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CREW SYSTEMS DIVISION

NASA - MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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(NASA-TM-X-70370) TEST REPORT FIREMAN'S HELMETS IMPACT TESTS (NASA) 68 p

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TEST REPORT
FIREMANS' HELMETS IMPACT TESTS

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## 1.0 INTRODUCTION

A test program was initiated by the Materials Development Section to determine the shock absorbing characteristics of various firefighters helmets alongwith a NASA prototype polyimide firefighters helmet.

The helmets tested were as follows:

a. NASA prototype - polyimide shell-foam type suspension

b. Gentex Corp./Model 140 - ABS shell - webbed suspension

c. Bullard Co./"hardboiled" - Fiberglass/polyester shell - webbed suspension

d. Bell Co./"Top Tex" - Fiberglass/polyester - foam type suspension

The NASA prototype polyimide helmet is described in greater detail in paragraph 3.0 below.

The tests were in accordance with ASA Z90.1-1966 "American Standard Specification for Protective Headgear for Vehicular Users" with the exception that a 2-inch diameter rather than a 1.9-inch radius impact anvil was used.

The impacts were accomplished by use of a verticle arc type impact apparatus with the helmet attached and the 2-inch diameter impact anvil anchored to the floor in the direct path of swing of the arc impactor.

Each helmet configuration was tested twice at a preconditioned temperature of +122°F and twice at a preconditioned temperature of +14°F with an impact energy of 50 ft. lbs.

## 2.0 OBJECTIVE

The objective of the tests was to determine the shock absorbing characteristics of the various helmets when tested in accordance with Z90.1-1966 and specifically to determine the characteristics of the NASA prototype helmet as compared to those helmets readily available on the commercial market.

## 3.0 TEST ARTICLE (POLYIMIDE HELMET) DESCRIPTION

The polyimide helmet was developed NASA Contract NAS 9-12502. The polyimid shell was manufactured for NASA under contract with North American Rockwell using E-type fiberglass over a stainless steel mandrel, impregnating the fiberglass with polyimide resin #4701 and then curing at high temperature. The suspension and face shield was installed by the American Sportswear Company, Inc. and is a standard system used by this company in the manufacturing of firefighters' helmets. American Sportswear also provided the mandrel used by North American Rockwell. Additional photographs of this particular helmet are shown in photographs #15, #16 and #17.

## 4.0 TEST EQUIPMENT

The test apparatus consisted of a hollow 1-inch diameter aluminum rod with a wooden mannequin head attached to one end and suspended from the other end as a simple pendulum; an impact anvil; temperature control box; 500 g accelerometer mounted in the mannequin head; data recording equipment, a calibrated scale to weigh the impact apparatus and a level-protractor to acquire the desired release angle. The test equipment is shown in photographs #1 and #2.

## 5.0 TEST CONDITIONS

Each helmet configuration was conditioned at +122°F for at least 4 hours but less than 24 hours and then impacted twice. The two impacts were separated by a distance of at least 1 1/2 inches. The helmets were then conditioned at a temperature of +14°F for a period of at least 4 hours but less than 24 hours and again impacted twice. The helmets were tested within 5 minutes from removal from the temperature control box. Each impact was with 50 ft lb. impact energy.

## 6.0 TEST PROCEDURE

The tests were conducted per document number MSC-EC-R-71-12 - "Test Procuedure - Firefighters' Helmet Impact Tests". The procedure is attached as Appendix #2 of this report. The procedure is in accordance with ASA Z90.1-1966 with the exception that a 2-inch diameter rather than a 1.9-inch radius impact anvil was used. ASA Z90.1-1966 is attached as Appendix #3 of this report.

A brief outline of the procedure is as follows:

a. Assemble impact tester to incorporate head per sketch #1 of Test Procedure

b. Suspend as a pendulum and determine the period of oscillation.

c. Calculate the center of percussion.

d. Mount accelerometer in mannequin head.

e. Weight assembly (see data sheet attached to test procedure).

f. Determine release angle (see data sheet attached to test procedure).

g. Pull assembly back to desired angle and install in temperature control box and maintain at desired temperature for at least 4 hours.

h. Take photographs of the test setup and movies during the impacts.

i. Impact.

j. Move approximately 1 1/2 inch and repeat impact

k. Install identical configuration into temperature of +14°F for at least 4 hours and repeat above steps.

## 7.0 ACCEPTABLE ACCELERATION LEVELS

The following consitutes rejection of the helmet per ASA Z90.1-1966.

a. Any peak acceleration exceeding 400 g's.

b. Accelerations between 200 and 400 g's if the total time of such acceleration measured at the 200 g level exceeds two (2) milliseconds.

c. Acceleration in excess of 150 g's for more than four (4) milliseconds.

## 8.0 TEST RESULTS

The NASA prototype firemans' helmet; the Gentex Corporation's Model 140 fireman's helmet; the Bullard Co.'s "Hardboiled Fireman's Helmet"; and Bell Company's "Top Tex" riot control helmet were installed into a temperature control box at a temperature of +122°F on 12/13/71 at approximately 3:30 pm. This temperature was maintained and the impact testing of the above helmets began on 12/14/71 at approximately 9:30 am.

There was no apparent damage to the NASA prototype helmet, a small crack occurred in the "Hardboiled" helmet, a large indentation formed in the model 140 helmet, and 2 small cracks occurred in the polyester coating of the riot helmet, as a result of the first 50 ft-lb impact.

The helmets were then placed back into the temperature control box and left for an additional 4 hours. The impact apparatus was raised

approximately 1 1/2 inches and a new release angle calculated and the helmets were impacted again. There was a small crcase which could be felt in the NASA prototype where the helmet was struck by the anvil; the crack in the "hardboiled" helmet was lengthened; the indentation in the Model 140 was made deeper and wider; and a small piece of the polyester coating flaked off the riot helmet as a result of this 50 ft lb impact series.

Photographs of the impact area after these impacts were shown in photographs #3 through #9.

Since there were additional helmets of the "hardboiled" and "Top Tex" configuration available new ones were used for the +14°F preconditioned temperature impacts. There was only one NASA prototype and one Model 140 helmet so these had to be used in all tests.

The helmets were placed in the temperature control box at a temperature of +14°F and left for four (4) hours. The helmets were impacted at this temperature on 12/15/71 with 50 ft-lbs energy.

Again there was very little damage to the NASA prototype helmet; the "hardboilded" helmet cracked to a greater extent than in the +122°F impacts and the "Top Tex" had two (2) small portions of the polyester coating flaked off as a result of the first 50 ft-lbs impact at +14°F. The Model 140 helmet was not impacted this time at the temperature because of the extensive damage resulting from the previous two (2) +122°F impacts. It was however impacted at +14°F once at a location far enough away from the previous impacts that this helmet portion was structurally sound. This is described in the tests below.

Since there was only an elapsed time of approximately one (1) minute during each impact of the above mentioned tests each helmet was placed back into the temperature control box immediately after impacting it so that an extra four (4) hour delay could be avoided.

The impacts were again conducted on all four helmets. There was very little damage to the NASA prototype helmet (a scuff mark were anvil hit); the "hardboiled" helmet cracked again; this was more of the polyester coating flaked off the "Top Tex"; and there was very little damage to the model 140 since the impact point this time was between two ridges of the helmet as a result of this 50 ft-lb test series.

Photographs of the impact areas after these impacts are shown in photograph #10 through #14.

A more detailed description of each impact is tabulated in Table 1 of this report.

All the helmets passed the acceleration levels as described in paragraph 6.0. Graphs of the accelerations are presented in Appendix #1 of this report.

## 9.0 CONCLUSIONS

The following conclusions can be made about the herein described impact tests of the fireman's helmets:

1. Although the impact anvil used constituted a more severe test than that described in ASA Z90.1-1966 each of the helmets still had good shock absorbing characteristics and passed the requirements of Z90.1-1966.

2. While all the helmets passed the shock absorption requirements there were some notable drawbacks to some of the helmets:

(a) The "hardboiled" helmet had sharp edges on the inside of the helmet which could cause head injury with either a sharper impactor o one of the same type used but with greater impact energy.

(b) The Model 140 helmet indented far enough on impacts to shatter a 1/16 inch thick plexiglass plate which was protecting the accelerometer mounted in the head.

3. The NASA prototype proved to be structurally sound helmet with very good shock absorbing characteristics which proved to be superior to the helmets tested in this test series.

The polyimide helmet is totally nonburing and can withstand short-term temperature exposures in excess of 1000°F. It is estimated that, on a mass-production basis, polyimide helmets can be manufactured for a unit price under $50 - which is competitive with the better commercially-available helmets. Polyimide helmets are brown, but can be painted or colored with metallized coatings.

The weight of the polyimide helmet is equivalent to other helmets of comparable configuration. Most, if not all, of the higher weight shown in Table #1 reflects from the heavier, better designed, suspension system.

It should be noted that the helmets used for comparison in this program were randomly selected and are not intended to represent all of the helmets presently available. It does appear to be a valid conclusion, however, based on this limited sampling, that the polyimide does hold significant promise as an improved material for firefighter head gear.

TABLE I

| IMPACT NUMBER | DATE | HELMET CONFIGURATION | WEIGHT OF HELMET | COND. TEMP | PEAK G's | REMARKS |
|---|---|---|---|---|---|---|
| 1 | 12/14/71 | NASA Prototype | 2 lb 8½ oz | +122°F(22 hrs) | 104 g's | No apparent damage visible after impact |
| 2 | | Bullard's/ "Hardboiled" | 1 lb 10 oz. | " | 101 g's | Small crack in middle ridge of helmet resulted |
| 3 | " | Gentex's/ Model 140 | 1 lb 2 oz | " | 152 g's | Large (2" dia. x 2" deep) indentation in middle ridge of helmet resulted |
| 4 | " | Bell's/ "Top-Tex" | 2 lb 5 oz | " | 138 g's | Two small cracks in polyester coating resulted |
| 5 | " | NASA Prototype | See Above | " | 95 g's | A small crease could be felt on edge of middle ridge but did not look like a crack |
| 6 | " | Gentex's/ Model 140 | " | " | See Remarks | Enlarged indentation caused by impact #3. Indentation on impact was deep enough to shatter a 1/16" thick plexiglass cover over the accelerometer and then strike the accelerometer causing accelerometer data to go off-scale |
| 7 | " | Bullard's/ "Hardboiled" | " | " | 86 g's | Enlarged crack caused by impact #2 |
| 8 | " | Bell's/ "Top-Tex" | " | " | 140 g's | Flaked off portion (¼" x 1/8") if polyester coating |



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TABLE I - Continued

| IMPACT NUMBER | DATE | HELMET CONFIGURATION | WEIGHT OF HELMET | COND. TEMP | PEAK G's | REMARKS |
|---|---|---|---|---|---|---|
| 9 | 12/15/71 | NASA Prototype | 2 lb $8\frac{1}{2}$ oz | $+14^{\circ}F$ (5 hrs) | 93 g's | No apparent damage after impact |
| 10 | " | Bullard's/ "Hardboiled" | " | " | 93 g's | Large crack in shell (approx. $1\frac{1}{2}$" long) |
| 11 | " | Bell's/ "Top Tex" | " | " | 120 g's | Cracked portion (approx. 1/8" X 1/2") of polyester |
| 12 | " | Bullard's/ "Hardboiled" | " | " | 64 g's | Another large crack which resulted in an overall crack after two impacts of approx. 4" |
| 13 | " | Bell's/ "Top-Tex" | " | " | 136 g's | Cracked another portion (approx 1/8" X 1/2" of polyester coating |
| 14 | " | NASA Prototype | " | " | 91 g's | No damage except a scuff mark where anvil slipped off ridge of helmet and struck helmet off top center. |
| 15 | " | Gentex's/ Model 140 | " | " | 55 g's | Very little damage since anvil struck between two ridges of helmet rather than on top of one ridge |



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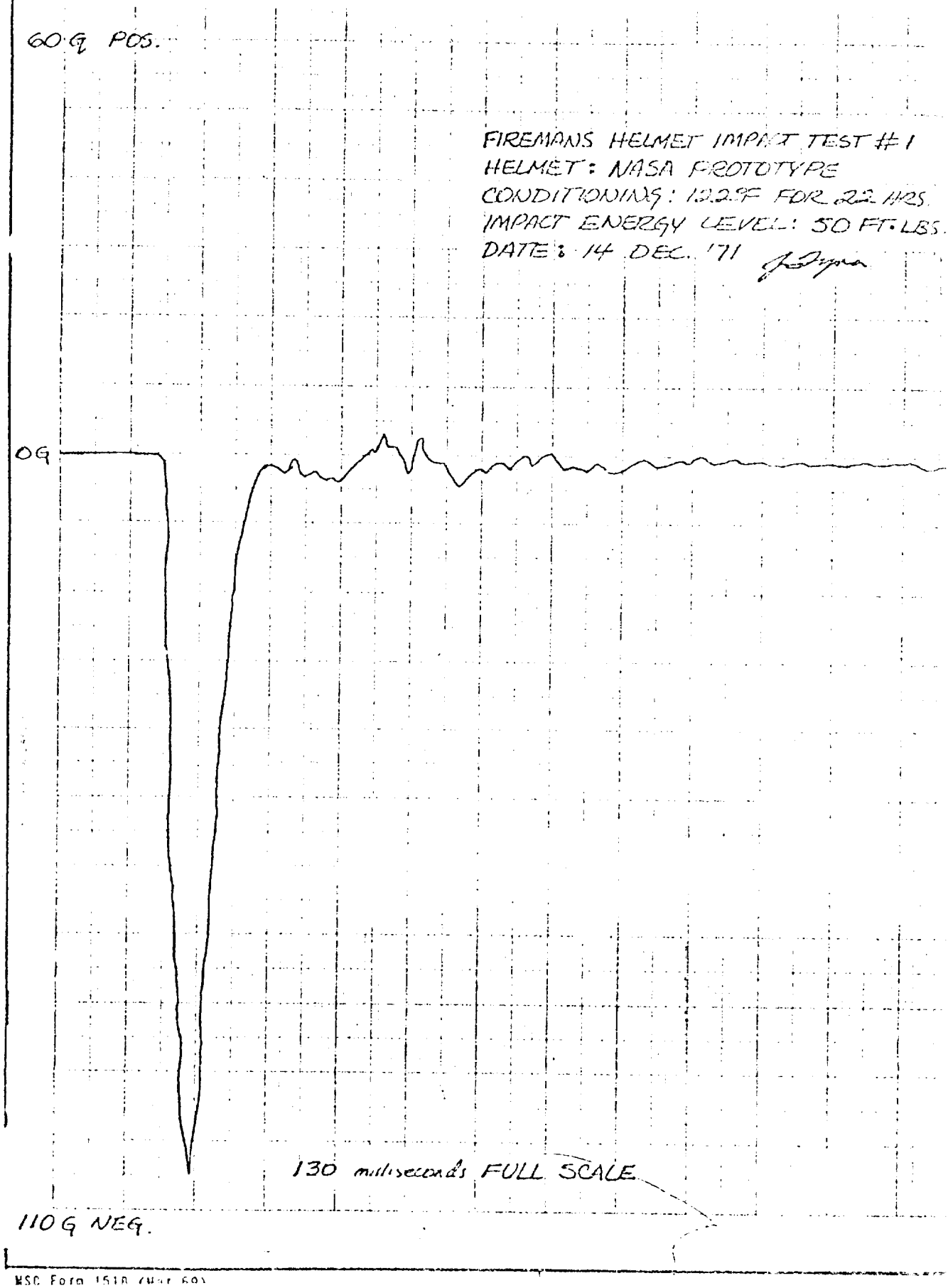
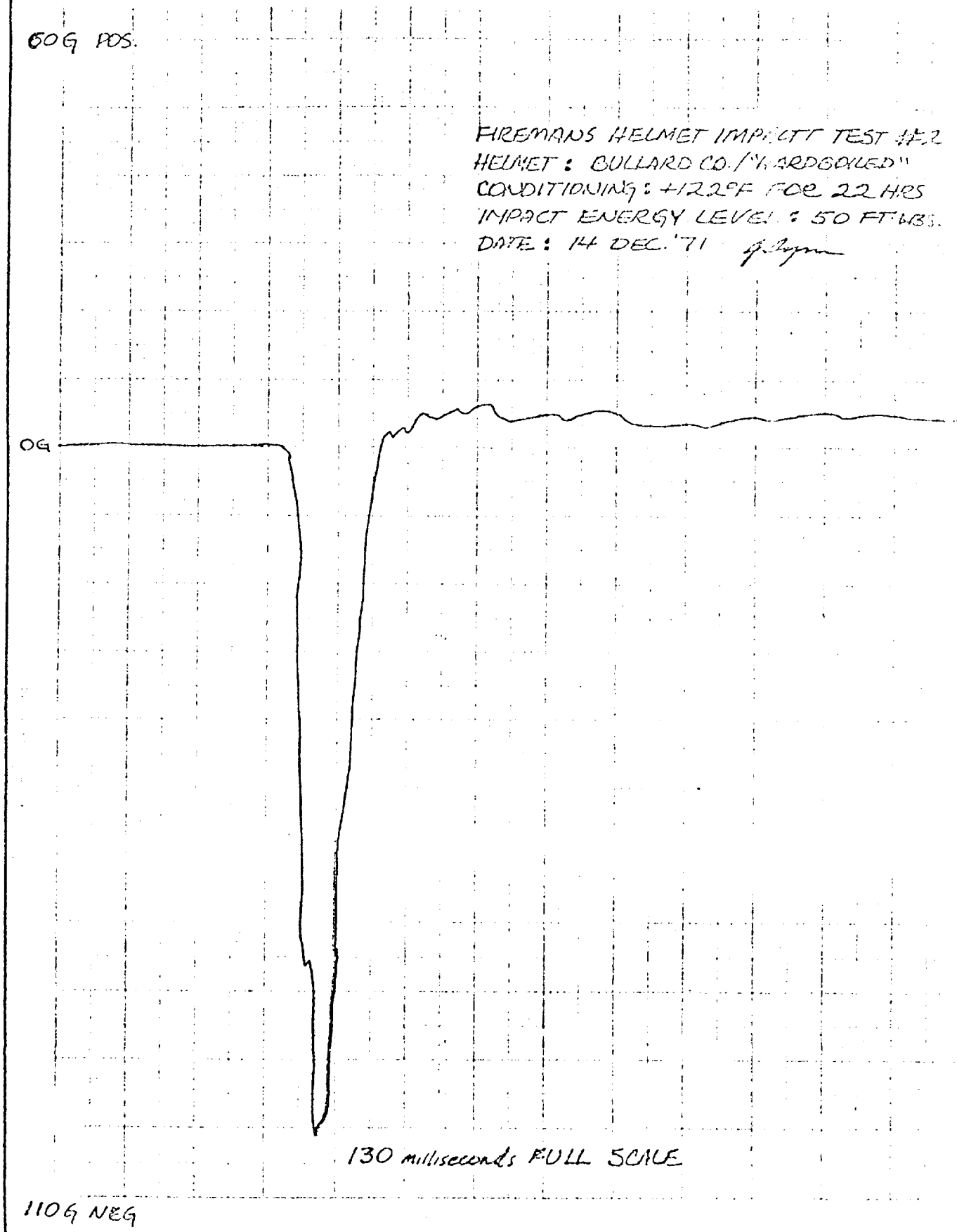
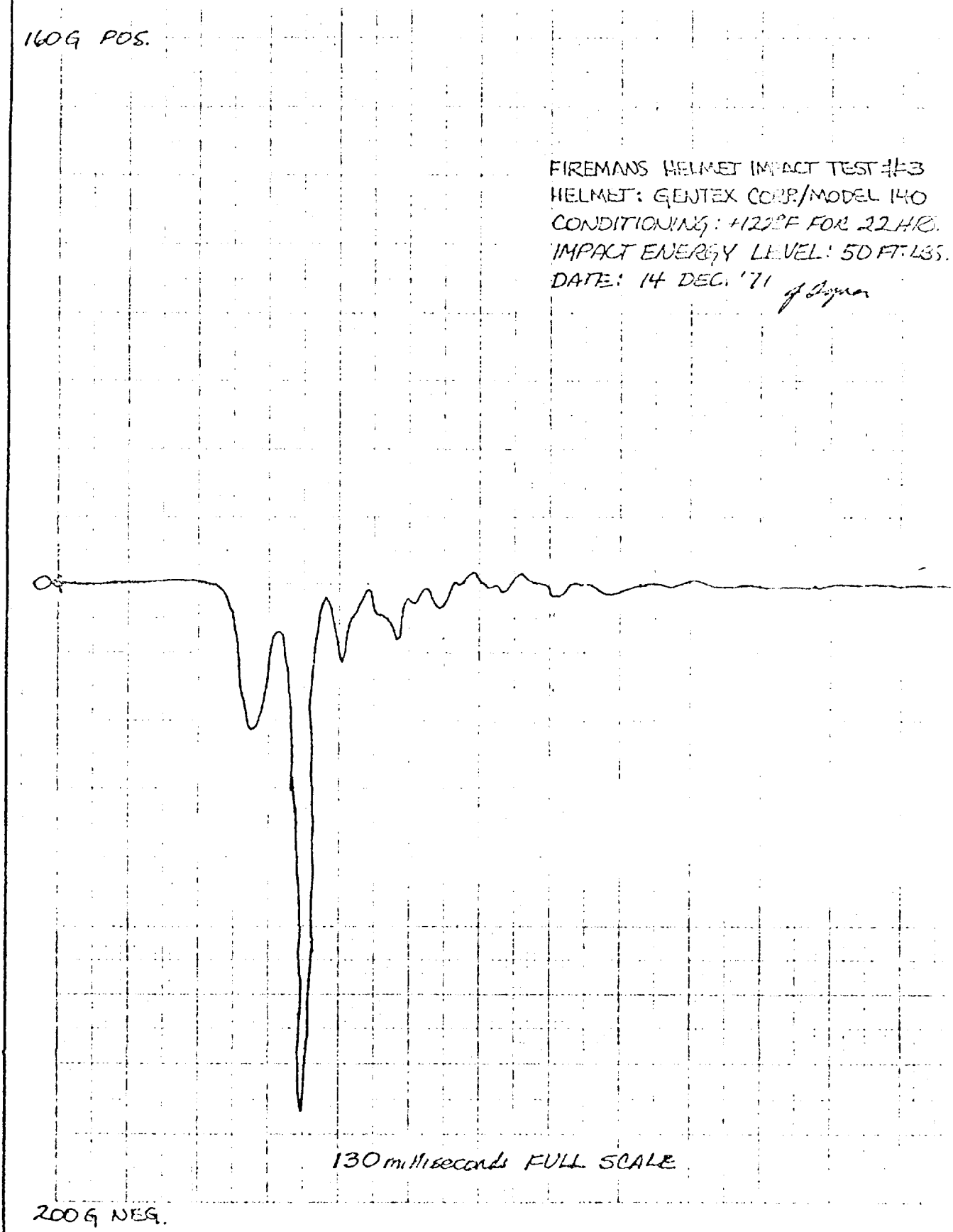
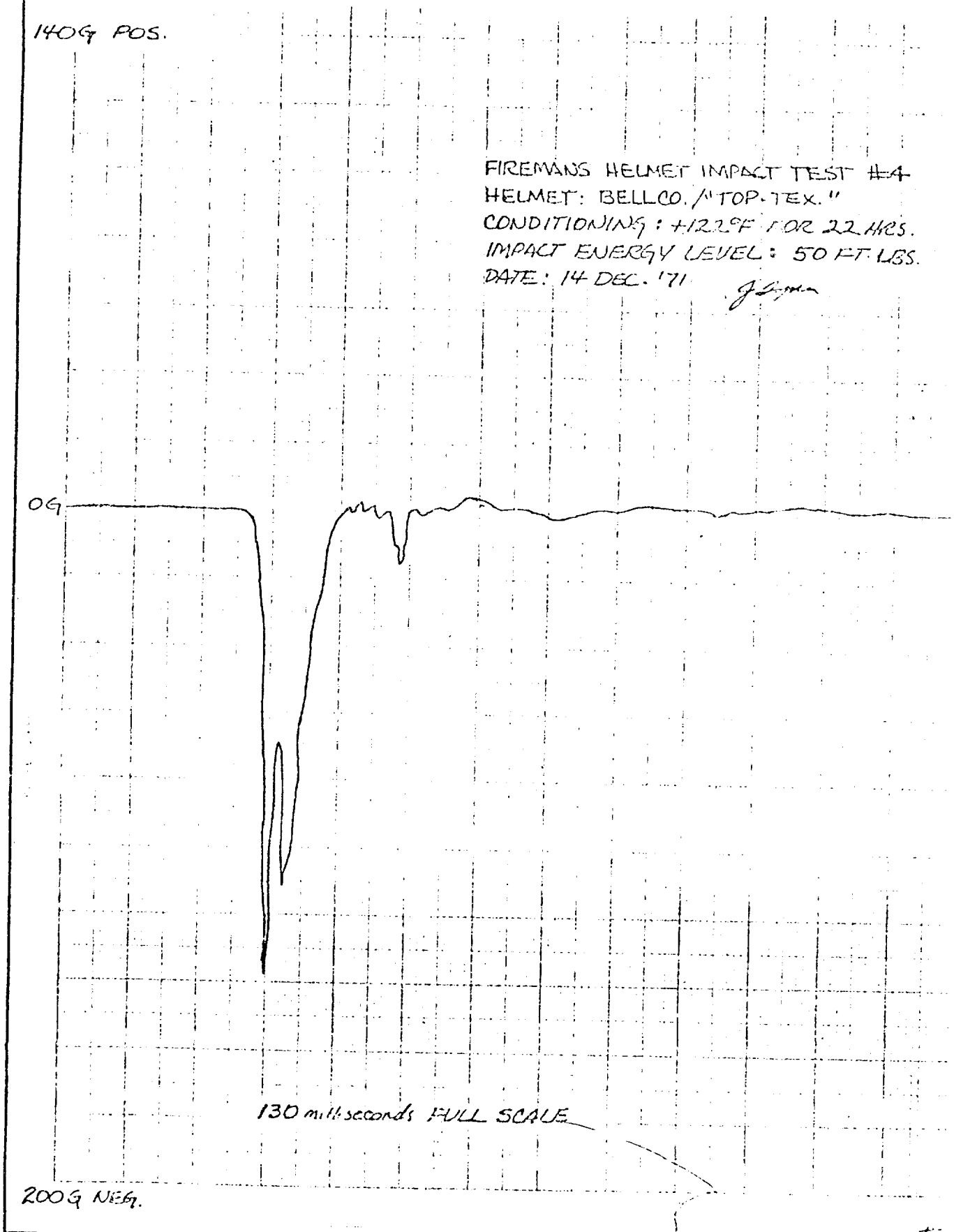
# APPENDIX I

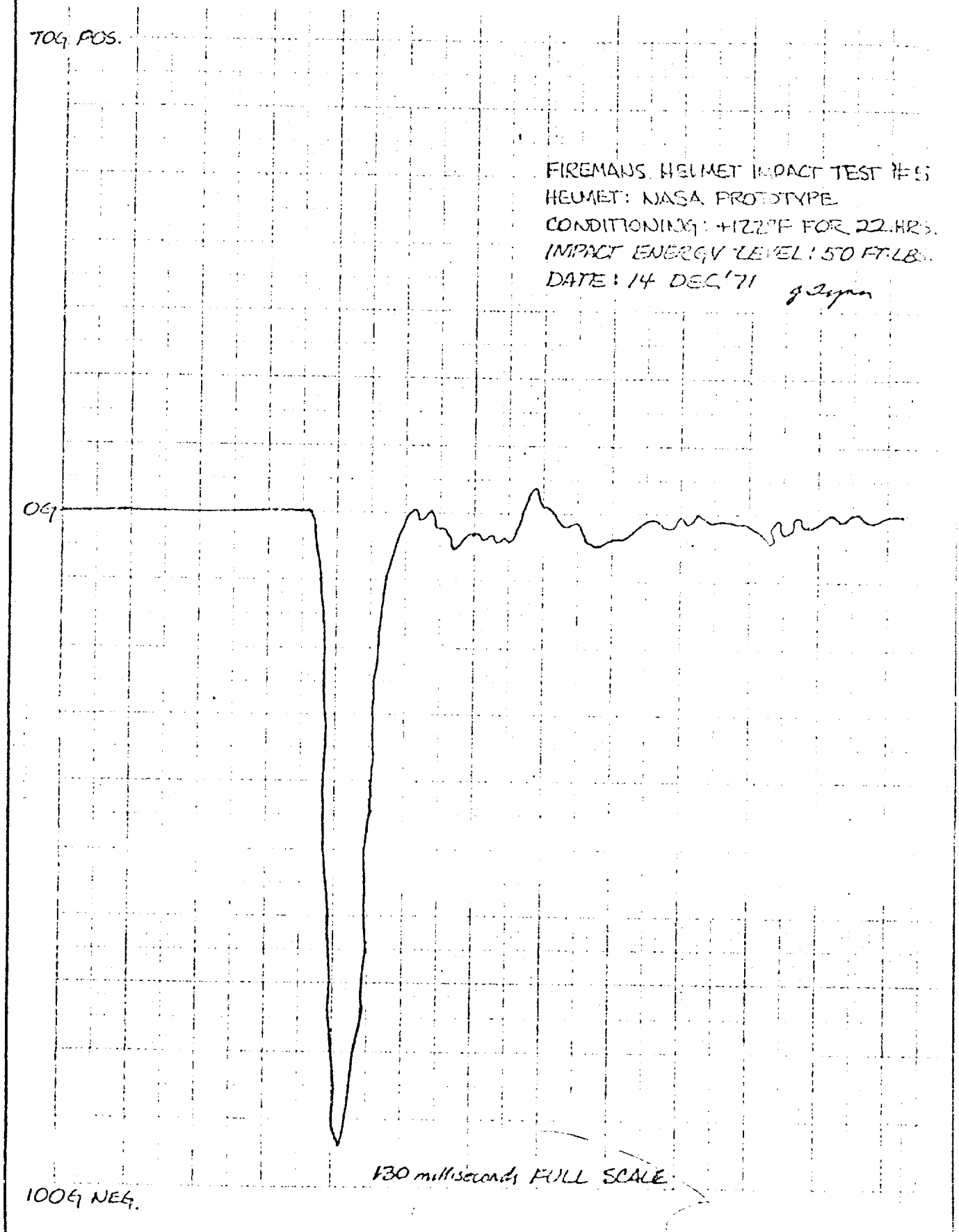
## ACCELEROMETER GRAPHS

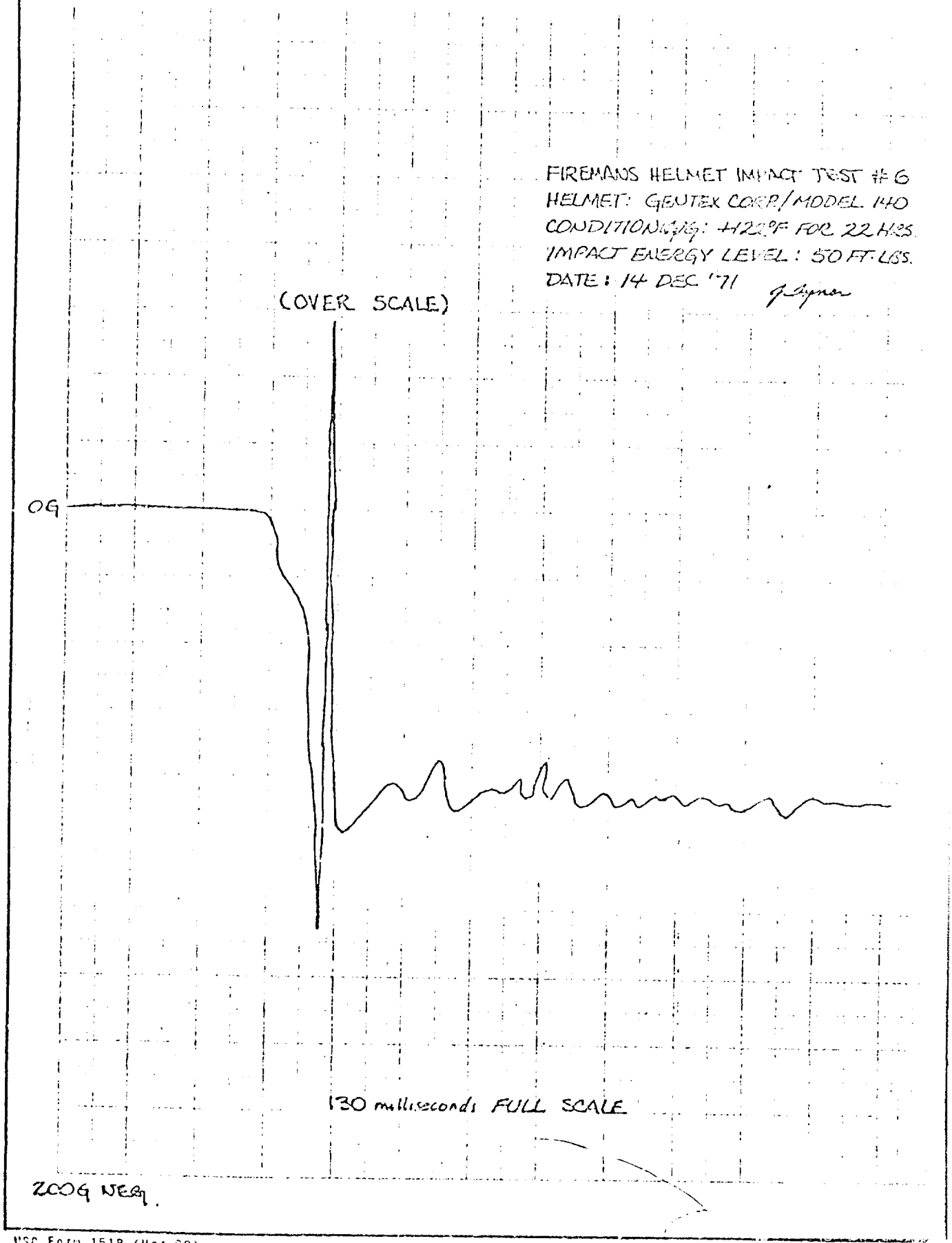

60 G POS.
FIREMANS HELMET IMPACT TEST #1
HELMET: NASA PROTOTYPE
CONDITIONING: 132°F FOR 22 HRS.
IMPACT ENERGY LEVEL: 50 FT·LBS.
DATE: 14 DEC. '71
0G
130 milliseconds FULL SCALE
110 G NEG.

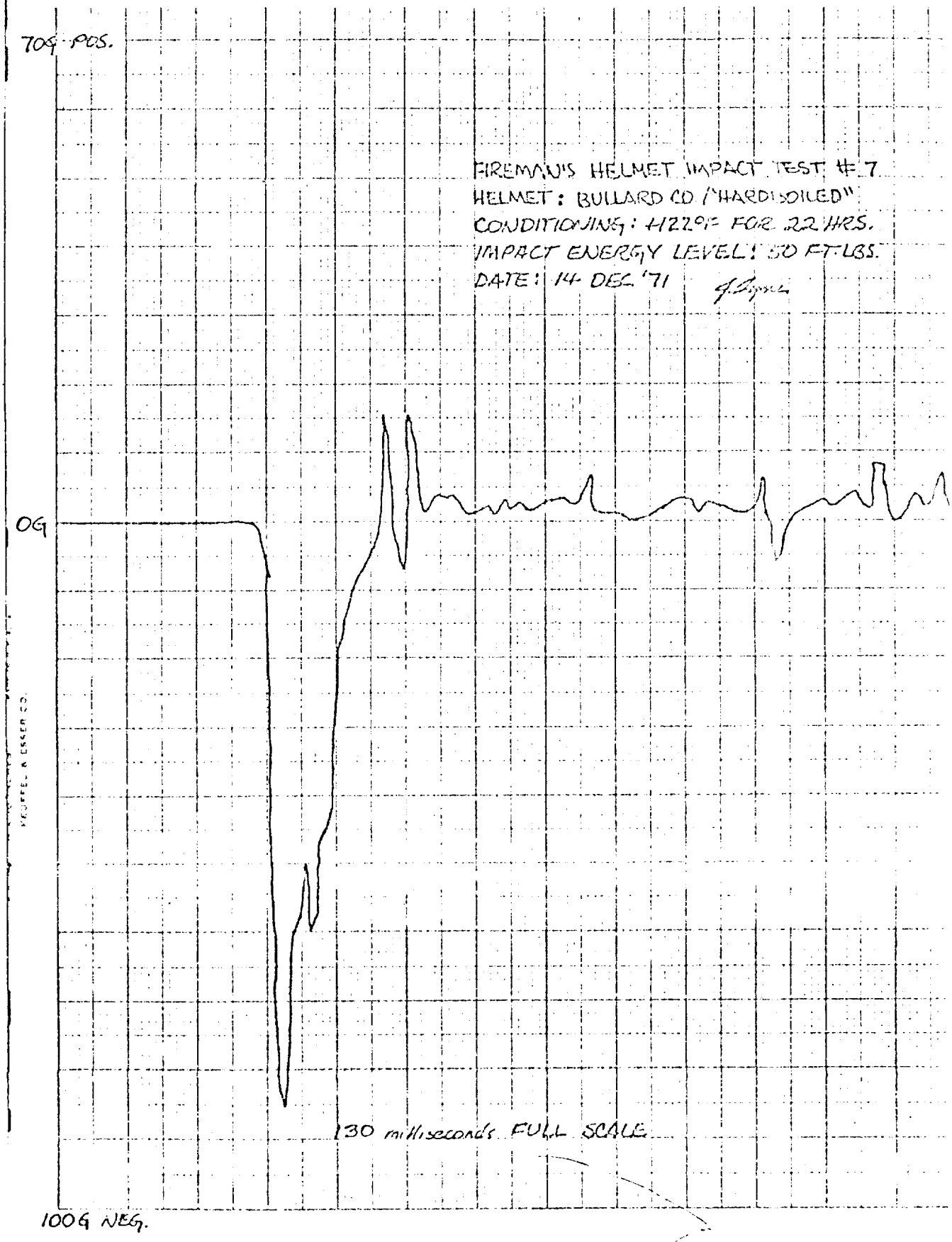

60G POS.
FIREMANS HELMET IMPACT TEST #2
HELMET: BULLARD CO./"HARDBOILED"
CONDITIONING: +122°F FOR 22 HRS
IMPACT ENERGY LEVEL: 50 FT-LBS.
DATE: 14 DEC. '71
0G
130 milliseconds FULL SCALE
110G NEG

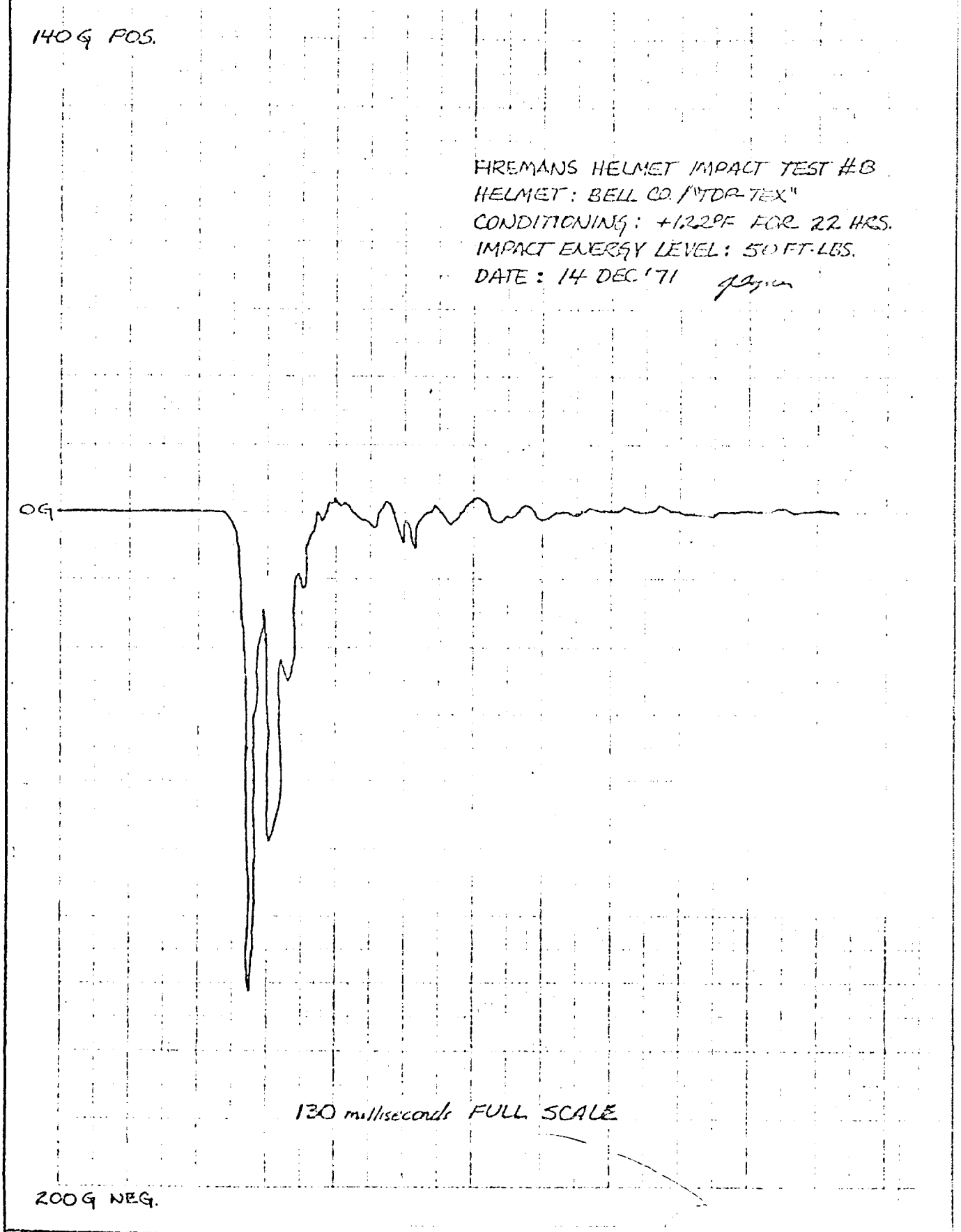

160G POS.
FIREMANS HELMET IMPACT TEST #3
HELMET: GENTEX CORP./MODEL 140
CONDITIONING: +120°F FOR 22 HR.
IMPACT ENERGY LEVEL: 50 FT-LBS.
DATE: 14 DEC. '71
0
130 milliseconds FULL SCALE
200G NEG.

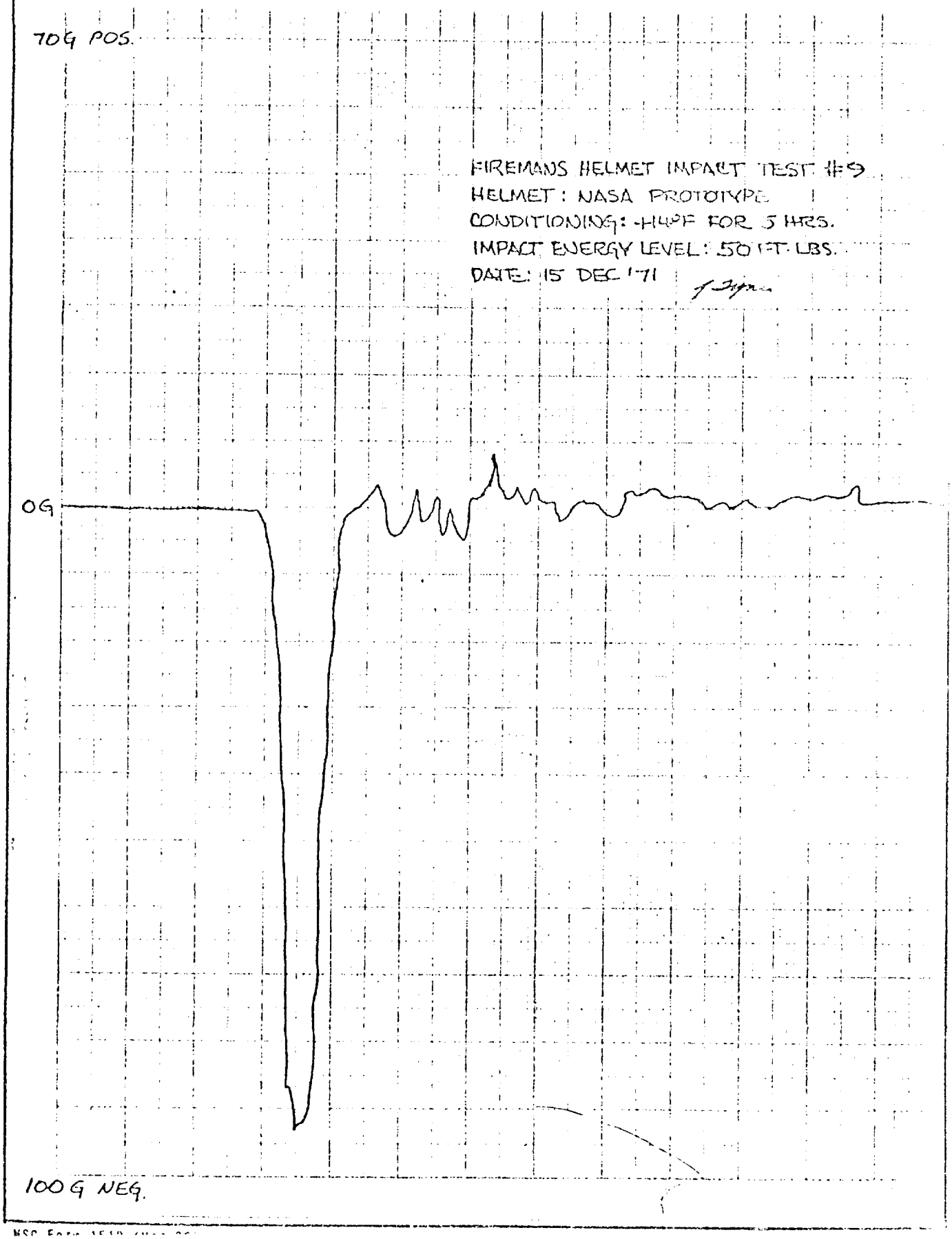

140G POS.
FIREMANS HELMET IMPACT TEST #4
HELMET: BELLCO. "TOP-TEX."
CONDITIONING: +122°F FOR 22 HRS.
IMPACT ENERGY LEVEL: 50 FT. LBS.
DATE: 14 DEC. '71
0G
130 milliseconds FULL SCALE
200G NEG.

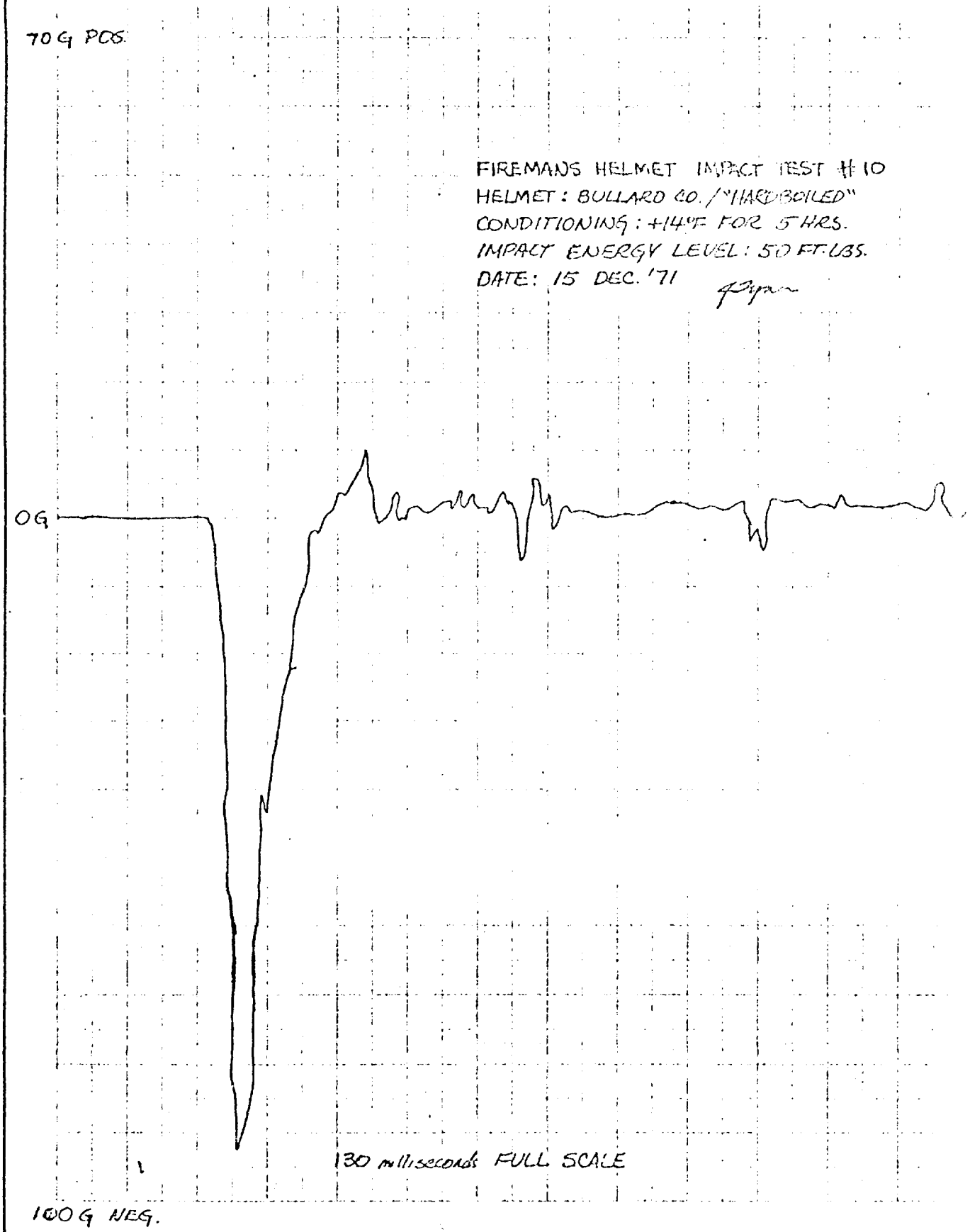

TOG POS.
FIREMANS HELMET IMPACT TEST #5
HELMET: NASA PROTOTYPE
CONDITIONING: +122°F FOR 22 HRS.
IMPACT ENERGY LEVEL: 50 FT-LBS.
DATE: 14 DEC '71
0G
130 milliseconds FULL SCALE
100G NEG.

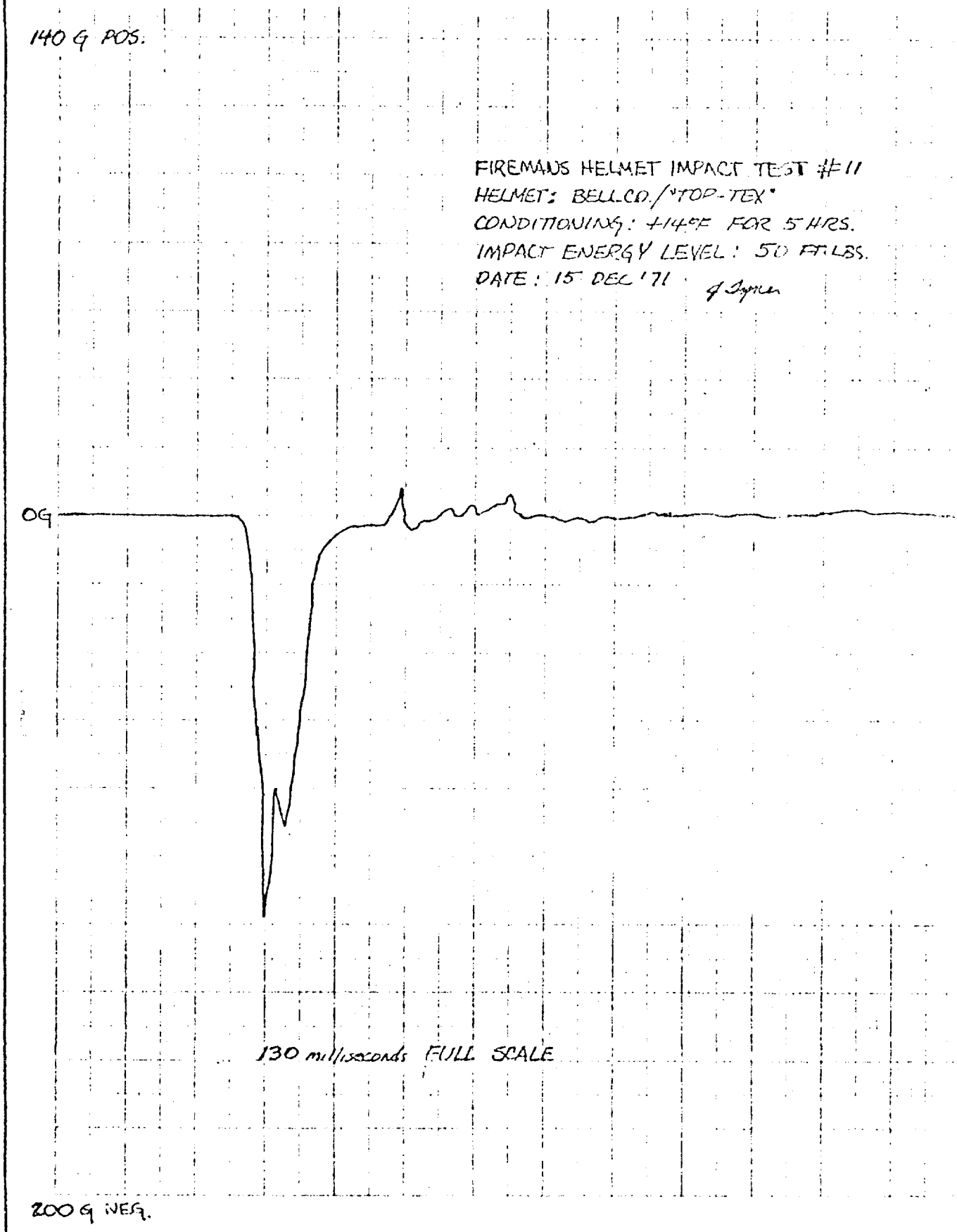

FIREMANS HELMET IMPACT TEST #6
HELMET: GENTEX CORP/MODEL 140
CONDITIONING: +122°F FOR 22 HRS.
IMPACT ENERGY LEVEL: 50 FT-LBS.
DATE: 14 DEC '71
(OVER SCALE)
0G
130 milliseconds FULL SCALE
200G NEG.

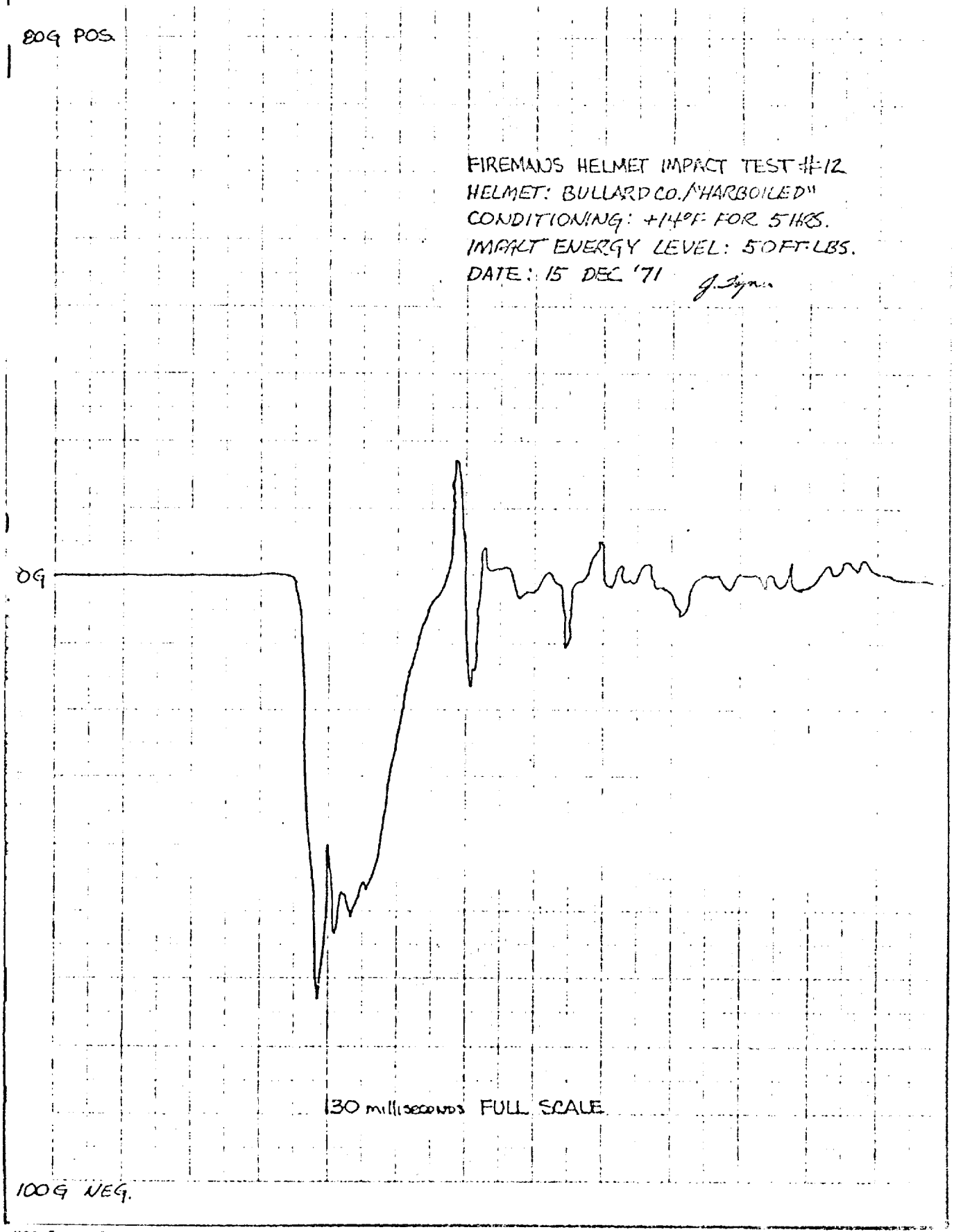

70G POS.
FIREMAN'S HELMET IMPACT TEST #7
HELMET: BULLARD CO ("HARDBOILED")
CONDITIONING: +122°F FOR 22 HRS.
IMPACT ENERGY LEVEL: 50 FT-LBS.
DATE: 14 DEC '71
0G
130 milliseconds FULL SCALE
100G NEG.

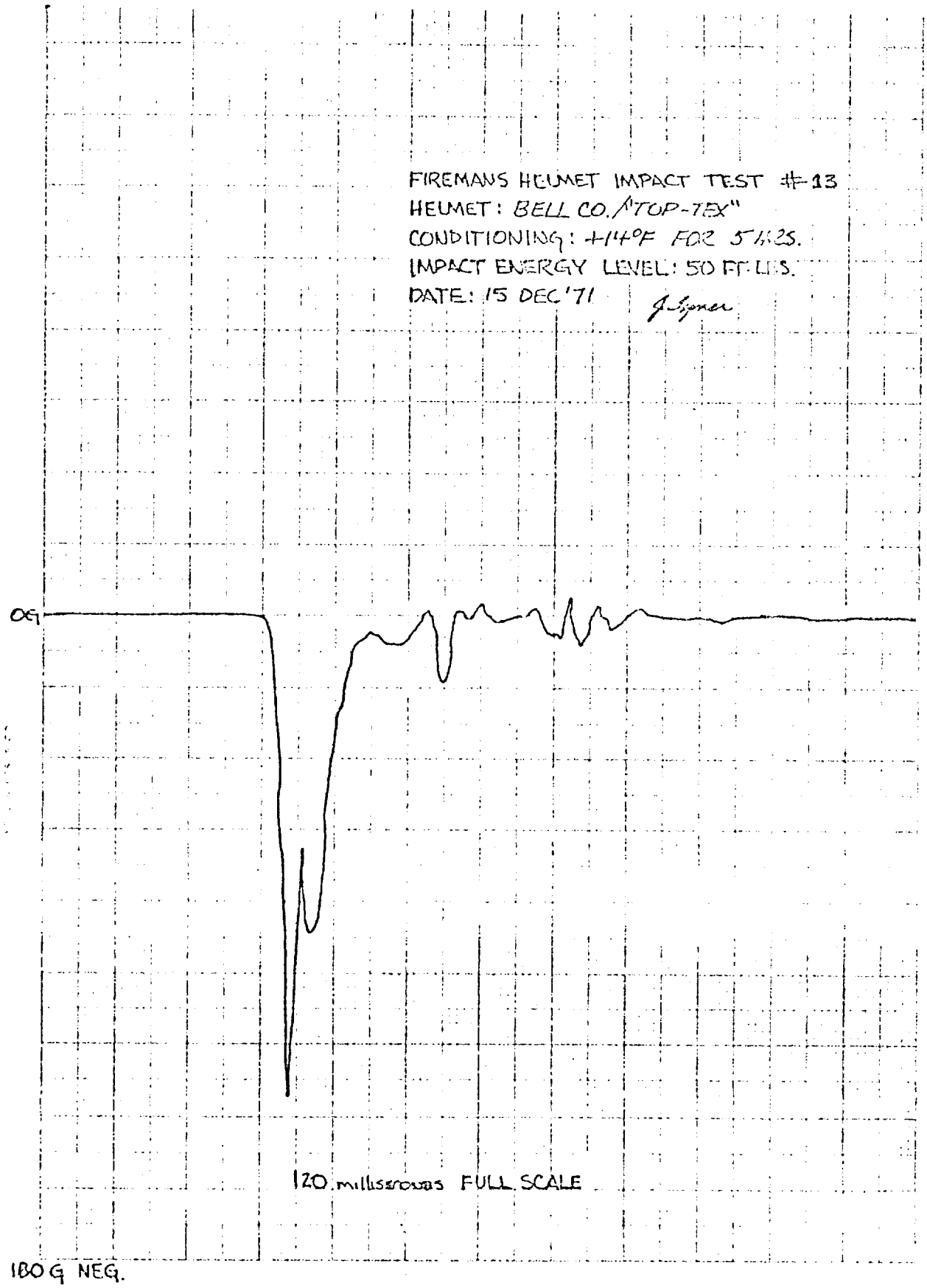

140 G POS.
FREMANS HELMET IMPACT TEST #8
HELMET: BELL CO. /"TOR-TEX"
CONDITIONING: +122°F FOR 22 HRS.
IMPACT ENERGY LEVEL: 50 FT-LBS.
DATE: 14 DEC '71
0G
130 milliseconds FULL SCALE
200 G NEG.

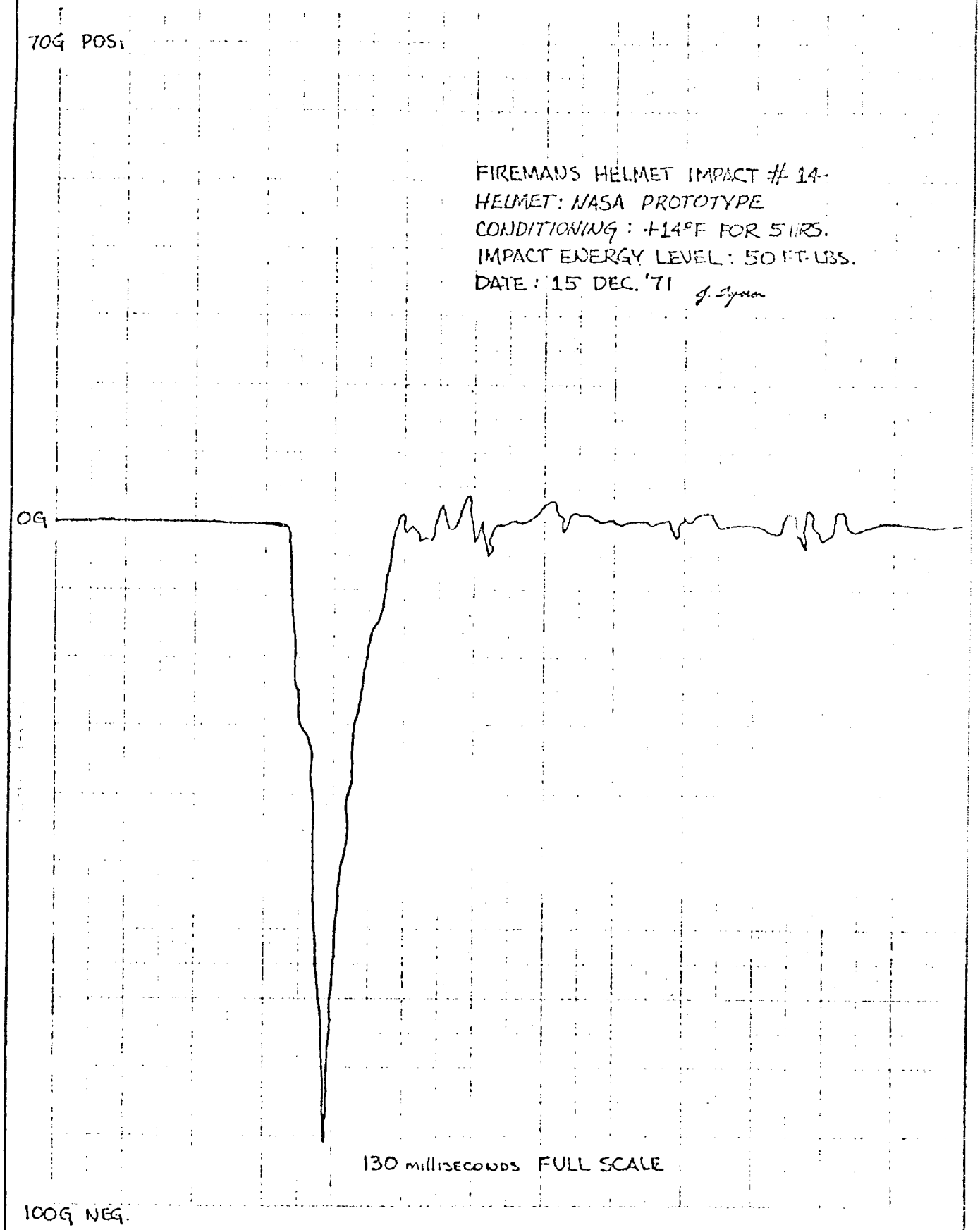

70G POS.
FIREMANS HELMET IMPACT TEST #9
HELMET: NASA PROTOTYPE
CONDITIONING: -140°F FOR 5 HRS.
IMPACT ENERGY LEVEL: 50 FT-LBS.
DATE: 15 DEC '71
0G
100 G NEG.

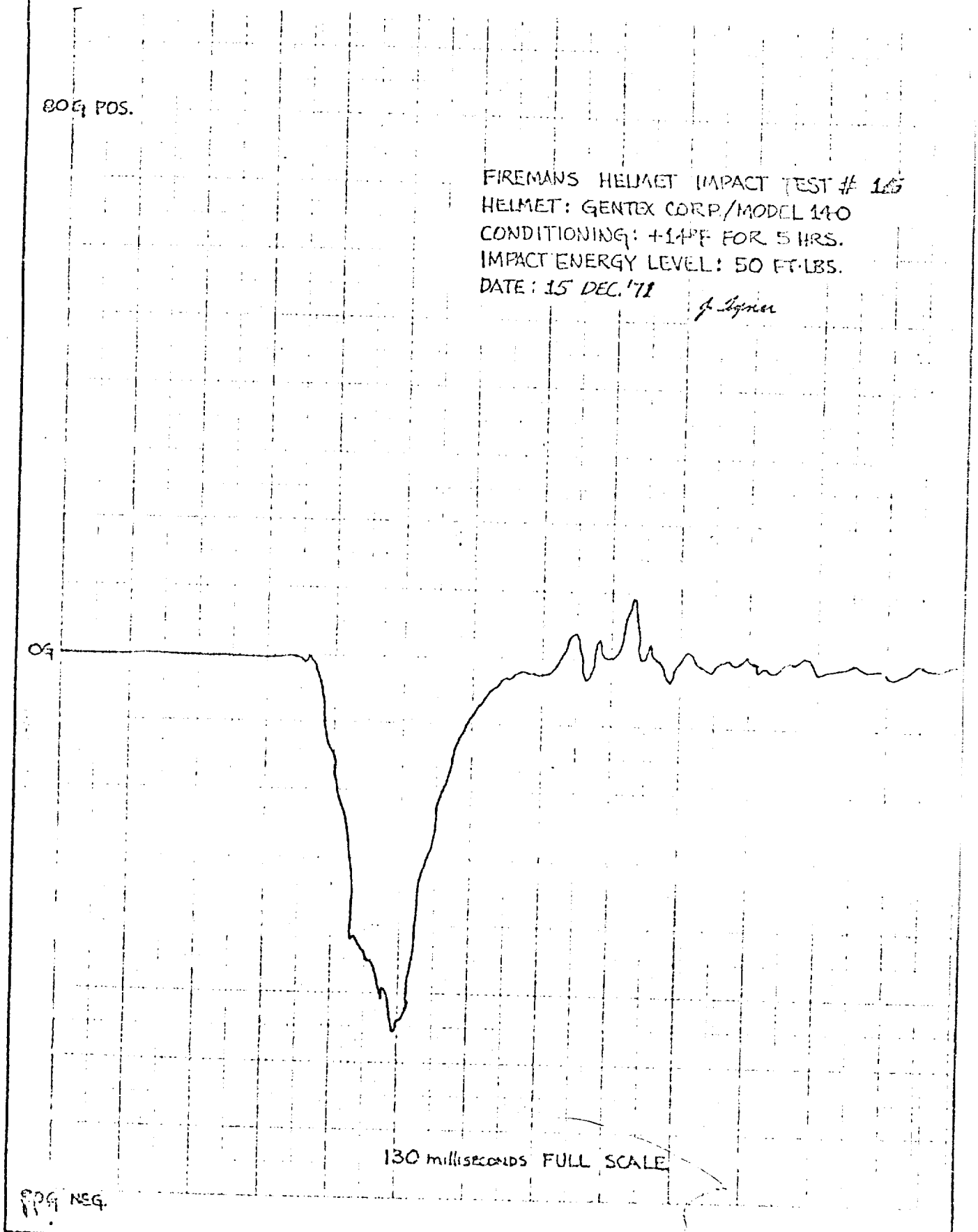

70 G POS.
FIREMANS HELMET IMPACT TEST #10
HELMET: BULLARD CO. / "HARDBOILED"
CONDITIONING: +14°F FOR 5 HRS.
IMPACT ENERGY LEVEL: 50 FT-LBS.
DATE: 15 DEC. '71
0G
130 milliseconds FULL SCALE
100 G NEG.


140 G POS.
FIREMANS HELMET IMPACT TEST #11
HELMET: BELL CO./"TOP-TEX"
CONDITIONING: +114°F FOR 5 HRS.
IMPACT ENERGY LEVEL: 50 FT-LBS.
DATE: 15 DEC '71
0G
130 milliseconds FULL SCALE
200 G NEG.


80G POS.
FIREMANS HELMET IMPACT TEST #12
HELMET: BULLARD CO./"HARBOILED"
CONDITIONING: +14°F FOR 5 HRS.
IMPACT ENERGY LEVEL: 50 FT-LBS.
DATE: 15 DEC '71
0G
30 milliseconds FULL SCALE
100G NEG.


FIREMANS HELMET IMPACT TEST #-13
HELMET: BELL CO. "TOP-TEX"
CONDITIONING: +114°F FOR 5 HRS.
IMPACT ENERGY LEVEL: 50 FT-LBS.
DATE: 15 DEC '71
0G
120 milliseconds FULL SCALE
180 G NEG.


70G POS.
FIREMANS HELMET IMPACT # 14-
HELMET: NASA PROTOTYPE
CONDITIONING: +14°F FOR 5 HRS.
IMPACT ENERGY LEVEL: 50 FT-LBS.
DATE: 15 DEC. '71
0G
130 milliseconds FULL SCALE
100G NEG.


80G POS.
FIREMANS HELMET IMPACT TEST # 16
HELMET: GENTEX CORP/MODEL 140
CONDITIONING: +14°F FOR 5 HRS.
IMPACT ENERGY LEVEL: 50 FT·LBS.
DATE: 15 DEC. '71
0G
130 milliseconds FULL SCALE
80G NEG.

# APPENDIX II

MSC-EC-R-71-12-Rev. A - "Test Procedure

Firefighters' Helmet Impact Test"

CREW SYSTEMS DIVISION

NASA - MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

MSC-04-630

# TEST PROCEDURE

# FIREFIGHTERS' HELMET

# IMPACT TESTS

DOC. NO. MSC-FC-R-71-12 DATE 10-27-71

| | |
|---|---|
| PREPARED BY: | Joe. D. Tyner, GE Project Engineer |
| | [illegible] |
| Approved by: | [illegible], NASA Project Engineer |
| APPROVED BY: | (SECTION) [illegible], Materials Development Section |
| APPROVED BY: | [illegible], Chief, Crew Equipment Branch |
| APPROVED BY: | (DIVISION) [illegible], Chief, Crew Systems Division |
| APPROVED BY: | |

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REVISIONS

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| 12-8-71 | J.D. Tyner | | | | | A |

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## 1.0 SCOPE

This document details the procedure for subjecting firefighters' helmets to impact testing according to American Standard's specification Z90.1-1966 requirements as modified.

## 2.0 OBJECTIVE

The objective of the test series is to determine the relative shock absorbing characteristics of various firefighters' helmets when impacted with a fixed hemispherically shaped anvil. The impact energy shall be 50 foot-pounds according to specification Z90.1-1966. An accelerometer shall be mounted within the head to determine the acceleration during impacts.

## 3.0 TEST ARTICLE DESCRIPTION

The tests shall be conducted on various commercially available helmet types and on the NASA prototype polyimide helmet. The helmets to be tested are the following:

| Designation | Manufacturer | Suspension | Shell |
|---|---|---|---|
| NASA Prototype | North American and American Sports Company | Foam-type | Polyimide |
| Model 140 | Gentex Corporation | Webbed support | ABS |
| "Hard Boiled" | E. D. Bullard Company | Webbed support | Fiberglass Polyester |
| | Bell-Top Tex | Foam-type | Fiberglass Polyester |

4.0 TEST FACILITY

These tests will be conducted by the special projects laboratory of the Crew Systems Division's Material Development Section. The test apparatus shall be a pendulum and a wooden mannequin head assembly as shown in photographs 1 and 2. A thermal control box from the special projects laboratory SAMS (simulated astronaut metabolic system) shall be used to precondition the helmets at the desired temperatures prior to each impact.

5.0 TEST PROCEDURE

5.1 Modify pendulum and wooden head assembly per sketch 1.

5.2 Suspend the impact head with a helmet mounted as a pendulum, and determine the period of oscillation. Determine period by swinging the pendulum through an arc of $<6^{\circ}$ amd timing the period through 10 oscillations.

5.3 Calculate the center of percussion of the impact assembly by the following formula: $L = gt^2/(2\pi)^2$ where L is the length from the pivot point to center of percussion, g is acceleration due to gravity, and t is the period of oscillation of the pendulum.

5.4 Bore a hole in the wooden mannequin head in the plane of the center of percussion per sketch 2.

5.5 Weigh and record weight of the impact assembly with a helmet mounted [illegible] head. [illegible] 11 lb-Hoz (impact assembly only) See Table 1 in cut report for wt. of each helmet added on)

5.6 Calculate the release angle required for a 50 foot-pound impact by the following formulas:

a. $E = mgh$ where m is the mass of the impact assembly, g is the acceleration due to gravity, and h is the verticle height when the center of percussion is raised.

b. $\theta = \cos^{-1}\left(\frac{L-h}{L}\right)$ where L and h are defined in 5.3 and 5.6 respectively.

5.7 Take photographs of the test setup.

5.8 Pull impact assembly back to the desired release angle as calculated in step 5.6 and install in thermal box.

5.9 Maintain the helmet in the thermal control box at -10°C (+14°F) for a minimum of 4 hours but less than 24 hours.

5.10 Begin countdown of 5-4-3-2-1 - Release. Turn accelerometer recorder on at count of 2.

5.11 Impact helmet. Do not let helmet strike the anvil more than once. Record impact data on data sheet.

5.12 Move impact assembly approximately 1-1/2 inches in any direction and impact the helmet again if the total time elapsed from step 5.10 is less than 5 minutes. If elapsed time is greater than 5 minutes, then return the helmet to the temperature control box at 40°C for the minimum time of 4 hours, and then repeat steps [illegible] 5.11. Record impact data on data sheet.

5.13 Position impact assembly so that the point of impact is 1-1/2 inches away from the two previous impacts.

5.14 Pull assembly to the release angle and install in thermal box.

5.15 Maintain helmet in the temperature control box at a temperature of 50°C (122°F) for a minimum of 4 hours and not more than 24 hours.

5.16 Begin countdown.

5.17 Turn recorders on at count of 2.

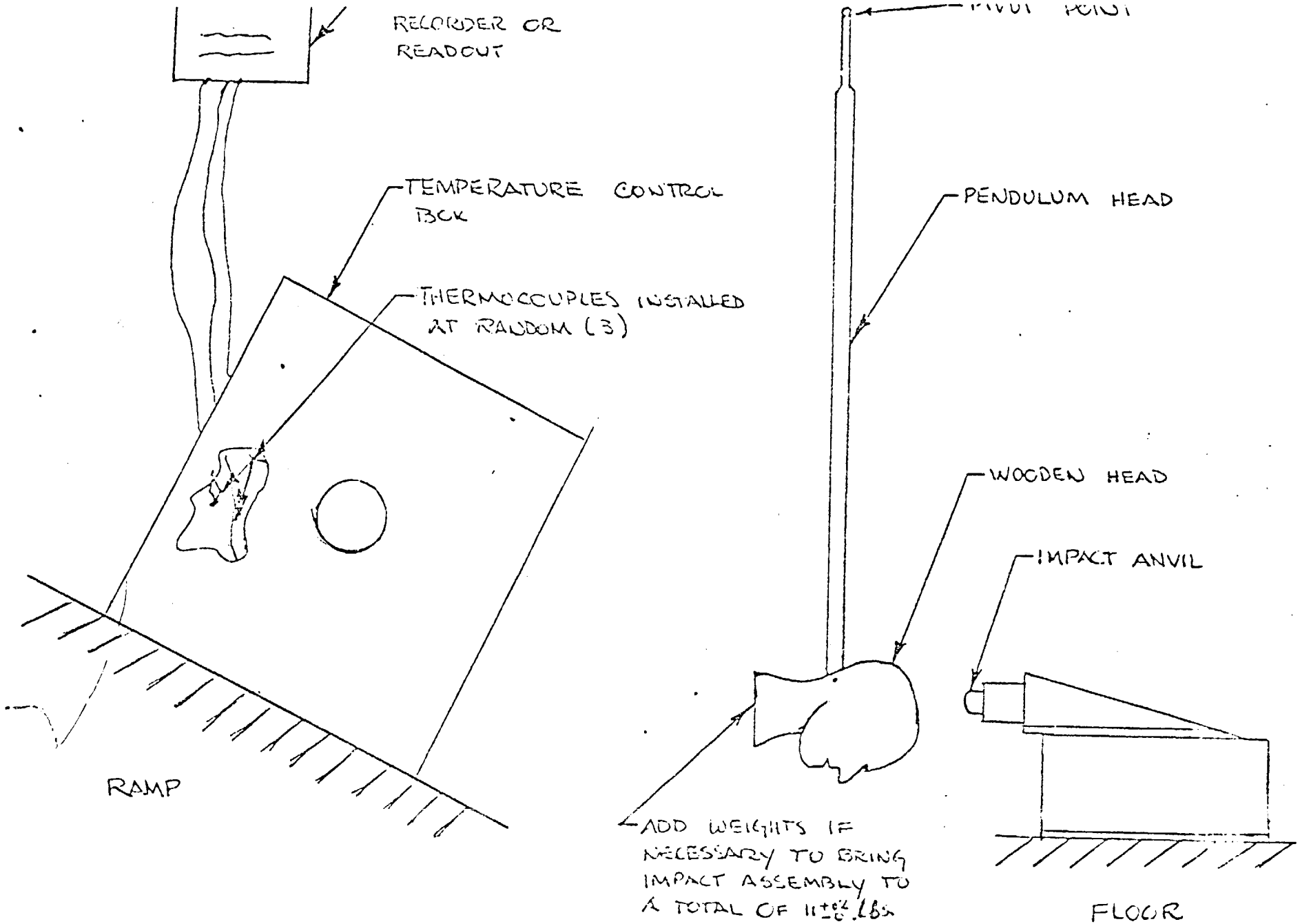
5.18 Impact helmet. Do not let the helmet strike the anvil more than once. Record impact data on data sheet.

5.19 If the total time from step 5.16 is less than 5 minutes then reposition the assembly so that the point of impact is 1-1/2 inches away from the previous impact points. Impact assembly again. If the total time elapsed is greater than 5 minutes then return the helmet to the temperature control box at 50°C (122°F) for a minimum of 4 hours and then repeat steps 5.14 through 5.18. Record impact data on data sheets.

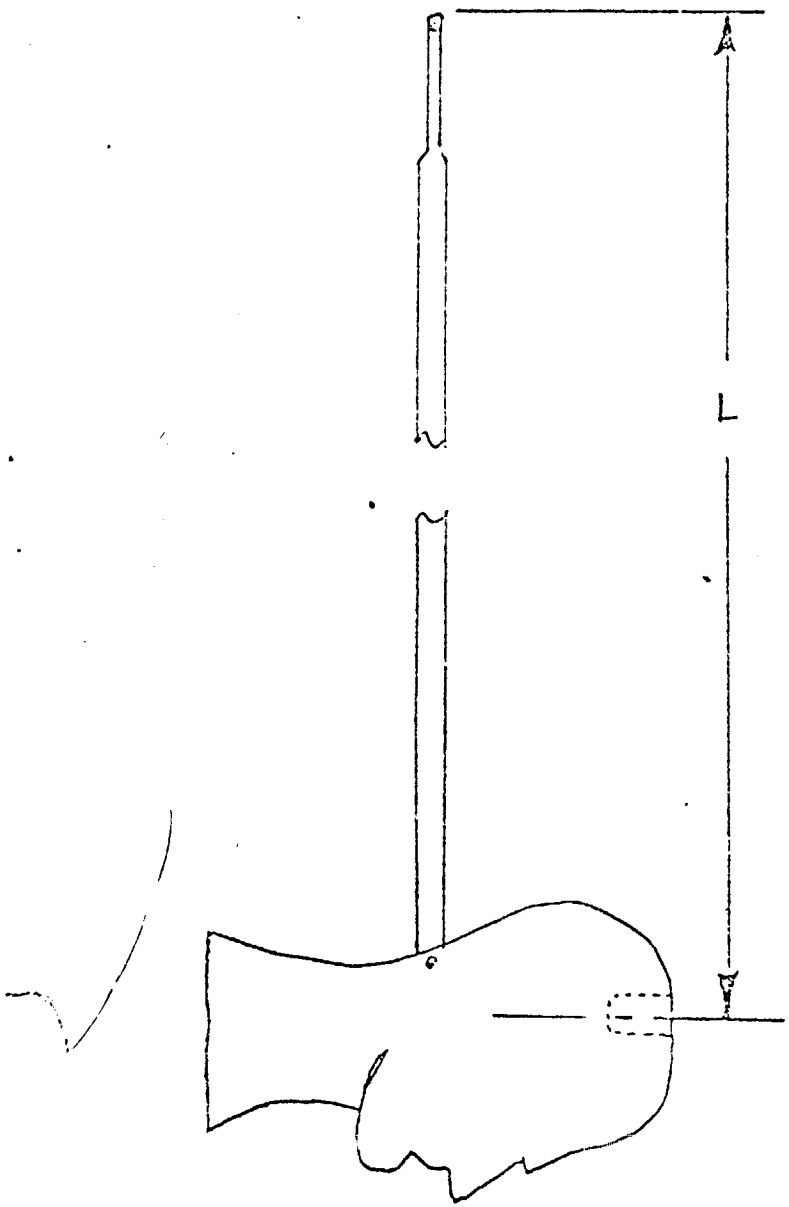
5.20 Repeat steps 5.7 through 5.19 for the remaining three helmets.

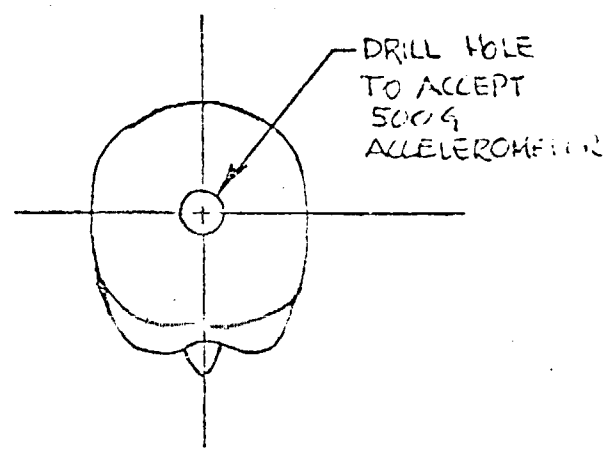
6.0 FINAL REPORT

Prepare a final report which includes all impact data, photographs, etc., and a discussion of the relative merits of the units tested.


RECORDER OR READOUT
TEMPERATURE CONTROL BOX
THERMOCOUPLES INSTALLED AT RANDOM (3)
RAMP
PENDULUM HEAD
WOODEN HEAD
IMPACT ANVIL
ADD WEIGHTS IF NECESSARY TO BRING IMPACT ASSEMBLY TO A TOTAL OF 11±0.1 lbs
FLOOR

12/8/71




SKETCH #2
(MODIFIED) 12/8/71 [illegible]

# APPENDIX III

Z90.1-1966 - "American Standard Specification for Protective Headgear for Vehicular Users"

ASA
Reg. U.S. Pat. Off.
Z90.1-1966
UDC 614.891.6.9

American Standard Specifications for

# rotective Headgear for Vehicular Users

USA Standard
This USA Standard is one of nearly [illegible] Standards approved as American Standards by the American Standards Association. On [illegible] 24, 1969, the ASA was reconstituted as the United States of America Standards Institute.

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Approved June 22, 1966
AMERICAN STANDARDS ASSOCIATION
INCORPORATED

# American Standard

*Registered United States Patent Office*

An American Standard implies a consensus of those substantially concerned with its scope and provisions. An American Standard is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of an American Standard does not in any respect preclude anyone, whether he has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard. American Standards are subject to periodic review and users are cautioned to obtain the latest editions. Producers of goods made in conformity with an American Standard are encouraged to state on their own responsibility in advertising, promotion material, or on tags or labels, that the goods are produced in conformity with particular American Standards.

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Printed in USA

# Foreword

(This Foreword is not part of American Standard Specifications for Protective Headgear for Vehicular Users, Z90.1-1966.)

On December 9, 1960 the Sports Car Club of America requested that the American Standards Association initiate a project to prepare specifications on the subject of road-users helmets. A general conference was held at the ASA headquarters in April 1961 which was attended by representatives from various consumer groups, helmet manufacturing companies, testing organizations, and both the Army and Naval branches of the military service. The Safety Standards Board established Sectional Committee Z90 and charged it with the responsibility for establishing a safety code for vehicular head protection. The scope of the committee was to establish safety requirements for head protection for automobile drivers engaged in high hazard activities or occupations, and for motorcyclists. The committee is presently considering the expansion of its scope to include headgear protection for other high hazard athletic activities such as football, baseball, and skiing.

There exists a great number of widely varying uses for protective headgear. The resulting differences in design requirements may result in very necessary compromises involving factors which include comfort, weight, visual, and auditory requirements as well as degree and extent of protection. It is therefore essential that any specific standard be applied or utilized only within the scope of its intended application.

Suggestions for improvement gained in the use of this standard will be welcome. They should be sent to the American Standards Association, Incorporated, 10 East 40th Street, New York, N.Y. 10016.

The organizations which participated in this work and the names of their representatives, as listed at the time this standard was submitted to the Sectional Committee for approval, are as follows:

George G. Snively, *Chairman* Asher Chapman, *Secretary*

| *Organization Represented* | *Name of Representative* |
|---|---|
| American Association for Automotive Medicine | H. A. Fenner, Jr |
| | A. J. Mirkin *(Alt)* |
| American Insurance Association | R. C. Ellis |
| American Motorcycling Association | L. A. Kuehler |
| American Mutual Insurance Alliance | F. H. Deeg |
| American Power Boat Association | C. Roberts |
| | W. A. Smith *(Alt)* |
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| | F. Heacox *(Alt)* |
| Cal Mil Plastic Products, Inc | R. L. Miller |
| Industrial Safety Equipment Association | Harley N. Trice |
| | C. Sumwalt *(Alt)* |
| International Association of Chiefs of Police | W. H. Franey |
| Rico Company | J. T. Johnson |
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| Mine Safety Appliances Company | H. N. Trice |
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| Snell Memorial Foundation | C. O. Chichester |
| Society of the Plastics Industry, Inc | H. N. Trice |
| Sports Car Club of America | A. Chapman |
| | G. G. Snively |
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| | E. R. Barron *(Alt)* |
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| U.S. Naval Aviation | C. L. Ewing |
| Wayne State University | L. M. Patrick |

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American Standard Specifications for

# Protective Headgear for Vehicular Users

## 1. Scope and Purpose

1.1 Scope. These specifications and test methods apply to protective headgear for wear by riders and occupants of vehicles engaged in potentially high hazard activities. This standard specifically excludes eye and face protective devices.

1.2 Purpose. These headgear are designed to mitigate the effects of a blow on the head received in the event of an accident.

1.3 Tests are given to ascertain compliance with the following requirements:

(1) Shock absorption properties of the helmet assembly under various conditions of temperature and humidity

(2) Penetration resistance

(3) Strength of the retaining harness and its attachments

## 2. Definitions

For the purpose of these recommendations the following definitions apply:

Basic Plane. A plane at the level of the external auditory meatus and the inferior margin of the orbit. Also referred to as the anatomical plane.

External Auditory Meatus. Refers to the external opening of the ear.

Harness. The complete assembly by means of which the protective headgear is maintained in position on the wearer's head.

Inferior Margin of Orbit. Bottom of the bony rim of the eye opening.

Orbit. The bony rim of the eye socket.

Projection. Any part that juts out or extends beyond the surface in abrupt fashion.

Protective Headgear. A device primarily intended to protect the upper part of the wearer's head against a blow. Some headgear may give protection to additional head areas.

Reference Plane. A plane 2.36 in. (60 mm) above and parallel to the basic (anatomical) plane, which shall be located on each head form.

Shell. The outer material that provides the general form of the headgear.

## 3. Construction

3.1 General. The construction of the helmet shall be essentially in the form of a shell containing the necessary means of absorbing impact energy. Any optional devices fitted to a shell should be so designed that they are unlikely to cause any injury to the wearer in the event of an accident.

3.2 The assembled helmet shall have a smooth external surface. There should be no external projections greater than $\frac{1}{8}$ in. (3 mm) above the outer surface of the shell of the helmet except a goggle clip, if required.

3.3 The goggle fitting shall project not more than $\frac{3}{16}$ in. (5 mm) above the outer surface of the helmet and be at the back of the helmet. If easily detachable, however, this requirement does not apply.

3.4 Rivet heads shall project not more than $\frac{1}{16}$ in. (1.6 mm) above the outer surface of the helmet and show no sharp edges.

## 4. Materials

4.1 The materials used in the manufacture of the various parts of a helmet should be of durable quality, i.e., their characteristics should not undergo appreciable alteration under the influence of aging or of the circumstances of use to which the helmet is normally subjected (exposure to sun, rain, cold, dust, vibrations, contact with the skin, effects of sweat, or of products applied to the skin or hair).

4.2 Materials commonly known to cause skin irritation or disease should not be used for those parts of the assembly which come into contact with the skin.

4.3 Materials of a new type shall be subject to study to determine applicability as specified in 4.2.

## 5. Extent of Protection

The extent of the area of protection shall be as marked on the standard head form with a reference plane line 2.36 in. (60 mm) above the basic plane.

All parts of the helmet above the reference plane shall attenuate shock transmission to at least the minimum

requirements specified in Section 10, Tests for Helmets and Section 11, Penetration Test.

No part of the protective system shall be inadvertently detachable.

## 6. Sampling for Testing

6.1 For qualification and routine testing, helmets should be taken in the condition as offered for sale.

6.2 In qualification testing the helmets will be required to satisfy all the tests; but when it has been shown by qualification tests that materials are equally protective in performance after exposure to low temperature, moisture, and heat, thereafter for routine testing of specimens consideration should be given to possible relaxation in respect of them by the testing authority, provided there is no change in materials or manufacture.

6.3 Number of Samples. Four helmets are required for qualification testing. Provision shall be made for marking the reference plane on the helmets prior to the test.

## 7. Conditioning for Testing

7.1 Low Temperature. The helmet shall be conditioned by being exposed to a temperature of −10°C ± 2°C for not less than 4 hours, nor more than 24 hours, in a mechanically cooled apparatus.

7.2 Water Immersion. A second helmet shall be immersed in water at a temperature of 25°C ± 5°C for a period of not less than 4 hours, nor more than 24 hours.

7.3 Heat. A third helmet shall be conditioned by being exposed to a temperature of 50°C ± 2°C for a period of not less than 4 hours, nor more than 24 hours.

7.4 All testing shall begin within five minutes from the time of removal from the conditioning equipment as indicated in 7.1, 7.2, and 7.3.

## 8. Labeling

Every helmet offered for sale shall bear a label which shall include the following statements:

(1) For adequate protection this helmet must fit comfortably and closely, and provide a range of peripheral vision of approximately 120 degrees.

(2) This helmet may be partially destroyed or damaged by a severe blow and even though such damage may not be readily apparent, any helmet subjected to severe impact should be returned to the manufacturer for inspection or should be replaced.

## 9. Tests for Helmets

9.1 Shock Absorption. Shock absorption shall be measured by imparted acceleration to an appropriately instrumented movable head form, by either of the following means: (1) dropping in guided fall upon a fixed rigid anvil, or (2) mounted on a freely pivoting arm and being impacted by an appropriate bobweight dropped in guided fall.

9.2 Acceptable Acceleration Levels

9.2.1 Any peak acceleration exceeding 400 G's shall be cause for rejection of the helmet.

9.2.2 Accelerations between 200 and 400 G's shall be cause for rejection of the helmet if the total time of such acceleration measured at the 200 G level exceeds 2 milliseconds.

9.2.3 Accelerations in excess of 150 G's for more than 4 milliseconds shall be cause for rejection of the helmet.

9.2.4 The acceptable acceleration levels set forth in this section shall apply to ambient temperature impact, low temperature impact, high temperature impact, and water immersion impact tests.

9.3 Each helmet shall be impacted with two identical impacts in not less than four sites. The impact sites shall be above the reference plane (2.1.7), and separated from each other by a distance equal to one-fifth or more of the maximal circumference of the helmet.

9.4 Two steel impacter or anvil configurations shall be used. One shall be flat, the other hemispherical.

9.5 The flat impactor shall have a minimum surface area of 19.6 square inches (127 square centimeters) i.e., 5-inch diameter face; the hemispherical impactor shall have a 1.9-inch (4.8 centimeter) radius.

9.6 An equal number of paired impacts shall be applied with each configuration.

9.7 The test head form shall be of low resonance magnesium alloy (K-1A), and shall weigh 11 + 0.2 − 0.0 pounds (5 kilograms + 0.091 − 0). This weight shall include the supporting arm if testing by dropping upon a rigid anvil [see 9.1(1)]. The same weight shall be used for the impacting bobweight if testing is done according to the pivoting head-form system [see 9.1(2)].

9.8 The impact energy utilized shall be 50 foot pounds (7.42 kilogram meters) with the hemispherical anvil face (54 in. or 134 cm drop) and 66 foot pounds (9.8 kilogram meters) with the flat anvil face (72 in. or 183 cm drop) if testing is in accordance with (1) of 9.1.

It shall be 120 foot pounds (17.8 kilogram meters) with the hemispherical striker (131 in. or 332 cm) and 160 foot pounds (23.8 kilogram meters) with a flat striker (175 in. or 443 cm) if testing is in accordance with (2) of 9.1.

## 10. Penetration Test

10.1 Sufficient exposure of the inner surface of the helmet shell shall be made by removing padding or harness material so as to allow the unpadded shell to rest upon a rigid head form. The head form shall contain a cylindrical cavity 1.77 in. (4.5 cm) in diameter whose vertical axis shall be centered with that of the striking point. This cavity shall contain a means of electrically recording the instantaneous vertical deflection of the inner surface of the shell within 0.394 in. (1 cm) of the axis, and record contact of the striker tip at a point 0.394 in. (1 cm) below the head form outer surface.

10.2 When tested in the above fashion, the maximum allowable vertical deflection shall not exceed 0.394 in. (1 cm), and penetration of the striker tip as recorded by electrical contact at this point shall not occur.

10.3 Conditions of Penetration Test.

10.3.1 The weight of the penetration test striker shall be 6 pounds 10 ounces (3.0 kilograms).

10.3.2 The point of the striker shall have an included angle of 60 degrees.

10.3.3 The radius of the striking point shall be 0.197 in. (0.5 mm).

10.3.4 The hardness of striking tip shall be 60 Rockwell (scale C).

10.3.5 The height of the fall shall be 39.37 in. (1 meter) as measured from the tip of the striker to the outer surface of the test head form.

## 11. Test of Retaining System

11.1 The helmet shall be placed upon a test head form with the chin strap fastened over a device approximating the shape of the bony structure of the lower jaw. This shall consist of two metal rollers, each $\frac{1}{2}$ in. (1.27 cm) in diameter, at a distance of 3 in. (7.61 cm) separation on center, which would serve to represent the jawbone.

The helmet shall be supported on the head form so that the points of attachment of the chin strap to the helmet will be subject to the same test as the strap itself.

11.2 A 300-pound (136 kilogram) weight or tension equivalent thereto shall be applied to the device retained by the chin strap. The strap and its attachments must support this weight without parting and without greater than 1 in. (2.54 cm) increase in the vertical distance of the chin strap from the helmet crown.

11.3 The test is designed to test the chin strap harness assembly only. If the helmet has a pad-type suspension that will allow the helmet to settle down over the head form, this settling should not be considered in determining elongation of the chin strap. The vertical movement should be recorded with respect to the strap and shell alone. It shall be tested for ultimate strength and for elongation under tension.

## 12. Preparation of Test Equipment

12.1 All equipment shall be turned on and allowed to warm up for at least 30 minutes or until equilibrium is reached, whichever time is greater, prior to any testing.

12.2 The instrumentation shall be calibrated according to the manufacturer's recommendation prior to and after each series of tests. If the system is out of calibration at the end of a test series, the entire series shall be discarded.

12.3 The entire system shall be checked before and after each series of tests by impacting a standardized section of a rigid foam plastic, and recording the acceleration-time history of the impact. If the acceleration-time history is out of predetermined tolerance, the entire series of tests shall be discarded.

12.4 A record shall be made of each impact and retained as a permanent record of the acceleration-time history.

## 13. Test Equipment

13.1 Head Form. A standard head form shown in Figs. 1-5 shall be used in all tests.[1]

13.1.1 *Center of Gravity.* The center of gravity of the head form including the crossarm shall lie within a cone with axis vertical and forming a 10-degree included angle with the apex at the point of impact.

13.1.2 *Weight.* The combined weight of the crossarm and head form shall be 11 + $\frac{2}{10}$-0 pounds (5 kilograms + 0.091 − 0).

13.1.3 *Acceleration Transducer.* The acceleration transducer shall be mounted with the sensitive axis aligned to within 5 degrees of the true vertical when the head form is in the impact position.

13.1.4 *Head Form Size.* Medium and large size helmets will be tested on a single head form size. Small size helmets of the same type will be approved if visual inspection shows the construction to be identical to those tested.

13.1.5 *Reference Plane.* The standard head form,

---

[1] It was necessary for the purposes of these recommendations and in order to give requirements for the extent of protection to define an artifical head form, both to serve as a basis for instrumentation during tests, and to provide fixed parameters for measurement. It is realized that the variation of human head shape is such that the artifical head form may not conform exactly to the shape of any random sample human head, a considerable amount of anthropological data has been reviewed in order to decide the limiting dimensions, and the head form selected is considered suitable to provide accurately fitting protective helmets for approximately 95 per cent of the population of all races.

Information concerning sources of an actual head form or pattern thereof may be obtained by a request addressed to Crager Industries, 5329 East Firestone Boulevard, South Gate, Calif. 90280.

on which the basic plane is marked, shall be positioned on a flat surface so that the basic plane is parallel to this surface. The reference plane shall be scribed on the helmet after it has been positioned on the test head so that the lowermost part of the leading edge at the front of the helmet is 2.36 in. (60 mm) above the basic plane.

**13.2 Low Temperature Box.** A controlled, mechanically-tooled temperature box at least 2 × 2 × 2 feet inside dimensions shall be available with controlled temperature capability of −10°C + 2°C. It shall hold the prescribed temperature for a minimum of 24 hours.

**13.3 High Temperature Box.** A controlled temperature box at least 2 × 2 × 2 feet inside dimensions shall be available with controlled temperature capability of 50°C + 2°C. It shall hold the prescribed temperature for a minimum of 24 hours.

**13.4 Acceleration Transducer.** The acceleration transducer shall have a natural frequency of 20,000 cycles per second or greater and be capable of withstanding a 2,000 G's shock without damage.

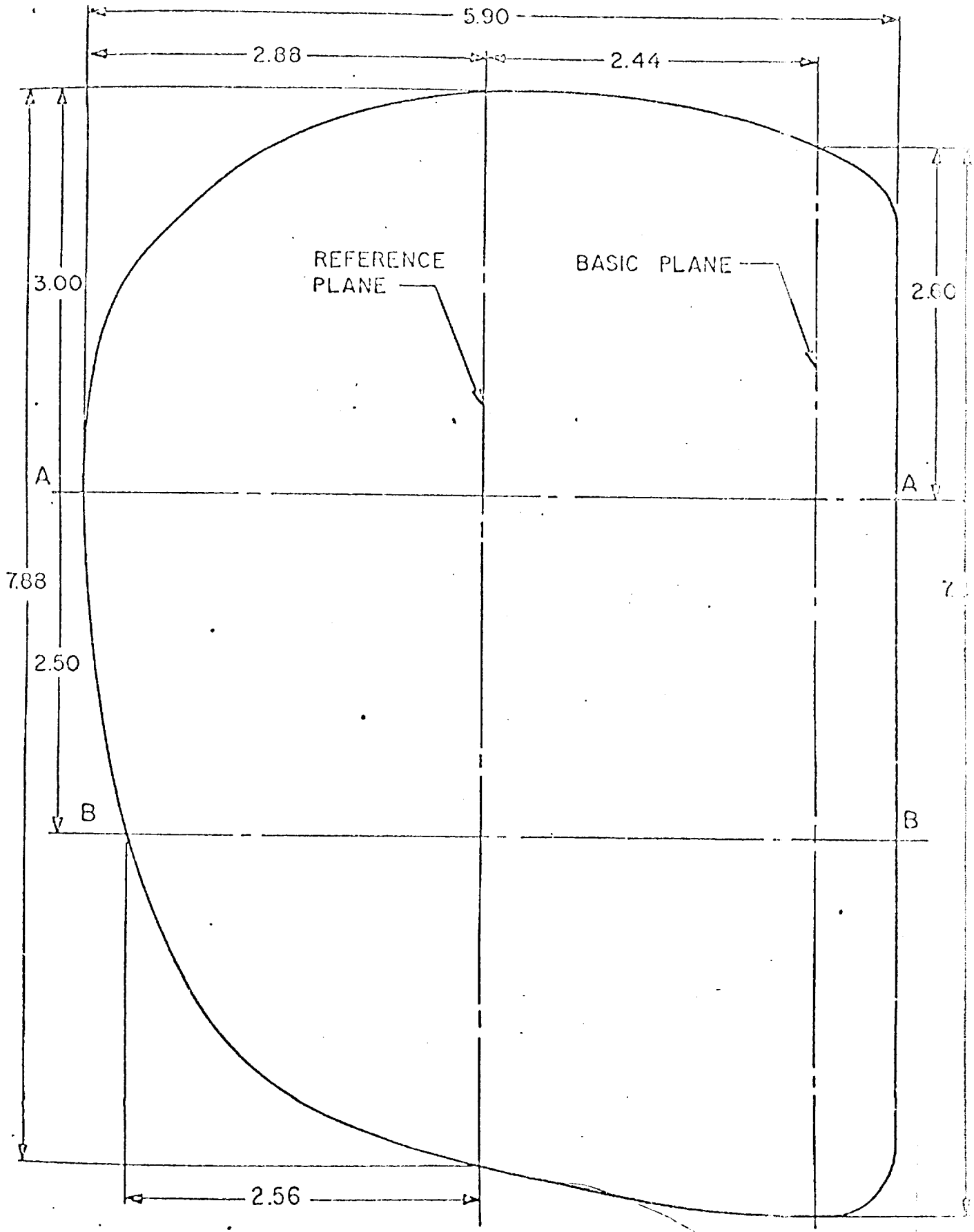


**Fig. 1**
**Contour at ℄**
**Standard Test Head Form for Vehicular Helmet**

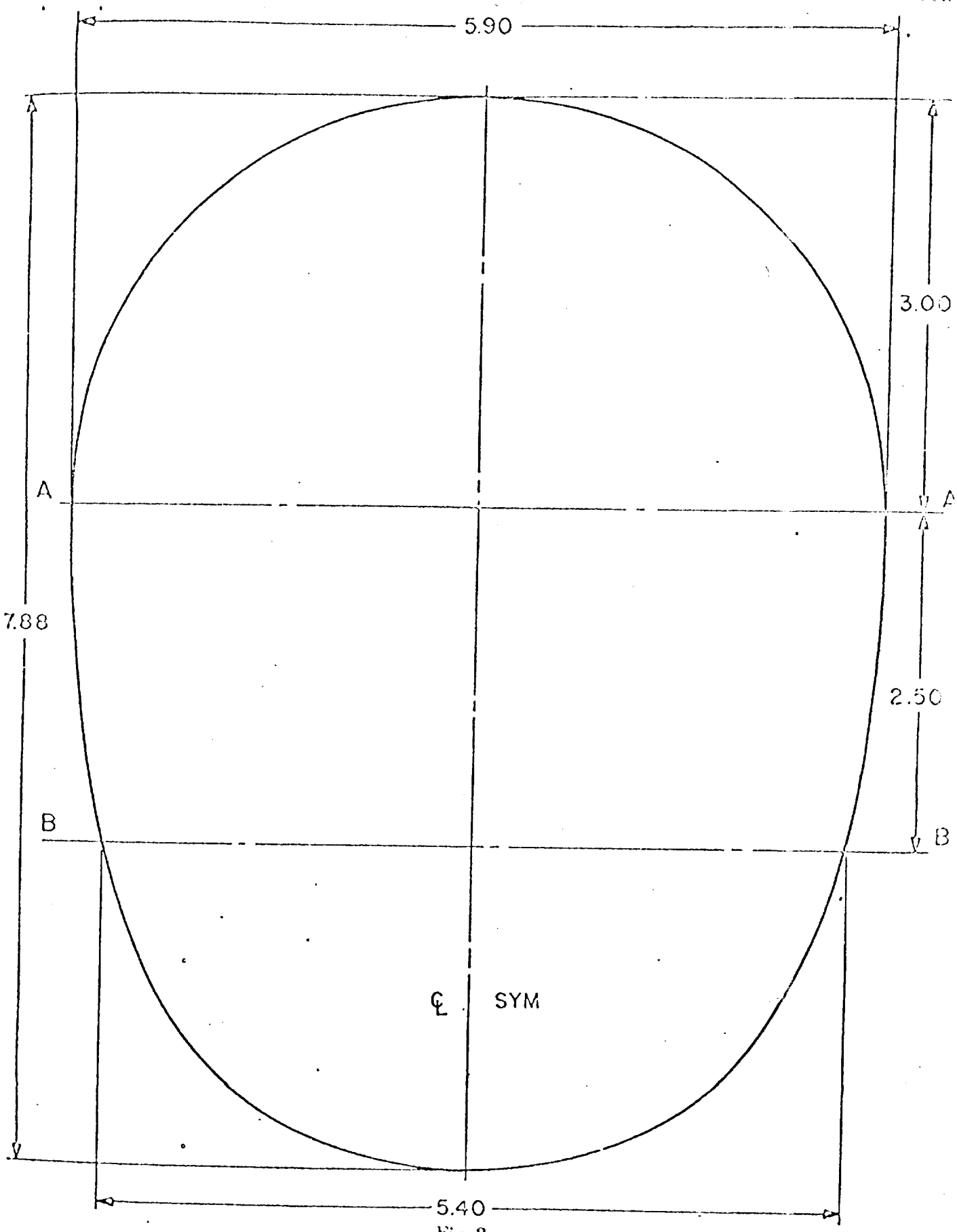


Fig. 2
Contour at Reference Plane
Standard Test Head Form for Vehicular Helmet

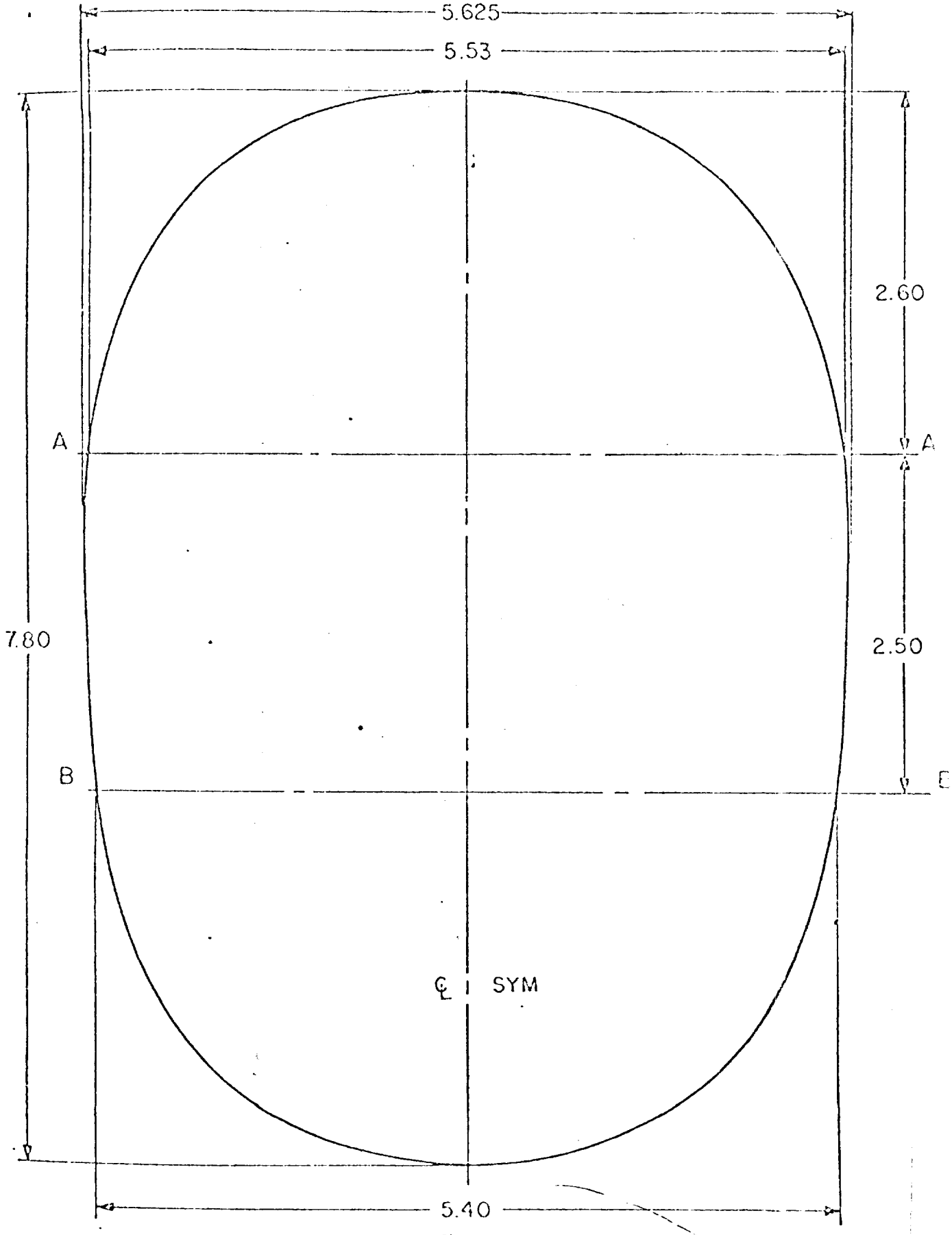


Fig. 3
Contour at Basic Plane
Standard Test Head Form for Vehicular Helmet

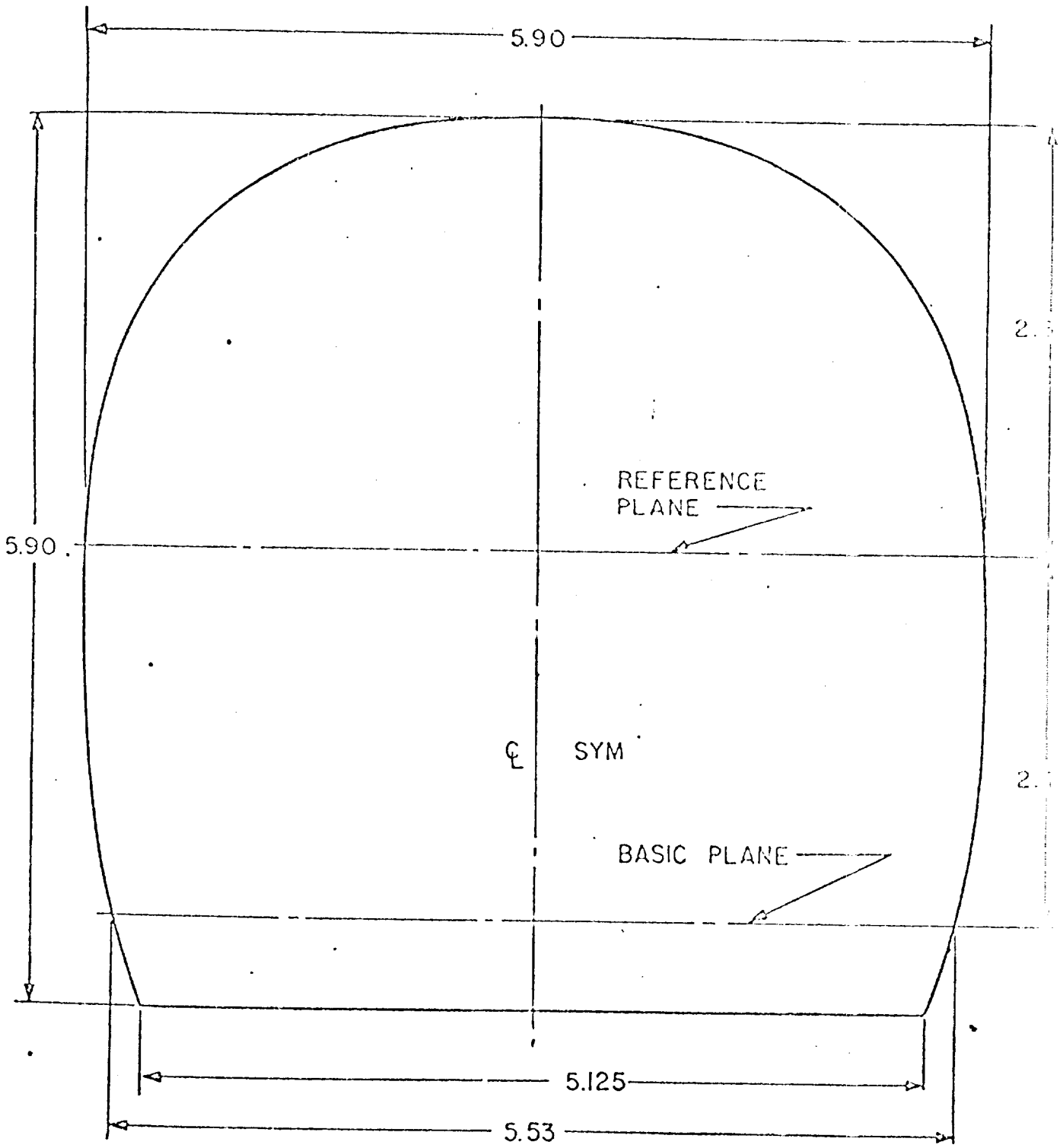


Fig. 4
Contour at Plane A-A
Standard Test Head Form for Vehicular Helmet

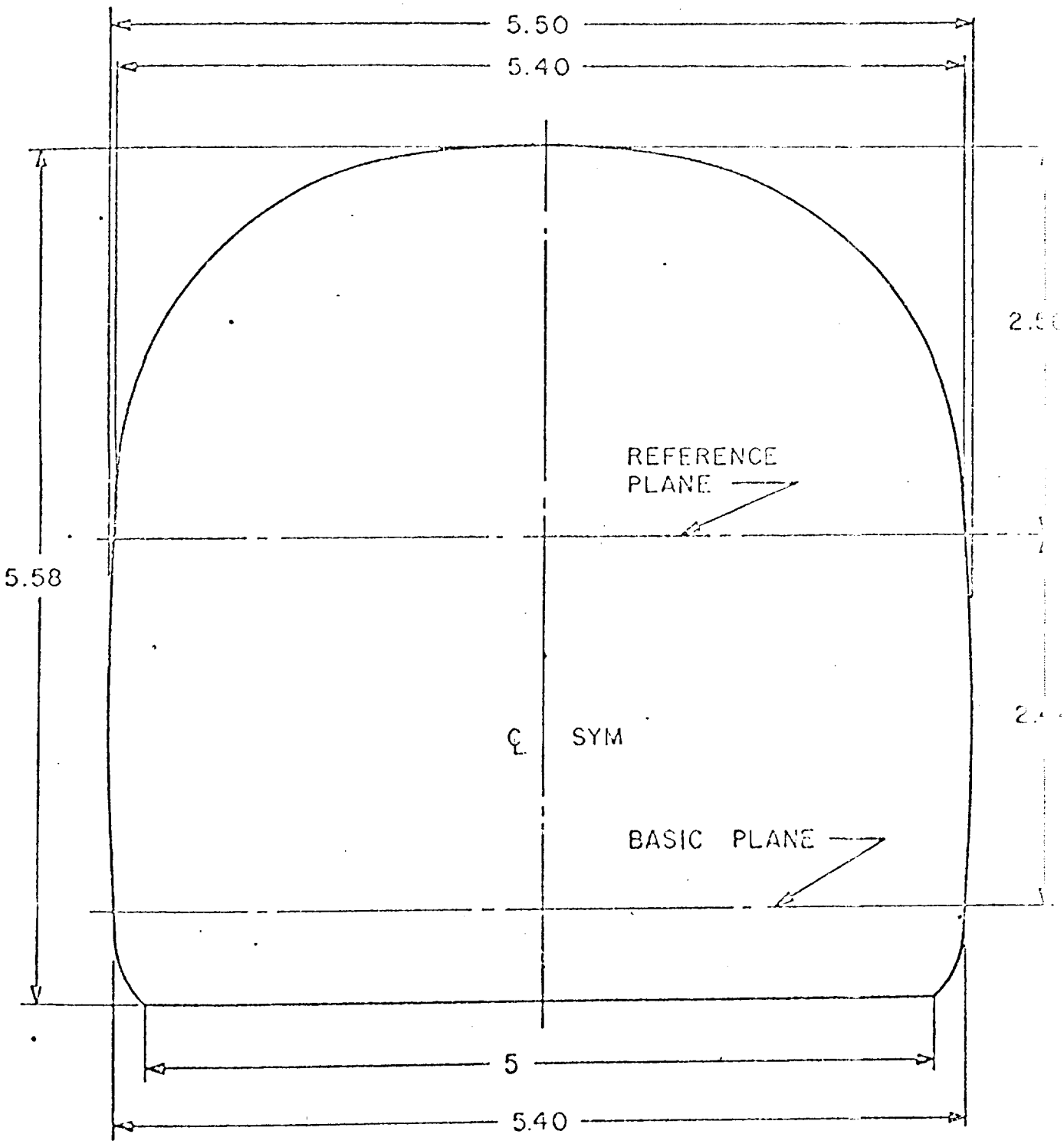


Fig. 5
Contour at Plane B-B
Standard Test Head Form for Vehicular Helmet

# AMERICAN STANDARDS

The standard in this booklet is one of over 2,600 standards approved to date by the American Standards Association, Incorporated.

The ASA provides the machinery for creating voluntary standards. It serves to eliminate duplication of standards activities and to weld conflicting standards into single, nationally accepted standards under the designation "American Standards."

Each standard represents general agreement among maker, seller, and user groups as to the best current practice with regard to some specific problem. Thus the completed standards cut across the whole fabric of production, distribution, and consumption of goods and services. American Standards, by reason of ASA procedures, reflect a national consensus of manufacturers, consumers, and scientific, technical, and professional organizations, and governmental agencies. The completed standards are used widely by industry and commerce and often by municipal, state, and federal governments.

The ASA, under whose auspices this work is being done, is the American clearinghouse and coordinating body for standards activity on the national level. Founded in 1918, it is a federation of 135 trade associations, technical societies, professional groups, and consumer organizations. Some 2,000 companies are affiliated with the ASA as company members.

ASA is the United States member of the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), and the Pan American Standards Commission (COPANT). Through these channels American industry makes its position felt on the international level. American Standards are on file in the libraries of the national standards bodies of more than 50 countries.

For a free list of all American Standards or information about membership in the ASA, write:

**American Standards Association**
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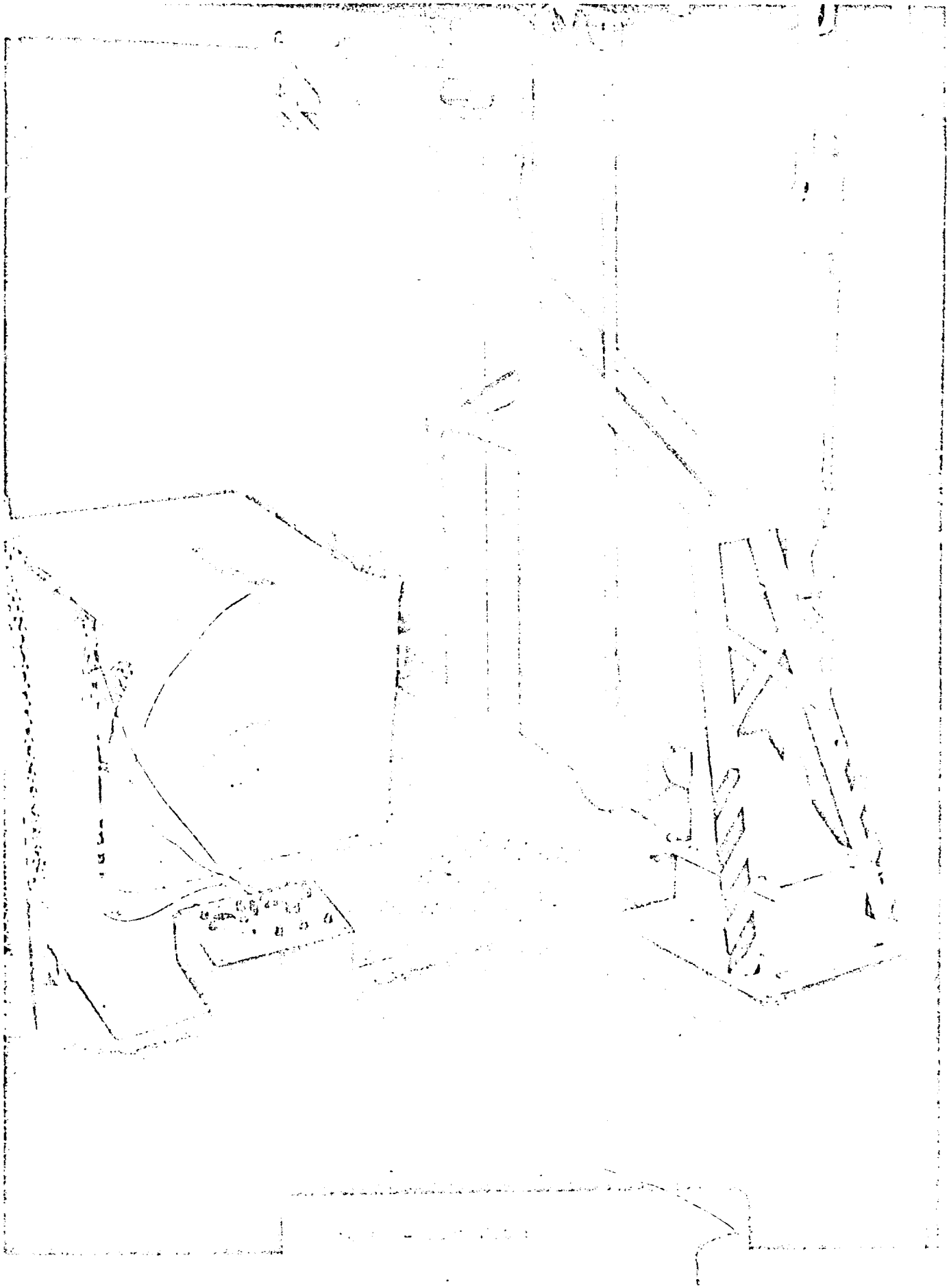
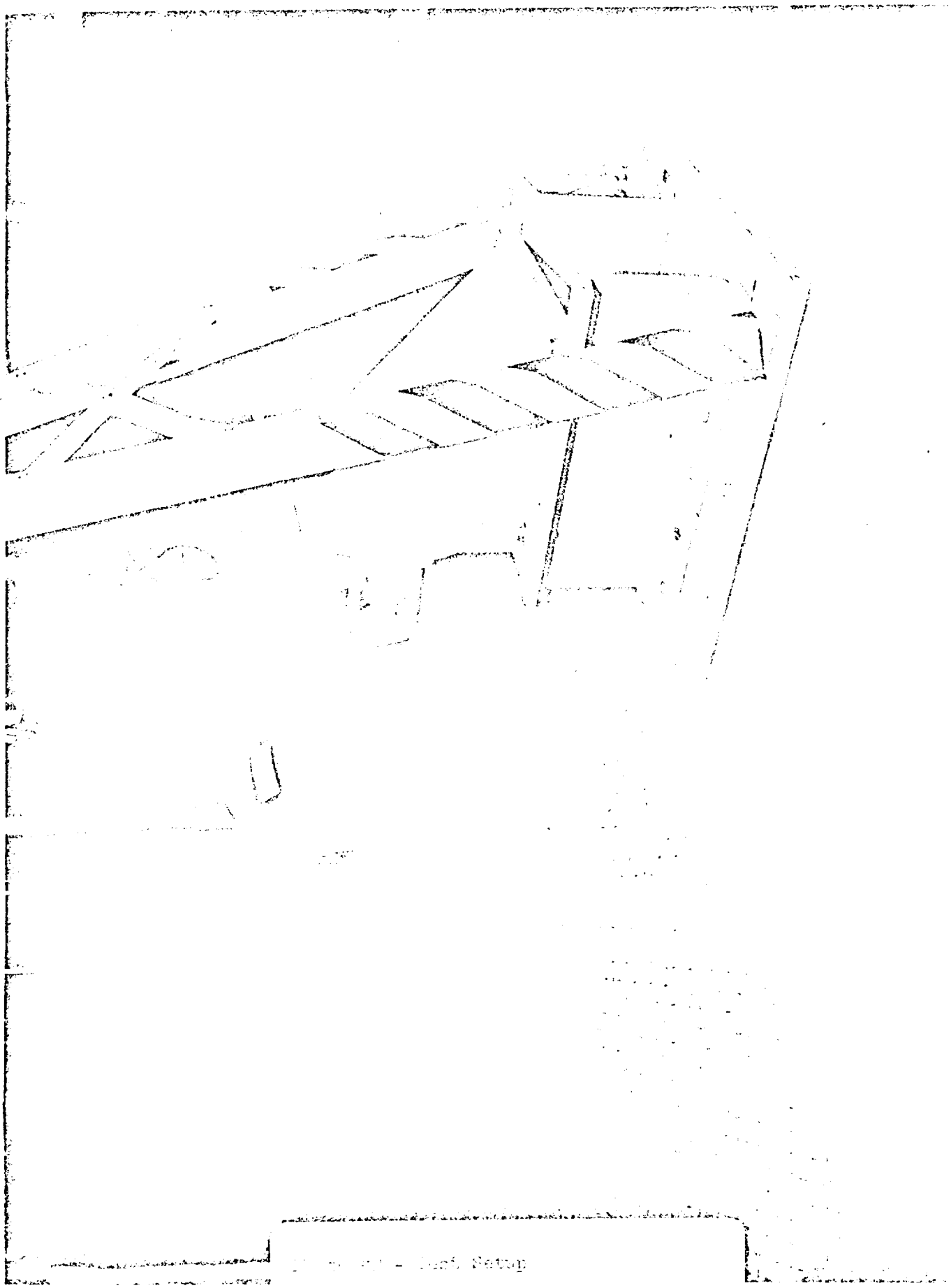
# APPENDIX IV

## Photographs





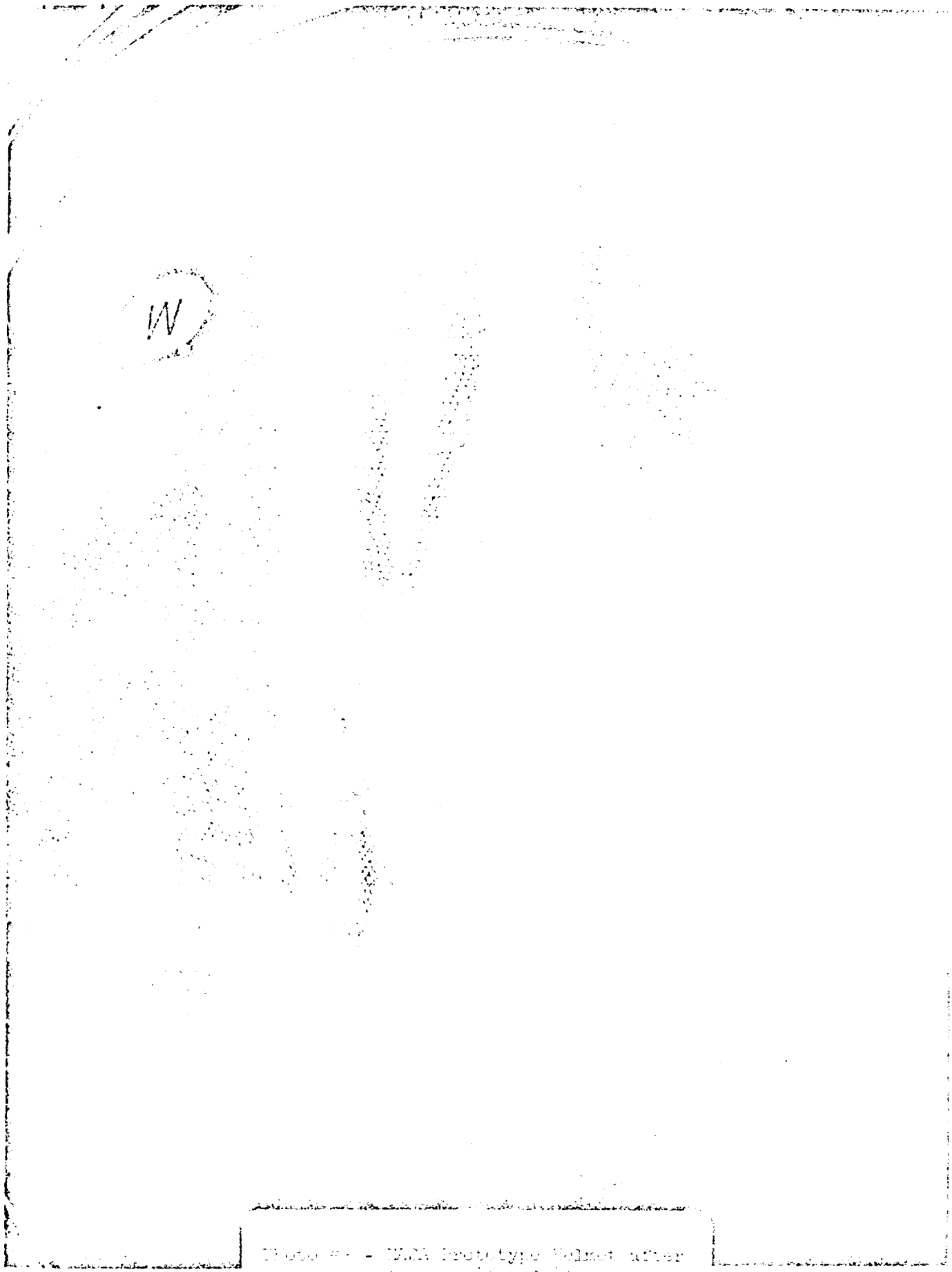


Photo #[illegible] - [illegible] Prototype Helmet after Impacts #[illegible] and #[illegible]

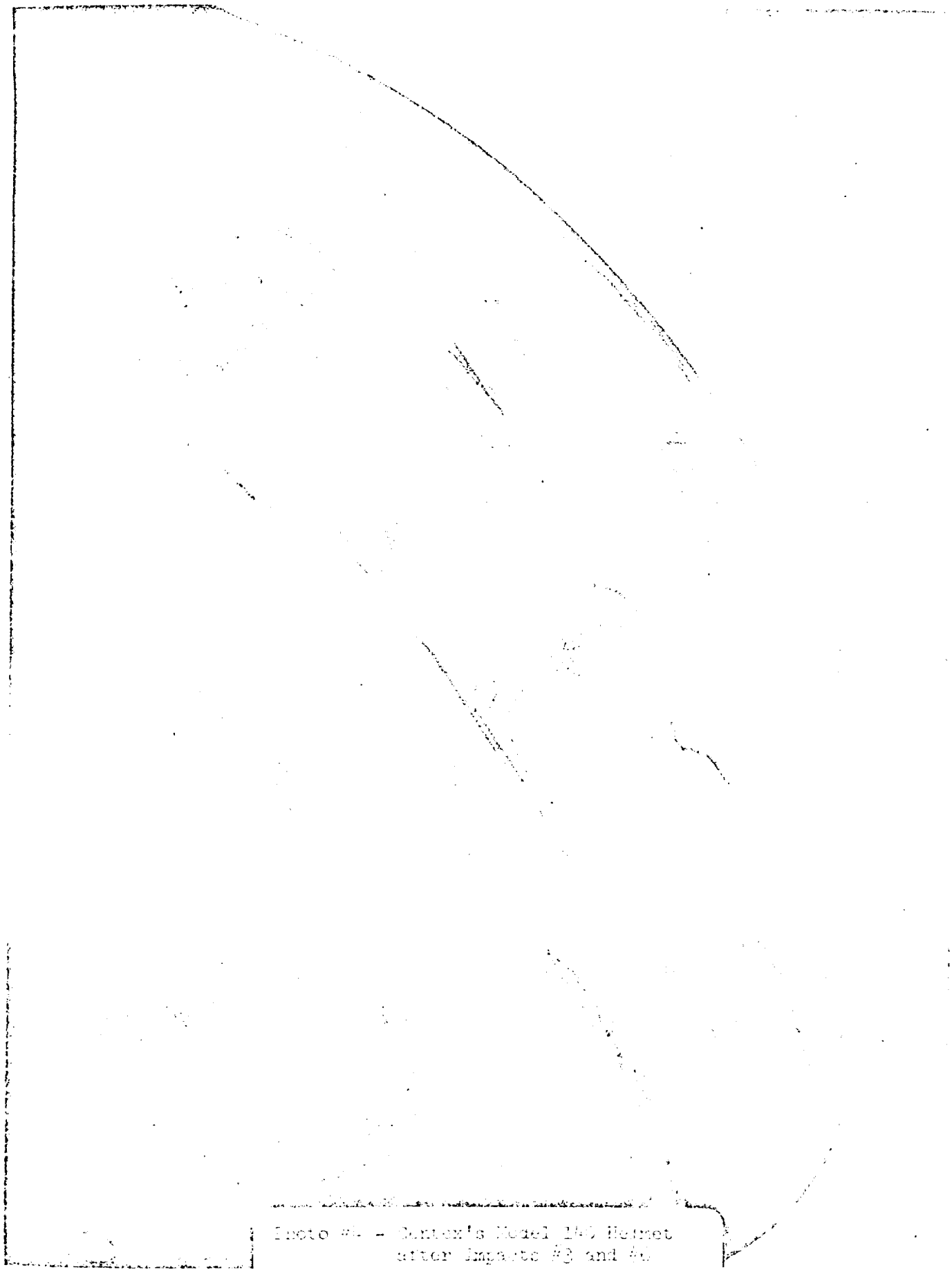


Photo #4 - Bantex's Model 140 Helmet
after Impacts #3 and #4

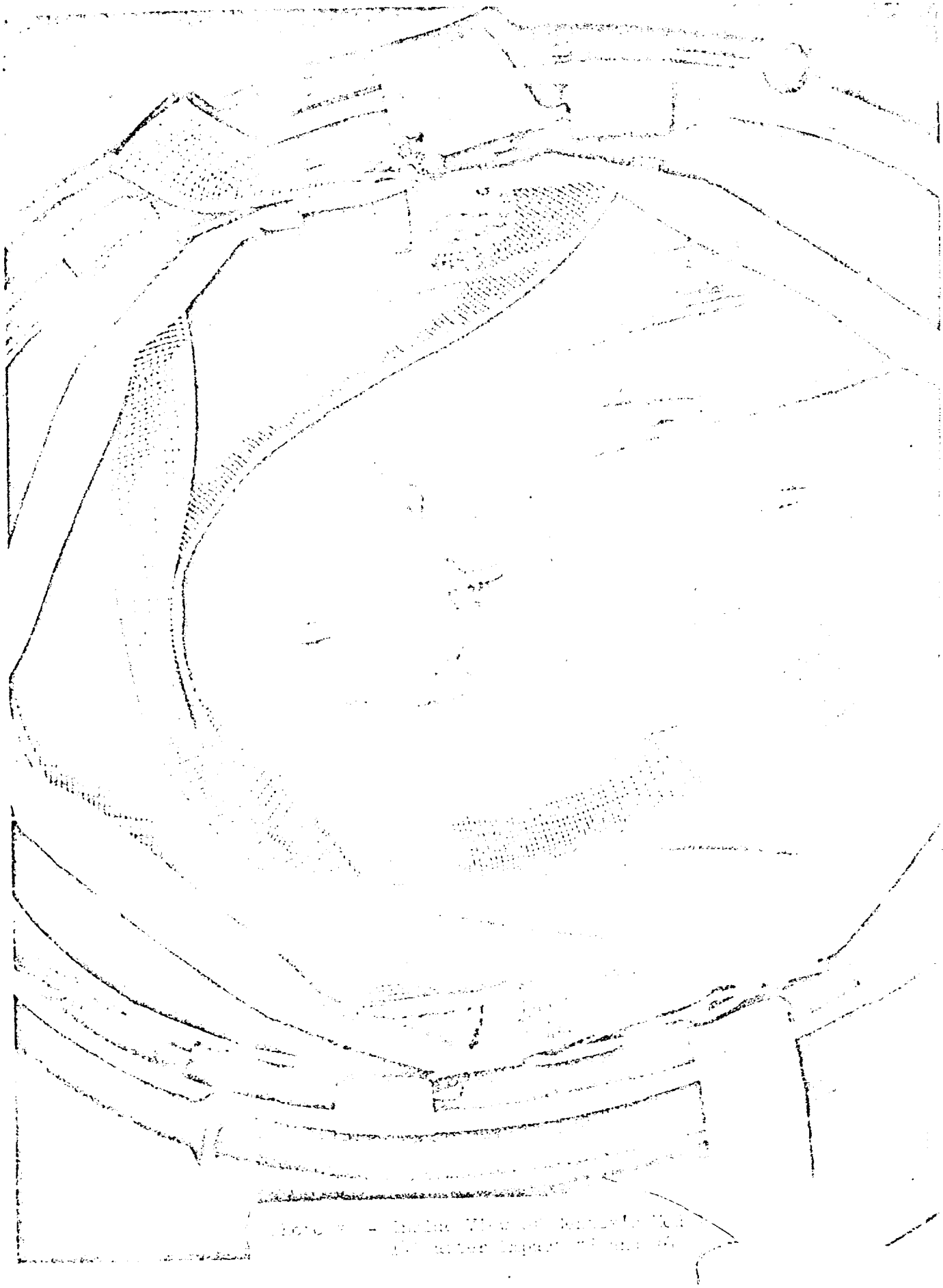
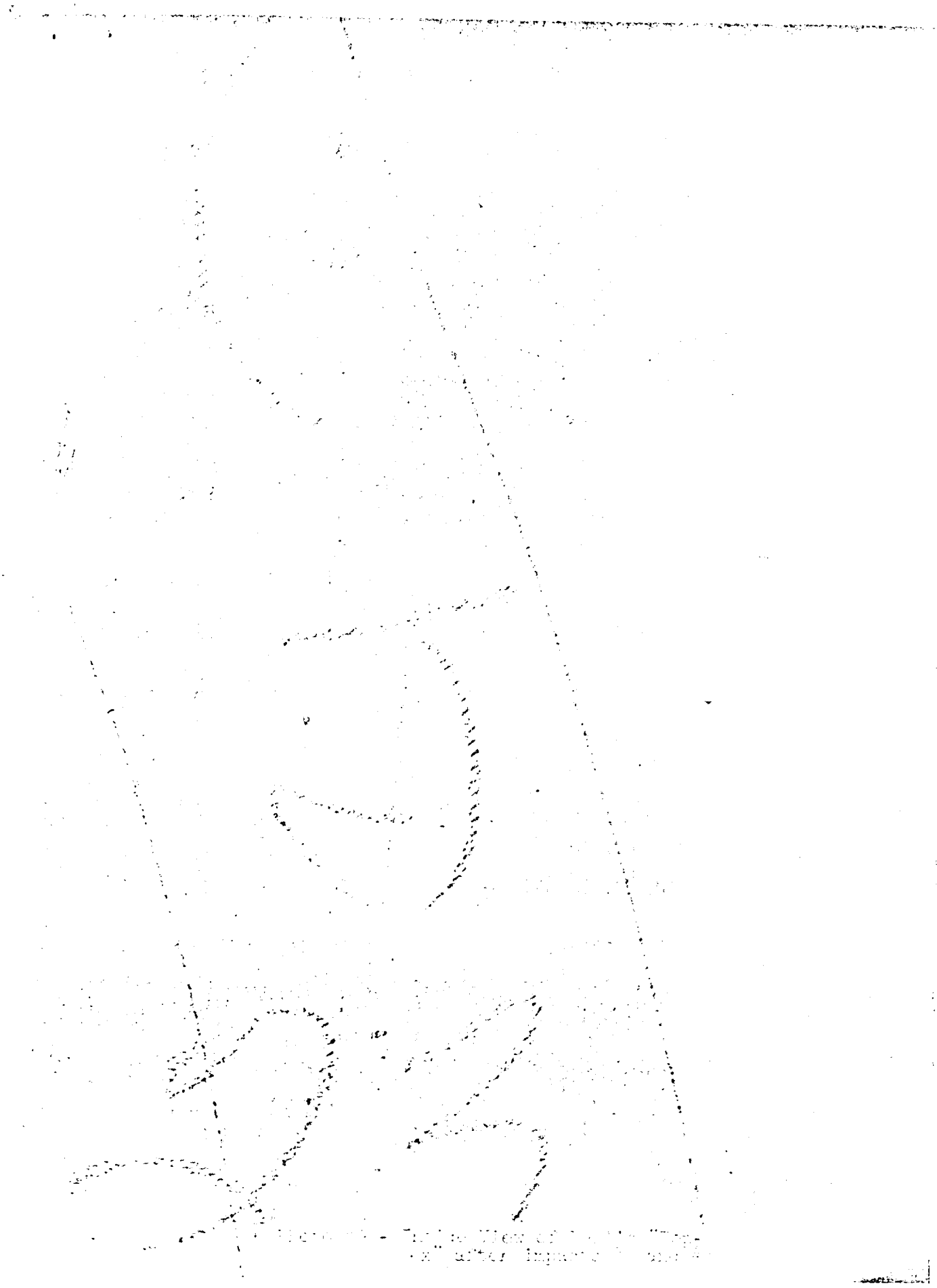


Photo #7 - Inside View of Pu Lard's "Hardboiled" Helmet after Impacts #2 and #7

Photo [illegible] - Bell's "Top-Tex" Helmet after impacts # - and #[illegible]



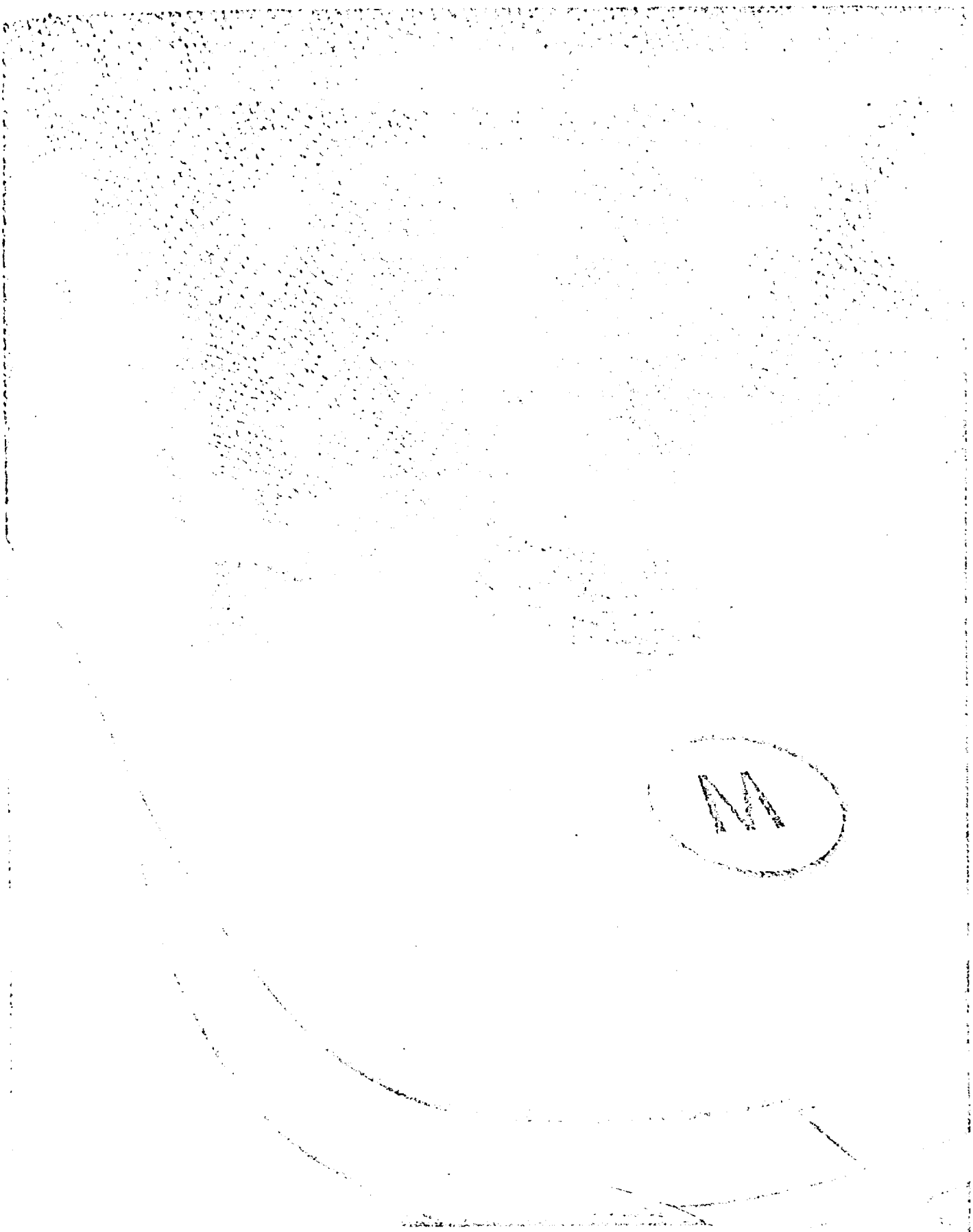


Photo #10 - NASA Prototype Helmet Showing Scuff Marks After Impacts #9 and #14

Figure [illegible] - [illegible]'s Model [illegible]
Drawing Area of [illegible]
[illegible]

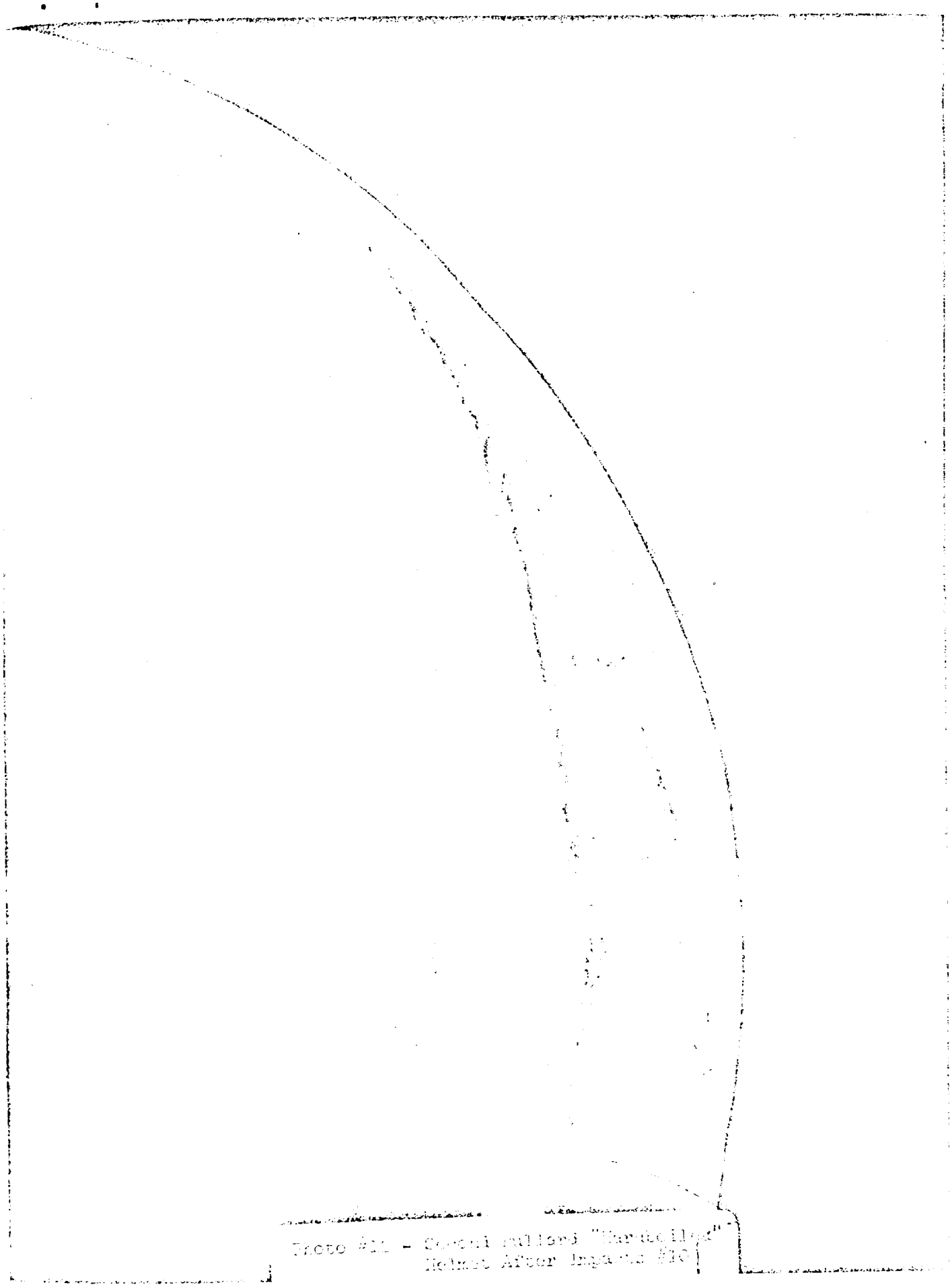


Photo #11 - Second Pullard "Hardboiled"
Helmet After Impacts #10

Photo #13 - Inside View of Second Bullard "Hardboiled" Helmet After Impacts #10 and #[illegible]

Photo #16 - Bell's "Crop-Lok" Helmet
After Impacts #11 and #13

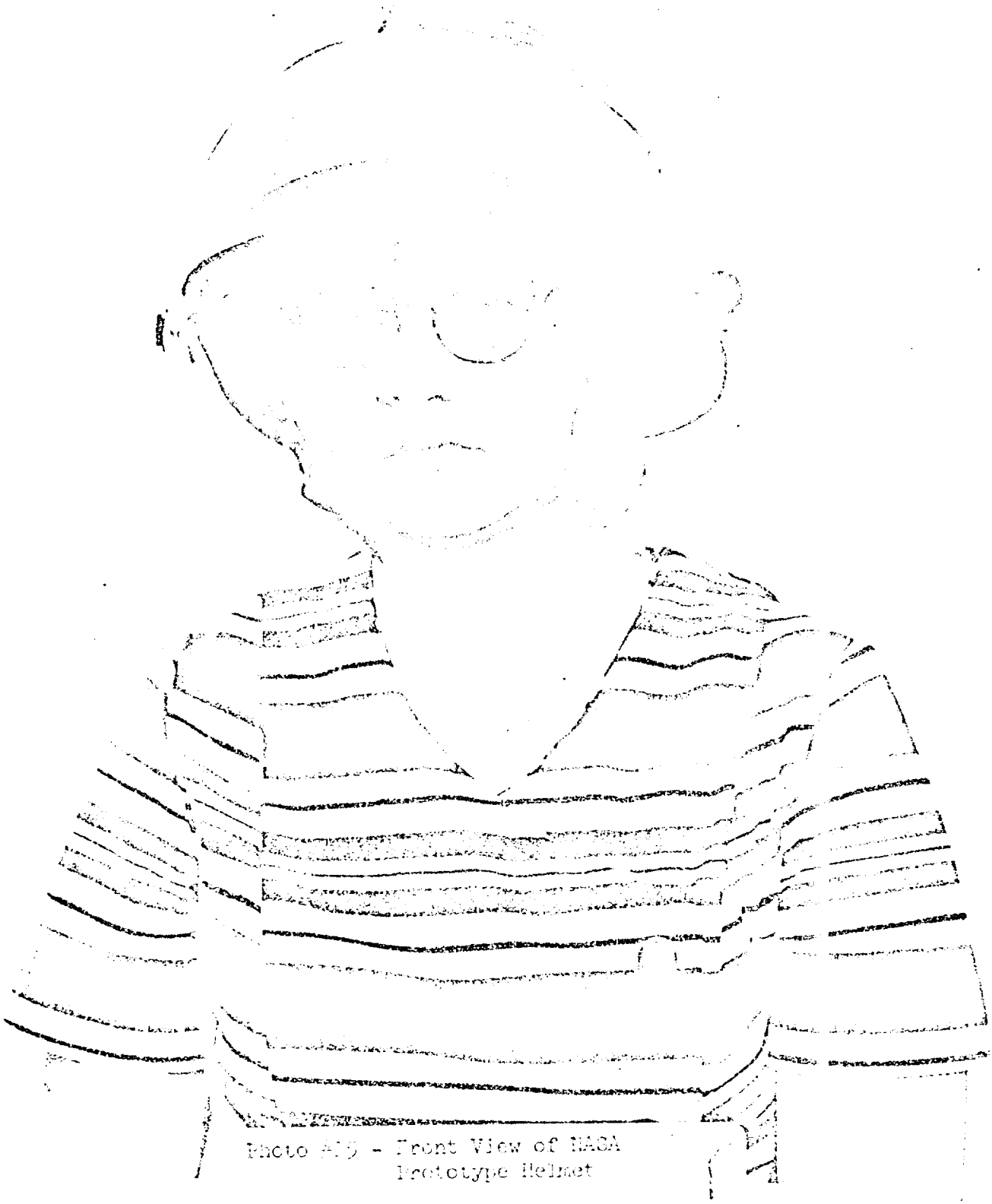


Photo #19 - Front View of NASA
Prototype Helmet

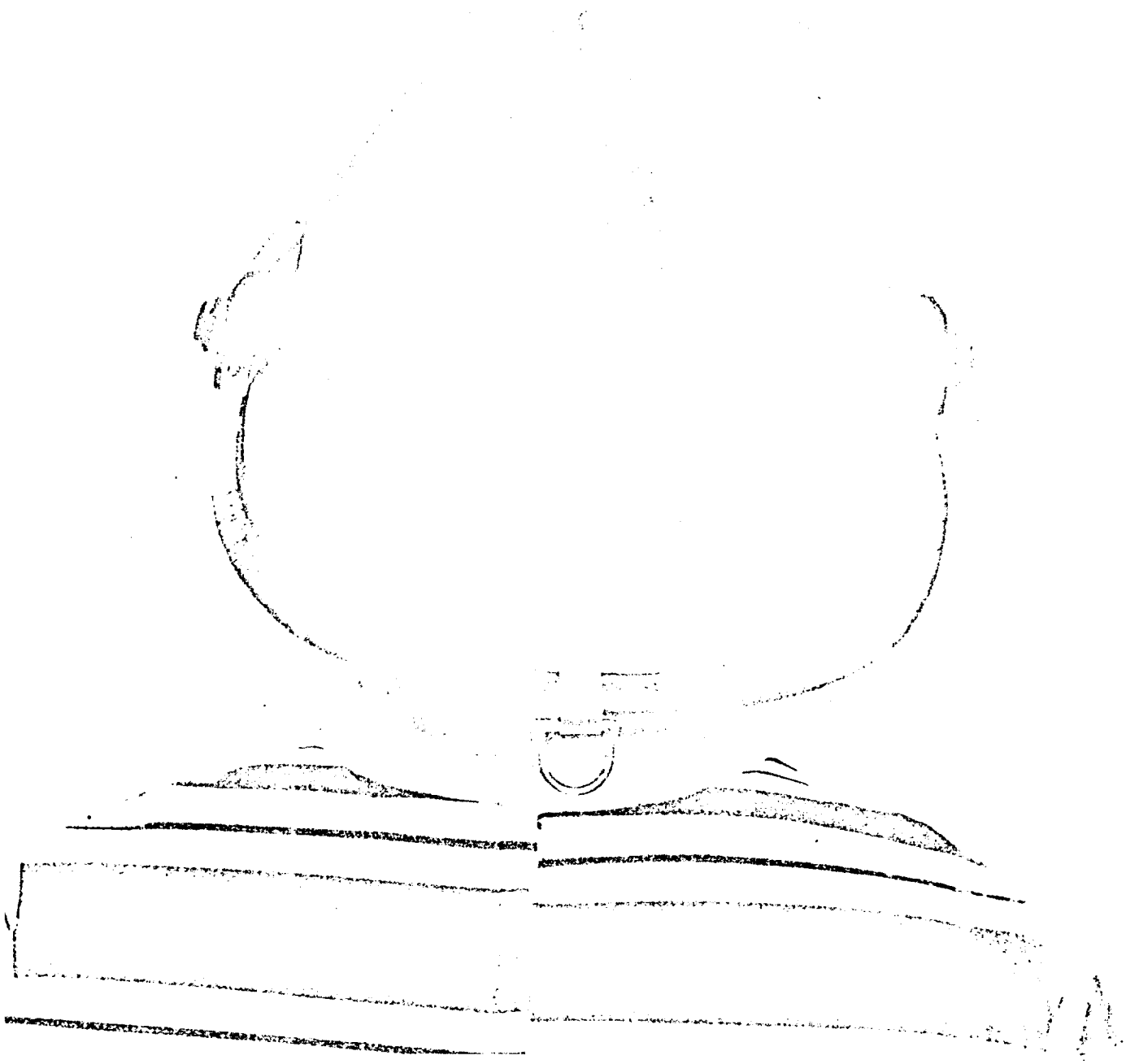


Photo [illegible] - Side View of NASA [illegible]
[illegible]

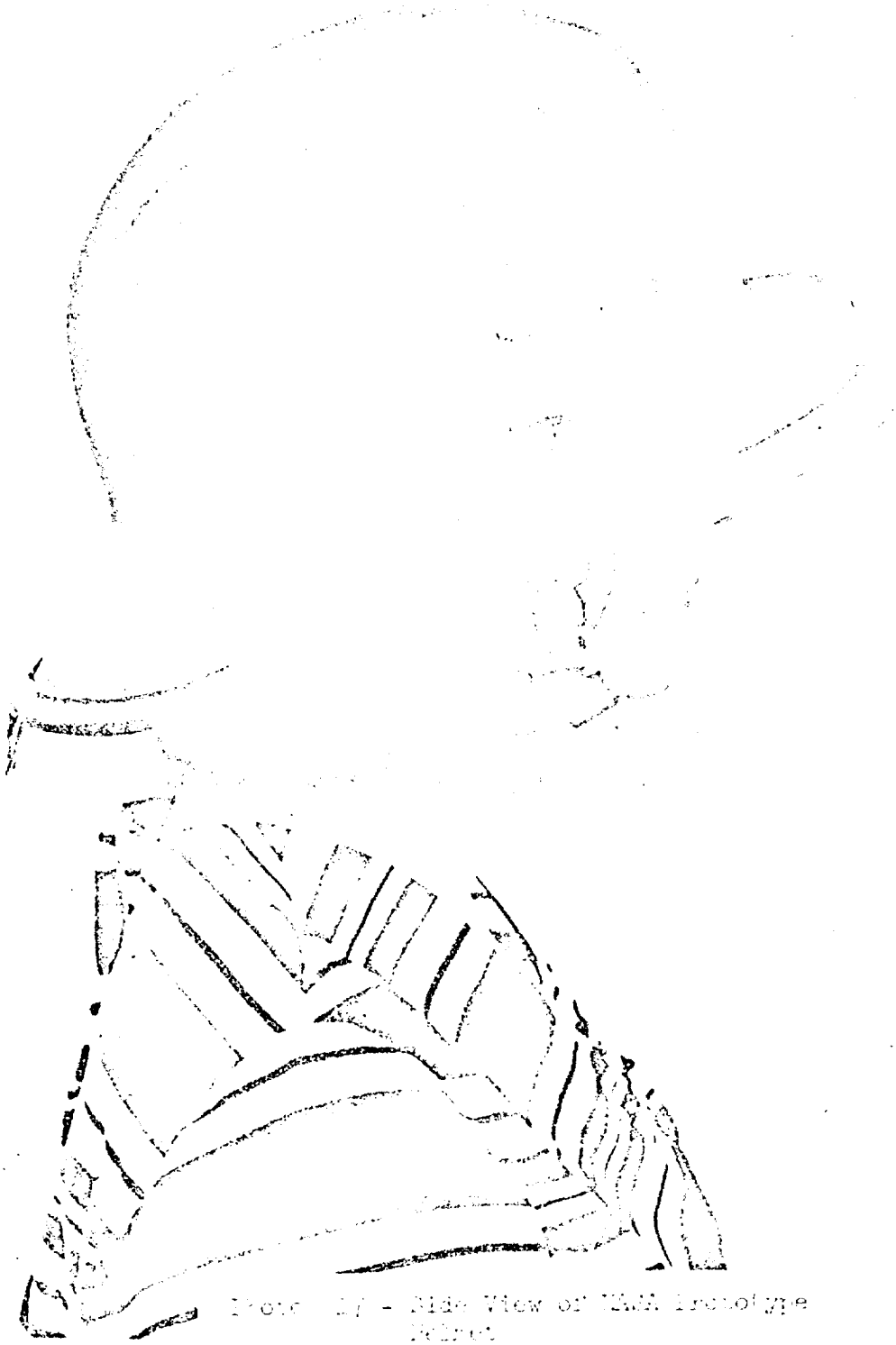


Photo 17 - Side View of NASA Prototype Helmet