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APERTURE CARD PLOTTER

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FINAL DEVELOPMENT REPORT
FOR
APERTURE CARD PLOTTER

This report covers the period October 1, 1967 to February 15, 1968

Francis Associates, Inc.
Marion, Massachusetts 02738

April 1968

Contract N00024-68-C-1045
Project Serial No. S2720 - Task 11682

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ABSTRACT

The Aperture Card Plotter was developed by Francis Associates, Inc., under Contract N00024-68-C-1045, for use with the Sippican Bathythermograph System and other applicable data recording instrumentation. The plotter provides an automatic means of recording temperature/depth traces in a manner suitable for integration with computerized transmission, storage, retrieval and readout systems.

Test operations using the prototype plotter developed under this contract showed the overall feasibility of the equipment. Functions such as write rate, lamp ignition, overheat and card-to-card repeatability were satisfactory, while long-term effects of vibration on spot intensity and lamp stability were possible problem areas requiring further tests.

Two problem areas were found with respect to calibrated accuracy: (a) the effect of temperature on the reference circuitry, and (b) the noncon-centricity or "droop" of the extended ball spline. To meet the original plotter specifications, it would be necessary to investigate and resolve these problems, and to provide the redesign effort required to fabricate a second engineering prototype plotter.

In addition, to develop a manufacturing design, functions such as programming circuitry, lamp ignition (power supply circuitry), and the time axis drive mechanism should be re-evaluated with respect to simplification and subsequent improvement in reliability.

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PART I

1. PURPOSE

This document represents the Evaluation Report pertinent to the Aperture Card Plotter development program performed by Francis Associates, Inc., under Contract N00024-68-C-1045, Item 4AA.

The report describes the results of the evaluation, and provides conclusions and recommendations. Equipment specifications are included.

2. GENERAL FACTUAL DATA

This section describes the Aperture Card Plotter characteristics that were evaluated, and the procedures that were used to obtain the results given in Section 3.

2.1 Program Sequencing Errors

A normal program is produced by carrying out the following operations in sequence: load card, turn on plotter, start lamp, load BT, drop BT, develop card. The resulting trace is shown in Fig. 1. The spot is in position 1 (0°C and 1500 ft.) at the beginning of the sequence. It moves automatically to position 2, waits there until the BT is dropped, and then the trace is completed.

a) Errors in program sequencing may be caused by any of several forms of interference, which cause the programming logic to skip to a condition other than that commanded by the normal input of information.

b) The requirement for operation is that a usable trace be produced when the plotter is operated in accordance with the specified procedure.

c) The procedure for test was as follows: Several hundred normal cycles were made with the plotter. Variations from normal sequence were noted. Abnormal operations were performed (example: not holding the cycle button during ignition), and the plotter was cycled at low and high temperature.

2.2 Overheat Shutdown

a) Overheating can occur under abnormal operating conditions (high ambient, too frequent cycling, or a combination of these conditions).

b) It is required that the overheat sensor detect any potentially damaging overheat conditions and turn off the lamp, reducing the system to standby power. Reignition cannot be accomplished until the system has cooled.

c) To test the above condition, the plotter was allowed to remain in the launch condition (lamp on), with high line voltage applied. The test was

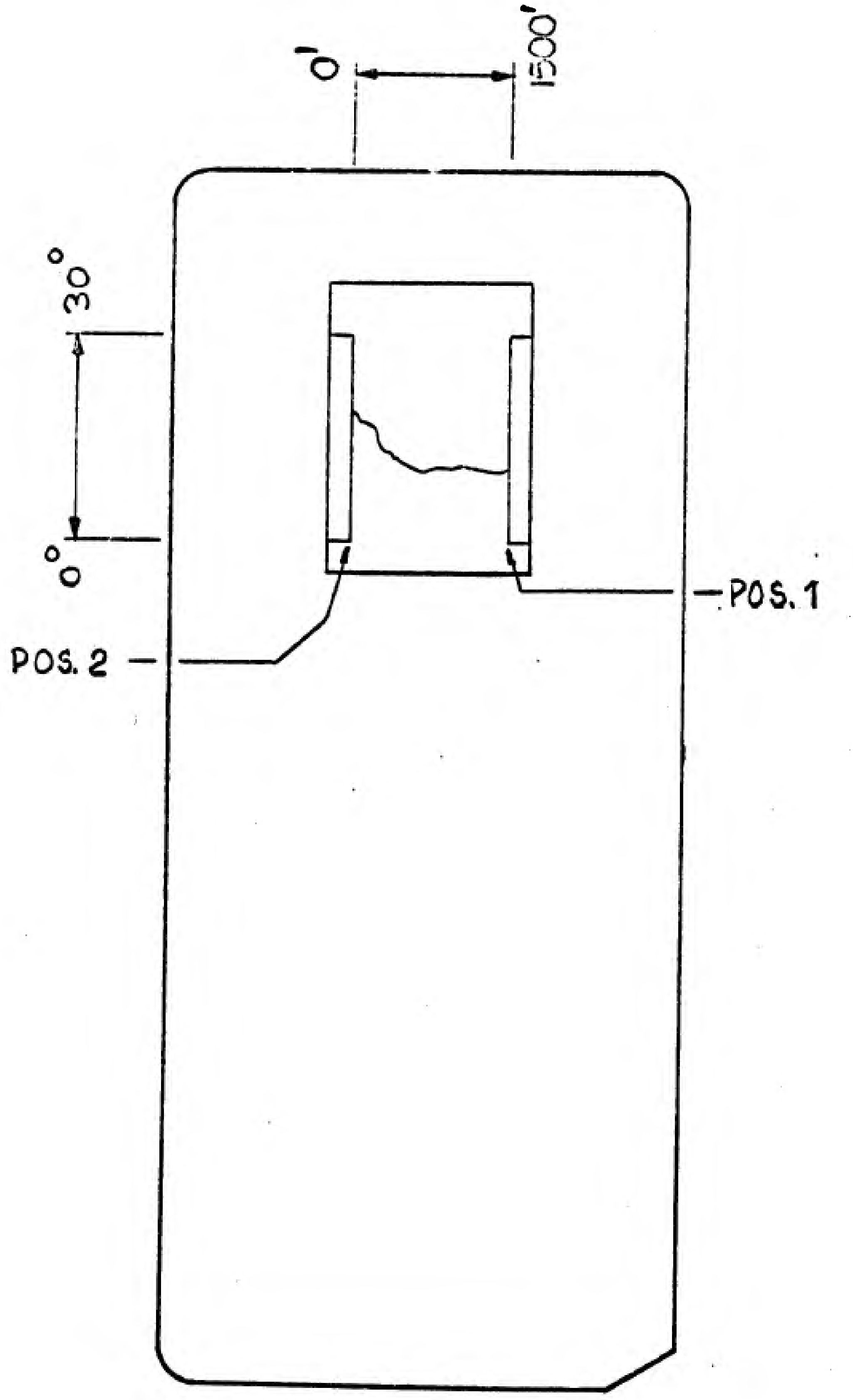


DIAGRAM OF APERTURE CARD

FIG.1

conducted at room temperature. Time to overheat and to cool down was measured at high line voltage and at normal line voltage.

2.3 Lamp Ignition Reliability

a) Ignition requirements vary from lamp to lamp and with the life of a given lamp. The power supply and ignition circuits must serve a broad range of lamp ignition requirements.

b) A lamp must be ignited reliably in two seconds or less.

c) Ignition time was observed for cold and hot lamps during several hundred operations.

2.4 Spot Intensity and Lamp Stability

a) Spot intensity and stability are a function of lamp life. As the lamp ages, the spot size increases, intensity decreases, and a shift in the center of the spot may become apparent.

b) The image must be round and blue-violet in color, with an intense white center. The white center must remain within the bounds of the image (as observed external to the window against which the aperture card is placed).

c) The image of the spot was examined before, about half-way through, and at the completion of 75 normal cycles under standard operating conditions.

2.5 Writing Rate

a) Maximum writing rate is defined as the maximum ΔT/foot which produces a usable trace on the aperture card.

b) With the system in a launched condition, triangular waves of several low frequencies were recorded, using a lamp which had at least 100 previous operations. The highest frequency producing a faint but still clearly discernible trace to the naked eye was converted to an equivalent in degrees F per foot and recorded as the maximum writing rate.

2.6 Calibrated Accuracy

a) Calibrated accuracy is the ability of the plotter to record a given input temperature on the card in the proper relationship to the reference marks.

b) Tentative requirements for accuracy to reference lines were set at:

Standard conditions	±0.2°F
RMS sum - any condition	±0.3°F

c) A card was accurately scribed by hand with a set of temperature reference lines corresponding to 30°F and 94°F. The plotter was then calibrated at standard conditions to match this pattern. Cards were traced under various conditions of high and low line voltage and temperature (at start-up and after running). Resistance inputs corresponding to 0° and 30°C, and 30°, 62° and 94°F were used. Comparisons were made between cards made at like conditions, and between cards made under differing external influences.

Straight line traces were drawn under varying line voltage inputs, and under the influences of an active and inactive developer circuit.

2.7 Card-to-Card Repeatability

a) For cases where the reference lines are not used (all tactical), the absolute accuracy of the plotter will be dependent on the consistency with which the card is positioned with respect to the plotter itself. Since the reference lines are not used, the data will be referred to two perpendicular card edges.

b) Tentative requirements for accuracy referred to the card edges were set at:

Standard conditions	±0.4°F
RMS sum - any condition	±0.6°F

c) Four cards were made, all at fixed line voltage (115V) and temperature (room ambient), since the effect of these influences had been examined separately. Resistive inputs corresponding to 30°, 62° and 94°F were used in combinations of two per card.

2.8 Dead Space

a) Dead space may be defined as the largest change in input signal which can occur without causing the plotter servo system to respond.

b) The goal for dead space was set at 0.05°F.

c) To measure dead space, single cycles of a low amplitude triangular wave were injected into the measuring system, with the servo at various points on the temperature scale. At the end (zero volts) of each cycle, the polarity of the waveform was reversed so that the trace alternately approached the original base reference line from above and below the indicated temperature. A frequency of 0.15 cps was used so that several cycles could be recorded during the 80-second launch condition.

In order to double-check the method, a passive circuit consisting of a capacitor and voltage divider was used. Step change inputs of alternating polarity were applied to the network and allowed to decay to a negligible voltage input.

2.9 Settling Time

a) Settling time is defined as the elapsed time between a step change input and when the following error is reduced to 1% of the step change.

b) The original goal for settling time was 100 milliseconds. During development of the servo, this goal was changed to 350 milliseconds to achieve a proper balance with the dead space and stability characteristics.

c) A storage oscilloscope input was connected to the feedback pot arm. A step change of BT resistance was fed into the system and the resulting voltage waveform on the feedback potentiometer arm was recorded on the storage oscilloscope. Time as outlined in definition (a) above was read directly from the recorded trace.

3. DETAIL FACTUAL DATA

The section describes in detail the results of the Aperture Card Plotter evaluation.

3.1 Program Sequence Errors

There are three major program sequence errors which may occur under the following conditions:

a) During ignition, the servo may shift from the offscale to the 0°C position. The xenon lamp will go out and have to be reignited 80 seconds later. The card trace will be valid; however, the 0°C reference line normally at the surface position will be replaced by 0°C reference line running from surface to 1500 ft. Occurrence is about 5% of the time.

b) At launch and during the normal BT trace recording, a step change in temperature of large amplitude (in the order of 20°F or so) may cause the programmer to skip the measuring mode. These step changes are unlikely except at launch when the BT could enter very warm water causing a slew in excess of 20°F. Even in this case, the occurrence is only about 2% of the time. The resulting trace is invalid.

c) An old xenon lamp will not extinguish at the end of the cycle and the develop lamp will not come on. The launch lamp will come on. The xenon lamp should be replaced. The trace will be valid.

3.2 Overheat

The plotter will not exceed its rated case temperature of 140°F when operating from 105V and ambient temperature of 75°F. With 120V input, overheat will occur after approximately one hour of continuous operation with the xenon lamp or after approximately three hours of cycling at five minute intervals. After overheat occurs, it is necessary to disconnect AC power to cool down in less than three hours. At room ambient (75°F) and with AC disconnected, the plotter cools within one half hour to a temperature which will allow ignition. There is no visual indication when adequate cooling has occurred.

3.3 Lamp Ignition Reliability

Since it is necessary to ignite the lamp for each cycle, the ignition characteristics were evaluated on a qualitative basis by observations made during tests 2.1 (Program Sequencing) and 2.4 (Spot Intensity and Lamp Stability). It was found that all lamps which produced an acceptable spot intensity and stability (i.e., "good lamps") could be ignited within two seconds. Although hot lamps could be reignited immediately in most cases, it was discovered by talking with the manufacturers and by our own experience that lamp life is degraded by repeated immediate reignition. A cooling-off period of at least two minutes should elapse under normal usage.

3.4 Spot Intensity and Lamp Stability

The spot intensity remains essentially constant throughout the life the xenon lamp. The effective intensity may, however, vary as the result of the bright center of the spot image moving off-center from the aperture contained in the collimating lens assembly. Under normal operation this will not occur until several hundred operating cycles have taken place. It was found that a physical shock which is directly transmitted to the lamp while it is operating may result in electrode deformation and result in spot motion. Considerable time was spent in determining whether the door latching action would result in damage to the lamp. It did not. It was further concluded that shock applied outboard of the mounts is attenuated sufficiently so that no damage to the lamp occurs. Life tests of several lamps prior to the completion of the plotter itself indicated a useful life of 300 to 500 cycles may be expected.

3.5 Maximum Write Rate

A total of fourteen cards was examined for the effects of slew rate on the recorded trace at low and high line voltage and at lowered temperatures (33°F). Cards made were not in sequence and variability in the traces was comparable to the variability observed previously in cards made under identical conditions, but at various times during the life of the xenon bulb. It was concluded that the effects of line voltage or temperature are less than the effects of bulb life.

Line width varies from trace-to-trace, but not as a function of slew rate. The effect of slew rate is primarily a change in density of the recorded trace. In all cases, the plotter was capable of producing a usable record from a triangular waveform having a frequency of 0.05 Hz. This is equivalent to a temperature gradient of 0.32°F per foot. In some cases a 0.64°F per foot gradient was recorded satisfactorily.

3.6 Calibrated Accuracy (Referred to Reference Lines)

Calibrated accuracy was examined in terms of:

a) Repeatability, with respect to the reference line positions, of several points on scale.

b) Location of the 62°F point with respect to 30°F and 96°F points (should be centered between them).

c) Comparison of above results taken from data at room temperature with that taken at near 0°C.

Ideally, the calibrated accuracy would be entirely dependent on the characteristic of the feedback potentiometer. Practically, however, this is not the case. The follower amplifier, which is fed by the potentiometer wiper arm, cannot present a high enough input impedance to have negligible effect on the calibration under all input conditions. Errors caused by the loading are, in fact, calibrated into the system. Since the follower input impedance is a function of temperature, a depressed ambient temperature test will give some indication of system calibration dependence on factors other than the potentiometer characteristic.

In order to directly compare results of successive runs, the following coordinate corrections were made to each card:

a) The 0°C/0' and 0°C/1500' calibration marks were adjusted to the same arbitrary value. All temperature data was corrected accordingly by applying the 0°/1500' correction plus a correction proportional to the difference of the two multiplied by the depth coordinate (referred to 1500 ft.).

b) The 30°C/0' and 30°C/1500' calibration marks were adjusted to another arbitrary value. All temperature data was corrected a second time by:

1) applying a span correction consisting of 0°-30°C difference at the 1500 ft. end, multiplied by temperature coordinate referred to 0°C and expressed as a ratio $\left(\frac{T-0°C}{30°-0°C}\right)$.

2) applying a second correction consisting of the difference between span at 1500' and span at 0', multiplied by the above ratio, and by the depth coordinate referred to 1500'.

An initial comparison of span (difference between 0°C and 30°C reference marks) for the various runs before any rotational or trapezoidal corrections are applied shows the following:

Card #	Ambient Condition	Span, 0 Feet	Span, 1500 Feet
6428	Room	1.248"	1.250"
6429	Room	1.245"	1.246"
6582	Cold	1.274"	1.255"
6583	Cold	1.259"	1.260"
6581	Cold		1.262"

It should be noted that in the 0 foot position, the ball spline is extended. It is possible that the discrepancy in span at 0 feet on runs 6582 and 6583 is the result of ball spline non-concentricity present in one of the two cases. There is no reason, as far as can be determined, to suspect this is the result of electrical interaction between temperature and depth signals. At any rate, the intent of the reference marks is to provide a means of eliminating absolute variations in plotter calibration. Assuming that any calibration change occurs linearly, the results below indicate the consistency of the plotter under two temperature conditions after correcting the data to fit a rectangular pattern of consistent dimensions in all cards (as described above).

T Input	(T Coordinate Data) 6582	6583	6528	6529	Coordinates: Spread, Fixed T	Spread, Variable T
0°C Ref.	1.260	1.260	1.260	1.260	--	--
0°C Input	1.262	1.261	1.258	1.263	0.22°F	0.22°F
30.1°F	1.295	1.296	1.297	1.297	0.05°F	0.09°F
62°F	0.584	0.580	0.577	0.575	0.18°F	0.40°F
94°F	-0.140	-0.145	-0.165	-0.168	0.22°F	1.26°F
30.0°C Input	0.029	0.027	0.011	0.008	0.13°F	0.94°F
30.0°Ref.					--	--
	Low Ambient Temperature.		Room Ambient			

From this data we may tentatively conclude that one or both of the internal reference circuits (0°C and 30°C) are shifting as a function of temperature and that they do not agree with a similar input from an external source. The most conclusive evidence of this is that the 30°C reference and 30°C external signals disagree significantly on all cards, similarly at like ambient temperatures.

On this supposition a check was made of the 62°F mark with respect to external inputs of 30.1°F and 94°F which were the calibration points. The 30.1°F data was shifted by 0.1°F to correspond to 30°F, and a coordinate midway between the two data points was compared to data taken for an external input of 62°F. It was found that:

a) At room ambient temperature, on two runs (6428 and 6429), the indicated temperature for a 62°F input differed from the mid-point of 30° and 94°F by -0.45° and -0.40°F, respectively.

b) At low temperature on two runs (6582 and 6583), the indicated temperature for a 62°F input differed from the mid-point of 30° and 94°F by -0.22° and -0.18°F, respectively.

In view of the disagreement between data from the internal reference circuits and the external inputs, one further modification of the data was performed. This consisted of taking the data which was already corrected to a rectangular pattern and using external inputs of 30.1°F and 94°F as the reference. The remaining external inputs (0°C, 62°F, and 30°C) were then corrected for span and zero using card 6528 as a reference. On this basis the worst spread of data occurred at 0°C but was only 0.31°F as compared to the spread of 1.26°F at 94°F by using the internally generated reference marks. Tabulated results are as follows:

	Variability at Room Ambient	Variability at Low Ambient	Total Variability
0°C	0.27°F	0.18°F	0.31°F
62°F	0	0.13°F	0.31°F
30°C	0	0.13°F	0.18°F

3.6.1 Line Voltage Effect

Effect of variations in line voltage was determined by introducing a fixed resistance input and producing a card while the input line voltage was programmed through five, 16-second segments--117, 129, 105, 129, 117V. Traces at the extremes and at the center of the scale showed no perturbation when the line voltage was step-changed, and all lines were straight. From this we can conclude that the calibration is independent of line voltage between 105 and 125V.

3.6.2 Developer Effect on Calibration

The preceding tests of accuracy and card-to-card repeatability were necessarily carried out with the developer circuit disconnected. It was found early in the test program that the cycling of the developer heaters shifts the calibration of the temperature axis, apparently because the variable loading of the power supply produces voltage changes which in turn shift the balance point in one or more of the servo amplifier stages.

The effect of developer cycling was measured at line voltages of 105 and 120V. Offsets were 0.2° and 0.4°F, respectively.

3.7 Card-to-Card Repeatability

For tactical purposes, the absolute accuracy of the plotter will be dependent on the consistency with which the card is positioned with respect to the plotter itself. The calibration reference lines would not be used; the data is therefore referenced to the edges of the card. The tests were made at fixed line voltage (115V) and temperature (room ambient) since the effect of these influences had been examined separately.

Four cards were made, using inputs corresponding to 30°, 62°, and 94°F in combinations of two inputs per card. All data was then measured with respect to the edges of the card, and data for similar inputs was plotted on the same coordinates (see Figure 2). It was found that the total spread for similar inputs on all cards was 0.008 inch or 0.36°F when the ball spline was in the extended position (0 depth). Total spread at the retracted position (1500 ft. depth) was 0.006 inch or 0.27°F. This reinforces the previous supposition that ball-spline non-concentricity contributes to variability of the results. A further comparison of these results to the spread of data with respect to the reference lines indicate (at a given ambient temperature) that the card positioning variability is approximately 0.15°F.

3.8 Dead Space

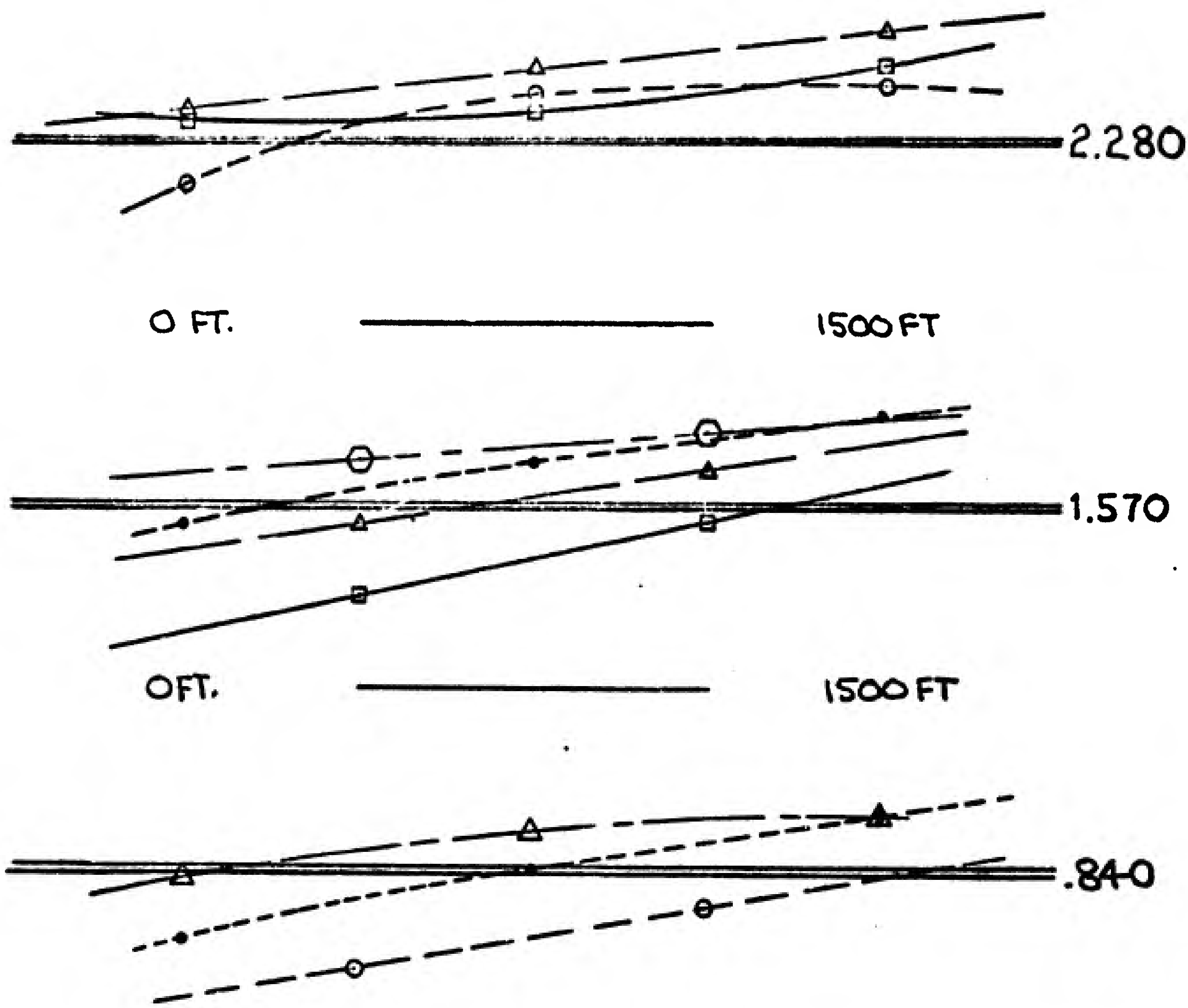
Measurements of dead space, using the triangular waveform means, were made at three points on scale. A total of eight cards were evaluated, two of which gave data inconsistent with the remainder. The data was plotted as shown in Fig. 3 through 11. The greatest dead space observed was approximately 0.003 inch or 0.14°F, and this occurred fairly consistently at 62°F. Observations at 28° and 96°F showed less dead space. Averages at the three points on scale were: at 28°, 0.09°F; at 62°, 0.1°F; at 96°, 0.04°F.

To corroborate these measurements, a completely passive circuit consisting of a capacitor and voltage divider was used. Step change inputs were applied to the network and allowed to decay to a negligible voltage input. This test was carried out repetitively on three different cards at the 62°F point. The worst case measurement was 0.16°F; the average was 0.13°F. It should be noted that observed dead space, by definition, is actually twice as great as the largest contribution to total error that can occur as the result of a change from positive to negative temperature gradient.

3.9 Settling Time

Observations and a picture of an oscilloscope trace of the error signal produced by applying an 0.8Hz square wave to the plotter input indicates that the servo settles out under any conditions in less than 350 milliseconds. This function is critical only when the probe is first dropped since no other condition produces a step change input. The servo is not velocity limited; therefore, it may be stated that regardless of the difference between 28°F (the "ready for drop" servo position) and the surface temperature, the servo will be tracking the thermistor output by the time the probe reaches a 7 foot depth.

BY .... DATE .... SUBJECT .... SHEET NO. .... OF ....
CHKD BY .... DATE .... JOB NO. ....



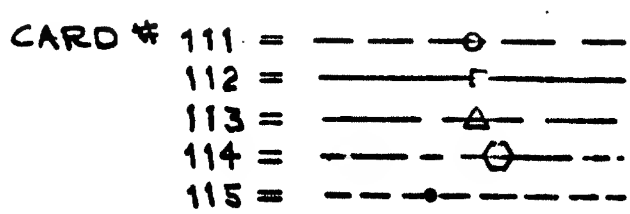


FIG. 2
CARD TO CARD
REPEATABILITY
T COORDINATE SCALE
.001" = 1 UNIT

BY DATE SUBJECT SHEET NO. OF
CHKD. BY DATE JOB NO.

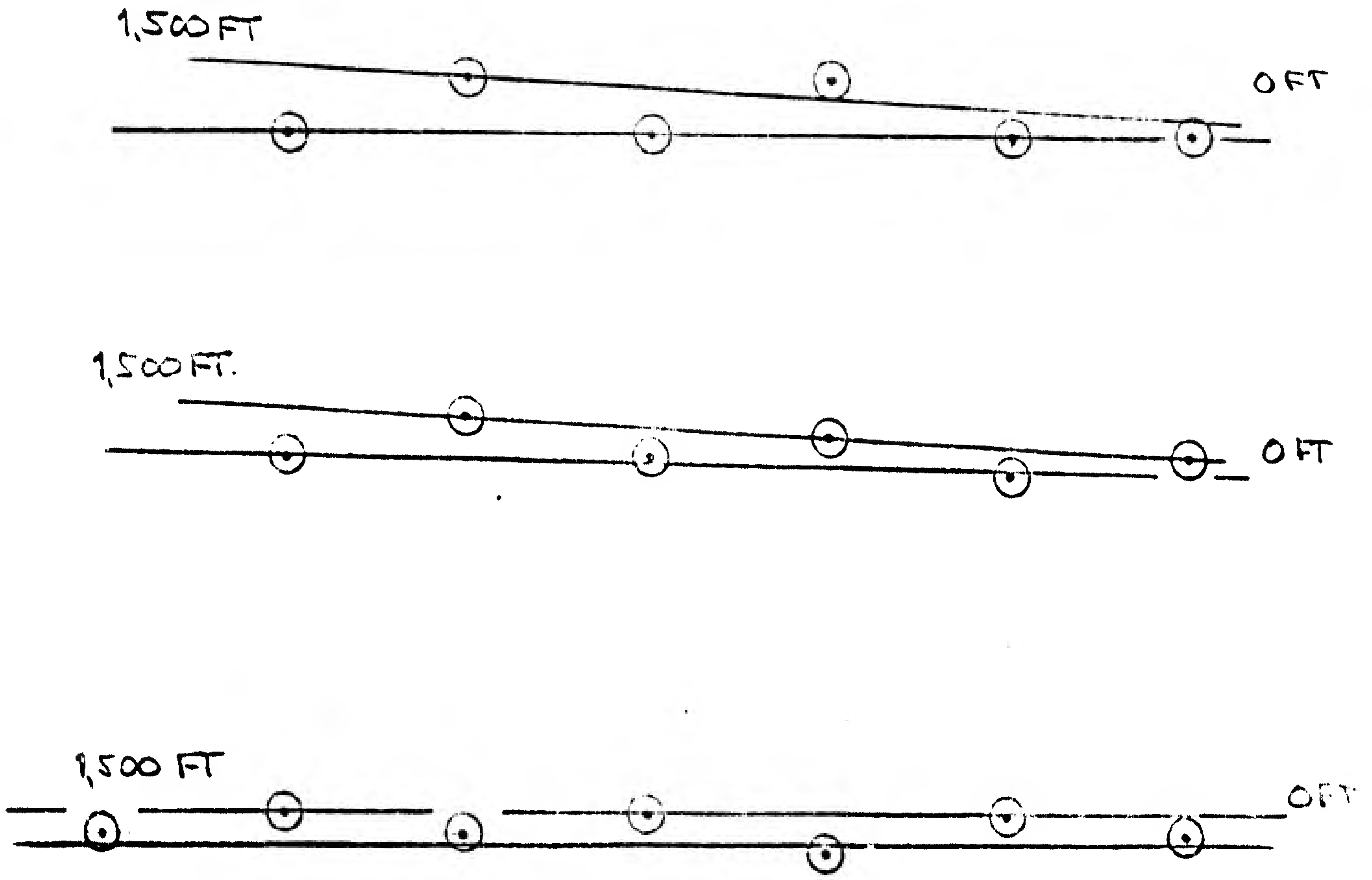


FIG. 3
DEAD SPACE
CARD NO. 110
T COORDINATE SCALE IS
.001" = 1 UNIT

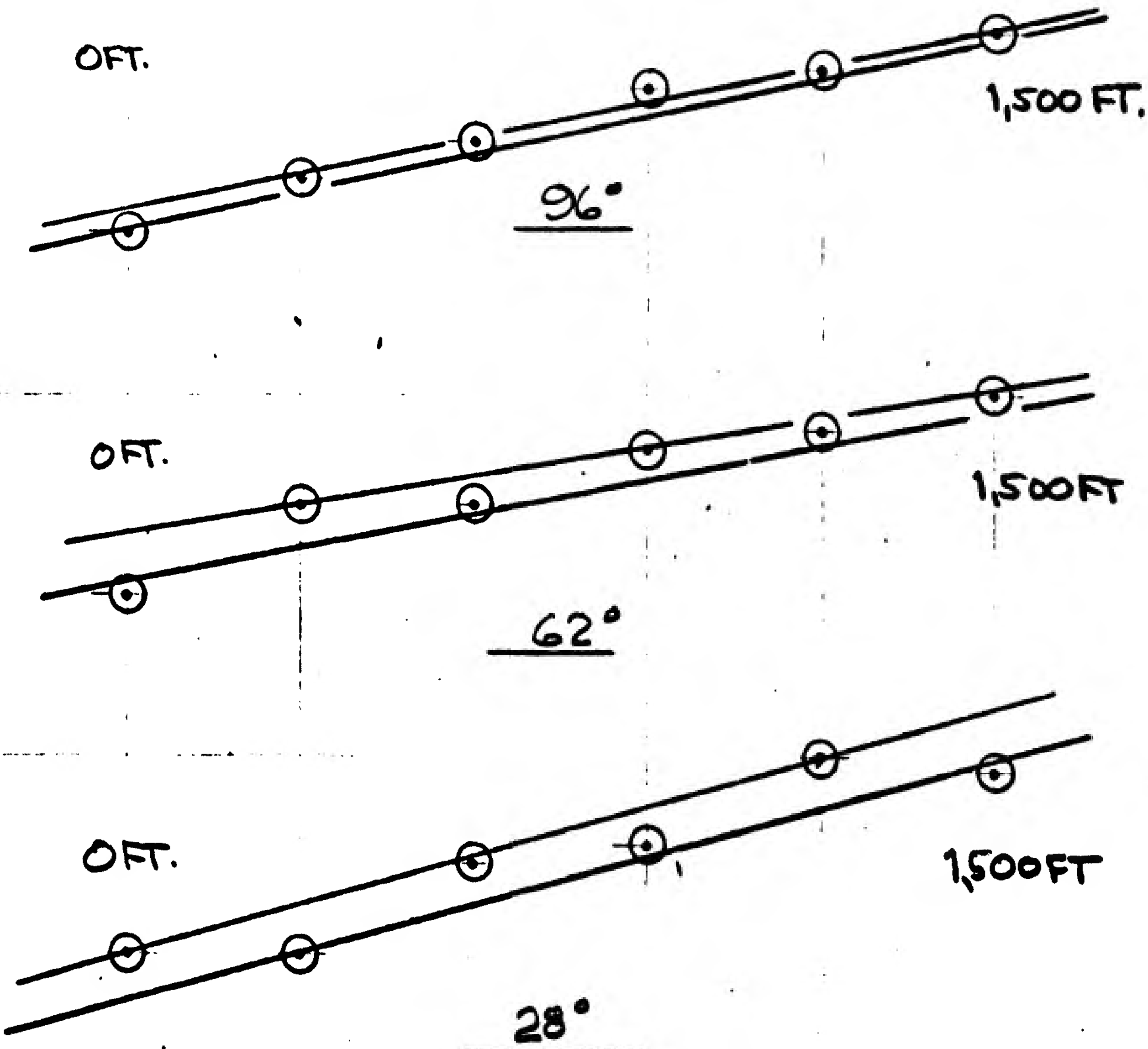


FIG. 4
DEAD SPACE
CARD NO. 11
T COORDINATE SCALE IS
.001" = 1 UNIT

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CHKD. BY........ DATE........ JOB NO........

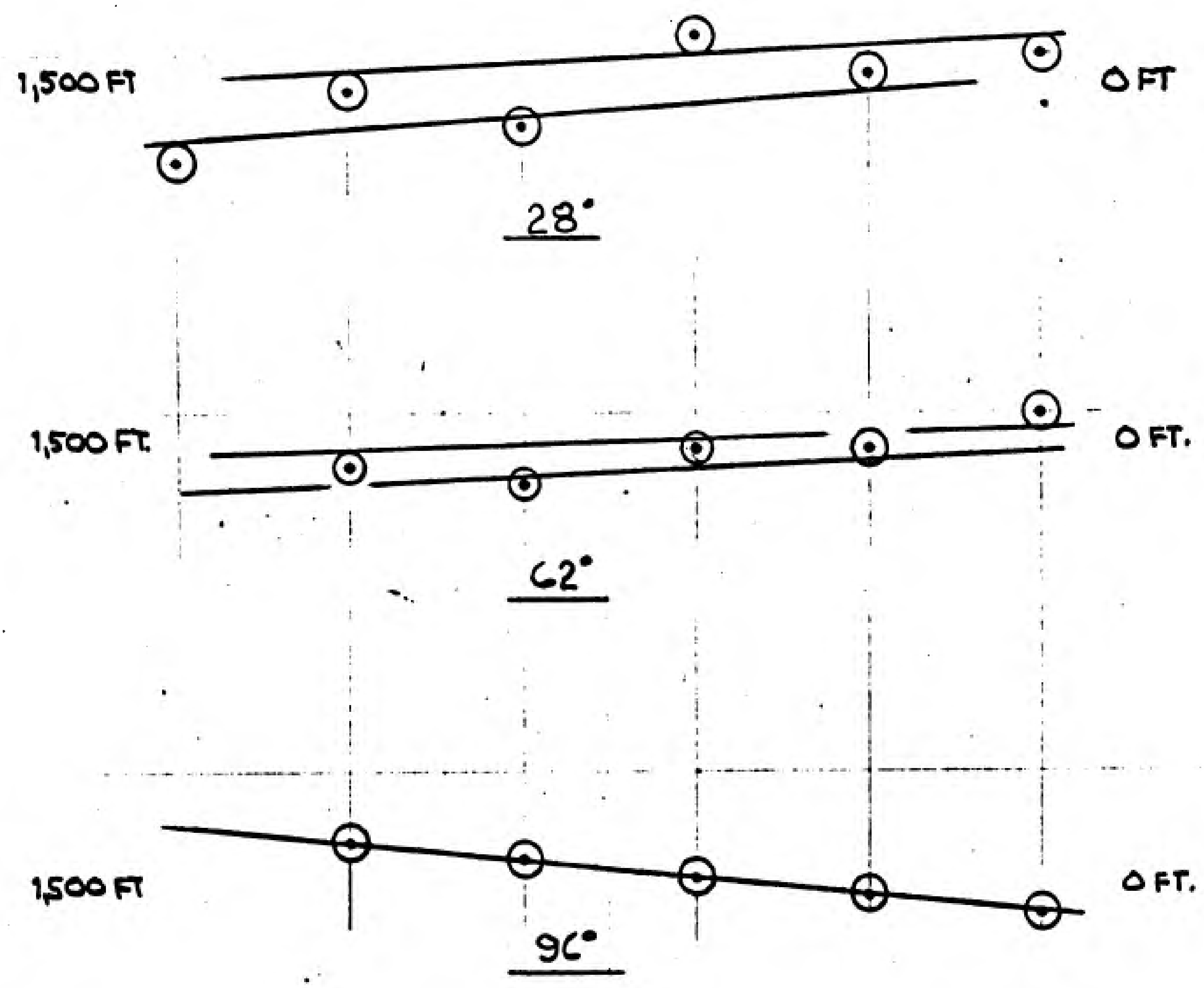

FIG. 5
DEAD SPACE
CARD NO. 109
T COORDINATE SCALE IS
.001" = 1 UNIT

BY .... DATE .... SUBJECT * 6628 .... SHEET NO. .... OF ....
CHKD. BY .... DATE .... JOB NO. ....

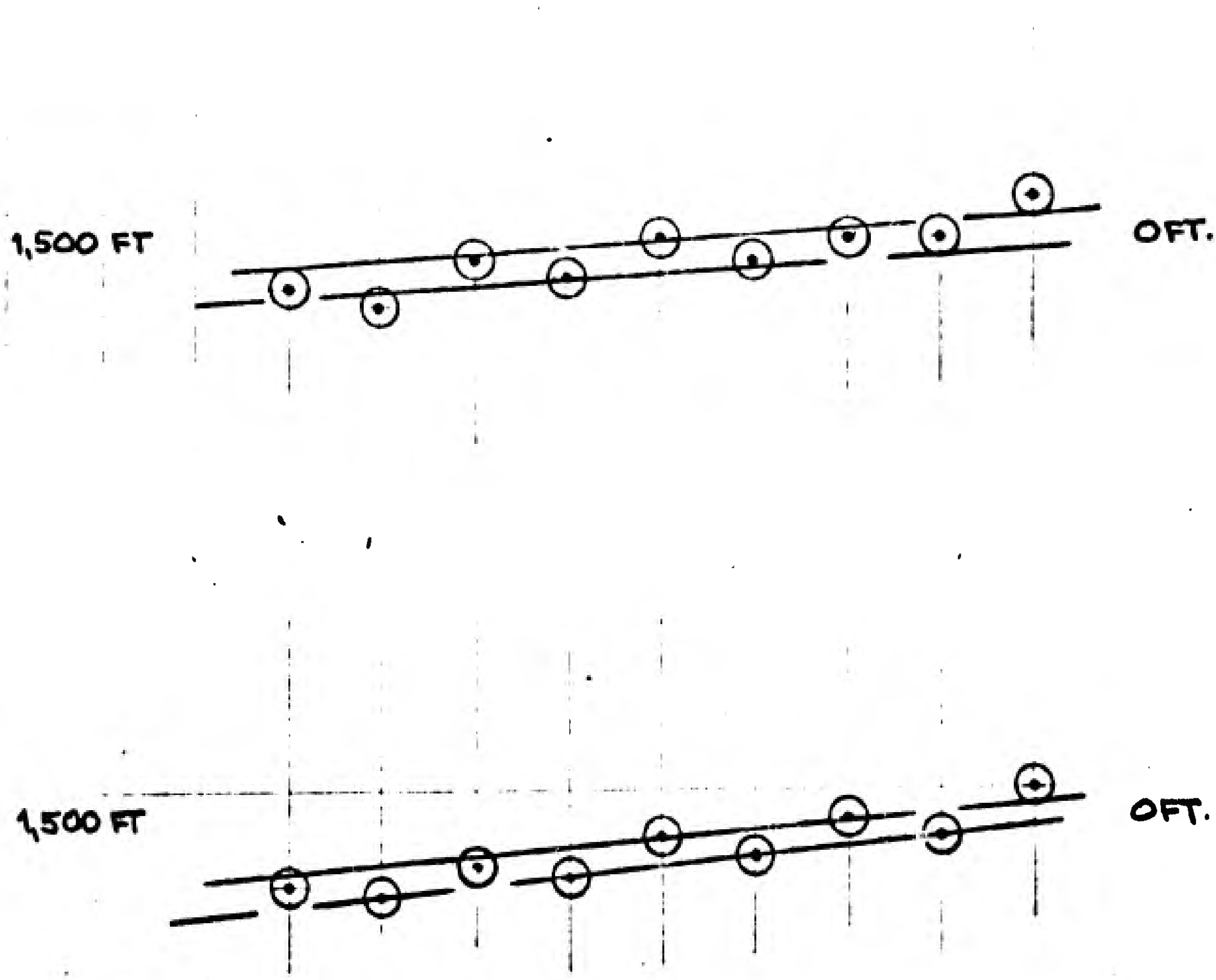

FIG. 6
DEAD SPACE
CARD NO. 6628
T COORDINATE SCALE IS
.001" = 1 UNIT

BY........ DATE........ SUBJECT #6623 SHEET NO. .... OF ....
CHKD. BY........ DATE........ JOB NO. ....

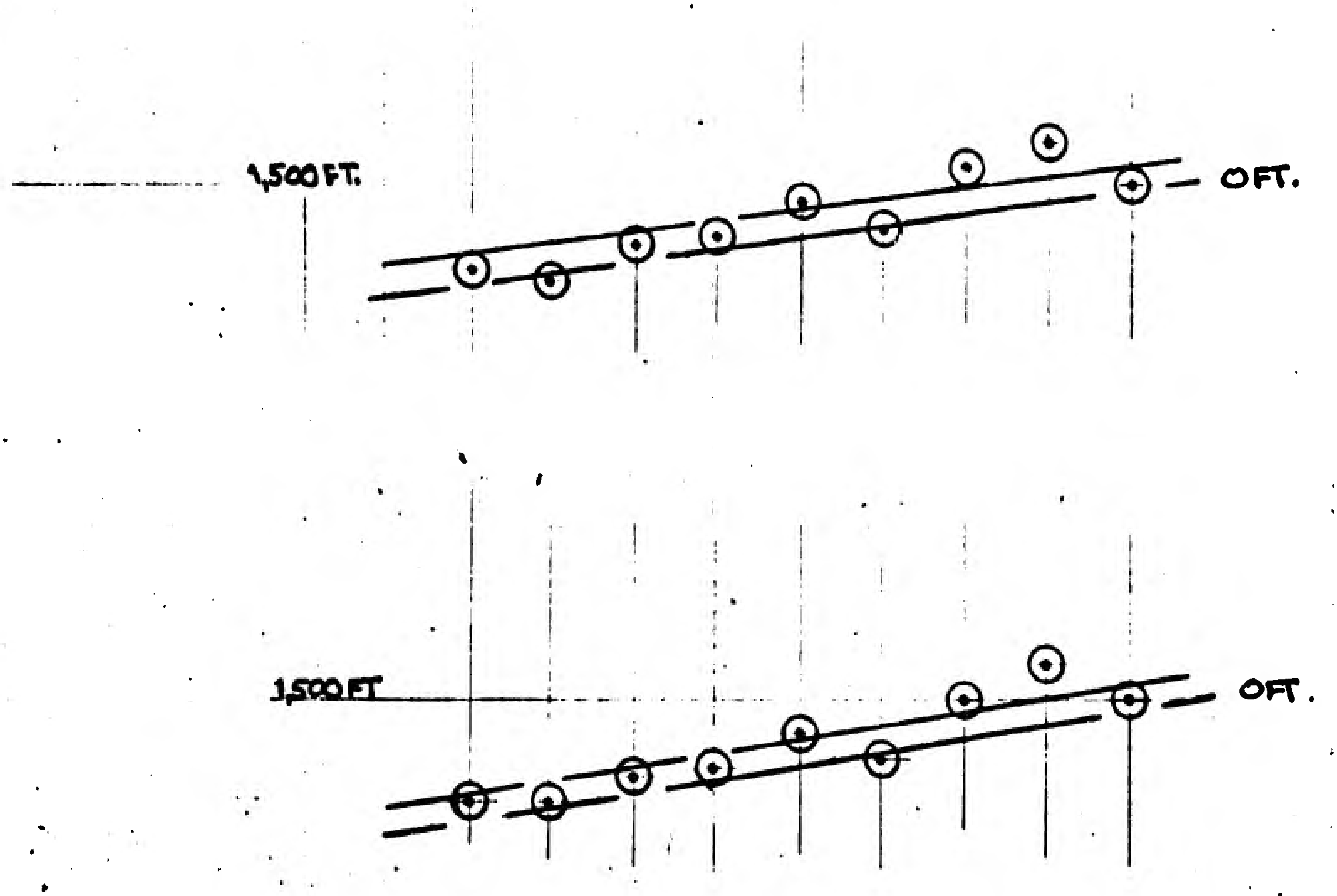

FIG. 7
DEAD SPACE
CARD NO. 6623
T COORDINATE SCALE IS
.001" = 1 UNIT

BY........ DATE........ SUBJECT #6622 .... SHEET NO. .... OF ....
CHKD. BY........ DATE........ JOB NO. ....

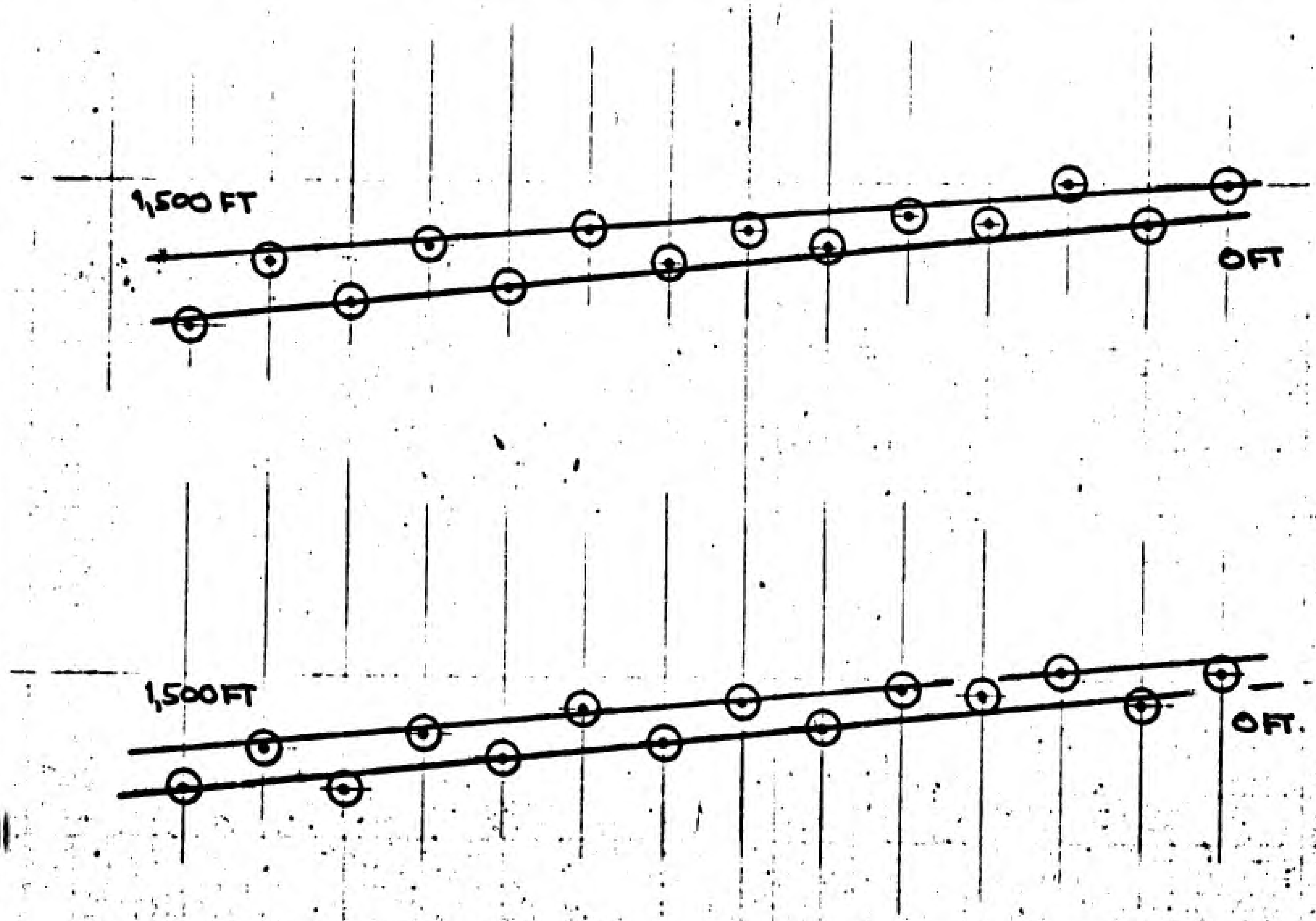

FIG. 8
DEAD SPACE
CARD NO. 6622
T COORDINATE SCALE IS
.001" = 1 UNIT

BY.................... DATE.............. SUBJECT .... SHEET NO ...... OF ......

CHKD. BY.......... DATE.............. JOB NO ......

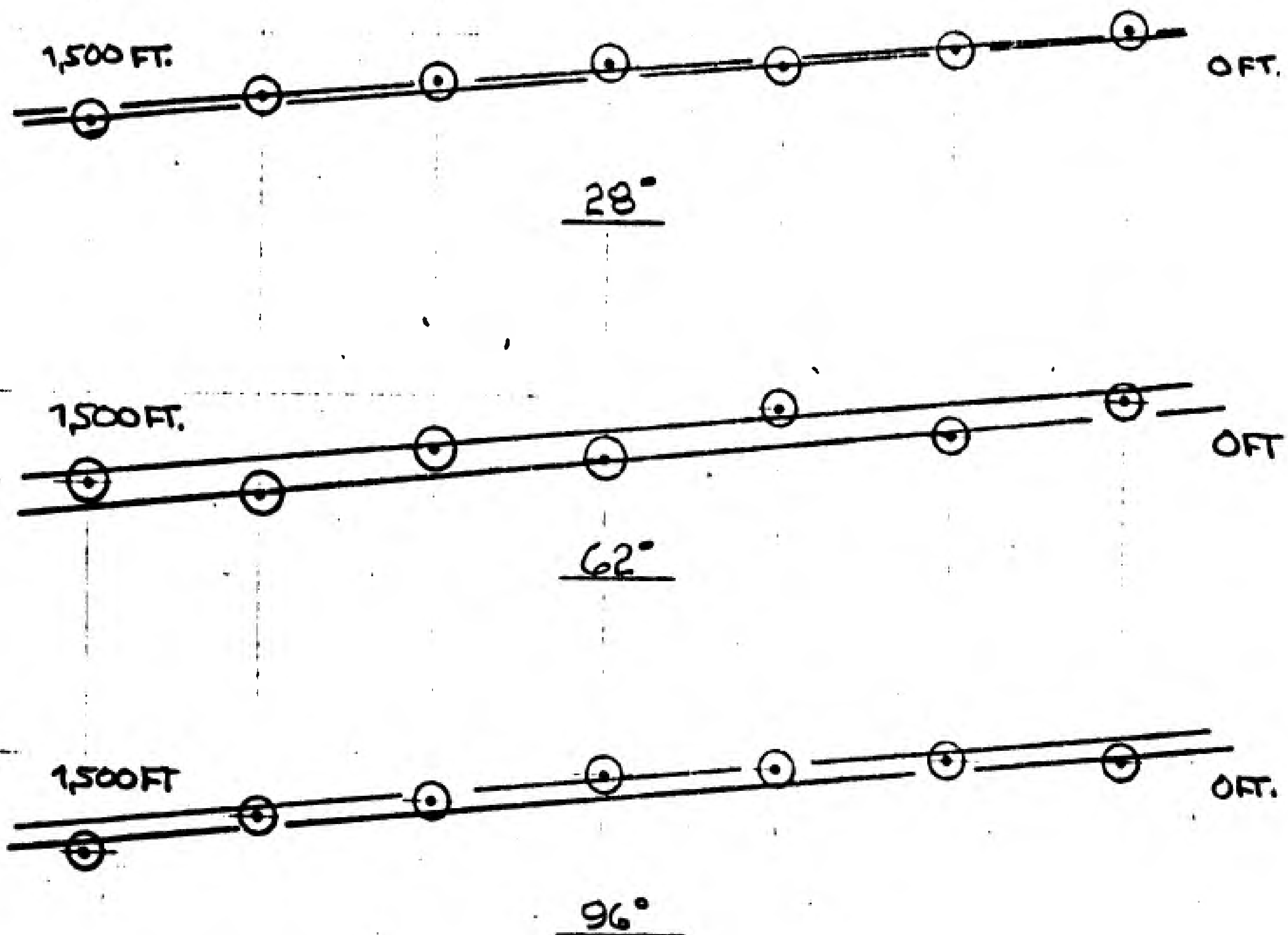

FIG. 9
DEAD SPACE
CARD NO. 6615
T COORDINATE SCALE IS
.001" = 1 UNIT

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CHKD. BY .... DATE .... JOB NO. ....

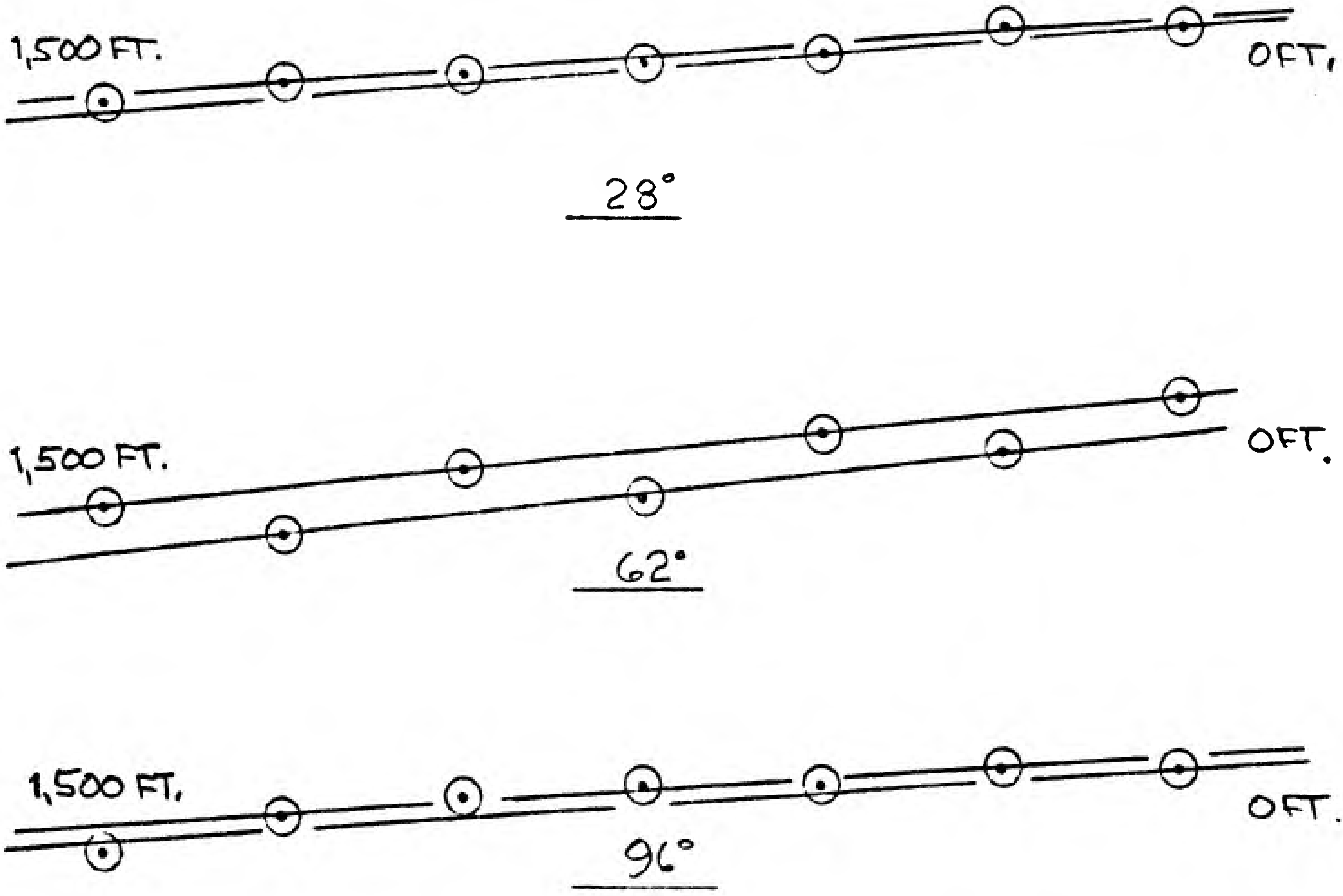

FIG. 10
DEAD SPACE
CARD NO. 6610
T COORDINATE SCALE IS
.001" = 1 UNIT

BY .... DATE .... SUBJECT 11 6602 .... SHEET NO .... OF ....
CHKD. BY .... DATE .... JOB NO. ....

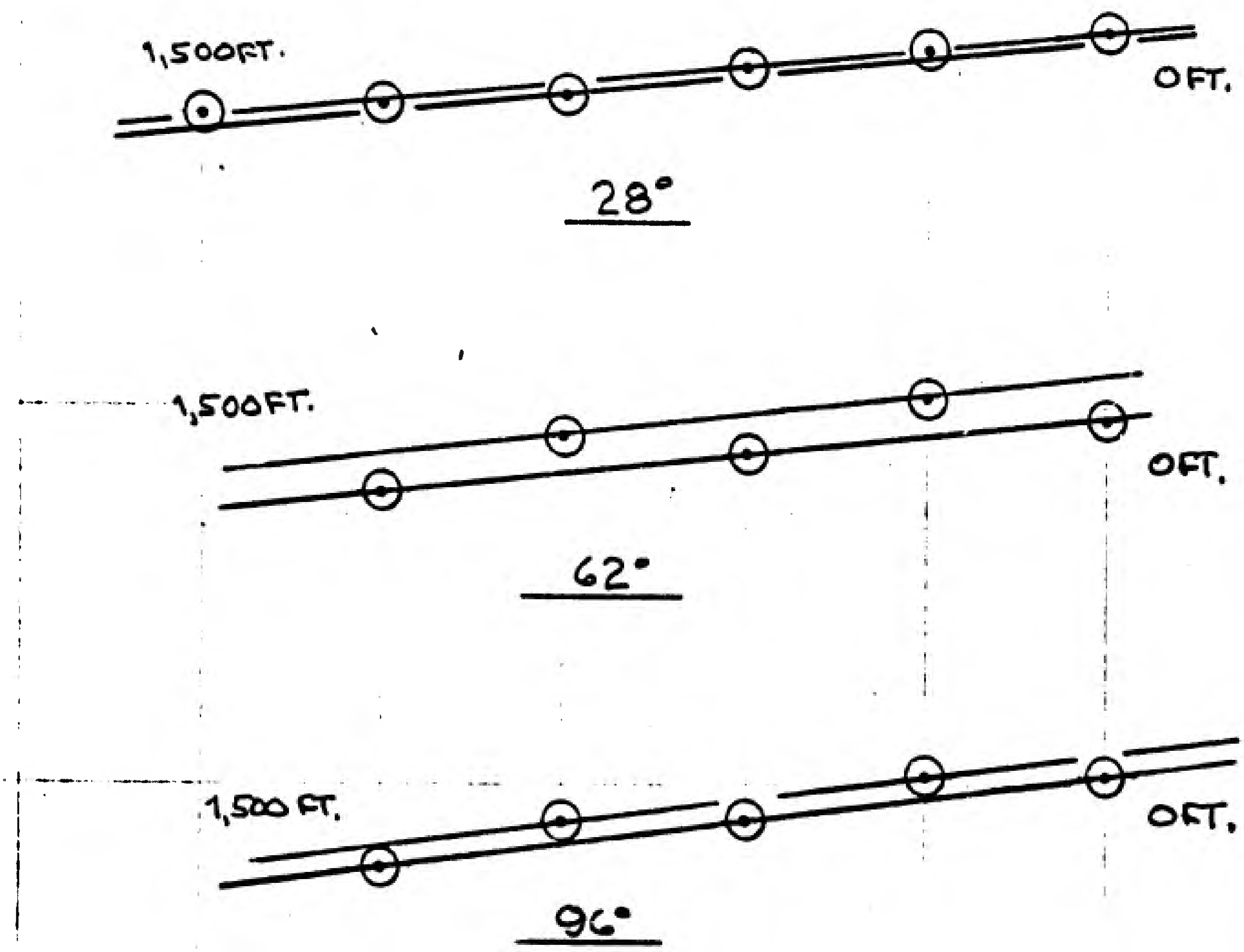

FIG. 11
DEAD SPACE
CARD NO. 6602
T COORDINATE SCALE IS
.001" = 1 UNIT

4. CONCLUSIONS

4.1 Discussion of Results

The overheat function, lamp ignition, and maximum write rate may be considered entirely satisfactory in the existing design.

Program sequence errors, except for the skipping of the measuring mode caused by a rapid step change (result (b)), do not make the trace invalid. Likelihood of occurrence of the rapid step in combination with a 2% probability of sequencing error is not considered great enough to justify any effort to correct this problem.

Spot intensity and lamp stability tests raise some doubt as to the long-term effects of vibration, or the cumulative effect of many physical shocks such as are caused by the latching of the door. The shock effect was discovered and investigated on only one lamp.

Although dead space does not meet the design goal, an improvement, of two to one from the results with the prototype is not considered a significant problem. This would make the worst case dead space 0.07°F.

Card-to-card repeatability is a little better than anticipated. The test results are more indicative of the considerable care used in installing the cards, than of the functionability of the card locating device associated with the door. Used by unskilled personnel, the locator as it presently functions could not be expected to produce the results reflected in this report.

Calibrated accuracy, referred to the reference lines, would be the primary consideration in a redesign effort. The results indicate two distinct problems. The most detrimental, that caused by the temperature effect on the reference circuitry, would be the simpler to solve. The nonconcentricity or "droop" on the extended ball spline poses a difficult mechanical problem;

considerable effort might be necessary to redesign or replace this component.

4.2 Tentative Specification

Operational Requirements

Minimum frequency of cycling - six per hour at any interval when operating at 75°F and 117V.

Human Engineering

Manual Operations: (in sequence)

1. Load card
2. Turn on unit
3. Start lamp
4. Load BT
5. Drop BT
6. Develop card

Minimum Automatic Features Required:

1. The system shall have a "launch" indicator and a "develop" indicator.
2. Must be able to determine condition of system or force cycle to known position after power interruption.
3. Overheat shut-off only at end of cycle.

Safety

Operator shall be protected from shock hazard, and lamp explosion. There shall be no sharp edges or corners with which the operator can come in contact when the unit is mounted and in operational condition. Any doors shall latch in both open and closed conditions. No damaging quantity of UV light to be observable by the operator.

Physical Characteristics

Mounting	Bulkhead
Weight	30 pounds maximum
Cooling	Free convection

Output - Analog

The analog record shall be on a water-resistant IBM aperture card 3.250 x 7.375 inches having a window size of 1.207 x 1.625 inches. The data shall be presented as a dark line on clear background. The scale of the record shall be:

Temp. -1°C	=	1 millimeter (approximately)
Depth - 20 meters	=	1 millimeter
80 meters	=	1 millimeter for 6,000 foot record

Input Power

Voltage 115V ± 10%, 60 to 400 Hz ± 5% (±20% voltage for 2 seconds)

Accuracy

The following accuracies include dead band and calibrated accuracy. Operating influences include specified limits of ambient temperature, power supply voltage (steady state, not transient), common mode stray (5VDC or 2V peak-to-peak at 0 to 1 MHz), vibration and humidity. "Under any conditions" means any combination of conditions within specified limits. For a detailed discourse on accuracy specifications, see ASA Specification C 39.4-1956. No allowance is included for the readout means (viewer, flying spot scanner), or the probe.

Temperature

1. Absolute referred to datum (edge or locating holes)

±0.4°F at standard conditions. Not including affect of humidity on the card, not to exceed ±0.5°F under extreme of any one influence, and RMS sum of all influences ±0.6°F maximum. Additional error from 0 to 100% R.H. ±0.15°F.

2. Differential between any two points

±0.3°F at standard conditions. Not to exceed ±0.4°F under any one influence. RMS sum of all influences ±0.5°F maximum.

3. Gradient accuracy

±0.15°F per 100 feet at gradients less than 1°F per 100 feet. Note: Approximately -0.25°F per 100 feet is isovelocity gradient.

4. Absolute accuracy with which reference marks can be put on a card

±0.05°F at standard conditions.

±0.1°F under any conditions.

5. Absolute accuracy using reference marks

±0.2°F at standard conditions.

±0.3°F under any conditions.

Depth

1. Absolute accuracy referred to datum (edge or locating holes)

±5 feet ±0.3% of indicated depth at standard conditions.

±5 feet ±0.5% of indicated depth at any condition.

Above does not include affect of 0 to 100% R.H. which is ±4 feet additional.

2. Absolute accuracy using reference mark

±0.2% of indicated depth under any conditions.

General Requirements on Trace

Width of recorded line - 0.005" maximum

0.05°F temperature change shall be observable on trace.

Maximum recorded slew rate -25°F per 100 feet.

Maximum servo slew rate -62°F in. 0.350 seconds.

Environmental

Equipment shall operate to environment of MIL-E-16400E with exception of temperature which shall be 0°C to +40°C.

PART II

1. RECOMMENDATIONS

In order to make the existing design function within the listed specifications, it would be necessary to:

a. Determine the reason for temperature sensitivity of the reference circuits and take appropriate corrective action.

b. Examine the ball spline function, determine whether the ball spline can be made to perform as required by the accuracy specifications; if it cannot, either revise specifications of the present design or design in another component as indicated.

It should be understood that these recommendations pertain to a second engineering prototype plotter. A program leading to redesign for a manufacturing design could reasonably include a thorough examination of several additional functions, with the objective of simplifying them, with a resultant increase in reliability. These would include:

a. Programming circuitry.

b. Lamp ignition - power supply circuitry.

c. Time axis drive means.

PART III

APPENDIX - DATA AND PLOTS

Program Sequence Errors

Fault	Cause	Result	Trace
Spot shift from offscale to 0°C position during pre-launch warm-up.	Ignition interference	On-scale 0°C ref. line from 0 to 1500 feet. Requires re-ignition at launch.	Valid, provided lamp is reignited Launch signal does not appear until lamp is on.
Skip of measure mode	Step change of temperature over 20°F. Can only occur at launch.	Occurrence only 2% of the time when step changes are applied. Extremely unlikely in operation.	Invalid
Lamp does not extinguish at end of cycle.	Worn out lamps. Should be replaced.	Develop lamp will not come on.	Valid when properly developed.

Overheat

Room Temperature	Line Voltage	Operating Condition	Time to Overheat
75°F	105V	Any	No
75°F	120V	Launch ready (xenon lamp on)	1 hour
75°F	120V	Cycling at 5 minute intervals	3 hours

Calibrated Accuracy - Uncorrected Data

Card #	6428	6429	6581	6582	6583
Ref. 0°C @ 0 ft.	2.249	2.234	----	2.175	2.241
Ref. 30°C @ 0 ft.	1.001	0.989	0.982	0.901	0.982
Ref. 0°C @ 1500 ft.	2.258	2.251	2.237	2.172	2.249
Ref. 30°C @ 1500 ft.	1.008	1.005	0.975	0.917	0.989
30.1°F	2.291	2.276	2.277	2.208	2.282
62°F	1.567	1.564	1.557	1.494	1.565
94°F	0.840	0.833	0.827	0.763	0.839
30°C	1,013	1.010	----	0.932	1.010
Condition	Room Temp.	Room Temp.	0°C	0°C	0°C

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13. ABSTRACT

The Aperture Card Plotter was developed by Francis Associates, Inc. under Contract N00024-68-C-1045, for use with the Sippican Bathythermograph System and other applicable data recording instrumentation. The plotter provides an automatic means of recording temperature/depth traces in a manner suitable for integration with computerized transmission, storage, retrieval and readout systems.

Test operations using the prototype plotter developed under this contract showed the overall feasibility of the equipment. Functions such as write rate, lamp ignition, overheat and card-to-card repeatability were satisfactory, while long-term effects of vibration on spot intensity and lamp stability were possible problem areas requiring further tests.

Two problem areas were found with respect to calibrated accuracy: (a) the effect of temperature on the reference circuitry, and (b) the nonconcentricity or "droop" of the extended ball spline. To meet the original plotter specifications, it would be necessary to investigate and resolve these problems, and to provide the redesign effort required to fabricate a second engineering prototype plotter.

In addition, to develop a manufacturing design, functions such as programming circuitry, lamp ignition (power supply circuitry), and the time axis drive mechanism should be re-evaluated with respect to simplification and subsequent improvement in reliability.

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