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Technical Library
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SEP 14 '65
3428-3

W. L. STEVENS - 1531

Re: Relative Susceptibility of High Energy Squibs to EMR (Mk 27 Test)

1. Type of Test

RF energy was induced in the Mk 27 circuitry in two manners: (1) a 10-foot conduit around the leads to the umbilical cable was directly excited; (2) the RF source was connected between the ground lines to the weapon and the weapon skin. These methods are known as "direct feeding" and "ground line feeding", respectively.

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2. Component Tested

All tests were made with LASL squibs.

3. Instrumentation

One LASL squib with the normal 4.5 ohm bridgewire was instrumented with a thin-film thermocouple by Denver Research Institute (DRI). In another, the LASL header assembly was replaced with a thermocouple-instrumented Navy Mk 70 (1.0 ohm) squib. The outputs from these thermocouples were displayed on a Midwestern Oscillograph.

In a number of squibs, the 4.5 ohm bridgewires were replaced with 0.1, 1.0, and 2.2 ohm Ni-Cr resistance wires. In addition, some tests were run with 23 and 47 ohm resistors in place of bridgewires. For these uninstrumented devices, bridgewire current was determined by use of a Tektronix type P6016 current probe used with a passive termination, type L preamp, and type 545 oscilloscope.

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An Empire Devices type CP-105 current probe coupled to a Hewlett-Packard bolometer and power meter was used to measure umbilical cable current during the tests.

4. System Calibration

The thermocouple instrumented devices were calibrated by imputting known DC currents to the bridgewires and noting the galvonometer deflections; calibration curves were made.

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Since there was no constant relationship between RMS and peak-to-peak values of bridgewire current (due to waveform distortion), no attempt to calibrate the scope probe was made. Manufacturer's specifications for the combination used are: accuracy within 3% in passband; 3 db down at 850 cps and 20 mcps.

Calibration of the Empire probe was accomplished by correlating its readings with those of a Weston RF milliammeter. (The Weston meter is flat within 2% to 65 mcps.) In general, the readings plotted showed this probe and bolometer combination to be nonlinear with both frequency and amplitude. Therefore, an attempt was made to calibrate at all of the exact points used in the testing.

5. Accuracy and Repeatability

Above 20 ma equivalent-DC-bridgewire-current, the maximum thermocouple readout error is ± 2 ma.

The scope-probe readout was plagued with stray pickup problems. When these problems were minimized, the maximum error was about 10%. However, repeatability was probably within about 4% (at peaks).

The scope probe had no visual effect on the recorder readout and, likewise, the removal of the recorder and associated equipment had no effect on the scope readout.

Repeatability of the Empire probe readout was as poor as 10% at times.

6. Data Normalization

All data was normalized to an umbilical current of 400 ma. This was done by assuming the recorder output to be proportional to the square of the umbilical current and the scope readings to be directly proportional. These assumptions are not necessarily true, but they help show the resonances. (Note that relative data between different bridgewires is not distorted by this normalization.)

7. Results

The major result of this study is shown in Graph #1. This graph shows the relative power into the different resistance bridgewires at the three main resonant frequencies. Data for Graph #1 was obtained from scope readings of peak-to-peak current on the dummy bridgewire assemblies during a direct feed test. The input power was assumed to be proportional to the squares of these peak-to-peak currents because there was little difference in waveshape for different resistance wires at the same frequencies. (Graph #2 shows the actual currents recorded.)

If the bridgewire were connected to an ideal current source, the bridgewire's resistance would not affect the current through it. This seems to be the case at points other than resonances.

At the resonances at 2.3 and 4.65 mcps, the input circuitry acted as a voltage source with an internal impedance of 4.5 ohms. At the resonance at 10.8 mcps, the internal impedance of the equivalent source was 22 ohms. The readings of the 23 and 47 ohm resistors were not plotted. In general, they were somewhat lower in induced power than the 4.5 ohm wire except at 10.8 mcps, where the 23 ohm device was the highest.

Graph #3 indicates the response of the 1 ohm thermocouple instrumented bridgewire (normalized to 400 ma input umbilical current). This response is quite typical of those found.

Graph #4 shows that the normalized response of the 0.1 ohm simulated bridgewire is the same shape as that of a real bridgewire (Graph #3). This graph is typical for all simulated bridgewires except for amplitude relationships at peaks.

Graph #5 shows the degree of correlation between the scope current probe and the thermocouple readings (gives an idea of waveform distortion). This helps explain why the two curves on Graph #3 are not proportional by 2.83. The rest of the error results from the normalization procedure.

All of the data noted above was found from direct feed testing. No usable data was obtained from the ground-line-feed test (above 200 kcps) because of the great susceptibility of the system to stray capacitance effects; the loop current through the weapon varied as much as 160%.

The low frequency, ground-line-feed test showed no responses at frequencies from 10 cps to 200 kcps, even with one amp input; first noticeable responses started at 300 to 500 kcps. These were too low to obtain accurately.

8. Conclusions

This study shows that reduction of bridgewire resistance does reduce the peaks of induced power but not in direct ratio; the reduction in power is always less. It remains to be seen whether the circuitry looking back from the bridgewire looks the same in the field as during a direct feed test. (Note that more power can be induced into a 1.0 ohm resistor than a 4.5 ohm resistor if the source impedance is 1.0 ohm.)

The resonance condition seems to take place whenever the equivalent source impedance is best matched to the bridgewire, as expected.

9. Recommendations

With any change in bridgewire resistance, there is a chance of creating a matched condition; a 1.0 ohm wire may show less response here than in another test simply because of the nature of the source. Therefore, installation of a high energy device could possibly make no difference in susceptibility.

One alternative would be to add another component in series with the bridgewire. A fairly large resistance, say 45 ohms, in this position could possibly eliminate most of the resonances. However, the real firing signal might have to be increased.

Another possibility would be to include a series diode. This diode would not only remove half of the average RF power reaching the bridgewire, but it would also offer a nonlinear impedance to the source, which could possibly preclude resonance from occurring. In addition, it would attenuate high frequencies and virtually eliminate forward currents below about one milliampere.

The alternatives given here have not been tested, but are merely offered as suggestions.

D. F. Palmer

D. F. PALMER - 7331-3

DFP:7331-3:jc

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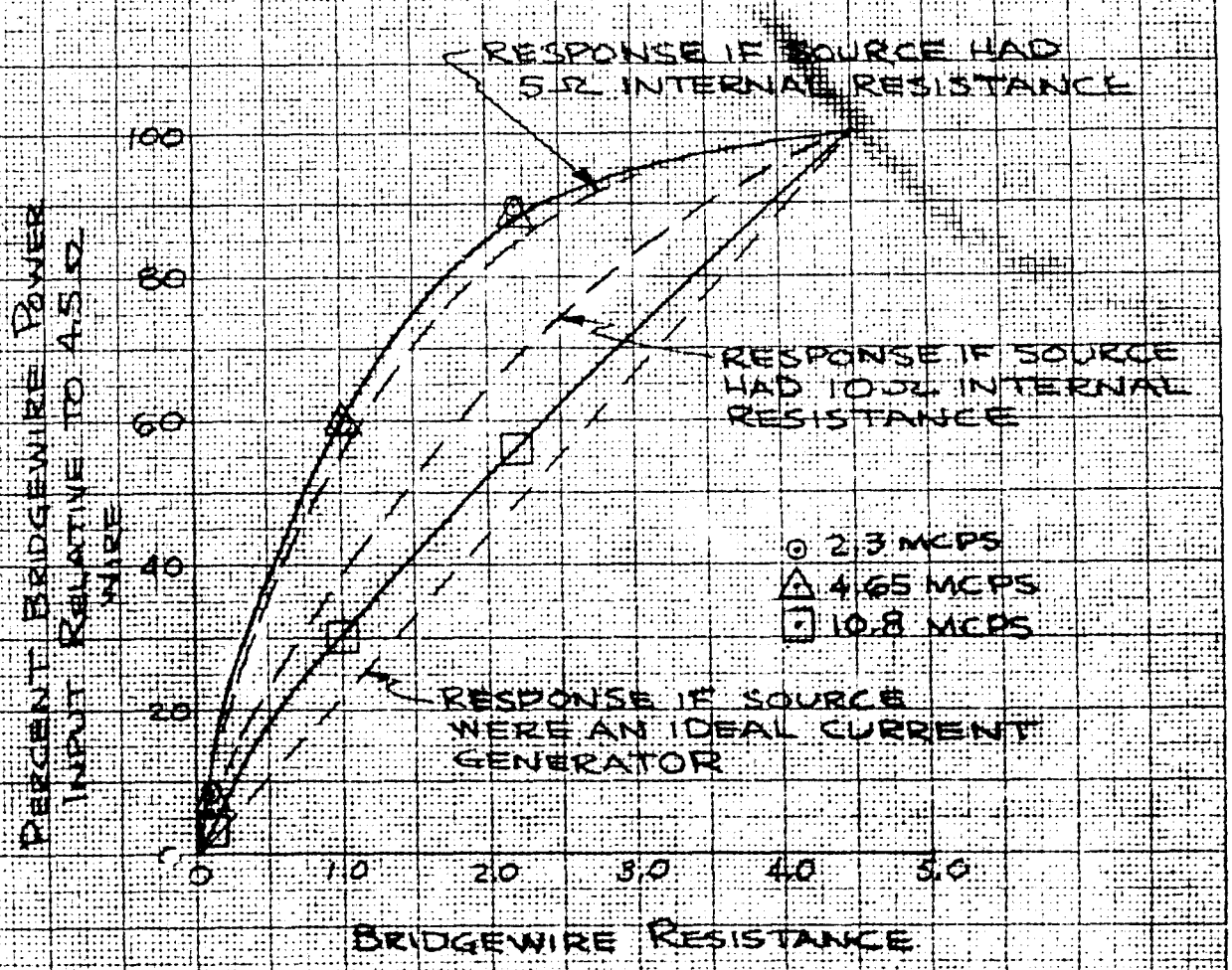

BRIDGEWIRE POWER INPUT VS BRIDGEWIRE RESISTANCE (AT RESONANT FREQUENCIES)

GRAPH #1

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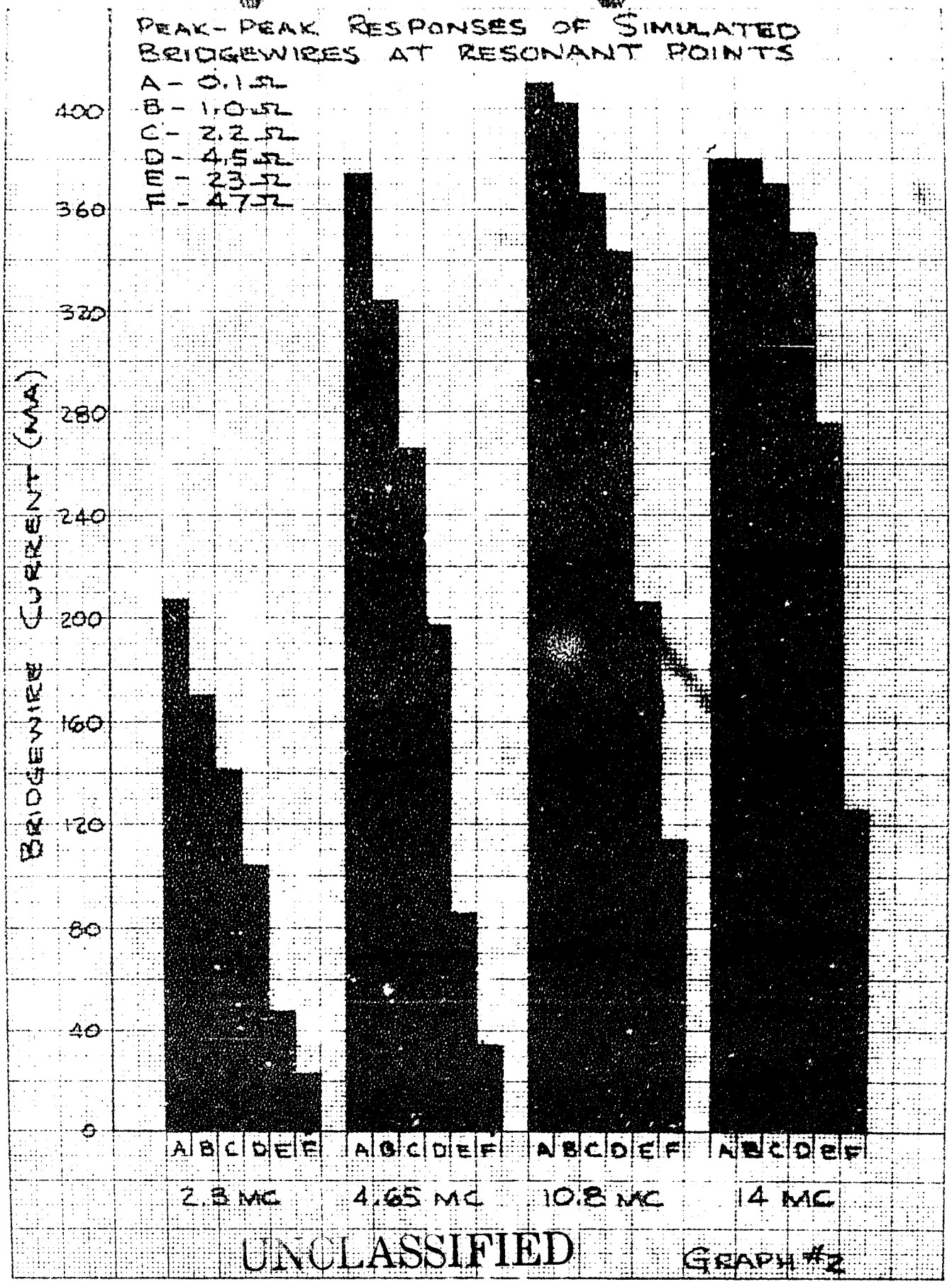
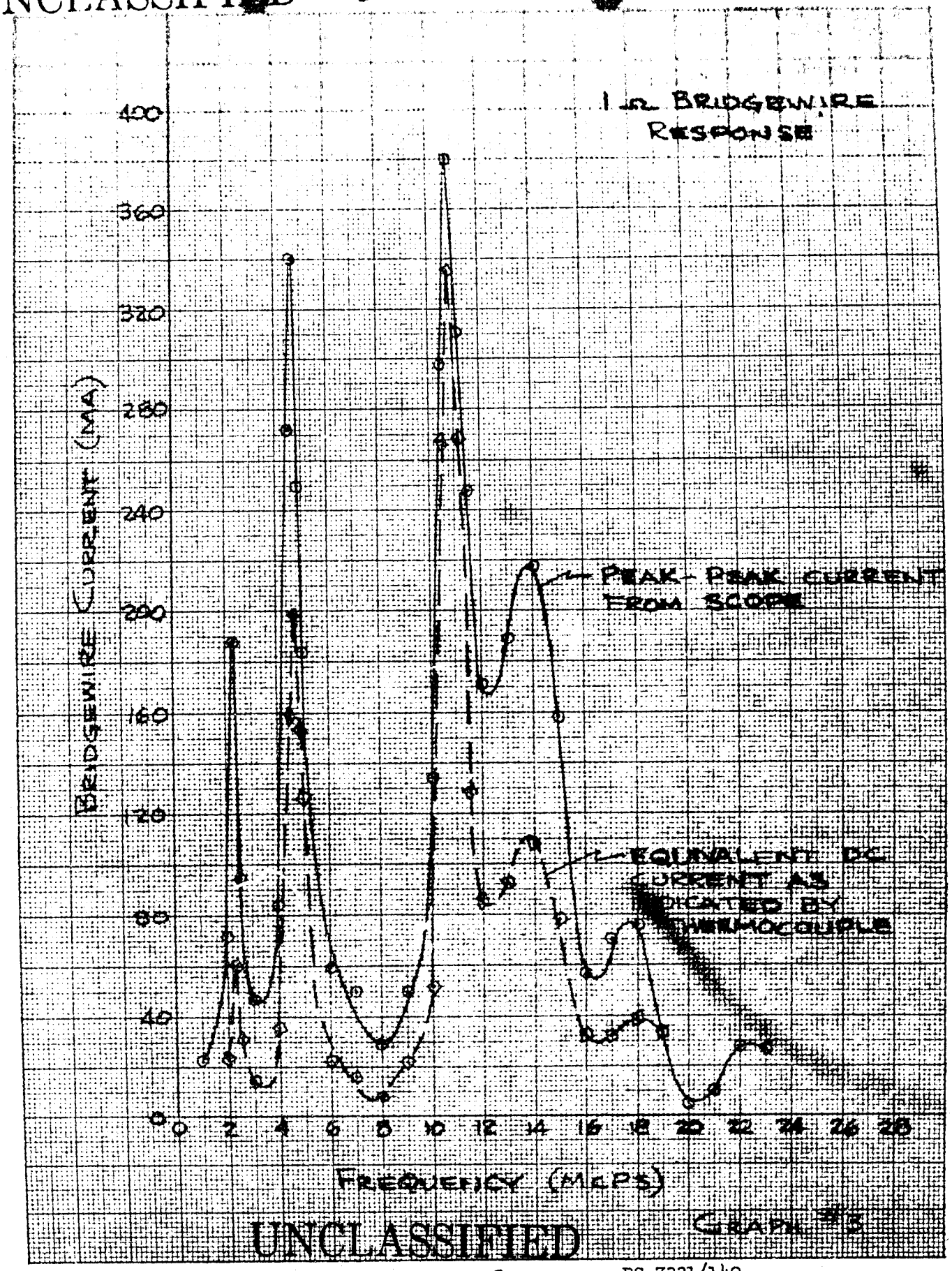

PEAK-PEAK RESPONSES OF SIMULATED BRIDGEWIRES AT RESONANT POINTS
A - 0.1Ω
B - 1.0Ω
C - 2.2Ω
D - 4.5Ω
E - 23Ω
F - 47Ω
BRIDGEWIRE CURRENT (MA)
400
360
320
280
240
200
160
120
80
40
0
A B C D E F
A B C D E F
A B C D E F
A B C D E F
2.3 MC
4.65 MC
10.8 MC
14 MC

GRAPH #2


1 Ω BRIDGEWIRE RESPONSE
PEAK-PEAK CURRENT FROM SCOPE
EQUIVALENT DC CURRENT AS INDICATED BY THERMOCOUPLE
BRIDGEWIRE CURRENT (MA)
400
360
320
280
240
200
160
120
80
40
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
FREQUENCY (MCPS)
GRAPH #2

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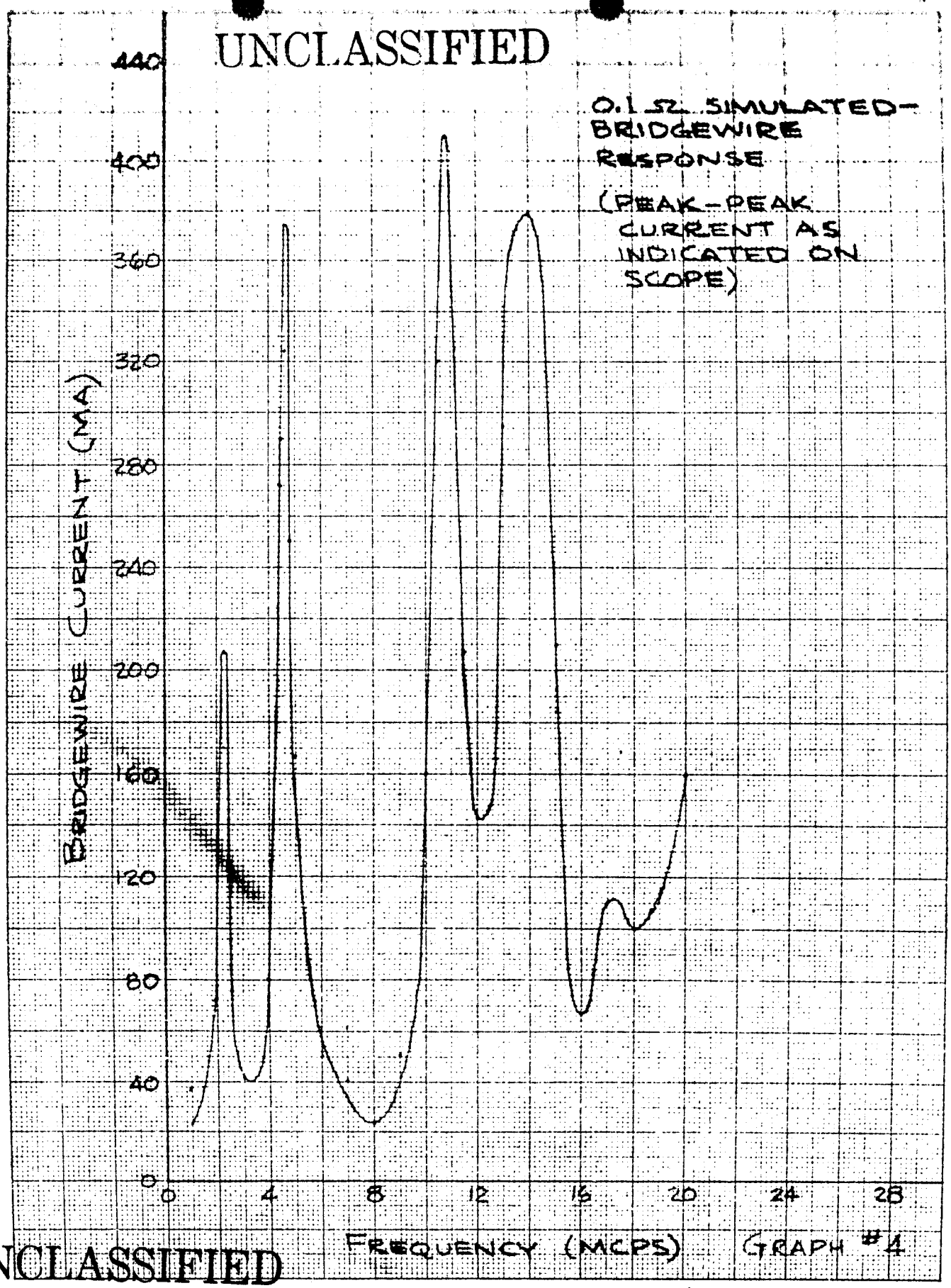

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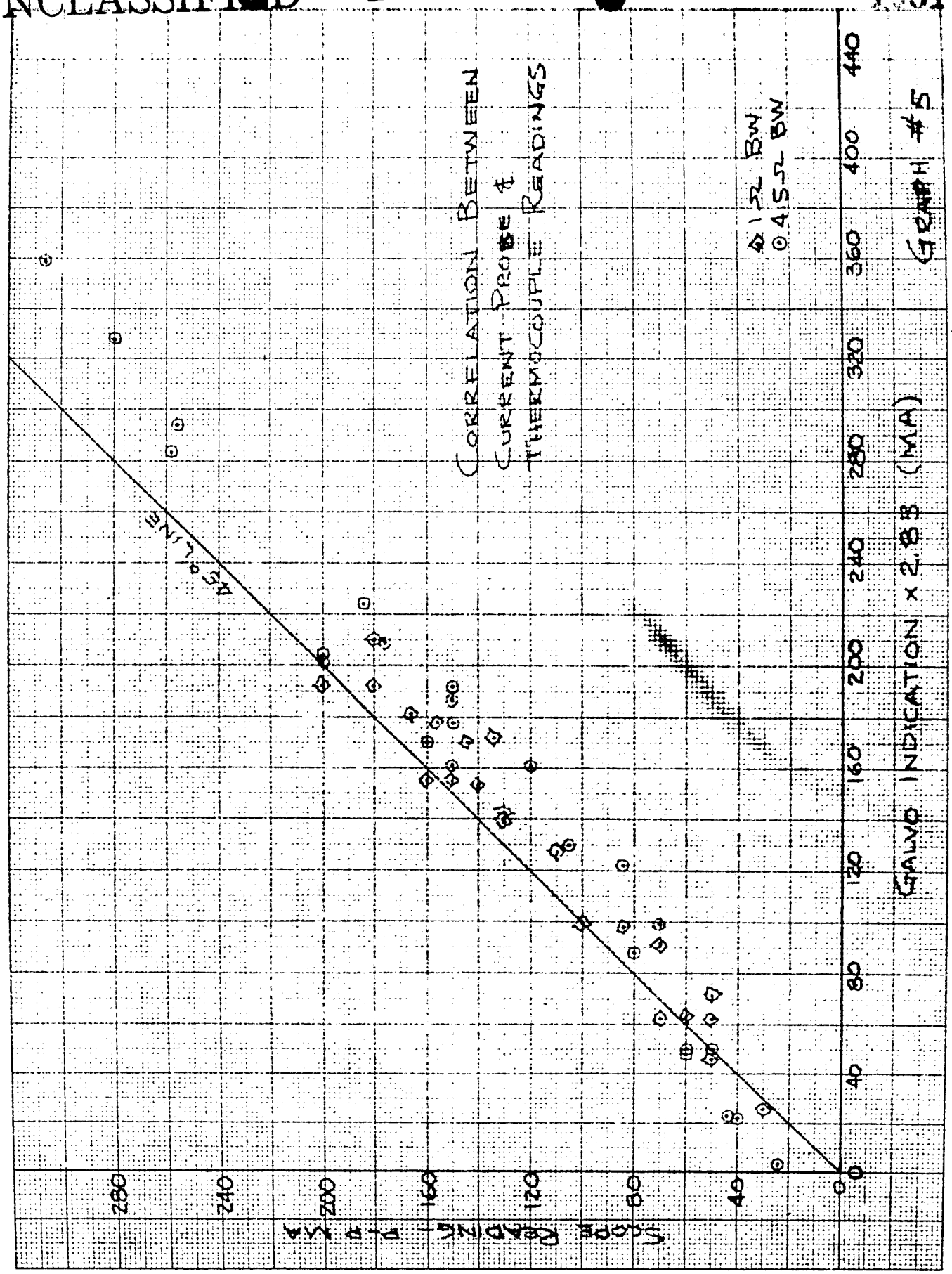

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