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11-M-1002

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Instrumentation Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

To: J. Robert Rogers

From: John B. Harper

Date: December 11, 1950

Subject: A-1 FCS GYRO PREDICTION COMPUTER COLD CHAMBER TEST

The gyro prediction computer of the A-1 FCS, System #9, manufactured by the Emerson Electric Manufacturing Co., St. Louis, Mo., was subjected to cold chamber tests at the Instrumentation Laboratory, MIT, during the month of November. From these tests the following results were obtained:

1) The time required for the prediction unit to reach operating temperature from -60° F is excessive, (45 to 60 minutes).

2) The signal generator null voltage drifts during warm-up.

3) There is no significant permanent shift of signal generator null due to temperature cycling or to variation in ambient temperature conditions.

The tests were conducted by placing the complete gyro prediction computer in an insulated box which contained dry ice and a blower to circulate air within the box. The computer was not in contact with the dry ice. A Brown recording thermometer with 12 thermocouples was used to measure the temperature at critical points within the computer and the chamber. No attempt was made to vary chamber pressure from atmospheric. The following items were recorded against time of operation:

1) Ambient temperature.

2) Time required for first damper cycle.

3) Signal generator null voltage.

4) Prediction unit characteristic time as determined with an automatic stop watch.

5) Temperature distribution within the gyro prediction computer housing or "kettle."

Heat sources within the prediction unit container consisted of the damper and space heaters, gyro wheels, and microsyn excitation. Copper-constantan thermocouples were mounted in the prediction unit container in the following places:

1) Elevation unit - bottom of damper housing.
2) " " - signal generator adjusting hole.
3) " " - torque motor adjusting hole.
4) " " - stiffness motor coil nearest adjustment hole.
5) " " - 180° away from 2) above.
6) Deflection Unit - signal generator adjusting hole.
7) " " - 180° away from 6) above.
8) " " - stiffness motor shunt resistor.
9) Bottom of "clover leaf" casting.
10) Junction of space heater support wires.
11) Top surface of "clover leaf" casting between . the elevation and deflection units directly in front of space heater.

Warm-up time for the unit is excessive, 45 minutes to one hour, after soaking at an ambient temperature of -50° to -60° F for a period of at least 12 hours. This time was measured from initial power application to first damper thermostat cycle. After once reaching operating conditions both damper and space heaters cycled satisfactorily regardless of ambient temperature. This indicates that there is enough heat capacity within the unit to keep it at operating temperature. Characteristic time measurements made on the elevation and deflection units, with an automatic stop watch, did not change with ambient temperature after the unit had warmed up.

The output of the deflection unit signal generator as recorded during warm-up and cooling changed in both amplitude and phase. Emerson calibration procedures call for the signal generator to be zeroed to the stiffness motor with a null voltage of less than 15 millivolts when the unit is at operating temperature, 135° F. The unit tested had a null voltage of 30 millivolts at operating temperature, although the possible null was between 5 and 10 millivolts. This 30 millivolt null corresponds to an error of approximately 1 1/2 milliradians at the computer shaft or 3 milliradians at the tracking line.

At low ambient temperature -50° to -60° F, and before warm-up, the null voltages are much higher, -- 0.1 volts. During warm-up from this ambient to operating temperature, the null shifts through 14 milliradians referred to the computer shaft, but repeats the 1 1/2 mil value given above when operating temperature is reached.

Temperature cycling of the unit, 2 cycles with system operating, and 2 thermal cycles to check hysteresis effects at room temperature, showed for this particular computer, no semi-permanent shifts and no lags in null voltage greater than 1 milliradian of computer shaft angle. In addition, all values of null voltage obtained at operating temperature after warm-up were reproducible to values within 1/2 milliradian of shaft angle.

The fact that lags of the order of 1 milliradian were seen in the course of a thermal cycle may be attributed in part to shifts in the center of gravity of the gyro. It is also possible that differential expansion axially of the computer shaft and computer housing may cause misalignment between rotor and stator of one or more microsyn units. A third possibility, judged less likely, is rotation of one microsyn stator relative to the other.

Other computer assemblies may or may not show as good reproducibility with temperature cycling as did this one. The basic design of microsyn mount involves the assembly of parts made of 4 different metals having different temperature coefficients of expansion, -- hypernik, dural, magnesium and steel -- and it is probable that the stability of the assembly is greatly dependent upon machining tolerances and assembly procedures.

Only if production unit nulls can consistently be found to be as reproducible as those of the computer from this Number 9 System, and if shock or vibration do not cause changes in microsyn zeros, can the present design be considered adequate.

Temperature gradients within 2 individual prediction unit assemblies are of the order of 5° - 10° F depending slightly on ambient temperatures. This variation with ambient temperature is caused by operation of the space heater at low ambient temperature. At an ambient of 70° F, internal heat from gyros and dampers is enough to open the space heater thermostat. These differences in temperature gradient had negligible effect (a small fraction of one milliradian) on the null voltage readings made after operating temperatures were reached.

From the results of the tests the following recommendations can be made to improve computer performance:

1) Because the warm-up time is excessive for low ambient temperatures, additional heaters should be installed for use during operations when low ambient conditions are encountered. These heaters could have thermostats set to turn off at +100° F.

2) It is desirable to investigate modification of microsyn mountings to eliminate any possibility of readjustment between dissimilar metals because of differential expansion during warm-up, and preferable to prevent changes in null voltage with temperature even if they are reproducible.

3) In any event, the signal generators should be adjusted for a minimum null voltage <u>after</u> the computer has reached operating temperature.

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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
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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

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