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NBSIR 79-1726 (EPA)

Electromagnetic Pest Control Devices

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National Engineering Laboratory
Center for Consumer Product Technology
Product Performance Engineering Division
National Bureau of Standards
Washington, DC 20234

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Final Report

Issued March 1979

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ꞏvironmental Protection Agency
ꞏfice of Enforcement, Pesticides, and Toxic
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U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, *Secretary*
Jordan J. Baruch, *Assistant Secretary for Science and Technology*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

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1.0 Executive Summary

At the request of the Environmental Protection Agency (EPA), the National Bureau of Standards, Center for Consumer Product Technology, evaluated eight models of electromagnetic pest controllers provided by EPA. The units were evaluated to characterize any detectable electromagnetic output but no judgment of the effectiveness of the devices as pest controllers was made.

Visual and X-ray inspection and electromagnetic measurements showed the units can be grouped into two categories based on characteristics of the output signal--the principal characteristics being either a pulse output or a 60 Hz AC output. For the pulse output devices, no significant external electromagnetic field was found. The 60 Hz units were found to generate detectable magnetic fields. For all units, the fields detected would be less than the earth's magnetic field at distances of three meters or more. Some common electrical equipment was found to generate electromagnetic fields of the same order of magnitude as that produced by these pest controllers.

2.0 Introduction

The National Bureau of Standards (NBS) was requested by the Environmental Protection Agency, Office of Enforcement, Pesticides, and Toxic Substances Enforcement Division, to perform a limited evaluation of eight models of electromagnetic pest controllers provided by EPA. Two samples of some models were provided. These controllers are electrical or electronic devices intended to rid an area of pests such as rodents, rabbits, roaches, termites, and fleas depending on the particular unit. NBS was requested to 1) characterize any measurable electromagnetic output, but was to make no judgment of the effectiveness of the devices as pest controllers; 2) determine if models have any commonality of their outputs which would allow grouping or classifying of similar units for biological testing; and 3) determine the feasibility of developing a standard test method for measuring and classifying units based on the nature of the output. Due to the time and resources available, the work was primarily directed to characterize and provide comparative measurements of the outputs, and to identify commonality between outputs. To the extent practical, quantitative measurements were made and operating principles or circuit components identified.

Nondestructive evaluation techniques were requested by EPA since limited samples were obtained and several were subsequently used by EPA for biological experiments to determine the effects on animals or insects. The units were to remain operable should further measurements be requested. The measurements were to use readily available equipment, where possible, so that further measurements could be made by independent laboratories if necessary.

The EPA was responsible for obtaining test samples and contacts with manufacturers. The EPA requested technical information and circuit diagrams but received only catalog or advertising type literature. It was assumed that the manufacturers did not choose to reveal this information. Many units were either potted or assembled with rivets, adhesive, or by other methods making nondestructive disassembly difficult. This construction limited the information obtained on circuits and components. Some units are battery-operated and their cases were opened to perform tests and inspect the battery supplies since batteries would be replaced in the field.

A review of literature at the beginning of the evaluation did not identify any published quantitative data on the electromagnetic fields from these devices. A subsequent paper by Wagner (1978)[1] reports data on several units.

3.0 Units Evaluated

The EPA furnished to NBS eight different types of electromagnetic pest controllers for evaluation. Two samples each of six of the types were furnished. A list of these electromagnetic pest controllers with an NBS assigned code for reference in data reporting and the EPA assigned sample number is given in Table 1. The letter refers to the type while the number designates the sample of that type. The NBS code is also used to identify the X-ray photographs in Appendix 2 and photographs of the outside of each unit in Figures 1 through 7. Units E1 and E2 were returned to EPA before photographs were obtained.

Table 1

Electromagnetic Pest Controllers

NBS Code	EPA No.
A1	Sample 131918 (03213)
A2	Sample 131918 (03199)
B1	Sample 131978A
B2	Sample 131978B
C1	Sample 168054
C2	Sample 168054
D	Sample 131901
E1	Sample 131902
E2	Sample 131903
F1	Sample 131905A
F2	Sample 131905B
G1	Sample 131906A
G2	Sample 131906B
H	Sample 123831

The units A1, A2, and B1, B2 are battery-operated. These units were received with batteries installed and the units operating. They have no on-off switch and operation is indicated by the periodic flashing of a small red light emitting diode (LED) in the center of the top of each case. Instructional material supplied with these units indicates that they should run for approximately six months at which time the batteries are to be replaced.

The other six types all operate from a 115 volt, 60 Hz, AC power supply. These likewise do not have an on-off switch but start immediately when plugged in. Units C, D, and E have a circuit fuse. Units F and G have both a circuit fuse and a small light to indicate when they are connected to the power supply. Unit H has an LED which periodically flashes to indicate when it is on.

4.0 Evaluation Procedure

Each unit was visually examined to the extent possible without destruction. One sample of each type was X-rayed to reveal hidden components, and each sample was subsequently

FIGURE 1 SAMPLE A1

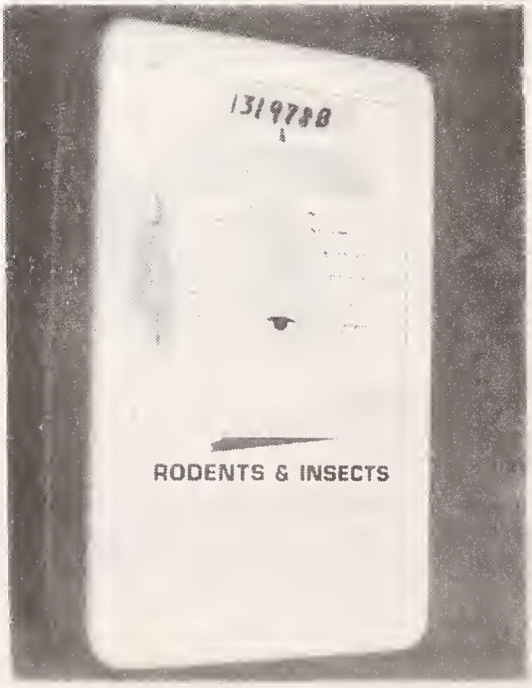

FIGURE 2 SAMPLE B2

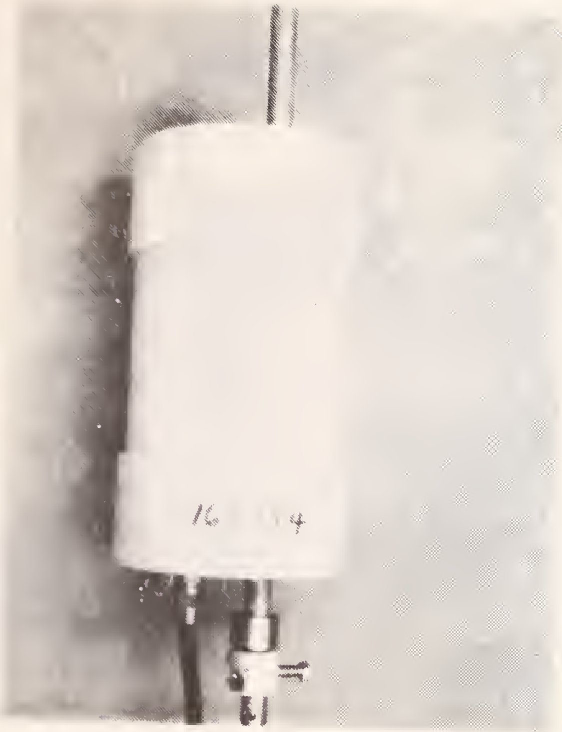

FIGURE 3 SAMPLE C1

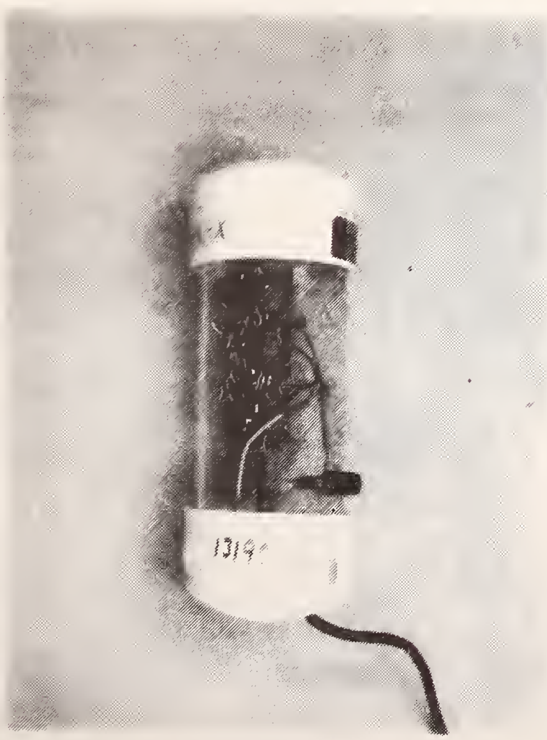

FIGURE 4 SAMPLE D

FIGURE 5 SAMPLE F1

FIGURE 6 SAMPLE G1

FIGURE 7 SAMPLE H

measured to characterize and, when possible, quantify any measurable electromagnetic field emitted.

4.1 X-Ray and Visual Examination

X-ray photographs (Appendix 2) were made of one sample of each of the types received. In most cases when a unit was X-rayed, three different photographs 90° apart were made to reveal all possible internal parts. The photographs at different angles (1) assist in revealing hidden parts, (2) reveal internal construction and parts location, (3) expose encapsulated (potted) integrated circuits, etc., and (4) assist in determining principles of operation. X-raying the units was considered to be nondestructive. Each unit was tested before and after X-raying and for six types, the X-rayed unit was compared to the non-X-rayed unit to verify that no change had occurred.

The visual examination was limited to outside inspection of the sealed units except for unit C2. Since A1, A2, B1, and B2 were battery-operated and the batteries had a finite life expectancy, the case screws were removed to inspect the battery packs and measure the operating current. It was also determined that it was necessary to open these units and make internal connections to the metal case and the battery to detect any signal. Unit C2 was opened for visual inspection. Its operation was found to be the same after opening as before opening.

4.2 Electromagnetic Measurements

Electromagnetic measurements for DC fields were made using a Schonstedt Model HSM-11 Station Magnetometer. This instrument can detect a field of 0.5 nanotesla and ambient fields can be neutralized to within 0.5 nanotesla (nT). The earth's field is approximately 50,000 nT or 0.5 gauss (10^5 nanotesla = 1 gauss). AC magnetic field measurements were made using a search coil as a detector. The coil consists of 250 turns of No. 34 insulated wire wound with close spacing in a single layer on a nonmagnetic form (phenolic) of 2-inch diameter. The overall length is approximately 2 inches. For sinusoidal steady state magnetic fields, the magnitude of the field can be calculated from the voltage output of the coil and the period of the waveform. Two of these search coils were used at times to make simultaneous measurements at different locations around the AC operated units. A dual-trace oscilloscope was used to display, measure amplitude, and analyze the AC or pulse type signals. With this equipment the outputs from two search coils to the unit under test could be examined and analyzed simultaneously. A dual channel DC amplifier-recorder was used in conjunction with the oscilloscope to make permanent records of the magnitude and frequency of the random or programmed on-off operation of certain units. The recorder input was from a search coil.

For magnetic fields at 60 Hz, this equipment can resolve less than 100 microtesla (1 gauss) peak-to-peak. The sensitivity increases in proportion to frequency. This coil is useable up to about 100 kHz which is in excess of any frequency measured or anticipated based on the size of the coils in the units which are visible in the X-rays. For the search coil used, the peak-to-peak magnetic field in microtesla is equal to 0.31 times the peak-to-peak voltage (V) in millivolts times the period (T) of the waveform in milliseconds, 16.7 ms for 60 Hz.

[magnetic field (μT) = 0.31 x V(mV) x T(ms)]

5.0 Results of Evaluation

General results on each unit examined are given in this section. More detailed results are given in Appendix 1.

5.1 Results of X-Ray and Visual Examination

Visual inspection and examination of the X-ray photographs and the electromagnetic measurements show similarities between different units. Units A1, A2, B1, B2, and H are similar except that the A's and B's are each powered by four 12-volt lantern-type batteries in parallel and H operates from 115 volts AC. The X-rays show that each has three coils and nine integrated circuits on a printed circuit board. The electronics all are encapsulated preventing further nondestructive circuit determination. In the A and B units, the coils and electronics are contained within sheet metal cubes: in the A units totally enclosed, in the B units with one side open which faces the ground when normally installed. The metal cube in A appears to be aluminum, the metal in B is magnetic. The cube in the A units is contained along with the batteries in a totally closed aluminum case. The metal in these units would act as an electrostatic shield. Only low frequency magnetic fields of any magnitude would be expected to penetrate the metal, particularly from the A unit's totally-closed case. Unit H does not have any metal shield.

The C, D, E, F, and G units appear similar. Each has multiple coils, from 2 to 6, which appear to be mounted on a magnetic core. The two coils in E are side by side, the others are all axial. Unit F1 appears to have three thryristor semiconductor switches which control the coil currents and Unit G2 appears to have a thermal switch mounted against each coil. Fuses and pilot lights are the only other significant components identifiable.

5.2 Results of Electromagnetic Measurements

DC Magnetic Field. The DC magnetic field measurements made using the magnetometer were confined to units B1 and B2. At any position of the probe relative to the unit, and before any data was taken, the ambient external fields were neutralized to about 1/2 nT. Then the unit was placed next to the probe and lined up as indicated by the instructions with the N (north) mark pointing north. A continuous chart recording was made of the change in the magnetic field due to the operation of the unit. The magnetometer probe was positioned in several locations around the unit to obtain the distribution profile of the field generated by the unit. Chart 1 shows a portion of a recording for unit B1 and chart 2 shows a recording for unit B2. The detectable change in the magnetic field is approximately 8-12 nT. During the testing, the opening of a laboratory door produced more field change than was recorded due to unit B1. There is a periodic shifting of the magnetic field that most likely is caused by the different internal digital type integrated circuits operating to produce pulses. The higher frequency components are discussed in a later paragraph. The magnitude of the detected changes of DC magnetic field are about 1/5000 of the earth's magnetic field.

The magnetometer recordings of the output of units B1 and B2 showed no significant differences between these units. Since the X-ray and visual examination showed that units A1 and A2 and H were very similar in construction, in parts and layout to B1 and B2, these were not checked using the magnetometer. They are covered in the following section, where higher frequency measurements are described.

AC Magnetic Field. The A, B, and H units were examined with the search coil and oscilloscope. No detectable output was found from any of these units. Therefore, other techniques were used to examine these units.(2)

The covers were removed from units B1 and B2. The oscilloscope high input lead was connected to the metal can and the ground lead connected to the negative battery terminal. Curves 1 and 2 are photographs of the oscilloscope patterns for units B1 and B2 respectively. These outputs appear to be digitally generated because of the low frequency and exact pattern repetition. Similar patterns were measured in units A1 and A2 between the metal box and the battery negative terminal. These are shown in curves 3 and 4 respectively. No metal can or box is used in unit H, as in A and B. The oscilloscope was connected between one of the coil leads and the negative side of the internal power supply. A similar pattern, shown in curve 5, was measured. Any external fields resulting from these internally measured signals was not determined by analysis and none were measured.

The other five units, C, D, E, F, and G, all produce 60 Hz magnetic fields measurable with the search coil. All units switch the fields on and off in a generally random pattern. The various coils may be energized at different times resulting in several levels of field strength depending on the number of coils energized. The coils are energized from several seconds up to several minutes depending on the particular unit. The long intervals and random patterns indicate some type of thermal sensor determines the switching. The outputs from these units are shown in charts 3 through 11.

The maximum fields were measured at various distances from each unit. The search coil voltage and the calculated magnetic fields are given in Table 2 for each unit. The largest fields were from unit C2 mounted on a 2.4 meter iron pipe.

Examination of the data in Table 2 shows a very rapid decrease in field strength as the search coil is moved away from each pest controller under test. At distances which are large compared to the diameter of the coil, the magnetic field from a current carrying coil decreases as the third power of the distance.[3] That is at 10 meters the field will be 1/1000 of the field at one meter. The measurements at the 0.15 and 0.3 meter distances are not far enough from the coils to follow this inverse cube relationship. Doubling the distance of the search coil from 0.15 m to 0.3 m from the unit reduces this detected field strength over a range of 3 to 18 times. These units are claimed to be effective over an area of 2 to 12 hectares[4] (5 to 30 acres). From the measurements at 0.3 m in Table 2, it can be calculated that at 3 m the fields from various units will be from 1/5 to 1/500 of the earth's field. The data in Table 3 shows the earth's magnetic field strength throughout the United States for a comparison. Figure 8 is a plot of the decrease in the electromagnetic field strength with distance from the C2 unit. The points at 0.3 m and 0.6 m (1 and 2 ft) are laboratory measurements. From 3 meters to 12 meters (10 to 40 feet) are calculations based upon the field decreasing as the third power of the distance. That is at 12 m the field will be $(1/4)^3$ times that at 3 m or approximately 0.3 microtesla (0.003 gauss).

6.0 Fields From Other Electrical Equipment

As a comparison between the 60 Hz fields generated by the pest controllers and those encountered from everyday 115 volt 60 Hz equipment, the field from several common items was measured and is shown in Table 4. A comparison between data in Table 2 with that in Table 4 indicates some common shop and household electrical equipment produce 60 Hz fields in the same order of magnitude as those generated by the pest controllers. The principal difference between those of the same magnitude is that the pest controllers are turned on and off in a fixed pattern or in a random pattern while the shop and household units usually operate for longer periods. These motor units can be random in their on-off operation. Some of the 115 volt 60 Hz motors showed pulses with larger magnitudes. Figure 9 is a bar graph of data from Table 4 showing a comparison of the electromagnetic fields of pest controllers and common 115 volt 60 Hz equipment when examined at a distance of 0.3 m (1 ft) to the

Table 2
EMF Versus Distance

Code	Coil Distance (1)	Signal mV (V)	Period ms (T)	Constant .31	Peak-to-Peak Microtesla .31 VT	Gauss	Comments
C2	closest (2)	15 000	16.7	.31	77 700	777	top (3)
	0.15 m (6 in)	500	16.7	.31	2 600	26	
	0.3 m (12 in)	60	16.7	.31	300	3	
C2	closest	18 000	16.7	.31	93 000	930	end (4) &
	0.15 m (6 in)	6 800	16.7	.31	35 000	350	8 ft pipe
	0.3 m (12 in)	2 300	16.7	.31	12 000	120	on unit
	0.6 m (24 in)	200	16.7	.31	1 000	10	
D	closest	150	16.7	.31	780	8	
	0.15 m (6 in)	30	16.7	.31	160	2	
	0.3 m (12 in)	10	16.7	.31	50	.5	
E2	closest	2 750	16.7	.31	14 000	140	
	0.15 m (6 in)	110	16.7	.31	600	6	
	0.3 m (12 in)	10	16.7	.31	50	.5	
F1	closest	1 250	16.7	.31	6 000	60	
	0.15 m (6 in)	200	16.7	.31	1 000	10	
	0.3 m (12 in)	60	16.7	.31	300	3	
G2	closest	3 500	16.7	.31	18 000	180	
	0.15 m (6 in)	360	16.7	.31	1 900	19	
	0.3 m (12 in)	20	16.7	.31	100	1	

(1) Search Coil; 250 turn, #34 insulated wire, 2-inch diameter, 2-inch length.

(2) Closest; search coil in contact with case of unit under test.

(3) Top; search coil located on top of unit.

(4) End; search coil located on end of unit

100 μT = 1 gauss

Table 3

Earth's Magnetic Field
(Geomagnetic Information, NOAA, Boulder, CO)

State	Microtesla (avg)	State	Microtesla (avg)	State	Microtesla (avg)
Alabama	53	Maryland	56	Rhode Island	56
Alaska	57	Massachusetts	56	South Carolina	54
Arizona	52	Michigan	59	South Dakota	59
Arkansas	55	Minnesota	60	Tennessee	55
California	51	Mississippi	54	Texas	52
Colorado	55	Missouri	57	Utah	54
Connecticut	56	Montana	58	Vermont	57
Delaware	56	Nebraska	57	Virginia	56
Florida	51	Nevada	53	Washington	57
Georgia	53	New Hampshire	57	West Virginia	57
Hawaii	36	New Jersey	56	Wisconsin	59
Idaho	57	New Mexico	53	Wyoming	57
Illinois	57	New York	57		
Indiana	57	North Carolina	55		
Iowa	58	North Dakota	60	U.S. Average	55 (.55 gauss)
Kansas	56	Ohio	57		
Kentucky	56	Oklahoma	55		
Louisiana	52	Oregon	55		
Maine	57	Pennsylvania	57		

100 microtesla = 1 gauss

Table 4
EMF From Electrical Equipment

Item	Coil Distance	Signal mV (p-p)	Period ms	Constant .31	Peak-to-Peak Microtesla = .31 VT	Gauss
Soldering Gun	close for max.	40	16.7	.31	207	2.1
Soldering Iron	close	10	16.7	.31	52	.5
Lab Power Supply	for maximum (close)	40	16.7	.31	207	2.1
Nonvented heater fan	for maximum (close)	20	16.7	.31	104	1.0
Transformer unloaded	for maximum (close)	80	16.7	.31	414	4.0
Bandsaw 1/4 HP motor	for maximum (close)	30	16.7	.31	155	1.6
Shop grinder	for maximum (close)	200	16.7	.31	1035	10.4
Hand drill 1/4 HP	for maximum (close)	1500	16.7	.31	7766	77.7
	.3 meter (1 ft)	20	16.7	.31	103.5	1.04
1/4" hand (different brand)	for max. (close)	100	16.7	.31	518	5.18
Kitchen Blender	.3 meter (1 ft)	10	16.7	.31	50.1	.5
Kitchen Blender[(1)]	.3 meter (1 ft)	400	16.7	.31	2070	20.7

[(1)] This is 60 Hz envelope of higher frequency pulses, probably brush noise, and would be similar to the pulse generating units A, B, and H1.

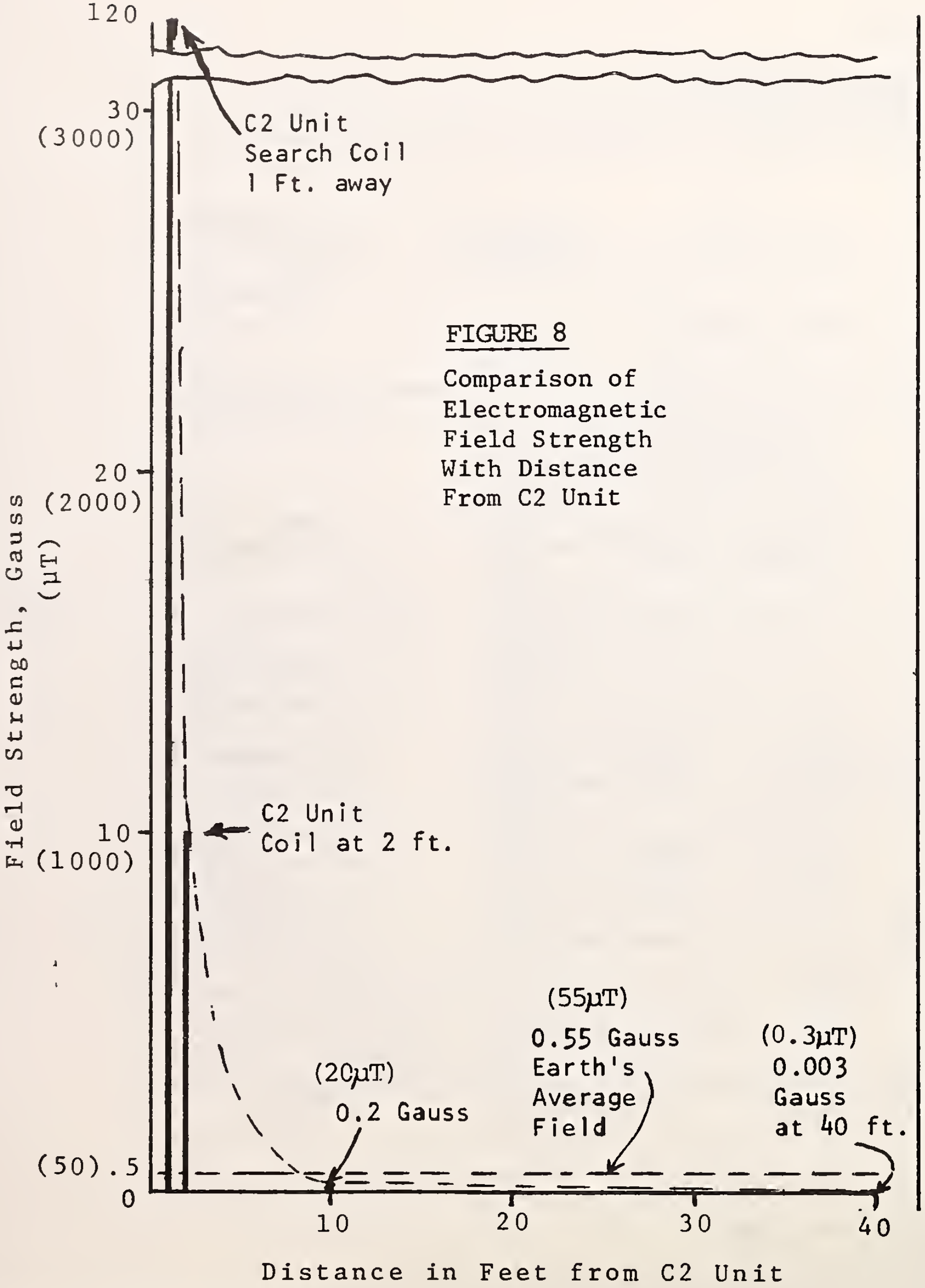

FIGURE 8

Comparison of Electromagnetic Field Strength With Distance From C2 Unit

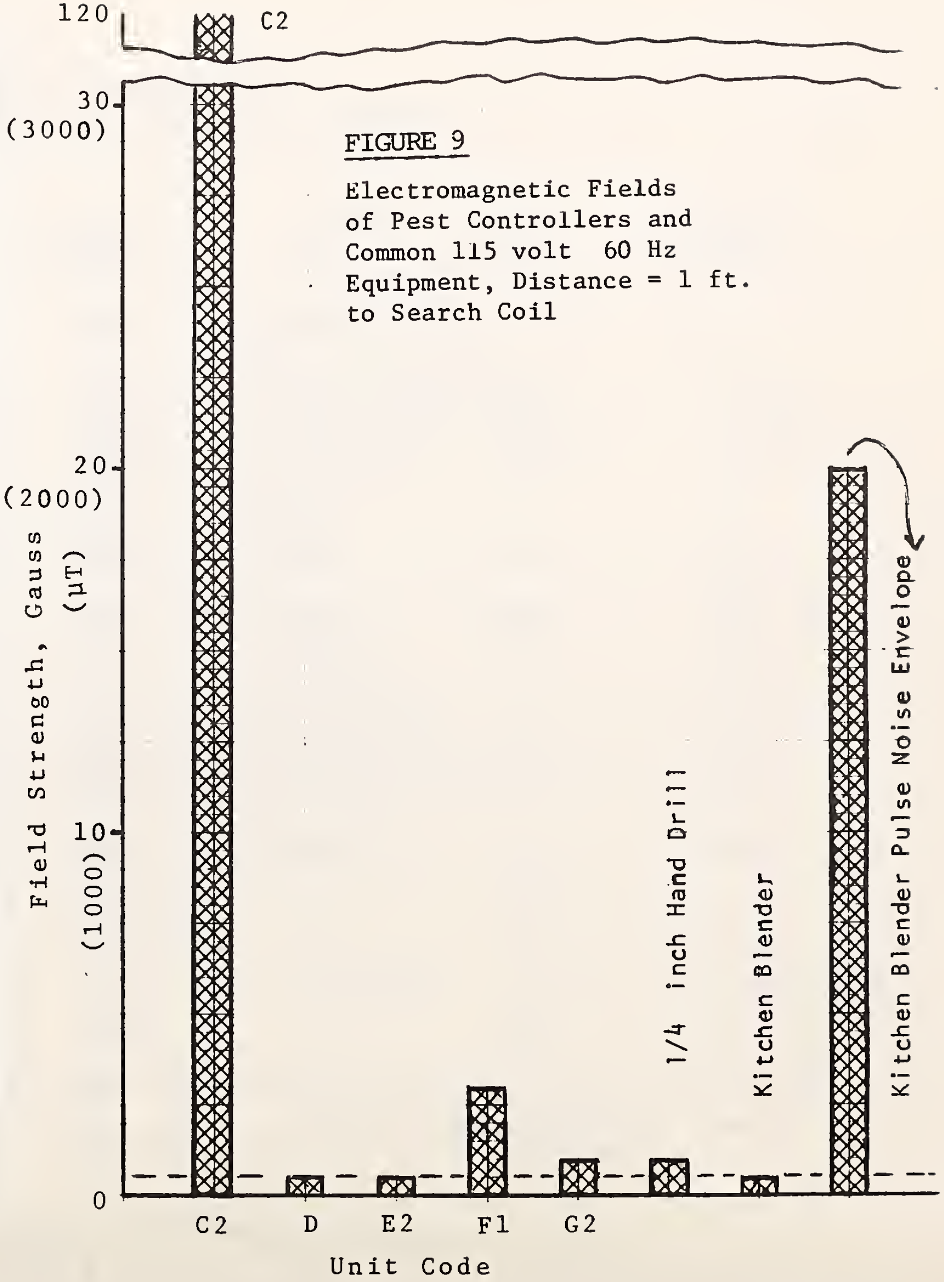

FIGURE 9

Electromagnetic Fields of Pest Controllers and Common 115 volt 60 Hz Equipment, Distance = 1 ft. to Search Coil search coil detector. The kitchen blender showed a 60 Hz envelope of high frequency pulses from the motor brushes and commutator in addition to a 60 Hz sine wave field.

7.0 Conclusions

The eight types of electromagnetic pest controllers furnished by EPA were examined. The NBS evaluation indicates these can be separated into two categories based on characteristics of the output signal: group 1, pulse output; group 2, 60 Hz sine wave output. Of the units evaluated, three (A, B, and H) are in group 1 and five (C through G) are in group 2.

Group 1 characteristics: 1) the units generate a low level, repetitive pulse pattern which was measurable by direct connection to the internal circuitry with an oscilloscope; 2) low power drain; 3) digital integrated circuits used to generate pulse pattern output. Evaluation of group 1 units resulted in no significant detectable external electromagnetic field with either a magnetometer or a search coil used as a detector with an oscilloscope. The only measurable signal from these units was found by direct connection to the metal case of two of the units and to the coil lead of the other unit with an oscilloscope. The short duration of both the positive and negative pulses for the units would produce very low average power radiated signals.

Group 2 characteristics: 1) output is a 60 Hz electromagnetic field; 2) operates from 115 volt, 60 Hz AC power; 3) have a random or repetitive on-off pattern; 4) appear to operate by driving various numbers of coils with 60 Hz AC.

The field generated by group 2 units was readily detectable by the search coil and oscilloscope. The electromagnetic fields from the 60 Hz units decrease very rapidly with distance from the unit as shown in Table 2. These fields will be less than the earth's magnetic field at three meters from any of the units. Figure 8 illustrates the rapid decrease of the electromagnetic field strength with distance. For a circular area of 2 to 12 hectares (5 acres and 30 acres) for which various units are claimed to be effective, the radius is approximately 76 meters and 200 meters (250 and 650 feet) respectively. For all units, the magnetic field emitted will decrease with the third power of the distance from the unit. For distances larger than 3 m, the earth's field would significantly exceed these emitted fields. These units transmit alternating fields which may vary in amplitude and "on" time. Figure 9 shows that some common 115 volt 60 Hz equipment generates electromagnetic fields in the same order of magnitude as produced by these pest controllers.

The NBS evaluation of this group of electromagnetic pest controllers indicates a standard test procedure can be developed for the group 2 devices to characterize their output. This would utilize standard laboratory equipment such as the volt-ohmmeter, oscilloscope, magnetometer, and chart recorders. For group 1 devices, a standard test procedure can be developed to determine if any significant external electromagnetic field is emitted.

The biological effects of the electromagnetic fields on rodents, insects, and other animals were not evaluated by NBS.

NOTES

(1) Wagner, R.E., "Outputs of Electromagnetic Devices, Their Effects on Drywood Termites," Pest Control, September 1978, p. 20.

(2) The TEM cell at NBS, Boulder, CO, was considered for additional measurements but was unavailable at the required time.

(3) Robert Plonsey and Robert E. Collin, Principles and Applications of Electromagnetic Fields, p. 242, McGraw-Hill Book Co., 1961.

(4) 2 hectares are contained within a circle of 80 meters in radius.

8.0 Appendix

1. Details of Evaluation by Unit

At least one type of each unit was measured for maximum current consumption during operation. These results are summarized in Table 5.

Unit A: Visual inspection was made of units A1 and A2. Since these were battery-operated, their cases were opened. Four 12-volt lantern type batteries in parallel supply power to the electronics which is contained in a metal cube in the center of a spun aluminum case. The case separates into two halves of upper and lower approximately equal sections. X-ray photographs of A1 show nine integrated circuits in the potting compound (three 16 pin and six 14 pin), several resistors and capacitors, and three coils mounted in a delta layout on top of the potting block. The coil's axes are parallel to the ground when the unit is installed as recommended. Laboratory testing and these photographs indicate that this unit uses digital circuitry to generate a pulse pattern output. The top portion of the case was removed to attach the oscilloscope probe to the metal box housing the electronics with the scope ground probe being connected to the negative terminal of the unit's battery power supply. The top of the metal box was placed back on the unit, but not screwed into place, being careful not to short out the oscilloscope connections to the case. This procedure reduced the 60 Hz pickup present and produced a noise-free pattern on the oscilloscope for analysis and the photographs, curve 3 (unit A1) and curve 4 (unit A2). Both units show a definite pattern repetition rate of approximately 6.4 seconds. This repetition rate coincides with the flashing of the LED indicator on top of the metal housing cover. The units are obviously operated from digital circuitry due to the exactly repeated output pattern. The units are supposed to be identical in output but there is significant variation between units A1 and A2 in the amplitude of the positive pulses within a pattern. This could be due to quality control problems or one unit not operating within design specifications.

Unit B: The X-ray photographs of unit B2 show that it also contains integrated circuits (six 14 pin and three 16 pin packages). Four 12-volt lantern batteries in parallel supply power for the unit. A metal cube with one side open houses the integrated circuits which are potted in an opaque material. Three coils in a delta form extend through the surface of this material. The coil's axes are parallel to the ground when the unit in its installed position. Likewise laboratory tests and these photographs indicate this unit uses digital circuitry to generate a pulse pattern output. This unit is housed in a plastic case with an LED mounted in the top to indicate the unit is operating. This LED flashes about every nine seconds.

The covers were removed from units B1 and B2. The oscilloscope was connected to the internal metal box for the high input lead and ground lead was connected to the negative battery terminal. Curves 1 and 2 are photographs of the oscilloscope pattern for units B1 and B2 respectively. This type of output is obviously digitally-generated because of the low frequency and exact pattern repetition. Units B1 and B2 have an equal number of positive pulses (24). Unit B1 has 26 negative pulses. Unit B2 shows two extra negative pulses of small amplitude between the normal spacing for the other negative pulses. These are probably due to a defective integrated circuit (IC) and not due to variation in the design since according to the manufacturer both units are supposed to be the same. The pulse pattern repeats approximately every 17.5 seconds. The small LED light on the top to indicate the unit is operating flashes approximately every nine seconds or twice for each pattern of pulses.

The two battery operated units, A2 and B2, were tested for output when installed in the ground. These were buried to 1/2 of their height (thickness) in the earth as recommended by the manufacturer. The oscilloscope was connected to the internal metal can and battery common terminal as in the laboratory tests. Unit A2 showed approximately a 40% decrease in output signal when the unit was in the earth relative to when it was tested in the laboratory.

For the other battery-operated unit, B2, installed in the earth, there was no change in the output signal relative to that measured in the laboratory.

Unit C: The unit C2 was X-rayed in two pieces because of its length. Both the top and base ends were photographed with approximately 45° rotation to reveal hidden parts. The photographs indicate six coils along a center rod with associated modular type circuitry printed circuit boards. There are three printed circuit boards. This unit was opened and inspection showed the six coils are connected as parallel pairs. Each pair is driven by one of the potted modules. There is some end-play between the coil retainers on the bottom and top of rod so the coils can slide along the rod when driven by opposing magnetic fields. From the chart recordings, photographs, and visual inspection of this unit, it is not possible to identify the type of components used to produce the output pattern shown in charts 3, 4, and 5.

Chart 3 is of unit C1 with a search coil[1] located around the top rod and one located around the bottom rod which was connected to a 2.4 meter iron pipe. From these the top search coil indicates a large amplitude 60 Hz (max. 15 V peak-to-peak) magnetic field of about four seconds duration that repeats every one minute and fifty seconds and a corresponding small field detected by the bottom search coil. Within this pattern, but not at uniform times, the top search coil indicated several reduced amplitude, four-second duration fields and the lower coil detected, at corresponding times, a larger amplitude field of approximately four seconds duration. Also in addition to these maximum fields in the bottom search coil, reduced fields were detected of approximately four seconds duration corresponding to similar detections in the top coil.

Similar recordings of unit C1 were made of unit C2. These are shown in charts 4 and 5. Chart 4 shows the calculations of the relative amplitudes from each coil for each approximately four second "on" time of the unit (max. 15.5 V peak-to-peak).

Chart 5 shows the output from the top search coil only for the period between 11 and 15 minutes after turn on. The top pair of coils is designed No. 3, middle pair No. 2, and lower pair No. 1. The pattern repeats every one minute and 50 seconds, but the operation of pairs 1 and 2 are not consistent in order of operation within the pattern. The difference in amplitude between the 1, 2, and 3 pairs of coils is due to the difference in each coil-pair distance from the search coil on the stub. The coil is closest to the No. 3 pair. The reason for the random on-off time of coil pairs 1 and 2 within the time pattern cannot be identified without more circuitry information or destructive examination of the encapsulated modules.

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(1) The search coil described was used to examine the characteristics of each unit for oscilloscope analysis and paper chart recording. Charts 3 through 11 are typical records of the outputs from the 115 volt 60 Hz units when detected by a search coil or coils. The chart speed in all recordings is 1 sec/mm with the smallest chart division equal to 1 mm. The minute marks are indicated down the center of the chart. The oscilloscope was used to determine that these units had 60 Hz outputs. The maximum amplitude detected by the search coil was determined from the oscilloscope calibration and indicated on each channel of recording. This reduced the time and confusion of adjusting the pen recorder to a specific level. All charts are a portion of a recording taken after each unit was turned on and run for some time. Recordings lasted from 15 minutes to nearly one hour to analyze the characteristics of each output.

When the unit C2 is initially turned on, all three coils are energized and the upper No. 3 pairs separate from the No. 2 and No. 1 pairs by the amount of travel possible for the coils along the rod, about 12 mm. This is accompanied by an audible vibration during the "on" time of about four seconds. This audible vibration also occurs when the 1 and 2 pairs are "on" simultaneously. Smaller audible vibrations were noticed when a single pair of coils was driven or for other combinations of pairs.

The driving signal to each pair of coils from its associated encapsulated module was measured as 115 volts 60 Hz during the four seconds period. When a pair of coils is being driven, they induced 60 Hz signal into the adjacent undriven pairs.

Unit D: Two X-ray photographs were made of unit D because of its length. This unit has a clear plastic center section. Visual inspection shows three coils mounted on a metal rod with some space between the coils so they can slide on the rod. A retainer on each end limits the travel. The X-ray photographs of unit D reveal very little additional identifiable circuitry. The random output pattern could be controlled by a thermostatic type switch which turns different coils on.

A paper chart recording was made of unit D (chart 6). The search coil was placed as near as possible along the clear plastic side, parallel to the center coil of the three coils mounted on the center rod. After initial startup, the unit turns off, but then operates in a random mode as shown in the chart. The output is low (0.26 volts peak-to-peak) as detected by the search coil. The duration of "on" time is variable. This unit appears to be controlled by a thermostatic type switch that is sensitive to the temperature of the unit which would also be affected by the ambient environment. This could produce the variation in time of operation and duration. The radiated field is always 60 Hz and can be less than one second in duration and up to several seconds after the initial startup. The lower amplitude signals are due to the random operation of the other coils which are not coupled as closely to the search coil as the center coil. This type of variable operation of different coils in a multi-coil unit was observed when testing units C1 and C2.

Unit E: The X-rays of unit E1 show two coils mounted adjacent to each other with their center axis spaced 75 mm apart. The coil centers are such that two units could be bolted together to increase the output fields. Each unit has a fuse. Other circuitry appears limited. The unit is also possibly controlled by a thermostatic switch.

The units E1 and E2 are also 115 volts 60 Hz powered pest controllers. Both are supposed to be identical and they operated essentially the same after the initial startup. Each was examined with two search coils placed on top with their axes on line with the axes of the internal coils as revealed by the X-rays. When unit 1 was turned on, a 60 Hz field was present from one coil for 15 minutes and then went off for 12 minutes. The other coil was on for 12 minutes and then off for 15 minutes. After the "off" time, the unit E1 produced a 60 Hz, 2.6 volt peak-to-peak sine wave. Duration of each transmission varied from less than one second to several seconds. Both of the coils would frequently be on simultaneously but would not necessarily start or stop at the same time. Examination of chart 7 reveals the random nature of the operation after warm-up between the time of 27 minutes and 31 minutes after turn-on. A very sensitive heat element that detects the temperature of each coil could produce this pattern. The ambient temperature would be a factor affecting the operating pattern.

Unit E2 exhibited similar characteristics as unit E1 except on startup each coil operated for approximately 3-1/2 and 2-1/2 minutes respectively, then both were off for 8-1/2 minutes. After this the random pattern shown in chart 8 began. All detected signals are 60 Hz sine waves and from 2.6 to 2.8 volts peak-to-peak at the search coils. This is the same amplitude as unit E1.

Unit F: The unit F1 consists of a metal box with an attached pipe. The X-rays show the box most likely contains three thyristor semiconductor switches and the pipe section contains several coils. The pipe and unit heat up with extended time of operation. Thermostats could be used to activate the thyristors to produce the pattern recorded in charts 9 and 10.

The output of units F1 and F2 were examined around the case with a search coil and the oscilloscope. Both are 115 volts 60 Hz powered units and radiate 60 Hz sine waves of varying amplitudes with time. Two search coils were used for charts 9 and 10, one located at the end of the unit and the other at the base of the case where the extension pipe exits. The coils were located for maximum output in these positions. The unit operated for approximately seven minutes at a constant amplitude, then the output dropped to a lower but constant amplitude (see chart 9). After approximately 11 minutes the unit went off. The detected amplitude at the higher level was 1.3 volts peak-to-peak at the base search coil and only 0.4 V p-p at the end search coil. Chart 10 shows the pattern of detected output after several minutes of operation (21 to 25 minutes). Other portions of the recording show reversal of low and high amplitudes but starting, stopping, and magnitude changes occur simultaneously with the two search coils in these positions. X-rays of the upper extension indicated circuitry in the upper sections and coils in the pipe. Even though the output is 60 Hz sine wave, this unit has a different on-off characteristic than the previous units which were on for much shorter times and more frequently.

Unit G: The G1 and G2 type units are designed to be clamped to a water pipe. They also are 115 volt 60 Hz powered. The unit G2 X-rays show two coils around a common center rod. They are spaced about 30 mm apart. The X-rays indicate a thermal activated switch is mounted against each coil. After initial turn on the temperature reaches the switching level of the heat sensor which turns off the associated coil. Thereafter, when the coil cools down, each coil is activated when its switch closes and runs until the switch opens.

Two search coils were also used to analyze unit G1, one located on top and the other on the side. Its output is a 60 Hz sine wave of 4.3 volts peak-to-peak from the top search coil and 2.5 volts peak-to-peak from the side search coil. After initial turn on the unit operated for nearly 25 minutes at its maximum peak amplitude at the side coil. After that the operation becomes random with various amplitudes and off times. Each amplitude change or off time was simultaneously reflected by the two search coils. Like the unit F1, all G1 "on" operations were longer than the other 115 V 60 Hz units (see chart 11).

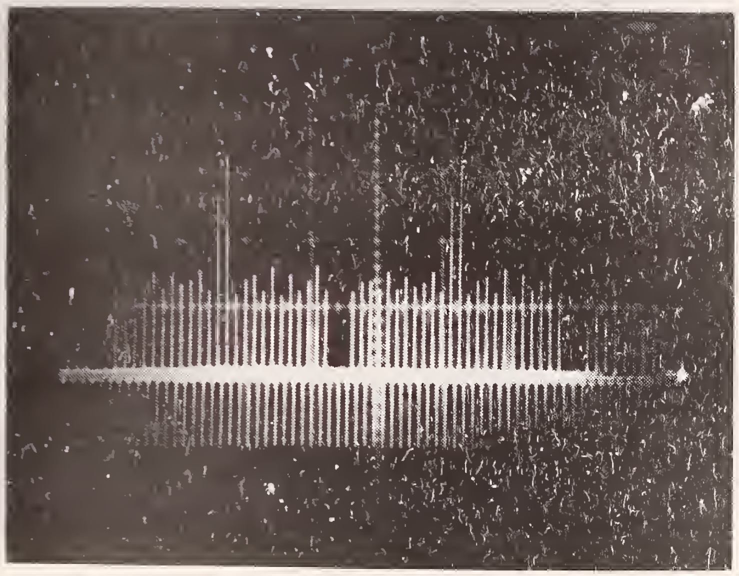
Unit H: The unit H is enclosed in a plastic case consisting of a base section containing all of the electronic circuitry either molded in place or bonded by other means. A top plastic piece is bonded to the base flange. On top of this cover is mounted an LED. The case is open along one side permitting inspection of the unit. The encapsulated electronics, transformer, and three coils are visible here. This opening was used to make electrical connections for the laboratory testing and measurements.

The X-ray photographs of the H unit shows a power supply, three coils coupled to the encapsulated module, and the module of six 14 pin and three 16-pin integrated circuits and other components.

The H unit is 115 volt 60 Hz powered. It contains a power supply to convert to 12 volts DC. The small light emitting diode on the case flashes about every six seconds (similar to Type A units) to indicate the unit is operating. The X-ray photographs revealed that the unit H contains electronic components similar to those in the A and B units except for the DC power supply. Therefore, it was tested for pulse output. No output was detectable using the search coil. The oscilloscope common lead was connected to the negative of the 12 volt supply. No metal case or box is used in the H unit as in A or B units. The oscilloscope probe was connected to one of the coil leads from the encapsulted electronic components to investigate any pulse output. The output is shown in the sketch, curve 5. The pulse pattern is repeated approximately every 12 seconds. This type of output is also obviously digitally generated because of the low frequency, exact pulse pattern repetition, and the integrated circuits used as shown by X-ray photographs. The maximum positive pulse output is over twice that of the B units but the intermediate low amplitude pulses are significantly less. The average power radiated is very low due to the short pulse duration and small amplitudes which likewise is characteristic of the A and B pulse units.

Table 5
Operating Voltages and Currents

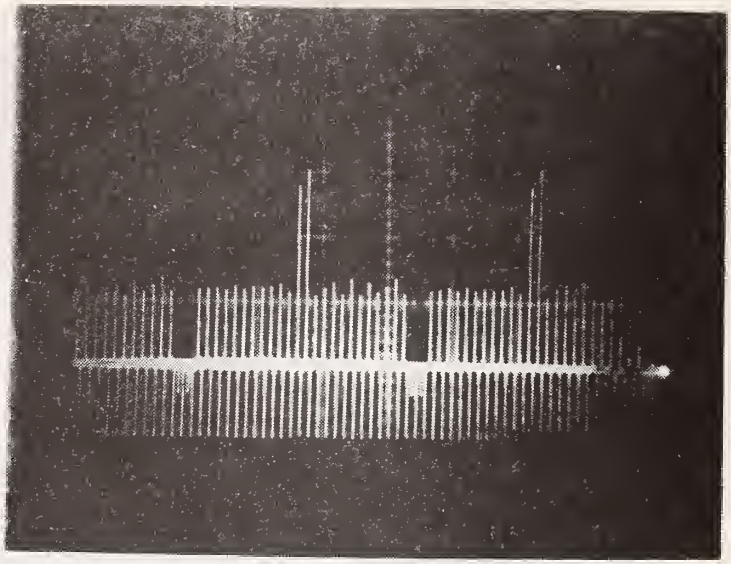
Code	Operating Volts	Max. Current
A1	12 V DC	6.2 mA
A2	12 V DC	2.2 mA
B1	11 V DC	2.3 mA
B2	11.2 V DC	3.1 mA
C2	115 V AC	3.1 A
D	115 V AC	9.4 A
E1	115 V AC	3.1 A
F1	115 V AC	2.6 A
G2	115 V AC	5.3 A



UNIT B 1: 6/8/78

Maximum Positive Pulse	:	2.3 V
Negative Pulse	:	.675 V
Sweep Rate	:	5 sec/cm
Pulse Rate	:	.35 sec
Pattern Rep. Rate	:	17.5 sec
Gain	:	.675 V/cm

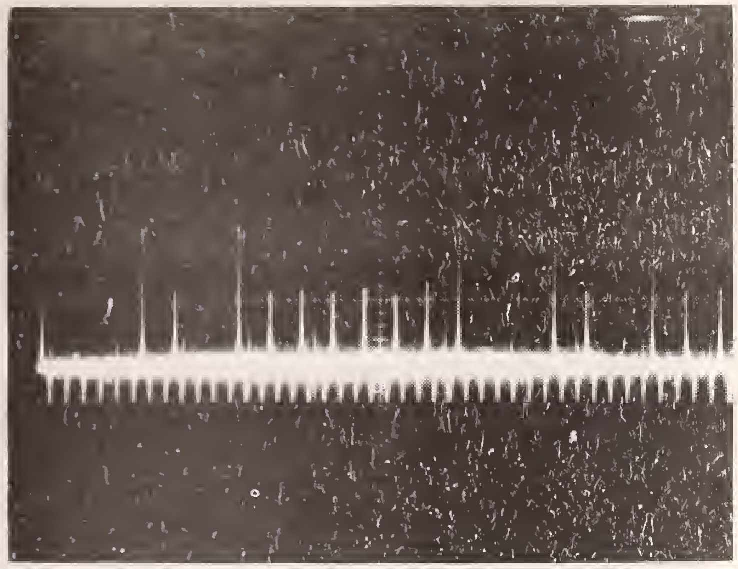
CURVE 1



UNIT B 2: 6/8/78

MAXIMUM POSITIVE PULSE	:	2.25 V
NEGATIVE PULSE	:	.825 V
SWEEP RATE	:	5 SEC/CM
PULSE RATE	:	.35 SEC
PATTERN REP. RATE	:	17.5 SEC
GAIN	:	.75 V/CM

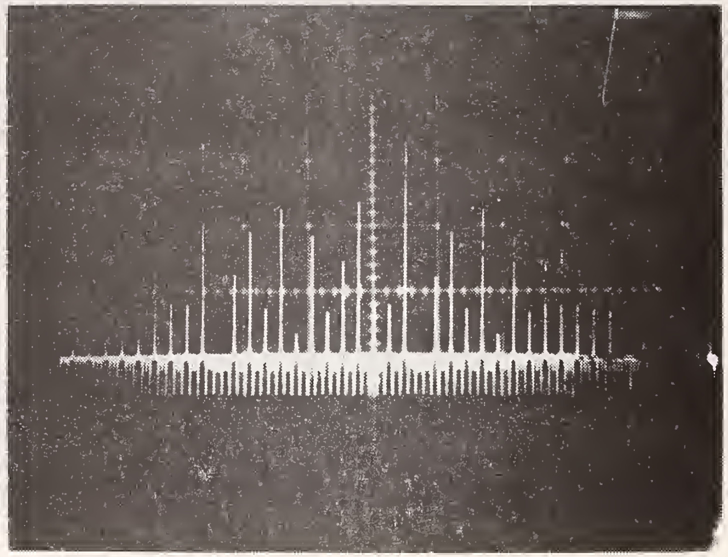
CURVE 2



UNIT A 1: 6/7/78

Maximum Positive Pulse	:	.51 V
Negative Pulse	:	.09 V
Sweep Rate	:	1 sec/cm
Pulse Rate	:	.18 sec
Pattern Rep. Rate	:	6.4 sec
Gain	:	.183 V/cm

CURVE 3



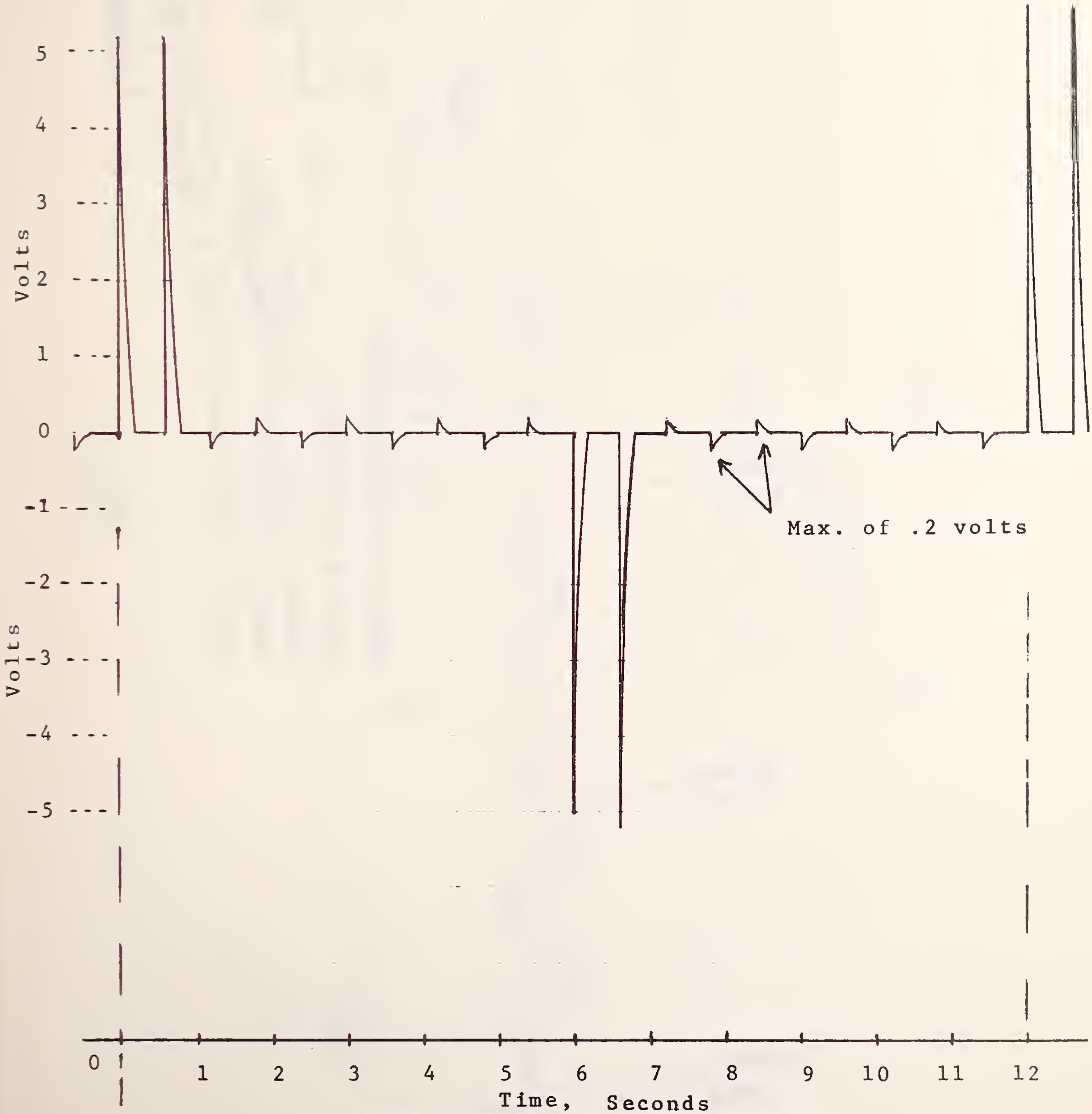
UNIT A 2: 6/8/78

MAXIMUM POSITIVE PULSE	:	.64V
NEGATIVE PULSE	:	.12V
SWEEP RATE	:	2 SEC/CM
PULSE RATE	:	.18 SEC
PATTERN REP. RATE	:	6.4 SEC
GAIN	:	.183 V/CM

CURVE 4

Curve 5: 10/23/78

Sketch of Output of Unit H 1
as shown on the Oscilloscope Display



Pattern Repeats ~ Every 12 Seconds

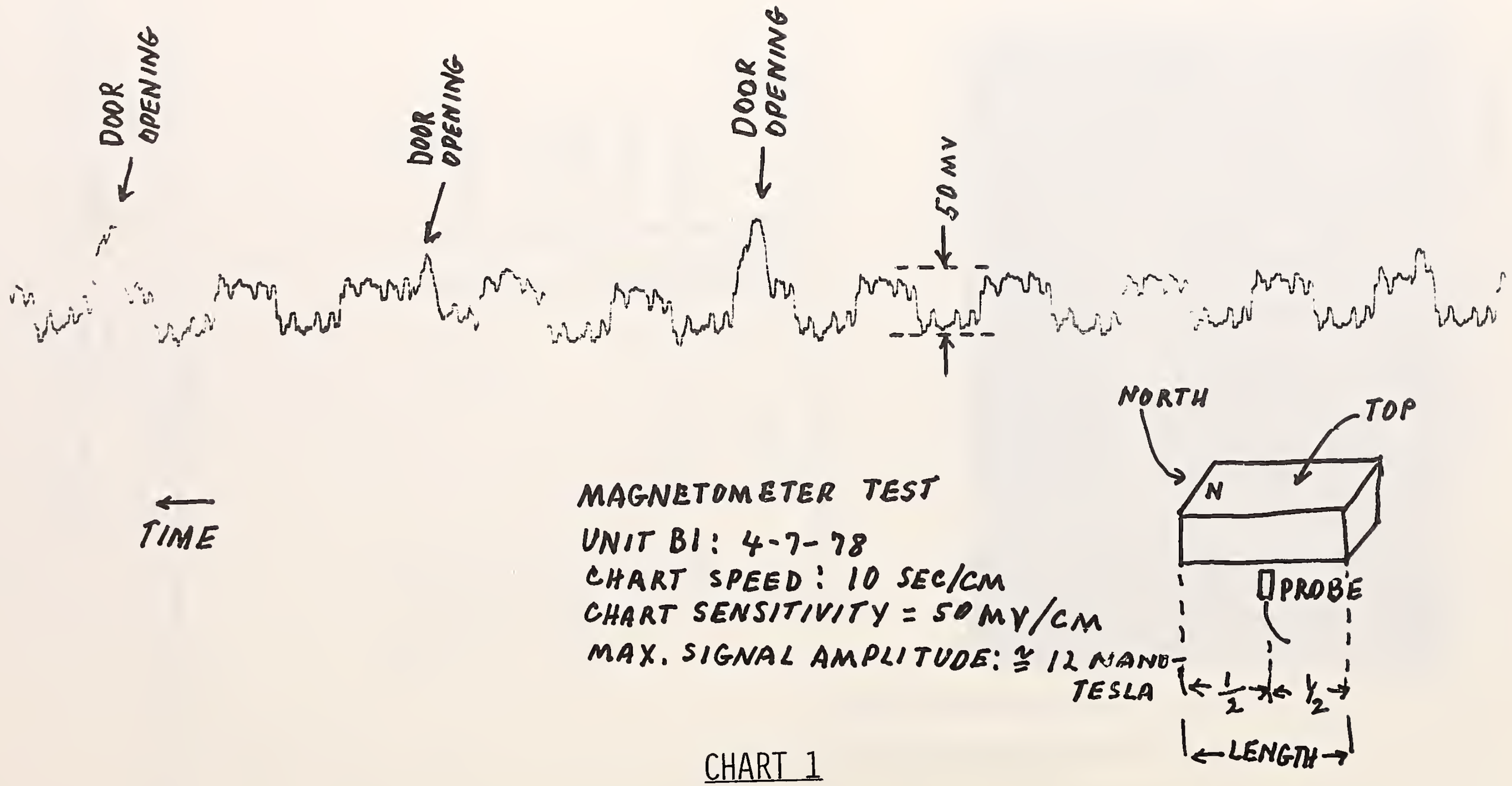

DOOR OPENING
DOOR OPENING
DOOR OPENING
50 MV
TIME
NORTH
TOP
N
PROBE
MAGNETOMETER TEST
UNIT BI: 4-7-78
CHART SPEED: 10 SEC/CM
CHART SENSITIVITY = 50 MV/CM
MAX. SIGNAL AMPLITUDE: ≅ 12 NANO-TESLA
1/2
1/2
LENGTH

CHART 1

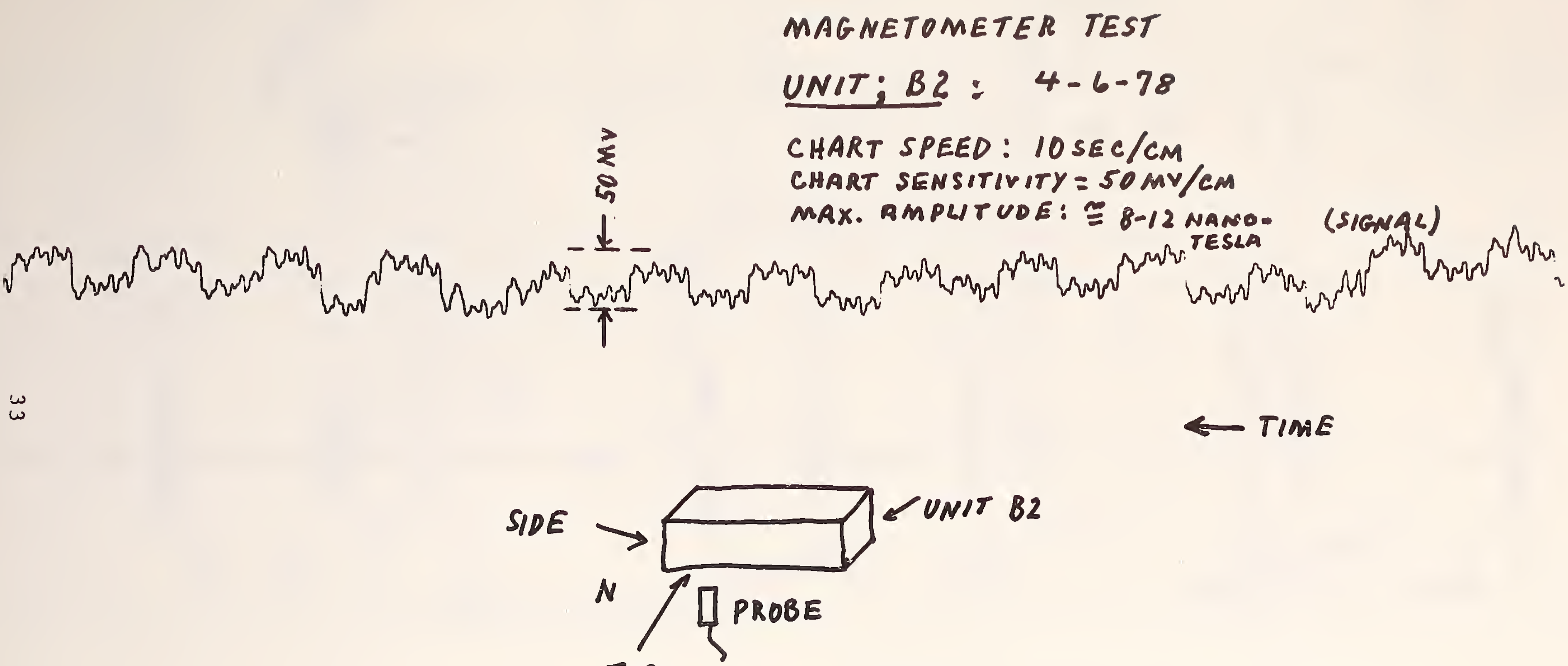
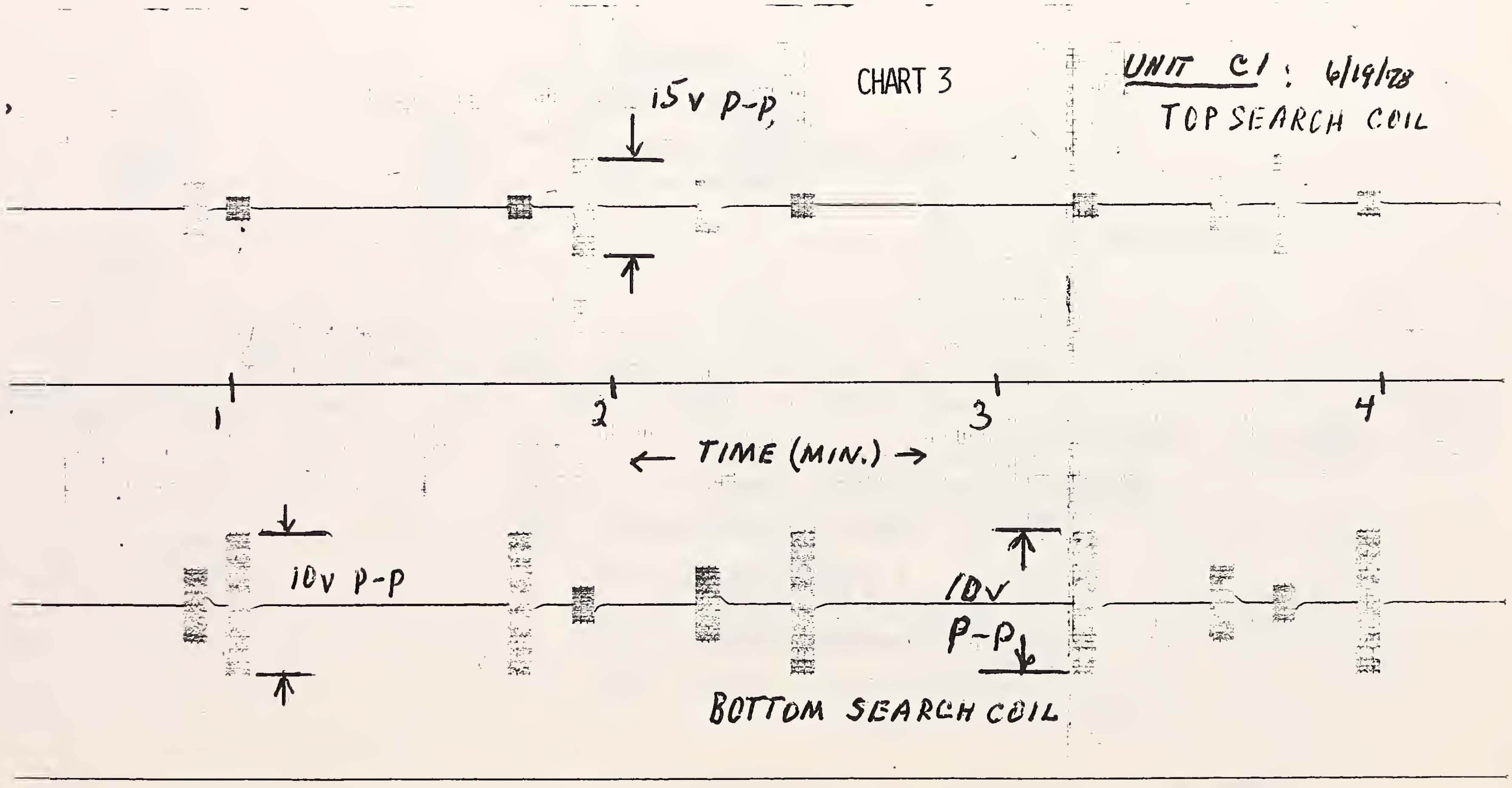
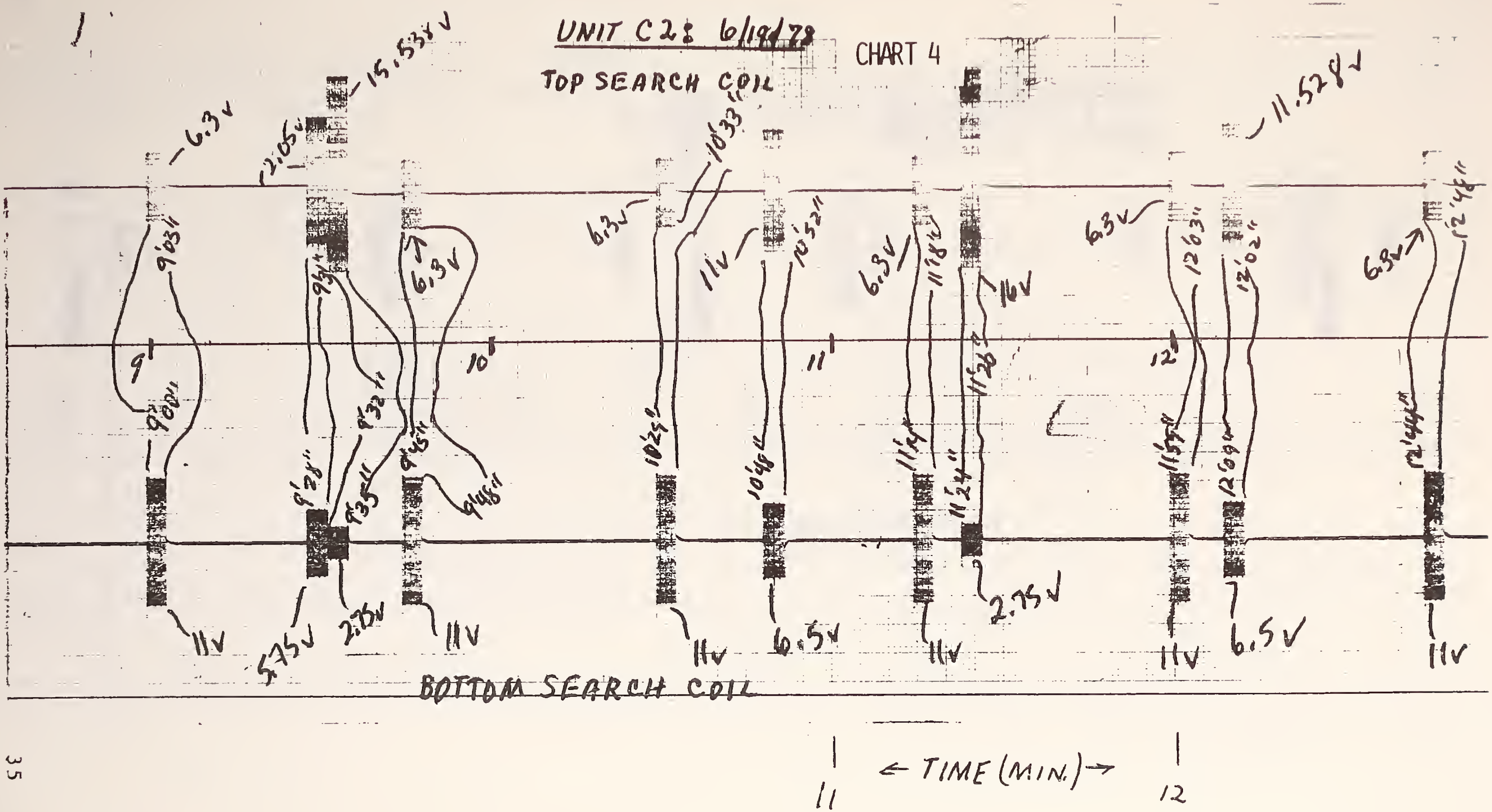
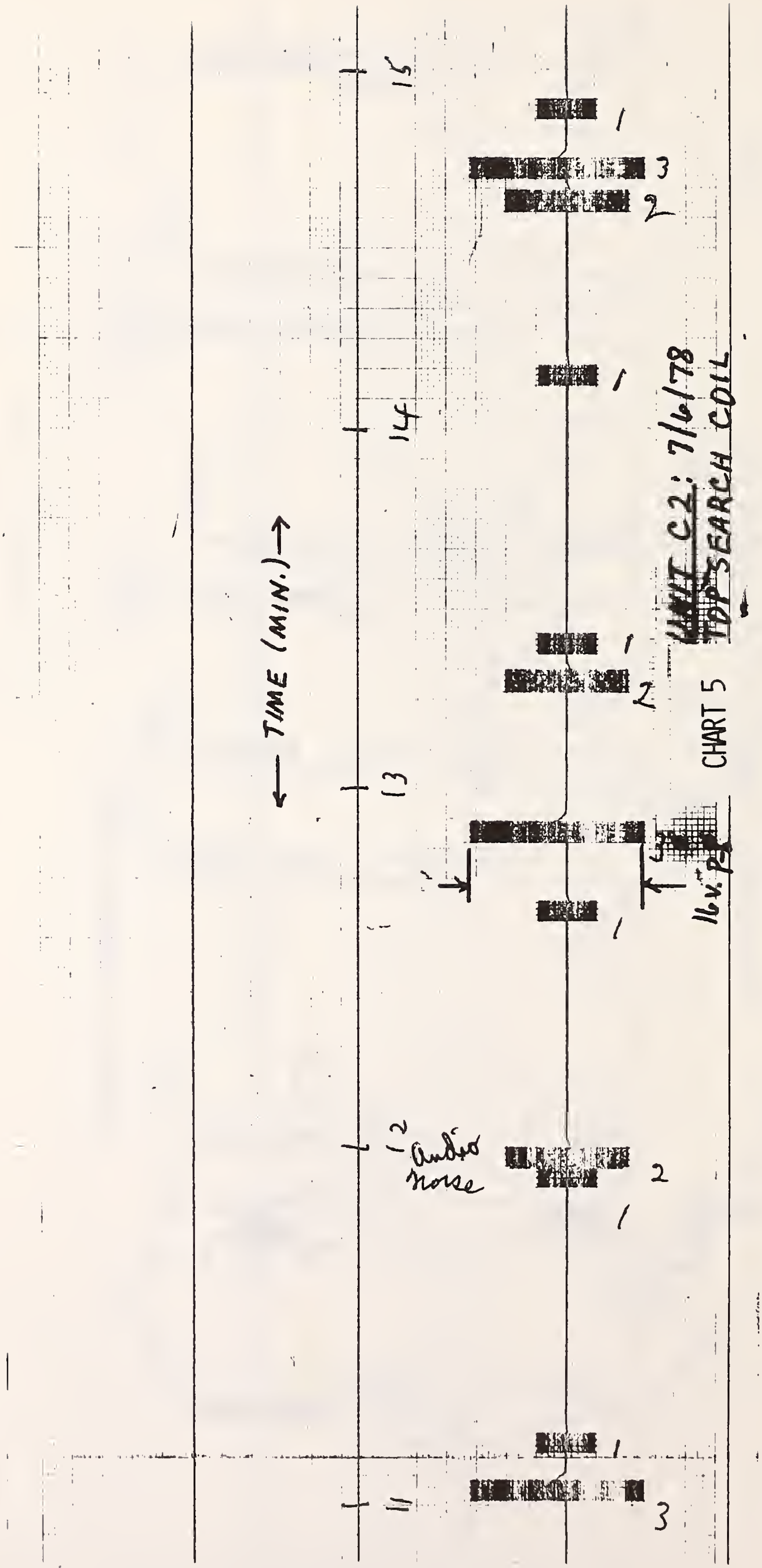

MAGNETOMETER TEST
UNIT; B2 ; 4-6-78
CHART SPEED: 10 SEC/CM
CHART SENSITIVITY = 50 MV/CM
MAX. AMPLITUDE: ≅ 8-12 NANO-TESLA
(SIGNAL)
50 MV
← TIME
SIDE
UNIT B2
N
PROBE
TOP

CHART 2

CHART 3


UNIT C1 : 6/19/78
TOP SEARCH COIL
15v p-p
1
2
3
4
← TIME (MIN.) →
10v p-p
10v
p-p
BOTTOM SEARCH COIL


UNIT C28 6/19/78
CHART 4
TOP SEARCH COIL
BOTTOM SEARCH COIL
← TIME (MIN.) →
11
12
6.3v
11v
15.538v
2.05v
5.75v
2.75v
6.5v
11.528v
16v
9'
10'
11'
12'
9'03"
9'00"
9'28"
9'32"
9'35"
9'45"
9'48"
10'24"
10'33"
10'48"
10'52"
11'14"
11'18"
11'24"
11'28"
11'59"
12'03"
12'02"
12'09"
12'44"
12'48"



← TIME (MIN.) →
11
12
13
14
15
Audio noise
16 V. P-P
UNIT C2: 7/6/78
TOP SEARCH COIL

CHART 5

CHART 6

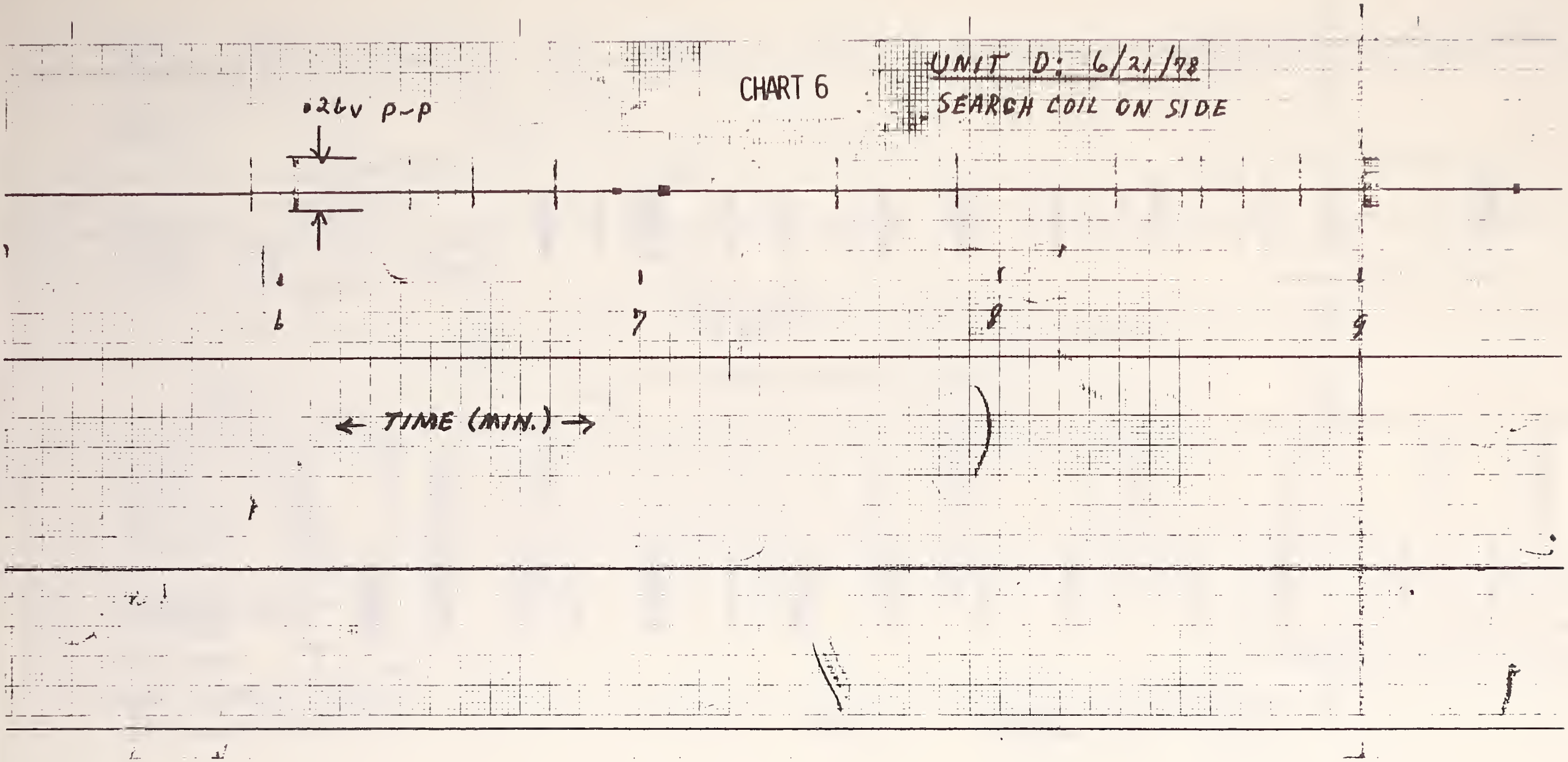
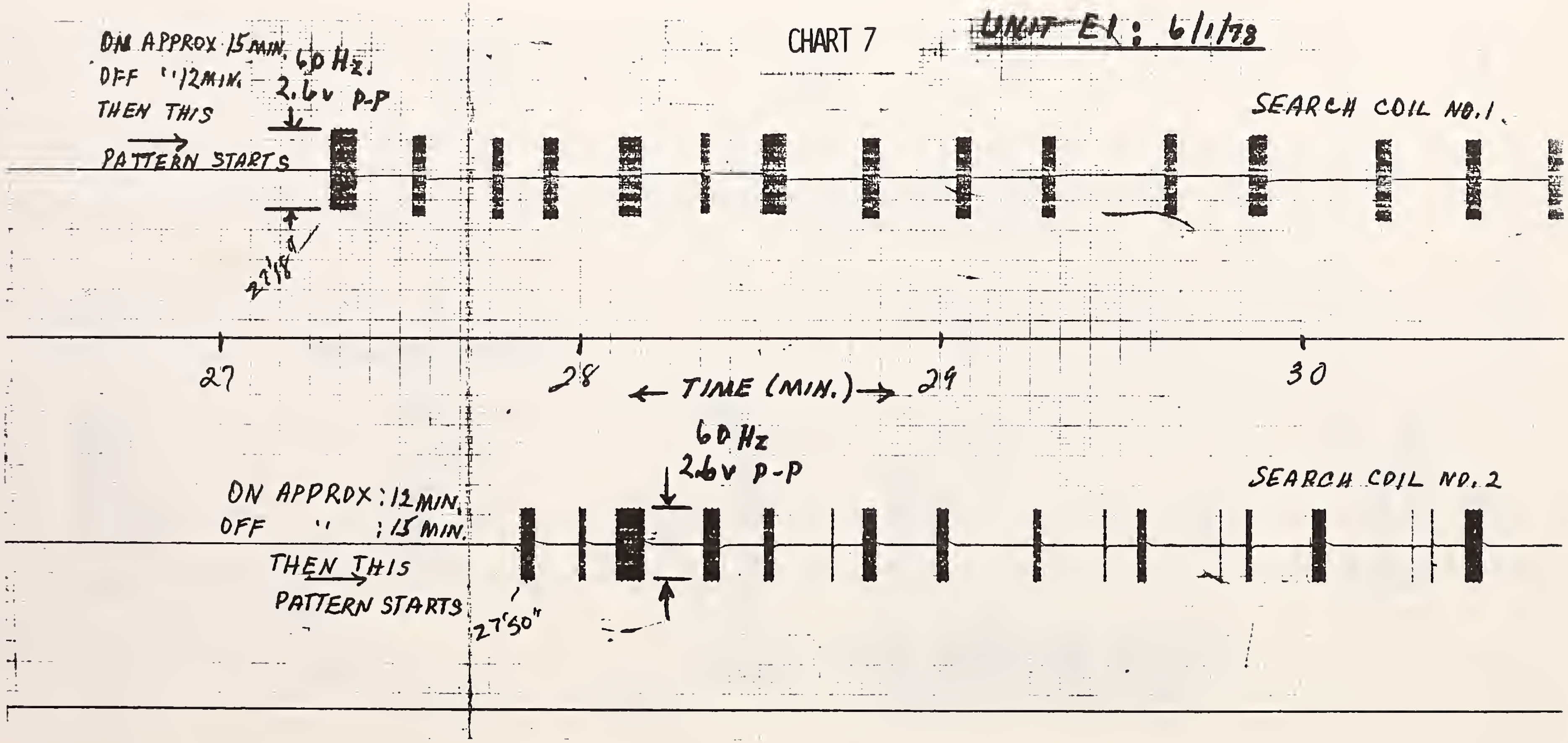


CHART 7


UNIT E1 ; 6/1/78
ON APPROX 15 MIN. 60 Hz.
OFF " 12 MIN. 2.6 v P-P
THEN THIS
PATTERN STARTS
27'18"
SEARCH COIL NO. 1
27
28
← TIME (MIN.) →
29
30
60 Hz
2.6 v P-P
SEARCH COIL NO. 2
ON APPROX : 12 MIN.
OFF " : 15 MIN.
THEN THIS
PATTERN STARTS
27'50"

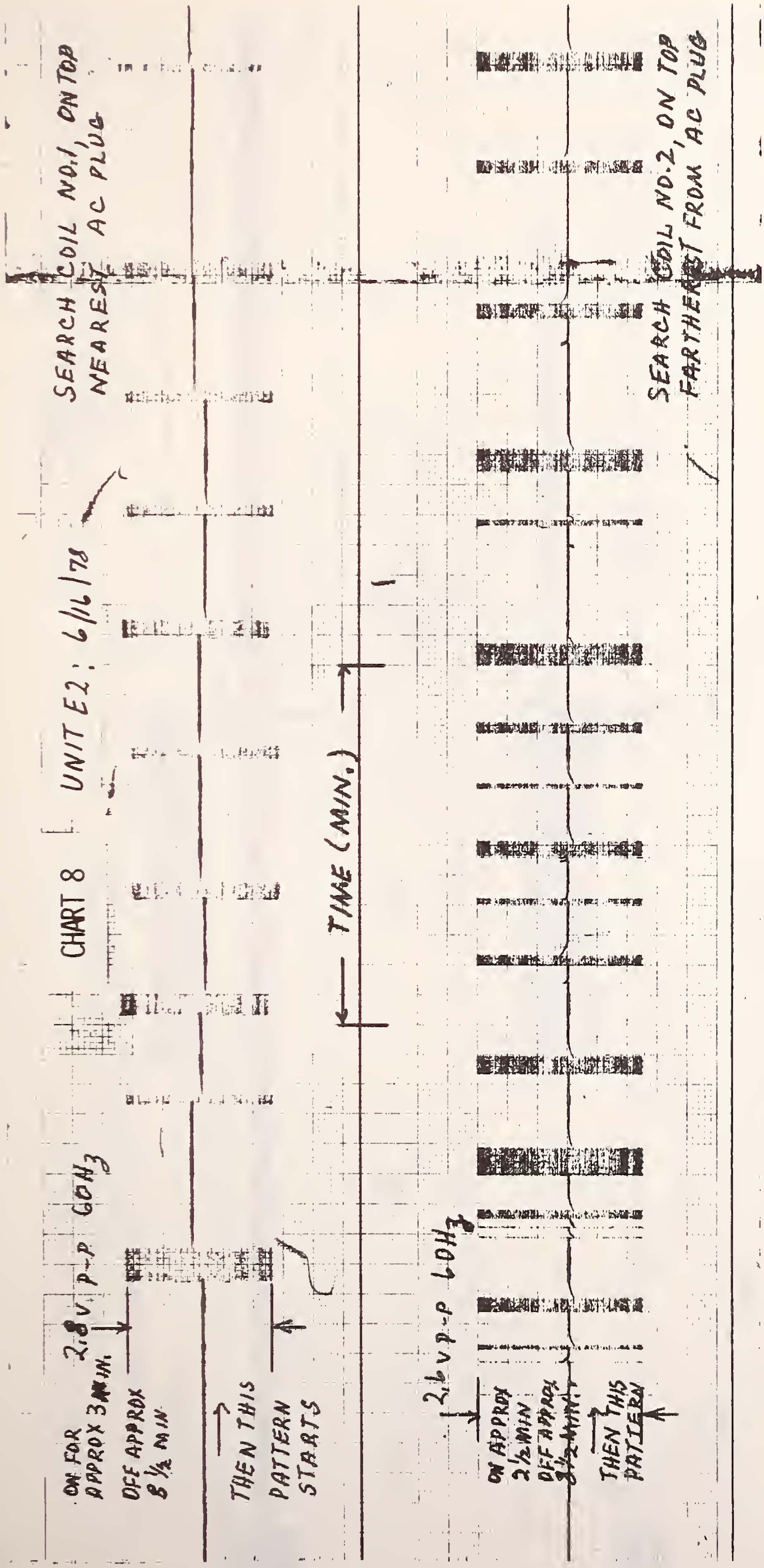


CHART 8
UNIT E2: 6/16/78
SEARCH COIL NO.1, ON TOP NEAREST AC PLUG
2.8 V. P-P 60 Hz
ON FOR APPROX 3 MIN.
OFF APPROX 8 1/2 MIN
THEN THIS PATTERN STARTS
TIME (MIN.)
2.6 V P-P 60 Hz
ON APPROX 2 1/2 MIN
OFF APPROX 3 1/2 MIN
THEN THIS PATTERN
SEARCH COIL NO. 2, ON TOP FARTHEST FROM AC PLUG

CHART 9

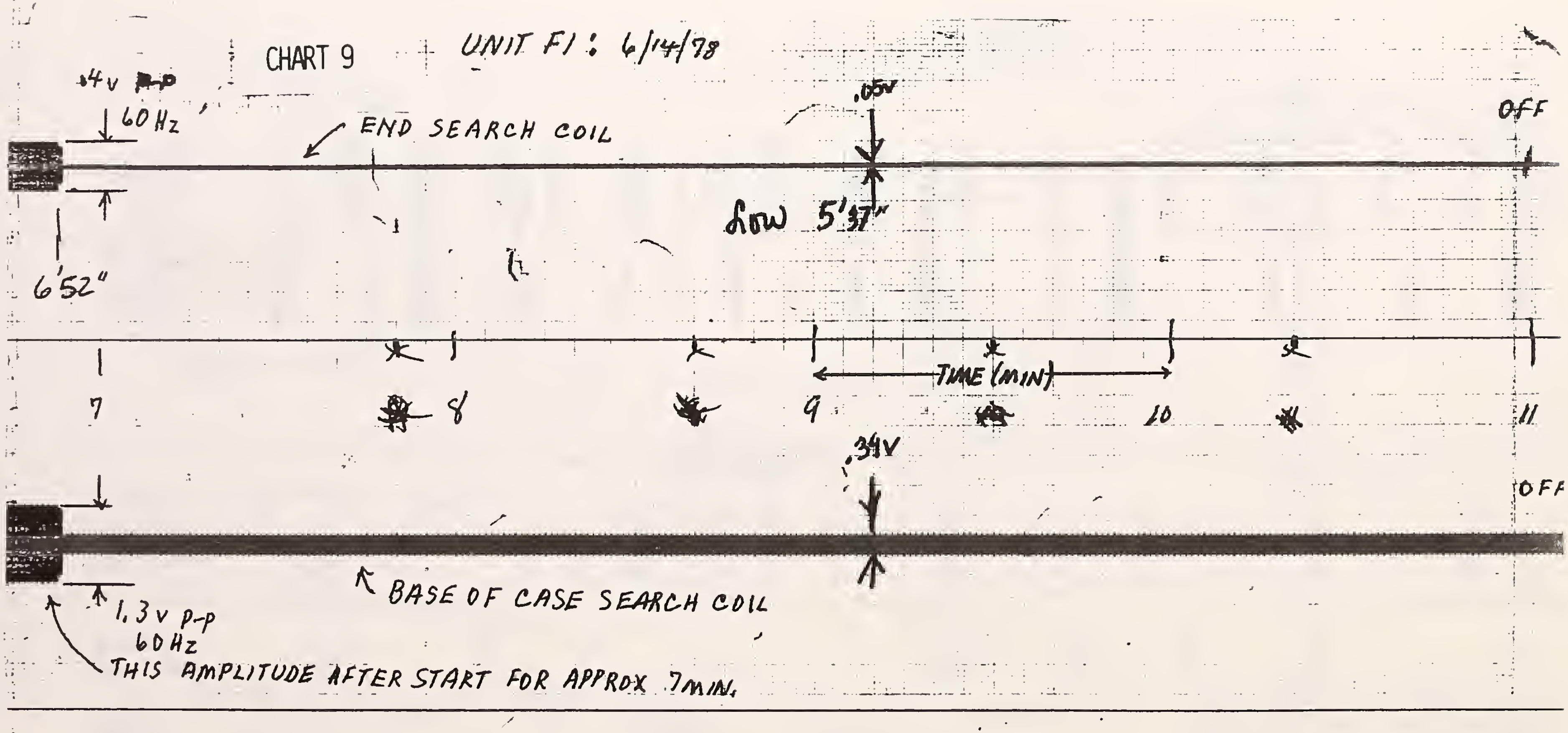

UNIT F1 : 6/14/78
.4v
60 Hz
END SEARCH COIL
.05v
OFF
Low 5'37"
6'52"
7
8
9
10
11
TIME (MIN)
.34V
OFF
BASE OF CASE SEARCH COIL
1.3 v p-p
60 Hz
THIS AMPLITUDE AFTER START FOR APPROX 7 MIN.

CHART 10

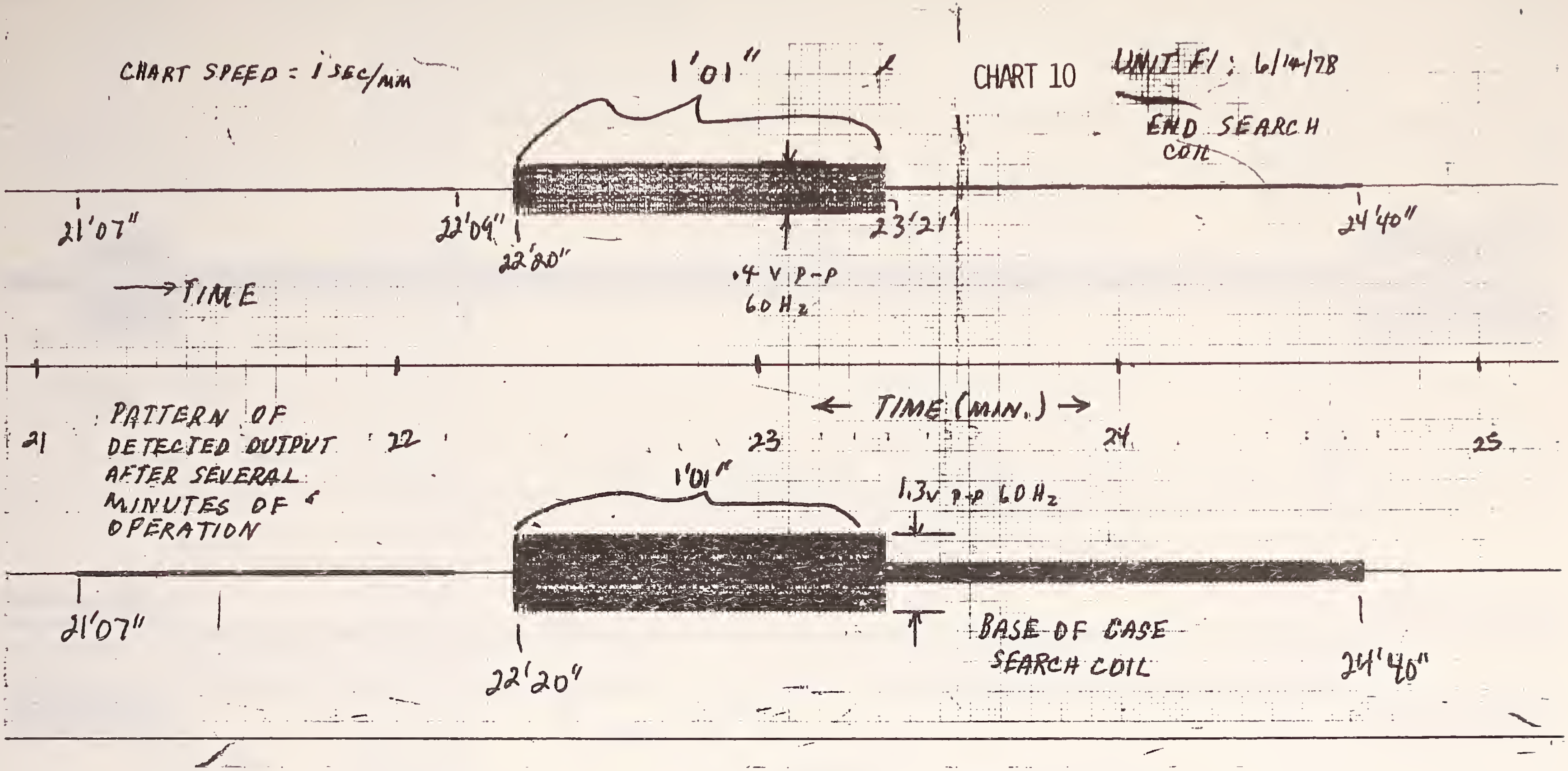


CHART SPEED = 1 sec/mm
1'01"
UNIT F1 ; 6/14/78
END SEARCH COIL
21'07"
22'09"
22'20"
23'21"
24'40"
→ TIME
.4 V P-P 60 Hz
← TIME (MIN.) →
21
22
23
24
25
PATTERN OF DETECTED OUTPUT AFTER SEVERAL MINUTES OF OPERATION
1'01"
1.3V P-P 60 Hz
21'07"
22'20"
BASE OF CASE SEARCH COIL
24'40"

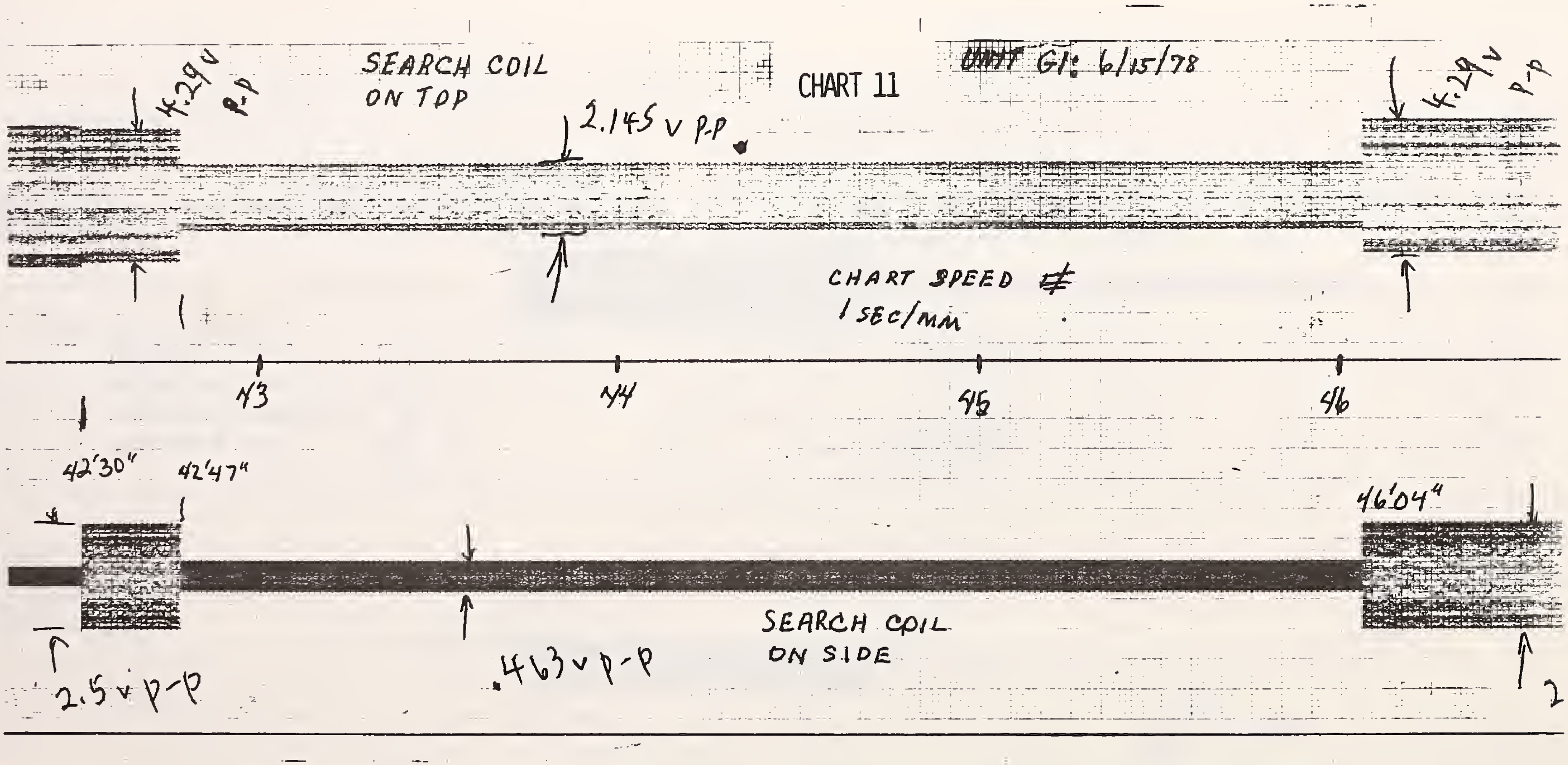
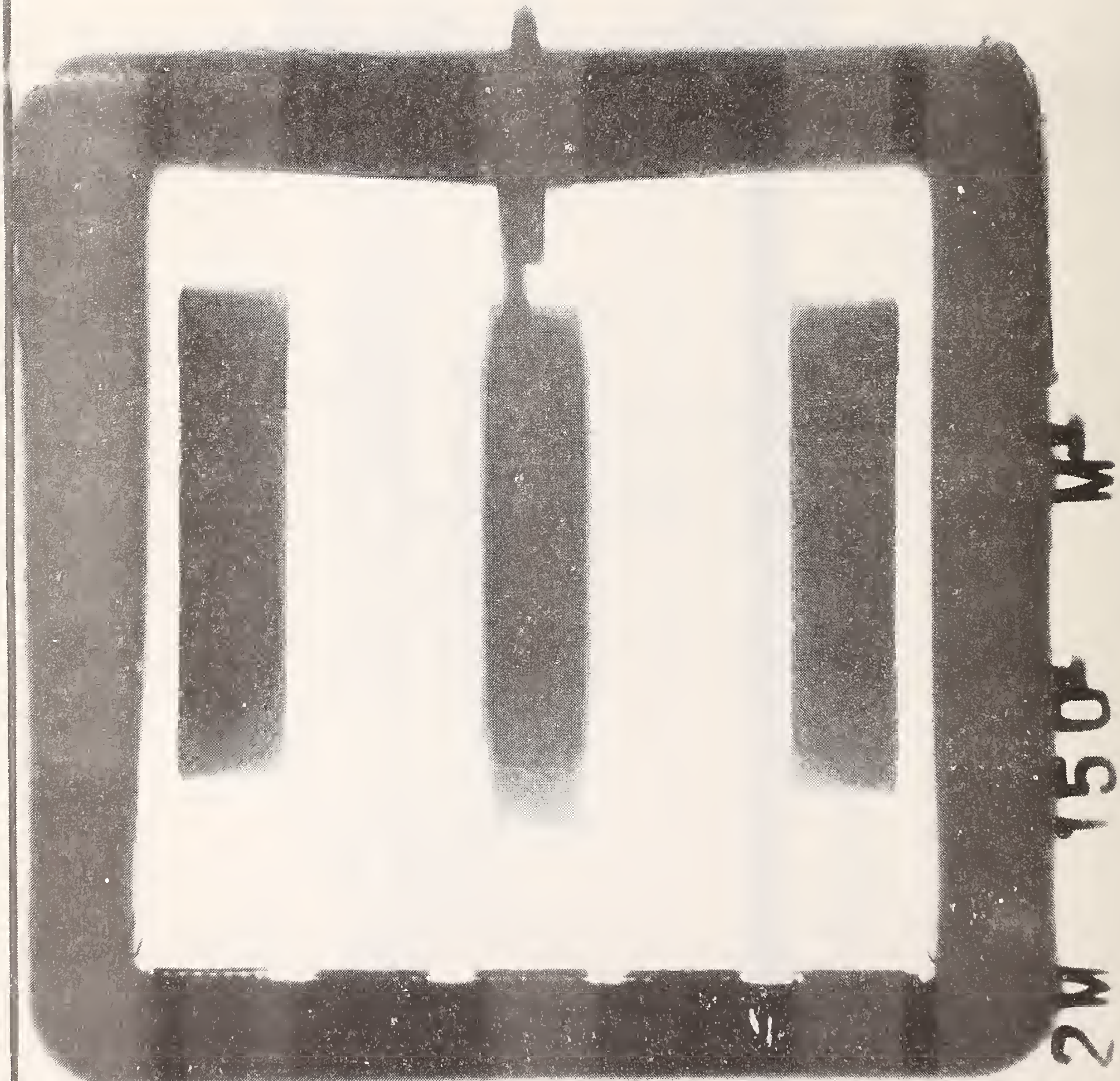


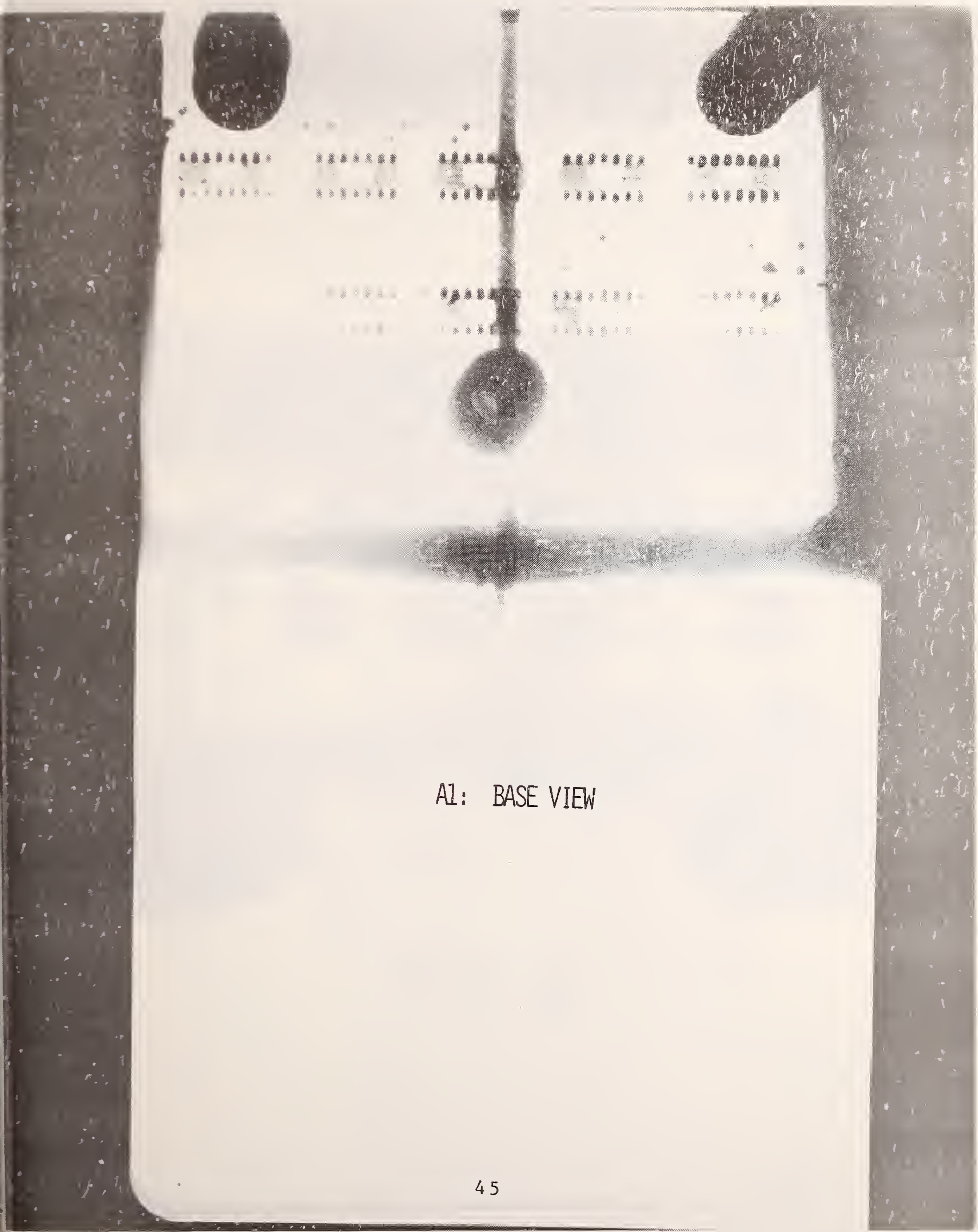
CHART 11
G1: 6/15/78
SEARCH COIL
ON TOP
4.29 v
p-p
2.145 v p-p
4.29 v
p-p
CHART SPEED
1 sec/mm
43
44
45
46
42'30"
42'47"
46'04"
SEARCH COIL
ON SIDE
2.5 v p-p
.463 v p-p
2

8.0 A P P E N D I X

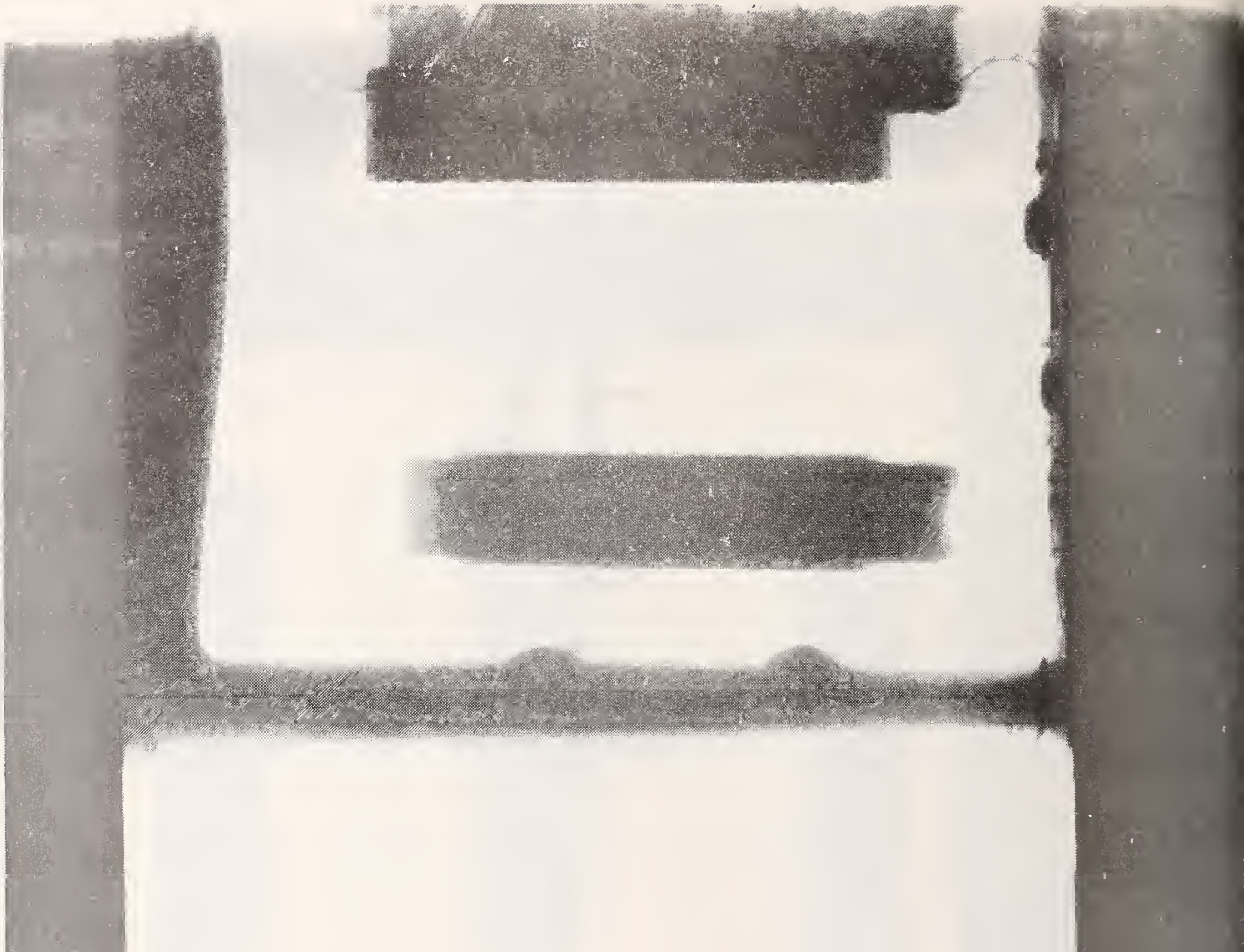
2. X-Ray Photographs



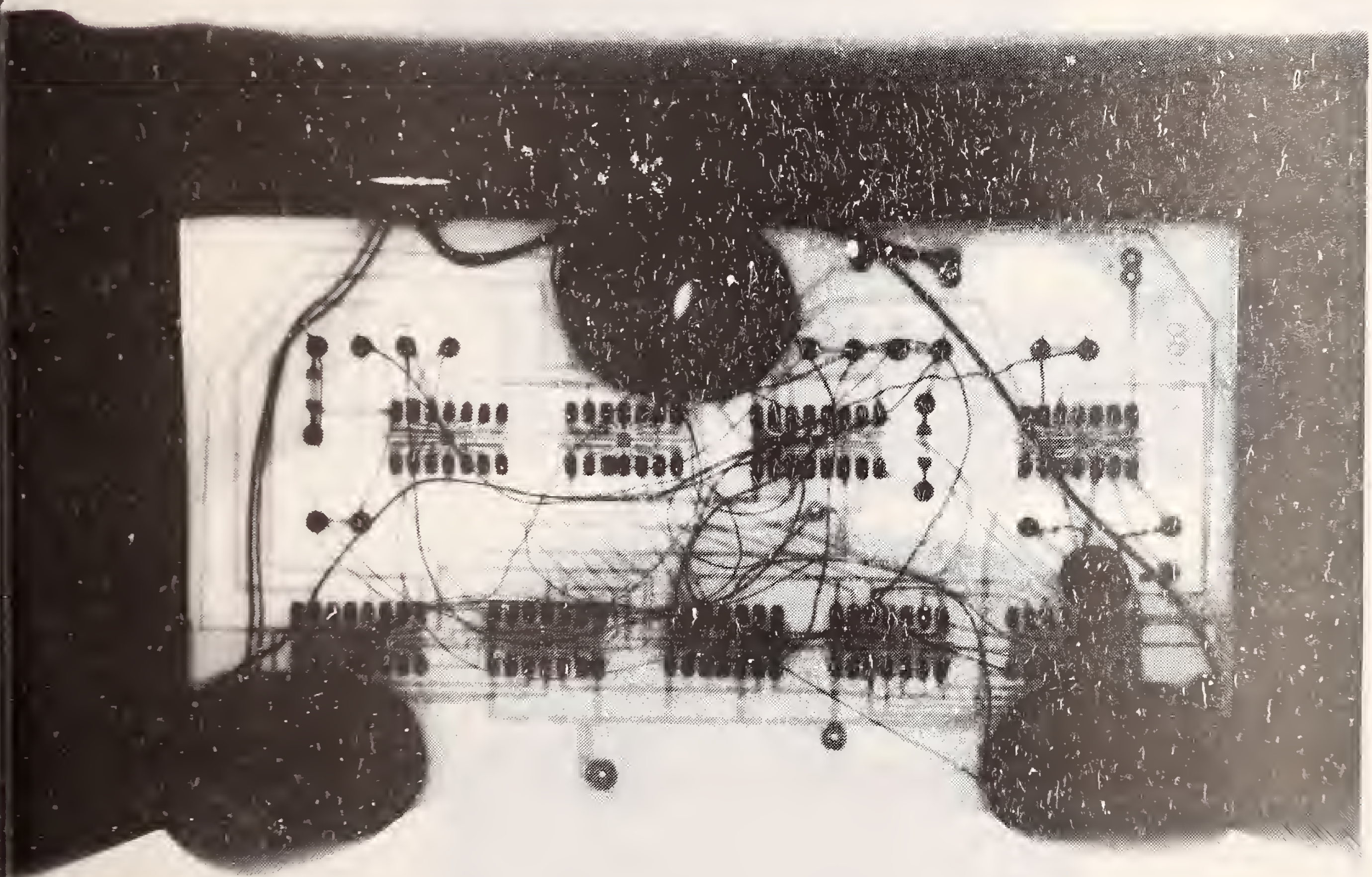
A1: TOP VIEW



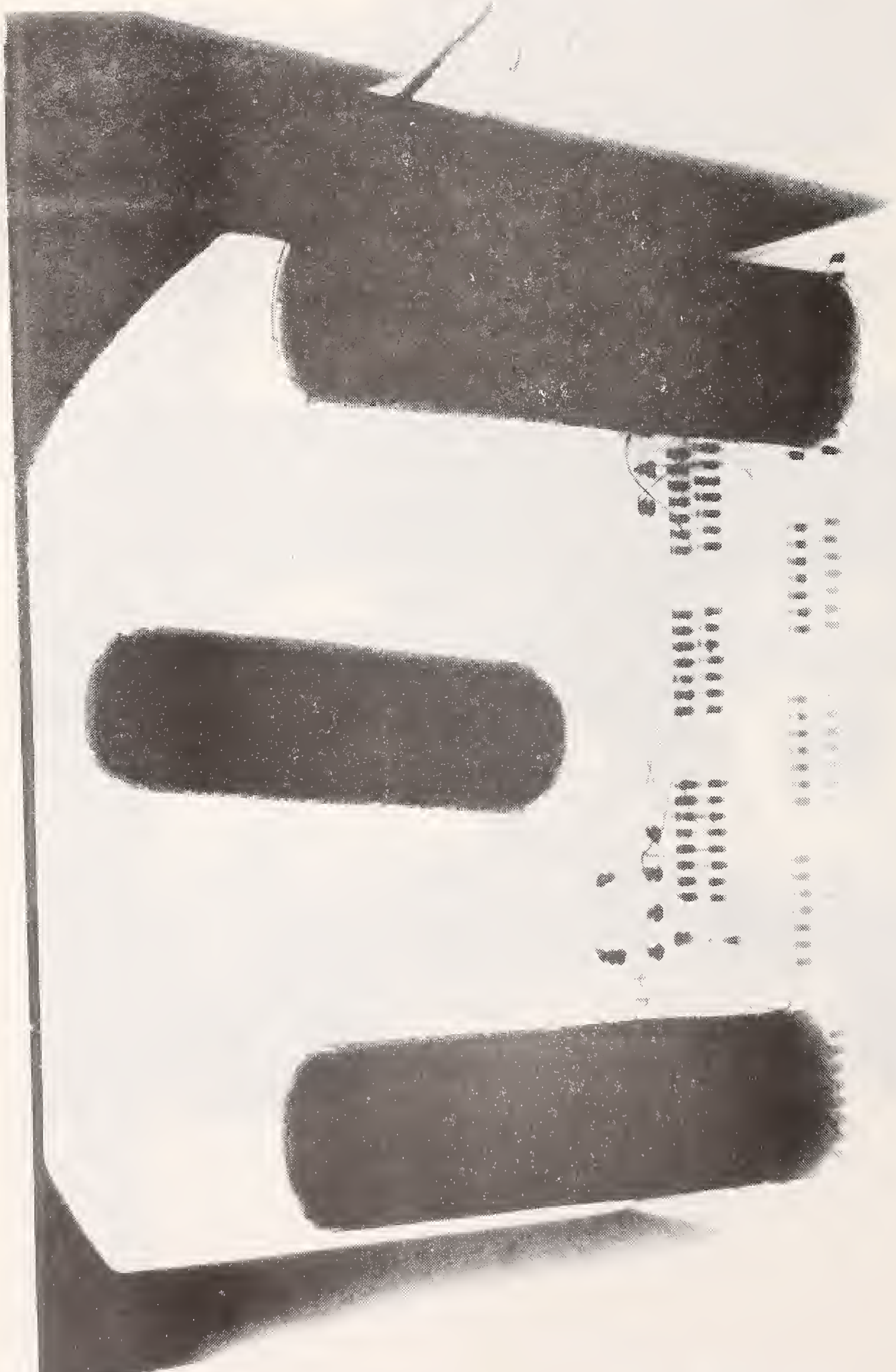
A1: BASE VIEW



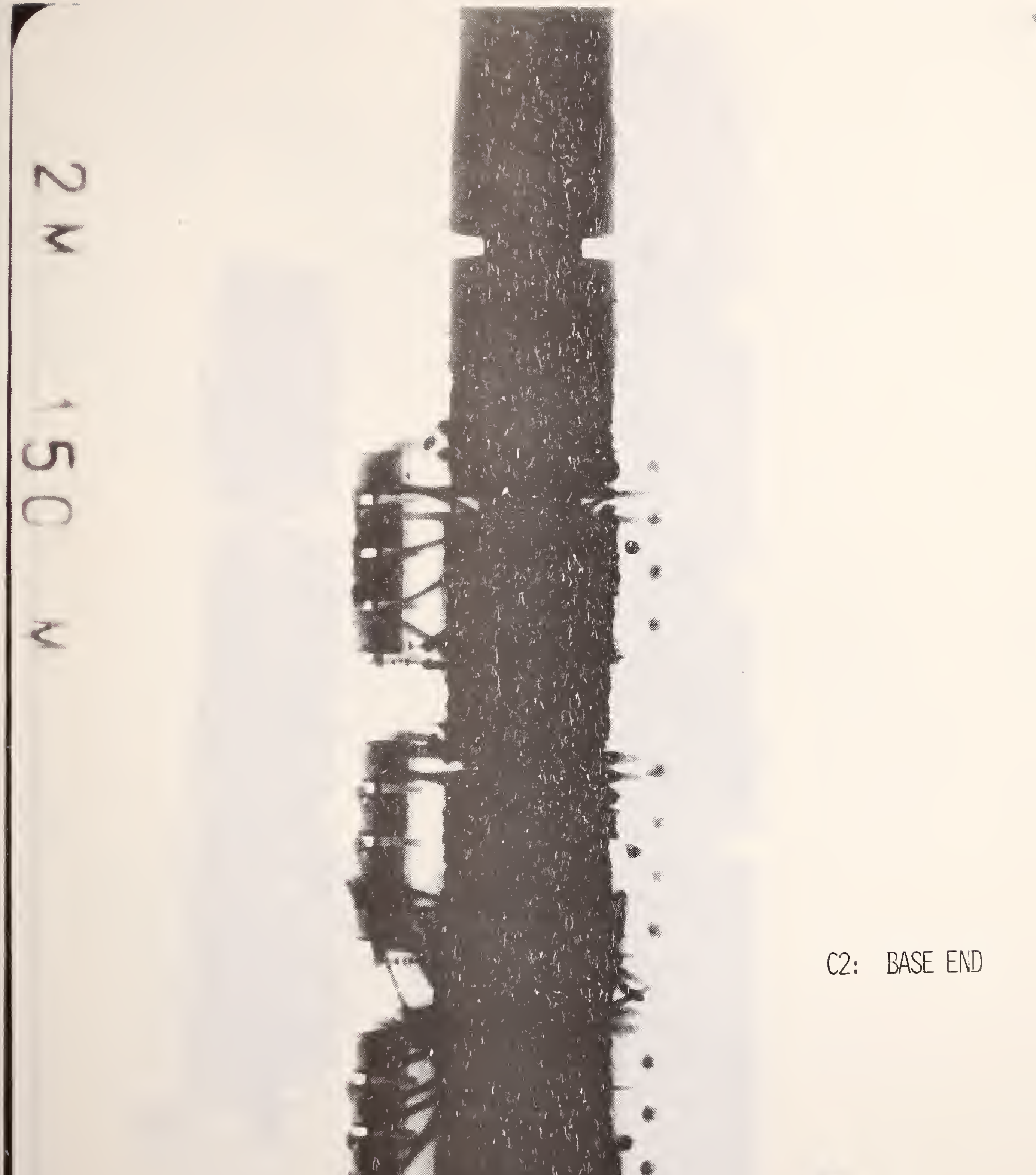
A1: SIDE VIEW



B2: BASE VIEW



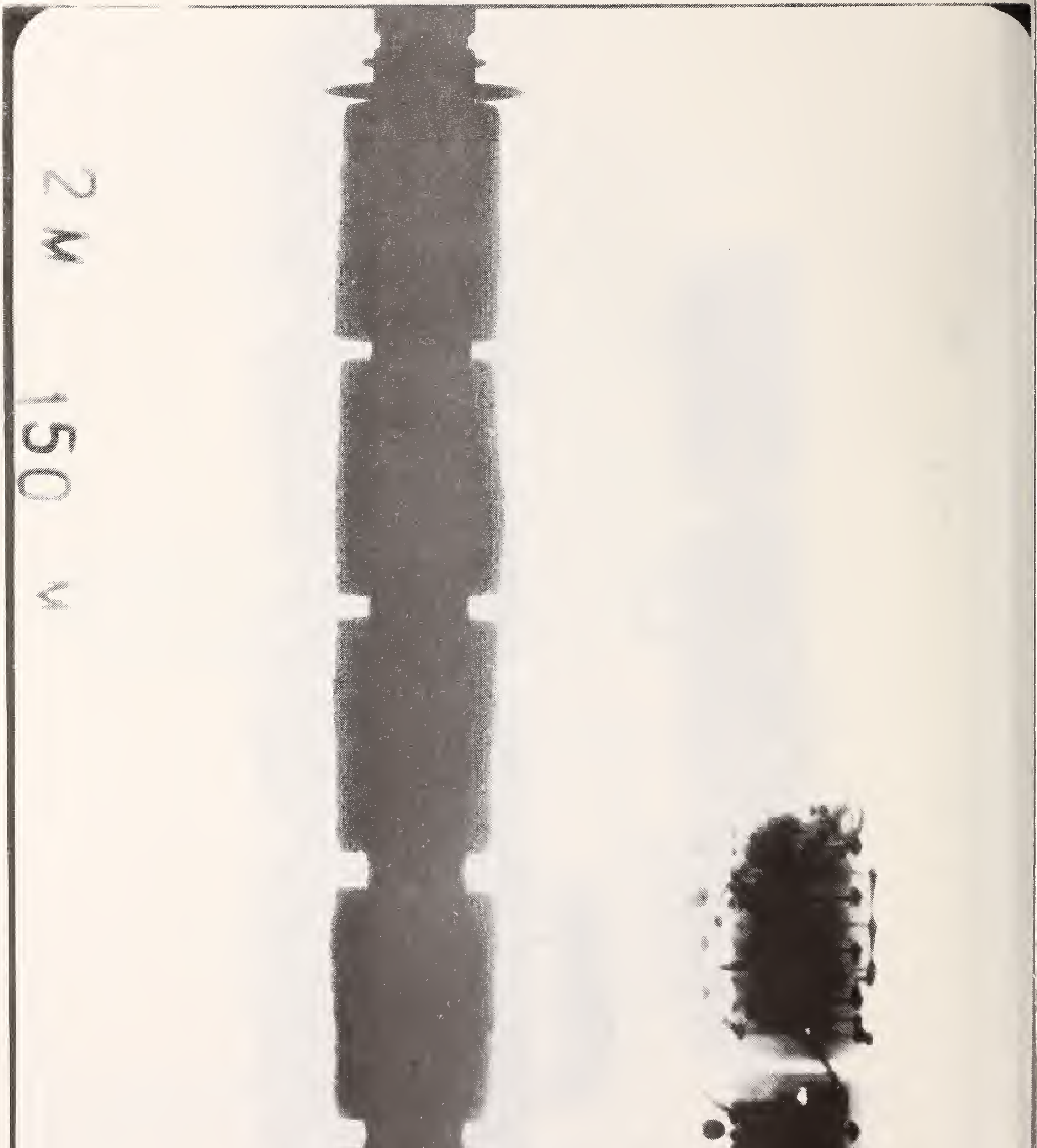
B2: ANGLE VIEW



C2: BASE END

C2: BASE END VIEW
(45^{O} ROTATION)

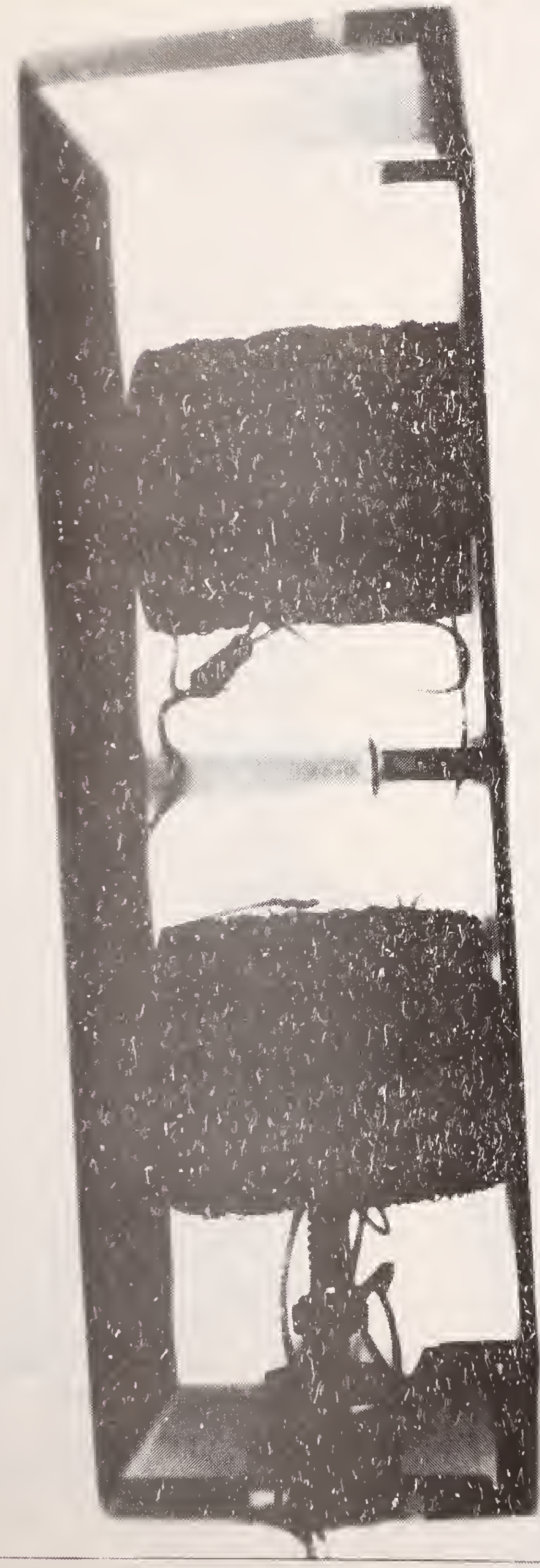
C2: TOP END



C2: TOP END
(45° ROTATION)

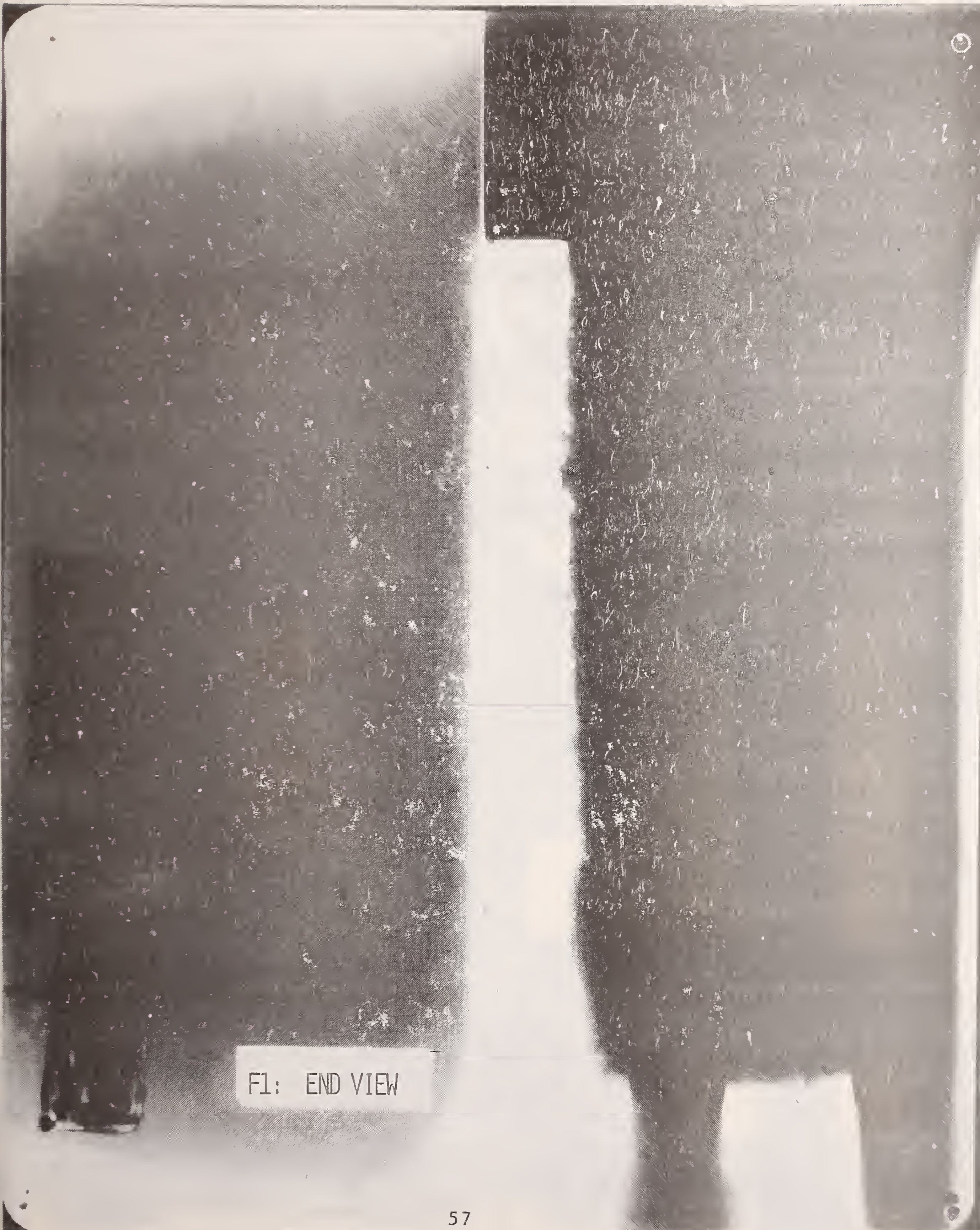
D: TOP END

D: POWER INPUT END

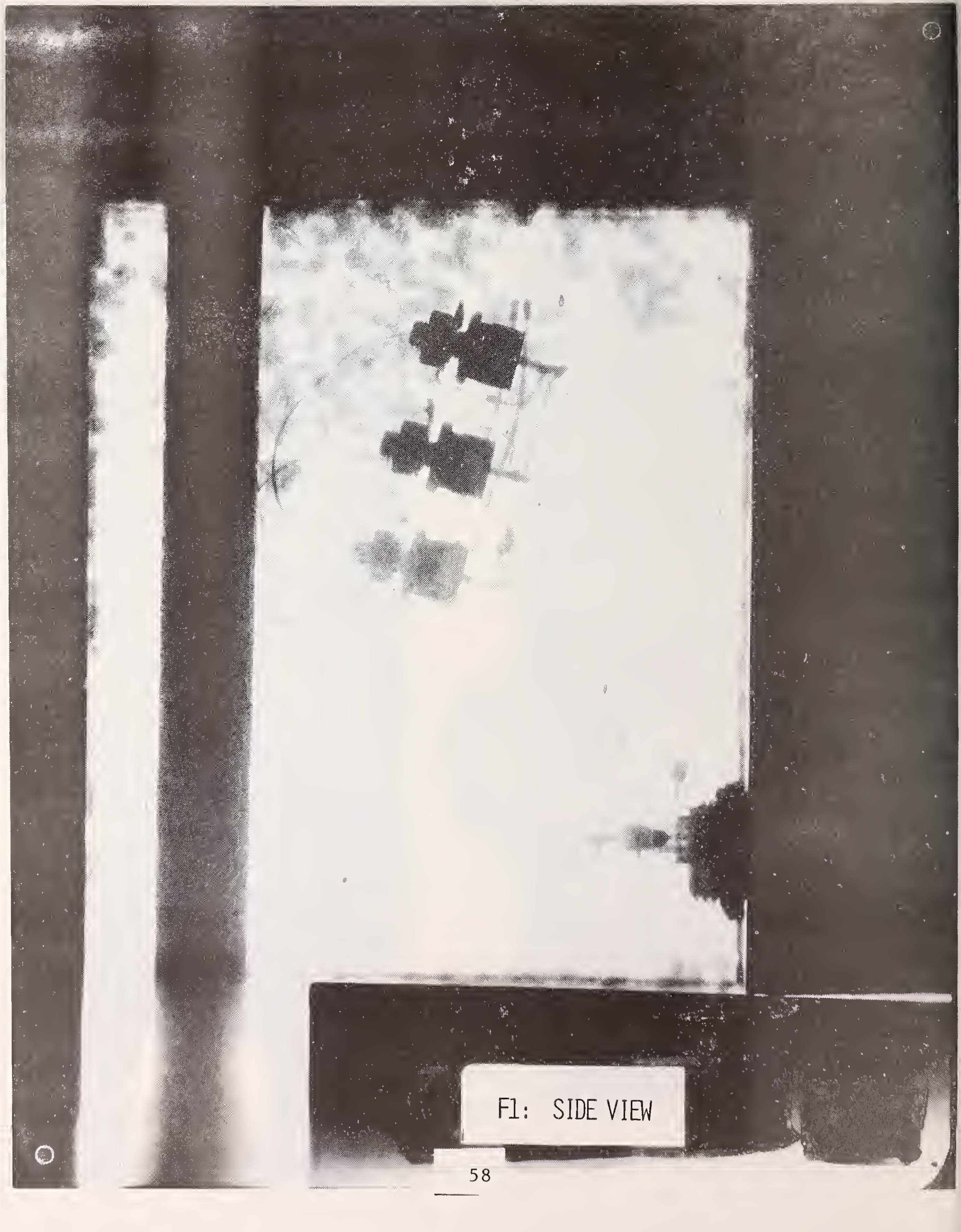


E 1: SIDE VIEW

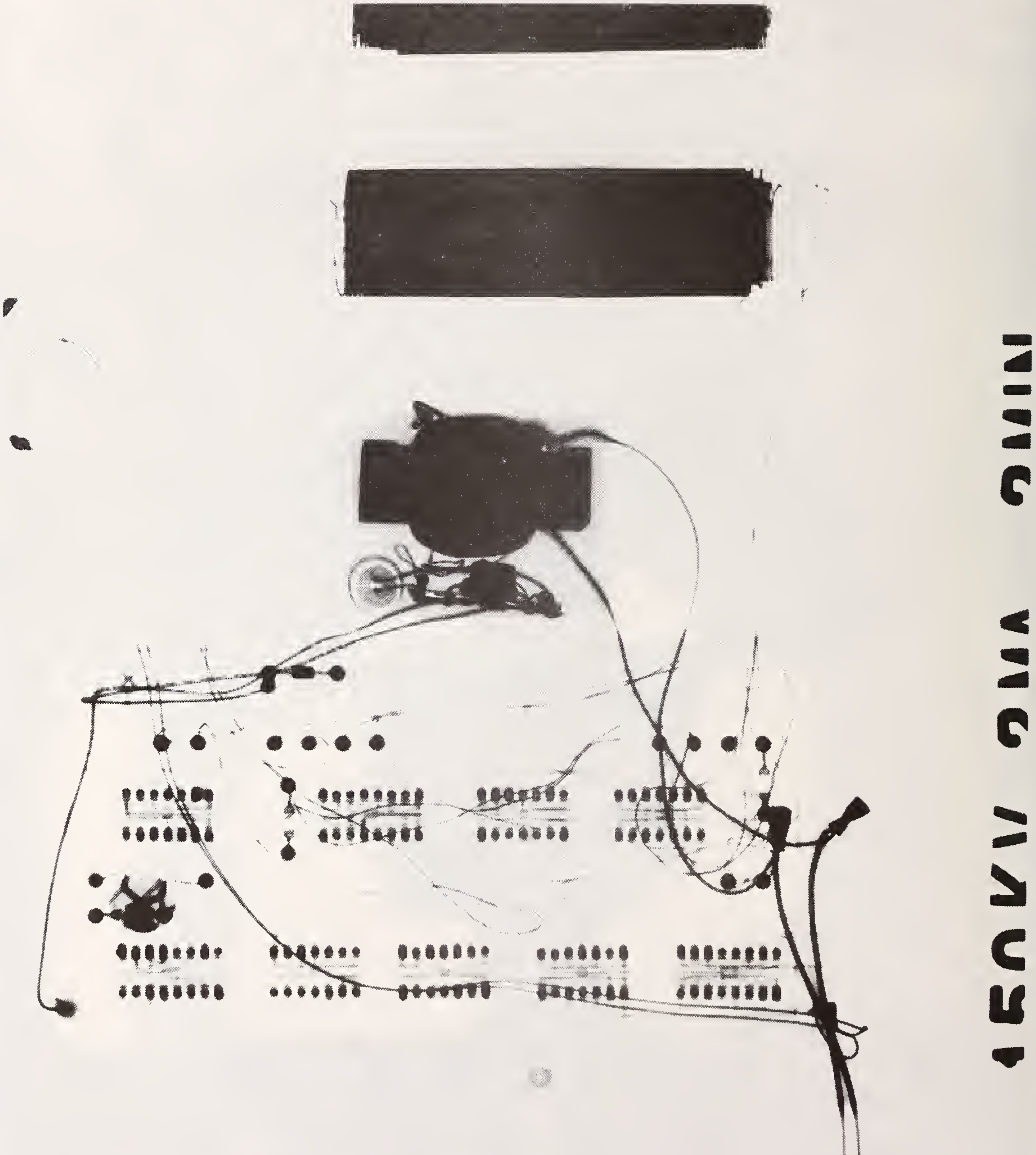
E 1: TOP VIEW



F1: END VIEW

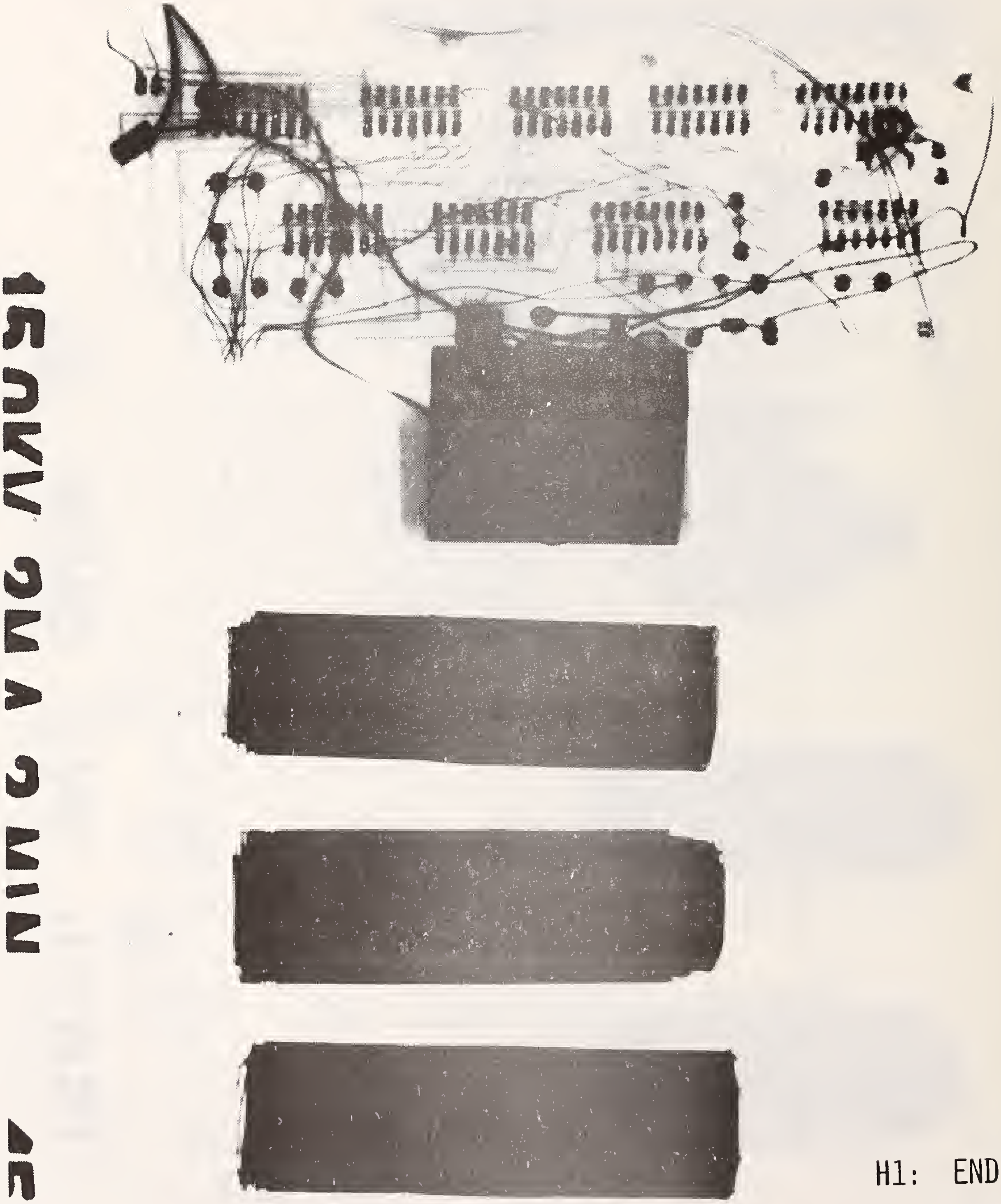

F1: SIDE VIEW


G2: SIDE VIEW



H1: TOP VIEW

H1: EDGE VIEW
(45^{0} ANGLE)



H1: END VIEW
(45^0 ANGLE)

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WASHINGTON, DC 20234

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401 M St., SW, Washington, D.C. 20460

13. Type of Report & Period Covered

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a si*

At the request of the Environmental Protection Agency (EPA), the National Bureau of Standards evaluated eight models of electromagnetic pest controllers provided by EPA. This evaluation was performed by the Center for Consumer Product Technology. The units were evaluated to characterize any detectable electromagnetic output but no judgment of the effectiveness of the devices as pest controllers was made.

Visual and X-ray inspection and electromagnetic measurements showed the units can be grouped into two categories based on characteristics of the output signal--the principal characteristics being either a pulse output or a 60 Hz AC output. For the pulse output devices, no significant external electromagnetic field was found. The 60 Hz units were found to generate detectable magnetic fields. For all units, the fields detected would be less than the earth's magnetic field at distances of three meters or more. Some common electrical equipment was found to generate electromagnetic fields of the same order of magnitude as that produced by these pest controllers.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Electromagnetic Pest Control Deivces
Electromagnetic Field Strength of Pest Control Devices
Pulse Type Pest Control Devices

18. AVAILABILITY ☐ Unlimited

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