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Critical Damage Phenomena Induced in Aerospace Polymers and Composites: Development, Fabrication and Verification of Experimental Multi-Fragment Generating Devices

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Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This report results from a contract tasking SOREQ Nuclear Research Center as follows: The contractor will investigate multi-fragment generating devices having controllable velocities and hit densities. A device will be fabricated and tested at the contractor's facility, with drawings and documentation then delivered under this contract.

15. SUBJECT TERMS
EOARD, Structural Dynamics, Structural Materials

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AQ F02-05-0815

Dr. A. H. Mayer - WL/ FIV - WPAFB

23 March, 1999

Dr. Z. Jaeger - Soreq NC

Subject: Design & Testing of "Fragment Generator" for High Hits Density

1. According to the agreement between WL/ FIV and Soreq NC, through the auspices of EOARD/ London, a simple explosive charge was designed so as to achieve the goals set forth by the agreement, both in writing and verbally.

These goals are:

A. Design of an explosive charge to accelerate a multitude of fragments to velocities in the range of 300-600 meters per second, so as to achieve high fragment hits density on a set of targets arranged around the charge.

B. To produce and test the a/m charge and to verify experimentally that the design goals are met.

2. The charge design uses tungsten pre-formed fragments 3.85*3.85*3.85 mm cubes (1.0 grams average weight), Detasheet explosive (sheet plastic explosive based on PETN), EBW initiation of the explosive (to enable the proper timing of the verification test). Three different velocities were planned, using three different explosive sheet thicknesses - 1, 2, 3 mm.

Drawings of the charge and of the test set up are attached.

The charge anvil is made of a thick walled steel tube, with aluminum rod tight fitted into it, to increase the rigidity of the anvil without too much weight addition. The explosive sheet envelopes the anvil with about 1/4 of the circumference with 1mm thickness, another 1/4 of the circumference with 2mm thickness and yet another with 3mm thickness. Half of the remaining quarter was used for the initiation and the other half for blocking the explosion from getting to the "wrong" end of the circle. The width of the explosive strip is 60mm, of which the central 31mm is covered by the fragments package. The rest of the width is split in half on each side of the frags package, and is covered by a thick and relatively wide, steel, confining ring. This arrangement is meant to reduce the edge effects on the frags.

An initiator attachment device is glued to the initiation end of the explosive strip, on the strip centerline.

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The total weight of the explosive in the charge is about 60 grams.
26 rows of 8 frags are laid on the 3mm strip (100mm long), 23 rows of 8 frags are laid on the 2mm strip (88mm long) and again 26 rows of 8 frags are laid on the 1mm strip. A total of 600 frags are arranged on the charge (600 grams weight). The 3 "extra" frag rows at the edges are to allow for edge effects at the start and finish edges of the explosive strip.
The initiation is at the 1mm end of the strip.
The threaded hole through the center of the anvil allows the placement of screws at both ends, for proper charge placement at the testing site.

3. The test arrangement is drawn in the attachment. A total of 9 targets were situated around the charge, in two circles. The inner circle was of 405 mm radius and the outer circle was of 661 mm radius. Assuming equal angular spread of the frags at the three section of the charge, the different radiuses should result in different hits density on the targets. The targets on the inner circle were of 203*203 mm, and those on the outer circle were of 300*300 mm. Two types of targets were used: Lexan and Composite (supplied by FIV). Wooden partitions Of 100*45mm cross-section were placed in a radial arrangement in front of the "meeting lines" of the target plates, to protect their edges.
The targets system was arranged on a 20mm plywood plate, with the inner targets centered using 48mm wooden spacers and with a hole at the center point for the charge placement screw. Another plywood plate was placed over the system and the whole system was secured using epoxy glue and staples.
Once the charge and targets system was ready, it was placed vertically and centered in front of an X-Ray pulser tube (300KV). The film cassette was composed of three 14"*36" films, laid one above the other to get a 39"*36" composite cassette (with about 1.5" overlap between films). The geometry gives a magnification factor of 1.195.
A single X-Ray flash was used, at the time of 526μs from initiation. The time was calculated to show the different sections of the frags spread on arcs at different distances from the charge surface, using the Detasheet detonation velocity (6.9 mm/μs at 1mm thickness, 7 mm/μs at 2mm and 7.1 mm/μs at 3 mm thickness) and the estimated frags velocity (using the Gurney expression for asymmetrical sandwich, with "infinite" anvil and with a Gurney Velocity of 2.2 mm/μs for the Detasheet).

4. Preliminary Test Results

A. The most prominent result is that the angular spread of the frags depends on the frags velocity, as given below.

Velocity range	Spread Angle
Low	±6.15(±0.15)°
Medium	±4.5(±0.5)°
High	±2.9(±0.2)°

B. The end frags of each frags row, those that touch the confining rings, are slower than those closer to the centerline of the explosive. The measured velocities are:

Velocity Range	Slowest Frags [m/s]	Fastest frags [m/s]	Avg. Fast [m/s]	Gurney vel. [mm/μs]
Low	280±5	333±10	317	2.11
Medium	365±25	440±20	439	2.075
High	475±25	540±20	542	2.087
			Average Gurney Velocity:	2.09±0.025

The ± ranges are for the frags which are at the trailing edge and at the leading edge of the frags arc, at various locations along the arc. The average of the fast frags relates to the group of fast frags and not to the fastest ones. This average value is used to estimate the Gurney velocity.

C. The impact patterns on the various targets are of a roughly rectangular shape:

Tgt. No.	Material	Circle	Velocity Range	Impacts Pattern	No. of Impacts	Ave. Hits Density
1	Lexan	Outer	L	22*16 cm	42	0.12
2	Lexan	Outer	H	21*8.5 cm	45	0.25
3	Lexan	Outer	M	21*13.5 cm	50	0.18
4	Comp.	Inner	H			
5	Lexan	Inner	H	14.5*6.5 cm	41	0.44
6	Lexan	Inner	M	10.5*8 cm	49	0.58
				(14.5*8 cm	54	0.47)
7	Comp.	Inner	M			
8	Comp.	Inner	L			
9	Lexan	Inner	L	14*11.5 cm	40	0.25

The hits density is given in [hits/cm^2].

In tgt no. 6, it is evident that the first row of frags from the Lower velocity range hit the edge of the tgt. In the above table, the second line relating to tgt. 6 gives the average hits density for the pattern that includes these frags. The first row relates only to the medium velocity frags, and it gives a rather high hits density.

Generally, it can be seen, that for a given velocity range, the hits density on the targets of the outer circle is roughly half that on the targets of the inner circle - as designed.

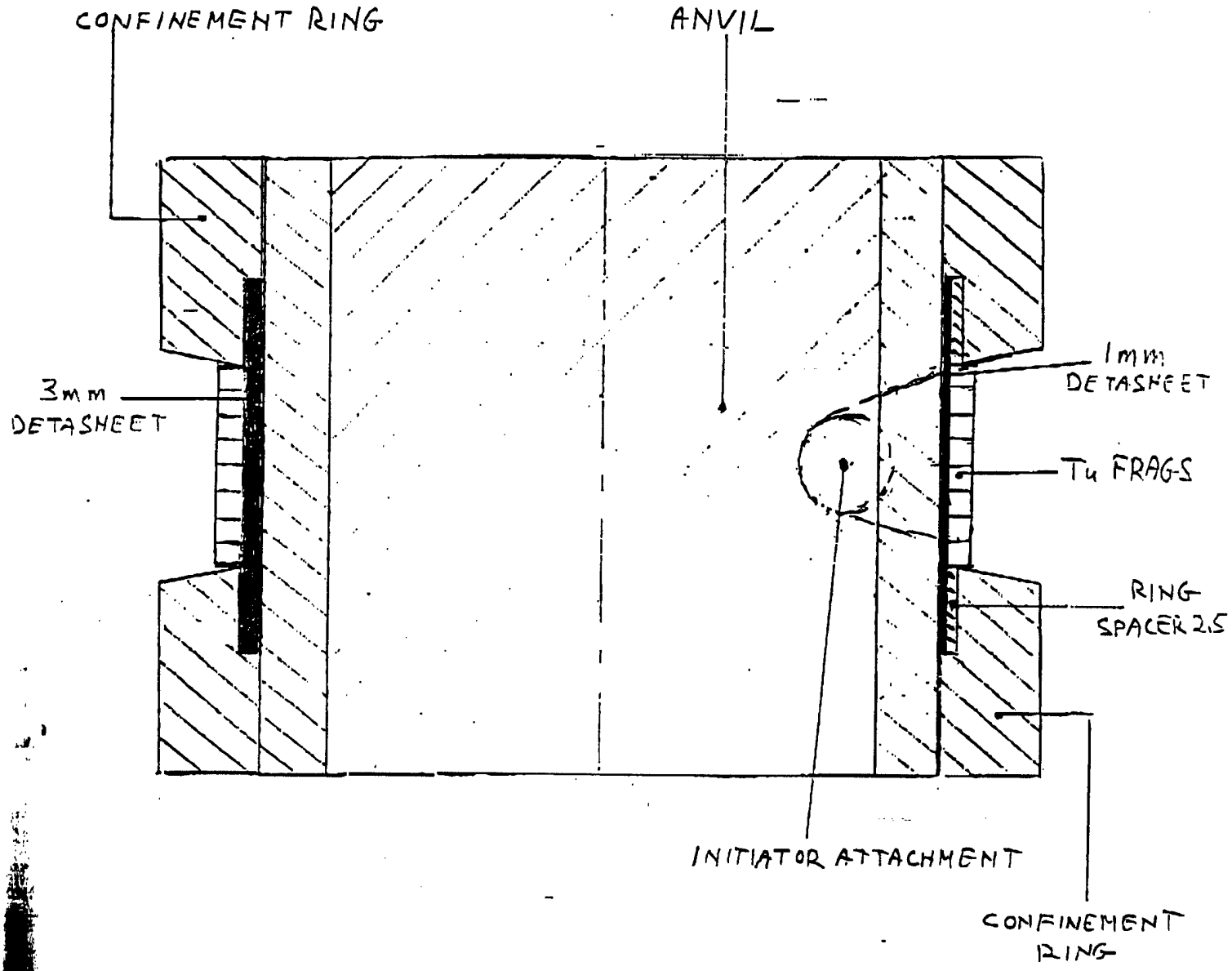
The damage to the targets is not discussed here.

Sincerely,

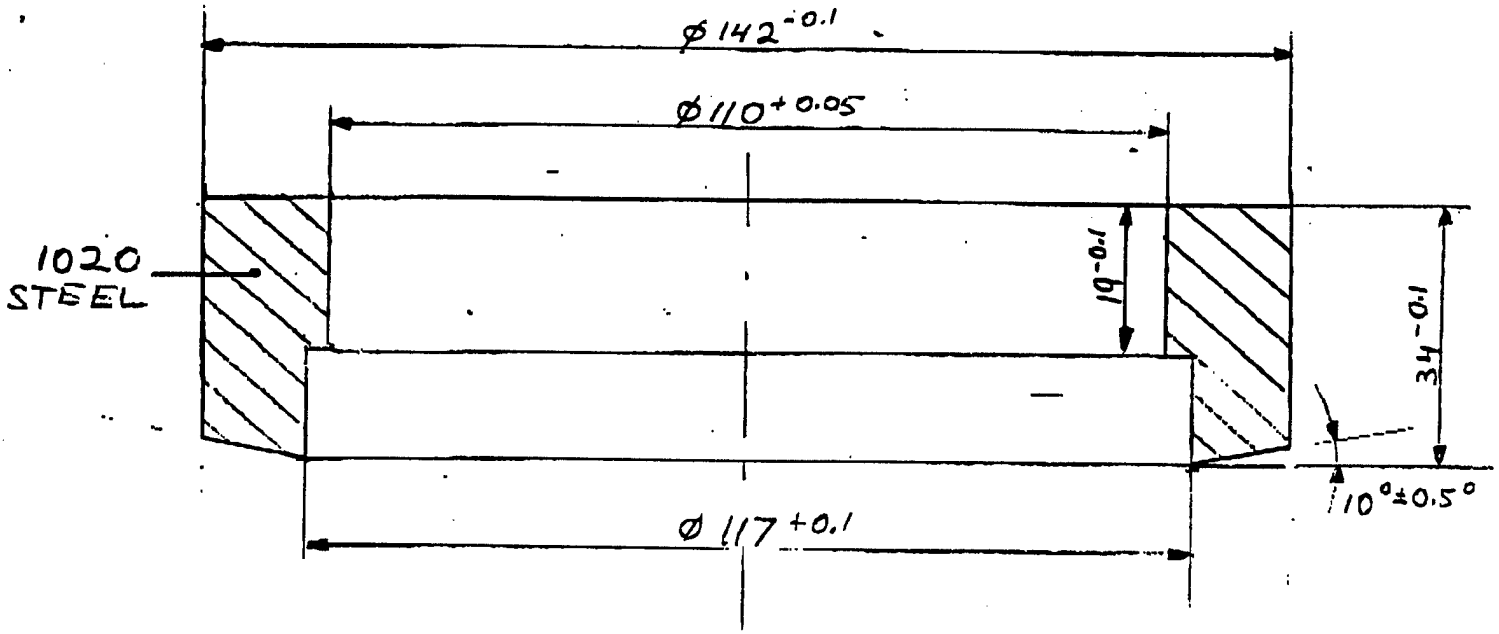
Y. Me-Bar

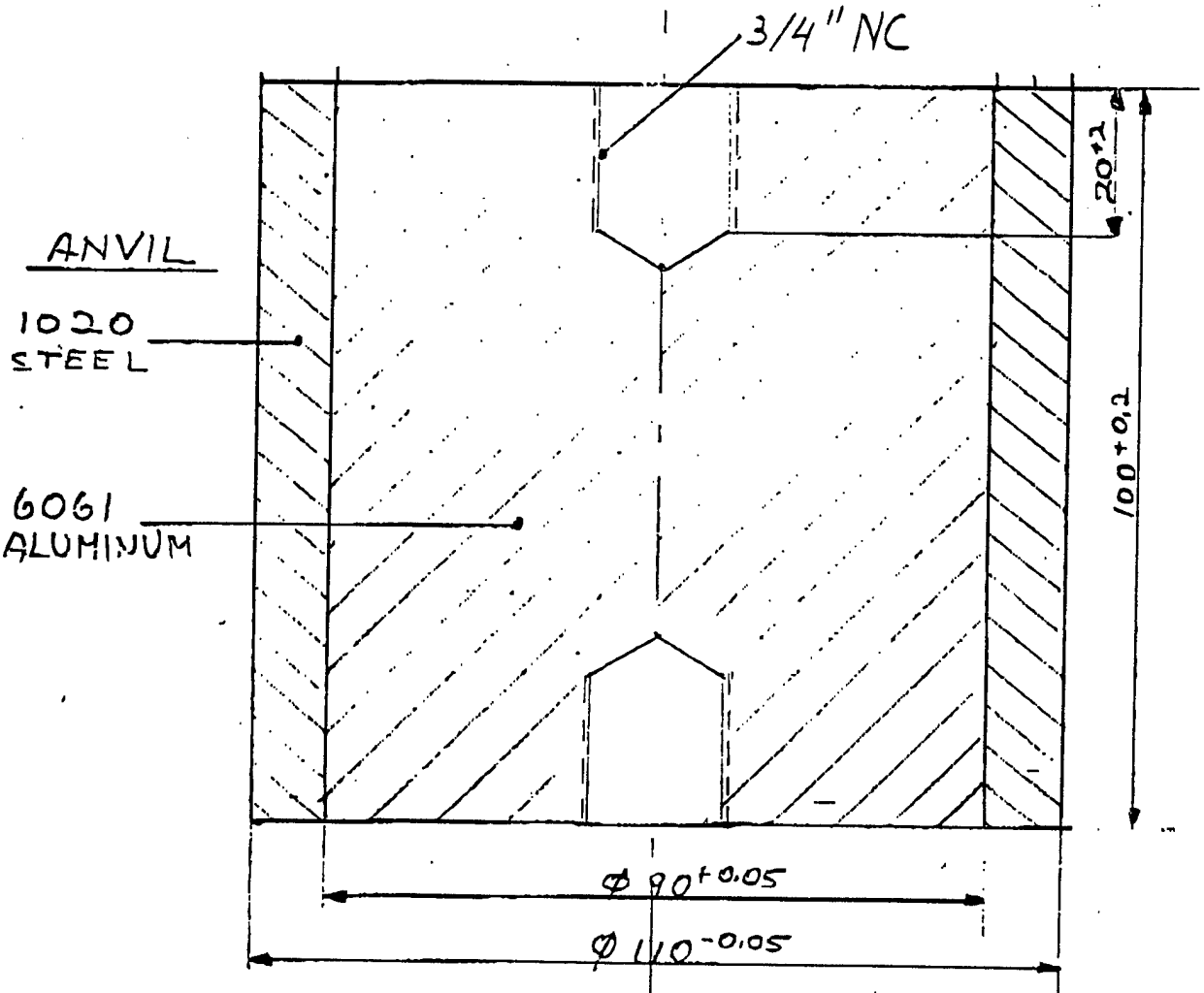
Rafael Ballistics Center

CHARGE ASSEMBLY



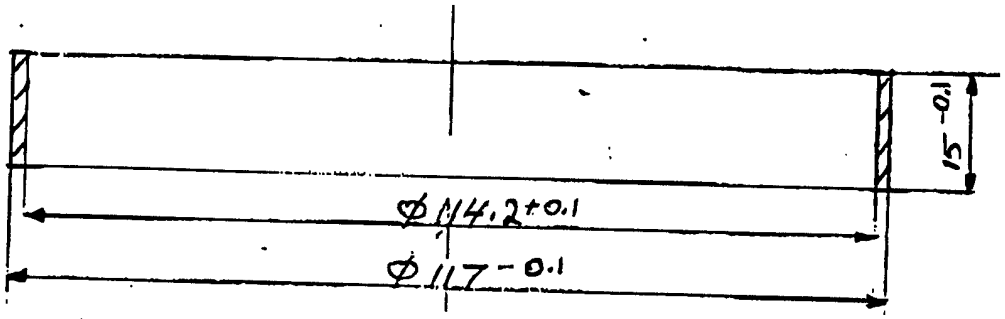
CONFINEMENT RING





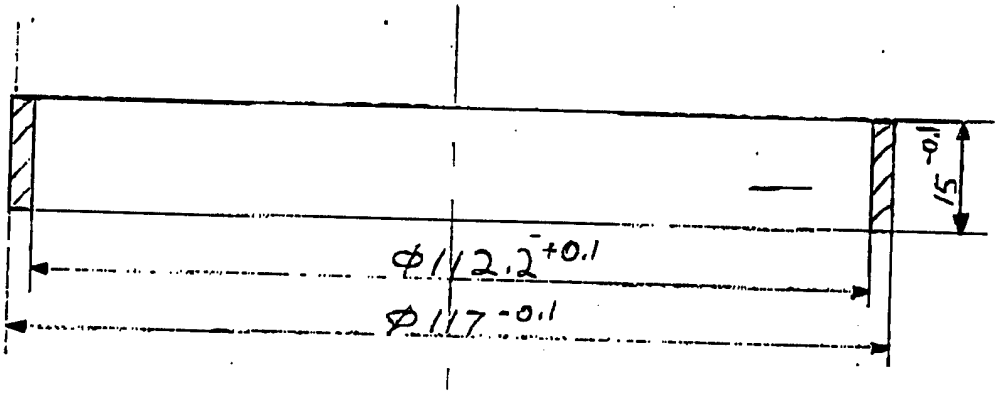
RING SPACER 1.5

1020 STEEL



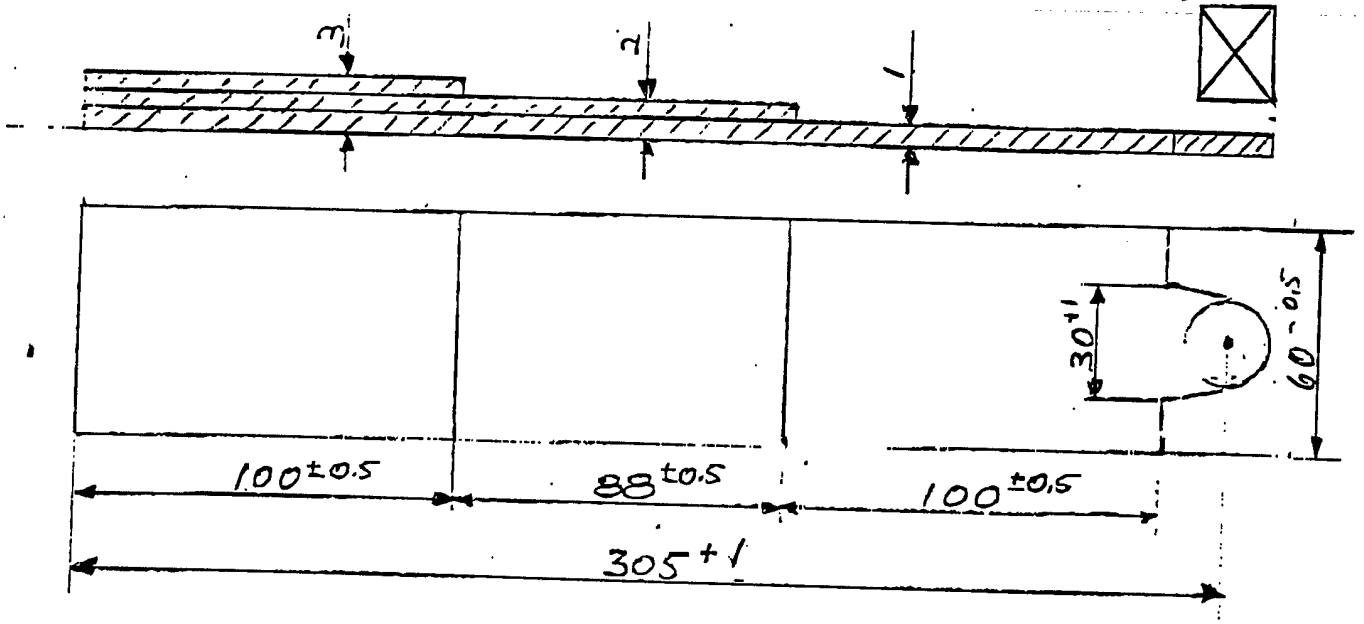
RING SPACER 2.5

1020 STEEL

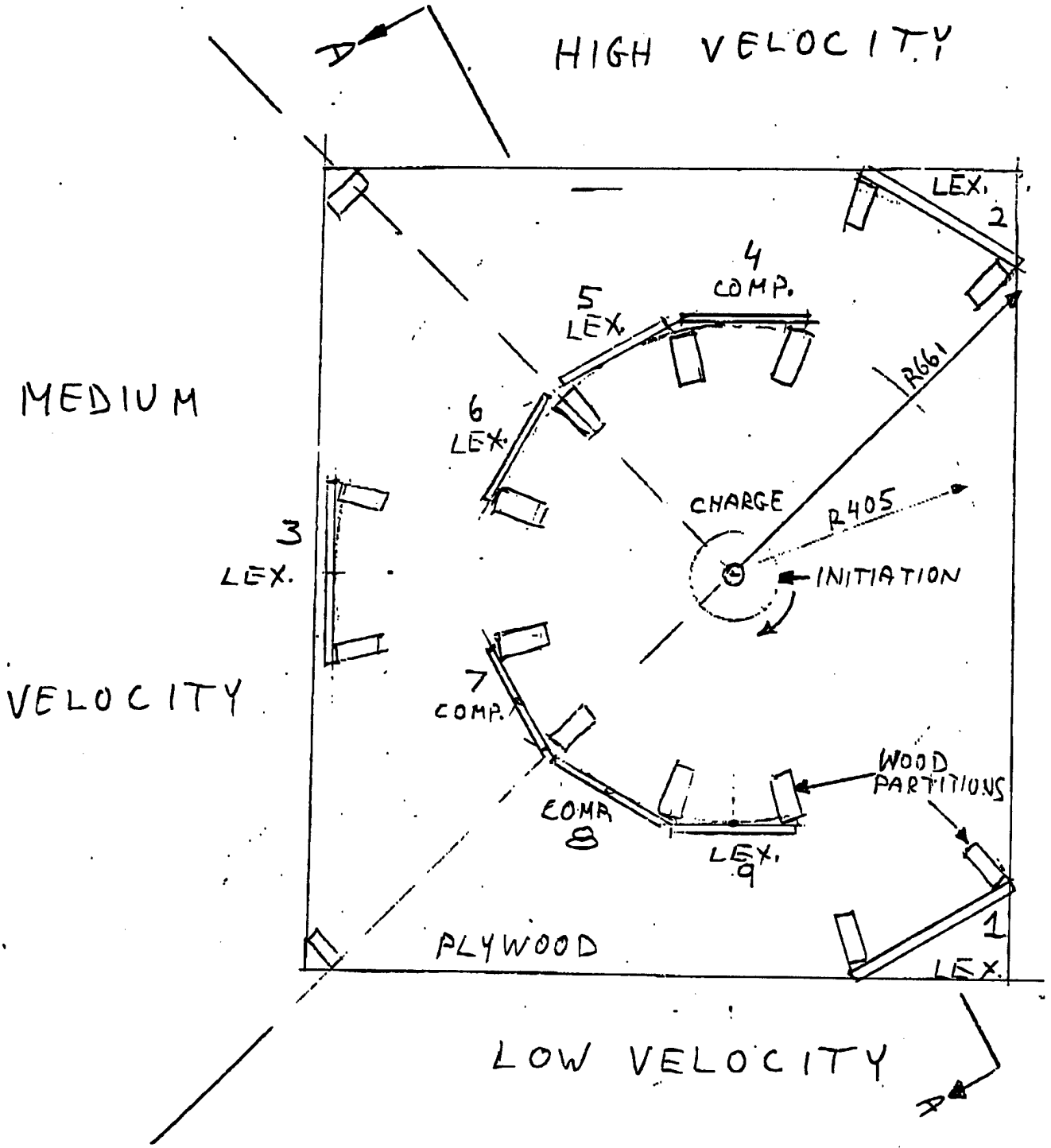


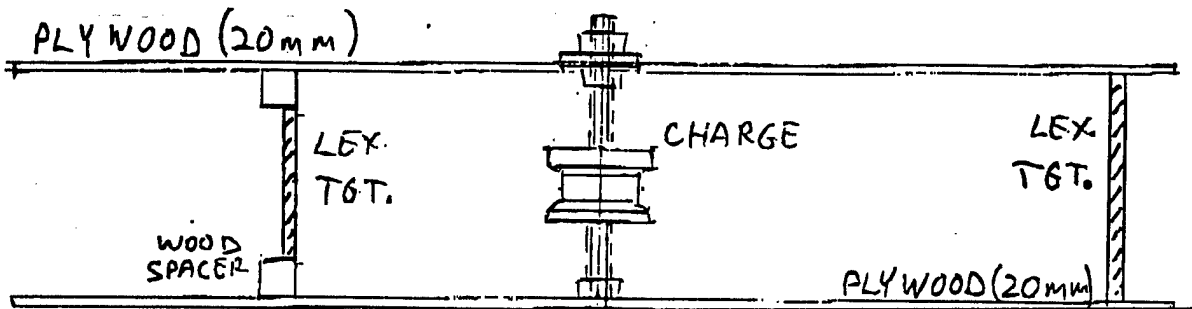
EXPLOSIVE (DETASHEET)

INITIATOR ATTACHMENT

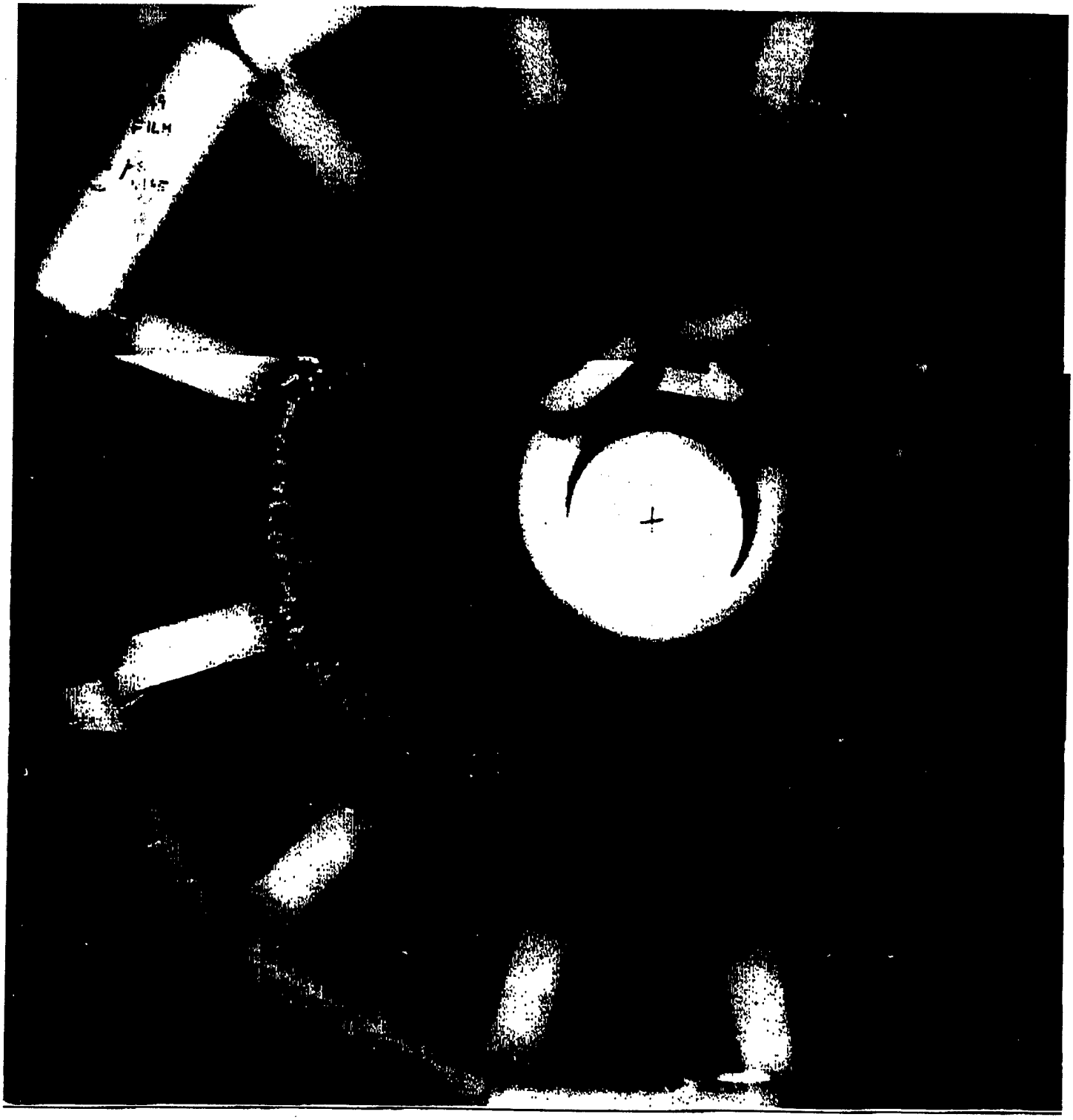


CHARGE- TARGETS SYSTEM





A-A


FILM