MASSACHUSETTS INSTITUTE OF TECHNOLOGY

# APOLLO

## GUIDANCE, NAVIGATION AND CONTROL

MIT INSTRUMENTATION LABORATORY

CAMBRIDGE 39, MASSACHUSETTS

Henry Howard
EG14

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

# APOLLO

## GUIDANCE AND NAVIGATION

Approved: Eldon C Hall Date: 9/12/68
ELDON C. HALL, DIRECTOR, DIGITAL DEVELOPMENT
INSTRUMENTATION LABORATORY

Approved: D. G. Hoag Date: 13 Sep 68
D. G. HOAG, DIRECTOR
APOLLO GUIDANCE AND NAVIGATION PROGRAM

Approved: Ralph R. Ragan Date: 20 Sept 68
RALPH R. RAGAN, DEPUTY DIRECTOR
INSTRUMENTATION LABORATORY

E-2280

# SOLID STATE DSKY STUDY

by

L. David Hanley

August 1968

MIT INSTRUMENTATION LABORATORY
CAMBRIDGE 39, MASSACHUSETTS

## ACKNOWLEDGMENT

This report was prepared under DSR Project 55-29470, sponsored by the Manned Spacecraft Center of the National Aeronautics and Space Administration through Contract NAS9-6823 with the Instrumentation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.

Messrs. R. E. Schulte, J. F. McKenna, and R. B. Kendal have been major contributors to this report.

E-2280

# SOLID STATE DSKY STUDY

## ABSTRACT

The component problems and the events leading to the DSKY redesign contract are described. In a separate section the problems involved in modifying the DSKY are discussed and a review is given of the available options and the reasons for selecting the final design. The appendices cover the test data measured on some representative modules.

by L. David Hanley

June 1968

TABLE OF CONTENTS

# SECTION 1

# INTRODUCTION

Before describing the results of the study, a summary of events leading to the DSKY redesign contract should be reviewed. The first indication of a problem occurred in early DSKYs delivered to the MIT/IL System Test Lab, when it was observed that segments failed to light. The Block I DSKYs utilizing the full crystal-can relay and new electroluminescent panels were the first to exhibit relay-failure modes. It was determined that vibration testing triggered the failure modes exhibited by the Block I relays. Because the relays were not exposed to a vibration environment, these failure modes were not detected during relay-life testing.

The Block II DSKY had similar problems. Out of eight Block II DSKYs at MIT/IL, eleven IDM modules and two electroluminescent light panels had to be replaced. These DSKYs were subjected to no more than ordinary handling conditions.

Early in 1966 it was concluded that the Babcock half-size crystal-can relays presently used in the Block II DSKYs were not of Apollo flight quality. The ACED critical material status report dated 18 July 1966 documented this fact. Subsequently, changes were made in the Babcock production line, a relay Flight Process Specification No. 1002341 (FPS) was introduced, and Filtors and ESI were brought in as new vendors. Additionally, the relay part numbers were changed to ensure that none of the old relays would find their way into flight equipment.

Changes in inspection requirements and the addition of new vendors did lead to relay improvement, but now, since the problem was defined, closer attention was given to the relay and its environment. Since particles and general contamination were the cause of most early failures, a vibration screen was introduced. When high transmissability was discovered in DSKY IDM modules, exposure of relays to a much higher vibration level than previously anticipated became apparent. As a result, the type and intensity of vibration levels became an important consideration.

A vibration profile that would subject the relays to a vibration environment compatible with the Apollo mission was devised. The vibration was successful in detecting additional contamination failures, but also revealed new open-contact failure modes. Earlier, it had been assumed that open contacts were caused by particles being lodged in the armature thus preventing contact closure. It was later determined that many of the opens were mechanically closed but exhibited high-resistance contacts. The hypotheses presented for the high-contact-resistance failure mode were never sufficiently backed by tests or data to determine origin and causes of the problem. The hypotheses did not explain the fact that most of the failures occurred at only one set of contacts.

Because of the defined dilemma, a test was devised whereby a lot of relays would be subjected to a sequence of intervals of vibration until an interval was reached during which no failures occurred. Eighty-five "good" Filtor relays were subjected to this test. The relays went through 16 vibration intervals before a zero-failure interval occurred,and then the test was stopped. In reviewing the data in which the distribution of failures up to the fifteenth interval was completely random, the question arose whether the zero-failure interval was also a random event. That is, would the 17th and 18th interval also generate zero failures or would additional failures be generated? Also, since only twenty-six relays survived, the effectivity of the vibration as a screen was questioned. A significant point of the test was that most of the opens again occurred at the fixed flexible contact which incorporated materials different than the other contacts.

Subsequently a relay FPS imposed a vibration screen on IDMs D1 through D35. When fully flight-processed relays were built into the IDMs, additional failures occurred and at least three DSKYs, which had vibration-screened IDMs, failed during sell-off.

In addition to the relay problems the electroluminescent panels exhibited light-intensity-level problems, continuous light degradation with use, and poor hermeticity. The light degradation is so severe that the electroluminescent panels must be limited to less than full brightness during test to conserve light intensity.

It is easy to lose sight of the DSKY problem since it only becomes evident in a vibration environment. During field use the handling of the DSKY will not likely introduce new failures. Although little is known about the particle behavior in a zero-G environment, it is conceivable that particles dislodged during boost could cause additional failures. Since the high-contact-resistance failure mode is still unresolved, one can only guess what will occur in these environments.

In summary, the following points should be made:

1. In spite of tighter inspection and introduction of a relay FPS, the Block II DSKY relay has continuously remained a component problem in the critical material review from the middle of 1966 to today.

2. A review of relay history indicates that no effective screen has been devised to assure the required reliability.

3. A failure mode exists for which the cause is unknown.

4. The state-of-the-art of relay manufacturing is not sufficiently advanced for the Apollo DSKY application, and the refinements imposed on the manufacturing process have yielded very little additional reliability.

5. The wear-out problem has not been investigated, although the number of relay-switching cycles is limited during ground test in an attempt to extend the relay life.

The preceding was given only to define "the areas of marginal reliability that exist in the Apollo design"[1], namely, the relays and electroluminescent panels. The next section will cover the ground rules of the present redesign, define some of the resulting problems, and discuss some of the still-unresolved problems.

---

[1] DSKY Work Statement.

## SECTION 2

## REDESIGN GROUND RULES

The following ground rules were considered for the DSKY redesign:

1. No physcial changes to the spacecraft.

2. No electrical changes to the spacecraft. Alarm power critically affects the DSKY. The power to drive the DSKY alarm panel comes directly from the spacecraft and is 0-to-5V ac, 400-cps in the command module, and 2-to-5V dc in the LM. These voltages are controlled by the common dimmer control in each spacecraft.

3. No computer program changes.

4. No DSKY frame changes. All modifications must be made to the plug-in modules of the DSKY. This rule was made because it appeared that field retrofit would be necessary before the first manned mission.

5. No wiring changes. If the DSKY were modified for the AAP extended missions then DSKY wire-wrap program changes would be advantageous, but this would not imply any hardware alternations to the DSKY frame.

6. Minimize number of relays.

7. Eliminate the electroluminescent panels.

# SECTION 3

# DSKY REDESIGN

The relays play a dominant role as both the logical and switching element in the present Block II DSKY. The DSKY receives a word from the computer which contains the data to be displayed and the data address. The address part of the word selects the bank of switching relays for which the data is intended. The data is then used to activate the coils of the latching relays which connect by relay contacts the appropriate electronic numeric or alarm segment.

Logical and storage functions previously performed by the DSKY relay are now accomplished by the standard Apollo computer flatpack integrated circuits. The flatpacks are mounted on weldable multilayer boards similar to the AGC logic modules. Much of the logic circuitry consists of flip-flops which store the information received from the computer. This function was previously performed by the latching relay. The outputs of the flip-flops drive the SCD 1006323 transistors which in turn switch the light bulbs on and off. The transistors replace the functions previously performed by the contacts of the switching relays.

For the most part, driving the numeric section is straightforward. When the design changes were originally proposed, consideration was given only to the elimination of the relays driving the numerics panel which was made possible by the advent of Pinlite numerics. A DSKY prototype was designed eliminating all the relays driving the numerics panel. This prototype was constructed using Pinlite numerics. (See Fig. 3.1)

No previous attempt had been made to eliminate the alarm relays even though the loss of an alarm relay constitutes a major system-reliability problem. The elimination of the alarm relays has, in the past, been avoided because of the electrical characteristics of the spacecraft. Since the alarm power supplied by the spacecraft is ac in the command module and dc in the LM, the elimination of the alarm relays is indeed difficult. The added stipulation that no power grounding of the spacecraft power be allowed in the DSKY further complicated the problem. The relay as a logic device is unique in that it can switch either ac or dc equally well and does not require the switched output signal to have a common ground with the input to the relay.

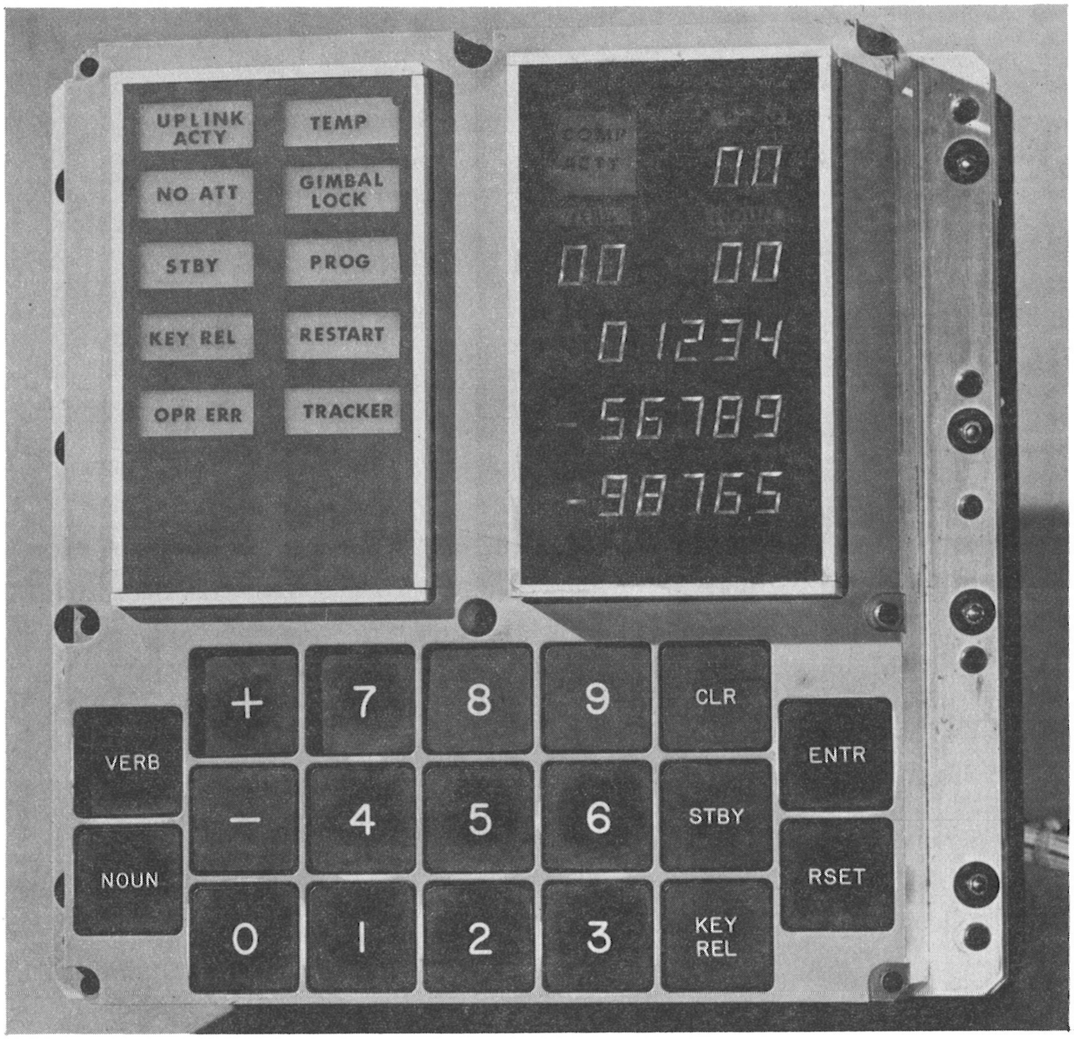

UPLINK ACTY
TEMP
NO ATT
GIMBAL LOCK
STBY
PROG
KEY REL
RESTART
OPR ERR
TRACKER
00
00
00
01234
-56789
-98765
+
7
8
9
CLR
VERB
ENTR
-
4
5
6
STBY
NOUN
RSET
0
1
2
3
KEY REL

Fig. 3.1 DSKY

The solution adopted by the present DSKY redesign is to drive the DSKY entirely with the computer power. The AGC supplies 28V and 14V to the DSKY, driving everything but the alarms. In the DSKY redesign the power supply converts 28V to a voltage suitable to drive the new panels. The generated voltage is proportional to spacecraft dimmer control input.

The original DSKY power supply furnished the 250V, 800-cps to the electroluminescent panel at a low power level. For the redesigned DSKY, the DSKY power supply is now required to power both the incandescent numerics and incandescent alarm panel. The original alarm panel required 250 ma per alarm segment which is too heavy a load for the redesigned DSKY power supply. Thus the requirement for a more efficient alarm panel was established. Even the newest alarm panel still presents at best a marginal condition. The alarm power is very close to the maximum that is available, and the alarm segments are still not intense enough to pass ICD requirements.

The present design does not require any wiring modification to a standard DSKY. The complete retrofit can be accomplished by plugging in a standard Block II DSKY, a numerics panel, an alarm panel, a power supply module, and the six new IDM modules. When this design originated, the alarm panel had been modified from 14 alarms. One of the problems encountered in the new design was powering the alarm modules without disturbing any of the existing wiring, including the wires carrying spacecraft power to the alarm panel. The four alarm segments that were no longer used did have wires that went to the alarm panel from the IDM modules, so that, by a complicated path from the power supply, to the IDM modules, to the alarm panel, the panel is powered without adding new wiring. This long path for the wiring of alarm power constitutes significant resistance. As the number of alarm segments are turned on, the light output of the segments decreases, indicating that the wiring resistance is not negligible.

The design, which does not modify the wiring, works as long as only 10 alarm segments are required. More recent negotiations disclosed the desire to return to the 14-segment alarm panel which would force the use of wiring changes for alarm power.

There are several additional problems in the present DSKY which have not received general discussion. One problem is related to dimming of the DSKY. In the spacecraft there is only one dimming control. The tracking characteristics of the numerics and alarm panels are shown in Appendix A. Figure A. 3 gives the latest changes to the NAA dimming control which help to alleviate some past problems (see Fig. A. 2). One problem that still has not been resolved is: When the astronaut turns the dimming pot down so he will not be bothered by the flashing numerics panel, the alarm panel is also dimmed so that in any emergency no alarm indication would be visible.

Another problem is that the present IL alarm and numerics panels do not conform to the ICD specifications. These discrepancies are:

1. The panels project beyond the face of the DSKY. Discussion with NAA personnel indicates that this would not be a serious problem since the crew couch excursion does not interfere with the panel location.

2. The numerics lettering size is less than 1/2-inch as called out by the present DSKY specification. Since the new numerics panel has much higher contrast than the electroluminescent panel and is much easier to read, this item can most probably be negotiated. Other numerics in the spacecraft are less than 1/2-inch.

3. The alarm segment areas are not as large as the old alarm segment, and the lettering is also smaller. This was required to reduce power. Maintaining the same area as the old segment would require about the same current (250 ma) per segment as the present alarm panel. The present new power supply is not capable of supplying enough power for the old alarm panel.

4. The color and light intensity do not meet the SCD requirements. An indication of the required work that must still be done with the vendor to correct the panel with respect to color and light uniformity is indicated in Appendix B.

## SECTION 4

## WORK REQUIRED TO COMPLETE DSKY REDESIGN

4.1 Numerics Panel

a. Improve the light uniformity across the numeric segment.

b. Establish uniformity in light intensity from segment to segment.

c. Reduce the overall height of the numerics panel.

d. Provide fireproofing by testing the present epoxy-filled material or by adding a glass face.

e. Qualify the numerics panel with respect to photometric, electrical, mechanical, and environmental conditions.

f. Run numerics light-bulb reliability tests.

g. Write an SCD on the numerics panel.

h. Establish adequate inspection criteria for the light bulbs to:

   h1. Provide reliability.
   h2. Provide light-intensity uniformity.
   h3. Eliminate light-intensity variations with time.

i. Modify the numerics packaging scheme to incorporate an all-welded construction.

j. Negotiate the ICD changes required by the change in numerics panel.

k. Write a photometric design requirement.

4.2 Alarm Panel

a. Improve the light uniformity across the alarm segment.
b. Establish uniformity in light intensity.
c. Determine methods of increasing the light-intensity efficiency by:
   c1. Decreasing segment cavity.
   c2. Decreasing segment area.

d. Improve segment color, both the white and yellow. This is especially difficult because of the requirement of operating at higher efficiency and at lower voltages.

e. Reduce the overall height of the alarm panel.

f. Provide fireproofing by testing the present alarm panel materials or by adding a glass face.

g. Qualify the alarm panel with respect to photometric, electrical, mechanical, and environmental conditions.

h. Run alarm-panel light-bulb reliability tests to determine failure modes. Since intensity and light tracking with the numerics panel is required, the light bulbs may be different from those used in numerics panel.

i. Establish adequate inspection criteria for the light bulbs to:
   i1. Provide reliability.
   i2. Provide light intensity conforming with voltage.
   i3. Eliminate light-intensity variations with time.

j. Modify the alarm package scheme to incorporate an all-welded construction.

k. Make the alarm panel the same height as the numerics panel.

l. Negotiate the ICD changes required by the changes in the alarm panel.

m. Write a photometric design requirements.

4.3 Alarm and Numerics Tracking Problem

When the light intensity on the numerics is reduced, the alarms are not visible. All Block II DSKYs exhibit this problem. The problem can be improved but not completely solved by providing a more efficient alarm panel. What would really be required is two power supplies, one to drive the numerics panel, the other to drive the alarm panel. This cannot be accomplished in the space presently provided in the power-supply module.

4.4 Present Redesign Ground Rules Review

a. The present wiring scheme is at best marginal.

b. If the number of alarm segments is increased to above ten, wiring changes are required.

4.5 Design Drawings

A new set of design drawings will be required.

4.6 New Relay

Provide a better relay full-crystal can. Since only five relays are used, a new and more reliable full-crystal-can relay could be used.

## SECTION 5

## CONCLUSIONS

The reason for considering a DSKY redesign is the poor reliability performance of the relays. Even with the special selection care and vibration screen the relays do not meet the requirements of an Apollo mission. To date the problems have been related to the workmanship area. The problem of relay wear-out has not been extensively studied and may still be a future problem.

There are several alternatives to a Block II DSKY retrofit.

1. Eliminate 112 relays and the electroluminescent numerics panel, leaving the present alarm panel and the relays driving the alarm panel. No DSKY wiring changes.

2. Eliminate 126 relays, the electroluminescent numerics panel, and the alarm panel. No DSKY wiring changes.

3. Eliminate 126 relays, the electroluminescent numerics panel, and the alarm panel. Add minor DSKY wiring changes.

4. Eliminate 126 relays, the electroluminescent numerics panel, and the alarm panel. Add major wiring changes.

5. Redesign the DSKY to eliminate 126 relays, the electroluminescent numerics panel, and the alarm panel. Add a new combined numerics and alarm panel which increases the number of display registers. DSKY wiring and structural changes are necessary.

The number of relays cannot be reduced below 6 because of the ICD requiring a relay interface with the spacecraft.

The first alternative involves a new numerics panel. The remaining changes are made in the power supply and IDM module. This approach eliminates most of the relays and the electroluminescent panel. The remaining problems associated with the incandescent numerics panel can be solved by providing adequate optical filtering in the panel face.

The second, third, and fourth alternatives require a new alarm panel in addition to the numerics panel. Even though the new alarm panels received to date look extremely promising, the question whether the alarm panel current will exceed the capacity of the power supply has not been resolved. The alarm panel can probably be made efficient by improved optical filters, a smaller light cavity, and a different filament in the light bulb. The alarm panel will probably require a small number of DSKY wiring changes because of excessive current and may even require a new power supply.

The fourth alternative with major DSKY wiring changes is necessary if all the IDM modules are to be interchangeable.

With the lead time required to get a new DSKY flight-qualified and approved, the fifth alternative must be considered. Since the projected requirements of the AAP missions require additional display capability, it may be desirable to completely redesign the DSKY. The lead time for the complete DSKY redesign would be equivalent to the third or fourth alternatives. It is feasible to double or triple the number of display registers in the same physical size as the existing Block II DSKY.

If an early field retrofit is necessary the only allowable choice is the first alternative, with a new numerics panel, a new power supply, and new IDM modules. New modules could be produced and tested and plugged into the DSKYs in the field. This alternative would also require the shortest lead time.

# APPENDIX A

## DSKY DIMMING CHARACTERISTICS

This appendix consists of three figures of DSKY dimming characteristics included for comparison.

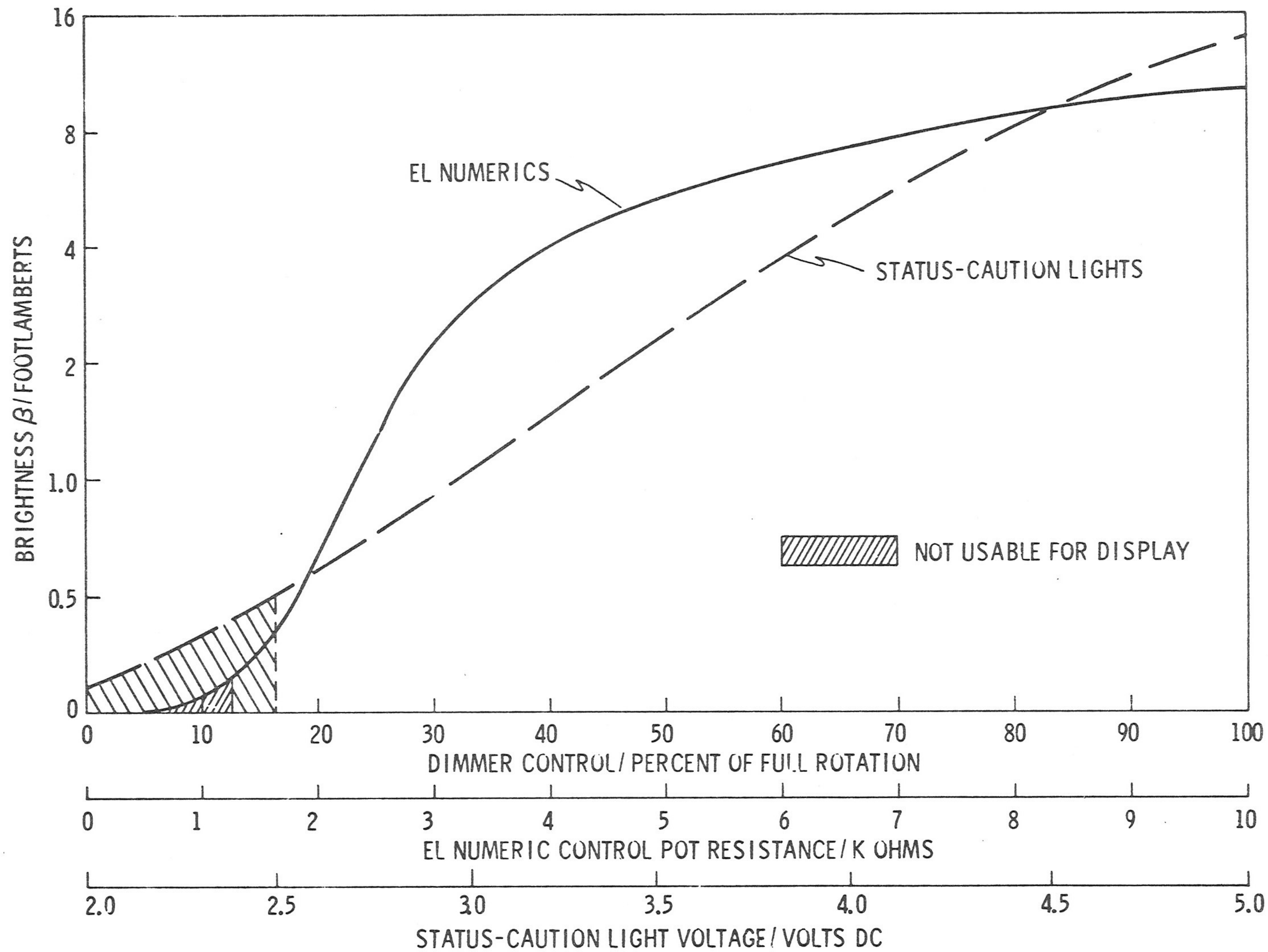



Fig. A. 1 GAEC DSKY Dimming Characteristics (estimated).

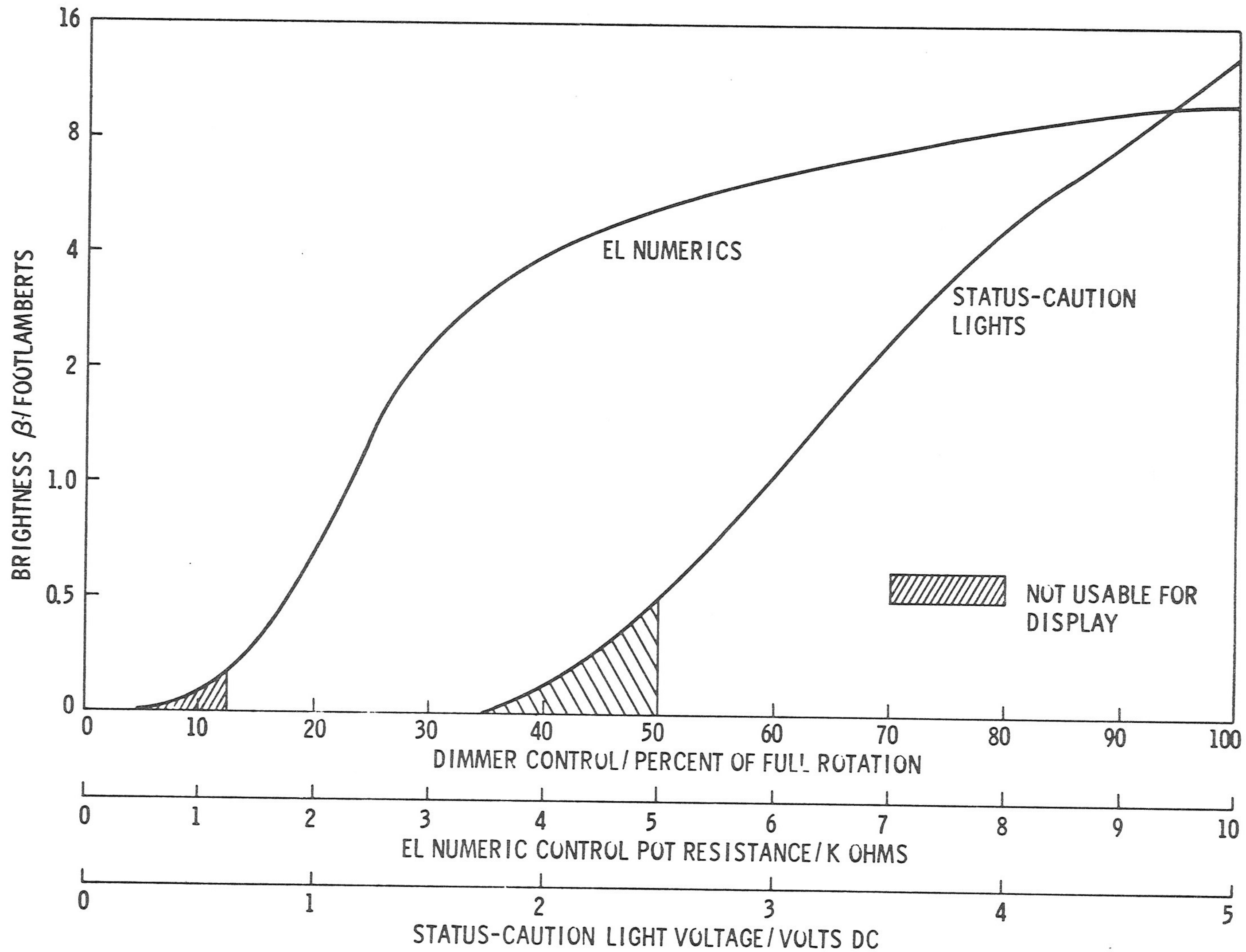



Fig. A.2 NAA DSKY Dimming Characteristics; Present Configuration

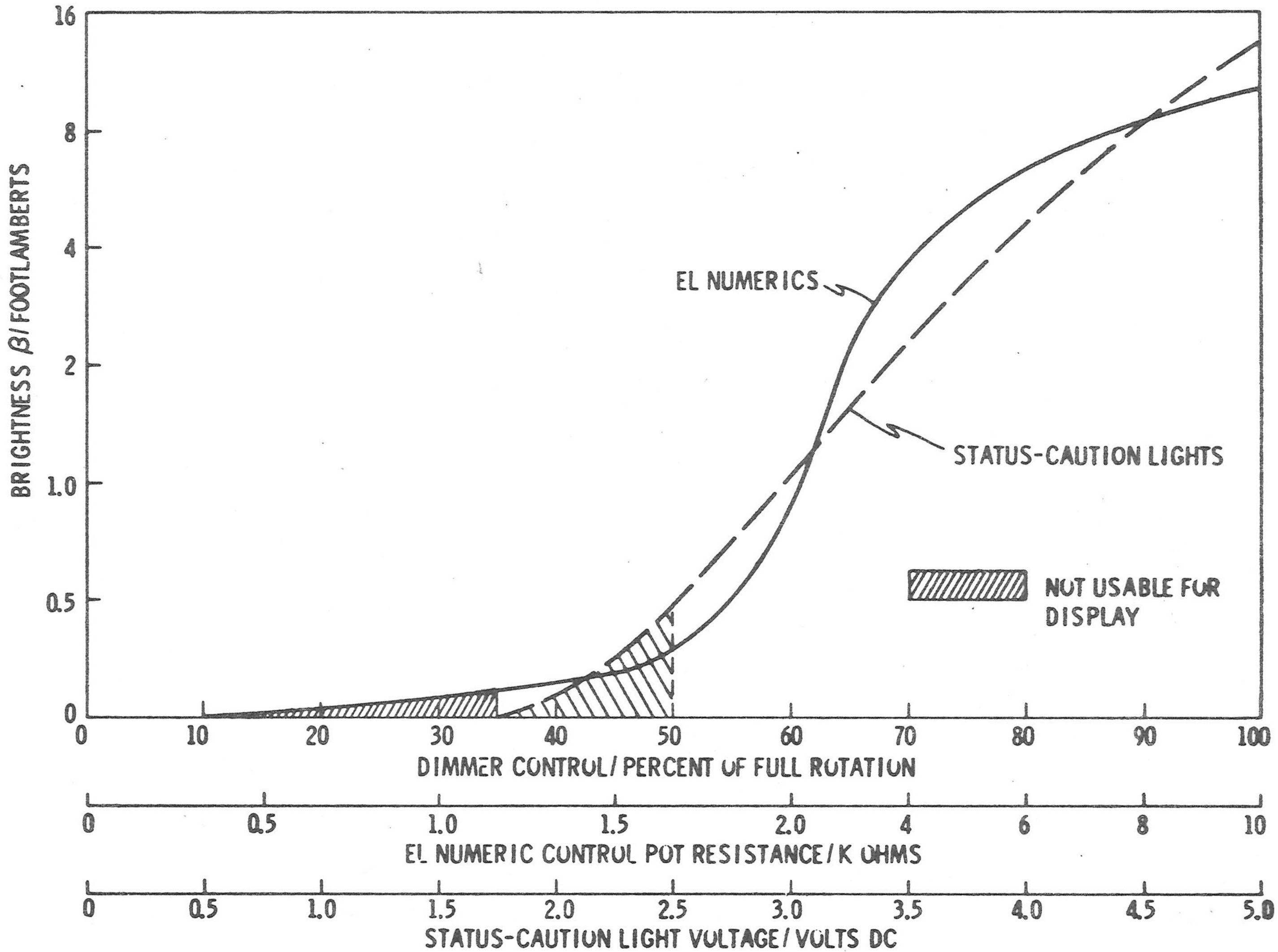



Fig. A. 3 NAA DSKY Dimming Characteristics; NAA Proposed Configuration

## APPENDIX B

## ENGINEERING EVALUATION OF INCANDESCENT NUMERICS AND ALARM PANELS

### B.1 Summary

Incandescent numerics panels were ordered from Pinlite and Tung-Sol.

The Pinlite unit consisted of long helical filaments strung between support pins to form the numerics segments. Because the long filaments are particularly vunerable to mechanical stress, an extensive vibration test was performed (section B.2). Figure B.1 shows the Pinlite construction.

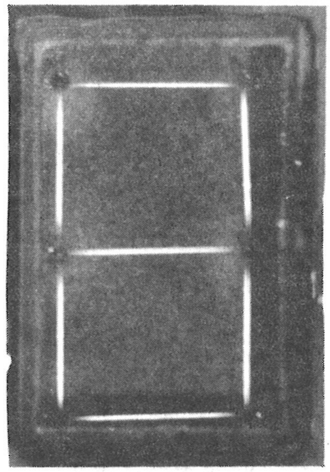
Section B.3 analyses the brightness, voltage, current, and uniformity measurement of the Tung-Sol numerics unit, which consists of small light pipes which make up the numeric characters illuminated by subminiature light bulbs. The material for the light pipes is "merlon" with the remaining panel consisting of filled epoxy. Figure B.2 shows the ends of the light pipes and emphasizes some of the non-uniformity of the segments. Even though Section B.3 points up many problems in the numerics panel, these problems have solutions. Most of the problems can be solved by adequate optical filtering.

The material used in the numerics panel may pass the fireproofing Apollo requirements. If they do not, provisions have been made to add a glass plate over the panel face similar to that which is used on the new Block II fireproofed alarm panel.

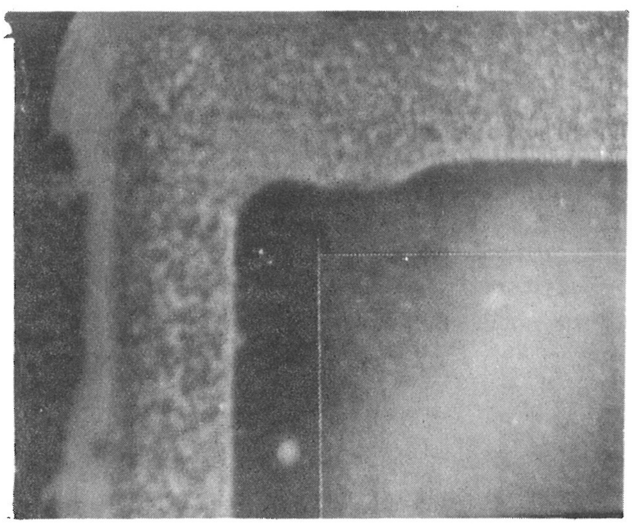
In conclusion, on the basis of the limited evaluation of Tung-Sol and Pinlite panels, the Tungs-Sol approach seems to be the best for a DSKY retrofit program.

### B.2 Pinlite Evaluation (DDG Memo 380)

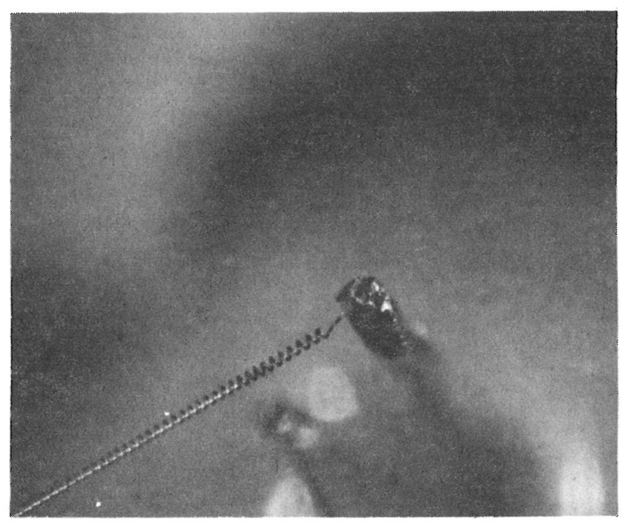
| | |
|---|---|
| TEST NO: | 1 |
| DESCRIPTION: | Lamp |
| VENDOR: | Pinlite, Inc. |
| VENDOR P/N: | 08-60 |
| DATA CODE: | January 1967 - three specimens |
| USAGE: | Display |



(a) 3.7× magnification



(b) 24.4× magnification



(c) 48.8× magnification

Fig. B.1 Pinlite

Initial Conditions

Three lamps were cemented on a fixture using Eastman 910; one lamp in each orthogonal position.

Vibration Limits

20-2000 cps in five minute sweeps up to 35 G's rms. Up to 40 G's at discrete frequencies, e.g., 500, 1000, 1500, and 2000 cps.

Shock Limits

50 G's one-half sine wave for 11-ms duration.

Wiring

All segments of each lamp connected in parallel.

Lamp Configuration

The lamp assembly consists of seven coiled silver tungsten filaments.

Object

To determine whether the following description samples will meet vibration and shock requirements. In addition, to locate resonant frequencies and to observe effects.

| Run | Freq (cps) | G Force (rms) | Lamp Voltage |
|---|---|---|---|
| 1) | 20-2000 | 5 G's | 2.5 volts |
| | No adverse effects noted. | | |
| 2) | 2000-20 | 10 G's | 2.5 volts |
| | Observed a dark spot that moved slowly back and forth on the top segment of Fig. A, at approximately 850, 650, and 475 cps. | | |

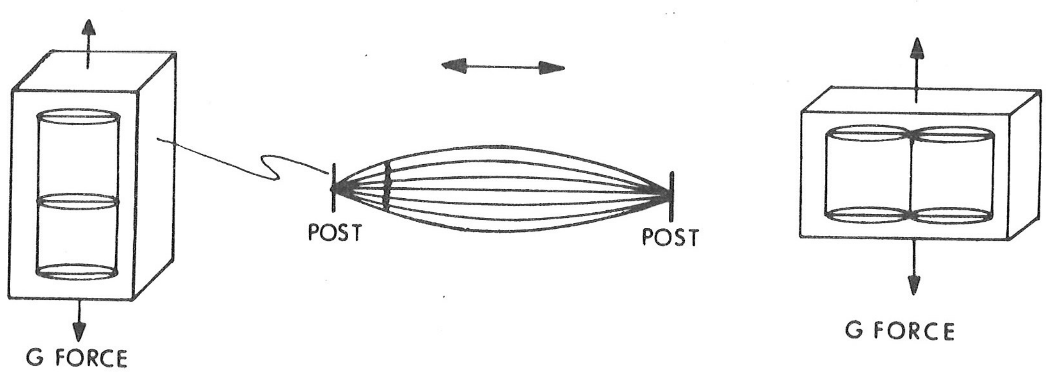



Fig. A

Fig. B

| Run | Freq (cps) | G Force (rms) | Lamp Voltage |
|---|---|---|---|
| 3) | 20-2000 | 15 G's | 2.5 volts |

Above 100 cps, the vertical segments had a similar pattern. Very close to the same amplitude as the horizontal segments. (Fig. A and B)

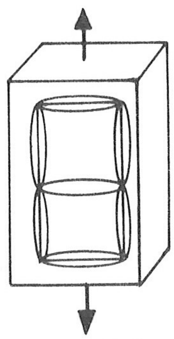
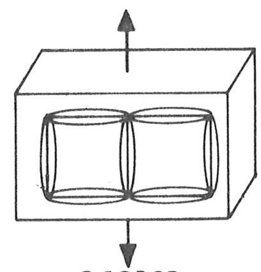



Fig. A

Fig. B




---

| | | | |
|---|---|---|---|
| 4) | 2000-20 | 20 G's | 2.5 volts |

Again observed dark spot that rippled along top segment Fig. A at 600 cps, and at 359 down to 100 cps.

---

| | | | |
|---|---|---|---|
| 5) | 20-2000 | 25 G's | 2.5 volts |

Vibrating string pattern on vertical segments as well as horizontal segments Fig. A. Dark spot appeared - 700 to 425 cps.

---

| | | | |
|---|---|---|---|
| 6) | 20-2000 | 30 G's | 2.5 volts |

Dark spot - 900 to 1100 cps top segment Fig. A.

---

| | | | |
|---|---|---|---|
| 7) | 2000-20 | 35 G's | 2.5 volts |

Dark spot from 100 cps down to 40 cps Fig. A top segment. Also present top segments of Fig. B.

---

| | | | |
|---|---|---|---|
| 8) | 2000-20 | 20 G's | Filament Voltage Off |

---

| | | | |
|---|---|---|---|
| 9) | 20-2000 | 30 G's | Filament Voltage On Set at 2.5 Volts |

Lamp operation normal.

---

| | | | |
|---|---|---|---|
| 10) | 2000-20 | 30 G's | 3.0 volts |

Dark spot noted at 700 cps and again at 70 cps - top segment Fig. A.

| Run | Freq (cps) | G Force (rms) | Lamp Voltage |
|---|---|---|---|
| 11) | 20-2000 | 30 G's | Filament Voltage Off |
| 12) | 2000-20 | 30 G's | Filament Voltage On Set at 3.5 Volts |

Dark spot noted at 1200 cps on down to 1000 cps, and again at 85 cps and down to 30 cps. Fig. A.

| Run | Freq (cps) | G Force (rms) | Lamp Voltage |
|---|---|---|---|
| 13) | 20-2000 | 30 G's | 4.0 volts |

At approximately 25 cps dark spot remained fixed - left third area of top segment Fig. A.

14) Lamps were left on overnight at 3.0 volts.

| Run | Freq (cps) | G Force (rms) | Lamp Voltage |
|---|---|---|---|
| 15) | 2000-20 | 35 G's | No Filament Voltage |
| 16) | 20-2000 | 35 G's | 3.0 volts |

Dark spot at 22 to 100 cps top segment Fig. A. Also on lower left segment Fig. B. This effect remained after G force reduced to 0. Permanent damage.

| Run | Freq (cps) | G Force (rms) | Lamp Voltage |
|---|---|---|---|
| 17) | 2000-20 | 35 G's | No Filament Voltage |
| 18) | 20-2000 | 35 G's | 3.5 volts |

Dark spot again top segment Fig. A with additional dark areas seen Fig. B, both top segments.

| Run | Freq (cps) | G Force (rms) | Lamp Voltage |
|---|---|---|---|
| 19) | 500 cps | 40 G's | 3.5 volts |
| | 1 kc/s | 40 G's | 3.5 volts |
| | 2 kc/s | 40 G's | 3.5 volts |
| | | 40 G's | 3.5 volts |

No new effects observed.

Shock Tests: (50 G's - 11 ms - 1/2 sine.)

Three shocks at 2.5 volts and three shocks at 3.5 volts - no lamp failure.

## Conclusions

Lamps are presently being disassembled to ascertain structural damages and reason for dark spot.

This effect may have been produced by a traveling wave progressively shorting one turn to an adjacent turn.

B. 3 "Tungsol" Evaluation (DDG Memo 1019)

A series of brightness measurements were made on several preliminary test modules. These test modules were fabricated by "Tungsol" and will possibly be developed into an advanced DSKY display. This report documents the results of these measurements and makes several recommendations to improve the quality of the lighting ware.

B. 3. 1 IL Numerics

A. Brightness

Figure B. 3 tabulates the brightness at five points in each segment. The data indicates large variations in average brightness from segment to segment (5. 0 fL to 13. 5 fL) and a large variation within each segment.

B. Uniformity

Segment uniformity varies considerably. All segments were of low brightness ($B_{low}$) at one or both ends. The uniformity ratio ($B_{high}/B_{low}$) for each segment should not exceed 1. 5. The uniformity ratio for the numeric (7 segments) should never exceed 2. 0 where $B_{low}$ is the dimmest point measured and $B_{high}$ is the brightest point measured.

Segment D shows dark shadows at both ends. This should be corrected.

C. Specularity

The light emitted from the numeric display is quite specular (not diffused). This is objectionable. The location of the bright spots on the display are dependent upon the viewing angle. As the observer's eye is moved, the bright spots shift position. A diffuser at the face of the display will correct this and improve uniformity (probably at the expense of additional power).

D. Apparent Color

The numeric display has a significant color shift from white to red as the voltage is decreased. This is not objectionable for a display of this type except, possibly, at the very low voltages. The color temperature of the lamp is quite low ($1500^{o}$ K) in this region. A diffuser may allow the display to extinguish at a somewhat higher color temperature. Perhaps some color filtering might be required.

B. 3. 2 Annunciator

A. Brightness

Figure B. 5 tabulates the brightness at 5 locations on each of two sample annunciators. The relative brightness of the white and yellow displays are not compatible.

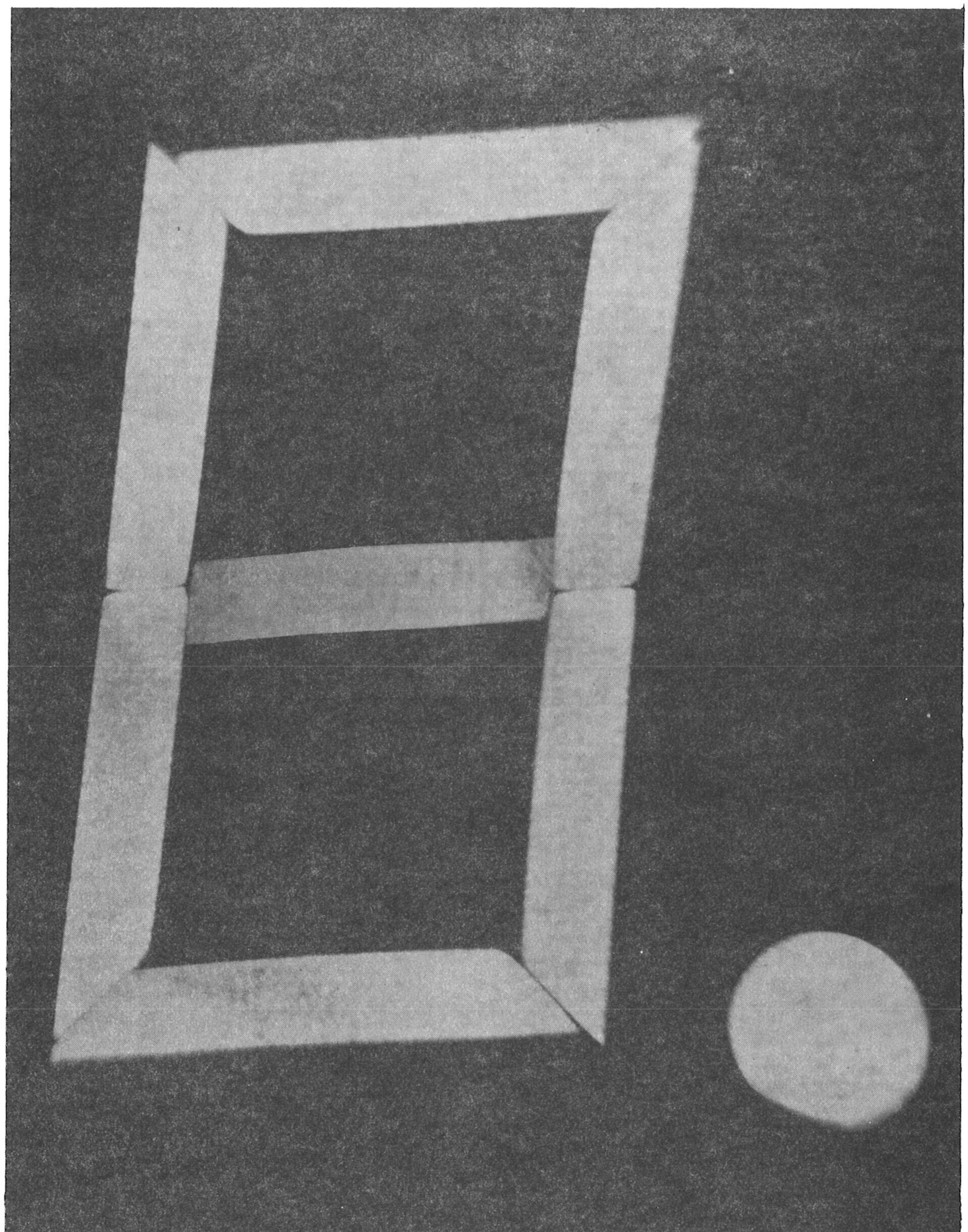
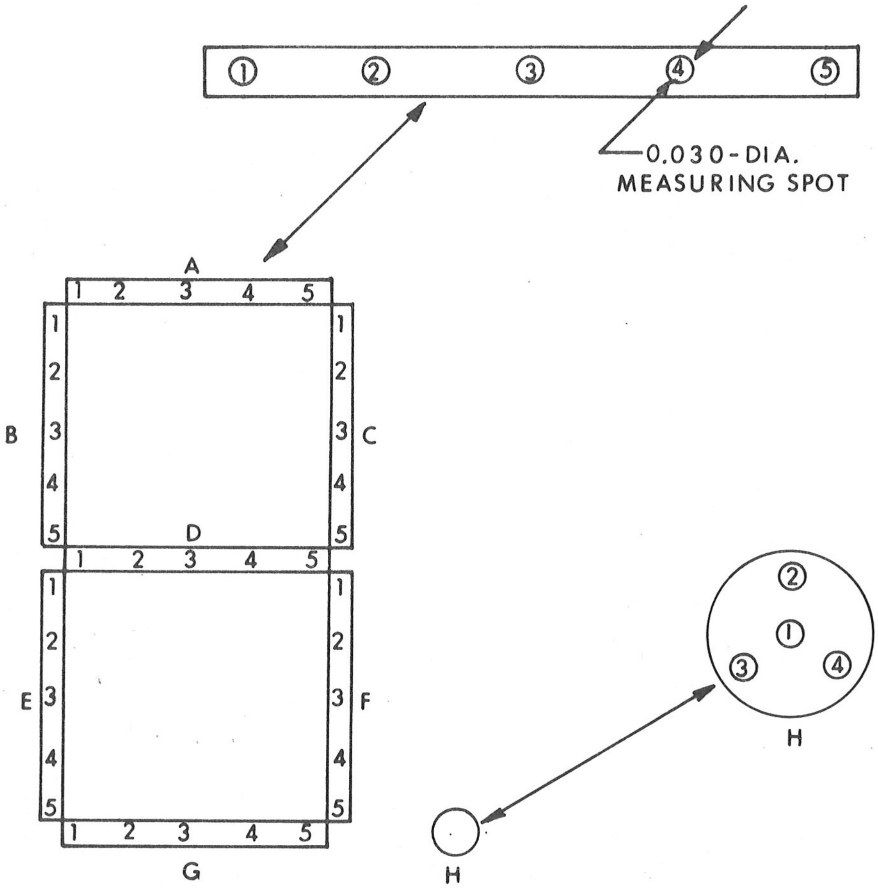


Fig. B.2 Tungsol numeric




| Voltage | Segment | Brightness (foot Lamberts) 1 | 2 | 3 | 4 | 5 | Average (fL) | Uniformity $B_{hi}/B_{lo}$ |
|---|---|---|---|---|---|---|---|---|
| 2.0 | A | 15.0 | 17.0 | 15.4 | 11.2 | 9.0 | 13.5 | 1.9 |
| | B | 9.0 | 14.0 | 14.0 | 13.5 | 12.0 | 12.5 | 1.5 |
| | C | 12.5 | 11.0 | 9.5 | 9.7 | 10.0 | 10.5 | 1.3 |
| | D | 4.5 | 9.5 | 12.3 | 10.8 | 4.3 | 8.3 | 2.7 |
| | E | 4.0 | 3.8 | 4.5 | 5.7 | 7.0 | 5.0 | 1.8 |
| | F | 7.5 | 7.0 | 7.0 | 7.5 | 8.5 | 7.5 | 1.2 |
| | G | 7.6 | 8.8 | 11.6 | 16.3 | 13.0 | 11.5 | 2.1 |
| | H | 14.5 | 11.0 | 12.2 | 16.5 | ---- | 13.5 | 1.5 |
| 3.0 | A | 70 | 100 | 88 | 70 | 66 | 79 | 1.5 |
| | B | 88 | 96 | 99 | 92 | 84 | 92 | 1.2 |
| | C | 71 | 69 | 67 | 67 | 72 | 69 | 1.1 |
| | D | 38 | 93 | 84 | 78 | 28 | 64 | 3.3 |
| | E | 36 | 40 | 48 | 57 | 66 | 49 | 1.8 |
| | F | 56 | 55 | 58 | 58 | 70 | 59 | 1.2 |
| | G | 59 | 55 | 78 | 97 | 92 | 76 | 1.8 |
| | H | 92 | 78 | 64 | 96 | -- | 82 | 1.5 |

Fig. B.3

| Voltage | Current (ma) | Brightness (fL) | Voltage | Current (ma) | Brightness (fL) |
|---|---|---|---|---|---|
| 5.02 | 20.0 | 500 | 2.41 | 13.2 | 18.5 |
| 4.72 | 20.0 | 380 | 2.22 | 12.7 | 12.5 |
| 4.52 | 19.4 | 320 | 1.98 | 12.0 | 7.0 |
| 4.27 | 18.4 | 255 | 1.78 | 11.2 | 4.0 |
| 4.02 | 17.6 | 185 | 1.60 | 10.6 | 2.2 |
| 3.77 | 17.0 | 140 | 1.41 | 9.9 | 1.2 |
| 3.59 | 16.5 | 114 | 1.28 | 9.2 | .65 |
| 3.40 | 16.1 | 90 | 1.05 | 8.7 | ..25 |
| 3.22 | 15.6 | 71 | .98 | 8.2 | .125 |
| 3.03 | 15.1 | 54 | .79 | 7.8 | .025 |
| 2.78 | 14.4 | 36 | .73 | 7.0 | .014 |
| 2.61 | 13.9 | 27 | | | |

Fig. B.4 IL Numeric Dimming Characteristics (Segment C, Point 3)

| Voltage | Display (Color) | Brightness (fL) | | | | | Average (fL) | Uniformity $B_{hi}/B_{lo}$ |
|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | | |
| 2.0V | PROG | 2.3 | 5.1 | 6.4 | 5.0 | 2.0 | 4.2 | 3.2 |
| 2.0V | STBY | 0.81 | 1.96 | 2.70 | 2.26 | 0.98 | 1.74 | 3.0 |
| 3.0V | PROG | 13.5 | 29.5 | 36.0 | 29.0 | 11.0 | 23.8 | 3.3 |
| 3.0V | STBY | 4.7 | 12.5 | 16.5 | 13.7 | 6.0 | 10.7 | 3.4 |

Fig. B. 5 Status/Caution Annunciator Brightness Distribution

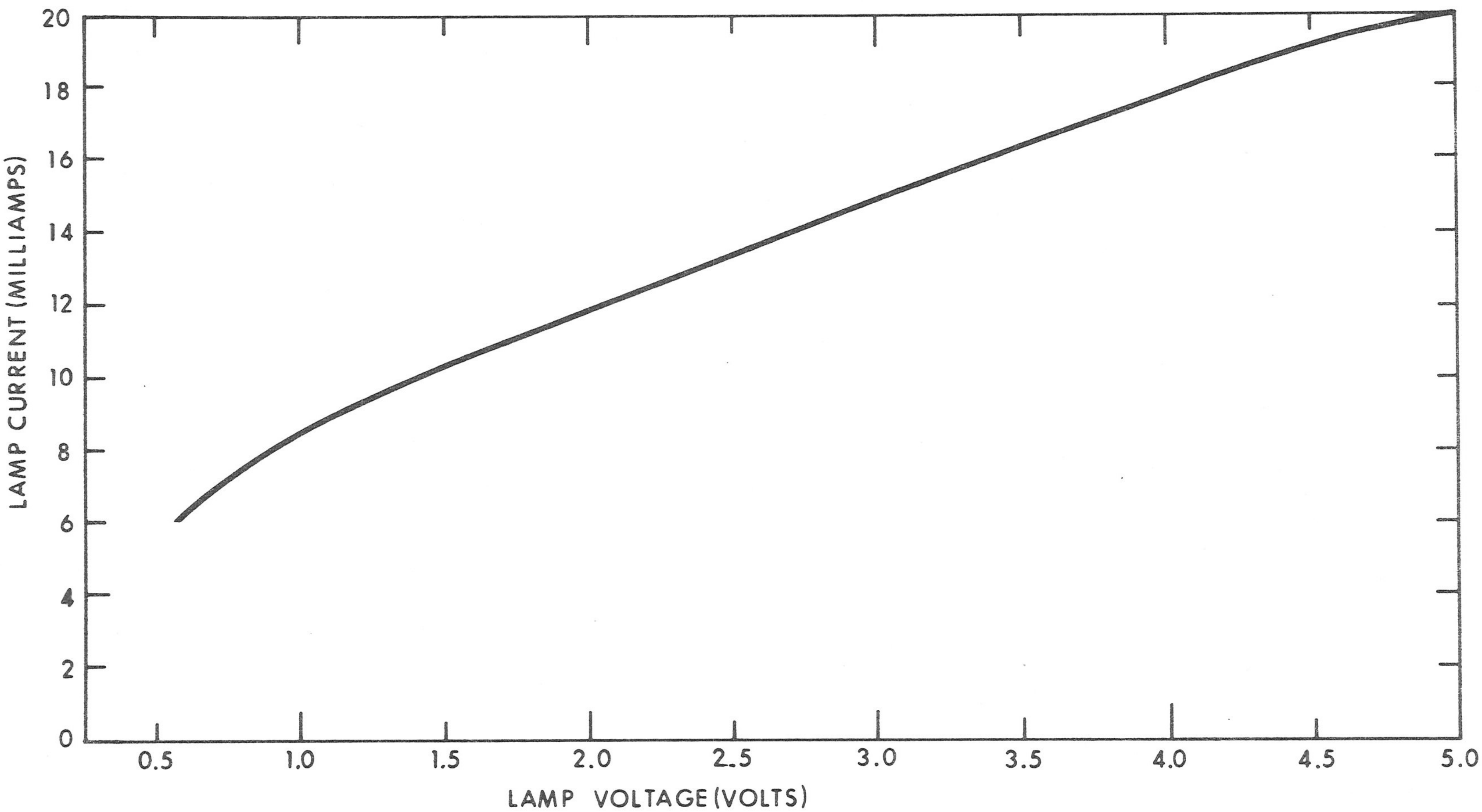



Fig. B. 6 Voltage/Current Characteristics per Lamp

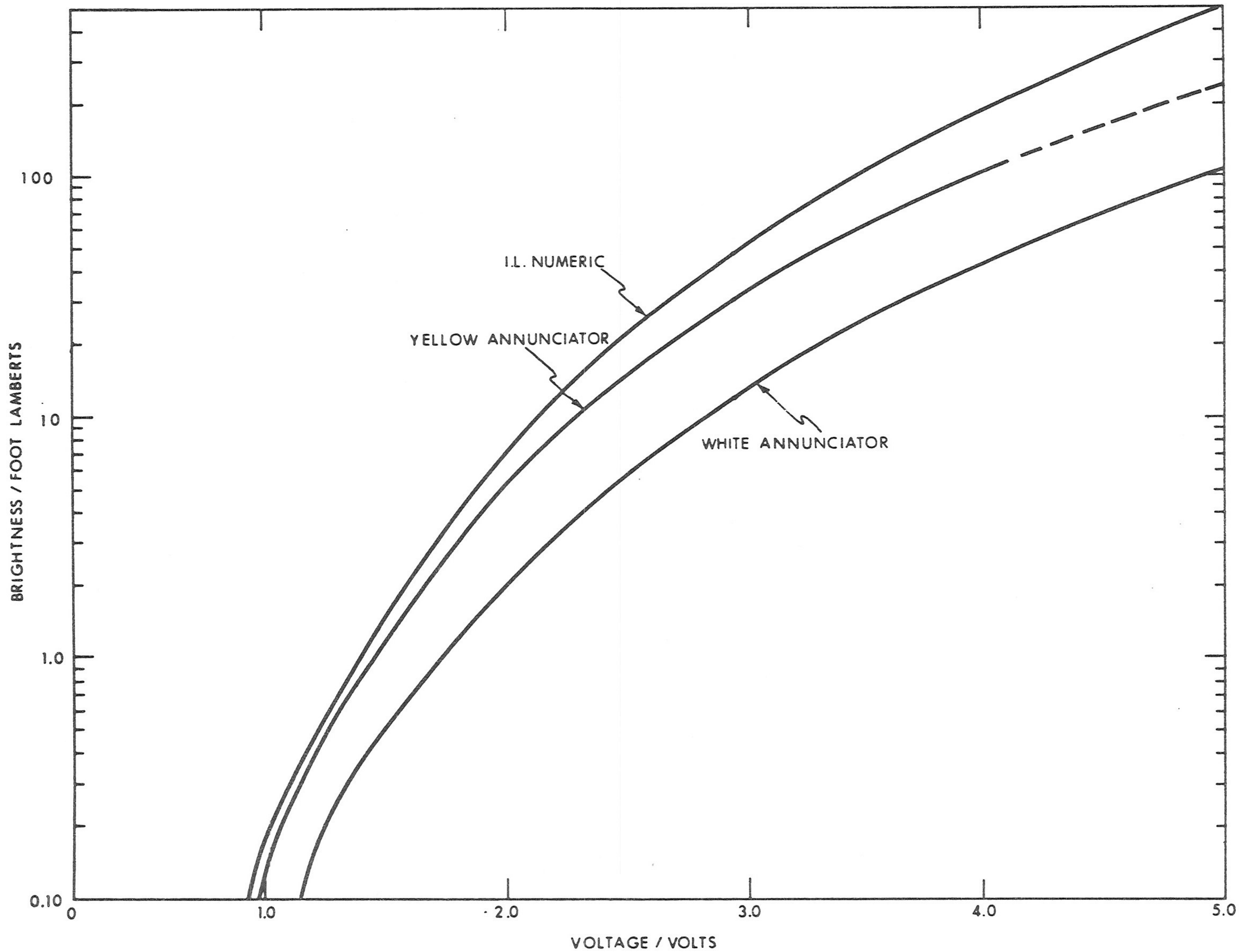



Fig. B. 7 Dimming Characteristics of Tungsol I. L. Numerics and Annunciators

B. Uniformity

Each display has a bright center with darkened ends. Uniformity ratio ($B_{high}/B_{low}$) is greater than 3.0 in both displays. This value must be reduced to 1.5 maximum. It appears that more diffuser is required in each display.

C. Specularity - No Problem.

D. Apparent Color

The yellow display is too pale. The white display shifts to red at a relatively high brightness level. To correct this, a higher color temp filament must be used and/or more filtering will be required.

E. Legend Size

The status/caution annunciator legend size is specified to be 0.530 inch × 1.109 inches with 0.156-inch-high characters. The samples furnished were considerably smaller than this. The size was approximately 0.375 inch × 1.000 inch with 0.125-inch-high characters.

B.4 Brightness Measurement Data of "Tungsol" Status/Caution Annunciators Located on a Prototype Advanced DSKY Display (DG Memo No. 1053)

On 15 April 1968, brightness measurements were taken of a status/caution display fabricated by "Tungsol". This display was powered by a prototype advanced DSKY. The power input to this DSKY was 28.0-V dc and 14.0-V dc. Lamp voltage was monitored at the output end of the DSKY IL power supply. There appears to be some line drop with the DSKY and Dimmer Control Circuits; therefore, the voltages specified in Table B.1 are not necessarily the voltages across the incandescent lamps.

Brightness measurements were made of two displays; one white-lighted "OPR ERR" status annunciator, and one yellow-lighted "GIMBAL LOCK" caution annunciator. The measurement spot was located at a position to measure an area of "nominal" brightness (see Fig B.8). The brightness/voltage measurements are presented in Table B.1.

Brightness uniformity was also measured. An approximate isobrightness map is shown in Fig. B.8. All measurements were made at 3.5-volt output from the DSKY IL power supply. It can be seen from Fig. B.8 that uniformity is quite good near the center of each display, but falls off considerably at the extreme ends. This should be improved if possible.

TABLE B.1

| DSKY IL Power Supply Voltage | Display Brightness* (foot Lambert) OPR ERR | GIMBAL LOCK |
|---|---|---|
| 3.5 | 12.7 | 14.0 |
| 3.0 | 6.2 | 6.8 |
| 2.5 | 2.5 | 3.0 |
| 2.0 | .76 | .97 |
| 1.5 | .07 | .18 |
| 1.0 | .005 | .06 |

*NOTE: Brightness values tabulated are for one energized display only. Energizing additional status/caution displays or IL numerics will cause a significant decrease in display brightness (approximately 5% decrease for each additional display). This may be a series design problem.

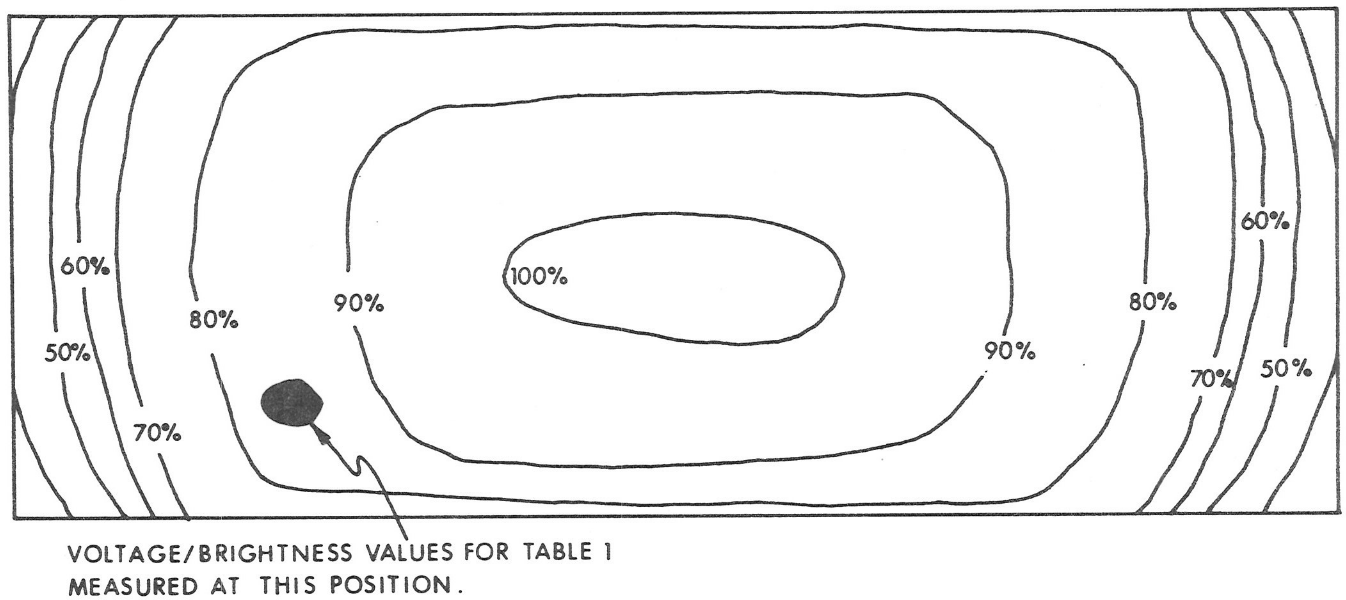



Fig. B. 8 Isobrightness of Tungsol Status/Caution Annunciators

No color measurements were made of the status/caution annunciators, but energized color was judged to be very poor. The status annunciators are "yellow-pink", and the caution annunciators are "orange-red". The neutral gray/white color of the unenergized display was judged to be quite good. Display markings appear to be "futura demibold" font and are very legible.

The IL numeric display was not measured during these tests. The following comments are still applicable from previous testing of this display.

a. The energized display emits specular light (not diffused properly).

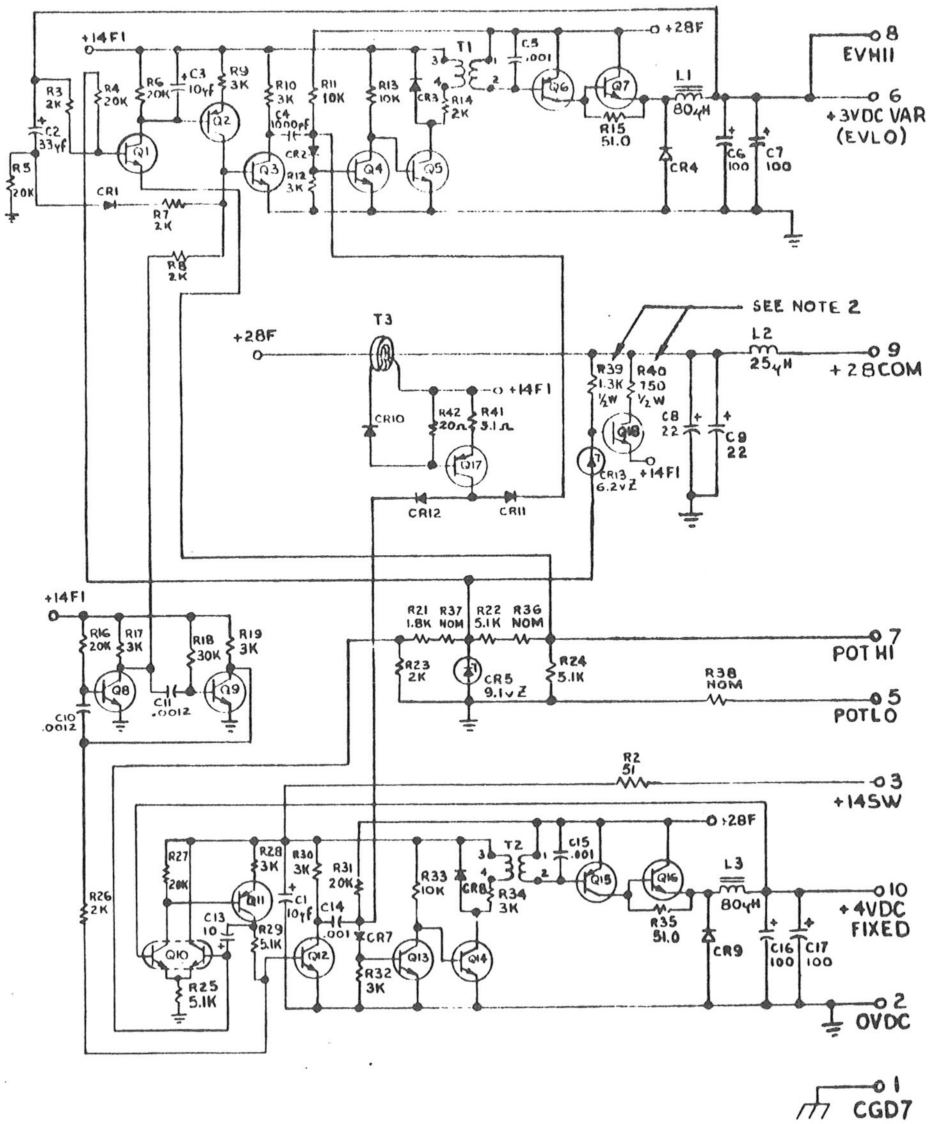
b. The brightness uniformity is poor.

c. The energized contrast is good (near zero).

# APPENDIX C

## DSKY POWER SUPPLY, IDM MODULE CIRCUITS, AND ANALYSIS

This appendix consists of the schematics of the power supply, the plots of the response of the power supply to varied-load conditions, and a schematic of the IDM modules.



NOTE: 1. ALL RESISTORS ARE 1/4 WATT
2. R39 & R40 CONSIST OF 2-1/4W RESISTORS EACH
3. Q18 (1006323) IS COIN HEADER

Fig. C.1 Power Supply

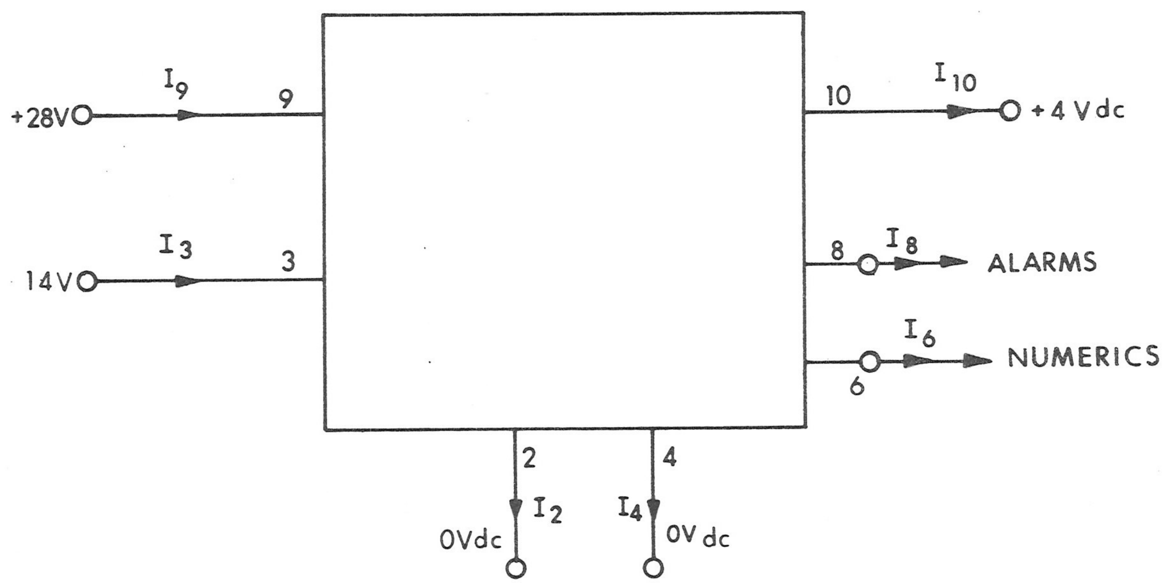



Fig. C. 2 Output/ Input Response of the New Power Supply for DSKY

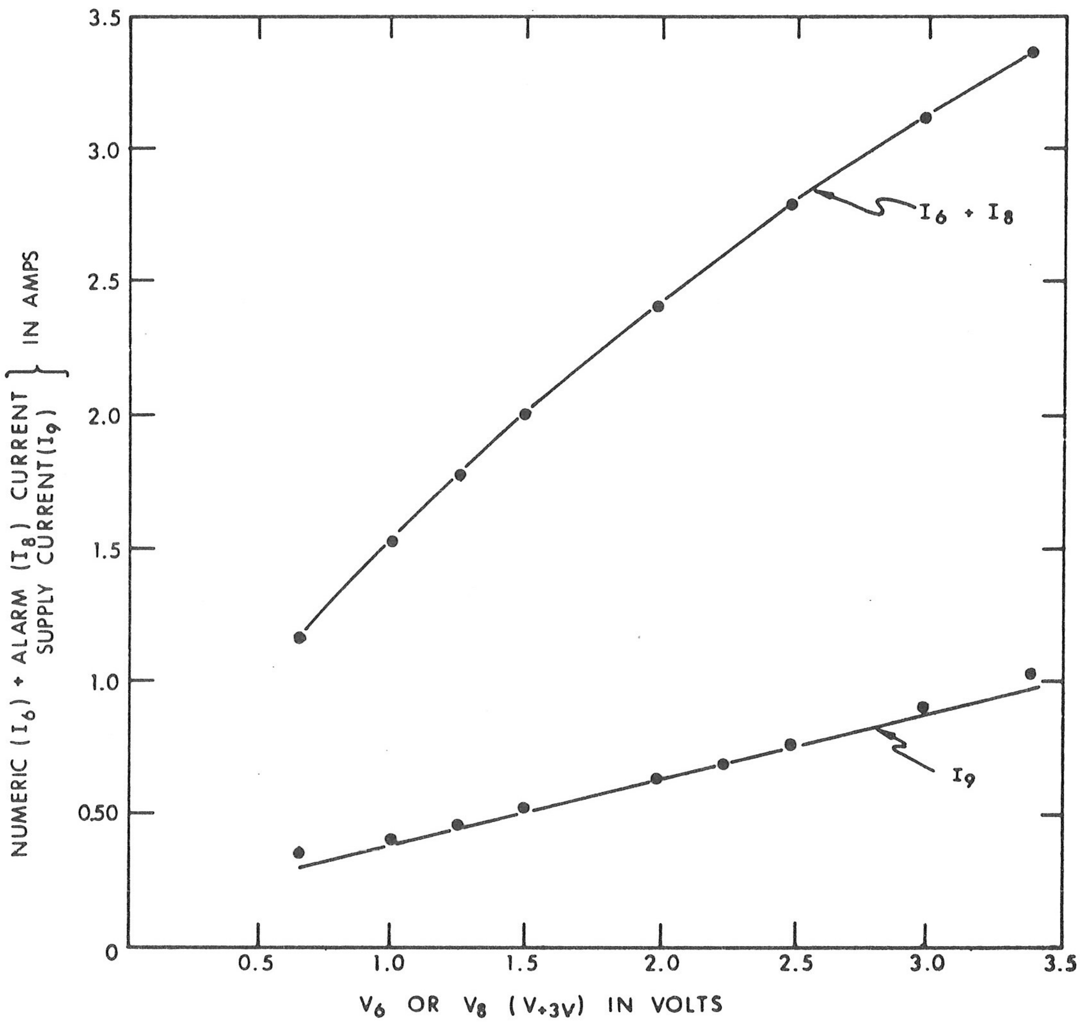



Fig. C.3 Brightness Pot Position ($V_{+3Vdc}$) versus $I_6+I_8$ and $I_9$; Supply Voltage at 26V, All Lights On

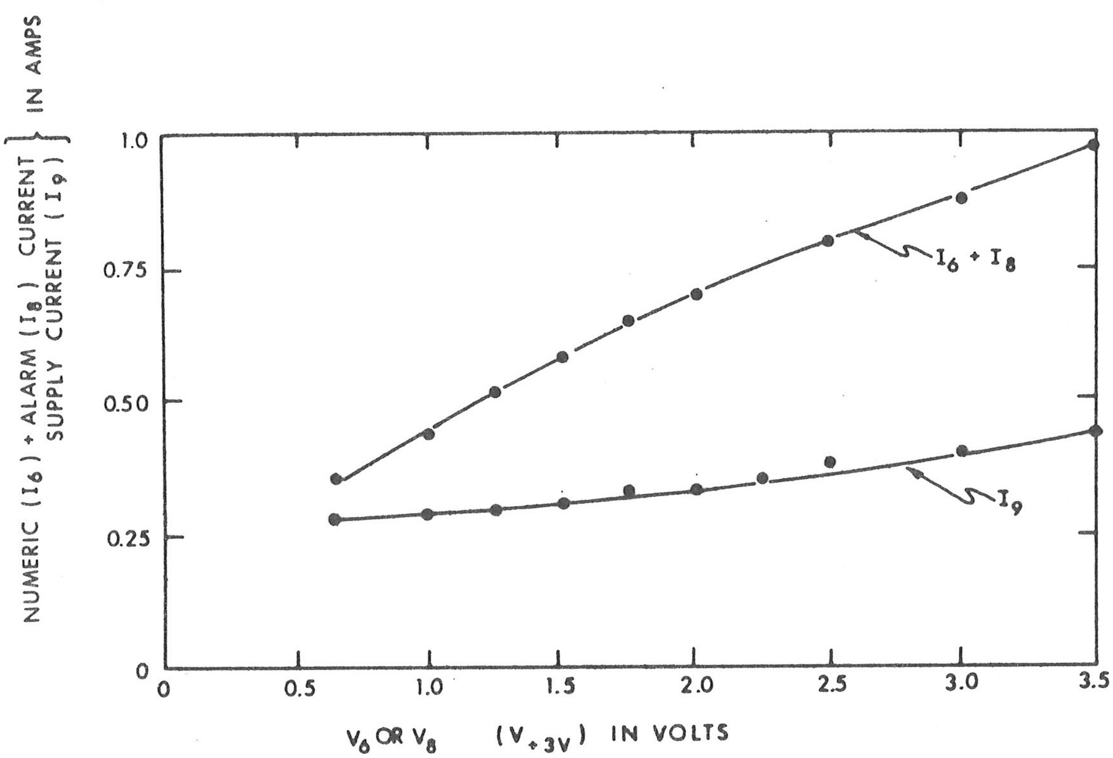



Fig. C. 4 Brightness Pot Position ($V_{+3Vdc}$) versus $I_6+I_8$ and $I_9$; Supply Voltage at 26V, All Numerics Off, All Alarms On

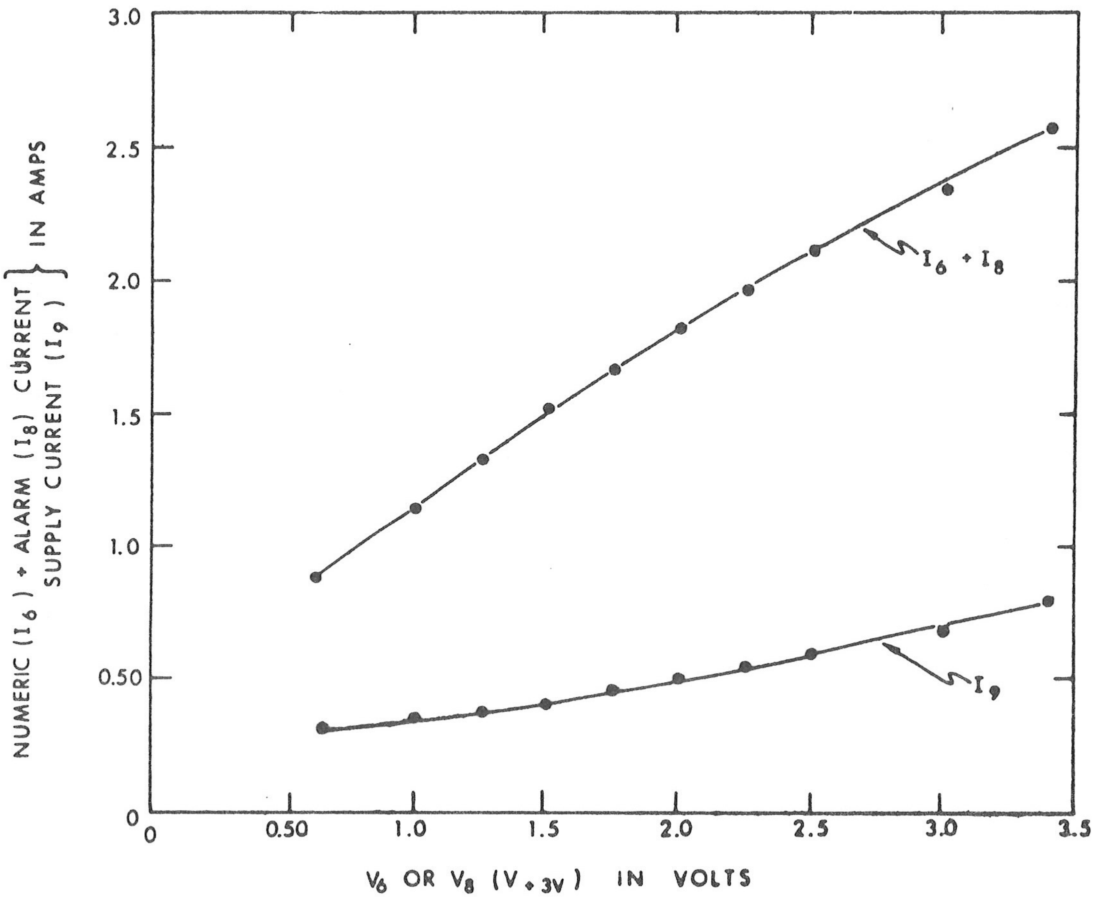



Fig. C.5 Brightness Pot Position ($V_{+3Vdc}$) versus $I_6+I_8$ and $I_q$;
Supply Voltage at 26V, All Numerics On, All Alarm Off ($I_8=0$)

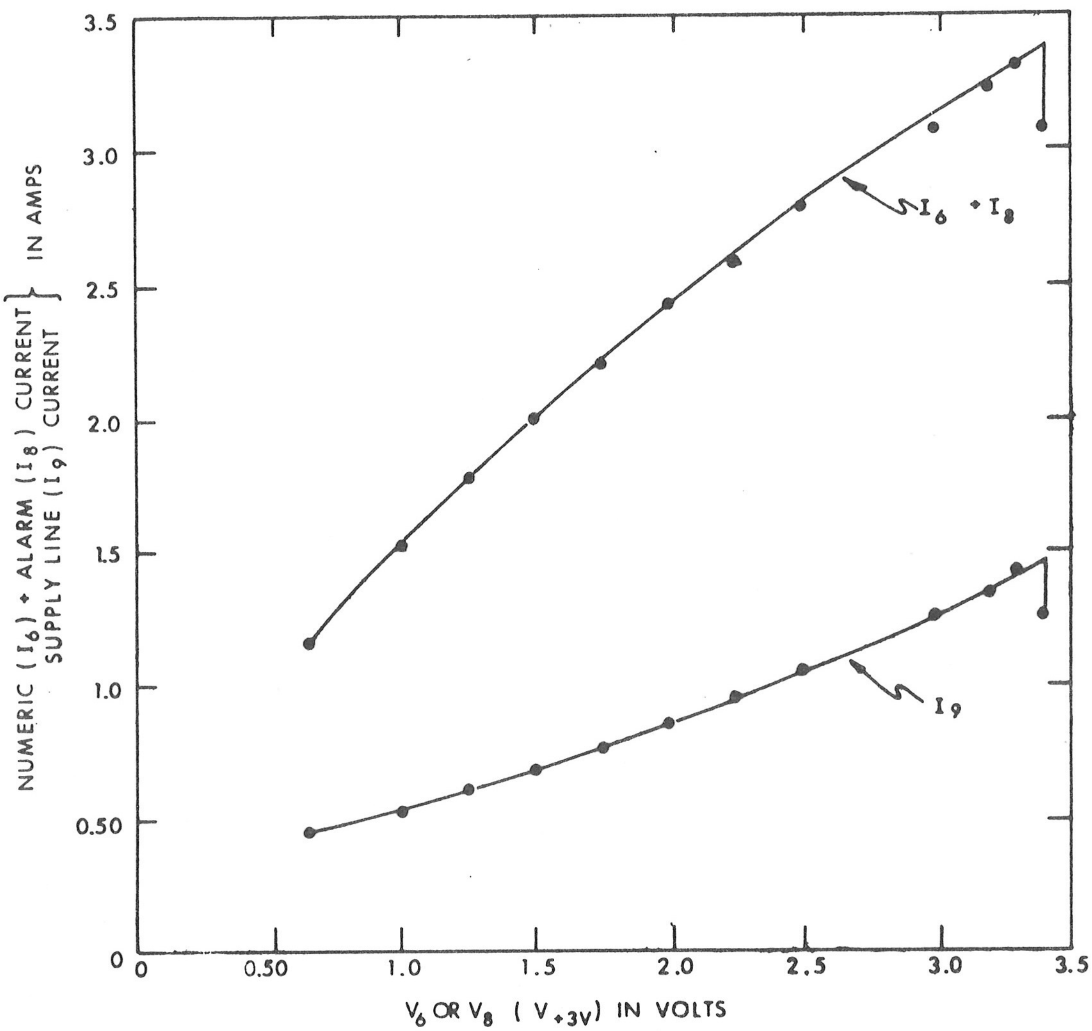



Fig. C.6 Brightness Pot Position ($V_{+3Vdc}$) versus $I_6+I_8$ and $I_9$; Supply Voltage at 18V, All Lights On

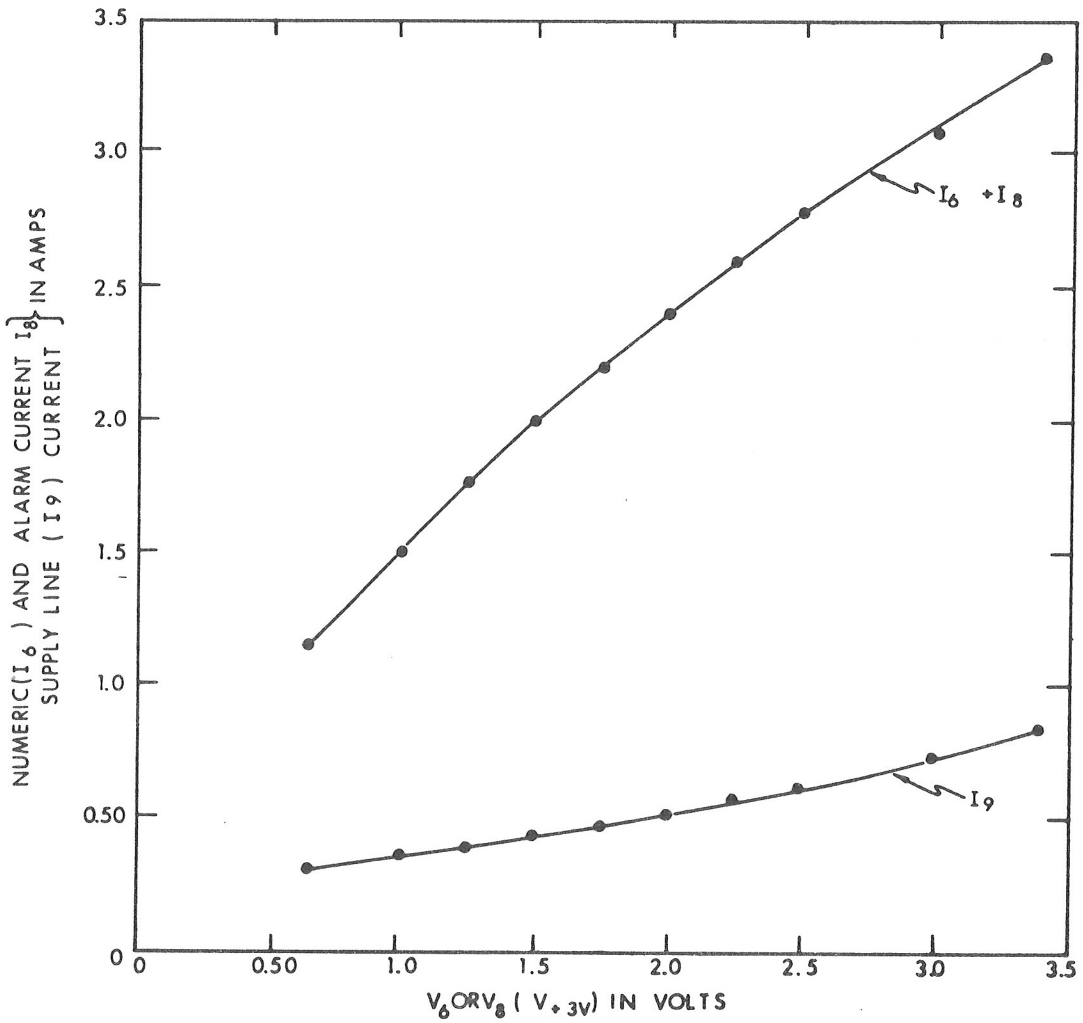
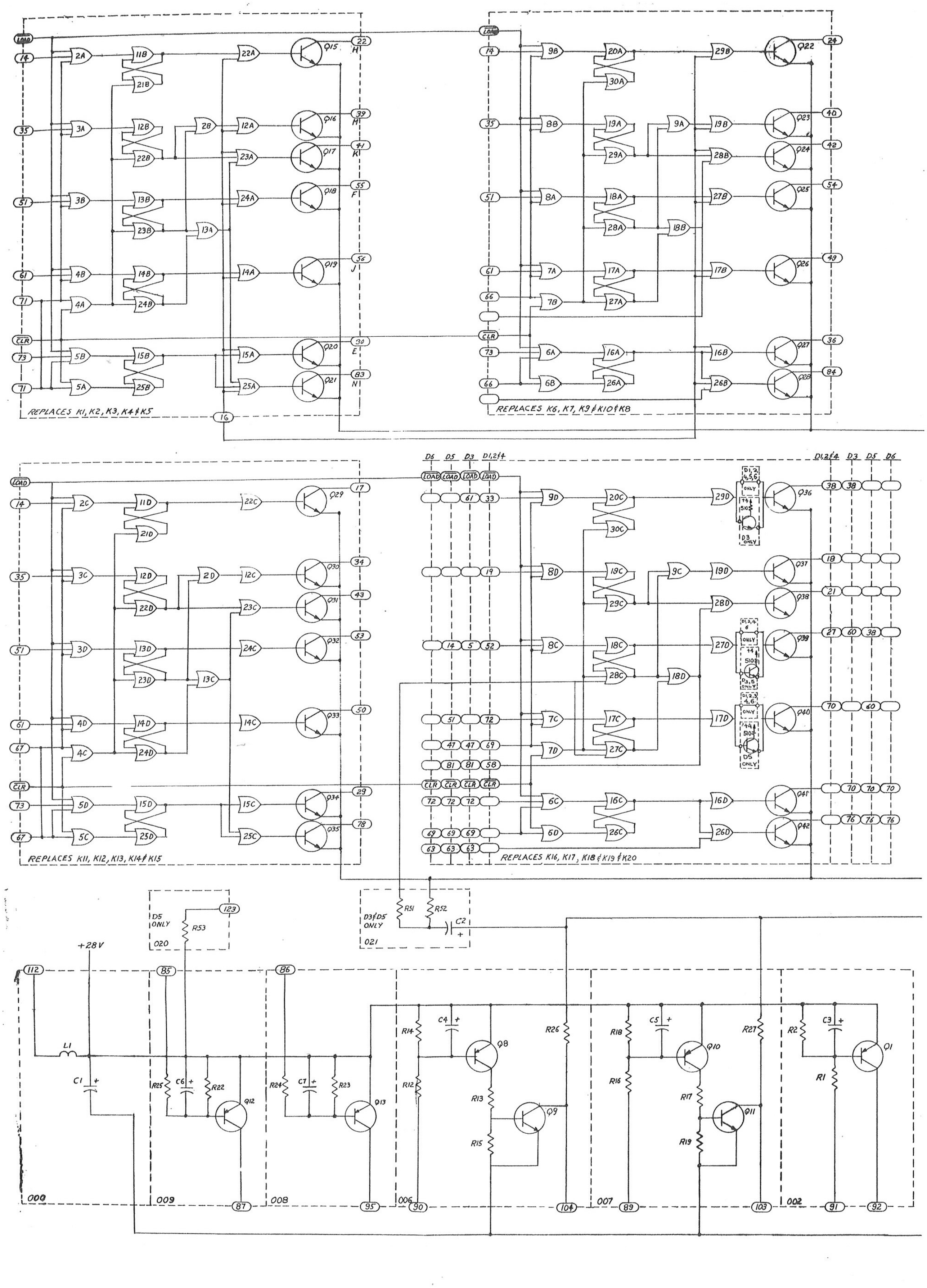
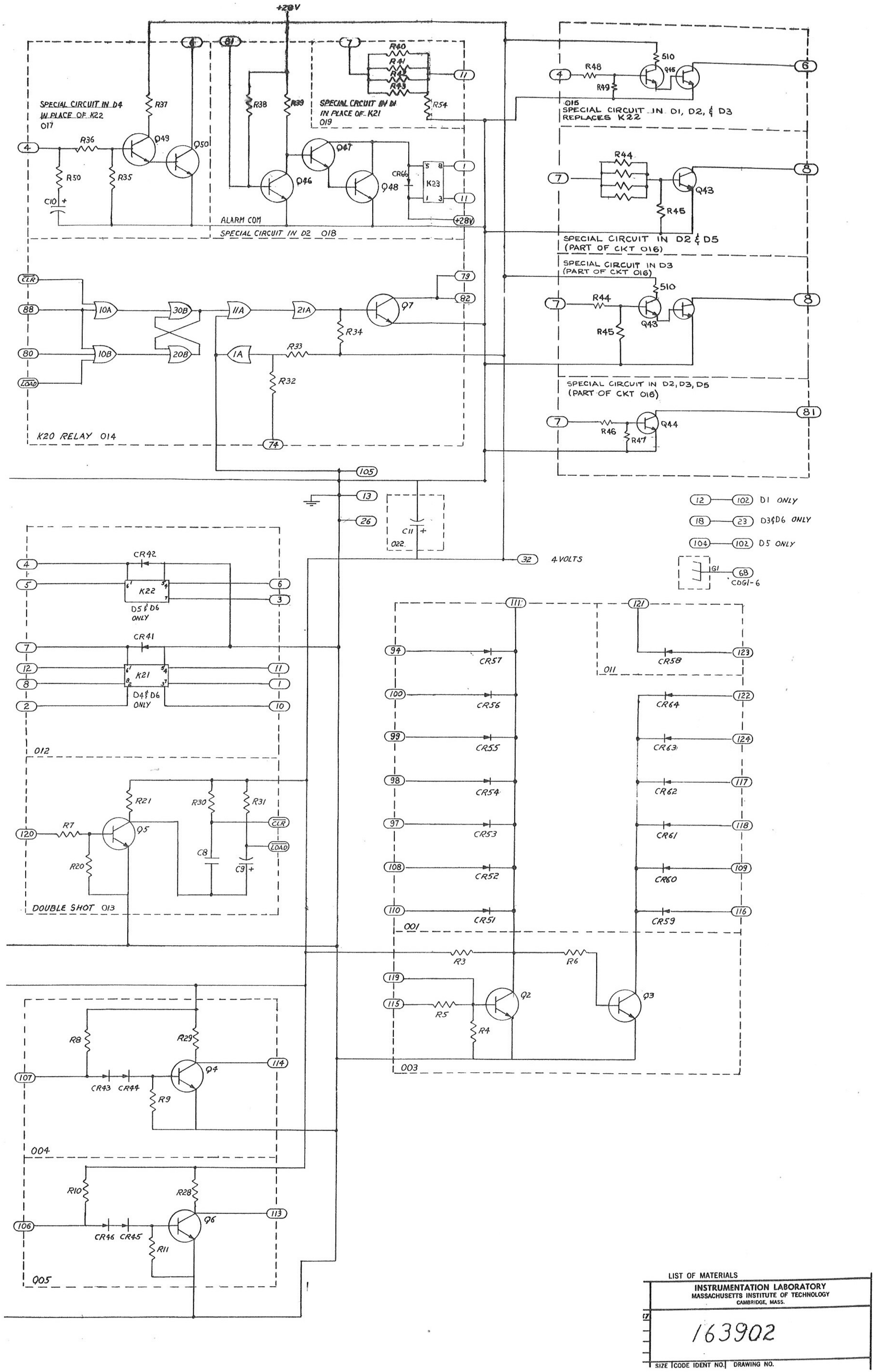



Fig. C.7 Brightness Pot Position ($V_{+3Vdc}$) versus $I_6+I_8$ and $I_9$; Supply Voltage at 33V, All Lights On.


REPLACES K1, K2, K3, K4 & K5
REPLACES K6, K7, K9 & K10 & K8
REPLACES K11, K12, K13, K14 & K15
REPLACES K16, K17, K18 & K19 & K20
D5 ONLY
020
D3/D5 ONLY
021
+28V
000
009
008
006
007
002


+28V
SPECIAL CIRCUIT IN D4
IN PLACE OF K22
017
SPECIAL CIRCUIT IN D1
IN PLACE OF K21
019
ALARM COM
SPECIAL CIRCUIT IN D2 018
016
SPECIAL CIRCUIT IN D1, D2, & D3
REPLACES K22
SPECIAL CIRCUIT IN D2 & D5
(PART OF CKT 016)
SPECIAL CIRCUIT IN D3
(PART OF CKT 016)
SPECIAL CIRCUIT IN D2, D3, D5
(PART OF CKT 016)
K20 RELAY 014
4 VOLTS
D1 ONLY
D3&D6 ONLY
D5 ONLY
CDG1-6
D5 & D6
ONLY
D4 & D6
ONLY
012
DOUBLE SHOT 013
011
001
003
004
005
LIST OF MATERIALS
INSTRUMENTATION LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASS.
163902
SIZE
CODE IDENT NO.
DRAWING NO.

E-2280

# DISTRIBUTION LIST

Internal

R. Battin
B. Barrett
D. Bowler
E. Copps
R. Crisp
A. Green
E. Hall
D. Hanley (10)
A. Hopkins
D. Hoag
R.B. Kendal
J. Kingston*
J. McKenna
A. Laats
J.H. Martin
J.E. Miller
J. Nevins
R. Ragan
W. Schmidt (MIT/MSC)
R. Schulte
N. Sears
R. Weatherbee
T. Zulon
Apollo Library (2)
MIT/IL Library (6)

* Letter of Transmittal Only.

External

National Aeronautics and Space Administration (18 + 1R)
Manned Spacecraft Center
Houston, Texas 77058

| | | |
|---|---|---|
| ATTN: | M. Jones | EG(5 + 1R) |
| | J. Perez | BG731 |
| | C. Brady | EG25 |
| | T. Chambers | EG25 |
| | R. Chilton | EG |
| | L. Danewood | BG55 |
| | P. Ebersol | EG26 |
| | C. Frasier | EG44 |
| | R. Gardner | EG |
| | R. Harland | PP7 |
| | M. Holley | EG44 |
| | H. Howard | EG44 |
| | W. Kelley | PP7 |
| | G. Xenakis | EG |

National Aeronautics and Space Administration (2)
600 Independence Avenue SW
Washington, D.C. 20546

| | | |
|---|---|---|
| ATTN: | P.D. Schrock | MLT |
| | H.M. Rhodes | MAT |

NASA/RASPO at MIT/IL EG442 (1)

Capt. M. Jensen