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TITLE: IMPROVED HOT-WIRE ELECTROEXPLOSIVE DEVICES

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IMPROVED HOT-WIRE ELECTROEXPLOSIVE DEVICES*

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1. INTRODUCTION

The general objectives of this investigation were to test several concepts directed at improving the initiation safety margins of hot-wire electroexplosive devices (EEDs) without resorting to brute force methods (e.g., 5 A/5 W no-fire). The improvements briefly investigated in this work were:

A. Header configuration designed to eliminate the possibility of initiation by pin-to-case arcing.

B. Header configuration designed to improve heat dissipation capabilities by increasing the bridgewire-post area.

C. Substitution of reacting metal bridgewire (BW) for conventional BW, with the desired goal of eliminating primary explosive materials (lead azide, styphnates, etc.) from the EED. A lowering of BW resistance also usually results from this substitution.

D. Ignition tests of potassium hexanitrodiphenylamine (KHND) which previous tests had indicated as a secondary explosive possibly suitable for replacements of the primary explosives in EEDs.

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2. TEST ARTICLES

The test articles consisted primarily of standard SE-1 heads configured as shown in Fig. 1. The arc-suppression concept utilized was developed in the Mk 101 detonator by the Naval Ordnance Laboratory.[1] For convenience and lower cost in these tests, a Lucite sleeve was fabricated as a charge holder. The explosive is confined to the explosive cavity as shown in Fig. 1, and any arcing between pins and case occurs between the serrated edge and the case without passing through the explosive. The additional surface area provided by the arc-suppression design is in good contact with the posts and thus serves to dissipate heat much more rapidly than the header posts alone. An aluminum-palladium Pyrofuze Hi-R BW (Trademark of Pyrofuze Corporation) was used as the bridgewire. Other reacting metal combinations are possible[2] but Pyrofuze wire was conveniently available. The Pyrofuze reaction begins at about 660°C (the melting point of aluminum) and proceeds in a violent and exothermic reaction to a temperature of 2200° to 2800°C. The reaction proceeds without support of oxygen, and the BW is consumed (a useful feature in EED applications where normal BWs often remain intact after initiation). This reaction gave rise to the thought that a secondary explosive might be reliably ignited by such a BW.

3. CHARACTERISTICS OF KHND

Several secondary explosives were tried in a search (which was by no means exhaustive) for one which could be ignited reliably by a Pyrofuze bridgewire. From this test series, KHND was selected. The potassium salt of 2, 2', 4, 4', 6, 6'-hexanitrodiphenylamine is a secondary explosive which has the following characteristics:

Molecular weight: 477.32

Heat of combustion: 1305 kcal/mole

Differential thermal analysis (Fig. 2)

Pyrolysis (Fig. 2)

Detonation temperature: ∿340°C

Impact Sensitivity (compared with RDX), BRL machine, 2.5 kg weight:

Test	Type 12	Type 12B
RDX	21.8	32.8
KHND	24.9	32.6

The spark sensitivity, as measured by LASL Group WX-2, is as follows:

	Spark Energy to Burst 3-mil Foil (in J)	Spark Energy to Burst 10-mil Foil (in J)
KHND (Coarse 6372-74)	0.529	0.575
KHND (Fine 6372-64)	0.513	0.425
Other Secondary Explosives:		
RDX (Impact Std)	0.21	0.96
HMX (Impact Std)	0.23	1.42
PETN (Du Pont)	0.19	0.75
Tetryl (Impact Std)	0.54	3.79
TNT (Impact Std)	0.46	3.75

In general, KHND is one of the more sensitive secondary explosives (although it is less impact-sensitive and spark-sensitive than some others). It appears to be reasonably stable under ordinary environmental testing (e.g., the desert cycle). As opposed to many secondary explosives, a KHND deflagration is relatively easily ignited and a detonation ensues if the material is confined.

In most hot-wire EEDs, a primary explosive is located next to the BW and is initiated by the BW heating. In the case of a detonator, the force of the primary reaction is used to initiate a secondary explosive (base charge) such as PETN.

Primary explosives (lead azide, lead styphnate, etc.) are much more spark sensitive than secondaries; primary explosives also proceed rapidly to detonation (rather than deflagration). Because of its more desirable properties, KHND was used in place of the primary explosive in EEDs during this brief investigation.

4. RESULTS OF TESTS

KHND of two grades (6372-64 fine and 6372-74 coarse) was used for experimental firing tests. Densities from 0.8 to 1.4 g/cm^3 in amounts of about 100 mg were used and all were successfully initiated. Various sizes of Pyrofuze wire were used down to 1-mil diameter with successful results. The arc-suppression header concept performed successfully and no pin-case electrostatic initiation could be induced.

A test was conducted using the conventional Mk 2 Mod 0 Squib, except that KHND was substituted for the normal DDNP/$KClO_3$ (diozodinitrophenol/ potassium chlorate) primary ignition charge. The objective of this test was to evaluate KHND performance in a fixed header BW design for comparison with the Mk 2 Mod 0 performance evaluated previously.[3] Radio-frequency power was applied in a direct-drive test and the results are portrayed in Figs. 3 and 4. In the pin-to-pin mode, slightly higher powers were required to ignite the KHND-loaded Mk 2 than the conventional Mk 2 as would be expected from the 340°C ignition temperature of KHND (as compared with approximately 280°C for DDNP/$KClO_3$). Note that the KHND was ignited in a "hot-wire" fashion. Figure 4 shows that KHND is much superior to the conventionally-loaded Mk 2 in a pin-to-case test. It should also be mentioned that the KHND pin-to-case firings were not detonations; an obvious deflagration occurred with resulting gas pressures which ruptured the case assembly.

It was found that KHND could be ignited in 40 μs when 15 A were applied to a 0.001-in.-diam Pyrofuze bridgewire in dc tests. The 0.001-in.-Pyrofuze BW devices could carry 500 mA continuously without detonation. When energy was supplied by a capacitor discharge unit (CDU), 0.02 J were required for initiation. Pyrofuze BWs of 0.003-in.-diam could carry 4.6 A continuously without detonation. Under CDU energy application, 0.192 J were required for initiation.

5. MK 71 ADAPTATION

As a further test of whether the basic features tested on the SE-1 head could be adapted to an operational device, the Mk 71 detonator (which is found in many operational weapons systems) shown in Fig. 5 was selected. Standard Mk 71 headers were procured, normal bridgewires were removed, the arc-suppression header and 0.001-in. Pyrofuze bridgewire were installed, and KHND (fine) explosive was used in place of the normal lead azide, lead styphnate primary charge. The following table summarizes the results:

Conventional Mk 71:

dc Characteristics:

Bridgewire resistance: 4 - 6 Ω

No-fire current: 94 mA

Median firing current: 144 mA

All-fire current: 220 mA

rf Sensitivity (av):

Pin-to-Pin:

at 420 MHz: 0.2 W required for firing

at 1000 MHz: 0.15 W required for firing

at 3200 MHz: 0.5 W required for firing

Pin to Case:

at 420 MHz: 0.2 W required for firing

LASL - Modified Mk 71:

dc Characteristics:

0.001 Pyrofuze BW resistance: 0.16 - 0.22 Ω

No-fire current: 0.5 A, 5 min

Median firing current: 1.0 A

All-fire current: Not determined

Electrostatic discharge sensitivity (25 kV, 500 pF, 5000 Ω)

Pin-to-Case: No-fire

rf Sensitivity:

Pin-to-Pin:

at 850 MHz: 5 W required for firing

Pin-to-Case:

at 850 MHz: 5 W required for firing

6. CONCLUSIONS

The tests which were conducted are far from complete (i.e., too few samples were used from which to derive any reasonable statistics) and further tests are necessary to refine various parameters prior to employment of these concepts in operational EEDs.

It appears, however, that the concepts suggested herein could result in hot-wire EEDs which exhibit markedly lowered electrostatic and electromagnetic radiation susceptibility without appreciable increases in normal mode firing energy.

REFERENCES

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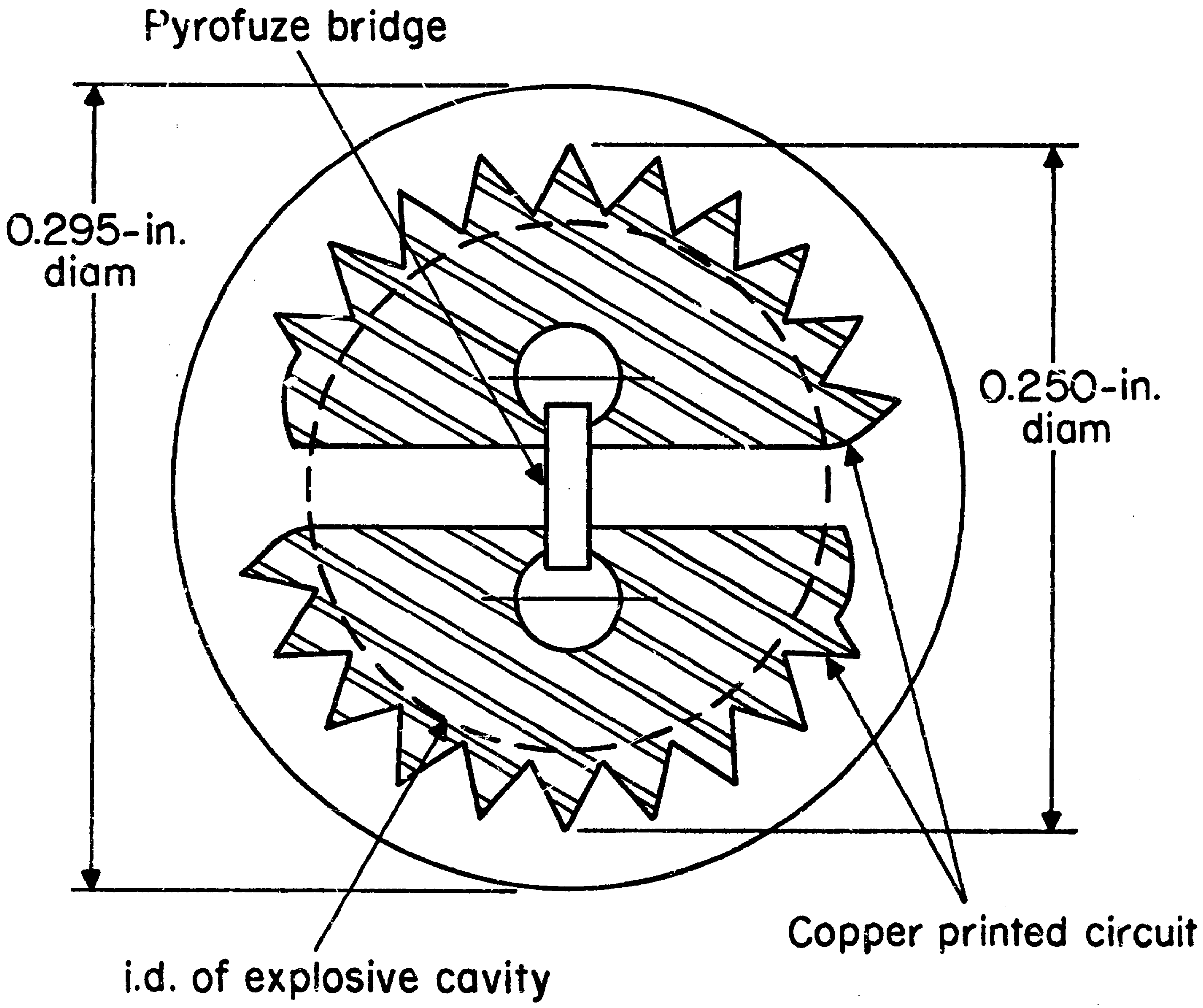


Fig. 1. Arc-dissipating bridge element.

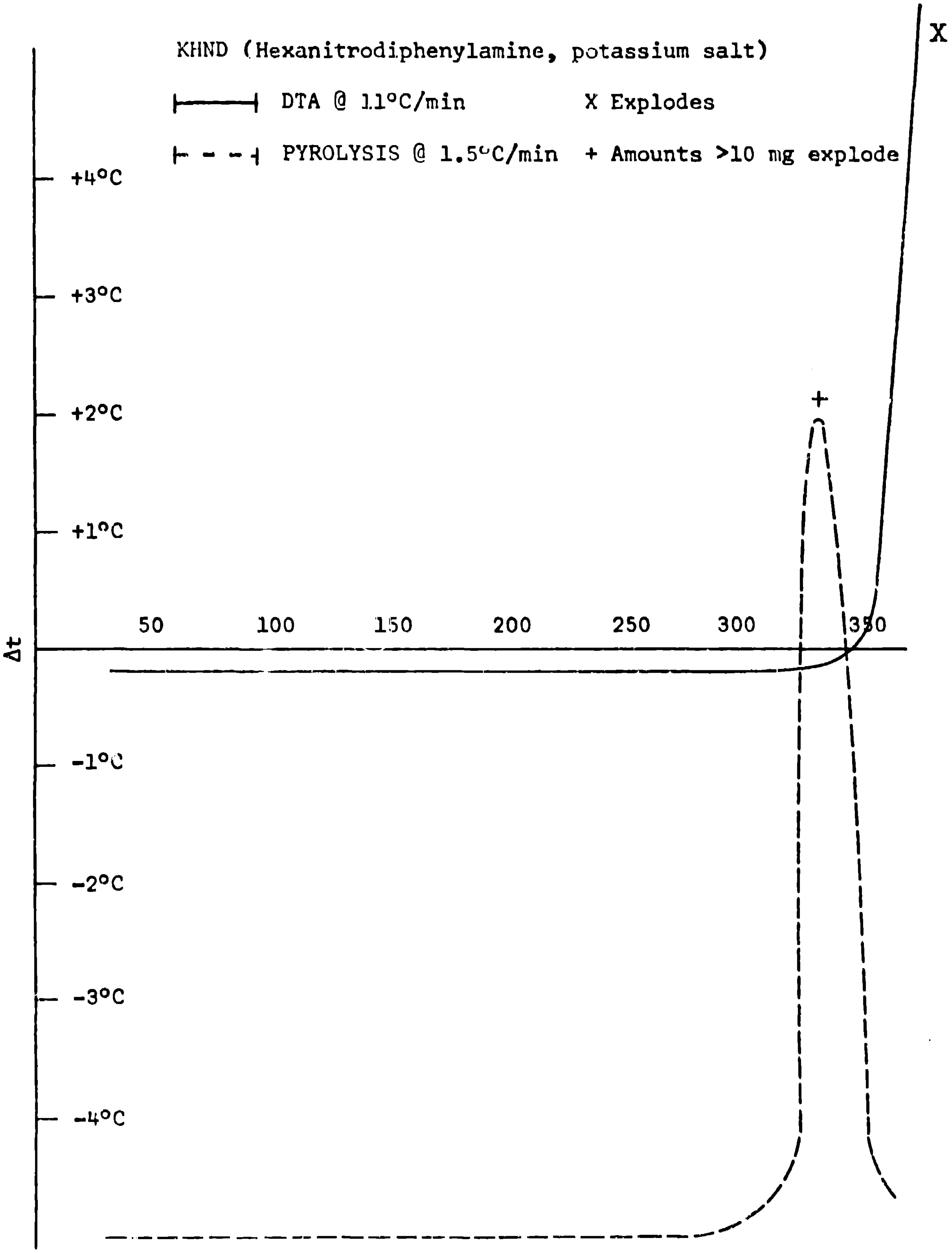


Fig. 2. Differential thermal analysis (DTA) and pyrolysis for KHND.

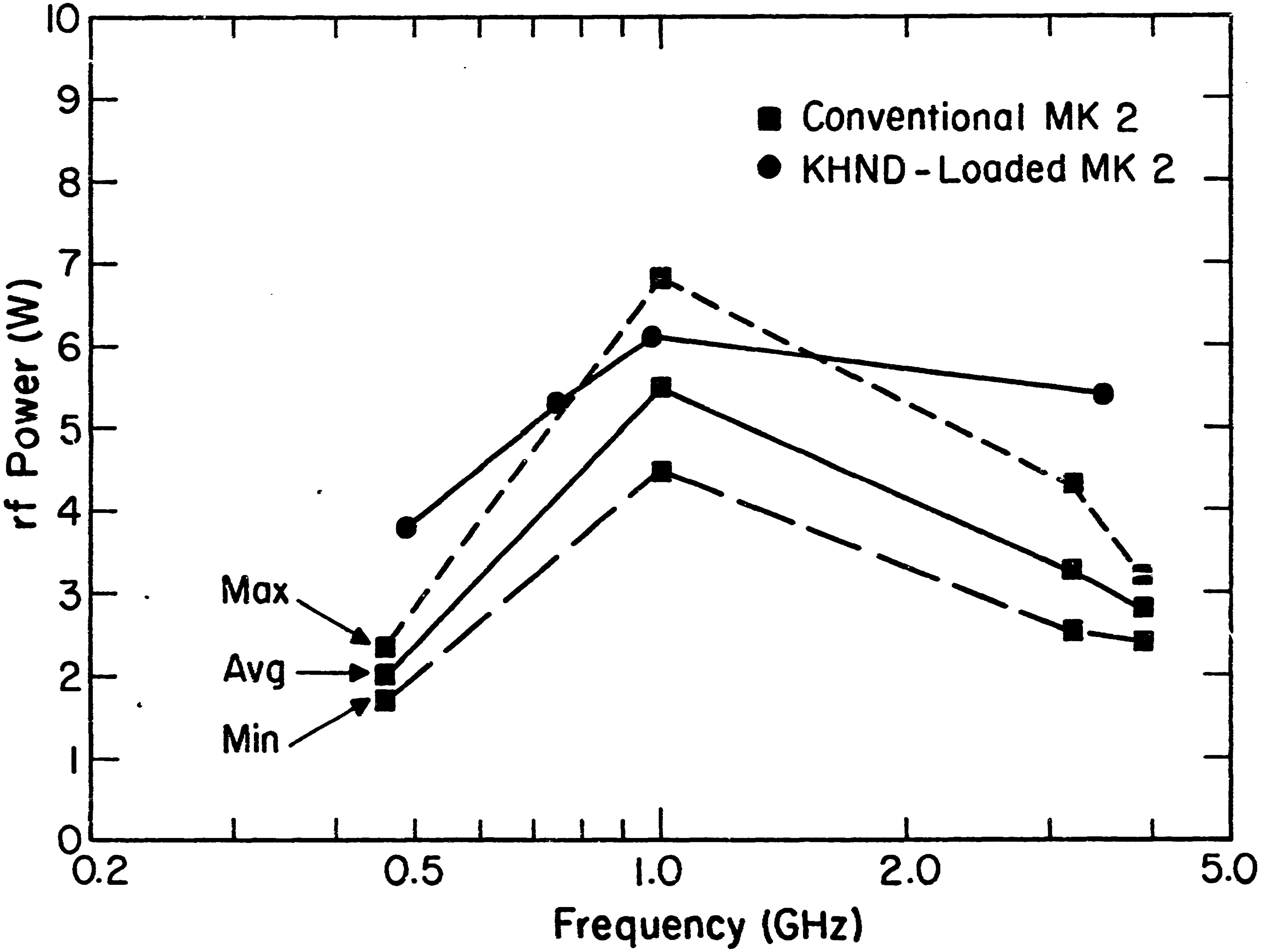


Fig. 3. rf sensitivity comparison 50-Ω source, pin-to-pin, Mk 2 Mod 0 squib.

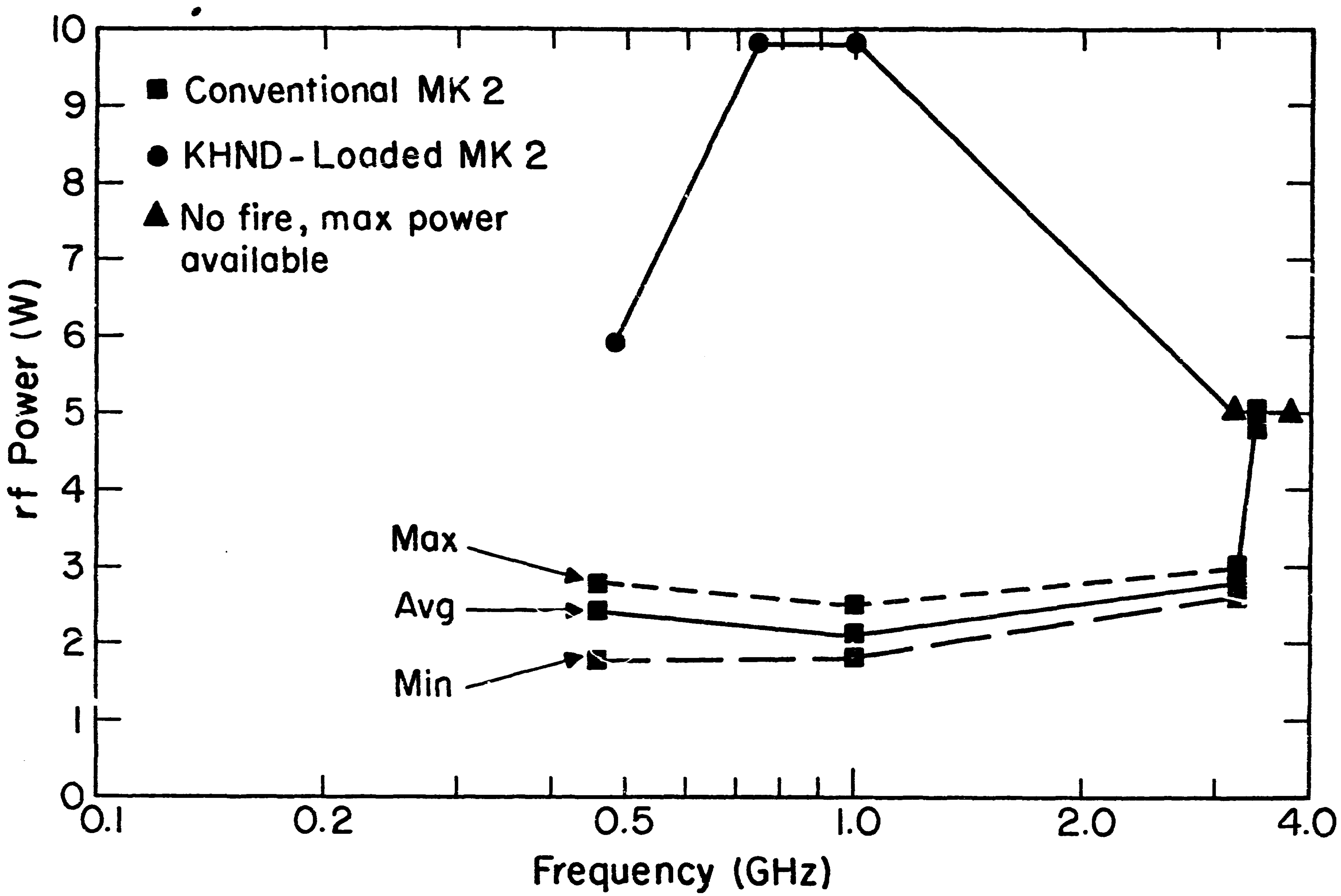
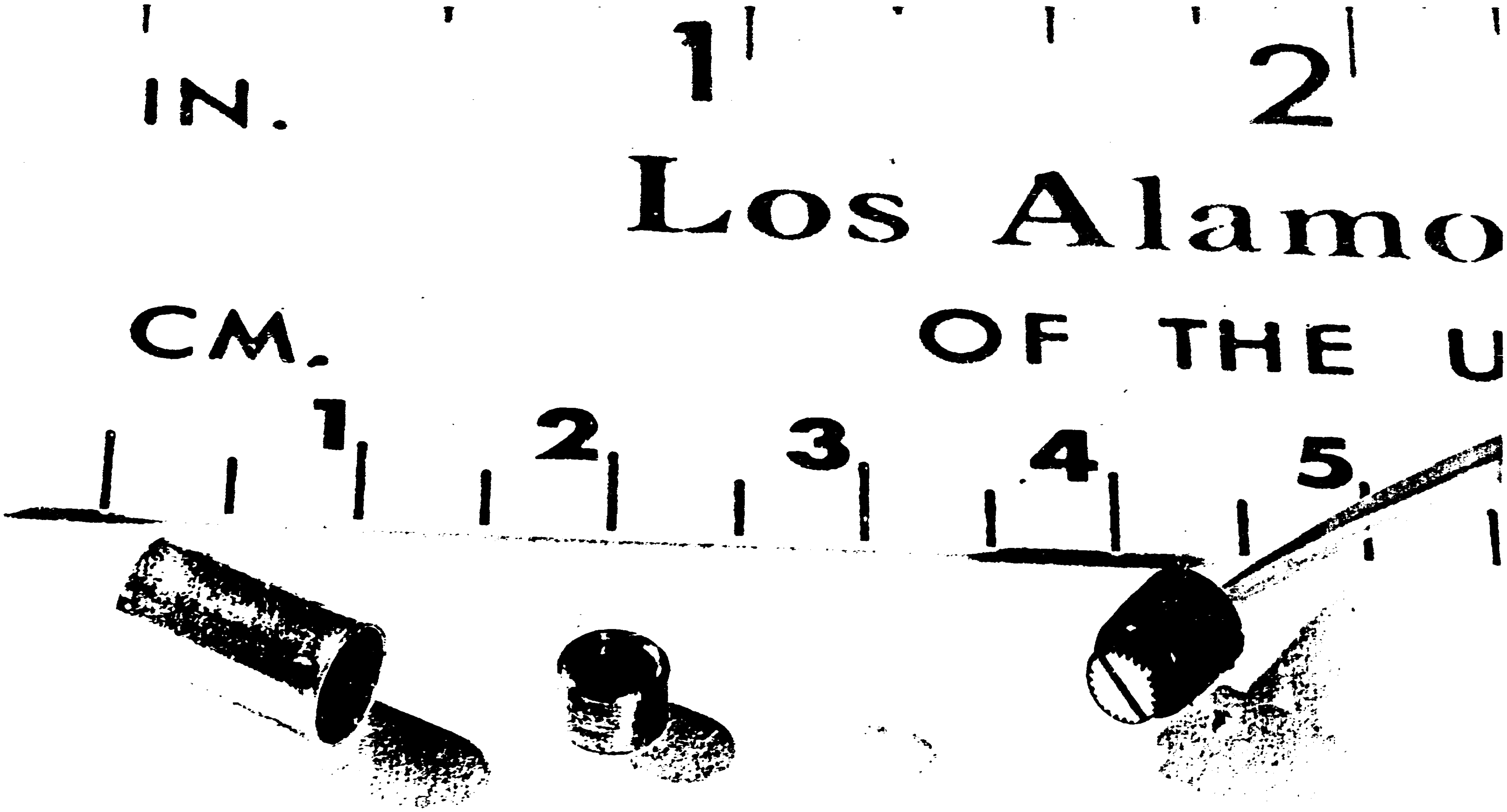


Fig. 4. rf sensitivity comparison 50-Ω source, pin-to-case, Mk 2, Mod 0 squib.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