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U S ARMY MISSILE COMMAND

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A SECOND STUDY ON REDUCTION OR ELIMINATION OF AIR CONDITIONING IN THE PERSHING GUIDANCE AND CONTROL COMPARTMENT

BY

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ABSTRACT

This report is on a second study to reduce or eliminate the air conditioning required by the Pershing Guidance and Control (G&C) Compartment. It contains a study of the hardware within the G&C Compartment operating at anticipated temperatures and suggests possible areas for component investigation and redesign.

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A SECOND STUDY ON REDUCTION OR ELIMINATION OF AIR CONDITIONING IN THE PERSHING GUIDANCE AND CONTROL COMPARTMENT

I. INTRODUCTION

This is the second report defining Phase III of a study to reduce or eliminate the air conditioning required by the PERSHING Guidance and Control (G&C) Compartment. The first report dealt with a study of the environment of launch sites, established a maximum temperature and solar radiation under which the PERSHING would be required to operate normally, and suggested a method for determining a new G&C Compartment operating temperature. This report deals with the performance of the guidance hardware at the new operating temperatures.

In the first report it was concluded that the PERSHING missile would be required to operate within present requirements when launched from an environment at or below 100 watts per square foot solar radiation and 110°F ambient temperature; above these conditions, the missile is to operate within a derated performance level to deliver the re-entry section within a derated CEP which will have to be established.

Under the maximum conditions of solar radiation and ambient temperature, with air at the ambient temperature being pumped into the G&C Compartment, the operating temperature of the G&C Compartment is expected to stabilize between 130°F and 140°F, the exact temperature is to be determined experimentally as described in the previous report. Once this temperature is established the G&C Compartment will be controlled at that temperature for all environments by adding heat if necessary. If the environment exceeds 110°F and 100 watts per square foot solar radiation, the G&C Compartment operating temperature may exceed 140°F. Operation will be permitted outside present PERSHING requirements at a derated performance level which will be established based on component occurrences at the higher operating temperature.

It is the purpose of this report to evaluate the performance of the guidance hardware under the new G&C Compartment operating temperature and suggest possible areas for redesign.

The following subsystems are to be evaluated:

1. Battery
2. Inverter
3. ST-120 Stable Platform
4. ST-120 Servo Amplifiers
5. Inertial Guidance Computer
6. Control Computer
7. Exploding Bridge Wire
8. Missile Networks

A. Missile Battery

The missile battery is the primary source of electrical power of the missile from when it is activated, a few seconds prior to liftoff, through separation. Although the battery output voltage is temperature sensitive, the output voltage is only slightly higher when operated at 140°F then at 77°F. Operation within PERSHING requirements can be obtained from the present battery at temperatures up to 165°F.

B. Inverter Considerations

The rotary inverter supplies a highly accurate 400 cps, 115 volt, 3 ϕ electrical power for the guidance hardware. Any malfunction in the inverter that would affect the voltage and frequency, would directly affect the accuracy of the missile since the inverter serves as the time base for the guidance system.

The inverter is rated to operate in an ambient temperature of 50°F to 125.6°F which is slightly below the anticipated G&C Compartment operating temperature.

Tests indicate that the inverter output is sensitive to temperature and that performance will be marginal at temperatures of 140°F. Three circuits which appear to be temperature sensitive in the inverter regulator controls are the frequency discriminator, frequency magnetic amplifier and voltage magnetic amplifier. At the anticipated operating temperature, it appears that the circuit parameters of the frequency discriminator and that the magnetic properties of the magnetic amplifier might change enough to affect the output voltage and frequency.

Tests should be performed to conclusively establish the operating limitations due to temperature, then if it is necessary temperature compensating networks could be added to improve the performance and reliability.

C. ST-120 Stable Platform Considerations

The ST-120 stable platform provides a reference with respect to inertial space from which attitude and acceleration signals are obtained during flight.

At present the ST-120 platform components are operated at a nominal temperature of 106.7°F in an ambient temperature of 77°F. Air bearing air, to float the gyro and accelerometer inner cylinders and pendulum slugs, is pumped to the ST-120 at 77°F. New operating temperatures for the air bearing air and ST-120 components will be established by the test program suggested in the first report. In the mean time, the air bearing air temperature is expected to be between 130°F to 140°F and the ST-120 operating temperature is expected to be approximately 160°F.

D. Gyros and Accelerometers

The AB-5 gyros and AMAB-3 accelerometers should not present a problem operating at temperatures of up to 160°F. It is anticipated that the gyros and accelerometers are capable of operating at temperatures up to 185°F without modification provided they are calibrated in the same environment that they are to be operated.

Although gyros are normally temperature sensitive, the AB-5 gyro and AMAB-3 accelerometer design has reduced the temperature sensitivity by using materials with similar thermal properties. Another technique to reduce temperature sensitivity is in mounting the gyro spin motors. The AB-5 spin motor is mounted symmetrically about the output axis, floated on each end, to reduce the effect of a movement of the rotor mass due to thermal expansion of the spin motor shift. The AMAB-3 gyro spin motor is floated on one end only permitting the spin motor mass to move to compensate for thermal expansion of the pendulous mass.

Before the gyros and accelerometers are to be manufactured for high temperature operation an investigation should be performed to determine reliability and life at the new operating temperature. Maximum operating temperature should be determined along with an evaluation of mechanical parts, tolerances and manufacturing procedures.

The carrier ring on which the gyros, accelerometers, pendulums and the porro prism are mounted is limited to ±15° movement in roll and yaw, and -15° to +135° movement in pitch by the gimbal system.

The carrier ring and gimbal structure materials were chosen for similar thermal properties to reduce the problems caused by thermal expansion. Up to temperatures of 180°F the present carrier ring and gimbal structure should be adequate, but an investigation should be performed to evaluate mechanical part fits, tolerances, and manufacturing techniques.

E. Servo Motors and Gear Trains

The torque output of the gimbal and accelerometer servo motors would have to be derated due to the increase in operating temperature. The present maximum torque ratings would theoretically have to be reduced by 7.0% and 7.7% for the accelerometer and gimbal servo motors, respectively, based on a gimbal operating change from 106.7°F to 150°F.

This derating of maximum torque should not seriously affect the system performance since there is a large safety factor to withstand a mass unbalance on the platform during flight. If the derated torque is found to be below that required the gear ratios could be changed or the motors could be replaced by higher torque units.

In meshing the gears of the gear trains care would have to be taken so that the mesh of each pass is neither too loose nor too tight when at the gimbal operation temperature.

F. Cable Harness on ST-120

The cable harness seems to present the most significant problem on the ST-120 platform. The present wire is 30 gauge, 6- by 38-stranded, silver plated copper wire with polyvinyl chloride insulation. The insulation is rated at 140°F. This wire has been used because of its flexibility which offers very little resistance to gimbal movement.

The temperatures anticipated would require a wire with a higher temperature insulation. An investigation would be required to find a suitable wire which should be tested in a platform. The torque, opposing carrier ring movement, would be determined at high and low temperature extremes as well as at the new gimbal operating temperature.

G. Gimbal Transducers

The gimbal attitude transducers, yaw and roll microsyns and pitch control transformer, are electrical pickoffs whose output voltage is proportional to the angle between the missile coordinates and the ST-120 stable platform coordinates. Tests indicate that these transducers are temperature sensitive particularly at the null voltage. The in phase and quadrature voltage at null will vary due to thermal expansion affecting the air gap between the rotor and stator and applying stress to the core material of the stator.

By temperature cycling the transducers in the ST-120 prior to calibration, operation within PERSHING requirements can be obtained.

H. Alinement Transducers and Porro Prism

The alinement tranducers, the yaw and pitch air bearing pendulums and the azimuth pickoff are used to level the ST-120 and aline it with the missile prior to flight.

The azimuth pickoff is a highly sensitive angle sensing transducer that is used to aline vane I of the missile with the ST-120 and aline the ST-120 to the firing azimuth. Any error in the null voltage due to temperature would affect the accuracy of the missile ST-120 alinement and the ST-120 firing azimuth alinement. To reduce the effect of temperature, similar materials have been used where possible in the gimbaling system to minimize the errors associated with thermal expansion. Temperature cycling in the ST-120 prior to calibration would also reduce the effects of thermal expansion by relieving mechanical stresses in mounting and in the magnetic circuit.

The pendulum is an air floated gravity sensitive device. It is not so sensitive to temperature since the slug is air floated. This practically eliminates problems associated with thermal expansion. Further, the air to float the slug is temperature controlled. Prior to installation on the ST-120, each pendulum should be tested at the operating temperature of the ST-120 to assure it is within the requirements for electrical and mechanical zero, scale factor, symmetry and linearity.

The alinement of the porro prism will definitely be affected by variations in temperature but will be repeatable for a specific temperature, therefore it is necessary that the platform be stabilized at the desired operating temperature during calibration.

I. Nulling Card

The nulling card which is used to adjust the calibration of the yaw and roll microsyns, the pitch control transformer, and the azimuth pickoff signals is not significantly affected by temperature. Normal operation can be obtained without any significant changes.

J. Heater Contacts

The heater control switches which sense gimbal temperature and ambient air temperature within the heater cover of the ST-120 would have to be changed based on the desired gimbal operating temperature determined in the first phase of the study.

K. Servo Amplifier Considerations

The servo amplifier box houses the servo amplifiers for the gyro and accelerometer stabilization loops, the pitch cam programmer and various excitation transformers. The present servo amplifier is required to operate in ambient temperatures up to 125°F. When the temperature is increased above 125°F, the performance deteriorates and only marginal performance can be expected at 160°F. Both the stabilizing networks and the gain of the power amplifier have been found to be temperature sensitive.

If the servo amplifier is to be operated in an environment of 140°F, an effort should be made to redesign the amplifiers for optimum stabilization at approximately 140°F. It will also be necessary to modify calibration procedures so that all operational tests of the amplifiers are to be performed at the internal ambient of the servo amplifier.

L. Pitch Cam Programmer

The pitch cam programming device which programs the missile in pitch during flight should not provide any serious problem in operating at temperatures up to 160°F, but in order to improve the reliability it may be necessary to replace the electromagnetic clutch brake by a unit with a higher temperature rating.

It will also be advisable to modify calibration techniques by performing all operational tests in an environment simulating the temperature conditions within the servo box.

M. Inertial Guidance Computer Considerations

The inertial guidance computer receives the acceleration signals from the ST-120 and converts them into suitable velocity and displacement terms to solve the cutoff equation and supply control signals to the control computer.

Although the guidance computer was not designed to operate in an ambient temperature above 125°F, reliability tests indicate that normal performance can be expected up to temperatures of 170°F and possibly higher. The results of these tests specify that there was no physical damage or variations in functional performance.

It will be necessary to review the potentiometers and servo motors to assure reliability at elevated temperatures.

Additional tests should be performed to investigate the reliability and life at these higher temperatures with special attention being paid to slant altitude-cross range integrator feedback capacitors. At an ambient temperature of 140°F, the temperature of the slant altitude integrator feedback capacitor would stabilize at 149°F. If the ambient temperature were to exceed 160°F, the temperature rating of the capacitor would be exceeded.

N. Control Computer Considerations

The control computer receives guidance signals from the ST-120 stable platform and the inertial guidance computer to compute the proper vane deflection maintaining proper course and damping missile oscillations.

Tests have been performed recently with the control computer operating at temperatures above 125°F but at present the results are inconclusive. Two temperature problems seem to be present, drift in the electronic assemblies and changing circuit parameters in the lead network. The most significant drift appears to occur in the demodulators and would result in an attitude error. The drift in the ±25 volt power supply does not present a serious problem since it would affect each guidance input proportionally and could be reduced by adjusting the voltage output with the control computer stabilized at the same temperature that the G&C Compartment is to be operated.

O. Main Distributor Considerations

The main distributor houses the electrical distribution circuits and the switching networks and will not be significantly affected by operating in an ambient temperature up to 160°F. The only electronic assembly, second stage ignition timer in the main distributor, appears to have sufficient temperature compensation to permit proper operation up to 160°F.

P. Exploding Bridge Wire System

The exploding bridge wire system will not be affected by a change in G&C Compartment operating temperature since in the tactical missile an improved design will be placed outside of the G&C Compartment and will not be subject to the temperature conditions of the G&C Compartment.

II. CONCLUSIONS

Until the first phase of the study, where a missile is subjected to a controlled environment to determine G&C Compartment and component operating temperatures, a cost breakdown for individual component investigations and redesign, will not be made. If such information were given at this time it would only tend to misinform the reader since relatively small changes in operating temperatures would affect the estimate.

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APPROVED:

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