post-test 2, attenuator in stroked condition.

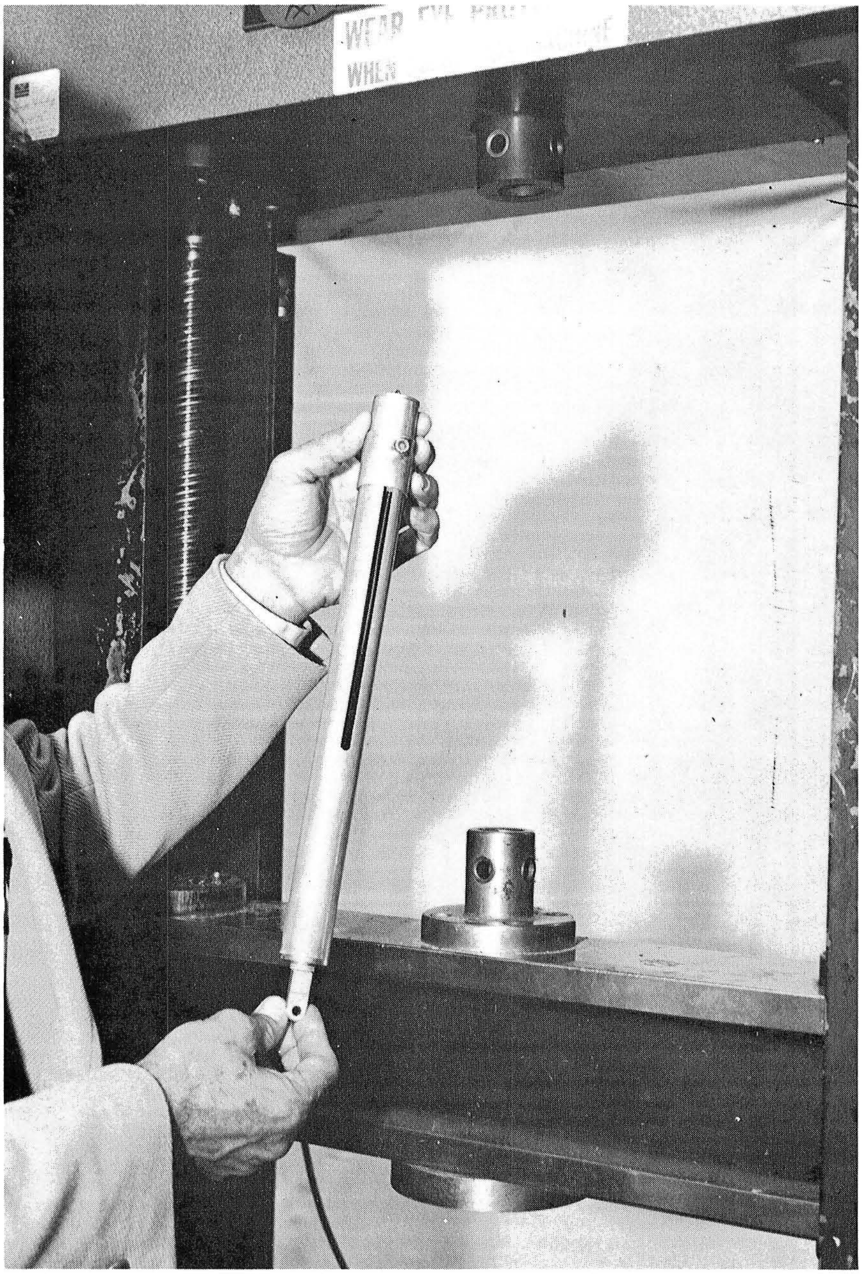


Figure 19. Trunion tube energy attenuator assembly.

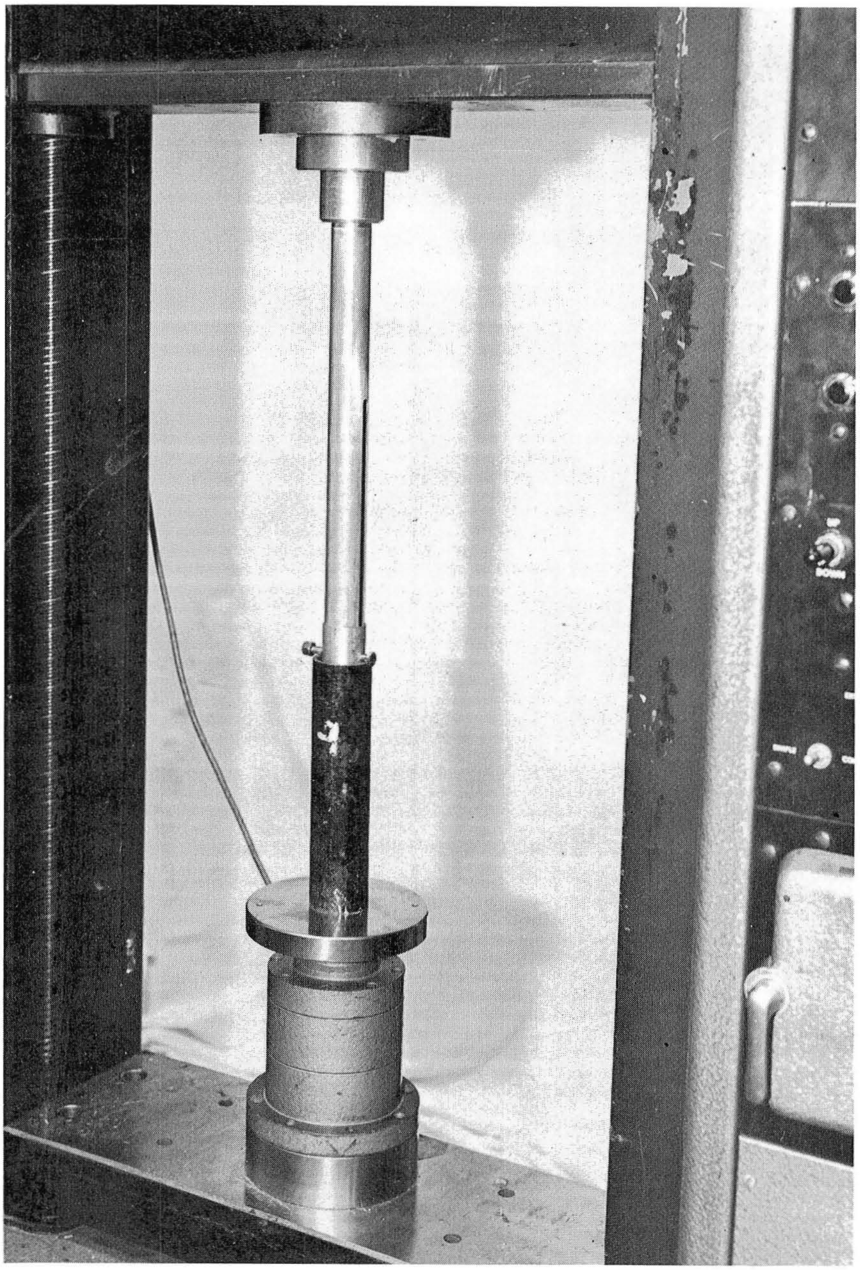


Figure 20. Pre-test 3, trunion tube energy attenuator.

wire of 2.54 mm (0.1 in.) diameter was used as the wire element. The attenuator was placed in the Instron test machine between the load cell at the bottom and the base plate at the top. A length of tubing was used between the load cell and the attenuator trunnion point to provide a space for the attenuator to stroke into (Figure 20).

A force was applied to the attenuator and was increased until a load of 4003 N (900 lbf) was reached at which point stroking began. An initial peak of 5160 N (1160 lbf) was recorded. The load dropped to 3825 N (860 lbf) within 0.03 m (1.0 in.) of stroking and settled at a load of approximately 3559 N (800 lbf) during the remainder of the stroke (Figure 21). The test was stopped at 0.163 m (6.4 in.) when the end of the attenuator contacted the test fixture. Figure 22 shows the attenuator after the test with the length of tubing, used for support, removed.

Energy Attenuator Static Test Summary

All of the attenuators tested functioned properly producing flat force/deflection curves. Initial peaks experienced with the tubular attenuators can be eliminated by the use of slack in the wire loop similar to that in the tension attenuator. Wire size may also be changed if the loads produced during stroking differ from the desired load determined by the load analysis study.

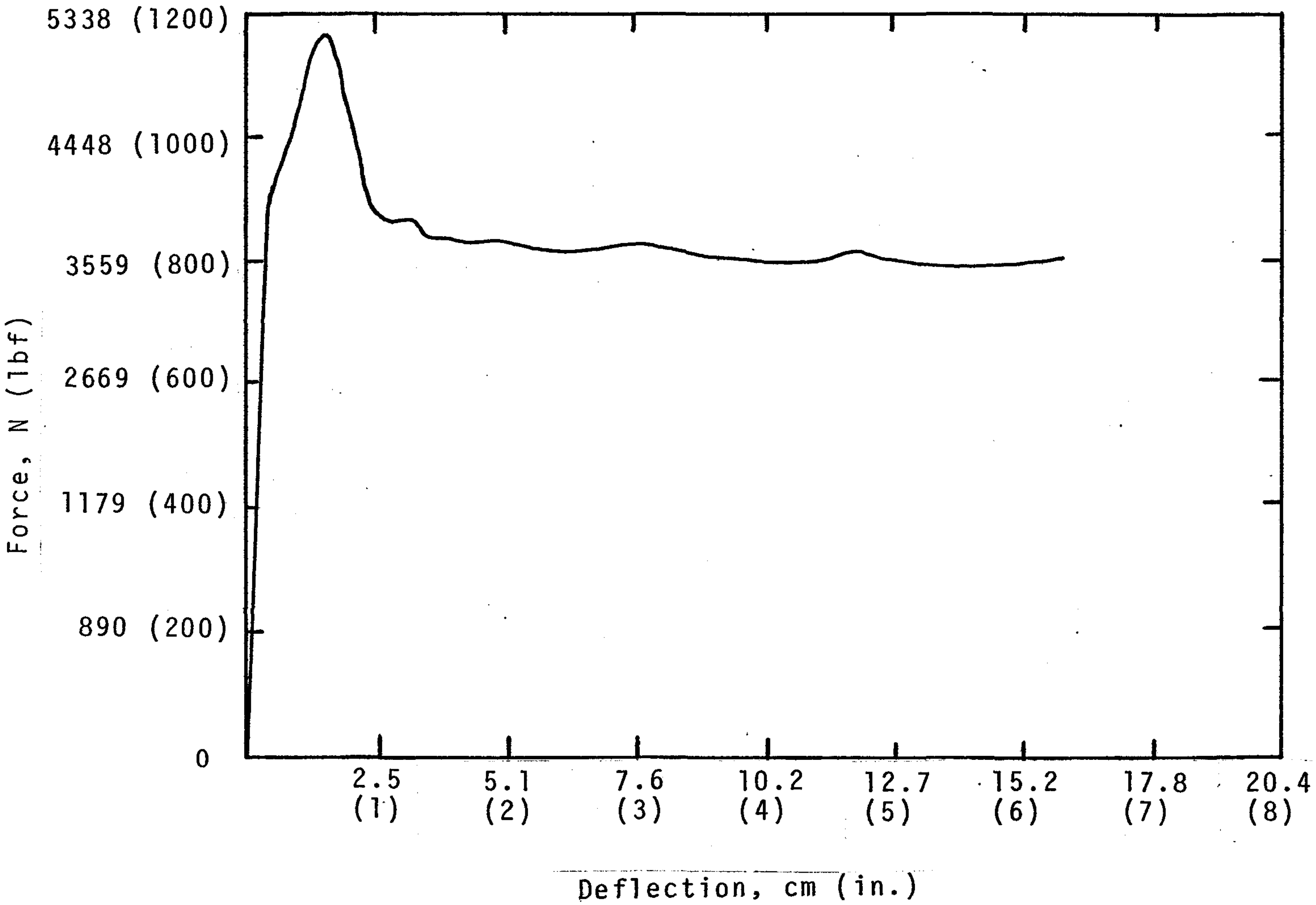


Figure 21. Tubular attenuator force/deflection.

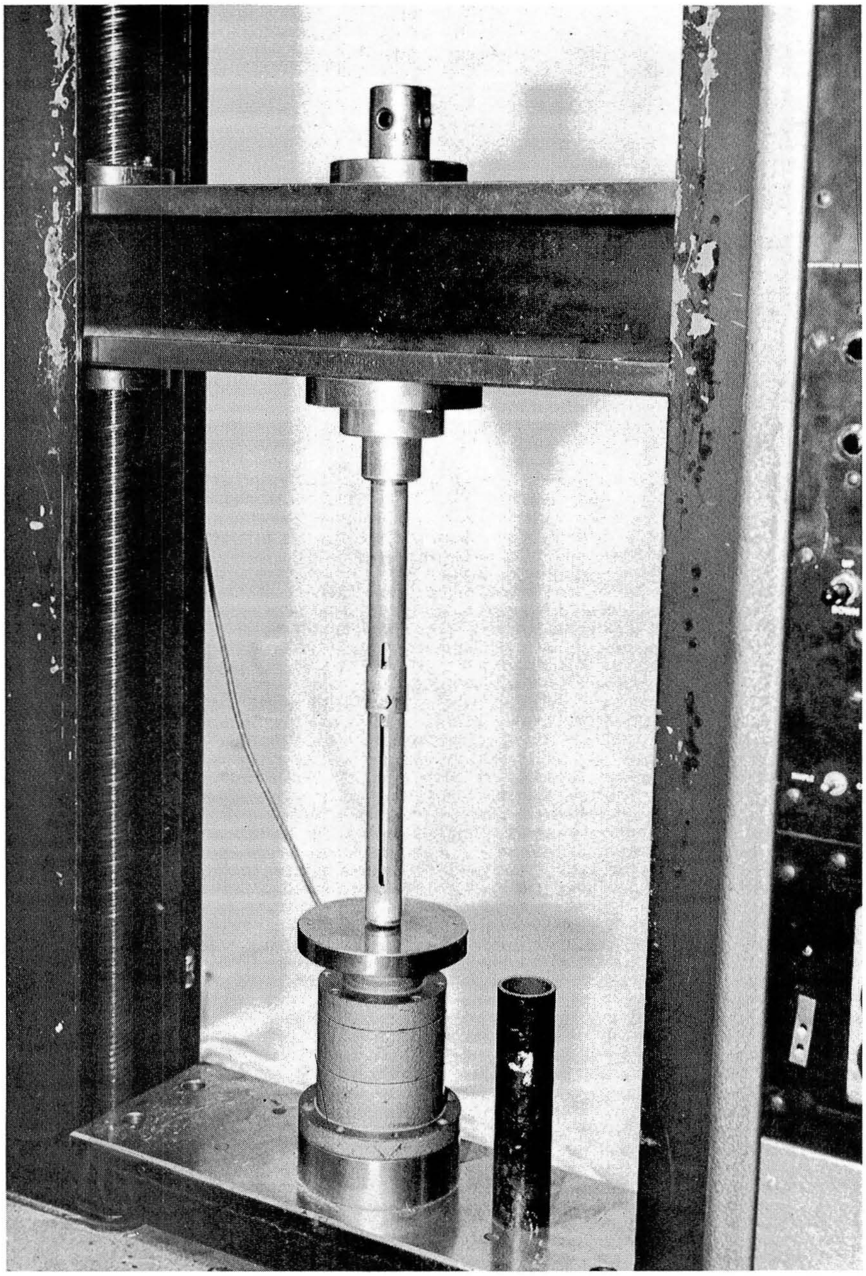


Figure 22. Post-test 3, attenuator in stroked condition.

APPENDIX A

STRUCTURAL ANALYSIS

The two seat concepts are shown in Figures A-1 and A-2 indicating the primary structural members and the notations used in subsequent analyses. The structural analysis summarizes the requirements and predicted performance.

Ceiling Suspended Seat Analysis

This concept was derived from the Boeing Vertol design for a U.S. Army troop seat. This seat has been satisfactorily tested and the selection of material and sizing has been retained substantially the same for this NASA seat. Changes have been made to attenuator limits to ensure maximum specified G limits are not exceeded for a 75 kg (165 lbm) occupant.

Applying simple Newtonian relationships to a seat/aircraft system results in occupant acceleration levels, velocities, and strokes as the total system comes to rest, subsequent to a selected impact condition. A floor acceleration characteristic was selected to be consistent, or as nearly so as possible, with the U.S. Army crashworthiness requirements in TR71-22 or TR77-13. These conditions are shown in Table I.

Figures A-3 and A-4 show variations with time of selected parameters for both a longitudinal impact and a three-axis 0.524 rad (30°) nose-down vertical impact. These data assumed 100% efficiency and were used to compute member loads as the seats stroked for use in the structural analyses.

Floor Mounted Seat Analysis

This seat introduces a new concept and more detailed analysis was performed to define the structure.

As for the previous seat concept, analyses were performed to define the variation of acceleration, velocity and displacement as functions of time. These results are included in Figures A-5 and A-6.

NASA GENERAL AVIATION PASSENGER SEAT:
CRASHWORTHY & CEILING SUSPENDED

BASIC GEOMETRY OF STRUCTURAL MEMBERS.

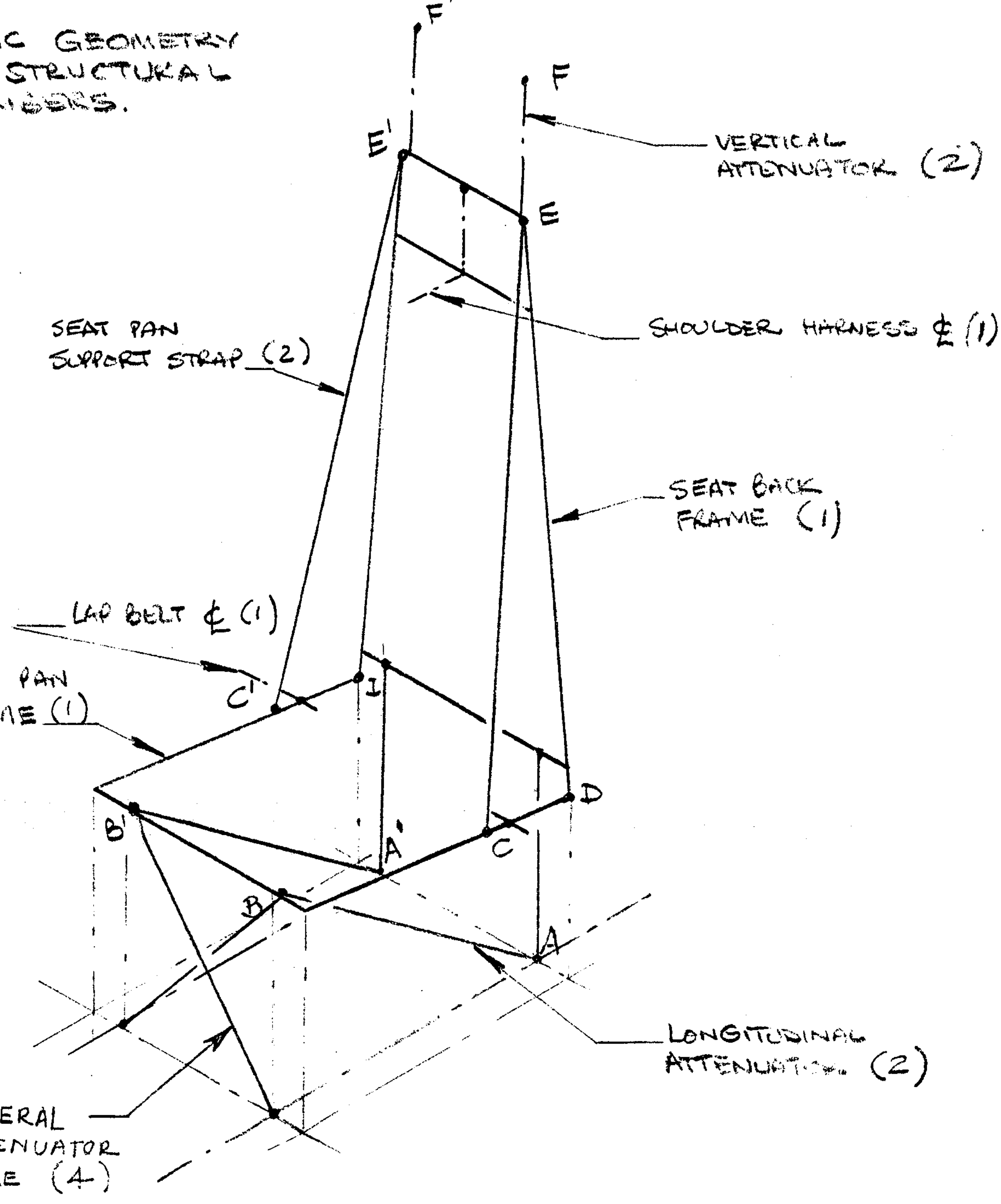


FIGURE: A-1

NASA GENERAL AVIATION PASSENGER SEAT : CRASHWORTHY & FLOOR MOUNTED.

THIS SEAT WILL BE DESIGNED FOR THE 0.524 rad (30°) NOSE DOWN CASE ONLY. THE TWO ATTENUATORS WILL BE SIZED TO LIMIT THE OCCUPANT 'G' LEVEL TO A VALUE OF 12 FOR THE INITIAL PART OF THE STROKE.

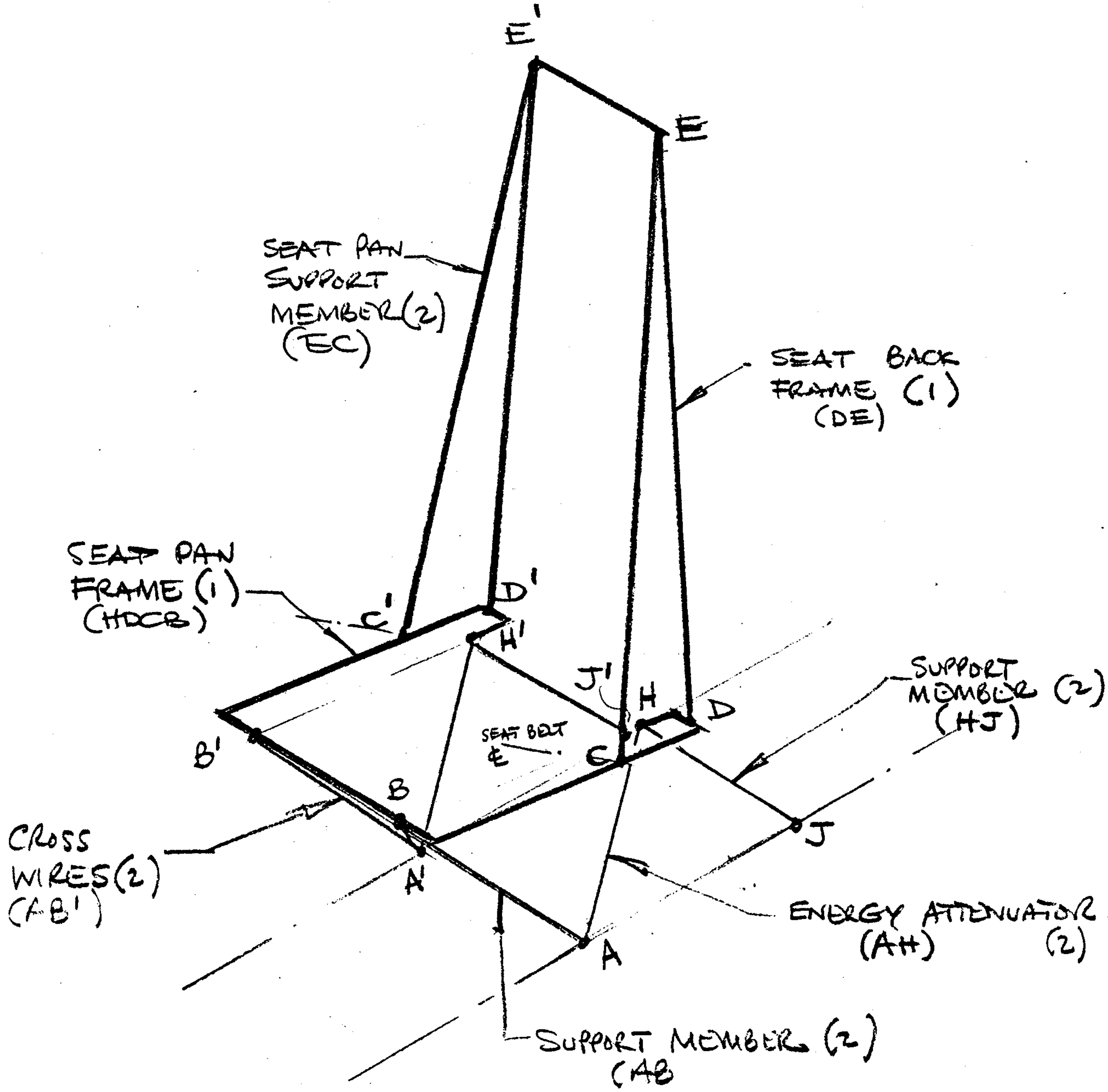


FIGURE . A-2

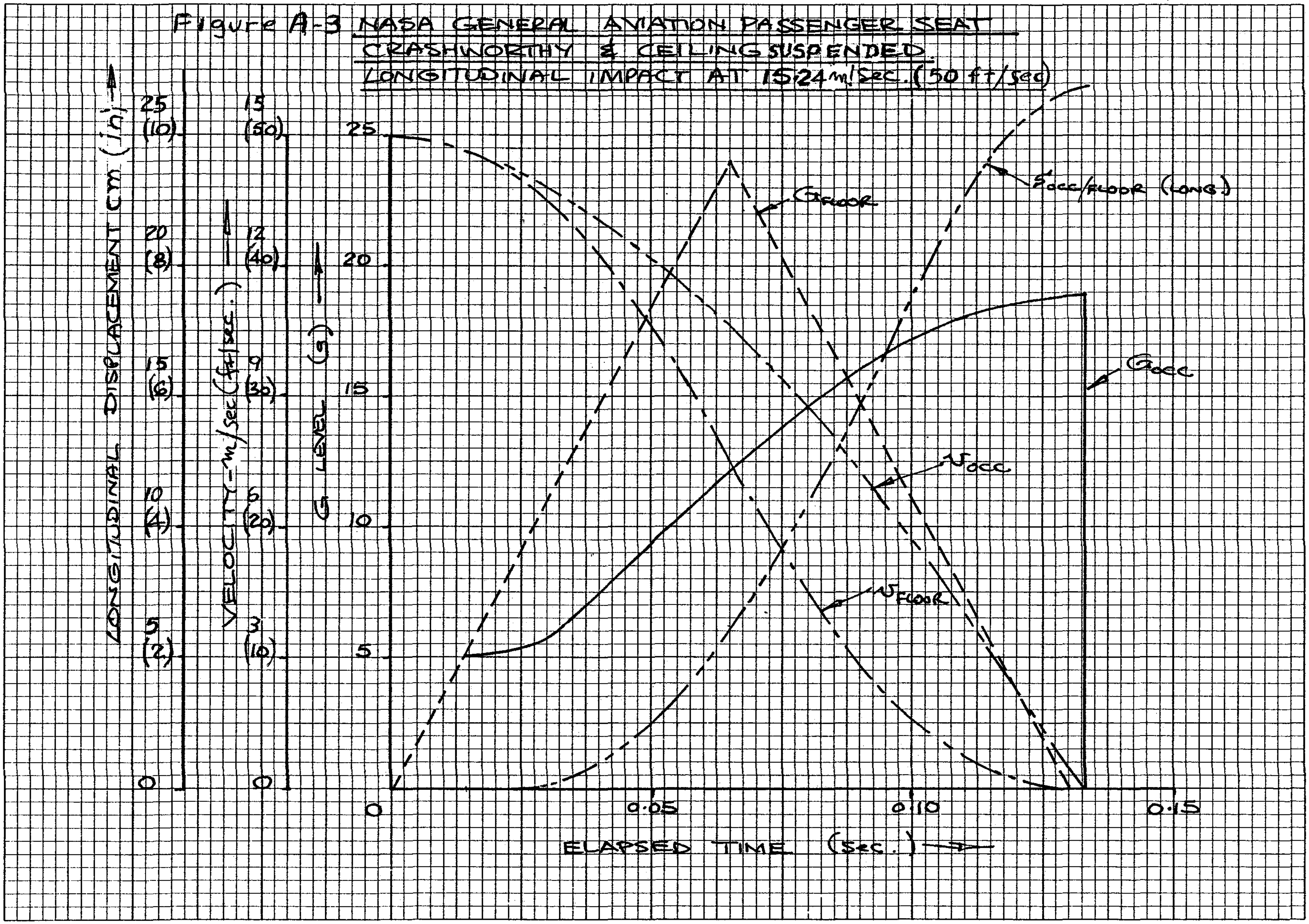
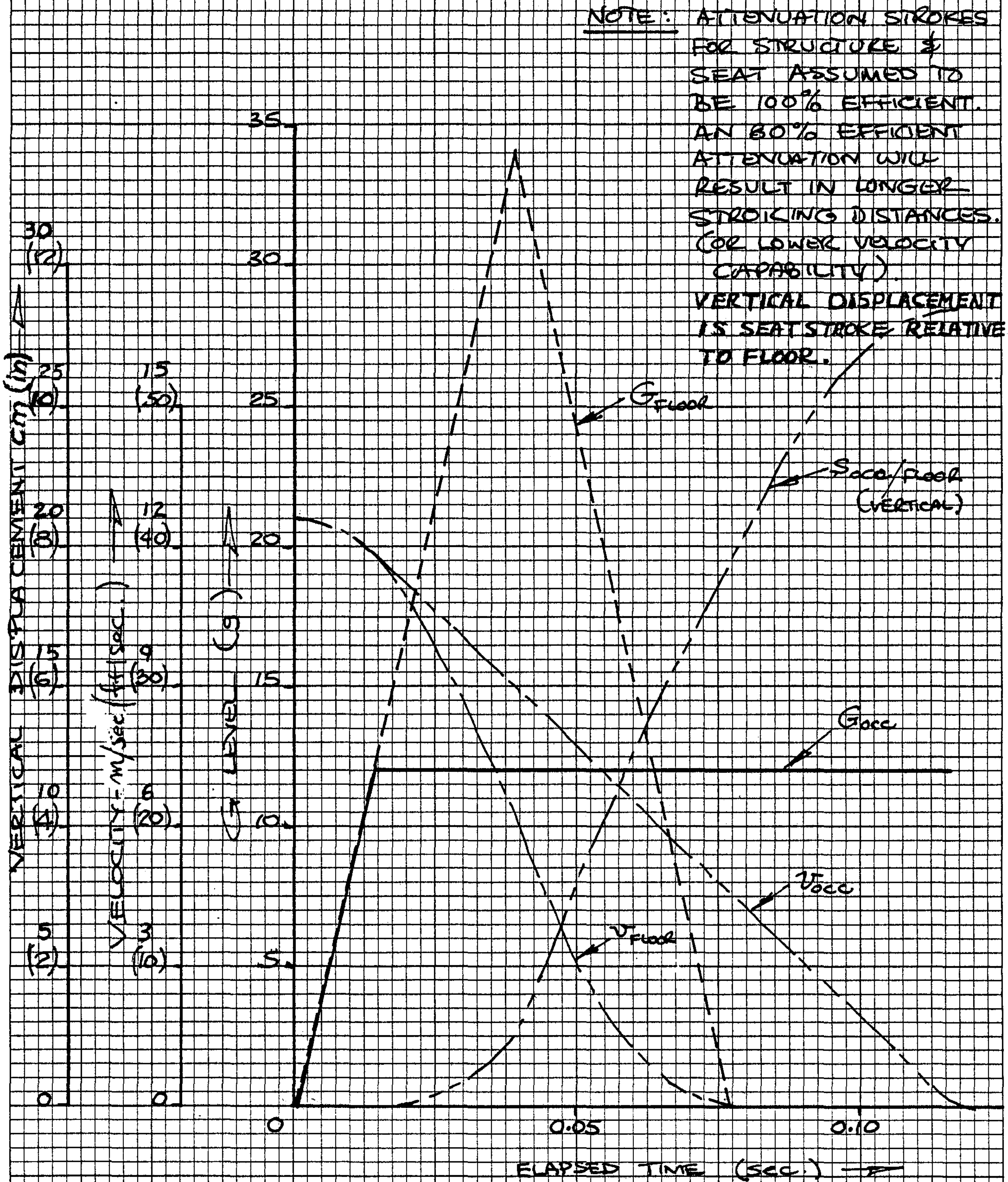


Figure A-3 NASA GENERAL AVIATION PASSENGER SEAT CRASHWORTHY & CEILING SUSPENDED. LONGITUDINAL IMPACT AT 15.24 m/sec. (50 ft/sec)

Figure A-4 NASA GENERAL AVIATION PASSENGER SEAT
CRASHWORTHY & CEILING SUSPENDED

0.524 rad (30°) NOSE DOWN IMPACT CONDITION (APPROXIMATED)
AT 12.8 m/sec. (42 ft/sec.)



THE BOEING COMPANY

NUMBER
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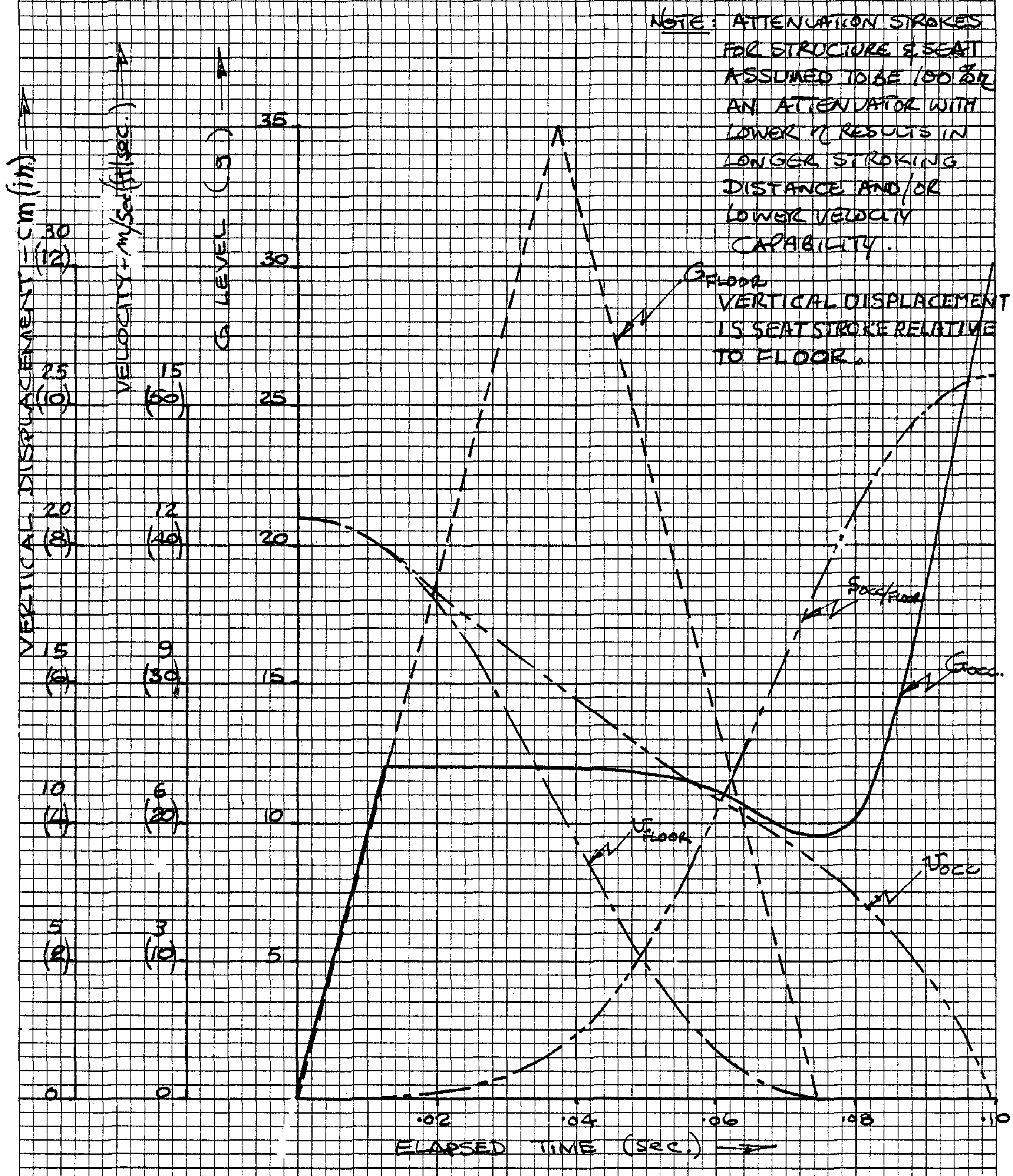
NASA GENERAL AVIATION PASSENGER SEAT.
CRASHWORTHY & FLOOR MOUNTED.

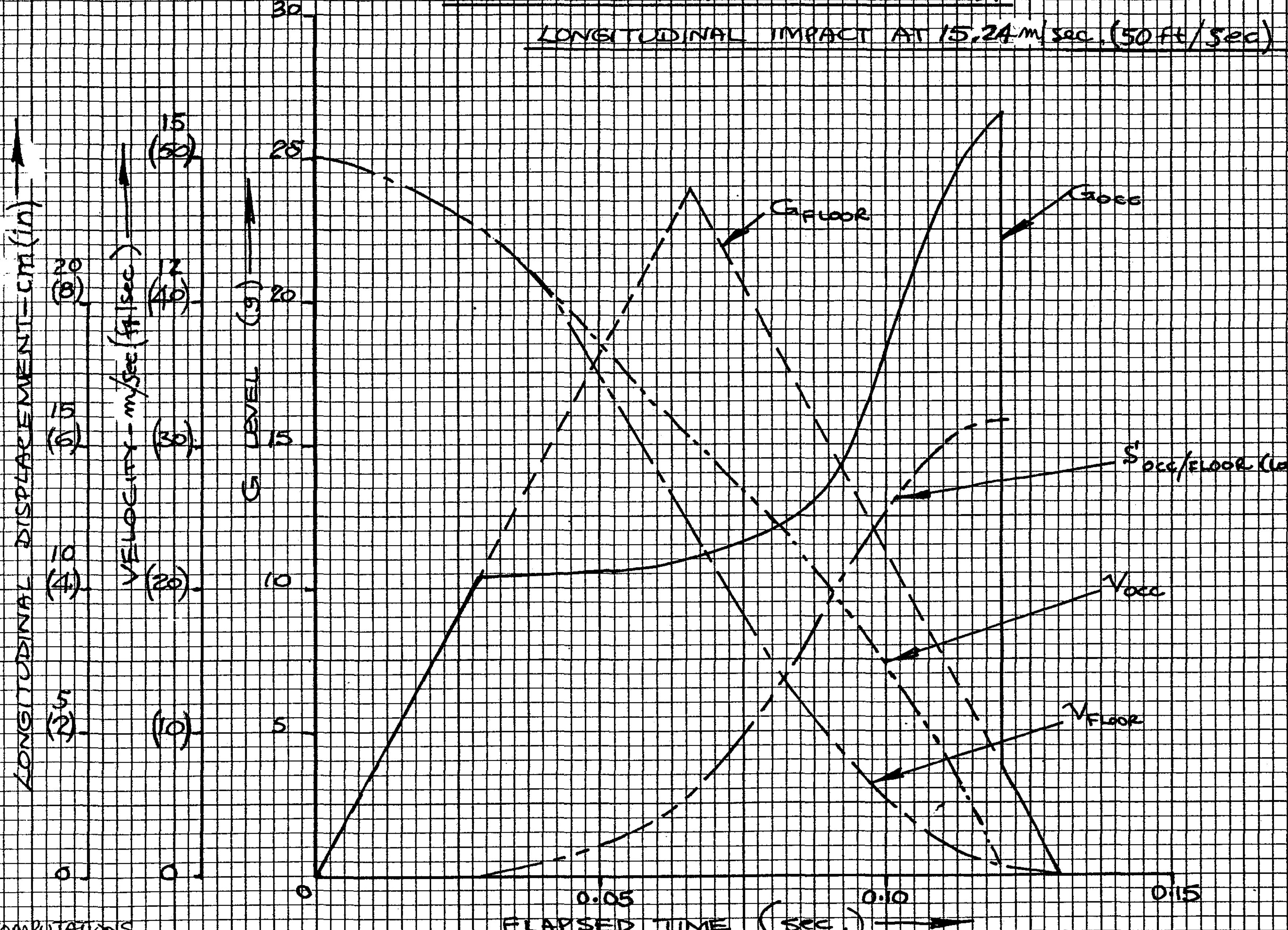
0.524 rad (30°) NOSE DOWN IMPACT CONDITION
(APPROXIMATED) AT 12.8 m/sec. (42 ft./sec.)



DIETZGEN CORPORATION
MADE IN U.S.A.
NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

Figure A-6 NASA GENERAL AVIATION PASSENGER SEAT CRASHWORTHY & FLOOR MOUNTED

LONGITUDINAL IMPACT AT 15.24 m/sec. (50 ft/sec)



(NOTE: COMPUTATIONS ASSUME 100% ATTENUATOR ?)

This seat posed greater structural loading especially so when approaching the end of its stroke. These variations are included in the detail analysis.

Discussion

It is important to remember that a certain pulse has been assumed to act at the aircraft floor. If such a condition is not compatible with a given installation then the total analysis must be recomputed to ensure realistic boundary conditions. If a given underfloor structure/landing gear combination is incapable of providing the assumed energy absorption, then the seat will only provide protection at a given lower velocity. An impact velocity much in excess of this recomputed lower velocity will result in higher occupant G levels which may be fatal, or structural failure of the seat which may be equally catastrophic.

A further factor which can dramatically influence the performance of a ceiling mounted seat is the relative displacement of the ceiling, relative to the floor, during the crash sequence. Excessive deformation which occurs concurrent with seat stroking can result in a drastically reduced stroking distance and occupant impact with the floor. To overcome this problem, adequate structural stiffness of the overhead frames is required when attenuators are attached.

Seat elements have been sized, wherever possible, using their full plastic capabilities; for the design case, crash condition permanent element deformations are expected. Some elements which experience low load levels have been sized using a criterion to preclude in-service damage, due to handling or normal wear and tear.

The detail structural analysis is as follows:

NASA GENERAL AVIATION PASSENGER SEAT, CRASHWORTHY, DETAIL STRUCTURAL ANALYSIS *

FOR THE TWO TYPES OF SEATS CONSIDERED THE FOLLOWING LOADING CRITERIA ARE ASSUMED TO ACCOMMODATE THE MOST LIKELY CRASH IMPACT CONDITIONS.

- OCCUPANT WEIGHT = 75 kg (165 lb)
- SEAT WEIGHT = 9 kg (20 lb)
- SEAT DESIGN LOADS FOR 30° NOSE DOWN EFFECTIVE IMPACT ANGLE. THESE LOADS WILL SIZE ATTENUATORS, ETC. (EXCEPT LONG. ON CEILING, MOUNTED SEAT).

TARGET G LEVELS: VERT → 30° = 12g MAX.
LONG. = 15g MAX.

TWO SEAT CONFIGURATIONS:

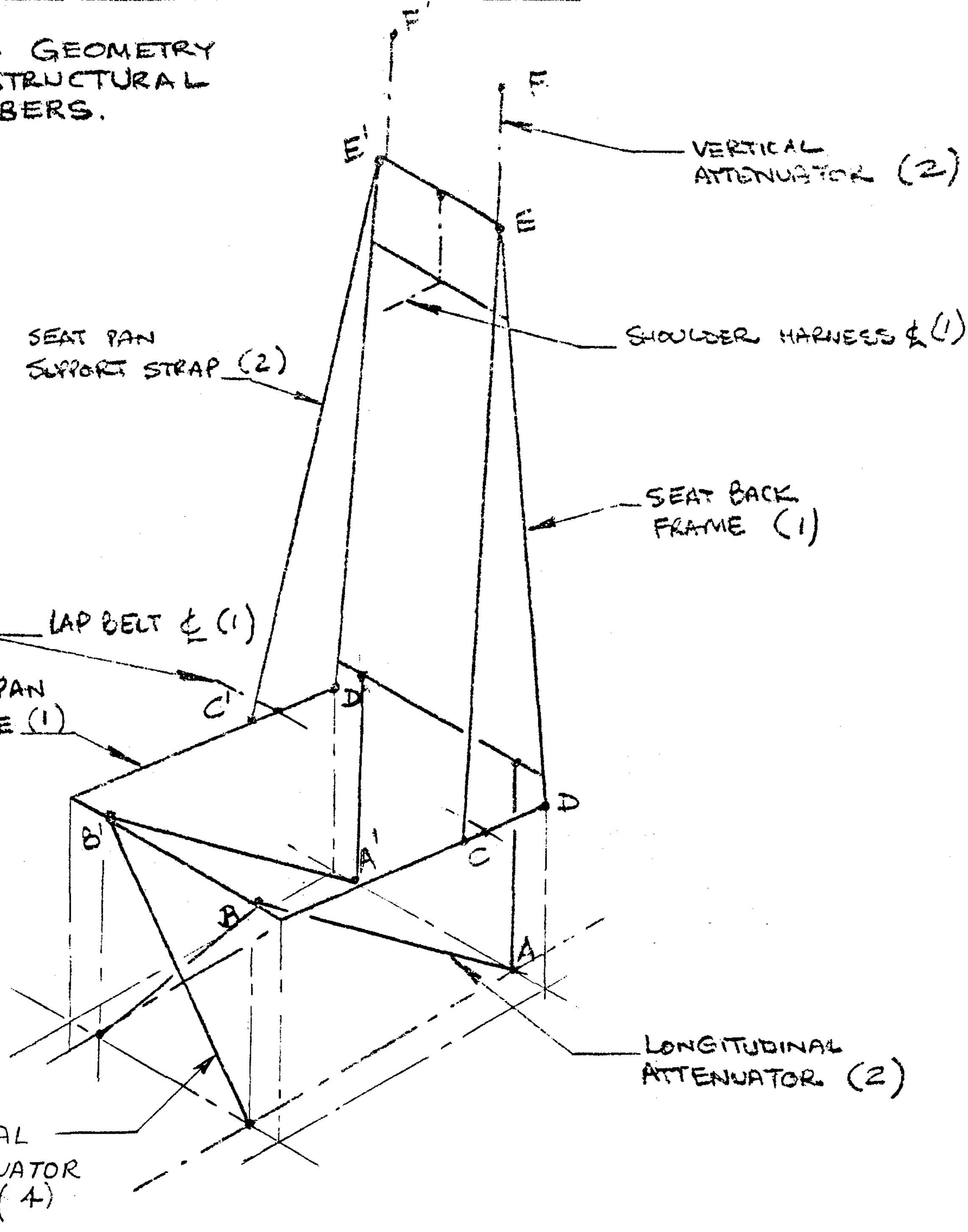
- CEILING SUSPENDED
- FLOOR MOUNTED.

THE FOLLOWING ANALYSIS WILL DEFINE SIZES OF STRUCTURAL ELEMENTS AND SHOW THE VARIATION IN 'G' LEVELS AS SEAT STROKING OCCURS.

* NOTE: Metric units have been used in this section when defining masses and on graphs. All supporting analysis has been computed using pounds (lb) and feet (ft.) units.

NASA GENERAL AVIATION PASSENGER SEAT: CRASHWORTHY & CEILING SUSPENDED

BASIC GEOMETRY OF STRUCTURAL MEMBERS.



NASA GENERAL AVIATION PASSENGER

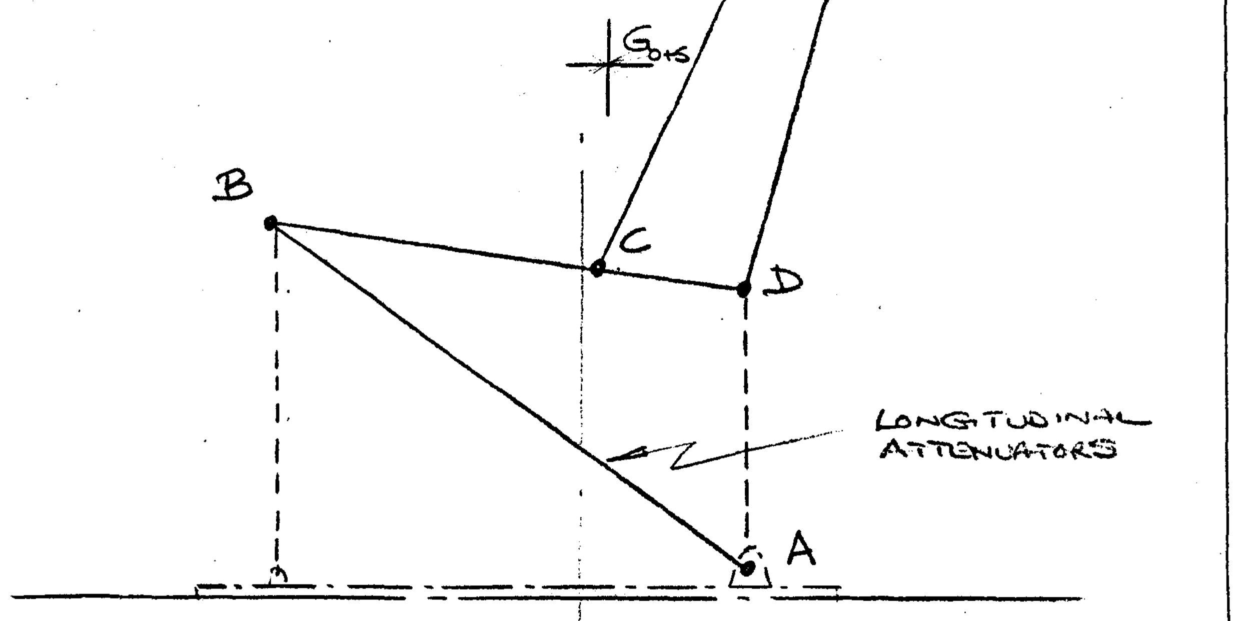
SEAT : CRASHWORTHY , CEILING SUSPENDED

SIDE ELEVATION
BASIC GEOMETRY.

(DRAWN TO SCALE.)

G_{O+S} = C.G. OF OCCUPANT + SEAT COMBINATION.

G_O ASSUMED TO BE 10" VERT & 6" LONGITUDINAL FROM SEAT REFERENCE POINT AS SHOWN IN TR 71-22 FIG. 3-28.

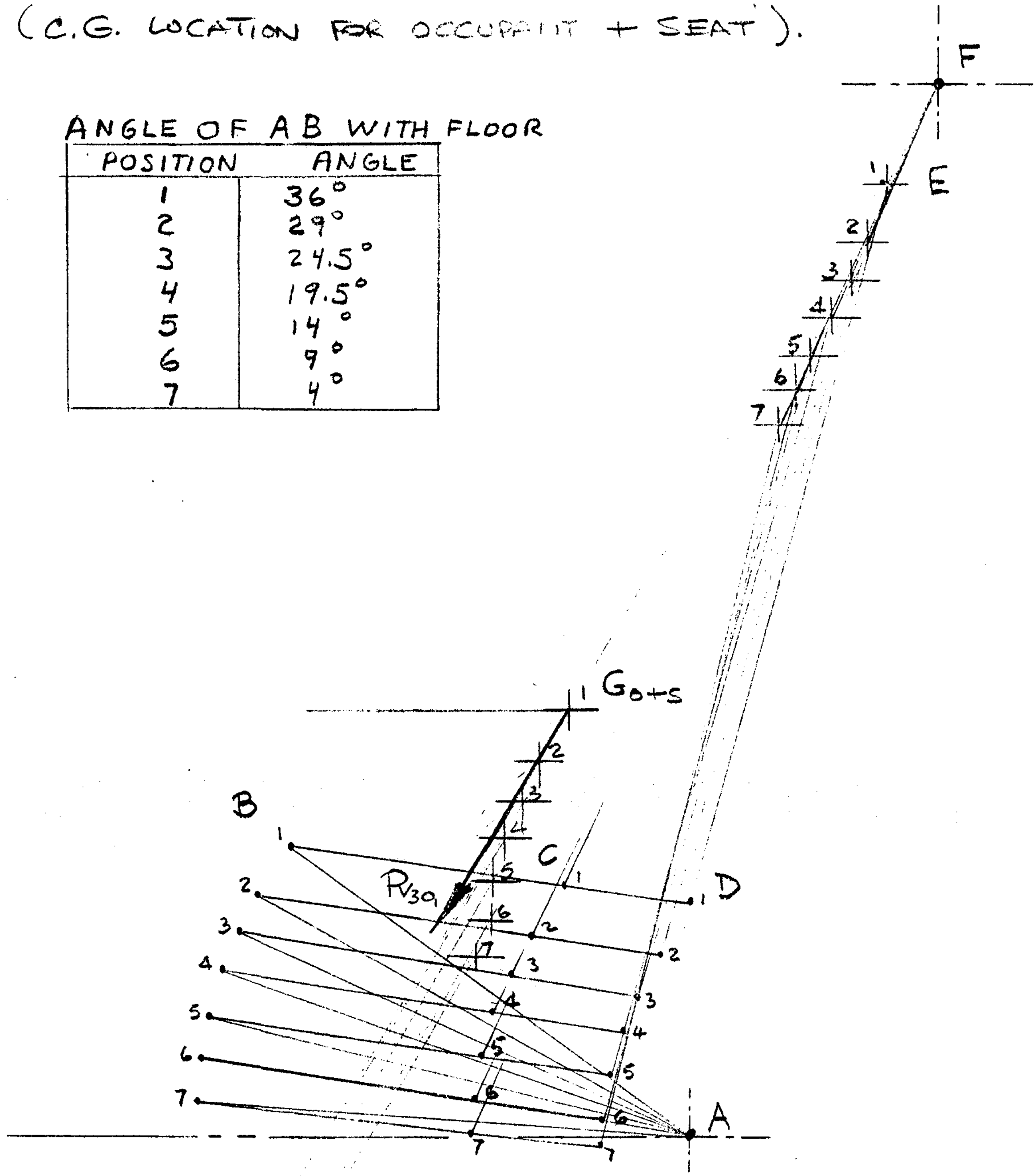


INCREMENTAL DISPLACED POSITION OF SEAT FOR CORRECT LINE OF ACTION OF VERTICAL ATTENUATOR LOAD. [illegible] POSITIONS, DRAWN TO SCALE.

(C.G. LOCATION FOR OCCUPANT + SEAT).

ANGLE OF AB WITH FLOOR

POSITION	ANGLE
1	36°
2	29°
3	24.5°
4	19.5°
5	14°
6	9°
7	4°



1. CONSIDERING THE 0.524 rad (30°) NOSE DOWN IMPACT CONDITION :-

ASSUME THAT ONLY VERTICAL ATTENUATORS STROKE.

EFFECTIVE LOADING, $P_{V_{30}}$

$$= 165 \times 0.8 \times 12 + 20 \times 12$$

$$= \underline{1824 \text{ lb.}}$$

(THIS VALUE CONSISTS OF TOTAL SEAT WEIGHT WITH 80% OF OCCUPANT WEIGHT EFFECTIVELY ACTING ON SEAT).

FROM THE PRECEDING DIAGRAM IT IS VISUALLY APPARENT THAT THE SEAT WILL TILT SLIGHTLY TO ALIGN THE LINES OF ACTION OF THE VERTICAL ATTENUATORS AND $P_{V_{30}}$.

THUS, THE ATTENUATOR LOAD LIMIT

$$= \frac{1}{2}(1824) = \underline{\underline{912 \text{ lb.}}}$$

IN STROKING FROM THE #1 POSITION TO #7 THE LINE OF ACTION OF THE ATTENUATOR LOAD, IS FOR PRACTICAL PURPOSES, IN LINE WITH THE APPLIED LOADING WHICH RESULTS FROM OCCUPANT G LEVELS. THIS INDICATES THAT THE SEAT WILL STROKE AND MAINTAIN A CONSTANT SEAT PAN ATTITUDE RELATIVE TO THE FLOOR PLANE OF THE AIRCRAFT. AS A RESULT OF THIS IT WILL BE ASSUMED THAT A CONSTANT OCCUPANT G LEVEL OF 12g WILL EXIST THROUGHOUT THE STROKE (ACTING ALONG A LINE 60° TO THE FLOOR PLANE). FOR A TOTAL STROKING DISTANCE OF 12.7 in. MEASURED AT THE C.G. AN ESTIMATE CAN BE MADE FOR THE REQUIRED STRUCTURAL STROKING DISTANCE TO PROVIDE THE OPTIMUM OCCUPANT PROTECTION FOR A 42 ft/sec. IMPACT VELOCITY. THE FOLLOWING COMPUTATIONS PROVIDE THIS.

ASSUMING 80% EFFICIENCY FOR THE ATTENUATOR :-

$$\text{ENERGY ABSORBED} = 12.7 \times 1824 \times 0.8$$
$$= 18532 \text{ in.lb}$$

EQUATING THIS TO CHANGE IN KINETIC ENERGY :-

$$\frac{18532}{12} = \frac{1}{2} \cdot \frac{185}{32.2} \cdot \Delta v^2$$

$$\underline{\Delta v = 23.2 \text{ ft/sec.}}$$

THIS VALUE REPRESENTS THE MAXIMUM IMPACT VELOCITY OF THE SEAT ACTING ALONE.

WITH A 42 FT/SEC REQUIREMENT :-

NEWTONIAN EQUATION $\left(42^2 - v^2\right) = 2g \cdot 12 \cdot 0.8 \cdot \frac{12.7}{12}$

$$u = 33.3 \text{ ft/sec.}$$

THUS THE AIRFRAME/LANDING GEAR COMBINATION MUST PROVIDE THE CAPABILITY TO ABSORB THE SURPLUS ENERGY CONCURRENT WITH THE SEAT STROKE.

__NOTE__ : CALCULATIONS HAVE ASSUMED NO CEILING-TO-FLOOR RELATIVE MOTIONS. IN AN ACTUAL INSTALLATION ACCOUNT MUST BE TAKEN OF ANY DEFORMATIONS WHICH OCCUR WHILE THE SEAT IS STROKING AS THE EFFECTIVE STROKING DISTANCE MAY BE REDUCED ACCORDINGLY.

2. CONSIDER THE LONGITUDINAL IMPACT CASE :

IN THIS CASE LOADING IS TRANSFERRED FROM THE OCCUPANT TO THE SEAT FRAME VIA THE RESTRAINT SYSTEM.

FOR A 15g LIMITATION AND AN OCCUPANT + SEAT WEIGHT OF 185 lb. :-

TOTAL LOAD ON SYSTEM = 2775 lb FOR INITIAL STROKING.

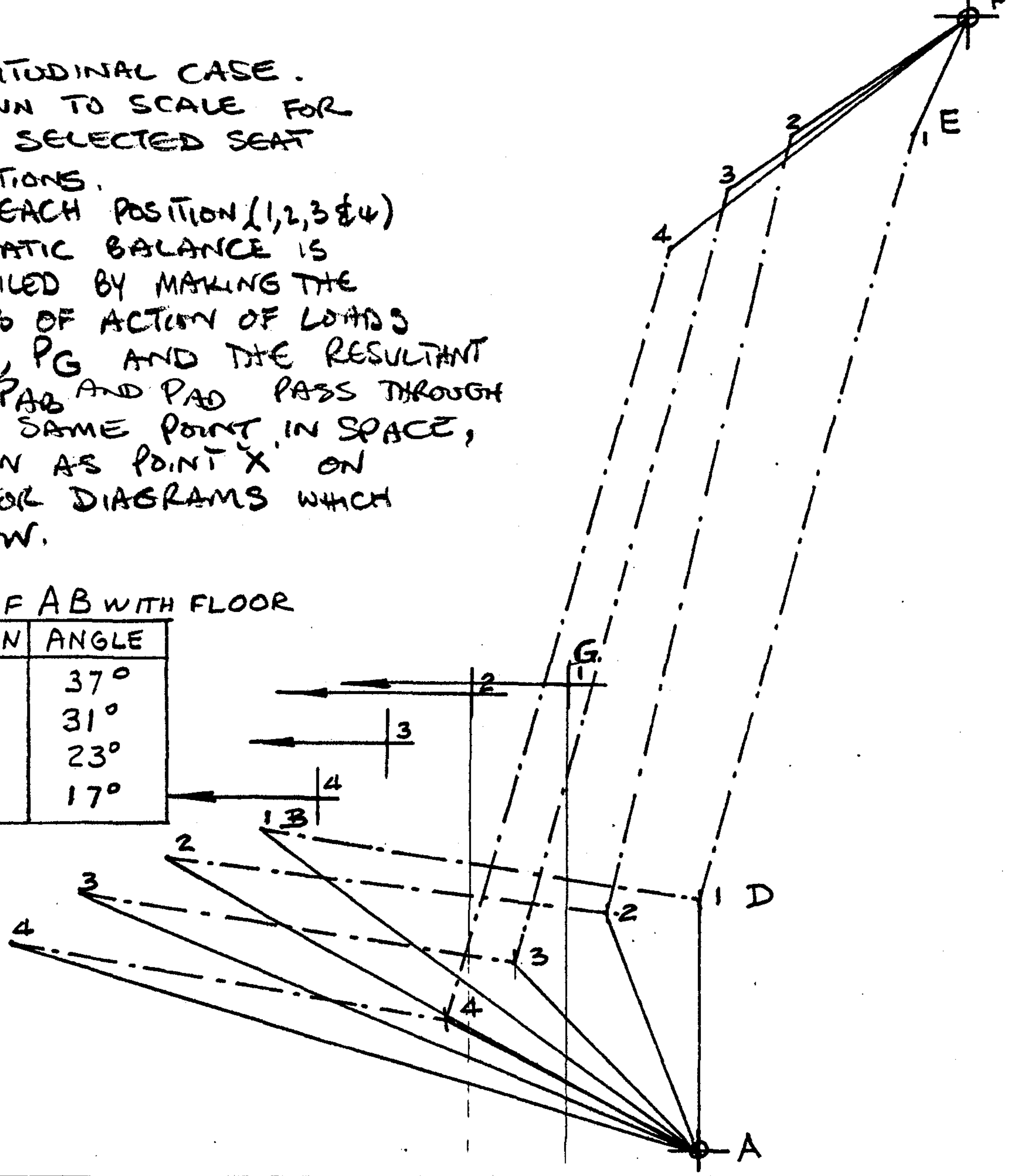
THIS LOADING IS RESISTED BY BOTH THE VERTICAL AND LONGITUDINAL ATTENUATORS. IN ADDITION, THE AFT LATERAL ATTENUATORS ALSO ABSORB SOME ENERGY DUE TO THEIR EXTENSION AS THE SEAT STROKES.

ASSUMING STROKED POSITIONS 1→4 AN OPTIMIZATION CAN BE MADE TO SELECT THE ATTENUATING LIMITS FOR MEMBERS AD & AB:—

NOTE:
- LONGITUDINAL CASE.
- DRAWN TO SCALE FOR THE SELECTED SEAT POSITIONS.
- FOR EACH POSITION (1, 2, 3 & 4) A STATIC BALANCE IS COMPILED BY MAKING THE LINES OF ACTION OF LOADS P_{EF}, P_G AND THE RESULTANT OF P_{AB} AND P_{AD} PASS THROUGH THE SAME POINT IN SPACE, SHOWN AS POINT 'X' ON VECTOR DIAGRAMS WHICH FOLLOW.

ANGLE OF AB WITH FLOOR

POSITION	ANGLE
1	37°
2	31°
3	23°
4	17°



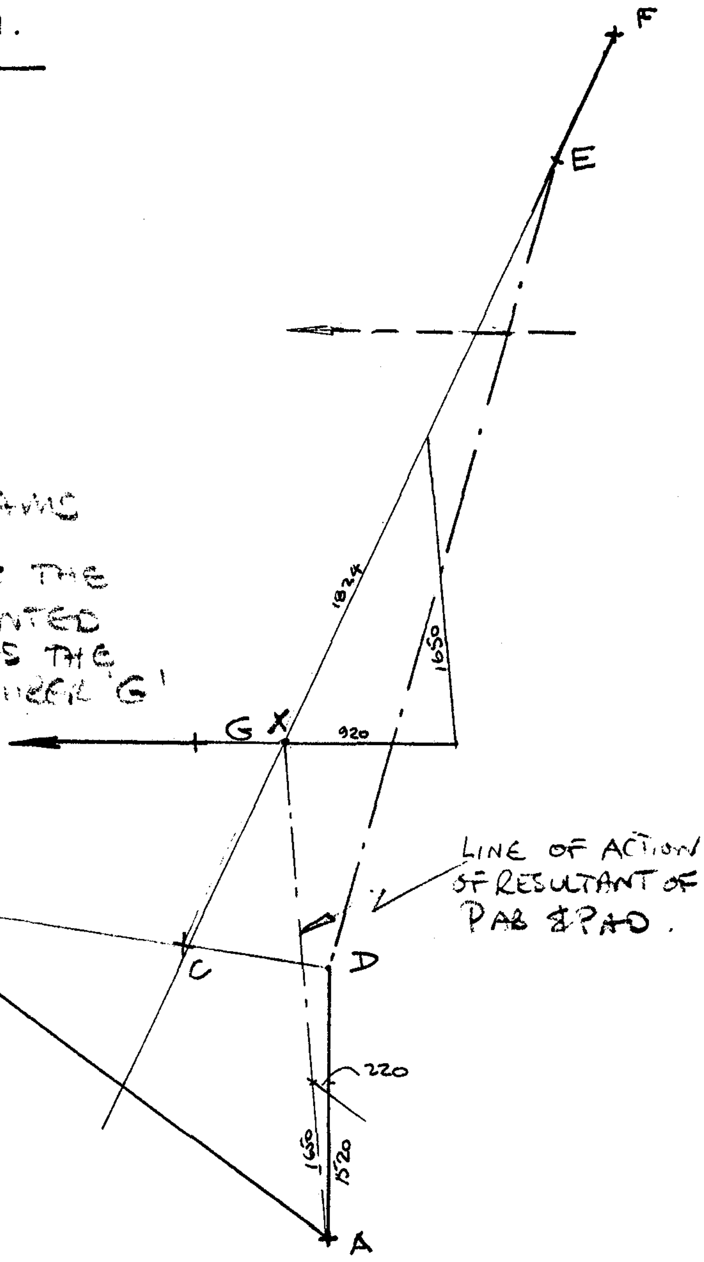
FOR LOAD COMPUTATION, INDIVIDUAL LOAD VECTOR DIAGRAMS HAVE BEEN CONSTRUCTED FOR POSITIONS 1 THROUGH 4; THESE ARE PRESENTED ON THE FOLLOWING SHEETS.

SIMILARLY :-

POSITION # 1 VECTOR DIAGRAM.

MEMBER	LOAD (lb)	EXTENSION. (in)
AB	220	—
AD	1520	—
EF	1824	—
G	920 (5g)	—

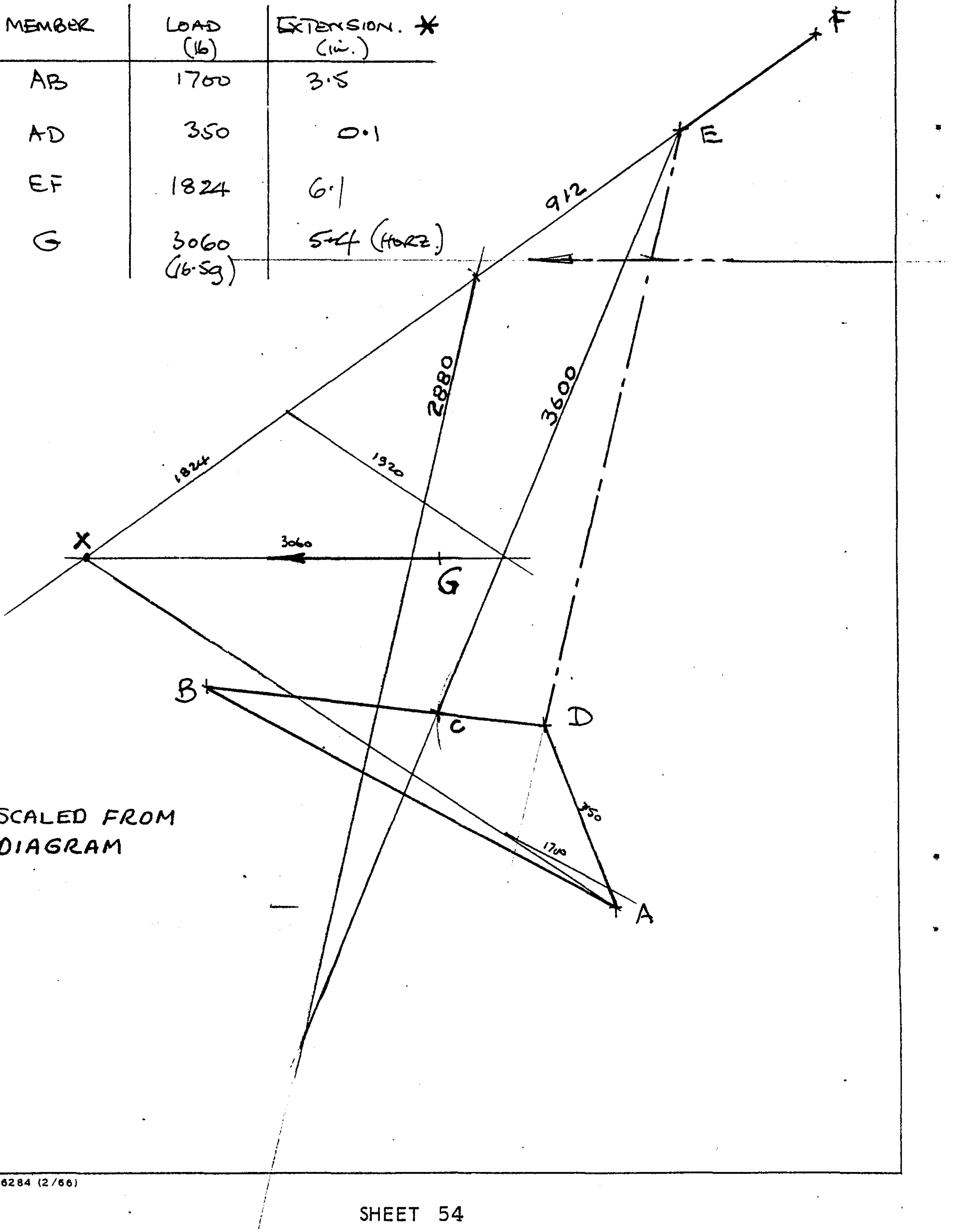
NOTE: FOR VECTOR DIAGRAMS THE LONGITUDINAL DISPLACEMENT OF THE C.G $_{0-5}$ IS PRESENTED IN THE TABLE AS THE EXTENSION OF MEMBER 'G'



SIMILARLY :-

POSITION # 2 VECTOR DIAGRAMS:

MEMBER	LOAD (lb)	EXTENSION. * (in.)
AB	1700	3.5
AD	350	0.1
EF	1824	6.1
G	3060 (lb.Sg)	5.4 (HORZ.)

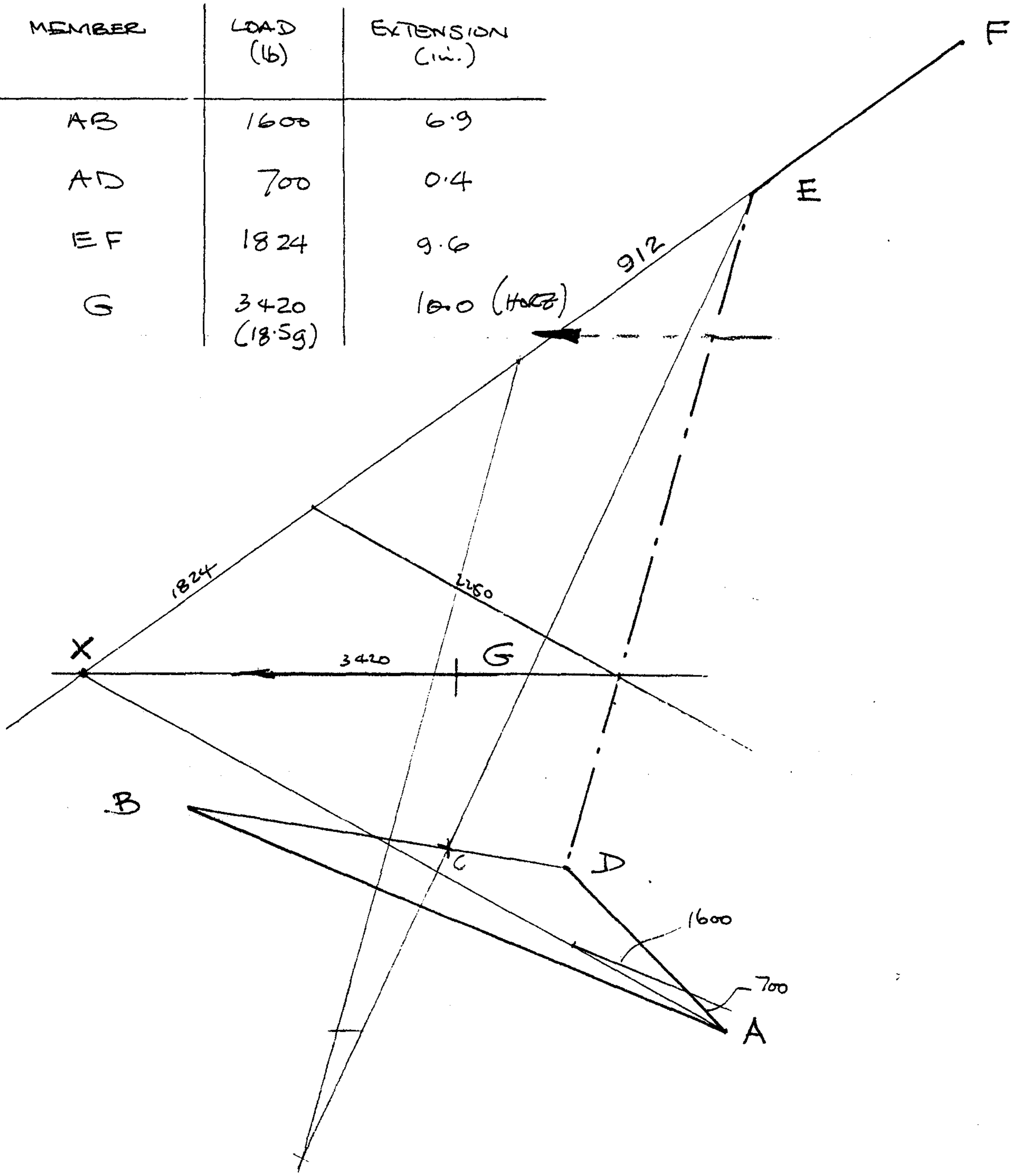


* SCALED FROM DIAGRAM

SIMILARLY :-

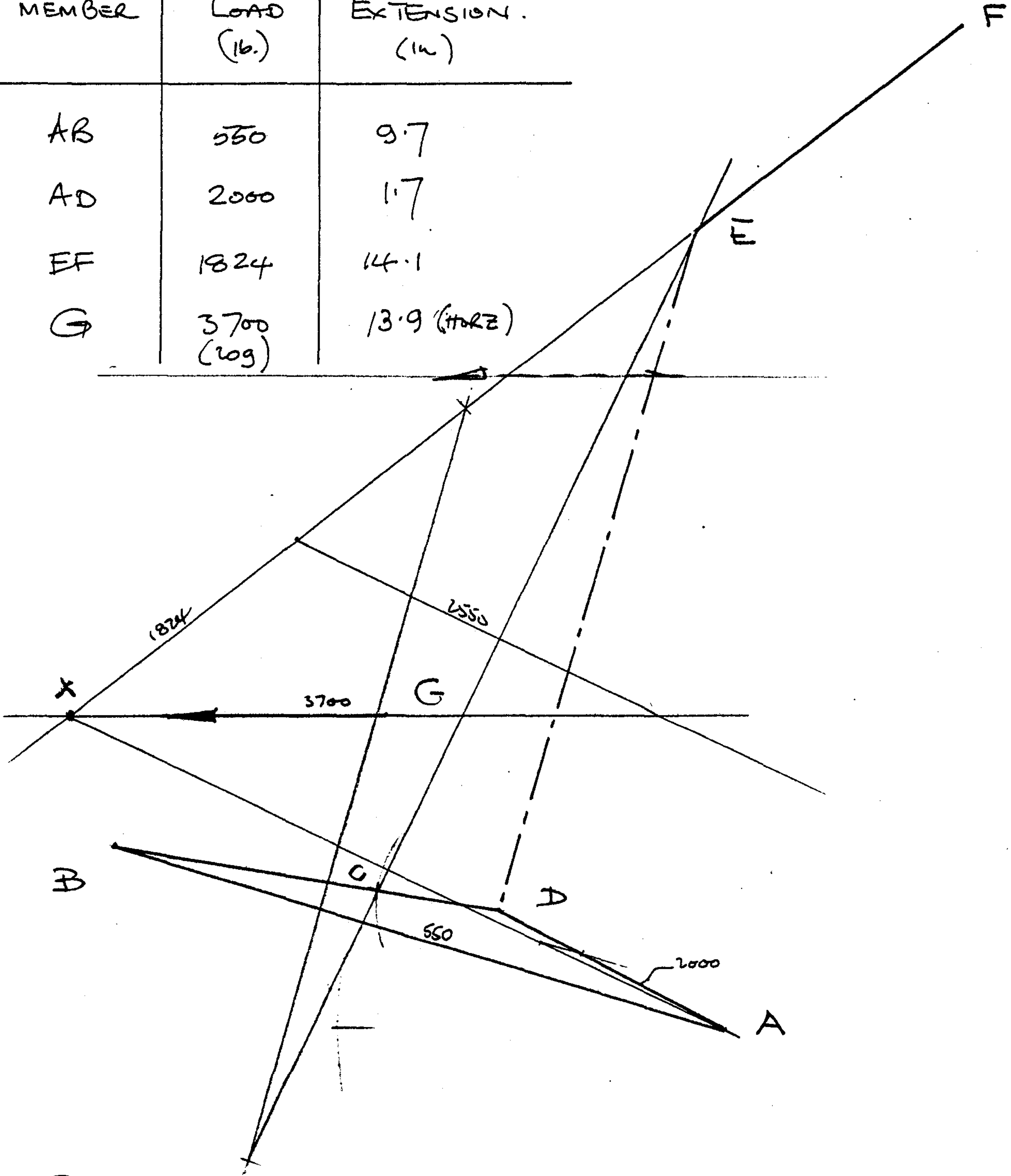
POSITION # 3 VECTOR DIAGRAMS:

MEMBER	LOAD (lb)	EXTENSION (in.)
AB	1600	6.9
AD	700	0.4
EF	1824	9.6
G	3420 (18.5g)	10.0 (HORZ)



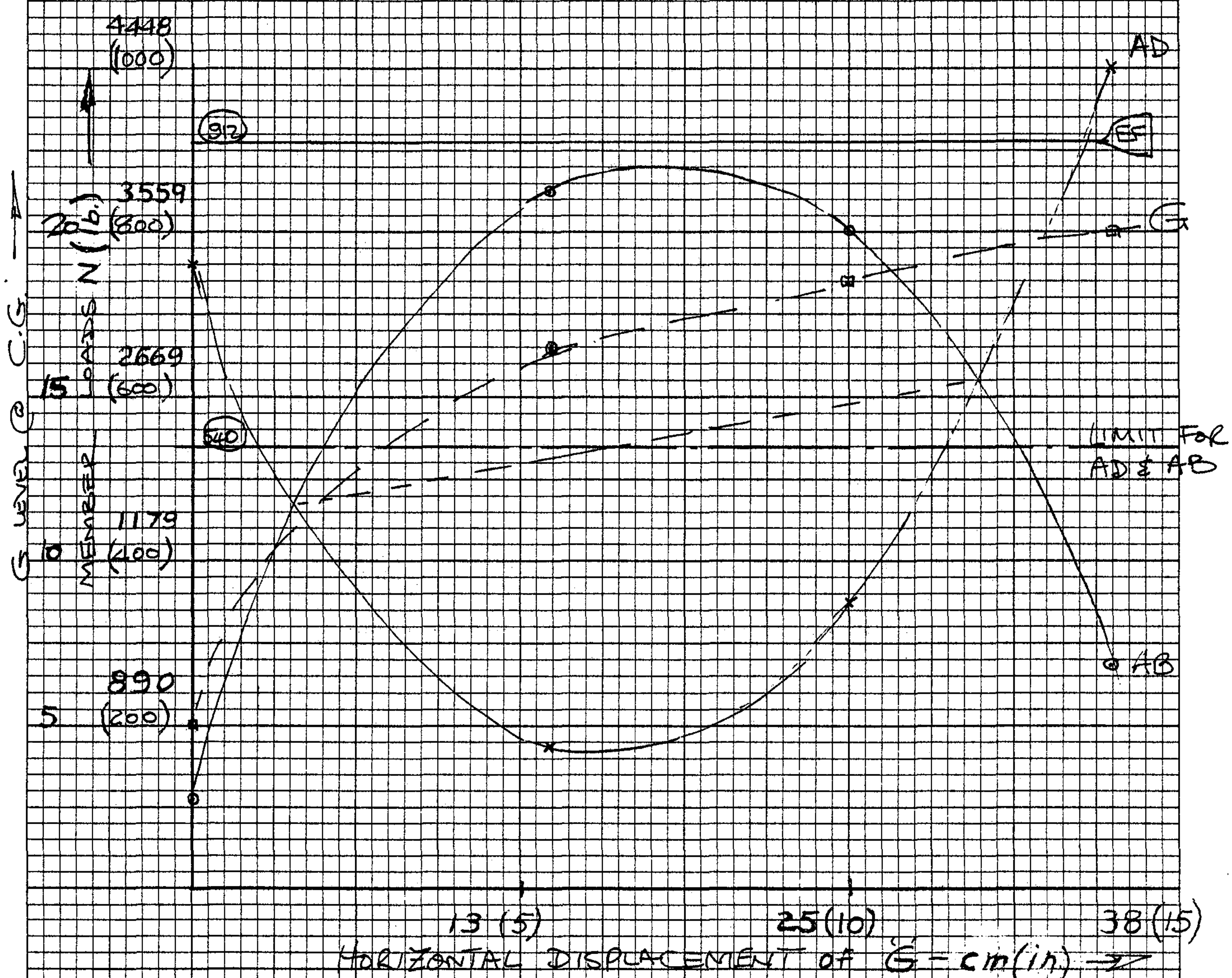
POSITION #4 VECTOR DIAGRAMS:

MEMBER	LOAD (lb.)	EXTENSION (in)
AB	550	9.7
AD	2000	1.7
EF	1824	14.1
G	3700 (20g)	13.9 (HORZ)



PLOTTING THE LOAD-DISPLACEMENT VALUES FOR POSITIONS 1 THROUGH 4 YIELD THE FIGURE ON P 57. THIS ALLOWS AN OPTIMIZATION OF ATTENUATOR LOAD LEVELS FOR MEMBERS AD AND AB. (NOTE: ONLY ONE LOAD LEVEL CAN BE SELECTED TO SATISFY AN AVERAGE CONDITION).

NASA CRASHWORTHY PASSENGER SEAT
CEILING SUSPENDED : LOAD & G LEVEL SUMMARY
LONGITUDINAL IMPACT



THE LATERAL ATTENUATOR CROSS WIRE LOADING WAS COMPUTED FOR THE COMPONENT IN THE X-Z PLANE. IF CROSS WIRES ARE USED THEN COMPONENT VALUE MUST BE ASSESSED.

COMPONENT IN X-Z PLANE = 540 lb.

ACTUAL MEMBER LOAD = 760 lb.

SUMMARY OF OPTIMIZED ATTENUATOR LOAD LEVELS:

VERTICAL ATTENUATOR LOAD = 912 lb.

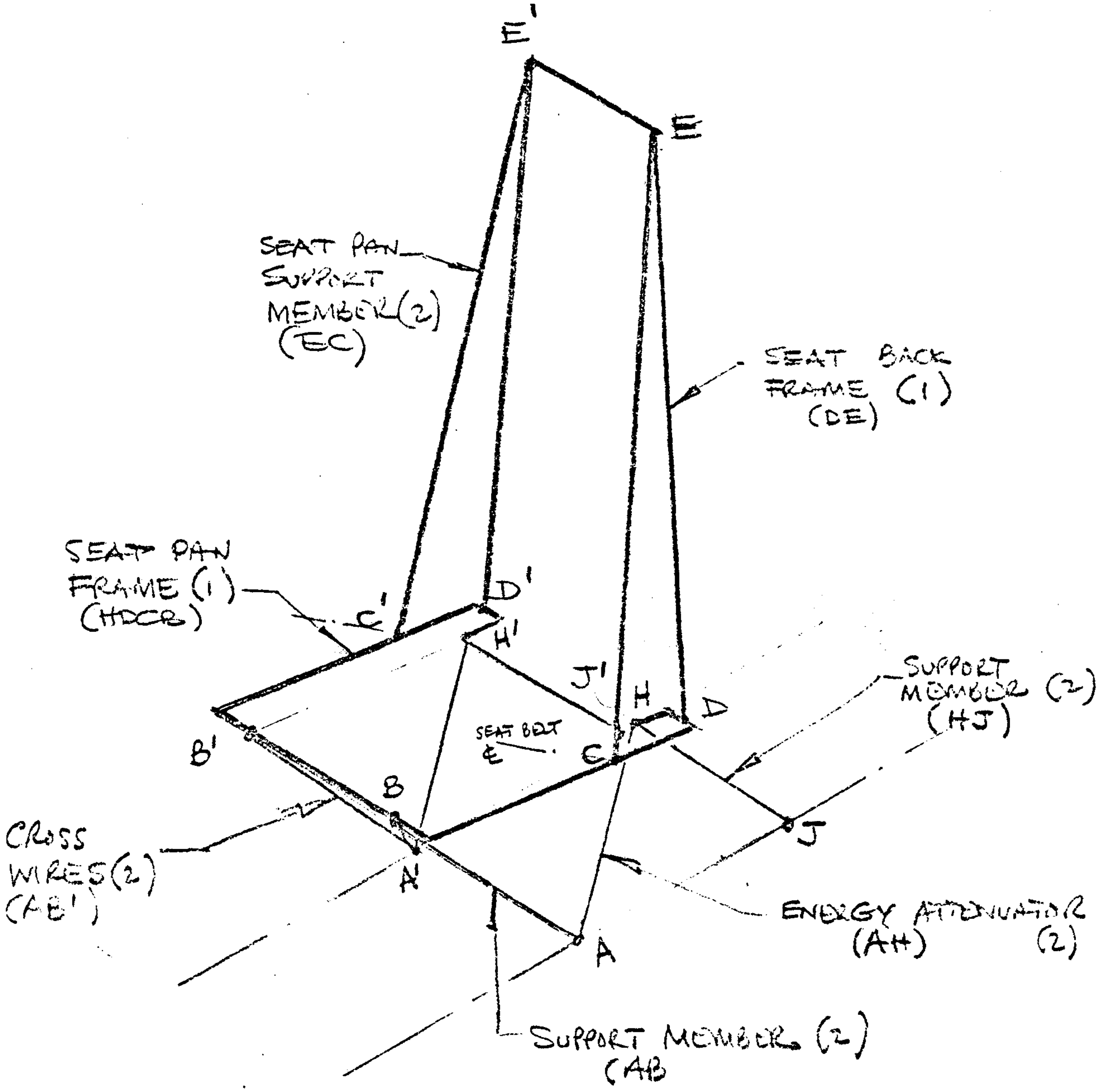
LONGITUDINAL " " = 540 lb.

LATERAL " " = 540 lb.

NOTE:
THESE VALUES ARE FOR INDIVIDUAL ATTENUATORS.

NASA GENERAL AVIATION PASSENGER SEAT: CRASHWORTHY & FLOOR MOUNTED.

THIS SEAT WILL BE DESIGNED FOR THE 30° NOSE DOWN CASE ONLY. THE ONLY ATTENUATOR WILL BE SIZED TO LIMIT THE OCCUPANT 'G' LEVEL TO A VALUE OF 12.



NASA GENERAL AVIATION PASSENGER SEAT:
CRASHWORTHY & FLOOR MOUNTED:

BASIC GEOMETRY.

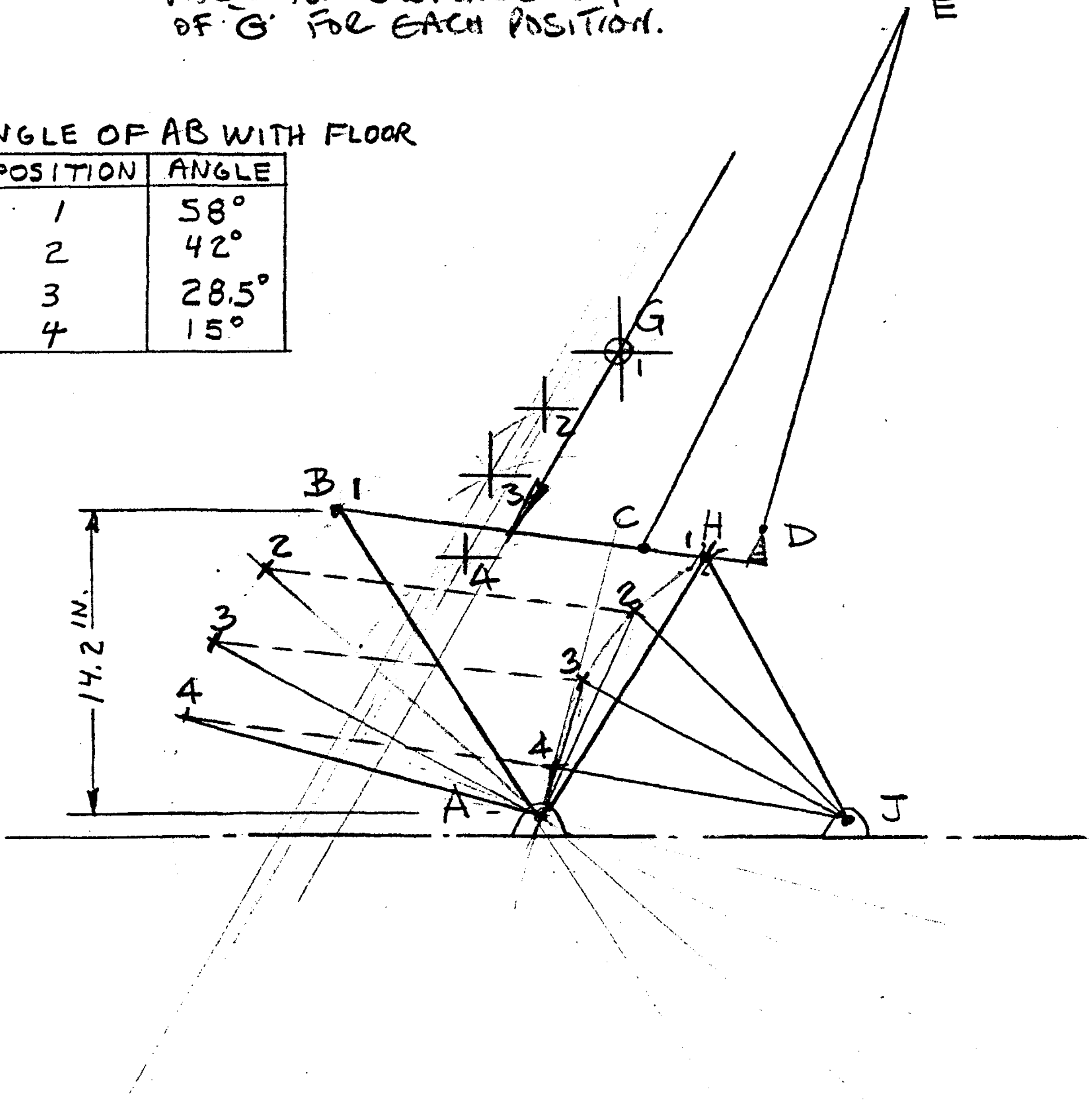
ELEMENT	LENGTH.-IN.
A B	17.10
A J	13.69
H J	13.44
B H	17.19

DRAWN TO SCALE

NOTE: POSITIONS 1 THROUGH 4 ARE NOT EQUISPACED. SEE TABLE ON NEXT PAGE FOR DISPLACEMENT OF G FOR EACH POSITION.

ANGLE OF AB WITH FLOOR

POSITION	ANGLE
1	58°
2	42°
3	28.5°
4	15°



FOR THE FOUR POSITIONS SHOWN AS THE SEAT STROKES THE FOLLOWING LOADS WERE COMPUTED FOR THE GEOMETRIES SHOWN FOR POSITIONS 1 THROUGH 4 ASSUMING STATIC EQUILIBRIUM FOR EACH POSITION.
ASSUMING A CONSTANT 1000 lb UNIT LOAD ACTING THROUGH THE C.G. AT THE SPECIFIED ANGLE OF 30° (UNIT LOAD CASE).

POSITION	P_{AB}	P_{AH}	P_{HJ}	VERT. DISPL. AT G (in)
1	−506	−1149	+627	0
2	−709	−1182	+967	2.7
3	−739	−1446	+1550	6.1
4	−3479	−621	+3858	9.6

NOW, THE STROKING ENERGY ATTENUATOR, AH, MUST HAVE A CONSTANT LOAD VALUE CORRECTING FOR THIS YIELDS :- (G_{OCC} MAX = 12 & $W_{EFF.}$ OF OCC + SEAT = 152)

POSITION	P_{AB}	P_{AH}	P_{HJ}	G_{OCC}
1	−923	−2096	+1144	12.0
2	−1257	−2096	+1715	11.7
3	−1071	−2096	+2247	9.5
4	−11738	−2096	+13017	22.0

(NOTE. THESE ARE TOTAL LOADS FOR 2 MEMBERS)

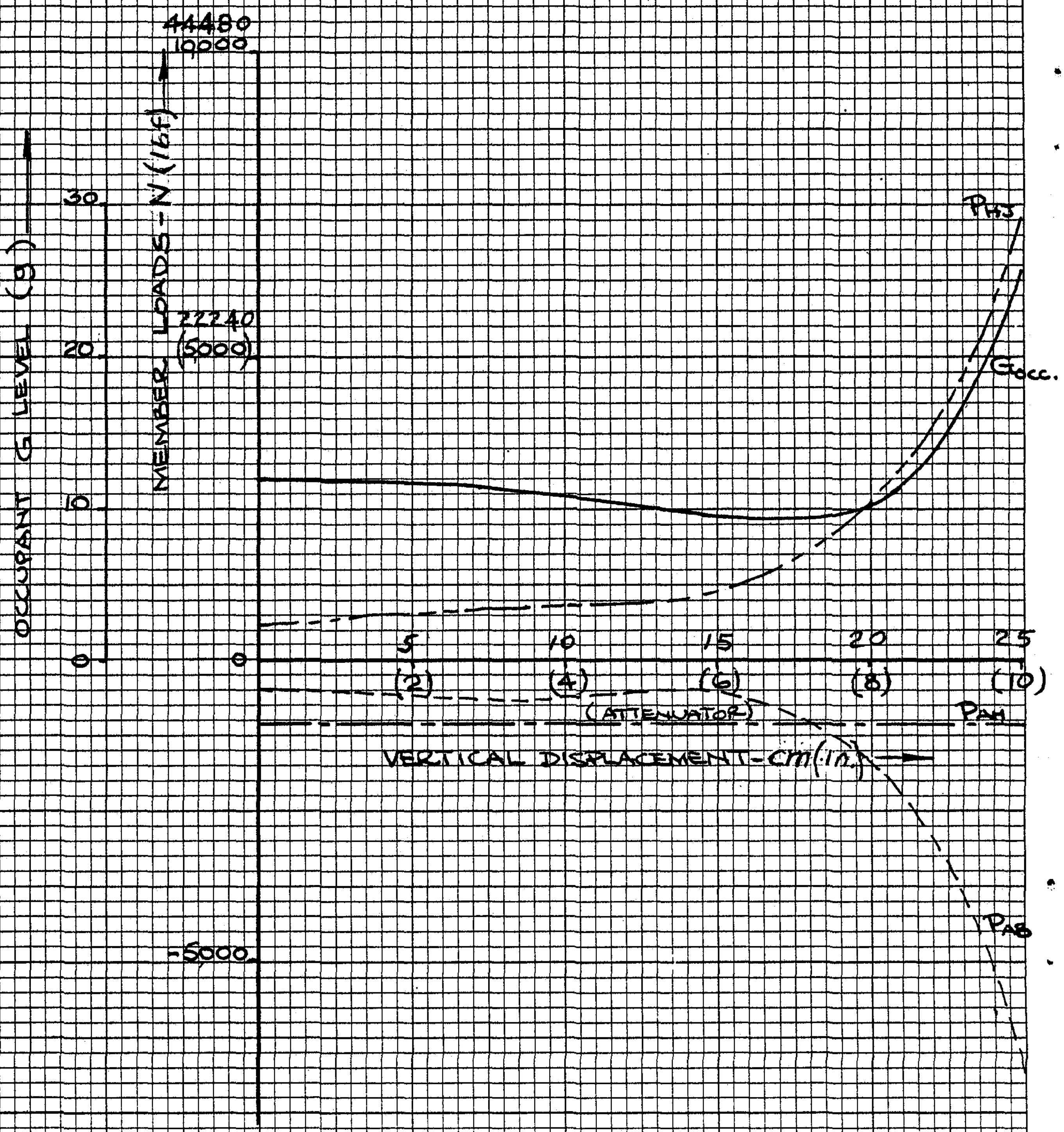
GRAPH ON SHT. 62 PLOTTED AT 1/2 THE ABOVE LOADS.

NASA GENERAL AVIATION PASSENGER SEAT

CRASHWORTHY & FLOOR MOUNTED

0.524 rad (30°) IMPACT : G LEVEL & MEMBER LOADS

{OCCUPANT + SEAT EFFECTIVE WEIGHT = 152 lb
ATTENUATOR STROKING LOAD = 1048 lb}



COMPUTATION OF $\ddot{G}$ LEVEL FOR LONGITUDINAL CASE

FOR LOAD LIMITATION FOR $P_{AH} = 2056$ lb (2 ATT.)

$\dot{G}_{LONG}$ LOAD :-

$$M_H :- \quad -P_{BA} \cdot \frac{12.8}{9.2} = G_L \, 185$$

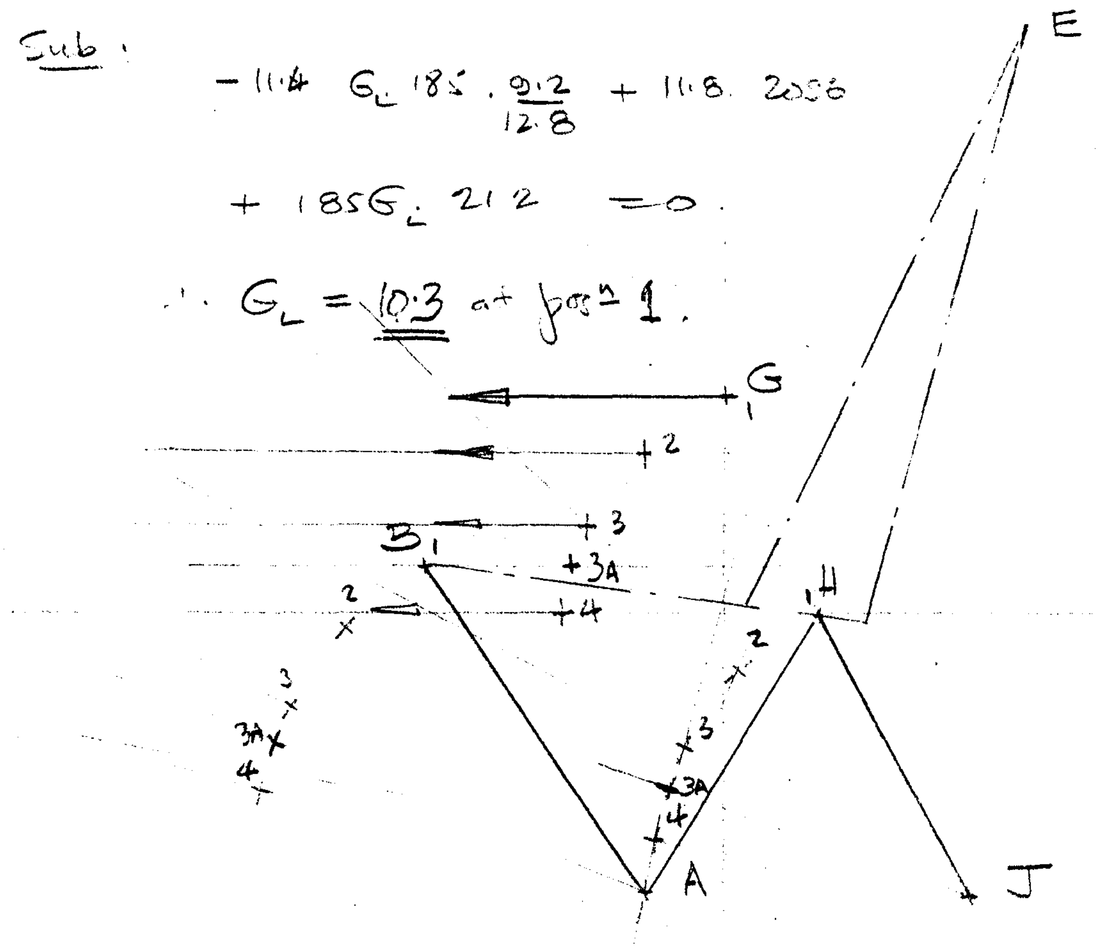
$$M_J :- \quad P_{BA} \, 11.4 + P_{AH} \, 11.8 + G_L 185 \cdot 21.2 = 0$$

Sub :

$$-11.4 \; G_L \, 185 \cdot \frac{9.2}{12.8} + 11.8 \cdot 2056$$

$$+ 185 G_L \, 21.2 = 0 .$$

$\therefore \; G_L = \underline{\underline{10.3}}$ at posn 1.



SIMILARLY FOR POSITIONS 2→4 :—
(P_{AH} = 2096 lb.)

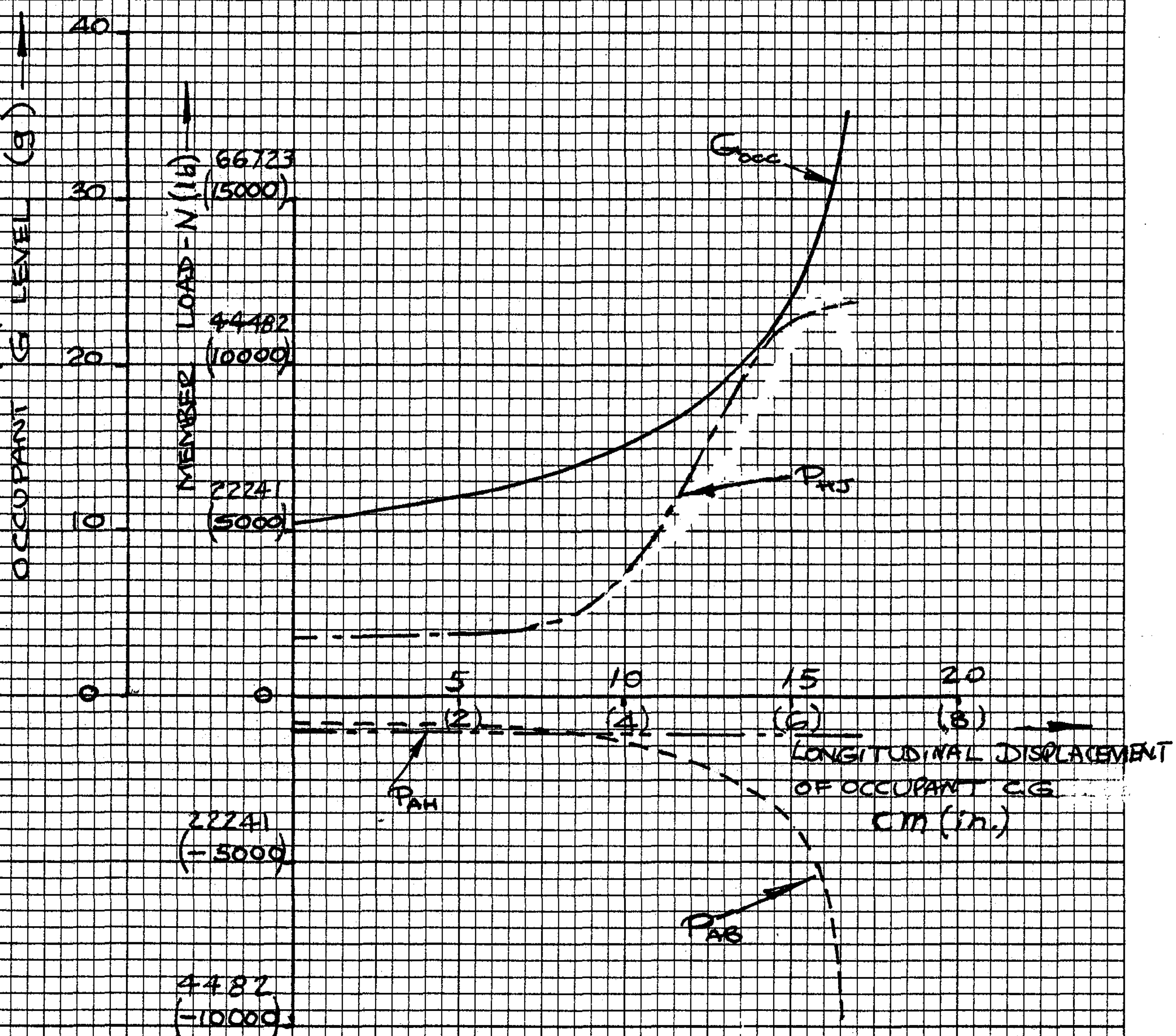
POSITION	P_{AB}	P_{HJ}	G_L	LONG. DISPL. OF G (in)
1	−1422	3430	10·3	0
2	−2486	5140	14·2	3·5
3	−6138	22308	22·9	5·9
3A	−14388	23152	39·6	6·7

(ACTUAL MEMBER LOADS ARE HALF THESE VALUES.)

NASA GENERAL AVIATION PASSENGER SEAT
CRASHWORTHY & FLOOR MOUNTED

LONGITUDINAL IMPACT: G LEVEL AND
MEMBER LOADS

OCCUPANT + SEAT WEIGHT = 84 Kg (185 lbm)
ATTENUATOR STROKING LOAD = 4662 N (1048 lbf)



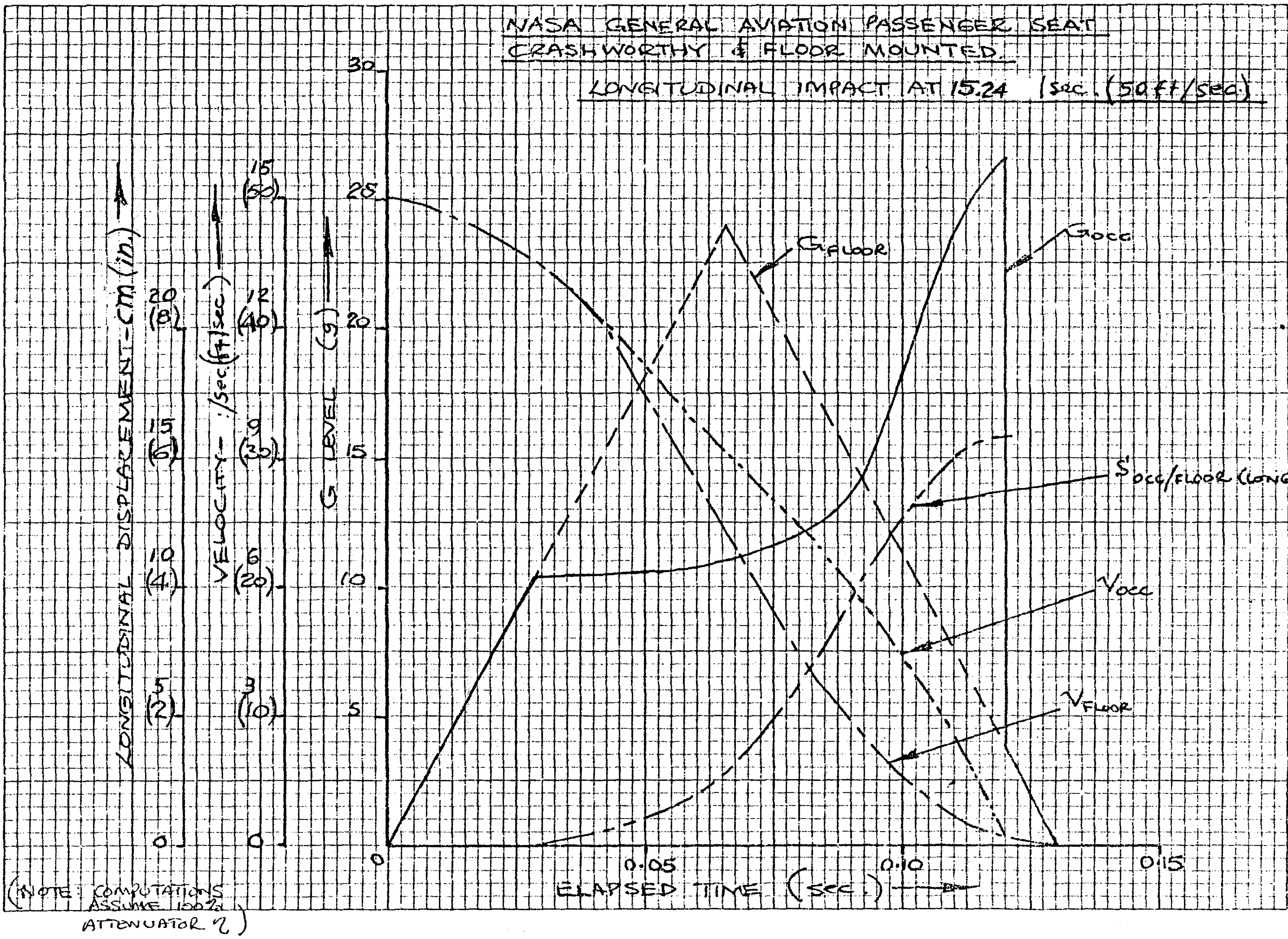
NASA GENERAL AVIATION PASSENGER SEAT CRASHWORTHY & FLOOR MOUNTED.

LONGITUDINAL IMPACT: ESTIMATE OF OCCUPANT 'G' LEVELS AND SEAT STROKE RELATIVE TO THE AIRCRAFT FLOOR.
IT IS ASSUMED, AS BEFORE, THAT THE TOTAL SEAT + OCCUPANT WEIGHT = 185 lb. AND THE ATTENUATOR LOAD SETTING IS THAT DEFINED BY THE VERTICAL IMPACT CASE.

THESE COMPUTATIONS USE SIMPLE NEWTONIAN RELATIONSHIPS FOR THE AIRCRAFT AND THE SEAT FOR AN IMPACT CONDITION DEFINED IN TR71-22: A TRIANGULAR PULSE AT THE AIRCRAFT FLOOR FOR 50 ft/sec. IMPACT VELOCITY WITH A PEAK G = 24 AND PULSE DURATION = 0.130 Sec.

t Sec	Δt Sec	AIRCRAFT FLOOR			SEAT + OCCUPANT			LONGITUDINAL MOTION OF SEAT RELATIVE TO FLOOR (in)
		V_F (ft/sec)	G_F	S_F (in)	V_S (ft/sec)	G_S	S_S (in)	
0	0	50	0	0	50	0	0	0
0.028	0.028	45.3	10.3	16.0	45.3	10.3	16.0	0
0.05	0.022	35.1	18.46	26.6	37.86	10.5	26.98	0.38
0.065	0.015	25.0	24.0	32.0	30.78	11.0	33.16	1.16
0.085	0.020	11.93	16.6	36.43	22.73	12.5	39.58	3.15
0.100	0.015	5.25	11.08	37.98	15.36	18.0	43.01	5.03
0.110	0.010	2.28	7.38	38.43	8.60	24.0	44.45	6.02
0.120	0.010	0.5	3.69	38.60	0	29.42	44.97	6.37
0.130	0.010	0	0	38.63	0	0	45.0	6.37

NOTE: TABLE VALUES DERIVED BY INCREMENTALLY CHANGING 't' AND COMPUTING ΔV and ΔS VALUES FOR THE AIRCRAFT FLOOR AND SEAT/OCCUPANT USING THE 'G' VS. STROKE CURVE FOR THE SEAT/OCCUPANT (P65) & THE 'G-t' CURVE FOR THE FLOOR



NUMBER
REV LTR

VERTICAL IMPACT : ESTIMATE OF OCCUPANT 'G' LEVELS AND SEAT STROKE RELATIVE TO THE AIRCRAFT FLOOR.

AS BEFORE, THE ASSUMED EFFECTIVE WEIGHT OF THE SEAT + OCCUPANT = 152 lb.

APPLYING SIMPLE NEWTONIAN THEORY FOR THE IMPACT CONDITION DEFINED IN TR 71-22 :-

TRIANGULAR PULSE AT THE AIRCRAFT FLOOR FOR 42 ft/sec. IMPACT VELOCITY WITH A PEAK G = 48 AND PULSE DURATION = 0.054

t_{sec}	Δt_{sec}	AIRCRAFT FLOOR V_F (ft/sec)	G_F	S_F (in)	SEAT + OCCUPANT V_S (ft/sec)	G_S	S_S (in)	VERTICAL MOTION OF SEAT RELATIVE TO FLOOR (in.)
0	0	42	0	0	42	0	0	0
.0068	.0068	40.69	12.0	3.37	40.69	12.0	3.37	0
.010	.0032	39.16	17.78	4.90	39.46	11.9	4.91	0.01
.020	0.01	30.57	35.56	9.08	35.63	11.9	9.42	0.34
.027	0.007	21.15	48	11.25	32.95	11.9	12.30	1.05
.030	0.003	16.77	42.67	11.93	31.80	11.9	13.47	1.54
.040	0.010	5.61	24.89	13.27	28.00	11.7	17.06	3.79
.045	0.005	2.32	16.00	13.51	26.25	10.0	18.69	5.18
.050	0.005	0.46	7.11	13.59	24.72	9.0	20.22	6.63
0.054	0.004	0	0	13.61	23.56	9.0	21.38	7.77
	.005				21.15	15.0	22.72	9.41
	.010				17.93	20.0	23.89	*10.28
	.010							

* THIS VALUE EXCEEDS THE AVAILABLE SEAT STROKE. ∴ REDUCE IMPACT 'G' LEVEL

FORM 46284 (2/66)

USING $G = 24$ AND $V = 42$ ft/sec, $t = 0.109$ sec

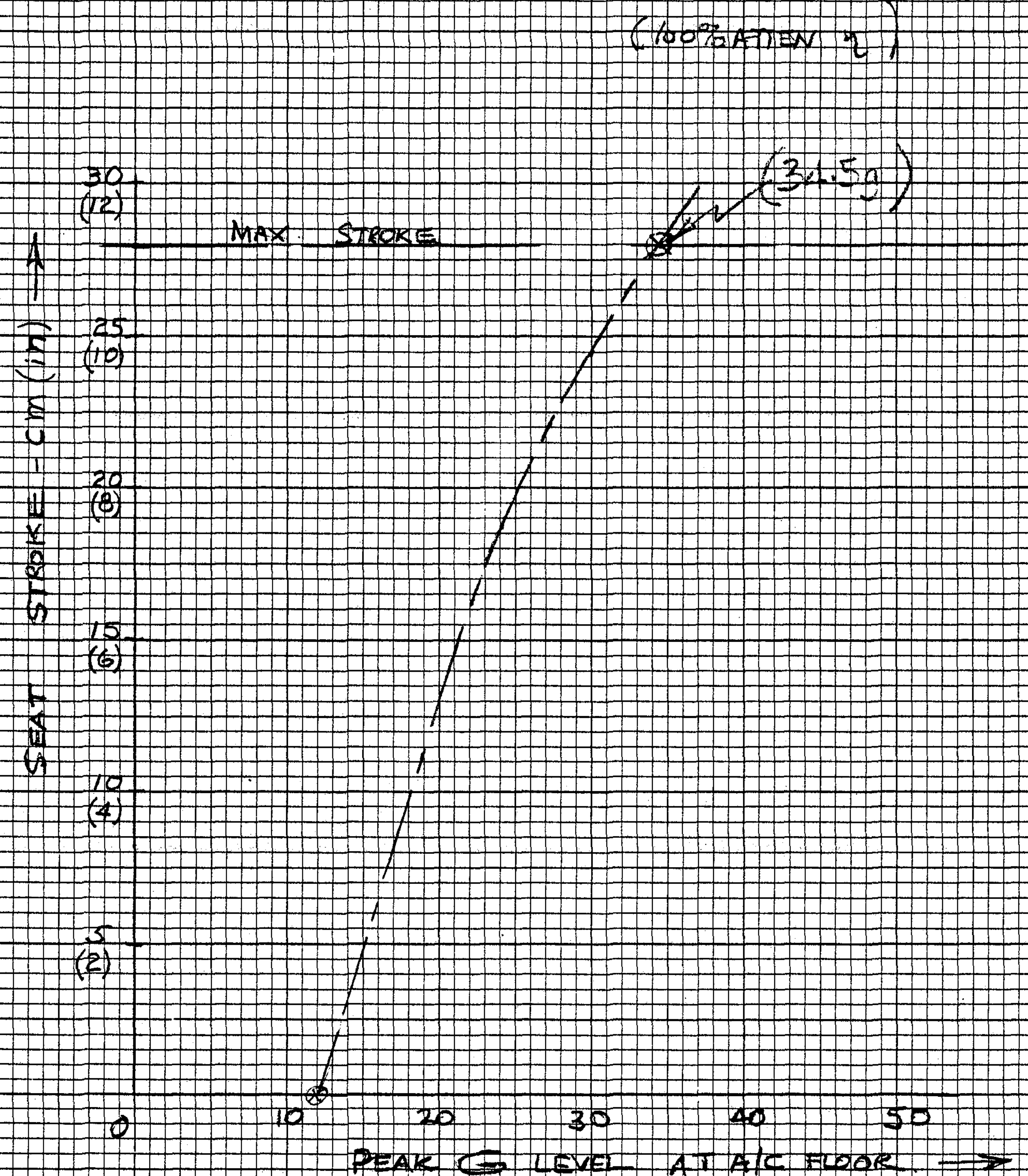
THEN FOR REVISED A/C FLOOR CONDITIONS -

t_{sec}	Δt_{sec}	AIRCRAFT FLOOR			SEAT + OCCUPANT			VERTICAL MOTION OF SEAT RELATIVE TO FLOOR (in)
		V_F (ft/sec)	G_F	δ_F (in)	V_S (ft/sec)	G_S	δ_S (in)	
0	0	42	0	0	42	0	0	0
0.01	·01	41·29	4·4	5.00	41·29	4·4	5.00	0
0.02	·01	39·16	8·8	9·83	39·16	8·8	9·83	0
·0273	·0073	36·72	12	13·15	36·72	12	13·15	0
·035	·0077	33·32	15·41	16·39	33·76	11·9	16·41	0·02
·045	·010	27·65	19·82	20·05	29·93	11·9	20·23	0·18
·0545	·0095	20·95	24	22·82	26·29	11·9	23·60	0·78
·065	·0105	13·62	19·38	25.00	22·27	11·9	26·66	1·66
·075	0.010	8·10	14·92	26·30	18·49	11·6	29·11	2·81
·085	0·010	4·00	10·52	27·03	14·85	11·0	31·11	4·08
·095	0·01	1·32	6·12	27·35	11·44	10·2	32·69	5·34
·109	·014	0	0	27·46	7·07	9·2	34·24	6·78
·119	·01	—	—		4·01	9·5	34·90	7·44
·129	·01	—	—		0·79	10·0	35·19	7·73
·133	·0025	—	—		0	8·9	35·2	7·74

COMPUTING FOR GMAX = 30 AT A/C FLOOR :—
(t_{TOT} = ·087)

t_{sec}	Δt_{sec}	AIRCRAFT FLOOR			SEAT + OCCUPANT.			VERTICAL MOTION OF SEAT RELATIVE TO FLOOR (in)
		V_F (ft/sec)	G_F	S_F (in)	V_S (ft/sec)	G_S	S_S (in)	
0	0	42	0	0	42	0	0	0
0.01	0.01	40.89	6.9	4.97	40.89	6.9	4.97	0
0.02	0.01	37.56	13.79	9.68	37.69	12	9.69	0.01
0.03	0.01	32.01	20.69	13.85	33.84	11.9	13.98	0.13
0.0435	0.0135	20.99	30.00	18.14	28.67	11.9	19.04	0.90
0.0535	0.01	12.44	23.1	20.15	24.85	11.8	22.25	2.10
0.0635	0.01	6.11	16.20	21.26	21.31	11.0	25.02	3.76
0.0735	0.01	2.00	9.31	21.75	18.09	10.0	27.38	5.63
0.087	·0135	0	0	21.91	13.96	9.5	29.98	8.07
0.097	·01				8.16	18.0	31.31	9.40
0.107	·01				0	25.0	31.60	9.79
·018	·008	38.46	12	8.78	38.46	12	8.78	0

NASA GENERAL AVIATION PASSENGER SEAT.
CRASHWORTHY & FLOOR MOUNTED.
VERTICAL IMPACT CAPABILITY



RECOMPUTING VALUES FOR $\acute{G} = 35\,g$.
$\Delta v = 42$ ft/sec.
$\Delta t = 0.0745$

t (sec)	Δt (sec)	AIRCRAFT FLOOR			SEAT + OCCUPANT			$S_{occ}/_{floor}$
		v_F (ft/sec)	G_F (g)	S_F (in)	v_S (ft/sec)	G_S (g)	S_S (in)	
0	0	42	0	0	42	0	0	0
0.01	0.01	40.488	9.392	4.949	40.488	9.392	4.949	0
0.02	0.01	35.952	18.783	9.535	36.64	12	9.58	0.05
0.03	0.01	28.392	28.175	13.396	32.78	12	13.74	0.34
0.0373	0.00727	21	35	15.550	29.932	12	16.513	0.96
0.0445	0.00727	13.609	28.175	17.704	27.152	11.8	19.036	1.33
0.0545	0.01	6.048	18.783	18.883	23.429	11.5	22.07	3.19
0.0645	0.01	1.512	9.392	19.337	20.048	10.5	24.679	5.35
0.0745	0.01	0	0	19.428	16.989	9.5	26.901	7.47
0.0845	0.01				12.803	13.0	28.689	9.26
0.0945	0.01				4.753	25.0	29.742	10.31
0.0994	0.0049				0	** 30.0	29.882 *	10.45

* THIS VALUE APPROXIMATES AVAILABLE SEAT STROKE.

** PEAK $\acute{G}$ DURATION < .005 SEC.

THUS, FOR AN IMPACT WITH A RESULTANT VELOCITY AT 30° TO THE GROUND PLANE A MAXIMUM G LEVEL OF APPROXIMATELY 35 FOR A 42 ft/sec. VERTICAL VELOCITY COMPONENT WILL RESULT IN THE SEAT STROKING TO ITS MAXIMUM POSITION.

SUCH AN IMPACT CONDITION REQUIRE THE FOLLOWING AIRFRAME CHARACTERISTICS:

STROKE OF AIRFRAME* = 19.43 in. (INCLUDING L/G)
TIME FOR AIRFRAME TO STROKE = 0.075 sec.

[NOTE: THESE VALUE WERE OBTAINED BY ASSUMING 42 ft/sec. VELOCITY COMPONENTS FOR BOTH THE AIRFRAME VERTICAL IMPACT AND SEAT 30° IMPACT. THIS IS NOT TRUE BUT BY IGNORING THE EFFECTS OF LONGITUDINAL COMPONENTS THE RESULT OBTAINED IS CONSIDERED ADEQUATE FOR ESTIMATING THE SEAT CAPABILITY.]

* THE AIRFRAME + L/G STROKE OBTAINED FROM TABLE ON P 71a.

FOR CEILING MOUNTED SEAT, 30° IMPACT:—

ASSUMING A 42 ft/sec. IMPACT VELOCITY AND A THE FOLLOWING "G vs t" RELATIONSHIP AT THE FLOOR OF THE AIRCRAFT:

Δ PULSE; $G_{MAX} = 30g$. $t = 0.087$ sec. FOR A 42 ft/sec ΔV.

COMPUTATION OF AIRCRAFT & SEAT + OCCUPANT RESPONSES USING SIMPLE NEWTONIAN RELATIONSHIPS YIELDS:—

t_{sec}	Δt_{sec}	AIRCRAFT FLOOR			SEAT + OCCUPANT			VERTICAL MOTION OF SEAT RELATIVE TO FLOOR (in.)
		V_F (ft/sec)	G_F	S_F (in.)	V_S (ft/sec)	G_S	S_S (in.)	
0	0	42	0	0	42	0	0	0
0.01	0.01	40.89	6.9	4.97	40.89	6.9	4.97	0
0.018	0.008	38.46	12	8.78	38.46	12	8.78	0
0.02	0.002	37.56	13.79	9.68	37.69	12	9.69	0.01
0.03	0.01	32.01	20.69	13.85	33.83	12	13.98	0.13
0.0435	0.0135	20.99	30.00	18.14	28.61	12	19.04	0.90
0.0535	0.01	12.44	23.10	20.15	24.75	12	22.24	2.09
0.0635	0.01	6.11	16.20	21.26	20.89	12	24.98	3.72
0.0735	0.01	2.00	9.31	21.75	17.03	12	27.25	5.50
0.087	0.0135	0	0	21.91	11.81	12	29.59	7.68
	0.01				7.95	12	30.78	8.87
	0.01				4.09	12	31.50	9.59
	0.01				0.23	12	31.76	9.85
	.0006				0	12	31.76	* 9.85

* THIS VALUE IS LESS THAN THE MAX. AVAILABLE STROKE OF 11.2 in.

FORM 46284 (2/66)

USING A G_{max} VALUE OF 34.0 :–

$t = .077$ FOR $\Delta V = 42$ ft/sec.

t_{sec}	Δt_{sec}	AIRCRAFT FLOOR			SEAT + OCCUPANT.			VERTICAL MOTION OF SEAT RELATIVE TO FLOOR (in)
		V_F (ft/sec)	G_F	S_F (in)	V_S (ft/sec)	G_S	S_S (in.)	
0	0	42	0	0	42	0	0	0
0.01	0.01	40.58	8.83	4.95	40.58	8.83	4.95	0
0.02	0.01	36.32	17.66	9.56	37.22	12	9.62	0.06
0.03	0.01	29.21	26.49	13.49	33.36	12	13.85	0.36
0.0385	0.0085	20.93	34.0	16.05	30.08	12	17.09	1.04
0.047	0.0085	12.65	26.49	17.76	26.80	12	19.99	2.83
0.057	0.01	5.54	17.66	18.85	22.94	12	22.97	4.12
0.067	0.01	1.28	8.83	19.26	19.08	12	25.49	6.23
0.077	0.01	0	0	19.79	15.22	12	27.55	7.76
0.087	0.01				11.36	12	29.14	9.35
0.097	0.01				7.50	12	30.27	10.48
0.107	0.01				3.64	12	30.94	11.15
0.116	.0094				0	12	31.15	11.36
0.036	0.0036	39.37	12.0	6.68	39.37	12	6.68	0

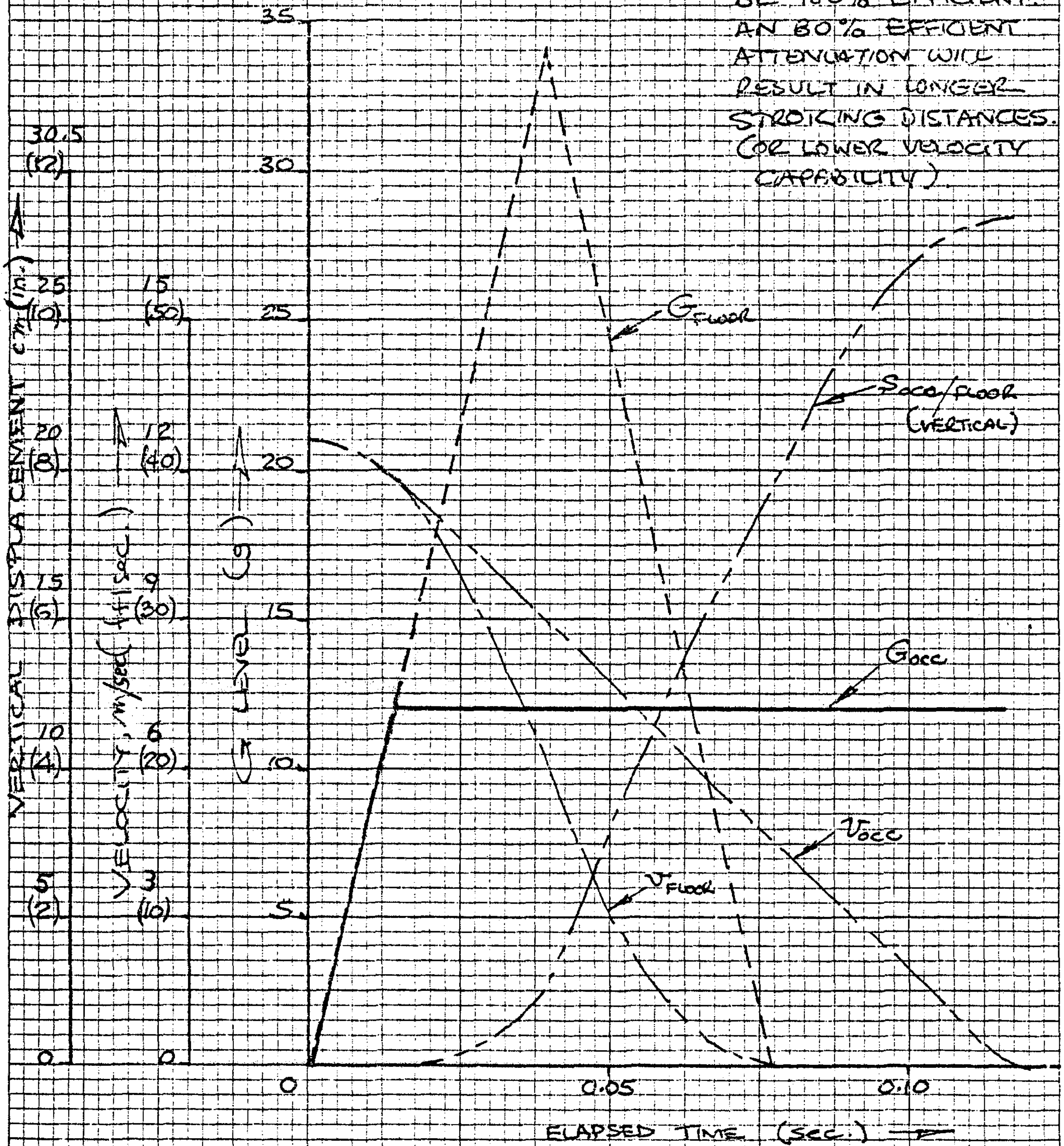
THE BOEING COMPANY

NUMBER
REV LTR

NASA GENERAL AVIATION PASSENGER SEAT
CRASHWORTHY & CEILING SUSPENDED

0.524 rad (30°) NOSE DOWN IMPACT CONDITION (APPROXIMATED)
AT 12.8 m/S (42 Ft/Sec)

NOTE: ATTENUATION STROKES FOR STRUCTURE & SEAT ASSUMED TO BE 100% EFFICIENT. AN 80% EFFICIENT ATTENUATION WILL RESULT IN LONGER STROKING DISTANCES. (OR LOWER VELOCITY CAPABILITY)



THE **BOEING** COMPANY

NUMBER
REV LTR

NASA GENERAL AVIATION PASSENGER SEAT.

CRASHWORTHY & CEILING SUSPENDED

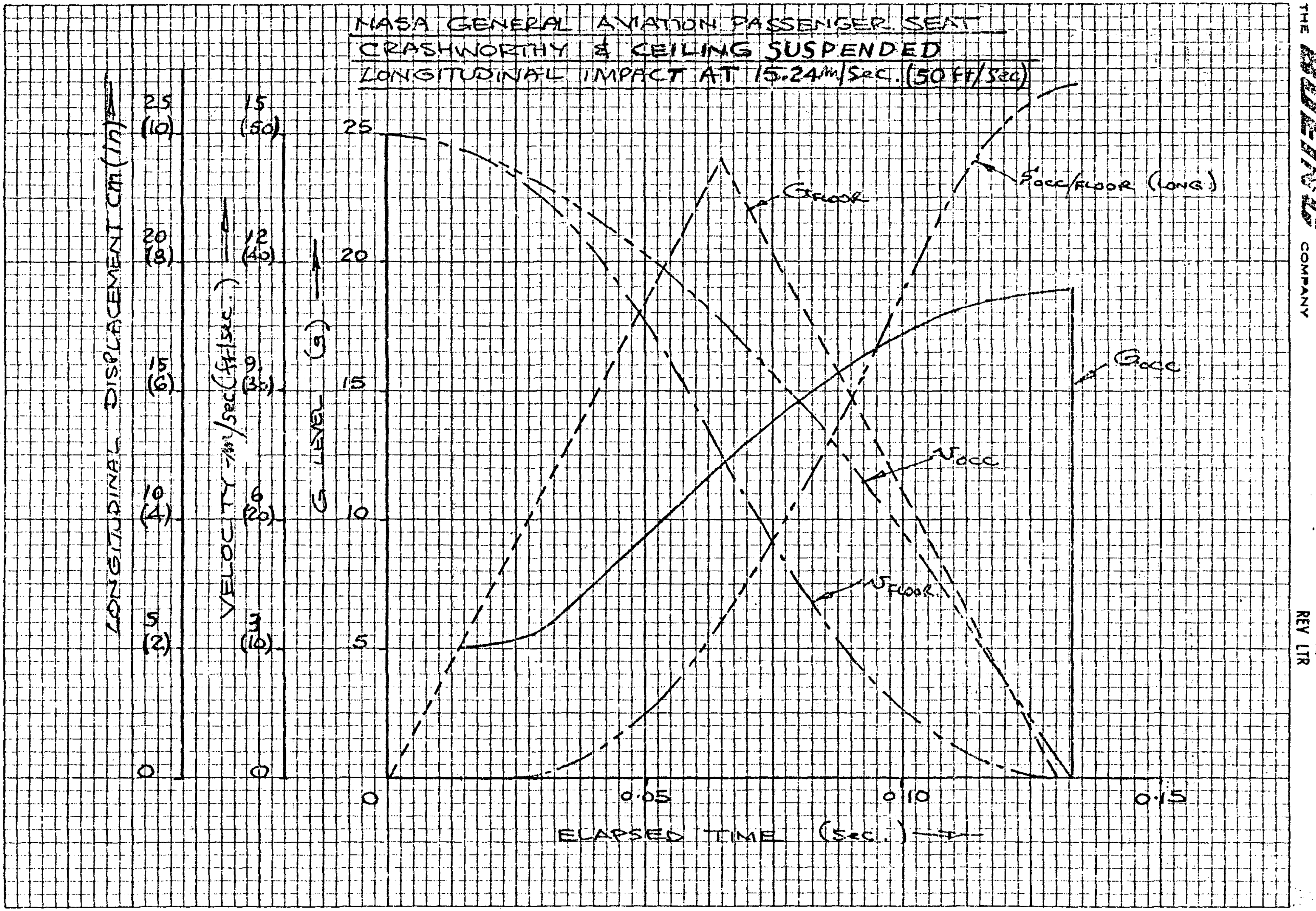
LONGITUDINAL IMPACT AT 15 m/SEC (ft/sec) - 24 G

		AIRCRAFT FLOOR			SEAT + OCCUPANT			LONGITUDINAL MOTION OF SEAT RELATIVE TO FLOOR (in)
t_{sec}	Δt_{sec}	V_F (ft/sec)	G_F	S_F (in)	V_S (ft/sec)	G_S	S_S (in)	
0	0	50	0	0	50	0	0	0
0.014	0.014	48.87	5	8.31	48.87	5	8.31	0
0.028	0.014	45.42	10.3	16.23	46.50	5.5	16.32	0.091
0.038	0.010	41.50	14.03	21.45	44.41	7.5	21.77	0.324
0.048	0.010	36.39	17.72	26.12	41.75	9	26.94	0.82
0.058	0.010	30.09	21.42	30.11	38.53	11	31.76	1.65
0.065	.007	24.97	24	32.42	35.88	12.5	34.89	2.47
0.072	.007	19.85	21.42	35.11	33.01	13	37.78	2.68
0.082	0.01	13.55	17.72	37.11	28.50	15	41.47	4.36
.092	0.01	8.44	14.03	38.43	23.43	16.5	44.59	6.16
.102	0.01	4.52	10.3	39.21	18.28	17.5	47.09	7.88
.116	0.014	1.07	5	39.68	10.21	18.3	49.48	9.80
.130	0.014	0	0	39.77	1.85	18.8	50.49	10.72
.133	0.003			39.77	0	19	50.52	10.75

FORM 46284 (2/66)

NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



THE BOEING COMPANY

SHEET 77

NUMBER
REV LTR

NASA GENERAL AVIATION PASSENGER SEAT

STRESS ANALYSIS:

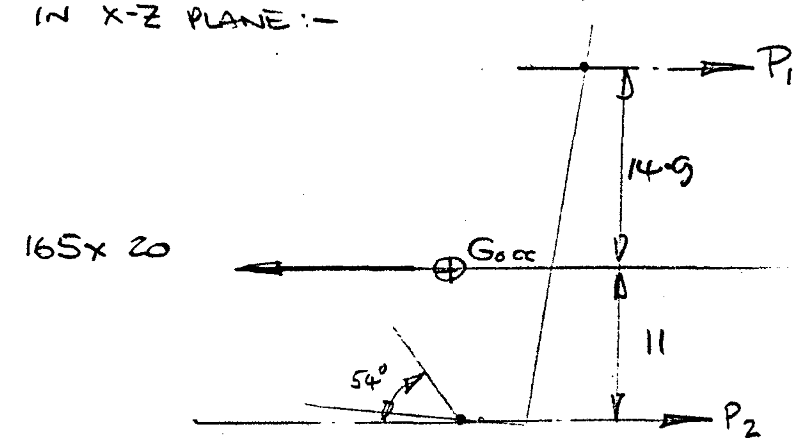
A SIMPLIFIED APPROACH IS USED TO SIZE THE SEAT STRUCTURAL MEMBERS AND FASTENERS. MAXIMUM LOADS COMPUTED PREVIOUSLY ARE USED TOGETHER WITH A DURABILITY CRITERION TO ASSURE THAT SELECTED TUBING HAS THE CAPABILITY TO WITHSTAND NORMAL "WEAR-AND-TEAR" EXPECTED DURING THE LIFE CYCLE OF THE SEAT.

ESTIMATES FOR SEAT PAN FABRIC LOAD DISTRIBUTIONS AND RESTRAINT HARNESS LOADING ARE INCLUDED IN THE ANALYSIS FOR EACH SEAT.

1. CEILING SUSPENDED SEAT:

RESTRAINT SYSTEM LOADING:-

IN X-Z PLANE:-



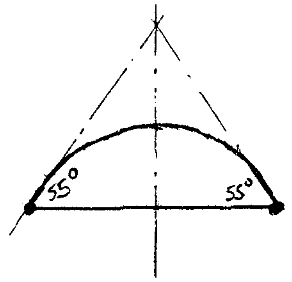
STATICALLY:-

$P_1 = 1402$ lb. = SINGLE INERTIA REEL LOAD ON SEAT.

$P_2 = 1898$ lb. = SEAT BELT LOAD COMPONENT IN X-Z PLANE.

NOTE; GEOMETRY SHOWN IS FOR ATTACHMENTS OF SHOULDER HARNESS, AND SEAT BELT TO SEAT FRAME. 54° ANGLE IS TYPICAL LAP BELT ANGLE, RELATIVE TO SEAT PAN, FOR AVERAGE OCCUPANT.

ACTUAL SEAT BELT LOAD, ASSUMING AN ANGLE OF 55° IN THE Y-Z PLANE, IS SHOWN BELOW :-



ALSO TAKING INTO CONSIDERATION THE ANGLE OF IN THE X-Z PLANE

$$\text{ACTUAL LOAD ON THE BELT} = \frac{P_L}{2} \cdot \frac{1}{\cos 55^\circ} \cdot \frac{1}{\cos 54^\circ}$$

$$= \frac{1805}{2} \cdot 1.743 \cdot 1.701$$

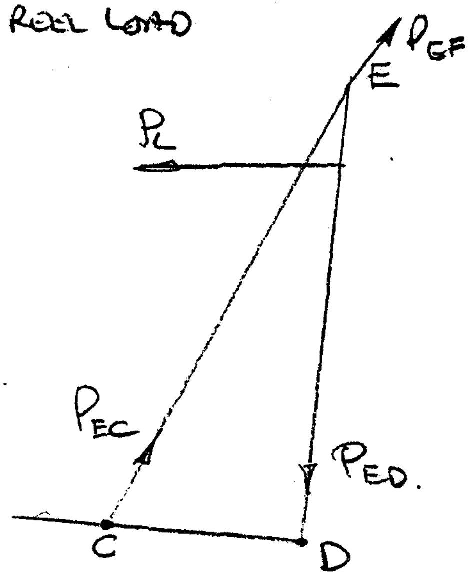
$$= \underline{\underline{2676 \text{ lb.}}}$$

THIS IS MAXIMUM LOADING AT SEAT BELT ATTACHMENT FITTING ON EACH SIDE OF SEAT PAN.

<u>LOADING IN MEMBERS EC & ED</u> :-

<u>30° NOSE DOWN CASE</u> (USING VECTOR DIAGRAMS DRAWN PREVIOUSLY).

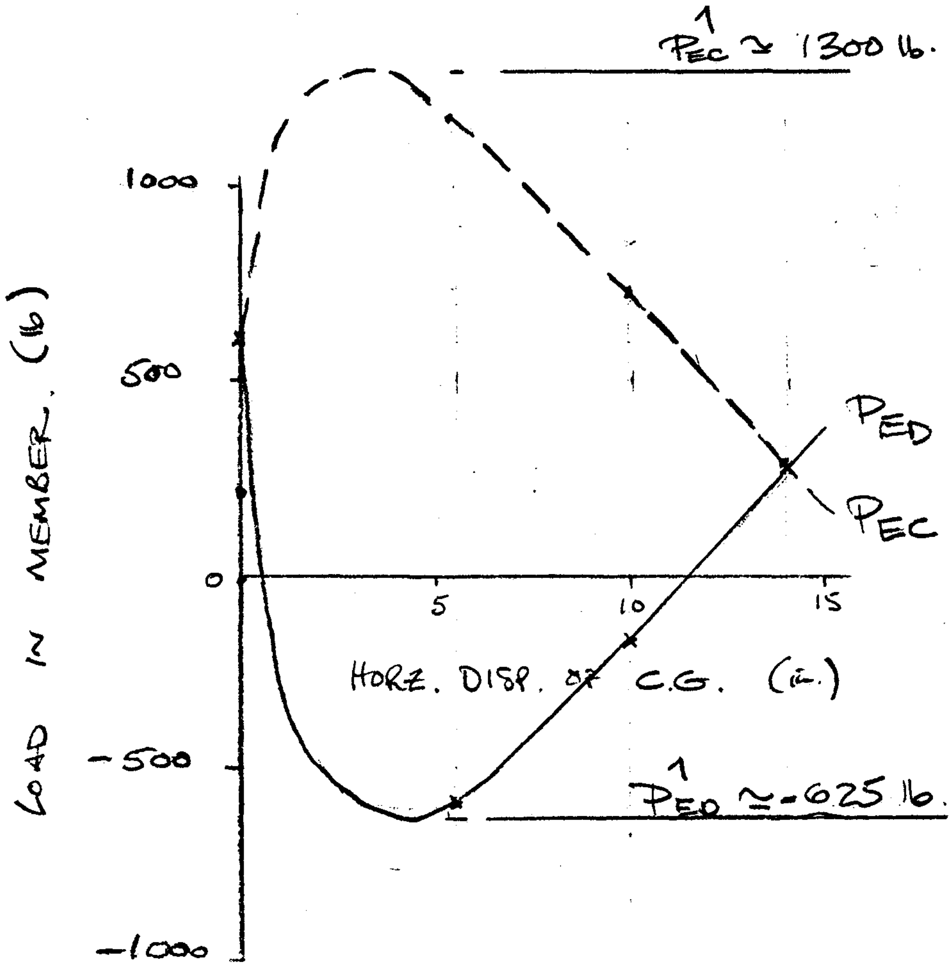
P_L = INERTIA REEL LOAD



LONGITUDINAL CASE:

VARIATION OF LOAD IN MEMBERS EC & ED AS THE LONGITUDINAL STROKE OF THE CG VARIES:-
(FROM PREVIOUS VECTOR DIAGRAMS)

POSITION	P_{EC}	P_{ED}
1	206	604
2	1193	-595
3	741	-164
4	299	286



30° CASE

VARIATION OF LOAD IN MEMBERS EC & ED AS A FUNCTION OF VERTICAL STROKE OF THE C.G.
(FROM PREVIOUS VECTOR DIAGRAMS).

1. ASSUMING NO SHOULDER HARNESS LOAD AND NO LOADING DUE TO THE OCCUPANT BEING FORCED INTO THE SEAT BACK :-

POSITION	VERT. DISPL. OF C.G. (in)	P_{EC_1} (lb)	P_{ED_1} (lb)
1	0	1064	+179
2	3.2	790	−135
3	5.5	638	−284
4	7.6	790	−135
5	10.3	866	−60
6	12.6	942	+15
7	14.8	1064	+135

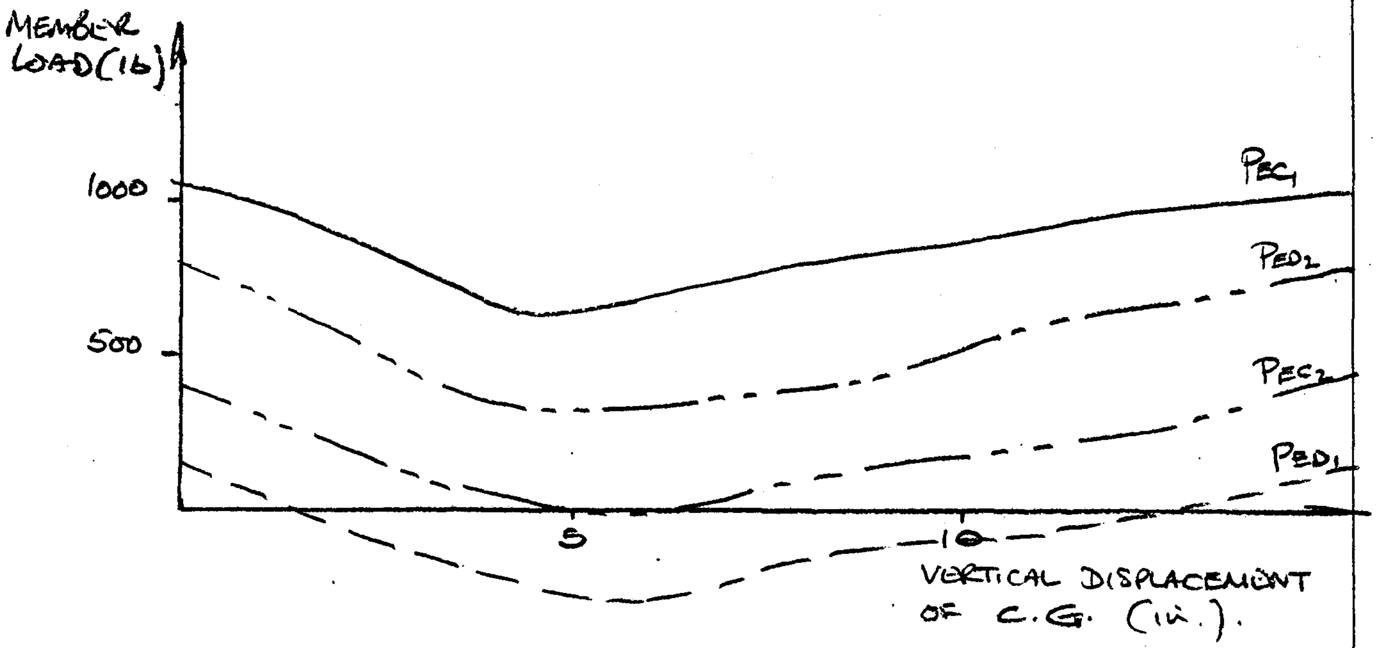
2. INCLUDING EFFECT OF SHOULDER HARNESS LOAD :-

		P_{EC_2}	P_{ED_2}
1	0	388	797
2	3.2	114	483
3	5.5	(−38)*	334
4	7.6	114	483
5	10.3	190	558
6	12.6	266	633
7	14.8	388	753

* MEMBER EC CANNOT RESIST COMP. LOAD.

FORM 46284 (2/66)

PLOTTING VARIATIONS OF LOAD WITH C.G. DISPLACEMENT FOR THE TWO CASES :—



FROM GRAPHS :—

MAX P_{EC} = + 1064 lb.

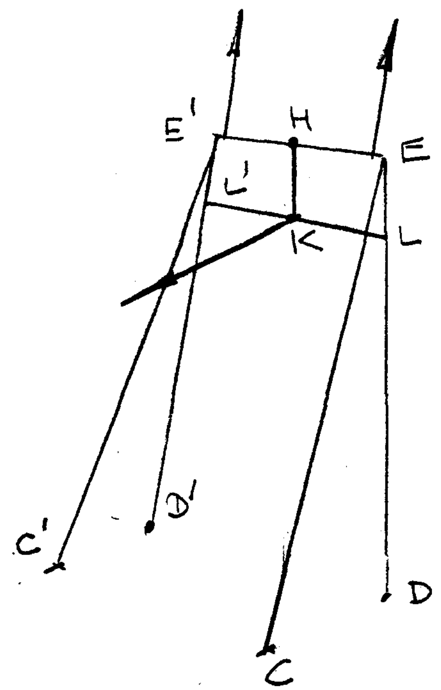
MAX P_{ED} = + 797 or — 284 lb.

THUS, FROM BOTH LONGITUDINAL & 30° CASES DESIGN LOADS :—

MEMBER EC, $P_{DES_{EC}} = 1300$ lb.

" ED, $P_{DES_{ED}} = -625$ lb.

SEAT BACK



DESIGN LOADS (ULT).

MEMBER EC, $P_{EC} = 1300$ lb.

MEMBER ED, $P_{ED} = -625$ lb.

IN ADDITION, LOCAL INTERNAL LOADING DUE TO INERTIA REEL INSTALLATION MUST BE CONSIDERED.

CONSIDER MEMBER LKL' :-

HARNESS LOAD APPLIED IN TWO PLANES, RESULTANT FORCE $= \sqrt{2} \cdot 1402$

$= \underline{1983 \text{ lb}}$

IF PINNED JOINTS ASSUMED, $\hat{M} = 1983 \times \frac{5}{2}$

$= \underline{4958 \text{ in.lb}}$

(EFFECTIVE LENGTH OF LKL' = 10")

FOR 1.5 O/D TUBE :- (7075-T6)

$\sigma_{ULT} = 78{,}000\,lb/in^2$

USING: $\sigma_{ULT} = \dfrac{My}{I}$ WHERE $I = \frac{\pi}{64}(D_o^4 - D_i^4)$

$(D_o - D_i)\frac{1}{2} = t$

NOW THIS CASE IS BETWEEN A PINNED END AND FIXED END CONDITION.

FOR PINNED ENDS, $\hat{M} = 4{,}958$ in.lb. AND $t = 0.04$ in.

FOR FIXED ENDS, $\hat{M} = 2479$ in.lb. AND $t = 0.02$ in.

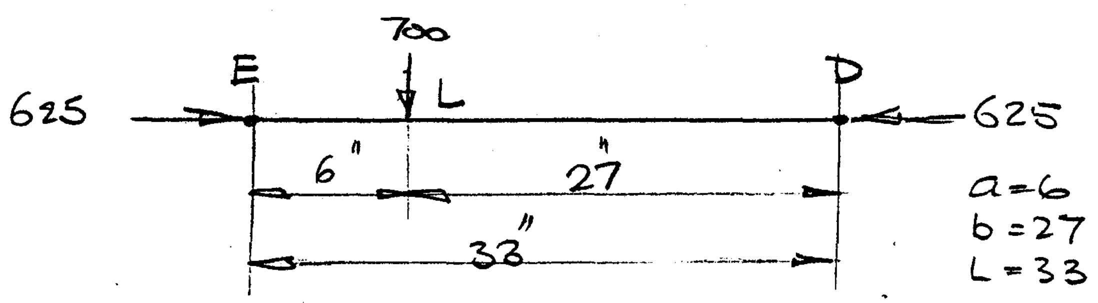
THUS A REASONABLE TUBE THICKNESS WILL BE 0.049. (THIS ALLOWS FOR LOSS OF MATERIAL AT JOINTS AND CONTAINS SOME ALLOWANCE FOR WEAR AND TEAR IN-SERVICE HANDLING.)

THE $I = \pi/64\,(1.5^4 - 1.402^4) = .059\ in^4$

(NOTE: SAME VALUE ADEQUATE FOR EHE')

CONSIDER MEMBER ED :-

EFFECTIVELY AN END LOADED STRUT WITH A LATERAL LOAD AT POINT L. (ASSUMED STRAIGHT).



FROM "ANALYSIS AND DESIGN OF FLIGHT VEHICLE STRUCTURES," E.F. BRUHN:- (TABLE A5.1, p A5.23)

FROM E TO L : $M = C_1 \sin\frac{x}{j} + C_2 \cos\frac{x}{j} + f(w)$

$C_1 = -\dfrac{Wj \sin\frac{b}{j}}{\sin\frac{L}{j}}$

where $j = \sqrt{\dfrac{EI}{P}}$

$C_2 = 0$

$= \sqrt{\dfrac{10^7 I}{625}}$

$f(w) = 0$

FOR THIS MEMBER IT WILL BE ASSUMED THAT:-

$t = 0.049 \quad (7075-T6)$
$D_o = 1.5$

THUS $I = 0.059 \text{ in}^4$ & $j = 30.72$

$$C_1 = \frac{-700 \cdot 30.72}{\sin 33/30.72} \cdot \sin 27/30.72 = \underline{-18816 \text{ in.lb}}$$

$$M = -18816 \sin x/j$$

AT $x = 6$, $\underline{M_L = 3726 \text{ in.lb}}$

FROM L TO D :-

$$C_1 = +\frac{W_j \sin a/j}{\tan L/j} = \frac{700 \cdot 30.72 \cdot \sin 6/30.72}{\tan 33/30.72}$$
$$= \underline{4844} \text{ in.lb.}$$

$$C_2 = -W_j \sin a/j = -700 \cdot 30.72 \cdot \sin 6/30.72$$
$$= -\underline{4258} \text{ in.lb.}$$

$\therefore$ MAXIMUM MOMENT $= (C_1^2 + C_2^2)^{1/2}$
$= \underline{6449 \text{ in.lb.}}$

FOR PLASTIC BENDING OF EXTRUDED TUBE :-

$K = 1.34$, $\sigma_{ULT} = 103\,000$ (7075-T6)

$$\therefore I_{MIN} = \frac{6449}{2} \cdot \frac{1.5}{103\,000} = \underline{0.047 \text{ in}^4}$$

THE ACTUAL MEMBER IS NOT STRAIGHT BUT HAS A BEND NEAR THE LOWER END. ADDITIONALLY SOME STRENGTH REDUCTION IS CAUSED BY THE JOINT FASTENER HOLES.

ASSUMING THAT THE MOMENT DUE TO THE BEND ACCOUNTS FOR THESE INCREASES IN MEMBER STRESS :-

ADDITIONAL MOMENT $= (15-8)\,0.5 \times 625 = 2188$ in lb.

SUMMING THIS AND OTHER MOMENT $= 8637$ in lb.

THIS REQUIRED $I = 0.063$ in^4.

NOW, THE SELECTED MATERIAL DIMENSIONS ARE THOSE USED ON A TROOP SEAT CONCEPT WHICH HAS BEEN TESTED SUCCESSFULLY AND WITHSTOOD LOADING SPECIFIED BY THE U.S. ARMY FOR REPRESENTATIVE HELICOPTER IMPACTS.

THUS MATERIAL TO BE USED IS

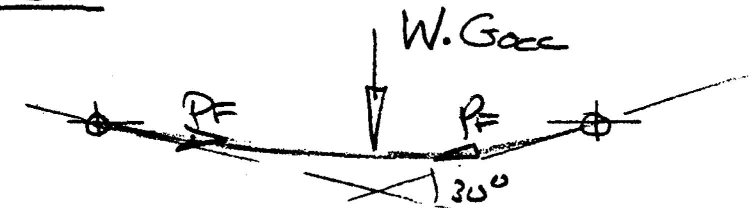
1.5 O.D. 0.049 WALL 7075-T6 TUBING.

SEAT PAN FRAME:

LOADING ON THE SEAT PAN FRAME RESULTS FROM DIRECT LOADING BY ATTACHED MEMBERS AND FABRIC LOADING PRODUCED BY OCCUPANT LOADING.

FABRIC LOADING:

ASSUME :-

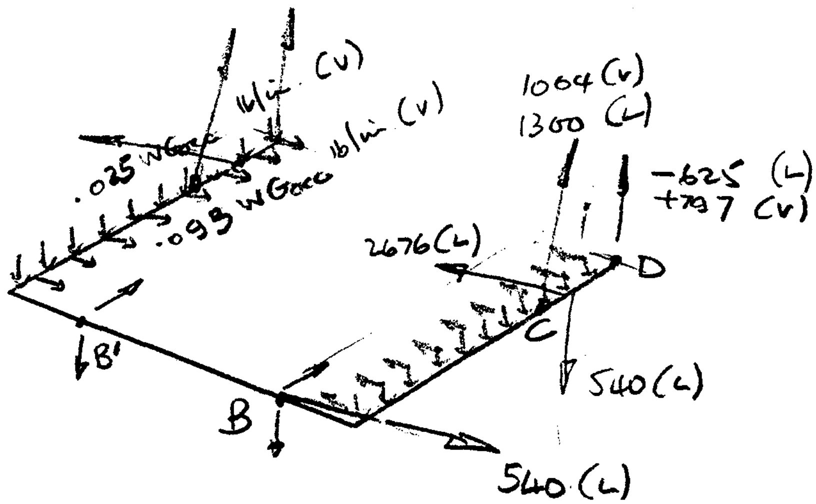


TENSION IN FABRIC $=$ W Gocc PER SIDE $= P_F$

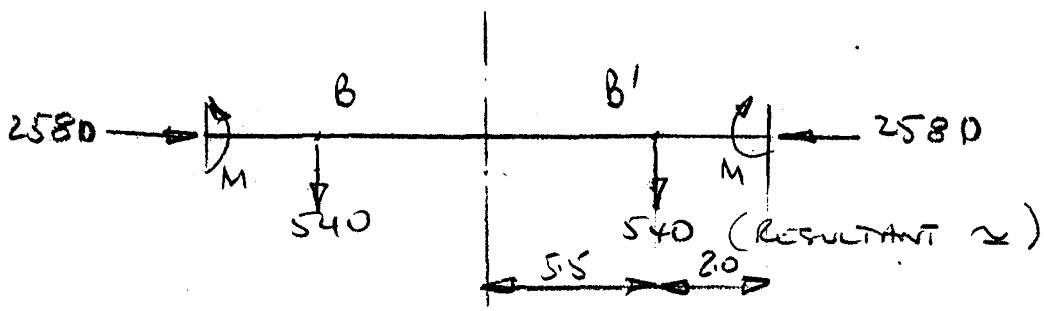
(FOR AN ASSUMED ANGLE OF 30° AS SHOWN)

THIS ASSUMES LOADING TAKEN BY TWO SIDE MEMBERS ONLY.

FRAME MEMBERS:



FRONT MEMBER:



CONSIDER TWO EXTREMES; (1) FIXED ENDS, (2) PINNED ENDS. ACTUAL CASE BETWEEN TWO.

FOR FIXED END:-

$$M = W\frac{ab}{\ell^2}(b+a) \quad \text{(ROARK p 112)}$$

$$= 540 \cdot 2 \cdot \frac{13}{15} = 936 \text{ in.lb}$$

MOMENT AT B $= 936 - 2 \times 540$
$= 144$ in.lb.

FOR PINNED END :

$$M_b = 1080 \text{ in.lb.}$$

MEMBER:

AL/ALLOY TUBE, 1.375 O.D. .083 WALL
6061-T6. ($\sigma_{ULT} = 38000$)

$$I = \frac{\pi}{64}\left(1.375^4 - 1.209^4\right) = 0.071 \text{ in}^4.$$

$$\sigma_b = \frac{1080 \cdot 1.375}{2 \times .071} = 10{,}458 \text{ lb/in}^2.$$

CONSERVATIVELY, ADDING EFFECT OF FABRIC LOADING (SAME AS SIDE MEMBERS AND ASSUMED IN SAME PLANE) ($w = 99$ lb/in)

FOR FIXED ENDS:

$$\hat{M} = 1856 \text{ in.lb.}$$

FOR PINNED ENDS :

$$\hat{M} = 2784 \text{ in.lb.}$$

SUMMING :-

$$\hat{M}_{PINNED} = 1080 + 2784 = 3864 \text{ in.lb.}$$

$$\therefore \sigma_b = \pm 37{,}416 \text{ lb/in}^2.$$

THIS VALUE DOES NOT INCLUDE EFFECT OF COMPRESSIVE LOAD.

FOR SELECTED TUBE SIZE, EULER LOAD = 311440 lb.

∴ ASSUME NO BUCKLING PROBLEM (SUPPORTED BY TEST RESULTS.)

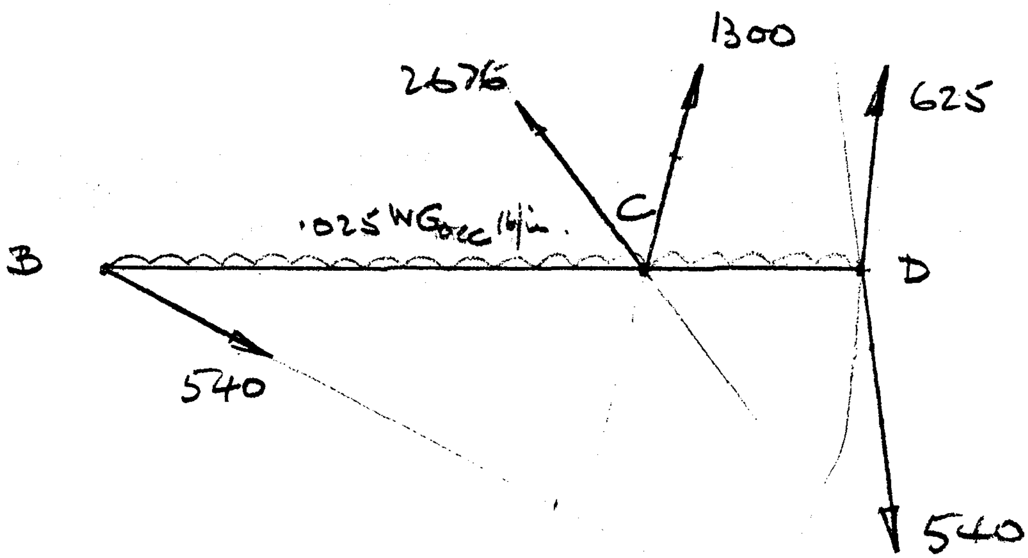
SUMMING BENDING & END LOAD STRESS

$$\text{MAX. STRESS} = -(37416 + 7196)$$
$$= -44612 \ \text{lb/in}^2.$$

(ULT FOR 7075-T6 = 83,000 lb/in².)

THUS TUBE SELECTION IS ACCEPTABLE.

SIDE MEMBER:



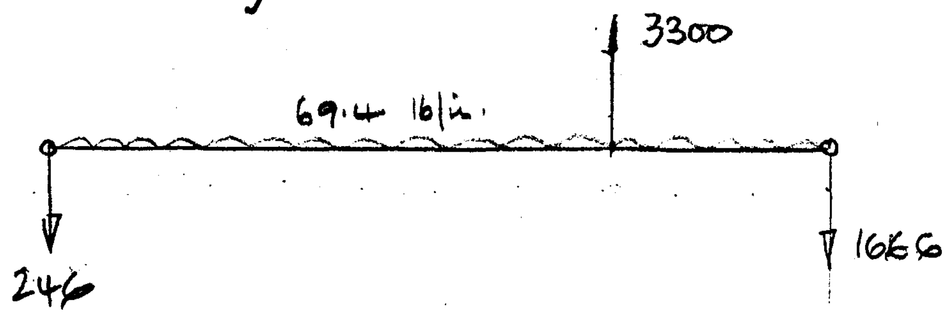
NOTE: THESE VALUES ARE MAXIMA AND DO NOT OCCUR SIMULTANEOUSLY.

FOR ANALYSIS PURPOSES $P_{AD} = 540$ AND BELT LOAD 2676 lb WILL BE ASSUMED CONSTANT. OTHER VALUES WILL BE ADJUSTED TO GIVE

APPROXIMATE EQUILIBRIUM:—

$P_{1300_C} \equiv 1246$ lb. (MOMENTS ABOUT D)

THUS:- (VERT PLANE)



$M_{MAX} = 10{,}624$ in lb.

TUBE: 1.5 OD 0.095 WALL 2024-T3.

$I = \frac{\pi}{64}\left[1.5^4 - 1.31^4\right] = 0.104 \text{ in}^4$

$\text{STRESS} = \frac{10624 \cdot 0.75}{0.104} = \underline{76{,}615} \text{ lb/in}^2$

ULT = 70,000 FOR 2024-T3.

FOR PLASTIC BENDING, K = 1.35 $\sigma_{ULT_B} = 92{,}000$ lb/in².

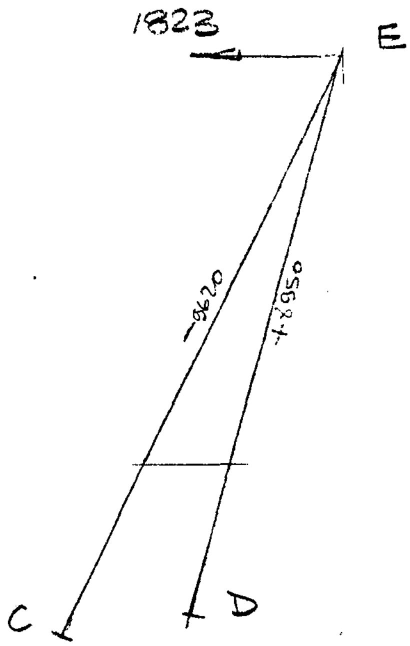
THIS TUBING ADEQUATE.

[NOTE: BENDING IN X-Y PLANE DUE TO FABRIC LOAD NOT CONSIDERED SINCE BENDING MOMENTS APPROX. SAME VALUES AS X-Z PLANE. IF LARGE DEFLECTIONS OCCUR THE SEAT CANVAS WILL SLACKEN AND MEMBRANE LOAD REDUCE]

ABOVE VALUES ALLOW SOME EXCESS CAPABILITY TO ALLOW FOR LOSS OF MATERIAL AT JOINT LOCATIONS.

FORM 11180 (6/67)

FLOOR MOUNTED SEAT BACK



SHOULDER INERTIAL REEL
MAX LOAD AT 26g = 1823 lb.

FROM DIAGRAM

P_{ED} = + 8950 lb

P_{EC} = − 9620 lb.

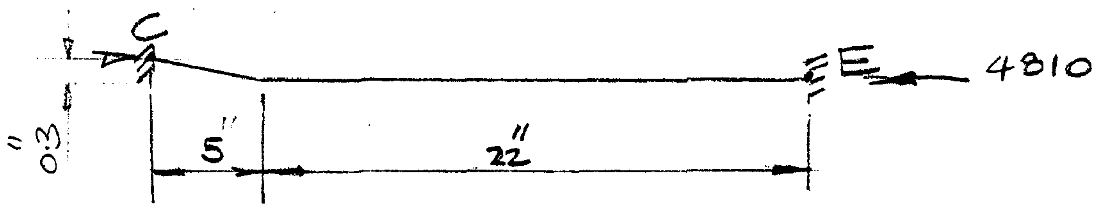
(TOTAL LOADS ON TWO MEMBERS)

NOTE: THE HARNESS INERTIA REEL LOAD IS ONLY LOAD ACTING ON SEAT BACK. THE SELECTED MAXIMUM 'G' CONDITION IS DESIGN CASE FOR MEMBERS.

MEMBERS: 1.25 O.D. 0.065 WALL 7075-T6

CONSIDER EC :-

KINKED COMPRESSION MEMBER.



APPROX TO STRUT WITH BENDING

M = 0.3 x 4810 = 1443 in.lb.

CONSIDERING CE AS SIMPLE AXIALLY LOADED COLUMN WITH END MOMENTS :-

FROM ROARK, p 150 CASE 7 :-

$$\hat{M} = M_1 \sec \frac{1}{2} U$$

$$U = \frac{l}{j}$$

$$j = \sqrt{\frac{EI}{P}}$$

$$\therefore \quad j = \sqrt{\left(\frac{10^7 \cdot .027}{4810}\right)} = \underline{\underline{23.69}}$$

$$U = \frac{l}{j} = \frac{27}{23.69} = \underline{\underline{1.14}}$$

$$\hat{M} = 1443 \sec \frac{1.14}{2}$$

$$= \underline{\underline{1714 \text{ in lb.}}}$$

$$\therefore \quad \hat{\sigma}_b = \frac{1714}{.027} \cdot \frac{1.25}{2} = \underline{\underline{39675 \text{ lb/in}^2}} \text{. AT MID-SPAN.}$$

MATERIAL : 7075-T6

SELECTED TUBING ADEQUATE WITH ALLOWANCE FOR JOINT STRENGTH REDUCTION, ETC., AND REACTION OF INERTIAL REEL MOUNTING LOADS. (ED ACCEPTABLE BY INSPECTION)

CROSS TUBES FOR INERTIAL REEL MOUNT AND STRAP REACTION :-

1.25 O.D. 0.065 WALL 7075-T6

COMPUTATIONS SIMILAR TO THOSE OF CEILING MOUNTED SEAT :-

LOAD ON TOP MEMBER $= \sqrt{2} \cdot 1823 = 2578$ lb.

$l = 10.5$

FIXED ENDS: $\hat{M} = \frac{1}{2} \cdot \frac{2578}{2} \cdot \frac{10.5}{2} = 3384$ in lb.

$$\sigma_b = 3384 \cdot \frac{1.25}{2} \cdot \frac{1}{.027} = 78333 \text{ lb/in}^2$$

FORM 11180 (6/67)

THUS MATERIAL SELECTED IS ADEQUATE SINCE $\sigma_{b\,ULT} = 83{,}000$ AND CORRECTION FOR PLASTIC BENDING HAS NOT BEEN INCLUDED. ALSO ALLOWS MARGIN FOR LESS THAN FIXED CONDITIONS AT BEAM ENDS.
IT MUST ALSO BE REMEMBER THAT THE MAXIMUM LOADING ONLY OCCURS AT THE END OF THE SEAT STROKE WHEN A 50 ft/sec. IMPACT OCCURS. THIS MAY RESULT IN SOME PERMANENT DEFORMATION BUT FAILURE IS NOT LIKELY.

THE LOWER CROSS MEMBER IS ACCEPTABLE BY INSPECTION SINCE THE LOADING IS LESS THAN FOR THE UPPER MEMBER AND THE TUBING SELECTED HAS THE SAME SECTION AND MATERIAL.

MEMBER AB:

MAXIMUM LOAD ≈ -4000 lb. (LONG. CASE)

$L = 17$ in.

$OD = 1.125 \quad I.D. = 0.995 \quad t = .065 \quad I = .031\ in^4$

$$\text{EULER LOAD} = \frac{\pi^2 \cdot 10^7 \cdot .031}{17^2} = 10{,}587 \text{ lb.}$$

$$\text{STRESS} = \frac{-4000}{.216} = -18{,}519 \text{ lb/in}^2$$

THIS GIVES ADEQUATE SECTION PROPERTIES FOR THE OPERATIONAL ENVIRONMENT AND ALLOWS FOR NON-STRAIGHTNESS, ETC.

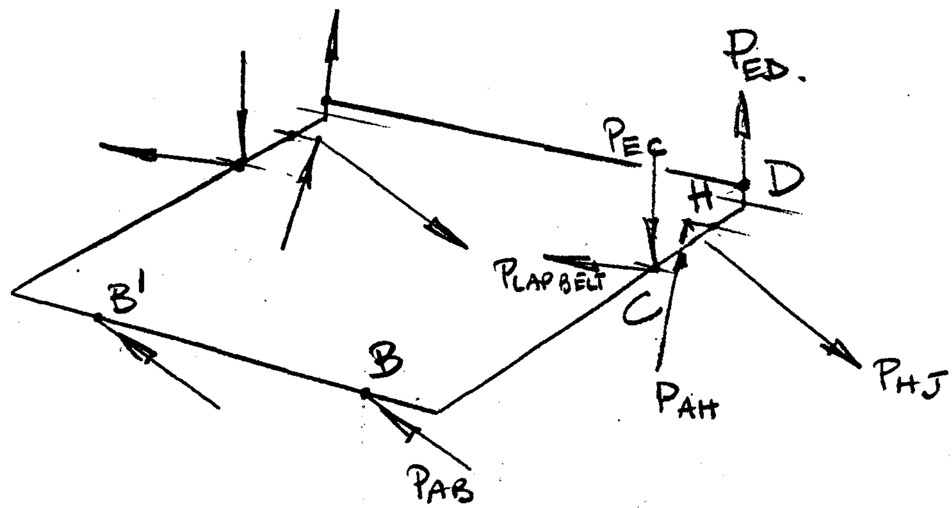
MEMBER HJ:

MAXIMUM LOAD $= +10{,}000$ lb.

SAME SECTION AS AB $\rightarrow$

$$\text{STRESS} = \frac{10000}{.216} = 46{,}296 \text{ lb/in}^2$$

SEAT PAN FRAME:
(LONGITUDINAL CASE)



MAXIMUM VALUES FROM LOAD ANALYSIS:

$P_{AB} = -4,000$ lb.

$P_{AH} = -1,048$ lb.

$P_{EC} = -4,810$ lb.

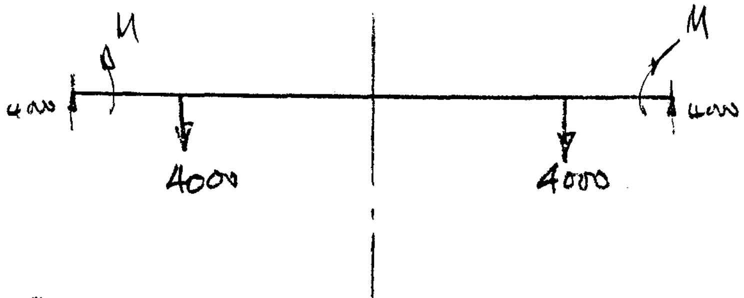
$P_{ED} = +4,475$ lb.

$P_{HJ} = +10,000$ lb.

$P_{LAP\ BELT} = +2,676$ lb.

NOTE: THESE VALUES OCCUR TOWARDS THE END OF THE SEAT STROKE AT POSITION B.

FRONT MEMBER: (USING SAME GEOMETRY AS CEILING MOUNTED SEAT).



$L = 15$

SEMI-FIXED:

$$M = 936 \times \frac{4000}{540} = 6933 \text{ in.lb.}$$

$$M_{MID} = 9,067 \text{ in.lb.}$$

$$D_o = 1.375$$

THUS:- (USING $\sigma_{bult} = 83000$)

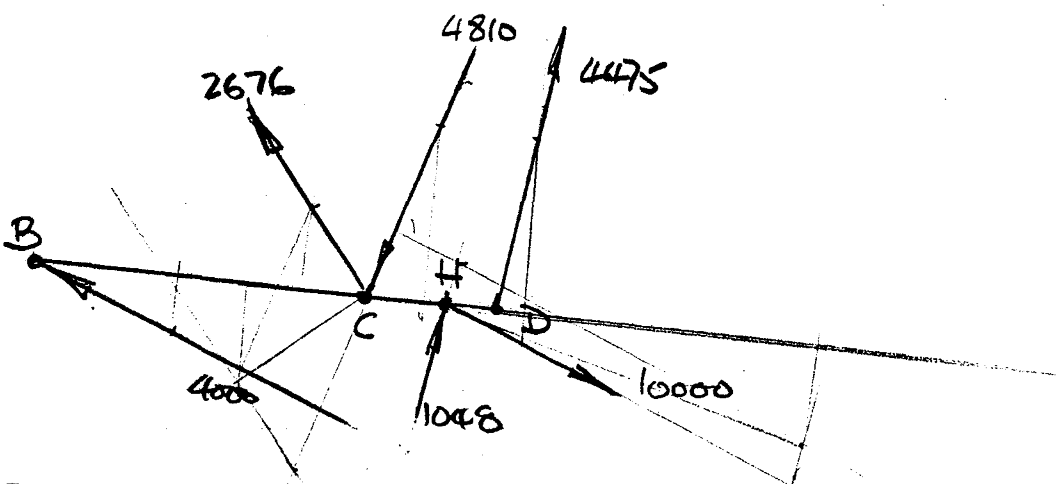
$$I_{MIN} = \frac{9067}{83,000} \cdot \frac{1.375}{2} = 0.075 \text{ in}^4.$$

$$\therefore D_i = 1.196$$

$$\equiv .090 \text{ WALL. TUBE } (7075\text{-}T6)$$

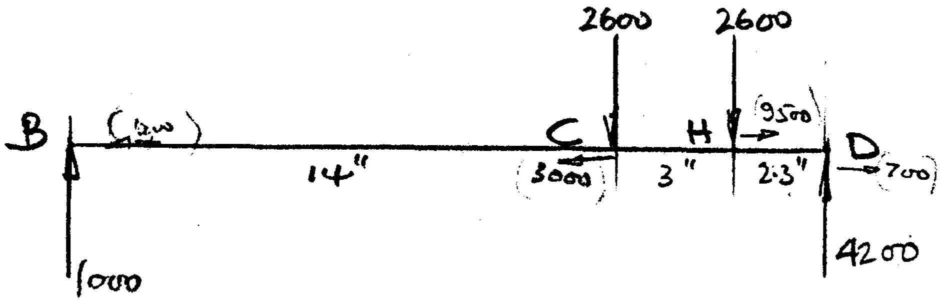
SIDE MEMBER:

1.50D TUBE
0.095 WALL
7075-T6.



[MAXIMA SHOWN, SOME ADJUSTMENT MAY BE NEEDED TO GIVE APPROXIMATE EQUILIBRIUM FOR ANALYSIS]

IN PLANE PERPENDICULAR TO SEAT PAN:-



$\hat{M} = 14{,}000$ in.lb.

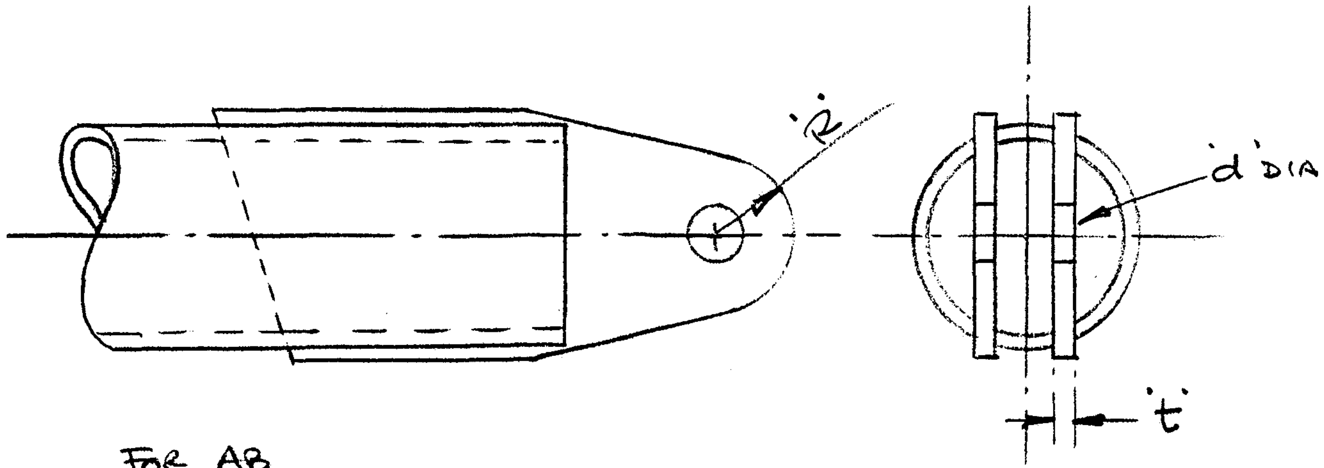
$\sigma_b = \frac{14000}{.104} \cdot .75 = 100{,}961$ lb/in^2.

$\sigma_T = \frac{1200}{.419} = 2864.$ $\quad \sigma_b + \sigma_T = 103{,}825$ lb/in^2.

PLASTIC ULT. = 104,000 lb/in^2. (7075-T6)

FITTINGS:

MEMBER AB: $P_{MAX} = -4000$ lb.



FOR AB,

$t = 0.1$
$R = 0.4$
$d = 0.25$

COMPRESSIVE AREA $= 2 \times 0.1 \times 0.25 = 0.05$

$\sigma_{BR} = \dfrac{4000}{0.05} = 80{,}000$ lb/in.²

ULT BEARING FOR 6061-T6 = 80,000 lb/in.²

FOR ¼ DIA. BOLT., DOUBLE SHEAR :-

ULT SHEAR = 3680 × 2 = 7,360 lb. (125 KSI MTL)

TOWARDS END OF SEAT STROKE LOCAL COMPRESSIVE FAILURE OF LUGS MAY OCCUR.

BOTH END OF AB ARE SIMILAR

MEMBER HJ : $P_{MAX} = +10{,}000$ lb.

END FITTING AT LOWER END SIMILAR TO THOSE ON MEMBER AB.

SINCE THE 'AB' DESIGN WAS ONLY ADEQUATE FOR A 4000 lb. COMPRESSIVE LOAD CHANGES IN DIMENSIONS AND/OR MATERIAL MUST BE MADE FOR THIS CASE.

USING 4130 STEEL :-

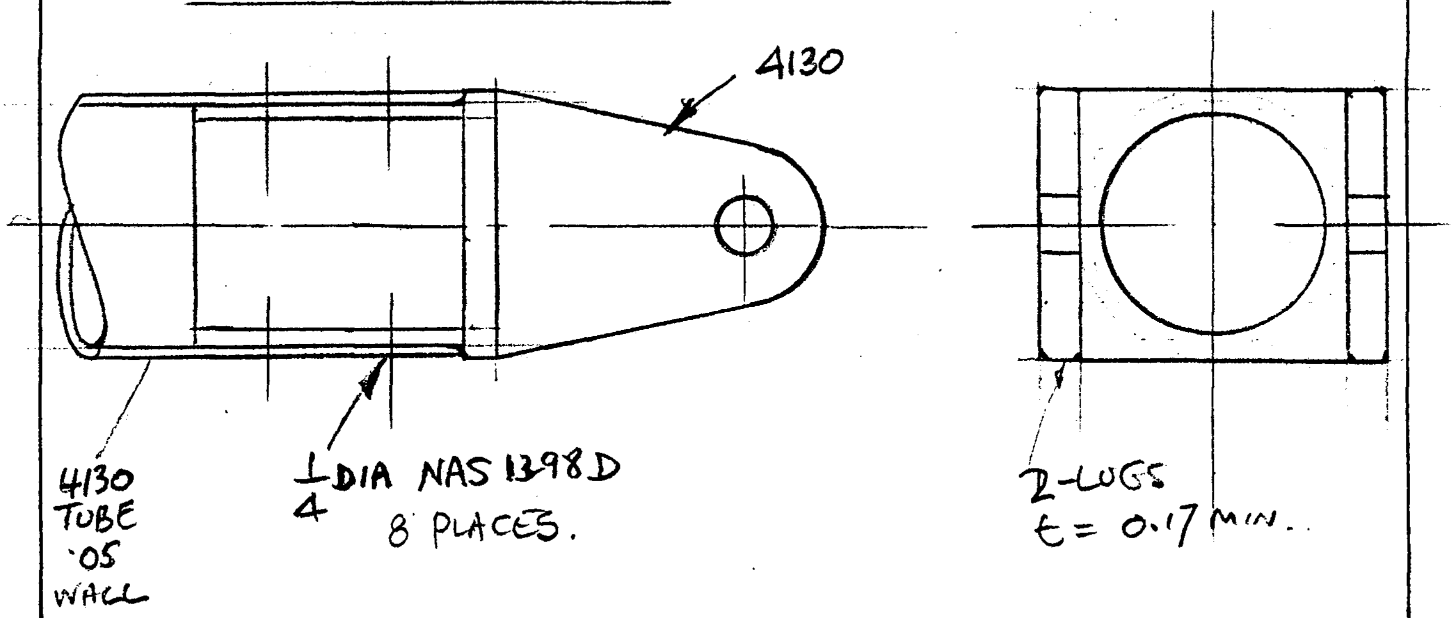
SHEAR ULT = 55,000 lb/in²

∴ THICKNESS OF EACH LUG (ASSUMING OTHER DIMENSIONS REMAIN THE SAME) :-

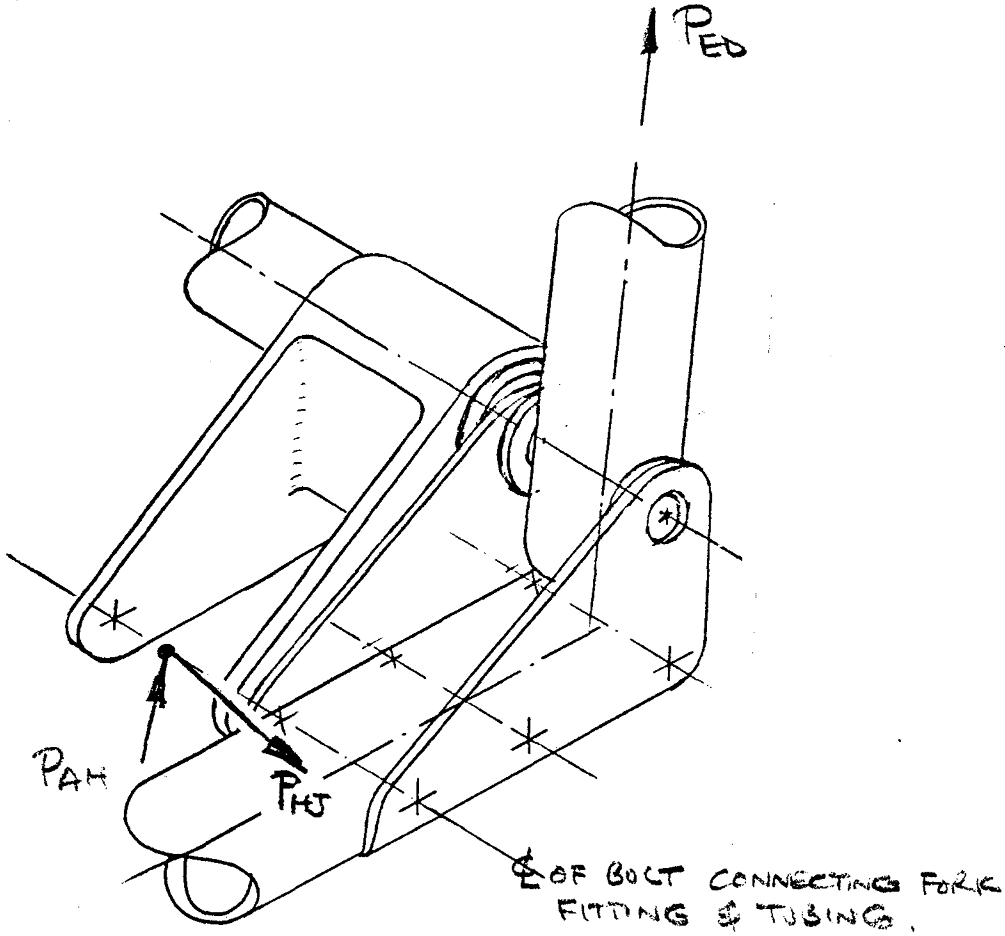
$$t = \frac{10000}{55000} \cdot \frac{1}{4 \times .27} = 0.17 \text{ MIN.}$$

TUBE SIZE CAN BE REDUCED TO A WALL THICKNESS OF 0.049 (APPARENT MIN. WALL AVAILABLE)

UPPER END FITTING : 4130 STEEL.



STRUCTURAL JOINT AT SEAT BACK-PAN FRAME JUNCTION.



PRIMARY LOADS TO BE TRANSMITTED BY STRUCTURE AND FASTENERS ARE AS SHOWN.
THE LOADS PEAK TOWARDS THE END OF THE SEAT STROKE AND INTEGRITY FOR THIS CONDITION WILL BE CONSIDERED.

FROM SEAT PAN LOADING:

P_{AH} = − 1048 lb. (ATTENUATOR LIMIT)

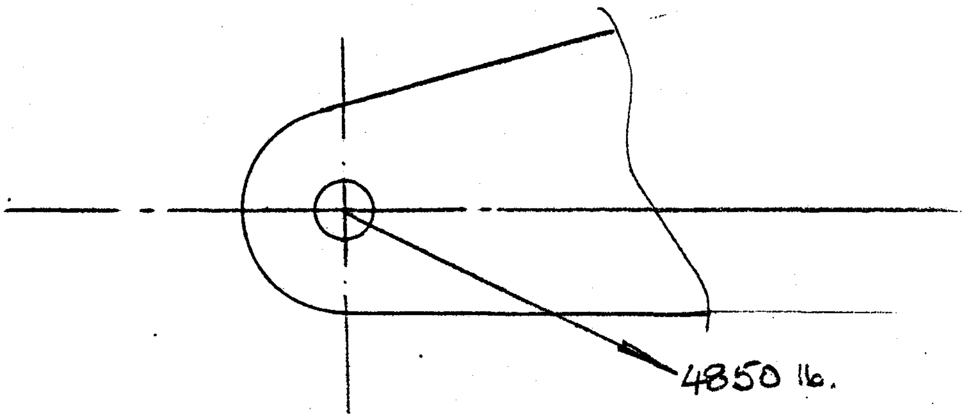
P_{HJ} = + 10,000 lb.

RESULTANT LOAD = 9700 lb. ACTING AT AN ANGLE OF $\simeq 15°$ TO THE SEAT PAN.

FOR BOLT IN DOUBLE SHEAR:

FOR 125KSI BOLT, 5/16 DIA REQUIRED.

LUG SIZES ON MACHINED FITTING:-



FOR BEARING: (USING $\sigma_{BR\,ULT} = 100{,}000$ FOR 7075-T6)

$t_{MIN_{BR}} = 0.155$ in.

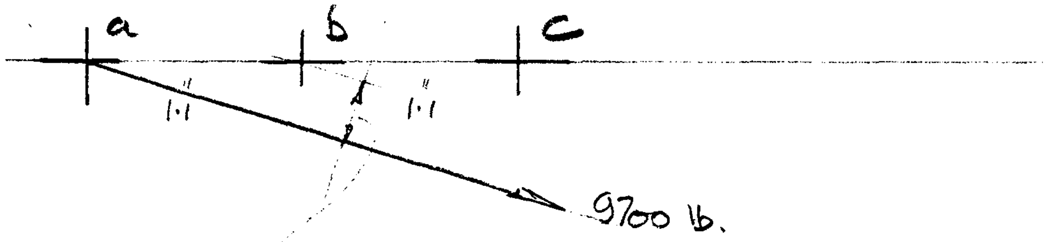
FOR SHEAR OUT: (USING $\sigma_{S\,ULT} = 46{,}000$ FOR 7075-T6)

$t_{MIN_S} = 0.08$ in.

DUE TO THE FREE LUG BEING LESS SUPPORTED THAN THE ONE ATTACHED TO THE SEAT PAN FRAME IT IS REASONABLE TO ASSUME THAT THE FREE LUG WILL BE SUBJECTED TO LOWER PROPORTIONATE LOADING AS PLASTIC DEFORMATION OCCURS.

THUS LUG THICKNESS WILL BE SELECTED TO BE 0.15 in. FOR MACHINEABILITY, DURABILITY, ETC.

ONCE THE LOADING IS INTRODUCED INTO THE FITTING IT MUST THEN BE REACTED BY THE THREE FASTENERS ATTACHING THE FITTING TO THE SIDE MEMBER OF THE SEAT PAN.



OFFSET = 0.32

TORQUE IN PLANE OF FASTENERS = 9700 × .32
= 3104 in. lb.

SHEAR / FASTENER DUE TO TORQUE = $\frac{3104}{2.1}$ = 1,478 lb.

SHEAR / FASTENER DUE TO 9700 = 3,230 lb

APPROX. MAX. SHEAR AT END FASTENERS = 4,600 lb.

CENTER FASTENER LOAD ≃ 3,230 lb

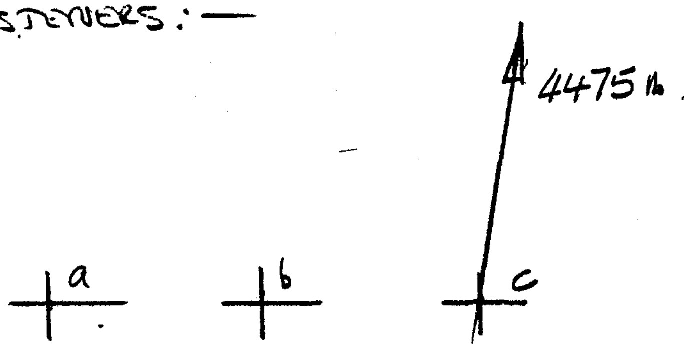
THUS 5/16 BOLTS (125 KSI MATL.) NEEDED AT 'a' AND 'c' AND A $\frac{1}{4}$ DIA. AT 'b'

[NOTE: IF 160 KSI MATERIAL USED FOR BOLTS OR HUCK BOLTS SIZE CAN BE REDUCED TO $\frac{1}{4}$ DIA. AT THE THREE LOCATIONS]

ATTACHMENT OF MEMBER ED TO SEAT PAN TUBE:

$P_{ED} = 4475$ lb.

THIS LOAD REACTED BY LUGS AND 6 SHEAR PLANES OF FASTENERS:—



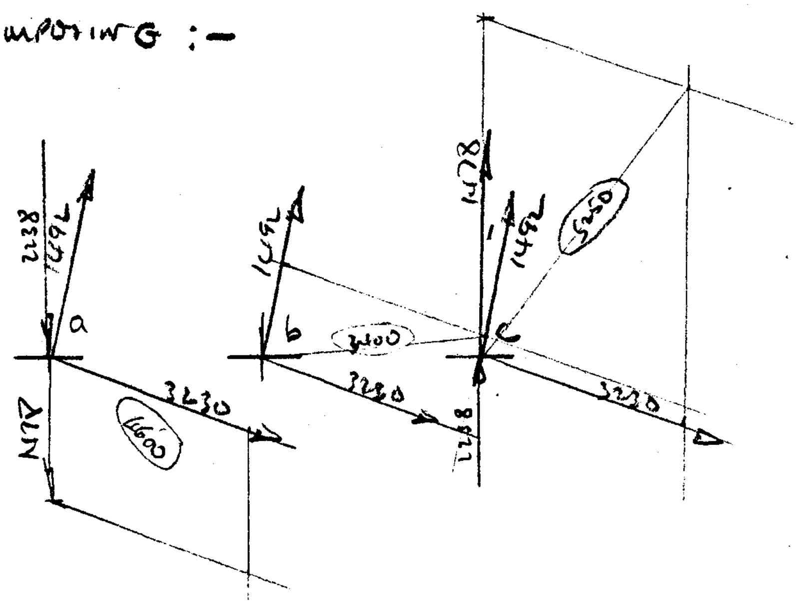
LOAD ON a, b & c DUE TO SHEAR = <u>1492 lb.</u>

LOAD ON a & c DUE TO OFFSET $= \frac{1.1 \times 4475}{2.2}$

$= \underline{2238 \text{ lb.}}$

NOTE: THESE SHEAR LOADS ARE ADDITIVE TO THOSE IMPOSED BY MACHINED FITTING.

SUPERIMPOSING:—

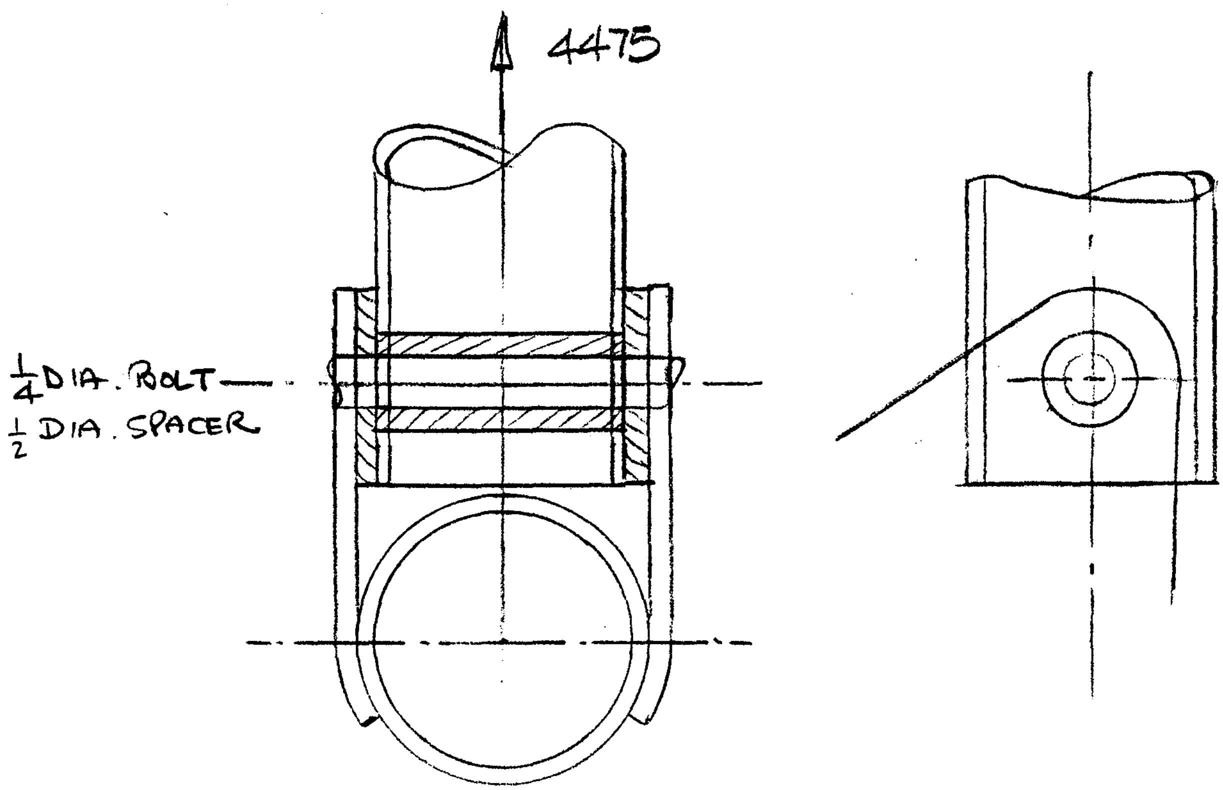


≤ 5208

RESULTANT LOADS:— 'a' = 4600 lb. 'b' = 3400 lb. 'c' = 5250 lb. } SELECTED FASTENERS ON P101 ADEQUATE

FORM 11180 (6/67)

MEMBER ED END ATTACHMENT:



SHEAR OUT AT BOTTOM OF TUBE ED :-

AREA = $0.35 \times t \times 4$ $\qquad \sigma_{S_{ULT}} = 45{,}000$ lb/in². (7075-T6)

$\therefore t_{MIN} = 0.072$ in.

BEARING : $\left(\sigma_{b_{ULT}} = 125{,}000 \right)$

$\sigma_b = 62153$ lb/in². $\therefore$ OK.

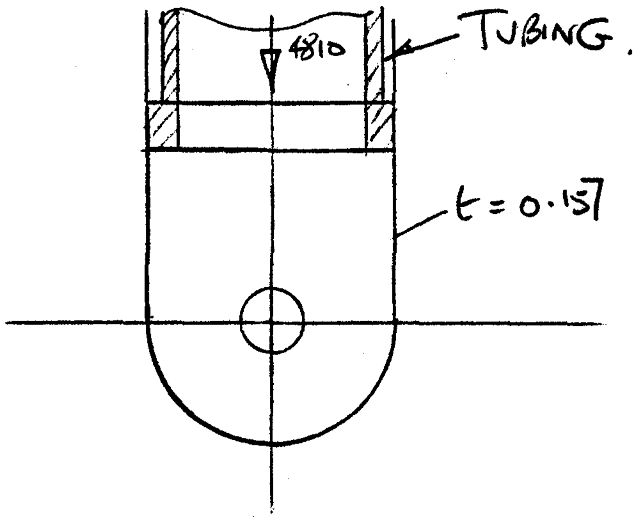
LUGS OF SIDE ATTACHMENTS:

$t_{min} = 0.072$ in.

FOR LATERAL STABILITY USE $t = 0.10$ in.

LOWER END FITTING OF MEMBER EC.

$P_{EC} = -4810$ lb.



BEARING STRESS $= \dfrac{4810}{0.313 \times .157 \times 2} = 48941$ lb/in² OK.

SHEAR ATTACHMENTS OF TUBE TO FITTING:

USING NAS 1398 5 D5-3 RIVETS :—

3 RIVETS ACCEPTABLE SINCE IN COMPRESSIVE CONDITION THE TUBE END WILL BEAR ON FITTING FLANGE TO TRANSMIT LOAD.