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U.S. NAVAL AIR DEVELOPMENT CENTER
JOHNSVILLE, PENNSYLVANIA

ENGINEERING DEVELOPMENT LABORATORY
Report Number NADC-ED-6029 14 December 1960

Digital Transducer Research Program 5935-M
First Annual Progress Report

Bureau of Naval Weapons
TED Project ADC-RS-7045

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SUMMARY

INTRODUCTION

There are two good reasons for digitizing signals which represent some physical dimension that exists continually in time and space. First, data in digital form are required by digital control computers and by digital data logging, data reduction, and data transmission equipment. Second, digital data can be stored for any length of time, transmitted over any distance, retransmitted, detected, and read as many times as necessary with no loss in accuracy. Analog signals are distorted by each of these processes and accuracy is lost. From the standpoint of accuracy, if data are to be digitized at all, the digitizing should be done as near as possible to the point of measurement, and preferably within the transducer itself.

The U. S. Naval Air Development Center (NAVAIRDEVCEN) initiated a research program to investigate the feasibility of a true digital transducer. A true digital transducer is defined as an instrument which measures physical motion and quantities and transmits the information in the form of discrete coded signals rather than as continuously varying analog currents and voltages. Such transducers are generally available for rotary motion (shaft position encoders) but not for small rectilinear movements.

SUMMARY OF RESULTS

A method was conceived to transform transducer rectilinear motion into a parallel binary pulse code by magnetic reluctance techniques. This noncontact technique generates digital signals representing the mechanical displacement of a magnetic armature, by successively altering the state of a matrix of magnetically permeable wire rods. The rods of the matrix are inductively coupled to the armature by an alternating or pulsed magnetic field. Sense windings about the rods are cross-connected to provide the desired code. Gray or natural binary digital codes can be provided.

Several psuedotransducer models were fabricated to demonstrate the feasibility of the magnetic technique. The first model provided an output of three binary digits for a rectilinear motion of three-quarters of an inch. The maximum output signal from this model was 0.5 millivolt. In later models, the three binary digits were provided for a rectilinear motion of one thirty-second of an inch, and the maximum output signal was increased to 20 millivolts.

Basic investigations revealed that: (1) The sense windings must be positioned as close as possible to the armature end of the rod; (2) a binary "one" and a binary "zero" can be generated simultaneously on the same rod; and (3) the armature signal is inductively coupled to the matrix through the magnetic rod and detected by the sense winding.

Detailed investigations of the magnetic reluctance technique revealed the following facts:

1. The matrix signal output varies logarithmically with the number of turns in the sense winding and the excitation signal amplitude.

2. The optimum matrix signal output was obtained from rods of Permalloy, a high-permeability alloy consisting of 79 percent nickel, 17 percent iron, and 4 percent molybdenum.

3. The matrix output varies exponentially with armature-matrix clearance.

4. The matrix output is not seriously affected by the sense winding wire size, excitation signal frequency, or pulse width.

5. A plot of the matrix output versus armature displacement indicates that the binary "zero" appears as a momentary point rather than a well defined segment. This transition results in ambiguous binary coded signals.

CONCLUSIONS

The basic investigations indicate that the magnetic reluctance technique can provide discrete signals in response to the movement of an a.c.- or pulse-excited armature across the face of a matrix of magnetically permeable rods. The matrix output signals are weak and an amplifier will be required in order to provide usable signals.

For optimum operation, matrices will be fabricated with Permalloy rods wrapped with sense windings of 32 turns each.

The matrix configuration which provides three-level voltage signals is inadequate because the binary "zero" is defined as a momentary point rather than as a clearly defined segment.

RECOMMENDATIONS

A practical, rectilinear-motion digital transducer should provide a minimum output of seven binary digits and have an accuracy of plus or minus one binary digit. The instrument should also be capable of providing an output signal which can be used directly by digital processing or control equipment. The following program is recommended to determine if the magnetic reluctance principle can provide the desired characteristics:

1. Investigate a matrix configuration which will generate two-level voltage signals in order to provide a digital output signal with a clearly defined binary "zero."

2. Investigate the use of multilayer matrices to provide increased resolution and capacity. This can be accomplished by designing and fabricating a basic single-layer matrix and then stacking the layers to provide the desired results.

3. Investigate the design and use of a multihead armature to provide increased resolution from simplified matrices by using a vernier armature-matrix approach.

4. Investigate new armature designs and configurations in order to provide larger output signals from the matrix.

5. Apply a confirmed technique to a displacement-type transducer.

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LITERATURE SURVEY

The Digital Transducer Research Program commenced with a comprehensive review of the state-of-the-art of digital transducer developments and their principles of operation. A bibliography of the reports which appeared useful is presented at the end of this report. Several important facts were revealed as a result of this study. First, with the exception of the well-known shaft position encoder, no true digital transducers were found. Second, the Rosemount Aeronautical Laboratories, University of Minnesota, completed the design and development of a digital pressure gage in 1954. This gage is a diaphragm-type pressure gage in which the capacitance between parallel plates is made to vary with applied pressure. This variable capacitance is associated with an oscillator to provide a frequency output which is a function of pressure. The frequency is counted over a fixed time interval to provide a digital number. This type device cannot be considered as a true digital transducer. Third, the Aerial Measurements Laboratory, Northwestern University, has a current study project to investigate the nature of digital transducers, their principles of operation, and user requirements. Fourth, Radio Corporation of America laboratories and Towson Laboratories are engaged in the design and development of digital transducers; their work, however, is of a proprietary nature and details of their developments are not available.

TRANSDUCER SURVEY

An investigation of the nature of analog transducers was conducted as part of this project. This study permitted the establishment of two basic categories for displacement-type transducers: those transducers exhibiting rectilinear displacement, and those exhibiting rotary displacement. The maximum rectilinear displacement presented is three-sixteenths of an inch; the maximum rotary displacement presented is 360 degrees or multiples thereof. Since rotary displacement can be represented in digital form by a shaft position encoder, the NAVAIRDEVCEN efforts were devoted to representing the rectilinear displacement of transducers in digital form.

DIGITAL TRANSDUCER TECHNIQUE

A unique method to transform rectilinear displacement into a parallel binary pulse code by magnetic reluctance techniques was conceived. This noncontact technique generates digital signals representing the mechanical displacement of an electromagnetic armature, by successively altering the state of a matrix of magnetically permeable wires or rods. The rods of the matrix are inductively coupled to the armature by an alternating or pulsed magnetic field. Windings about the rods are cross-connected to provide the desired code. Gray or natural binary digital codes can be provided.

This magnetic technique employs the variation in the magnetic field strength about the armature and the binary-connected sense windings in the matrix to generate three-level voltage signals. The positive and negative peaks can be arbitrarily designated as binary "ones" and the null designated as a binary "zero." The signals are generated in response to the movement of an a.c.-excited electromagnetic armature across the matrix of magnetically permeable rods. The series-connected sense windings about the rods form a coded pattern which provides a binary representation of the rectilinear displacement of the armature.

THEORY OF OPERATION

The basic operating principles of the magnetic reluctance digital transducer are shown in figure 1. The ferrite rods and the associated sense windings form the matrix, which is positioned so that the ends of the magnetically permeable rods are exposed to the magnetic field generated by the excited armature. The magnetic field is large enough to encompass the entire matrix regardless of the armature position. The total signal induced in the series-connected sense windings is the algebraic sum of the signals induced in the individual sense windings. The sense windings are located on alternate rods and interconnected so that successive windings are opposite in polarity.

When the armature is aligned with a rod containing a sense winding, the magnetic field about this rod is increased. This results in increased magnetic induction and a strong signal in the sense winding about the rod. Positive and negative signals in proportion to the magnetic field illustrated in figure 2 are induced in the sense windings on the remaining rods. The algebraic sum of these signals results in an output signal having the polarity of the strongest induced signal. This signal corresponds to a binary "one." Depending upon the polarity of the armature-aligned sense winding, a binary "one" may be represented by a positive or negative signal. Logical circuitry on the output of the transducer will detect the presence of both signals and transform them into one signal representing a binary "one."

When the armature is aligned with a rod which does not contain a sense winding, the magnetic field about the rod is increased. There is, however, no winding to sense the increased induction in this rod. Positive and negative signals in proportion to the magnetic field illustrated in figure 2 are induced in the sense windings. The algebraic sum of these signals results in a zero or minimum output signal, which corresponds to a binary "zero."

The preceding paragraphs describe the principles of operation for one binary digit. The theory is applicable to successive binary digits, which are provided by adding to the matrix properly interconnected sense windings for each additional binary digit.

FEASIBILITY INVESTIGATION

Several rectilinear displacement-type pseudotransducers were fabricated to determine the feasibility of the proposed magnetic technique. The preliminary models demonstrated the feasibility of the technique, but were not indicative of the limits of resolution or capacity. In the original model, the armature was moved linearly across the ends of rods, forming the matrix as indicated in figure 1. In this configuration, the armature travel could not be maintained within the desired limits. To approach the desired limits of travel, the armature was made slightly larger than the matrix and then moved across the matrix at a small angle as indicated in figure 3. In this manner, the armature displacement could be reduced beyond the optimum matrix rod spacing.

A digital transducer employing these magnetic techniques is composed of an armature and a matrix. The armature generates an a.c. or pulsed magnetic field, as illustrated in figure 2, to provide inductive coupling between the armature and the matrix, and as the name implies, provides the basic analog displacement. The matrix generates coded output signals in response to the movement of the armature, to define the exact position of the armature within the limits of the matrix.

The original matrix was made up of eight rods, each containing sense windings which were interconnected so that windings on adjacent rods were in series opposition. The armature consisted of a magnetic pole piece, about which a coil and shielding had been wound. As the pulse-excited armature was moved across the matrix, a pulse train of alternate positive and negative pulses with a null between the pulses was generated. This was easily interpreted as the least significant digit of a binary code, and the positive pulse was arbitrarily designated as a binary "one," while the negative pulse was designated as a binary "zero."

The original matrix revealed several facts which were important in the fabrication of later matrices. First, the sense windings must be positioned as close as possible to the armature end of the rod in order to generate the maximum signal. This indicates that the armature field does not effectively penetrate the full length of the rod. Second, a binary "one" and a binary "zero" can be simultaneously generated on separate sense windings on the same rod. Third, the armature signal is inductively coupled to the matrix through the magnetic rod and detected by the sense winding. No signal is coupled to the sense winding without the rod.

A three-bit matrix composed of eight 0.010-inch-diameter No. 152 Alloy rods spaced 0.09375 of an inch apart, with three rows of sense windings, was constructed. The individual sense windings, consisting of 15 turns of No. 40 AWG enameled copper wire, were interconnected externally to provide the three rows of series-connected sense windings. A transistor amplifier connected to each row of sense windings elevated the 0.5-millivolt matrix output signal, which represents a binary "one," to a signal level capable of turning on an indicator lamp. The on-off combination of the three lamps indicated the position of the armature with respect to the matrix for an armature travel of 0.75 of an inch.

A second three-bit matrix with the same specification as the first, except that the rod spacing was 0.025 of an inch, was fabricated. With this configuration, a binary count of eight was obtained for an armature travel of seven thirty-seconds of an inch.

A wider armature was then designed and operated with the matrix rotated 82 degrees from the horizontal. In this configuration, it was possible to obtain a binary count of eight for an armature travel of one thirty-second of an inch. This matrix provided a satisfactory output in the natural binary and in the reflected binary or Gray codes.

After studying the output signals obtained during these preliminary tests, it was concluded that the resolution could be increased by arbitrarily designating the null between the pulses as a binary "zero" and the positive and negative pulses of the train as binary "ones." This was accomplished by positioning an inactive rod (one without a sense winding) between every two active rods. The inactive rod defines the mechanical location of the binary "zero." A rod may be considered active or inactive, depending upon which row of series-connected sense windings is observed. All additional matrices fabricated during this period employed this technique.

PROCEDURE FOR CONSTRUCTION OF THE MATRIX

1. A length of rod is mounted on each of the four semicircular discs of the matrix wiring jig illustrated in figure 4(a). A closeup view of the matrix is provided in figure 4(b).

2. The first semicircular disc is rotated 90 degrees and the sense winding wrapped around the center of the rod. The first disc is returned to its normal position, the second disc is rotated 90 degrees, and the sense winding is placed on this rod. The process is repeated until a sense winding is placed on each rod.

3. When the matrix wiring is completed, the matrix is transferred to the mold so that the rods are located in the slots and the sense windings in the channel as indicated in figure 4(a). A closeup of a single layer is shown in figure 4(c). The matrix rods are cut from the jig and the rods are used to secure the matrix in the mold.

4. The matrix is potted in an epoxy resin and a mold cover secured until the epoxy has set. The rods are then cut and trimmed and the matrix is removed from the mold.

5. Several of these basic matrices are made and stacked together. The fine sense-winding leads are connected to terminals and the entire device is repotted. When set, the face of the matrix is honed smooth and is ready for operation.

PROCEDURE FOR CONSTRUCTION OF THE ARMATURE

1. The core of the armature is cut to the desired size and configuration. Perfection Mica Company Conetic iron foil, 0.024 of an inch thick, has been used as the core material for the armatures.

2. The core is wrapped with 50 to 400 turns of No. 36 AWG enameled copper wire. Heavier leads are then attached to the windings.

3. The core and windings are covered with Conetic iron foil shield. The shield is separated from the tapered edge of the core by 0.001 of an inch. Gaps around the windings are potted for protection. Several of the armatures which were made are illustrated in figure 5.

EMPIRICAL INVESTIGATIONS

A series of empirical investigations to determine the optimum material and parameters of the matrix and armature were conducted. Various rod and sense-winding parameters were investigated in multirod and single-rod matrix configurations. As expected, higher output signals were experienced with the single-rod matrix configuration because of the cancelling effect resulting from polarity of the interconnected sense windings in the multirod matrix configurations. The armature investigation was limited to variations in the excitation signal and the armature-matrix clearance. A complete armature investigation will be conducted during the next period. The following paragraphs provide a detailed account of the empirical investigations.

Armature Tests

Experiments were carried out using various armatures to explore the effects of armature-matrix clearance and armature excitation pulse width on the matrix output.

Five armatures were evaluated. The output of a single active coil in a matrix resulting from various armature displacements is shown in figure 6. It can be seen that armature D provided the best output. The characteristics of the various armatures are shown in figure 5.

Armature D was aligned with a single active rod and sense winding in a matrix configuration. The sense-winding output was observed as the armature was gradually moved away from the matrix. Figure 7 illustrates the exponential curve resulting from this test. In all further tests, armature-matrix clearances were maintained at 0.001 of an inch.

With the armature aligned with the single active rod, the excitation pulse width was varied and the matrix output observed. Figure 8 represents the matrix output for rods of Permalloy and No. 142 Alloy. Since the output was not severely affected by pulse width, a 10-microsecond pulse was arbitrarily chosen.

Effect of the Number of Turns in the Sense Winding

Experiments were conducted to determine the effect of the number of turns in the sense winding on the matrix output, and to optimize the ratio of matrix output to number of turns in the sense winding. Single-rod matrices fabricated with sense windings of many magnitudes and configurations were subjected to the magnetic field from the same armature. The results of this test for constant armature excitation signals are illustrated by the series of logarithmic curves of figure 9. For convenience, the sense windings were limited to 32 turns. This provided a matrix output of approximately 20 millivolts.

Experiments were also conducted to determine the width of the effective magnetic field about single-rod matrices. Figure 10 reveals that the magnetic field is a distorted bell curve approximately 18 millimeters wide. These tests also revealed that the matrix output is increased by overlapping the turns in the sense winding.

Material Tests

Matrices were fabricated from the materials listed in table I to determine the effect these materials have on the matrix output. A single-layer, one-bit matrix was used for this demonstration. The matrix was fabricated so that the nine rods (four active, and five inactive) were removable. In this way, all samples were tested under the same conditions within the same matrix. During this test, the sense-winding output of each active rod was observed as the armature moved across the matrix. The matrix outputs for the various materials are shown in figures 11 through 15. These tests revealed that the optimum signal output was obtained using matrices constructed of Permalloy as illustrated in figure 15.

TABLE 1

Materials Tested

Material	Composition
Nilvar	31% Ni, 64% Fe, 5% Co
No. 142 Alloy	41% Ni, 59% Fe
No. 152 Alloy	51% Ni, 49% Fe
Permalloy	79% Ni, 17% Fe, 4% Mo
Iron	100% Fe

These tests were also conducted with the matrix interconnected to provide counting action as a function of armature displacement. The results of this action for the various materials are illustrated in figures 16 through 20, from which it can be seen that Permalloy (figure 20) provided the largest signal output.

The results of these tests also revealed that the binary "zero," which is represented by the output signal null, is clearly defined at the zero-crossing only. This condition makes it very difficult to provide an accurate digital output, but can be remedied by placing opposite polarity sense windings on adjacent rods. The magnetic field about the armature and binary-connected sense windings in the matrix will then be used to generate two-level voltage signals. The positive excursion of the output signal will be arbitrarily designated as a binary "one," and the negative excursion as a binary "zero." The resolution obtainable with this configuration is half of what was obtained with the original configuration. This matrix configuration will be investigated during the next period.

Sense-Winding Wire Size

Trials were made to determine if the wire size in the sense winding had any effect on the matrix output. Enameled copper wire Nos. 36, 40, and 44 AWG was used for these tests. Number 40 AWG copper will be used in the handmade matrices because it is easier to work with.

As the fabrication techniques are improved, the sense windings will be made from No. 44 AWG copper wire, or finer, in order to reduce the matrix size.

Excitation Signal Frequency

Tests were conducted to determine the effect of armature excitation signal frequency on the matrix outputs. The armature was excited with 15-volt, 10-microsecond pulses in the frequency range from 600 to 50,000 cycles per second, and no significant change was observed in the matrix output. Erratic operation was noted above 50,000 cycles per second. The device also performed satisfactorily when strobed with a single 15-volt, 10-microsecond pulse.

Rod Spacing

A single-layer matrix with 18 rods and 18 sense windings was constructed for the purpose of checking the effect of rod spacing on the matrix output. The sense windings were connected in series opposition for (1) every rod, (2) every second rod, (3) every third rod, and (4) every fifth rod. As the distance between the active rods was increased, the average matrix output varied in the following sequence: 12, 18, 22, and 24 millivolts.

Rod Length

One rather puzzling effect was noted during the first of a series of tests to determine the effect of rod length on the matrix output. As a No. 142 Alloy rod was decreased in length from 0.7 to 0.2 of an inch in small increments, it was observed that the matrix output varied parabolically and that the output was modulated by a distorted sinusoid, with maximum occurring at increments of 0.2 of an inch. The test was conducted using several other alloys, but the parabolic output was not modulated. When the test was repeated using No. 142 Alloy, the original conditions were not duplicated. It was, therefore, concluded that the modulated output is not normal matrix behavior and that the peculiar effect may have been caused by the heterogeneity of the rod material or the adhesion of magnetic particles to the rod. From the results of the tests, it was also concluded that the rod length should be at least 0.3 of an inch long.

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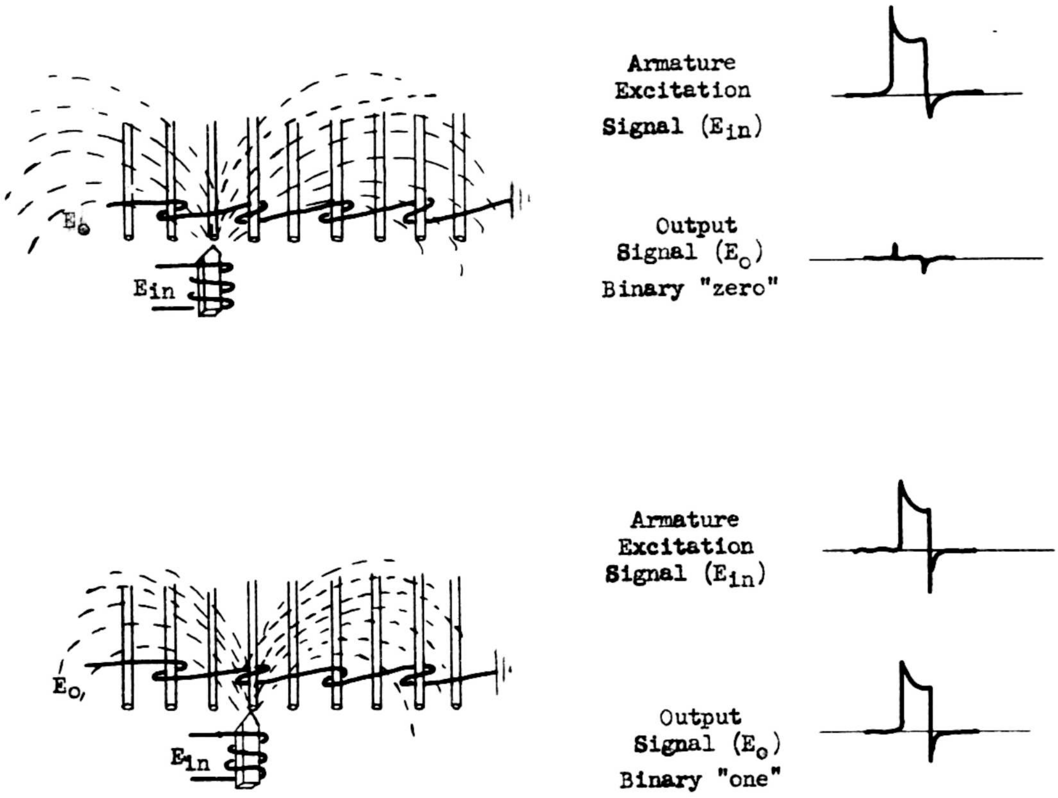


Figure 1
Digital Transducer

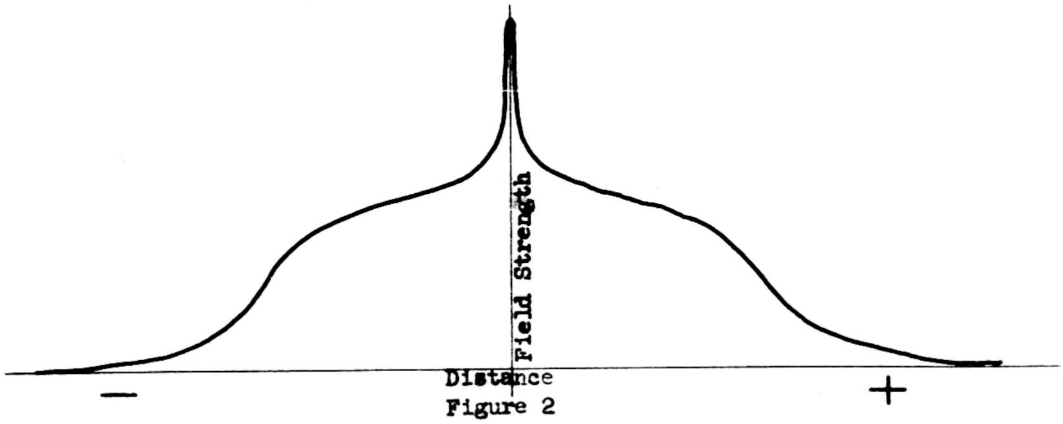
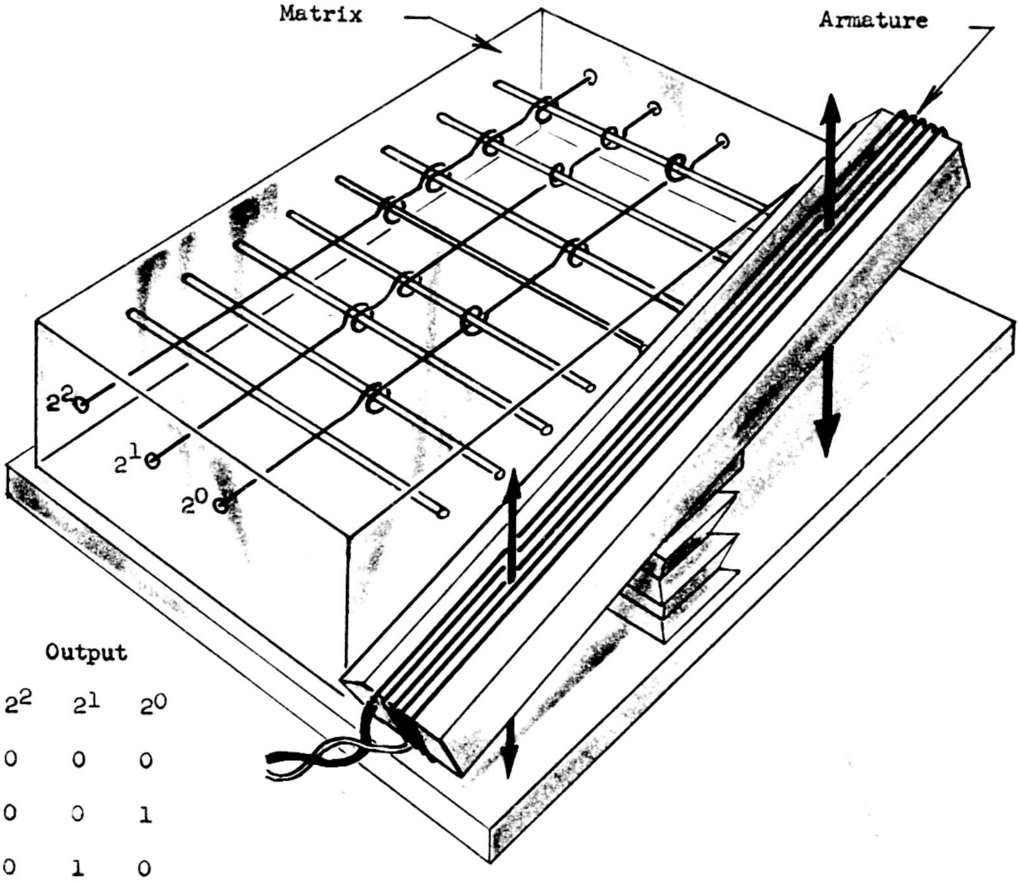


Figure 2

Magnetic Field Strength vs. Distance from Armature



Output		
2^2	2^1	2^0
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

Figure 3. Digital Transducer

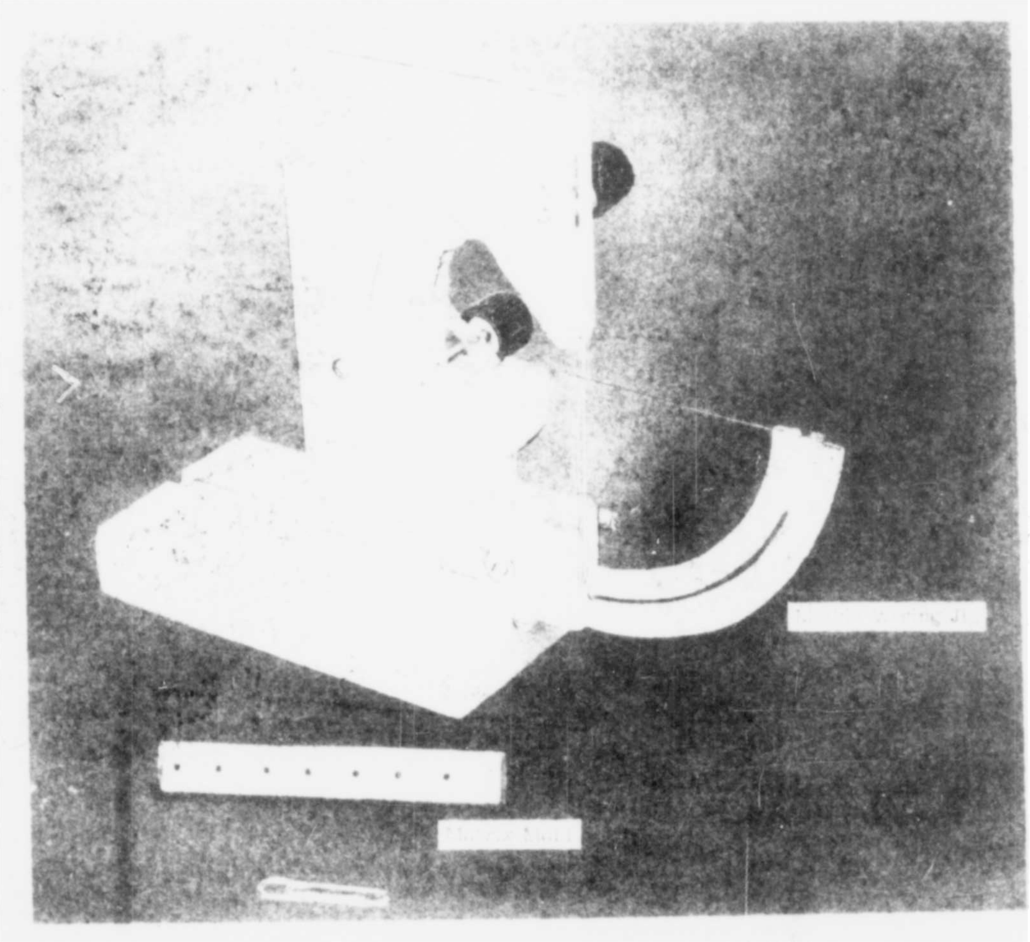


Figure 4(a). Matrix Wiring Jig and Mold

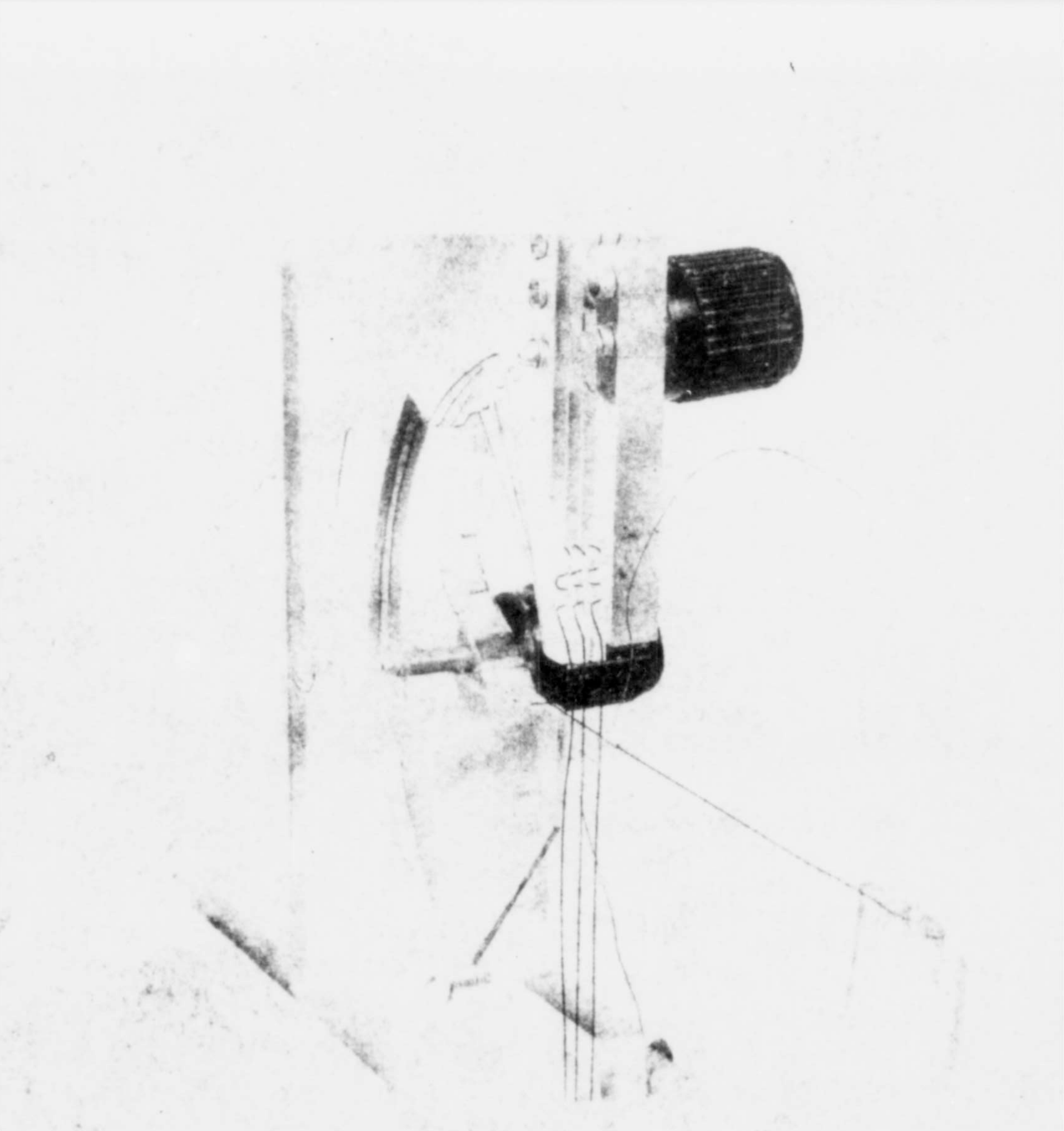


Figure 4(b). Matrix Wiring Jig

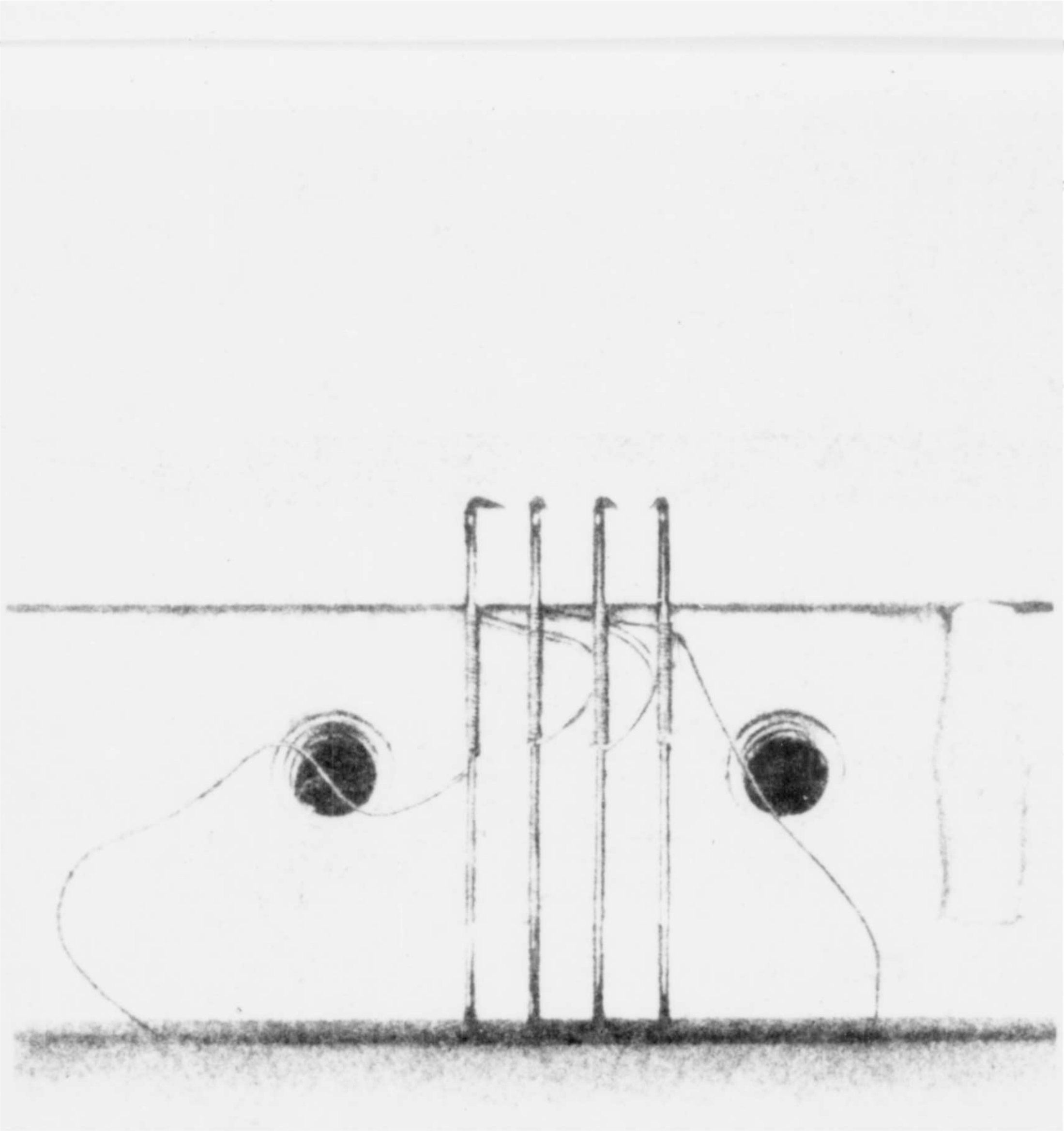


Figure 4(c). Matrix Mold

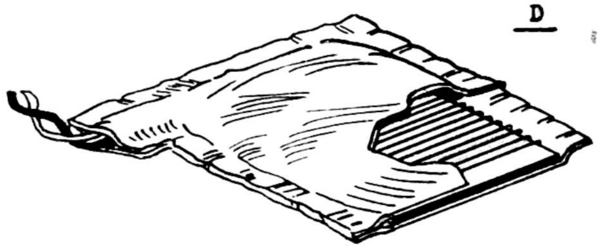
Armature D

Size: 5/8" x 5/8" x 1/8"

Core: Conetic 0.005" x 1/2" x 1/2"; tapered to 0.004" at active edge

Coil: 200 turns No. 36 AWG enameled copper wire; d.c. resistance 7 ohms

Shielding: Conetic 0.001" air gap between shield and core



Armature E

Size: 3/4" x 3/4" x 1/4"

Core" Conetic 0.025" x 3/4" x 5/8"; tapered to 0.001" at active edge

Coil: 300 turns No. 36 AWG enameled copper wire; d.c. resistance 10 ohms

Shielding: Conetic, tapered on outside; approx. 0.001" air gap between core and shield

Armature F

Size: 3/4" x 5/16" x 1/4"

Core: Conetic 0.025" x 1/2" x 5/16"; tapered to 0.004" at active edge

Coil: 250 turns No. 36 AWG enameled copper wire; d.c. resistance 7 ohms

Shield: Conetic; tapered on outside; approx. 0.002" air gap between core and shield

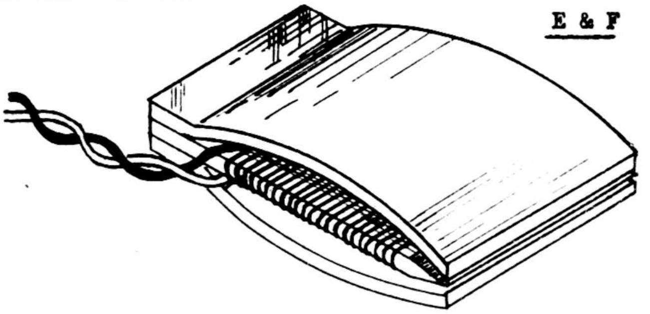


Figure 5. Armature Construction

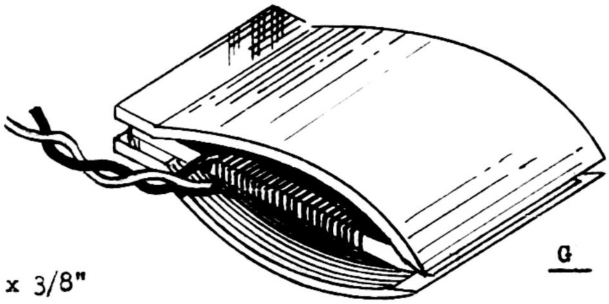
Armature G

Size: 3/4" x 3/4" x 1/4"

Core: Conetic 0.024" x 3/4" x 5/8"; tapered to 0.001" at active edge

Coil: 300 turns No. 36 AWG enameled copper wire; d.c. resistance 10 ohms

Shielding: Conetic; tapered on inside; approx. 0.003" air gap between core and shield



G

Armature H

Size: 1" x 3/4" x 3/8"

Core: Conetic 0.024" x 5/16" x 3/4" diameter; tapered to 0.004" at each active edge

Coil: 200 turns No. 36 AWG enameled copper wire, each active edge; total d.c. resistance 200 ohms

Shielding: Conetic; outside shield covers winding only; inside shield full-length.

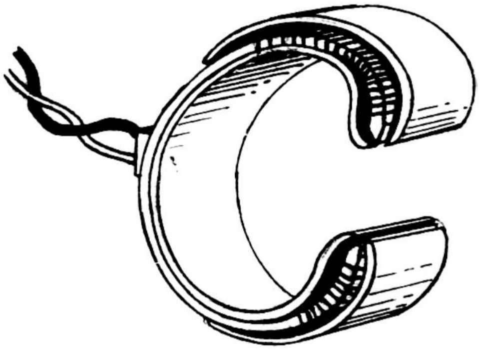


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Figure 5. (Continued)

Armature Input: 15 volts 10 microseconds

Armature Clearance: 0.001 inch

Armature Matrix Angle: 25 degrees

Matrix: Single Active Rod in 13-element matrix

Rod Material: No. 142 Alloy; 0.010 inch in diameter

Sense Windings: 17 turns No. 40 AWG copper wire

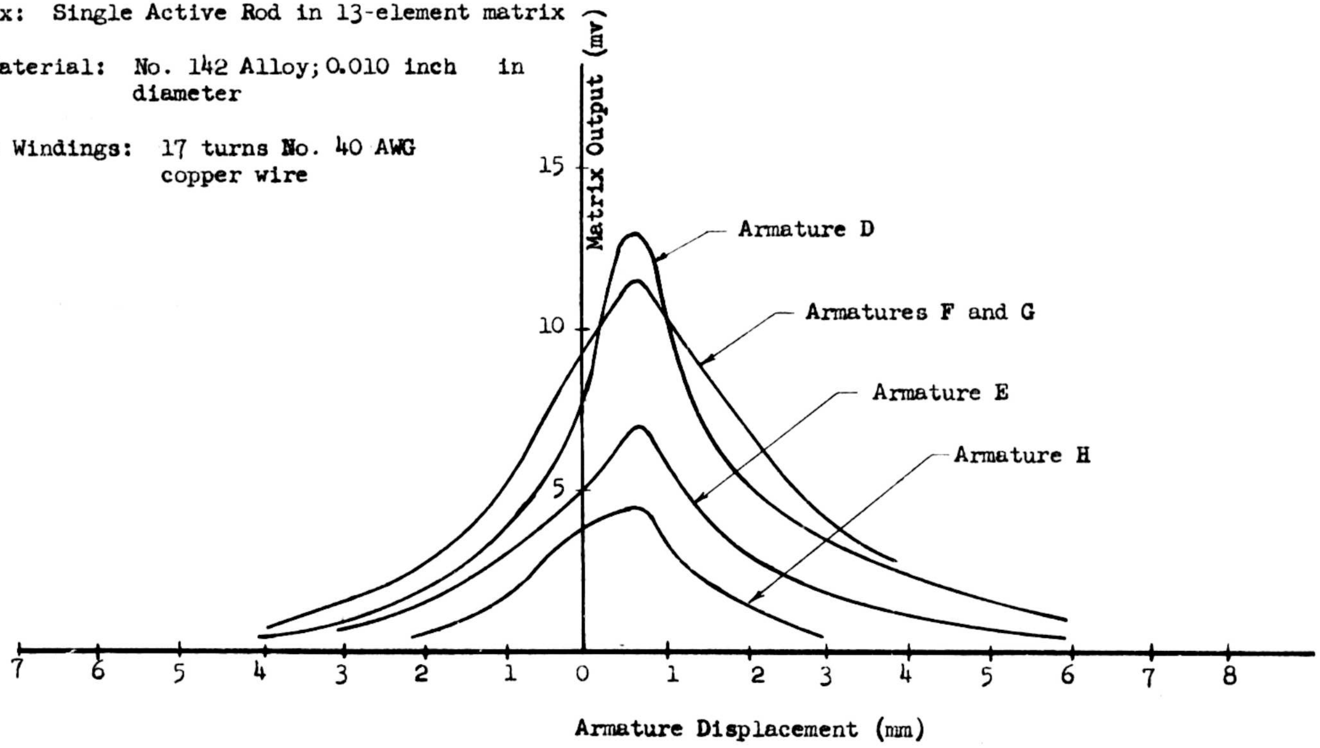


Figure 6. Matrix Output vs. Armature Displacement for Various Armatures

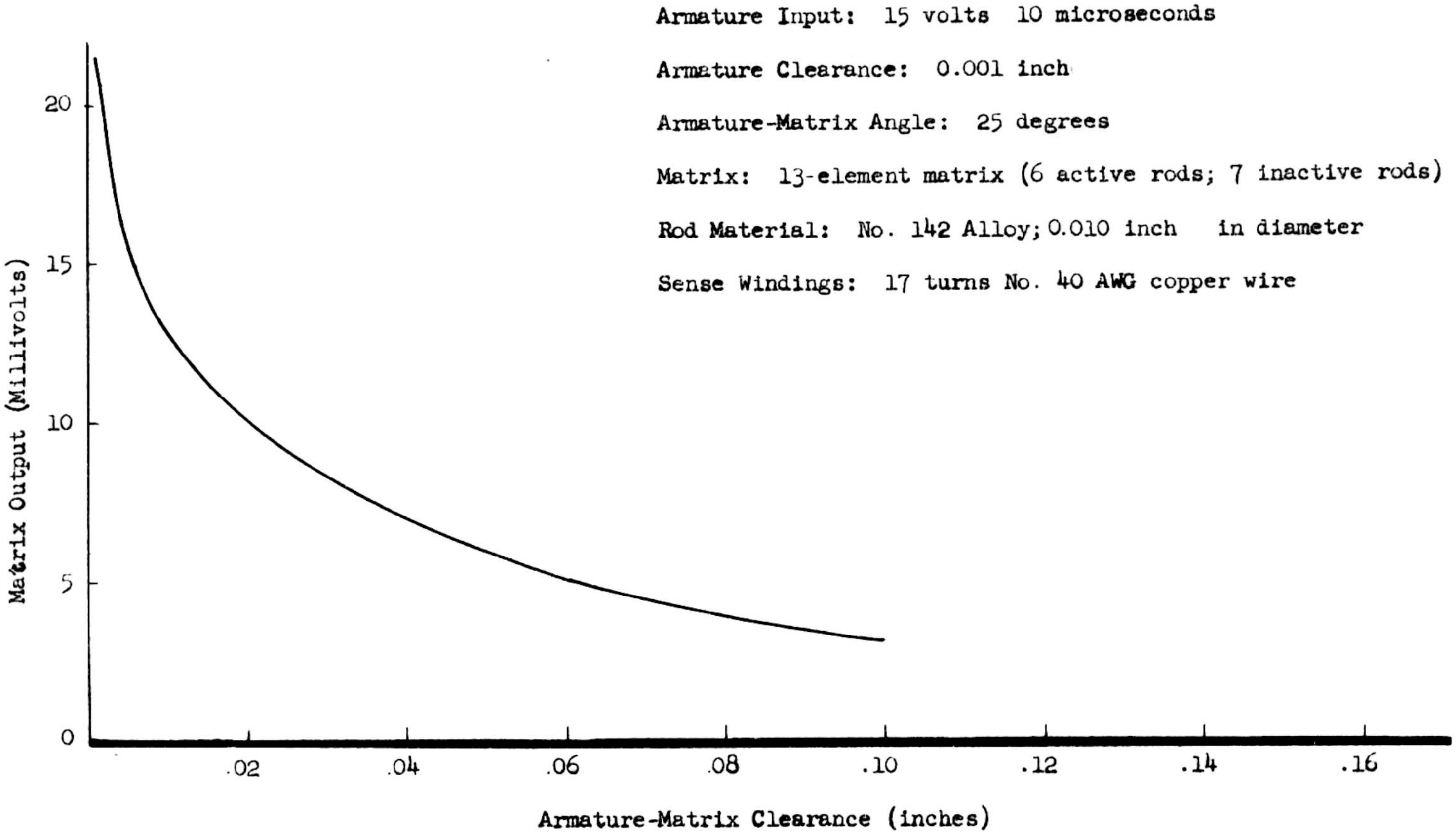


Figure 7. Matrix Output vs. Armature-Matrix Clearance

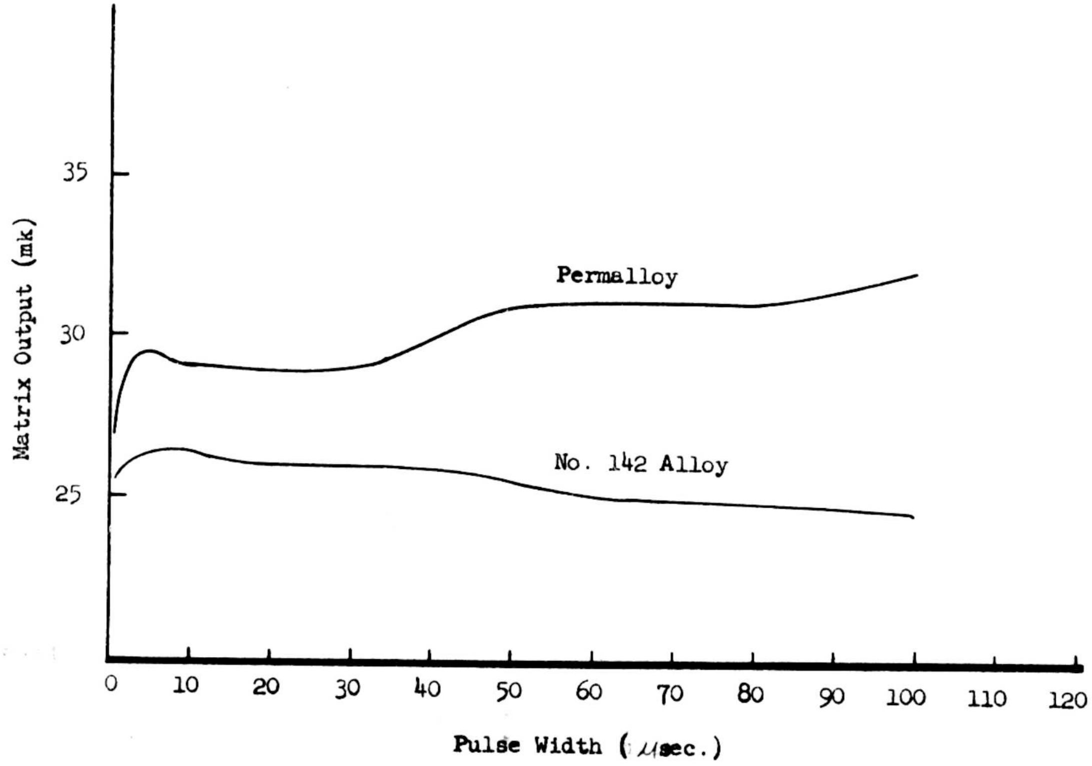


Figure 8. Matrix Output vs. Pulse Width

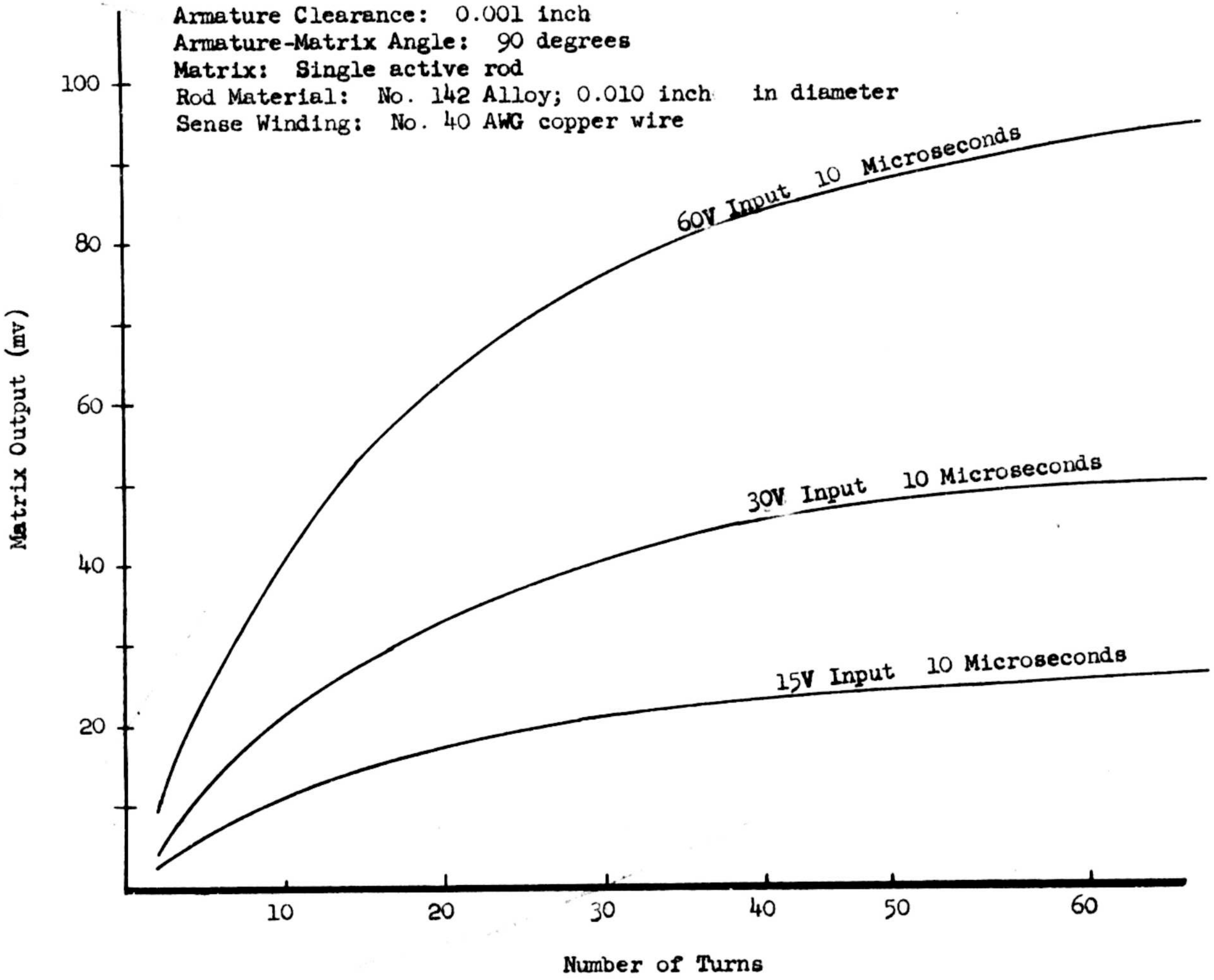
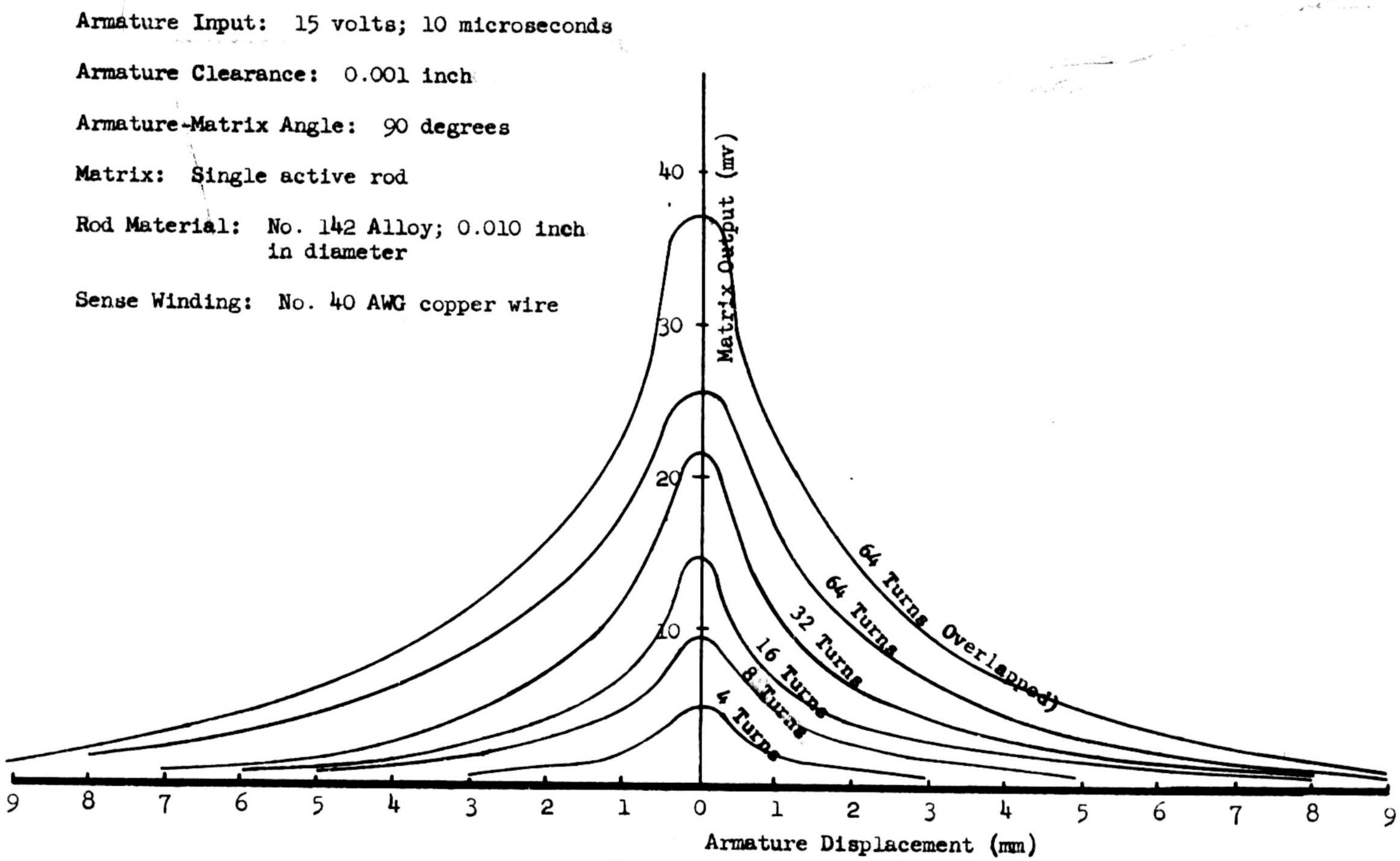


Figure 9. Matrix Output vs. Number of Turns in Sense Winding



Armature Input: 15 volts; 10 microseconds

Armature Clearance: 0.001 inch

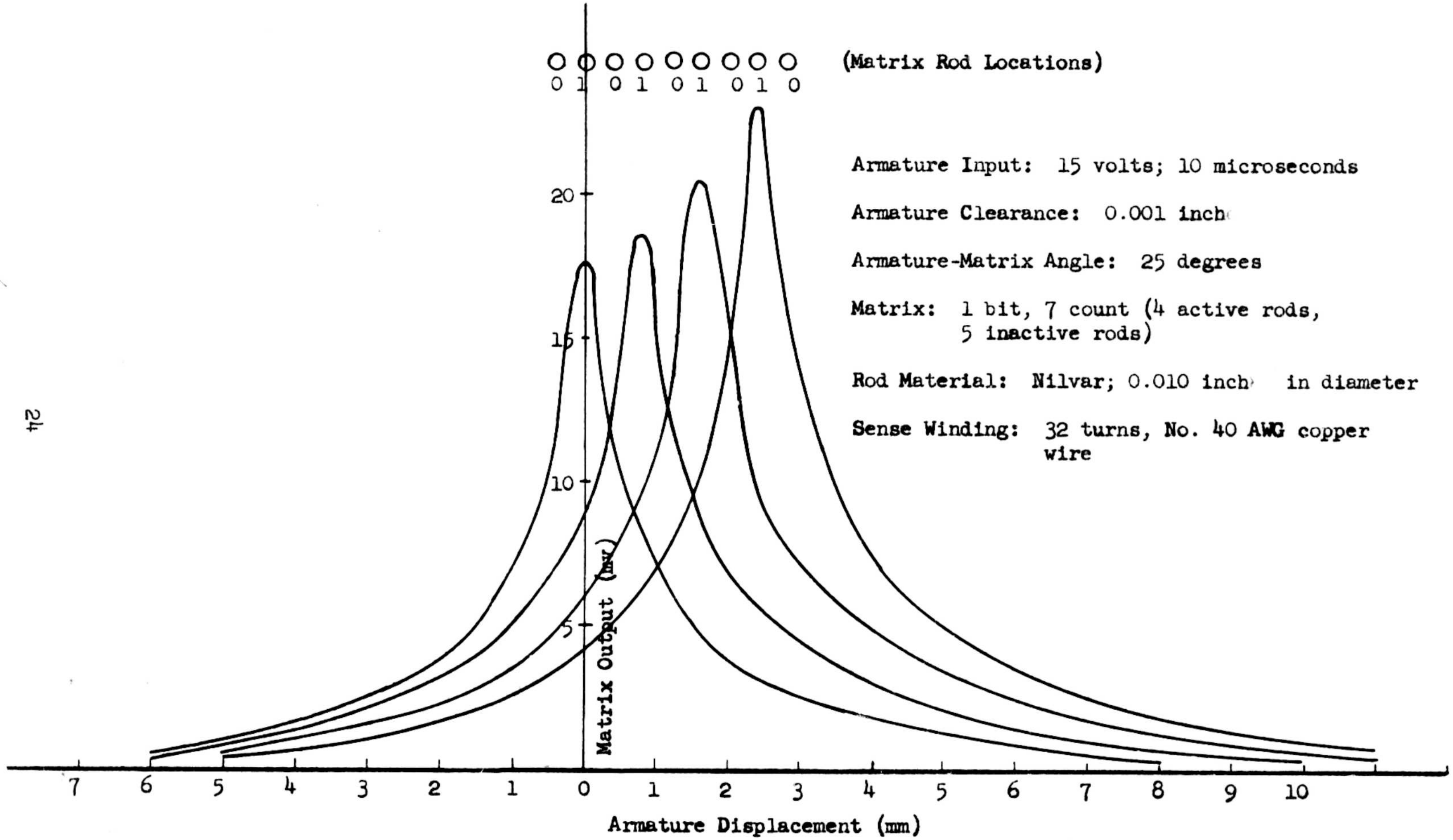
Armature-Matrix Angle: 90 degrees

Matrix: Single active rod

Rod Material: No. 142 Alloy; 0.010 inch in diameter

Sense Winding: No. 40 AWG copper wire

Figure 10. Matrix Output vs. Armature Displacement



Armature Input: 15 volts; 10 microseconds

Armature Clearance: 0.001 inch

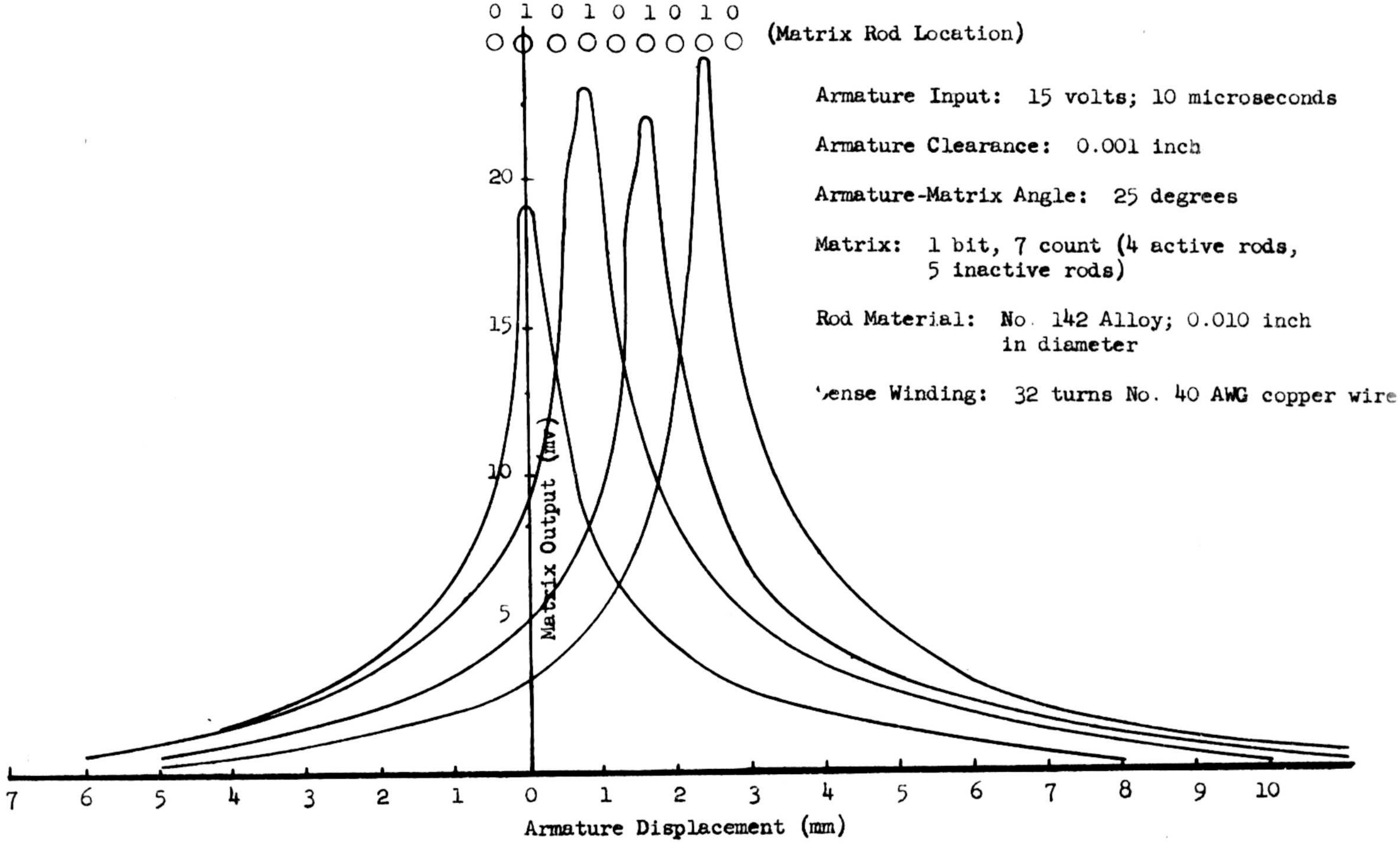
Armature-Matrix Angle: 25 degrees

Matrix: 1 bit, 7 count (4 active rods,
5 inactive rods)

Rod Material: Nilvar; 0.010 inch in diameter

Sense Winding: 32 turns, No. 40 AWG copper
wire

Figure 11. **Nilvar, Matrix Output (Inactive)**



Armature Input: 15 volts; 10 microseconds

Armature Clearance: 0.001 inch

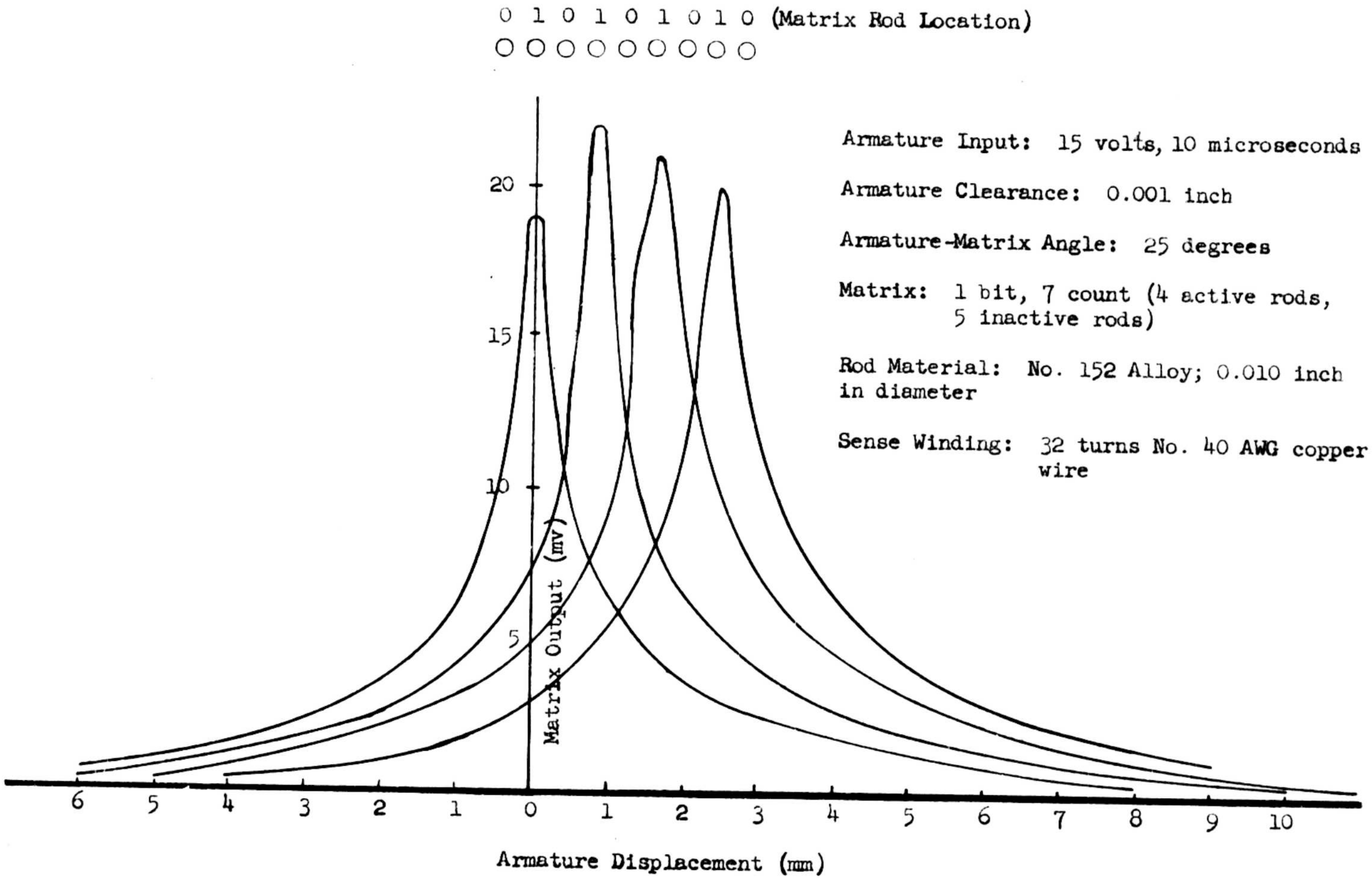
Armature-Matrix Angle: 25 degrees

Matrix: 1 bit, 7 count (4 active rods,
5 inactive rods)

Rod Material: No. 142 Alloy; 0.010 inch
in diameter

Sense Winding: 32 turns No. 40 AWG copper wire

Figure 12. No. 142 Alloy, Matrix Output (Inactive)



Armature Input: 15 volts, 10 microseconds

Armature Clearance: 0.001 inch

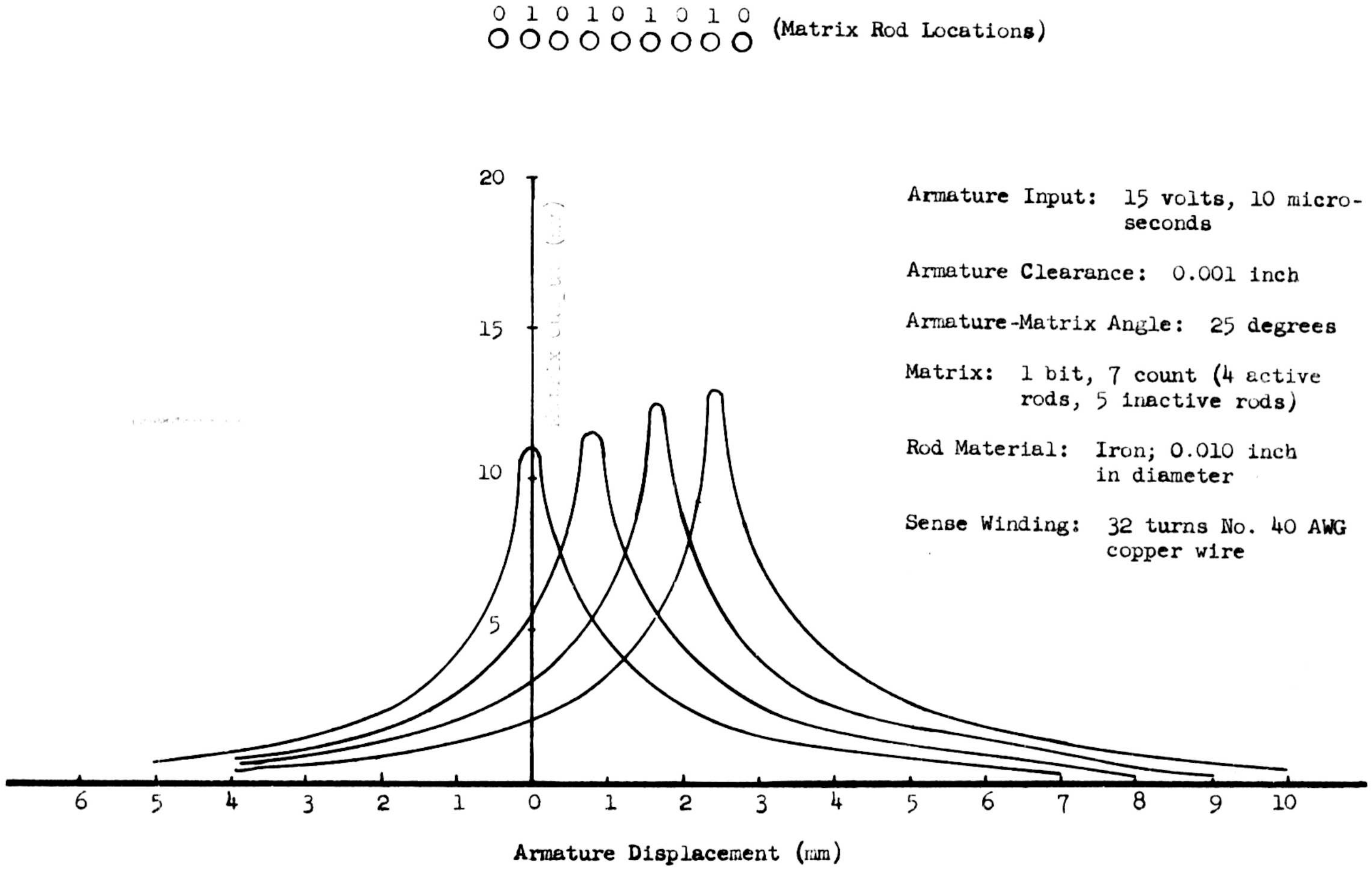
Armature-Matrix Angle: 25 degrees

Matrix: 1 bit, 7 count (4 active rods, 5 inactive rods)

Rod Material: No. 152 Alloy; 0.010 inch in diameter

Sense Winding: 32 turns No. 40 AWG copper wire

Figure 13. No. 152 Alloy, Matrix Output (Inactive)



Armature Input: 15 volts, 10 microseconds

Armature Clearance: 0.001 inch

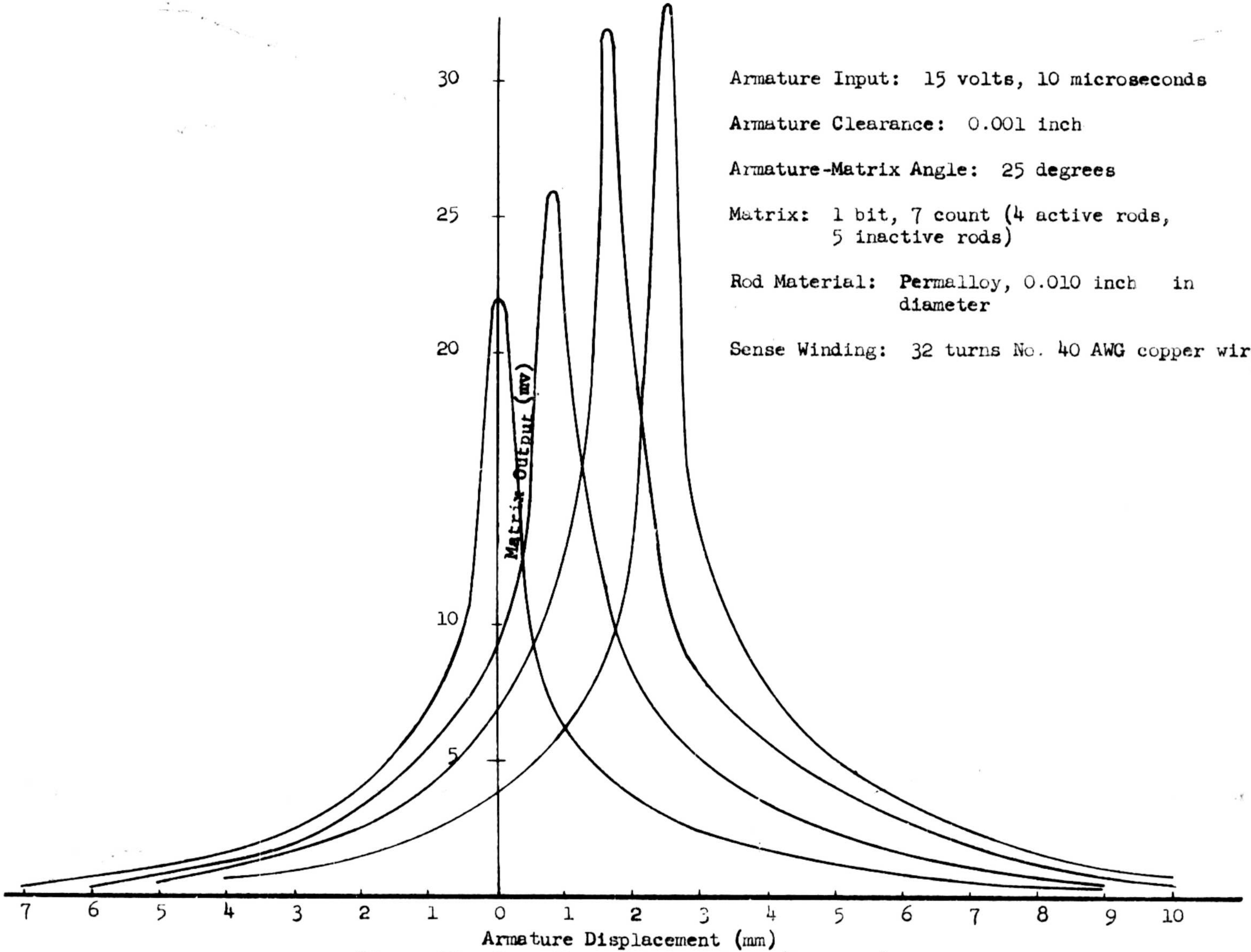
Armature-Matrix Angle: 25 degrees

Matrix: 1 bit, 7 count (4 active rods, 5 inactive rods)

Rod Material: Iron; 0.010 inch in diameter

Sense Winding: 32 turns No. 40 AWG copper wire

Figure 14. Iron, Matrix Output (Inactive)



Armature Input: 15 volts, 10 microseconds

Armature Clearance: 0.001 inch

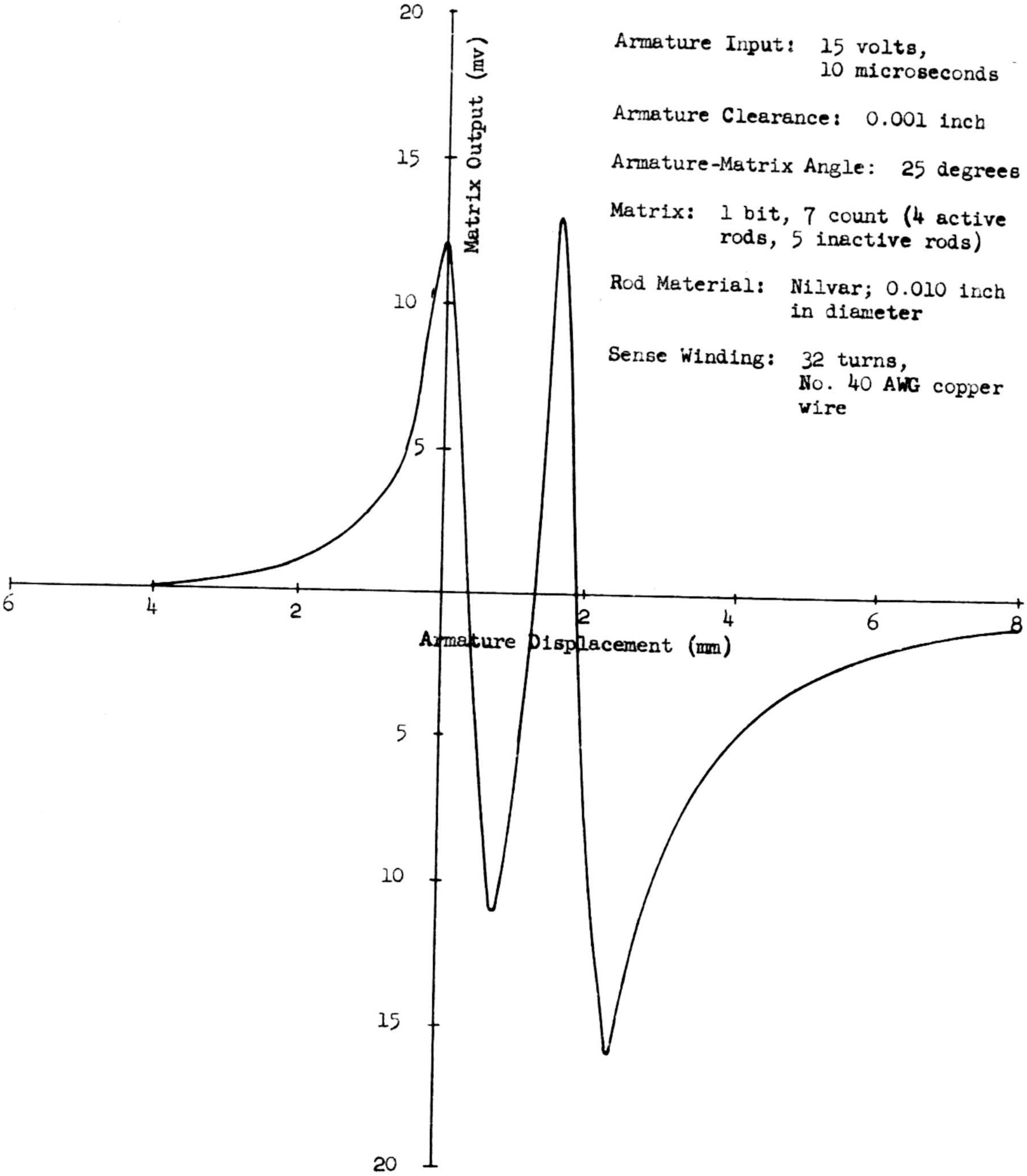
Armature-Matrix Angle: 25 degrees

Matrix: 1 bit, 7 count (4 active rods,
5 inactive rods)

Rod Material: Permalloy, 0.010 inch in
diameter

Sense Winding: 32 turns No. 40 AWG copper wire

Figure 15. Permalloy, Matrix Output (Inactive)



Armature Input: 15 volts,
10 microseconds

Armature Clearance: 0.001 inch

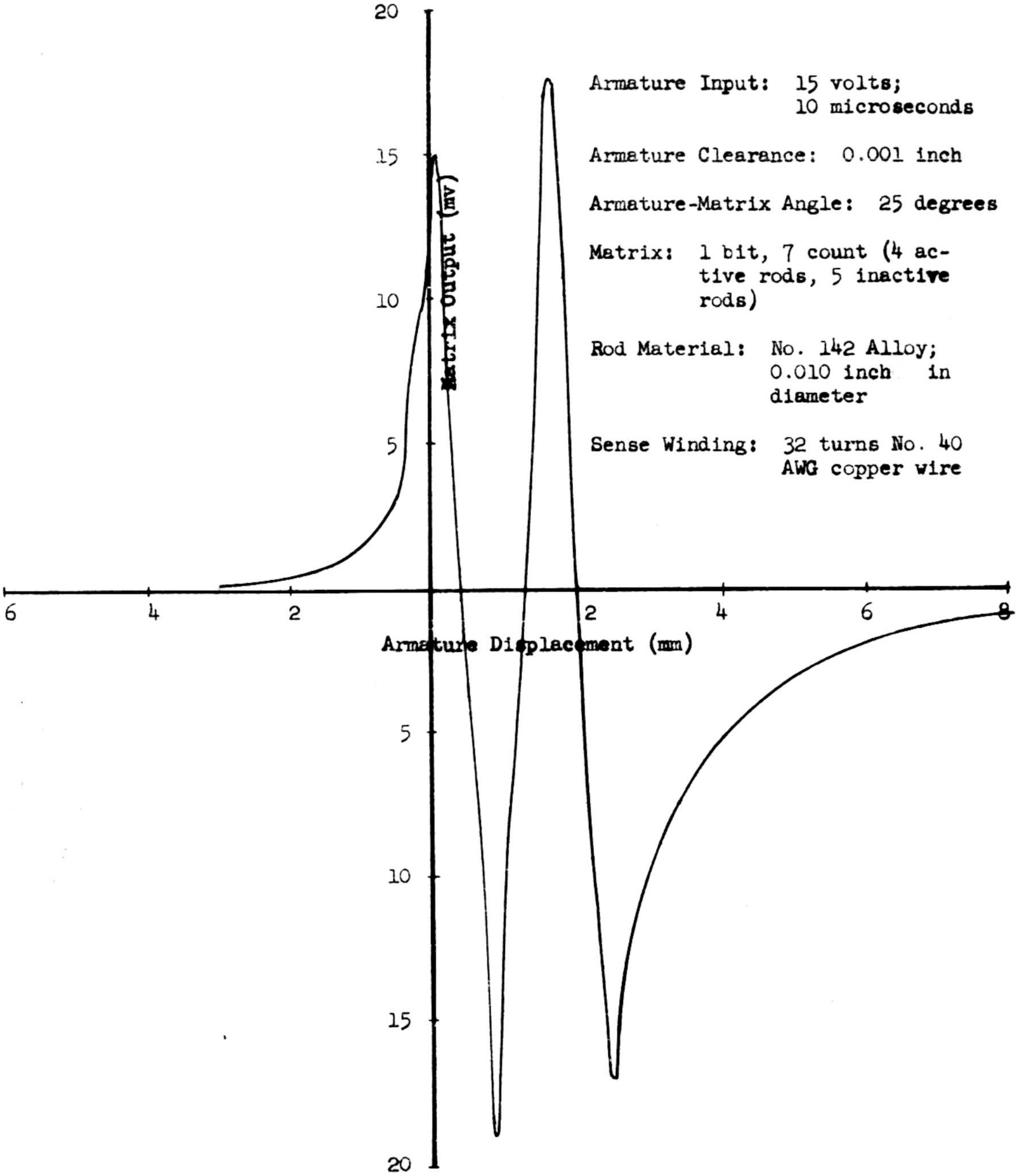
Armature-Matrix Angle: 25 degrees

Matrix: 1 bit, 7 count (4 active rods, 5 inactive rods)

Rod Material: Nilvar; 0.010 inch in diameter

Sense Winding: 32 turns,
No. 40 AWG copper wire

Figure 16. Nilvar, Matrix Output (Active)



Armature Input: 15 volts;
10 microseconds

Armature Clearance: 0.001 inch

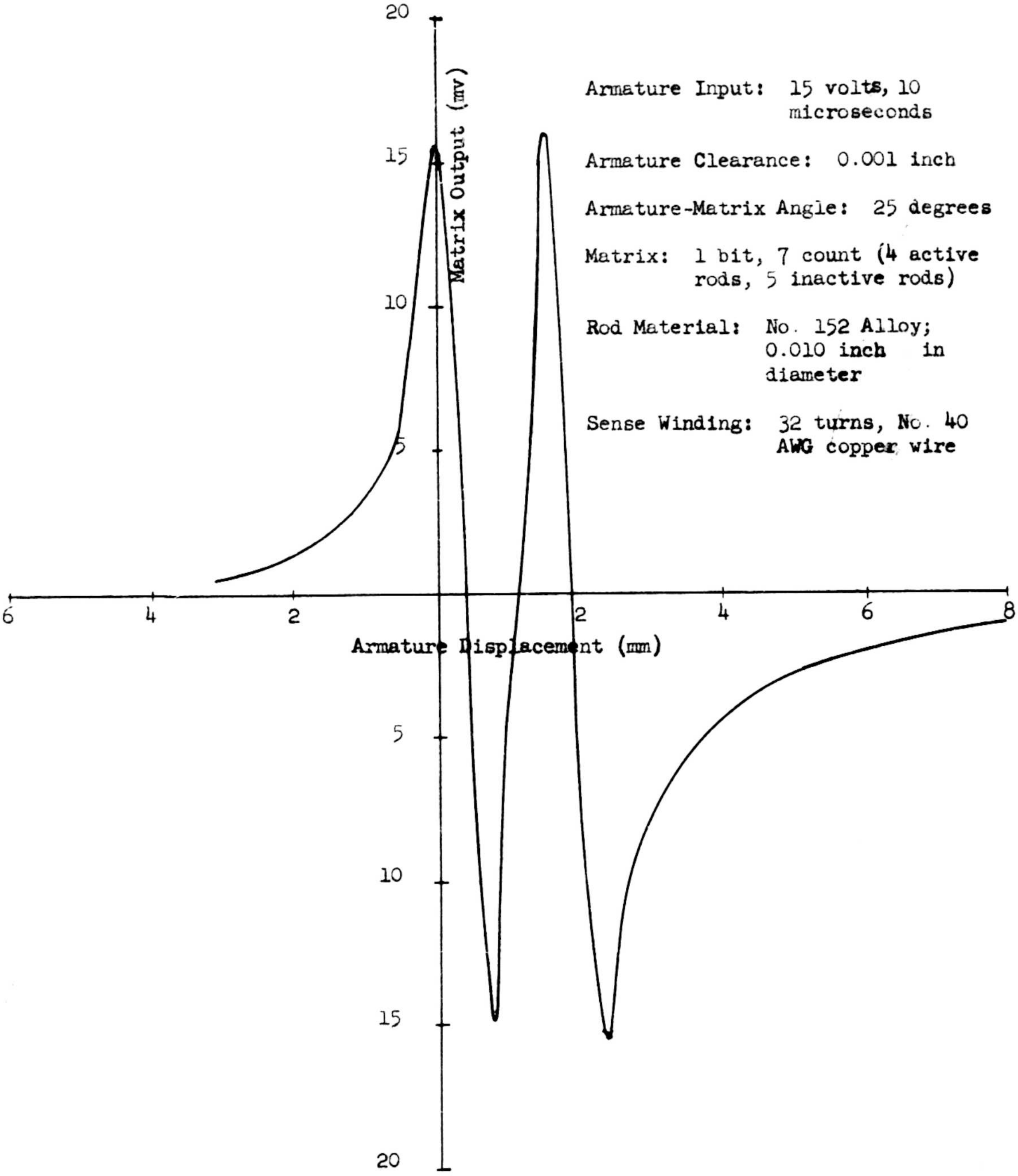
Armature-Matrix Angle: 25 degrees

Matrix: 1 bit, 7 count (4 active rods, 5 inactive rods)

Rod Material: No. 142 Alloy; 0.010 inch in diameter

Sense Winding: 32 turns No. 40 AWG copper wire

Figure 17. No.142 Alloy, Matrix Output (Active)



Armature Input: 15 volts, 10 microseconds

Armature Clearance: 0.001 inch

Armature-Matrix Angle: 25 degrees

Matrix: 1 bit, 7 count (4 active rods, 5 inactive rods)

Rod Material: No. 152 Alloy; 0.010 inch in diameter

Sense Winding: 32 turns, No. 40 AWG copper wire

Figure 18. No. 152 Alloy Matrix Output (Active)

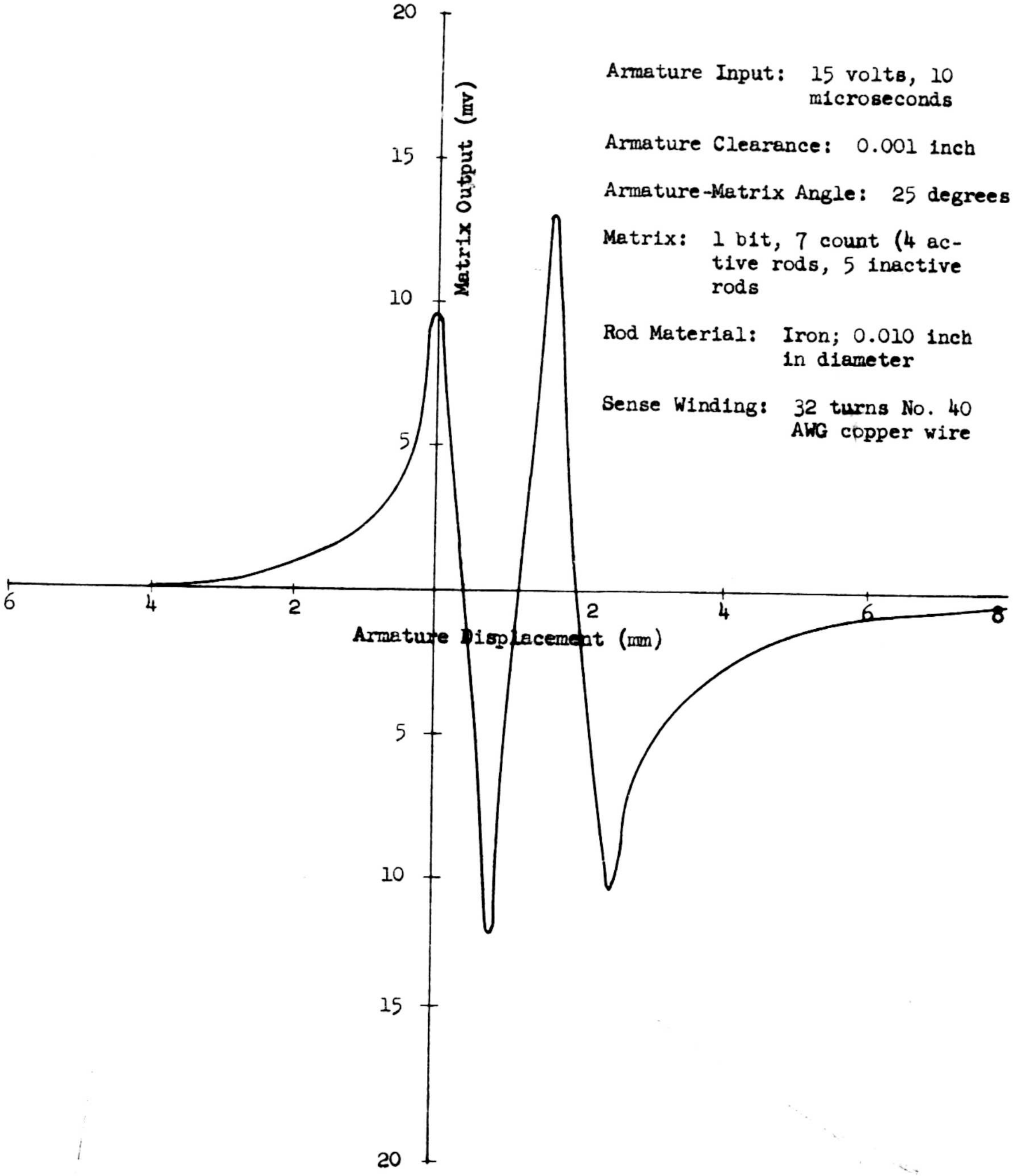
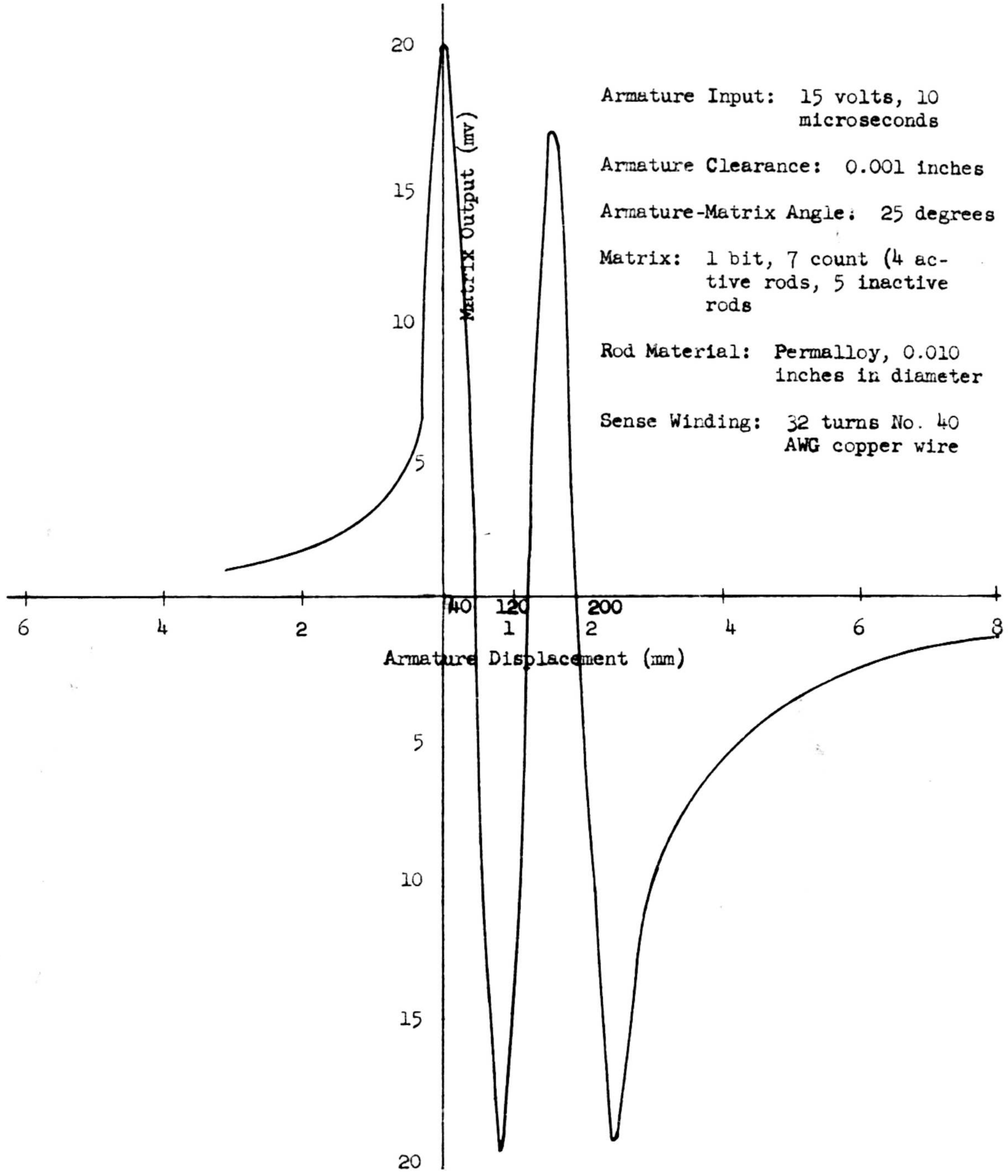


Figure 19. Iron Matrix Output (Active)



Armature Input: 15 volts, 10 microseconds

Armature Clearance: 0.001 inches

Armature-Matrix Angle: 25 degrees

Matrix: 1 bit, 7 count (4 active rods, 5 inactive rods

Rod Material: Permalloy, 0.010 inches in diameter

Sense Winding: 32 turns No. 40 AWG copper wire

Figure 20. Permalloy Matrix Output (Active)

U. S. NAVAL AIR DEVELOPMENT CENTER, JOHNSVILLE, PA.
ENGINEERING DEVELOPMENT DEPARTMENT

1. Report NADC-ED-6029
2. TED Proj ADC-RS-7045

Digital Transducer Research Program 5935-M; First Annual Progress Report; John R. Wullert and Charles L. Bossard, 33 pp., 14 December 1960

This report describes a method to transform transducer rectilinear motion into a parallel binary pulse code by magnetic techniques. Digital signals representing the mechanical displacement of the magnetic armature are generated by successively altering the state of a matrix of magnetically permeable wire rods. A pseudotransducer model demonstrated the feasibility of the magnetic technique by generating three binary digits for a rectilinear motion of one thirty-second of an inch. A bibliography of reports which appeared useful in the design of a digital transducer is also presented.

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