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HEIGHT-OF-BURST SOUND RANGING SYSTEM FOR A SUPERSONIC ROCKET

JOHN R. FRISTER

APRIL 1971

PICATINNY ARSENAL
DOVER, NEW JERSEY

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13. ABSTRACT

Documentation in this report was provided by the Instrumentation Division, Technical Services Directorate for a jungle penetration fuze program. The Fuze Research Engineering Division of Picatinny Arsenal requested height-of-burst (HOB) measurements in a jungle environment for an electronic fuze incorporated in a supersonic rocket.

plus or minus

A sound-ranging system, successfully developed and fabricated in 1967 by the Technical Services Directorate at Picatinny Arsenal, was utilized with some modifications of acoustic sensors and amplifiers. The accuracy of the HOB data received by this system can optimally be ± 5% based on evaluations at Picatinny Arsenal and Aberdeen Proving Ground. This accuracy depends on precise operator measurements in system setup and data reduction procedures, monitoring meteorological conditions in real time and monitoring sound velocity in real time.

The details of a successful approach to HOB of supersonic rockets as determined by these fuze tests are included in this report together with the HOB test data and results. In these tests two electronic timing fuzes were compared in a jungle environment; no discernable difference between their performance was measured. (U)

For classification purposes the rocket and fuze nomenclature and specific operational details of the system under test have been omitted from this report. This information may be obtained from the author from persons with proper clearance and the need to know.

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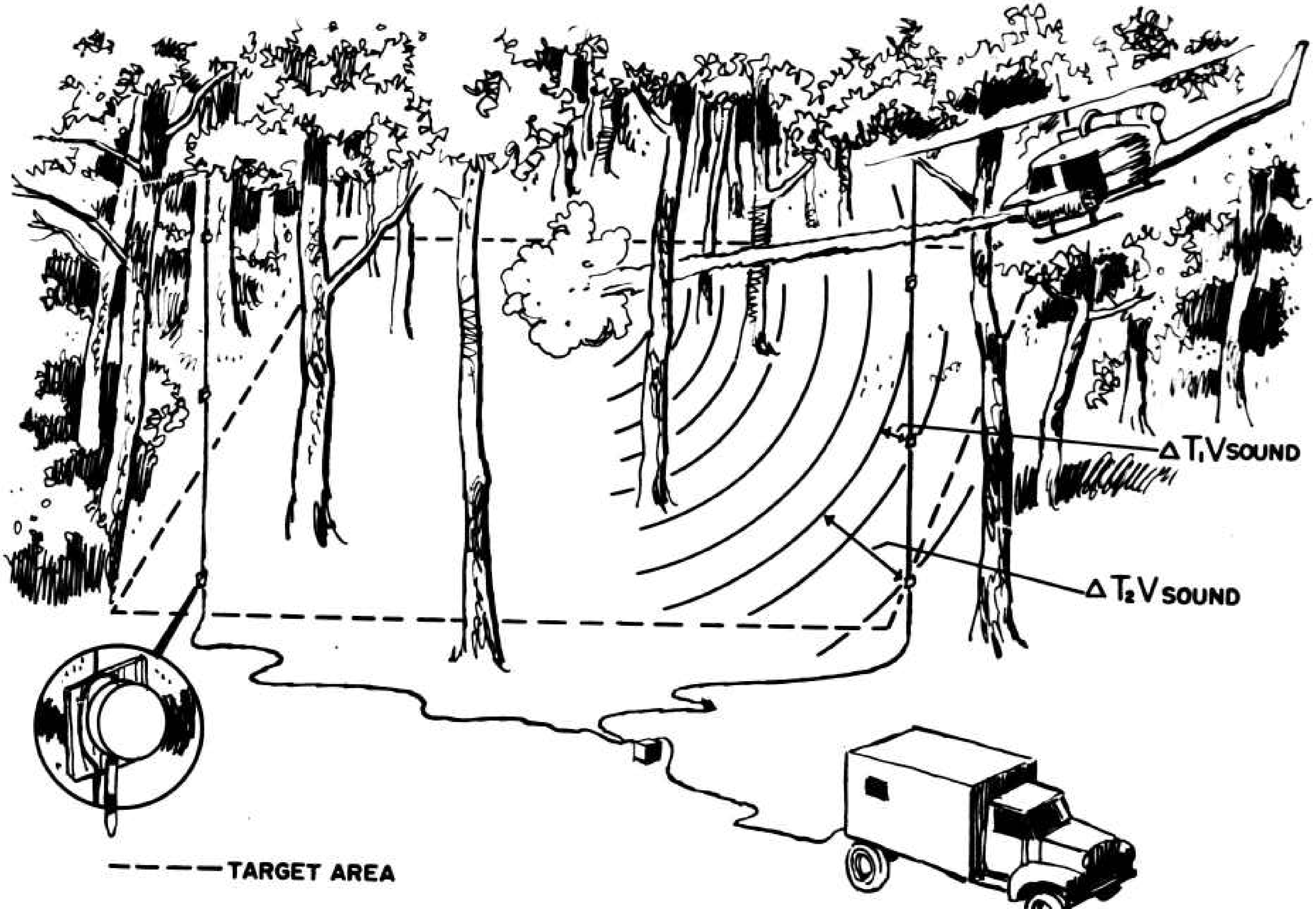

HOB SOUND RANGING SYSTEM

SUMMARY

Documentation in this report was provided by the Instrumentation Division, Technical Services Directorate for a jungle penetration fuze program. The Fuze Research Engineering Division of Picatinny Arsenal required height-of-burst (HOB) measurements in a jungle environment for an electronic fuze incorporated in a supersonic rocket.

A sound-ranging system, successfully developed and fabricated in 1967 by the Technical Services Directorate at Picatinny Arsenal, was utilized with some modifications of acoustic sensors and amplifiers. The accuracy of the HOB data received by this system can optimally be ± 5% based on evaluations at Picatinny Arsenal and Aberdeen Proving Ground. This accuracy depends on precise operation measurements in system setup and data reduction procedures, monitoring meteorological conditions in real time and monitoring sound velocity in real time.

The details of a successful approach to HOB of supersonic rockets as determined by these fuze tests are included in this report together with the HOB test data and results. In these tests two electronic timing fuzes were compared in a jungle environment; no discernable difference between their performance was measured.

For classification purposes the rocket and fuze nomenclature and specific operational details of the system under test have been omitted from this report. Persons with the proper clearance and the need to know may obtain this information from the author.

CONCLUSIONS

The HOB sound ranging system as modified for a supersonic rocket proved to be successful in providing accurate HOB and position coordinate data in the presence of sonic boom and rocket noise.

The unique hardware and array arrangement required for this test emphasizes the necessity for design evaluation preceding each HOB mission. A universal sound ranging system concept cannot be applied, as proven by past performance. Previous failures in attempting to measure HOB of supersonic rockets resulted directly from inflexible use of conventional sound ranging hardware, techniques and data reduction methods.

To insure maximum benefit from this system, the poles should be placed in line with the trajectory and the distance between poles not less than two or more than four times the height of the pole.

RECOMMENDATIONS

The Sound Ranging System for HOB measurements has been field-proven for various types of ordnance items. This system should continue to be developed for future HOB and Sound Ranging Programs requiring greater accuracies.

The instrumentation system to measure HOB varies with each application to the extent that a universal concept cannot be employed. Each program must be evaluated to determine the correct arrangement to be used.

Although, for a helicopter-fired supersonic rocket, a dual pole system provided accurate HOB data, an automated data reduction system should be designed and developed.

Emphasis should be placed on the development of real time meteorological and sound velocity instrumentation; an estimated increase in accuracy of one to three times can be expected with these developments.

THE SOUND RANGING SYSTEM

Development

The HOB Sound Ranging System was developed at Picatinny Arsenal by TSL's Instrumentation Section in 1966. The results of this development can be found in (Reference 1).

Design - Three Transducer System

A typical sound ranging Transducer System layout is shown below and in Drawing 1 (Appendix C). For this Transducer System, the mathematical solution can be obtained from the geometry:

$$n_1 = c\ (t_2 - t_1)$$

$$n_2 = c\ (t_3 - t_1)$$

where c= velocity of sound

$$R^2 = x^2 + y^2 \qquad (1)$$

$$(R + n_1)^2 = x^2 + (L - y)^2 \qquad (2)$$

$$(R + n_2)^2 = x^2 + (2L - y)^2 \qquad (3)$$

expanding (2) and (3) and substituting (1) for x,

$$R^2 + 2Rn_1 + n^2{}_1 = R^2 + y^2 + L^2 - 2L_y + y^2 \qquad (4)$$

$$R^2 + 2Rn_2 + n^2{}_2 = R^2 + y^2 + 4L^2 - 4L_2 + y^2 \qquad (5)$$

which reduces to

$$2Rn_1 + n^2{}_1 = L^2 - 2L^y \qquad (6)$$

$$2Rn_2 + n^2{}_2 = L^2 - 4L^y \qquad (7)$$

solving for R from (6)

$$R = \frac{L^2 - 2Ly - n_1^{\ 2}}{2n_1} \qquad (8)$$

substituting in (7)

$$2 \; \frac{L^2 - 2Ly - n^2_1}{2n_1} \; n_2 + n^2_2 = 4L^2 - 4Ly$$

solving for y

$$y = \frac{L^2 (4n_1 - n_2) + (n_1 n_2)(n_1 - n_2)}{2L (2n_1 - n_2)} \qquad (9)$$

Substituting this value of y in (8) yields a value for R.

Having measured the velocity of sound (c) and the microphone time differentials, the height-of-burst, y, and radial horizontal distance, x, can be computed. If horizontal coordinates are required with this system, two additional horizontal microphones are needed, preferably positioned at a mutual angle of 90°, or, a second pole is required.

Sound Ranging Dual Pole Layout

A typical layout of transducers is shown in Figure 1 and Drawing 1. Accuracy during the measurement of the distance between poles and the height of transducers is essential, since the overall accuracy of Height of Burst data depends on these measurements.

The advantage of the second pole is that it yields a redundant cross check as well as three dimensional position coordinates.

Data Acquisition Technique

Each sensor is an LC-13 Blast Pressure Transducer. The output of each transducer is amplified by an integrated circuit, battery-powered (12 volts DC), autogain control amplifier.

The electrical signal from the transducers, located at the impact area, is transmitted to the instrumentation van over vinyl-covered, multi-conductor cable.

The length of transmission line depends on the location of the instrumentation van with respect to the input area. The extremely low output impedance of the electronics permit transmission of signals over upwards of 5000 feet of cable.

The electrical signals are then recorded on magnetic tape; each signal is recorded on a separate channel of a seven-track I.R.I.G. tape recorder.

A time reference of one kilohertz, sinewave, is superimposed on a recording channel. Voice commentary for labeling and identification is superimposed on another channel.

The data is recorded at 15 inches per second (ips).

Data Reduction Technique

The test data is reproduced from the magnetic tape recorder at a playback speed of 1-7/8 in/sec, thereby expanding time by a factor of eight. A permanent visual record of the sound impulse from each round is produced by transferring these signals from magnetic tape during playback while recording the signals on a recording oscillograph. This reproduction technique provides one millisecond time markers approximately ½ inch apart; therefore it is possible to measure time intervals with an accuracy of ± 0.0001 seconds.

Figure 2 is a representation of a typical oscillograph record obtained from test firings. The differential time measurements are referenced to the transducer located at the bottom of the pole, this sets the sign convention for all time measurements.

If, for example, the top transducer receives the sound first, the reading, with respect to the top transducer, is considered a negative time measurement. Thus, the differential times T1 and T2 are measured, by hand, by data reduction personnel. Where;

T_1= differential time between bottom transducer and middle transducer.

T_2= differential time between bottom transducer and top transducer.

An Olivetti-Underwood Programma 101, desk top computer has been programmed to yield the solution to the above derived equations from the differential times, velocity of sound and transducer array dimensions. A nomograph figure 3, derived via an IBM 360 allows a good approximation for field data reduction for "first look" data.

Calibration and Field Check-Out

The velocity of sound for a test area has been determined by exploding an M80 Simulator (fire cracker) below and in line with any three transducers mounted on a pole. Since the distances between transducers are known, measurement of the time of propagation between transducers allows the calculation of the velocity of sound.

The M80 Simulator can also be used as an impulsive sound source to check the accuracy of the Height of Burst system. An M80 is attached to a tree at known cooruinates with respect to the pole system. The M80 is detonated and the sound impulses are recorded. The differential arrival times provide a height measurement directly from the field nomograph. This is compared with the known height of burst. A maximum of 3% error between calculated and measured heights is acceptable. Errors greater then 3% can be directly attributed to wind and temperature gradients.

THE ELECTRONIC SOUND RANGING DATA ACQUISITION SYSTEM

The electronic system is shown in block diagram form in figure 4. The complete system can be resolved into its essential subassemblies as follows:

Transducer

The transducer utilized in this system conforms to the following specifications:

Operating temperature range from -4° to +150°F
Piezoelectric active element
Ability to measure shock fronts in excess of Mach 2
Sensitivity -107db re 1v/ubar
Resonant frequency greater than 120 kHz
Waterproof
Omnidirectional
Dynamic range: 60db
Standard stock availability Model LC-13 or equal

Amplifier (SRA-1), Sound Ranging Transducer

Each transducer is connected to a corresponding SRA-1, amplifier (figure 5). This amplifier was designed and fabricated by the TSD, it conforms to these specifications:

Voltage Requirement, + 12 Volts DC, single ended
Current Requirement, + 12 milliamps
Voltage Gain, + 44db.
Frequency Response, 15 Hz to 100 kHz ± 1.5 db.
Input Impedance, 1 Megohm
Output Impedance, 0.2 ohms
Automatic Gain Control Range, 24 db
Distortion before AGC action - less than 0.6% (2 volts PP output)
Shock Proof & unaffected by dust, dirt, or moisture

Field Junction Box

This module (Drawing 2), fabricated at Picatinny Arsenal, couples each amplifier power source, a 12 volt battery, to its corresponding amplifier; by locating this module in the field, the distance from the power sources to the amplifiers can be held to a minimum. This prevents undue radio interference and avoids power waste from long lines. Power can be applied remotely from the instrumentation van.

Van Junction Box

This module (Drawing 3), also fabricated at Picatinny Arsenal, couples the microphone amplifier output to the magnetic tape recorder for permanent data storage, interconnects the one kHz Time Mark Generator to the tape recorder in parallel with a microphone amplifier output for the recording of a time base for data reduction, provides a 28-volt power source to the field junction box relays that in turn provides the remote power source capability for the microphone-amplifier units, provides outputs to the loudspeaker speaker monitor, and finally, connects the tape recorder to the Visicorder.

Tape Recorder

The Tape Recorder utilized for this system (photograph 1) conforms to the following specifications:

Seven channel, ½ inch tape IRIG format
Tape speeds: 15 inches/sec, 7.5, 3.75, 1.875
Nominal input level: 0.5-10 volts r.m.s.
Nominal output level: 1 volt re OVU
Input impedence: 10,000 ohms unbalanced
Output impedence: 100 ohms unbalanced
Frequency response: 50-10,000 HZ + 3db @ 15 i.p.s.
Operating temperature: 30° - 100°F
Wow & Flutter: less than .15% @ 15 i.p.s.
Standard Stock Availability:
Model Sp-300 FM-Direct Recorder/Reproducer or equal

Time Mark Generator

The Time Mark Generator utilized for this system should be a very stable sine wave oscillator that will supply 1 volt r.m.s. into 50 ohms @ 1000 HZ with a stability of 10 parts per million error in frequency in 24 hours.

Visicorder and Associated Amplifier

The oscillograph recorder utilized for this system (Photograph 2) conforms to these minimum specifications:

Seven recording channels
Six inch chart width
50 inches per second chart speed
8,000 HZ glavonometer frequency response
30° - 100° operating temperature range

Standard Stock Availability: direct recording Visicorder oscillograph.

System Requirements

The most stringent requirement for this system is the ability to record & accurately measure the differential times arriving at the microphones when a source of impulsive sound is present.

Advantages of Pole System

Utilizing a pole system allows the operator to obtain "first look" Height of Burst data immediately at the test site once differential times are read from the oscillograph recording. The Height of Burst can be read directly from a nomograph. A nomograph for a 100-foot pole system can be seen in Figure 3. Although this nomograph eliminates the time delay required for translating and processing recorded data from the test site on a laboratory computer, the field reduced data should only be considered first look and the laboratory reduction is still necessary.

The Sound Ranging Pole System is limited in vertical range only by a multiple of the height of the pole. Since impact or ground burst monitoring is highly desirable for most ammunition test evaluation, the Pole System is a most practical system.

Test Evaluation - Picatinny Arsenal

This test evaluation was performed at Picatinny Arsenal utilizing a 50-foot pole system to determine sensitivity and saturation recovery time of transducers due to:

1. Rocket motor noise
2. Fragments
3. Excessive db level from item function

The following configurations of transducers and amplifiers were evaluated in all test conditions:

1. AJ1342 Microphone/MA-100 Amplifier
2. LC-50 Hydraphone/SRA-1 Amplifier
3. LC-13 Blast Pressure Transducer/SRA-1 Amplifier

Testing was performed systematically at distances from 10 feet to greater than 300 feet from the pole at heights of -10 to + 75 feet.

Test 1: A composition charge was initiated as a sound source. Microphone and transducer subsystems were evaluated for sensitivity, saturation and recovery time.

The db level of the C-4 charge when initiated was comparable to a supersonic rocket loaded with a supplemental booster charge.

Test 2: A supersonic rocket motor was fired in a static test stand. Microphone and transducer subsystems were evaluated for sensitivity and saturation recovery time.

Test 3: A supersonic rocket motor was fired in a static test stand. While the rocket motor was burning, a composition charge was fired. Microphones and transducer subsystems were evaluated for sensitivity and saturation recovery time.

Test 4: A rifle was fired, the bullet aimed to pass close to the pole system. This test was repeated for varying distance, azimuth angles and elevations with respect to the pole. Evaluations were made for sensitivity and saturation recovery time due to the simulation of fragmentation.

Results of Picatinny Testing

Configuration I: AJ-1342 Microphone/MA-100 Amplifier

This configuration proved unsatisfactory. The rocket motor noise level saturated the microphone, as did the shock fronts induced by the fragments and a composition charge initiated near a microphone. Recovery time of the sensors was unacceptable for obtaining the data acquisition rates anticipated. Figure 6 depicts a typical record of saturation due to rocket motor noise; Figure 7 shows a typical record resulting from fragmentation.

Configuration 2: LC-50 Hydraphone/SRA-1 Amplifier

Although some usable data was obtained, problems similar to Configuration 1 were observed. Therefore, Configuration 2 was also deemed unacceptable.

Configuration 3: LC-13 Blast Pressure Transducer/SRA-1 Amplifier

This configuration proved acceptable for Tests 1-4. Increased dynamic range eliminated the rocket motor noise problem. If the sensor saturated from a shock front, the recovery time, aoproximately 10 milliseconds, was sufficiently fast to obtain accurate data. Figure 8 is a typical record of static firing of a supersonic rocket motor and a composition charge simultaneously; the charge is clearly dissernable.

Recommendations from Picatinny Testing

As a result of the testing at Picatinny Arsenal, it was recommended that additional testing be conducted at Aberdeen Proving Ground employing a duel 50-foot pole system, LC-13/SRA-1 Sensors and helicopter launched supersonic rockets.

Testing Aberdeen Proving Ground

A dual 50-foot Sound Ranging Pole System was erected in an open field. The poles were in line with the direction of fire and placed 200 feet apart. LC-13 transducers and SRA-1 amplifiers were used throughout. A helicopter was employed to air launch the supersonic rockets which were loaded with a supplemental booster charge. The rockets were fired into the impact area from an altitude of 500 feet at an angle of 15° with respect to the horizontal; the total range to impact was 2,000 feet. The velocity of each of the 26 rounds fired was approximately Mach 2 or twice the speed of sound. Figure 2 shows a typical record of a test round.

Results of Aberdeen Testing

Evaluation of the oscillograph recording revealed the presence of shock fronts and their ground reflections, the shock front caused by the supersonic velocity of the projectile; this was followed by the burst data, as depicted in Figure 2. By interpreting the presence of the shock fronts and their reflections with respect to the direction of flight and pole location, this system proved 90% reliable generating errors no greater than ± 5%.

Recommendations from Aberdeen Testing

From the results of the testing conducted at Picatinny Arsenal and Aberdeen Proving Ground, it was recommended that the Height of Burst Sound Ranging System be utilized for testing electronic timing fuzes on supersonic rockets in a jungle environment such as the Tropic Test Center in the Canal Zone, Panama.

IV. PANAMA TESTING

Procedure

A dual pole sound ranging system was erected in a pre-selected high jungle canopy area. Due to the location of the impact area and the varying sizes of the trees, it was necessary to erect pole systems of different heights, 100 and 75 feet. The poles were in line with the line of fire and 152 feet apart. LC-13 transducers and SRA-1 amplifiers were used throughout. Again, a tactical helicopter was employed to air launch supersonic rockets which were loaded with supplemental booster charges and type C-1 spotting charges.

258 rounds were fired from an altitude of 800 feet and at an angle of 15° with respect to the horizontal for a total range to burst of 1,500 feet. The velocity of each round, at the burst point, was approximately Mach 2. Approximately half the rounds were equipped with Fuze A and half Fuze B.

Results

Of the total of 258 rounds fired, 160 rounds functioned within the reliable operational range of the sound ranging system. Of these 160 rounds, 65 rounds were considered excellent Height of Burst data, 78 rounds were considered good Height of Burst data, and 17 rounds were considered moderately reliable Height of Burst data.

The criteria for the quality of the data was as follows: Excellent, where two pole data correlated and fell within the range of 5% expected error deviation, such that the position coordinates can be considered accurate within a maximum 20% deviation with a 95% confidence level; Good, where one pole data fell within the range of 10% expected error deviation, such that the position coordinates can be considered accurate within a maximum 30% deviation with a 90% confidence level; Moderately Reliable, where one pole data fell within the range of greater than 10% error deviation, such that the position coordinates can be considered accurate within a maximum 30% deviation with a decreasing confidence level with reported range. Data that was not reported due to the fact that the round fell out of the operational range of the array, functioned at slant ranges exceeding 300 feet.

Of the 65 rounds considered excellent data, 45 were selected for statistical comparison; the position coordinates of these rounds are accurate within a maximum deviation of 10% with a 95%

confidence level. 21 of these rounds were fired with fuze A and 24 of these rounds were fired with fuze B.

For the A fuze group, the mean height of burst (HOB) equaled 59.6, the median 54 ft, the standard deviation 25.2 ft. For the B fuze group, the mean HOB equaled 61.5 ft, the median 53.4 ft and the standard deviation 24.7 ft. The means of the two fuze groups were equal within 3.1%, the medians within 1.1% and the standard deviation within 2.0%. A typical burst distribution is shown in Figure 9.

In a comparison of all 160 rounds, Figure 10 shows a plot of burst height verses frequency of burst height; 80 of these 160 rounds were equipped with the type A fuze and 80 with the type B fuze. Based on the above, there was no dissernable difference between the burst height performance of the two fuzes.

The remaining 98 rounds were not reported and can be put into two groups: 55 rounds either landed outside the operational range of the array, did not function or were ripple fired; 43 rounds were not recorded due to either system transmission line breaks or instrumentation failure. Also, of the 160 reported rounds, 35 were reported as one pole data when, in fact, these particular rounds where fired when undected faults in the transmission lines where present.

A complete summary of the data is supplied in appendix.

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APPENDIX A

Panama Test Results

A. PANAMA TEST RESULTS

ROUND NUMBER	FUZE TYPE	HEIGHT OF BURST IN FEET		DISTANCE FROM POLE 1 IN FT	
		POLE 1	POLE 2	X	Y
5	A	75	--	--	--
6	A	105	--	--	--
7	A	103	--	--	--
8*	A	32	26	--	--
10*	A	25	29	120	-43
11*	A	61	62	23	+45
12	A	72	57	--	--
13*	A	90	80	103	-78
14	A	--	69	--	--
15	A	--	91	--	--
16	B	--	35	--	--
17	B	--	51	--	--
18	B	70	--	--	--
19	B	33	50	--	--
21	B	--	66	--	--
23	B	--	53	--	--
24*	B	52	48	91	-53
25	B	--	38	--	--
26	B	86	68	68	-122
27	B	--	47	--	--
30*	A	65	71	--	--
31	A	--	54	--	--
32	A	104	--	--	--
35*	B	54	53	--	--
37	B	--	39	--	--
38	B	25	--	--	--
39	A	--	35	--	--
42	A	--	72	--	--
43	B	--	82	--	--
44	B	--	110	--	--
45	B	--	78	--	--
46	B	--	34	--	--
47	B	--	48	--	--
48	B	--	76	--	--
49	A	--	78	--	--
51	A	--	124	--	--
52	A	--	107	--	--

ROUND NUMBER	FUZE TYPE	HEIGHT OF BURST IN FEET		DISTANCE FROM POLE 1 IN FT	
		POLE 1	POLE 2	X	Y
53	A	--	72	--	--
55*	B	86	86	110	+64
56*	B	56	52	197	-91
57*	B	60	57	42	-112
58*	B	92	88	--	--
59*	B	50	50	--	--
60	A	60	34	--	--
62	A	75	53	--	--
63	A	--	84	--	--
64*	A	60	57	39	-177
65	A	121	--	--	--
66*	B	61	53	170	-191
68	B	75	--	--	--
69	B	--	98	--	--
70*	B	98	80	--	--
71	B	67	--	--	--
73	A	--	85	--	--
74	A	--	57	--	--
83	A	101	70	--	--
84	A	128	--	--	--
87	A	47	63	--	--
88	A	98	--	--	--
89	B	132	--	--	--
90	B	38	23	--	--
91	B	65	43	--	--
92	B	64	--	--	--
93	B	61	81	--	--
94	B	89	70	--	--
95*	A	77	86	--	--
96*	A	48	59	--	--
97	A	--	95	--	--
98*	A	127	116	--	--
101*	B	117	126	--	--
103	B	--	113	--	--
104*	B	54	46	--	--
105*	A	45	53	--	--
106	A	14	5	--	--
107*	A	38	31	--	--
108	A	13	26	--	--
109	A	--	61	--	--

ROUND NUMBER	FUZE TYPE	HEIGHT OF BURST IN FEET		DISTANCE FROM POLE 1 IN FT	
		POLE 1	POLE 2	X	Y
111	B	66	52	--	--
112	B	1	5	--	--
113	B	11	26	--	--
114	B	--	90	--	--
115	B	11	15	--	--
116	A	94	64	--	--
117*	A	93	111	52	+75
118*	A	55	53	304	+115
120*	A	45	46	--	--
121	A	13	-2	--	--
122*	B	28	33	--	--
124*	B	52	48	16	+71
125*	B	53	52	58	-159
127*	B	40	39	287	+109
128*	A	42	42	--	--
129*	A	51	49	-141	154
130	A	32	46	--	--
131	A	92	61	--	--
132	A	9	7	--	--
133*	A	85	72	--	--
134	B	83	53	--	--
136*	B	53	53	--	--
137*	B	71	74	--	--
138	B	64	42	--	--
139*	B	89	91	--	--
140	A	--	29	--	--
141	A	87	59	--	--
143*	A	53	52	58	+159
144*	A	64	64	31	+212
147	B	28	20	--	--
149	B	41	20	-89	98
150*	B	86	104	--	--
151	B	--	19	--	--
152	B	102	--	--	--
153	A	--	48	--	--
155*	A	27	33	--	--
156*	A	71	70	177	+119
157	A	--	36	--	--
158	A	36	--	--	--
160*	B	66	62	210	+28

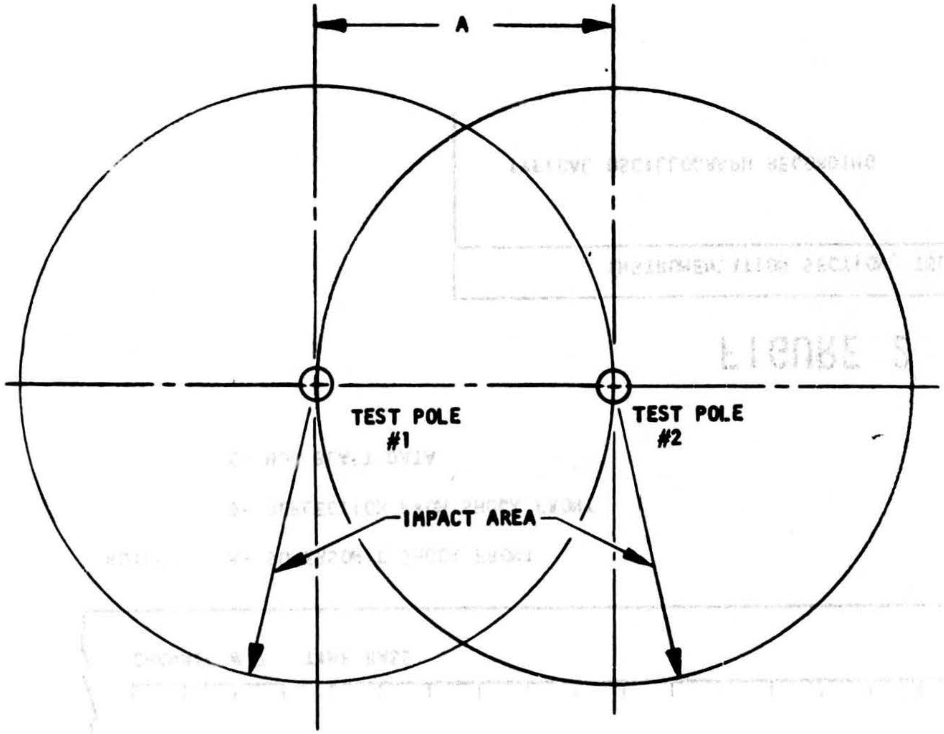
ROUND NUMBER	FUZE TYPE	HEIGHT OF BURST IN FEET		DISTANCE FROM POLE 1 IN FT	
		POLE 1	POLE 2	X	Y
161	B	--	81	--	--
162*	B	22	27	--	--
163*	B	65	65	--	--
164*	B	56	50	102	+65
166	A	--	43	--	--
167	A	--	11	--	--
168	A	--	74	--	--
169	A	--	18	--	--
170	A	--	33	--	--
171	B	--	38	--	--
172	B	--	29	--	--
173	B	--	63	--	--
174	B	--	51	--	--
175	B	--	66	--	--
178	A	--	43	--	--
180	A	--	61	--	--
181	A	--	28	--	--
182	A	--	49	--	--
186*	B	30	30	154	-106
190	A	--	84	--	--
193	A	--	64	--	--
194	A	--	59	--	--
195	B	--	25	--	--
198	B	--	61	--	--
199	B	--	45	--	--
201	A	--	66	--	--
202	A	--	70	--	--
203	A	--	70	--	--
205	A	--	104	--	--
206	A	--	51	--	--
207	B	--	42	--	--
210	B	--	53	--	--
211	B	--	28	--	--
212	B	--	79	--	--
213	A	--	53	--	--
214	A	--	65	--	--
216	A	--	53	--	--
217	A	--	72	--	--
219	B	--	64	--	--

ROUND NUMBER	FUZE TYPE	HEIGHT OF BURST IN FEET		DISTANCE FROM POLE 1 IN FT	
		POLE 1	POLE 2	X	Y
220	B	--	49	--	--
222	B	--	38	--	--
223	B	--	102	--	--
224	B	--	19	--	--

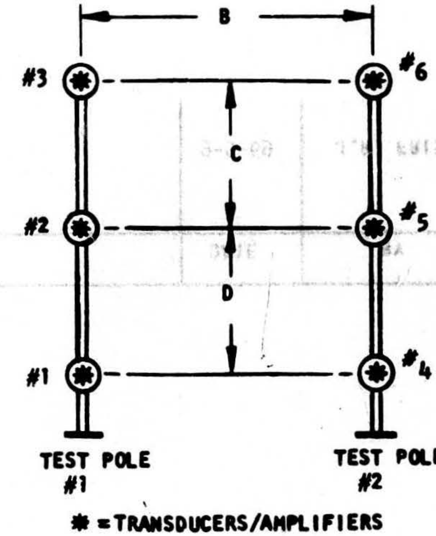
*These are the 45 round selected for statistical analysis.

APPENDIX B

Figures



TOP VIEW



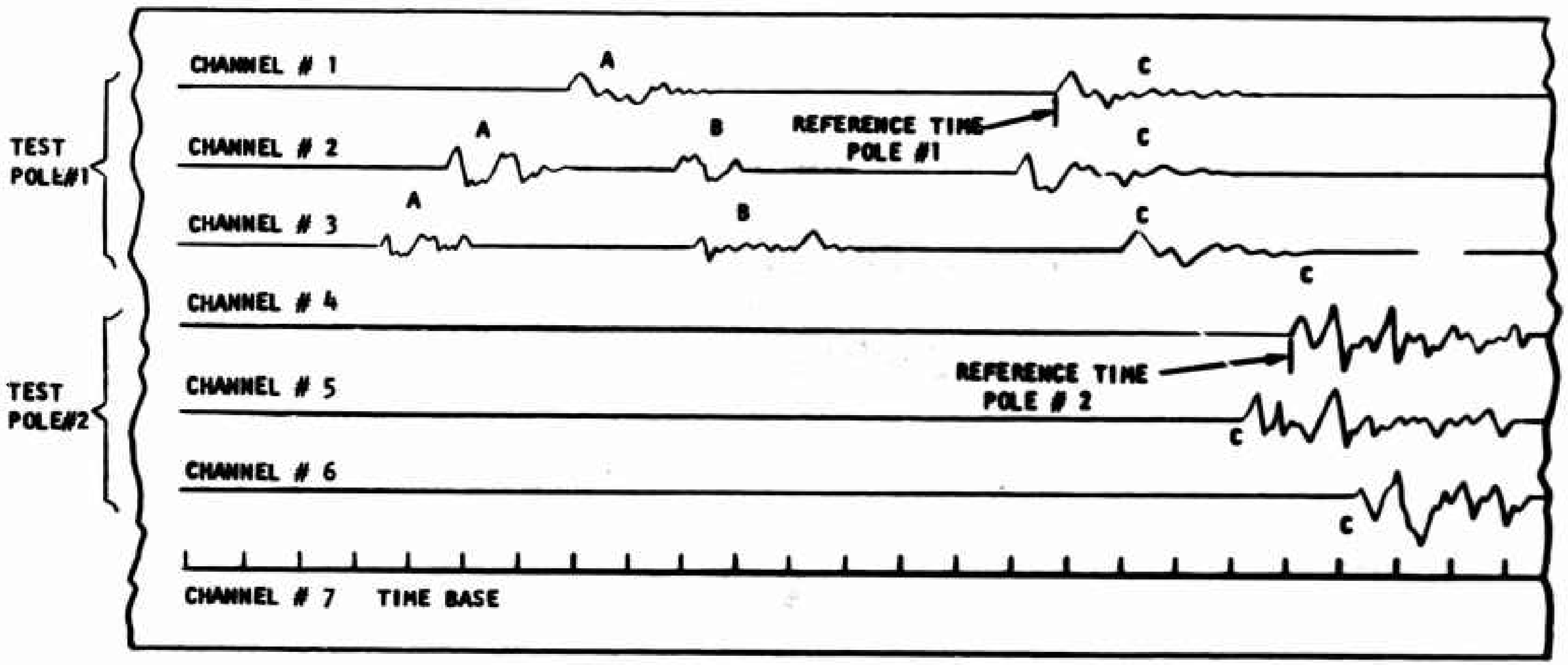
SIDE VIEW

DISTANCE TABLE
A - 200'
B - 200'
C - 25'
D - 25'

NOTES:-
TOLERANCE ON DISTANCE
MEASUREMENTS ± 0.5"

FIGURE 1

INSTRUMENTATION SECTION, TSL	DATE	BY
DUAL POLE LAYOUT	9-5-69	J.R. FRISTER



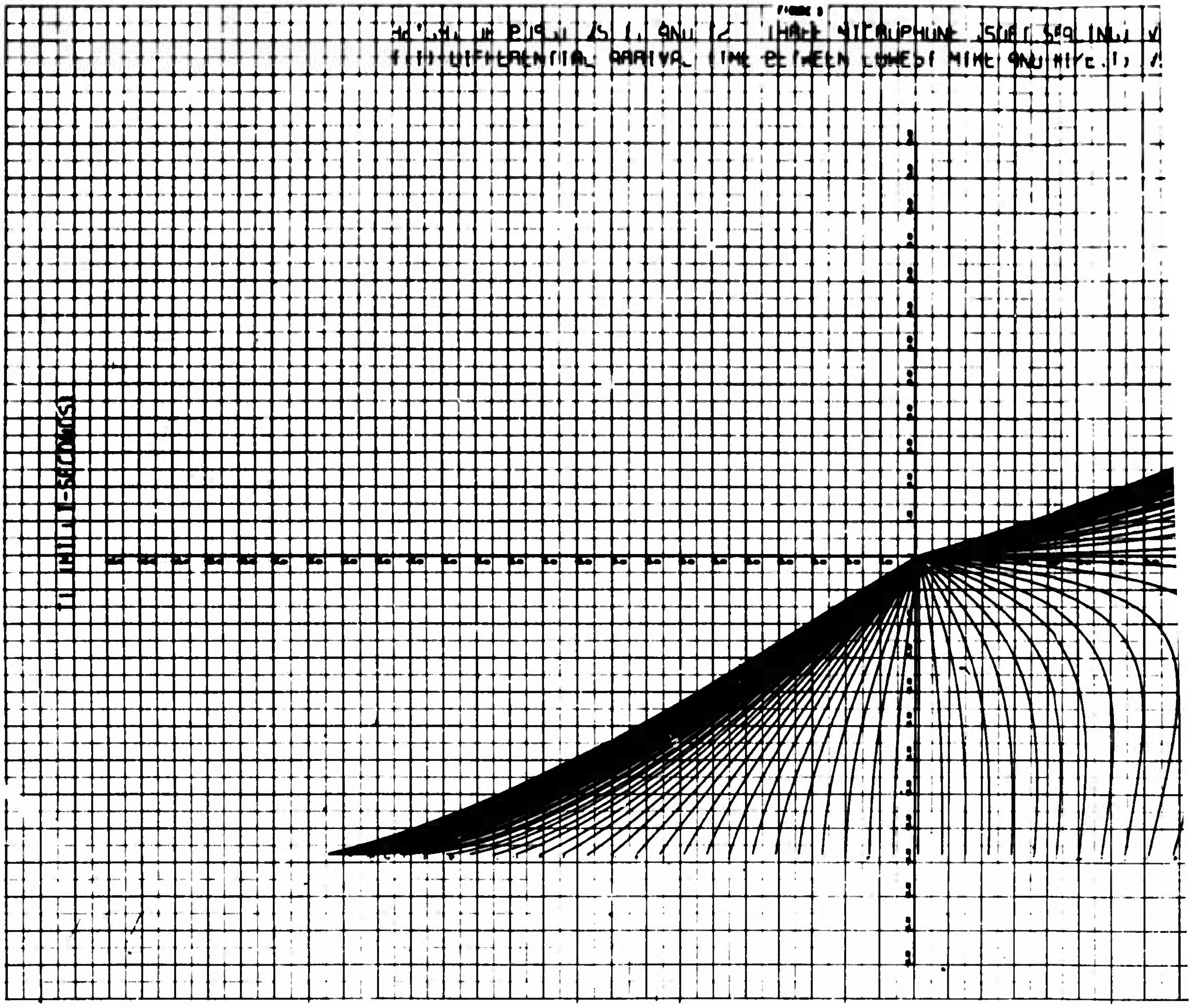
NOTES: A- SUPERSONIC SHOCK FRONT

B- REFLECTION FROM SHOCK FRONT

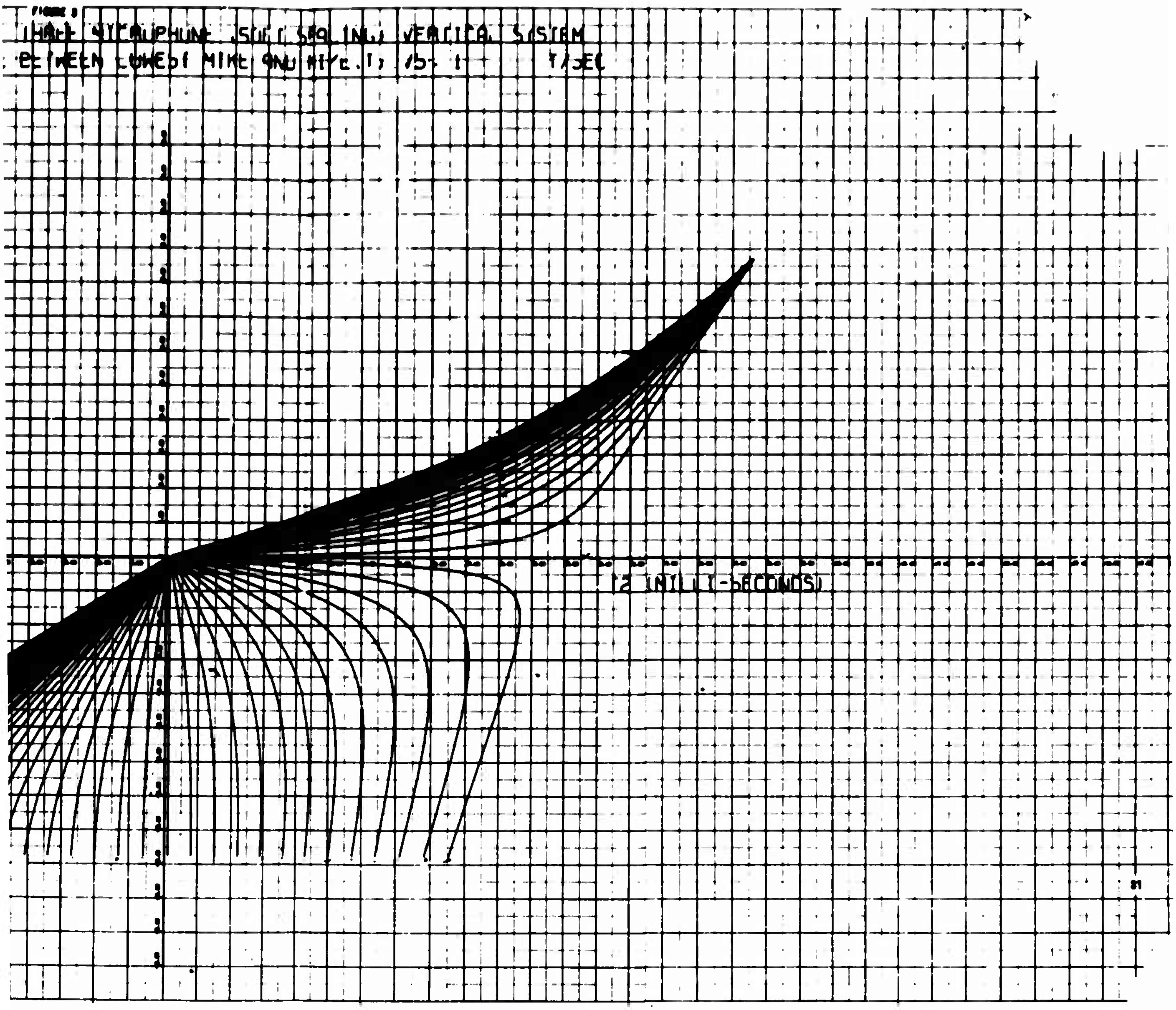
C- HOB BLAST DATA

FIGURE 2

INSTRUMENTATION SECTION, TSL	DATE	BY
TYPICAL OSCILLOGRAPH RECORDING	9-5-69	J.R. FRISTER



A



B

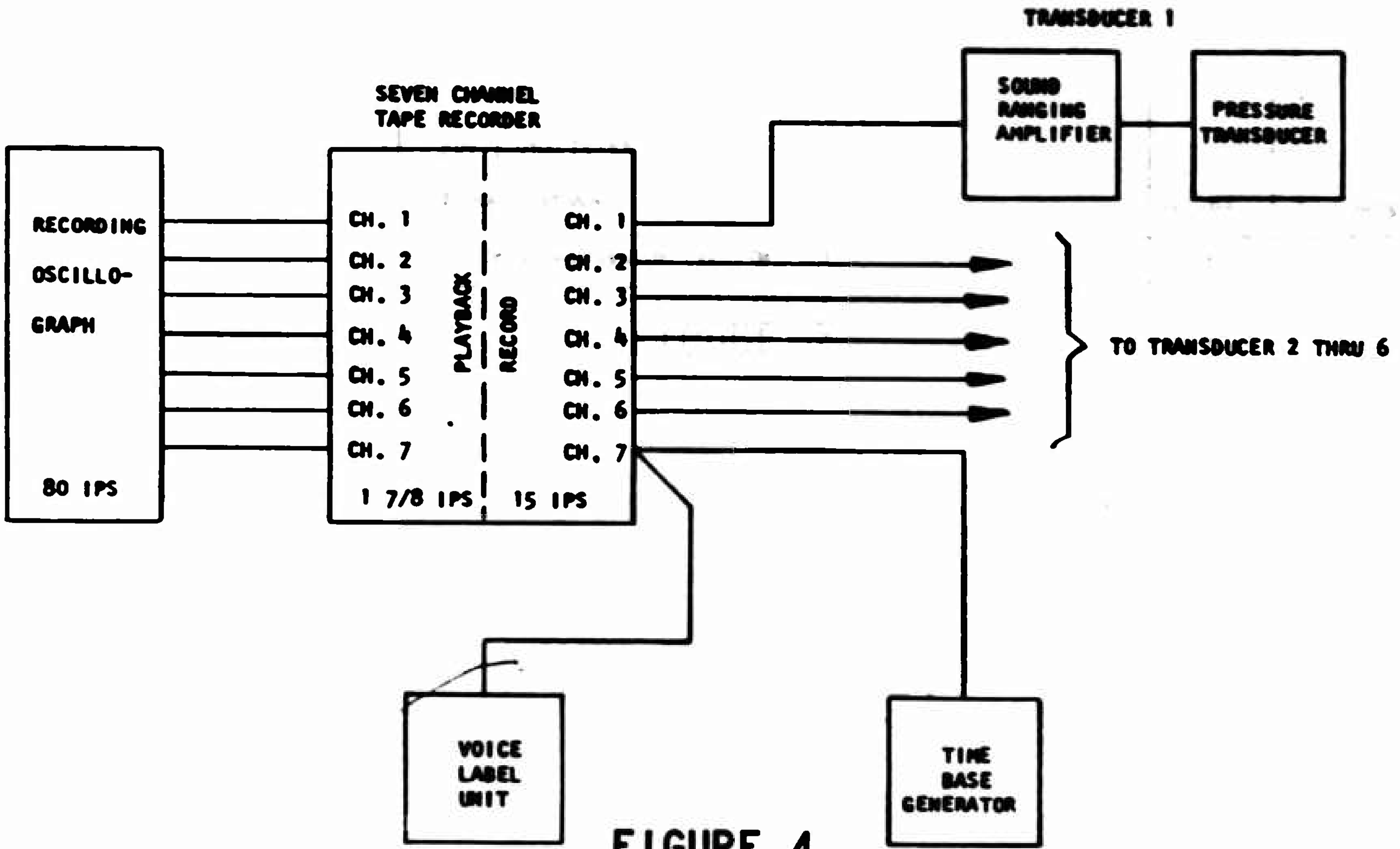


FIGURE 4

INSTRUMENTATION SECTION, TSL	DATE	BY
BLOCK DIAGRAM OF INSTRUMENTATION SYSTEM	9/5/69	J.R. FRISTER

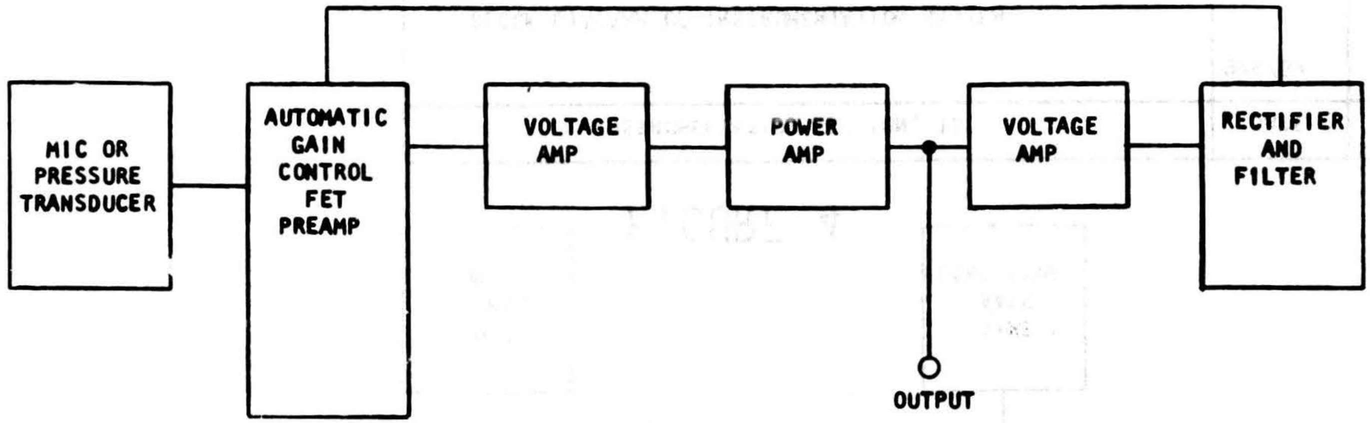
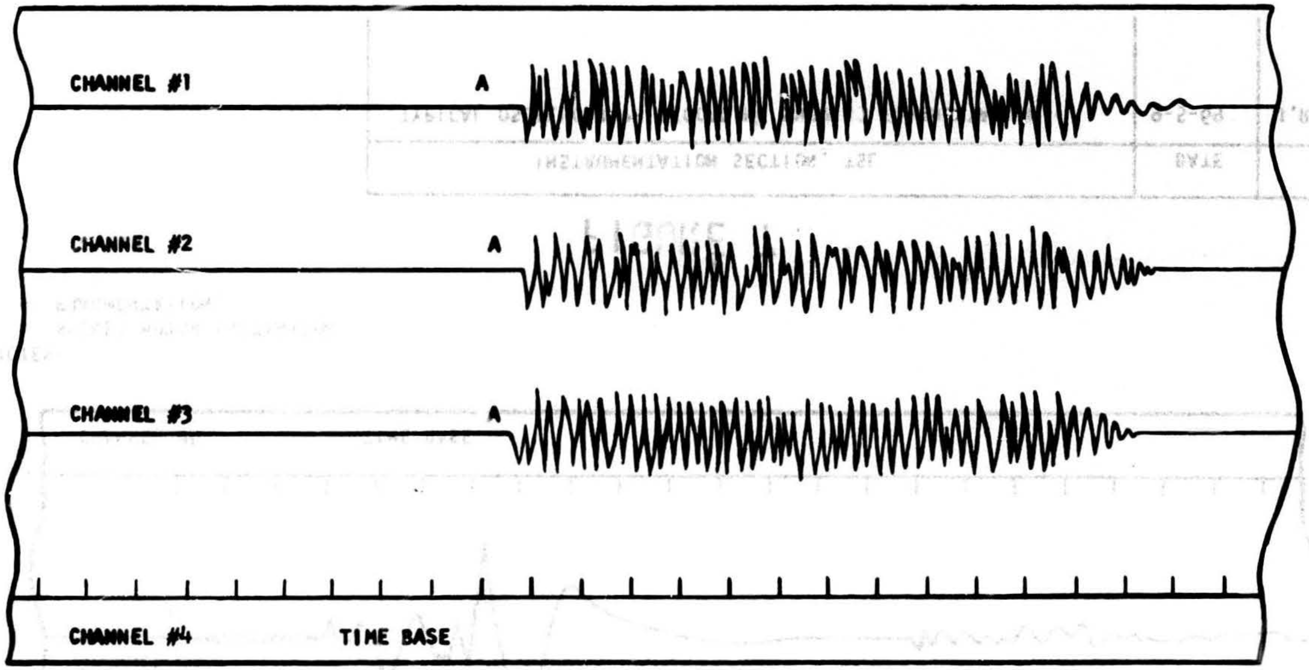


FIGURE 5

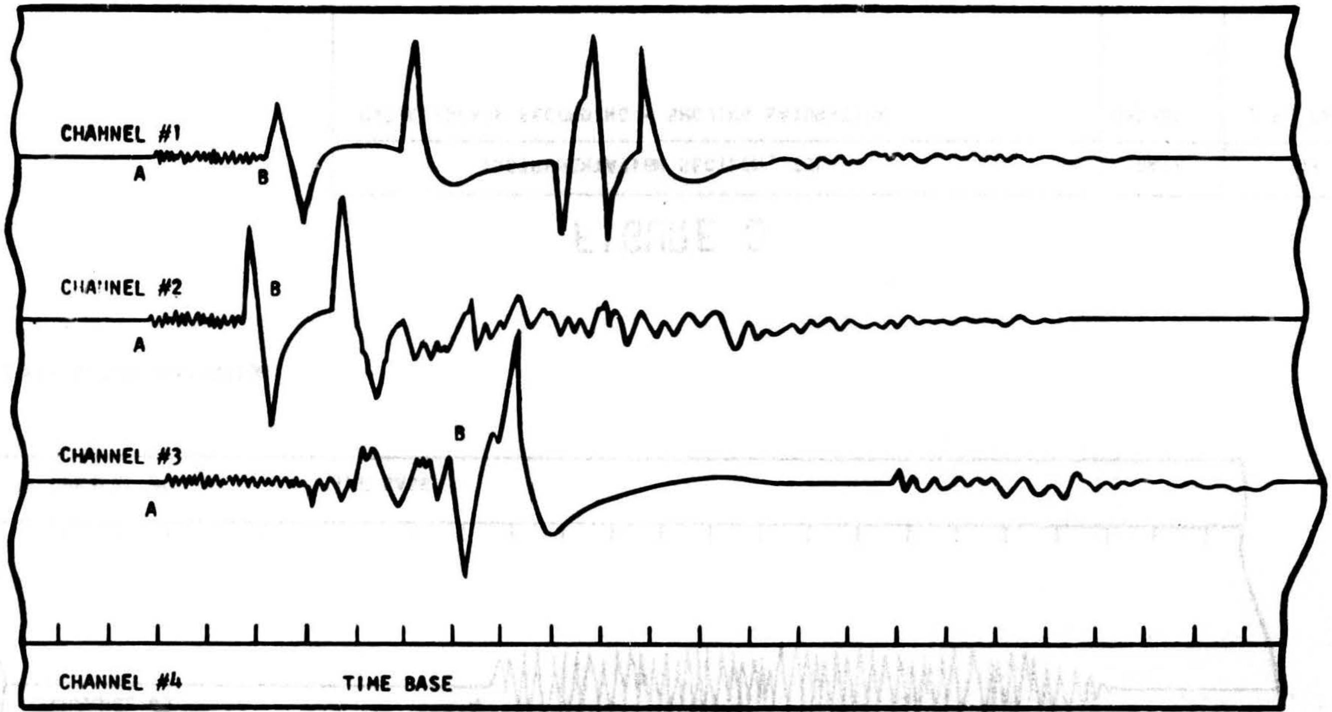
INSTRUMENTATION SECTION, TSL	DATE	BY
BLOCK DIAGRAM SRA-1 AMPLIFIER	9-5-69	D. RAMER



NOTES:
A- ROCKET MOTOR INITIATION.

FIGURE 6

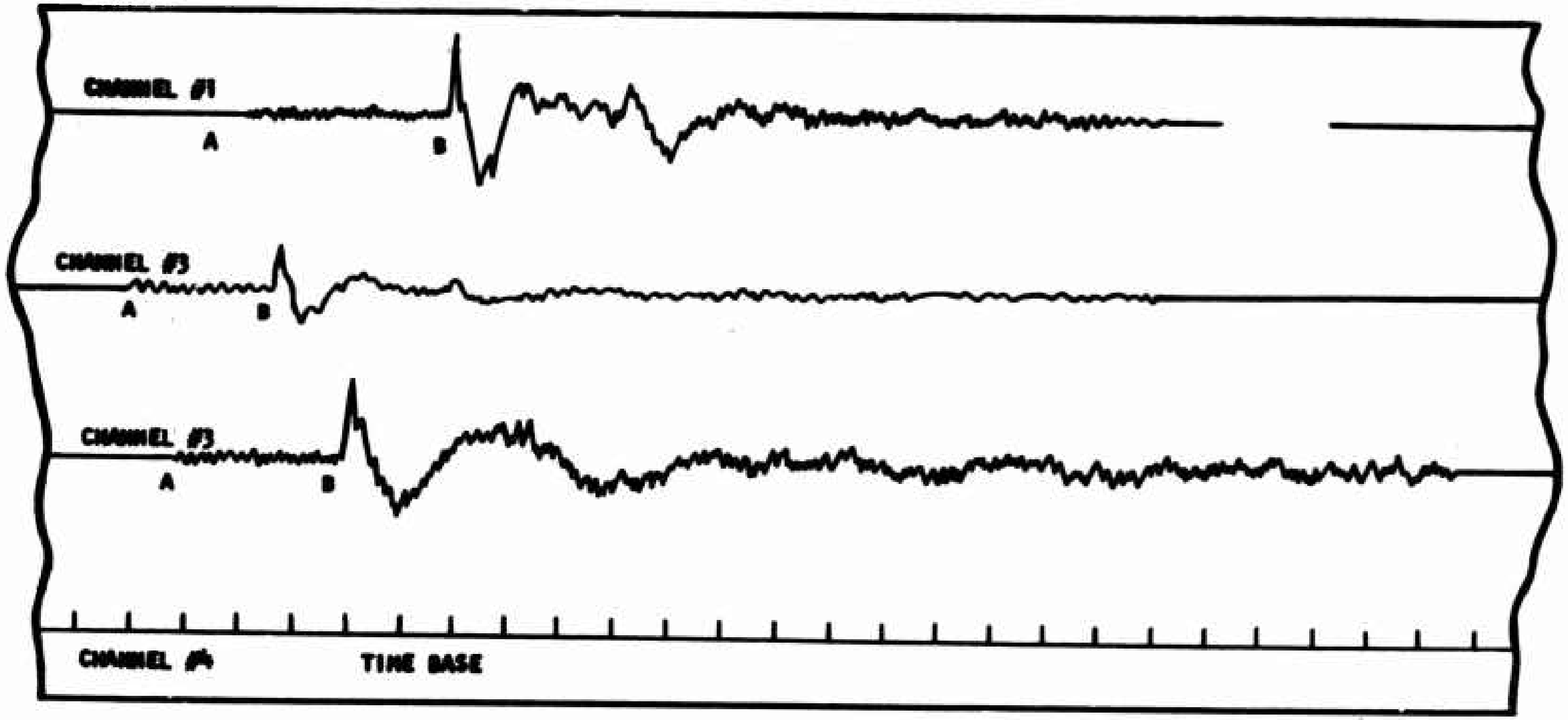
INSTRUMENTATION SECTION, TSL	DATE	BY
OSCILLIGRAPH RECORDING - SHOWING SATURATION	9-5-69	J.R. FRISTER



NOTES:
A- ROCKET MOTOR INITIATION.
B- FRAGMENTATION.

FIGURE 7

INSTRUMENTATION SECTION, TSL	DATE	BY
TYPICAL OSCILLOGRAPH RECORDING SHOWING FRAGMENTATION	9-5-69	J.R. FRISTER

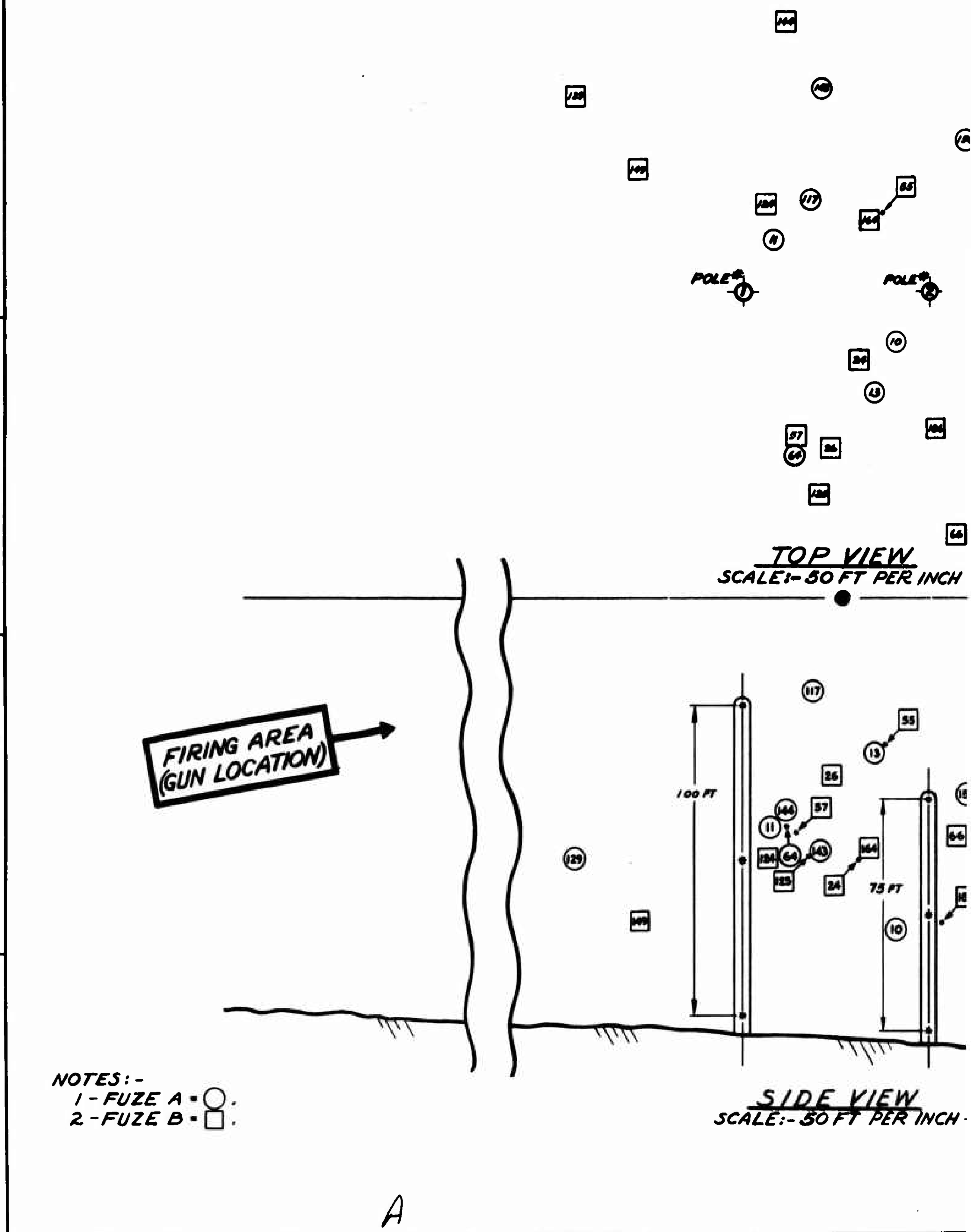


NOTES:-
A- ROCKET MOTOR INITIATION.
B- C-4 BLAST DATA.

FIGURE 8

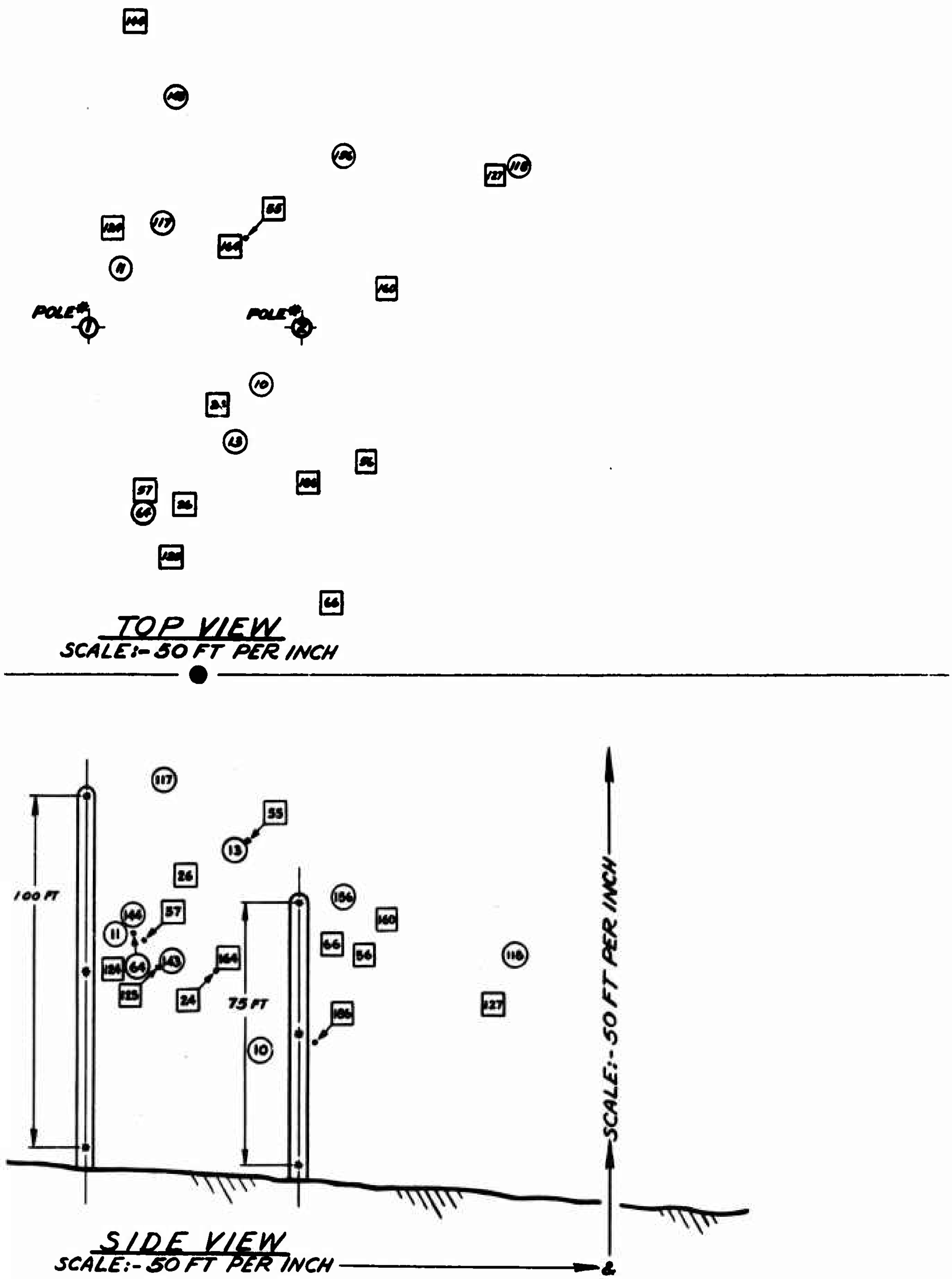
INSTRUMENTATION SECTION, TSL	DATE	BY
OSCILLOGRAPH RECORDING WITH LC 13 BLAST TRANSDUCER	9-5-69	J.R. FRISTER

FIGURE 9



TOP VIEW
SCALE:- 50 FT PER INCH
POLE #1
POLE #2
FIRING AREA (GUN LOCATION)
100 FT
75 FT
SIDE VIEW
SCALE:- 50 FT PER INCH
NOTES:-
1 - FUZE A = ○.
2 - FUZE B = □.

FIGURE 9

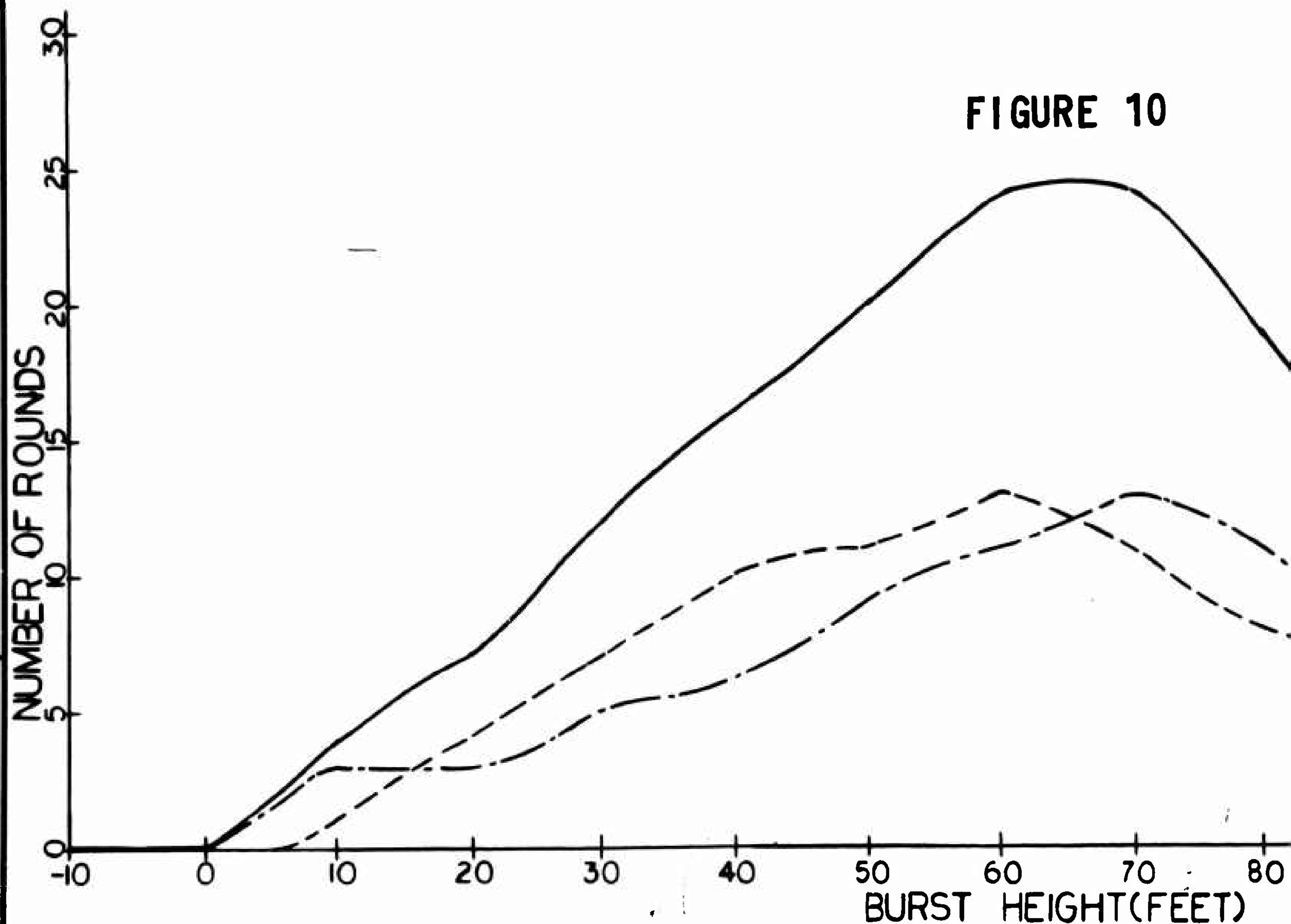


INSTRUMENTATION SECTION, TSD	DATE	BY
H.O.B. - X, Y COORDINATES. ELECTRONIC FUZE PROGRAM	1-9-70	J.R. FRISTER

E D C B A

B

FIGURE 10



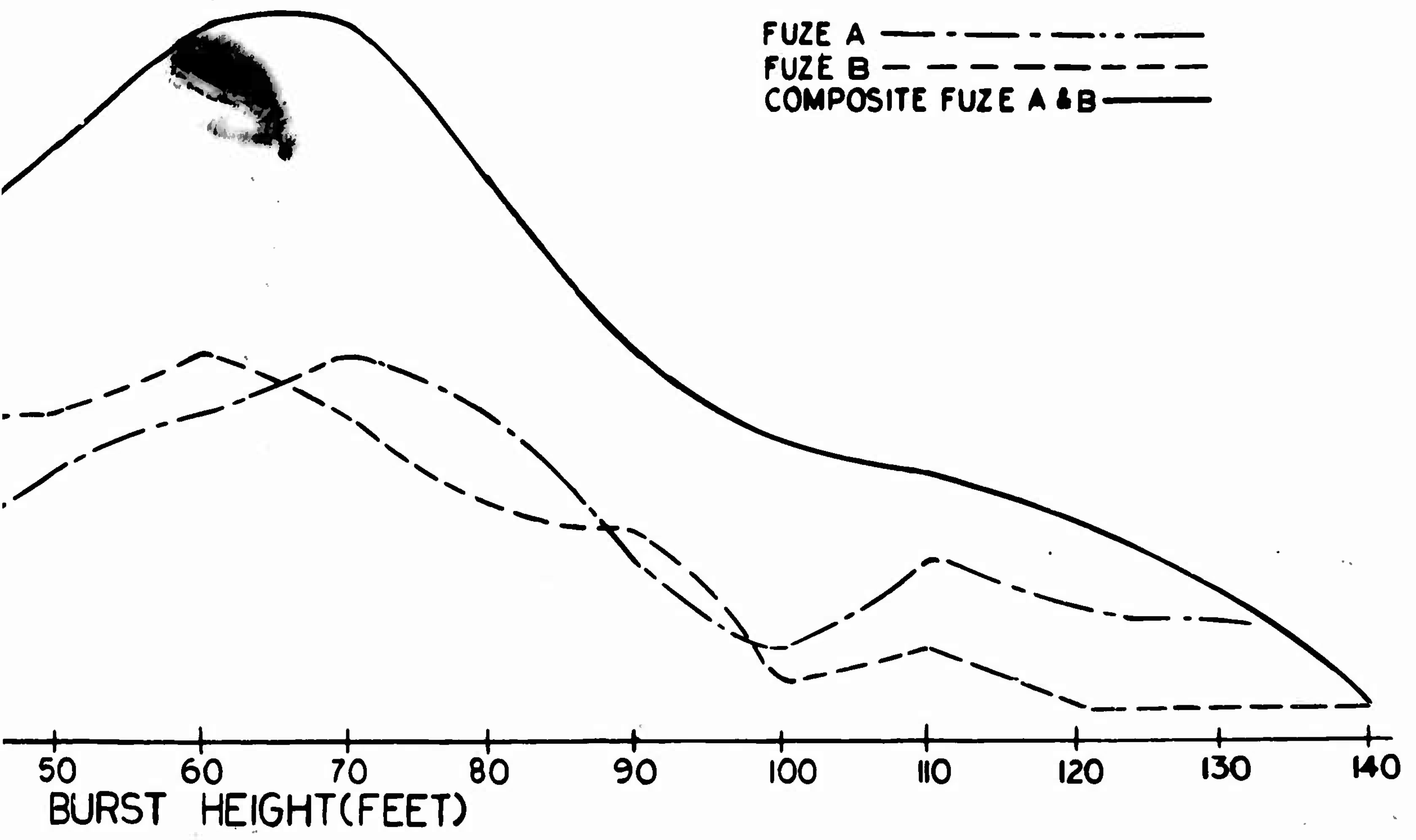
		MECHANICAL PROPERTIES		UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	ORIGINAL DATE
		YP		TOLERANCES ON DECIMALS ±	DRAFTSMAN
		TS		FRACTIONS ± ANGLES ±	ENGR
		EL2			ENGR
NEXT ASSY	USED ON	RA		MATERIAL	
APPLICATION		BH			SUBMITTED
DO NOT	APPLY PART NO.			HEAT TREATMENT	
DO	AS SPECIFIED	RH		FINAL PROTECTIVE FINISH	APPROVED

AMC 1030-4-R
1 JAN 63

A

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVA

FIGURE 10

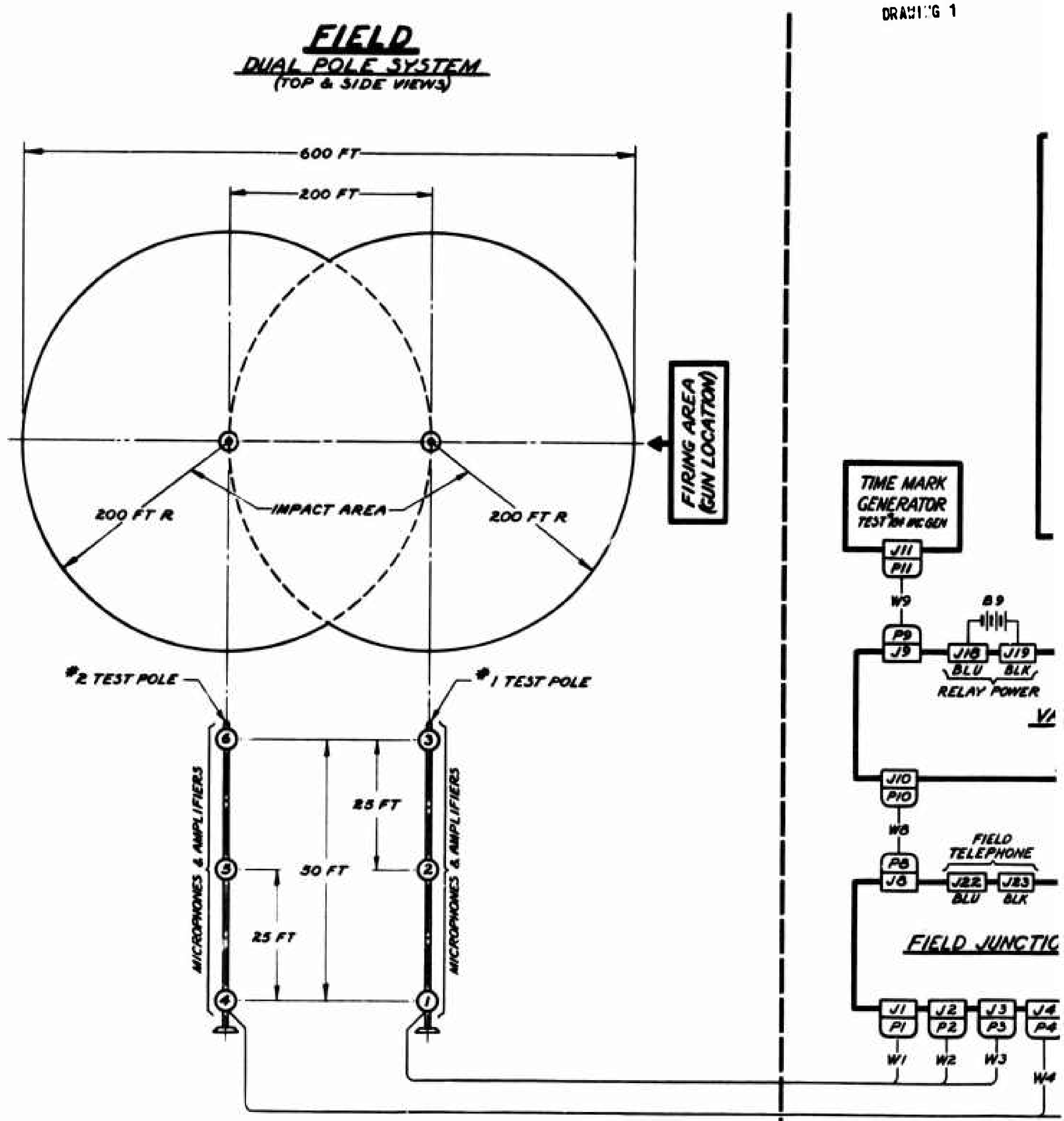


PART NO.

OTHERWISE SPECIFIED IONS ARE IN INCHES	ORIGINAL DATE OF DRAWING		PICATINNY ARSENAL DOVER, NEW JERSEY
I DECIMALS ± ANGLES ±	DRAFTSMAN	CHECKER	BURST HEIGHT DENSITY ELECTRONIC FUZE PROGRAM
	ENGR	ENGR	
	ENGR	ENGR	
IT	SUBMITTED		SIZE B / CODE IDENT NO. 19203
VE FINISH	APPROVED		SCALE / UNIT WT. / SHEET

B

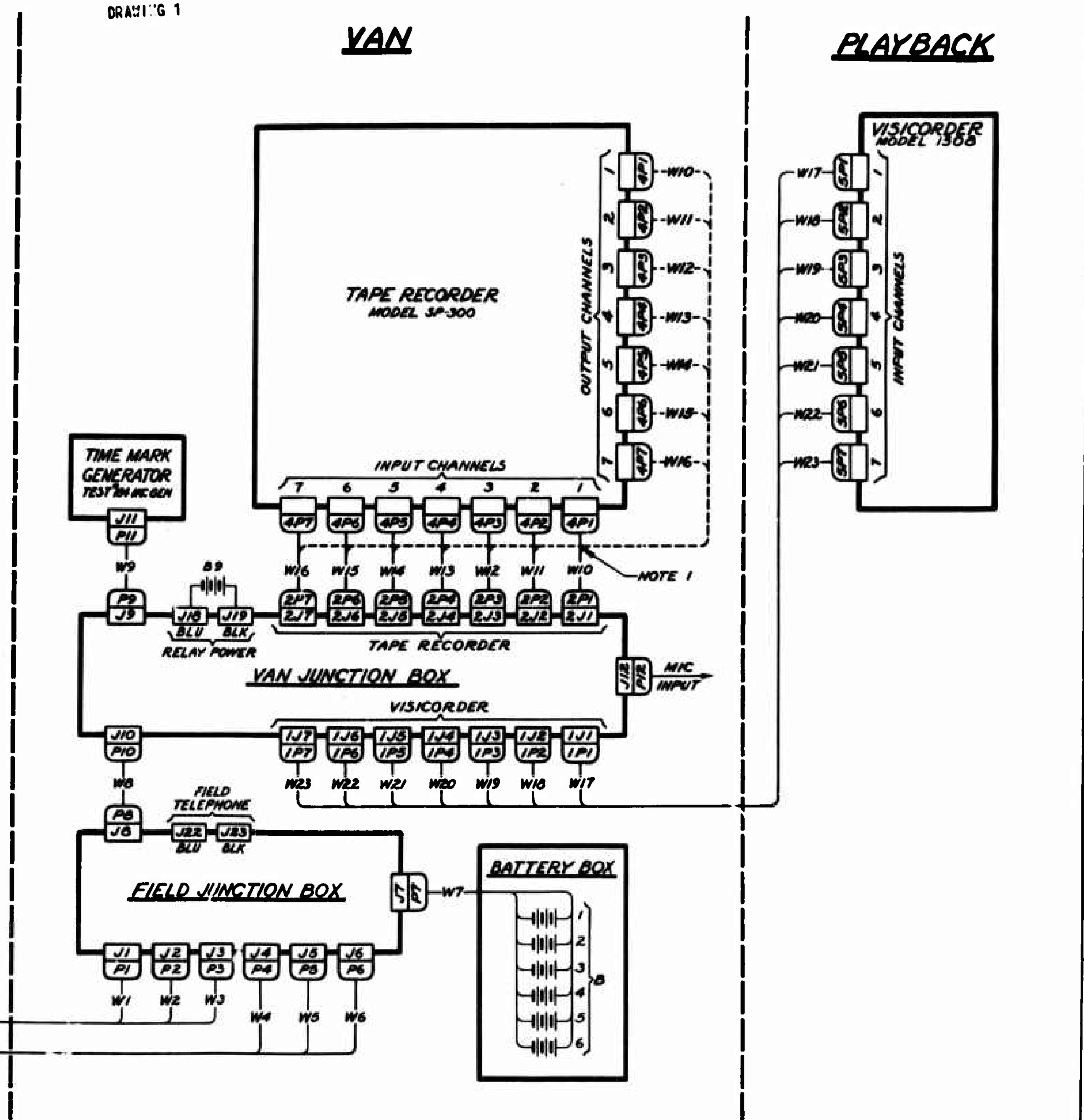
DRAWING 1



NOTES:-
1-REMOVE FROM INPUT AND PLACE IN OUTPUT CHANNELS OF TAPE RECORDER; FOR PLAYBACK.

A

DRAWING 1



NEXT ASSY	USED ON
APPLICATION	

MECHANICAL PROPERTIES

DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS ±
FRACTIONS ± ANGLES ±

ORIGINAL DATE OF DRAWING: 5 SEPT 1969

DRAFTSMAN | CHECKER | ENGR | ENGR

PART NO.

U.S. ARMY MUNITIONS COMMAND
PICATINNY ARSENAL, DOVER, NEW JERSEY 07801

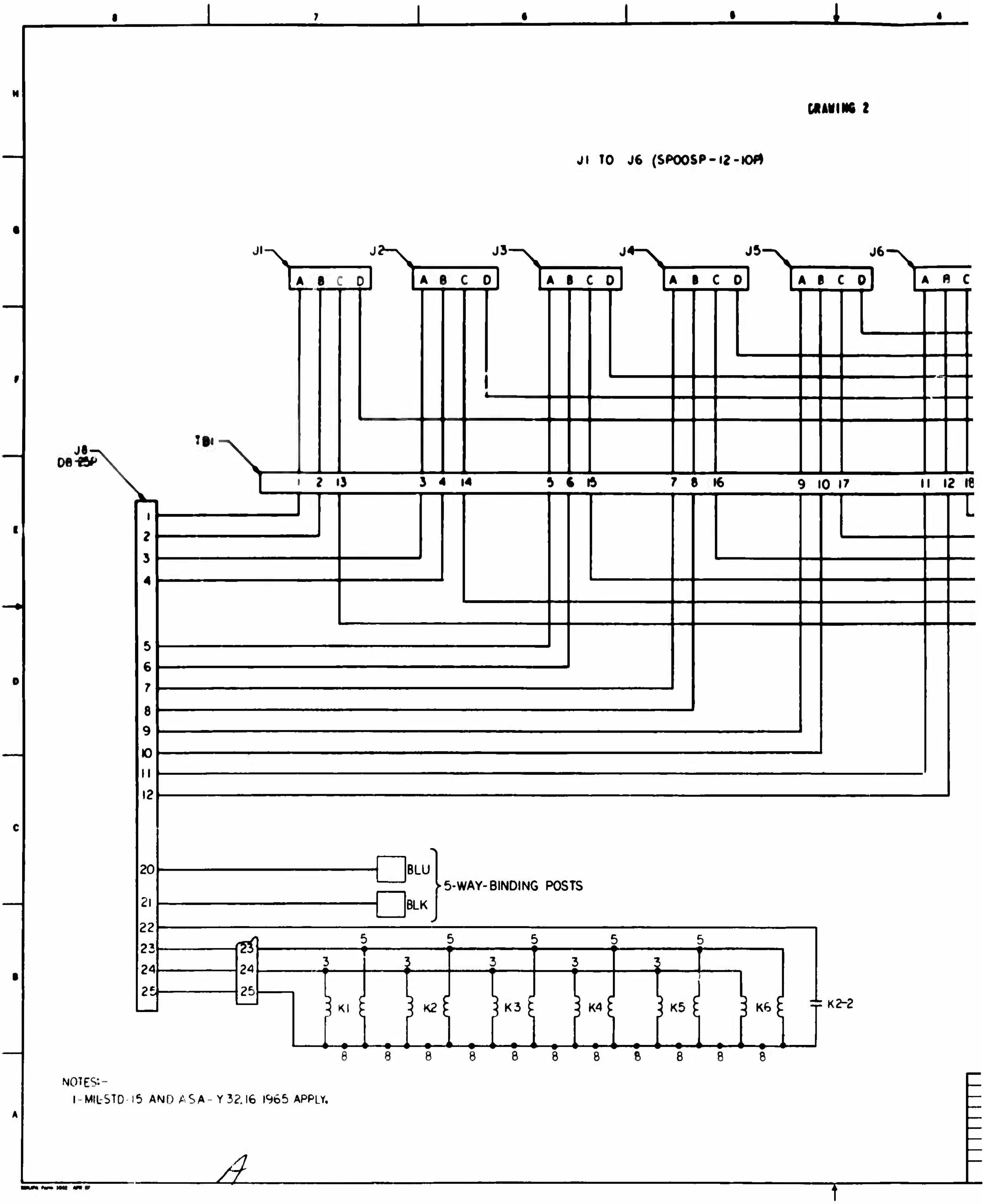
DUAL POLE HOB SYSTEM
BLOCK DIAGRAM

SIZE F | CODE IDENT NO 19203 | P 9251965

SCALE ~ | UNIT WT | SHEET

B

DRAWING 2

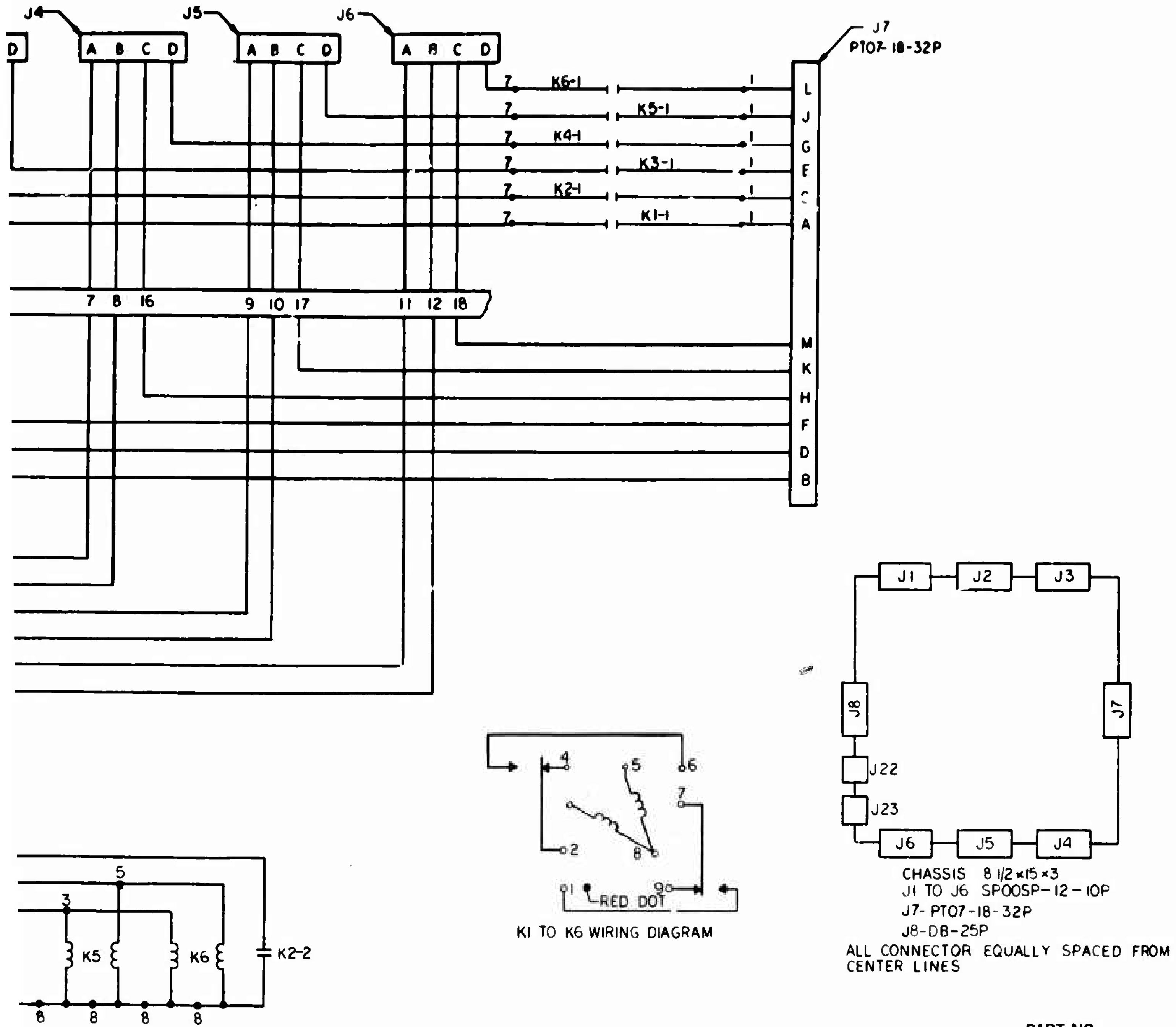


NOTES:-
1-MIL-STD-15 AND ASA-Y32.16 1965 APPLY.

A

DRAWING 2

'O J6 (SPOOSP-12-10P)



K1 TO K6 WIRING DIAGRAM

CHASSIS 8 1/2×15×3
J1 TO J6 SPOOSP-12-10P
J7- PT07-18-32P
J8-DB-25P
ALL CONNECTOR EQUALLY SPACED FROM CENTER LINES

PART NO.

NEXT ASSY	USED ON	MECHANICAL PROPERTIES	DO NOT SCALE DRAWING. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON DECIMALS ±. FRACTIONS ± ANGLES ±
APPLICATION			

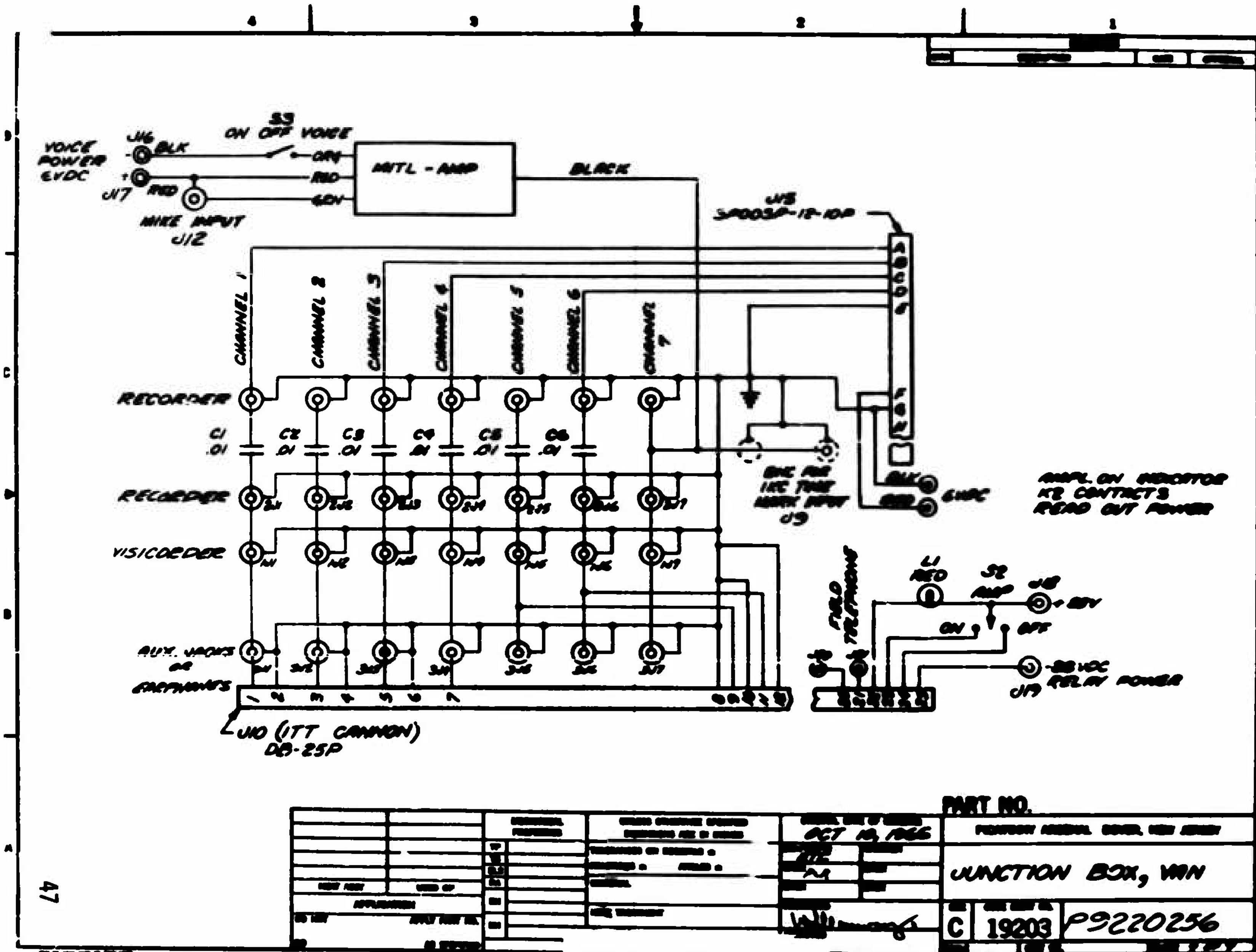
ORIGINAL DATE OF DRAWING: OCT 10, 1966

U.S. ARMY MUNITIONS COMMAND
PICATINNY ARSENAL, DOVER, NEW JERSEY 07801

FIELD JUNCTION BOX
WIRING DIAGRAM

SIZE F | CODE IDENT NO 19203 | P9220256

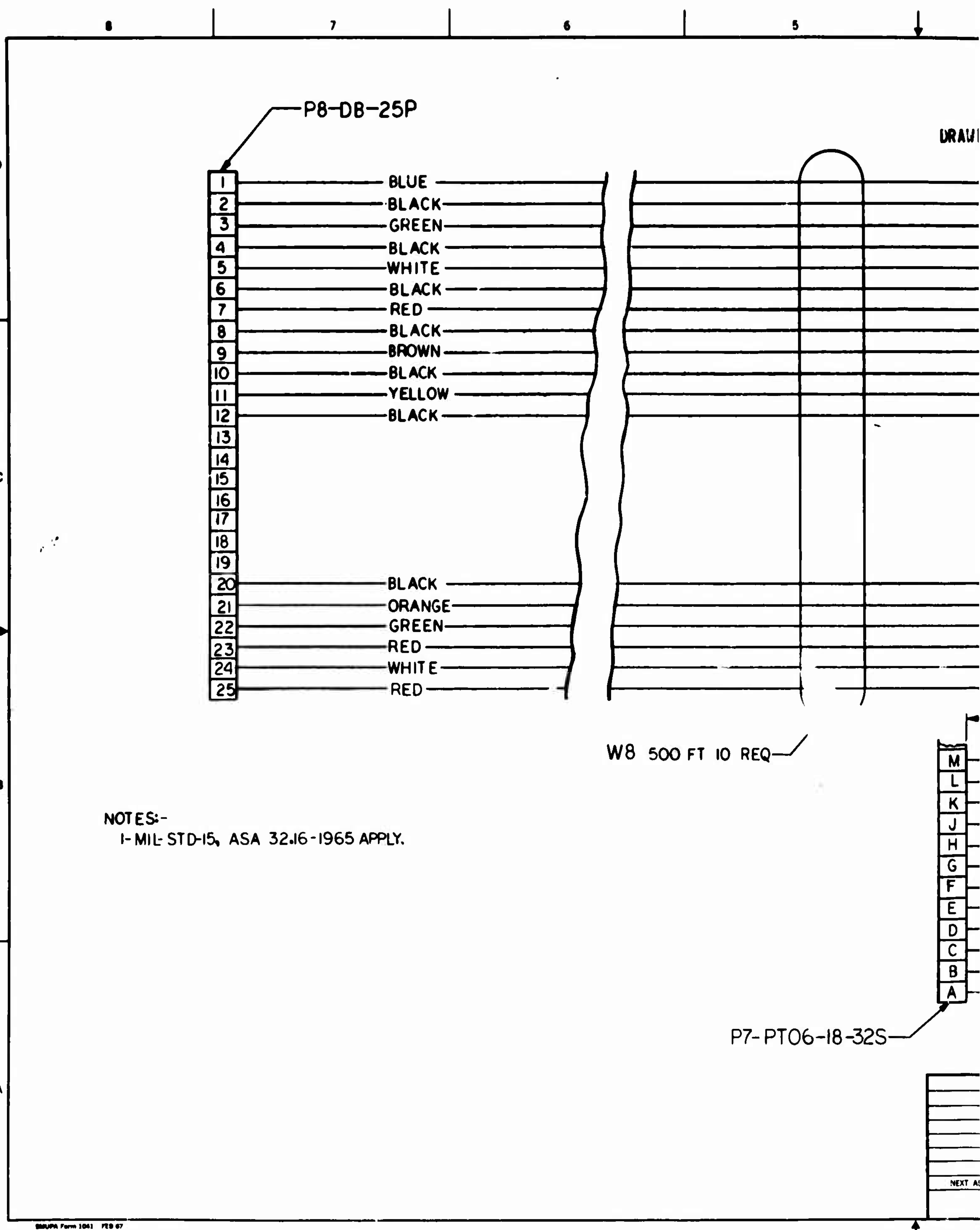
SCALE | UNIT WT | SHEET


VOICE POWER 6VDC
J16 BLK
J17 RED
MIKE INPUT J12
S3 ON OFF VOICE
MITL - AMP
BLACK
J15 SP003P-12-10P
CHANNEL 1
CHANNEL 2
CHANNEL 3
CHANNEL 4
CHANNEL 5
CHANNEL 6
CHANNEL 7
RECORDER
C1 .01
C2 .01
C3 .01
C4 .01
C5 .01
C6 .01
RECORDER
VISICORDER
AUX. JACKS OR EARPHONES
J10 (ITT CANNON) DB-25P
BNC FOR IRC TIME MARK INPUT J9
6VDC
AMPL. ON INDICATOR K2 CONTACTS READ OUT POWER
FIELD TELEPHONE
L1 RED
S2 AMP
ON
OFF
J18 +28V
J19 -28 VDC RELAY POWER
PART NO.
OCT 10, 1966
JUNCTION BOX, VAN
C 19203 P9220256

DRAWING 3

APPENDIX D

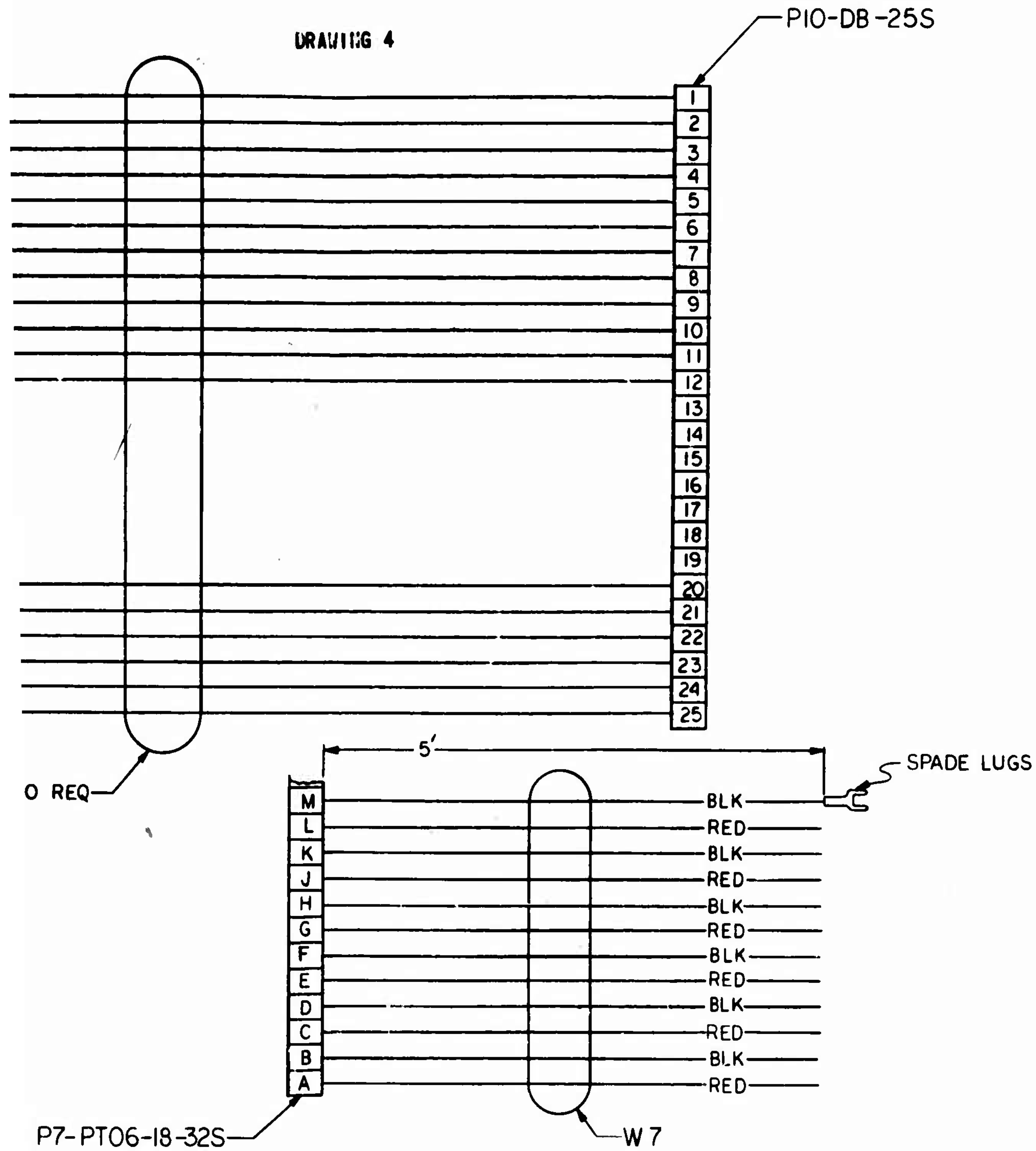
Photographs



NOTES:-
1- MIL-STD-15, ASA 32.16-1965 APPLY.

REVISIONS		
SYM	DESCRIPTION	DATE

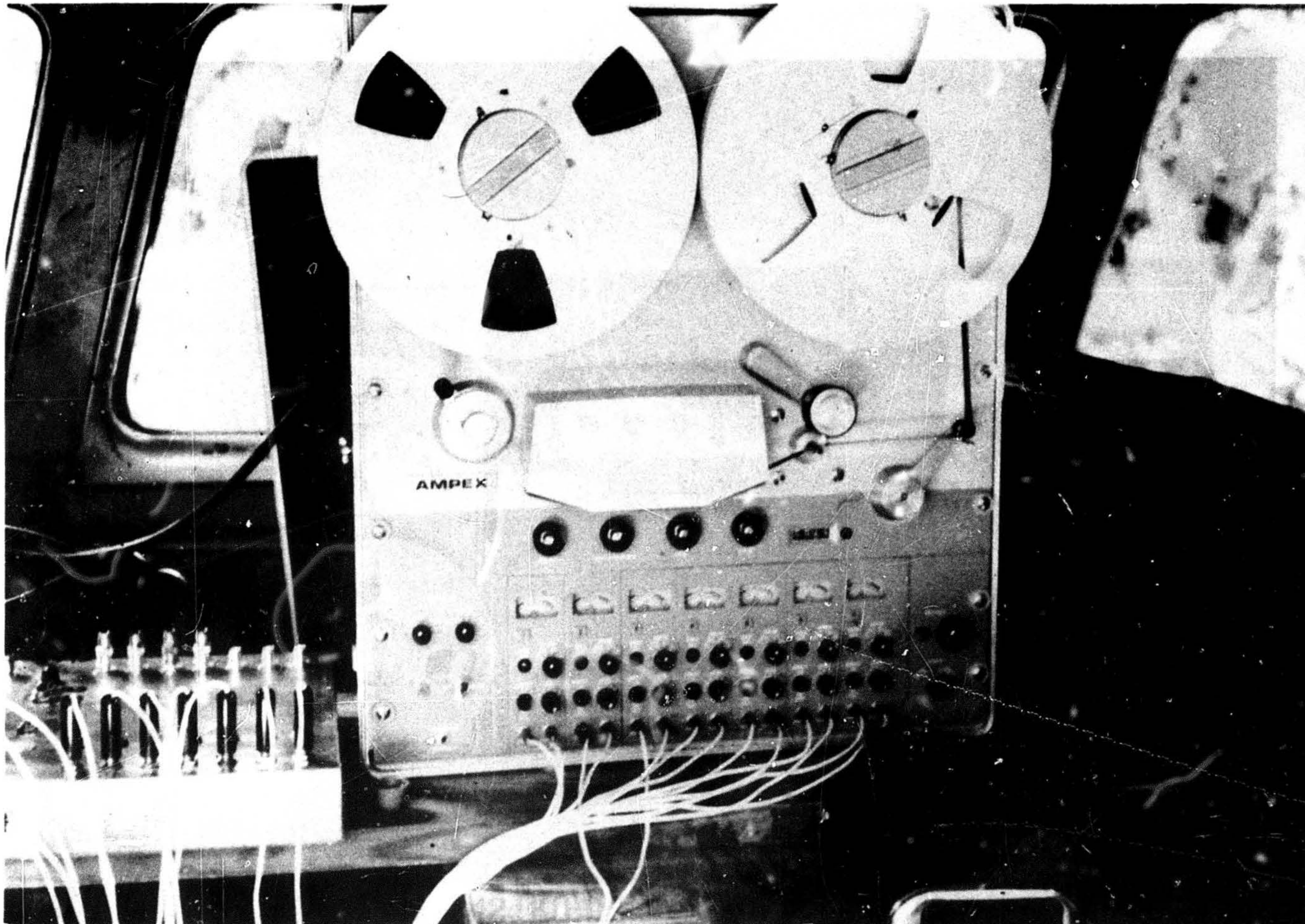
DRAWING 4



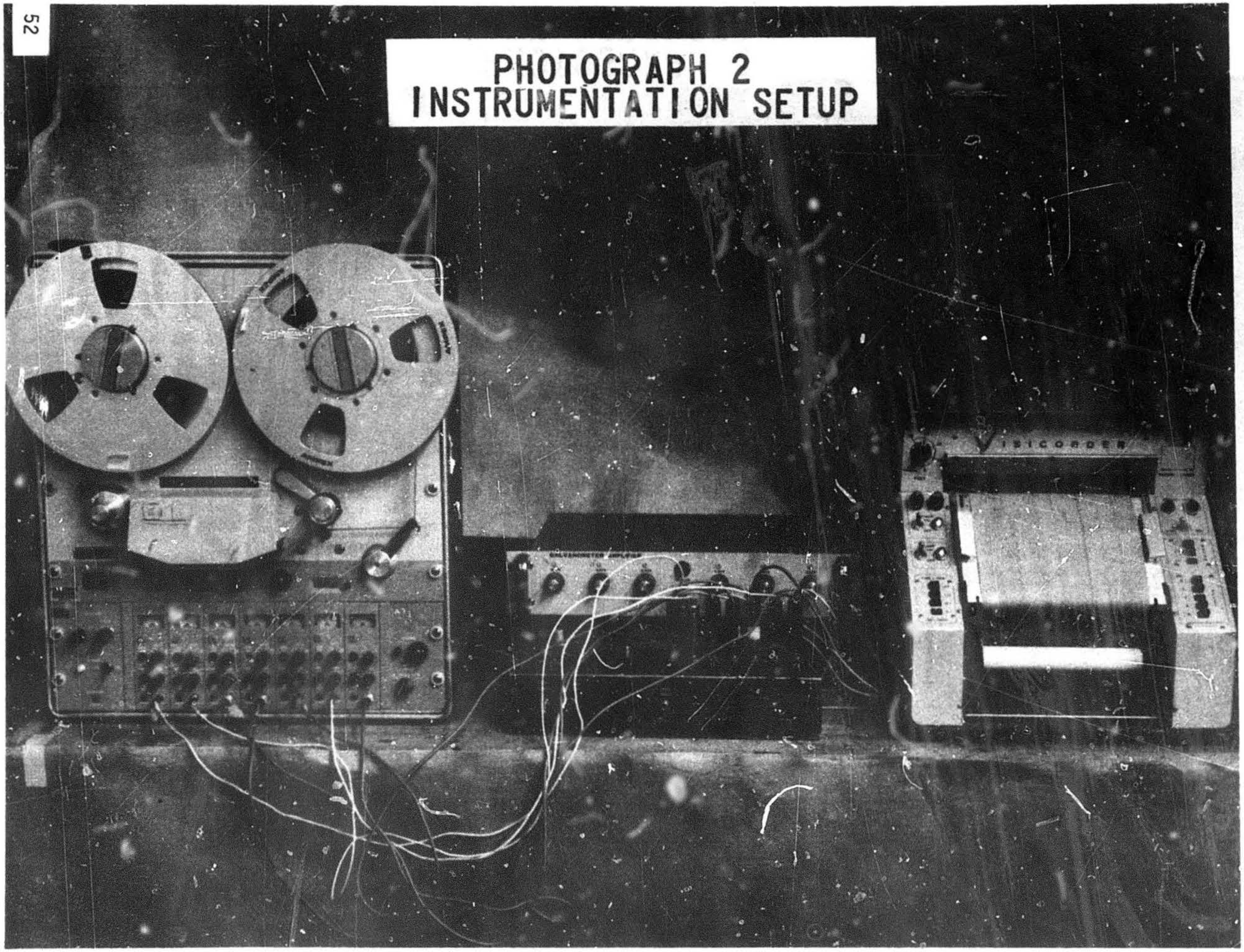
PART NO.

		MECHANICAL PROPERTIES	DO NOT SCALE DRAWING UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	ORIGINAL DATE OF DRAWING OCT 10, 1966	U.S. ARMY MUNITIONS COMMAND PICATINNY ARSENAL, DOVER, NEW JERSEY 07[illegible]
		YP	TOLERANCES ON DECIMALS ±	DRAFTSMAN RJD	CHECKER
		TS	FRACTIONS ± ANGLES ±	ENGR RJB	ENGR
		EL2		ENGR	ENGR
		RA			W7,W8 CABLE DIAGRAM
		BH			SIZE D
NEXT ASSY	USED ON	RH			CODE IDENT NO 19203
APPLICATION					P 9220256
					SCALE / UNIT WT / SHEET

B



PHOTOGRAPH 1
TAPE RECORDER



PHOTOGRAPH 2
INSTRUMENTATION SETUP