Tables

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Summary

Thermal test (R782420) was performed on Pershing II W86 earth penetrator (EP) unit TA6-29 from April 21, 1981, through May 18, 1981. The EP is nominally 6 to 7 inches in diameter by 64 inches long and is packaged inside an aluminum canister.

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Forty-two chromel-alumel (type K) thermocouples were used to instrument the unit. Thermal test conditions were based on the Pershing II W86 Stockpile-to-Target Sequence (STS) thermal environments.[1]

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Test Objectives

The purpose of the thermal test was twofold. One objective was to obtain data to help provide an understanding of the steady-state heat transfer and the transient response of the EP to varying thermal environments. The other objective was to provide temperatures for specific internal components during specific worst-case environments as defined in the STS thermal environments. The environments for the second objective are also the desired environments for the first objective. Some specific subobjectives of the first objective were to look for anomalies and unexpected results, to check the validity of some specific assumptions used in numerical thermal modeling,[2] and to provide a data base to compare numerical thermal model results to experimental data.

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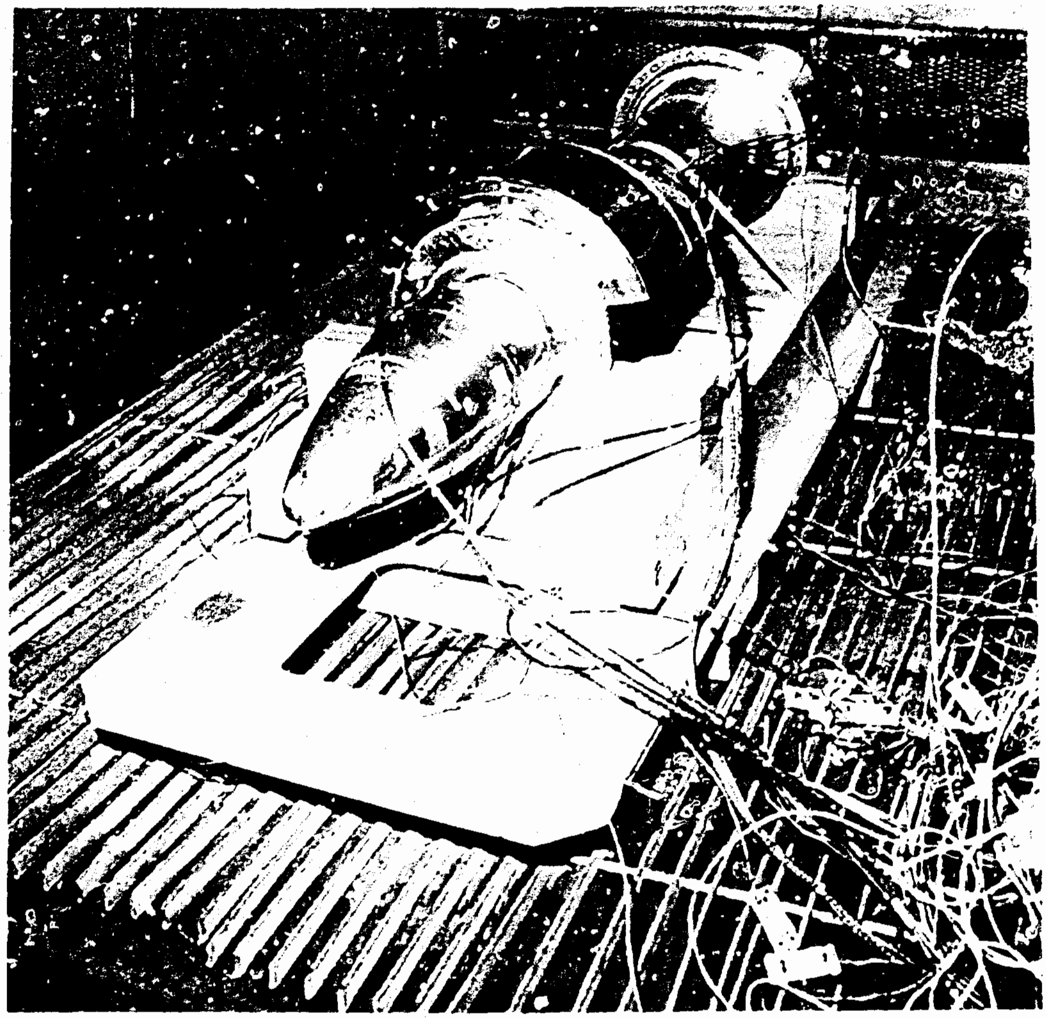

Figure 2. Front Left (South) Side View of TA6-29 Test Unit in Environmental Chamber EC-17

To attain the thermal shock conditions on the unit, the unit was moved from the chamber to the laboratory (which was at a different temperature), or vice versa. For the moderate to cold thermal shock, the unit was first moved from the chamber (which was essentially at lab temperature) into the laboratory. The chamber was cooled to the desired temperature. The thermal shock occurred when the unit was moved from the moderate temperature lab into the cold chamber. Similarly, for the cold to moderate thermal shock, the thermal shock occured when the unit was moved from the cold chamber into the moderate temperature laboratory. The chamber was then brought to the moderate (controlled) temperature and the unit was placed in the chamber. The moderate-to-hot and hot-to-moderate thermal shocks were done in a similar manner. Figure 6 shows the unit outside the chamber while waiting for the chamber to establish a new temperature condition.

Test Results

Test Chamber Environments

As previously mentioned, the actual test chamber temperature history for the entire 28-day test is shown in Figure 5. More detailed plots of the daily cycle temperature histories are given in Figures 7, 8, and 9, for cold, moderate, and hot cycles, respectively. All cycles were begun between 0900 and 1000 hours. Shown in Figures 7, 8, and 9 are the temperature histories beginning at 0900 hours of the second day and also the desired (specified) temperature profiles. Table 3 tabulates the data shown in Figures 7, 8, and 9. The actual and desired (specified) temperatures for the thermal shock and transient portions of the test are given in Table 4.

The mechanical cam adjustment to control temperature in EC-17 did not provide accurate control of the temperature, but it was close enough to provide a good test. The one obviously missed setting was after the moderate daily cycles (Figure 5). An "after the fact" improved procedure to eliminate such discontinuities would be to set the constant chamber temperature by using the cycle cam positioned at the start/stop time of the cycle (and therefore at that temperature) but with the cam not rotating. Then cycles could be initiated by engaging the cam to turn at the proper time and similarly disengaging the cam to discontinue cycling. The cams were cut by hand and the sensitivity of the cams is approximately 0.017-in./°C, which makes accurate control very difficult.

Component Temperature Extremes

The components within a War Reserve (WR) unit must be designed to function under a range of temperatures. In this subsection, the extreme values of temperature of each component are presented. Table 5 gives the temperature extremes for the canister, foam, and the Earth-Penetrator case. The temperature values for the foam are inferred from thermocouples located adjacent to the foam. [redacted]

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components do not have thermocouples directly attached to them, but thermocouples are located on a surface adjacent to the component. Table 7 gives the temperature extremes in the nuclear assembly. Within the Interface Unit, the minimum temperature is essentially the same for all components, and the range in values for the minimum temperature is −33.566°C to −32.707°C, at a time of 210.3611 hours after the start of the test. Likewise, the maximum temperature in the Interface Unit was 63.864°C to 64.657°C, at a time of 509.3611 hours after the start of the test. Since there were no heat producing components in the unit, there is no reason to expect temperature differences within the unit in a slowly varying environment.

Spatial Temperature Distributions in Test Unit

Spatial temperature distributions are given for both steady-state environments and the diurnal cycles. The steady-state results are given in Figures 10, 11, and 12 for the moderate, cold, and hot environments, respectively. The temperatures are plotted versus axial position, and the difference in temperature between inside and outside locations allows the temperatures for all thermocouples to be displayed on one plot (except for the thermocouples in the interface unit). In Figure 10, the thermocouple identification for each temperature-position point is labeled. (Figure 10 should be used as a guide to correlate thermocouple identification and temperature-position points for subsequent plots since the shapes of the curves for other conditions are similar.) The particular times for the steady state plots in Figures 10, 11, and 12 are four days after a thermal shock and immediately before a daily cycle.

The daily cycle temperature results are given in Figures 13, 14, and 15 for cold, moderate, and hot cycles, respectively. Temperature values are shown

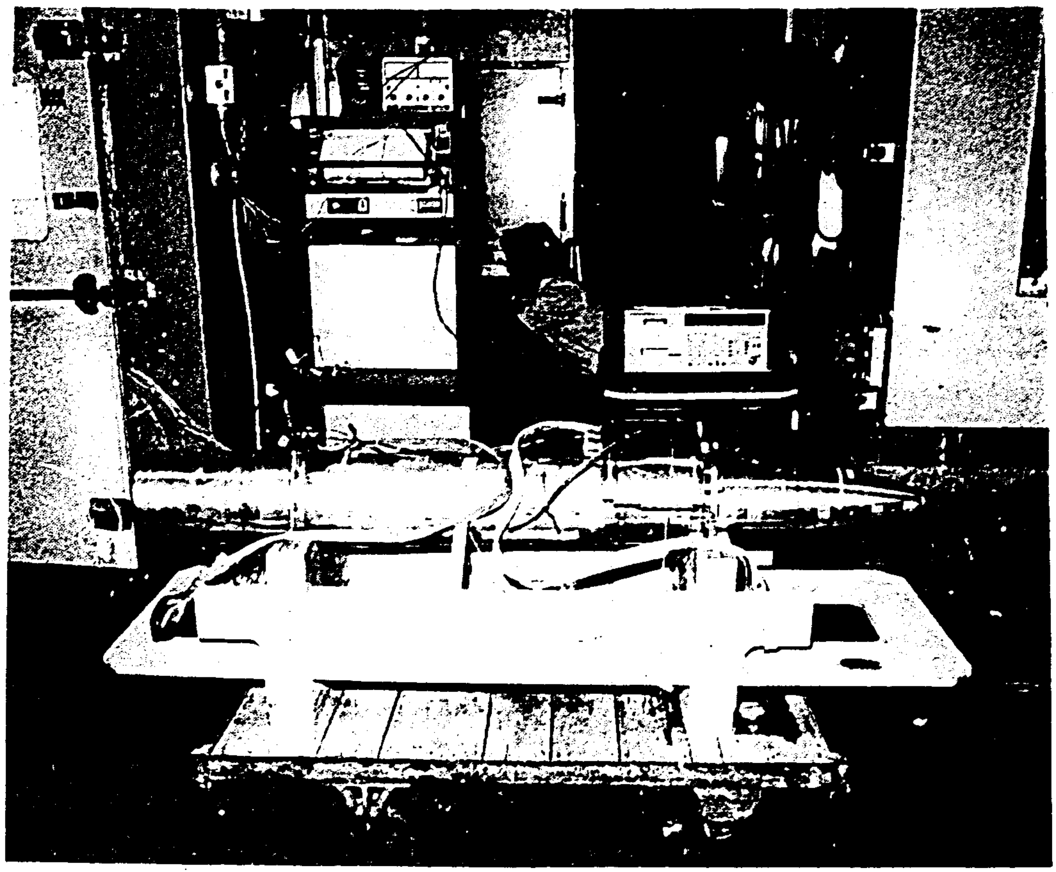

Figure 6. TA6-29 Test Unit Outside of Chamber During Thermal Shock

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Table 7. Temperature Extremes at Locations on Nuclear Assembly

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every three hours during the cycle, beginning at 0900 hr on the second day of the cycle. The chamber temperatures during the cycles are plotted in Figures 7, 8, and 9 for the cold, moderate, and hot cycles, respectively. Maximum internal temperatures occur during the hot cycle.

mum temperature was 0800 to 0900 hr, which lags the minimum of the surrounding air temperature (−34°C at 0400 hr) by 4 to 5 hours. An additional form of the data, temperature versus time, for all components during the diurnal cycles is given in Appendix B.

Thermal Shock Transients for Selected Components

Temperature histories for the thermal shock conditions for selected thermocouples are given in Figures 16, 17, 18, and 19 for moderate-to-cold, cold-to-moderate, moderate-to-hot, and hot-to moderate thermal shocks, respectively.

The plots for each thermal shock condition are plotted on two time scales, 0 to 100 hr, which shows the relative response of the inner components, and 0 to 4 hr, which shows the response of the outer components. Because of the insulating affect of the foam and the large thermal mass (mass x specific heat) of the EP case, the internal components respond very slowly.

Time history plots for every thermocouple are given in Appendix B. Also given in Appendix B are temperature vs axial position plots for various times during the thermal shock transients. Time history plots of temperatures in the interface unit are given in Appendix B. The locations of the thermocouples in the interface unit are given in Appendix A.

Discussion of Test Data

Generally, the thermal test went well and most of the data appear to be good. This section, will discuss some of the anomalies and reasons for suspecting that thermocouples TC28 and TC30 gave erroneous readings. These thermocouples are located on the EP case.

First, consider the expected temperatures on the penetrator case as recorded by thermocouples TC8, TC10, TC21, TC28, TC30, and TC32. It would be expected that the temperature would rise near axial stations 20 in. and 50 to 60 in. due to internal heat-producing components. Considering that thermocouple TC32 was located on the inside of the aft case, and that the foam is thicker on the aft end, it seemed reasonable to expect TC32 to read higher; in fact TC32 more closely matched TC25 (which was on the other side of the nuclear section and mounted similarly with respect to the nuclear section) than other thermocouples on the penetrator case. The temperature of TC28 seemed to be depressed from what would be expected, especially for the cold steady-state (Figure 11) and the cold cycle (Figure 13). The temperature for TC30 seemed to be depressed from what would be expected, especially during moderate and hot steady-state (Figures 10 and 12) and moderate cycle (Figure 14). During the hot cycle (Figure 15), TC30 followed the aluminum canister temperature more closely than the other EP case thermocouples. TC30 was suspect during the test, and upon disassembly, it was discovered that a small amount of green flexible foam was between TC30 and the EP case. Time history plots in Appendix B show that TC28 and TC30 have different characteristics than the other thermocouples on the EP case.

The thermal shock testing involved moving the unit into or out of the environmental chamber, from or to the laboratory. In those cases where the thermal shock occurred by going out of the chamber into the laboratory, a definite change in the aluminum canister temperature was noted when the unit was placed back in the "room temperature" chamber. This is explained by the difference between natural convection from the canister while in the laboratory and forced convection when in the chamber. (Chamber temperature is controlled by circulating either heated or cooled air.)

Another anomaly is that in the high temperature environment, TC7, located in the nuclear section and radially outward from TC2 and TC2P, increased in temperature above the temperature of TC2 and TC2P.

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APPENDIX B

Temperature Plots

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