AD-A092 072 NEW MEXICO INST OF MINING AND TECHNOLOGY SOCORRO TER--ETC F/G 19/1
HIBAL PROGRAM. PRELIMINARY WARHEAD-DESIGN. VOLUME II. APPENDICE--ETC(U)
SEP 80 N00024-79-C-5333
UNCLASSIFIED NMT/TERA-T-80-1356-U-VOL- NL

1 of 2

NMT/TERA-[illegible]-T-80-1356-U

HIBAL PROGRAM
PRELIMINARY WARHEAD-DESIGN
VOLUME II
(APPENDICES)

PREPARED FOR

NAVAL SEA SYSTEMS COMMAND
CODE: 62R54
WASHINGTON, D. C. 20632

CONTRACT NO. N00024-79-C-5333

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15 SEPTEMBER 1980

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IN REPLY REFER TO
G34:ARH:dmc
8800
OCT 03 1980

From: Commander, Naval Surface Weapons Center
To: Distribution

Subj: HIBAL Program, Preliminary Warhead Design

Encl: (1) NMT/TERA Report No. T-80-1356-U HIBAL Program Preliminary Warhead Design Volume I
(2) NMT/TERA Report No. T-80-1356-U HIBAL Program Preliminary Warhead Design Volume II (appendices)

1. The HIBAL Program was initiated in FY79 as part of the Army/Navy Area SAM Advanced Prototyping Program in NAVSEA 62R5 to develop and demonstrate new fragmentation warhead technology for defeat of bomber aircraft. The program is being conducted by the New Mexico Institute of Mining & Technology with technical support from NSWC and NWC/CL. The primary emphasis has been on obtaining fuel ingestion kills by penetrating through the large bomber fuel tanks with a relatively large fragment having good hydrodynamic penetration capability. This same fragment design has also been shown to yield improved capability against aircraft engines and on-board ordnance. The enhancement in end-game effectiveness has been found to produce not only higher probability-of-kill (P_k) but also a redundancy of killed components which should yield reduced susceptibility of P_k to future changes in target descriptions and vulnerability models. Development of this technology is nearing completion with the final Prototype Demonstrations scheduled for early FY81.

2. In the course of this program, a considerable amount of warhead technology has been developed in the areas of liquid penetration, fuel dump capability and fragmentation control. A series of four reports is planned to document this technology to ensure maximum utilization of this data. These reports will include:

a. Fragment Drag through Liquids
b. Vulnerability Modeling Procedures for Fuel Cells
c. Preliminary Warhead Design
d. End Game Analyses

In addition, a separate report will be published documenting the Prototype Demonstration firings against running engines as well as a final report summarizing all work under this program.

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3. Enclosures (1) and (2), Preliminary Warhead Design, are the first published in this series of reports. This report documents the application of the HIBAL fragment designs to four warhead configurations from 80 to 200 lb using both controlled fragmentation, with an opposed grooving technique, and preformed hexagonal fragments. Full scale warhead test results verify the ability to predict warhead performance and establish guidelines to successfully obtain good fireformed HIBAL fragments. These tests have also formed the basis for defining warhead characterizations for each of the HIBAL configurations.

An additional 135 lb warhead and 200 lb annular warhead are currently being tested to verify the new fragmentation control guidelines. These tests will be reported separately.

4. The four HIBAL configurations were selected to be compatible with current and projected missile systems. These designs represent Advanced Development Concepts. Application of the HIBAL technology to a specific missile system warhead design will require more extensive design tradeoffs in a number of areas including threat spectrum weighting, encounter conditions, warhead size, warhead shape, length-to-diameter ratio, and structural design.

L.N. WILLIAMS, III
BY DIRECTION

NMT/TERA NO. T-80-1356-U

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APPENDIX I

SUMMARY OF FRAGMENT MAT TESTS CONDUCTED IN SUPPORT OF THE FIREFORMED FRAGMENT WARHEAD DESIGNS

APPENDIX I

SUMMARY OF FRAGMENT MAT TESTS CONDUCTED IN SUPPORT OF THE FIREFORMED FRAGMENT WARHEAD DESIGNS

The test program began in January, 1980 with a series of fragment mat tests. The purpose of these tests was to provide for preliminary investigation of some of the parameters influencing the opposed groove technique. Most of the tests were unsuccessful attempts to fireform fragments of the desired shape and weight, and were useful only in a negative sense - providing data on what choices of opposed groove designs won't work. The details of all the tests and their results are presented in tables I-1 through I-6. The tables are cross referenced with the drawings of the fragment mats, figures I-1 though I-19).

Summary of Test Results

The three most significant results of the mat test program were:

1. The tests demonstrated that wide groove angles (90 to 120 degrees) required a relatively dense inert filler material, such as steel, copper, or lead had to be placed in the outside grooves to achieve proper fragment fireforming.

2. 4130 steel was selected as the baseline warhead case material because more success was achieved in generating fragments of the desired shape and weight with this material.

3. Opposed groove depths for the 8-inch O.D. fireformed warhead were provided.

TABLE I-1

TEST DATA FOR 1-1/8" DIAMETER x 3/8" THICK CIRCULAR FRAGMENTS

TEST NO. PNO----0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS — H. E. SIDE: GROOVE ANGLE (DEGREES)	GROOVE CHARACTERISTICS — H. E. SIDE: GROOVE ANGLE (INCHES)	GROOVE CHARACTERISTICS — OUTSIDE: GROOVE ANGLE (DEGREES)	GROOVE CHARACTERISTICS — OUTSIDE: GROOVE ANGLE (INCHES)	FILLER MATERIAL	FRAGMENT CHARACTERISTICS: RECOVERED FRAGMENT WEIGHT (GRAINS)	FRAGMENT CHARACTERISTICS: CALCULATED THEORETICAL WEIGHT (GRAINS) ALLOWS FOR GROOVING LOSS	FRAGMENT CHARACTERISTICS: % RECOVERED WT. / THEORETICAL WT.	COMMENTS
118A	CRS	1	90	1/8	90	1/8	ALUMINUM	473	637	74.2	Failed at 45° from bottom of inside groove, toward rough edge outside.
118B	CRS	1	90	1/8	90	1/8	STEEL	585	637	91.8	Extremely smooth sides, good fragment.
121A	CRS	1	120	1/8	120	3/32	COPPER	465	608	76.5	Failed at 45° from bottom of inside groove, toward outside rough edge.
121B	CRS	1	120	3/32	120	3/32	MAGNESIUM	415	642	64.6	Very poor fragment, neighbors borrowed center.
121C	CRS	1	120	3/32	120	1/16	COPPER	622	668	93.1	Smooth, but sharp edge.
122A	4130	1	120	3/32	120	3/32	STEEL	NOT RECOVERED	642	-----	Fragment was not recovered.
122B	4130	1	90	1/8	90	1/8	RUBBER	528	637	82.9	Similar to 118A above.
122C	4130	1	90	1/8	90	1/8	CERRO-TRU	658	637	103.0	Similar to 121C above.
122D	4130	1	120	3/32	120	1/8	STEEL	NOT RECOVERED	608	-----	Fragment was not recovered.

NOTE: All fragments were fired from a 6-1/2" x 6-1/2" x 6-1/2" box, with the booster located at the center of the rear of the box. Estimated fragment initial velocity is 5900-ft/sec.

TABLE I-1 (continued)

TEST DATA FOR 1-1/8" DIAMETER x 3/8" THICK CIRCULAR FRAGMENTS

TEST NO. PHO---0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS H. E. SIDE GROOVE ANGLE (DEGREES)	GROOVE CHARACTERISTICS H. E. SIDE GROOVE ANGLE (INCHES)	GROOVE CHARACTERISTICS OUTSIDE GROOVE ANGLE (DEGREES)	GROOVE CHARACTERISTICS OUTSIDE GROOVE ANGLE (INCHES)	FILLER MATERIAL	FRAGMENT CHARACTERISTICS RECOVERED FRAGMENT WEIGHT (GRAINS)	FRAGMENT CHARACTERISTICS CALCULATED THEORETICAL WEIGHT (GRAINS) ALLOWS FOR GROOVING LOSS	FRAGMENT CHARACTERISTICS % RECOVERED WT. / THEORETICAL WT.	COMMENTS
122E	4130	1	120	1/16	120	1/16	COPPER	653	694	94.1	Borrowed at center, med. rough edge.
122F	4130	1	120	1/16	120	1/32	CERRO-TRU	662	711	93.1	Similar to 122E.
122G	CRS	1	90	1/16	90	1/16	CERRO-TRU	685	712	96.0	Similar to 122E and 122F.

NOTE: All fragments were fired from a 6-1/2" x 6-1/2" x 6-1/2" box, with the booster located at the center of the rear of the box. Estimated fragment initial velocity is 5900-ft/sec.

TABLE I-2

TEST DATA FOR 1-1/8" DIAMETER x 1/2" THICK CIRCULAR FRAGMENTS

TEST NO. PRO---0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS H. E. SIDE GROOVE ANGLE (DEGREES)	GROOVE CHARACTERISTICS H. E. SIDE GROOVE ANGLE (INCHES)	GROOVE CHARACTERISTICS OUTSIDE GROOVE ANGLE (DEGREES)	GROOVE CHARACTERISTICS OUTSIDE GROOVE ANGLE (INCHES)	FILLER MATERIAL	FRAGMENT CHARACTERISTICS RECOVERED FRAGMENT WEIGHT (GRAINS)	FRAGMENT CHARACTERISTICS CALCULATED THEORETICAL WEIGHT (GRAINS) ALLOWS FOR GROOVING LOSS	FRAGMENT CHARACTERISTICS % RECOVERED WT. / THEORETICAL WT.	COMMENTS
123A	4130	1	30	1/16	30	1/16	LAMINAC	736	771	95.0	Significant "Borrowing" along edges.
123B	4130	1	30	1/16	30	1/32	LAMINAC	621	774	80.0	Failure = 45° to Groove Sides.
123C	4130	1	90	1/16	90	1/16	LAMINAC	NOT WEIGHED	755	----	Fragment scabbed.
123D	4130	1	90	1/16	90	1/16	CERRO-TRU	732	755	97.0	Extremely smooth sides.
123E	4130	1	45	1/16	45	1/16	CERRO-TRU	721	768	94.0	Extremely smooth sides.
124A	4340	1	90	1/16	90	1/16	CERRO-TRU	725	755	96.0	First sweep test, borrowing along edges.
124B	4340	1	45	1/8	45	1/8	PLASTIC / CERRO	564	739	76.0	Cerro half of frag O.K., Laminac half no good.

NOTE: All fragments were fired from a 6-1/2" x 6-1/2" x 6-1/2" box, with the booster located at the center of the rear of the box. Estimated fragment initial velocity is 5900-ft/sec.

TABLE I-3

TEST DATA FOR RECTANGULAR FRAGMENTS 1-1/6" x 11/16" x 1/2" THICK

TEST NUMBER PNO 0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS: EXPLOSIVE SIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	OUTSIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	FILLER MATERIAL	FRAGMENT CHARACTERISTICS: RECOVERED FRAGMENT WEIGHT (Grains)	CALCULATED THEORETICAL WEIGHT (Grains) ALLOWS FOR GROOVING LOSS	% RECOVERED WEIGHT / THEORETICAL WEIGHT	COMMENTS
123F	4340 H.R.	2	45	0.125	45	0.125	45	0.125	45	0.125	LAM.	633	680	0.93	GOOD.
124C	4340 H.R.	2	45	0.063		0.063	45	0.031	45	0.031	LAM. CERRO	696	717	0.97	BORROWING ON ENDS.
124D	4340 H.R.	2	45	0.063	45	0.063	45	0.063	45	0.063	LAM.	702	712	0.99	BORROWING ON ENDS.
125A	4340 H.R.	3	45	0.094	45	0.125	45	0.063	45	0.063	LAM. NONE	718	690	1.04	SOME BORROWING.
125B	4340 H.R.	3	45	0.125	45	0.156	45	0.063	45	0.063	NONE	658	691	0.95	GOOD BREAKOUT ALL AROUND.
125C	CRS*	4	45	0.125	45	0.125	45	0.063	45	0.063	NONE	NOT MEAS.	696	----	MAT BROKE AT SAW-CUTS, NOT GROOVES.
128A	CRS*	5	45	0.130	45	0.140	45	0.063	45	0.063	NONE	NOT MEAS.	693	----	MAT BROKE AT SAW-CUTS, NOT GROOVES.
128B	CRS*	6	45	0.150	45	0.160	45	0.063	45	0.063	NONE	736	684	1.08	"BORROWING" ON ALL FOUR SIDES - NO SHOCK FRACTURE.
129A	CRS*	6	45	0.175	45	0.175	45	0.063	45	0.063	NONE	---	674	----	FRAGMENT NOT RE-COVERED

* The exact material is unknown but based on hardness readings after heat treatment it is presumed to be 1025.

TABLE I-3 (continued)

TEST DATA FOR RECTANGULAR FRAGMENTS 1-1/6" x 11/16" x 1/2" THICK

TEST NUMBER PNO ___0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS – EXPLOSIVE SIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	EXPLOSIVE SIDE: GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	EXPLOSIVE SIDE: GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	EXPLOSIVE SIDE: GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	OUTSIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	OUTSIDE OF MAT: GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	OUTSIDE OF MAT: GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	OUTSIDE OF MAT: GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	FILLER MATERIAL	FRAGMENT CHARACTERISTICS: RECOVERED FRAGMENT WEIGHT (Grains)	CALCULATED THEORETICAL WEIGHT (Grains) ALLOWS FOR GROOVING LOSS	% RECOVERED WEIGHT / THEORETICAL WEIGHT	COMMENTS
129B	CRS*	6	45	0.125	45	0.160	45	0.063	45	0.063	NONE	687	698	98.4	"BORROWING" ON NON-BOOSTER END OF FRAGMENT.
129C	CRS*	7	45	0.125	45	0.160	45	0.063	45	0.063	NONE	750	698	1.07	"BORROWING ON BOOSTER END OF FRAGMENT.
129E	CRS*	7	45	0.094	45	0.160	45	0.063	45	0.063	NONE	733	700	1.05	"BORROWING" ON BOOSTER END OF FRAGMENT.
129F	1018CRS	8	45	0.110	45	0.160	45	0.063	45	0.063	NONE	---	702	----	NO BREAK AT ONE GROOVE PARALLEL TO ROLLING GRAIN.
130B	1018CRS	8	45	0.110	45	0.175	45	0.063	45	0.063	NONE	---	691	----	NO BREAK AT ONE GROOVE PARALLEL TO ROLLING GRAIN.

* The exact material is unknown but based on hardness readings after heat treatment it is presumed to be 1025.

TABLE I-4

TEST DATA FOR RECTANGULAR FRAGMENTS 1-1/16" x 11/16" x 3/8" THICK

TEST NUMBER PNO___0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS — EXPLOSIVE SIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	GROOVE CHARACTERISTICS — OUTSIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	FILLER MATERIAL	FRAGMENT CHARACTERISTICS: RECOVERED FRAGMENT WEIGHT (Grains)	CALCULATED THEORETICAL WEIGHT (Grains) ALLOWS FOR GROOVING LOSS	% RECOVERED WEIGHT / THEORETICAL WEIGHT	COMMENTS
129D	1018CRS	9	120	0.063	120	0.063	90	0.031	90	0.031		---	511	----	FRAGMENT DID NOT BREAK AT GROOVES.
13CA	1018CRS	9	120	0.063	120	0.063	90	0.094	90	0.094		---	459	----	BREAK STARTED AT OUTSIDE OF LENGTH-WISE GROOVES, BUT NOT COMPLETED.
131A	1018CRS	10	120	0.070	120	0.070	120	0.045	120	0.045		440	495	0.89	FRAGMENT BROKE AT ALL GROOVES.
			45	0.125	45	0.125	45	0.063	45	0.063					
131B	1018CRS	10	120	0.070	120	0.070	120	0.045	120	0.045		---	500	----	FRAG DID NOT BREAK AT GROOVES.
			45	0.094	45	0.094	45	0.063	45	0.063					
131C	1018CRS	11	120	0.040	120	0.040	45	0.063	45	0.063		---	527	----	FRAG BROKE AT END GROOVES, BUT NOT AT LONGITUDINAL.
			45	0.090	45	0.090									
131D	1018CRS	11	120	0.054	120	0.054	120	0.054	120	0.054		477	503	0.95	FRAG BROKE AT ALL GROOVES.
			45	0.090	45	0.090	45	0.090	45	0.090					

TABLE I-4 (continued)

TEST DATA FOR RECTANGULAR FRAGMENTS 1-1/16" x 11/16" x 3/8" THICK

TEST NUMBER PNO___0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS: EXPLOSIVE SIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	GROOVE CHARACTERISTICS: OUTSIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	FILLER MATERIAL	FRAGMENT CHARACTERISTICS: RECOVERED FRAGMENT WEIGHT (Grains)	CALCULATED THEORETICAL WEIGHT (Grains) ALLOWS FOR GROOVING LOSS	% RECOVERED WEIGHT / THEORETICAL WEIGHT	COMMENTS
201A	1018CRS	11	120 / 45	0.054 / 0.125	120 / 45	0.054 / 0.125	45	0.063	45	0.063		444	510	0.87	RESULTS VERY SIMILAR TO 131A.
201B	1018CRS	11	120 / 45	0.054 / 0.094	120 / 45	0.054 / 0.094	45	0.063	45	0.063		---	517	----	FRAG DID NOT BREAK AT LONGITUDINAL GROOVES.
204A	1018CRS	11	120 / 45	0.058 / 0.110	120 / 45	0.058 / 0.110	45	0.063	45	0.063		485	512	0.95	GOOD FRAG -

TABLE I-5

TEST DATA FOR RECTANGULAR FRAGMENTS 1-1/16" x 3/4" x 1/2" THICK

TEST NUMBER PHO___0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS — EXPLOSIVE SIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDI-CULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDI-CULAR TO ROLLING GRAIN (inches)	OUTSIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDI-CULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH-PERPENDI-CULAR TO ROLLING GRAIN (inches)	FILLER MATERIAL	FRAGMENT CHARACTERISTICS: RECOVERED FRAGMENT WEIGHT (Grains)	CALCULATED THEORETICAL WEIGHT (Grains) ALLOWS FOR GROOVING LOSS	% RECOVERED WEIGHT / THEORETICAL WEIGHT	COMMENTS
205A	4340 (AS RECEIVED)	12	120 / 45	0.080 / 0.140	120 / 45	0.080 / 0.140	45	0.080	45	0.080		723	670	1.08	CELOTEX RECOVERY.
206A	4340 (AS RECEIVED)	12	120 / 45	0.080 / 0.140	120 / 45	0.080 / 0.150	45	0.080	45	0.080		504	732	0.69	CRACKED 3' SHEET HIT FLAT ON. (Penetrometer)
206B	4340 RC-42 800° DRAW	12	120 / 45	0.080 / 0.140	120 / 45	0.080 / 0.150	45	0.080	45	0.080		502	732	0.68	DENTED 3' SHEET HIT FLAT ON. (Penetrometer)
206C	4340 725° DRAW RC-47	12	120 / 45	0.080 / 0.140	120 / 45	0.080 / 0.150	45	0.080	45	0.080		357	732	0.49	FRAGMENT SPALLED NO VISIBLE AL. ON RECOVERED FRAGMENT. (Penetrometer)
207A	4340 750° DRAW RC-50	12	120 / 45	0.080 / 0.140	120 / 45	0.080 / 0.150	45	0.080	45	0.080		240	732	0.33	FRAGMENT BROKE UP (Penetrometer)
207B	4340 900° DRAW RC-40	12	120 / 45	0.080 / 0.140	120 / 45	0.080 / 0.150	45	0.080	45	0.080		485	732	0.66	FRAGMENT HIT END ON PENETRATED SHEET 34' NO DENT 35' SHEET PARTIAL SCABBED AL. ON SCABBED PART. (Penetrometer)

TABLE I-5 (continued)

TEST DATA FOR RECTANGULAR FRAGMENTS 1-1/16" x 3/4" x 1/2" THICK

TEST NUMBER PNO___0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS — EXPLOSIVE SIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	GROOVE CHARACTERISTICS — OUTSIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	FILLER MATERIAL	FRAGMENT CHARACTERISTICS: RECOVERED FRAGMENT WEIGHT (Grains)	CALCULATED THEORETICAL WEIGHT (Grains) ALLOWS FOR GROOVING LOSS	% RECOVERED WEIGHT / THEORETICAL WEIGHT	COMMENTS
208A	4340 1000° DRAW RC-33	12	12[illegible] / 45	0.080 / 0.140	120 / 45	0.080 / 0.155	45	0.080	45	0.080		459	732	0.63	DENTED SHEET @ 4'. (Penetrometer)
211A	4340 1000° DRAW RC-33	12	120 / 45	0.080 / 0.140	120 / 45	0.080 / 0.155	45	0.080	45	0.080		---	732	0.62	CELOTEX RECOVERY.
211B	4340 AS RECEIVED	12	120 / 45	0.080 / 0.140	120 / 45	0.080 / 0.155	45	0.080	45	0.080		---	732	----	FRAGMENT NOT FOUND.
212A	304 STAINLESS STEEL	12	120 / 45	0.080 / 0.140	120 / 45	0.080 / 0.155	45	0.080	45	0.080		---	732	----	CELOTEX RECOVERY FRAGMENT SCABBED.
212B	4340 AS RECEIVED	12	120 / 45	0.080 / 0.140	120 / 45	0.080 / 0.155	45	0.080	45	0.080		460	732	0.62	CELOTEX RECOVERY.
212C	4340 AS RECEIVED	12	120 / 45	0.080 / 0.140	120 / 45	0.080 / 0.155	45	0.080	45	0.080		547	732	0.75'	CELOTEX RECOVERY INSIDE GROOVES FILLED WITH LAMINAC.

TABLE I-5 (continued)

TEST DATA FOR RECTANGULAR FRAGMENTS 1-1/16" x 3/4" x 1/2" THICK

TEST NUMBER PNO 0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS: EXPLOSIVE SIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	EXPLOSIVE SIDE OF MAT: GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	EXPLOSIVE SIDE OF MAT: GROOVE ANGLE PERPENDI-CULAR TO ROLLING GRAIN (degrees)	EXPLOSIVE SIDE OF MAT: GROOVE DEPTH PERPENDI-CULAR TO ROLLING GRAIN (inches)	OUTSIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	OUTSIDE OF MAT: GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	OUTSIDE OF MAT: GROOVE ANGLE PERPENDI-CULAR TO ROLLING GRAIN (degrees)	OUTSIDE OF MAT: GROOVE DEPTH PERPENDI-CULAR TO ROLLING GRAIN (inches)	FILLER MATERIAL	FRAGMENT CHARACTERISTICS: RECOVERED FRAGMENT WEIGHT (Grains)	CALCULATED THEORETICAL WEIGHT (Grains) ALLOWS FOR GROOVING LOSS	% RECOVERED WEIGHT / THEORETICAL WEIGHT	COMMENTS
213A	4340 ANNEALED 1625	12	120 / 45	0.080 / 0.140	120 / 45	0.080 / 0.155	45	0.080	45	0.080		531	732	0.73	SHOCK FRACTURE GOOD ON ONLY THREE SIDES.
213B	4340 AS RECEIVED	12	120 / 45	0.080 / 0.140	120 / 45	0.080 / 0.155	45	0.080	45	0.080		530	732	0.72	SHOCK FRACTURE GOOD ON ONLY THREE SIDES
213C	4340 15 MIN HEATTREAT	12	120 / 45	0.080 / 0.140	120 / 45	0.080 / 0.155	45	0.080	45	0.080		541	732	0.74	SHOCK FRACTURE GOOD ON ONLY THREE SIDES.
213D	4340 AS RECEIVED	12	120 / 45 (LAMINAC - FILLED)	0.080 / 0.14?	120 / 45	0.080 / 0.155	45	0.080	45	0.080		502	732	0.69	OUTSIDE CORNERS SCABBED ON THREE SIDES.
214A	4340 AS RECEIVED	13	24 / 26 (SOME BENDING INSIDE GROOVES BY PRESS; 0.140" GROOVE PARRALLEL GRAIN WAS CRACKED)	0.125 / 0.140	30 / 26	0.125 / 0.140	45	0.062	45	0.062		711	689	1.03	CLEAN FRACTURES ON 0.140 DEEP GROOVES, SOME BORROWING ON 1/8 DEEP GROOVES.
214B	1018CRS	14	120 / 45 (1/2 LAMINAC FILLED INSIDE)	0.080 / 0.125	120 / 45	0.080 / 0.125	120	0.062	45	0.062		812	674	1.20	BORROWING ON ALL FOUR SIDES, NO SCABBING.

TABLE I-5 (continued)

TEST DATA FOR RECTANGULAR FRAGMENTS 1-1/16" x 3/4" x 1/2" THICK

TEST NUMBER PNO___0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS: EXPLOSIVE SIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDI-CULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDI-CULAR TO ROLLING GRAIN (inches)	OUTSIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDI-CULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDI-CULAR TO ROLLING GRAIN (inches)	FILLER MATERIAL	FRAGMENT CHARACTERISTICS: RECOVERED FRAGMENT WEIGHT (Grains)	CALCULATED THEORETICAL WEIGHT (Grains) ALLOWS FOR GROOVING LOSS	% RECOVERED WEIGHT / THEORETICAL WEIGHT	COMMENTS
214C	1018CRS	15	30	0.125	30	0.125	45	0.063	45	0.063		810	703	1.15	BORROWING ALL FOUR SIDES, NO SCABBING.
215A	1018CRS	16	37	0.140	37	0.140	45	0.063	45	0.063		444	760	0.58	SCABBED.
215B	4340 AS RECEIVED	17	30	0.140 LAMINAC FILLED	30	0.140	45	0.063	45	0.063		---	---	----	SCABBED.
215C	4340 AS RECEIVED	17	37	0.150 LAMINAC FILLED	37	0.150	45	0.063	45	0.063		---	---	----	BORROWING ALONG OUTSIDE GROOVES.
215D	1018	18	45	0.075 / 0.085 LAMINAC FILLED	45	0.090 / 0.110	45	0.090 / 0.110	45	0.090 / 0.110		---	---	----	0.090" DEEP GROOVE ACROSS GRAIN, DID NOT BREAK
215E	4130 AS RECEIVED	19	45	0.075 / 0.085 LAMINAC FILLED	45	0.085 / 0.120	45	0.075 / 0.085	45	0.085 / 0.120		---	---	----	0.075" DEEP GROOVE PARALLEL TO GRAIN DID NOT BREAK. 0.120" DEEP GROOVE ACROSS GRAIN TOO DEEP. 0.085" LOOKED GOOD BOTH DIRECTIONS.

(This mat 7/16-inch thick)

TABLE I-5 (continued)

TEST DATA FOR RECTANGULAR FRAGMENTS 1-1/16" x 3/4" x 1/2" THICK

TEST NUMBER PNO___0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS – EXPLOSIVE SIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	GROOVE CHARACTERISTICS – OUTSIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	FILLER MATERIAL	FRAGMENT CHARACTERISTICS: RECOVERED FRAGMENT WEIGHT (Grains)	CALCULATED THEORETICAL WEIGHT (Grains) ALLOWS FOR GROOVING LOSS	% RECOVERED WEIGHT / THEORETICAL WEIGHT	COMMENTS
218A	4130 AS RECEIVED	18	45	0.110 0.110	45	0.125 0.115	45	0.100 0.110	45	0.125 0.115	LAMINAC FILLED (ALL GROOVES, INSIDE & OUT)	624	752	0.83	.125" GROOVE ACROSS GRAIN TOO DEEP. .115" GROOVE ACROSS GRAIN O.K. SOME BORROWING ON BOTH GROOVES WITH GRAIN. NO FRAGMENT DAMAGE OR DEFORMATION FROM STEEL.
2183	4130 AS RECEIVED	18	45	0.095	45	0.105	45	0.095	45	0.105	LAMINAC FILLED (ALL GROOVES, INSIDE & OUT)	732	760	0.96	FRAG HIT ON CORNER BETWEEN END & OUTSIDE FACE OF FRAGMENT, SOMEWHAT CORNER ON. NO VISIBLE LOSS IN WEIGHT FROM PLATE IMPACT.
218C	STAINLESS 304 AS RECEIVED	18	45	0.095	45	0.115	45	0.095	45	0.105	LAMINAC FILLED (ALL GROOVES, INSIDE & OUT)	---	---	----	ONE GROOVE PARALLEL TO ROLLING GRAIN DID NOT BREAK. FRAG HIT FLAT-ON, WAS ABOUT 1-1/6"x1-1/4x 1/2" AS RECOVERED AND WEIGHED 1178 GRAINS.

TABLE I-5 (continued)

TEST DATA FOR RECTANGULAR FRAGMENTS 1-1/16" x 3/4" x 1/2" THICK

TEST NUMBER PNO___0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS — EXPLOSIVE SIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDI-CULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDI-CULAR TO ROLLING GRAIN (inches)	OUTSIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDI-CULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDI-CULAR TO ROLLING GRAIN (inches)	FILLER MATERIAL	FRAGMENT CHARACTERISTICS: RECOVERED FRAGMENT WEIGHT (Grains)	CALCULATED THEORETICAL WEIGHT (Grains) ALLOWS FOR GROOVING LOSS	% RECOVERED WEIGHT / THEORETICAL WEIGHT	COMMENTS
218D	4130 AS RECEIVED	18	45 ALL GROOVES LAMINAC FILLED (INSIDE AND OUT)	0.095	45	0.105	45	0.095	45	0.105		728	760	0.96	FRAG HIT ON CORNER BETWEEN INSIDE FACE AND SIDE OF FRAG-MENT NO VISIBLE LOSS IN FRAG WEIGHT FROM IMPACTS
218E	STAINLESS 304 AS RECEIVED	18	45 ALL GROOVES LAMINAC FILLED	0.115	45	0.125	45	0.115	45	0.125		727	747	0.97	"BORROWING" EVIDENT ON 3 SIDES. THE END WHERE NO BORROWING EVIDENCE LOOKS LIKE IT MAY HAVE BROKEN OFF IN CELOTEX.
218F	4130 AS RECEIVED	18	45 ALL GROOVES LAMINAC FILLED	0.115 .105	45	0.115 0.125	45	0.115 0.105	45	0.115 0.125		802 TARGET + CELOTEX ONLY	---	----	BORROWING ON .105" GROOVE PARALLEL TO GRAIN .115" GROOVES O.K. .125" GROOVE ON END LOOKS SIMI-LAR TO .115" GROOVE

TABLE I-5 (continued)

TEST DATA FOR RECTANGULAR FRAGMENTS 1-1/16 x 3/4" x 1/2" THICK

TEST NUMBER PNO___0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS: EXPLOSIVE SIDE OF MAT				GROOVE CHARACTERISTICS: OUTSIDE OF MAT				FILLER MATERIAL	FRAGMENT CHARACTERISTICS			COMMENTS
			GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)		RECOVERED FRAGMENT WEIGHT (Grains)	CALCULATED THEORETICAL WEIGHT (Grains) ALLOWS FOR GROOVING LOSS	% RECOVERED WEIGHT / THEORETICAL WEIGHT	
219B	STAINLESS 304 AS RECEIVED	18	45 ALL	0.105 GROOVES	45 LAMINAC	0.105 FILLED	45	0.105	45	0.105		832	TARGET = CELOTEX ONLY		"BORROWING" EVIDENT ON TWO SIDES; OTHER TWO MAY HAVE LOST FINS IN CELOTEX. TINY CRACKS IN OUTSIDE FACE.
219C	STAINLESS 304 AS RECEIVED	18	45 ALL	0.105 GROOVES	45 FILLED	0.115 WITH	45 LAMINAC	0.105	45	0.115		847	TARGET = CELOTEX ONLY		BORROWING ON ALL 4 SIDES. TINY CRACKS ON OUTSIDE FACE.
219D	STAINLESS 304 AS RECEIVED	18	45 ALL	0.105 GROOVES	45 FILLED	0.105 WITH	45 LAMINAC	0.105	45	0.105		514	---	----	FRAGMENT BROKE, (NOT SCABBED)
220A	STAINLESS 304 AS RECEIVED	18	45 ALL	0.105 GROOVES	45 FILLED	0.125 WITH	45 LAMINAC	0.105	45	0.125		698 CELOTEX + 2 .025" STEEL PLATES	---	----	BORROWING ON ALL FOUR SIDES "FINS" ON TWO SIDES BROKEN OFF BY STEEL OR CELOTEX
220B	STAINLESS 304	18	45 ALL	0.095 GROOVES	45 FILLED	0.105 WITH	45 LAMINAC	0.095	45	0.105		841 CELOTEX + 1 EA. 1/16" ALUMINUM ON FRONT OF PACK	---	----	BORROWING ON ALL FOUR SIDES, NO WEIGHT LOSS FROM CELOTEX EVIDENT. IMPACT FACE "PITTED".

TABLE I-5 (continued)

TEST DATA FOR RECTANGULAR FRAGMENTS 1-1/16" x 3/4" x 1/2" THICK

TEST NUMBER PNO___0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS: EXPLOSIVE SIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	OUTSIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	FILLER MATERIAL	FRAGMENT CHARACTERISTICS: RECOVERED FRAGMENT WEIGHT (Grains)	CALCULATED THEORETICAL WEIGHT (Grains) ALLOWS FOR GROOVING LOSS	% RECOVERED WEIGHT / THEORETICAL WEIGHT	COMMENTS
220C	4130 HEAT TREAT 1600°, DRAW @800°- 1 hr. RC-45	18	45 ALL	0.095 GROOVES	45 FILLED	0.105 WITH	45 LAMINAC	0.095	45	0.105		710 CELOTEX .025"	--- + 2 SHEETS STEEL	----	SOME "BORROWING" LEFT ON ONE END. FINS MAY HAVE BROKEN OFF AT IMPACT.
220E	STAINLESS 304 AS RECEIVED	18	45 ALL	0.085 GROOVES	45 FILLED	0.095 WITH	45 LAMINAC	0.085	45	0.095		496 .080" AL	766 + F-89 TIP + CELOTEX	0.65 TANK SKIN	FRAGMENT WEIGHT LOST AT IMPACT FROM AROUND EDGES OF FRAGMENT IMPACT FACE
220F	4130 1600° HEAT TREAT WATER QUENCH DIACON 800°-1 hr. RC-44	18	45 ALL	0.095 GROOVES	45 FILLED	0.105 WITH	45 LAMINAC	0.095	45	0.105		710 PENETRO-	760 METER 2 SHEETS	0.93 .025" STEEL	FRAGMENT IN GOOD CONDITION FRAGMENT ONLY MEASURES .440" THICK

TABLE I-5 (continued)

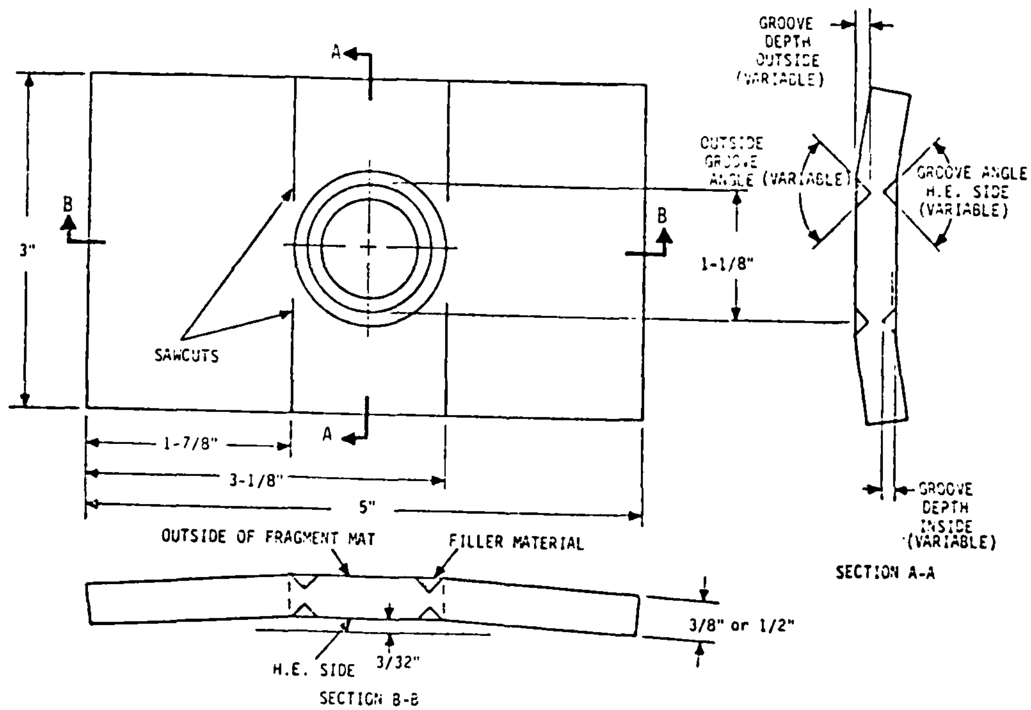
TEST DATA FOR RECTANGULAR FRAGMENTS 1-1/16" x 3/4" x 1/2" THICK

TEST NUMBER PNO___0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS: EXPLOSIVE SIDE OF MAT				GROOVE CHARACTERISTICS: OUTSIDE OF MAT				FILLER MATERIAL	FRAGMENT CHARACTERISTICS			COMMENTS
			GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)	GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDICULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDICULAR TO ROLLING GRAIN (inches)		RECOVERED FRAGMENT WEIGHT (Grains)	CALCULATED THEORETICAL WEIGHT (Grains) ALLOWS FOR GROOVING LOSS	% RECOVERED WEIGHT / THEORETICAL WEIGHT	
221A	4130 HEAT TREAT 1600° 850°DRAW RC-43	18	45	0.095	45	0.105	45	0.095	45	0.105		693	760	0.91	W. H. CHOICE =800° DRAW (W"S SUPERIOR TO 850° DRAW)
												PENETROMETER + 2 SHEETS .025"STEEL			
221B	STAINLESS 304 AS RECEIVED	18	45	0.100	45	0.120	45	0.100	45	0.120		688	755	0.91	SOME BORROWING EVIDENT ON ONE END BUT OTHERWISE GOOD. THIS CHOICE O.K. FOR BOOSTER END OF W.H.
			ALL GROOVES FILLED WITH LAMINAC									2 SHEETS .025" STEEL & CELOTEX			
221C	STAINLESS 304 (AS RECEIVED)	19	45	0.065	45	0.075	45	0.065	45	0.075		607	677	0.92	FRAG BROKE INTO 2 MAJOR PIECES
			THIS FRAG 7/16" THICK									KC-97 FUEL CELL (INTEGRAL)			

TABLE I-6

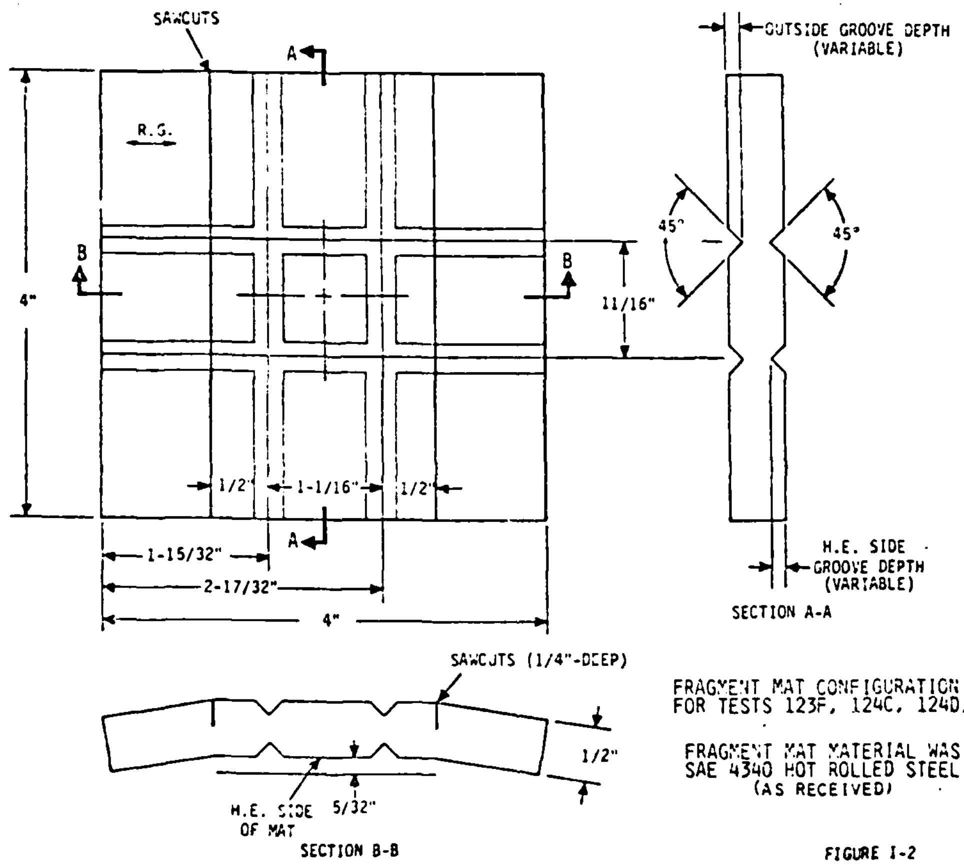
TEST DATA FOR RECTANGULAR FRAGMENTS 1-1/16" x 3/4" x 7/16" THICK

TEST NUMBER PNO____0	FRAGMENT MATERIAL	REFER TO FIGURE NO.	GROOVE CHARACTERISTICS — EXPLOSIVE SIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PER. ENDI-CULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDI-CULAR TO ROLLING GRAIN (inches)	OUTSIDE OF MAT: GROOVE ANGLE PARALLEL TO ROLLING GRAIN (degrees)	GROOVE DEPTH PARALLEL TO ROLLING GRAIN (inches)	GROOVE ANGLE PERPENDI-CULAR TO ROLLING GRAIN (degrees)	GROOVE DEPTH PERPENDI-CULAR TO ROLLING GRAIN (inches)	FILLER MATERIAL	FRAGMENT CHARACTERISTICS: RECOVERED FRAGMENT WEIGHT (Grains)	CALCULATED THEORETICAL WEIGHT (Grains) ALLOWS FOR GROOVING LOSS	% RECOVERED WEIGHT / THEORETICAL WEIGHT	COMMENTS
221D	304 STAINLESS STEEL	19	45	0.065	45	0.075	45	0.065	45	0.075		--- TARGET	559 = KC-97 FUEL CELL, FROM ABOVE	---- 1/2 FILLED,	FRAGMENT HIT SANDBAG STRIPPER PRIOR TO IMPACT. FRAGMENT NOT FOUND. NO DAMAGE TO FUEL CELL.
222A	4130 HEATTREAT @1600° 800° DRAW RC-45	19	45	0.080	45	0.080	45	0.080	45	0.080		500 TARGET	672 = F-89 TIP TANK	0.74 SKIN + CELOTEX	NO SCABBING, FRAGMENT BROKE @ IMPACT. SOME MINOR BORROWING EVI-DENT ON REMAINING END OF THE FRAGMENT.
222B	4130 HEATTREAT @1600° 800°DRAW RC-45	19	45 INSIDE	0.070 GROOVES	45 FILLED	0.080 WITH LAMINAC	45 1/2" WITH FILLED.	0.070 OUTSIDE SOLDER,	45 GROOVES 1/2 PARTIALLY	0.080 FILLED		528	557	0.95	GROOVES COMPLETELY FILLED WITH SOLDER = PERFECT. THOSE PARTIALLY FILLED = SOME BORROWING.



FRAGMENT MAT CONFIGURATION FOR TESTS PN0118A0 THROUGH PN0124C0, CIRCULAR FRAGMENTS

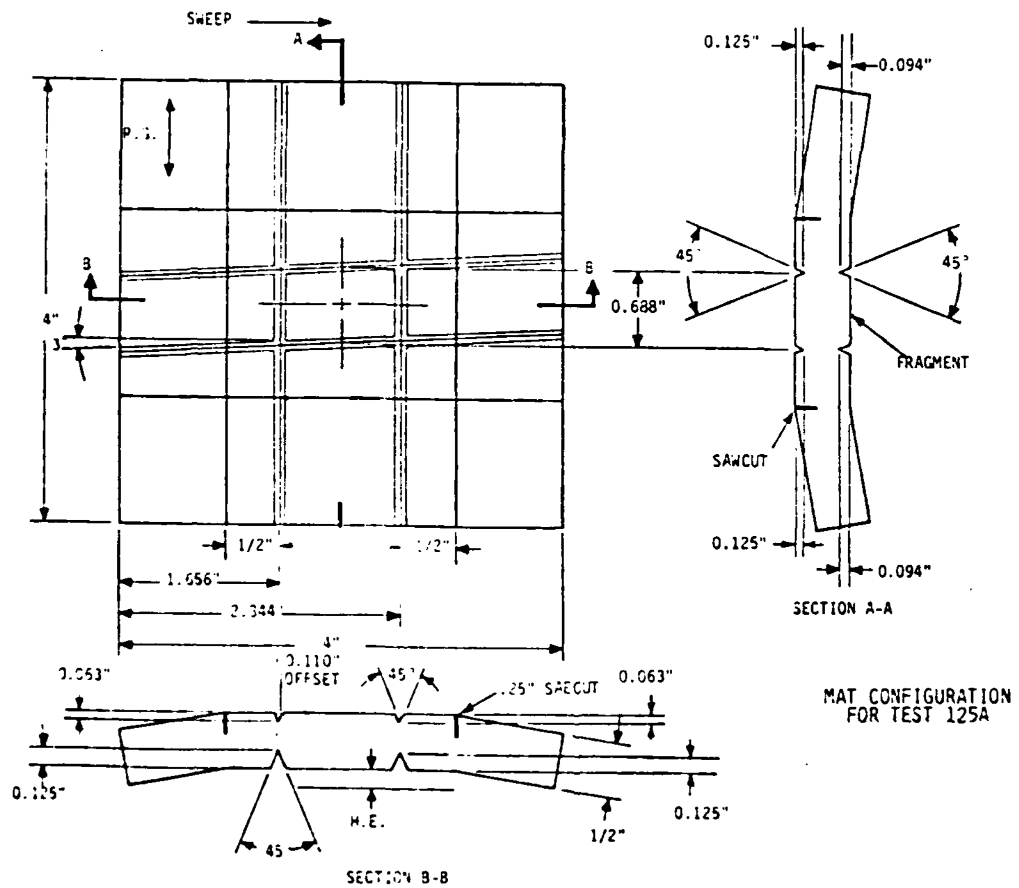
FIGURE I-1



FRAGMENT MAT CONFIGURATION FOR TESTS 123F, 124C, 124D.

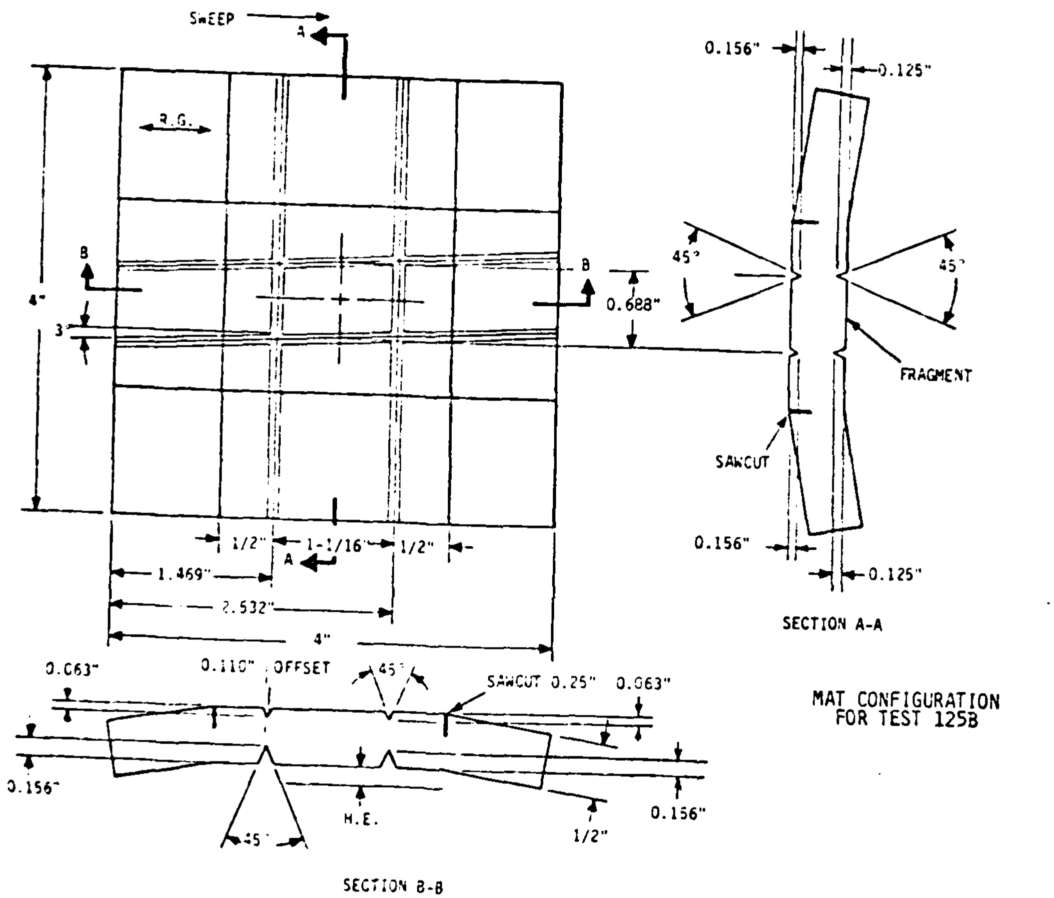
FRAGMENT MAT MATERIAL WAS SAE 4340 HOT ROLLED STEEL (AS RECEIVED)

FIGURE I-2



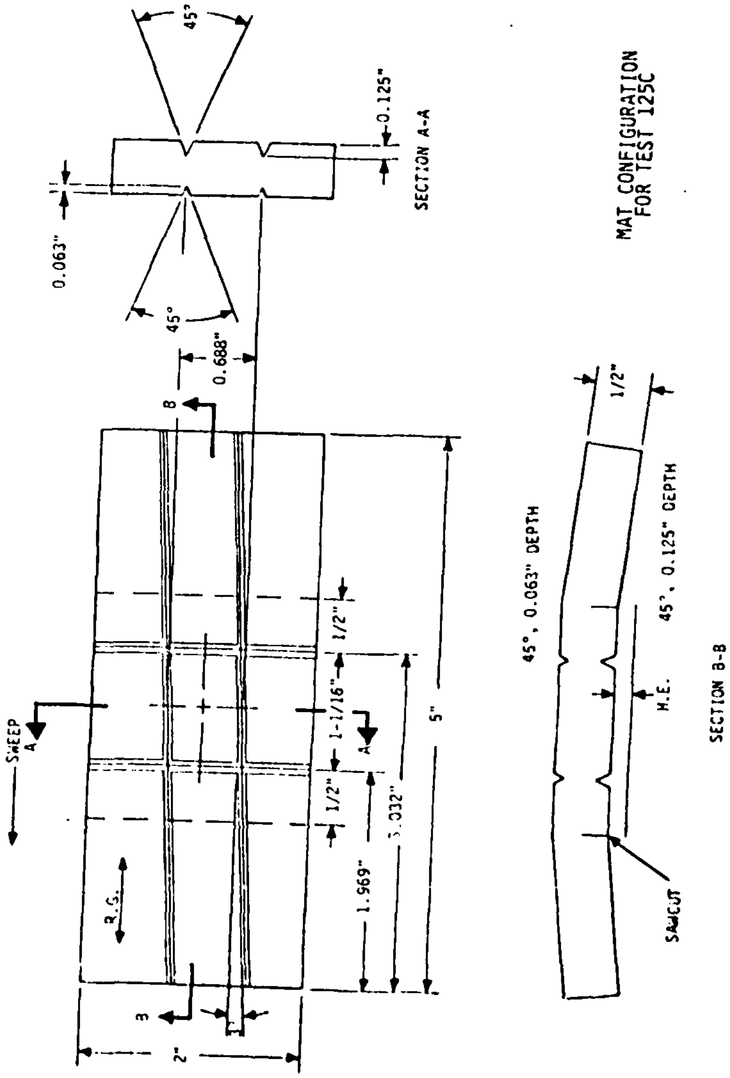
MAT CONFIGURATION
FOR TEST 125A

FIGURE I-3a



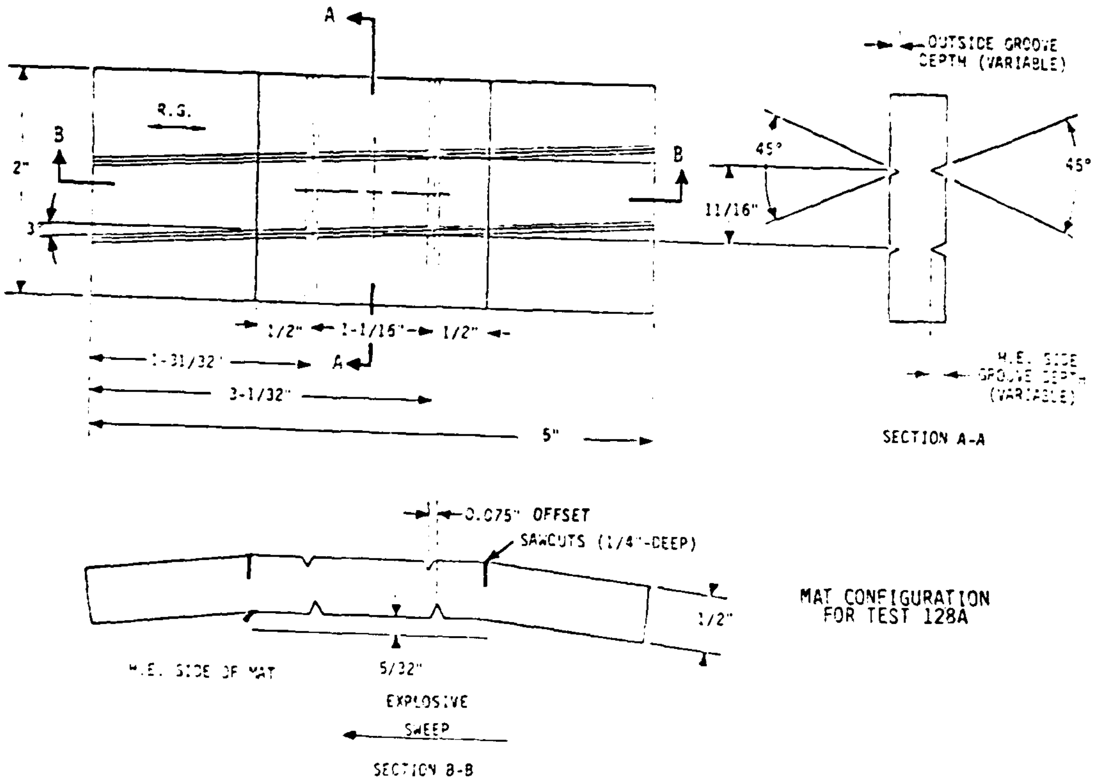
MAT CONFIGURATION
FOR TEST 125B

FIGURE I-3b



MAT CONFIGURATION FOR TEST 125C

FIGURE I-4



MAT CONFIGURATION FOR TEST 128A

FIGURE I-5

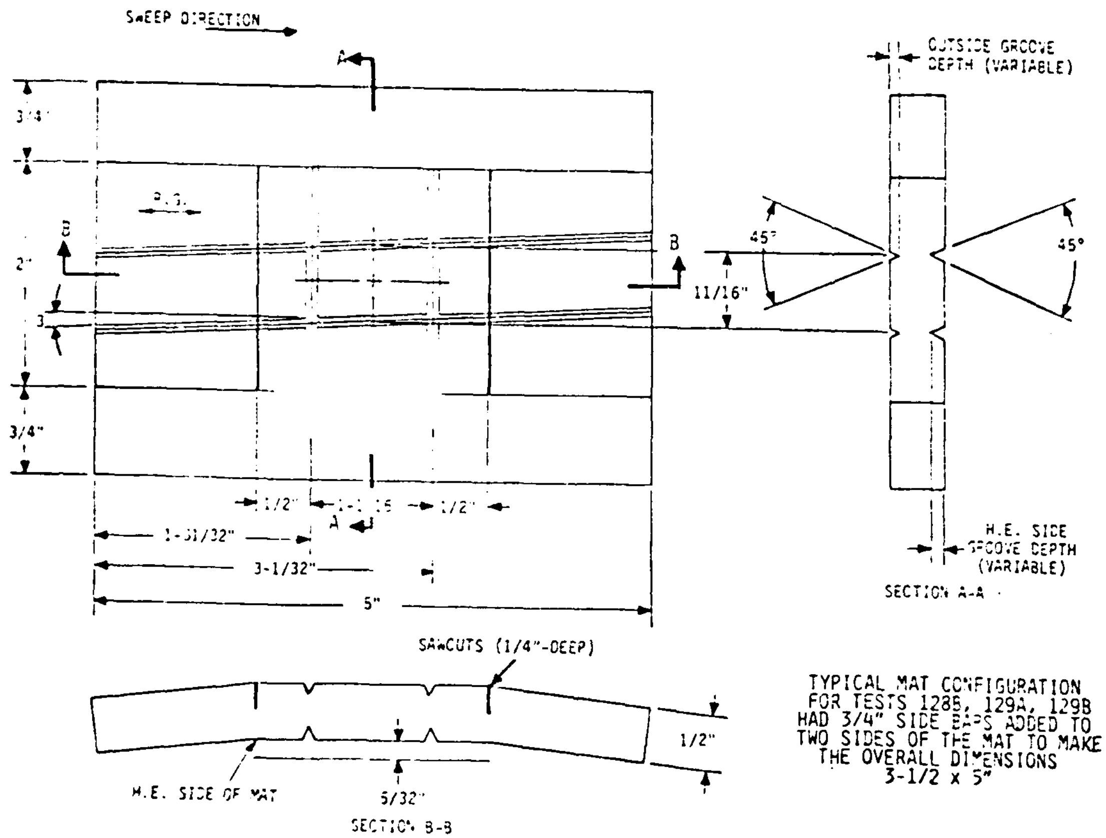
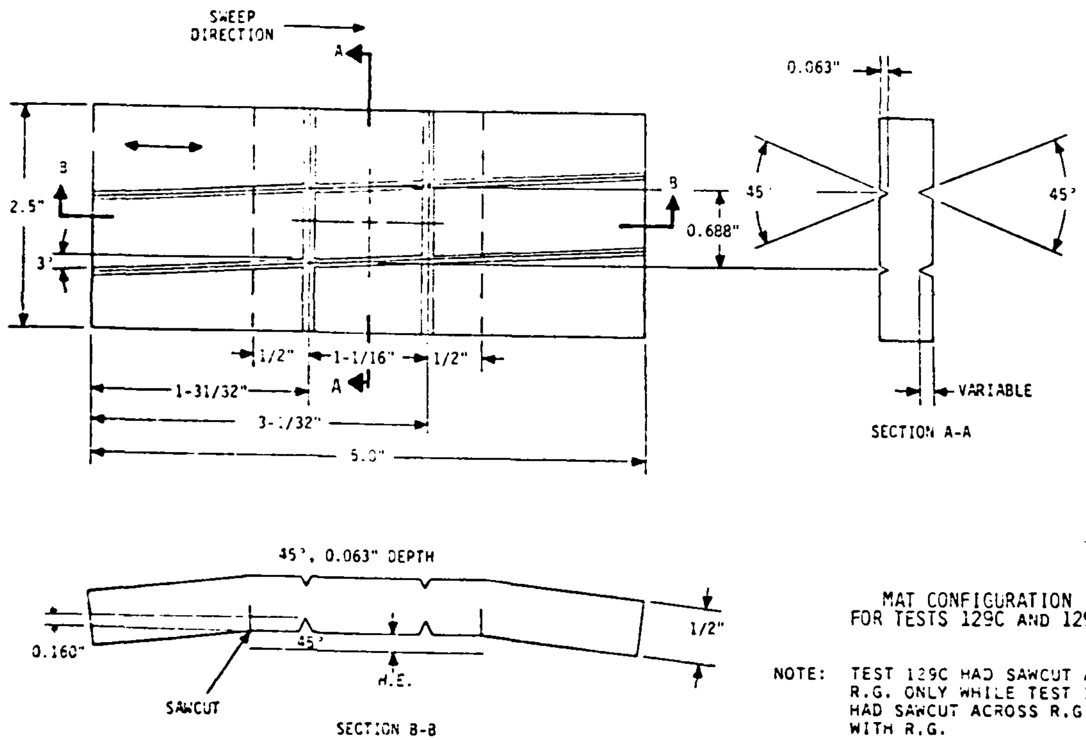

SWEEP DIRECTION
A
B
3/4"
2"
3
3/4"
1/2"
1/2"
1-31/32"
3-1/32"
5"
11/16"
45°
45°
OUTSIDE GROOVE DEPTH (VARIABLE)
H.E. SIDE GROOVE DEPTH (VARIABLE)
SECTION A-A
SAWCUTS (1/4"-DEEP)
1/2"
H.E. SIDE OF MAT
5/32"
SECTION B-B
TYPICAL MAT CONFIGURATION
FOR TESTS 128B, 129A, 129B
HAD 3/4" SIDE BARS ADDED TO
TWO SIDES OF THE MAT TO MAKE
THE OVERALL DIMENSIONS
3-1/2 x 5"

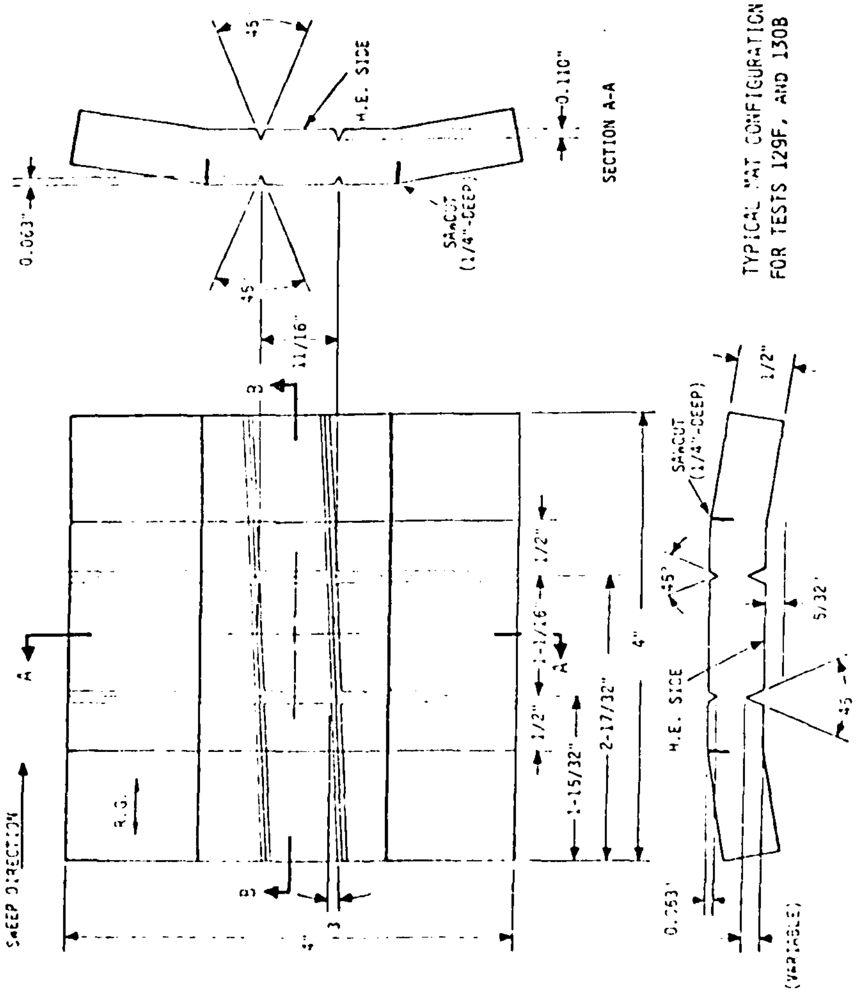
FIGURE I-6



MAT CONFIGURATION
FOR TESTS 129C AND 129E

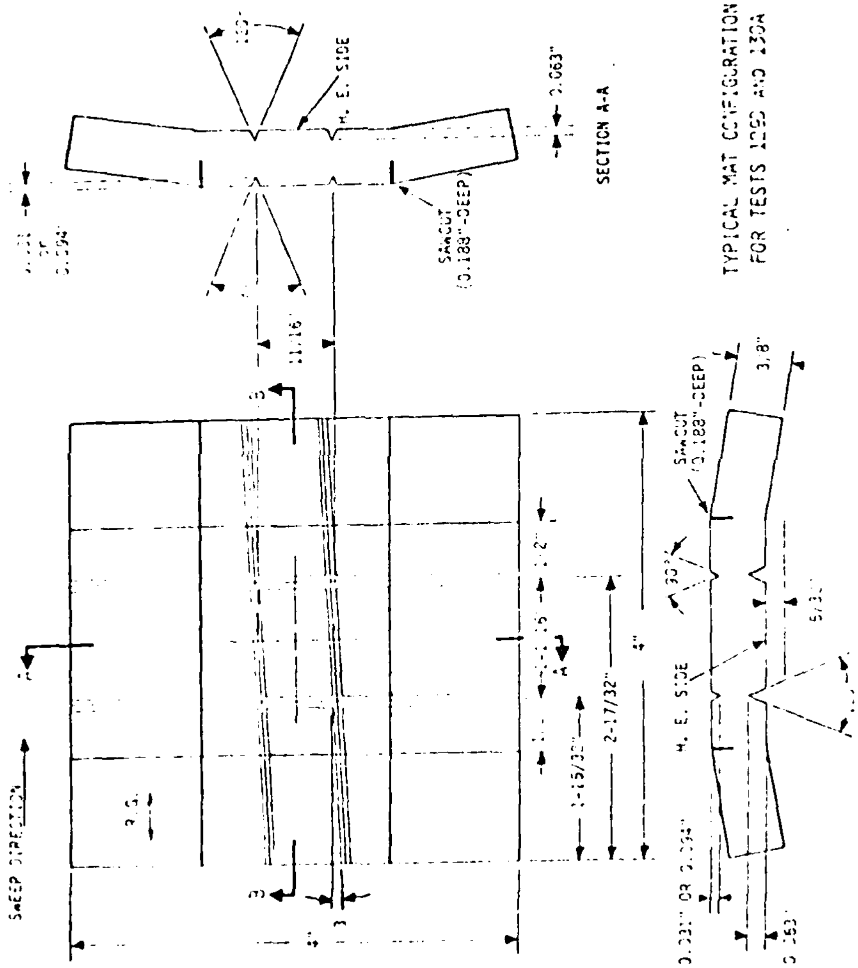
NOTE: TEST 129C HAD SAWCUT ACROSS R.G. ONLY WHILE TEST 129E HAD SAWCUT ACROSS R.G. AND WITH R.G.

FIGURE I-7



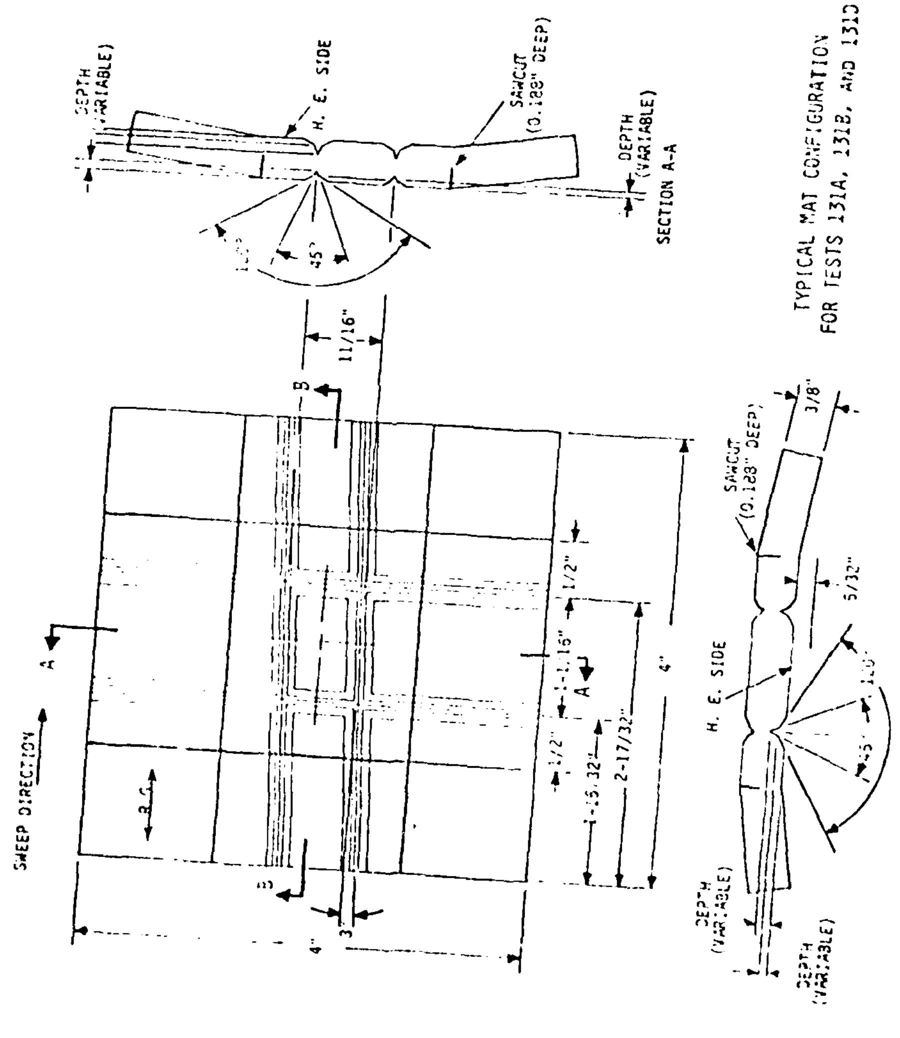
TYPICAL MAT CONFIGURATION FOR TESTS 129F, AND 130B

FIGURE I-8



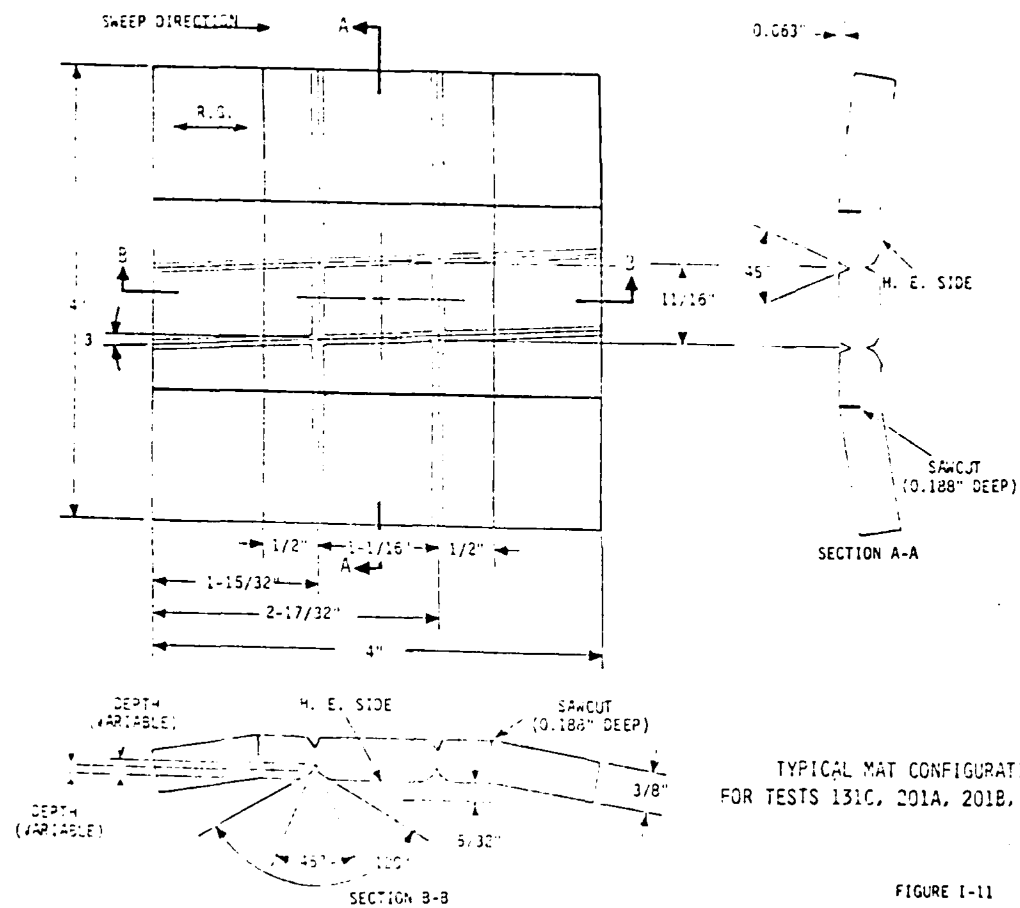
TYPICAL MAT CONFIGURATION
FOR TESTS 129D AND 130A

FIGURE I-9



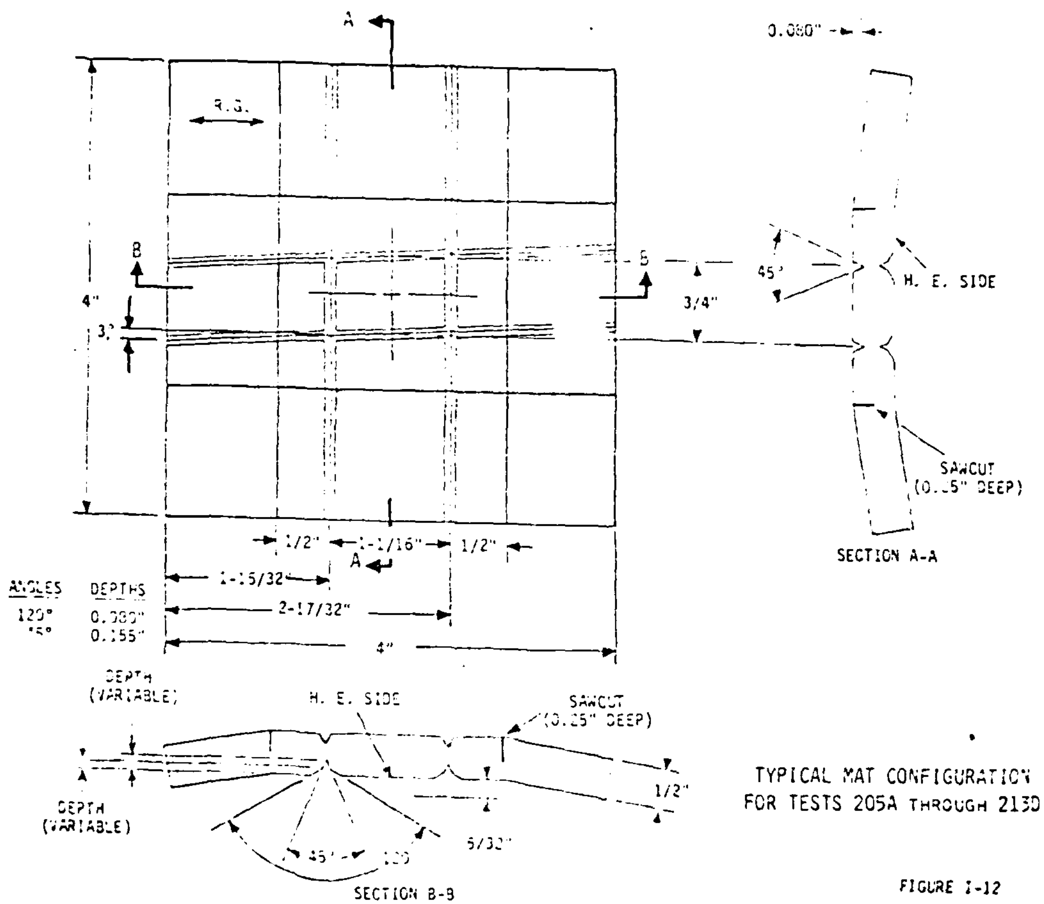
TYPICAL MAT CONFIGURATION
FOR TESTS 131A, 131B, AND 131D

FIGURE I-10



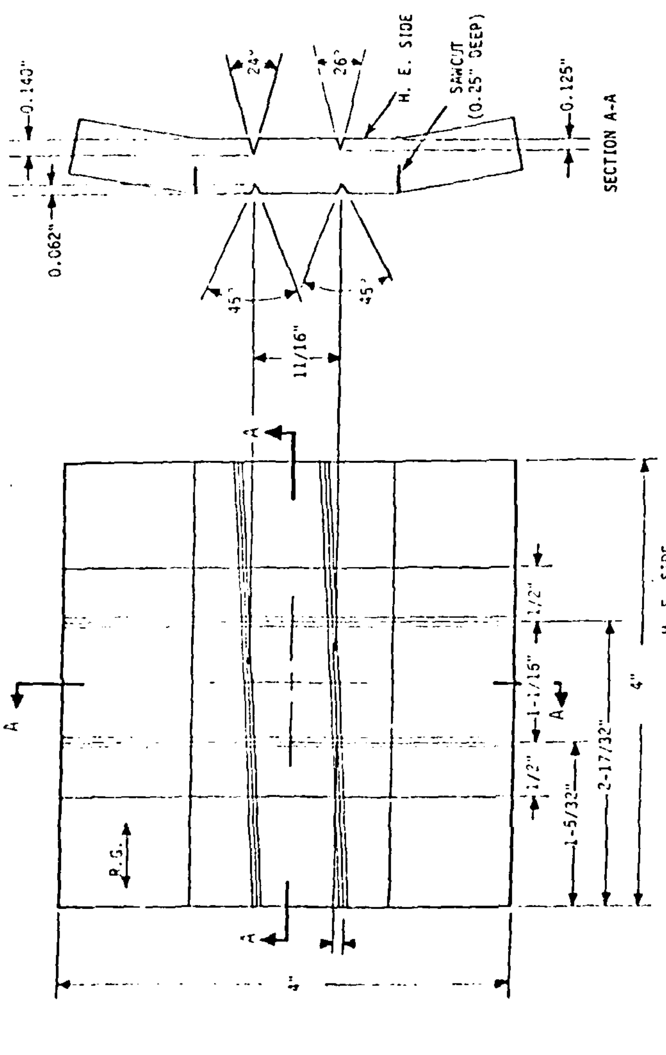
TYPICAL MAT CONFIGURATION
FOR TESTS 131C, 201A, 201B, AND 204A

FIGURE I-11



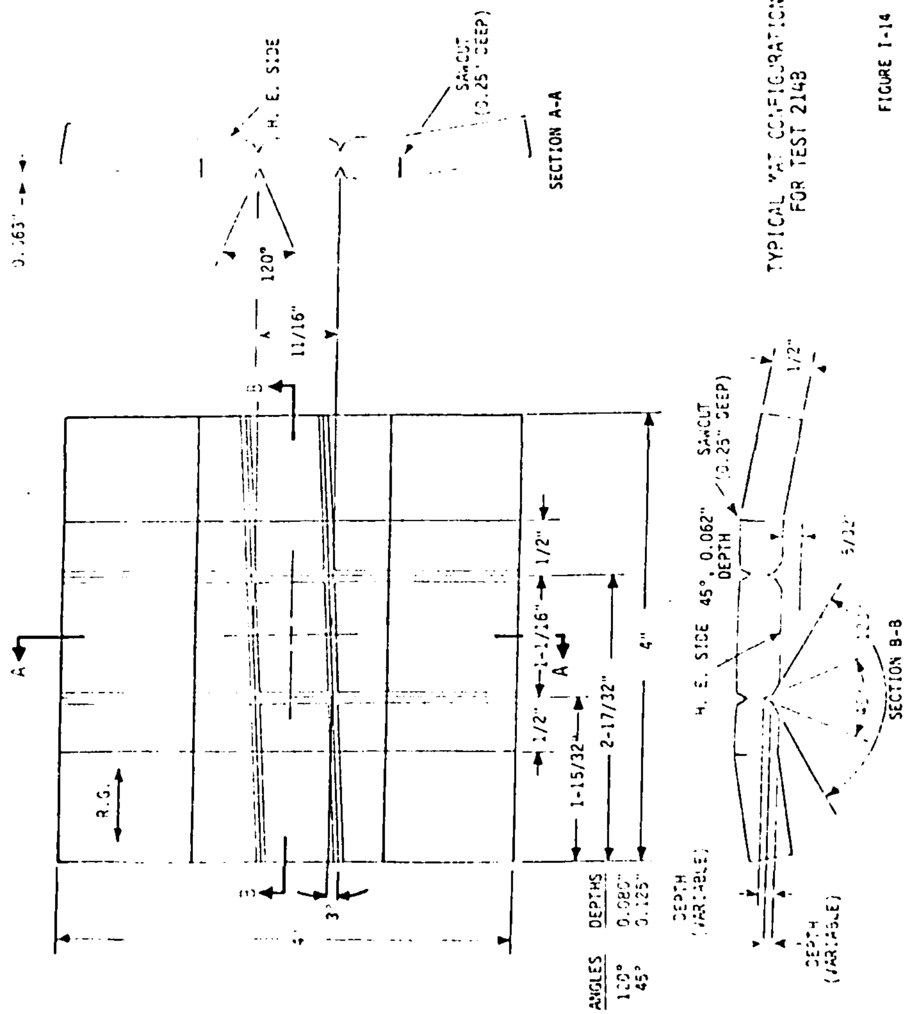
TYPICAL MAT CONFIGURATION
FOR TESTS 205A THROUGH 213D

FIGURE I-12



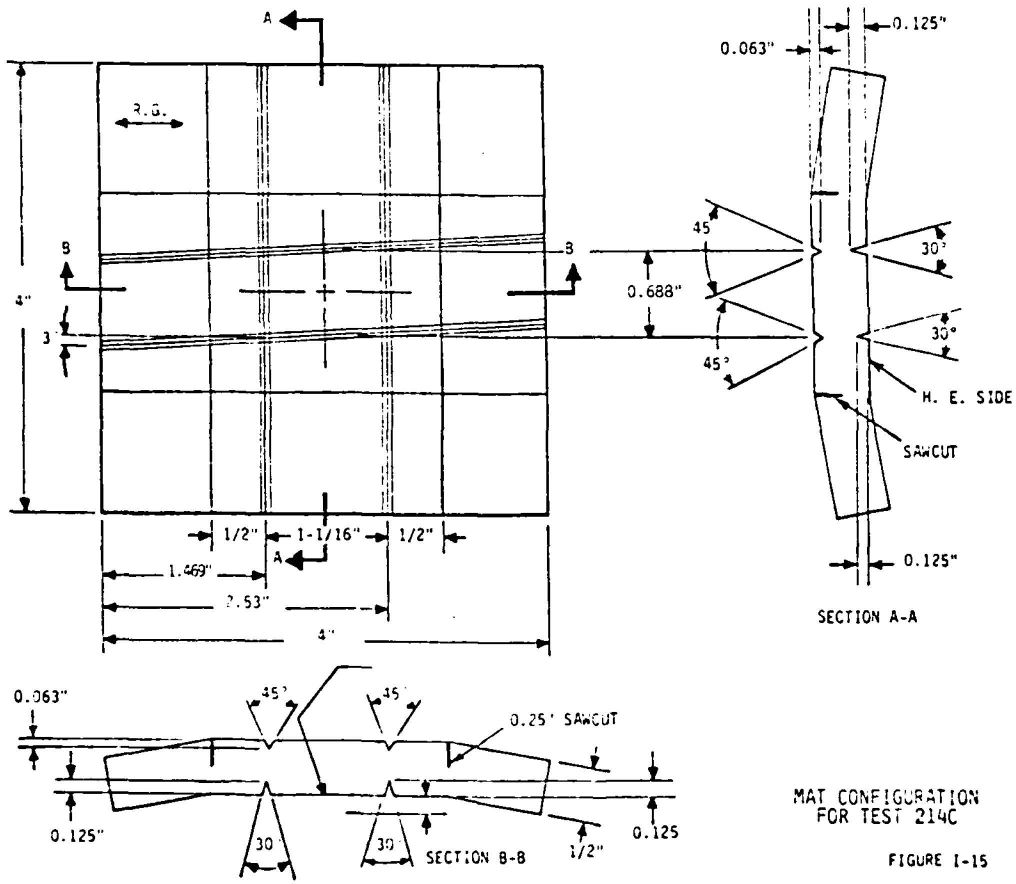
TYPICAL MAT CONFIGURATION FOR TEST 214A

FIGURE I-13



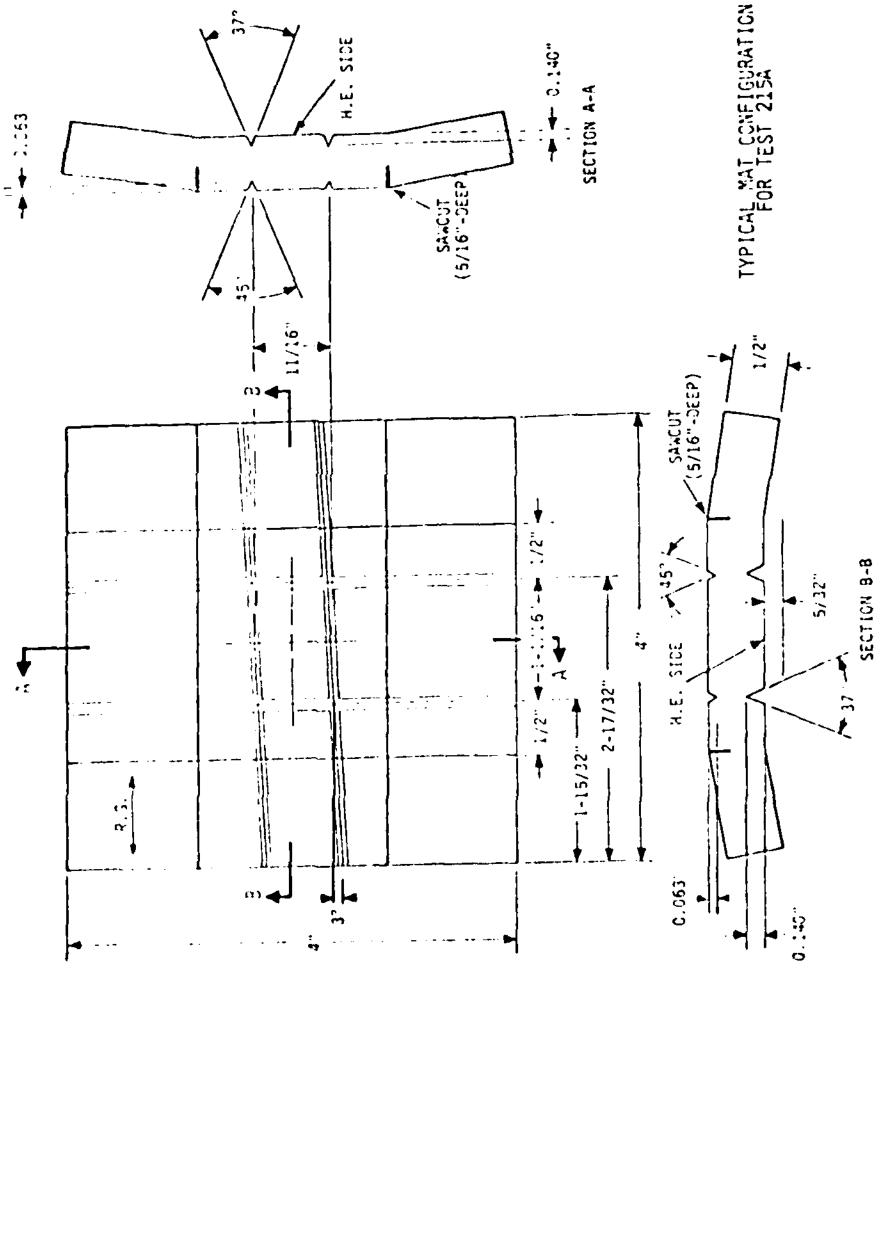
TYPICAL MAT CONFIGURATION
FOR TEST 2143

FIGURE I-14



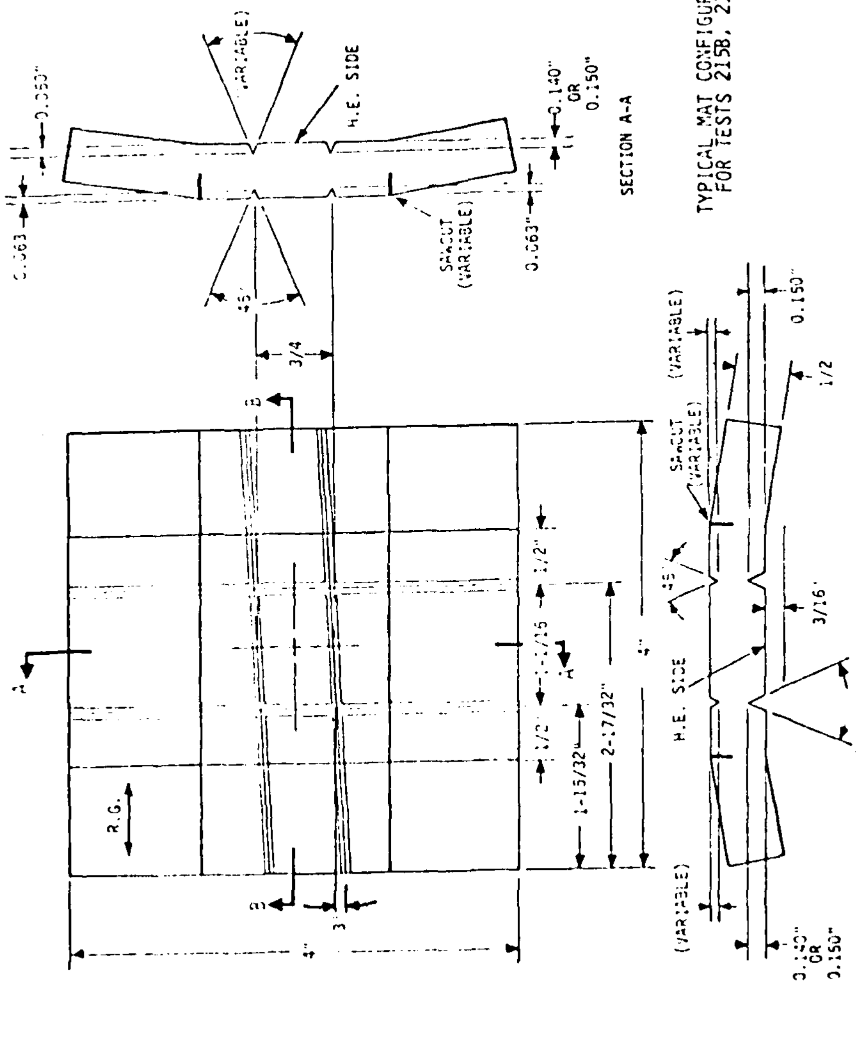
MAT CONFIGURATION
FOR TEST 214C

FIGURE I-15



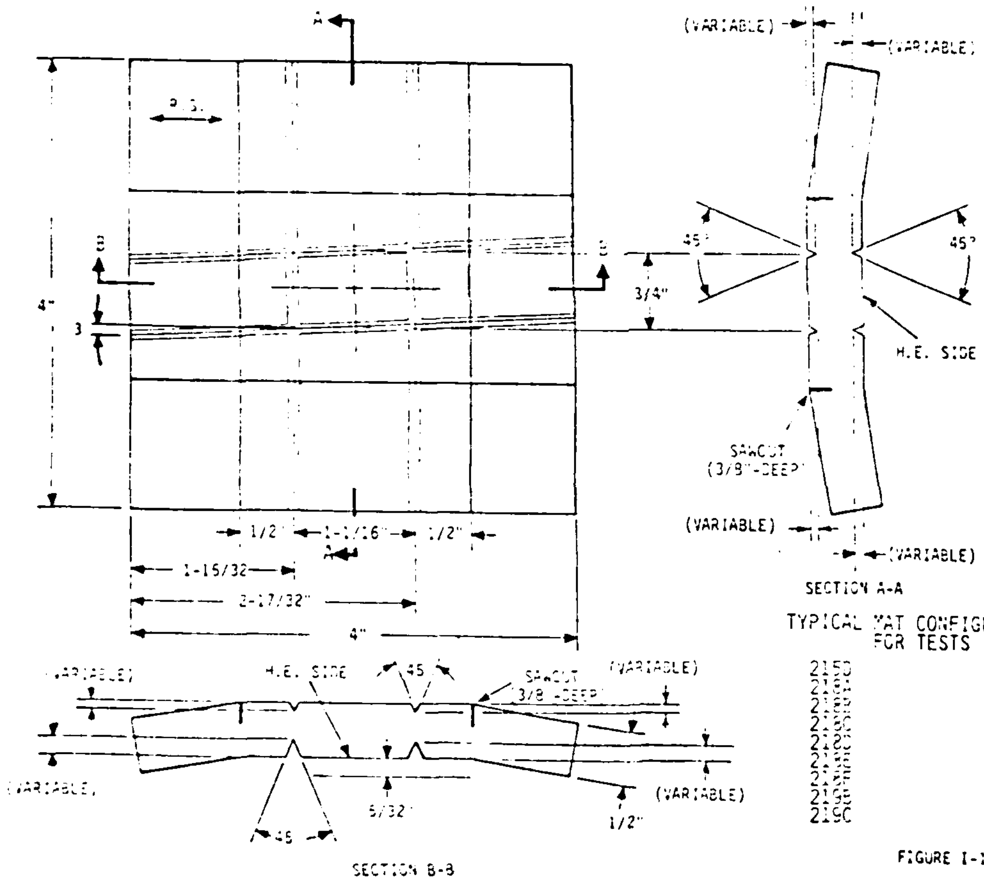
TYPICAL MAT CONFIGURATION FOR TEST 215A

FIGURE I-16



TYPICAL MAT CONFIGURATION FOR TESTS 215B, 215C

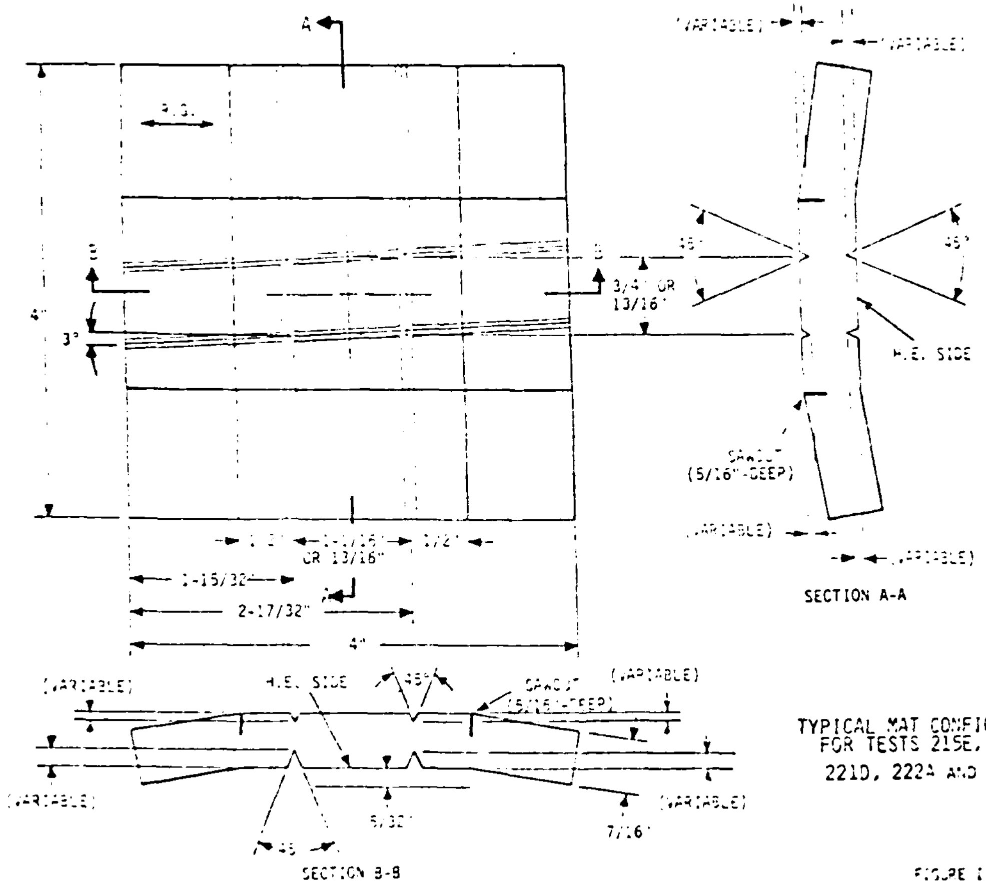
FIGURE I-17



TYPICAL MAT CONFIGURATION FOR TESTS

215D	219D
[illegible]	220A
[illegible]	220B
[illegible]	[illegible]
[illegible]	220E
[illegible]	220F
[illegible]	221A
219B	221B
219C	221C

FIGURE I-18



TYPICAL MAT CONFIGURATION
FOR TESTS 215E,
221D, 222A AND 222B

FIGURE I-19

APPENDIX II

RESIDUAL WEIGHT OF 560-GRAIN FRAGMENTS AFTER 10,000-FT/SEC IMPACTS WITH THIN STAINLESS STEEL TARGETS

APPENDIX II

RESIDUAL WEIGHT OF 560-GRAIN FRAGMENTS AFTER 10,000-ft/sec IMPACTS WITH THIN STAINLESS STEEL TARGETS

INTRODUCTION

One of the design objectives of the HIBAL warhead program is to achieve fragments which, within the constraints placed upon the fragment shape and weight by other design considerations, will maximize penetration capability in fuel. The penetration capability of the fragment in fuel is a function of how well the fragment retains its shape and weight after impact with the target skins. Stainless-steel skins are postulated for one of the targets in the HIBAL-threat spectrum, and analysis shows that fragment impact-velocities of 8000-ft/sec to 12,000-ft/sec are common for this target.

In this part of the program, fragments were explosively launched at about 10,000-ft/sec at stainless steel targets, to investigate the relative capabilities of various fragment materials to retain their shape and weight after impact.

FRAGMENT AND FRAGMENT-MAT-PROJECTOR DESCRIPTIONS

The fragment size chosen for study was 1/2" x 3/4" x 3/4", 560-grains, because (1) 3/4-inch-square bar stock was readily available in the materials tested, (2) 560-grains is within the fragment-weight range being considered for HIBAL warhead designs, and (3) the 1/2-inch thickness is representative of the case thickness of the 11-1/2-inch-diameter HIBAL-warhead designs.

The fragments were sawcut and positioned in a fragment mat as shown in Figure II-1, with sixty-four fragments in each fragment mat. Four materials (16 fragments each) were represented in each fragment mat. The total weight of the sixteen fragments for each material was recorded for each test. The fragments were stamped with letters which corresponded to the types of steels used in the tests for identification after recovery. The fragment mat was positioned on a 200-lb C-4 explosive charge, as shown in Figure II-2.

TEST DESCRIPTION

The fragment mat was fired at a 30° obliquity to the stainless-steel skin targets. Celotex was used to recover the fragments, and Fastax cameras were used to obtain fragment velocities. A typical arena is shown in Figure II-3. Two thicknesses of stainless-steel skins were tested, 0.047-inch and 0.035-inch. In addition, one test was conducted against an aluminum-plate-array target, consisting of 3 sheets of 0.090"-2024-T3 plate separated by 1-ft intervals. The three plates were at 30° obliquity, as shown in Figure II-4. This test was conducted to determine how multiple aluminum skin hits would affect fragment residual weight.

FRAGMENT MATERIALS TESTED

The materials tested included the following types of steel: SAE 1018, 4130, 4140 and 4340; 5-317 and 5-876 Carpenter tool steel; Armco HY-80 and SSS-100 steel; AISI-S7 special purpose tool steel; type 416 and 17-4 AISI 630 stainless steel; and a stainless steel of unknown alloy.

Properties of the materials tested are presented, along with the plottings of the data for each material. Note that, for some materials, differing heat treatments were used to evaluate the effects of variations in material hardness. The unknown stainless alloy was available, and was tested with the reasoning that if it appeared to be a better material for surviving impacts than the other materials, the analysis of the alloy would be performed.

TEST RESULTS

Seven tests were conducted. Table II-1 summarizes the test parameters in each of the tests. The results are first presented for each fragment material and, then, the fragment materials are compared in a final summary (Figure II-17). The basis for the curves used in Figure II-17 appears in the discussion of the individual fragment-materials. The data for alloy-steel fragments are plotted in Figure II-17. The mild-steel data are plotted on the overlay of Figure II-17.

The recovered fragments appeared to have lost weight in two different ways, by erosion of the metal as it passed through the target, and by brittle fracturing. Examples of the two types of weight loss are presented in the photograph in Figure II-18.

A. Mild Steel (SAE 1018)

Mild-steel fragments were tested against the 0.047"-inch stainless steel target and the 2024-T3 plate array target. The test data are plotted in Figure II-5. The recovered fragments from the two target-types show similar deformation; the fragments were "mashed" on the impact face, and somewhat pitted on the impact face. The distribution of recovered fragment weights is similar for the two targets, the weight loss appearing to have occurred from "erosion" of the fragment, as opposed to fracturing. For the final summary figure; the data from the two targets were combined into a single curve.

B. SAE 4130

The SAE 4130 fragments were tested against one target, the 0.035"-inch stainless steel, for two hardnesses, RC-38 and RC-42. The data are plotted in Figure II-6. The fragment deformation was similar for the two hardnesses, and the distribution of recovered fragment weights was also similar for the two hardnesses. The fragments were mashed on the impact side, but not as much as were the mild steel fragments. The fragments appeared to have lost most of their weight due to erosion, as opposed to fracturing. The data for the two hardnesses were combined into one curve for the final summary Figure II-17.

C. SAE 4140

SAE 4140 fragments were tested against the three targets; 0.035"-inch stainless steel, 0.047"-inch stainless-steel, and the 0.090"-inch 2420T3 plate array. Fragments tested against the 0.035"-inch stainless-steel target were RC-40. The fragments tested against the plate array target and 0.047"-inch stainless-steel were RC-45.

The distribution of recovered fragment weights fired against the 0.047"-inch stainless-steel target differs somewhat from the distribution of recovered fragment weights fired against the plate-array target. Since the appearance of these two sets of fragments is similar (for both sets, fragments lost weight due to fracture failures rather than from erosion), it is believed that the plotted dispersion in recovered fragments weights may be due to the sample size of the data.

There is also a difference in appearance between the fragments fired at the 0.035"-inch steel,which were RC-40, and the RC-45 fragments fired at the other two targets, which were RC-45. The RC-40 fragments mashed more at impact than did the harder fragments, and appeared to have lost weight due to erosion, as opposed to fracturing.

Only the data from the RC-40 fragments fired against the 0.035"-inch steel were used in the final summary figure, because the dispersion between the data was deemed to be too great to allow for the combining without further testing.

Data for (SAE) 4140 are shown in Figures II-7 and II-7A. The analysis shown is for 4142, which differs from 4140 only in carbon content. In fact, one steel supplier lists both 4140 and 4142 as equivalent.

D. SAE 4340

SAE 4340 fragments were tested against the 0.035"-inch stainless-steel targets. Two hardnesses were evaluated, RC-43 and RC-38. The data are plotted in Figure II-8. The distribution of fragment weights recovered were very similar for the two hardnesses, but the appearance of the two fragments were somewhat different. The harder fragments appear to have lost their weight due to fracturing, while the softer fragments were mashed and lost their weight due to erosion. For Figure II-17, the data for hardnesses were combined into one curve.

E. 17-4 AISI 630 (STAINLESS)

This material was tested against the 0.035"-inch stainless-steel target for two different hardnesses, RC-42 and RC-34. The data are plotted in Figure II-9. The difference in hardness between the recovered fragments was evident because the softer fragments mashed more on the impact face. However, fragment weight loss due to fracturing was evident for both hardnesses.

F. TYPE 416 (STAINLESS)

This material was tested against the 0.035"-inch stainless-steel target. The material hardness was RC-45. The data are plotted in Figure II-10. The fragments fractured into small pieces at impact.

G. STAINLESS STEEL (UNKNOWN ALLOY)

This material was tested against the 0.047"-inch stainless-steel target, and the 0.090"-inch 2024-T3 plate-array target. The data are plotted in Figure II-11.

The recovered fragments were similar to one another, for both targets. For most of the fragments, the weight-loss appeared to be from erosion, but a few also showed fractured. This material was not plotted in the final summary figure, because it was not tested against the 0.035"-inch stainless-steel target.

H. CARPENTER 5-317

This material was tested against all three targets. The fragment material hardness on all the tests was RC-41 to RC-42. The data are plotted in Figure II-12. The recovered fragments were similar to one another, for all three targets. Only a few fragments had fractured; most appear to have lost weight from erosion. The distributions of recovered-fragment weights are similar for the

0.035"-inch steel-target and the 0.090"-inch 2024-T3 plate-array target. The fragments impacting the 0.047"-inch stainless-steel target lost somewhat less weight than the fragments impacting the other targets. The data from the 0.035"-inch stainless-steel target are plotted in summary Figure II-17.

I. AISI-S7

This material was tested against the 0.035"-inch stainless steel target. Two material hardnesses were tested, RC-43 and RC-50. The data are plotted in Figure II-13. Only two of the RC-50 fragments were recovered, and those were fractured.

The RC-42 fragments, which lost a significant amount of weight, did so because of fracturing. The data from the RC-42 fragments are plotted in Figure II-17.

J. CARPENTER 5-876

This material was tested at RC-43 hardness against the 0.035"-inch stainless-steel target. The data are plotted in Figure II-14. The two recovered fragments which lost the most weight were fractured; the four which lost 10% - 15% of their weight did so by erosion. The fragments were mashed and pitted on their impact side, a result very similar to other fragment materials of the same hardness.

K. HY-80

HY-80 (Figure II-15) was tested against the 0.035"-inch stainless-steel target. Two fragment material hardnesses were tested, RC-38 and RC-41. Only three fragments of the RC-41 hardness were recovered, whereas fifteen of the RC-38 hardness were recovered. Differences in appearance occurred between the RC-38 fragments and the RC-41 fragments, The RC-38 fragments being mashed significantly more than the RC-41 fragments, and many fractures also occurring in the RC-38 fragments. The RC-41 fragment data were used in the final summary-figure.

L. SSS-100

The SSS-100 was tested at RC 42-43 against the 0.035"-inch stainless-steel target. The data are plotted in Figure II-16. The appearance of the fragments indicates that fragment weight was lost primarily from fracturing.

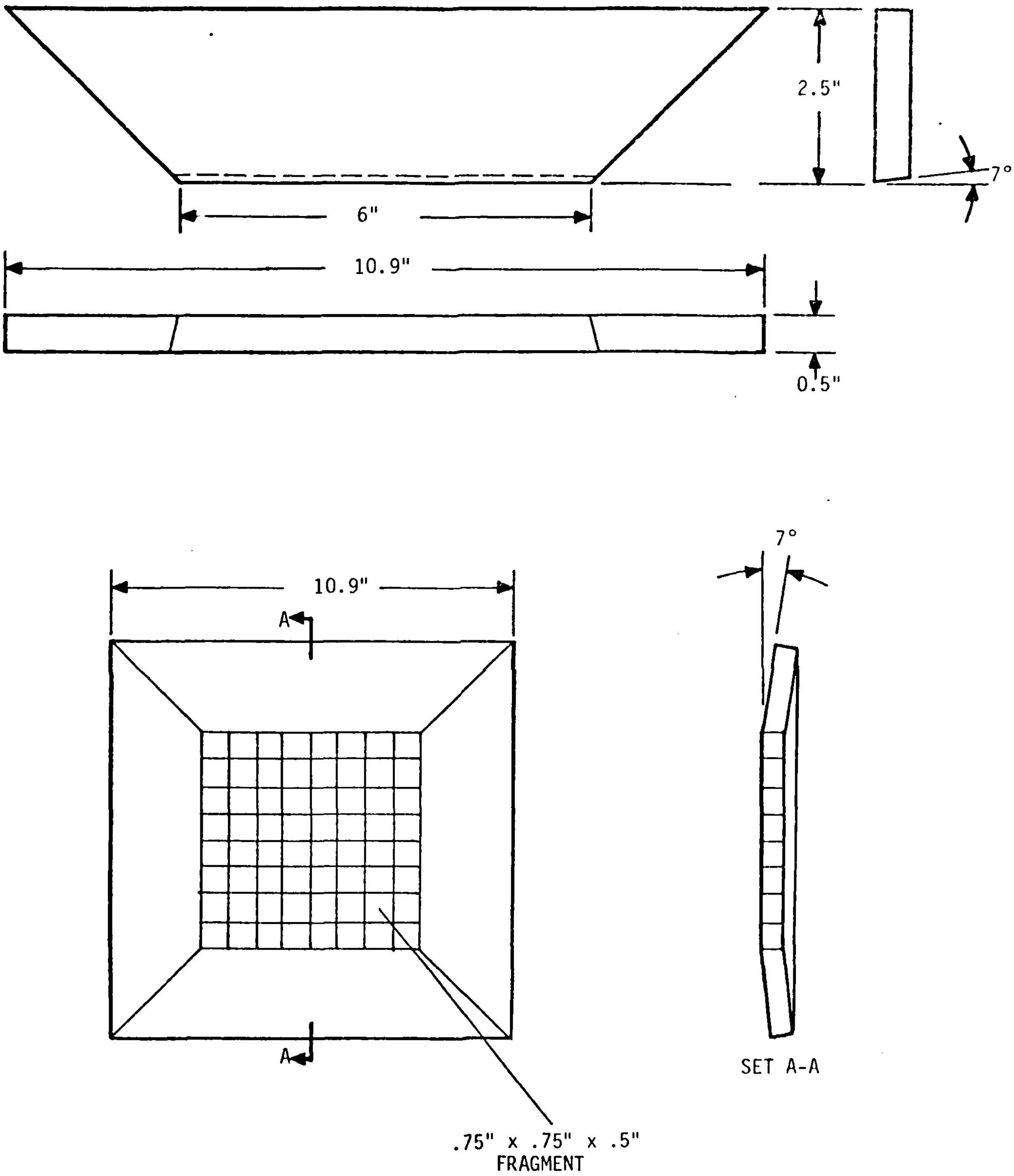
CONCLUSIONS

1. The most important conclusion is that there are several, viable candidate-steels which, with proper heat treatment, show good survival capability at 10,000-ft/sec impacts.

2. Insufficient data exist to provide quantitative values at this time but, from the appearance of the fragments, it is apparent, that the heat treatment may affect the survival capability of some alloys more than it does other alloys.

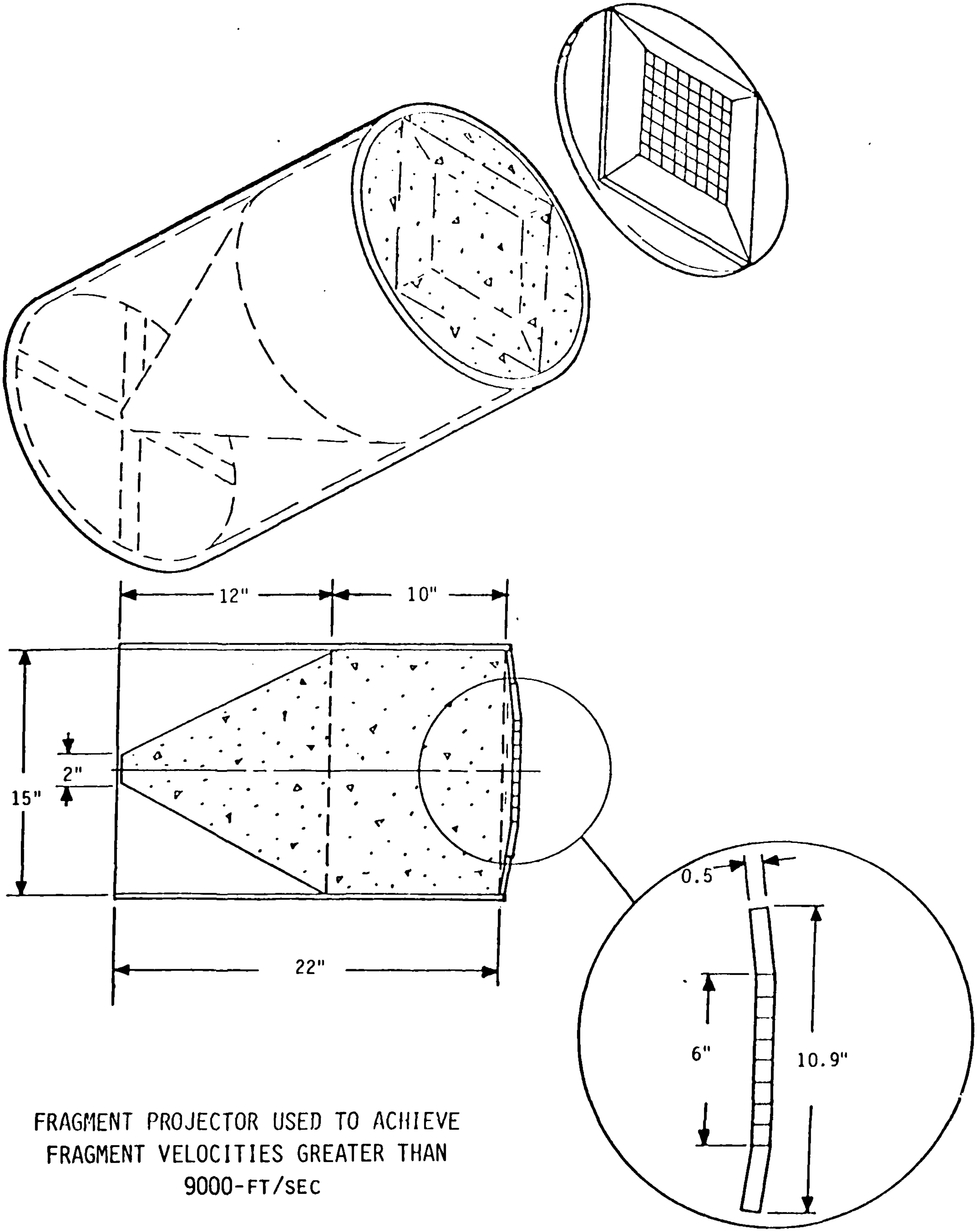
3. The appearance of the fragments suggests that there was no major difference in the "toughness" of the three targets tested.

4. Fragment-weight loss was due to both fracturing and erosion. Figure II-18 compares two fragments which lost weight by fracturing (left) to one fragment which lost weight by erosion (right).



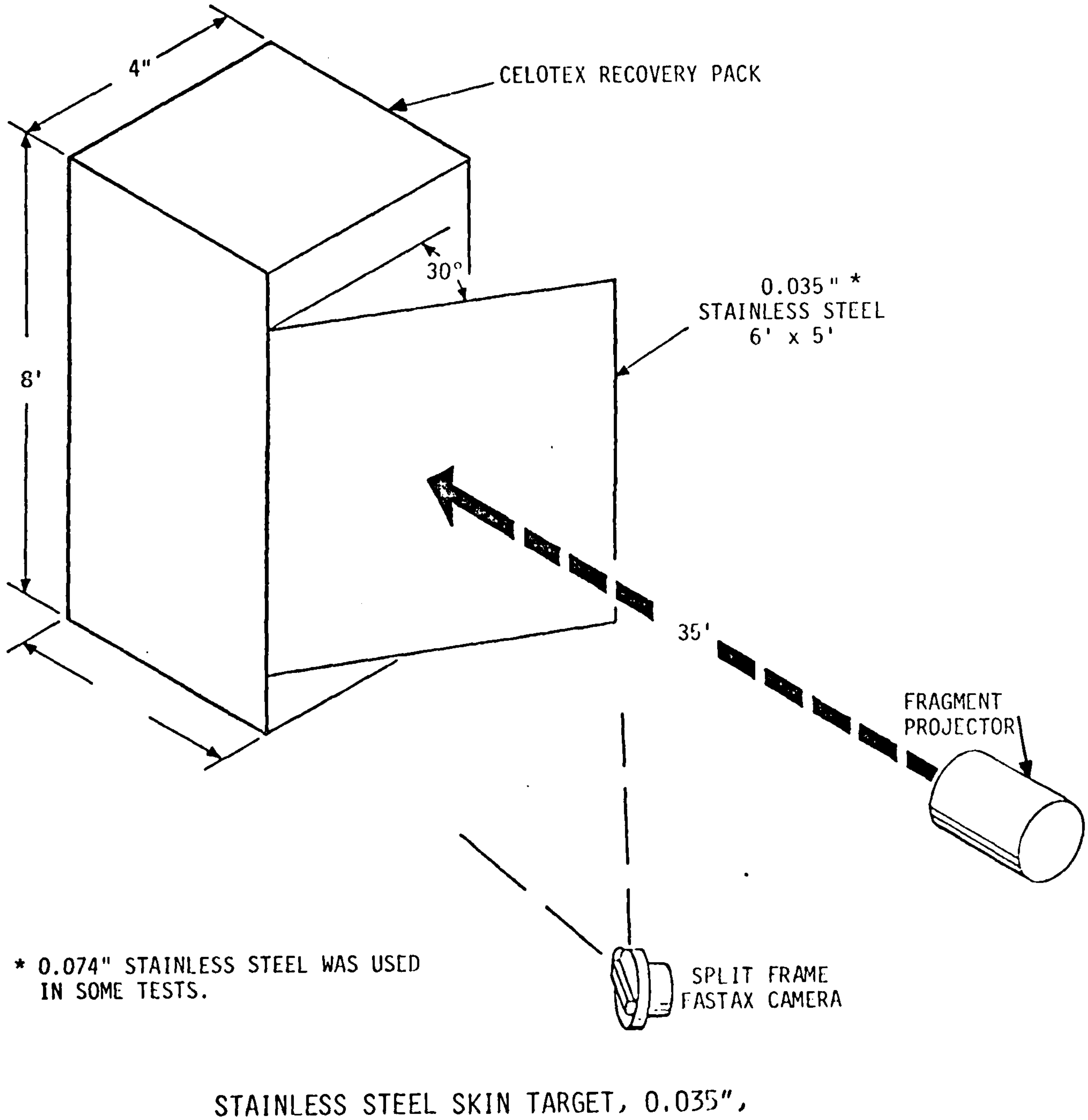
DETAIL OF MAT CONSTRUCTION

FIGURE II-1



FRAGMENT PROJECTOR USED TO ACHIEVE
FRAGMENT VELOCITIES GREATER THAN
9000-FT/SEC

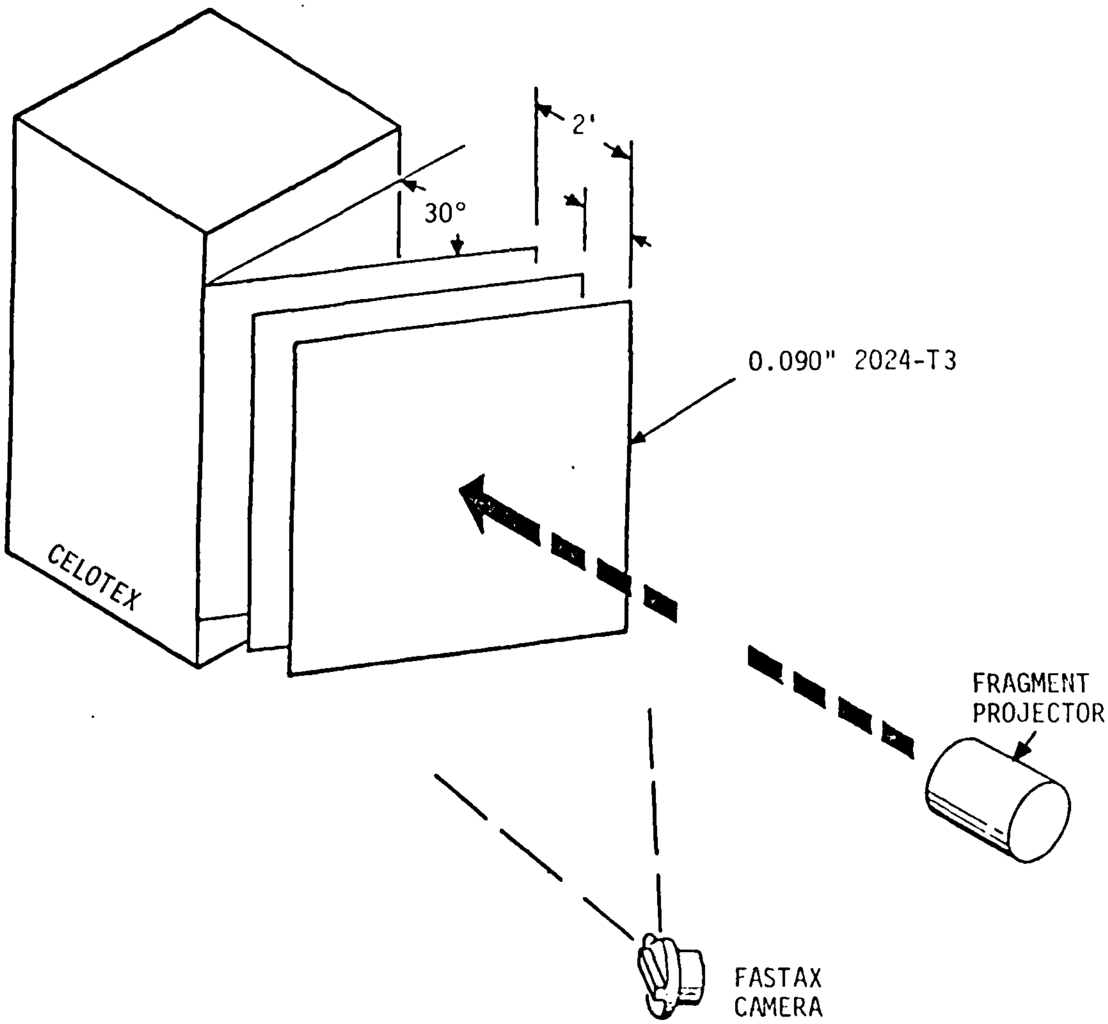
FIGURE II-2



* 0.074" STAINLESS STEEL WAS USED IN SOME TESTS.

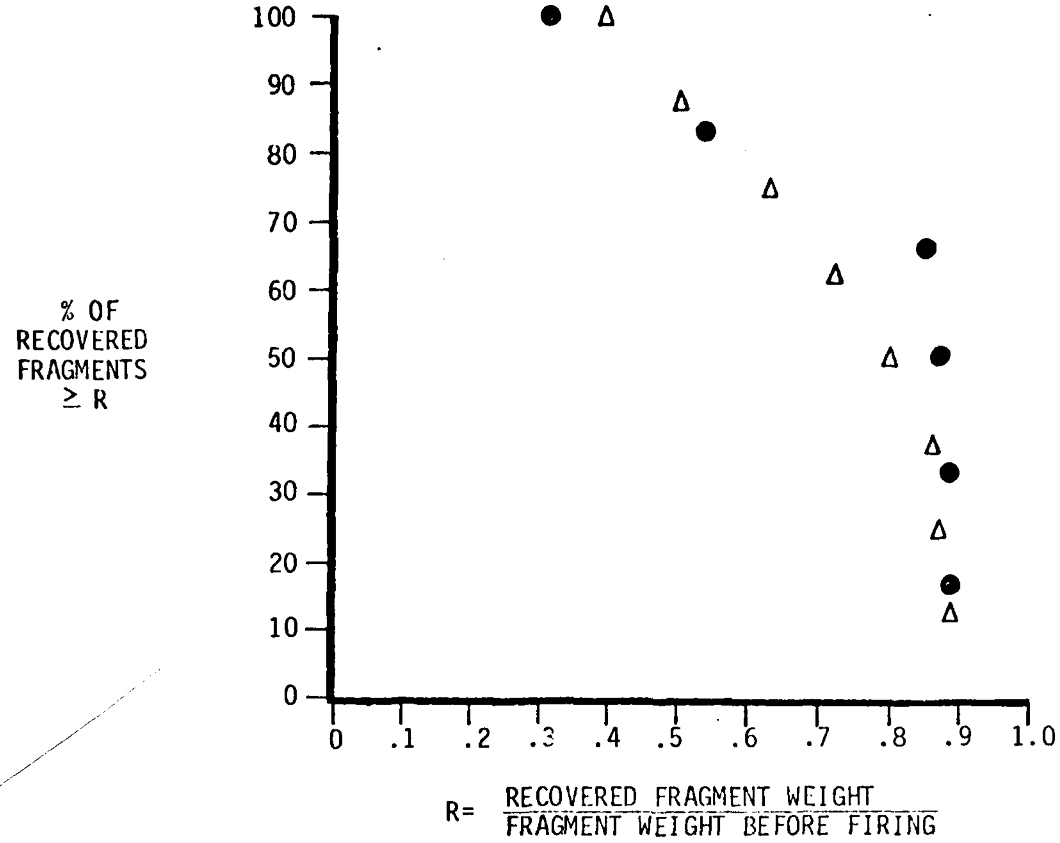
STAINLESS STEEL SKIN TARGET, 0.035", SHOWING CAMERA AND FRAGMENT PROJECTOR LOCATION

FIGURE II-3



ALUMINUM PLATE ARRAY TARGET USED TO DETERMINE FRAGMENT RESIDUAL WEIGHT FOLLOWING MULTIPLE ALUMINUM SKIN HITS

FIGURE II-4

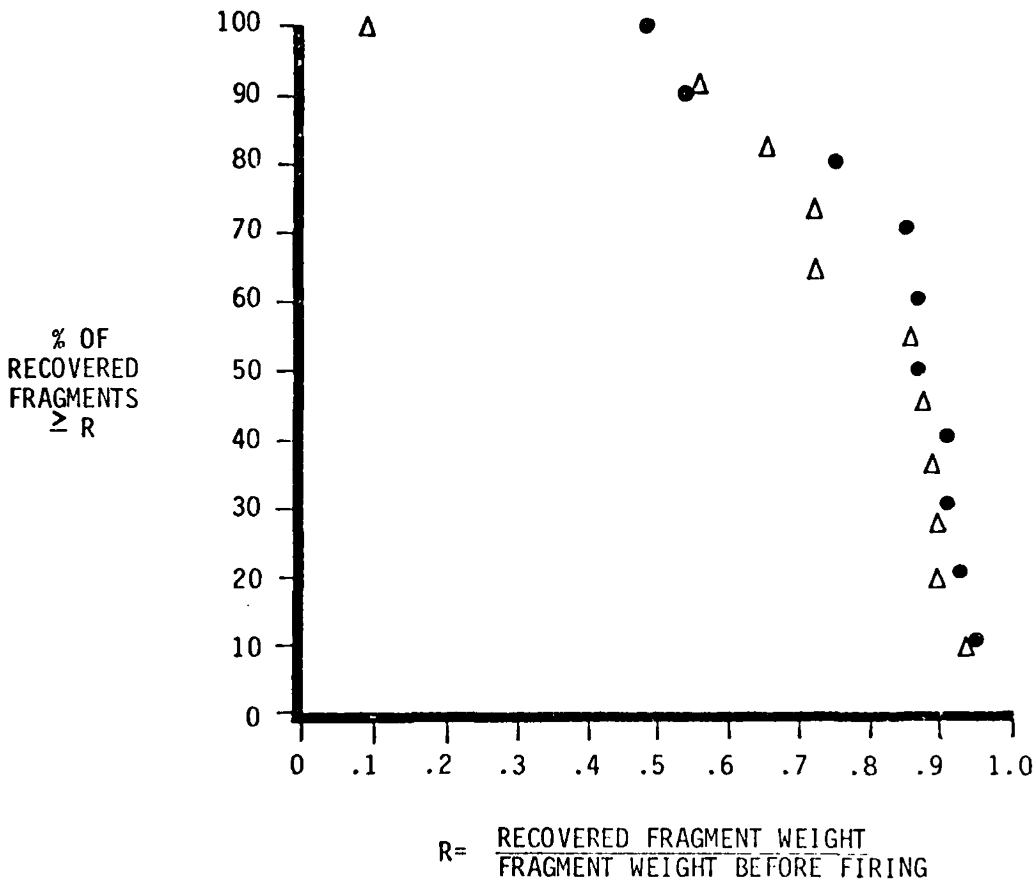


LEGEND

- Δ TEST SN0509A0 DATA, .047" STAINLESS STEEL TARGET
- ● TEST SN0514A0 DATA, .090" 2024-T3 PLATE ARRAY TARGET

TEST DATA FOR MILD STEEL FRAGMENTS

FIGURE II-5



LEGEND

● DATA FROM TESTS SN0520A0 and SN0602A0, .035" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC42, 43

△ DATA FROM TEST SN0605A0, .035" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC38

TEST DATA FOR SAE 4130 STEEL FRAGMENTS

4130

Analysis		Critical Range		Thermal Treatment	
Carbon	.28/.33	Ac_1	1400°F	Forge	2150° - 2250°F
Manganese	.40/.60	Ac_3	1510°F	Normalize	1600° - 1700°F
Phosphorus	.035 Max.	Ar_3	1400°F	Anneal	1500° - 1600°F
Sulphur	.04 Max.	Ar_1	1305°F	Harden	1550° - 1650°F oil or water
Silicon	.15/.30				
Chromium	.80/1.10				
Molybdenum	.15/.25				

MECHANICAL PROPERTIES

	Tensile	Yield	Elongation	Red. Area	Brinell	Izod
As Rolled	100,000	60,000	25	60	212	—
Annealed	80,000	56,000	28	57	149	53

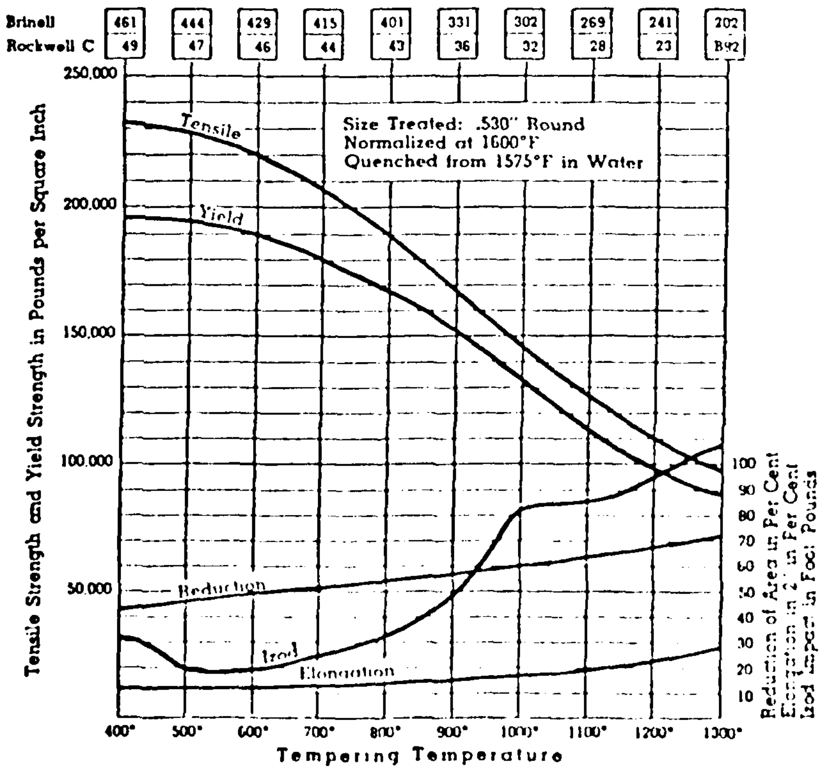
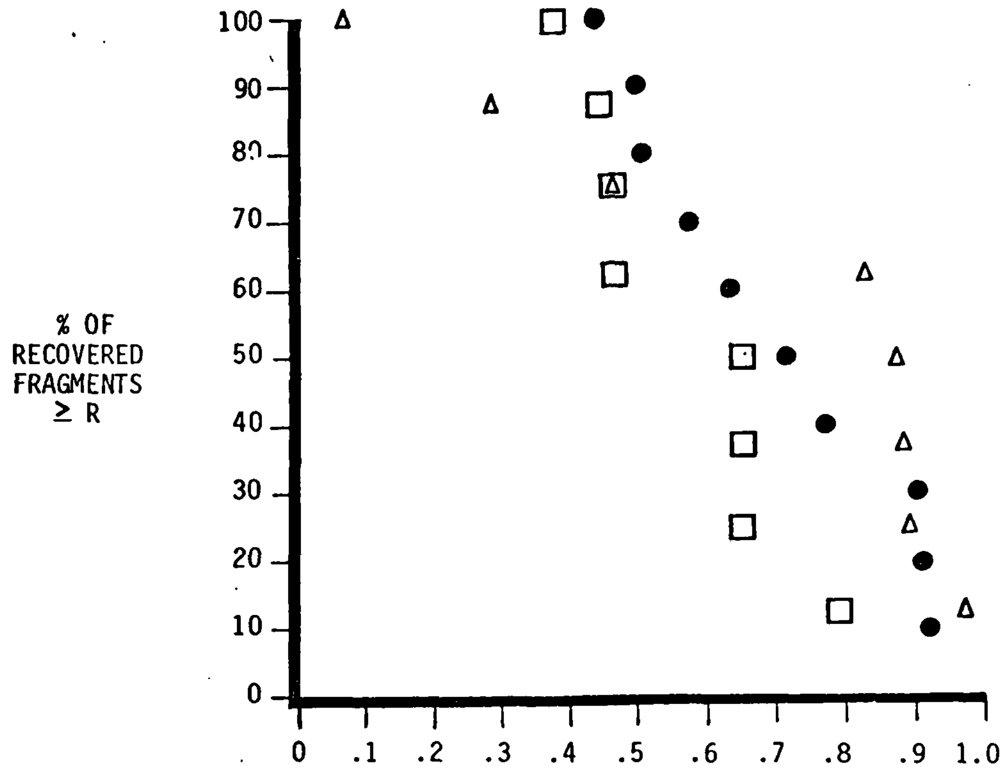


FIGURE II-6A



R= RECOVERED FRAGMENT WEIGHT / FRAGMENT WEIGHT BEFORE FIRING

LEGEND

● TEST SN0509A0 DATA, .047" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC45

Δ TEST SN0605A0 DATA, .035" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC40

□ TEST SN0514A0 DATA, .090" 2024-T3 PLATE ARRAY TARGET, FRAGMENT MATERIAL HARDNESS = RC45

TEST DATA FOR SAE 4140 STEEL FRAGMENTS

FIGURE II-7

4142

Analysis		Critical Range		Thermal Treatment	
Carbon	.40/.45	Ac_1	1395°F	Forge	2100° - 2200°F
Manganese	.75/1.00	Ac_3	1450°F	Normalize	1600° - 1700°F
Phosphorus	.035 Max.	Ar_3	1330°F	Anneal	1450° - 1550°F
Sulphur	.04 Max.	Ar_1	1280°F	Harden	1525° - 1625°F, oil
Silicon	.15/.30				
Chromium	.80/1.10				
Molybdenum	.15/.25				

MECHANICAL PROPERTIES

	Tensile	Yield	Elongation	Red. Area	Brinell	Izod
As Rolled	140,000	90,000	20	45	285	- -
Annealed	95,000	60,000	26	60	187	67

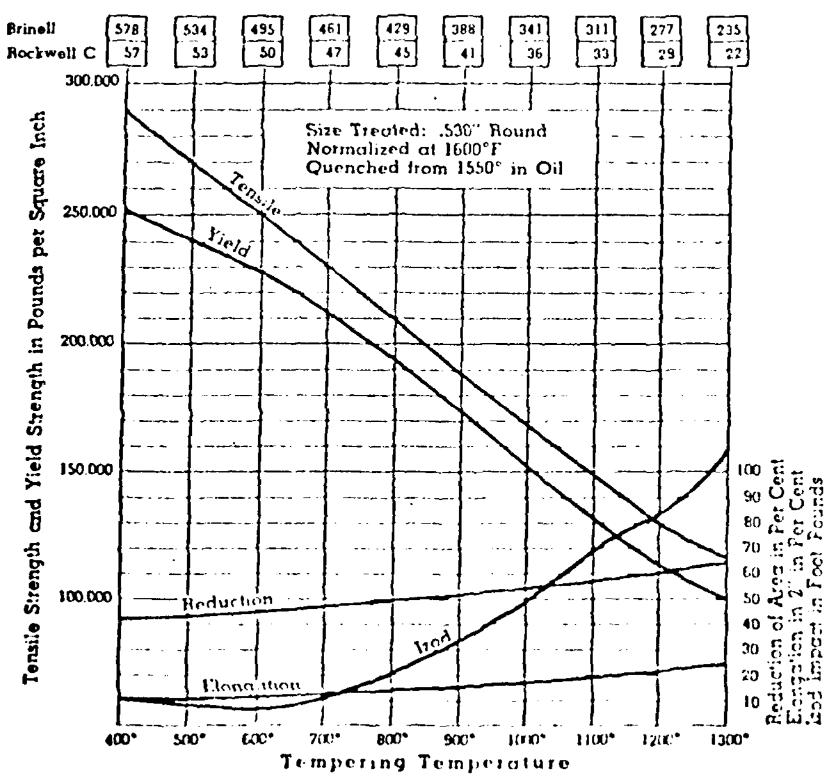
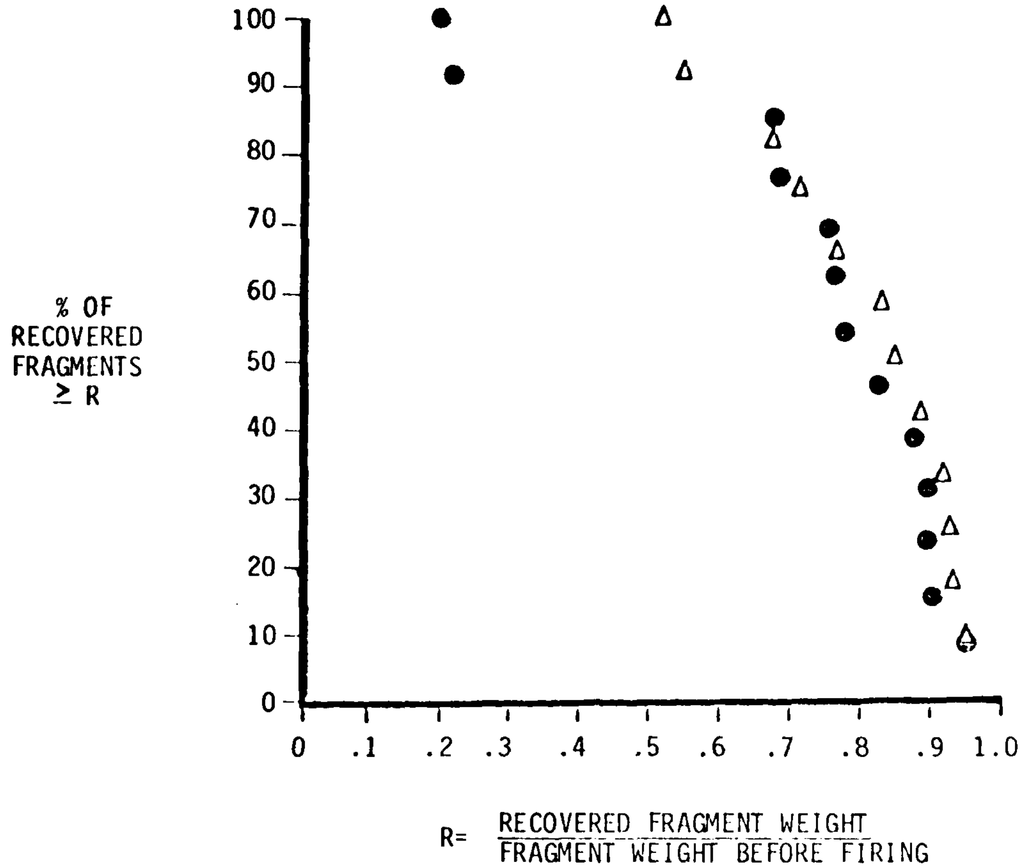


FIGURE II-7A



LEGEND

● DATA FROM TESTS SN0522A0 AND SN0602A0, .035" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC43

Δ DATA FROM TEST SN0605A0, .035" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC38

TEST DATA FOR SAE 4340 STEEL FRAGMENTS

FIGURE II-8

4340

Analysis		Critical Range		Thermal Treatment	
Carbon	.38/.43	Ac_1	1350°F	Forge	2200° - 2300°F
Manganese	.60/.80	Ac_3	1415°F	Normalize	1600° - 1700°F
Phosphorus	.035 Max.	Ar_3	890°F	Anneal	1500° - 1600°F
Sulphur	.04 Max.	Ar_1	720°F	Harden	1475° - 1575°F, oil
Silicon	.15/.30				
Chromium	.70/.90				
Nickel	1.65/2.00				
Molybdenum	.20/.30				

MECHANICAL PROPERTIES

	Tensile	Yield	Elongation	Red. Area	Brinell	Izod
As Rolled	178,000	100,000	10	30	363	—
Annealed	110,000	66,000	23	49	197	25

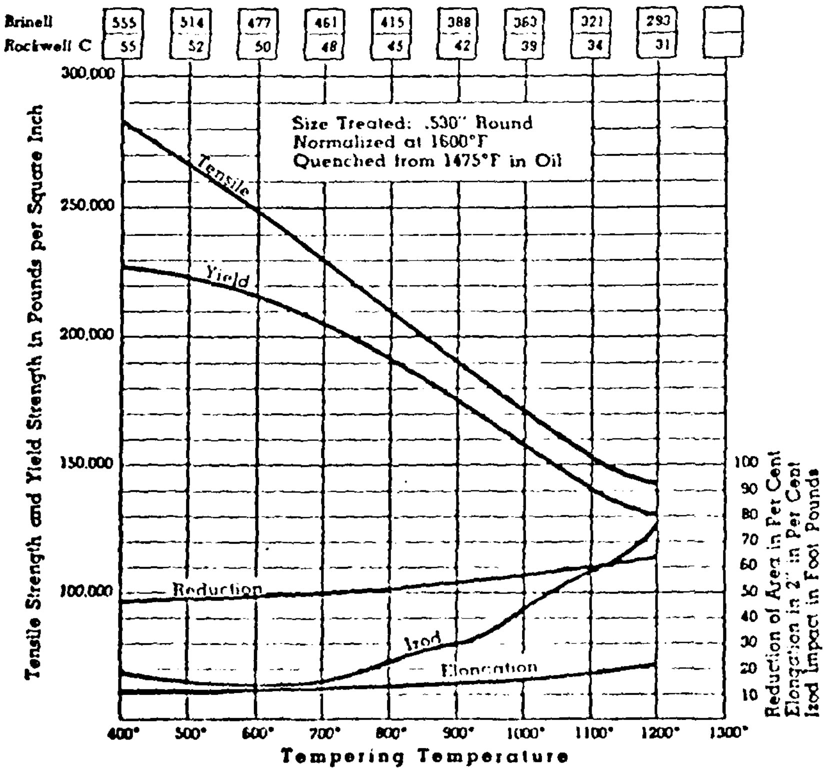
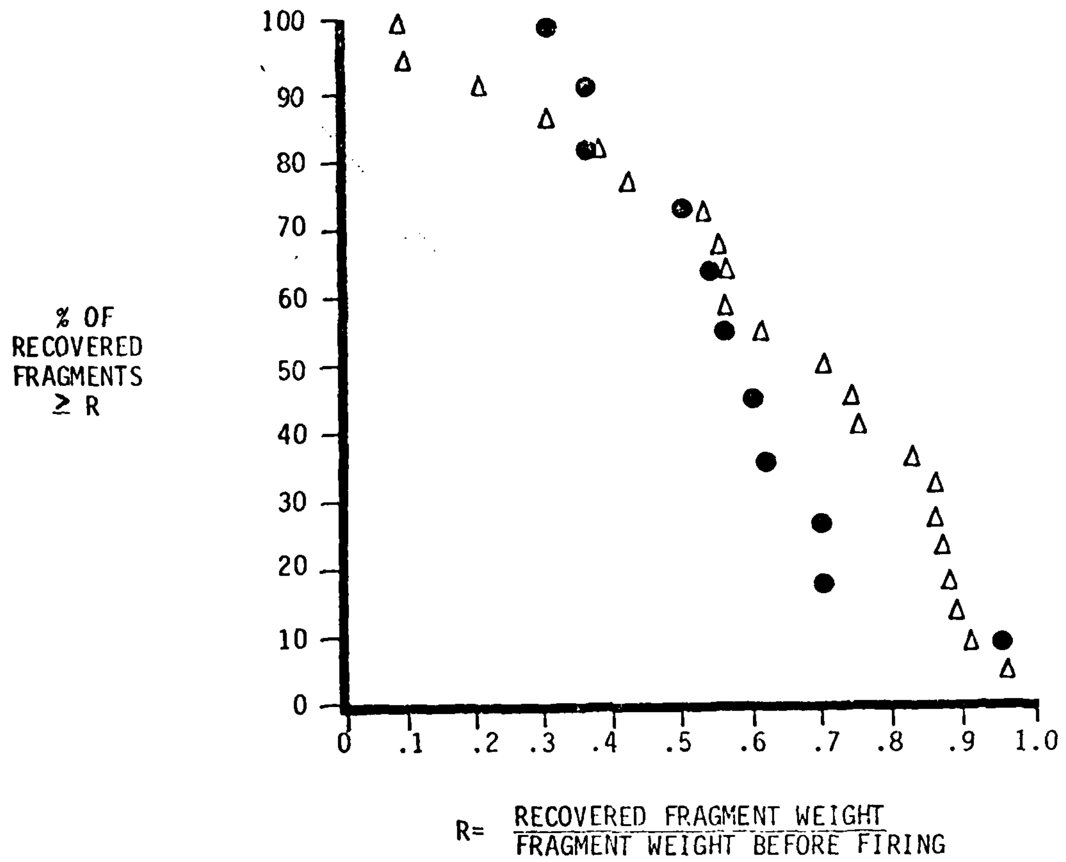


FIGURE II-8A



LEGEND

● TEST SN0522A0 DATA, .035" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC42

Δ TEST SN0526A0 AND TEST SN0602A0 DATA, .035" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC34

TEST DATA FOR 17-4 AISI 630 STEEL FRAGMENTS

FIGURE II-9

17-4
AISI 630
Precipitation Hardening Stainless Bars and Billets

Color Marking: Ends painted Blue and Yellow

This is a chromium-nickel grade of stainless steel that may be hardened by a single low-temperature precipitation-hardening heat treatment. Excellent mechanical properties at a high strength level may be obtained by such treatment. Scaling and distortion are minimized.

The strength and corrosion resistance properties of 17-4 hold up well in service temperatures up to 800°F.

Fabrication techniques for this steel are similar to those established for the regular stainless steel grades. This material machines well, has excellent welding characteristics, and forges easily. The combination of excellent mechanical and processing properties makes this grade adaptable to a wide variety of applications.

ANALYSIS

C Max.	Mn Max.	P Max.	S Max.	Si Max.	Cr	Ni	Cu	Cb +Ta
.07	1.00	.04	.03	1.00	15.50/17.50	3.00/5.00	3.00/5.00	5xC/.45

SPECIFICATIONS—AMS-5643 and ASTM A 564 Type 630 are generally applicable.

APPLICATIONS—Used where high strength and good corrosion resistance are required, as well as for applications requiring high fatigue strength, good resistance to galling, seizing and stress corrosion. Suitable for intricate parts requiring machining and welding, and/or where distortion in conventional heat treatment is a problem.

CORROSION RESISTANCE—The corrosion resistance of 17-4 is superior to that of hardenable straight chromium grades such as Type 410. It approaches the corrosion resistance of the chromium nickel grades. In many corrosive media it is equal to such grades as Type 302. Corrosion resisting properties will be affected by such conditions as surface finish and aging heat treatment.

MECHANICAL PROPERTIES—The following may be considered as average or typical room-temperature properties:

Condition	Tensile Strength (psi)	Yield Strength (psi)	Elongation in 2"	Reduction of Area	Rockwell "C" Hardness
A (Annealed)	150,000	110,000	10%	40%	34
H 900 (Hardened at 900°)	200,000	185,000	14%	50%	44
H 1150 (Hardened at 1150°)	145,000	125,000	19%	60%	33

AMS-5643 requires the following after precipitation heat treating at 900°F:

Tensile Strength (psi)	Yield Strength (psi)	Elongation in 2"	Reduction of Area: 3" Thick & Under	Reduction of Area: 3" Thick to 8" Thick
190,000 Min.	170,000 Min.	10% Min.	40% Min.	35% Min.

MACHINABILITY—This grade has a machinability rating of 48% in the annealed condition (Condition A), with surface cutting speed of 80 feet per minute. In the overaged condition (H 1150 M), the machinability rating is 76%, with surface cutting speed of 125 feet per minute.

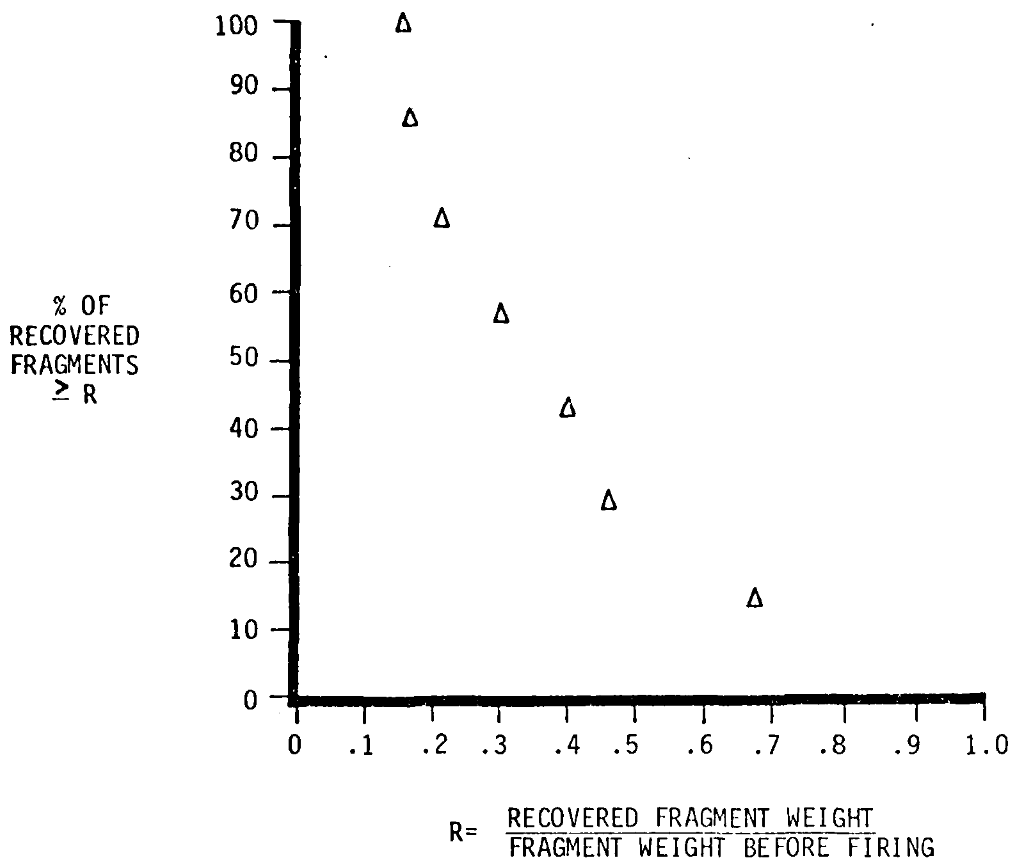
WELDING—Readily weldable by all the commercial processes. Preheating and post-heating practices used for the standard hardenable stainless grades are not required.

FORGING—Forge between 2050°F and 2150°F. Do not forge below 1850°F. Forgings are air cooled to 90°F or lower. Large or intricate forgings should be equalized at some temperature between 1900°F and the forging temperature before air cooling.

ANNEALING (Condition A)—The annealing (solution treatment) temperature is 1900°F. Material under 3" in thickness may be oil quenched. Material over 3" thick should be air cooled. Maximum Brinell hardness on sections under 3" is 341; over 3", 363.

HARDENING—

Condition H 900—900°F for 1 hour, air cool. Rockwell "C" 44 Average.
Condition H 1025—1025°F for 4 hours, air cool. Rockwell "C" 38 Average.
Condition H 1150—1150°F for 4 hours, air cool. Rockwell "C" 33 Average.



LEGEND

Δ DATA FROM TESTS SN0522A0 AND SN0526A0. .035" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC45

TEST DATA FOR TYPE-416 STEEL FRAGMENTS

FIGURE II-10

TYPE 416

Analysis

Carbon .... .15 Max.
Manganese .... 1.20 Max.
Phosphorus .... .04 Max.
Sulphur .... .18/.35
Silicon .... 1.00 Max.
Chromium 12.00/13.50

Thermal Treatment

Forge ....2100° - 2300°F. Cool slowly.
Process Anneal ...... 1200° - 1400°F. (Brinell 170-207.)
Full Anneal ....1550° - 1650°F. Furnace cool. (Brinell 137-167.)
Harden ....1700° - 1850°F. Cool rapidly.
Temper ....400° - 1400°F. (Tempering between 700° and 1050°F is not recommended.)

TYPICAL MECHANICAL PROPERTIES

	Tensile	Yield	Elongation	Red. Area	Brinell	Izod
Annealed Bars	75,000	40,000	30	60	155	70

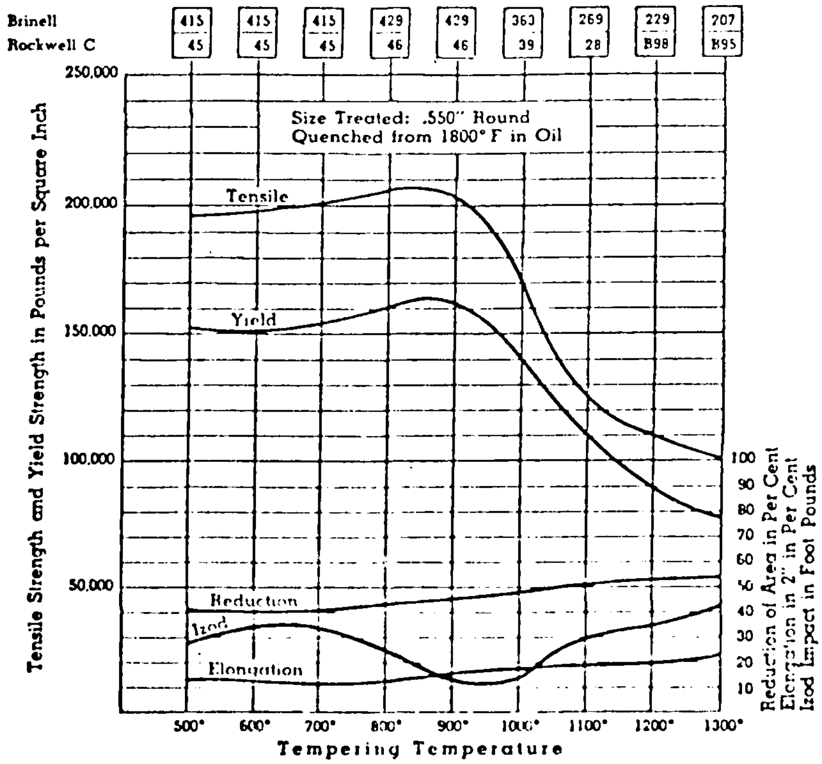
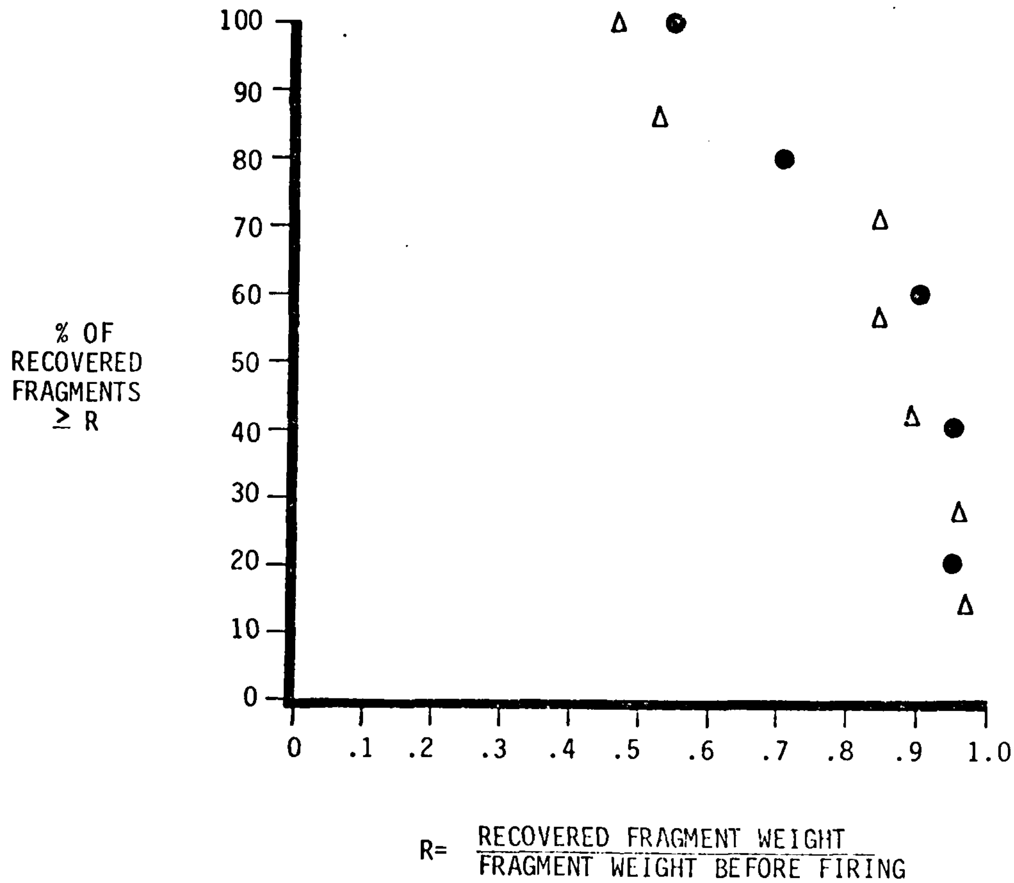


FIGURE II-10A

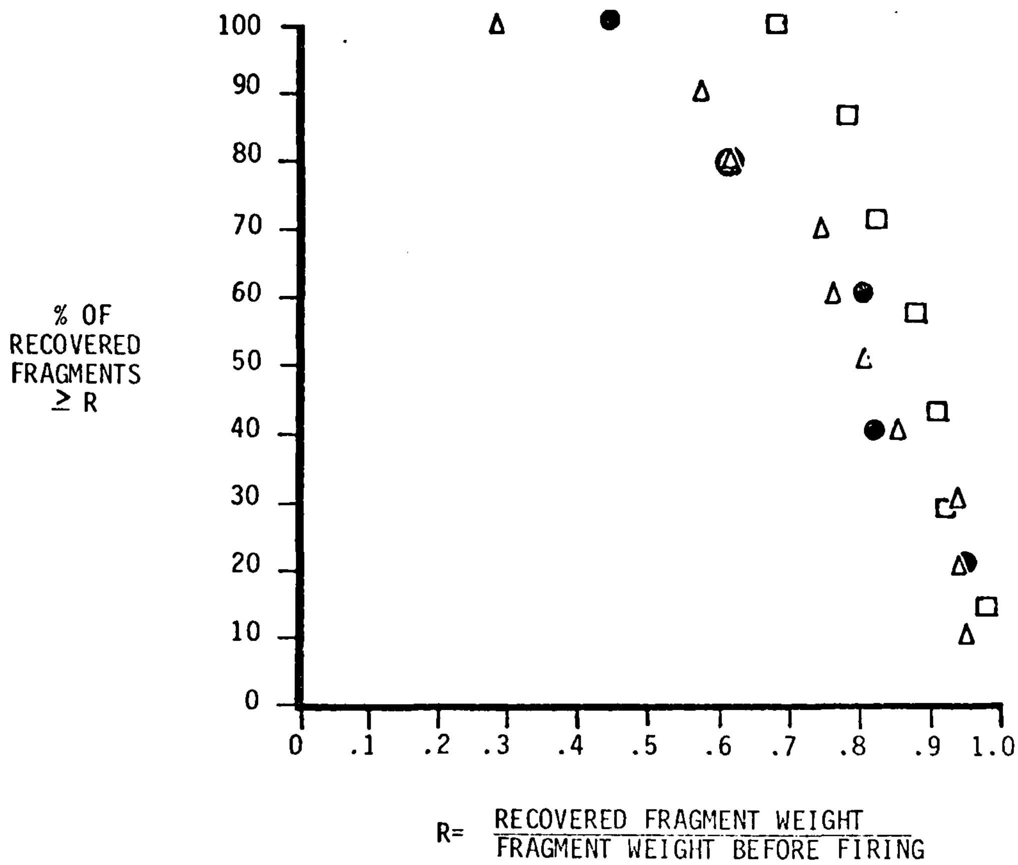


LEGEND

● TEST SN0509A0 DATA, .047" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = BHN77

TEST DATA FOR STAINLESS STEEL (UNKNOWN ALLOY) FRAGMENTS

FIGURE II-11



LEGEND

● TEST SN0514A0 DATA, .090" 2024-T3 PLATE ARRAY TARGET, FRAGMENT MATERIAL HARDNESS = RC42

□ TEST SN0509A0 DATA, .047" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC42

Δ TEST SN0605A0 DATA, .035" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC41

TEST DATA FOR CARPENTER 5-317 STEEL FRAGMENTS

FIGURE II-12

CARPENTER NO. 5-317

TYPE ANALYSIS:

Carbon	.50%
Manganese	.50
Silicon	.20
Chromium	1.00
Nickel	1.75

INSTRUCTIONS FOR WORKING NO. 5-317

FORGING: Forge from a temperature of not over 2100°F, allow to cool in air in a dry place.

NORMALIZING: Heat to 1550°F, and cool in air.

ANNEALING: Heat to 1400°F and cool slowly. Brinell hardness approximately 180 to 200.

HARDENING: Heat to 1450° to 1500°F and quench in oil.

DRAWING: No. 5-217 is drawn in two separate ranges-depending upon the parts being made.

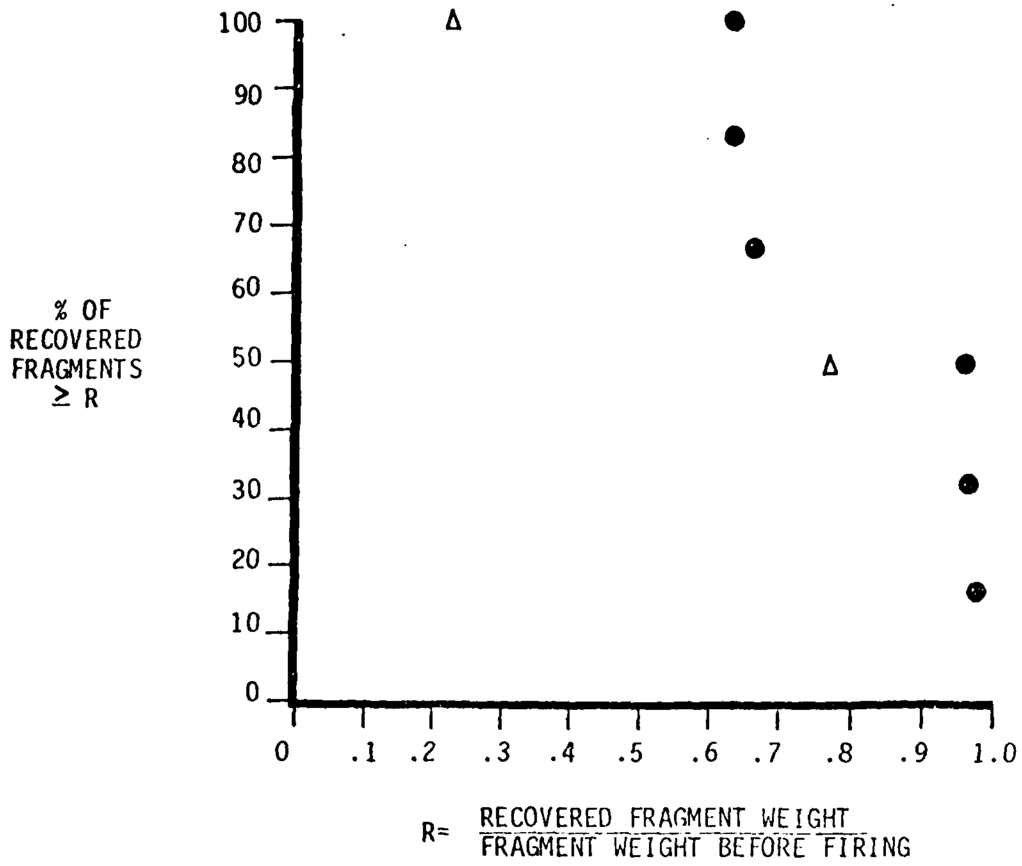
EFFECT OF DRAWING TEMPERATURES
SECTION 1/2" TO 2" - OIL QUENCHED FROM 1450 F

DRAWING TEMPERATURE	ROCKWELL	SCIEROSCOPE	BRINELL
As hardened	C-56	77	578
300°F	C-56	77	578
350°	C-55	75	555
400°	C-54	73	534
450°	C-53	72	534
500°	C-53	72	534
550°	C-52	70	514
600°	C-50	67	495

AVERAGE PHYSICAL PROPERTIES

SIZE OF TEST SECTION AND LOCATION OF TEST BAR	HARDENING PROCEDURE	DRAWING TEMPERATURE	TENSILE STRENGTH IN lbs./sq. in.	YIELD POINT IN lbs./sq. in.	ELONGATION, % in 2"	REDUCTION OF AREA,	HARDNESS VALUES TAKEN ON OUTSIDE OF FULL SIZED SECTION: BRINELL HARDNESS	SHORE HARDNESS	ROCKWELL HARDNESS
1/2" to 1-1/4" round or thick. Test from CENTER of section.	Oil quenched from 1450°F.	700°F	249,000	228,000	10.5	32.0	444	61	C-46
		800°	220,000	201,000	15.5	39.0	415	57	C-44
		900°	194,000	170,000	14.5	45.5	375	52	C-40
		1000°	170,000	149,000	16.5	51.5	33[illegible]	46	C-35
		1100°	150,000	128,000	17.5	56.0	293	42	C-31
1-1/4" to 2-1/2" round or thick. Test MIDWAY between center and surface.	Oil quenched from 1475°F	700°	220,000	200,000	9.5	34.0	429	59	C-45
		800°	200,000	183,000	11.5	41.0	401	55	C-42
		900°	181,000	163,000	13.0	46.0	352	49	C-37
		1000°	159,000	143,000	16.5	52.0	311	44	C-33
		1100°	136,000	121,000	20.0	56.0	269	38	C-28
2-1/2" to 5" round or thick. Test MIDWAY between center and surface.	Oil quenched from 1500°F	700°	210,000	170,000	8.0	31.5	401	55	C-42
		800°	187,000	160,000	11.5	33.0	375	52	C-40
		900°	168,000	142,000	13.0	42.0	341	48	C-36
		1000°	149,000	125,000	17.0	49.0	311	44	C-33
		1100°	131,000	108,000	19.5	55.0	269	38	C-28

FIGURE II-12A



LEGEND

Δ TEST SN0520A0 DATA, .035" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC50

● TEST SN0602A0 DATA, .035" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC43

TEST DATA FOR AISI-S7 STEEL FRAGMENTS

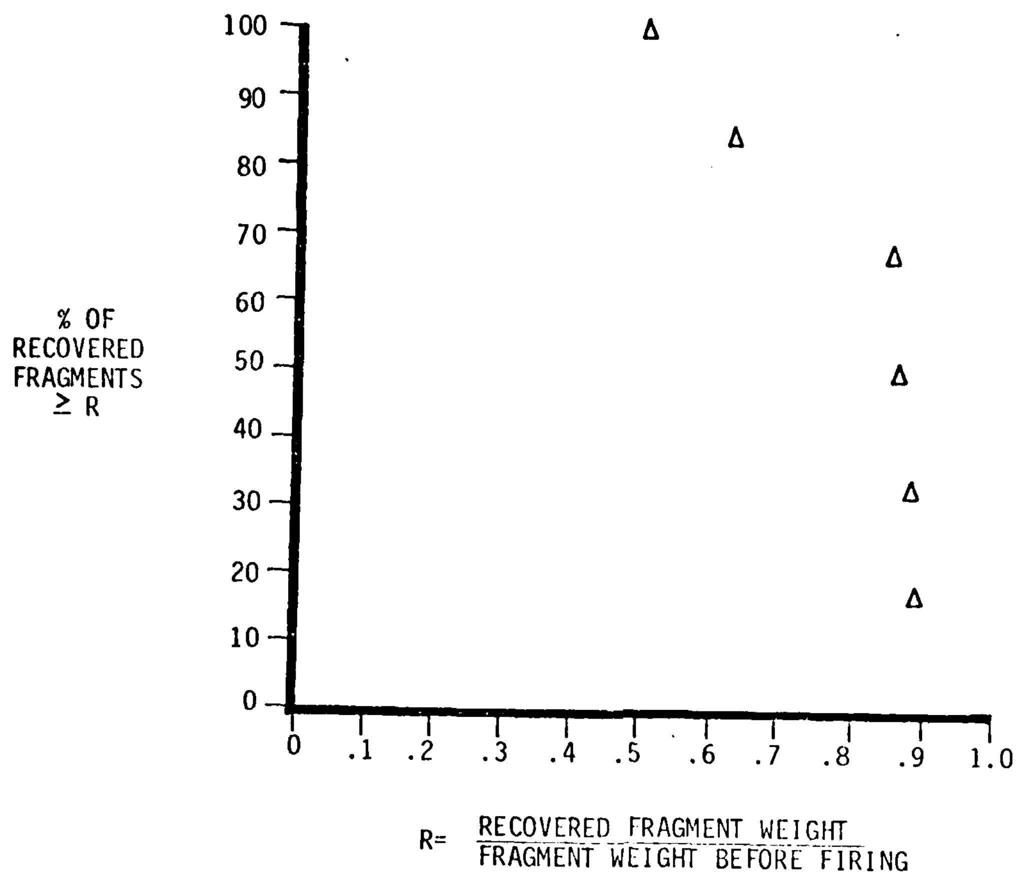
FIGURE II-13

AISI-S7 TOOL STEEL

CHROME-MOLY
AIR HARDENING

TYPICAL ANALYSIS	C .45/.55 Mn .20/.80 Si .20/1.00 Cr 3.00/3.50 Mo 1.30/1.80 V .20/.30
WEAR RESISTANCE	GOOD
TOUGHNESS	BEST
NON-DEFORMING	GOOD
RED HARDNESS	GOOD
MACHINABILITY	GOOD
FORGING Start at__________ Do not forge below________	 2000-2050°F 1700°F
ANNEALING Temperature__________ Max. cooling rate/hr______ Brinell hardness________	 1500-1550°F 25°/hr. down to 1000°; then air cool 197
HARDENING Hardening temperature_____ Quench medium__________	 1725°F To 2-1/2"-Air Over 2-1/2"-Oil (until black)
TEMPERING Temperature__________ Rc hardness__________	 400-1000°F 58-51

FIGURE II-13A



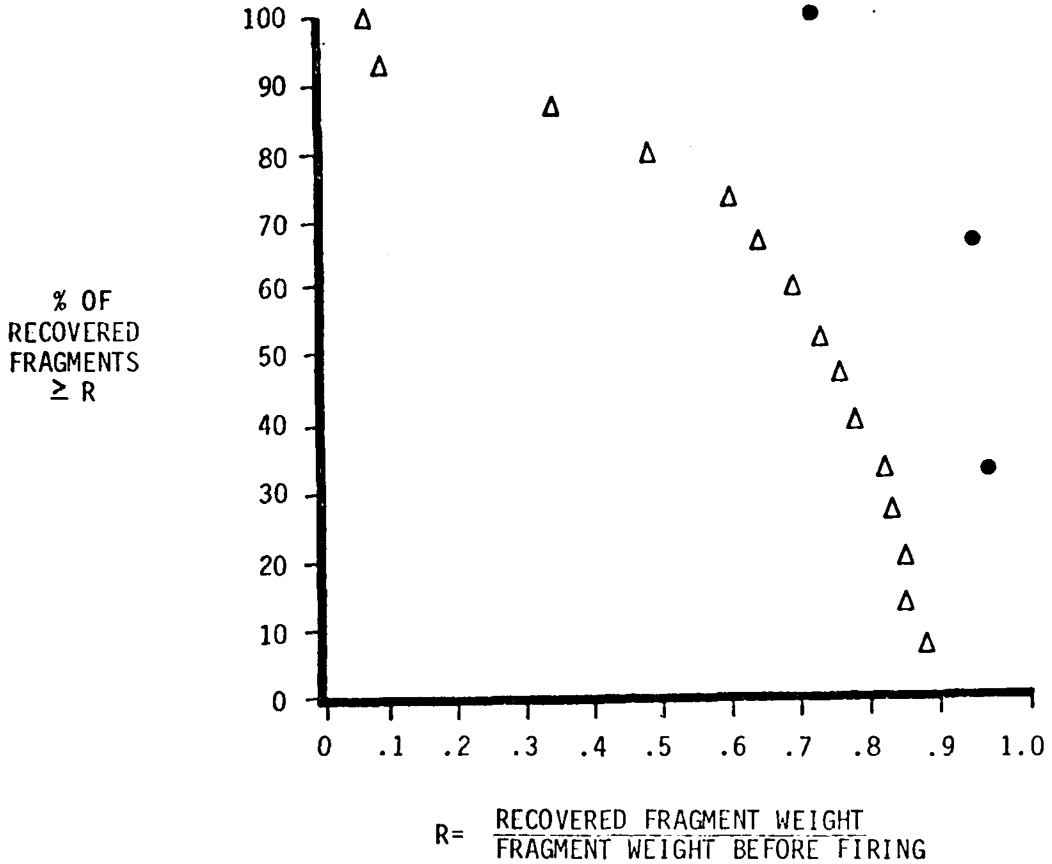
LEGEND

Δ TEST SN0520A0 DATA, .035" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC42

TEST DATA FOR CARPENTER 5-876 STEEL*

* No longer manufactured, no data on properties found

FIGURE II-14



LEGEND

△ TEST SN0526A0 DATA, .035" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC38

● TEST SN0520A0 DATA, .035" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC41

TEST DATA FOR ARMCO HY-80 STEEL FRAGMENTS

FIGURE II-15

HY-80

CHEMICAL COMPOSITION HEAT ANALYSIS %		MECHANICAL PROPERTIES		
CARBON (max)	.18**	THICKNESS, inches	3/16 to 3/4	3/4 to 6
MANGANESE	.10/.40	TENSILE STRENGTH*	*	*
PHOSPHORUS* (max)	.025	YIELD STRENGTH psi	80,000/ 100,000	80,000/ 100,000
SULPHER*	.025			
SILICON (max)	.15/.35	ELONGATION** % IN 2" MIN	19 FLAT SPECIMEN FIG. 4***	20 FLAT SPECIMEN FIG. 5***
NICKEL	2.00/3.25			
CHROMIUM	1.00/1.80			
MOLYBDENUM	.20/.60	REDUCTION IN AREA MIN, % LONGITUDINAL		55
		TRANSVERSE		50
OTHERS	MAXIMUM RESIDUALS PERMITTED TITANIUM - 0.02 VANADIUM - 0.03 COPPER - 0.25			

* The percent of P and S combined shall not be more than 0.040.

** 0.20 max C applies for plates 6" thick and over.

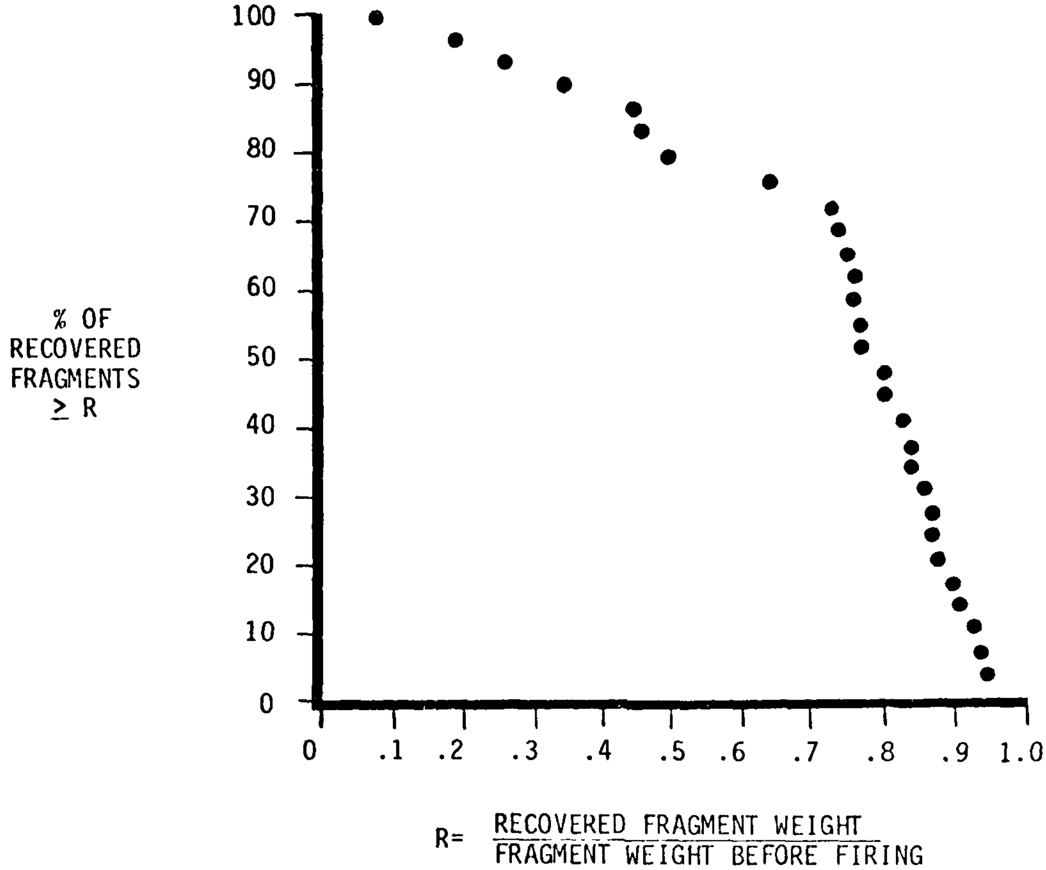
*** For bars and billets the range is 2.00/3.25%.

* Specification does not include ultimate tensile strength. Test values reported for information only.

** For plates 3/16" to 1/4" in thickness, elongation requirement shall be 14% for HY-80/

*** See ASTM A 370 for flat and round specimen dimensions.

FIGURE II-15A



LEGEND

● DATA FROM TESTS SN0522A0 AND SN0526A0, .035" STAINLESS STEEL TARGET, FRAGMENT MATERIAL HARDNESS = RC42, 43.

TEST DATA FOR SSS-100 STEEL FRAGMENTS

FIGURE II-16

SSS-100

HEAT CHEMICAL COMPOSITION (%)

ALLOY	C	Mn	P	S	Si[1]	Cr	Mo	Ti	Cu[2]	B
SSS 100 A514 & A517 Grade E	.12/.20	.40/.70	.035 max	.040 max	.10/.35	1.40/2.00	.40/.60	.04/.10	-	.0015/.0050

TENSILE PROPERTIES
Plates (transverse specimen)

ALLOY	PLATE THICKNESS	MINIMUM YIELD STRENGTH (ksi)	STRUCTURAL QUALITY[1] (A514) TENSILE STRENGTH (ksi)	STRUCTURAL QUALITY (A514) ELONG. in 2" (min %)	STRUCTURAL QUALITY (A514) RED. OF AREA (min %)	PRESSURE VESSEL QUALITY (A517) TENSILE STRENGTH (ksi)	PRESSURE VESSEL QUALITY (A517) ELONG. in 2" (min %)	PRESSURE VESSEL QUALITY (A517) RED. OF AREA (min %)
SSS-100	3/16" to 2-1/2" incl.	100	110/130	16	35[2]	115/135	16	35
	over 2-1/2" to 6" incl.	90	100/130	14	45	105/135	14	45

HARDNESS RANGE*
Water quenched and tempered - 235/293 BHN thru 3/4"-thick A514 plate

MODULUS OF ELASTICITY*
In Tension - 20.5×10^6 psi
In Compression - 30.9×10^6 psi

MODULUS OF RIGIDITY*
11.9×10^6 psi

SHEAR STRENGTH*
60 to 65% of tensile strength

POISSONS'S RATIO*
0.29

COEFFICIENT OF THERMAL EXPANSION - 70 F TO 1200 F*
SSS 100 - 7.7×10^{-6} in/in/F
SSS 100A - 7.5×10^{-6} in/in/F

ELECTRICAL RESISTIVITY*
28 micro ohm-cm at 75 F

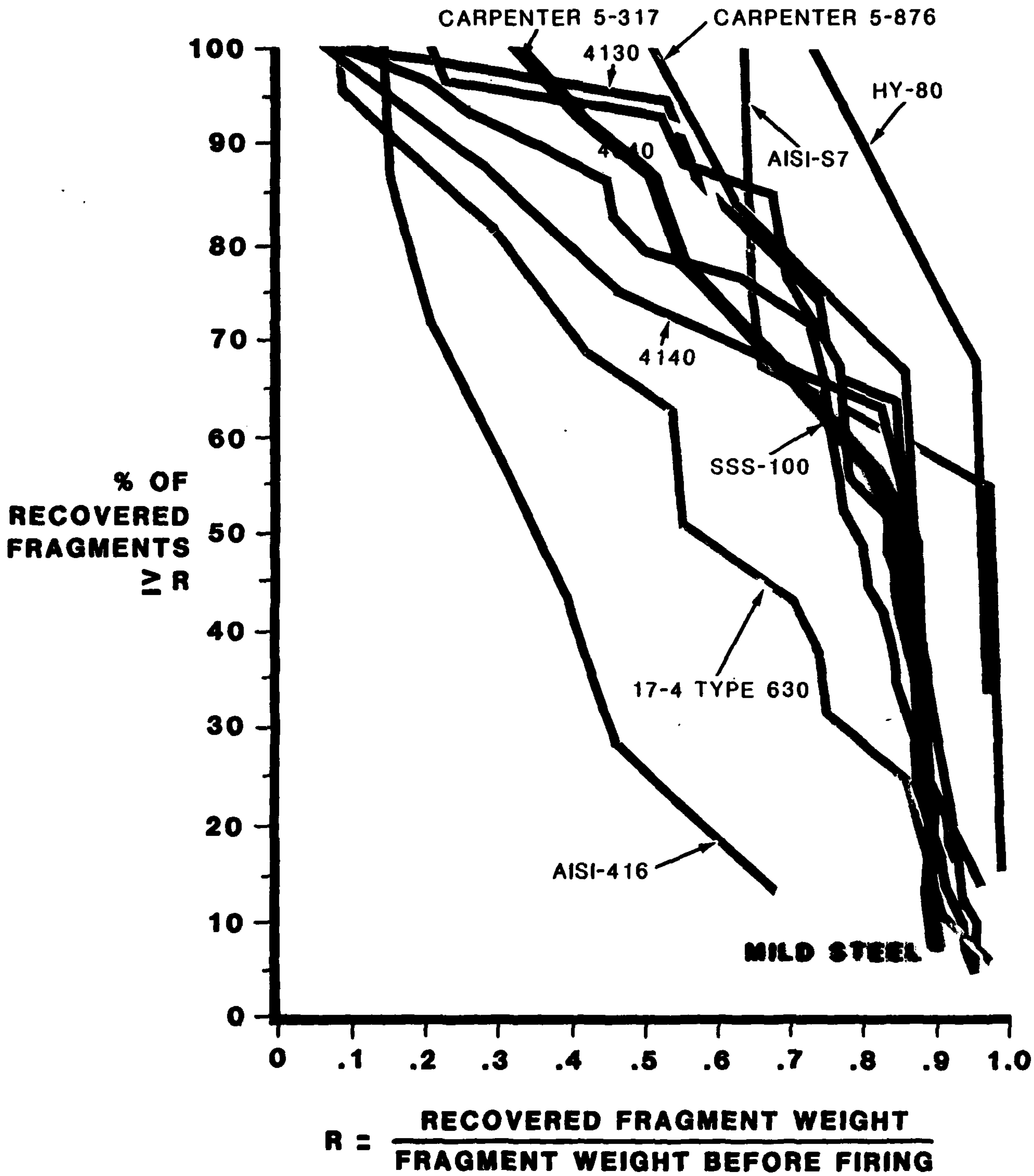
ATMOSPHERIC CORROSION RESISTANCE*
SSS 100 - 4 to 6 times carbon steel without copper
SSS 100A - 2 to 4 times carbon steel without copper
SSS 100B - 3 to 5 times carbon steel without copper

ELEVATED TEMPERATURE STRENGTH*
Short time elevated temperature strength at 900 F is about 3 times that of carbon structural steel.

For service temperatures of 650 to 900 F, consult the creep and stress rupture data on page 14 for selecting allowable design stresses.

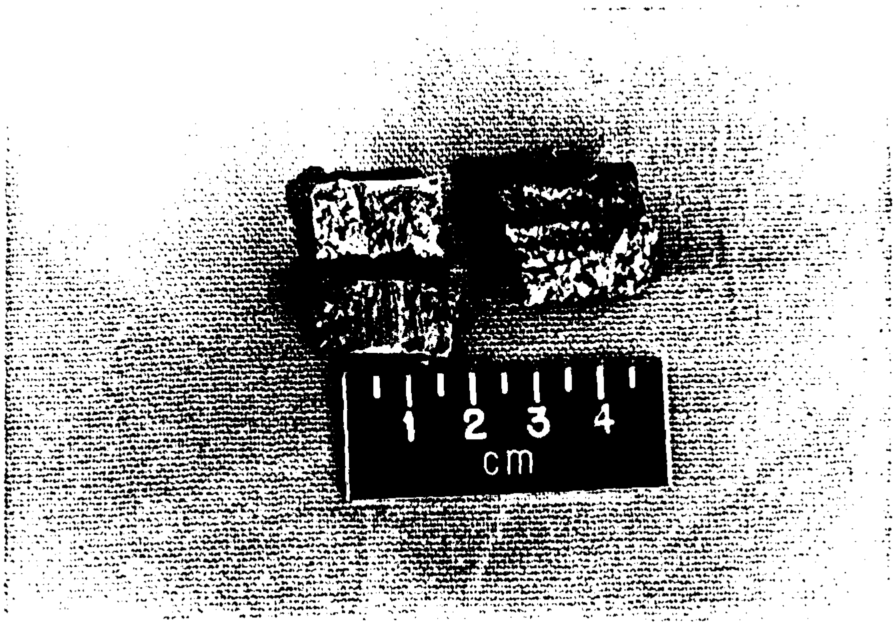
*Values for these engineering properties are based on testing a limited number of plates. They represent only "Typical Engineering Properties" and are not specification requirements. Armco does not warrant or guarantee these properties.

FIGURE II-16A



SUMMARY OF DATA FOR 560 GRAIN ALLOY STEEL FRAGMENTS IMPACTING .035" STAINLESS STEEL AT 30° OBLIQUITY, AT 10,000 FT/SEC.

FIGURE II-17



EXAMPLES OF TWO FRAGMENTS (LEFT) WHICH LOST WEIGHT DUE TO FRACTURING, AND ONE FRAGMENT WHICH LOST WEIGHT DUE TO EROSION

FIGURE II-18

TABLE NO. II-1
SUMMARY TABLE OF
FRAGMENT SURVIVAL TESTS

SN TEST SERIES

TEST NO. SNO----0	FRAGMENT MATERIAL	TARGET	FRAGMENT HEAT TREAT	FRAGMENT HARDNESS	AVE. FRAG. WT. BEFORE FIRING (grains)	% RECOVERED WT. / ORIGINAL WT.	COMMENTS
509A	Stainless Steel	.047" S.S.	NONE	BHN-77	574	77	
	Carpenter 5-317	.047" S.S.	NONE	RC-42	570	85	
	Mild Steel 1018	.047" S.S.	NONE	BHN-167	576	71	
	SAE 4140	.047" S.S.	800° F Draw	RC-45	564	68	
514A	Stainless Steel*	.090" 2024-T3 3 Sheets	NONE	BHN-77	558	78	
	Carpenter 5-317	.090" 2024-T3 3 Sheets	NONE	RC-42	552	73	
	Mild Steel 1018	.090" 2024-T3 3 Sheets	NONE	BHN-167	559	69	
	SAE 4140	.090" 2024-T3 3 Sheets	800° F Draw	RC-45	545	56	
520A	ARMCO HY-80	.035" S.S.	800° F Draw	RC-41	552	89	
	AISI-S7	.035" S.S.	800° F Draw	RC-50	549	50	
	SAE 4130	.035" S.S.	800° F Draw	RC-42	549	83	

* Found on project, exact alloy will be determined if performance warrants.

TABLE NO. II-1
SUMMARY TABLE OF FRAGMENT SURVIVAL TESTS
SN TEST SERIES

TEST NO. SNO---0	FRAGMENT MATERIAL	TARGET	FRAGMENT HEAT TREAT	FRAGMENT HARDNESS	AVE. FRAG. WT. BEFORE FIRING (grains)	% RECOVERED WT. / ORIGINAL WT.	COMMENTS
	Carpenter 5-876	.035" S.S.	800° F Draw	RC-43	549	76	
522A	ARMCO SSS-100	.035" S.S.	No Draw	RC-43	565	79	
	17-4 AISI 630	.035" S.S.	900° F AIR	RC-42	534	56	
	AISI-416	.035" S.S.	800° F	RC-45	522	51	
	SAE 4340	.035" S.S.	800° F Draw	RC-43	549	81	
526A	ARMCO HY-80	.035" S.S.	900° F Draw	RC-38	563	63	
	ARMCO SSS-100	.035" S.S.	900° F Draw	RC-42	540	72	
	AISI-416	.035" S.S.	900° F	RC-45	522	18	
	17-4 AISI 630	.035" S.S.	As Received	RC-34	544	62	Erosion, Steel may be too soft.
	SAE [illegible]	.035" S.S.	900° F Draw	RC-43	516	93	
	[illegible]	.035" S.S.	1200° F (Draw in oven)	RC-43	556	95	One fragment broke in half (not scabbed)
		.035" S.S.	900° F	RC-43	517	75	One fragment broke in half (not scabbed)

TABLE NO. II-1
SUMMARY TABLE OF
FRAGMENT SURVIVAL TESTS

SN TEST SERIES

TEST NO. SNO--0	FRAGMENT MATERIAL	TARGET	FRAGMENT HEAT TREAT	FRAGMENT HARDNESS	AVE. FRAG. WT. BEFORE FIRING (grains)	% RECOVERED WT. / ORIGINAL WT.	COMMENTS
	17-4 AISI 630	.035" S.S.	1150° F 4 hrs.	RC-34	438	95	One fragment scabbed.
605A	Carpenter 5-317	.035" Steel	1000° F Draw	RC-41	555	75	
	SAE 4140	.035" Steel	1000° F Draw	RC-40	555	65	
	SAE 4340		1000° F Draw	RC-38	555	81	
	SAE 4130		1000° F Draw	RC-38	555	79	

APPENDIX III

METHODOLOGY FOR PREDICTING WARHEAD FRAGMENT VELOCITY AND POLAR EJECTION ANGLE CHARACTERIZATIONS

APPENDIX III

METHODOLOGY FOR PREDICTING WARHEAD FRAGMENT VELOCITY AND POLAR EJECTION ANGLE CHARACTERIZATIONS

This appendix describes the methodology used by NMT to predict fragment ejection angles and velocities for single-end initiated warheads. An example calculation is presented for the 19" annular, 200-lb warhead design.

The basic model for predicting polar ejection angles and fragment velocities for single-end initiated warhead is presented in Figure III-1. A fragments' polar ejection angle and velocity is dependent upon the fragments' center-of-length distance from the booster-end of the warhead. The vertical scale against which the fragments' polar angle and velocity are plotted is the location of the fragments' center-of-length with respect to the booster-end, expressed as a percent of the warhead length.

For polar ejection angle prediction, three curves are plotted; one is generated from NMT characterization data on warhead tests over the past ten years, a second curve is reproduced from Waggeners report[1], and a third curve is shown which represents the "eyeball-fit" average of the first two. The "average" curve is used for polar angle predictions. The NMT velocity curves are intended to apply to warheads whose case thickness falls between 3 and 5% of the warhead outside diameter.

NMT's prediction for fragment velocities begins with the equation published by C. R. Brown.* The equation is:

$$v = \alpha \sqrt{\frac{C/m}{\left[1 + \frac{C}{6m}\left(\frac{3 - B^2 - 8\sqrt{B} + 6B}{(1-B)(1-\sqrt{B})^2}\right)\right]\left(1 + \sqrt{B} + \frac{D}{2L}(1-B)\right)}}$$

where v = initial velocity of metal casing (ft/sec)

C/m = ratio of charge weight to metal weight

B = fraction of solid charge weight removed from center of the warhead; $B = \left(\frac{r_o}{r}\right)^2$ where r_o = inner radius and r = outer radius of the explosive

α = constant

D/L = ratio of outer diameter of the explosive to the length of the explosive

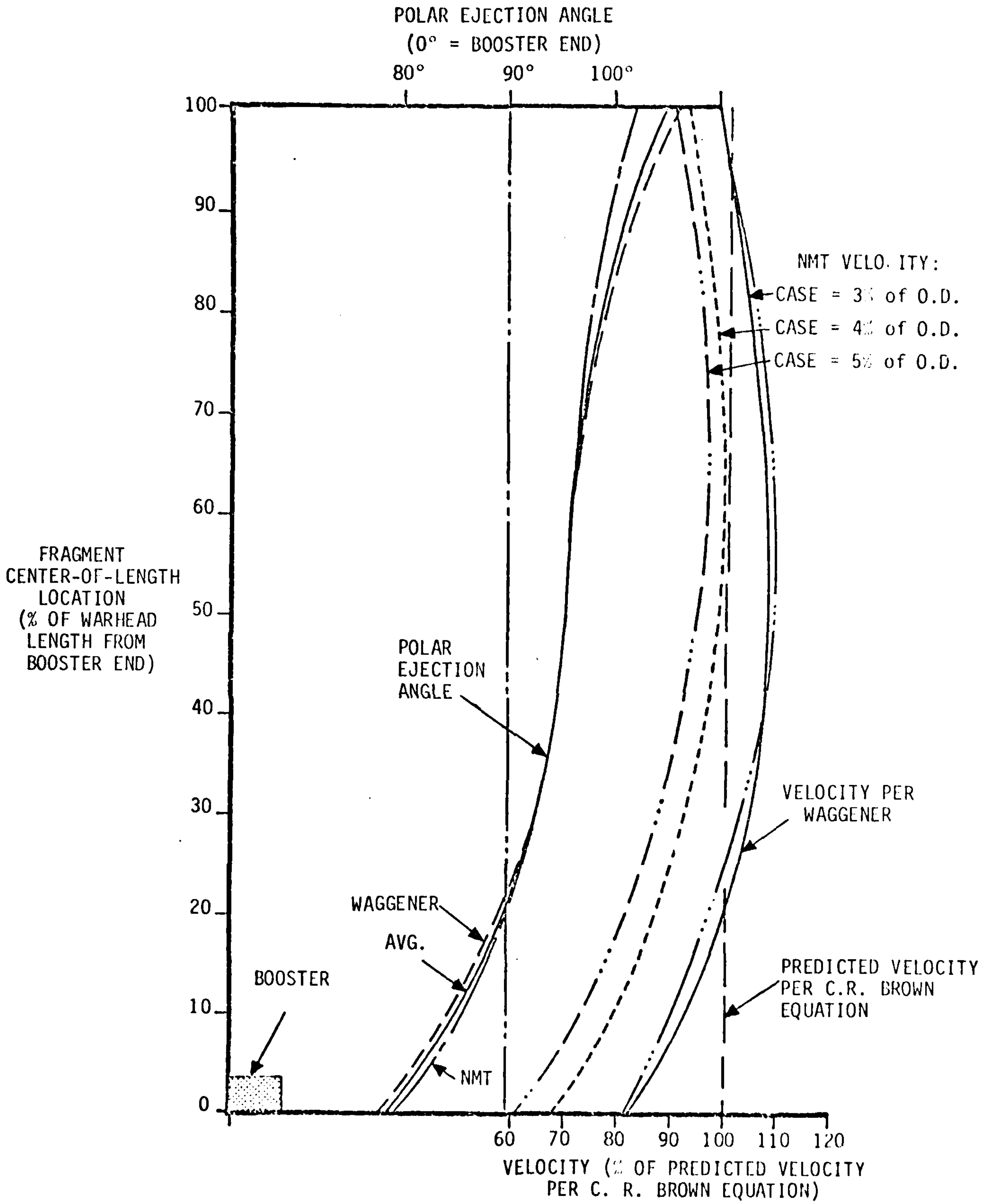
---

[1] A preliminary, unnumbered, copy of a report entitled "The Performance of Axially Initiated Cylindrical Warheads", Sam Waggener, Naval Surface Weapons Center/Dahlgren.

* Report No. TD-999, Extension of the Gurney Derivation to Solid and Hollow Cylindrical Warheads Having Finite L/D by C.R. Brown, Johns Hopkins Univeristy, Applied Physics Laboratory, May 1968 - Report Declassified.

NMT uses α = 9300 for C-4 explosive. The velocity predicted for a warhead using this equation is the 100% value indicated in Figure III-1. This value of velocity is then used in conjunction with the appropriate velocity curve to the fragment velocity as a function of its location along the length of the warhead.

Note that the predicted fragment velocities do not account for any velocity loss through a shroud. For a typical shroud (e.g. about 0.100-inch aluminum) 5 percent loss is a good estimate of velocity loss.



NMT METHODOLOGY FOR PREDICTING WARHEAD CHARACTERIZATIONS
FOR SINGLE-END INITIATED WARHEADS

FIGURE III-1

APPENDIX IV

19-INCH-DIAMETER WARHEAD-SECTOR CALIBRATION-TESTS

APPENDIX IV
19-INCH-DIAMETER WARHEAD-SECTOR CALIBRATION-TESTS

A. BACKGROUND

The HIBAL program includes a plan to conduct a test of a HIBAL warhead against an aircraft target with a running engine, to demonstrate the HIBAL-warhead capability to cause fuel-ingestion kills of the engine. One solution to the blast problem created by an explosive charge of the size associated with a 135 to 200-lb warhead is to fire a sector of a warhead (which would greatly reduce the weight of the explosive involved). Two[1] tests were conducted of approximately 60-degree sectors of a 19-inch-diameter warhead, to demonstrate that both the fragment pattern and velocity representative of the complete warhead[2] could be achieved (with the significantly-reduced explosive weights of the sectors).

B. SECTOR DESIGNS

The sector designs are presented in Figures IV-1 and IV-2.

1. Test QN0811A0

The warhead sector had a 0.438-inch case-thickness, and was 11.5-inch long. The case was SAE 4130, hardened by quenching in water and drawn at a temperature of 800-degrees (F), to RC-42. There were thirteen, circumferential opposed-grooves to provide for fourteen rows of equal length (0.821-inch) fragments. Eleven of the circumferential opposed-grooves provided for 0.100-inch remaining metal between the opposed grooves. The two circumferential grooves closest to the booster-end of the warhead provided for 0.235-inch remaining metal[3].

The longitudinal opposed grooves were spaced 0.770-inch apart (inside), and were 0.130-inch deep, inside and outside, to provide for 0.178-inch remaining metal. The recovered fragment weights were expected to be between 440 and 470-grains.

The weight of explosive (C-4) in this sector was 23-lb, and the case weight was 14-lb.

---

[1] Both 7/16-inch and 1/2-inch case-thicknesses were tested, these two thicknesses providing the desired static-ejection-velocity for shroud-thickness choices of 0.080-inch and 0.020-inch, respectively.

[2] The desired fragment pattern would be identical to that obtained in Test QN0409A0 of a full scale 19-inch diameter warhead; the desired fragment velocity would be about 6000-ft/sec, slightly higher than static ejection velocities of the warhead, to approximate the dynamic enhancement occurring in the intercept environment.

[3] The normal shock wave incidence to the fragment case near the booster end provides for proper lengthwise breakout with more metal remaining between the opposed grooves.

2. Test QN0819A0

The warhead sector had a 0.5-inch case thickness and was 11-inch long. The case was SAE 4130, hardened by quenching in water and drawn at a temperature of 800-degrees(F), to RC-42. There were thirteen rows of equal length (0.821-inch long) fragments plus a short ring (0.321-inch long) on the non-booster end[4]. Eleven of the thirteen, circumferential opposed-grooves provided for 0.100-inch remaining metal between the opposed grooves. The two circumferential opposed grooves closest to the booster-end provided for 0.185-inch remaining metal between the opposed grooves[3]. The longitudinal grooves were spaced 0.808-inch apart (inside), and were 0.140-inch deep, inside and outside, to provide for 0.220-inch remaining metal.

The expected recovered fragment weight was 518-grains (based on 15% weight loss in fireforming). The explosive weight was 24-lb, and the case weight was 16-lb.

C. TEST ARENAS

The test arenas are presented in Figures IV-3 and IV-4. Both test arenas included a Celotex pack to recover fragments, and a witness sheet for characterizing fragment pattern and velocity. The arenas differed only in the height of the Celotex packs and witness sheets, the second test (QN0819A0) providing for 12-ft-high witness sheets and Celotex because in the first test (QN0811A0) the booster-end row of fragments went over the top of the 8-ft-high witness-sheets and celotex.

D. TEST RESULTS

1. Test QN0811A0, (0.438-inch-thick case)

The recovered fireformed fragments were of excellent quality in terms of both fragment shape and weight. The weights of the recovered fragments are presented in Table IV-1

The fragment pattern measurements and calculated polar ejection angles are presented in Table IV-2. The velocity and polar ejection angle data are presented in Figure IV-5.

2. Test QN0819A0 (0.5-inch-thick case)

The recovered fireformed-fragments were of excellent quality, in terms of both fragment weight and shape. The weights of the recovered fragments are presented in Table IV-3.

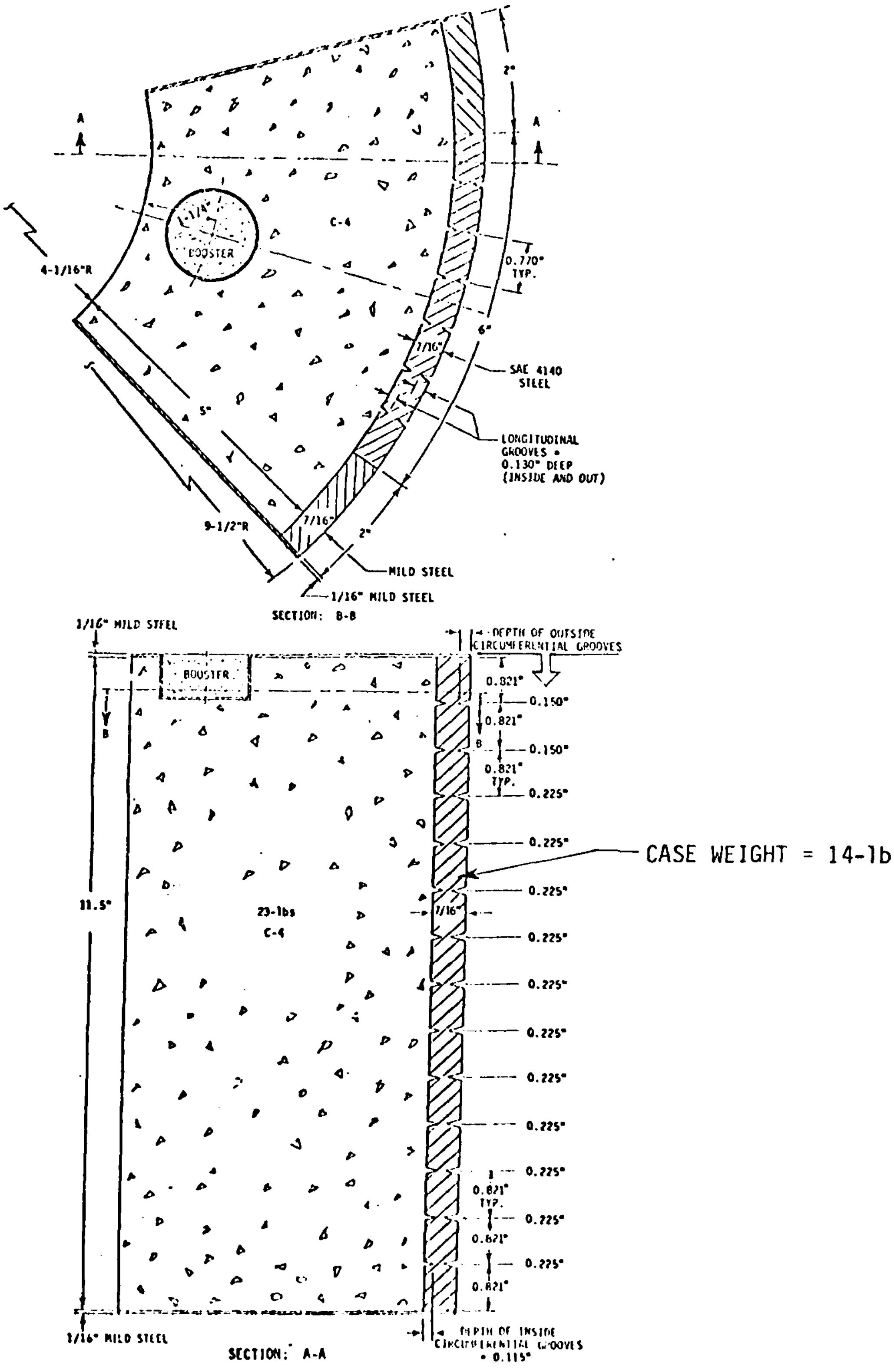
The fragment-pattern measurements and calculated polar-ejection-angles for the fragments are presented in Table IV-4. The velocity and polar-ejection-angle data are presented in Figure IV-6.

E. CONCLUSIONS

The fragment polar ejection angles were nearly identical to those measured in the 19-inch diameter annular warhead test (QN0409A0) and the fragment velocities were somewhat higher than the warhead, as desired. Thus, the primary conclusion of these tests is that the warhead sector from test QN0819A0 can be used in the running engine demonstration tests.

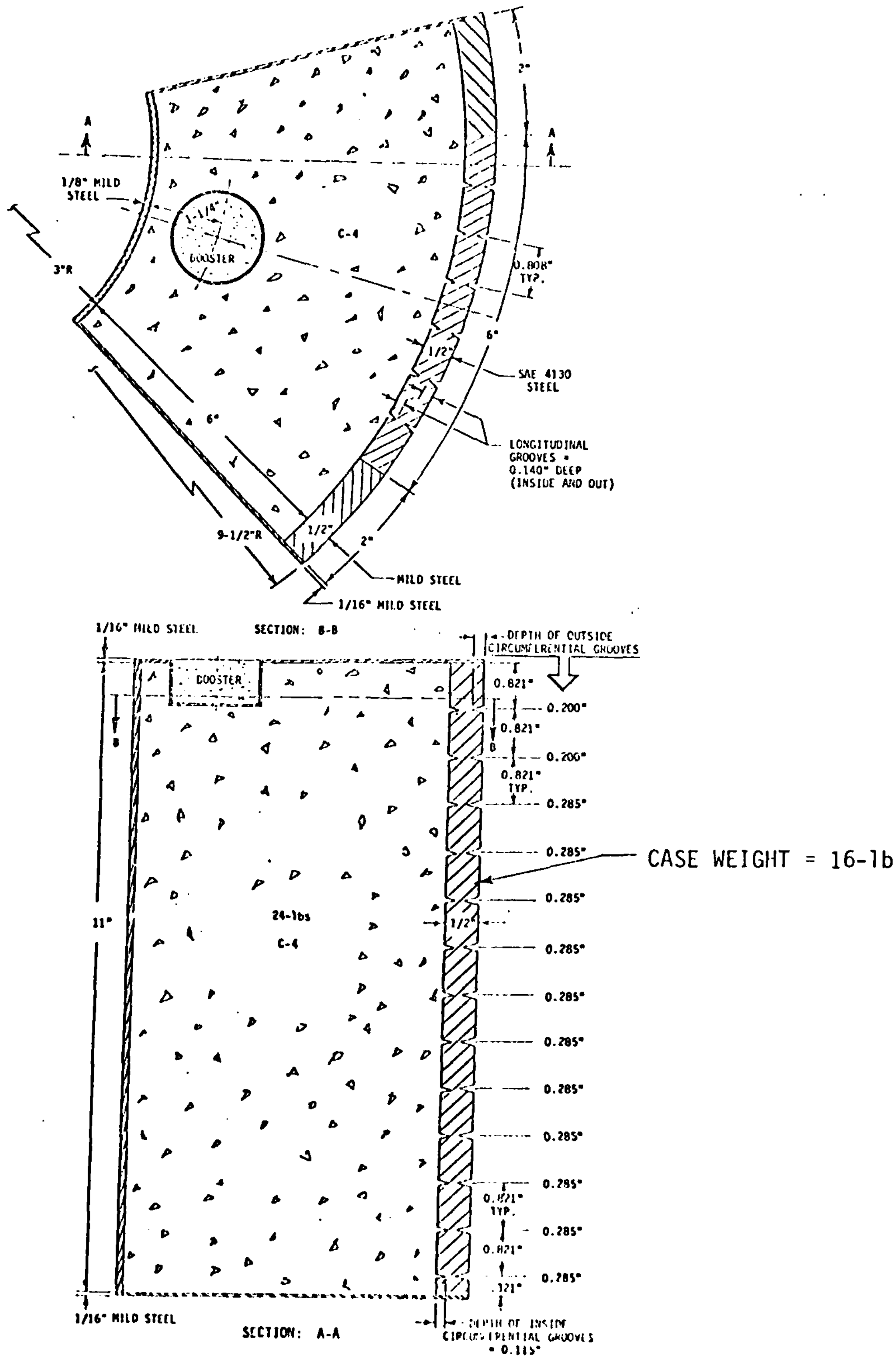
---

[4] The fragment case was originally made 11.5-inch long with fourteen rows of equal length fragments. One-half inch was cut off the non-booster end of the case to correspond to the length associated with a 19-inch diameter 10.6-inch I.D., 200-lb annular warhead.



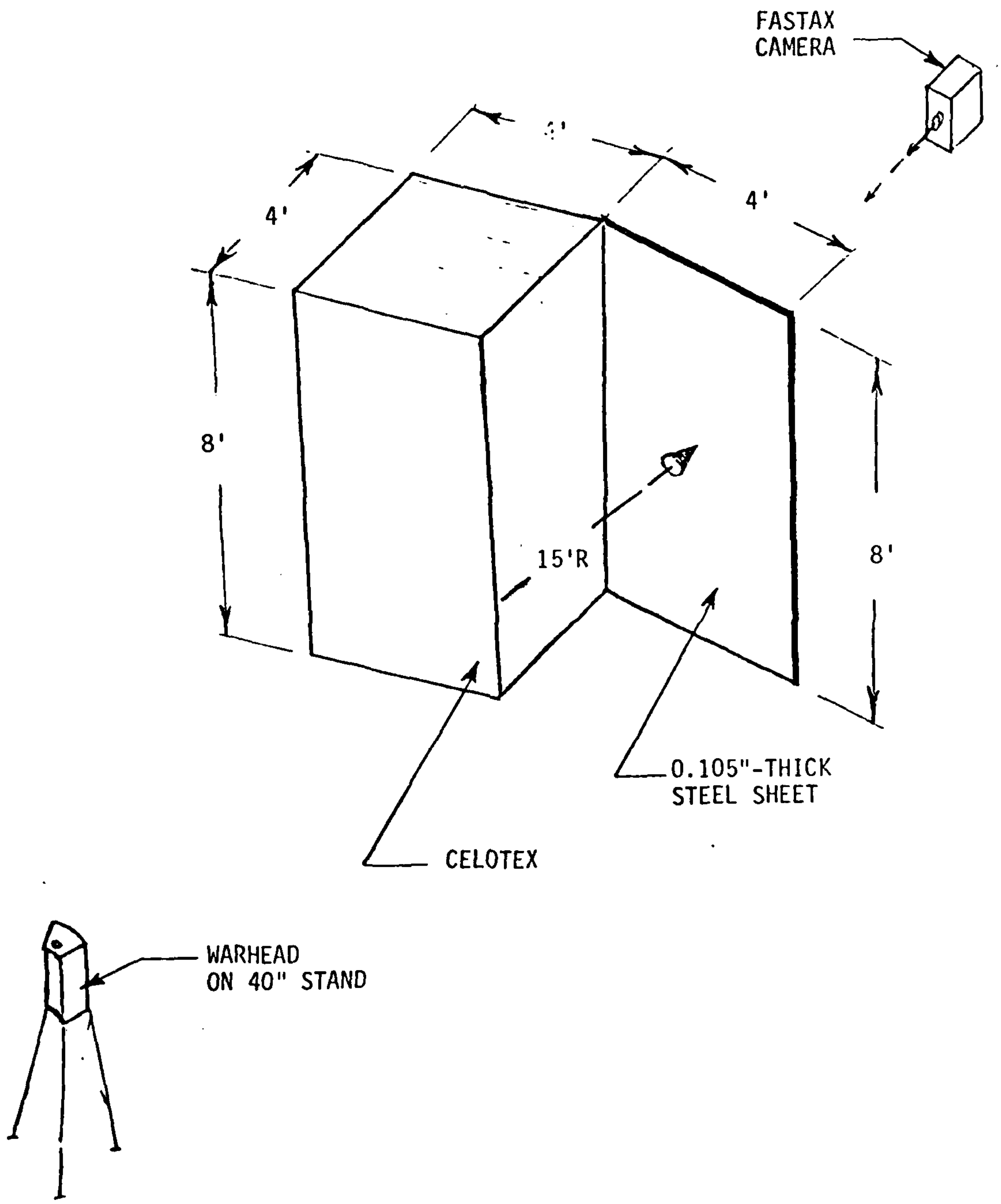
19-INCH-O.D. WARHEAD-SECTOR TEST
ON0811A0

FIGURE IV-1

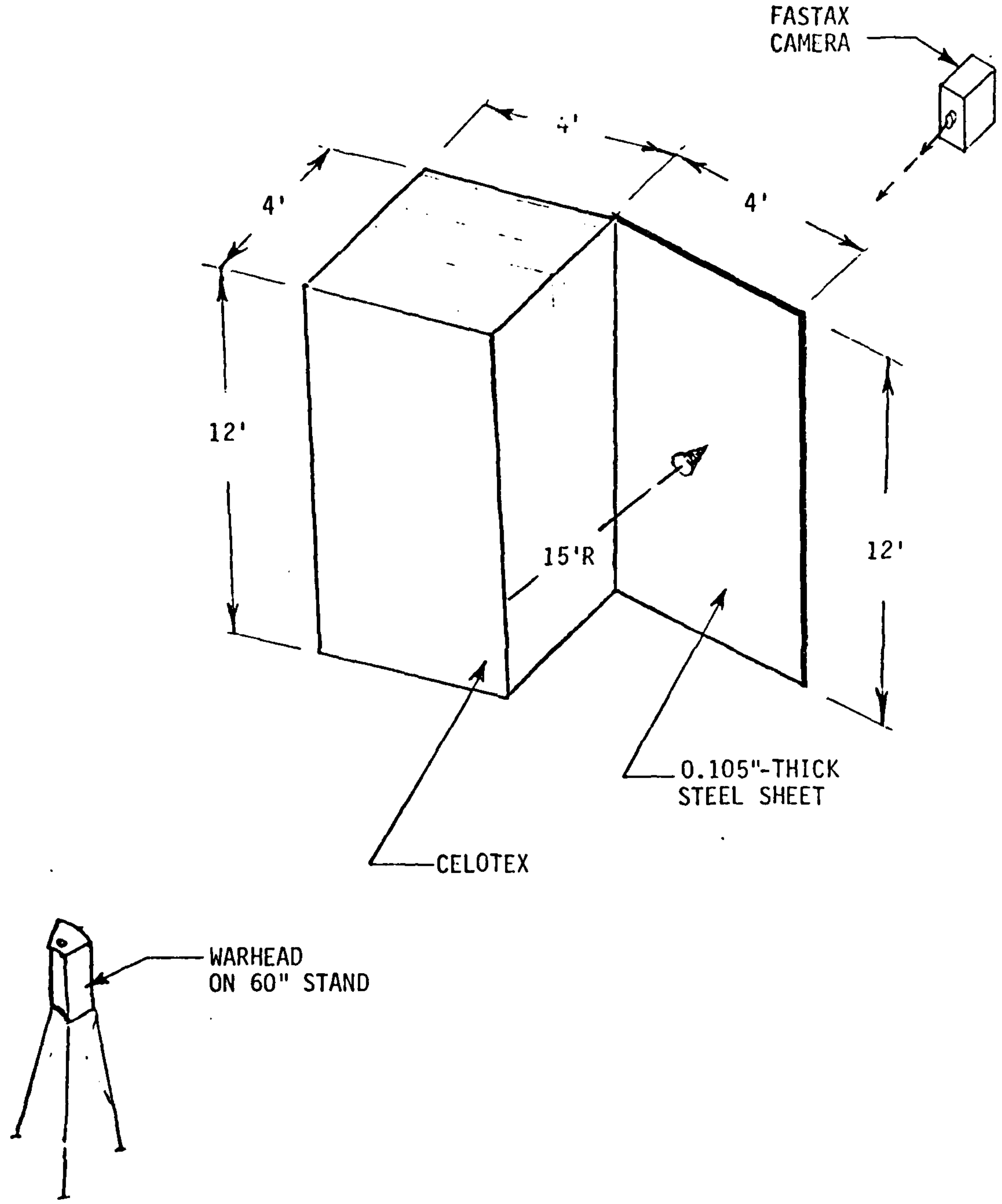


19-INCH-O.D. WARHEAD-SECTOR TEST
QN0819A0

FIGURE IV-2

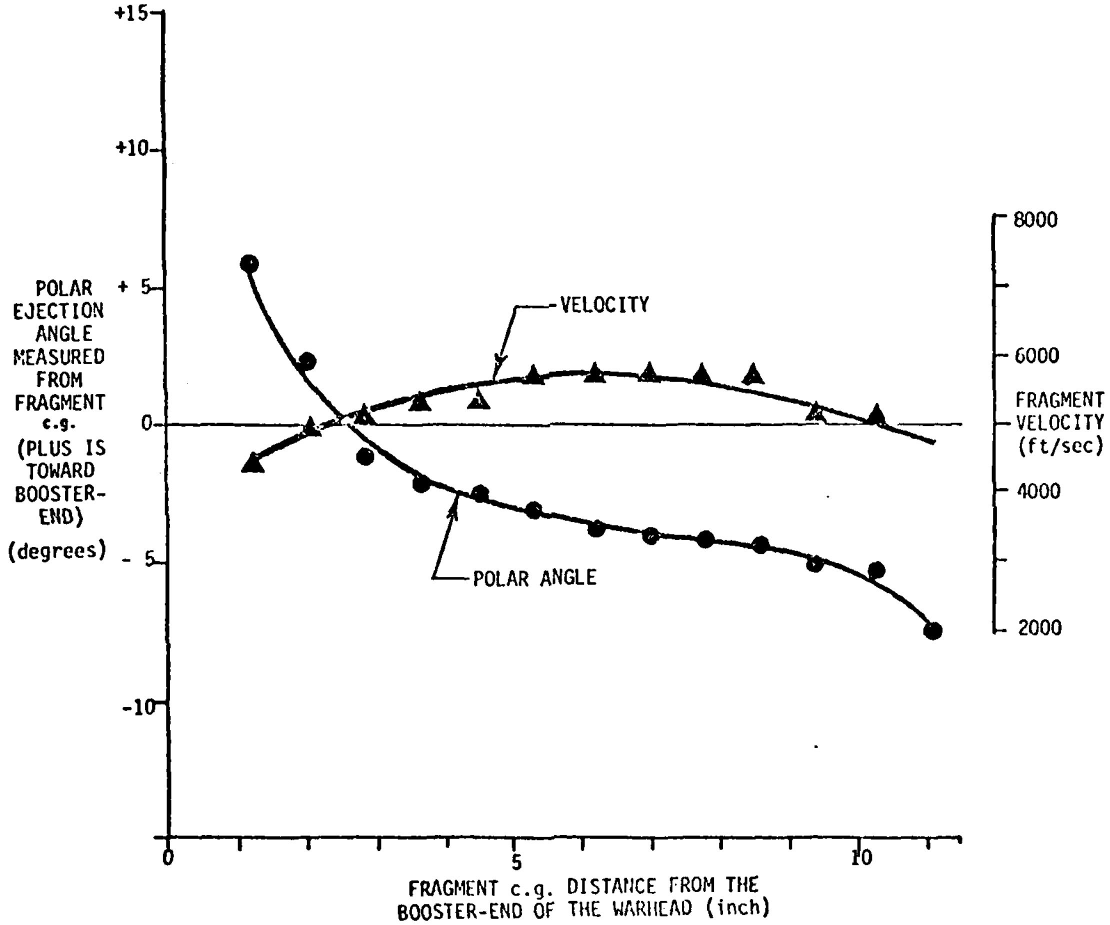


ARENA FOR
TEST QN0811A0



ARENA FOR
TEST QN0819A0

FIGURE IV-4



FRAGMENT EJECTION CHARACTERISTICS
(POLAR ANGLE & VELOCITY)
FOR A 60-DEGREE-SECTOR OF A 19-INCH O.D. ANNULAR FIREFORMED WARHEAD
TEST NO. QN0811A0

FIGURE IV-5

AD-A092 072   NEW MEXICO INST OF MINING AND TECHNOLOGY SOCORRO TER--ETC F/G 19/1
HIBAL PROGRAM. PRELIMINARY WARHEAD-DESIGN. VOLUME II. APPENDICE--ETC(U)
SEP 80   N00024-79-C-5333
UNCLASSIFIED   NMT/TERA-T-80-1356-U-VOL-   NL

2 of 2

END
DATE FILMED
1-8
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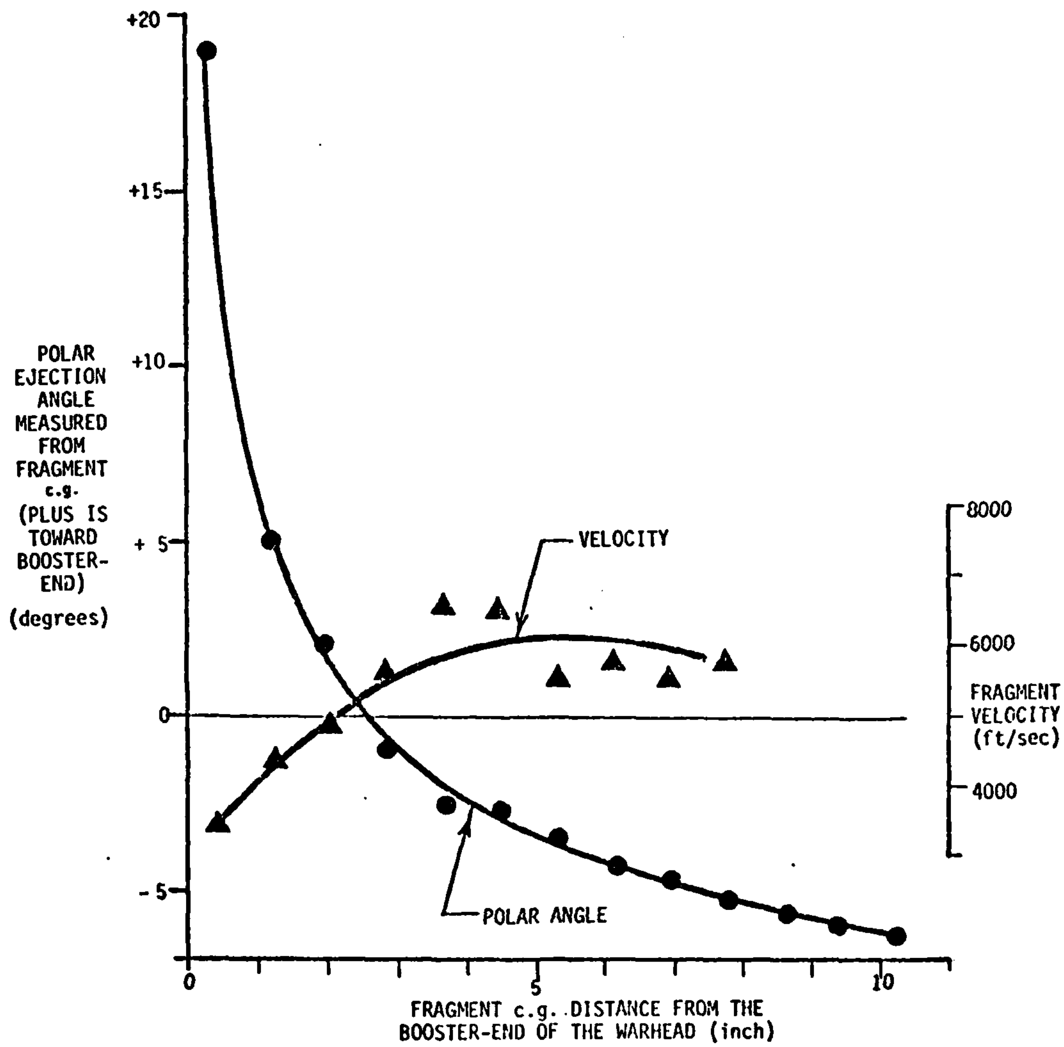

FRAGMENT EJECTION CHARACTERISTICS
(POLAR ANGLE & VELOCITY)
FOR A 60-DEGREE-SECTOR OF A 19-INCH O.D. ANNULAR FIREFORMED WARHEAD
TEST NO. QN0819A0

FIGURE IV-6

TABLE IV-1
WEIGHTS OF RECOVERED FRAGMENTS
TEST QN0811A0

(NOTE: FRAGMENT PREDICTED WEIGHT WAS 440 to 470-grains)

425
387*
482
441
426
437
436
422
458
497
439
410
442
422
414
431
415
431
474
385*

AVERAGE FRAGMENT WEIGHT = 439-grains

* Fragments hit steel banding strip on Celotex

TABLE IV-2

TABLE OF FRAGMENT HIT LOCATIONS ON 15-FT WITNESS SHEET AND CALCULATED POLAR EJECTION ANGLES

TEST QN0811A0

FRAGMENT ROW NO. (ROW 1 = BOOSTER END ROW)	FRAGMENT C.G. DISTANCE FROM BOOSTER-END OF WARHEAD (inch)	FRAGMENT COLUMN NUMBER 1		FRAGMENT COLUMN NUMBER 2	
		HIT LOCATION RELATIVE TO BOOSTER-END OF WARHEAD (inch)	CALCULATED POLAR EJECTION ANGLES (degrees)	HIT LOCATION RELATIVE TO BOOSTER-END OF WARHEAD (inch)	CALCULATED POLAR EJECTION ANGLE (degrees)
1	- 0.4	*	*	*	*
2	- 1.2	+17.8	+6.0	+17.0	+5.8
3	- 2.1	+ 4.8	+2.2	+ 5.0	+2.2
4	- 2.9	- 5.3	-0.8	- 5.8	-0.9
5	- 3.7	- 8.8	-1.6	-10.5	-2.2
6	- 4.5	-11.5	-2.2	-12.8	-2.6
7	- 5.3	-15.0	-3.1	-15.0	-3.1
8	- 6.2	-17.5	-3.6	-17.8	-3.7
9	- 7.0	-18.0	-3.5	-20.3	-4.2
10	- 7.8	-19.3	-3.6	-21.8	-4.4
11	- 8.6	-21.8	-4.2	-24.0	-4.9
12	- 9.4	-25.0	-4.9	-26.3	-5.3
13	-10.3	-26.0	-5.0	-28.0	-5.6
14	-11.1	-34.3	-7.3	-35.5	-7.7

* Fragments from Row 1 went over top of witness sheet.

TABLE IV-3

WEIGHTS OF RECOVERED FRAGMENTS
TEST QN0819A0

FRAGMENT ROW NO. (ROW-1 = BOOSTER END ROW)	RECOVERED FRAGMENT WEIGHTS (grain) (NOTE: FRAGMENT PREDICTED WEIGHT WAS 518-grains)		
1	*	*	**
2	565	588	574
3	545	549	**
4	525	519	**
5	520	525	531
6	523	531	**
7	532	526	529
8	529	522	**
9	523	520	514
10	514	526	**
11	514	515	523
12	509	512	**
13	534	529	472***

* Scabbed.

** Fragments exited side of Celotex and were not recovered.

*** Fragment hit steel banding strip on Celotex.

TABLE IV-4

TABLE OF FRAGMENT HIT LOCATIONS ON 15-FT WITNESS SHEET AND CALCULATED POLAR EJECTION ANGLES

TEST QN0819A0

		FRAGMENT COLUMN NUMBER 1		FRAGMENT COLUMN NUMBER 2	
FRAGMENT ROW	FRAGMENT C.G. DISTANCE FROM BOOSTER-END OF WARHEAD (inch)	FRAGMENT IMPACT LOCATION AT 15-ft RADIUS RELATIVE TO THE BOOSTER-END OF THE WARHEAD (inch)	CALCULATED FRAGMENT POLAR EJECTION ANGLE (degrees)	FRAGMENT IMPACT LOCATION AT 15-ft RADIUS RELATIVE TO THE BOOSTER-END OF THE WARHEAD (inch)	CALCULATED POLAR EJECTION ANGLE (degrees)
1	- 0.4	+64.0	+19.7	+59.8*	+18.4*
2	- 1.2	+15.5	+ 5.3	+14.0	+ 4.8
3	- 2.1	+ 3.3	+ 1.7	+ 5.0	+ 2.2
4	- 2.9	- 4.5	- 0.5	- 6.3	- 1.1
5	- 3.7	-12.0	- 2.6	-11.3	- 2.4
6	- 4.5	-13.3	- 2.8	-12.8	- 2.6
7	- 5.3	-15.8	- 3.3	-17.0	- 3.7
8	- 6.2	-19.3	- 4.2	-19.8	- 4.3
9	- 7.0	-22.3	- 4.8	-21.5	- 4.6
10	- 7.8	-25.0	- 5.5	-23.5	- 5.0
11	- 8.6	-26.5	- 5.7	-26.3	- 5.6
12	- 9.4	-28.5	- 6.0	-28.3	- 6.0
13	-10.3	-30.5	- 6.4	-30.0	- 6.3

* Average of two pieces, fragment apparently broke prior to impact.

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