UNCLASSIFIED

AD NUMBER
AD001811
CLASSIFICATION CHANGES
TO: unclassified
FROM: confidential
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
FROM: Controlling DoD Organization: Department of Defense, Attn: Public Affairs Office, Washington, DC 20301.
AUTHORITY
OSD/WHS case no. 11-M-1005, ltr dtd 31 Mar 2011; OSD/WHS case no. 11-M-1005, ltr dtd 31 Mar 2011

THIS PAGE IS UNCLASSIFIED

AD – 1811

H

11-M-1005

Massachusetts Institute of Technology
Instrumentation Laboratory
Hood Building
Cambridge, Massachusetts

CONFIDENTIAL

AD-1811

June 4, 1948

MEMORANDUM

To: Colonel R. E. Jarmon, MCREXG
Chief, Armament Laboratory
Engineering Division
Air Materiel Command
Wright-Patterson Air Forces Base
Dayton, Ohio
Attn. Mr. Warren Hansen MCREXO56
From: J. Robert Rogers
Subject: Correction to memorandum of May 24, 1948
on S-9 computer changes

The following correction should be made on all copies of the subject memorandum.

Page 4, paragraph 1. The report recommends bypassing the screens of the GAKS windage amplifier output tubes to ground. The screen bypass resistors should be returned to the cathodes of these tubes in all cases, to maintain the pentode characteristics of the output tubes. Where gain control is desired by variation of feedback voltage, the cathode resistor may be replaced by a wire-wound potentiometer, with the feedback voltage taken from the arm. In this case feedback and screen bypass condensers should have separate terminals. If approximate adjustment of fixed gain channels is needed, it should be made by appropriate choice of feedback resistor value relative to input mixing resistor value.

Accordingly, the fixed gain channels should remain unchanged as suggested in the first part of the second paragraph on page 4.

J. Robert Rogers

J. Robert Rogers

JRR/kw

AD-1811

CONFIDENTIAL

Instrumentation Laboratory, MIT
J. Robert Rogers
May 25, 1948

CIRCUIT CHANGES FOR S-9 COMPUTER

(Supplementing Report of April 20, 1948)

Changes in the S-9 computer circuits found desirable during the last month are presented below. The changes include minor corrections to the previous report and additional changes in the computer circuits which have been found necessary since that report was issued.

I CORRECTIONS TO REPORT OF APRIL 20, 1948

1. Page 2. Resistor number R3440 in the load circuit of the velocity-range wind rectifier has not been removed. The schematic drawing is correct as it stands.

2. The load potentiometer in the same rectifier circuit (located on the range gear box) is connected as a potentiometer and not as a variable resistor. This point was correctly shown in the drawing on page 2 of the April 20 report. No pins were available in the connectors for the connection to the arm of the 10K potentiometer. The lead from the arm has been wired directly across to the sensitivity amplifier subchassis and does not go as indicated in the drawing to pin X of J2001. This pin is used between the end of the potentiometer and R3440. The range variable 10K resistor in the density rectifier load circuit was not changed from a variable resistor to a potentiometer connection. The change is less essential for this circuit because the variable part of the rectifier load is only 10K out of over 200K. If a higher resistance linear range potentiometer is used in this circuit, however, it might be desirable to connect it also as a potentiometer to provide more linear operation for the density input to sensitivity.

II CHANGES MADE IN THE EQUIPMENT SINCE APRIL 20, 1948

1. Sensitivity Amplifier

A. R3431, V_{ins} mixing resistor, has been reduced from 200 to 100K.

B. R3432, the range wind mixing resistor, has been reduced from 100K to 50K.

These changes have been made in order to increase the gain of the velocity-range wind amplifier to permit obtaining the correct scale factors with the new range potentiometer load for this channel. If a higher (20K) resistance range potentiometer were used, the change could be omitted.

C. Tests have been conducted to determine the stability margin for the sensitivity amplifier. Indications are that the modulator changes recommended in the April 20th report will materially assist in reducing the d-c voltage error from input to output of this amplifier. Such a reduction is desirable because the error, which may be nearly 1% in the working range, is not linear with the input sensitivity voltage. In addition, a reduction of error is desirable because it would minimize the dependence of the sensitivity calibration on the characteristics of particular tubes used in the power amplifier. Work on this circuit is continuing and a separate report will cover it in more detail. The circuit has been found to be completely stable even with materially increased amplifier gain.

2. Windage Amplifier

A. Some instability has been observed in each of the windage amplifier channels connected so as to have variable gain. The difficulty has been traced to the use of a 10K gain control potentiometer connected across 1K cathode resistor of the 6AK6 amplifier tube. At middle settings of the gain control pot, the arm has an impedance to ground of the order of 2.5K to 1K. This impedance is common to the feedback circuit and to the screen bypass circuit for the output amplifier tube. Fluctuations in screen current with signal are therefore fed back to the amplifier input circuit as voltage in phase with the signal input. To prevent this action, it is desirable to bypass the screens of those tubes in stages operating with variable gain control, directly to ground. It would also be desirable to bypass the screens of the fixed gain channels to ground, because some feedback voltage can be developed across the 1K cathode resistors. (The present circuit uses a screen bypass condenser and a feedback condenser in the same can and having a common terminal.) The two-section condenser can be used for screen bypasses and separate condensers are desirable for the feedback circuit.

Leaving the present arrangement on the fixed gain channel will give a slightly higher gain for it which is desirable as it permits the variable gain channel to be adjusted to a gain setting which is either higher or lower than that of the fixed channel by at least enough to take care of the maximum tolerance in torque motor winding sensitivity. If the fixed gain channel is bypassed directly to ground, the feedback resistor should be increased in value to recover the gain which may be lost. It is desirable to incorporate the amplifier gain control in the same amplifier channel for both elevation and deflection sytems.

B. When the amplifier gains had been standardized for the present unit, it was found that identical cathode resistors for V2403 and V2503 are desirable. The value found correct for R2516 and R2416 is 40K.

C. The A and B inputs to the elevation windage system have been interchanged and the level potentiometer R2444 is now in the "B" channel of this amplifier. The "A" term is $V_{ind}\ K_{d/d_o} \cos A$. The "B" term is $(K_3 + K_4\dot{R}_o) \sin B$ (variable input.)

D. The input level control R2544 for the deflection windage system should be put in the lead 518 instead of 507 so that it controls the "B" input for this system.

The above changes are necessary because, in order to assure that the windage amplifier operates to multiply correctly, care must be taken to keep the "A" input larger when at its operational minimum than is the "B" input at its maximum value. Accordingly, no attenuation should be put in the "A" input, and adjustment of the output of the system should be made by attenuating the "B" input. This requirement arises from the fact that the windage rectifiers are not phase-sensitive and they do not recognize any difference between a value of (A-B) where B is smaller than A, and one where B is the same amount larger in amplitude than A.

In practice, it is probably desirable to use a level of the B input somewhat greater than would satisfy the above requirement under all conditions, as the maximum value of B occurring with the minimum value of A would represent an extreme and unlikely condition. Some error under this input condition can be accepted in order to have the advantages of using an appreciable B channel signal level for the more probably expected operating inputs.

It should be noted that with this arrangement, the possibility of a-c pickup on the input mixing points of the windage amplifiers becomes more important than it is when nearly equal large signals can be used. To the extent possible, attenuation should be introduced in the input gain control on the windage chassis and short direct leads from mixing resistors to tube grids must be used. Care should be taken in the location of mixing resistors to avoid stray fields.

E. In addition to the problems of direct pickup on signal circuits, it has been found necessary with the present equipment to take additional precautions to prevent circulating ground currents by bonding together the various subchasses and by extreme care in returning the grounds of such external units as resolvers to appropriate points.

Circulating ground currents gave rise to difficulty in obtaining the best calibration in both windage amplifiers and also in the sensitivity velocity and range-wind system. It is understood that Emerson is incorporating an extra filament lead within the computer to eliminate the chassis return for filament circuits. This change is highly desirable and the mounting of all computer subchasses in one rack will be of further assistance. It is recommended that separate ground return wires be installed in the system cabling between the resolvers in the turret and the computer. The resolvers should not be grounded in the turret. The only ground used should be at the computer. With these precautions, a minimum of difficulty should be encountered.

F. Because of the torque angle gradient of present torque motors, it is recommended that the adjustment of windage amplifier over-all gain be made to obtain the desired deflections at a prediction angle equal to 5/2 of the desired curvature correction and on the opposite side of zero from that obtained if no other torques than the sensitivity and windage torques are applied to the computer shaft. This procedure and the reasons for it were discussed in a memorandum dated April 20, 1948, which was attached to the report on changes on that date. The system has since been found to provide a practical calibration although it requires the use of additonal balance weights. It will be unnecessary when more precise torque motors become available.

Care should be taken to check the windage torque motors before assembling in the prediction computer to be sure that they are within 5% of equal sensitivity for torques in both directions and, more important, to ascertain that both windings of each motor follow correctly a square law.

3. Miscellaneous

It has been found that excitation of the gravity drop winding (with no input to the gravity drop amplifier) results in a change in the sensitivity of the elevation prediction computer. The elevation sensitivity motor shunt should be adjusted to give the correct sensitivity when the gravity drop winding is excited.

There is some pickup of gyro wheel frequency in the gravity drop torque motor bridge which causes small fluctuations in the prediction output if the wheel frequency is several cycles removed from the computing circuit frequency. It is understood that Emerson is providing shielding to eliminate this in future units.

It would be desirable to investigate the possibility of regulating the a-c input to the gravity drop winding and possibly also the excitation to the range rate generator, both of which are operated from the a-c line with regulation of ± 5%. It is possible that this can be done with the use of a suitable ballast tube providing that care is taken to operate the tube with an essentially resistive load so that changes of input amplitude will not result in appreciable phase change in the current through the windings. No attempt has been made to work out any arrangement for this in the Instrumentation Laboratory.

Instrumentation Laboratory, MIT
To: J. Robert Rogers
From: John B. Harper, Jr.
Subject: S-9 Calibration Procedures
May 25, 1948

III CALIBRATION PROCEDURE FOR S-9 ELECTRONIC COMPUTER CIRCUITS

This report describes in detail the calibration procedure found to be most satisfactory for the S-9 computer during tests conducted at MIT up to May 25th, 1948. No essential changes are considered necessary in the calibration of the prediction computer assemblies under the procedures reported by J. B. Harper, Jr. on June 30, 1947.

The calibration procedures below are to be carried out with the equipment operating at normal line voltage of 115 volts at a line frequency of 400 cycles. Gyro wheel drive frequency should also be 400 cycles. A warmup period of one half-hour should precede any calibration work. The required values for the various component parts of the computing system are obtained by calculation from the computer calibration equations, of which a revised copy is attached. The procedures below apply to a tail cone installation of a system to control caliber .50 Mark 8 A. P. I. ammunition for which the coefficients are given in column 2 of sheet 4 of the calibration equation summary.

Plots of the required performance based on these equations are in use at Emerson and at MIT. Tables are included in this report for the required curvature, gravity drop, and angle of attack corrections. These tables will permit checks of performance under the full range of each of the input variables.

In using the calibration charts prepared by Emerson it should be pointed out that the tables for prediction time (t_p) should not be used as a direct basis for calibration of the sensitivity function. Instead, the sensitivity requirements of the S-9 calibration equations should be met by the equipment. If the adjustment results in errors in sensitivity at some values of the inputs, the errors should be allowed to fall nearer to the t_p curves. Every attempt should be made, however, to minimize the errors. The t_p curves are based on special course assumptions so made as to permit separation of variables and do not represent requirements for best solution of practical prediction problems.

The procedures below are given in the order in which it has been found convenient to make the adjustments.

VELOCITY DENSITY CHASSIS

This chassis provides excitation for the nonlinear and linear density pickoffs. It amplifies the nonlinear density pickoff output to provide excitation for the indicated air speed unit. The output of the airspeed unit is in turn amplified to provide excitation for the azimuth resolver and the angle of attack pickoff.

Determine the AC reference voltage variation available when the potentiometer in the shunt resistance circuit is varied. Set this voltage to a value that is approximately half-way between the maximum and minimum values available and record the value. If at any future time it is necessary to change the regulation tube it will then only be necessary to reset this voltage using an accurate meter without doing a complete recalibration on the entire computer. The a-c reference voltage should vary between 7 and 10 volts, and 8.5 volts is a reasonable value.

First check the output of the two density units by plotting a curve of pickoff voltage vs. density. The output of the linear density pickoff should be a straight line. The nonlinear density unit is checked with the aid of the table shown below. The pickoff output voltage observed should give a curve displaced from the desired curve by a fixed voltage equal to the pickoff output at $d/d_o = 0$.

d/d_o	K_{d/d_o}
1.0	1.0
0.8	0.921
0.6	0.815
0.4	0.667
0.2	0.429
0.0	0.0

Assume that at $d/d_o = 0.0$ and 0.6 the K_{d/d_o} curve is correct. Set up a K_{d/d_o} scale on the curve obtained using the values shown in the above table. Check to determine if the other values of K_{d/d_o} fall on the curve. If they do not, adjust the nonlinear density linkage until the curve is matched.

R2612 sets the reference bias for the K_{d/d_o} pickoff. It is so set that at $K_{d/d_o} = 0.0$ the excitation to the indicated air speed pickoff is zero. This density is inconvenient to obtain and more accurate results can be obtained by the following procedure which checks the pickoff function at higher density values. The ratio of $K_{d/d_o} = 0.921$ to $K_{d/d_o} = 0.667$ is 1.382. This corresponds to $d/d_o = 0.8$ and 0.4 respectively. Measure the excitation to the indicated air speed pickoff at these two densities. Determine their ratio. Adjust R2612 until a ratio of 1.382 is obtained. Plot a curve of indicated air speed pickoff excitation voltage vs. density and check to determine that it follows the K_{d/d_o} vs. d/d_o curve as before and that at $K_{d/d_o} = 0.0$ the excitation to the air speed pickoff is zero.

R2624 sets the bias for the V_{OS} pickoff. It is so set that at $V_{ind.}$ = 0 m.p.h. there is no excitation to the azimuth resolver or the angle of attack pickoff. Plot a curve of azimuth excitation vs. indicated air speed. Set R2524 so that the curve when extrapolated passes through zero and there is no excitation to the azimuth resolver.

R2501 controls the excitation to the density units. It is so set that at $V_{ind.}$ = 500 m.p.h. and d/d_o = 1 the excitation to the azimuth resolver is the maximum obtainable without noticeable distortion when viewed with an oscilloscope. This gives a resolver excitation of about 6 volts.

CURVATURE CORRECTION CHASSIS

There are two separate channels on this chassis. The angle of attack channel amplifies the output of the angle of attack pickoff. The output excites the angle of attack elevation resolver whose secondary delivers a signal to the gravity drop amplifier. The range rate channel amplifies the output of the range rate generator and sets in constants for the calibration equations. The output excites the angle of attack elevation resolver whose secondary delivers a signal to the gravity drop amplifier. The range rate channel amplifies the output of the range rate generator and sets in constants for the calibration equations. The output excites the range rate elevation resolver whose secondary delivers signals to the gravity drop system and to the elevation windage system. This channel also furnishes signals directly to the range channel of the sensitivity amplifier and to the deflection windage system.

A seperate motor driven Kollsman drag cup generator, type 653-04302 is connected to the input of the range rate amplifier and excited from T3050S.

[illegible]

R2823 is turned up until there is noticeable distortion at the excitation to the elevation resolver when viewed with an oscilloscope (about 6 volts). Turn R2823 back until there is no distortion and record the output voltage. Adjust R2823 to give 0.553 of this voltage. Drive the Kollsman generator so that its speed corresponds to a range rate of + 1200 ft./sec. (3.125 RPM correspond to 1 foot/second of range rate). R2815 is then set to give the original amplifier output voltage that was used to set R2823. Plot a curve of elevation resolver excitation vs. range rate to determine whether the calibration is correct.

R2800 sets E_α into the gravity drop curvature correction calibration equations, by determining the level of excitation to the angle of attack amplifier.

SENSITIVITY CHASSIS

There are a number of separate channels in the sensitivity amplifier. These channels are range and range rate, relative density, and indicated air speed and range wind. Each is adjusted to match its own set of calibration curves by measuring the sensitivity produced by the amplifier and comparing it against that shown on the curves. Set R3470 by means of a resistance bridge so that the cathode of the output stage has a resistance of 300 ohms. R3447, the modulator balancing potentiometer, and C________, the modulator balancing capacitor, is set to give the cleanest square wave form at the plates of V3410 when viewed with an oscilloscope.

RANGE RATE CHANNEL

Using a range rate input of zero, the potentiometers in the range "T" are adjusted as follows:

(1) Obtain the sensitivity for a range of 6000 ft. Adjust R3419, the low limit adjustment for long ranges, until the required sensitivity is obtained.

(2) Using a range of 3000 ft. adjust R3415, the range rate output potentiometer, until the required sensitivity is obtained.

(3) Using a range of 1000 ft. adjust R3416, the high limit adjustment for short ranges, until the required sensitivity is obtained.

(4) Repeat the above steps until a good match is obtained at all points.

(5) Final values are obtained by using various values of range and range rate.

R3401 sets the level of the applied range rate signal and is set in conjunction with the above adjustments. Range was read from the range dial driven by the range servo.

DENSITY CHANNEL

R3421 determines the level of excitation to the amplifier. R3420 is a reference bias potentiometer and is adjusted so that the d/d_o output as a function of d/d_o has an intercept when extrapolated to $d/d_o = 0$, of 0. It is better to have the output correct over the range from $d/d_o = 0.2$ to $d/d_o = 0.8$ than to have exactly 0 at the best vacuum obtainable. R3428 determines the load resistance of the channel and is used to set the constant term in the calibration equation $K_1 + K_2R$. Throughout the remainder of the calibration a range rate of zero is used. When the potentiometers are adjusted the density correction match is checked by changing the range and density. All inputs except range rate and density are shorted to ground.

VELOCITY AND RANGE WIND CHANNEL

R3430, the $V_{ind.}$ excitation level potentiometer, is set so that at a range of 5000 feet the measured sensitivity for V_{ind} alone (range wind input shorted) agrees with that on the curve.

R3429 sets the level of the range wind input and is adjusted to give the correct sensitivity at a range of 5000 feet when both V_{ind} and range wind inputs are effective.

The velocity input was calibrated by using sensitivity curves obtained from the calibration equation neglecting the effect of range wind, density, and range rate. The density input is shorted to ground and R3430 set to give the desired value of sensitivity. A check is then made to assure that sensitivity is correct with all inputs effective and, if necessary, R3429 is readjusted.

WINDAGE CORRECTION CHASSIS

There are three separate channels on this chassis, the elevation windage system, the deflection windage system, and the gravity drop system.

GRAVITY DROP SYSTEM

This channel receives signals from the angle of attack and range rate elevation resolvers. It mixes and amplifies these two signals and applies them to opposite points of the bridge connected gravity drop winding.

For correct operation of this circuit it is necessary that the phase of the voltage applied to the bridge from the excitation be very closely that of the signal applied from the output transformer T2402 of the gravity drop amplifier. A phase difference of 7 to 10 degrees will result chiefly in a small reduction of the sensitivity of the circuit, but may also increase the sensitivity of the channel to changes of line frequency.

Adjustment of the system is made as follows:

With the angle of attack meter set to give zero output, and with zero range rate, adjust R2110, which controls the excitation current to the gravity drop torque motor bridge, until the computer shaft deflects 6.3 mils against a 2-second sensitivity. The curvature correction torque motor for the elevation system should be disconnected. The above procedure establishes the correct gain for the gravity drop correction. The angle of attack correction is adjusted by R2800, which controls the gain of the amplifier, exciting the angle of attack elevation resolver. With the inputs to the system shown below, adjust R2800 for a shaft deflection of 12.7 mils.

$$S_{p(WL)} = 2 \text{ seconds}$$

$$V_{(ind)} = 450 \text{ m.p.h.}$$

$$\alpha = 150 \text{ mils}$$

$$K_{d/d_o} = .921 \ (d/d_o = .8)$$

$$\dot{R}_o = 0 \text{ feet per second}$$

$$E = 0$$

The table below gives the performance of the gravity drop and angle of attack system required for varying input conditions.

(used in May 25, 1948, report.

Instrumentation Laboratory, MIT
To: J. Robert Rogers
From: John B. Harper, Jr.
Subject: S-9 Calibration Procedures
November 4, 1947

GRAVITY DROP CALIBRATION DATA

Variable range rate

$\dot{R}$	A_c
1200	17.9
900	16.6
600	15.3
300	14.0
0	12.7
-300	11.4
-600	10.1
-900	8.8
-1200	7.4

$V_{ind.}$ = 450 m.p.h.
S_{wp} = 2 sec.
$K_{d/do}$ = .921
E = 90°
A = 180°
α = 150 mils

Variable E

E	A_c
90	0
60	6.3
30	11.7
0	12.6
-30	11.7
-60	6.3
-90	0

$V_{ind.}$ = 450 m.p.h.
S_{wp} = 2 sec.
$K_{d/do}$ = .921
α = 150 mils
$\dot{R}$ = 0 ft./sec.
A = 180°

Variable S_{wp}

S_{wp}	A_c
1	6.3
2	12.7
3	19.0
4	25.4
5	31.7

$V_{ind.}$ = 450 m.p.h.
$K_{d/d}$ = .921
α = 150 mils.
$\dot{R}$ = 0 ft./sec.
E = 90°
A = 180°

Variable $K_{d/do}$

$K_{d/do}$	A_c
1.0	13.2
.921	12.7
.815	12.2
.667	11.0
.434	9.2

$V_{ind.}$ = 450 m.p.h.
S_{wp} = 2 sec.
α = 150 mils.
$\dot{R}$ = 0 ft./sec.
E = 90°
A = 180°

Variable $V_{ind.}$

$V_{ind.}$	A_c
100	7.8
200	9.2
300	10.6
400	12.6
500	13.4
600	14.8

S_{wp} = 2 sec.
α = 150 mils
$\dot{R}$ = 0 ft./sec.
$K_{d/do}$ = .921
E = 90°
A = 180°

Variable α

α	A_c
0.0	6.49
.050	8.56
.100	10.6
.150	12.7

$V_{ind.}$ = 450 m.p.h.
S_{wp} = 2 sec.
$K_{d/do}$ = .921
R = 0 ft./sec.
E = 90°
A = 180°

ELEVATION WINDAGE SYSTEM

This channel obtains its inputs from the range rate elevation resolver and the azimuth resolver. One amplifier serves to add, and by means of a phase inverter, the other amplifier to subtract the two input signals. The output of each channel is connected to one winding of a torque motor where effective multiplication of the two input signals takes place to solve the calibration equation.

There are three potentiometers used to calibrate this system and they are adjusted in the following order:

(1) With both inputs tied together, adjust the potentiometer in the cathode circuit of the phase inverter for a minimum signal in the output of the A-B amplifier. This adjustment sets the effective gain of the phase inverter to a value of 1.

(2) Short the B input to ground and adjust the gain of the A-B channel for a computer shaft position of zero. This adjustment is made with no stiffness current and equalizes the effective gain of the two amplifiers to correct for variations in the torque motor windings. The inputs used for these two adjustments are arbitrary but should be at least half of the maximum "A" term values possible.

The third adjustment is the magnitude of the "B" input which determines the magnitude of the curvature correction obtained. This input should be adjusted only after the phase inverter and the relative channel gain are correct. The adjustment should be made with the computer shaft deflected against the curvature correction torque to a prediction angle on the opposite side of zero from that which would be caused by the correction torque only. The magnitude of this angle should be 5/2 of the correction torque required for the particular input conditions. It is measured by disconnecting the torque motor and observing the change in prediction angle caused thereby. It is necessary to use a fixture for displacing the shaft to the desired angle so designed that the torque produced does not vary with the gyro gimbal position, as otherwise an error in the apparent curvature correction will be made. Adjustment of the "B" input to the curvature correction amplifier is then made until the desired curvature correction angle is obtained. The following table gives the requirements for the elevation windage system for various input conditions.

Used in report of May 25, 1948

To: J. Robert Rogers
From: John E. Warner, Jr.
Subject: Calibrating Procedures
November 4, 1947
Page 12, Part III

ELEVATION WINDAGE CALIBRATION DATA

Variable $\dot{R}$

$\dot{R}$	A_c
1200	89.0
900	79.3
600	69.3
300	59.4
0	49.4
-300	39.5
-600	29.5
-900	19.5
-1200	9.6

$V_{ind.}$ = 450 m.p.h.
S_{wp} = 2 sec.

K_{d/d_o} = .921

A = 180°
E = 90°,

Variable E

E	A_c
-90	-49.3
-60	-42.7
-30	-24.6
0	0
30	24.6
60	42.7
90	49.3

$V_{ind.}$ = 450 m.p.h.
S_{wp} = 2 sec.
$\dot{R}$ = 0 ft./sec.
K_{d/d_o} = .921
A = 180°

Variable A

A	A_c
90	0
120	24.6
150	42.7
180	49.3
210	42.7
240	24.6
270	0

$V_{ind.}$ = 450 m.p.h.
S_{wp} = 2 sec.
$\dot{R}$ = 0 ft./sec.
K_{d/d_o} = .921
E = 90°

Variable $V_{ind.}$

$V_{ind.}$	A_c
100	10.9
200	21.9
300	32.9
400	43.8
500	54.9
600	65.3

S_{wp} = 2 sec.

$\dot{R}$ = 0 ft./sec.

K_{d/d_o} = .921

A = 180°

E = 90°

Variable S_{wp}

S_{wp}	A_c
1	24.7
2	49.3
3	73.[illegible]
4	98.[illegible]
5	[illegible]

$V_{ind.}$ = 450 m.p.h.

S_{wp} = 2 sec.

$\dot{R}$ = 0 ft./sec.

K_{d/d_o} = .921

A = 180°

E = 90°

Variable K_{d/d_o}

K_{d/d_o}	A_c
1	53.5
.921	49.3
.815	43.6
.[illegible]	35.[illegible]
.[illegible]	[illegible]

$V_{ind.}$ = 450 m.p.h.

S_{wp} = 2 sec.

$\dot{R}$ = 0 ft./sec.

A = 180°

E = 90°

DEFLECTION WINDAGE SYSTEM

This system solves its calibration equation in the same manner as the elevation windage system. It receives inputs from the range rate amplifier and the azimuth resolver. This system is set up in the same manner as the elevation system. The following table shows the shaft angles for various inputs for the deflection windage system.

Used in report of May 25, 1948

To: J. Robert Rogers
From: John B. Harper, Jr.
Subject: Calibration Procedures at Emerson
November 4, 1947
Page 14, Part III

DEFLECTION WINDAGE CALIBRATION DATA

Variable $\dot{R}$

$\dot{R}$	A_c
1200	-89
900	-79.2
600	-69.1
300	-59.2
0	-49.3
-300	-39.3
-600	-29.4
-900	-19.5
-1200	- 9.6

$V_{ind.}$ = 450 m.p.h.
S_{wp} = 2 sec.
$K_{d/do}$ = .921
A = 90°

Variable $K_{d/do}$

$K_{d/do}$	A_c
1	-53.6
.921	-49.3
.815	-43.7
.667	-35.7
.434	-23.3

$V_{ind.}$ = 450 m.p.h.
$\dot{R}$ = 0 ft./sec.
S_{wp} = 2 sec.
A = 90°

Variable A

A	A_c
90	-49.3
120	-42.7
150	-24.6
180	0
210	24.6
240	42.7
270	49.3

$V_{ind.}$ = 450 m.p.h.
S_{wp} = 2 sec.
$K_{d/do}$ = .921
$\dot{R}$ = 0 ft./sec.

Variable S_{wp}

S_{wp}	A_c
1	-24.7
2	-49.3
3	-73.5
4	-98.7
5	-123

$V_{ind.}$ = 450 m.p.h.
$\dot{R}$ = 0 ft./sec.
A = 90°
$K_{d/do}$ = .921

Variable $V_{ind.}$

$V_{ind.}$	A_c
100	-10.9
200	21.9
300	-32.9
400	-43.8
500	-54.9
600	-65.8

$\dot{R}$ = 0 ft./sec.
S_{wp} = 2 sec.
$K_{d/do}$ = .921
A = 90°

6-27-5959

CALIBRATION EQUATIONS OF THE S-9 COMPUTER

SIGHT SENSITIVITY:

$$S_{p(WP)} = \frac{K_s^2}{[i_{R_o} + i_{d/d_o} + i_{(wi)R} + i_{\dot{R}_o} + i_{V_{(GS)(ind)}}]^2} \text{ seconds}$$

Where K_s is a proportionality constant of the sight, dependent upon the elastic restraint motor sensitivity and sight indicating system sensitivity. The current excitation to the elastic restraint torque motor is the sum of the following component currents:

$$i_{R_o} = \frac{K_o K_s}{\sqrt{R_o}}$$

$$i_{d/d_o} = -(K_1 + K_5 R_o) K_s (d/d_o)$$

$$i_{(wi)R} = K_s K_{d/d_o} K_{(wi)R} R_o V_{(GS)(ind)} \cos Az_{(GL)}$$

$$i_{\dot{R}_o} = \frac{K_s K_7 \dot{R}_o}{\sqrt{R_o}}$$

$$i_{V_{(GS)(ind)}} = K_s K_{d/d_o} K_{V_{(GS)(ind)}} R_o V_{(GS)(ind)}$$

CURVATURE AND JUMP CORRECTIONS (radians)

$$(CC)_{(wi)d} = S_{p(WP)} (K_3 + K_4 \dot{R}_o) V_{(GS)(ind)} K_{d/d_o} \sin Az_{(GL)}$$

$$(CC)_{(wi)e} = S_{p(WP)} (K_3 + K_4 \dot{R}_o) V_{(GS)(ind)} K_{d/d_o} \cos Az_{(GL)} \sin E_{(GL)}$$

$$(CC)_{(gr)e} = S_{p(WP)} K_8 (K_3 + K_4 \dot{R}_o) \cos E_{(GL)}$$

$$(CC)_{(\alpha)e} = S_{p(WP)} K_\alpha V_{(GS)(ind)} K_{d/d_o} \cos E_{(GL)} \alpha$$

$$(JC)_{(wi)e} = -K_{J(wi)} V_{(GS)(ind)} K_{d/d_o} \sin Az_{(GL)}$$

With the following assumptions:

$$(CC)_{(gr)d} = 0$$

$$(CC)_{(a)d} = 0$$

$$(JC)_{(wi)d} = 0$$

DIMENSIONS:

R = Present range in ft.

$\dot{R}_o$ = Present range rate in ft. per sec.

I = Current in amps.

$V_{(GS)(ind)}$ = Indicated gun station velocity in miles per hour

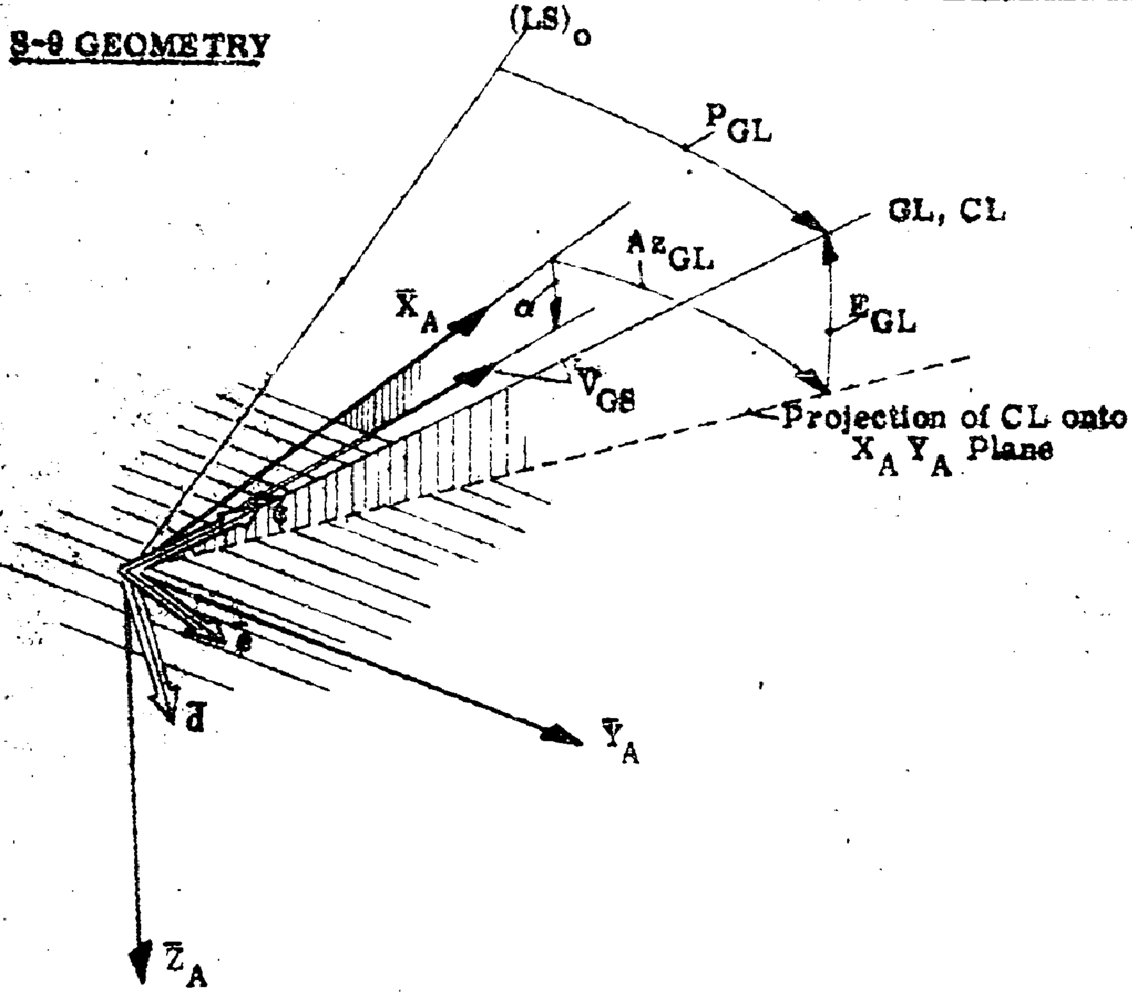
K_s = Proportionality constant of the sight in amps x $sec^{\frac{1}{2}}$

$s_{p(WP)}$ = Sensitivity of prediction computer for angular velocity of the controlled line input and prediction angle output, in seconds.

d/d_o = Nondimensional atmospheric density ratio.

NOTE: The material in these pages taken from:
Data of Philpott Feb. 1946,
Data checked and dimensions added by R. Gras 3/10/47
Symbols revised by Gras, Rogers & Ehrenfried 1/28/48

S-8 GEOMETRY



$\bar{X}_A, \bar{Y}_A, \bar{Z}_A$ -- Right-hand system of rectangular coordinates fixed in gun station aircraft, with $\bar{X}_A$ chosen along the forward direction of the no-lift line and the plane $X_A Y_A$ chosen normal to the plane of symmetry of the aircraft.

$\bar{c}, \bar{e}, \bar{d}$ -- Right-hand system of rectangular coordinates formed by controlled line, elevation axis, and deflection axis unit vectors, with $\bar{e}$ lying in the $X_A Y_A$ plane

PREDICTION ANGLE SOLUTION:

$$\bar{P}_{GL} = L \cdot (\overline{CC})_{(total)} \cdot (\overline{JC})_{(total)}$$

INSTRUMENTATION LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE MASS.

PREPARED BY ADE

DATE: 1/29/48

CONFIDENTIAL

SHEET [illegible] OF [illegible]

CALIBRATION CONSTANTS OF [illegible] COMPUTER

CONSTANT	AMMUNITION: .50 CAL. MARK 8 A. P. I. MV = 2870 fps. — TAIL CONE	NOSE CONE	20 M.M. 1 TURN 125.586 CAL. SHELL T23 P.O. FUZE T71E4 M.V. 2750fps — TAIL CONE	NOSE CONE	DIMENSIONS
K_o	53.572	53.572	52.440	52.440	$sec^{-\frac{1}{2}}\ ft^{\frac{1}{2}}$
K_1	.051	.051	.08	.08	$sec^{-\frac{1}{2}}$
K_3	-1.191×10^{-4}	-1.191×10^{-4}	-1.5×10^{-4}	-1.5×10^{-4}	$hr\ mi^{-1} sec^{-\frac{1}{2}}$
K_4	-8.0×10^{-8}	-3.1×10^{-8}	-1.3×10^{-8}	-4.1×10^{-8}	$hr\ mi^{-1} ft^{-1}$
K_5	1.62×10^{-5}	1.62×10^{-5}	1.53×10^{-5}	1.53×10^{-5}	$ft^{-1} sec^{-\frac{1}{2}}$
K_7	$-.005$	0	$-.006$	$-.0035$	$sec^{\frac{1}{2}}\ ft^{\frac{1}{2}}$
K_8	-54.5	-54.5	-48.6	-48.6	$mi\ hr^{-1}$
$K_{V(OS)(ind)}$	-2.5×10^{-8}	-2.5×10^{-8}	-2.5×10^{-8}	-2.5×10^{-8}	$sec^{-\frac{1}{2}} hr\ mi^{-1} ft^{-1}$
$K_{(wi)R}$	-3.38×10^{-8}	-3.38×10^{-8}	-5.3×10^{-8}	-5.3×10^{-8}	$sec^{-\frac{1}{2}} hr\ mi^{-1} ft^{-1}$
$K_{J(wi)}$	$-.0115 \times 10^{-3}$	$-.0115 \times 10^{-3}$	$-.0165 \times 10^{-3}$	$-.0165 \times 10^{-3}$	$mi^{-1}\ hr$
K_α	10^{-4}	10^{-4}	10^{-4}	10^{-4}	$hr\ mi^{-1} sec^{-1}$
K_s^2	4.141×10^{-3}	4.141×10^{-3}			$amp^2\ sec$
K_{d/d_o} For $d/d_o = 0$	0	0	0	0	None
K_{d/d_o} For $d/d_o = .4$	.667	.667	.563	.563	None
K_{d/d_o} For $d/d_o = .8$	.921	.921	.854	.854	None
K_{d/d_o} For $d/d_o = 1.0$	1.000	1.000	1.000	1.000	None

65535-48-9

AD-1811

UNCLASSIFIED

~~SECRET~~

DEPARTMENT OF DEFENSE
WASHINGTON HEADQUARTERS SERVICES
1155 DEFENSE PENTAGON
WASHINGTON, DC 20301-1155

MAR 3 1 20[illegible]

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER
(ATTN: WILLIAM B. BUSH)
8725 JOHN J. KINGMAN ROAD, STE 0944
FT. BELVOIR, VA 22060-6218

SUBJECT: OSD MDR Cases 11-M-1002, -1003, -1005, -1007, -1008, and -1009

We have reviewed the attached documents and have no objection to declassification in full. The information you requested is provided in the table below:

OSD Case Number 11-M-	**Current Controlling Agency**	**Current Controlling Official**	**Current Distribution Control Statement**	**Current Overall Classification Level**	**Current Downgrading Instructions**	**Current Declass. Instructions**
1002	WHS	OSD Records Official	A Release Unlimited	C	N/A	N/A
1003	WHS	OSD Records Official	A Release Unlimited	C	N/A	N/A
1005	WHS	OSD Records Official	A Release Unlimited	C	N/A	N/A
1007	WHS	OSD Records Official	A Release Unlimited	C	N/A	N/A
1008	WHS	OSD Records Official	A Release Unlimited	S	N/A	N/A
1009	WHS	OSD Records Official	A Release Unlimited	S	N/A	N/A

If you have any questions, contact me by phone at 703-696-2197 or by e-mail at storer.robert@whs.mil or robert.storer@whs.smil.mil.

Robert Storer

Robert Storer
Chief, Records and Declassification Division

Enclosures:
1. DTIC request
3. Six documents

~~SECRET~~

UNCLASSIFIED [redacted]