NSL 65-138-3
MARCH 1966

DEVELOPMENT OF A METEOROID PENETRATION DISTRIBUTED TRANSDUCER

THIRD QUARTERLY REPORT FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

SUBMITTED IN RESPONSE TO

CONTRACT NAS-8-20194

NORTHROP SPACE LABORATORIES
3401 West Broadway, Hawthorne, California 90250

NORTHROP CORPORATION

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Prepared For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
ATTN: PR-EC
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

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SUMMARY

The primary objective of the third quarter work plan was the initiation and partial completion of the impact test schedule as specified in the Proposal of January 1965. This has been largely achieved. Calibration impact tests have been carried out at three different hypervelocity facilities using 50μ borosilicate spheres, 2.8 mg lexan slugs, and 10 - 100μ iron fragments as projectiles. Certain number of preliminary data were also obtained and have been partially analyzed.

SECTION 1.0

INTRODUCTION

The third quarter work plan, as outlined in the last quarterly report, had as its primary objective the initiation and partial completion of the impact test schedule specified in the Proposal of January 1965. This objective has been achieved and calibration impact tests have been carried out at three different hypervelocity facilities using 50μ borosilicate spheres, 2.8 mg lexan slugs, and 10 - 100μ iron fragments as projectiles. The accessory recording equipment has also been checked out satisfactorily on locations under actual experimental conditions and, therefore, immediate future plans include proceeding with the test schedules and carrying out a thorough analysis of obtained data.

Section 2.0 contains calibration data and a brief description of the system tests. Section 3.0 contains preliminary impact results which are tentatively discussed and partly analyzed. Progress achieved in the third quarter of the contractual work and work plans for the last quarter are outlined in Section 4.0.

SECTION 2.0

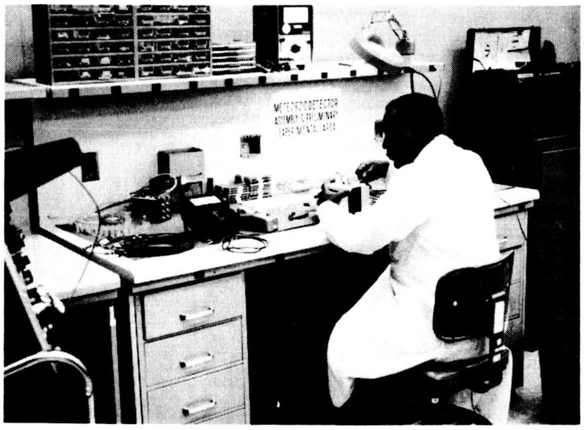
SYSTEM TESTS AND CALIBRATION

The recording system was first thoroughly tested - by parts, and as a whole - in the NSL laboratory with relatively low velocity impacts employed to simulate hypervelocity impact conditions as closely as possible. These tests have been discussed in the Second Quarterly Report. However, before actual data tests could have been undertaken, calibration and check-out tests of the instrumentation had to be performed on location in the actual experimental settings. These tests are briefly discussed in this section.

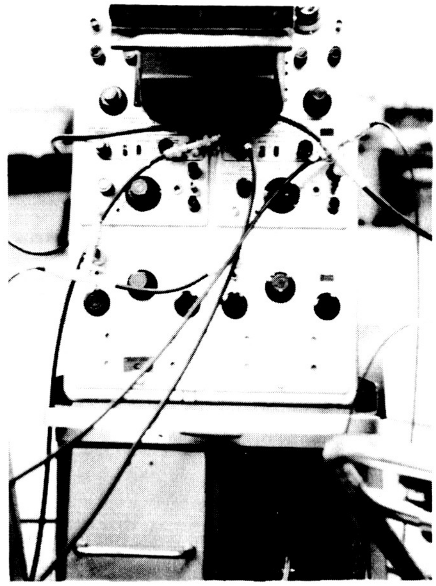
The first series of tests employed impacts by 2.8 mg lexan projectiles with velocities ranging between 20,000 and 26,000 ft/sec. Figure 2-1 shows, besides the experimental target assembly area at NSL, the recording instrumentation as it was used during the tests. A diagram of a typical recording system arrangement is shown on Figure 2-2. A particular arrangement of this sort depends to a large degree on the type of equipment (oscilloscopes, etc.) that is available at the site, and also on the type of synchronizing and timing signals obtainable from the hypervelocity projector, as well as noise pick-up conditions, etc. Settings of the oscilloscopes gains, time bases, etc., must be empirically determined for each test series.

Five oscilloscopes are shown on Figure 2-2. Four of these have been used to record transducers outputs and one oscilloscope was used to show correspondence between the particle velocity, timing pulses from the projector, particle impact time, and NSL trigger output. Where possible each transducer output was recorded at two gain levels to accommodate amplitude variations caused by differences in distances travelled by the stress wave from the point of impact to the particular transducer in question, and also by the variation in the projectile velocity.

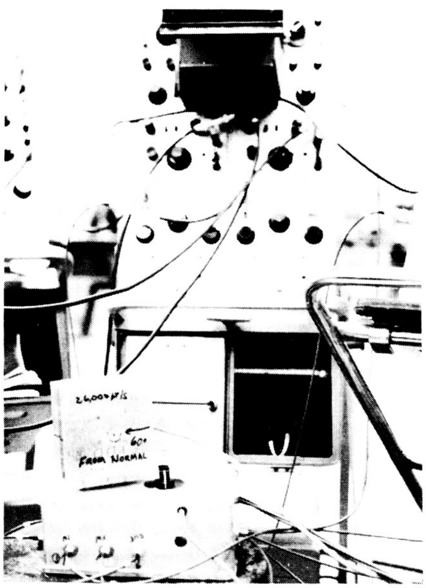
Figures 2-3 through 2-16 show the actual data obtained in the 2.8 mg lexan projectile impact test calibration series.



Experimental Target
Assembly at NSL



Cabling and Line
Terminations on
Master Gating
Oscilloscope



Target Assembly and
Amplifiers on Location

Master Gating
Oscilloscope

Instrumentation on Location
During Test Series

FIGURE 2-1 TARGET ASSEMBLY AND INSTRUMENTATION

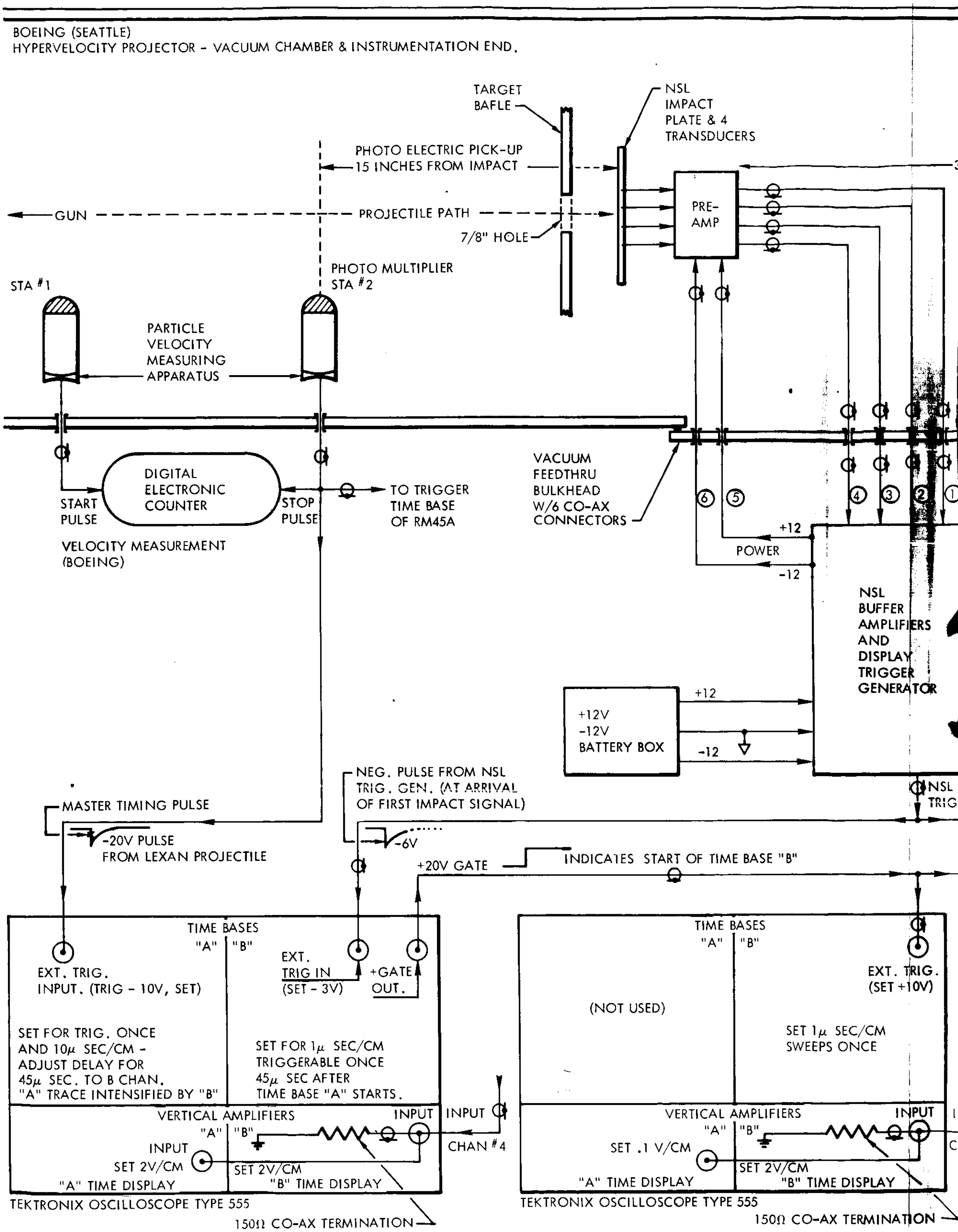
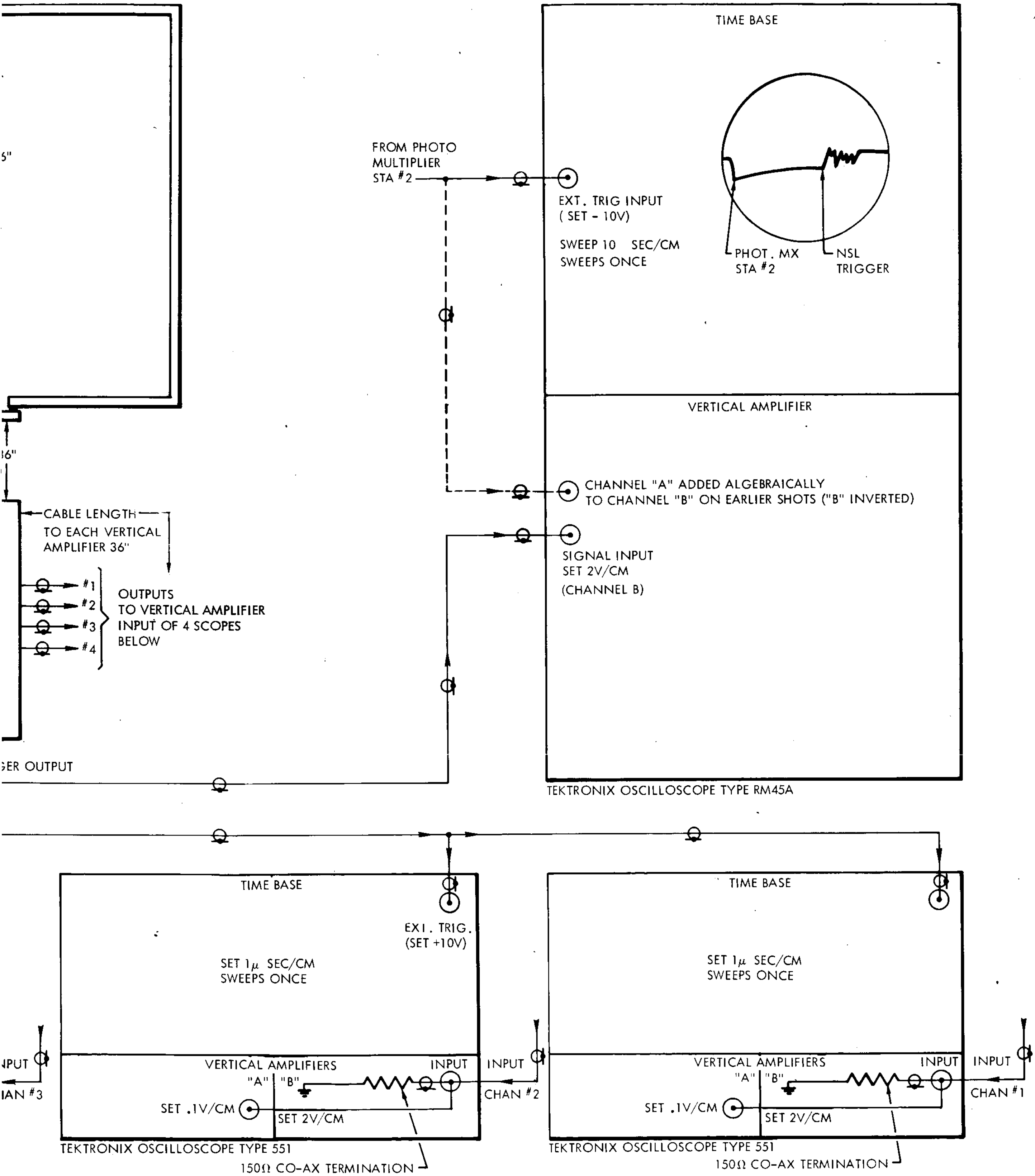
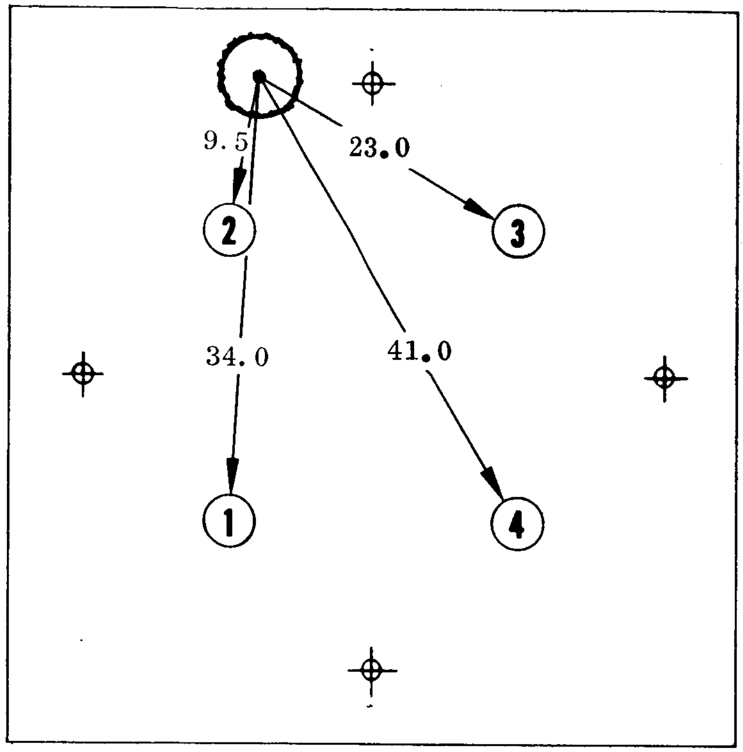


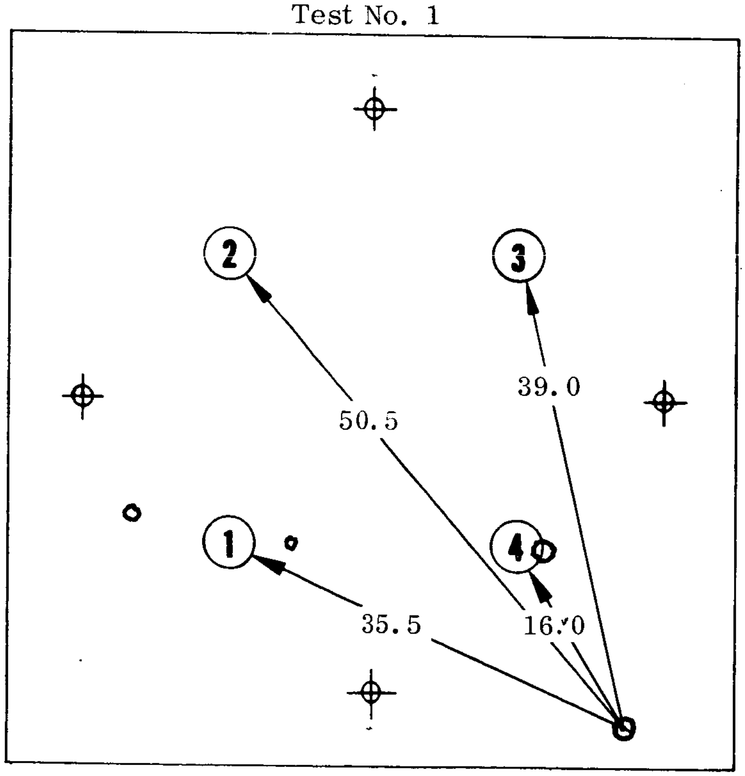
FIGURE 2-2 RECORDING EQUIPMENT ARRANGEMENT (Lexan for Tests 5 - 10)



TIME BASE
FROM PHOTO MULTIPLIER STA #2
EXT. TRIG INPUT (SET - 10V)
SWEEP 10 SEC/CM
SWEEPS ONCE
PHOT. MX STA #2
NSL TRIGGER
VERTICAL AMPLIFIER
CHANNEL "A" ADDED ALGEBRAICALLY TO CHANNEL "B" ON EARLIER SHOTS ("B" INVERTED)
SIGNAL INPUT
SET 2V/CM
(CHANNEL B)
TEKTRONIX OSCILLOSCOPE TYPE RM45A
5"
36"
CABLE LENGTH TO EACH VERTICAL AMPLIFIER 36"
#1
#2
#3
#4
OUTPUTS TO VERTICAL AMPLIFIER INPUT OF 4 SCOPES BELOW
ER OUTPUT
TIME BASE
EXT. TRIG. (SET +10V)
SET 1μ SEC/CM
SWEEPS ONCE
VERTICAL AMPLIFIERS
"A"
"B"
INPUT
SET .1V/CM
SET 2V/CM
TEKTRONIX OSCILLOSCOPE TYPE 551
150Ω CO-AX TERMINATION
NPUT
IAN #3
INPUT
CHAN #2
TIME BASE
SET 1μ SEC/CM
SWEEPS ONCE
VERTICAL AMPLIFIERS
"A"
"B"
INPUT
SET .1V/CM
SET 2V/CM
TEKTRONIX OSCILLOSCOPE TYPE 551
150Ω CO-AX TERMINATION
INPUT
CHAN #1

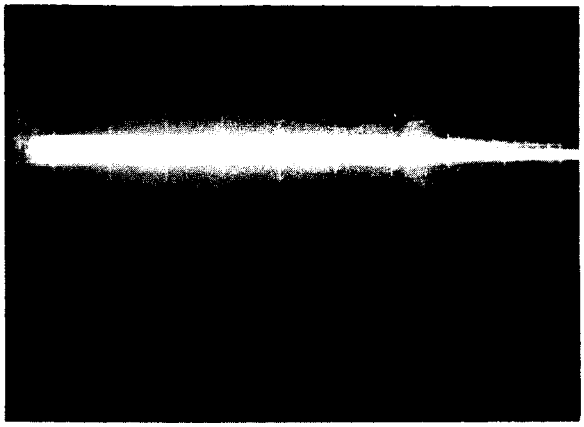


Test No. 1



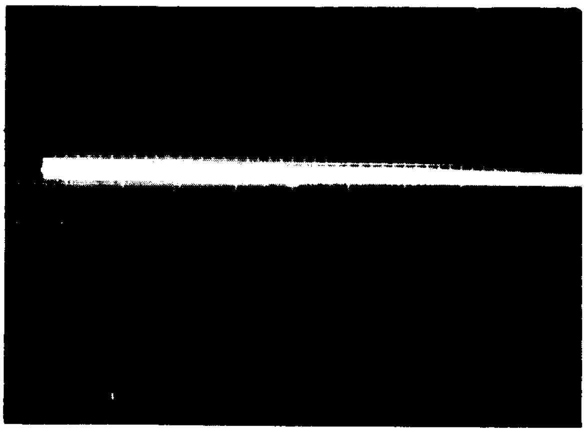
Test No. 2

FIGURE 2-3 LOCATION OF IMPACT AREAS; TEST NOS. 1 AND 2
(Distances between impact area centers and transducer edges shown in millimeters)
PROJECTILE: LEXAN SLUG (2.8 mg)



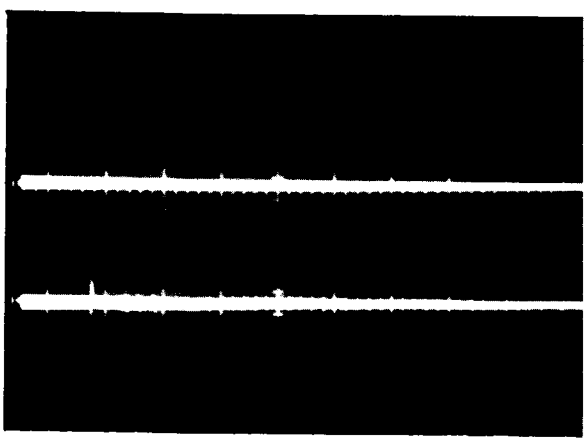
Channel 1

Upper: 10μ sec/div. (cm)
2V/div. (cm)
Lower: 10μ sec/div. (cm)
0.05V/div. (cm)
Gain (Xducer/Scope): 0.73



Channel 2

Upper: 10μ sec/div. (cm)
2V/div. (cm)
Lower: 10μ sec/div. (cm)
0.05V/div. (cm)
Gain (Xducer/Scope): 0.73

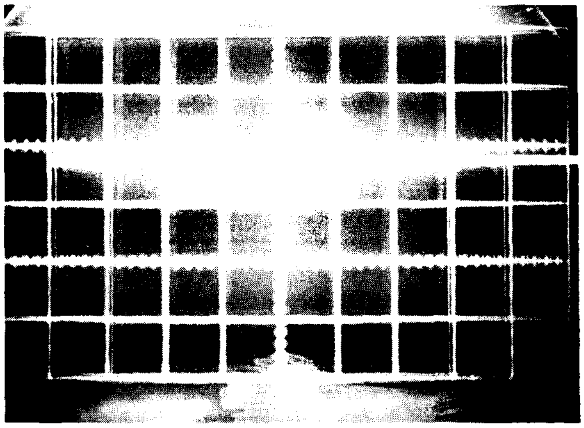


Channel 3

Upper: 10μ sec/div. (cm)
2V/div. (cm)
Lower: 10μ sec/div. (cm)
0.05V/div. (cm)
Gain (Xducer/Scope): 0.73

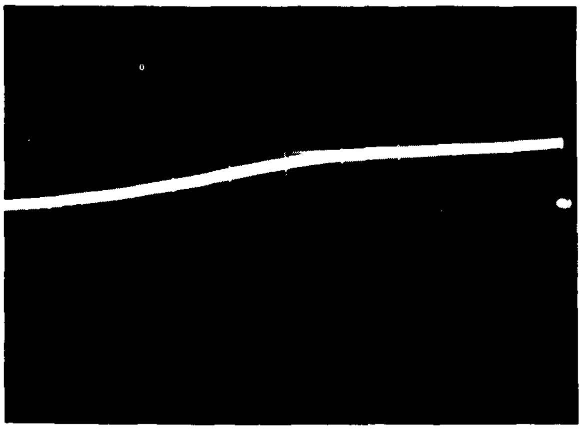
FIGURE 2-4
IMPACT TEST NO. 1
(Channels #1, 2, 3)
27 January, 1966 - Shot #1

PROJECTILE: LEXAN SLUG (2.8 mg)



Channel 4

Upper: 10μ sec/div. (cm)
2V/div. (cm)
Lower: 10μ sec/div. (cm)
0.05V/div. (cm)
Gain (Xducer/Scope): 0.73



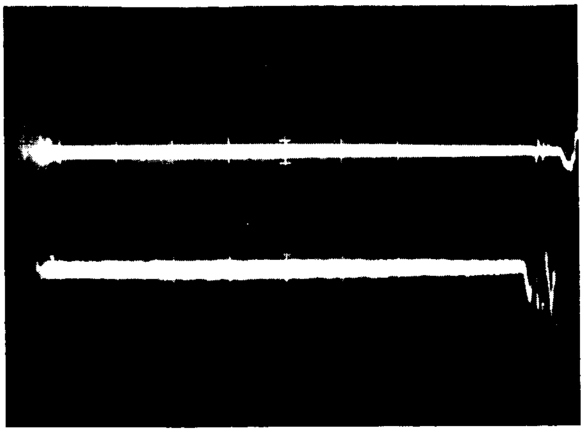
NSL Trigger Display

10μ sec/div. (cm)
2V/div. (cm)

Additional Data

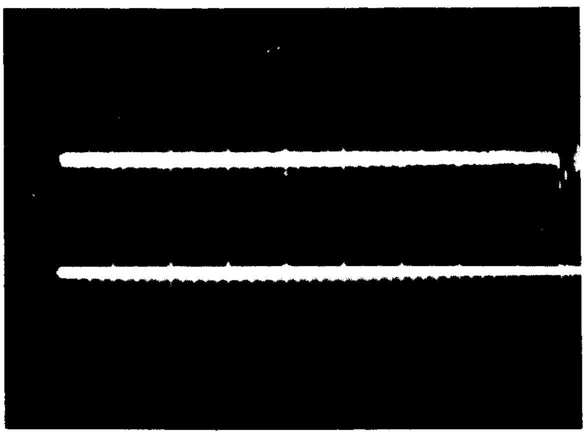
- All oscilloscopes triggered by velocity measuring phototube circuit (35μ sec delay added)
- Projectile Velocity: 27,200 ft/sec
- NSL Trigger not employed
- Transducers: Quartz X cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

FIGURE 2-5
IMPACT TEST NO. 1
(Channel #4 and NSL Trigger Display)
27 January, 1966, - Shot #1
PROJECTILE: LEXAN SLUG (2.8 mg)



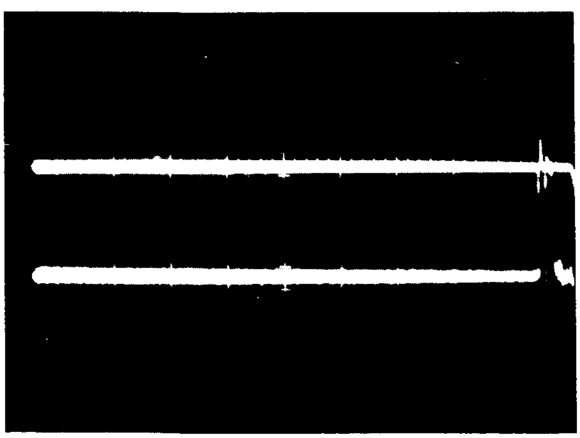
Channel 1

Upper: 5μ sec/div. (cm)
2V/div. (cm)
Lower: 5μ sec/div. (cm)
0.05V/div. (cm)
Gain (Xducer/Scope): 0.73



Channel 2

Upper: 5μ sec/div. (cm)
2V/div. (cm)
Lower: 5μ sec/div. (cm)
0.05V/div. (cm)
Gain (Xducer/Scope): 0.73

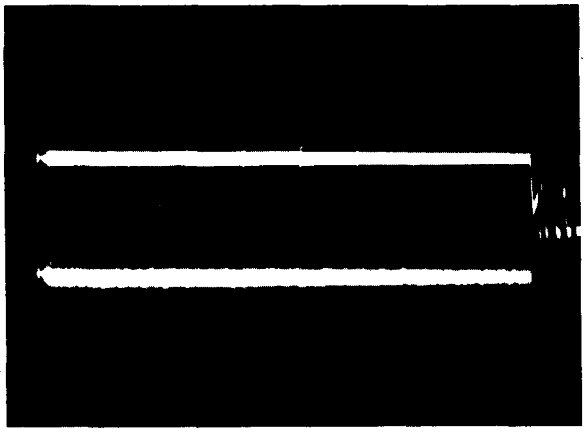


Channel 3

Upper: 5μ sec/div. (cm)
2V/div. (cm)
Lower: 5μ sec/div. (cm)
0.05V/div. (cm)
Gain (Xducer/Scope): 0.73

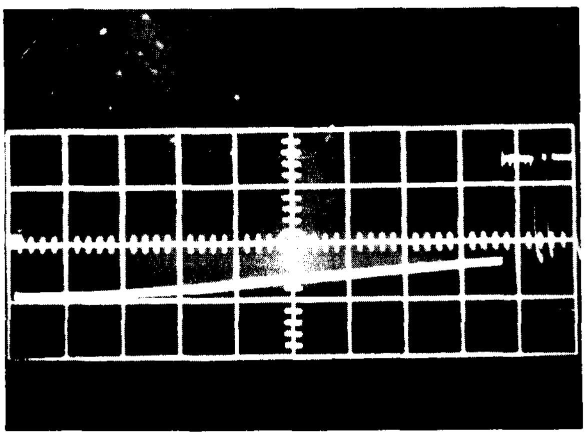
FIGURE 2-6
IMPACT TEST NO. 2
(Channels #1, 2, 3)
28 January, 1966 - Shot #1

PROJECTILE: LEXAN SLUG (2.8 mg)



Channel 4

Upper: 5μ sec/div. (cm)
2V/div. (cm)
Lower: 5μ sec/div. (cm)
0.05V/div. (cm)
Gain (Xducer/Scope): 0.73



NSL Trigger Display (Inverted and Velocity Measuring Phototube Negative Pulse Added)

10μ sec/div. (cm)
2V/div. (cm)

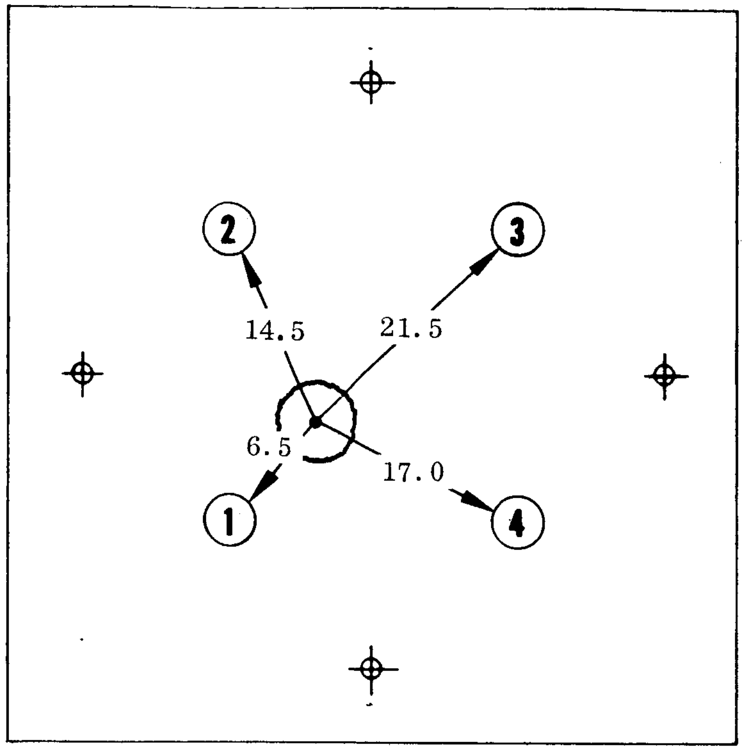
Additional Data

- All oscilloscopes triggered by velocity measuring phototube circuit (transducer displays delayed by 40μ sec)
- Projectile disintegrated
- Projectile velocity: (of fragments) approximately 16,000 ft/sec
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

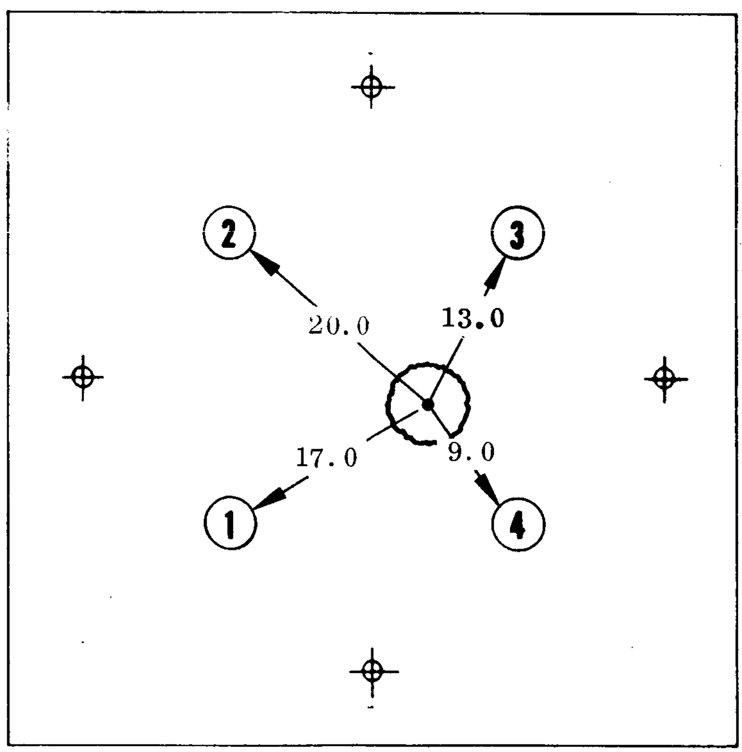
FIGURE 2-7

IMPACT TEST NO. 2
(Channel #4 and NSL Trigger Display)
28 January, 1966 - Shot #1

PROJECTILE: LEXAN SLUG (2.8 mg)



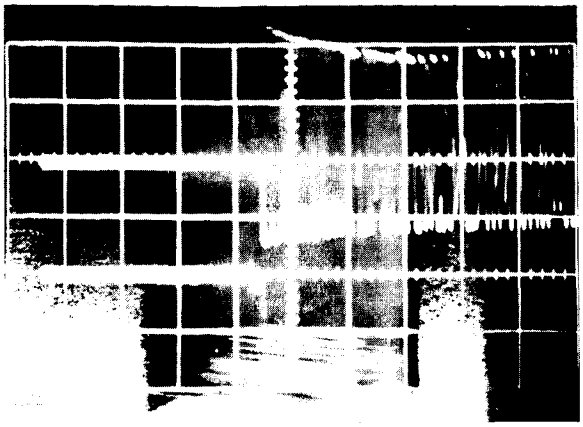
Test No. 3



Test No. 4

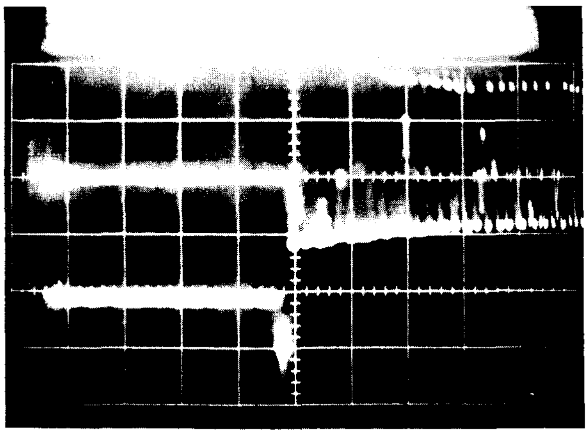
FIGURE 2-8 LOCATION OF IMPACT AREAS; TEST NOS. 3 AND 4
(Distances between impact area centers and transducer edges shown in millimete

PROJECTILE: LEXAN SLUG (2.8 mg)



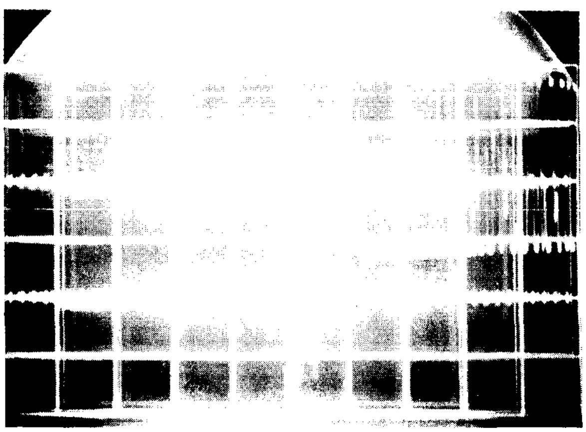
Channel 1

Upper: 5μ sec/div. (cm)
2V/div. (cm)
Lower: 5μ sec/div. (cm)
0.05V/div. (cm)
Gain (Xducer/Scope): 0.73



Channel 2

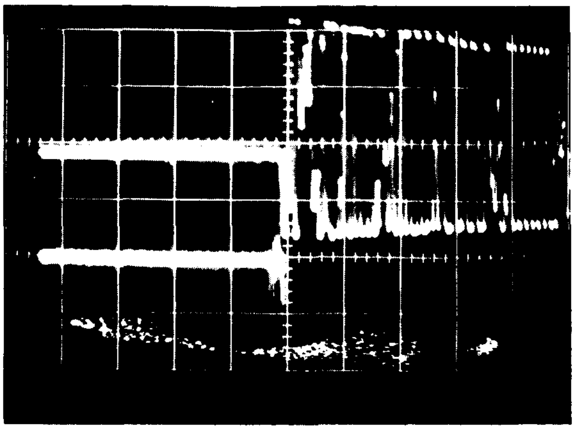
Upper: 5μ sec/div. (cm)
2V/div. (cm)
Lower: 5μ sec/div. (cm)
0.05V/div. (cm)
Gain (Xducer/Scope): 0.73



Channel 3

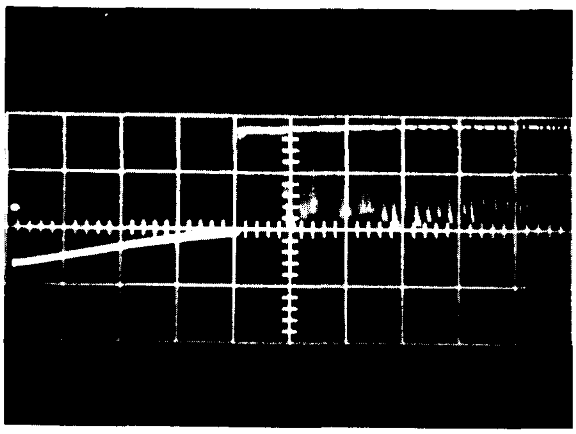
Upper: 5μ sec/div. (cm)
2V/div. (cm)
Lower: 5μ sec/div. (cm)
0.05V/div. (cm)
Gain (Xducer/Scope): 0.73

FIGURE 2-9
IMPACT TEST NO. 3
(Channels #1, 2, 3)
28 January, 1966 - Shot #2
PROJECTILE: LEXAN SLUG (2.8 mg)



Channel 4

Upper: 5μ sec/div. (cm)
2V/div. (cm)
Lower: 5μ sec/div. (cm)
0.05V/div. (cm)
Gain (Xducer/Scope): 0.73



NSL Trigger Display (Inverted and Velocity Measuring Phototube Negative Pulse Added)

10μ sec/div. (cm)
2V/div. (cm)

Additional Data

- All oscilloscopes triggered by velocity measuring phototube circuit (transducer displays delayed by 40μ sec)
- Projectile velocity: 22,300 ft/sec
- 5 mil mylar sheet attached to the target impact face
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

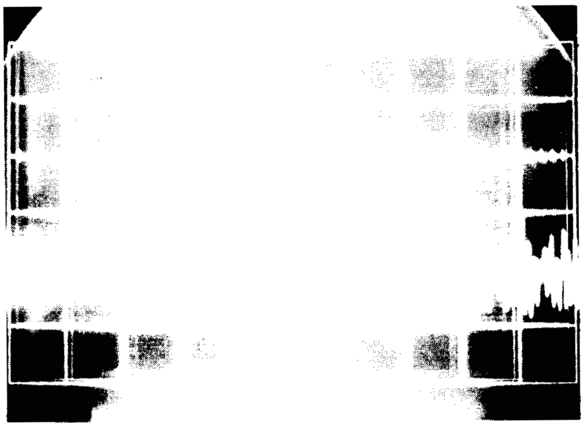
FIGURE 2-10
IMPACT TEST NO. 3
(Channel #4 and NSL Trigger Display)
28 January, 1966 - Shot #2

PROJECTILE: LEXAN SLUG (2.8 mg)

Channel 1

Upper: 5μsec/div. (cm)
2V/div. (cm)
Lower: 5μsec/div. (cm)
0.05V/div. (cm)

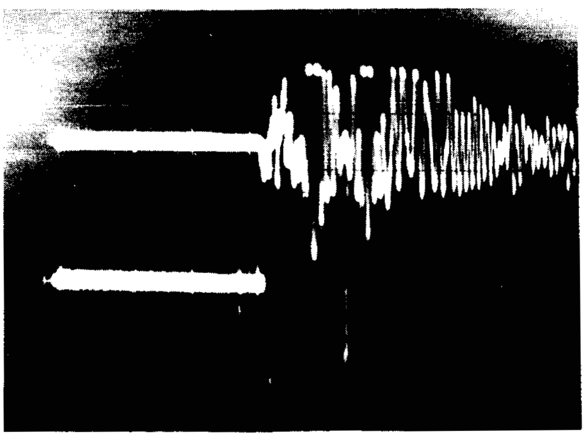
Gain (Xducer/scope): 0.12



Channel 2

Upper: 5μsec/div. (cm)
2V/div. (cm)
Lower: 5μsec/div. (cm)
0.05V/div. (cm)

Gain (Xducer/scope): 0.12



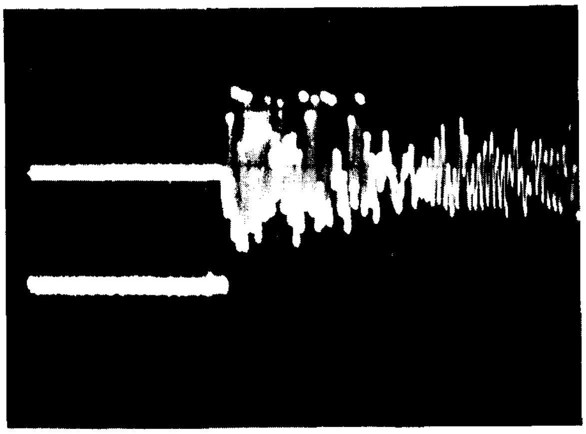
Channel 3

Upper: 5μsec/div. (cm)
2V/div. (cm)
Lower: 5μsec/div. (cm)
0.05V/div. (cm)

Gain (Xducer/scope): 0.12

FIGURE 2-11
IMPACT TEST NO. 4
(Channels #1, 2, 3)
1 February, 1966 - Shot #1

PROJECTILE: LEXAN SLUG (2.8 mg)



Channel 4

Upper: 5μsec/div. (cm)
2V/div. (cm)
Lower: 5μsec/div. (cm)
0.05V/div. (cm)

Gain (Xducer/scope): 0.12

NSL Trigger Display

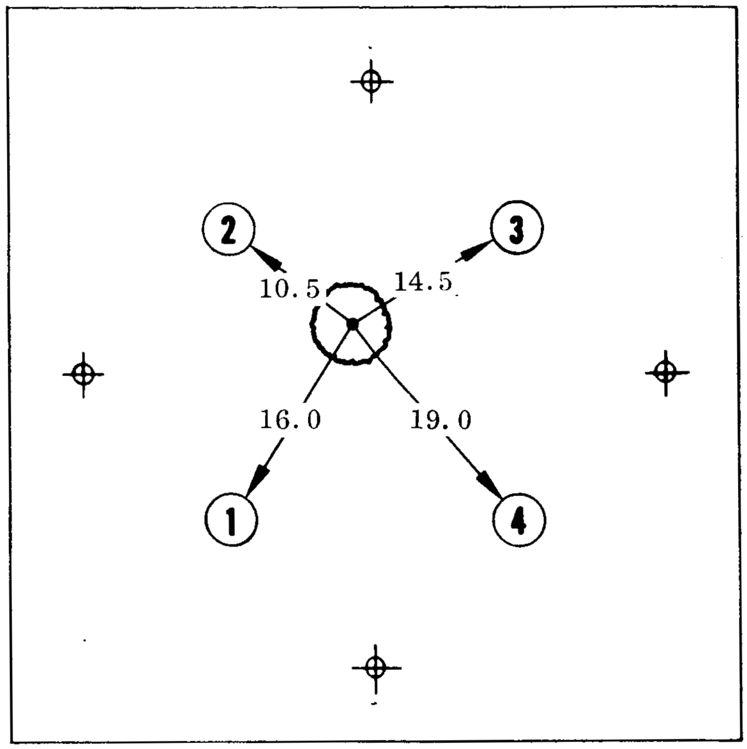
1μsec/div. (cm)
2V/div. (cm)

(Baseline has drifted downward)

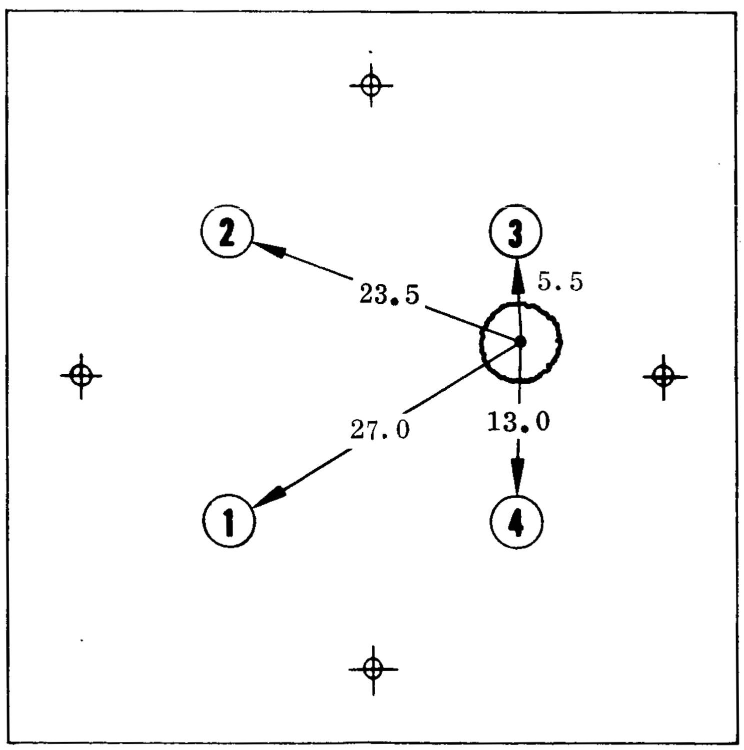
Additional Data

- Channels 1, 2, 3, and 4 triggered by velocity measuring phototube circuit (40 sec delay added)
- Trigger Display oscilloscope triggered by NSL trigger cirucit
- Projectile velocity: 25,050 ft/sec
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

FIGURE 2-12
IMPACT TEST NO. 4
(Channel #4 and NSL Trigger Display)
1 February, 1966 - Shot #1
PROJECTILE: LEXAN SLUG (2.8 mg)



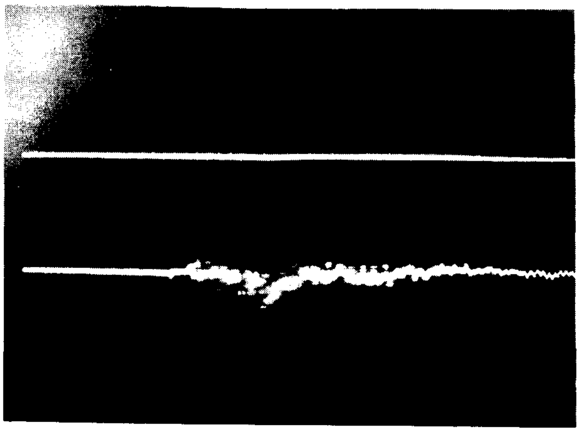
Test No. 5



Test No. 6

FIGURE 2-13 LOCATION OF IMPACT AREAS; TEST NOS. 5 AND 6
(Distances between impact area centers and transducer edges shown in millimeters)

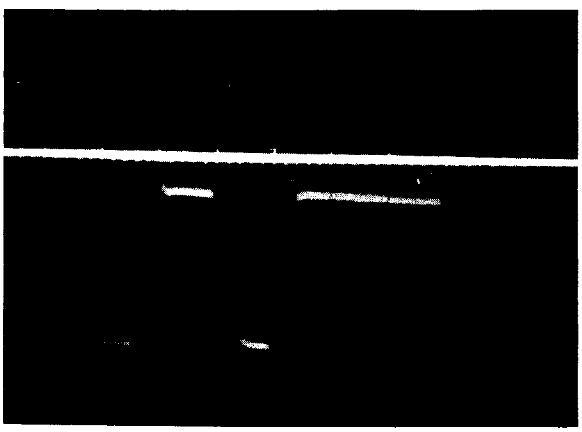
PROJECTILE: LEXAN SLUG (2.8 mg)



Channel 1

Upper: 5μsec/div. (cm)
2V/div. (cm)
Lower: 5μsec/div. (cm)
0.05v/div. (cm)

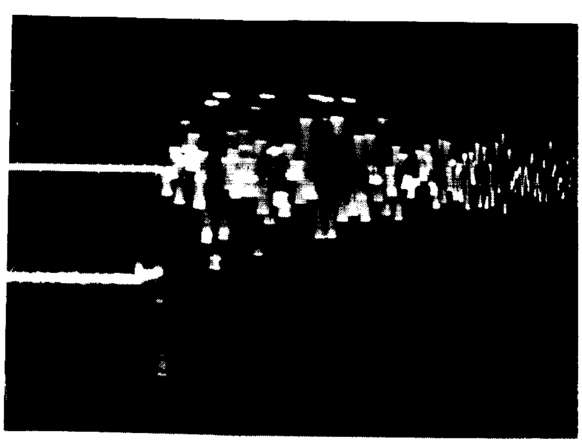
Gain (Xducer/scope): 0.12



Channel 2

Upper: 5μsec/div. (cm)
2V/div. (cm)
Lower: 0.2μsec/div. (cm)
2V/div. (cm)

Gain (Xducer/scope): 0.73



Channel 3

Upper: 5μsec/div. (cm)
2V/div. (cm)
Lower: 5μsec/div. (cm)
0.05V/div. (cm)

Gain (Xducer/scope): 0.12

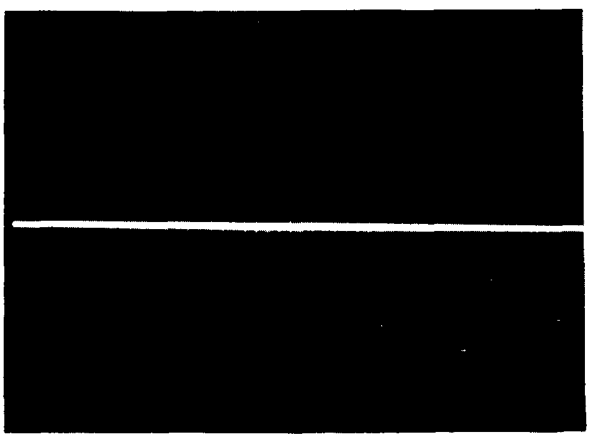
FIGURE 2-14
IMPACT TEST NO. 5
(Channels #1, 2, 3)
2 February, 1966 - Shot #1
PROJECTILE: LEXAN SLUG (2.8 mg)

Channel 4

Upper: 5μsec/div. (cm)
2V/div. (cm)

Lower: 5μsec/div. (cm)
0.05V/div. (cm)

Gain (Xducer/scope): 0.12



NSL Trigger Display

10μsec/div. (cm)
2V/div. (cm)

(oscilloscope input not connected)

Additional Data

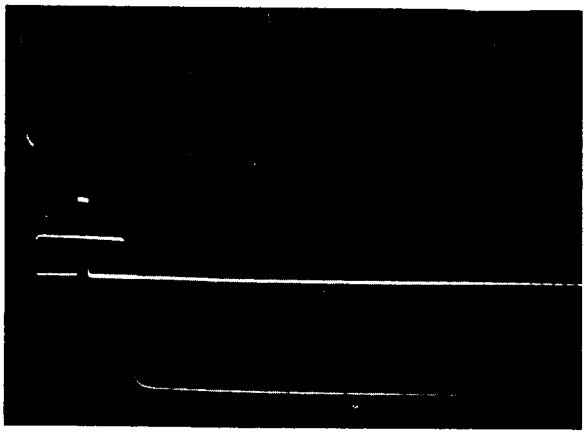
- Channel 1 transducer was shorted
- Projectile velocity: 24,600 ft/sec
- Impact point selected closer to transducer #2
- Upper trace of channel #2 triggered by velocity measuring phototube circuit
- Lower trace of Channel #2 triggered by NSL trigger
- Oscilloscopes (except #2) triggered by velocity measuring phototube circuit (45μsec delay added)
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

FIGURE 2-15
IMPACT TEST NO. 5
(Channel #4 and NSL Trigger Display)
2 February, 1966 - Shot #1

PROJECTILE: LEXAN SLUG (2.8 mg)

Channel 3

Upper: 10 μ sec/div. (cm)
2V/div. (cm)
Lower: 1 μ sec/div. (cm)
2V/div. (cm)
Gain (Xducer/Scope): 0.73



Trace Intensity Test

Upper: 10 μ sec/div. (cm)
2V/div. (cm)
Lower: 1 μ sec/div. (cm)
2V/div. (cm)
(Channel 1 subsequent to Impact Test)

Traces show output from a double pulse generator with upper trace intensified during sweep time of lower trace

Additional Data

- Upper trace of channel #3 triggered by velocity measuring phototube circuit
- Lower trace of channel #3 (and those of channels #1, 2, and 4 not shown here) triggered by NSL Trigger circuit
- Photographs of channels #1, 2, and 4 not included, trace intensity was too low to be recorded
- Projectile velocity: 21,650 ft/sec
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

FIGURE 2-16

IMPACT TEST NO. 6
(Channel #3 and Trace Intensity Test)
3 February, 1966 - Shot #1

PROJECTILE: LEXAN SLUG (2.8 mg)

Data from test #1 show little pulses which helped to determine various time delays and amplitude settings. Since the impact occurred outside the designated area the results are not completely representative. In test #2 the projectile disintegrated but some information as to the delays was obtained. The Trigger Display recording indicates that the NSL trigger functioned correctly, responding to the first arrived pulse from channel 4.

The first acceptable hypervelocity impact was achieved in test #3. It indicated that gain settings were too high and that all channels saturated. The gain was lowered in test #4 but some channels still partly saturated. However, most data were properly recorded.

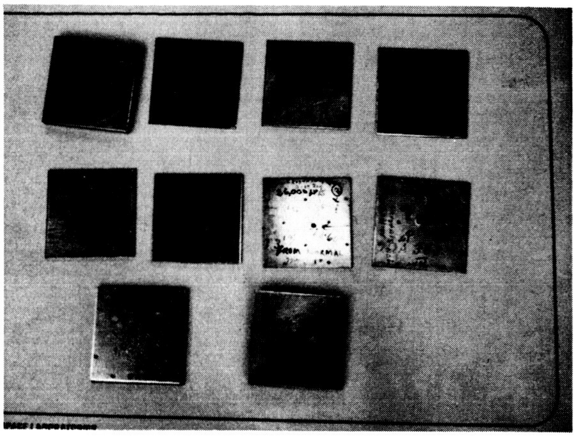
The NSL trigger was actually employed for the first time in test #5. The first arriving pulse from channel 2 led to a trigger pulse that initiated the sweep of channel 2 traces. The channel 1 traces indicate that the corresponding transducer was shorted. the recorded noise on the more sensitive trace being due to cross-channel pick-up in the preamplifiers.

The NSL trigger pulse was employed to initiate sweeps of traces corresponding to all channels (except the upper trace of channel 3) in test #6 but the intensity levels were set too low to be photographically recorded. In order to verify the intensity distribution on the upper trace of channel 3 photograph, a double pulse was inserted in the same fashion as original data. The lower photograph on Figure 2-16 shows that the intensity of the upper trace of channel 3 is coincident with the sweep time of the lower trace.

In further tests the recording equipment functioned satisfactorily and the obtained results are discussed in Section 3.0 as Preliminary Data. Impacted target plates are shown on Figure 2-17.

Similar test series as the above was undertaken with iron fragments as projectiles and the results are reported on Figures 2-17 to 2-32. Similar considerations as those discussed in the lexan protectiles impact series also obtain here. Figures 2-17 through 2-19 show details of the hypervelocity facility and instrumentation used during the tests and Figures 2-20 through 2-32 contain the actual data.

A number of calibration tests were also performed at a facility which accelerates borosilicate spheres of 50 and 90 microns in diameter to velocities over 40,000 ft/sec by the exploding foil method. The NSL recording system was slightly modified to provide higher gain. A vacuum feed-through bulkhead had also to be fabricated to facilitate coupling of the sensor outputs to the preamplifiers.

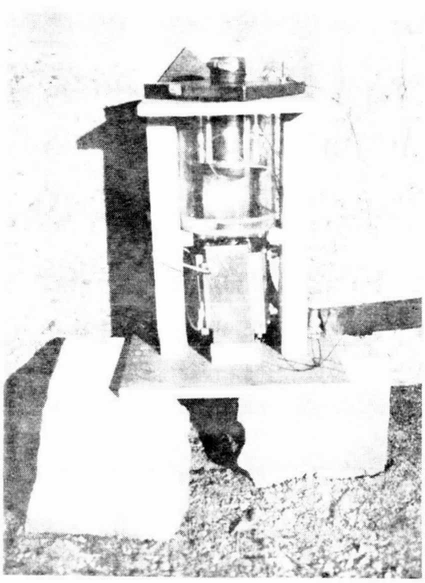


Targets Impacted by 2.8 mg Lexan Projectiles
at Velocities of 20,000 - 26,000 ft/sec

G. E. Hypervelocity Facility Accelerating 10 - 100 μ Iron Fragments

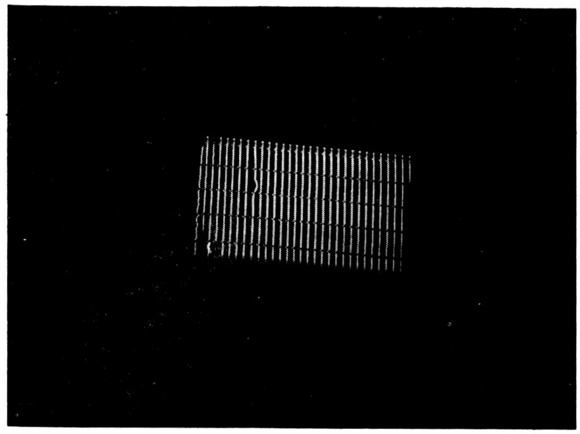
FIGURE 2-17 IMPACTED TARGETS AND GENERAL ELECTRIC COMPANY HYPERVELOCITY FACILITY

Vacuum Chamber with
Explosive Charge on
Top

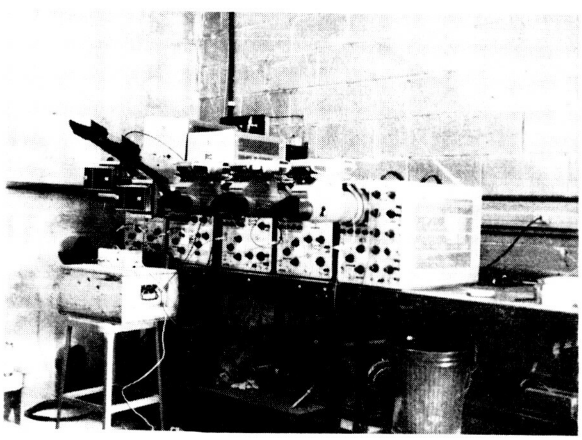


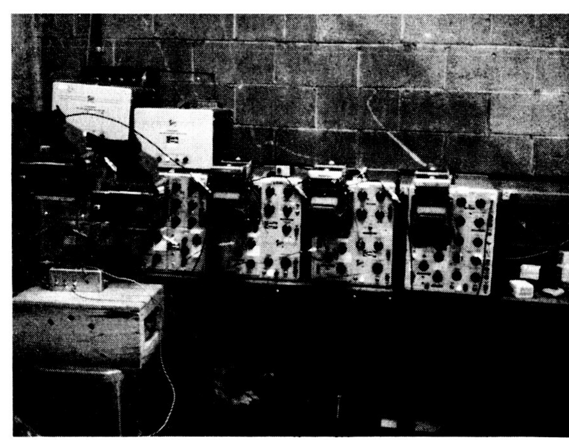
Vacuum Chamber with
Explosive Charge on Top
and Sensor Mounted with
Preamplifiers Below

FIGURE 2-18 VACUUM CHAMBER WITH EXPLOSIVE CHARGE AND TARGET ASSEMBLY



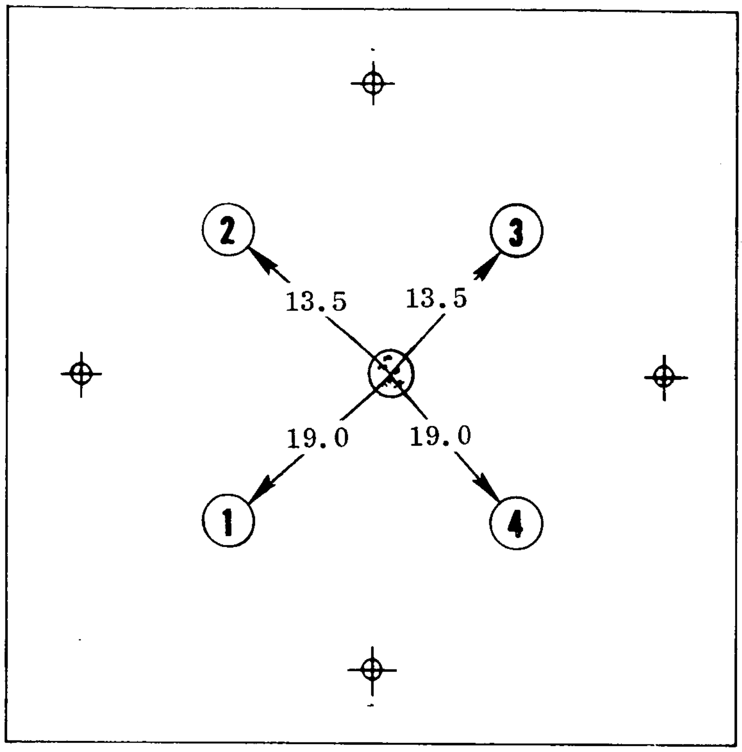
Velocity Measurement Recording
(Distance between screens = 4",
time elapsed = 11.2 μ sec,
velocity = 29,7000 ft/sec)



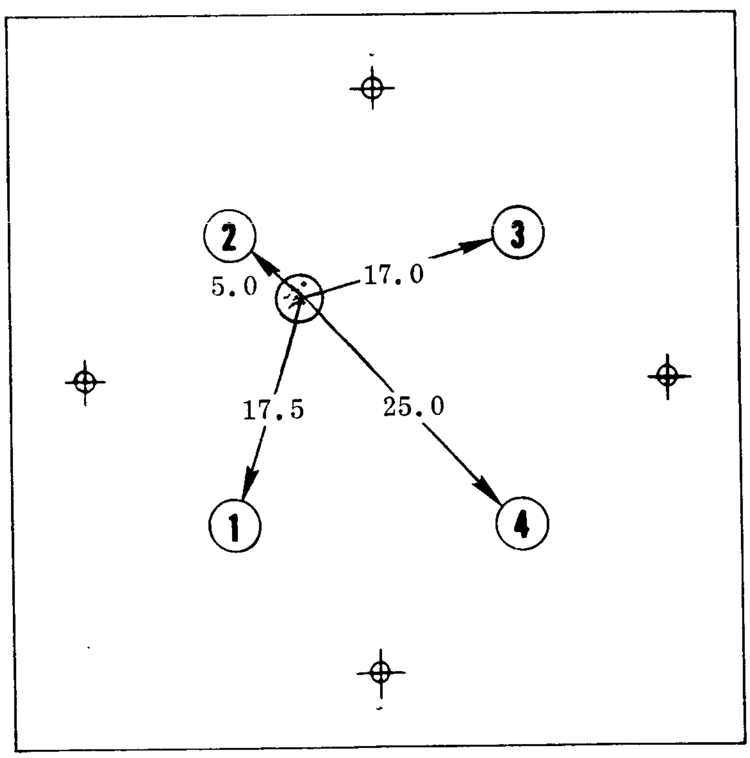


Recording Instrumentation for Iron Fragments Impact Tests

FIGURE 2-19 RECORDING INSTRUMENTATION AND VELOCITY MEASUREMENT FOR IRON FRAGMENTS IMPACT TESTS



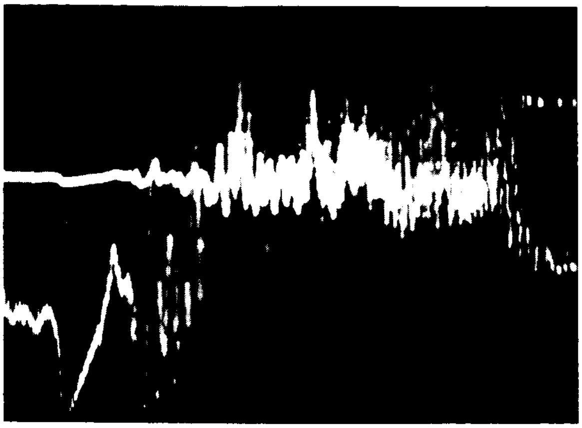
Test No. 1



Test No. 2

FIGURE 2-20 LOCATION OF IMPACT AREAS; TEST NOS. 1 AND 2
(Distances between impact area centers and transducer edges shown in millimeters)

PROJECTILE: IRON FRAGMENTS (10 - 100μ)

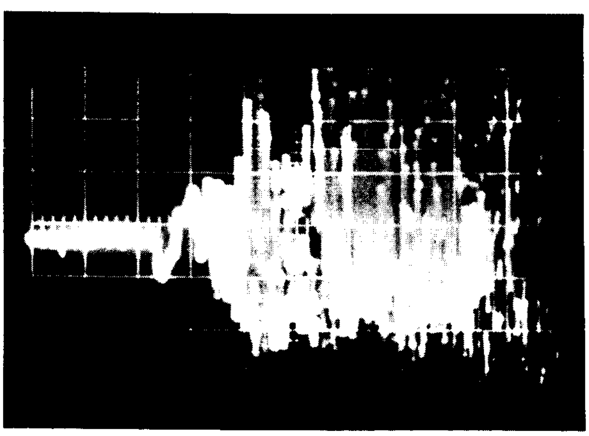


Channel 1

Upper: 5 μ sec/div. (cm)
2V/div. (cm)
Lower: 5 μ sec/div. (cm)
0.1V/div. (cm)
Gain (Xducer/Scope): 50

Channel 2

5 μ sec/div. (cm)
0.5V/div. (cm)
Gain (Xducer/Scope): 50

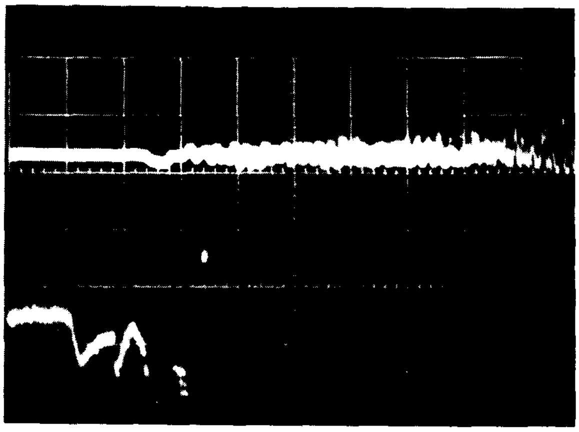


Channel 3

5 μ sec/div. (cm)
0.5V/div. (cm)
Gain (Xducer/Scope): 50

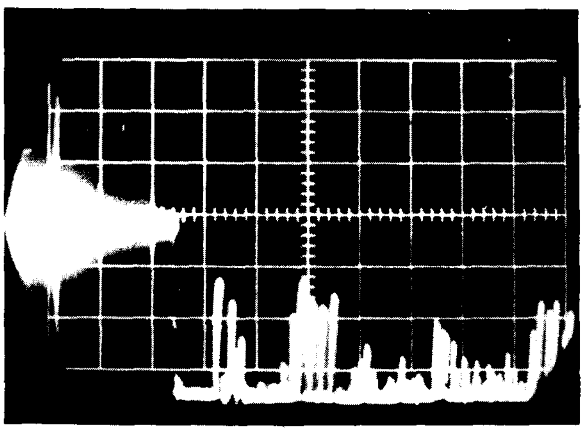
FIGURE 2-21
IMPACT TEST NO. 1
(Channels #1, 2, 3)
23 February, 1966 - Shot #1

PROJECTILE: IRON FRAGMENTS (10 - 100μ)



Channel 4

Upper: 5 μsec/div. (cm)
2V/div. (cm)
Lower: 5 μsec/div. (cm)
0.1V/div. (cm)
Gain (Xducer/Scope): 50



NSL Trigger Display

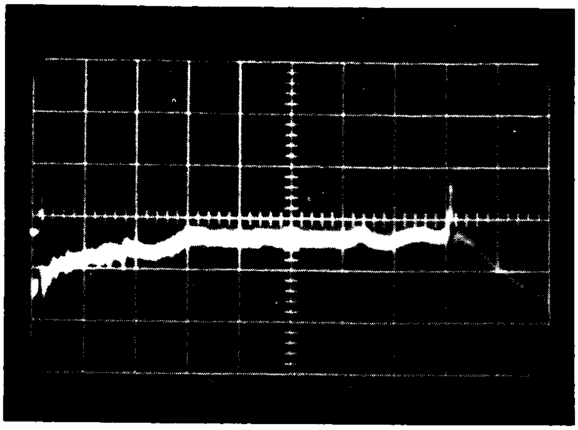
5 μsec/div. (cm)
1V/div. (cm)

Additional Data

- All oscilloscopes triggered by velocity measuring circuit (20μ sec delay added)
- Projectile velocity: approximately 30,000 ft/sec
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

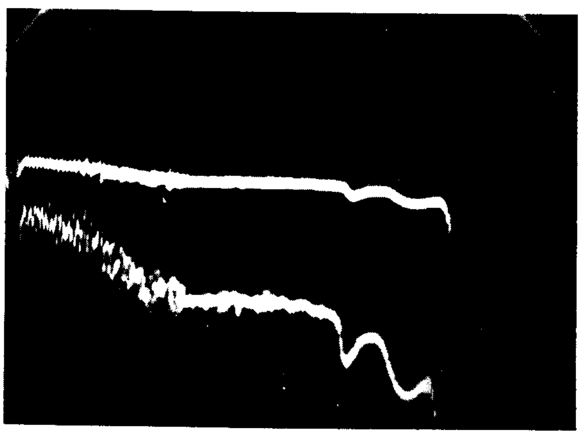
FIGURE 2-22
IMPACT TEST NO. 1
(Channel #4 and NSL Trigger Display)
23 February, 1966 - Shot #1

PROJECTILE: IRON FRAGMENTS (10 - 100μ)



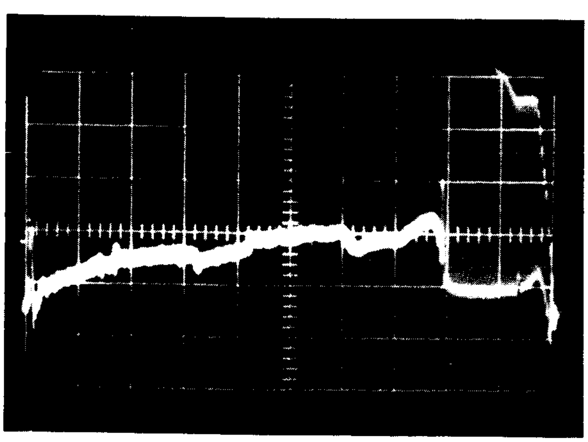
Channel 1

2 μsec/div. (cm)
0.5V/div. (cm)
Gain (Xducer/Scope): 50



Channel 2

Upper: 2 μsec/div. (cm)
1V/div. (cm)
Lower: 2 μsec/div. (cm)
0.2V/div. (cm)
Gain (Xducer/Scope): 50

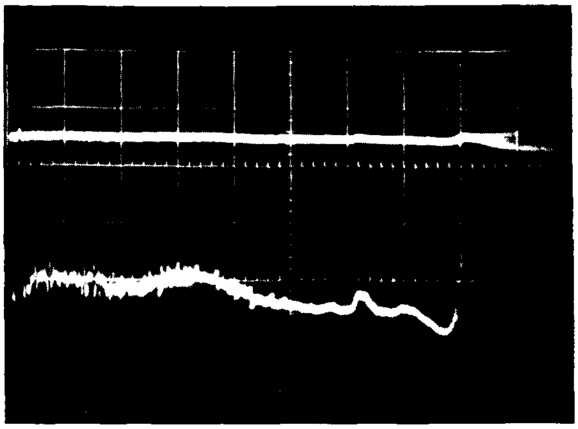


Channel 3

2 μsec/div. (cm)
0.5V/div. (cm)
Gain (Xducer/Scope): 50

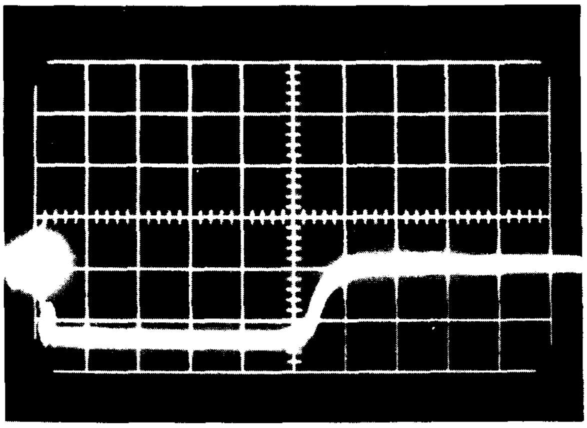
FIGURE 2-23
IMPACT TEST NO. 2
(Channels #1, 2, 3)
24 February, 1966 - Shot #1

PROJECTILE: IRON FRAGMENTS (10 - 100μ)



Channel 4

Upper: 2 μsec/div. (cm)
1V/div. (cm)
Lower: 2 μsec/div. (cm)
0.2 sec/div. (cm)
Gain (Xducer/Scope): 50



NSL Trigger Display

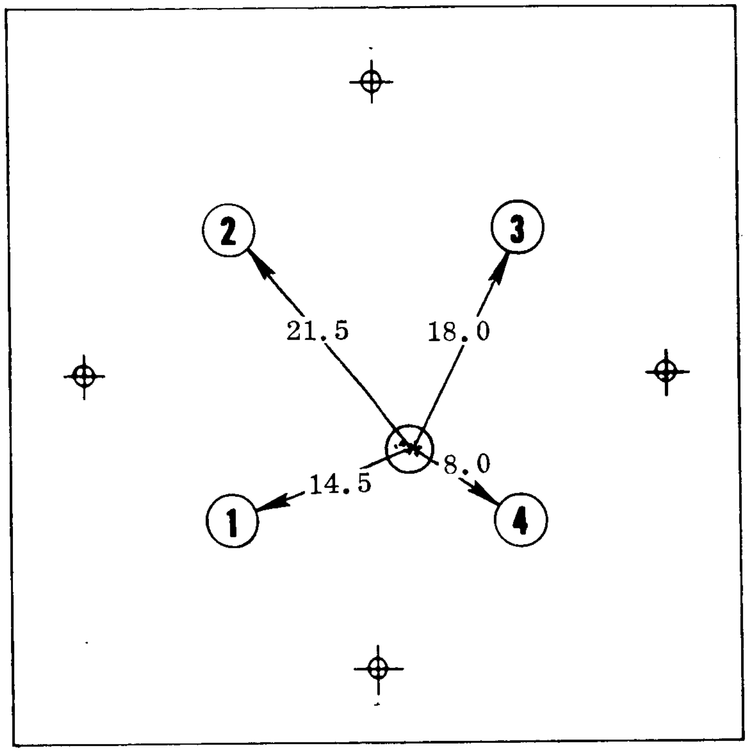
2 μ sec/div. (cm)
2V/div. (cm)

Additional Data

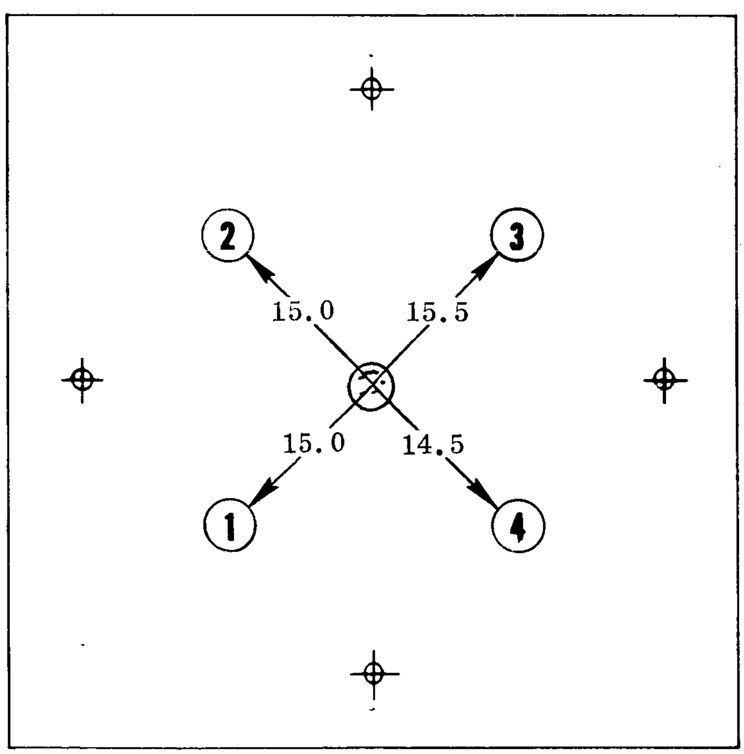
- All oscilloscopes triggered by velocity measuring circuit (20μ sec delay added)
- Projectile velocity: approximately 30,000 ft/sec
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

FIGURE 2-24
IMPACT TEST NO. 2
(Channel #4 and NSL Trigger Display)
24 February, 1966 - Shot #1

PROJECTILE: IRON FRAGMENTS (10 - 100μ)

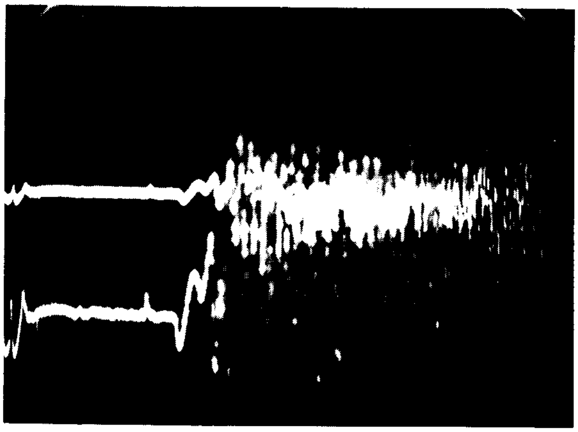


Test No. 3



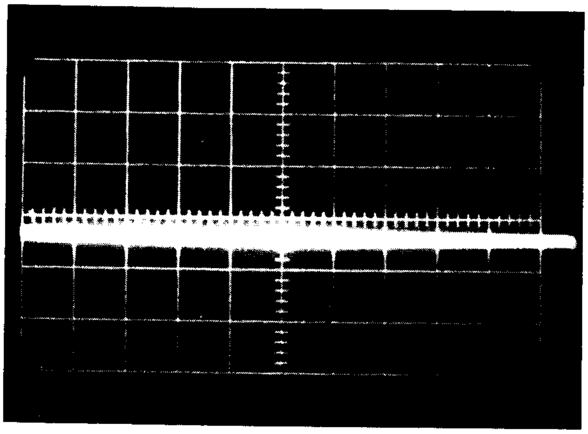
Test No. 4

FIGURE 2-25 LOCATION OF IMPACT AREAS; TEST NOS. 3 AND 4
(Distances between impact area centers and transducer edges shown in millimeters)
PROJECTILE: IRON FRAGMENTS (10 - 100μ)



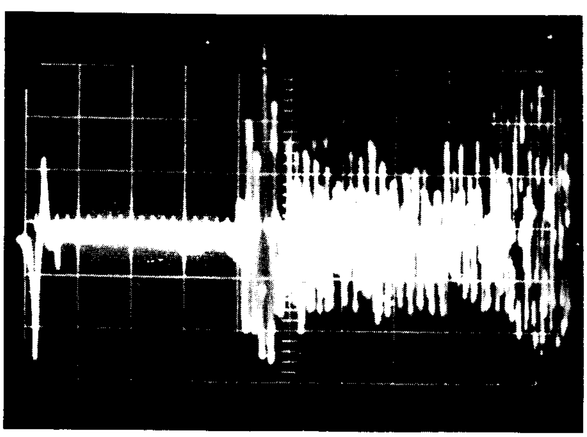
Channel 1

Upper: 5 μ sec/div. (cm)
1V/div. (cm)
Lower: 5 μ sec/div. (cm)
0.2V/div. (cm)
Gain (Xducer/Scope): 50



Channel 2

5 μsec/div. (cm)
0.5V/div. (cm)
Gain (Xducer/Scope): 50

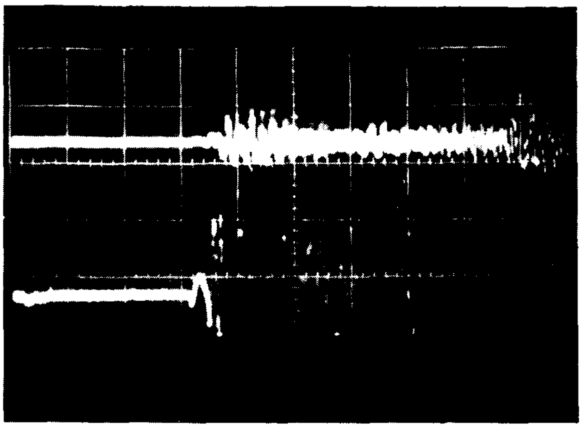


Channel 3

5 μ sec/div. (cm)
0.5V/div. (cm)
Gain (Xducer/Scope): 50

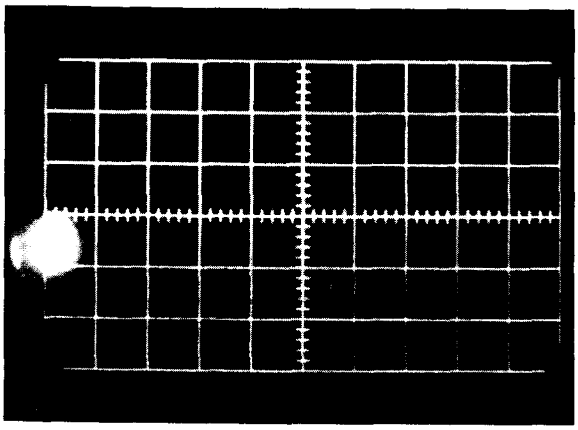
FIGURE 2-26
IMPACT TEST NO. 3
(Channels #1, 2, 3)
24 February, 1966 - Shot #2

PROJECTILE: IRON FRAGMENTS (10 - 100μ)



Channel 4

Upper: 5 μ sec/div. (cm)
1V/div. (cm)
Lower: 5 μ sec/div. (cm)
0.2V/div. (cm)
Gain (Xducer/Scope): 50



NSL Trigger Display

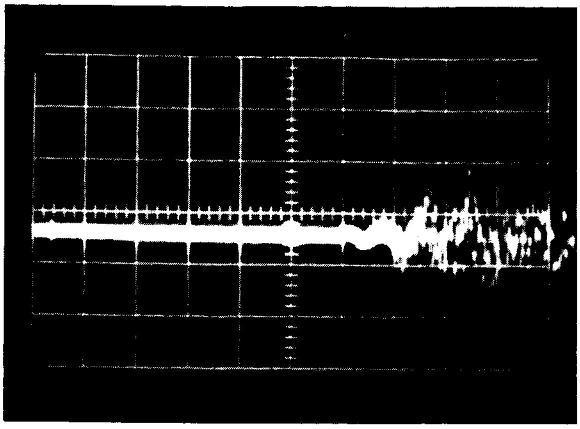
5 μ sec/div. (cm)
2V/div. (cm)

Additional Data

- All oscilloscopes triggered by velocity measuring circuit (20μ sec delay added)
- Projectile velocity: approximately 30,000 ft/sec
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

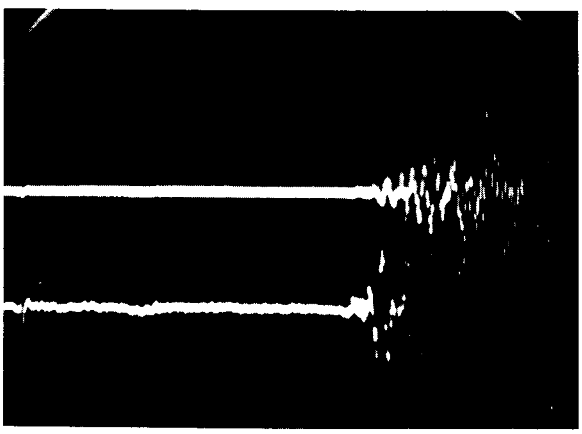
FIGURE 2-27
IMPACT TEST NO. 3
(Channel #4 and NSL Trigger Display)
24 February, 1966 - Shot #2

PROJECTILE: IRON FRAGMENTS (10 - 100μ)



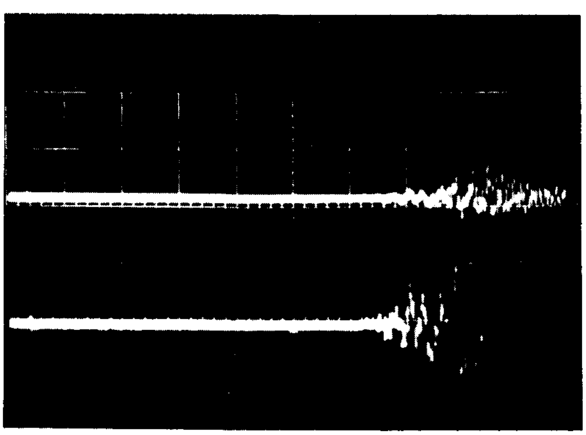
Channel 1

3 μsec/div. (cm)
0.5V/div. (cm)
Gain (Xducer/Scope): 50



Channel 2

Upper: 3 μsec/div. (cm)
1V/div. (cm)
Lower: 3 μsec/div. (cm)
0.2V/div. (cm)
Gain (Xducer/Scope): 50

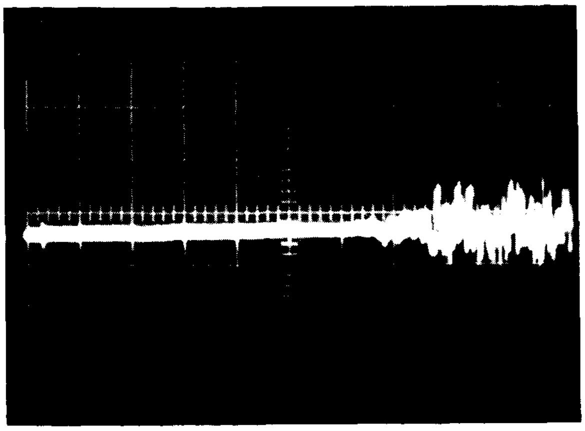


Channel 3

Upper: 3 μsec/div. (cm)
1V/div. (cm)
Lower: 3 μsec/div. (cm)
0.2V/div. (cm)
Gain (Xducer/Scope): 50

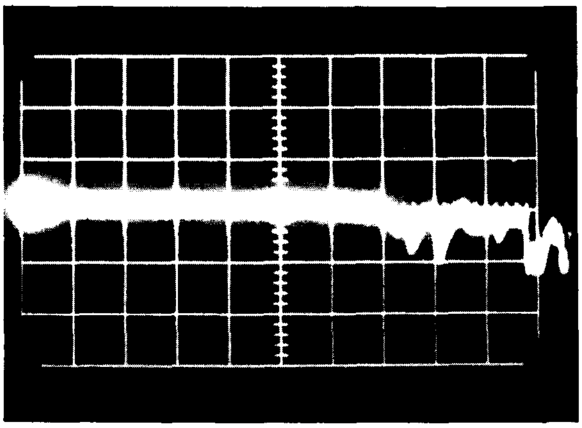
FIGURE 2-28
IMPACT TEST NO. 4
(Channels #1, 2, 3)
25 February, 1966 - Shot #1

PROJECTILE: IRON FRAGMENTS (10 - 100μ)



Channel 4

3 μsec/div. (cm)
0.5V/div. (cm)
Gain (Xducer/Scope): 50



NSL Trigger Display

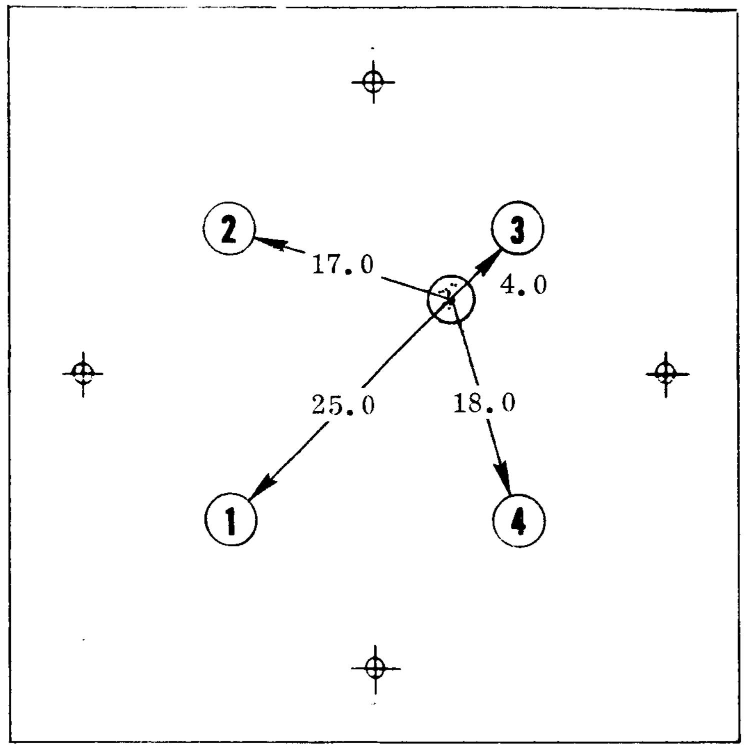
3 μsec/div. (cm)
2V/div. (cm)

Additional Data

- All oscilloscopes triggered by velocity measuring circuit (20μ sec delay added)
- Projectile velocity: approximately 30,000 ft/sec
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

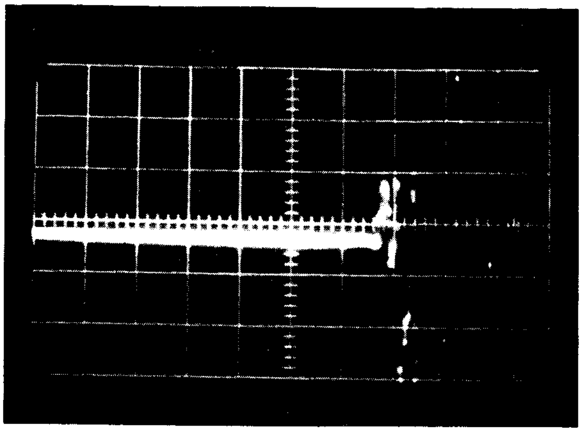
FIGURE 2-29
IMPACT TEST NO. 4
(Channel #4 and NSL Trigger Display)
25 February, 1966 - Shot #1

PROJECTILE: IRON FRAGMENTS (10 - 100μ)



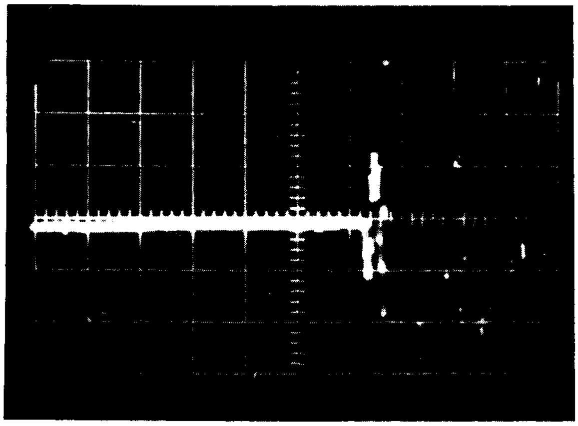
Test No. 5

FIGURE 2-30 LOCATION OF IMPACT AREAS; TEST NO. 5
(Distances between impact area centers and transducers edges shown in millimeters)
PROJECTILE: IRON FRAGMENTS (10 - 100μ)



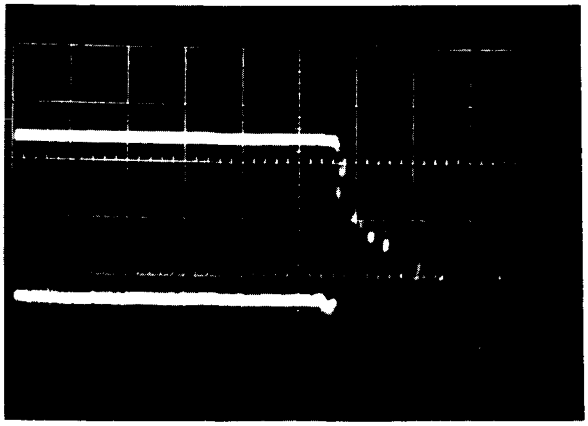
Channel 1

3μ sec/div. (cm)
0.5V/div. (cm)
Gain (Xducer/Scope): 50



Channel 2

3μ sec/div. (cm)
0.5V/div. (cm)
Gain (Xducer/Scope): 50

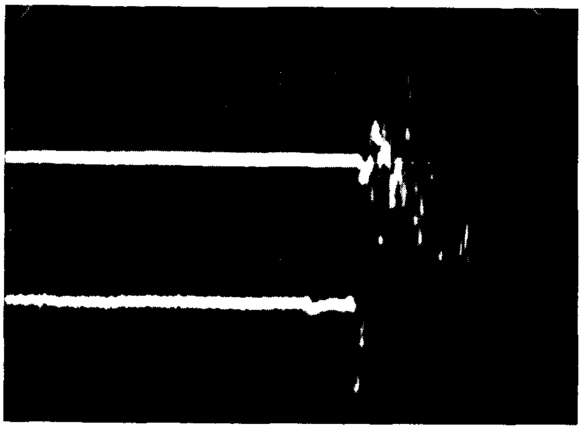


Channel 3

Upper: 3μ sec/div. (cm)
1V/div. (cm)
Lower: 3μ sec/div. (cm)
0.2V/div. (cm)
Gain (Xducer/Scope): 50

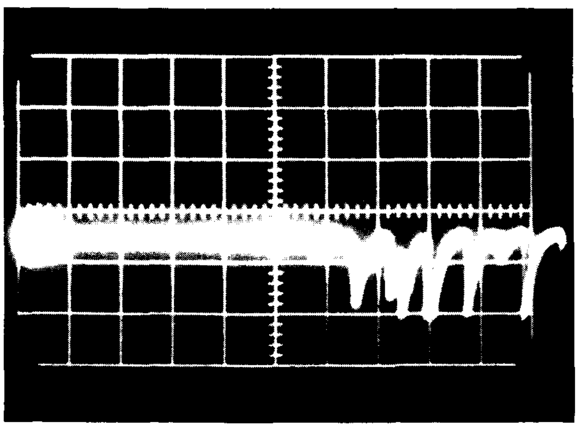
FIGURE 2-31
IMPACT TEST NO. 5
(Channels #1, 2, 3)
28 February, 1966 - Shot #1

PROJECTILE: IRON FRAGMENTS (10 - 100μ)



Channel 4

Upper: 3μ sec/div. (cm)
1V/div. (cm)
Lower: 3μ sec/div. (cm)
0.2V/div. (cm)
Gain (Xducer/Scope): 50



NSL Trigger Display

3μ sec/div. (cm)
2V/div. (cm)

Additional Data

- All oscilloscopes triggered by velocity measuring circuit (20μ sec delay added)
- Projectile velocity: approximately 30,000 ft/sec
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

FIGURE 2-32
IMPACT TEST NO. 5
(Channel #4 and NSL Trigger Display)
28 February, 1966 - Shot #1

PROJECTILE: IRON FRAGMENTS (10 - 100μ)

The first several tests consisted of monitoring the signal outputs of the four channels and the NSL trigger when the exploding foil projector was fired but no particles were allowed to impact upon the sensor target plate. Results indicated that no serious noise pick up problems existed if adequate precautions were observed.

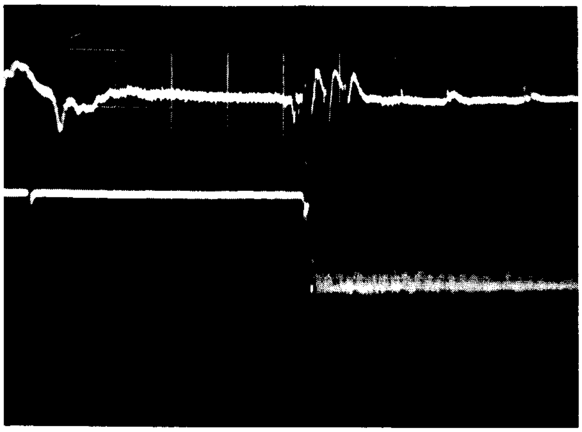
The gun-firing pulse was used to trigger the velocity and data recorders pertaining to the performance of the gun. The same pulse was also employed as the master trigger pulse to initiate the NSL oscilloscopes so that all subsequent recorded events could be compared and correlated. The tests indicated that the NSL equipment should be triggered 100 μsec after the firings pulse and that during this period the NSL triggering arrangement should be rendered inoperative. During this time, noise pick-ups occur (due to a multi-kV discharge) that could interfere with reliable data recording. A Tektronic oscilloscope of the 555 type was adjusted so that after being initiated by the firing pulse. it would provide a trigger pulse after 100 μsec delay which would bring the oscilloscopes into "triggerable" setting. The first NSL trigger pulse which would arrive after this time would then initiate the sweeps.

In addition, a photomultiplier was employed to view the impact flashes so that times of projectiles arrivals and their integrity could be monitored. Some representative data from these tests are shown on Figures 2-33 and 2-34.

Figure 2-33 indicates that a noise pulse initiated a false trigger pulse 140 μsec after the gun has been fired. Extraneous noise pick-up was also introduced through the photomultiplier channel during this time. After 360 μsec several impacts occurred. spaced about 10 μsec. Due to the lack of precise trace synchronization it may only be assumed that the first NSL trigger pulse coincided with the first impact. This assumption seems validated when the waveform recorded is more closely analyzed. The lower photo in Figure 2-33 indicates that the noise pulse of about 30 mV produced the false trigger pulse discussed above. The peak signal from the transducer was about 300 mV.

No impacts occurred during the sweep time of the trace on the upper photograph in Figure 2-34. In the lower picture, however, the trace was initiated by the NSL trigger and output waveforms corresponding to impacts may be observed. Impact times read off from this photograph correlate exactly with the times measured by the phototube flash recordings. The low frequency signal may have been caused by a shock wave propagated down the barrel.

The tests, in summary, yielded information about the signal and noise levels. NSL instrumentation performance, delays to be accommodated, and about the general problems of the particular experimental settings.



Target Impact Flashes

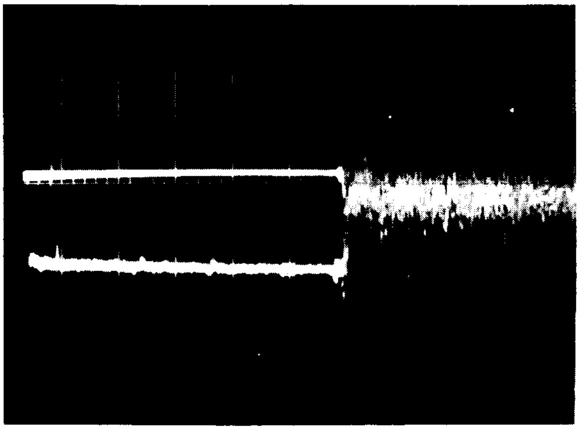
Upper: 50μ sec/div. (cm)
2V/div. (cm)

NSL Trigger Output

Lower: 50μ sec/div. (cm)
2V/div. (cm)

Both traces delayed 100μ sec after firing pulse

Trigger Level: 10mV (Ref. to input)



Transducer Output Signal

Upper: 50μ sec/div. (cm)
2V/div. (cm)

Lower: 50μ sec/div. (cm)
0.1V/div. (cm)

Both traces delayed 100μ sec after firing pulse

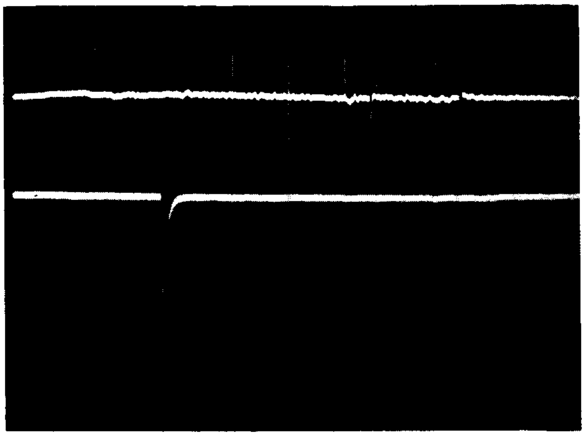
Gain (Xducer/Scope): 40

Additional Data

- Projectile: 50 micron borosilicate glass spheres
- Projectile velocity: 40,000 ft/sec
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

FIGURE 2-33
IMPACT TEST NO. 1
(Shot #6680)

PROJECTILE: BOROSILICATE GLASS SPHERE (50 Micron)



Target Impact Flashes

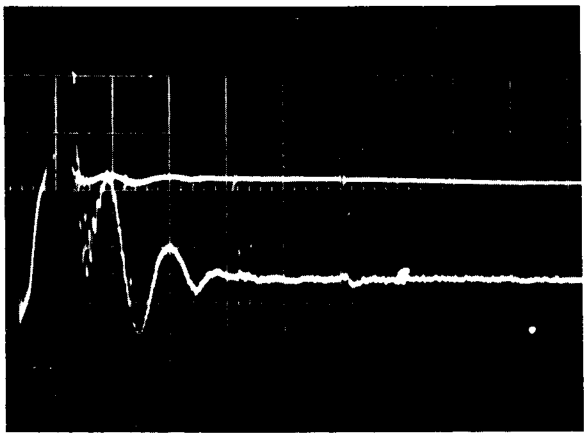
Upper: 50μ sec/div. (cm)
2V/div. (cm)

NSL Trigger Output

Lower: 50μ sec/div. (cm)
2V/div. (cm)

Both traces delayed 300μ sec after firing pulse

Trigger Level: 10mV (Ref. to input)



Transducer Output Signal

Upper: 50μ sec/div. (cm)
2V/div. (cm)

Lower: 50μ sec/div. (cm)
0.1V/div. (cm)

Both traces were triggered by NSL trigger pulse which occurred after the end of above sweep (Impacts verified by Impact Flash Recordings)

Gain (Xducer/Scope): 40

Additional Data

- Projectile disintegrated (originally a 50 micron borosilicate glass sphere)
- Projectile velocity: 47,000 ft/sec
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

FIGURE 2-34
IMPACT TEST NO. 2
(Shot #6679)

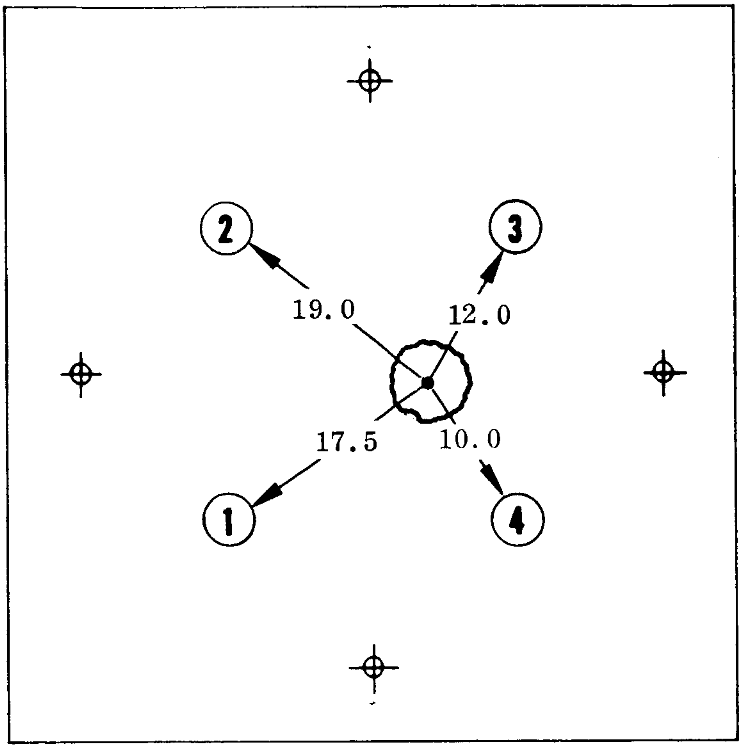
PROJECTILE: BOROSILICATE GLASS SPHERE (50 Micron)

SECTION 3.0

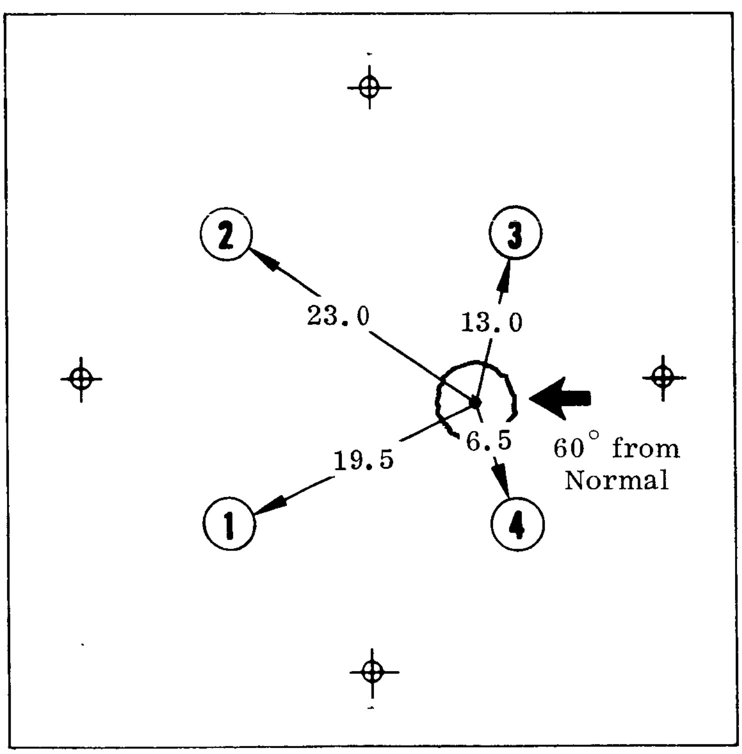
PRELIMINARY DATA

Several hypervelocity impact tests were performed with 2.8 mg lexan slugs as projectiles. These tests were performed subsequently to the calibration shots discussed in Section 2.0 (see Figures 2-3 through 2-16). The data from these preliminary tests are presented on Figures 3-1 through 3-10. In most cases clear, accurate pictures were obtained which allow at least a partial analysis. A preliminary correlation of the arrival times and the distances travelled by the stress waves in the sensor target plate from the point of impact to the particular transducer in question was attempted and the results are tabulated in Table 3-1. The data are plotted on the diagram in Figure 3-11. Despite the uncertainties in triggering delays and interpretation of some of the traces the data points referring to the first arriving stress pulses fall closely along a straight line which corresponds to the velocity of 6.2 mm/μsec. This agrees well with the expected velocity of the longitudinal (fastest) stress waves which would be generated in non-negligible magnitudes in explosion-like processes which occur during hypervelocity impacts. These waves would be followed by slower transverse, flexural waves which should produce transducer outputs of considerably larger amplitudes. This may be observed on nearly all the traces in Figures 3-1 through 3-10.

The preliminary data indicate that satisfactory progress is being made and that the design of the experimental target assembly, together with the recording instrumentation should allow acquisition of valuable information when all the impact tests are completed and all data thoroughly analyzed.



Test No. 7



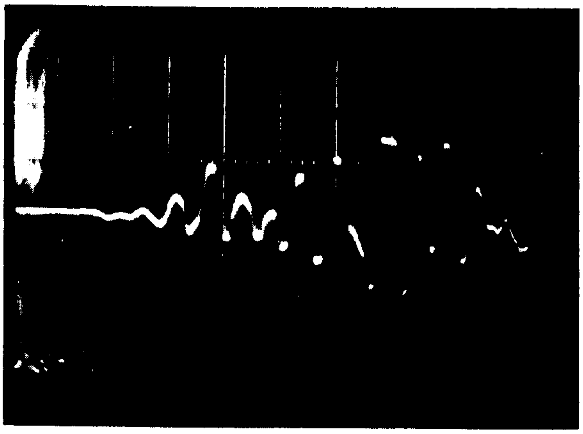
Test No. 8

FIGURE 3-1 LOCATION OF IMPACT AREAS; TEST NOS. 7 AND 8
(Distances between impact area centers and transducer edges shown in millimeters)

PROJECTILE: LEXAN SLUG (2.8 mg)

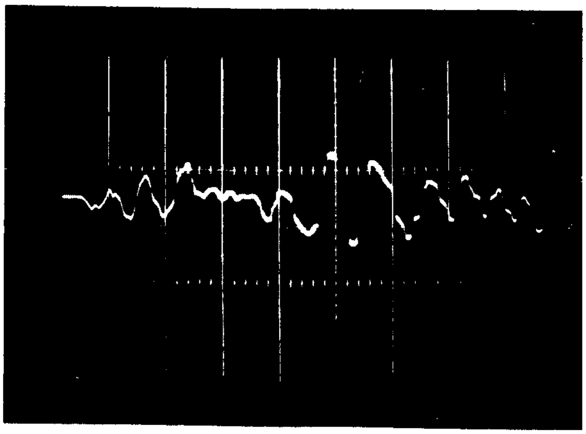
Channel 1

Upper: 1 μ sec/div. (cm)
2V/div. (cm)
Lower: 1 μ sec/div. (cm)
0.05V/div. (cm)
Gain (Xducer/Scope): 0.12



Channel 2

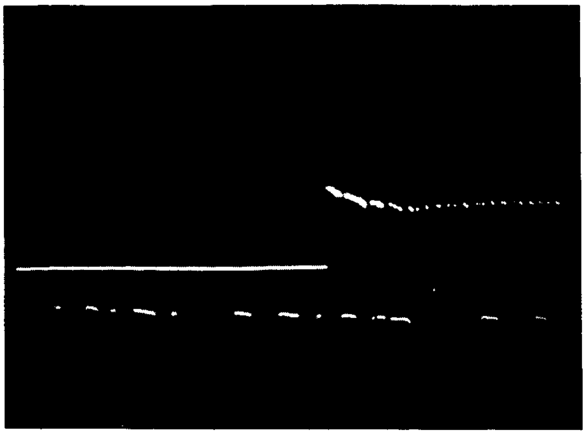
Upper: 1 μ sec/div. (cm)
2V/div. (cm)
Lower: 1 μ sec/div. (cm)
0.05V/div. (cm)
Gain (Xducer/Scope): 0.12



Channel 3

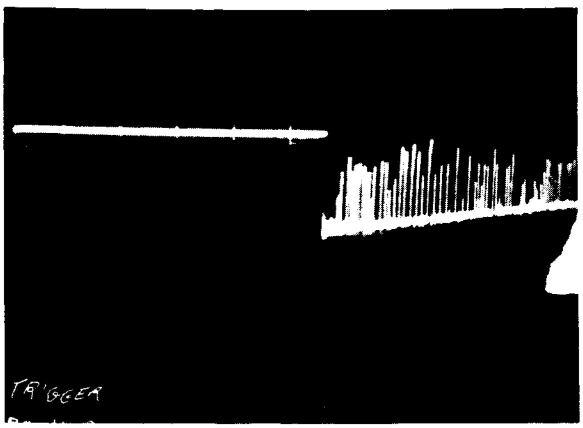
Upper: 1 μ sec/div. (cm)
2V/div. (cm)
Lower: 1 μ sec/div. (cm)
0.05V/div. (cm)
Gain (Xducer/Scope): 0.12

FIGURE 3-2
IMPACT TEST NO. 7
(Channels #1, 2, 3)
3 February, 1966 - Shot #2
PROJECTILE: LEXAN SLUG (2.8 mg)



Channel 4

Upper: 10 μsec/div. (cm)
2V/div. (cm)
Lower: 1 μsec/div. (cm)
2V/div. (cm)
Gain (Xducer/Scope): 0.73



NSL Trigger Display

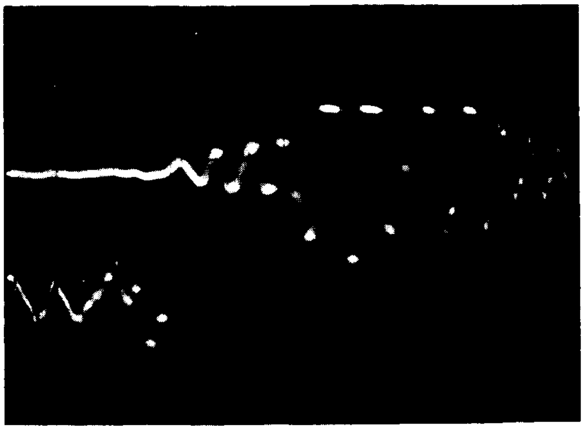
10 μsec/div. (cm)
2V/div. (cm)

Additional Data

- Upper trace of channel #4 and NSL Trigger Display were triggered by velocity measuring phototube circuit
- Lower trace of channel #4 and those of channels #1, 2, and 3 for triggered by NSL Trigger circuit
- Projectile velocity: (Approximately) 22,000 ft/sec
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

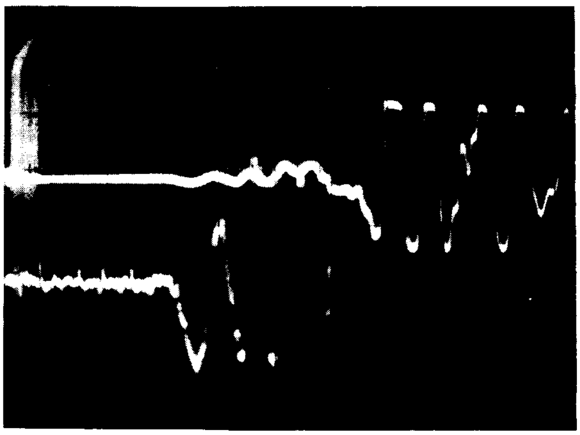
FIGURE 3-3
IMPACT TEST NO. 7
(Channel #4 and NSL Trigger Display)
3 February, 1966 - Shot #2

PROJECTILE: LEXAN SLUG (2.8 mg)



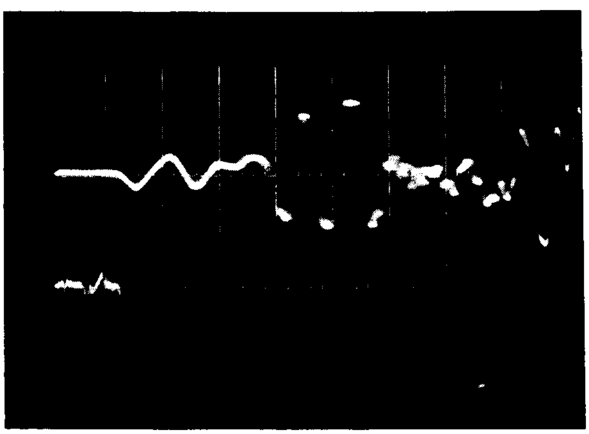
Channel 1

Upper: 1 μsec/div. (cm)
2V/div. (cm)
Lower: 1 μsec/div. (cm)
0.1V/div. (cm)
Gain (Xducer/Scope): 0.12



Channel 2

Upper: 1 μsec/div. (cm)
2V/div. (cm)
Lower: 1 μsec/div. (cm)
0.1V/div. (cm)
Gain (Xducer/Scope): 0.12

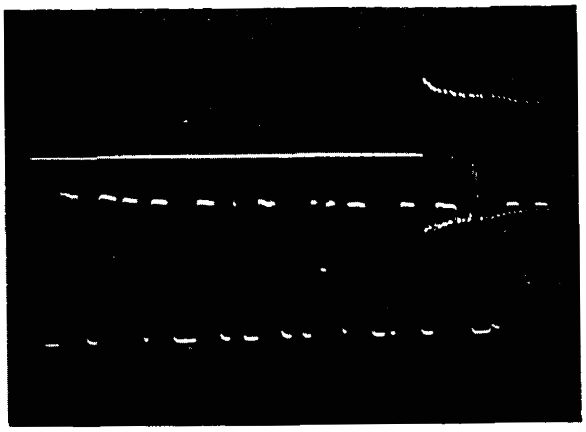


Channel 3

Upper: 1 μsec/div. (cm)
2V/div. (cm)
Lower: 1 μsec/div. (cm)
0.1V/div. (cm)
Gain (Xducer/Scope): 0.12

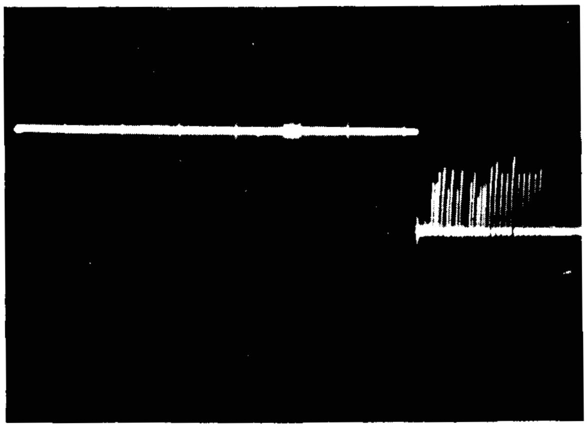
FIGURE 3-4
IMPACT TEST NO. 8
(Channels #1, 2, 3)
4 February, 1966 - Shot #1

PROJECTILE: LEXAN SLUG (2.8 mg)



Channel 4

Upper: 10 μsec/div. (cm)
2V/div. (cm)
Lower: 1 μsec/div. (cm)
2V/div. (cm)
Gain (Xducer/Scope): 0.73



NSL Trigger Display

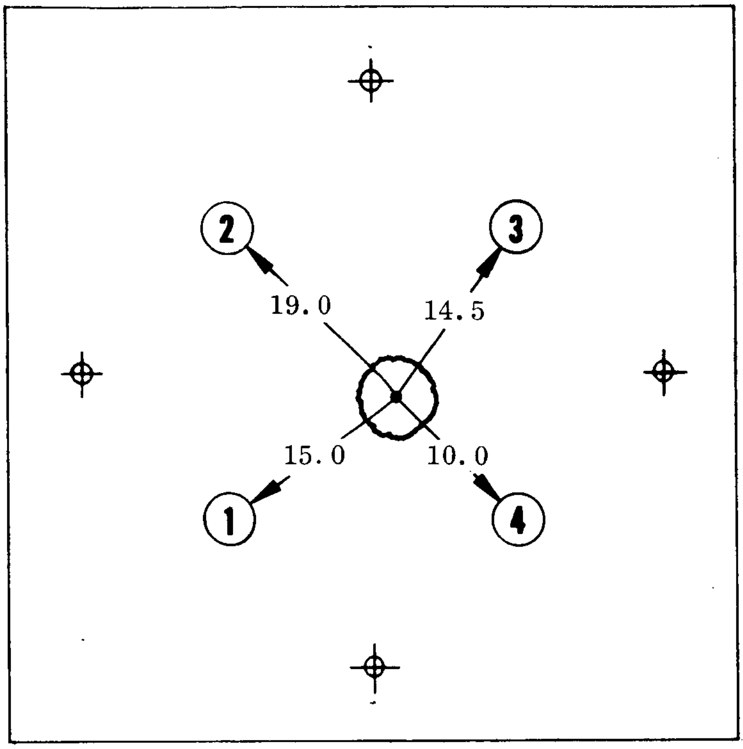
10 μsec/div. (cm)
2V/div. (cm)

Additional Data

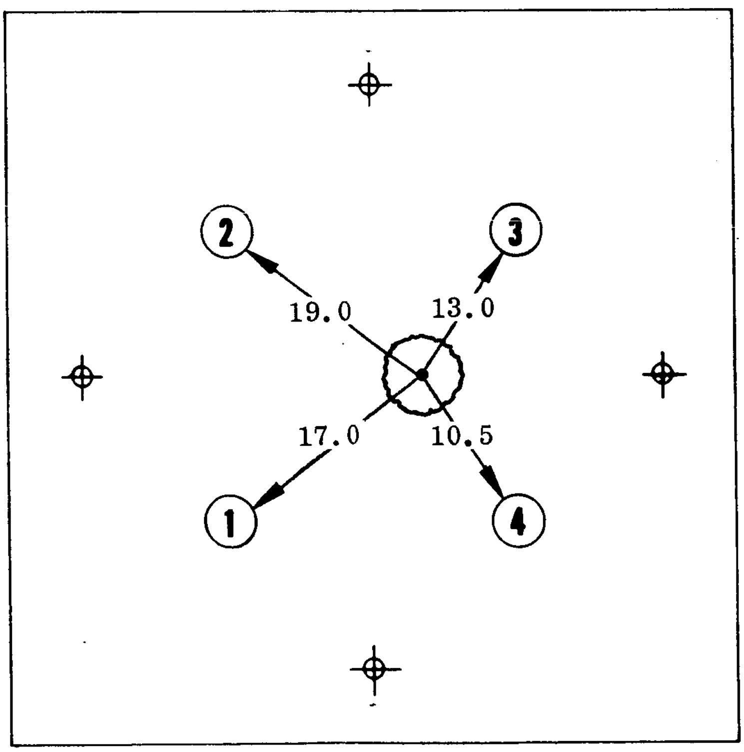
- Upper trace of channel #4 and NSL Trigger Display were triggered by velocity measuring phototube circuit
- Lower trace of channel #4, intensity of upper trace, and traces for channels #1, 2, and 3 were triggered by NSL Trigger circuit
- Projectile velocity: 26,000 ft/sec
- Oblique impact, 60^{o} from normal
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

FIGURE 3-5
IMPACT TEST NO. 8
(Channel #4 and NSL Trigger Display)
4 February, 1966 - Shot #1

PROJECTILE: LEXAN SLUG (2.8 mg)

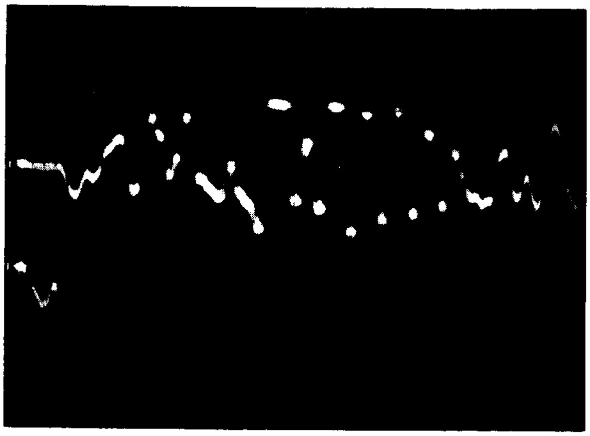


Test No. 9



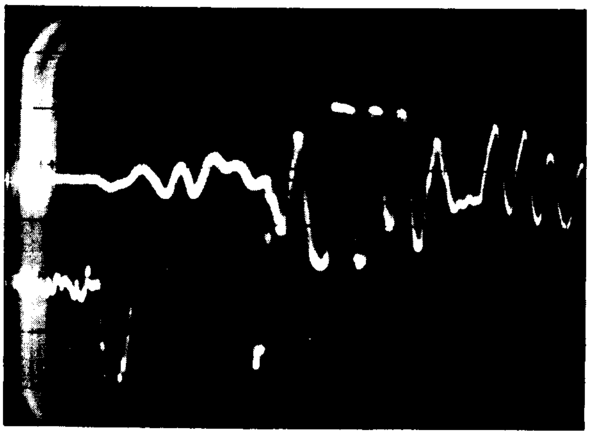
Test No. 10

FIGURE 3-6 LOCATION OF IMPACT AREAS; TEST NOS. 9 AND 10
(Distances between impact area centers and transducer edges shown in millimeters)
PROJECTILE: LEXAN SLUG (2.8 mg)



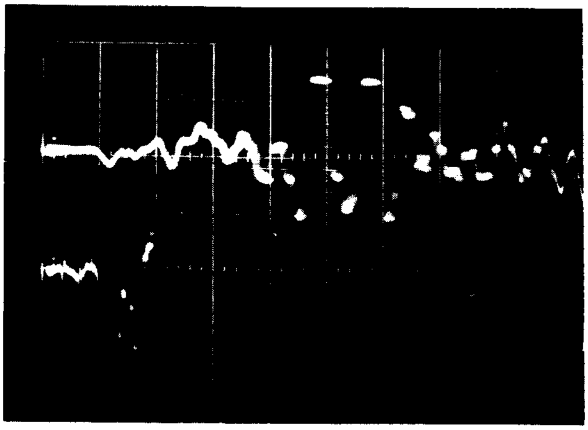
Channel 1

Upper: 1 μ sec/div. (cm)
2V/div. (cm)
Lower: 1 μ sec/div. (cm)
0.1V/div. (cm)
Gain (Xducer/Scope): 0.12



Channel 2

Upper: 1 μ sec/div. (cm)
2V/div. (cm)
Lower: 1 μ sec/div. (cm)
0.1V/div. (cm)
Gain (Xducer/Scope): 0.12

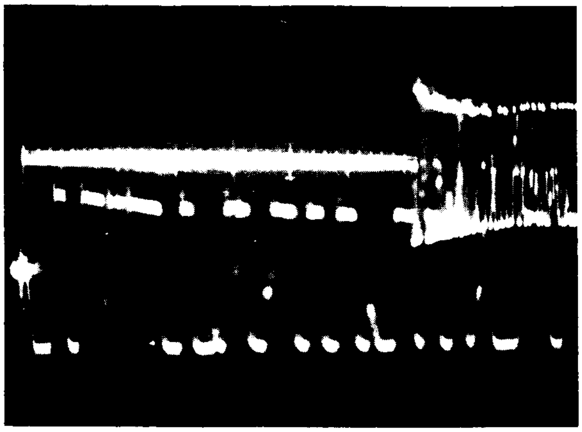


Channel 3

Upper: 1 μ sec/div. (cm)
2V/div. (cm)
Lower: 1 μ sec/div. (cm)
0.1V/div. (cm)
Gain (Xducer/Scope): 0.12

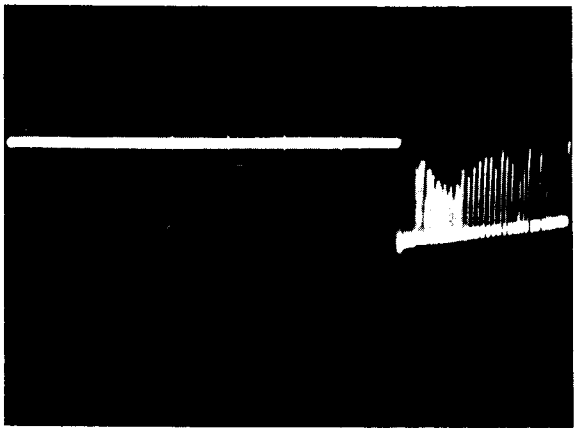
FIGURE 3-7
IMPACT TEST NO. 9
(Channels #1, 2, 3)
4 February, 1966 - Shot #2

PROJECTILE: LEXAN SLUG (2.8 mg)



Channel 4

Upper: 10μ sec/div. (cm)
2V/div. (cm)
Lower: 1μ sec/div. (cm)
2V/div. (cm)
Gain (Xducer/Scope): 0.73



NSL Trigger Display

10μ sec/div. (cm)
2V/div. (cm)

Additional Data

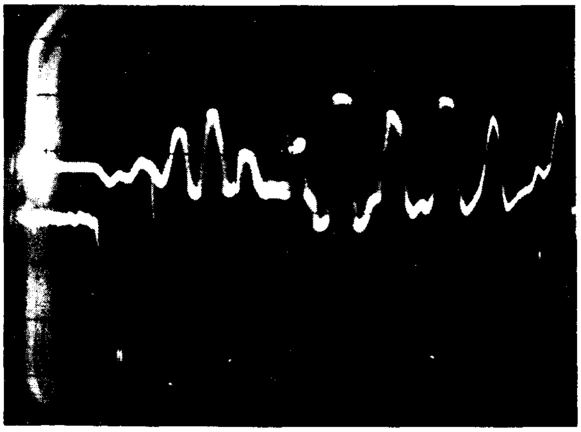
- Upper trace of channel #4 and NSL Trigger Display were triggered by velocity measuring phototube circuit
- Lower trace of channel #4, intensity of upper trace, and traces for channels #1, 2, and 3 were triggered by NSL Trigger circuit
- Projectile velocity: 20,900 ft/sec
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

FIGURE 3-8
IMPACT TEST NO. 9
(Channel #4 and NSL Trigger Display)
4 February, 1966 - Shot #2

PROJECTILE: LEXAN SLUG (2.8 mg)

Channel 1

Upper: 1μ sec/div. (cm)
2V/div. (cm)
Lower: 1μ sec/div. (cm)
0.1V/div. (cm)
Gain (Xducer/Scope): 0.12



Channel 2

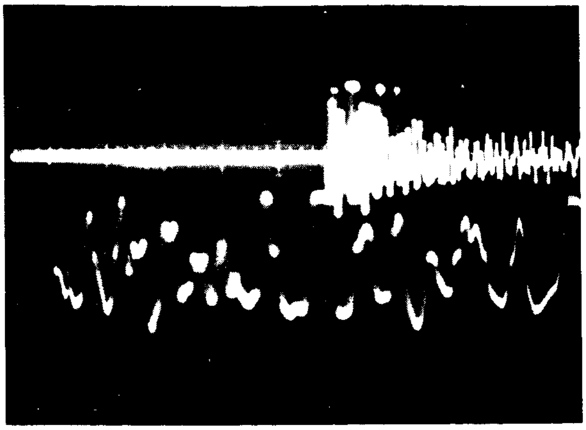
Upper: 1μ sec/div. (cm)
2V/div. (cm)
Lower: 1μ sec/div. (cm)
0.1V/div. (cm)
Gain (Xducer/Scope): 0.12

Channel 3

Upper: 1μ sec/div. (cm)
2V/div. (cm)
Lower: 1μ sec/div. (cm)
0.1V/div. (cm)
Gain (Xducer/Scope): 0.12

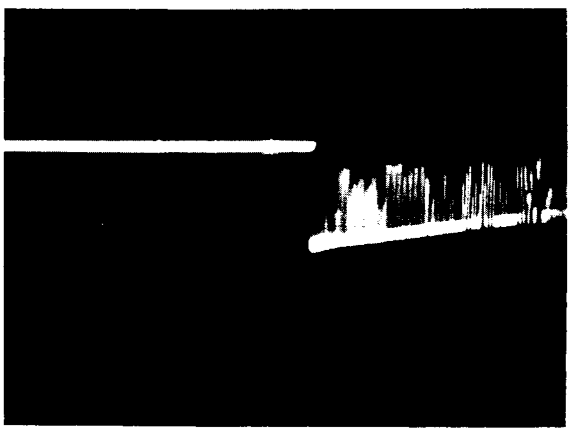
FIGURE 3-9
IMPACT TEST NO. 10
(Channels #1, 2, 3)
4 February, 1966 - Shot #3

PROJECTILE: LEXAN SLUG (2.8 mg)



Channel 4

Upper: 10μ sec/div. (cm)
2V/div. (cm)
Lower: 1μ sec/div. (cm)
2V/div. (cm)
Gain (Xducer/Scope): 0.12



NSL Trigger Display

10μ sec/div. (cm)
2V/div. (cm)

Additional Data

- Upper trace of channel #4 and NSL Trigger Display were triggered by velocity measuring phototube circuit (45 μ sec delay added)
- Lower trace of channel #4, intensity of upper trace and traces for channels #1, 2, and 3 were triggered by NSL trigger circuit
- Projectile velocity: 25,600 ft/sec
- Transducers: Quartz X-cut wafers 0.25" in diameter and 0.063" thick
- Impact Plate: 4" x 4" x 1/8" 2024-T3 Aluminum

FIGURE 3-10
IMPACT TEST NO. 10
(Channel #4 and NSL Trigger Display)
4 February, 1966 - Shot #3

PROJECTILE: LEXAN SLUG (2.8 mg)

TABLE 3-1

ARRIVAL TIMES AND DISTANCES TRAVELLED BY STRESS WAVES

		Delay t μsec/(mm)	Crater to Xducer distance d (mm)	Distance difference Δd from triggering Xducer	$v = \frac{\Delta d}{t}$ (μsec/mm)
Test #7					
Channel	1.	1.17* (10.5)*	17.5	7.5	6.41*
	2.	1.44 (13.0)	19.0	9.0	6.26
	3.	0.31 (2.75)	12.0	2.0	6.45
	4.	trigger	10.0	-	-
Test #8					
Channel	1.	2.22* (20.0)*	19.5	13.0	5.86*
	2.	3.00 (27.0)	23.0	16.5	5.5
	3.	1.11 (10.0)	13.0	6.5	5.86
	4.	trigger	6.5	-	-
Test #9					
Channel	1.	0.78 (7.0)	15.0	5.0	6.41
	2.	1.50 (13.5)	19.0	9.0	6.0
	3.	0.78 (7.0)	14.5	4.5	5.77
	4.	trigger	10.0	-	-
Test #10					
Channel	1.	-	17.0	6.5	-
	2.	1.33 (12.0)	19.0	8.5	6.39
	3.	0.44 (4.0)	13.0	2.5	5.68
	4.	trigger	10.5	-	-

* Unreliable or ambiguous data

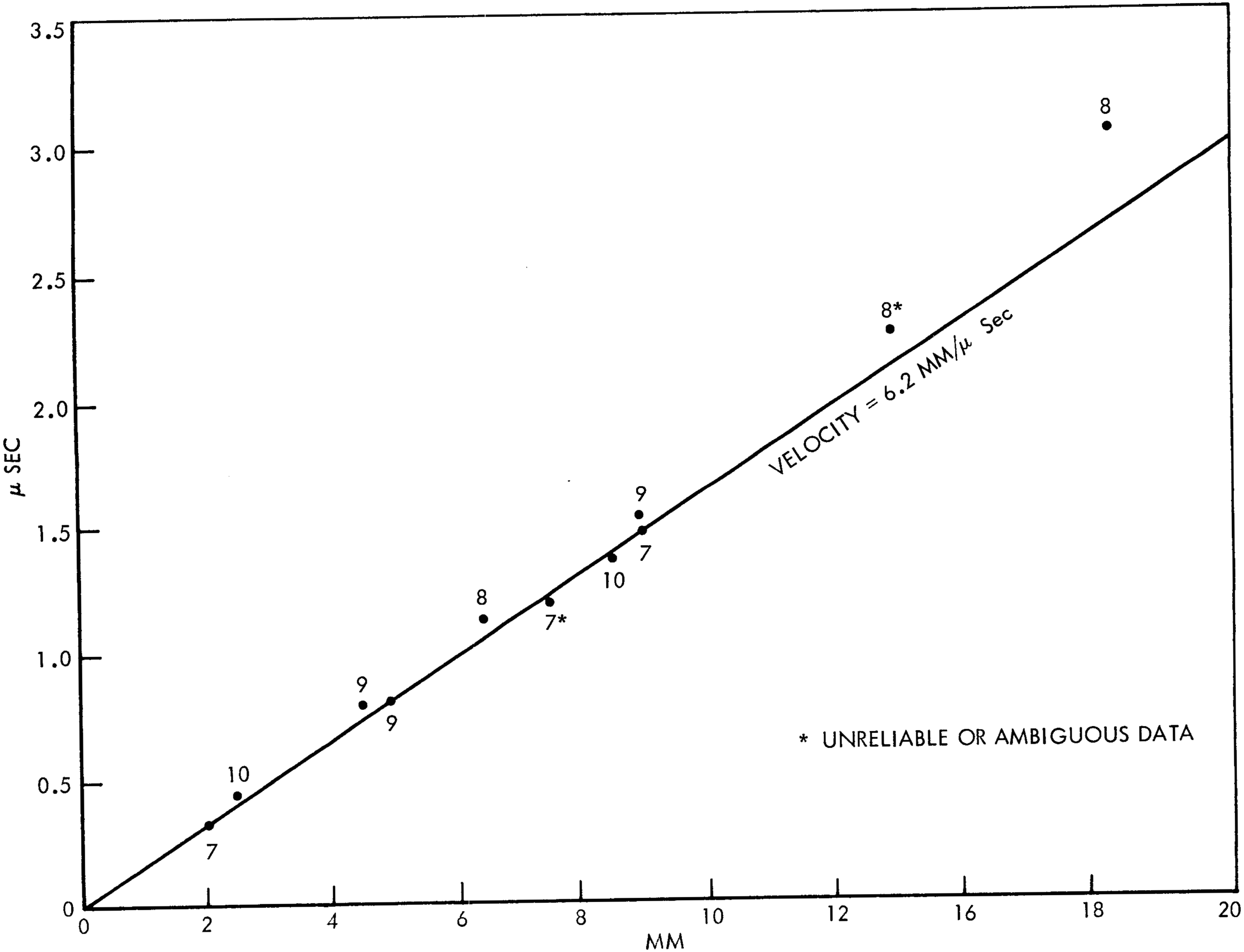


FIGURE 3-11 TIME OF ARRIVAL VS DISTANCE TRAVERSED DIAGRAM

SECTION 4.0

PROGRESS REVIEW AND FUTURE PLANS

The primary objective of the third quarter work plan was to initiate, and partly carry out, the impact test schedule outlined in the Proposal of January 1965 which resulted in the award of the present contract. This has been largely accomplished and calibration hypervelocity impact tests have been carried out with 2.8 mg lexan slugs, 50μ borosilicate spheres, and 10-100μ iron fragments. Accessory recording instrumentation has been checked out, calibrated, and the approximate signal levels established. Several tests have been performed employing the calibrated equipment and yielded preliminary results that have been discussed in Section 3.0.

The optical design for the laser hypervelocity impact simulator as described in the last quarterly report was completed, and the equipment assembled on the granite optical table. Alignment procedures were specified, and several minor changes were made in the optical assembly so as to facilitate this alignment. A He-Ne low divergence laser beam, passing through a small aperture, was used both on-axis and at right angles to effect the alignment. Its wavelength, 6328Å, is suitable here since it is close to the ruby wavelength of 6943Å and will easily pass through ruby so that strong reflection can be seen from the roof-top back end of the ruby rod. After minor modifications, each of the numerous possible images reflected back on to the aperture were made to converge to a single spot. Also, the optimum D.C. Kerr cell voltage for proper phase shifts has been determined (29KV). First attempts to Q-switch have just been made and, although lasing was achieved, pulse widths have so far been much too broad. Possible problems are under investigation, some modifications may still be necessary. For example, an anti-reflection MgF coating of the ruby flat face may be needed so that local area lasing within the cavity will not occur. Also, the Trion laser is being tried in series with an NSL designed ruby laser amplifier to examine its characteristics in terms of the simulation experiment. A great deal more variation of delay time must be tried for each of these experiments, in order to find the optimum solution.

The bulk of the hypervelocity impact tests will be carried out in the last quarter of the contract work as planned. Data will be then analyzed and results presented in the final report. These will also include impacts at oblique angles to the target surface (such as in the test #8 described in section 3.0). Polar plots will be attempted for normal and non-normal impacts and the two cases will be compared. If successful, this experiment would show the possible non-symmetrical spatial distribution of stress waves generated on impact and propagating along the sensor target plate away from the crater. Any such discovered directional effects will be analyzed and their use for refining further the analytical capability of the sensor will be discussed in the final report.