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Vibration and Thermal Vacuum Qualification Test Results for a Low-Voltage Tungsten-Halogen Light

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VIBRATION AND THERMAL VACUUM QUALIFICATION TEST RESULTS

FOR A LOW-VOLTAGE TUNGSTEN-HALOGEN LIGHT

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SUMMARY

The results of a space flight qualification test program for a low-voltage, quartz tungsten-halogen light are presented. The test program was designed to qualify a halogen light for use in the Pool Boiling Experiment, a Get Away Special (GAS) payload that will be flown in the space shuttle payload bay. Vibration and thermal vacuum tests were performed. The test results indicated that the halogen light will survive the launch and ascent loads, and that the convection-free environment associated with the GAS payload system will not detrimentally affect the operation of the halogen light.

INTRODUCTION

The Pool Boiling Experiment (PBE) is a payload designed to fly in the NASA Get Away Special (GAS) payload system. The purpose of the experiment is to determine the effects of heat flux and liquid subcooling on nucleate pool boiling in a long-term reduced gravity environment. The boiling will occur in a small, sealed test chamber. A film camera and lighting system were designed to film the boiling process through windows in the test chamber. In the course of developing and qualifying the lighting system, a variety of tests were performed on candidate light sources (ref. 1). Because of special restrictions imposed by the experiment's science and engineering requirements, a GE Q20T3CL 24-V, 20-W lamp, potted into an MR-11 dichroic reflector, was chosen as the flight light source.

Two concerns over the use of halogen lamps in a space experiment were addressed in the test program: (1) the ability of the tungsten filament to withstand launch- and ascent-induced vibrations, and (2) excessive heating of the lamp and reflector during operation in a buoyant-convection-free environment.

The GE Q20T3CL is a bare lamp and is not available as a lamp-reflector assembly. Hence, the lamp had to be potted into the MR-11 dichroic reflector. Bare MR-11 reflectors are difficult to obtain, so a GE Q35MR11/SP lamp-reflector assembly was purchased and its reflector was salvaged by removing the original 12-V lamp. An elastomeric adhesive, GE RTV102, was used to pot the Q20T3CL lamp into the salvaged reflector. The adhesive, which was easy to obtain, was expected to be of more help in dampening vibration than the rigid silica epoxy that commercial lamp manufacturers use for potting lamps. It should be noted that no specific testing was performed to validate this hypothesis.

Because of a science requirement to minimize the amount of IR radiation transmitted into the PBE test chamber, a Melles Griot IR mirror (part number 03

MHG 007), attached in front of the lamp, was included in the light assembly design. The mirror reflected nearly all of the forward-directed IR radiation back toward the lamp and out the backside of the dichroic reflector. There was some concern that the reflected IR radiation might raise the temperature of the lamp too much during operation.

Although halogen lamps are designed to operate at relatively high temperatures, the lamp design and the experiment itself dictate how high the temperatures can be. The molybdenum strip in the lamp seal is restricted to operation at less than 662 °F (350 °C), or degradation of the seal can occur. A degraded seal could cause a loss of the high-pressure gas inside the lamp and thereby lead to failure of the filament. The experiment design also imposes a unique temperature limit. The test chamber where the boiling activity occurs is filled with R-113 (trichlorotrifluoroethane), a fluid that is normally quite benign. However, if R-113 should leak from the test chamber and come into contact with the two halogen lamps on the exterior of the test chamber, and if any part of the lamps were at a temperature of 572 °F (300 °C) or higher, the R-113 could thermally decompose into fluorine, chlorine, and other products. Since these by-products are so corrosive, ensuring that the operating temperature of the lamps will not reach the R-113 thermal breakdown threshold becomes very important.

BACKGROUND

Tungsten-halogen lamps are quite similar to normal tungsten filament lamps, except that they have a trace of halogen (normally bromine) added to the fill gas and they operate with higher internal gas pressures. The addition of the halogen results in a regenerative cycle of the evaporated tungsten; this explains why the halogen lamps are capable of operating at higher temperatures, and thus higher efficiencies, than standard tungsten lamps. In order for the halogen cycle to operate, the internal wall temperature of the lamp must be at least 482 °F (250 °C) (ref. 2). When operated at rated voltage, the lamps are designed to run at this temperature in 1-g environments.

The present PBE lighting system design requires two lights that will be operated at different voltages, 14 and 24 V dc, at different times during the experiment. At 14 V dc, the temperature of the quartz lamp interior wall will not reach a temperature high enough to cause the regenerative halogen cycle to function. This condition is not detrimental to the filament, because the reduced voltage decreases the filament temperature to a point where evaporation of the tungsten is negligible (ref. 2). At lower than rated voltage, the expected lifetime of the lamp tends to increase, albeit at the expense of luminous efficiency.

The concern about high lamp-operating temperatures prompted the performance of several thermal vacuum tests to verify that the steady-state operating temperatures would remain lower than the R-113 thermal decomposition limit of 572 °F (300 °C). These tests sought to replicate the cooling conditions that will exist inside the GAS canister during flight operations.

PRIOR FLIGHT DATA

A GAS payload, the Halogen Lamp Experiment (HALEX), was flown on STS 41G to gain a better understanding of the operation of halogen lamps in reduced gravity environments. The investigators, Schmitt and Stapelmann (ref. 3), concluded (1) that there were no detectable disturbances of the halogen cycle (i.e., no deposits of tungsten on the bulb), and (2) that the surface characteristics of the filament after flight were as expected. Furthermore, they concluded that the absence of convection (under microgravity) inside the lamp reduced the convective heat transfer from 5 percent to about 2 percent; this reduced heat transfer, in turn, increased the tungsten filament temperature by about 68 °F (20 °C) and the light efficiency by about 8.8 percent. The lamp flown in the HALEX experiment was a 45-W unit that was designed as a precursor to a 300-W lamp to be used in a materials processing experiment. The 45-W lamp was operated for about 58 hr during space flight.

DESCRIPTION OF FLIGHT LIGHT ASSEMBLY

The design of the flight light assembly is illustrated in figure 1. The main bracket is made from 6061-T6 aluminum. The dichroic reflector is sandwiched between the main bracket and the front IR mirror holder. An adhesive, silicone RTV, was used to glue the reflector to the main bracket and to glue the IR mirror to the front mirror holder. A small amount of RTV was used between the reflector and the IR mirror, but care was taken not to seal the mirror to the reflector. A commercial ceramic electrical connector supplied power to the lamp. The connector had no locking features, so it was safety wired to the main bracket.

TEST

Equipment

Thermal testing was done in a small vacuum chamber that was equipped with electrical feed-throughs for both power and thermocouple leads. The minimum pressure obtained in the bell chamber was approximately 0.2 psia (1.4 mbar); this was deemed sufficient to decrease convective cooling to a small order effect.

For vibration testing, the NASA Lewis Vibration Measurement and Test facility was utilized. A small aluminum adapter bracket was fabricated to allow the lamp assembly to be mounted in a cantilever manner similar to the experiment flight mounting.

Procedure

Other than a few minutes of normal operation at rated voltage, the light assembly received no special preconditioning prior to the start of qualification testing. The light assembly was first vibration-tested and then, subsequently, used for the thermal vacuum testing.

Vibration testing. - Two phases of vibration testing were performed: in the first phase, the lamp-reflector assembly itself was hard-mounted directly to the vibration table; in the second phase, it was assembled into a flightlike mounting bracket and then attached to the vibration table.

Low-level-sine-sweep and random inputs were applied during both test phases. During the hard-mount sine-sweep tests, 5-, 10-, and 15-g rms inputs were applied over a range of 5 to 2000 Hz. With the flightlike mounting hardware, the sine-sweep test was performed at 5 g rms with an accelerometer on the bracket to record the response. A 13.4-g rms random vibration input was constructed from data given in the Get-Away-Special experimenter handbook (ref. 4) (see fig. 2); this input was applied to both mounting configurations of the lamp-reflector assembly.

During the hard-mount tests, the lamp-reflector assembly was subjected to vibration along the two axes that corresponded to directions parallel and perpendicular to the filament's coil. During the tests involving the lamp-reflector assembly and the flightlike mounting bracket, vibrations were applied along the three principle axes of the mounting bracket.

Thermal testing. - After the vibration tests, thermal tests were conducted in an ambient pressure environment and then in a vacuum chamber. The room-pressure tests helped to establish a baseline from which to compare the thermal vacuum test data. The lamp-reflector assembly was left in the flightlike mounting bracket and instrumented with J-type thermocouples on the exterior of the lamp wall. The thermocouples were attached at two places on the exterior wall, at one place on the backside of the dichroic reflector, and at one place on the front side of the IR mirror. Figure 1 illustrates the placement of the thermocouples.

The thermal tests were conducted for periods lasting approximately 16 min, in order to allow the light assembly to attain a steady-state temperature.

During the thermal tests, the light assembly was clamped to an 8-oz block of Al 6061, which in turn was placed on a block of G-11 material. This was done to simulate, in a conservative manner, the mounting of the light assembly in the experiment. In reality, the flight light assembly will mount to a much larger thermal mass, so the test represented a more severe condition than would be experienced during flight.

TEST RESULTS

Vibration Test Results

The light assembly was subjected to the vibration tests outlined earlier. No filament failure occurred, and no audible evidence of resonance was detected. An accelerometer placed on the flightlike mounting bracket showed a structural resonance at about 1300 Hz. The response of the light bracket is illustrated in figure 3.

Thermal Test Results

Ambient pressure. - The temperatures attained during ambient pressure operation are shown in figure 4. The maximum temperature was recorded by the thermocouple on the lamp exterior sidewall; the lowest temperature was recorded by the thermocouple on the mirror.

Vacuum. - The temperatures attained during vacuum testing are shown in figure 5. The temperature distribution was about the same as that obtained for the ambient pressure test, but the temperatures increased under the vacuum condition. The maximum steady-state temperature of the lamp exterior wall did not rise above 550 °F (288 °C). Note, however, that the lamp wall temperature under vacuum test conditions was approximately 50 to 60 °F (10 to 16 °C) higher than that recorded during ambient pressure tests; this difference is close to the HALEX experiment results reported by Schmitt and Stapelmann.

DISCUSSION OF TEST RESULTS

The presence of a structural resonance of the flight light bracket at about 1300 Hz is not considered to be detrimental to the lamp. The vibration environment inside the GAS canister during ascent, which is discussed in reference 5, indicates that the bulk of the vibration input occurs at frequencies under 1000 Hz. Vibration testing showed that the flight lamp will withstand vibrations in the frequency range of 5 to 2000 Hz; these test results concur with the general characteristics of lamps built with a C-6 type of coiled filament.

The vacuum operating temperature of the bulb sidewall (the hottest surface) was shown to be about 22 °F (12 °C) below the decomposition temperature limit of the R-113 fluid. This temperature is considered to be conservative, because a relatively small thermal mass was used during the vacuum test. In addition, during STS flight the GAS canister will have a 10 psia dry-nitrogen environment that will afford some degree of conductive cooling from the bulb to the surrounding reflector.

The temperature data appear to track with data taken during the HALEX GAS payload flight. The increase in lamp temperature due to operation in a reduced gravity environment will be associated with an increase in light efficiency and luminous output.

The PBE photographic system was tested with various voltages for the light, and the system design was shown to be tolerant of the expected changes in the lamp's luminous output due to increased lamp efficiency under microgravity conditions.

CONCLUDING REMARKS

The GE Q20T3CL lamp, potted with RTV adhesive into an MR-11 dichroic reflector, was demonstrated to be capable of withstanding environments similar to those experienced by Get-Away-Special class payloads. The tests showed that the flight light assembly will withstand the vibration loads typical of a Get-Away-Special payload and that the absence of convective cooling does not cause a prohibitive increase in the bulb operating temperature when the bulb is operated at its rated voltage, 24 V dc.

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REFERENCES

1. Ling, J.S.; and Laubenthal, J.R.: Design and Test of a Compact Optics System for the Pool Boiling Experiment. NASA TM-102530, 1990.
2. Gilway Technical Lamp Engineering Catalog 160. Gilway Co., Woburn, MA, 1989.
3. Schmitt, G.; and Stapelmann, J.: Halogen Lamp Experiment, HALEX. 1985 Get Away Special Experimenter's Symposium, L.R. Thomas and F.L. Mosier, eds., NASA CP-2401, 1986, pp. 141-149.
4. Get Away Special (GAS) Small Self-Contained Payloads: Experimenter Handbook. Goddard Space Flight Center, 1989.
5. Talapatra, D.C.: Analysis of STS-3 Get Away Special (GAS) Flight Data and Vibration Specification for GAS Payloads. NASA TM-85000, 1983.

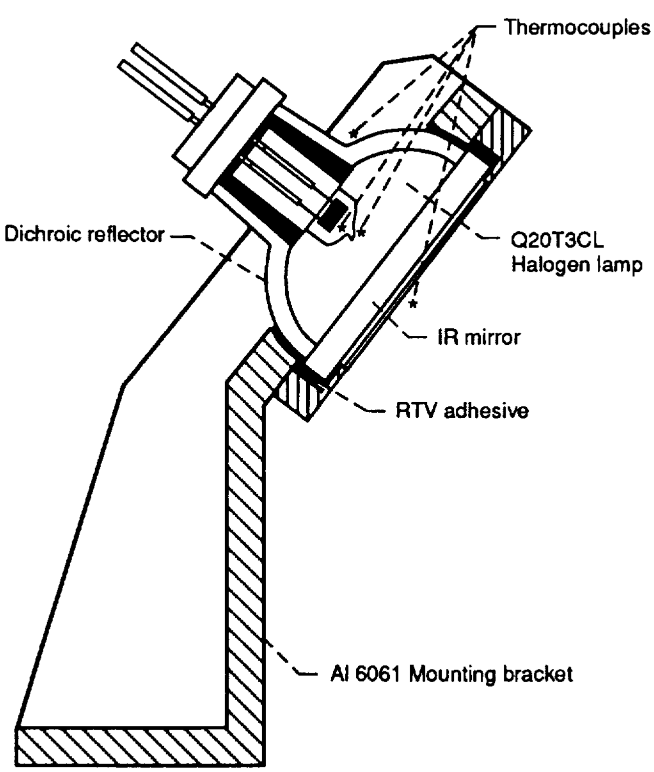

Figure 1.—Flight light assembly design.

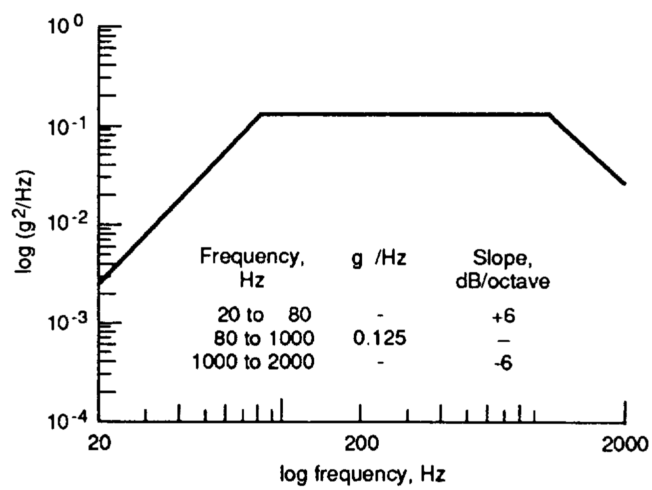

Figure 2.—Random vibration spectification; 40 sec in each axis.

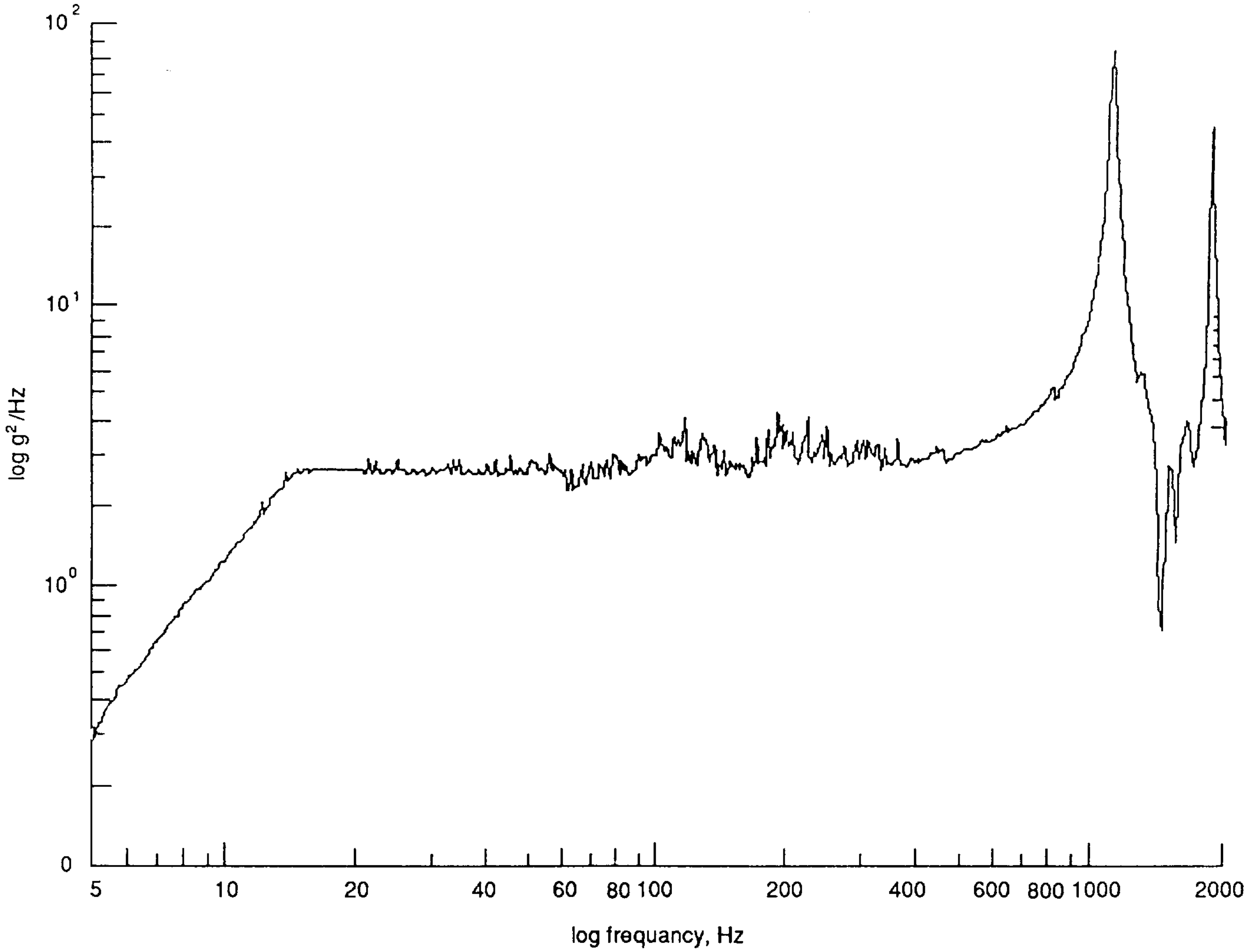

Figure 3.—Response of light bracket to vibration test.

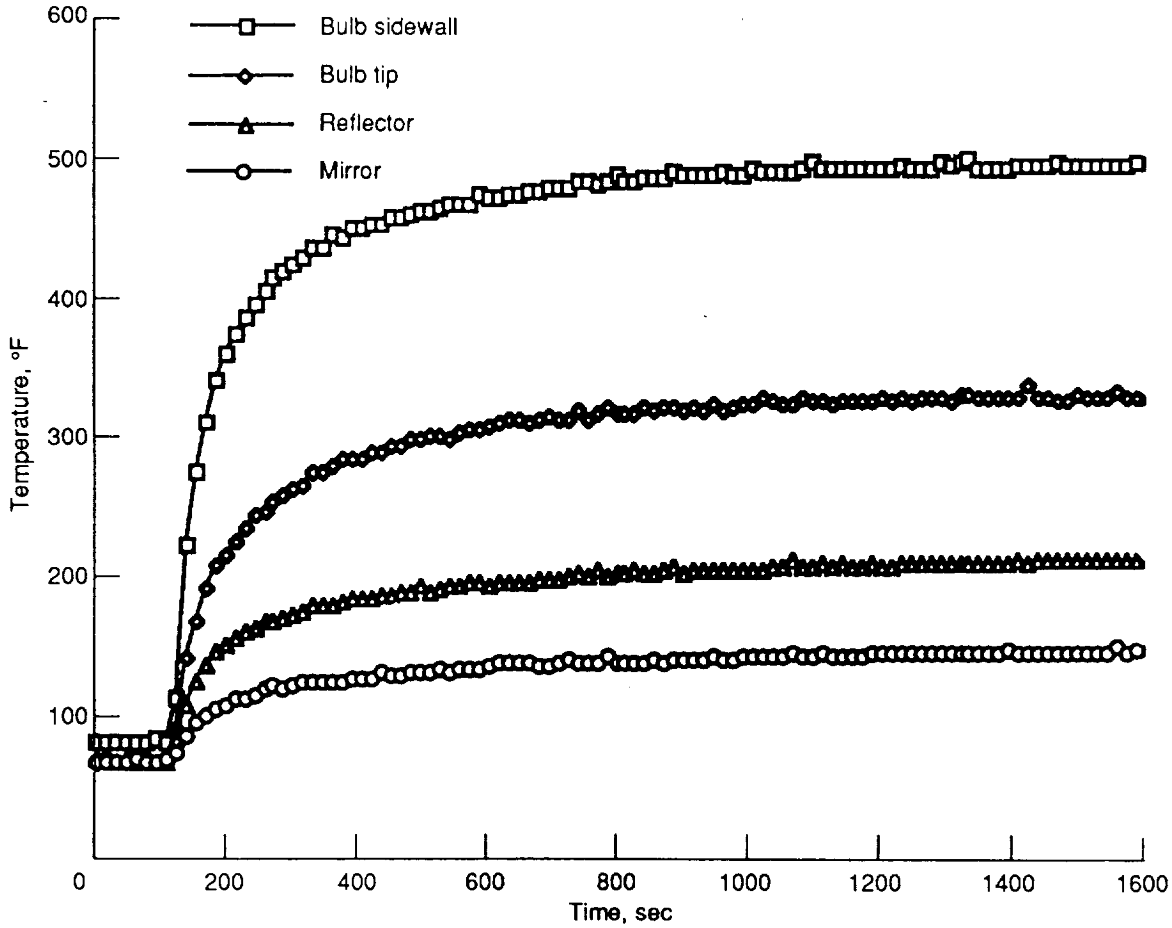

Figure 4.—Ambient pressure operation test results for the PBE flight light assembly at 24 V dc.

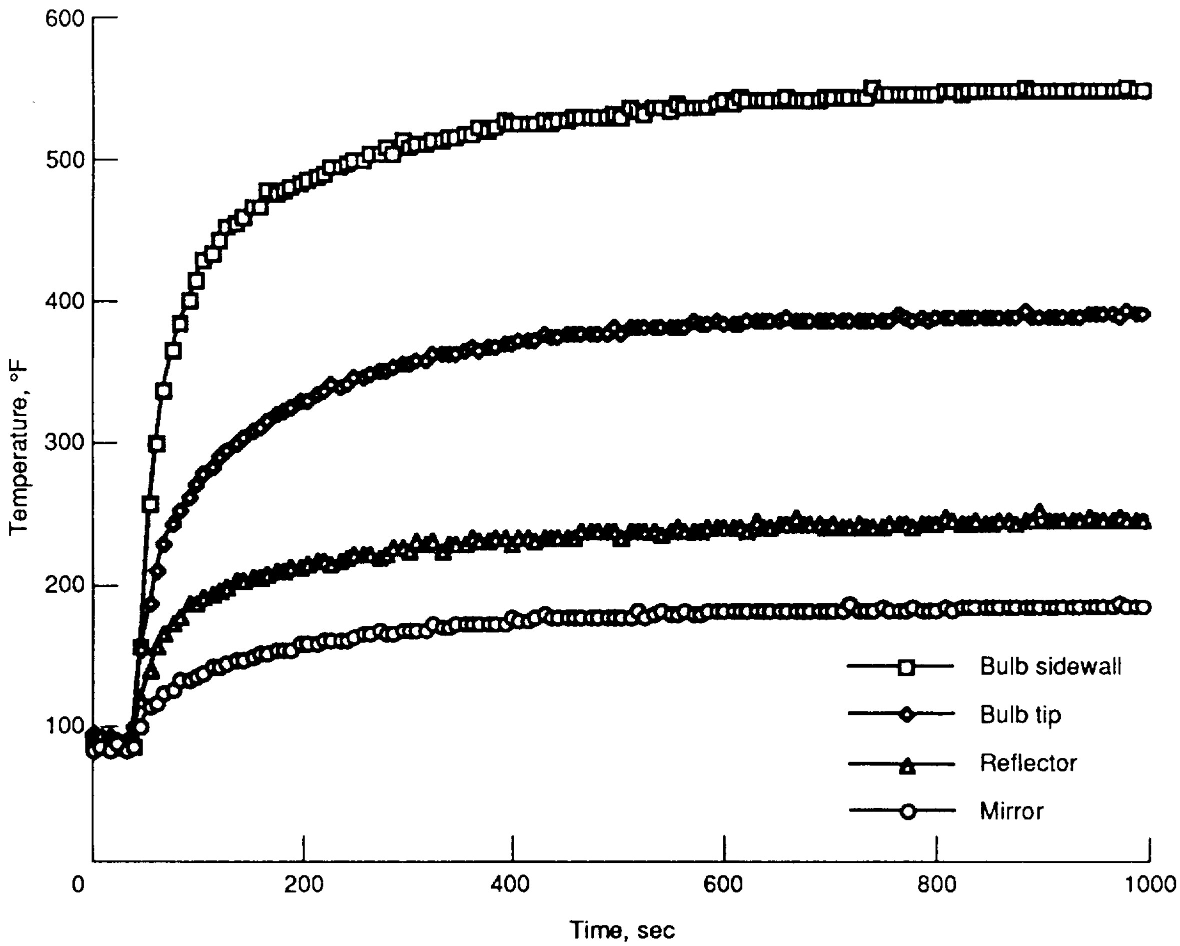

Figure 5.—Vacuum operation test results for the PBE flight light assembly at 24 V dc.

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