FLIGHT TESTS OF AN OFF-SCHEDULE DISTANCE COMPUTER

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SUMMARY

An off-schedule distance computer built by Minneapolis-Honeywell Regulator Company was loaned to the Civil Aeronautics Administration, Office of Technical Development for evaluation tests. The computer settings required are, anticipated ground speed and estimated arrival time. The computer contains a clock-driven potentiometer which derives a voltage proportional to the product of the desired ground speed and the time remaining before the expected arrival time, and a servo-system for comparing this voltage with a voltage proportional to the distance to destination which is obtained from a course line computer. The difference between the two voltages is a measure of the distance "off-schedule" and is presented visually by utilizing the horizontal needle of the instrument landing system deviation indicator.

The flight tests described in this report indicate that distances of 100 miles or less may be flown according to pre-set ground speeds with an approximate error in time of arrival of plus or minus one minute provided due allowance for wind conditions has been made in setting the ground speed so as not to exceed the air speed limitations of the aircraft. Considerable difficulty was encountered in pre-estimating ground speeds which could be maintained. This introduces a problem in the use of such equipment.

INTRODUCTION

An aircraft equipped with a course line computer[1], an omnireceiver, and a distance measuring equipment (DME) receiver has the necessary equipment to fly with precision any selected course over terrain on which are located combined omnirange and DME beacon stations. Visual indications of the amount and direction of deviations from course, as well as the distance from the destination to the aircraft, are derived by the course line computer and are available to the pilot This fixes the position of the aircraft, but gives no information as to the progress of the aircraft with respect to a desired schedule. Such information may be calculated, however, since the distance to go is always known Calculations at intervals would be necessary to determine the deviation from schedule. To present visually and continuously the deviation from schedule, an off-schedule distance computer was built by the Minneapolis-Honeywell Regulator Company and was loaned to the Civil Aeronautics Administration, Office of Technical Development, for evaluation tests in February 1948

The use of the off-schedule distance computer (OSD) presupposes that the aircraft is being flown along a straight track to the destination Continuous distance to destination information is supplied to the OSD by the course line computer. The horizontal needle of the deviation indicator instrument is utilized to present visually an indication of the distance in miles that the aircraft is ahead or behind a schedule which is determined by pre-setting the OSD computer controls to the desired ground speed and the resulting time of arrival at the destination By proper control of the air speed, the pilot may keep the needle centered and thus expect to arrive at the destination "on schedule."

The OSD computer discussed in this report is not a production model but was constructed of standard components in order to investigate the performance of such a computer. A photographic view of the computer is shown in Fig. 1. The theory of operation of the computer is given only in brief since this report is intended to deal primarily with flight testing.

DESCRIPTION

The principal components of the OSD computer are, amplifier, off-schedule distance potentiometer, schedule speed potentiometer, junction box, and a clock assembly which includes the schedule potentiometer A general view of the computer is shown in

[1] F. J. Gross and Hugh Kay, "Initial Flight Tests and Theory of an Experimental Parallel Course Computer", Technical Development Report No 83, September 1948.

Fig 1 It should be reiterated that the particular computer tested is not a production model. On the front panel, Fig 2, are located the clock assembly, the schedule speed potentiometer, and the motor-driven off-schedule distance indicator Around the clock face is a housing which contains the schedule potentiometer This potentiometer and its indicator may be rotated around the clock face by the ARRIVAL TIME knob which is located on the upper right side of the schedule potentiometer housing Immediately behind the front panel and attached to the back side is the servo-motor. Behind the servo-motor and attached to the base is the amplifier The junction box with four AN connectors is mounted on supports over the amplifier In order, from the front, the connectors contain the following circuits

1. Spare
2. Course line computer (incoming "Distance-to-Destination" voltage)
3. Power (115 volts, 400 cps, 60 watts)
4. Cross-pointer meter (to horizontal needle)

Inputs to the computer necessary for operation are the distance to destination voltage supplied by the parallel course computer and power. Hand settings required are the time of arrival and the scheduled ground speed The output of the computer is in the form of a deflection of the horizontal needle of the deviation indicator showing the distance in miles ahead or behind schedule for the particular settings of ground speed and arrival time in use The deflection indications are so arranged that an upward deflection of the needle shows the aircraft to be behind schedule while a downward deflection of the needle indicates that the aircraft is ahead of schedule With the aircraft at a given distance from the destination and a given ground speed set into the computer, there is only one setting of the time of arrival that will center the deviation indicator horizontal needle Once the needle is centered, its position is maintained by adjusting the air speed of the aircraft By maintaining the needle centered, the pre-set ground speed is made good at all points on the course, and the aircraft should arrive at the destination at the pre-set arrival time

THEORY OF THE OSD COMPUTER

The function of the OSD computer is to accept from the course line computer a voltage e_1 proportional to the distance to destination and compare it with another voltage e_2 derived within the OSD computer which is proportional to the product of the desired ground speed and the "time to go " The difference between the two voltages e_3 is a measure of the deviation from schedule The voltage e_2 derived within the computer must change continuously in such a manner as to be always proportional to the product of the pre-set ground speed and the time remaining before the time of arrival.

A simplified schematic diagram of the computer is shown in Fig. 3. Setting in the desired ground speed positions the slider of the schedule speed potentiometer and, in effect, gives a voltage proportional to the ground speed. This voltage is fed to the schedule potentiometer. Setting in the time of arrival positions the schedule potentiometer in such a way as to feed a voltage e_2 to its slider that is proportional to the product of the ground speed and the period of time existing between the time of setting and the arrival time. After the initial setting, the clock mechanism moves the slider of the schedule potentiometer so as to maintain a voltage e_2 which is always proportional to the product of the desired ground speed and the time remaining before the arrival time.

The two voltages e_1 and e_2 are compared through summing resistors. Their difference e_3, after being amplified, is fed to a servo-motor which drives the slider of the off-schedule distance potentiometer. At some position on the potentiometer, the slider will feed in a voltage e_4 of the correct magnitude to cancel the difference voltage e_3 At this point, the rotation of the servo-motor will cease, and the amount of rotation will be indicated by a pointer on the servo-motor shaft before a dial calibrated in miles ahead or behind schedule The servo-motor also drives a separate potentiometer to furnish deviation indicator deflections. The potentiometer feeds a ring-type demodulator which is a phase-sensitive rectifier The output of the rectifier is indicated by the deviation indicator. Not previously mentioned, but shown on the schematic, is the velocity generator which is coupled to the servo-motor. Rotation of the servo-motor shaft causes an emf e_5 to be generated in the velocity generator. This emf is fed back into the servo-motor amplifier.

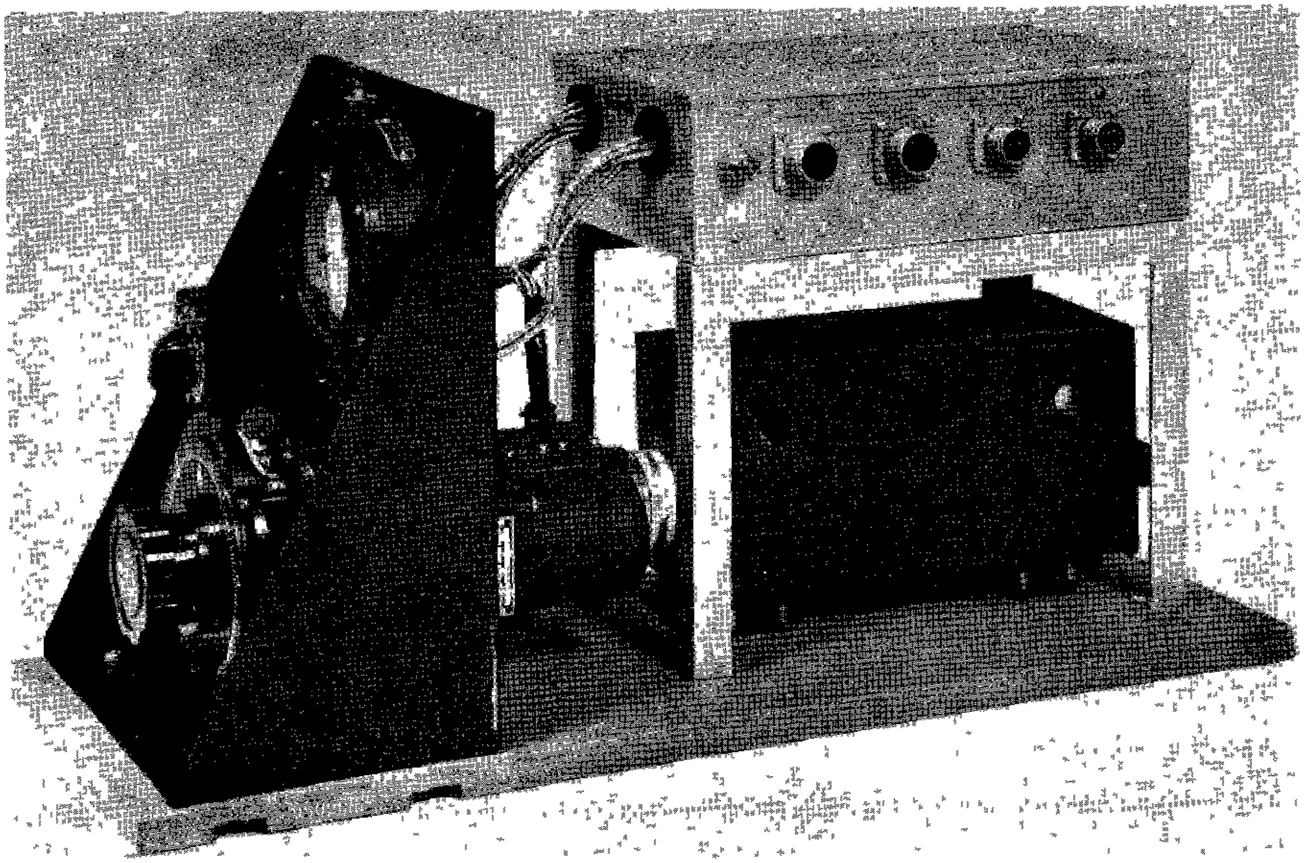


Fig. 1 Minneapolis-Honeywell Off-Schedule Distance Computer, Model 1

It tends to prevent hunting and effects smoother operation

If the aircraft is flown with the deviation indicator centered, the distance to destination voltage e_1 as supplied by the parallel course computer must always equal the voltage e_2 which is proportional to the product of the desired ground speed and the time remaining before the time of arrival. Thus a schedule may be maintained and the meeting of a pre-set arrival time assured.

RESULTS

In order to test the OSD computer operationally, tracks were flown along a section line which contained numerous check points. The course on the course line computer was selected to conform to the section line, and the destination was selected as a check point approximately 90 miles distant. The course was flown by visual reference to the section line rather than by following the deviation indicator deflections. The deviation indicator deflections were recorded, however, and were found to be in very close agreement with the actual course No deflection was found to be more than two miles, and an error of this magnitude occurred for a very small percentage of the time The average error in distance to destination was 2 0 miles Over each check point, readings were taken of the indications of both computers, the indicated aircraft performance, and the time

A tabulation of the readings taken during a typical test flight is shown in Fig 4 The results of the same test are plotted in Fig 5 In Curve A the product of scheduled ground speed and elapsed time is plotted versus elapsed time This represents ideal performance Curve B shows the actual result as obtained by plotting the true distance to the various check points against the elapsed time Curve C shows the difference between the distance-to-destination from the starting point and the distance-to-destination from the check points as indicated by the course line computer This, in effect, gives the indicated

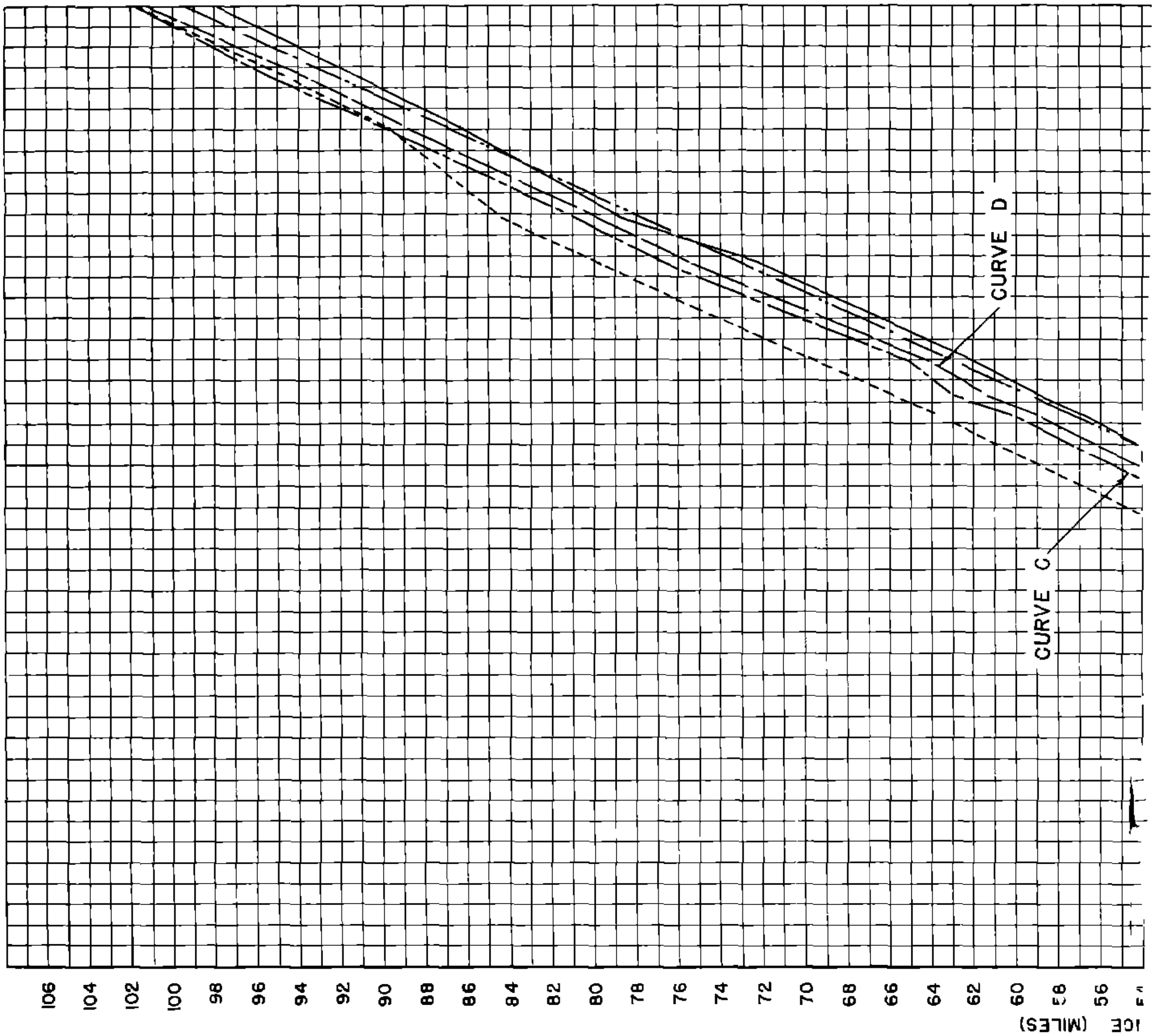
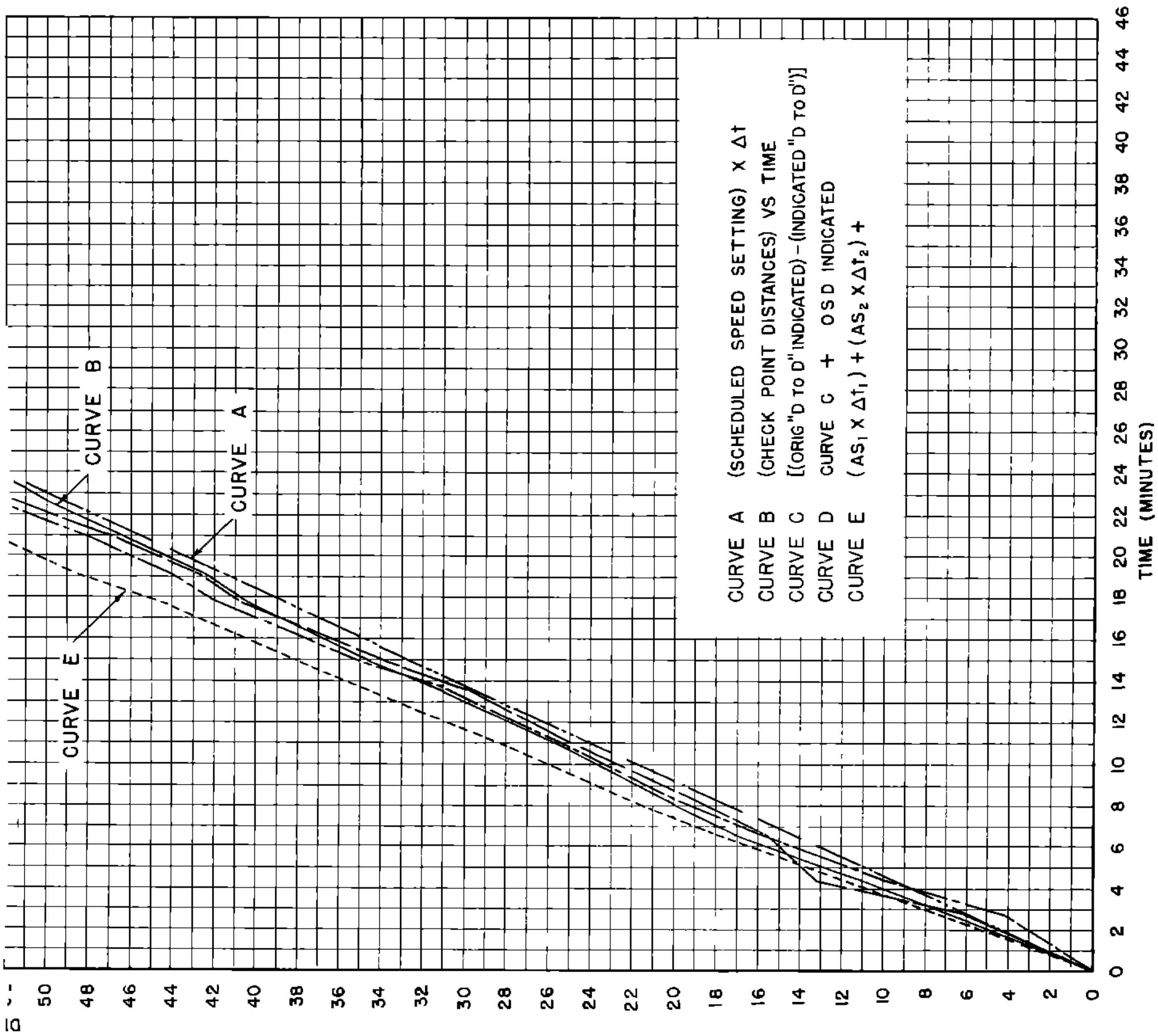


Fig 5 Results o



ypical Test Flight

distance traveled in the time elapsed In other words, Curve C is proportional to the distance-to-destination information being fed into the OSD computer by the course line computer.

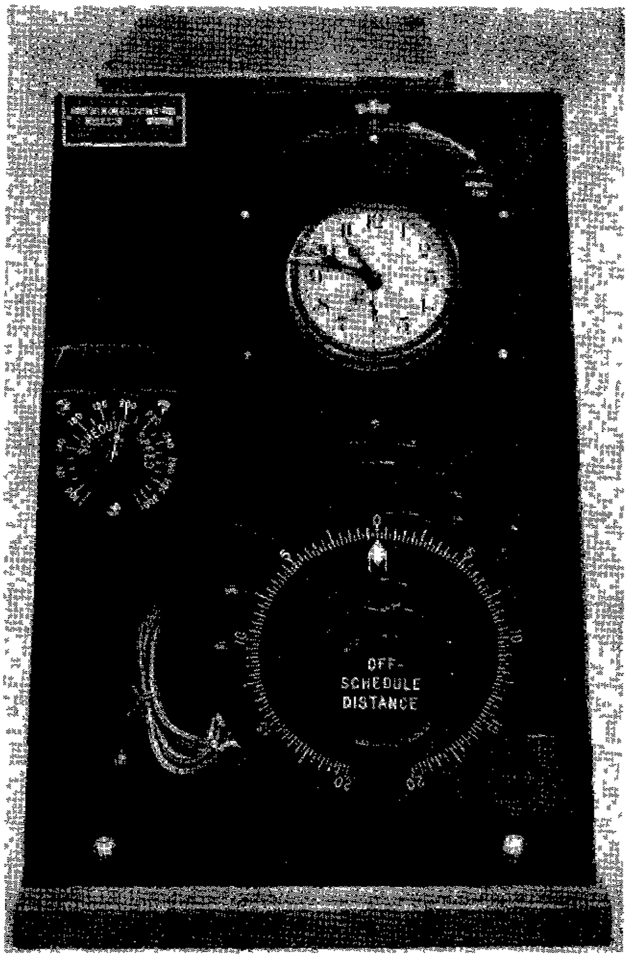


Fig 2 Front View, Off-Schedule Distance Computer

The difference between Curves B and C is the error in the distance-to-destination information introduced by the course line computer, assuming the off-track distance to be negligible. Curve D was obtained by adding to Curve C the indicated off-schedule distance of the OSD computer as recorded over the check points. The difference between Curve D and Curve A is the OSD computer error The product of the true air speed and the increment of time associated with it gives a distance equivalent to the travel of the aircraft in still air Curve E is a plot of the summation of these distances for the total time indicated. The difference between Curve E and Curve B is an indication of the wind conditions encountered.

In the beginning, a sensitivity setting of four miles per small division on the deviation indicator was tried The setting proved impractical in that off-schedule distances were too large when they became apparent An aircraft one division (four miles) behind schedule would require 24 minutes to regain its schedule if a correction in ground speed of ten mph was applied With a sensitivity of one division per mile, an off-schedule distance of one division could be regained in six minutes by a correction of ten mph The tests described were made with a sensitivity setting that gave a deviation indicator deflection of one division per mile off schedule (30 μa per mile). The error of 0 9 minute in arrival time for the particular flight test given is representative of the errors in all the flights conducted

In maintaining a schedule precise to one minute or less over a distance of 100 miles

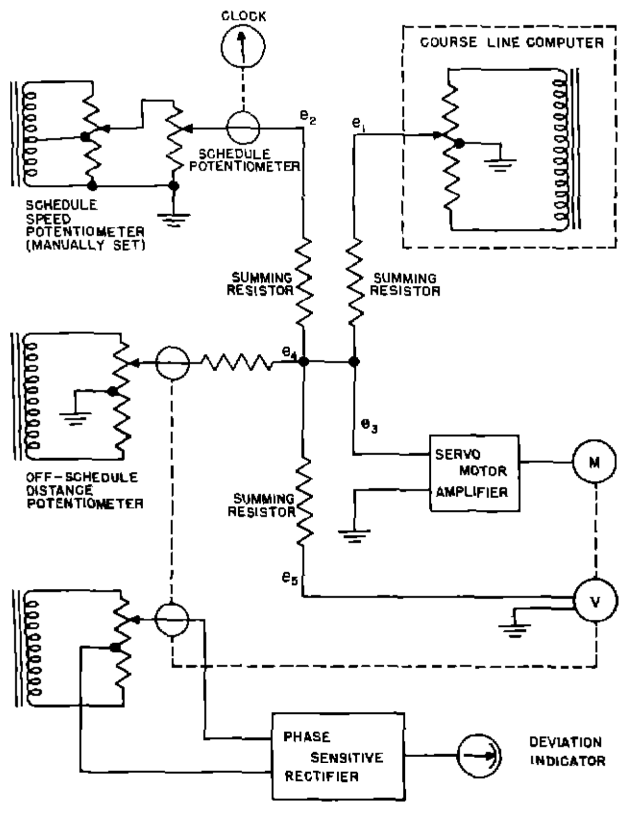


Fig 3 Simplified Schematic Diagram of the Off-Schedule Distance Computer

CHECK POINTS	OFFSET-Miles	COURSE-Degrees	ALONG TRACK DISTANCE-Miles	DISTANCE-Miles	BEARING-Degrees	DISTANCE TO DESTINATION-Miles	ARRIVAL TIME SETTING	SCHEDULE SPEED SETTING-mph	TIME	OFF-SCHEDULE DISTANCE-Miles	INDICATED AIR SPEED-mph	INDICATED ALTITUDE Feet	TEMPERATURE Degrees C	TRUE AIR SPEED-mph	MAP DISTANCE TO DESTINATION Miles	DISTANCE TRAVELED Miles	ELAPSED TIME Minutes	Δt-Minutes	CORRECTED AVERAGE AIR SPEED-mph	[(AIR SPEED) x Δt]	[(AIR SPEED)$_1$ x Δt$_1$] + [(AIR SPEED)$_2$ x Δt$_2$] +	[ORIG DIST TO DEST IND] - DIST TO DEST INDICATED	(PREVIOUS COLUMN) + (OFF-SCHED DIST IND)
	B-D COMPUTER READINGS						OSD COMPUTER READINGS				AIRCRAFT PERFORMANCE				COMPUTED VALUES								
64	9 6L	268 5	56 5	44 5	251	99	11 07 8	130	10 22 6	0 0	150	5000		162	98 0	0 0	0 0	0.0	162	—	—	0	0 0
63				37 5	249	95			25 2	2 0L	150	5000		162	91 6	6 4	2 6	2 6	162	7 03	7 03	4	6 0
62				35 0	248	89			27 0	3 25L	159	5000		172	86 9	11 1	4 4	1 8	167	5 01	12 04	10	13 25
61				27 0	245	83			29 2	0 25R	150	5000	10	162	80 9	17 1	6 6	2 2	167	6 13	18 17	16	15 75
60				23 5	243	79			30 9	0 75R	110	4900		119	77 5	20 5	8 3	1 7	140	3 97	22 14	20	19 25
59				19 0	235	74			33 4	0 5R	140	4980		152	72 8	25 2	10 8	2 5	136	5 7	27 84	25	24 5
58				13 5	222	68			36 2	1 0R	135	4980		146	66 6	31 4	13 6	2 8	149	6 9	34 74	31	30 0
57				11 5	219	64			37 5	1 25R	130	4980		141	63 5	34 5	14 9	1 3	143	3 1	37 84	35	33 75
56				9 4	181	57			40 4	1 25R	130	4980		141	57 4	40 6	17 8	2 9	141	6 8	44 64	42	40 75
55				9 4	164	55			41 7	1 25R	121	4920		131	55 6	42 4	19 1	1 3	136	3 9	48 54	44	42 75
54				10 5	145	51			43 5	1 25R	120	4940		130	—	—	20 9	1 8	130	3 9	52 44	48	46 75
53				13 0	128	46			45 4	1 25R	110	4940		119	47 7	50 3	22 8	1 9	124	3 9	56 34	53	51 75
52				18 5	114	39			48 9	1 25R	120	4920		130	41 3	56 7	26 3	3 5	125	7 3	63 64	60	58 75
51				21 0	110	36			50 0	1 5R	120	4940	10	130	38 9	59 1	27 4	1 1	130	2 4	66 04	63	61 5
50				23 0	108	34			51 5	1 0R	122	4940		132	36 2	61 8	28 9	1 5	131	3 3	69 34	65	64 0
49				29 0	103	28			53 9	1 5R	120	4940		130	31 0	67 0	31 3	2 4	131	5 2	74 54	71	69 5
48				34 0	100	22			56 4	1 5R	114	4940		124	25 8	72 0	33 8	2 5	127	5 3	79 84	77	75 5
47				38 0	98	18			58 5	1 25R	121	4940		131	19 3	78 7	35 9	2 1	128	4 5	84 34	81	79 75
46				46 5	95	9			11 02 8	1 25R	112	4900		122	11 6	86 4	40 2	4 3	126	5 4	89 74	90	88 75
84				51 5	93	4			05 2	1 5R	110	4900		119	6 9	91 1	42 6	2 4	120	4 8	94 54	95	93 5
85				59 0	94	-3			08 7	0 5R	120	4900		130	0 0	98 0	46 1	3 5	125	7 3	101 84	102	101 5

Fig. 4 Calculated and Recorded Data of a Typical Test Flight

great difficulty was encountered in pre-estimating ground speed settings which could be maintained without exceeding the performance limitations of the aircraft. This problem arises from the fact that insufficient information is available regarding wind conditions aloft and is also aggravated by changes in wind conditions which occur during a flight Using the most recent weather station information available before a flight, predicted ground speeds were at times so different from the actual result obtained that air speeds outside the performance range of the aircraft would have been necessary to maintain the desired schedule On several occasions, in borderline cases, pilots were forced to fly the Douglas aircraft used in the tests at an air speed of 95 to 100 mph to maintain a ground speed setting of 140 mph. On other occasions, air speeds of 180 to 190 mph were necessary to meet the schedule.

CONCLUSIONS

The OSD computer offers a method by which more accurate control of aircraft schedules may be maintained. It requires continuous distance to destination information which must be supplied by a course line computer This, in turn, requires information from a bearing and distance facility such as an omnirange and distance measuring equipment (DME) station. The flight tests described in this report indicate that distances of 100 miles or less may be flown according to preset ground speeds with an approximate error in time of arrival of plus or minus one minute, provided due allowance for wind conditions has been made in setting the ground speed so as not to exceed the air speed limitations of the aircraft.

The OSD computer will be of value in aircraft maintaining precise schedules, but the tests have demonstrated the need for some sort of an indicator giving continuous ground speed indications. Such an indicator would reduce greatly the estimating required to determine ground speed settings, especially if reports from aircraft already in flight could be obtained.

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