Falcione

Engineering Note E-533

<u>IMPORTANT</u>

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Digital Computer Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: **EFFECT OF CURRENT PULSE DURATION ON THE PULSE RESPONSE OF M.T.C. MEMORY CORES**

To: Group 62 and 63 Engineers

From: P. K. Baltzer

Date: March 10, 1953

Abstract: The pulse response of ferrite memory cores, that will be used in M.T.C., has been found as a function of Current Pulse Duration. It has been found that reduction of Current Pulse Duration to 1.5 microseconds is the practical limit for best operation. Calculations made concerning signal discrimination of memory arrays indicate that discrimination of signals from 64 x 64 arrays of M.T.C. cores will be marginal--even using a Post-Write disturbing pulse when writing ones in the memory.

The "access time" of a computer memory is of utmost importance concerning its integration into the computer as a whole. The access time of a coincident current memory will be a function of the number of necessary current pulses for a given operation, the current pulse duration, and unavoidable "red tape" time. An investigation has therefore been made on the effect of current pulse duration on the pulse response of the cores that will make up the M.T.C. memory.

When cores are used in a coincident memory plane the Delta output is cumulative as noise and thus is increasingly important as the size of a memory plane is increased. This is shown in E-488[1] where Delta is also defined. Due to the extremely high ratio of the Undisturbed One output to the Delta output (of the order of 1000 for long current pulse lengths) considerable difficulty has been experienced in measurement of Delta. This difficulty is the effect of the Read-Write output which tends to paralize the scope pre-amplifier during measurement of the Delta output. The difficulties just described have been overcome by measuring Delta for this investigation using the circuit shown in Figure 1, where groups of cores connected in series are indicated as a single large core. Standard pulse output response is sensed from Group A. Delta is measured as the output of Group A, B and C which are so connected as to give Delta from Group A and B while the Read-Writes from Groups A and B are cancelled by those of Group C. The information obtained from this experiment is

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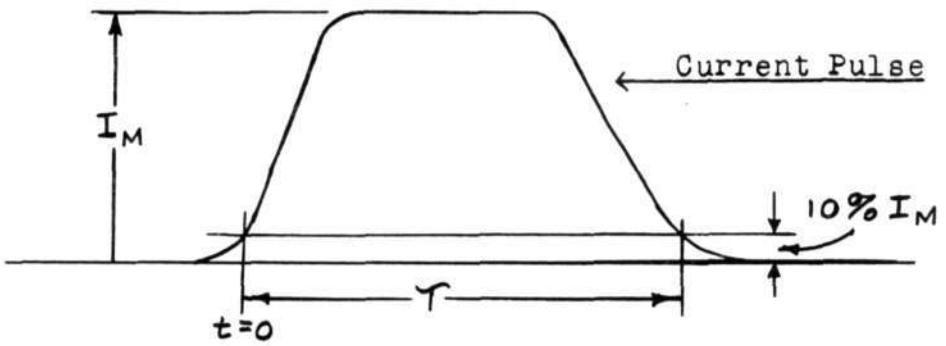
[1] Engineering Note E-488 Delta$_{NS}$ In Ceramic Array #1 by E. A. Guditz

therefore an average for 100 cores.

The cores tested were a General Ceramic ferrite, body MF-1326B - die F-291. These cores were taken from Lot #4 and had already been selected, by the Production Test Group, for M.T.C. with a Disturbed One output of 0.11 and 0.12 volts at .57 μsec.

The Current Pulse Duration (τ) is defined as the time from 10% of maximum current on the rise of the pulse to 10% of maximum current on the fall of the pulse. The rise time of the current pulse was 0.2 μsec. from 10% to 90% of maximum current and the fall time 0.3 usec. from 90% to 10% of maximum current.



The complete test cycle for a given measurement consisted of 40 Read-Write pulses and then 40 Half-Selecting pulses, with a P.R.F. of 5,000 cycles. The actual sequence of pulses for each particular group of cores indicated in Figure 1 is shown in Figure 2 for each measurement made.

The Undisturbed One output has been found as a function of Current Pulse Duration (see Figure 3). The output is a maximum at τ = 1.2 μs for all driving forces. This can be attributed to the fact that, as the current Pulse Duration (τ) is decreased from 4 usec to 1.2 usec, a different hysteresis loop is traversed in the two cases.

Typical Undisturbed One output pulses and the corresponding Hysteresis Loops are shown in Figure 4 for the same driving force (ampere turns), but different values of Current Pulse Duration. Output pulse "α" is the result of the core being driven by 10 μsec. pulses, and "β" is the result of being driven by 1.2 usec. pulses. The output pulses correspond to the following travel on the Hysteresis Loops, for pulse "α" the core is changed from the state at point 1 to that at point 2, whereas for pulse "β" the core is changed from the state at point 3 to that at point 4. The flux change for pulse "β" is about 85% of that for pulse "α" as is found by integration over the positive portion of each. Output pulse "γ" is the result of the core being driven by 1.2 usec. pulses before being sensed and then read by pulsing the core with a 10 μsec. pulse. Pulse "γ" exactly duplicates pulse "β" except as indicated. The difference in the wave forms is of course indicative of the reason for the different hysteresis loops. Insufficient energy is available for short current pulse duration to switch domains that have higher resistance to change, caused either by the geometry of sample or variations within the material itself. Hence, there is an increase of the number of domains of reverse magnetization present at the remanent point 3 as compared to those present at point 1. These additional domains of reverse magnetization at point 3 are also in areas that were hard to magnetize from the point 1. Hence, the total effect of short pulse duration is not only to shorten the pulse output, but also to increase the initial rate of change of flux to the extent that the maximum for the case where τ = 1.2 μs is greater than that for longer current pulse excitation. As the current pulse duration is further reduced of course the core is no longer able to switch and the Undisturb Output falls off rapidly.

Curves of the <u>Disturbed One</u> output are shown as a function of Current Pulse Duration in Figure 5. The effectiveness of Half-Selecting Pulses is heightened as the Current Pulse Duration is reduced, since a smaller effective Hysteresis Loop is involved. For NI_m = 90 amp turns the half amplitude pulse evidently does not greatly exceed the knee of the basic hysteresis loop even for the entire range of Current Pulse Duration from 4 μsec down to 1.2 μsec. Therefore, for the case of NI_m = 90 amp turns the Half-Selected output pulse is very short, as compared to those for the higher driving forces, at low values of Current Pulse Duration. If the number of Half-Selecting Pulses were increased sufficiently the full disturbing effect would be realized even for the higher driving forces. Hence, to duplicate this worst situation as far as possible the length of the Half-Selecting pulses was kept a constant of 20 μsecs for the measurement of both the <u>Disturbed One</u> and the <u>Disturbed Zero</u>. The effect of the disturb overcame the effect discussed concerning the increase of the Undisturbed One at τ = 1.2 μs for the case of NI_m = 90 A-T but for higher driving forces even this large number of disturbs (40) and the long duration of the Half-Selecting current pulses was not sufficient to offset the effect causing the maximum previously discussed for the Undisturbed One.

Since it is planned to sense the output of a core in time, all other measurements of output voltages have been made at the time to the maximum value of the <u>Disturbed One Output</u>. This time has been found as a function of Current Pulse Duration (see Figure 6). There is a reduction of almost 40% as Current Pulse Duration is reduced from 4 μsecs. to 1.2 μsecs.

The <u>Disturbed Zero</u> increases greatly for shorter Current Pulse Duration (see Figure 7), with τ = 1.5 μsecs being marginal. This is caused by two effects. Firstly, the <u>Disturbed Zero</u> is measured at the time to the maximum of the <u>Disturbed One</u> output, which falls off rapidly as τ is decreased (Figure 6). Secondly, the actual magnitude of the output signal also increases since the Half-Selecting pulses become increasingly more effective in disturbing the state of the core as the actual hysteresis loop traversed becomes smaller and smaller. As was mentioned previously the length of the Half-Selecting current pulses was kept a constant of 20 μsecs for measurement of the Disturbed Zero; thus greatly increasing the effective number of Half-Selecting current pulses for short values of Current Pulse Duration.

The First Half-Selected One, First Half-Selected Zero, First Delta and Second Delta output voltages were all measured with all current pulses in the test sequence having the same Current Pulse Duration (see Figures 9 to 11). All these voltages are defined in E-488, in which their importance concerning the use of cores in a coincident current memory is also explained. All of the above mentioned output voltages increase sharply at low values of Current Pulse Duration with $\tau = 1.5$ μsecs again being marginal. The reasons for this are the same as those given for the similar increase of the Disturbed Zero for the same values of Current Pulse Duration.

It should be noted that pulse data was also taken for the Current Pulse Duration of 10 μs and was found in all cases to be identical with data taken at $\tau = 4$ μs.

With reference to E-488, the worst output of a core containing a One in the memory or containing a Zero is as follows:

$$I_D - 2NS_1^1 - (n-2)\delta_2$$

and

$$O_D - 2NS_0^1 + 2\delta_1 + (n-4)\delta_2$$

where I_D = Disturbed One Output
O_D = Disturbed Zero Output
NS_1^1 = First Half-Selected One
NS_0^1 = First Half-Selected Zero
δ_1 = First Delta
δ_2 = Second Delta
n = Number of coordinate lines in memory plane

For the case where a Post-write Half-Selecting pulse is added to the writing sequence in a memory the corresponding worst conditions become:

$$I_D + 2NS_0^2 - n\delta_2$$

and

$$O_D - 2NS_0^2 + (n-2)\delta_2$$

where NS_0^2 is the Second Half Selected Zero
Since neither a NS_1^1 or a NS_0^1 are now not possible with each core in a disturbed state.

The Discrimination Ration (R_D) of a memory will be defined as follows for the case without a Post-Write Disturb.

$$R_D{}^U \equiv \frac{I_D - 2NS_1{}^1 - (n-2)\delta 2}{O_D - 2NS_C{}^1 + 2\delta_1 + (n-4)\delta_2}$$

and for the case with a Post-Write Disturb

$$R_D{}^D \equiv \frac{I_D + 2NS_O{}^2 - n\delta_2}{O_D - 2NS_O{}^2 + (n-2)\delta_2}$$

$R_D{}^U$ and $R_D{}^D$ are shown in Figure 12 for a 32 x 32 array with NI_m = .950 amp turns and in Figure 13 for a 64 x 64 array with NI_m = .950 amp turns. In general the post-write disturb increases R_D by about a factor of 2. For the 64 x 64 array the R_D at 1.5 us is increased from 2 to 3.5 which is still very low and R_D does reach a value of 8 until τ = 2.5 us using the Post-Write Disturb pulse. Hence the expedient of breaking up a 64 x 64 plane into 4 - 32 x 32 sensing quadrants may become necessary if low values of Current Pulse are deemed necessary.

It should be noted that the pulse response obtained in this experiment is an average for 100 cores and as such the Discrimination Ratio calculated from these values is also an average value. Some distribution is to be expected about the mean value, therefore the Discrimination Ratio as calculated is optimistic to this extent.

Signed P. K. Baltzer
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Approved DRB
David R. Brown

PKB/djd
A-54127
A-54128
A-54160
A-54109
A-54159
A-54110
A-54161
A-54111
A-54164
A-54165
A-54166
A-54172
A-54171

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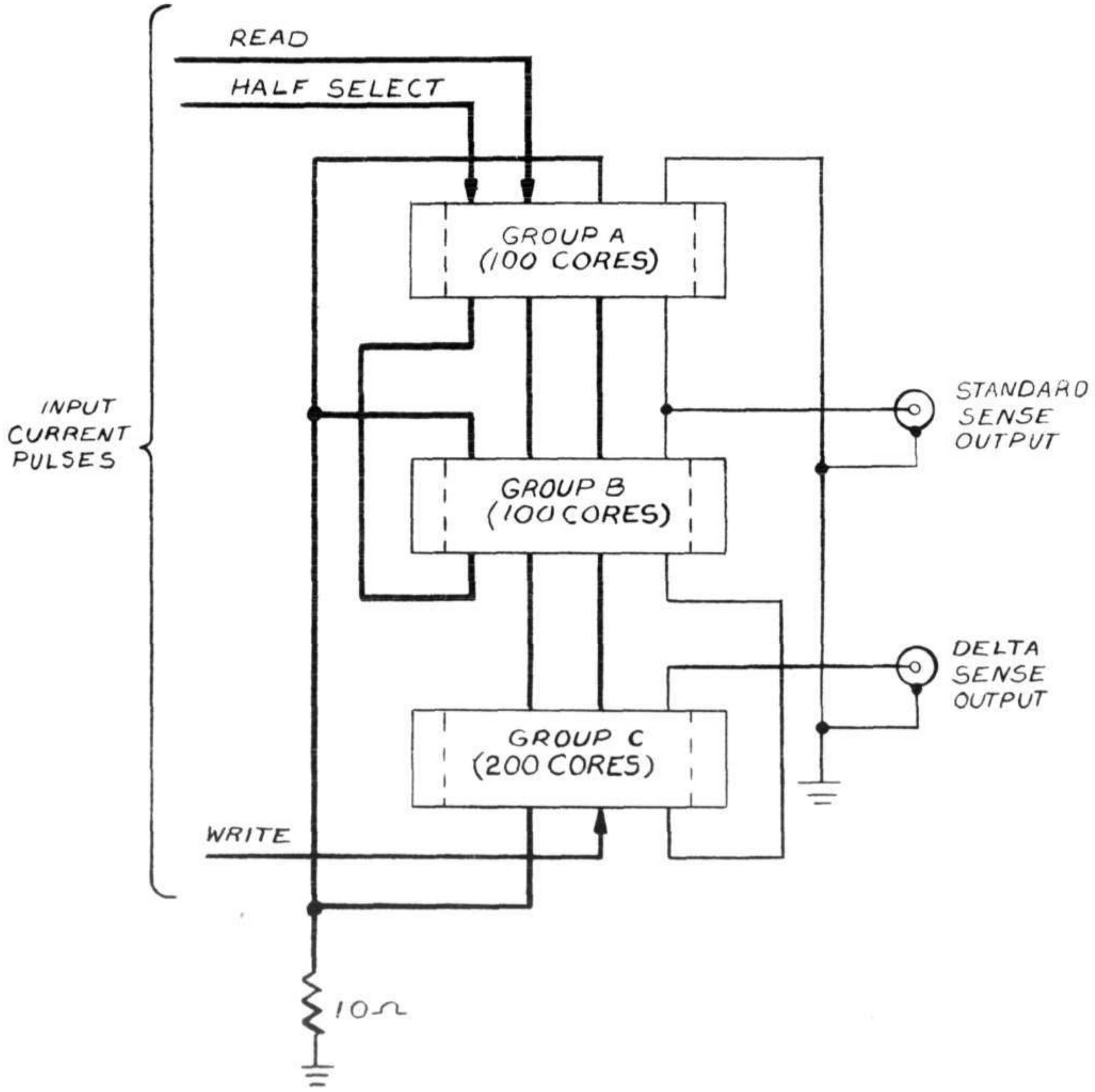

FIG. 1
TEST BOARD SCHEMATIC
FOR
DELTA MEASUREMENT

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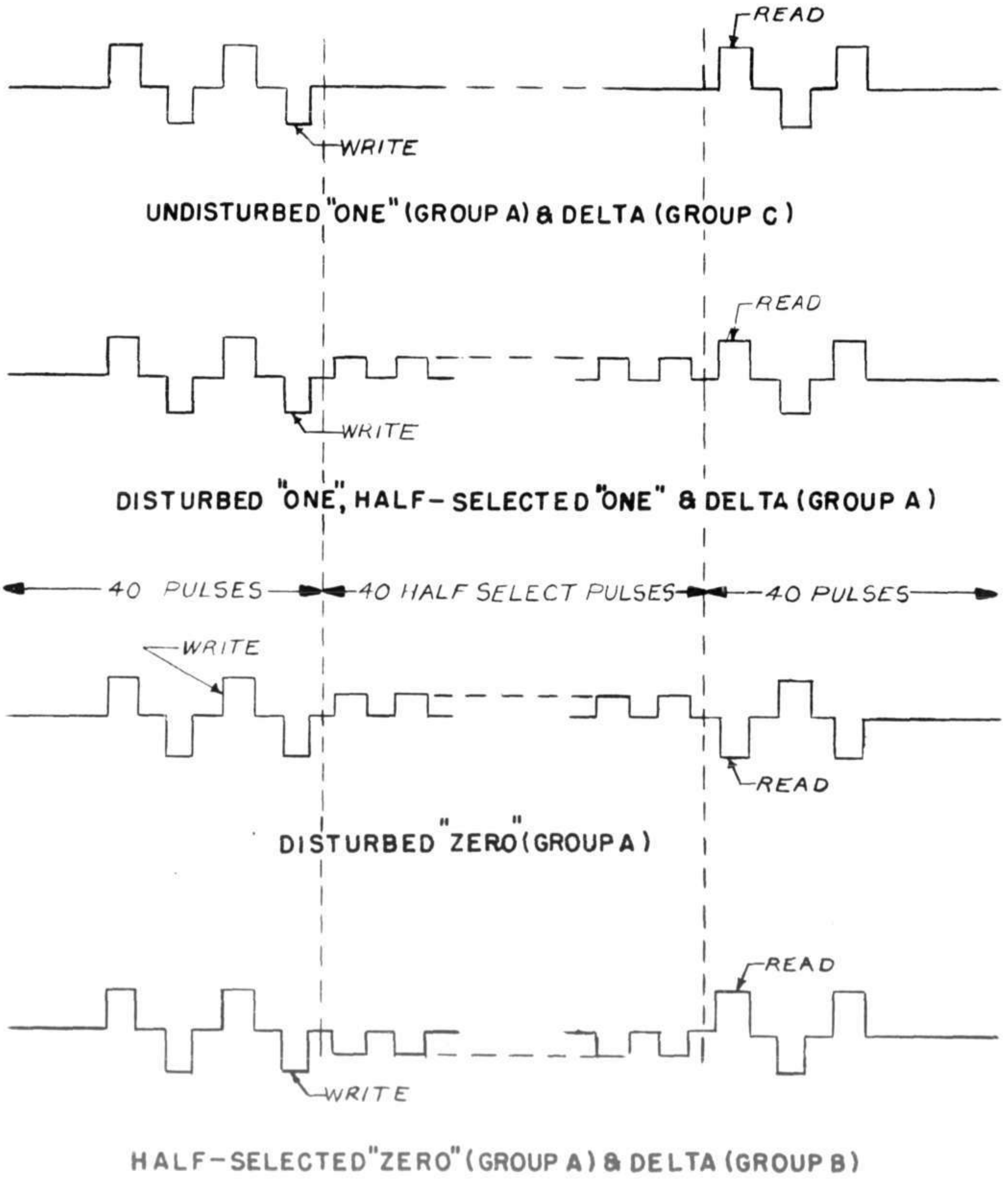

FIG. 2
INPUT CURRENT PULSE SEQUENCE

A-5412

-54160

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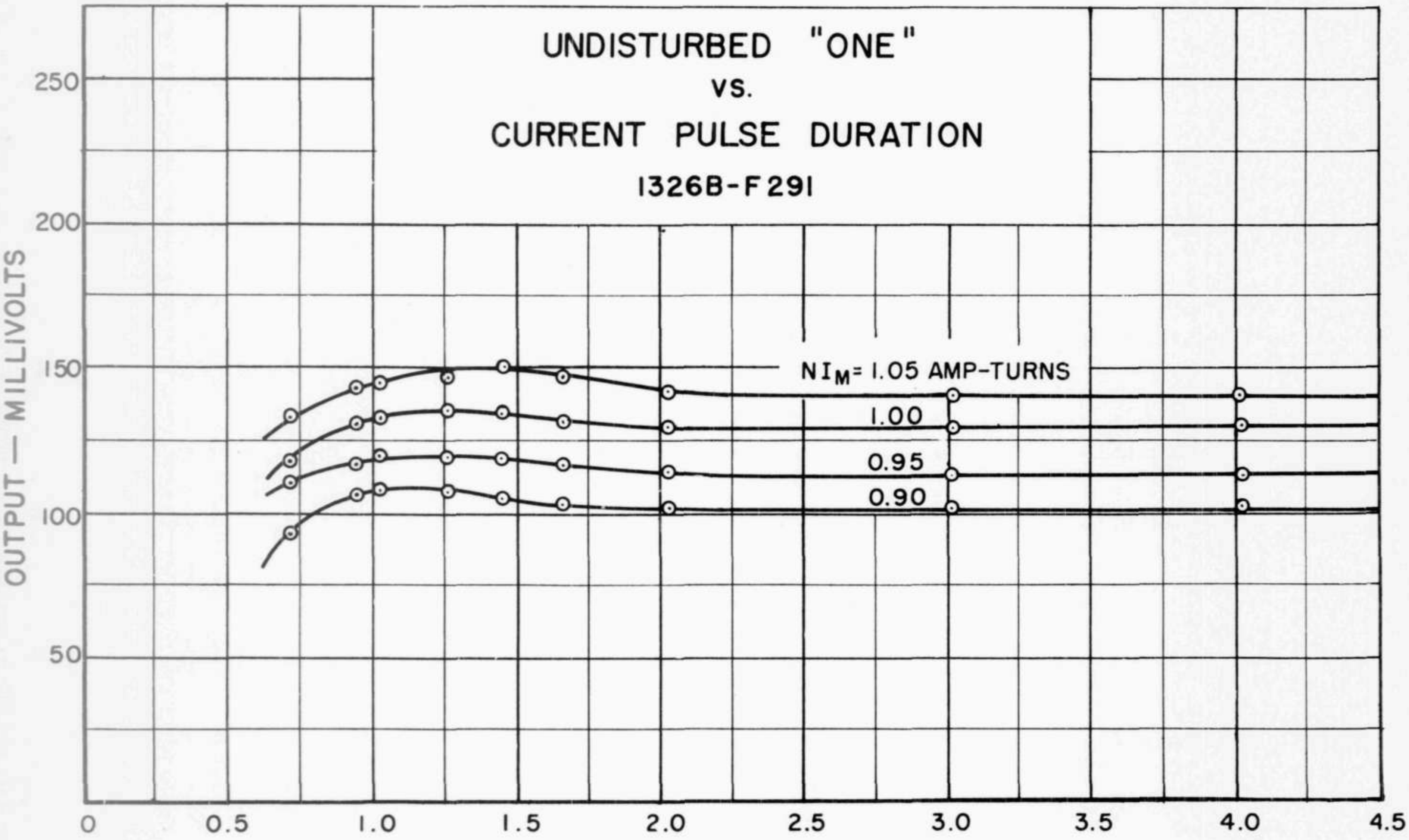
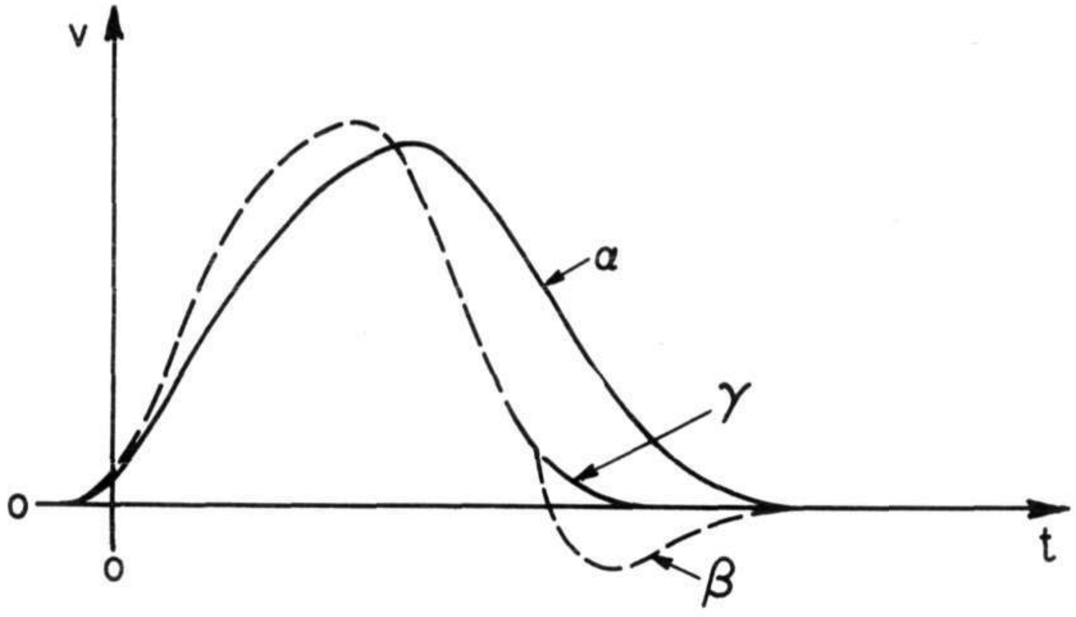
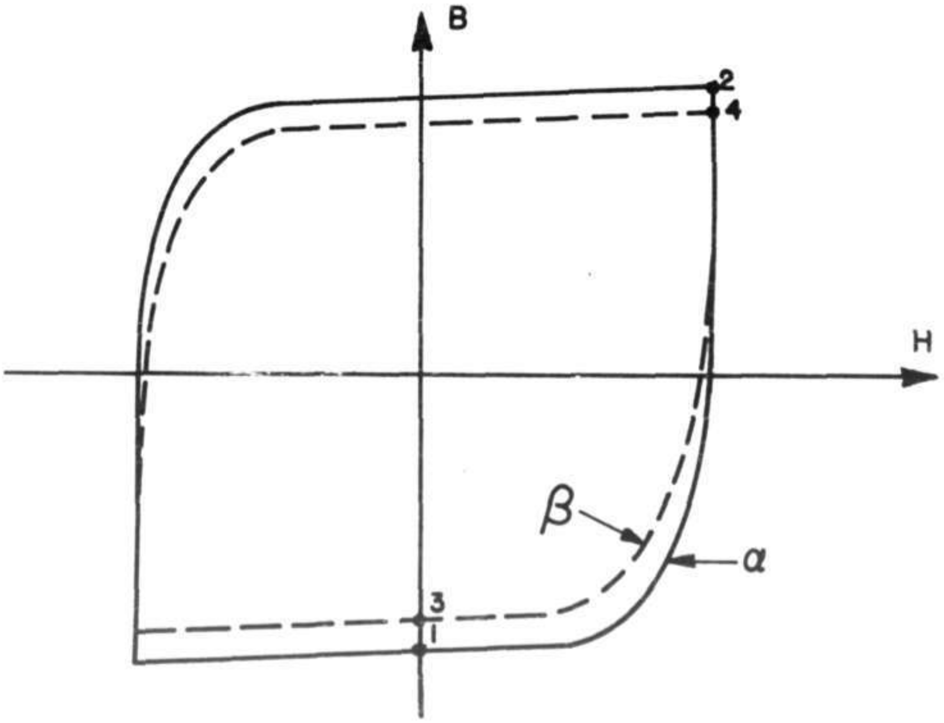


CURRENT PULSE DURATION — μ SEC

FIG. 3



TYPICAL UNDISTURBED "ONE" OUTPUT



TYPICAL DYNAMIC HYSTERESIS LOOP

FIG. 4

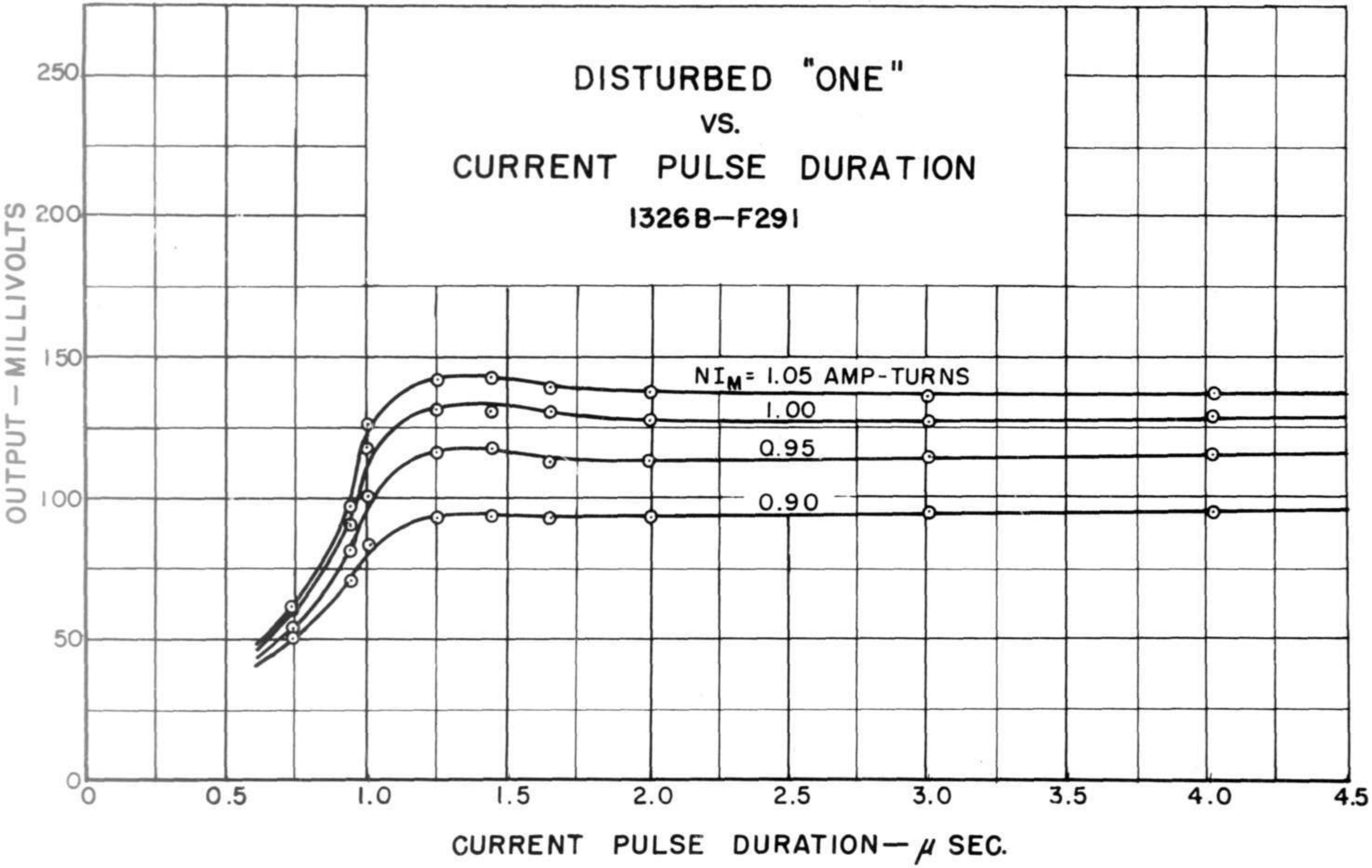

DISTURBED "ONE"
VS.
CURRENT PULSE DURATION
1326B—F291
NI$_M$= 1.05 AMP-TURNS
1.00
0.95
0.90
OUTPUT — MILLIVOLTS
0
50
100
150
200
250
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
CURRENT PULSE DURATION— μ SEC.

FIG. 5

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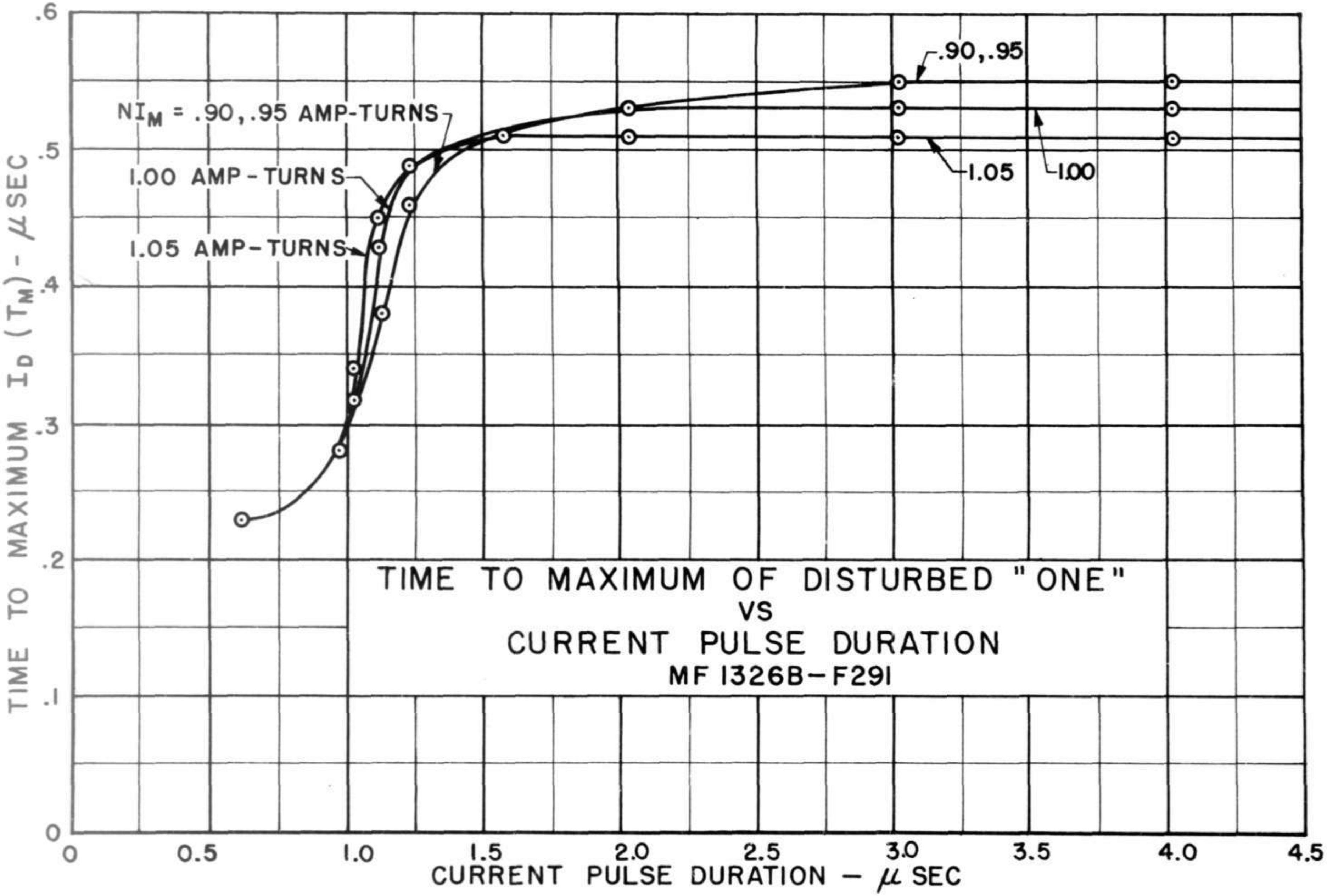

TIME TO MAXIMUM OF DISTURBED "ONE"
VS
CURRENT PULSE DURATION
MF 1326B-F291

FIG. 6

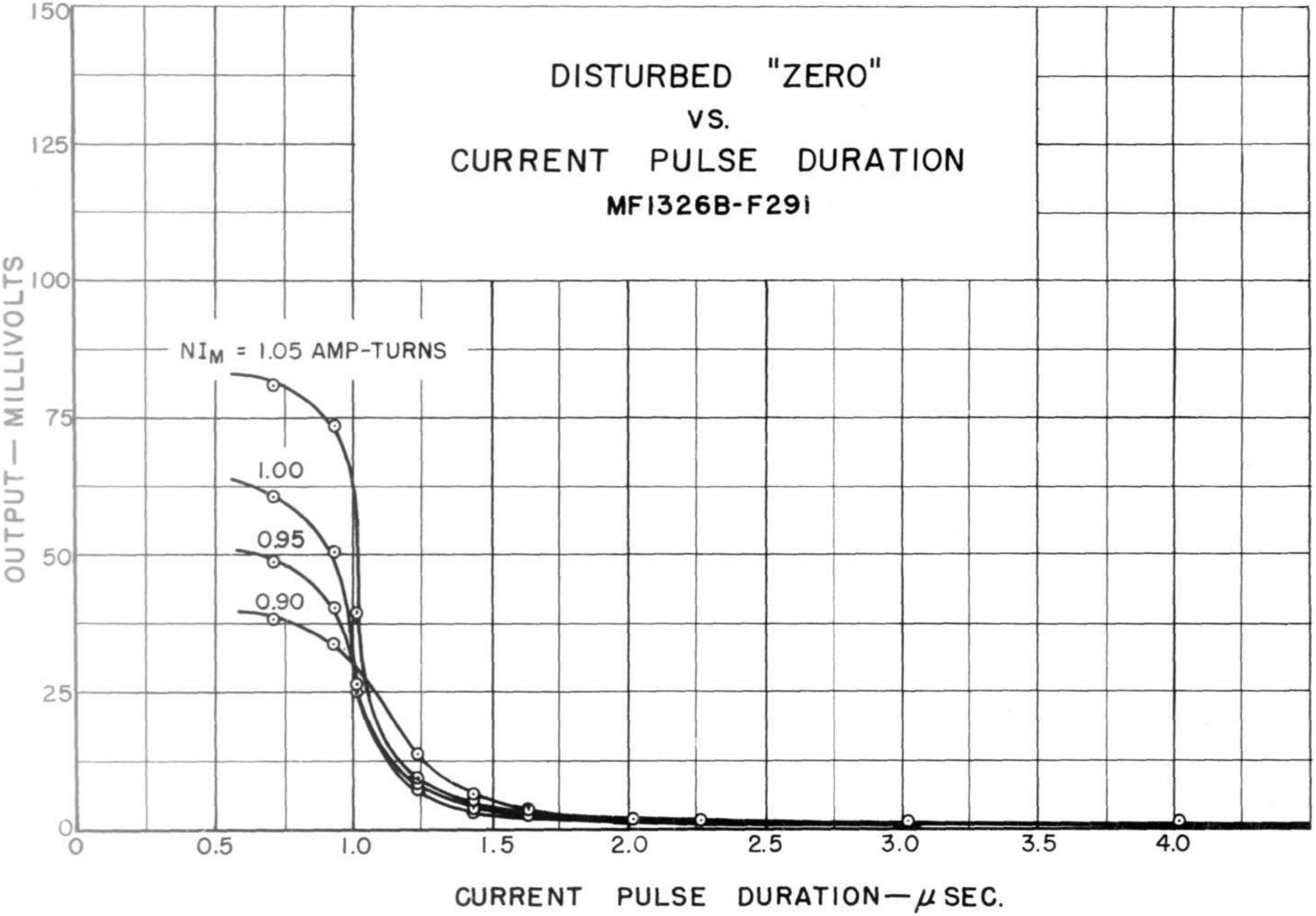
DISTURBED "ZERO"
VS.
CURRENT PULSE DURATION
MF1326B-F291
NI_M = 1.05 AMP-TURNS
1.00
0.95
0.90
OUTPUT — MILLIVOLTS
0
25
50
75
100
125
150
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
CURRENT PULSE DURATION — μ SEC.

FIG. 7

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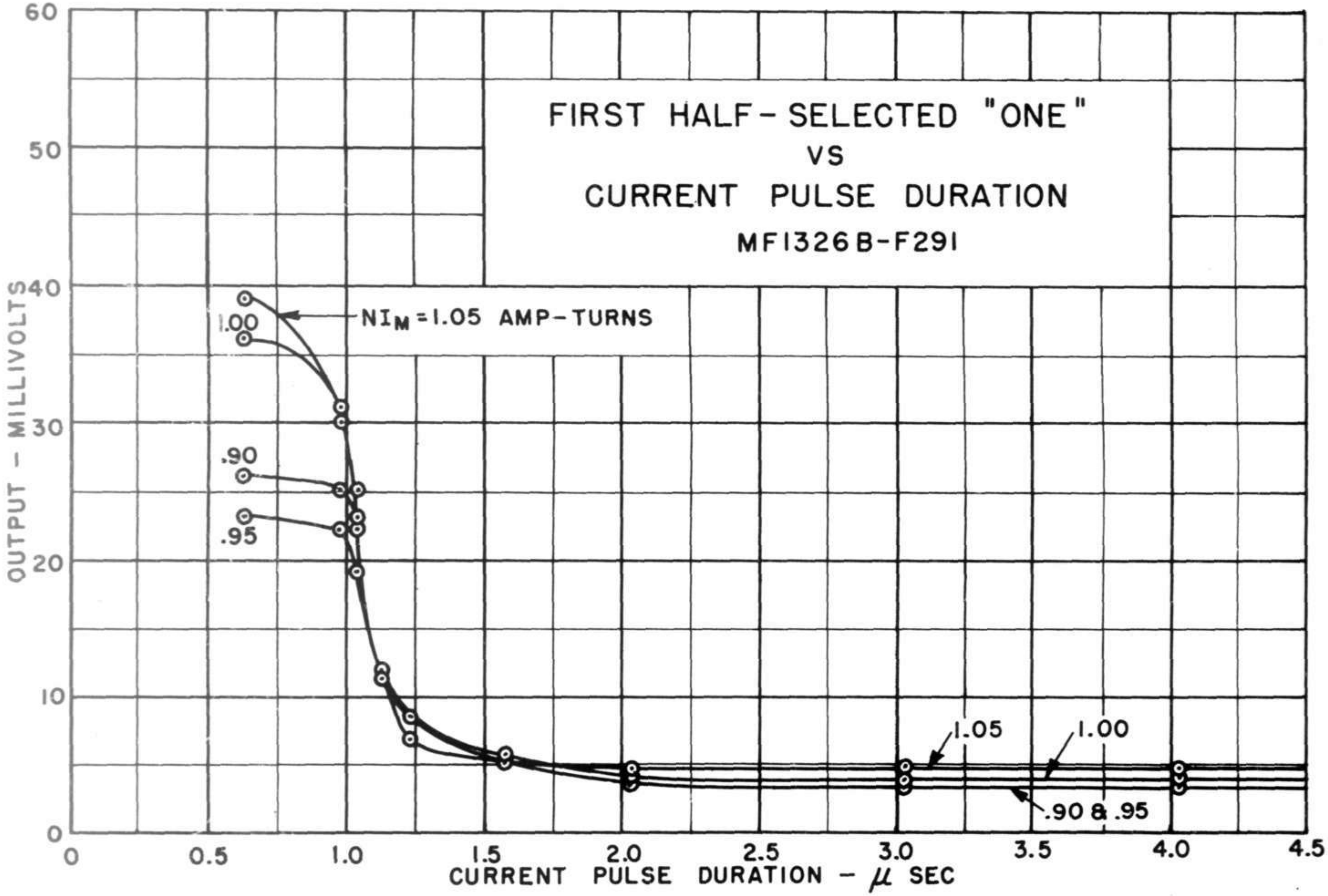

FIG. 8

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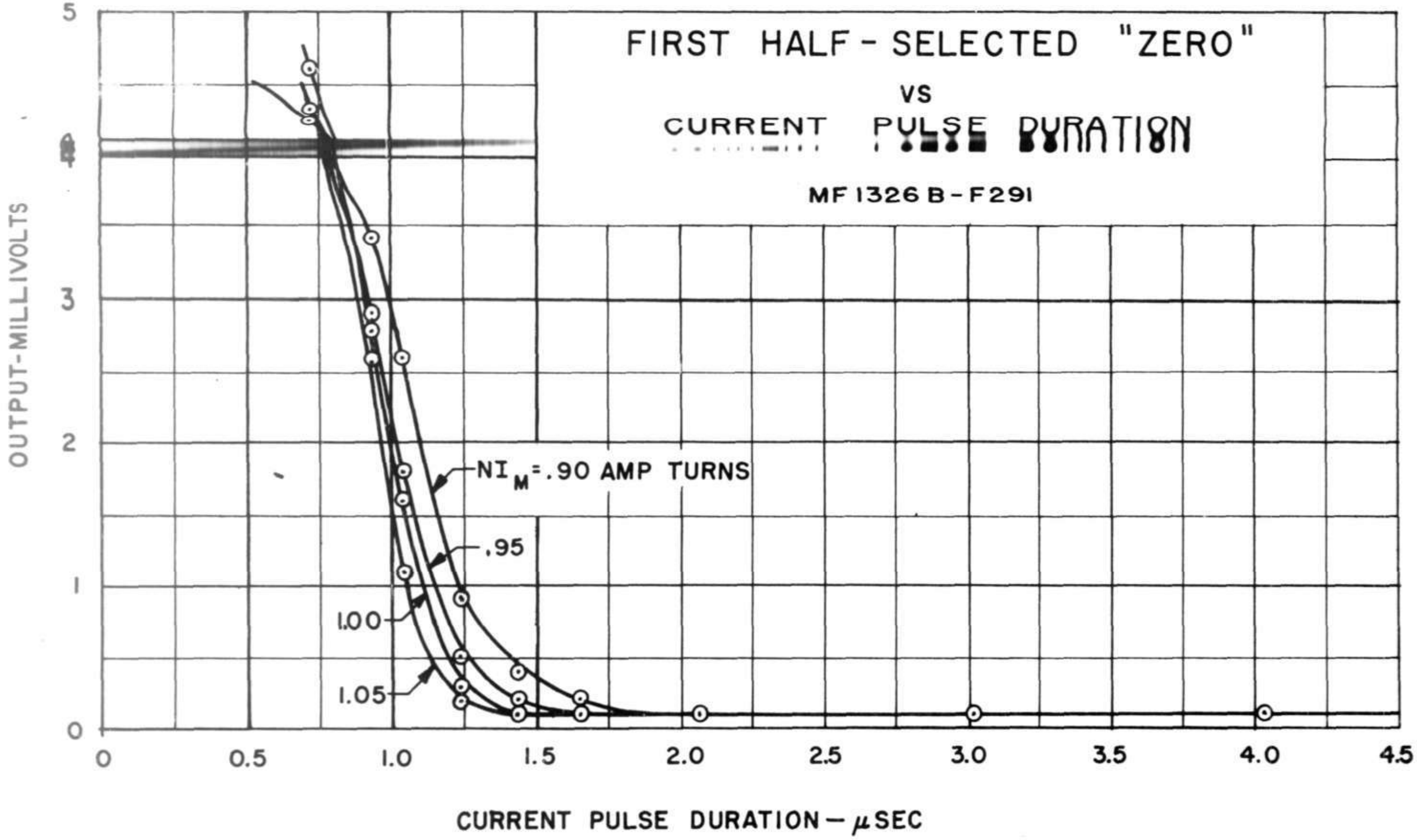

FIG. 9

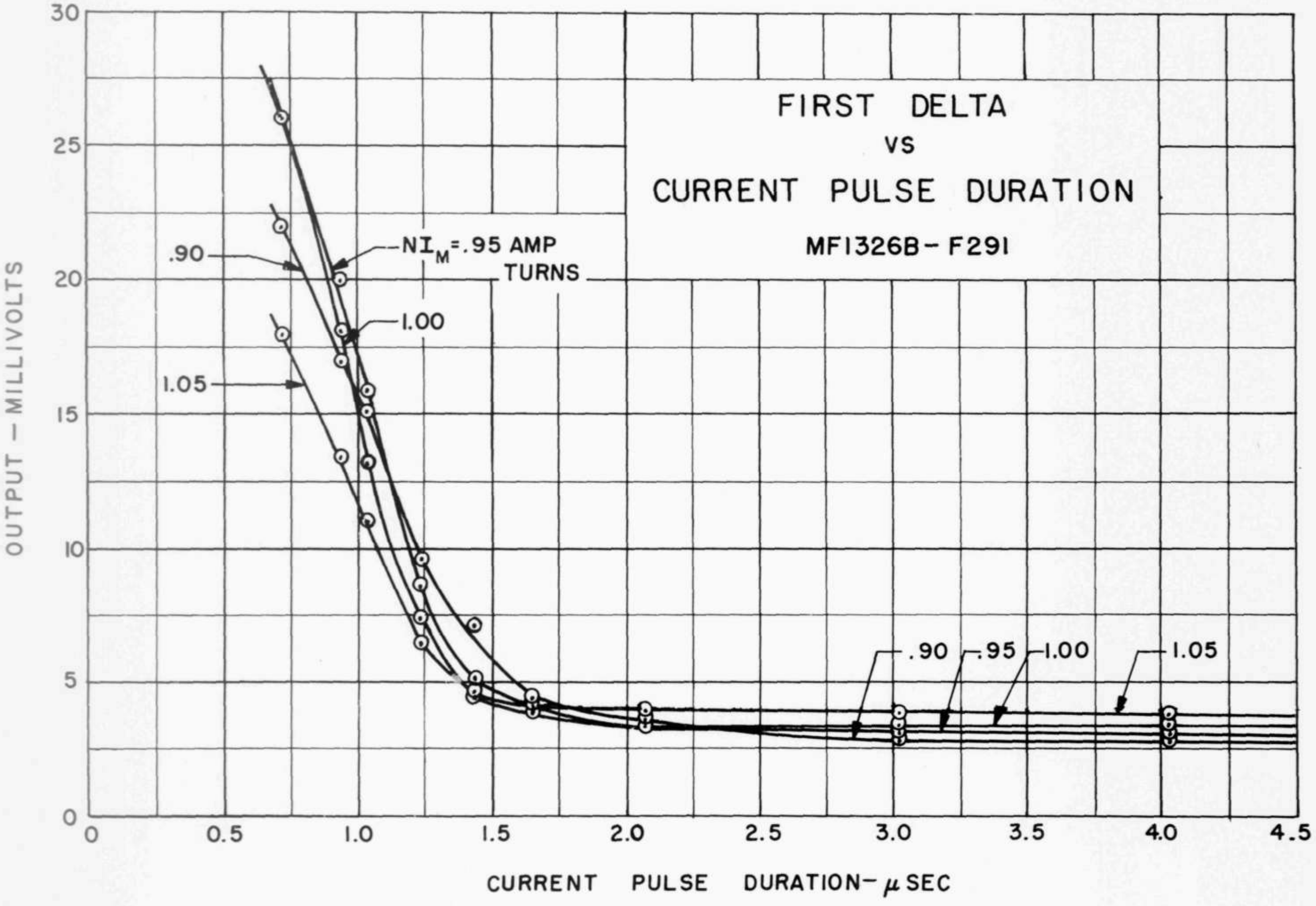
FIRST DELTA
VS
CURRENT PULSE DURATION
MF1326B-F291
NI_M=.95 AMP TURNS
.90
1.00
1.05
.90
.95
1.00
1.05
OUTPUT — MILLIVOLTS
0
5
10
15
20
25
30
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
CURRENT PULSE DURATION—μSEC

FIG. 10

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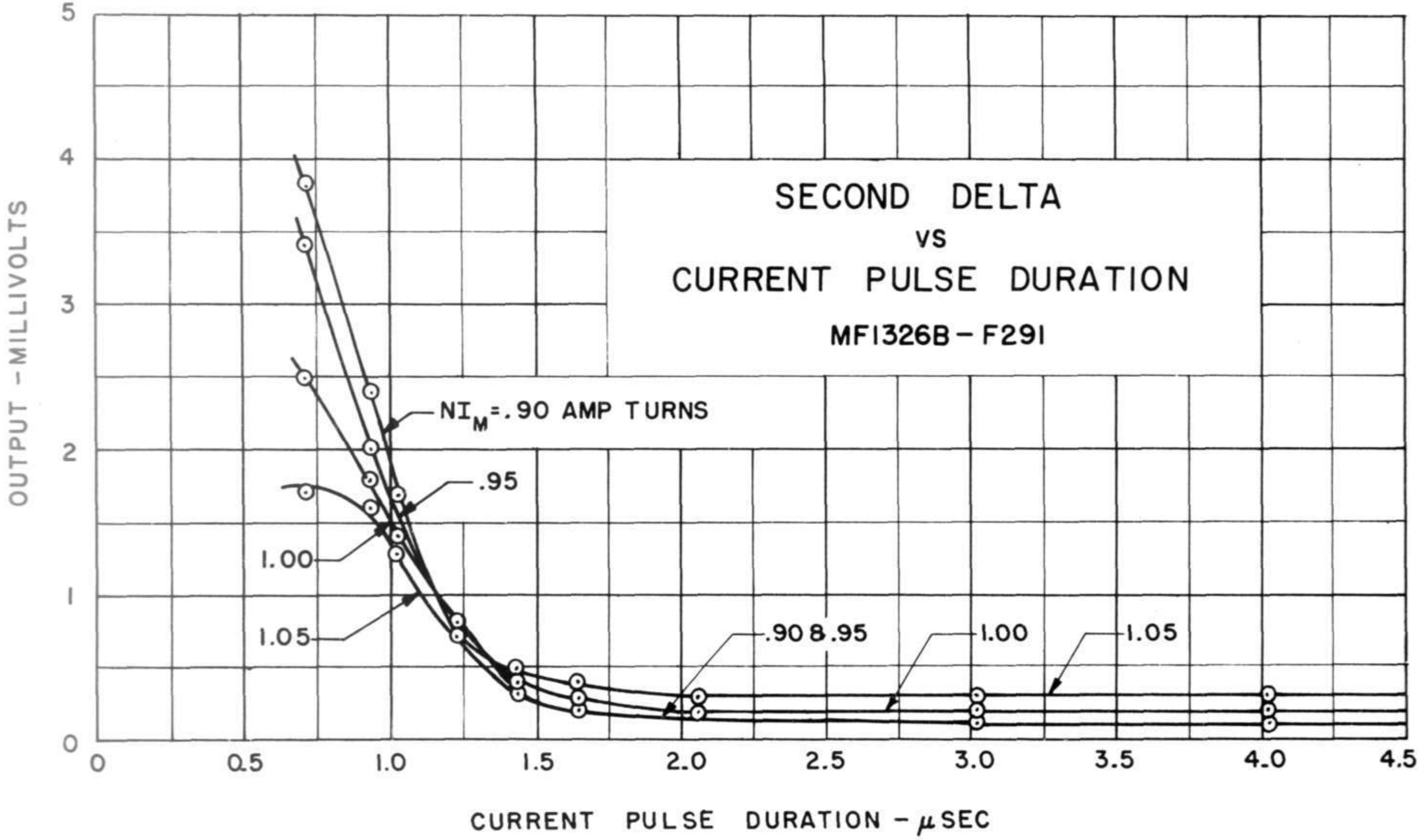

FIG. 11

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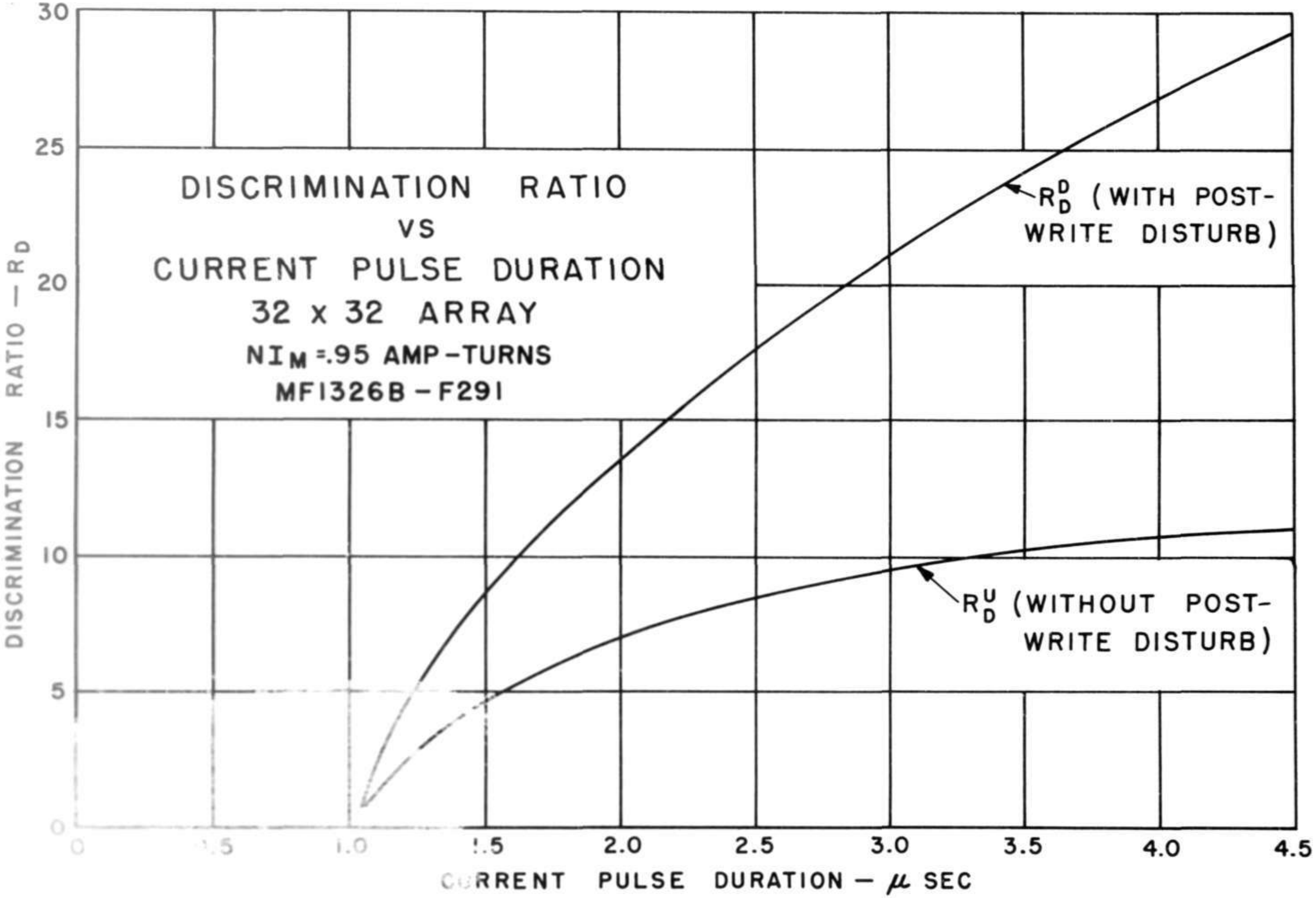

FIG. 12

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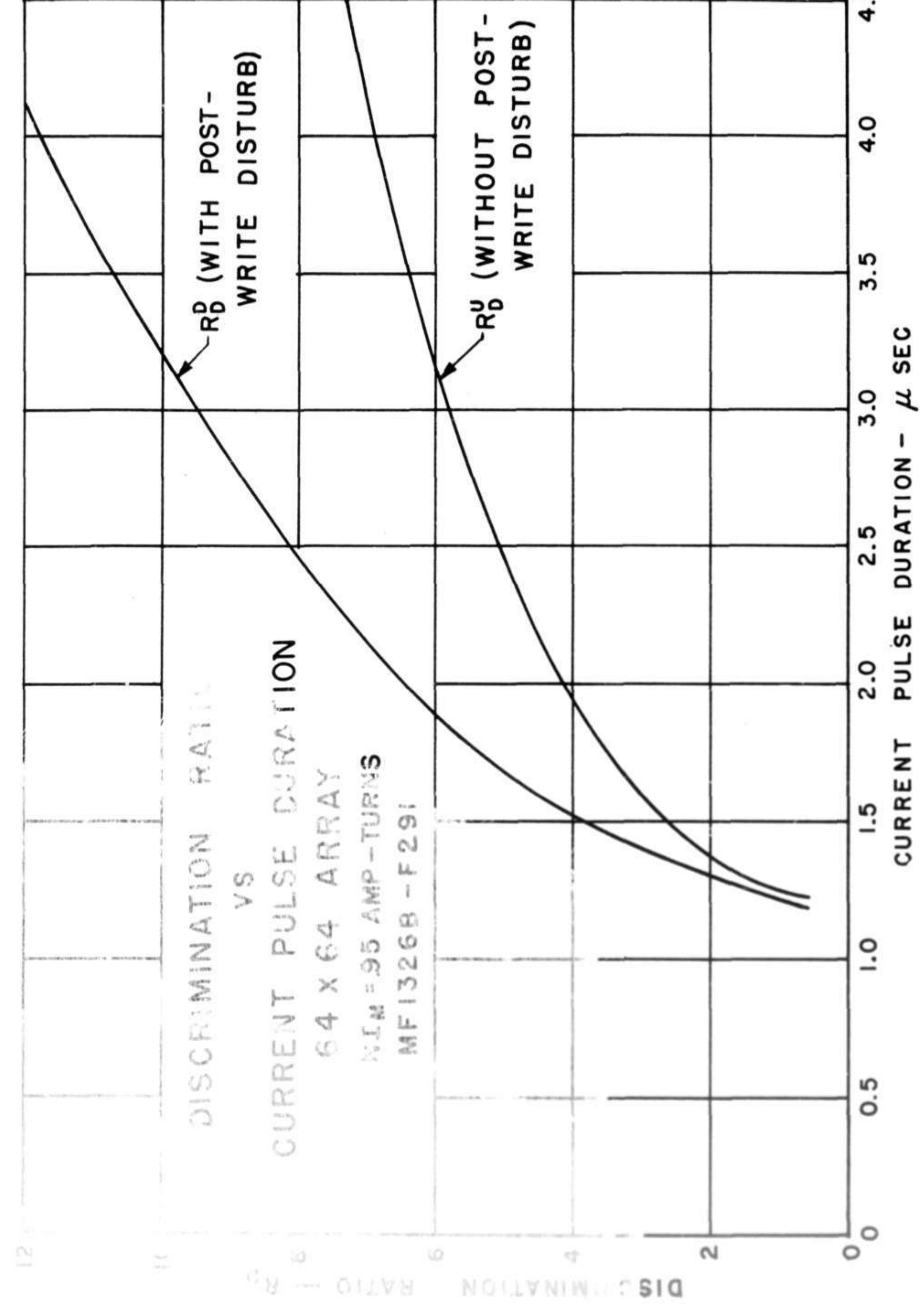

FIG. 13

A-54171