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TITLE: APPLICATION OF SLAPPER DETONATOR TECHNOLOGY TO THE DESIGN OF SPECIAL DETONATION SYSTEMS

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APPLICATION
OF
SLAPPER DETONATOR TECHNOLOGY
TO THE
DESIGN OF SPECIAL DETONATION SYSTEMS

by

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INTRODUCTION

Along with other laboratories, Los Alamos has been developing slapper detonator technology for the past decade. From this work, a line of specialized detonation systems is in process of evolving. Some of these systems will be described.

Since slappers are relatively new and not well known, it seems best to begin with a short discussion on slappers, per se. Following that, an outline of manufacturing techniques developed by Los Alamos will be given. From this base, the evolution of the specialized systems can be understood.

EXPLODING BRIDGEWIRE DETONATORS (EBW)

Slapper detonators are near relatives of the older (40 years) EBW detonators, and we can start by looking at how EBWs work. Their basic elements are shown in Fig. 1. The electrical bridge is most commonly a round bridge-wire, but other forms including printed circuit configurations have been used. The low-density explosive is pressed against the bridge. The booster pellet(s) is then placed over the low-density material. The detonator is fired by passing a high current through the bridge, usually from a capacitor charged to a high (1-5 kV) voltage. When the system is properly designed, the

EBW ELEMENTS

1. Electrical Bridge
2. Low Density Explosive
3. High Density Booster Pellet

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bridgewire literally explodes and that explosion sets off the low-density material next to the bridge.

SLAPPER DETONATORS

Slapper detonators also have three basic elements, as shown in Fig. 2. That they are near relatives can be seen at this point. Both begin with a bridge that is electrically exploded and that explosion ultimately sets off the detonator. The second element discloses the difference. In slappers, the bridge is covered by a thin film of plastic and there is no explosive next to it. When the bridge explodes, it drives the plastic film through the air gap, impacting (slapping) on the high-density pellet. If the system has been properly designed, the impact sets off the pellet.

This initiation mode obtains a number of advantages over the EBW mode. Perhaps the most important is the fact that essentially any explosive can be initiated by a slapper. EBWs are limited to PETN, RDX, and possibly HMX. An EBW using HNS is not feasible, but an HNS slapper is. Even the insensitive high explosives such as TATB have been initiated by slappers. Thus, they have a versatility not possessed by EBWs. Of course, the firing set size has to increase as one goes up the scale of insensitivity.

A design constraint for slappers is that a flat bridge be used because the flyer should be reasonably flat in the region of impact. This has led all workers in the field of slappers to use printed-circuit-type bridges. Bridges have been vapor deposited onto rigid substrates (alumina, glass) and onto plastic films such as Mylar and Kapton. They have also been made by photoetching of metal-plastic laminates. At Los Alamos, the material called Microclad, a product of Fortin Laminating Corporation, Sylmar, California, has been found to be a very satisfactory starting material for photoetched bridges. Furthermore, it was learned that the Microclad material is in common use for making beam lead circuit in the microcircuits industry, using reel-to-reel processing through all steps of the photoetching process. At Los Alamos, bridges are made by reel-to-reel processing.

Flat cables are used with slappers for electrical efficiency. At Los Alamos, this has led to building the slappers onto the flat cables, rather than attaching the two elements together. Flat cables are made by photoetching copper/Kapton (or copper/Mylar) laminates. Perhaps a natural line of thought is that cable might also be made by reel-to-reel processing, and the

SLAPPER ELEMENTS

1. Electrical Bridge
2. "Flyer"
3. Air Gap
4. High Density Booster Pellet

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FIG. 2

subsequent assembly of bridges and detonator parts might also be done reel-to-reel. Mound (operated by Monsanto Research for DOE, Miamisburg, Ohio) has in fact developed such a process. Figures 3, 4, 5, and 6 show this in concept form.

One result of this approach to the design of slappers is that more than one bridge - more than one slapper - can be built onto a cable at very little extra cost or modification of the process. Thus, not only individual slapper assemblies can be made at low cost by using reel-to-reel processing but also more complex, multibrige assemblies can be made inexpensively. This point has influenced the development of the specialized systems described, but the development of a bidirectional slapper was at least as important.

BIDIRECTIONAL SLAPPER

The concept of using slapper units to produce specifically shaped detonation fronts arose with the development of a bidirectional detonator system that uses a single-bridge element to propel flyers in opposite directions, detonating two explosive pellets. Construction of a single-bridge, bidirectional slapper circuit is shown in Fig. 7. The circuit, etched from approximately 4.6- μm Microclad copper on 50.8- μm -thick Kapton, is folded on itself around an insulating film. Without the indicated relief, the resulting laminate would become an ordinary unidirectional slapper. The relief hole permits the Kapton on the ground-return side of the assembly to be laminated directly onto the bridge. Thus, the bridge is covered on both sides with an equal thickness of Kapton (plus a thin layer of glue on one side), and slapper detonators can be built on both sides of the laminate. Special care must be taken to make the layer of glue between the bridge and the flyer very thin, so that the flyer with the glue is propelled with nearly the same velocity as that without glue. A 25.4- μm sheet of polyester cast adhesive glues the opposite side flyer onto the bridge. Test results show a bias time of 0.010 - 0.020 μs between pellets.

An alternate bidirectional slapper assembly that uses two bridge elements, placed back-to-back, to propel slappers in either direction is shown in Fig. 8. The assembly designated as the ER-347 detonator ensures that both slappers are propelled with equal velocity, thus avoiding the bias time between the pellets. This model is also easier to manufacture.

TAPE PROCESS

FLAT CABLE MANUFACTURE

UPPER COVER
COAT

CONDUCTOR

LOWER COVER
COAT

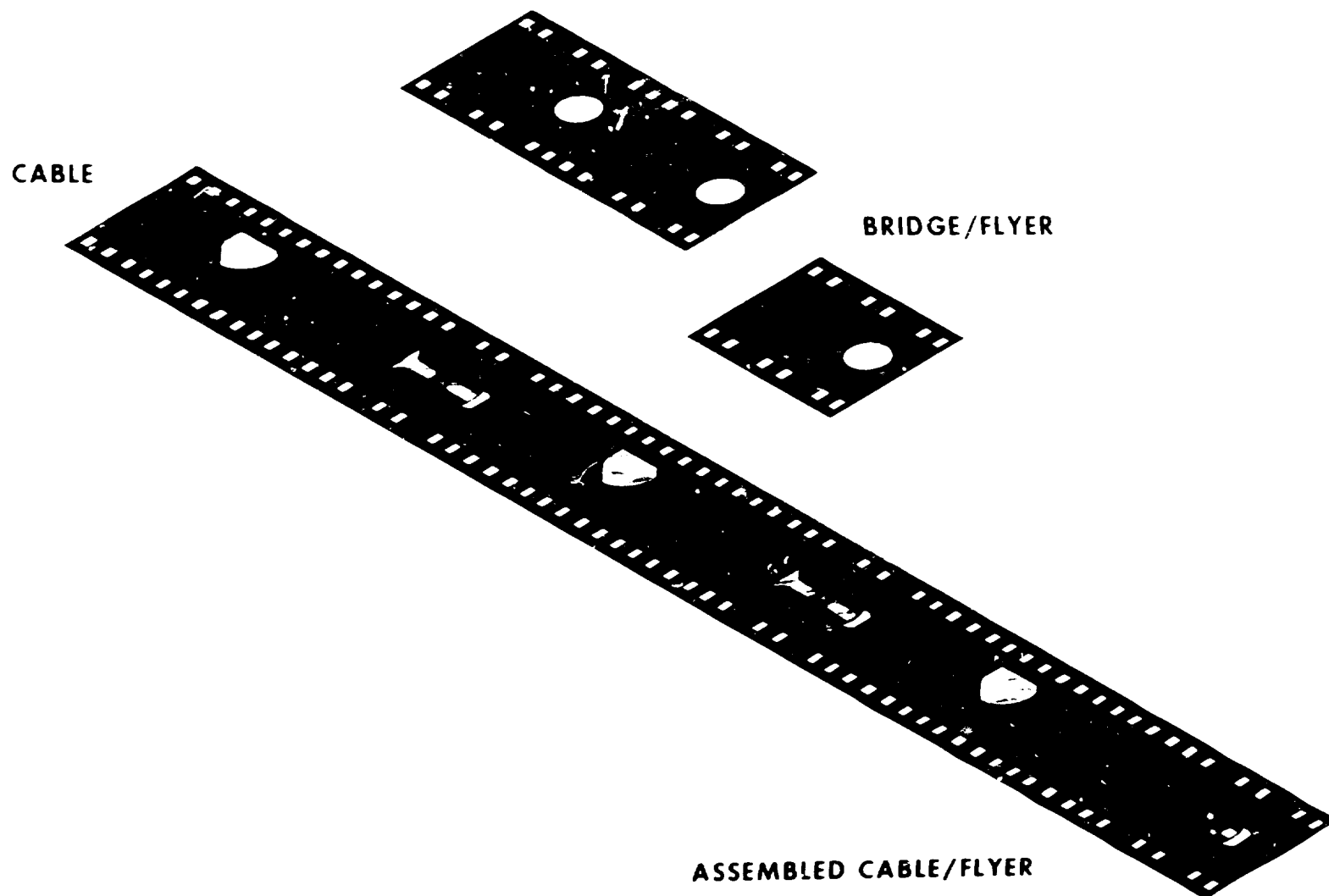
ASSEMBLED CABLE



FIG. 3

TAPE PROCESS

CABLE/BRIDGE/FLYER ASSEMBLY



LSA

FIG. 4

CABLE/FLYER-BARREL/BACKER/CUP ASSEMBLY OPERATION

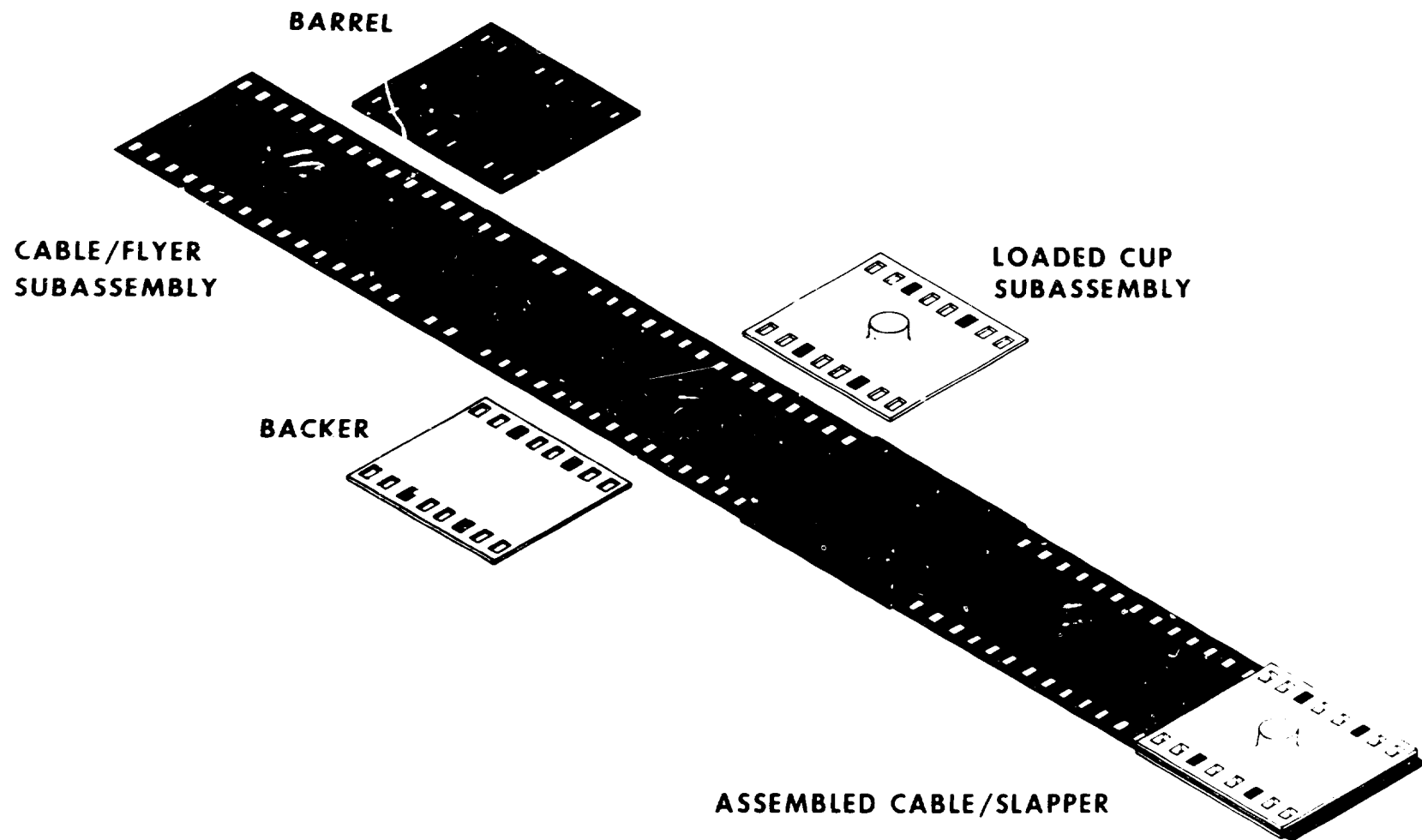


FIG. 5

TRIMMING/FERRUL INSTALLATION OPERATION

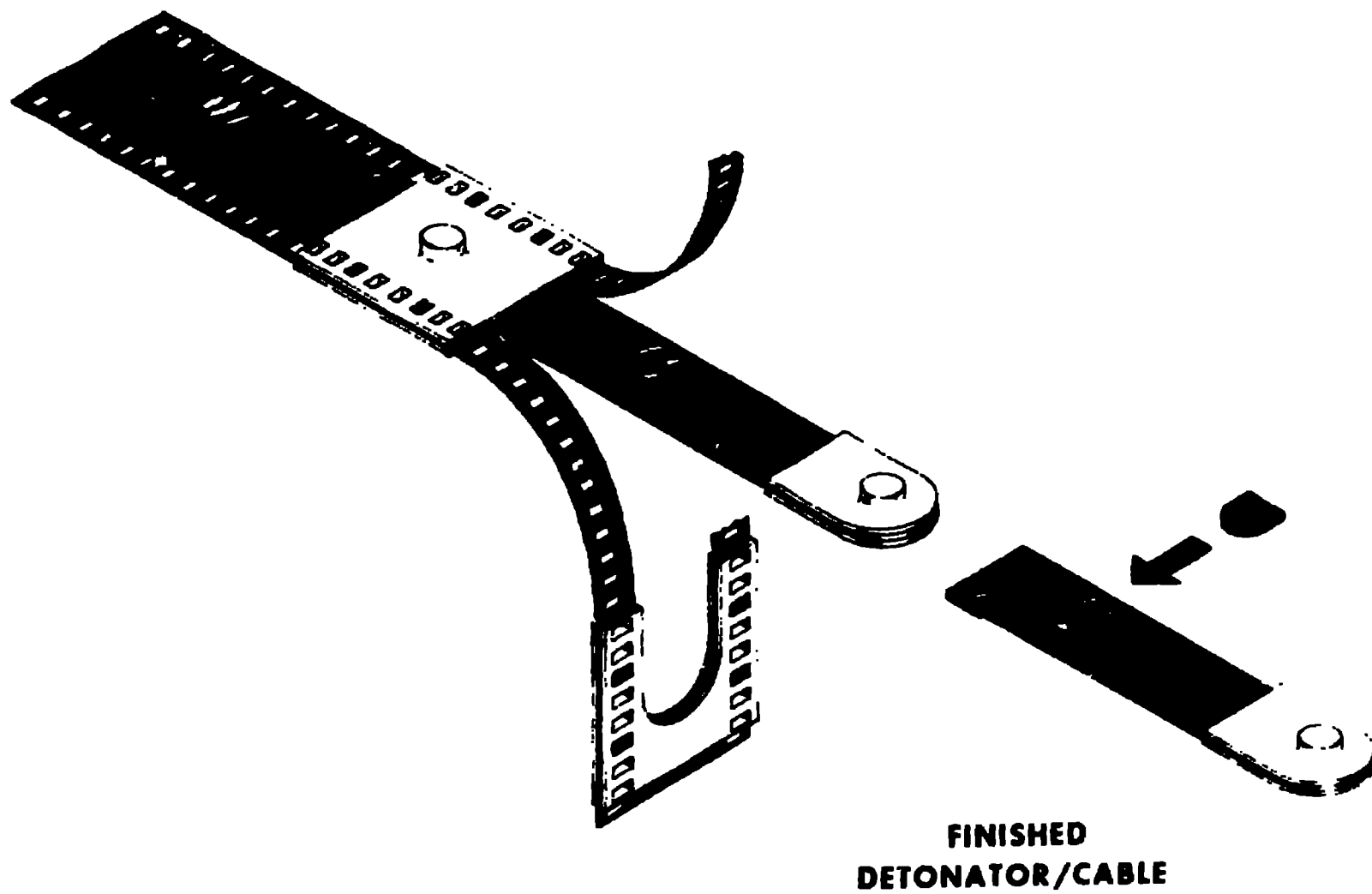
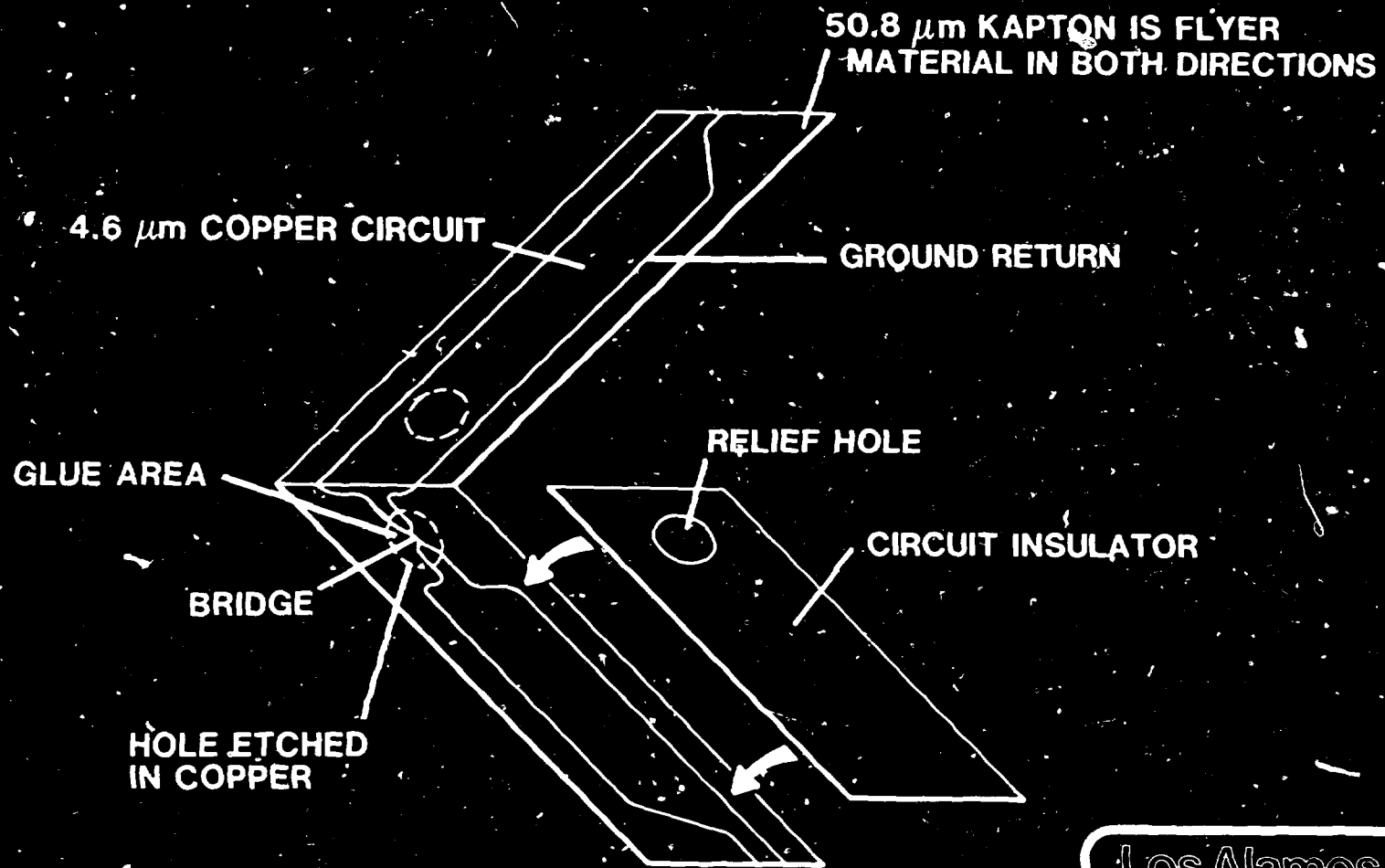


FIG. 8

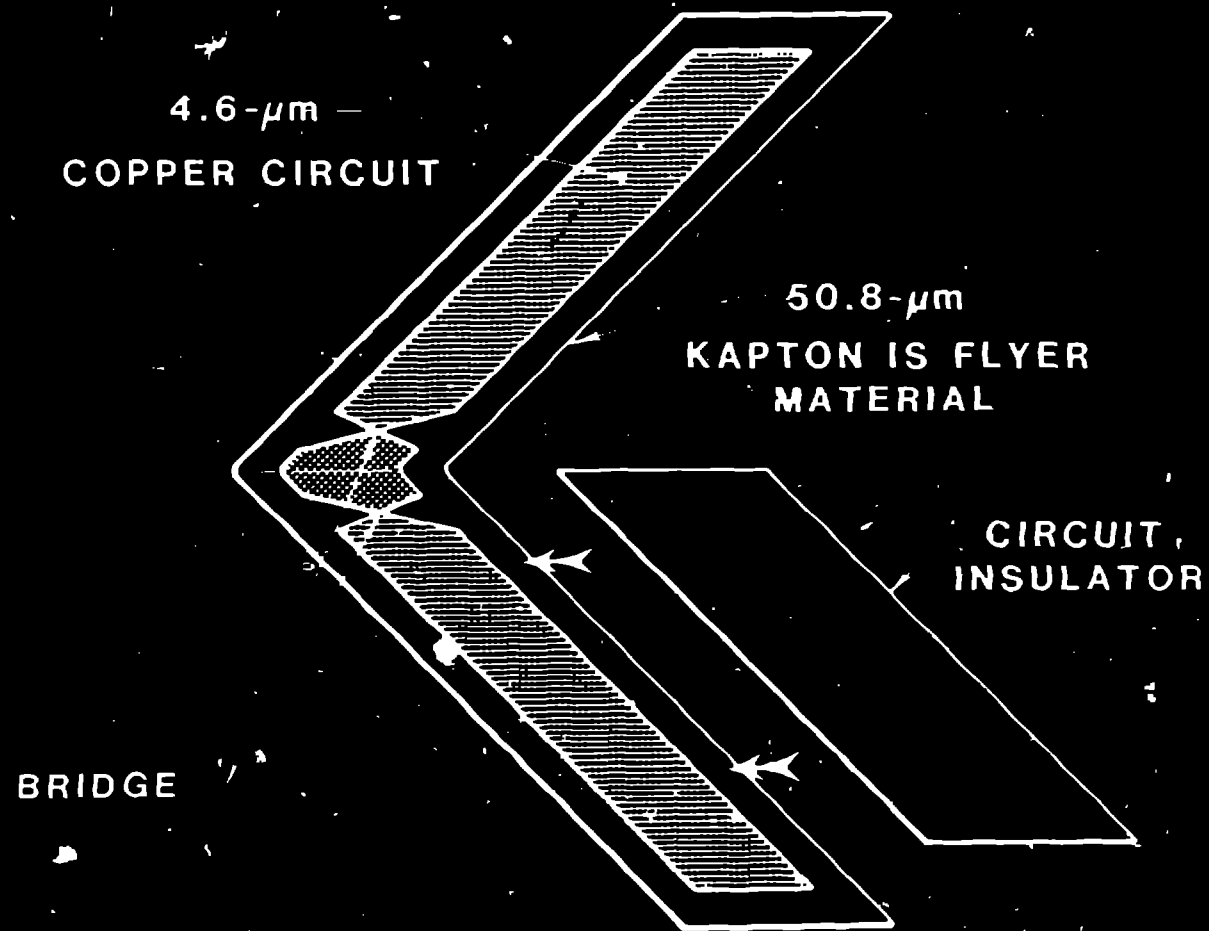
SINGLE-BRIDGE BI-DIRECTIONAL SLAPPER CIRCUIT CONSTRUCTION



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FIG. 7

ER-347 SLAPPER CIRCUIT CONSTRUCTION



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FIG. 8

SPHERICAL DETONATION SYSTEM

A spherical detonation front is produced when two slappers are propelled in opposite directions, initiating explosive pellets whose detonation fronts merge at points away from the electrical circuit to form a spherical front. Figure 9 is an assembly drawing of a spherical detonation system. Figure 10 shows an exploded view of the same device that has a bidirectional slapper circuit firing PETN pellets inset in 1.8 g/cm³ TATB hemispherical pellets. The hemispherical pellets are machined to accommodate both the initiating pellets and slapper circuit assembly.

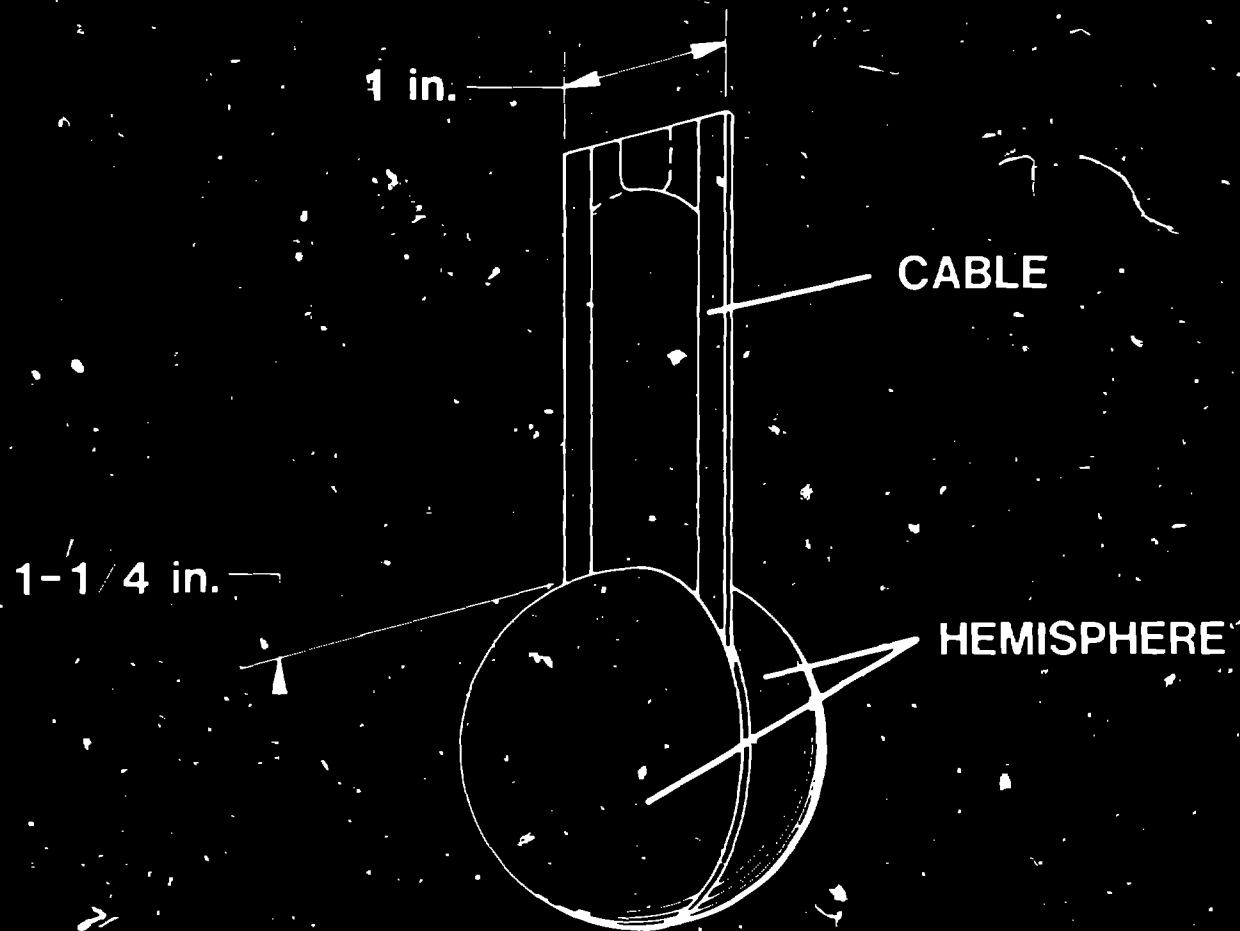
In this type of assembly, each detonation wave must spread in a hemispherical fashion. To best achieve this goal, the size of the initiating pellet is adjusted experimentally. Several experiments were conducted using 12.7-mm-diameter initiating pellets of different lengths. The experiments were viewed using a streak camera. An ideal spherically expanding detonation wave produces perfectly flat traces. Figure 11 shows the traces obtained using 5.7-mm-long pellets. The side-to-side time difference in this shot was 10 ns. The perturbation caused by the slapper assembly is shown in the middle trace.

CYLINDRICAL DETONATION SYSTEM

A cylindrical detonation system has been developed using a linear array of double-sided slapper detonators placed at uniform intervals along the axis of a cylinder. Each detonation center provides a spherical detonation front that eventually coalesces with the others producing a cylindrical detonation front.

Figure 12 is an expanded view of a 12-bridge system. The bridges are spaced $\frac{1}{2}$ in. apart. The explosives system consists of the initiating pellets (PETN) and hemicylinders of a booster charge. In all systems used to date, the initiating pellets are 6.35 mm long by 12.7 mm in diameter. The 12-point circuit uses two 12-bridge arrays placed back-to-back with precise tooling. A common-ground return path separates the two circuits, which are fired in parallel and operate as conventional unidirectional slappers. For this type of assembly, the sapphire barrels are replaced by spacers. The bridges and spacers make up the slapper/cable assembly. Assembled, the slappers shown in Fig. 13 have a combined thickness of 1 mm, which is thin enough to represent a

SPHERICAL DETONATION SYSTEM



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FIG. 9

BI-DIRECTIONAL SLAPPER DETONATOR SYSTEM COMPONENTS

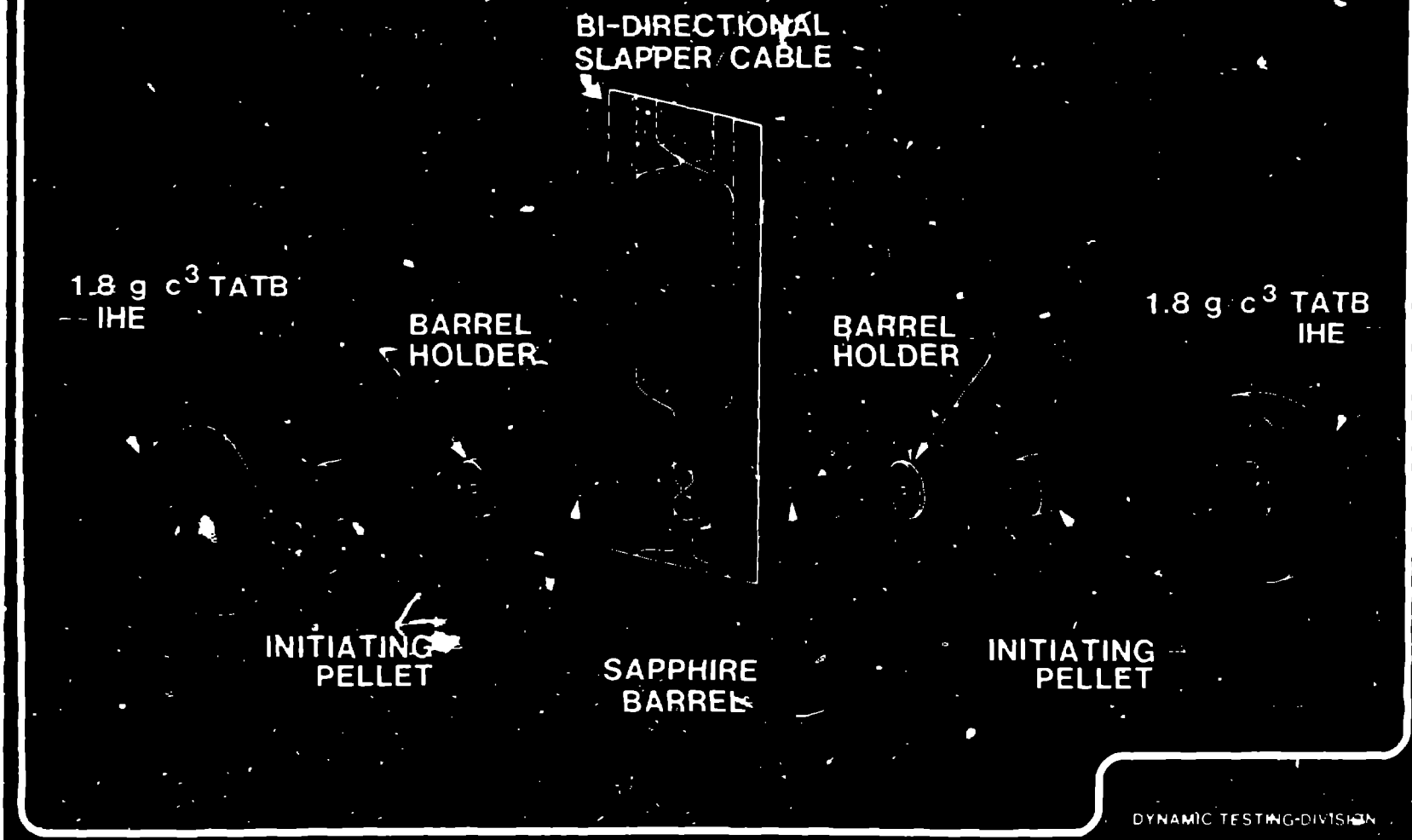


FIG. 10

FILM RECORD — SPHERICAL DETONATOR ASSEMBLY WITH 5.7-MM LONG PETN PELLETS

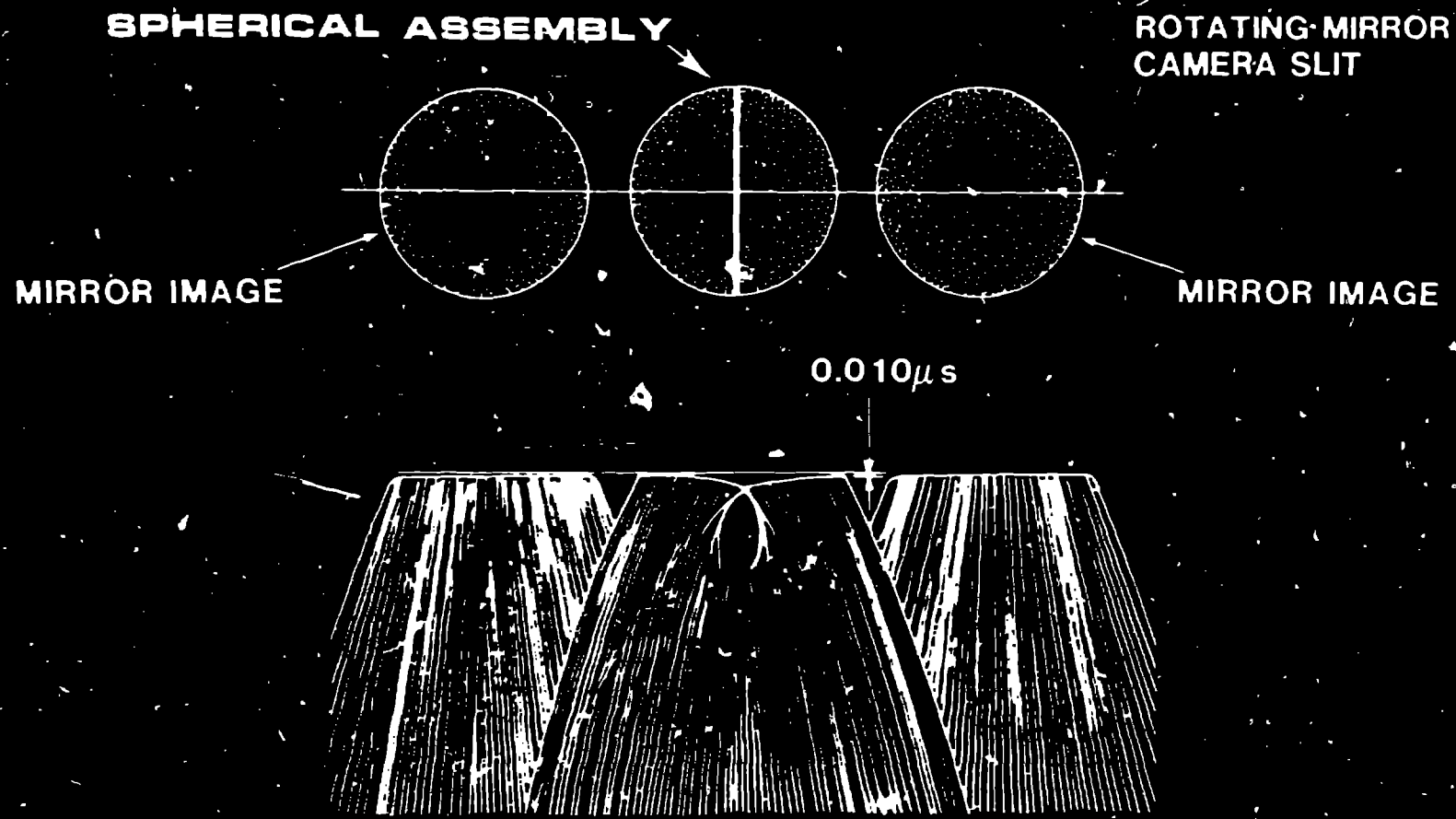


FIG. 11

EXPANDED VIEW OF A TWELVE-BRIDGE CYLINDRICAL HE SYSTEM

PBX 9501
BOOSTER

CABLE SLOT

INITIATING
PELLETS

SPACER

SLAPPER CABLE

SPACER

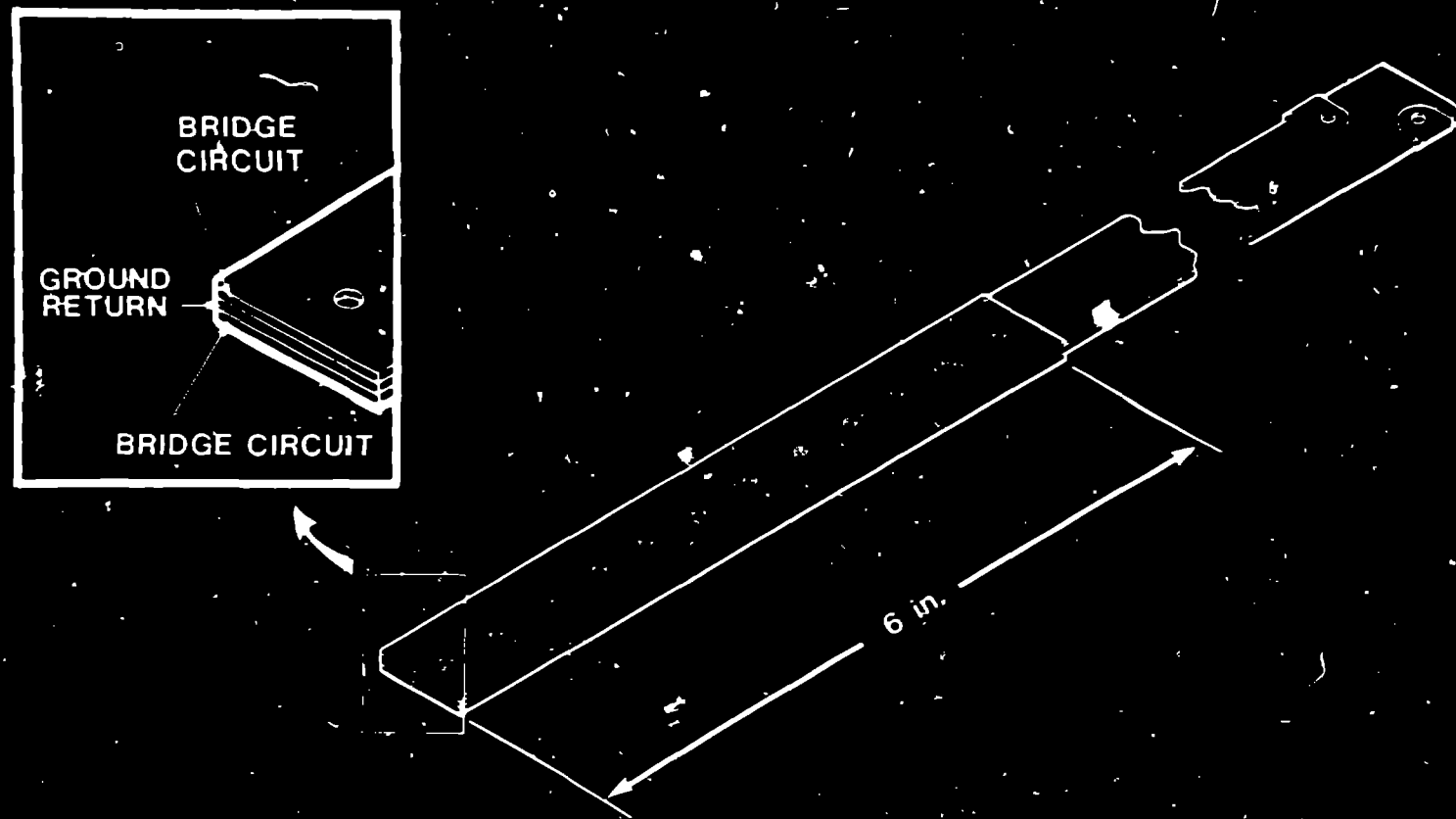
INITIATING
PELLETS

PBX 9501
BOOSTER

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FIG. 12

ER-343 SLAPPER/CABLE ASSEMBLY



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FIG. 13

negligible perturbation to the overall cylindricality of the explosion. A complete 12-bridge HE assembly, designated the ER-343 detonator, is shown in Fig. 14. Firing tests have shown that the 24 pellets in the ER-343 fire with a standard deviation of 0.01 to 0.02 μ s.

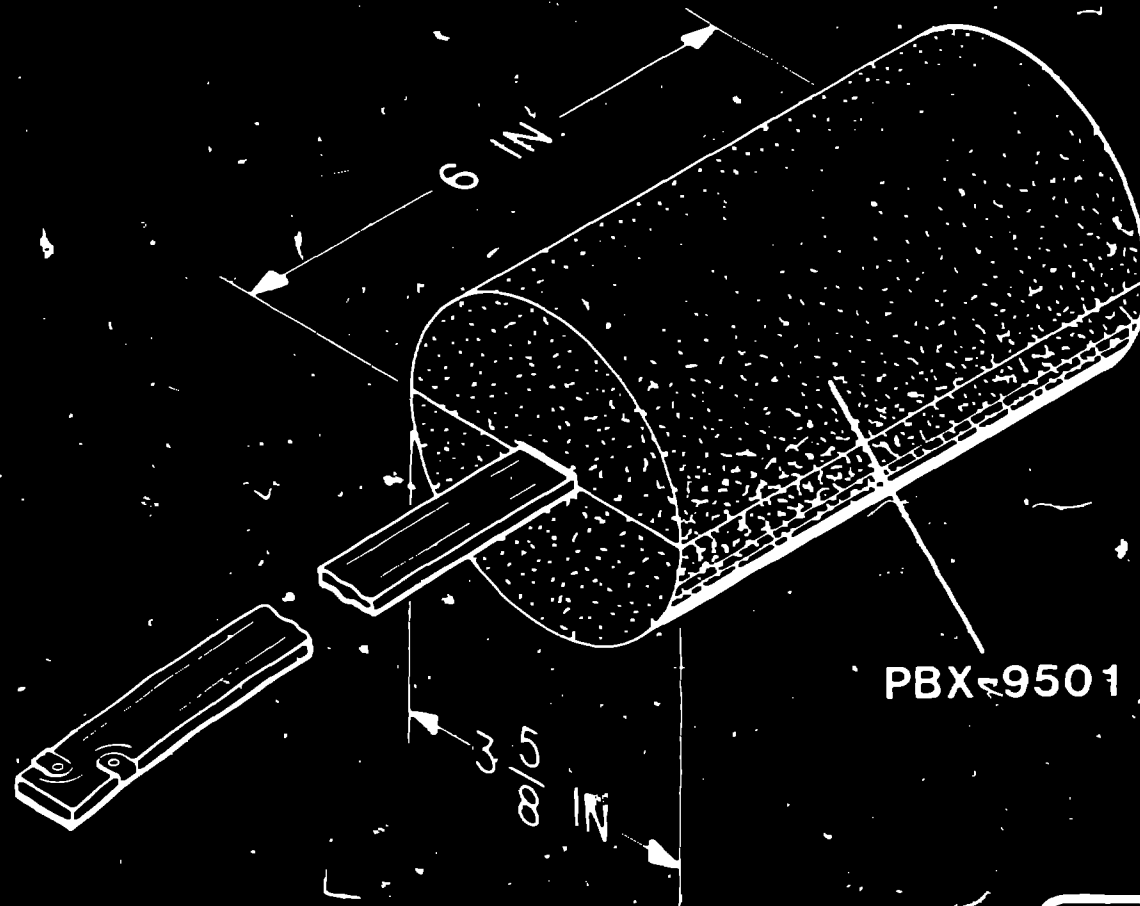
Tests to determine the cylindricality of the ER-343 detonator are set up as shown in Fig. 15. The detonator is assembled in a brass containment cylinder. A high-speed framing camera was used for viewing both the side and axis of the cylinder. The uniformity of early wall displacement is an indirect measure of the simultaneity of detonation front arrival at the cylinder inner wall. The length of the metal cylinder is made greater than that of the HE assembly to force gas expansion away from the viewing area. A generous chamfer at each end of the HE assembly when overfilled with RTV silicone reduced the shock-pressure gradient in the copper at the air/explosive interface preventing early wall rupture. The firing-stand's vertical plate was marked with an ink grid to serve as a geometrical reference on the axial view so that expansion asymetrics could be measured and traced. A 45° rotation of the assembly prevented this potentially troublesome joint in the 9501 from dominating the action in the side view. Figure 16 shows framing camera pictures from one test. Frame 1 shows the tube just as it is beginning to move. Frame 8 shows the tube 7 μ s later. Note the straightness of the profile edge and of the grid lines, both indicating a high degree of cylindricality of the explosion. Figure 17 shows how two ER-343 assemblies can be placed end-to-end to cover a 12-in. region.

A 30-in. system, with bridges spaced at 1-in. intervals, has also been developed. It is called the ER-349. In this case, the electrical circuit is more elaborate (and the slapper assembly thicker) than in the ER-343. Figure 18 shows how the assembly is constructed. Each set of 30 bridges is fed at the ends, with the circuit grounded at the middle. Thus, there are four parallel branches, with 15 bridges in series in each branch. The HE assembly is similar to the ER-343, as shown in Fig. 19.

EXTERNAL LINE GENERATOR

The initiation of a line on an external surface can be done by simply placing slappers only on one side of the cable. Figure 20 shows in concept form how a plane-wave generator can be built up by placing a number of slapper assemblies alongside each other on a slab of explosive. Figure 21 shows how

ER-343 HE ASSEMBLY



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FIG. 14

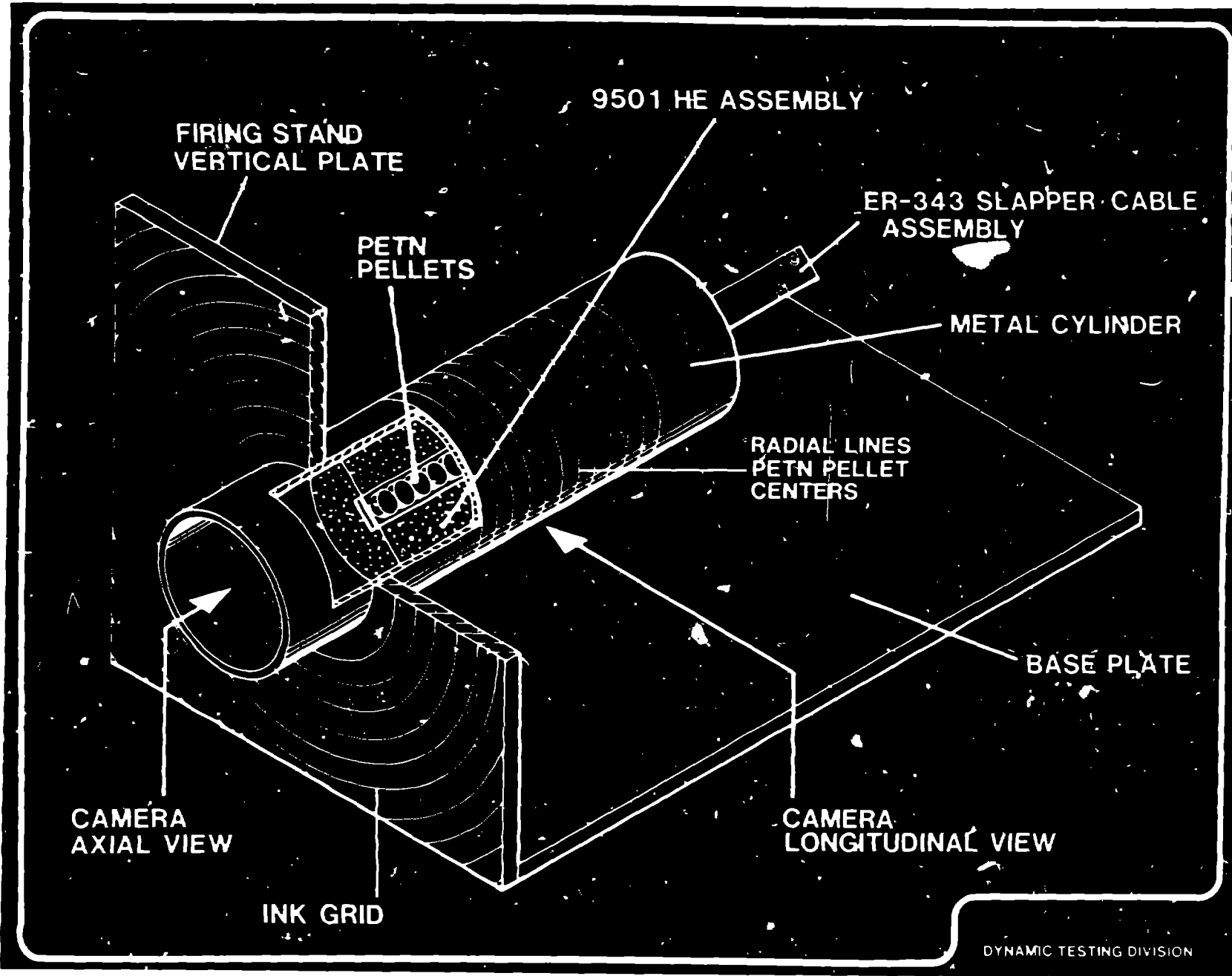
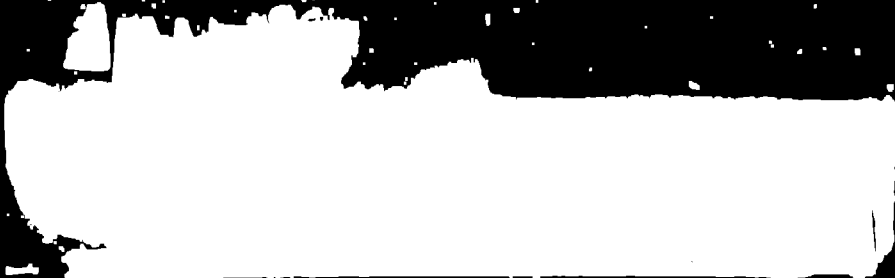
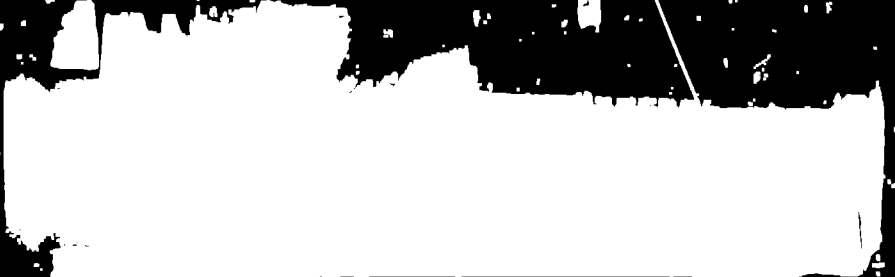


FIG. 15

Shot No. H-193



Frame No. 1 - 5.0 μ s

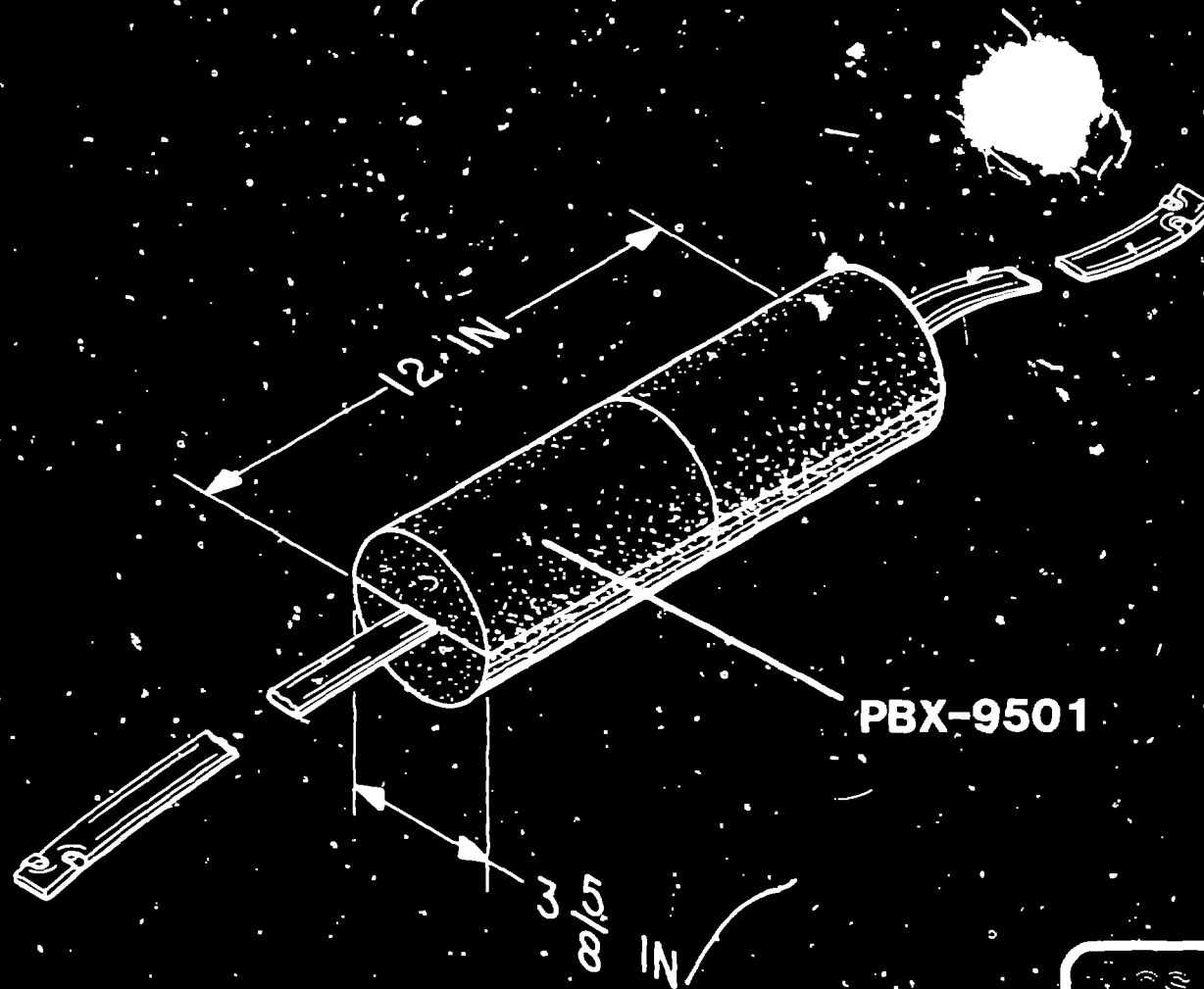


Frame No. 8 - 12.0 μ s

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FIG. 16

HE CYLINDRICAL SYSTEM WITH TWO ER-343 ASSEMBLIES



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FIG. 17

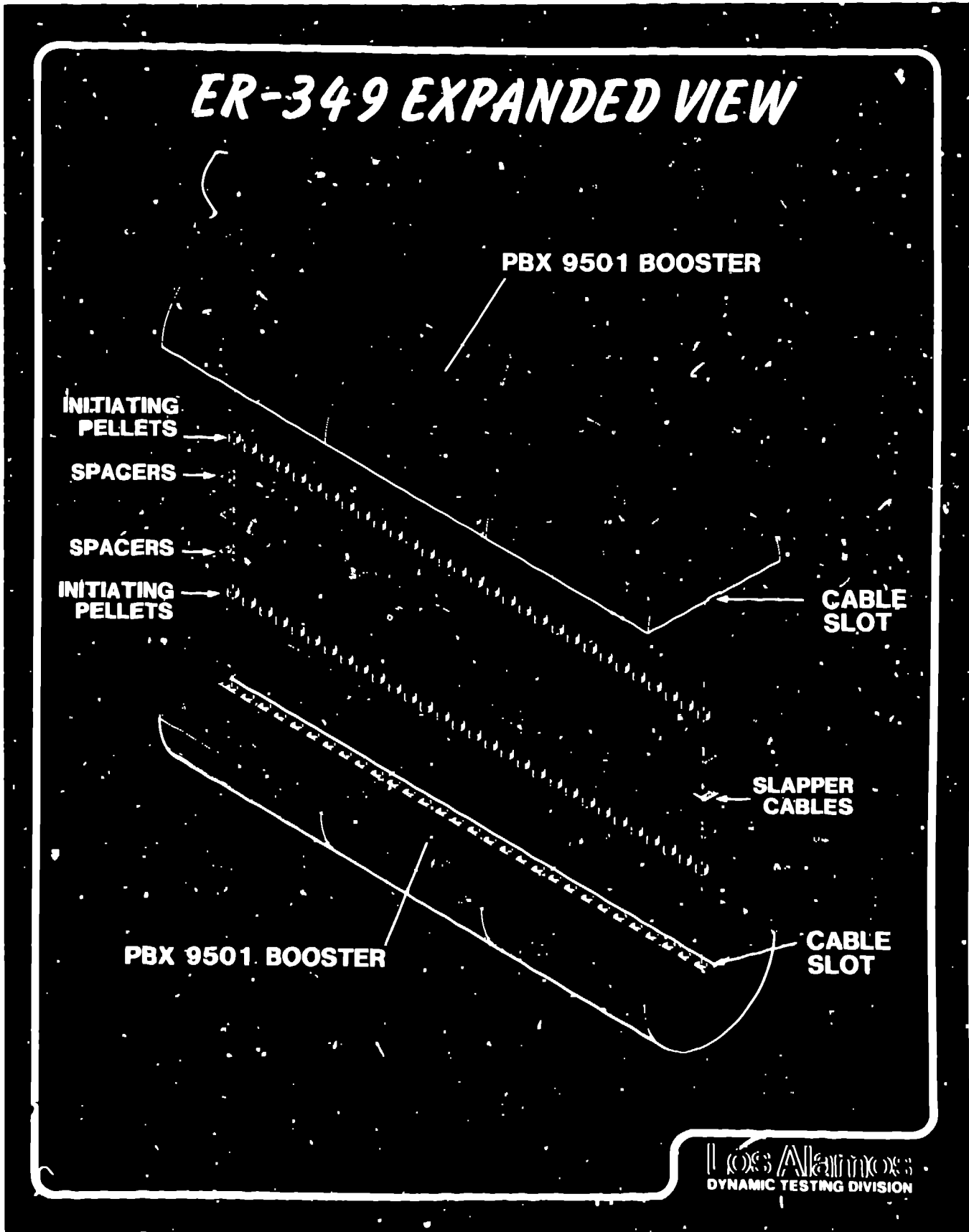
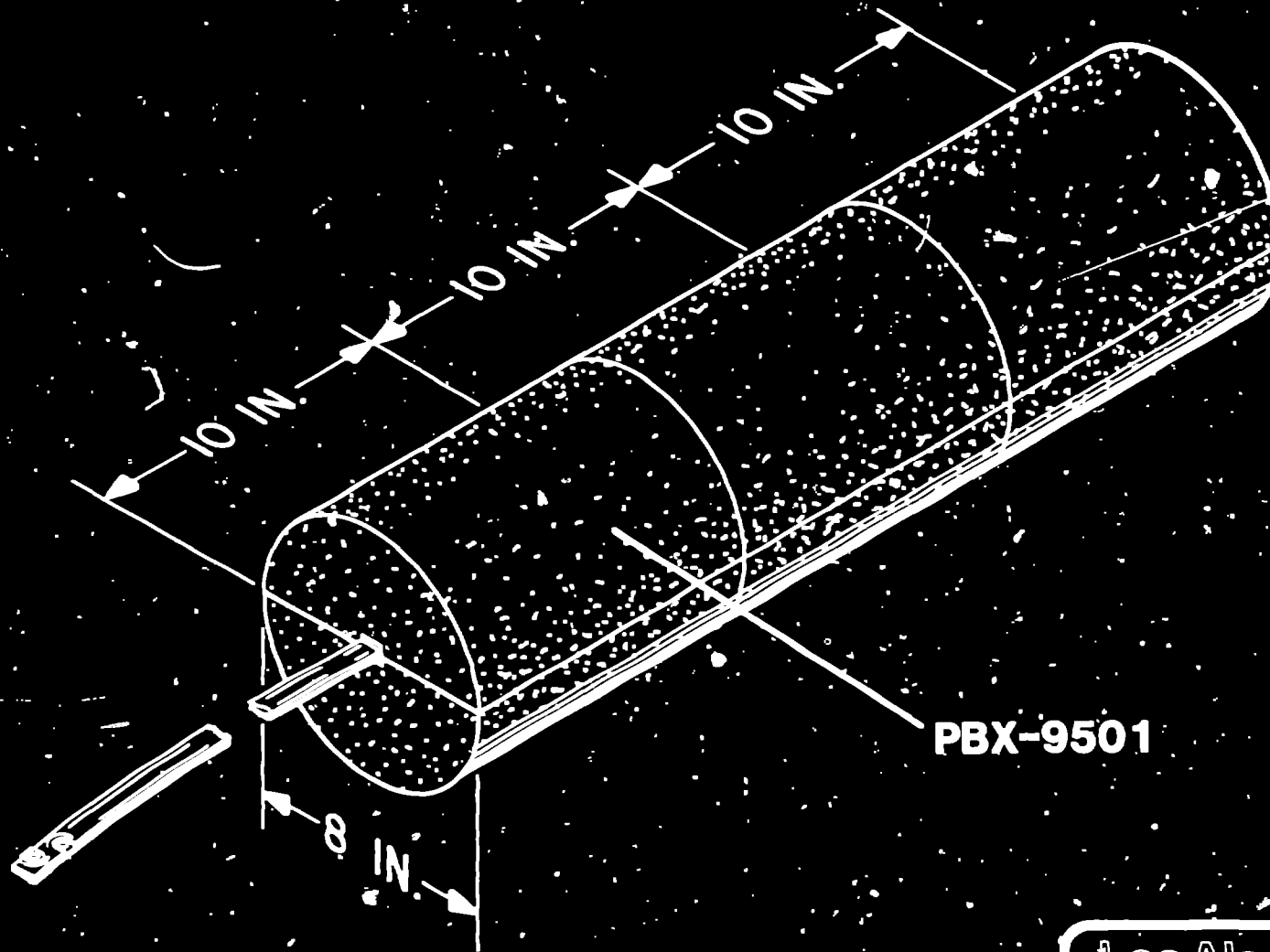


FIG. 18

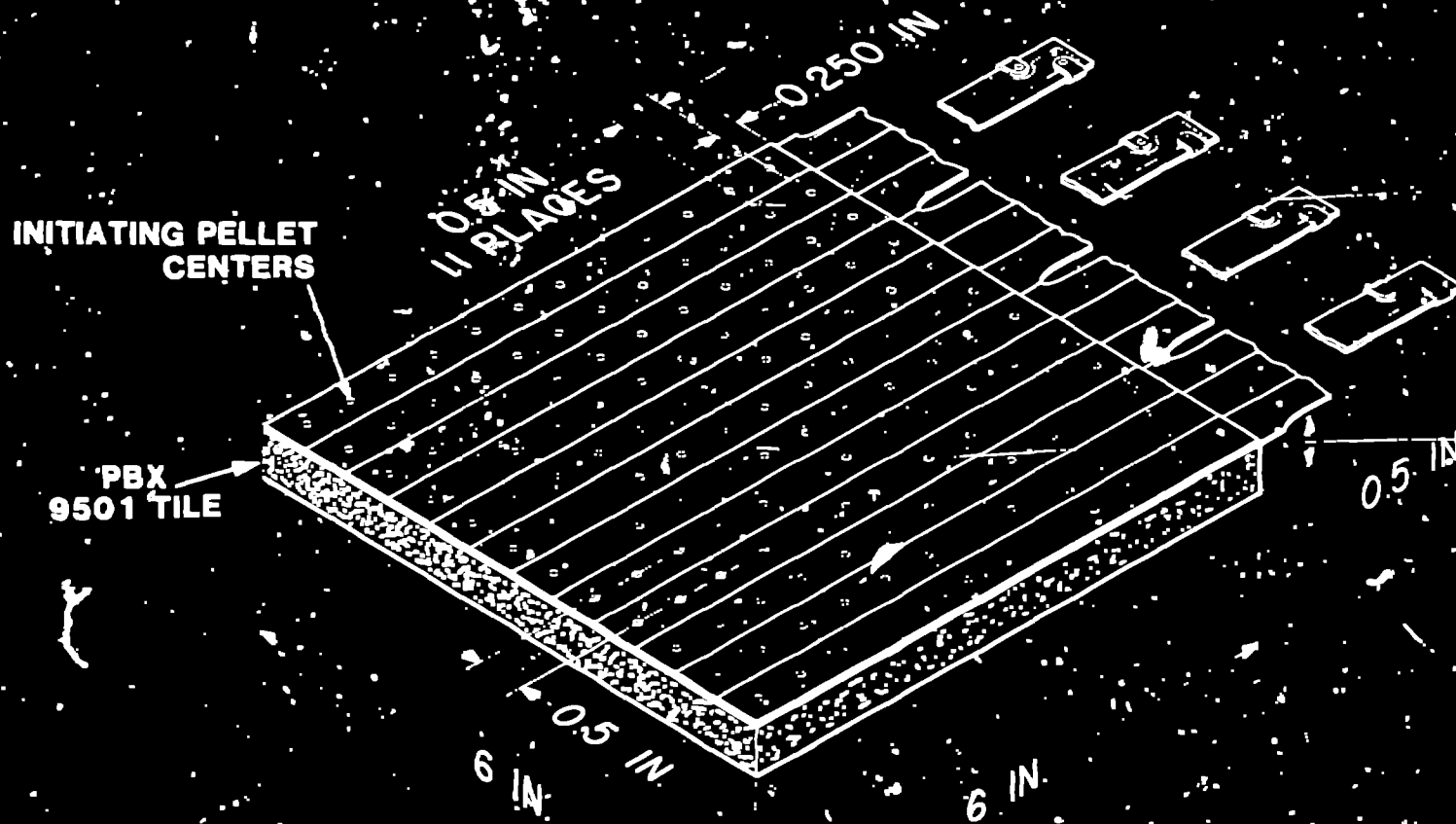
ER-349 HE ASSEMBLY



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FIG. 19

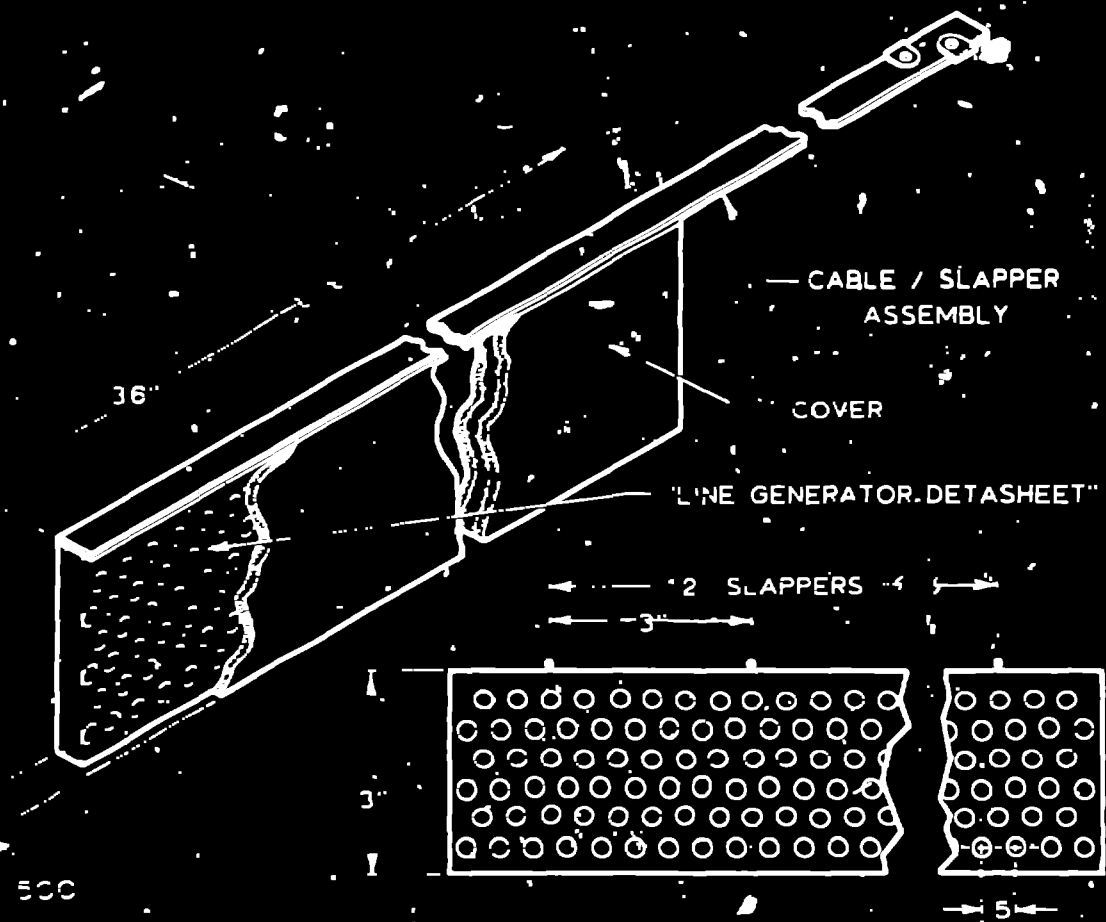
144 SLAPPER PLANE WAVE GENERATOR



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FIG. 20

ER-348 36-INCH LONG LINE MODULE



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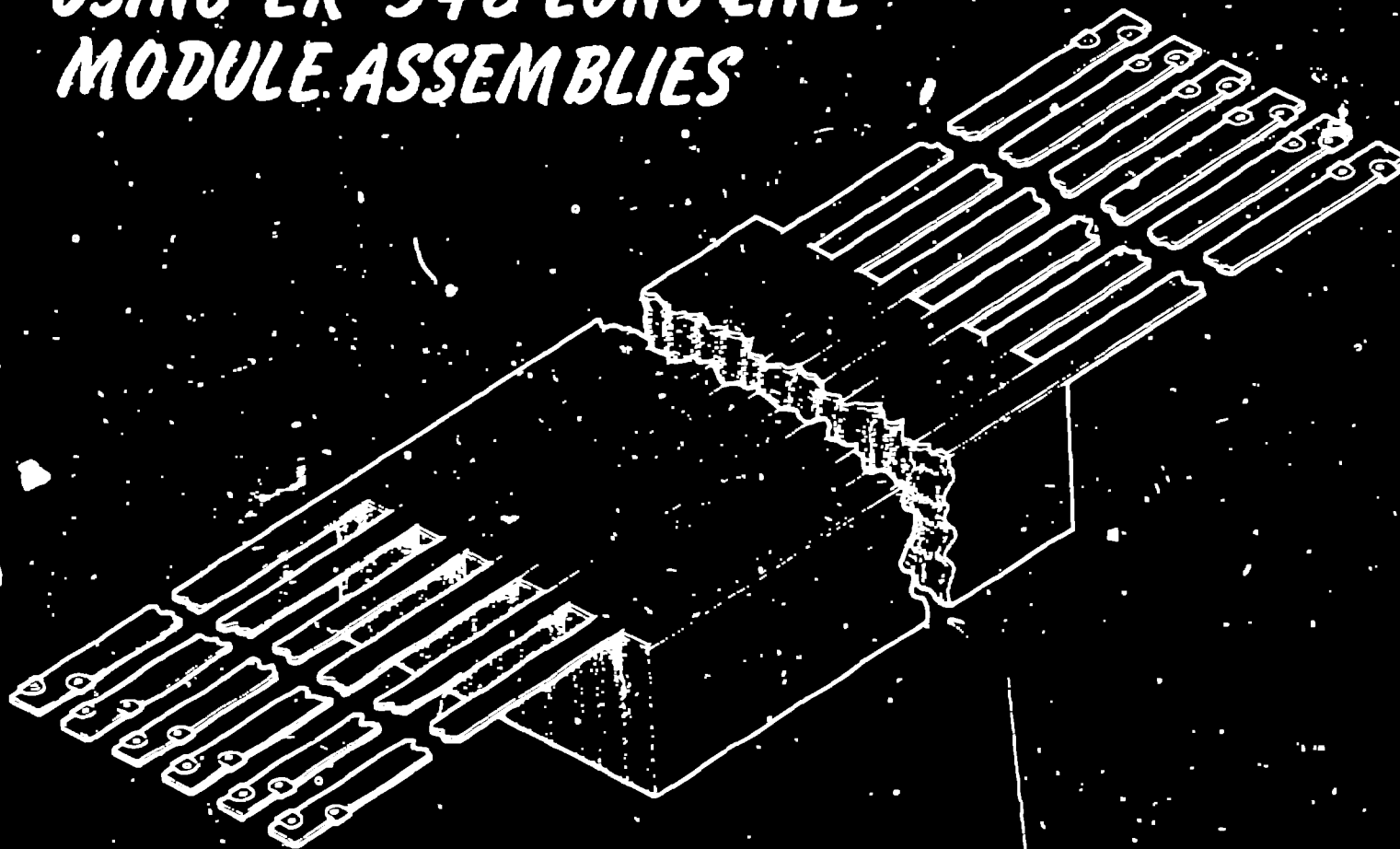
FIG. 21

longer lines can be initiated without adding to the number of slappers by making use of Detasheet with properly spaced holes. Finally, Fig. 22 shows how the ER-348 assemblies can be stacked to cover an area. By using the 30-bridge parallel-series arrangement and spacing the slapper about 3 in. apart, a 6-ft sq area could be covered with 180 ER-348 assemblies.

CONCLUSION

An extremely versatile line of special detonation systems has been developed at Los Alamos. With reel-to-reel processing, the cost of the special slapper assemblies can be kept low.

**PLANE WAVE GENERATOR
USING ER-348 LONG LINE
MODULE ASSEMBLIES**



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FIG. 22