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# DESIGN AND FABRICATION OF AN EXPERIMENTAL ELECTROLUMINESCENT DISPLAY PANEL

L. (N) ADDIS, B. J. WIERENGA, AND C. E. BLANCHARD
Instrument Division
Lear Siegler, Inc.

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FLIGHT DYNAMICS LABORATORY
AIR FORCE SYSTEM COMMAND
WRIGHT-PATTERSON AIR FORCE BASE
OHIO

112

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## FOREWORD

This report presents a summary of the work done to develop an experimental display panel using electroluminescence with which to conduct cockpit lighting evaluations. The work was performed under Air Force Contract F33615-67-C-1583 for which Captain Bruce M. Bertram and Lieutenant David Turney served as task engineers. This task is an element of Project 6190 for which Mr. John H. Kearns serves as Project Engineer. Mr. James A. Townsend, Group Leader, contributed the conceptual display design of the Runway Displacement Indicator.

The work effort covers the period 1 March 1967 through 15 April 1969. The work effort at LSI was conducted by Baldwin Wierenga, Clark Blanchard, James Skripka, Robert Kurti and Ernest Verhulst. Lercy Addis was the LSI project engineer. The effort was performed for the Air Force Flight Dynamics Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, under contract F33615-67-C-1583.

This report was submitted by the author in July 1969 and bears the LSI internal publication number GRR-016-0669.

This technical report has been reviewed and is approved.

Loren A. Anderson

LOREN A. ANDERSON, Lt Col, USAF
Chief, Control Systems Research Branch
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## ABSTRACT

This report describes in detail the work expended by the Instrument Division of Lear Siegler, Inc. to design and develop an experimental electroluminescent display panel. This panel includes all displays necessary for the pilot to operate the aircraft. The format for the display was derived from the PIFAX program. The displays are grouped in three categories

a. Light reflecting or flood lighted. This category includes all the mechanical, EL-wedge lighted displays.

b. Transilluminated or back lighted. This category includes all the EL backlighted panels and displays.

c. Light emitting. This category includes all the solid state electroluminescent displays that utilize high contrast for light reflectance control.

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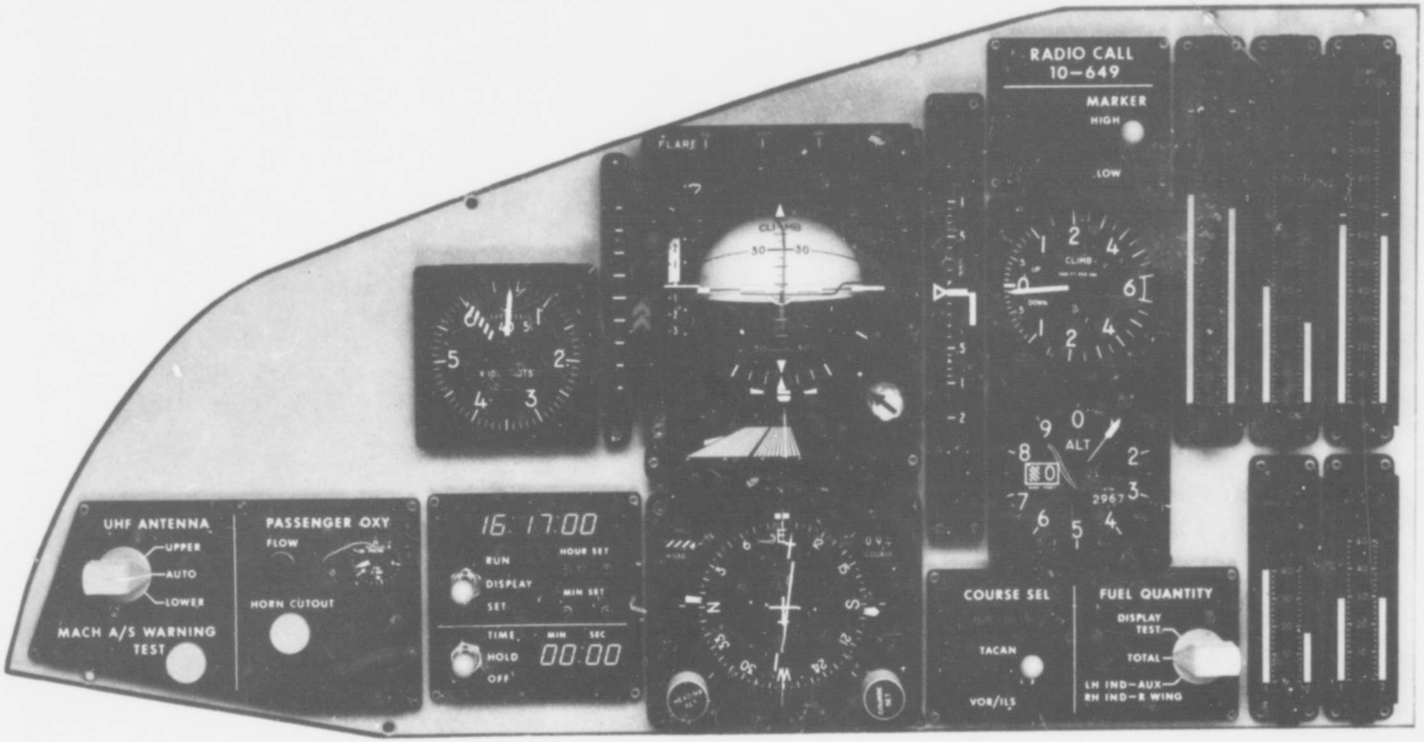



ELECTROLUMINESCENT LIGHTED FLIGHT INSTRUMENT PANEL
FIGURE 1

## SECTION I

## INTRODUCTION

This program (AF Contract F33615-67-C-1583) was initiated 1 March 1967 by the Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, with the Instrument Division of Lear Siegler, Inc. This program had a single objective -- to develop an experimental display panel capable of presenting, through the use of advanced solid state and electromechanical techniques, clear and unambiguous flight control information.

The experimental panel developed under this contract is intended to be a tool which will be utilized to study all aspects of aircraft instrument panel lighting under actual flight conditions. Controls and adjustments are made available on the panel to both trim the panel lighting for maximum uniformity and/or vary the light intensity contour across the face of the instrument panel. These will enable the experimenter to evaluate instrument panel lighting fully under all flight ambient conditions.

This panel -- to be installed in a T-39 jet trainer -- demonstrates the three lighting techniques currently in use within the Air Force and those contemplated for near future application. These three lighting techniques are

- Light reflecting display illumination
- Transillumination
- Light emitting displays

It is recognized by the lighting industry that the most important single factor governing instrument and panel lighting is light uniformity. If the light is not uniform within and between instruments, the pilot will either lose information in the poorly lighted areas of the display, or suffer degradation of dark adaptation due to the brighter hot spots. The non-uniform light intensity problem, coupled with the problem of non-uniform color, also increases the pilot's eye strain and fatigue.

The lack of lighting uniformity is recognized as a serious problem in all operational aircraft. For example, tactical aircraft pilots in southeast Asia are often required to find poorly lighted or unlighted targets concealed in the jungle. They find it impossible to attain the level of dark adaptation required to perform these tasks, due to the poor instrument lighting in their cockpits. As a result they turn off the instrument lights. cover the warning lights with masking tape, chewing gum, or anything else that is handy, and fly by starlight.

Electroluminescence is a cold, area source of light, and the light emitted is uniform over the entire light-emitting surface of the lamp. This is true at all applied voltages and thus at all resulting light levels -- from dim to bright. Also, since the color of the light is dependent primarily on the EL phosphor composition, and secondly on the frequency of the excitation voltage, the color is independent of the amplitude of the applied voltage and therefore does not change as the brightness of the lamp is varied. In addition the color is, in a layman's terms, softer and more pleasing to the eye, and less apt to cause eye strain or fatigue.

It is seen, then, that the two important characteristics of light intensity uniformity and color uniformity are attainable with EL and are lacking with the incandescent bulb.

Basic to the design of aircraft displays are the requirements for high reliability, minimum weight and size, and low power consumption. It is increasingly difficult for today's electromechanical instruments to meet these requirements because of the inherent complex assemblies of rotating pointers, revolving drums, moving tapes, gear trains, precision meter movements, servomotors, slip rings, and lighting systems. If the instrument requirements such as high reliability, minimum weight and size, and low power consumption are to be met, it is necessary to employ the conversion of electrical signals to information presentations using solid-state techniques rather than rely on the movement of mass for information presentation. Digital control, improved reliability, insensitivity to shock and vibration, minimized display weight, reduced size and power requirements, non-catastrophic failure, fast response, format versatility, and scale variability, all tend to motivate the use of solid-state techniques for the presentation of display information.

Cargo aircraft pilots complain of loss of information due to shadows or displays that disappear or appear "too bright" as the overall panel lighting intensity is varied.

The source of this lighting problem is the incandescent bulb. Up to now the incandescent bulb has been the most effective source of light which could be used to illuminate instruments and panels. But the characteristics of the lighting which they provide fall well short of desired goals. There are two basic reasons why the incandescent bulb is less than ideally suited for lighting aerospace crew stations. First, the light emitted from the subminiature lamps comes from an extremely small filament, hence, the bulb approaches a point source of light with respect to the larger surface area of the instrument it is illuminating. The light on the display face is brightest near the bulbs or the light source such as the wedge in the ADI, and the portions of the display further from the source become darker depending on how far they are from the source. When the light intensity is reduced, the non-uniformity of the light distribution becomes worse.

The second problem encountered with the incandescent bulb is non-uniform color. The color of the light within an instrument is dependent upon (1) the temperature of the filament of the bulbs emitting the light and (2) the characteristics of any filters through which the light must pass. The color will, by definition, change as the brightness of the bulbs is reduced.

The T-39 panel employs electroluminescence (EL) as a solution to the lighting problem. In its most elementary form, an EL lamp is a layer of a light-emitting phosphor sandwiched between two electrically conductive surfaces called electrodes. When a voltage of the proper form is applied across the electrodes, light is emitted from the phosphor material. To make the light useful, one of the electrodes must be transparent so the light can get out of the lamp and be seen by the observer. Normally this is accomplished by applying a clear conductive coating to one side of a piece of glass. Then the phosphor is deposited (usually by spraying) on the clear conductive coating, and the second electrode is then deposited on the back of the phosphor layer. This electrode is normally some metallic material such as aluminum or indium which is evaporated onto the phosphor layer. The shape of the lamp is defined by the shape of the two electrodes, which can be made in any desired geometric shape or size.

Two EL phosphor colors are utilized in the T-39 lamps. These colors -- green and yellow -- were selected because they offer the best brightness-life potentials available in todays EL phosphors. The green and yellow light emitting displays utilize these basic color phosphors without color conversion. The white lighting in the trans-illuminated and light reflecting displays is accomplished by "color converting" the green phosphor emission through a dye conversion process developed by LSI for use on the LEM spacecraft instruments.

The instrument panel format selected for the electroluminescent panel was derived from the PIFAX instrument group developed jointly by the Air Force and the Federal Aviation Agency. As such, displays are incorporated which were developed for use in manually controlled and/or monitored Category III-c landings. These displays have been changed slightly in format so as to be more adaptable to solid-state implementation.

The landing instrument group clustered around the attitude director indicator and the engine instrument group at the right of the panel offer ideal opportunities to demonstrate the unique advantages of electroluminescence. These displays demonstrate the wide choice of formats and scale selections that are available to the EL designer. See Figure 1.

With these two groups of displays, LSI was able to demonstrate an annunciator panel, a moving pointer that expands in width, and a new concept in limit markers. Each will be described in detail in later sections of this report.

## SECTION II

## PROGRAM DEVELOPMENT

This program to develop an electroluminescent flight instrument panel for the T-39 was initiated March 1, 1967, as a one-year development program. A system of modified PERT diagrams was utilized to plan and record program progress. The system PERT diagram, Figure 2, shows that schedule slippages due to various factors caused a total program delay of approximately one year, which resulted in the delivery of the T-39 electroluminescent panel on April 15, 1969.

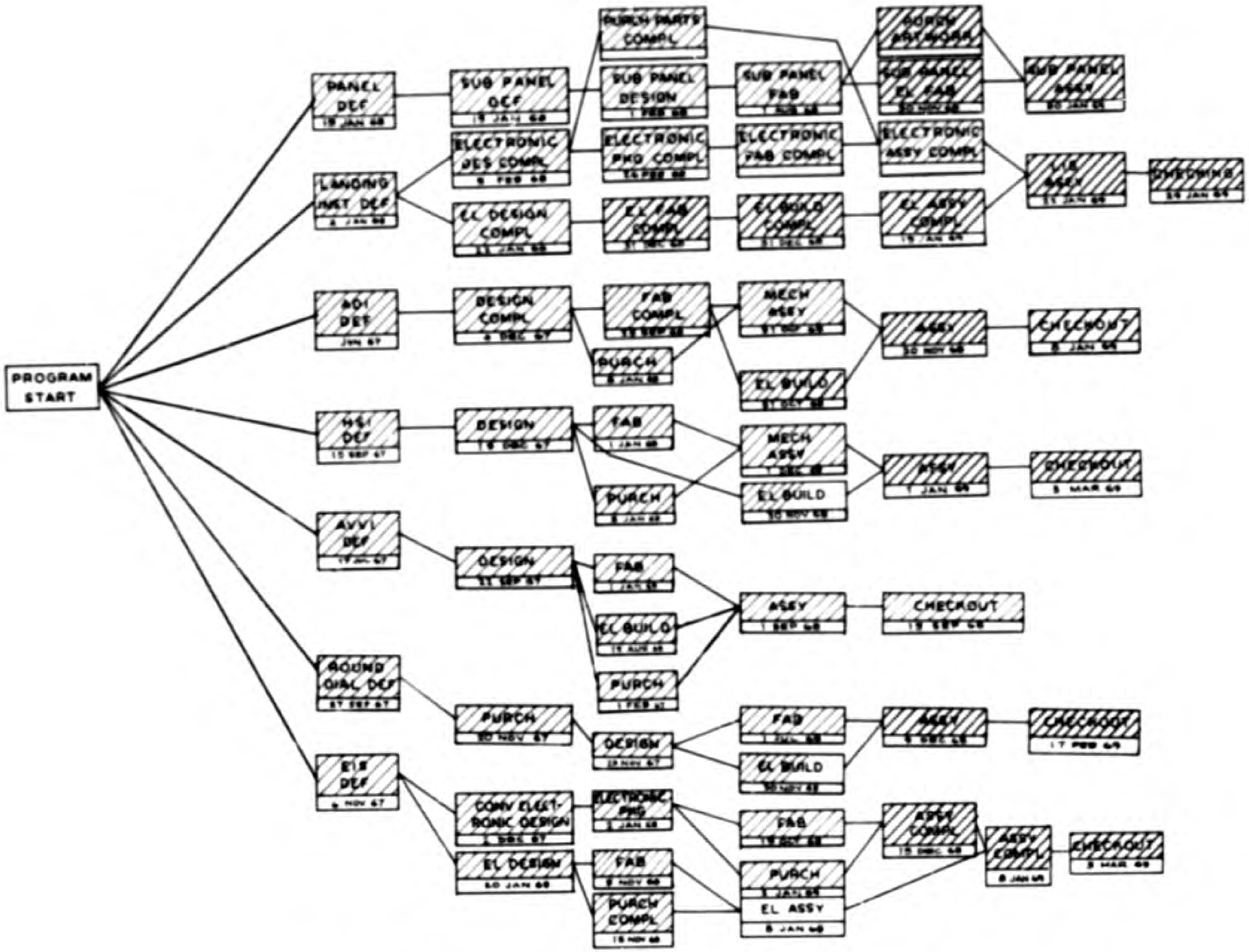
Some of the factors which contributed to this one year delay were:

a. Non-availability of aircraft system interface information - the panel was originally scheduled to go in aircraft No. 649; however, during the program, changes were made so that the panel could be installed in aircraft No. 868. The intended installation of the panel fluctuated between these two aircraft, with the eventual outcome that the panel is now to be installed in aircraft No. 649.

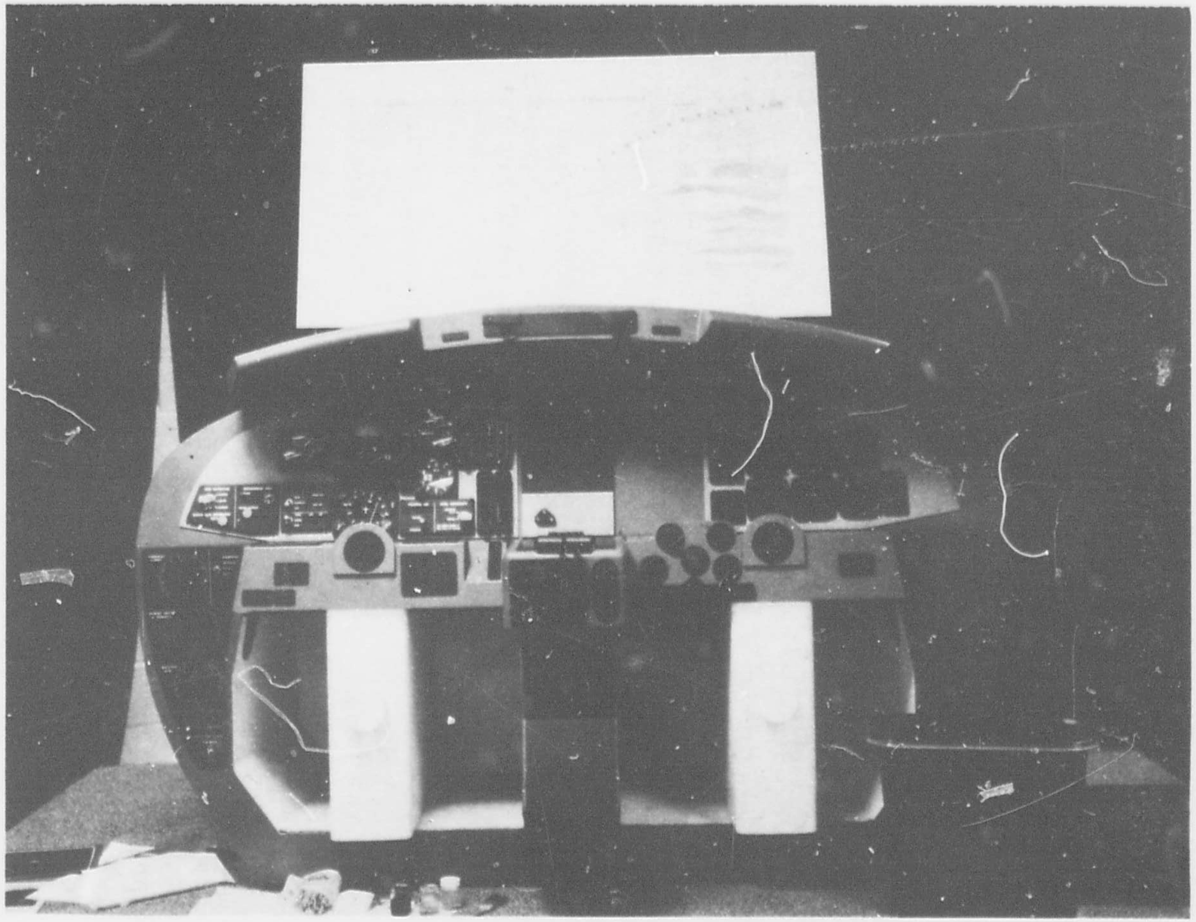
b. Inability of vendors to produce to the required schedule and specification - a ceramic back plate for the electroluminescent emitting lamps on the panel was developed with vendor cooperation. After LSI had devoted approximately 3 months to developing this back plate concept, the vendor withdrew their support and stated that they would not be able to furnish the back plates to the required specifications. This meant that LSI had to develop a new back plate configuration.

c. During the period of the contract, LSI suffered a prolonged labor strike. This strike was in progress for approximately four months and resulted in that amount of slippage to the EL panel.

On April 15, 1969, a formal delivery and presentation of the panel to the Air Force was conducted at LSI. As a preparation for this ceremony, the electroluminescent panel was installed in a T-39 mock-up, and the instruments were suitably driven with a simulator to produce a real time simulation of an instrument approach and landing. This demonstration was made to approximately 40 Air Force personnel. The panel installed in the mockup is shown in Figure 3.




CURRENT STATUS OF T-39 ADVANCED DISPLAY SYSTEM
FIGURE 2



T-39 EL PANEL IN SIMULATOR
FIGURE 3

## PRELIMINARY WORK

The application of electroluminescence to an aircraft instrument panel required that three areas be clarified:

a. The brightness contrast criteria for viewing light-emitting displays in all ambients had to be investigated to ascertain that EL could indeed provide a display with adequate contrast to be seen in all operating environments.

b. The temperature environment of the T-39 had to be evaluated and an adequate electroluminescent display life provided.

c. The various lighting techniques applicable to present and future aircraft cockpit lighting problems had to be identified so they could be represented on the EL panel if it would truly be able to serve as a lighting evaluation tool.

### Preliminary Flight Test Preparation

Flight and ground tests were initiated by LSI and the Air Force to determine the EL brightnesses required and the panel operating temperatures. Sample lamps and a portable power supply were built for the flight test. These lamps were evaluated in the T-39 in flight and provided data on:

a. The effectiveness of the new high contrast techniques.

b. The brightness at which the EL displays must be operated to be visible to the pilot.

c. The optimum tilt angle for each display on the panel.

d. The amount of and entry point of direct sunlight on the pilot's instrument panel.

It was anticipated that the main problem to overcome would be the specular reflections from bright objects in the cockpit; therefore, lamps were developed to reduce or eliminate this potential problem area. A tilting base for the lamp was fabricated so the operator could determine the optimum tilt angle for all display locations on the panel. The power supply was marked off in percentage of full scale to reduce any operator tendency to select the lamp operating voltage for other than optimum readability. Five pieces of equipment were fabricated for use on this flight test:

a. A portable power supply.
b. A tilting lamp base.
c. Three test lamps.

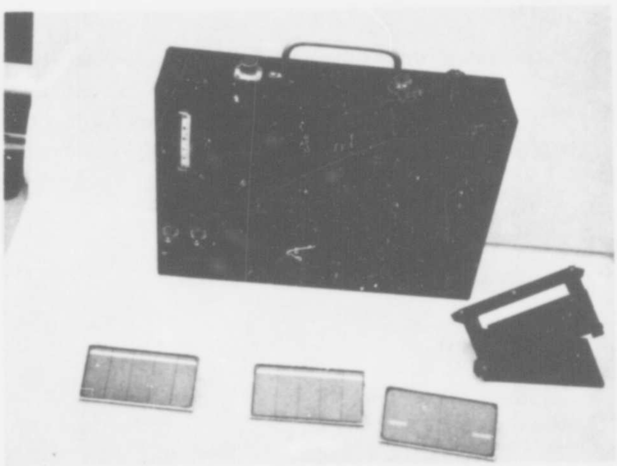
This equipment is shown in Figure 4.

Portable Power Supply

The battery-powered supply was designed to be hand-held during the test. It furnished 1,000-cycle excitation for the lamps. The scale was graduated from 0 to 100% full scale and the output voltage range of the power supply was selected to bracket the brightness attained by the lamps at 250V, 400 cycle. The increased frequency did not cause a visible color shift on the lamps.

Test Lamps

Three test lamps of varying percent transmission and reflectance were built. These lamps were compared with the landing sequence indicator (see Table I). The test lamps were excited with 250V, 400 cycles sine wave. The sequence indicator shown as a reference was excited with 500V, 400 cycles, sine wave. The test lamps were 1-3/4" x 3-1/2" x 2/10" thick. They were hermetically sealed, using metal-



FLIGHT TEST EQUIPMENT
FIGURE 4

## TABLE I
## PANEL BRIGHTNESS MEASUREMENT RESULTS

| Lamp | Excitation Volts-Freq. | % Trans. of Contrast Filter | Original Brightness | Brightness Through Contrast | % Reflectance | Color |
|---|---|---|---|---|---|---|
| Landing Sequence | 500V 400 Hz | 27% | 74 | 20 | 3.2% | Green |
| Lamp #1 | 250V 400 Hz | 24% | 51 | 12 | 5.5% | Green |
| Lamp #5 | 250V 400 Hz | 17% | 47 | 8 | 2.7% | Green |
| Lamp #9 | 250V 400 Hz | 27% | 52 | 14 | 5.3% | Green |
| Landing Sequence | 500V 400 Hz | 27% | 51.7 | 14 | 3.2% | Yellow |
| Lamp #1 | 250V 400 Hz | 24% | 23.7 | 5.7 | 5.0% | Yellow |
| Lamp #5 | 250V 400 Hz | 17% | 20.6 | 3.[illegible] | 2.1% | Yellow |
| Lamp #9 | 250V 400 Hz | 27% | 23.0 | 6.2 | 4.8% | Yellow |

to-metal and glass-to-metal seals. The display format consisted of two 14-stroke alpha numeric characters - one green and one amber. The alpha numeric characters were 0.725" high x 0.35" wide. They have a 15° slant and the individual segments are 0.050" wide. The glass substrate employs an advanced high contrast filter construction that features elimination of electrical losses and improvement in total reflection by the elimination of the reflections from the front electrode. The values shown in Table I indicate the decrease in brightness due to the 250V excitation. The effect of the improved high contrast in reducing specular glare and thus increasing the visibility of the lamps is not evident in Table I. This is an important feature of the test lamps, as was evidenced in the test flight.

### Tests Performed

Three types of tests were flown in the T-39.

a. Brightness measurements on the panel.
b. Brightness of the lamp for readability.
c. The amount and location of direct sunlight on the panel.

## Panel Brightness

The electroluminescent panel for the T-39 is shown in Figure 1. A bright diffuse reflector disk was mounted at various locations on the panel. The brightness readings were taken with a portable spectro-spot photometer, Type UB-1. The brightness of the disk did not vary appreciably with panel location; however, clouds or direct sunlight did affect it greatly.

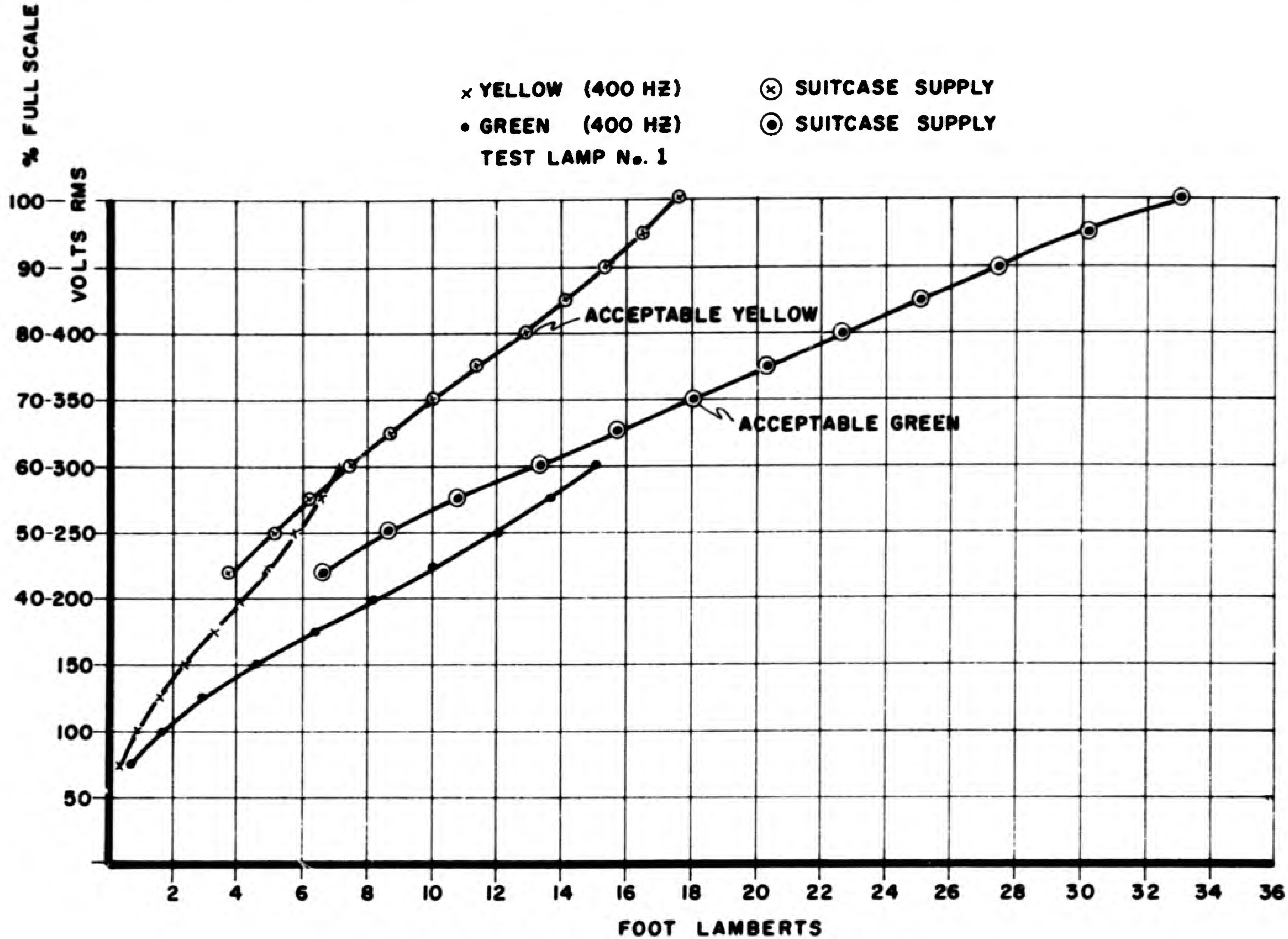
Table II is a summary of the results of the panel brightness measurements. The reflector disk had a diffused reflectance of approximately 80%. The brightness values in Table II are the uncorrected measured values.

## Lamp Visibility

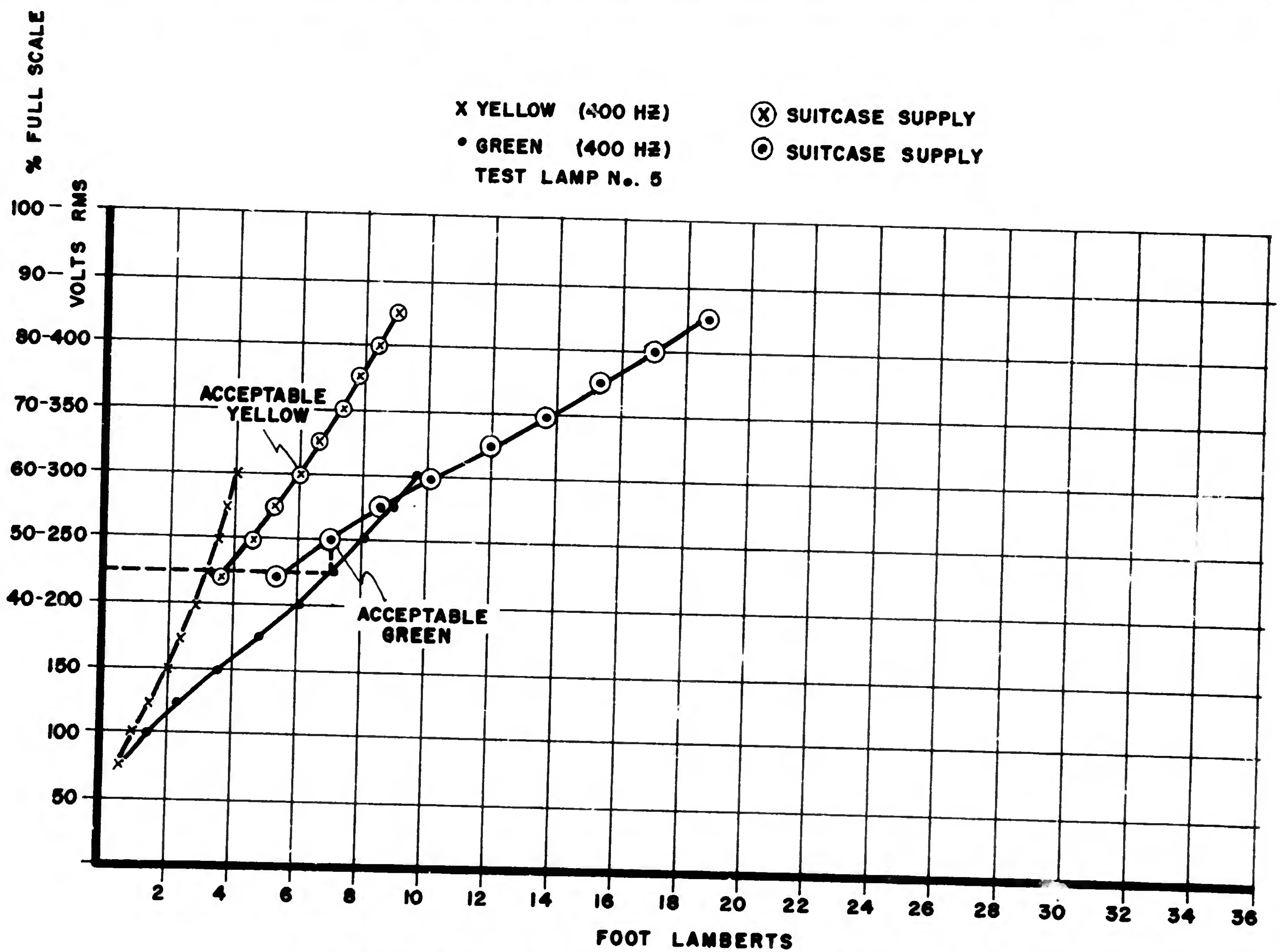
Figures 5, 6, and 7 are plots of data taken from lamps 1, 5, and 9, respectively, prior to the flight test. The points designated by dots and crosses were taken with 400 cycle lamp excitation. The dots and crosses encircled are with the portable power supply. Points of acceptable readability are shown for each lamp with the lamp mounted in the lower right center of the T-39 panel. These points were taken when the lamp was not in direct sunlight. Acceptable brightness values for the yellow and green for each lamp are indicated on the plots. It may be seen that the green values for the lamps 5 and 9 are within the region attainable with 250V, 400 cycle, excitation. The yellow, however, does not reach an acceptable brightness with the 250V, 400 cycle, excitation. The yellow thus requires an excitation frequency of greater than 400 cycles to be visible in the T-39.

TABLE II
PANEL BRIGHTNESS READINGS

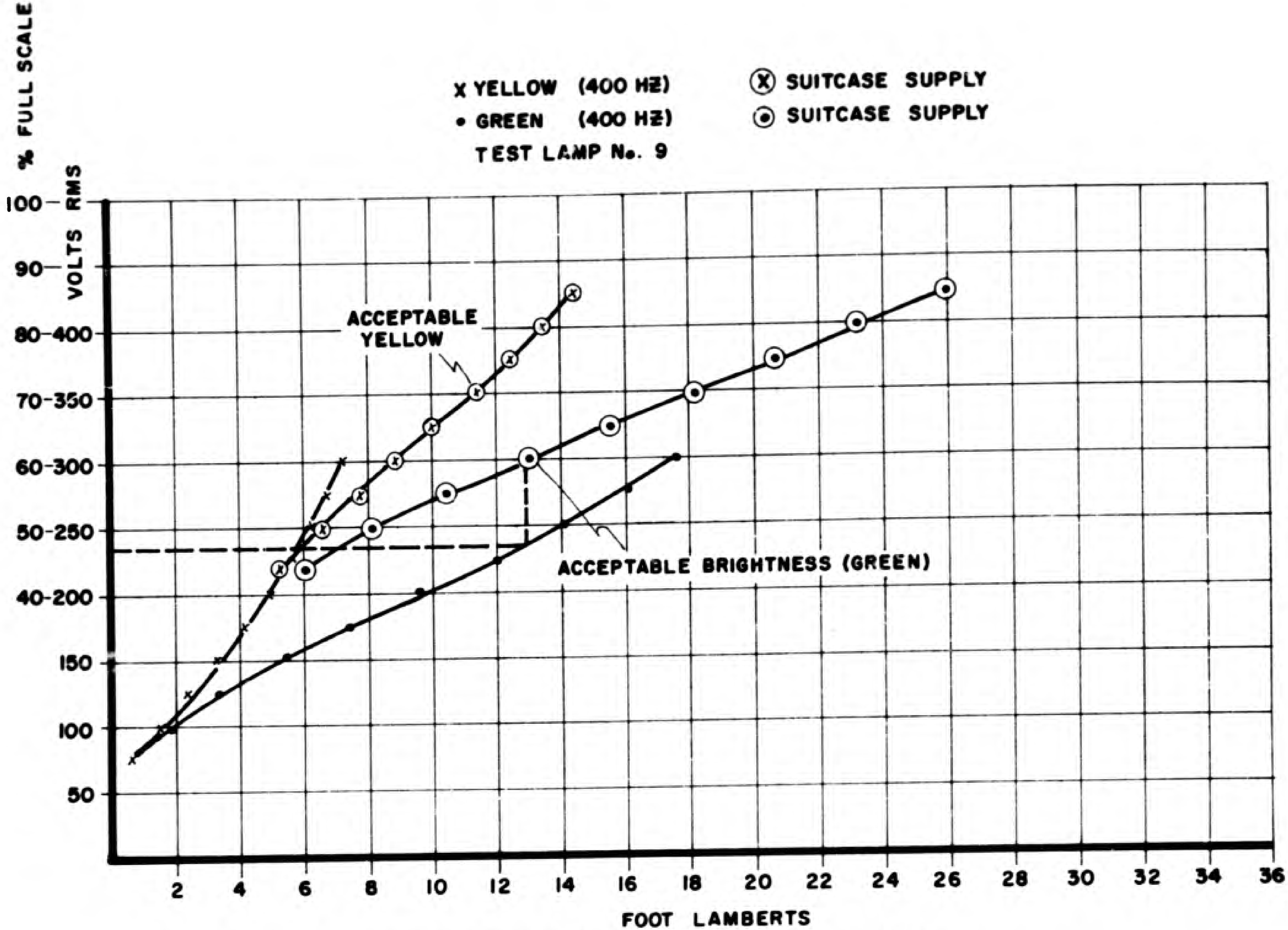
| Disc Location | Type of Illumination | Measured Brightness, Ft-Lamberts |
|---|---|---|
| Panel Scan | Indirect | 70-90 |
| Lower Right | Indirect | 90 |
| Lower Right | Indirect diffused by cloud | 310 |
| Lower Right | Direct Sun | 6, 500 |




BRIGHTNESS-VOLTAGE CURVE FOR TEST LAMP
FIGURE 5




BRIGHTNESS-VOLTAGE CURVE FOR TEST LAMP
FIGURE 6




BRIGHTNESS-VOLTAGE CURVE FOR TEST LAMP
FIGURE 7

### Direct Sunlight Ambient

It was at first thought that direct sunlight illumination of the T-39 instrument panel would not be a problem. Direct sunlight, however, can strike the panel by coming through the rear windows as shown in Figure 8. During this initial flight test evaluation, it was determined that -- although the electroluminescent displays were visible in the bright sunlight ambient -- it did not have sufficient contrast for the pilot to be able to extract information from them without concentration. Further investigation in the T-39 during this same flight revealed that the high contrast display was visible in a higher light ambient than the caution light enunciator panel located in the center console. From the curves taken during this flight test, it was determined that a display emission of 17 foot-lamberts through the contrast layers would be visible in all ambients if the light falling on the displays was controlled with a polarizing filter.

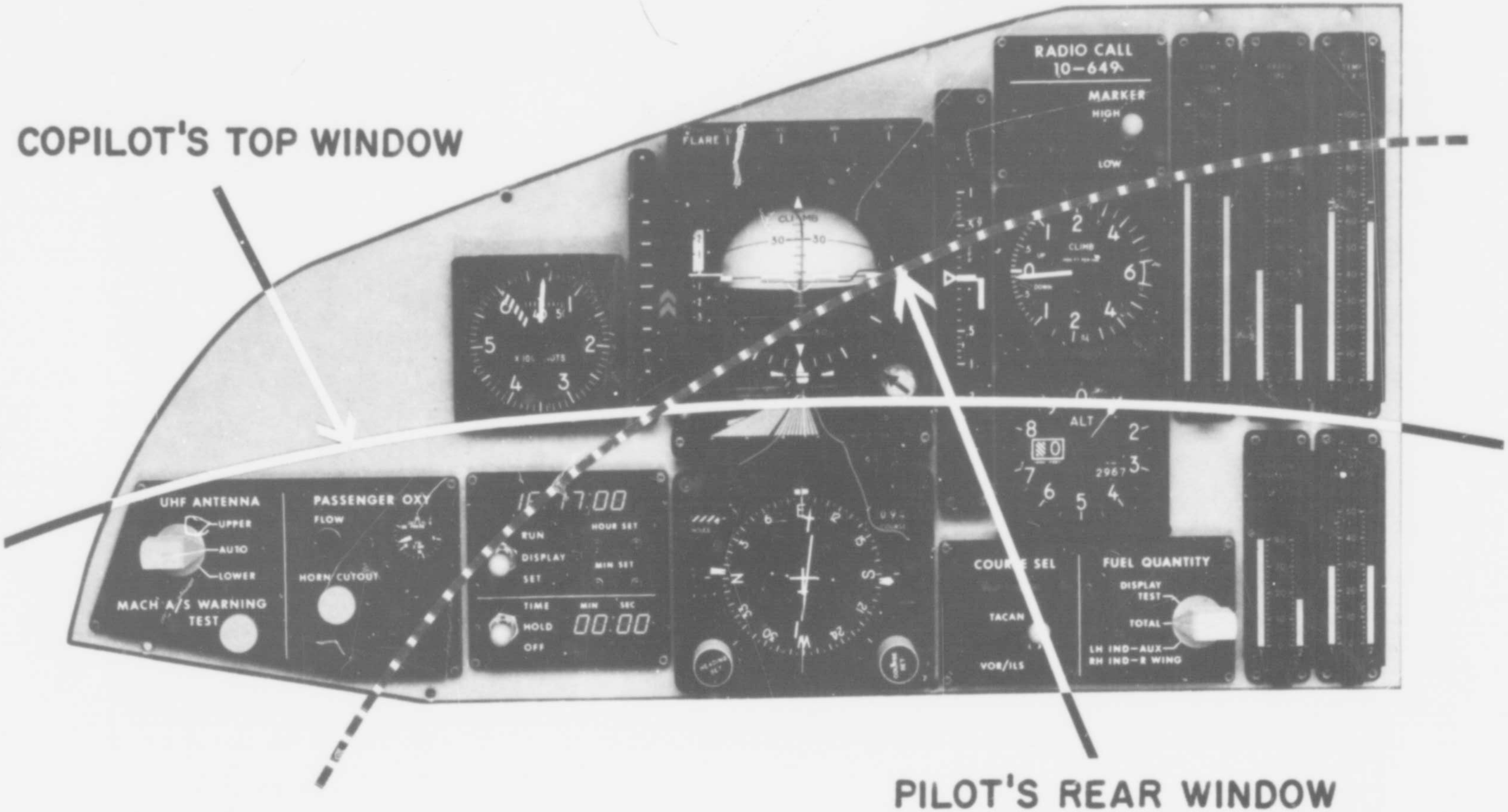
Control of light entering the cockpit and falling on the face of the displays was affected by the addition of polarizing filters on the displays and cross polarizing filters on the rear windows of the aircraft to limit the amount of light that would be re-reflected from the display surface. This polarizing light control was tried on a second flight test and was found to be effective in controlling the light, thus rendering the displays visible in all light ambients including direct with the 17 foot-lamberts brightness.

The definition of life for the EL displays was made on this flight test. Life of the emitting displays on the T-39 panel is defined as that point in time which, with an increasing voltage, the displays will no longer maintain 17 foot-lamberts display brightness through the filters.

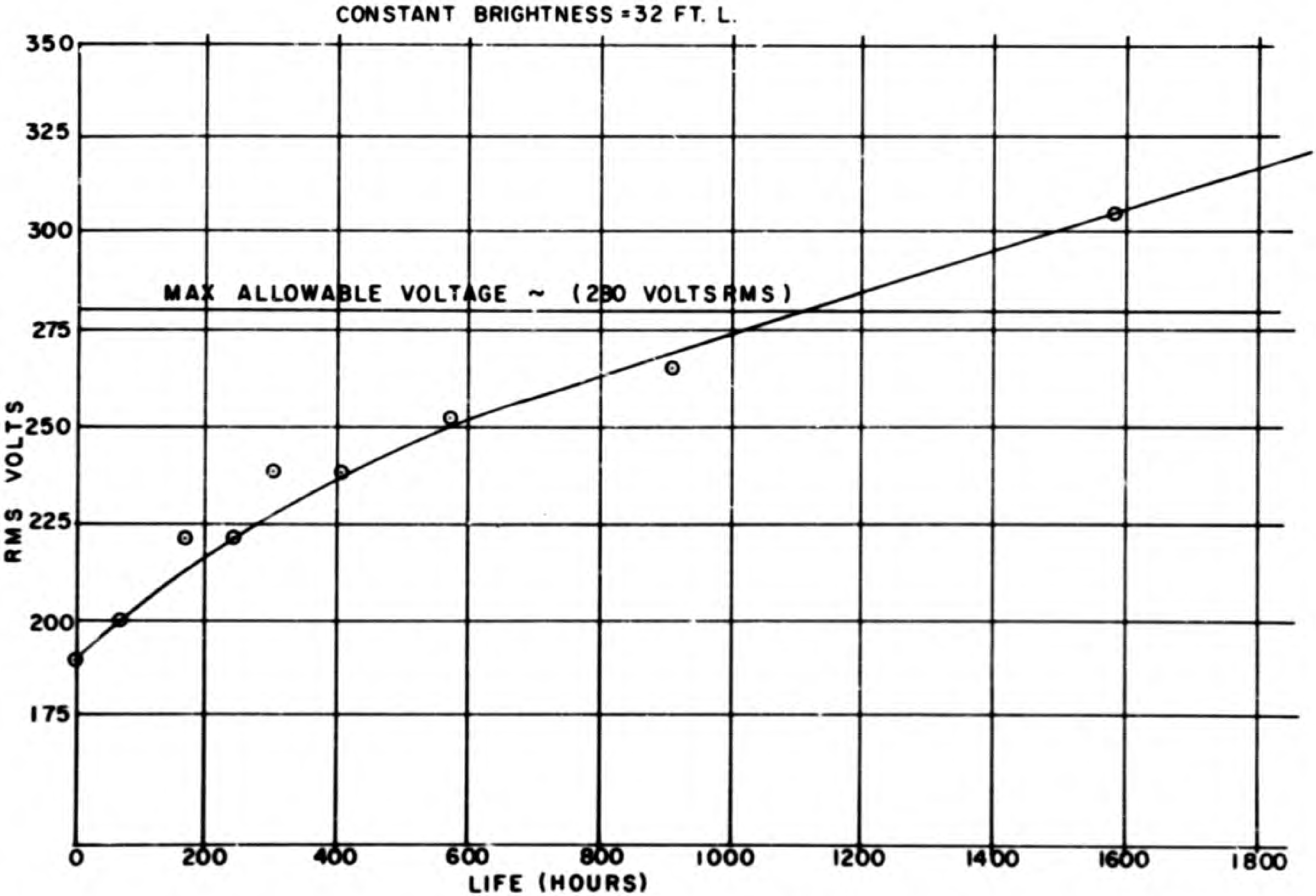
Life test of lamps during the T-39 program assured that a minimum of 1,000 hours would be attainable with the high contrast lamps used on both the engine instruments and the landing instruments. A typical EL lamp life test curve at room temperature is shown in Figure 9. This shows the life of the green and the yellow phosphors with the 800 cycle full wave rectified excitation that is necessary to maintain a display brightness of 17 foot-lamberts of the yellow phosphor.

### Heat Analysis

The phosphor life and brightness of operating displays deteriorate under heat. This deterioration occurs only when the displays are operating in a heated environment; the storage of an EL lamp in a hot ambient will not degrade its life so long as the ambient is not sufficient to break down the structure of the lamp. This deterioration occurs as the lamp temperatures are raised from near absolute zero. For practical purposes, however, lamp life is based on a room ambient of




PANEL WITH DIRECT SUNLIGHT AREAS DELINEATED
FIGURE 8




T-39 EL LAMP LIFE TEST
FIGURE 9

70°F. Life deterioration from the 70°F point is not greatly accelerated until temperatures beyond 110°F are reached in lamp operation. Since panel ambients in the T-39 were measured and found to be in excess of 160°F, it was obvious that some consideration had to be given to the amount of heat that would be directed on the EL displays. A two-fold approach to the problem was undertaken:

a. A heat analysis of the electroluminescent lamp structure, with its associated electronics, was completed.

   A heat transfer analysis was run on the T-39 EL indicators. The analysis technique was similar to that used on the IBM-MOL program except that the computer was used in obtaining the solution of the heat transfer circuits.

   The hottest indicator was the pressure indicator. The parameters which were used in the analysis are the following:

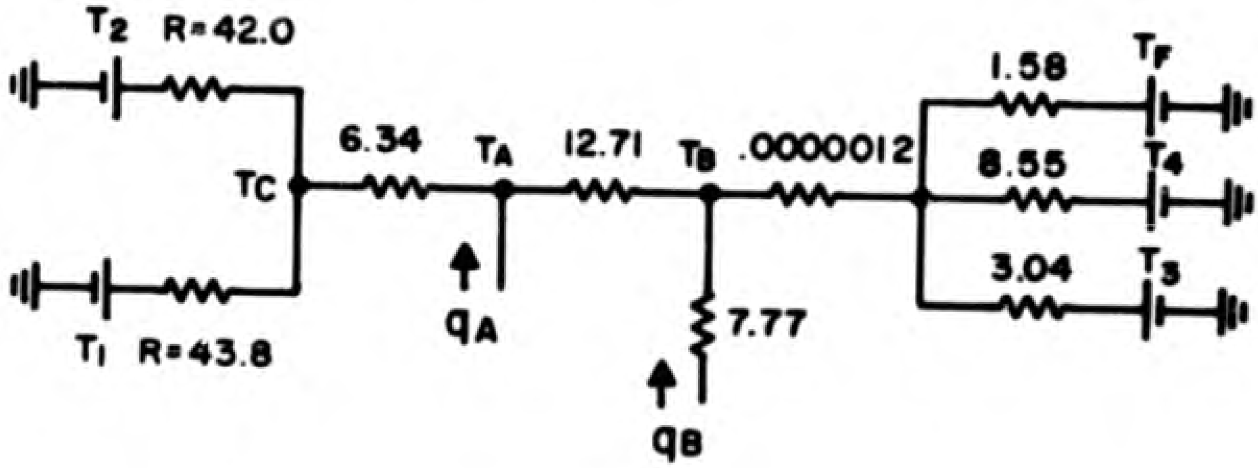
| | | |
|---|---|---|
| Cockpit ambient temperature | 70°F | $T_1$ |
| Cockpit wall temperature | 90°F | $T_2$ |
| Panel temperature | 120°F | $T_F$ |
| Behind panel ambient temperature | 100°F | $T_3$ |
| Behind panel wall temperature | 110°F | $T_4$ |
| Power dissipation in lamp | 0.5 watts | $9_A$ |
| Power dissipation in electronics | 4.8 watts | $9_B$ |

   The resulting steady state temperatures were calculated to be the following:

| | | |
|---|---|---|
| Temperature of EL lamp | 115.7°F | $T_A$ |
| Temperature of case | 120.4°F | $T_B$ |
| Temperature of polarizer | 107.6°F | $T_C$ |

   The heat transfer circuit can be simplified to the one shown in Figure 10.

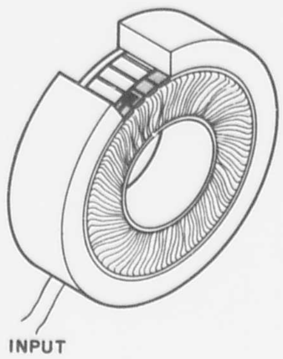
b. A concentrated effort was made to determine the heat sources in the panel and to reduce the heat from those sources so that the overall panel ambient would be more acceptable to electroluminescent displays. This study revealed that most of the heat was being generated by the two primary flight instruments -- the attitude director indicator, which accounted for approximately 30 volt-amps power comsumption, and the horizontal situation indicator, which accounted for approximately 50 volt-amps power consumption. Thermocouples placed between the ADI and HSI registered temperatures slightly in excess of 160°F after the displays had been operating for a 2-hour period.




HEAT TRANSFER CIRCUIT
FIGURE 10

It was determined that the use of DC torquers in these displays would reduce their heat output significantly (see Figure 11). A program was begun, therefore, to replace the AC servo drives in these two instruments with DC servo drive mechanisms. This program involved the complete redesign of the internal mechanism of each display. The advantage of the DC servo mechanism to the EL panel application is, primarily, reduced power consumption. Since the DC servo motor consumes power only when it is being driven, there is no fixed phase excitation and no quadrature. This factor enabled LSI to reduce the power consumed by the attitude indicator from the 30 volt-amps of the AC servo drive unit to approximately 8 volt-amps for the DC servo drive unit, with a corresponding decrease in heat generated. A similar reduction in heat generation from 50 va to approximately 10 va was effected by the application of DC servo drive components in the horizontal situation indicator. The application of DC servos to these two instruments allows LSI to predict a panel operating temperature between the ADI and HSI in the order of 110°F, which will permit the electroluminescent displays to maintain their long life.

Other advantages of the DC torquer mechanisms are: reduced gear trains which decreases the number of bearings and gear




DC TORQUERS
FIGURE 11

passes to be used, thus increasing their reliability; increased coupling stiffness which allows them to follow at higher rates and to reverse more readily; and increased response characteristics.

## Lighting Techniques

Before becoming involved in a program to develop a tool for panel lighting evaluation, it was necessary to determine the various types of lighting techniques which should be incorporated in the electroluminescent panel.

All aircraft cockpit panel lighting can be broken into three basic categories, or techniques. These encompass all of the displays in present day aircraft, as well as those that are planned for near future aircraft. They are:

a. Light reflecting displays.
b. Transilluminated displays.
c. Light emitting displays.

## Light Reflecting Displays

In this category are the displays which utilize lamps mounted internal to the instrument to illuminate the display elements. These lamps may either floodlight the elements directly or they may be mounted to a light wedge through which the light is piped by a series of internal reflections to be emitted in a pattern determined by the wedge designer. Displays in this category rely on the contrast developed between the display elements and their backgrounds for visibility in all ambients. Internal lighting merely supplements normal ambients to retain the display contrast through the various ambients. Examples of light reflecting displays would be the attitude indicator, the horizontal situation indicator, the altimeter, airspeed indicator, and vertical velocity.

## Transilluminated Displays

The category of transilluminated displays involves those displays that are back lighted. A lamp is mounted behind the display surface and light is transmitted through the display surface. Varying light transmission characteristics between the display surface and the surrounding surfaces cause the display to be seen. The lamp behind merely supplements the daylight visibility of this type of display. The light transmission through the various display elements is varied to attain the desired lighting effect for nighttime visibility. Examples of transilluminated displays would be the transilluminated panels, the passenger oxygen indicator, and the altitude/vertical velocity indicator.

Light Emitting Displays

The third lighting technique is that of light emitting displays. These displays rely on contrast developed by the light source between the display element and its background for visibility in all ambients. These displays require maximum contrast for visibility in high brightness ambients, for, if this contrast is not present, the display will not be seen. This is the category or technique into which most electroluminescent displays fall. The light emitting displays include the engine instruments, the various landing instruments, the clock, and pilot "C"-select fail display located on the course select panel.

## SECTION III

## DISPLAY DEFINITION

The development of the electroluminescent panel for the T-39 aircraft required that all display parameters of the T-39 be examined to ascertain that the electroluminescent panel would give the pilot the information he needed to fly the aircraft. A display definition chart was developed to assist in this examination. On this chart all display parameters were listed and categorized so that each would be covered in the final presentation. This display definition chart is shown in Figure 12. It includes the various parameters that the pilot requires to fly the aircraft, the location of these, how they are combined into multipurpose displays, the range of the parameters, the types of indices, the various colors or color coding as required, the type of lighting, the mechanism that is used to drive each display, the signal input characteristics, and the origin of the input signal.

The display parameter chart reflects all of the inputs that the pilot will see on the electroluminescent panel. It is a compilation of the basic information needed to design the T-39 electroluminescent panel. Many of the displays were very easy to place on the display parameter chart. All inputs were well defined. The signal characteristics were known or easy to attain.

Some information, however, was very difficult to obtain. This included some of the landing instruments where little or no thought had been given to the derivation of localizer rate and speed error rate. The signals for these parameters varied with the assigned aircraft so it was difficult in the beginning of the program to establish the signal inputs for localizer and speed since they could not be tied down until the specific aircraft was determined.

Engine instrumentation was also a problem area during the development of the display development. Much of the information existed but it was not in a form that was readily available to LSI. The fuel quantity system on the T-39 was especially difficult since the fuel sensing capacity bridge circuit is a closed circuit and is supplied by one manufacturer -- Simmonds Precision. It was felt that adding other output devices to the capacitive bridge would change the output of the bridge

## T-39 PANEL, DISPLAY DEFINITION CHART

| | PARAMETER | LOCATION OF | TYPE OF DISPLAY | RANGE | SCALE FACTOR | MAJOR INDICES | INTERMEDIATE INDICES | MINOR INDICES | COLOR | INDEX | LIGHTING REQ'D | BRIGHTNESS | READABILITY | MECH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ADI OFF FLAG | ADI | FLAG | IN VIEW OR OUT OF VIEW | | | | | | | | | | |
| 2 | PITCH | ADI | SPHERE (MOVING SCALE) | ±90 | 1° MOVEMENT 1° PITCH | EACH 10° | EACH 5° | EACH 1° THRU [illegible] | PITCH UP-BLUE [illegible] PITCH DOWN-FED STD 595 | PITCH UP-BLACK PITCH DOWN-WHITE | WHITE E-L WEDGE | | [illegible] | CLEAR SERV |
| 3 | ROLL | ADI | MOVING BANK POINTER | 360 | 1° MOVEMENT PER 1° ROLL | EACH 30° THRU | EACH 10° THRU 20 | EACH 5° THRU ±25° | BLACK | WHITE | WHITE E-L WEDGE | | | CLEAR SERV |
| 4 | FLIGHT PATH ANGLE | ADI | MOVING TAPE SCALE | ±30 | .3 INCHES PER DEG. | EACH DEGREE | NONE | NONE | POS. FPA GREY # FED NEG FPA BLACK # STD 595 | POS FPA BLACK NEG FPA WHITE | WHITE E-L WEDGE | | | DC T DRIV |
| 5 | VERTICAL F.D. | ADI | POINTER BAR | ±.7 8 INCHES | 2.2 MILLIAMPS PER 7.8" DEFLECTION | NONE | NONE | NONE | NONE | *DAYGLOW ARC YELLOW | WHITE E-L WEDGE | | | D'AR |
| 6 | HORIZONTAL F.D. | ADI | POINTER BAR | ±.7 8 INCHES | 2.2 MILLIAMPS PER 7.8" DEFLECTION | NONE | NONE | NONE | NONE | *DAYGLOW ARC YELLOW | WHITE E-L WEDGE | | | D'AR |
| 7 | GLIDE SLOPE DEV. | ADI | POINTER | ±2 DOTS DEV. | 150 MICROAMPS PER 2 DEVS | 2 DOTS | NONE | NONE | WHITE DOTS ON BLACK BACKGROUND | *DAYGLOW ARC YELLOW | WHITE E-L WEDGE | | | D'AR |
| 8 | TURN RATE | ADI | POINTER | ±2 INDEX WIDTHS | 1 MILLIAMP PER 2 INDEX WIDTHS | 1 & 2 MIN TURN | NONE | NONE | BLACK & WHITE | WHITE | WHITE E-L WEDGE | | | D'AR |
| 9 | INCLINOMETER | ADI | SENSITIVE BALL | | | | | | | | WHITE E-L WEDGE | | | GRAV ING |
| 10 | G.S. ALARM | ADI | FLAG | IN VIEW OR OUT OF VIEW | 250 MICROAMPS FOR OUT OF VIEW | — | — | — | — | *DAYGLOW FIRE ORANGE | WHITE E-L WEDGE | | | D'AR |
| 11 | V.F.D. ALARM | ADI | FLAG | IN VIEW OR OUT OF VIEW | 250 MICROAMPS FOR OUT OF VIEW | — | — | — | — | *DAYGLOW FIRE ORANGE | WHITE E-L WEDGE | | | D'AR |
| 12 | RADAR ALT. | AVVI | TAPE | 0 TO 1000 FT | VARIABLE-SEE CURVE PP 17[illegible] | NONE | NONE | NONE | — | BLACK WHITE SEPARATION | WHITE E-L BACK LITE | | | A.C SERV |
| 13 | ALT RATE | AVVI | TAPE | 0 TO ±20,000 FPM | VARIABLE-SEE CURVE PP 17[illegible] | EACH 1000 FT PER MINUTE | NONE | EACH 100 FT PER MINUTE | WHITE MARKS ON BLACK BACKGROUND | WHITE TRIANGLE WITH BLACK CENTER | WHITE E-L BACK LITE | | | A.C SERV |
| 14 | AVVI OFF FLAG | AVVI | FLAG | IN OR OUT OF VIEW | OUT OF VIEW WHEN GROUNDED | | | | *FIRE ORANGE WITH BLACK LETTERS | BLACK | WHITE E-L BACK LITE | | | DC SOLE |
| 15 | MACH IAS | MACH IAS | ROUND DIAL | 0 – 650 KTS | | EACH 500 KTS | EACH 100 KTS | | BLACK WITH WHITE MARKINGS | WHITE | WHITE E-L WEDGE | | | [illegible] |
| 16 | BARO ALT. | ALTIMETER | ROUND DIAL | -1000 FEET TO +50,000 feet | | EACH 1000 FT ON COUNTER | EACH 100 FT | EACH 50 FT | BLACK WITH WHITE MARKINGS | WHITE | WHITE E-L WEDGE | | | BELL |
| 17 | BARO ALT RATE | ALT RATE | ROUND DIAL | ±6000 FPM | | EACH 1000 FPM | EACH 500 FPM | EACH 100 FPM | BLACK WHITE MARKINGS | WHITE | WHITE E-L WEDGE | | | BELL |
| 18 | | | | | | | | | | | | | | |
| 19 | AZIMUTH | HSI | AZIMUTH RING | 360° ROTATION | 1°/1°[illegible] | EACH 30° [illegible] | EACH 10° | EACH 5° | BLACK WITH WHITE MARKINGS | WHITE | WHITE E-L WEDGE | | | [illegible] |
| 20 | SELECTED HDG | HSI | POINTER | 360° ROTATION | 1° PER 1° | USES AZIMUTH SCALE | USES AZIMUTH SCALE | USES AZIMUTH SCALE | USES AZIMUTH SCALE | WHITE WITH BLACK LINE | WHITE E-L WEDGE | | | TORQU |
| 21 | COURSE | HSI | POINTER | 360° ROTATION | 1° PER 1° | USES AZIMUTH SCALE | USES AZIMUTH SCALE | | | [illegible] | WHITE E-L WEDGE | | | [illegible] |
| 22 | COURSE DEV | HSI | POINTER BAR | ±2 DOTS DEV | 75 MICROAMPS PER DOT | 2 DOTS | — | — | BLACK WITH WHITE DOTS | WHITE | WHITE E-L WEDGE | | | D'AR |
| 23 | BEARING [illegible] | HSI | POINTER | 360° ROTATION | 1° PER 1° | USES AZIMUTH SCALE | USES AZIMUTH SCALE | USES AZIMUTH SCALE | USES AZIMUTH SCALE | WHITE WITH BLACK LINE | WHITE E-L WEDGE | | | [illegible] |
| 24 | COURSE DEV WARN | HSI | FLAG | IN OR OUT OF VIEW | 250 MICROAMPS FOR OUT OF VIEW | — | — | — | — | *DAYGLOW FIRE ORANGE | WHITE E-L WEDGE | | — | D'AR |
| 25 | TO-FROM | HSI | FLAG | OFF TO FROM | +225 Ma – TO -225 Ma – FROM | — | | | WHITE | | WHITE E-L WEDGE | | | D'ARS |
| 26 | DISTANCE | HSI | TAPE | 0 – 999 MILES | 1 MI PER MI | EACH MILE | | | BLACK WITH WHITE MARKS | | WHITE E-L WEDGE | | | SYNC REPE |
| 27 | HSI OFF | HSI | FLAG | IN VIEW OR OUT OF VIEW | OUT OF VIEW WHEN GROUNDED | — | | | | *DAYGLOW FIRE ORANGE | WHITE E-L WEDGE | | | SOLE |
| 28 | DME SHUTTER | HSI | FLAG | IN VIEW OR OUT OF VIEW | OUT OF VIEW WITH +28 VDC | | | | BLACK WHITE CHECKER MATCH | | WHITE E-L WEDGE | | | SOLE |
| 29 | | | | | | | | | | | | | | |
| 30 | COURSE SET | HSI | KNOB & 360° COUNTER | 360° | | EACH 1 | | | BLACK BACKGROUND WHITE NUMERALS | | WHITE E-L WEDGE | | | MANU |
| 31 | HDG SET | HSI | KNOB | 360° | | | | | | | | | | |
| 32 | | | | | | | | | | | | | | |
| 33 | LOCALIZER | LOCALIZER DISPLAY | E-L POINTER | 47 SEGMENTS | | FIXED LUBBER LINE | | | EL GREEN | WHITE | LUBBER LINE | 17 FL. | WITH [illegible] | [illegible] |
| 34 | LOCALIZER RATE | LOCALIZER DISPLAY | E-L RATE FIELD | 47 SEGMENTS | EXTENSION OF LOC | FIXED LUBBER-LINE | — | — | E-L GREEN | WHITE | LUBBER LINE | 17 FL. | [illegible] | [illegible] |
| 35 | HEADING ERROR | LOCALIZER DISPLAY | E-L POINTER | 2 TRIANGLES & 49 SEGMENTS | 30 SEG INCH ADJUSTABLE | FIXED LUBBER-LINE | — | — | E-L YELLOW | WHITE | LUBBER LINE | 17 FL. | > [illegible] | [illegible] |
| 36 | RANGE/RUNWAY WIDTH | LOCALIZER DISPLAY | VARY WIDTH OF LOC POINTER | 300 FT TO TOUCHDOWN | NON LINEAR | | | | EL GREEN | WHITE | | 17 FL. | | [illegible] |
| 37 | | | | | | | | | | | | | | |
| 38 | | | | | | | | | | | | | | |

DISPLAY PARAMETERS CHART
FIGURE 12 (1 of 2)

REVISION: 8
DATE: 15 APRIL 1969



| EADABILITY | DISPLAY ACCURACY MECHANISM | | DIRECTION | SPEED | SPECIFIC INFORMATION | INPUT SIGNAL TYPE | SIGNAL ORIGIN | DISPLAY LOAD | LIMIT LINE | DISPLAY INITIATE SIGNAL | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | |
| °FOR ± 0° | GEARLESS SERVO | 4° | SPHERE MOVES UP FOR PITCH DOWN | 90° PER SECOND | | SYNCHRO 11.8V LEG TO LEG | VERTICAL GYRO | | | | | | |
| | GEARLESS SERVO | 2° | POINTER MOVES RIGHT FOR RIGHT BANK | 300° PER SECOND | BOTTOM MOUNTED ROLL SCALE | SYNCHRO 11.8V LEG TO LEG | VERTICAL GYRO | | | | | | |
| | DC TORQUE DRIVE | 4° | TAPE MOVES UP FOR DEC. FPA | 6° PER SECOND | | SYNCHRO 11.8V LEG TO LEG | FPA COMPUTER | | | | | | |
| | D'ARSONVAL | 7 | MOVES TO RIGHT FOR RIGHT BANK COMMAND | | MOVES TO RIGHT WITH APPLICATION OF 10 MILLIAMPS | DC INTO 1K OHMS | FLIGHT DIRECTOR COMPUTER | 1 KΩ | | | | | |
| | D'ARSONVAL | 7 | MOVES UP FOR PITCH UP COMMAND | | MOVES DOWN WITH APPLICATION OF 10 MILLIAMPS | DC INTO 1K OHMS | FLIGHT DIRECTOR COMPUTER | 1 KΩ | | | | | |
| | D'ARSONVAL | 7 | MOVES UP FOR BEAM ABOVE AIRCRAFT | | MOVES UP WITH APPLICATION OF [illegible] MILLIAMP | DC INTO 1K OHMS | GLIDE SLOPE RECEIVER | 1 KΩ | | | | | |
| | D'ARSONVAL | 7 | | | | DC INTO 1K OHMS | TURN RATE GYRO | 1 KΩ | | | | | |
| | GRAVITY ACTING ON BALL | | | | | | | | | | | | |
| | D'ARSONVAL | | IN VIEW INDICATES OUT OF TOLERANCE G.S. SIGNAL | | | DC INTO 1K OHMS | GLIDE SLOPE RECEIVER | 1 KΩ | | | | | |
| | D'ARSONVAL | | IN VIEW IN INDICATES OUT OF TOLERANCE SIGNAL | | | DC INTO 1K OHMS | FLIGHT DIRECTOR COMPUTER | 1 KΩ | | | | | |
| | AC SERVO | | MOVES UP FOR DECREASING ALTITUDE | | | 0 to +40 VDC | RADAR ALTIMETER | 10 KΩ | | | | | |
| | AC SERVO | | MOVES UP FOR INCREASING ALT RATE | | | .25 VAC PER 1000 ft. PER MIN. | | 25 KΩ | | | | | |
| | DC SOLENOID | | | | SHUTTER COVERS OFF INDICATION | 115V 400 Hz COMMON FOR INFO VALID | | | | | | | |
| | BELLOWS | | POINTER CW FOR INCREASING SPEED | | | PITOT-STATIC | | | | | | | |
| | BELLOWS | [illegible] | POINTER CW FOR INCREASING ALTITUDE | | BARO SET KNOB & DIAL RANGE 28.[illegible] - 30.0 | PITOT-STATIC | | | | | | | |
| | BELLOWS | MIL-I-27196 | POINTER CW FOR INC RATE | MIL-I-27196 | | PITOT STATIC | | | | | | | |
| | | | | | | | | | | | | | |
| | TORQUE MOTOR | [illegible] | INCREASING HEADING NUMBERS CW | 40° PER SECOND | | SYNCHRO 11.8V LEG TO LEG | DIRECTIONAL GYRO | | | | | | |
| | TORQUE MOTOR | [illegible] | INCREASING HEADING ROTATES CCW | 40° PER SECOND | MANUAL SET BY MODEL 3825A CONTROLLER | SYNCHRO 11.8V LEG TO LEG | MODEL 3825A CONTROLLER | | | | | | |
| | TORQUE MOTOR | ±1 | INCREASING COURSE ROTATES CCW | 90 PER SEC | " | " | " | | | | | | |
| | D'ARSONVAL | [illegible] | MOVES LEFT FOR COURSE LEFT | | | DC INTO 1K OHMS | LOCALIZER RECEIVER | 1 KΩ | | | | | |
| | TORQUE MOTOR | [illegible] | MOVES LEFT FOR STATION LEFT | 90° PER SEC | | SYNCHRO 11.8V LEG TO LEG | ADF | | | | | | |
| — | D'ARSONVAL | — | IN VIEW INDICATES OUT OF TOLERANCE LOC SG | | | DC INTO 1K OHMS | FLIGHT DIRECTOR COMPUTER | | | | | | |
| | D'ARSONVAL | | TO INDICATE COURSE TO STATION | | | DC INTO 250 Ω | VOR | 150Ω to 200Ω | | | | | |
| | SYNCHRO REPEATER | | | | | SYNCHRO | TACAN | | | | | | |
| | SOLENOID | | IN VIEW INDICATES FAILURE | | | 115V 400 HZ GROUND | | | | | | | |
| | SOLENOID | | IN VIEW FOR DME INOP | | | 28 VDC | TACAN | | | | | | |
| | | | | | | | | | | | | | |
| | MANUAL | | KNOB CW FOR INC COUNT | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| [illegible]TH VARIES | EL | | POINTER LEFT FOR LOC LEFT | | | ±150 [illegible] | ILS LOC. | 1000 OHMS | | + 28 | | | |
| 1 SEGON 7 OFF ETC | EL | | FIELD LEFT FOR RIGHT RATE | | REP. Rate 0-2 per sec. | ±150 MVDC | ILS LOC | FROM ABOVE | | + 28 | | | |
| [illegible] ON THE | EL | | DESIRED HDG TO KEY EL PTR TO HT | | POINTER WIDTH 3 SEGMENTS | AC FROM HSI COURSE DATUM | HSI | 10,000 OHMS | | + 28 | | | |
| | EL | | MAX. WIDTH FOR MIN. RANGE | | WIDTH EXP THRESHOLD ADJ FROM 300 FT | +40 MV PER FT | RADAR ALTIMETER | | | SELECT RADAR ALTIMETER | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

# T-39 PANEL, DISPLAY DE

| | PARAMETER | LOCATION OF | TYPE OF DISPLAY | RANGE | SCALE FACTOR | MAJOR INDICES | INTERMEDIATE INDICES | MINOR INDICES | COLOR | INDEX | LIGHTING REQ D | BRIGHTNESS | READA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | SPEED ERROR | SPEED ERROR DISPLAY | BAR GRAPH | ± [illegible] | 2FT. [illegible] SEG | | | | EL GREEN EL YELLOW | | | [illegible] FL. | |
| 40 | SPEED ERROR RATE | SPEED ERROR DISPLAY | [illegible] RATE FIELD | | [illegible] LINES IN | | | | EL GREEN | | | [illegible] FL. | |
| 4[illegible] | LANDING SEQUENCE | LANDING SEQUENCE | EL ANNUNCIATOR | [illegible] TO T.D. | | [illegible] | [illegible] | | EL GREEN EL YELLOW | | | [illegible] | |
| 42 | | | | | | | | | | | | | |
| 43 | | | | | | | | | | | | | |
| 44 | | | | | | | | | | | | | |
| 45 | [illegible] RPM [illegible] | ENGINE INST | [illegible] | [illegible] | [illegible] SEGMENT | EACH | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| 46 | E.G.T. [illegible] | ENGINE INST | [illegible] | [illegible] | [illegible] SEGMENT | EACH | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| 47 | [illegible] E.T.P. | ENGINE INST | [illegible] | [illegible] | [illegible] | [illegible] | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 48 | | | | | | | | | | | | | |
| 49 | | | | | | | | | | | | | |
| 50 | DISPLAY TEST SWITCH | LOWER LEFT OF [illegible] | 3 POSITION SWITCH W/ LITED LEGEND | | | | [illegible] | | | [illegible] | WHITE | | |
| 5[illegible] | | | | | | | | | | | | | |
| 52 | FUEL QTY [illegible] | FUEL DISP | [illegible] | [illegible] | [illegible] | [illegible] | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| 53 | FUEL FLOW [illegible] | FUEL DISP | [illegible] | [illegible] | [illegible] | [illegible] | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| 54 | | | | | | | | | | | | | |
| 55 | | | | | | | | | | | | | |
| 56 | | | | | | | | | | | | | |
| 57 | REAL TIME | CLOCK | [illegible] | | | [illegible] | | | [illegible] | | [illegible] | | |
| 58 | TIME TO GO | CLOCK | [illegible] | | | [illegible] | | | [illegible] | [illegible] | [illegible] | | |
| 59 | TIMER SELECT | CLOCK | TOGGLE SWITCH | 3 POSS SWITCH | | SET DISPLAY RUN | | | WHITE | [illegible] | [illegible] | | |
| [illegible] | TIME SET | CLOCK | PUSH BUTTON | [illegible] | | | | | WHITE | [illegible] | [illegible] | | |
| [illegible] | $O_2$ FLOW | LIGHT | WARNING LIGHT | [illegible] | | | | | [illegible] | | [illegible] | | |
| [illegible] | CYLINDER PRESSURE $O_2$ | [illegible] | [illegible] | [illegible] | | [illegible] | | [illegible] | [illegible] | [illegible] | [illegible] | | |
| [illegible] | [illegible] WARNING HORN CUTOUT | SWITCH | PUSH BUTTON | | | | | | WHITE | | [illegible] | | |
| [illegible] | | | | | | | | | | | | | |
| [illegible] | | | | | | | | | | | | | |
| [illegible] | PILOT'S COURSE SELECT FAIL | | INCANDESCENT LAMP | | | | | | | | NONE | | |
| [illegible] | TACAN/VOR-ILS | LOWER CENTER OF PANEL | TWO POSITION TOGGLE SWITCH | | | | | | | LEGEND | WHITE | | |
| [illegible] | [illegible] | [illegible] | [illegible] | | | | | | | | [illegible] | | |
| [illegible] | | | | | | | | | | | | | |
| 70 | VHF ANTENNA | LOWER LEFT OF PANEL | [illegible] POSITION SW. W/ LIGHTED LEGEND | | | | | | | LEGEND | WHITE | | |
| 71 | MAR. BCN. HIGH/LOW | UPPER RIGHT OF PANEL | [illegible] POSITION TOGGLE SWITCH | | | | | | | LEGEND | WHITE | | |
| 72 | RADIO C[illegible] | UPPER RIGHT OF PANEL | LEGEND | | | | | | | LEGEND | WHITE | | |
| 73 | | | | | | | | | | | | | |
| 74 | | | | | | | | | | | | | |
| 75 | | | | | | | | | | | | | |
| 76 | | | | | | | | | | | | | |
| 77 | | | | | | | | | | | | | |
| 78 | | | | | | | | | | | | | |
| 79 | | | | | | | | | | | | | |

## SPLAY DEFINITION CHART

REVISION [illegible]
DATE 15 APRIL 1969

(SHEET 2 of 2)

| RIGHTNESS | READABILITY | DISPLAY ACCURACY MECHANISM | | DIRECTION | SPEED | SPECIFIC INFORMATION | INPUT SIGNAL TYPE | SIGNAL ORIGIN | DISPLAY LOAD | DISPLAY INITIATE SIGNAL | LIMIT LINE | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 FL. | | EL | | [illegible] | | | 46 MV RT | [illegible] COMP | 1000 [illegible] | + 28 VDC | | | | |
| 17 FL. | | EL | | [illegible] | | START AT 1 [illegible] PER SECOND | FROM ABOVE | | FROM ABOVE | + 28 VDC | | | | |
| [illegible] FL. | | EL | | [illegible] | | [illegible] FINAL [illegible] | [illegible] DISCRETE | [illegible] BOX | 25 MA PER SEG | | | | | |
| [illegible] FL. | | [illegible] | | [illegible] | | | [illegible] FREQUENCY | [illegible] | | | 104% | | | |
| [illegible] | | [illegible] THERM | | [illegible] | | | [illegible] THERMOCOUPLE | [illegible] | | | 677 DEG | | | |
| [illegible] | | [illegible] THERM | | [illegible] | | | [illegible] ROTATION | | | | | | | |
| | | | | | | | | CONVERTER CONTROL | | | | | | |
| [illegible] | [illegible] | [illegible] | | [illegible] | | [illegible] | AC VOLTAGE | [illegible] | [illegible] MEG MIN. | | | | | |
| [illegible] | [illegible] | [illegible] | | [illegible] | | [illegible] | [illegible] ROTATION | [illegible] | [illegible] | | | | | |
| | | [illegible] | | [illegible] | [illegible] PER SE[illegible] | | PULSES PER SECOND | [illegible] | | | | | | |
| | | [illegible] | | [illegible] | [illegible] PER SE[illegible] | | PULSES PER SECOND | [illegible] | | | | | | |
| | | | | | [illegible] | | | [illegible] TIMER | | | | | | |
| | | [illegible] | | | | [illegible] | [illegible] | [illegible] SWITCH | [illegible] | | | | | |
| | | [illegible] | | [illegible] | | [illegible] | [illegible] | [illegible] TRANSDUCER | | | | | | |
| | | [illegible] | | | | [illegible] | MANUAL | MANUAL | | | | | | |
| | | | | | | | + [illegible] VDC | | [illegible] | | | | | |
| | | [illegible] | | [illegible] BRIGHTNESS | | [illegible] | MANUAL | MANUAL | | | | | | |

DISPLAY PARAMETERS CHART
FIGURE 12 (2 of 2)

and would, therefore, make an error in the total system. Simmonds was contacted and stated than an AC voltage existed within their instruments that could be utilized to drive the EL displays. This was utilized in the T-39 installation since round dial engine instruments are required on the center panel for flight safety and back-up displays.

## SECTION IV

## INSTRUMENT DESIGN

The various instruments on the T-39 EL panel were defined by the display parameters chart. These were divided into three major instrument groups during the design and build phase with product responsibility assigned accordingly. These three groups were:

- Flight Instruments
- Engine Instruments
- Landing Instruments

### FLIGHT INSTRUMENTS

The flight instrument group consists of the attitude director indicator, the horizontal situation indicator, the altitude vertical velocity indicator, the altimeter, the vertical velocity indicator, and the airspeed indicator. All of these displays utilize electroluminescent lighting for display illumination. All except the altitude vertical velocity indicator are light reflecting or flood lighted displays. The altitude vertical indicator is a transilluminated or back lighted display. These displays are of primary importance to the pilot since they furnish him with the basic information that he needs to fly the aircraft. The following paragraphs define in detail the mechanism used to accomplish each of the displays:

#### Attitude Director Indicator (Model 4058Y)

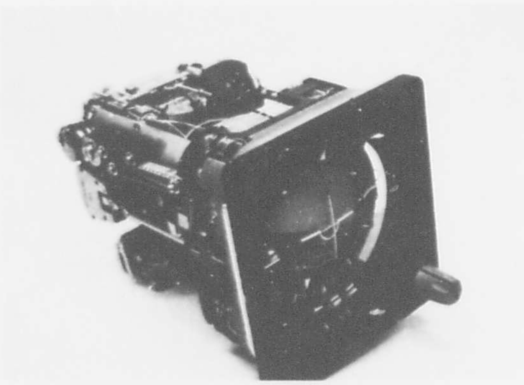
This unit provides basic pitch and roll information presented on a moving sphere. Precise pitch markings in the sphere, color, and the precision bank indices were developed on the pilot's factors study program. The indicator also includes a display of flight path angle. This moving tape display is located on the left side of the attitude indicator and ranges between zero and ± 30 degrees flight path angle. The parameter is used during the descent in an ILS approach to extend the glideslope sensitivity. A normal flight path angle is established during the ILS approach on glideslope. When the glideslope signal becomes erratic, this normal flight path is flown to the flare point, thus extending the glideslope beam. The horizontal and vertical flight director pointers are also located on the attitude director indicator. These pointers provide command information for the pilot during various flight director modes.

Raw data glideslope information is provided by the orange pointer on the left next to the flight path angle tape.

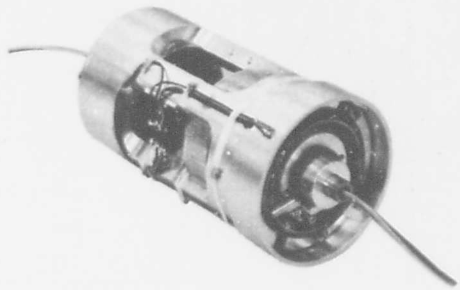
The two remaining displays on the attitude indicator are the turn rate display and the inclinometer tube forming a turn and bank indicator located at the bottom of the indicator.

Various warning flags are associated with the ADI. There is the "off" flag which annunciates that either power is off to the attitude indicator or a faulty gyro signal is being received. The flag at the top of the display provides assurance that the proper information is being presented on the vertical flight director. The glideslope flag at the left beside the glideslope pointer provides assurance that the proper information is being displayed on the glideslope pointer.

The ADI utilizes direct drive DC servo mechanisms to drive the pitch and roll displays. The Model 4058Y is shown in the photograph in Figure 13. The DC torquer and an associated synchro follow-up is coupled directly to the roll axis of the indicator. There are no associated gears nor idler stages. A similar mechanism is employed inside the attitude sphere to provide the basic pitch mechanization. A photograph of the pitch torquer synchro package is shown in Figure 14. A block diagram schematic of the attitude director indicator showing all its various functions is given in Figure 15.



MODEL 4058Y ADI MECHANISM
FIGURE 13



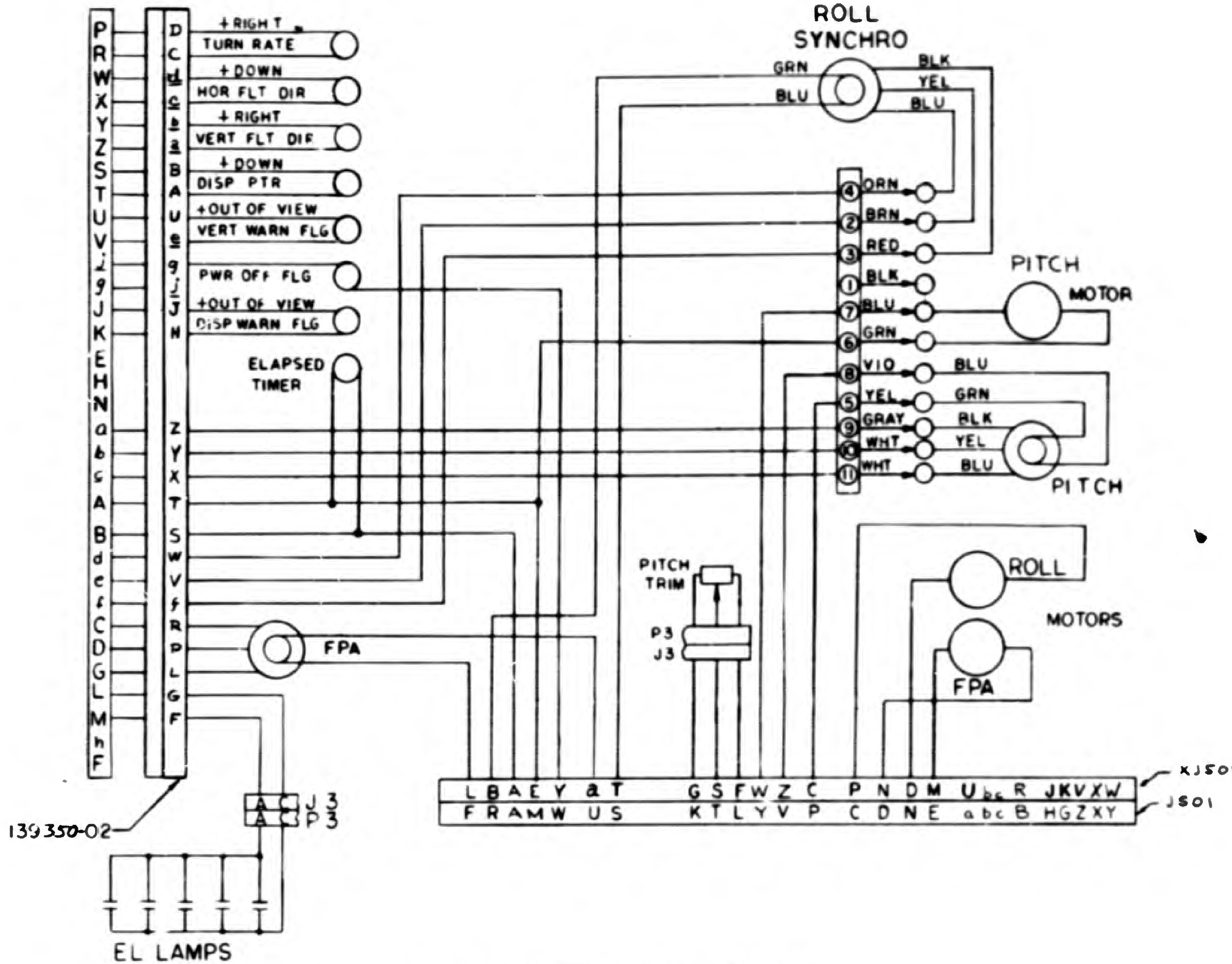
MODEL 4058Y ADI PITCH AXIS
FIGURE 14

D'Arsonval meter mechanisms provide the displays of flight director commands, glideslope deviation, and turn rate.

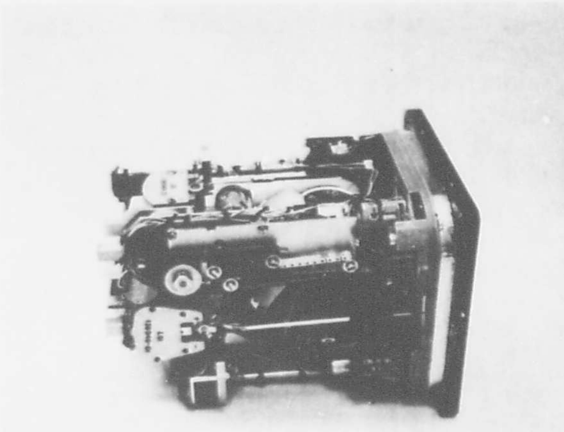
A compromise was made to the gearless approach with the flight path angle display. This was originally intended to be a completely gearless display, but it was found that making this display gearless would increase the length of the indicator significantly; therefore, a path angle mechanization was chosen which reduced the number of gears over that which would have been required for a similar AC mechanization but did not eliminate gears altogether. The path angle tape unit provides satisfactory response under all ambients and still has advantages of reduced heat and power consumption.

The small number of gear passes will not contribute significantly to the reliability factor of the overall unit. A picture of the flight path angle drive mechanism is shown in Figure 16. This mechanism is a module and can be detached from the overall attitude indicator for repair and/or replacement as necessary.

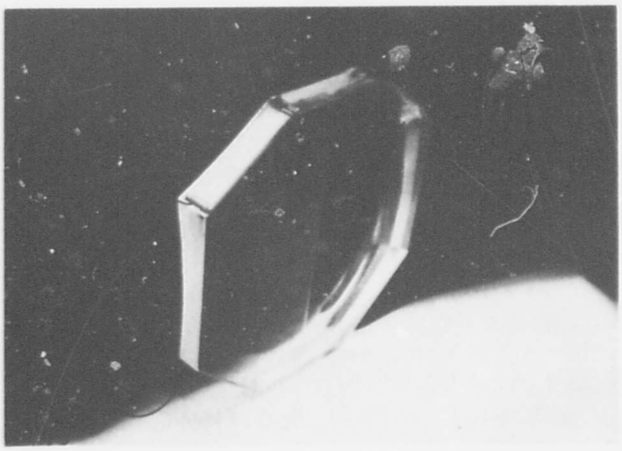
Figure 17 shows the ADI lighting subassembly. Electroluminescent lamps, mounted at the top and the sides of the indicator wedge, pump




ADI SCHEMATIC BLOCK DIAGRAM
FIGURE 15



FLIGHT PATH ANGLE MECHANISM
FIGURE 16



ADI EL LIGHTING SUBASSEMBLY
FIGURE 17

light throughout the wedge. The wedge shape is varied so that more light is directed down toward the bottom of the displays and is reflected up under the bottom of the attitude director indicator sphere. This area is most difficult to light and is the one in which most designers apply additional lamps inside the sphere or beneath the roll scale markings to direct light up onto the sphere.

The installation data dimensions for the Model 4058Y attitude director indicator are given in Figure 18. Figure 19 gives the indicator connector pin assignments. These are the same pins as are utilized in the Model 4058E presently in use in the pilot's factors study. With the exception of the electroluminescent lighting lamp excitation, these have been placed on spare pins in the Model 4058E so that the two units can be utilized interchangeably if desired.

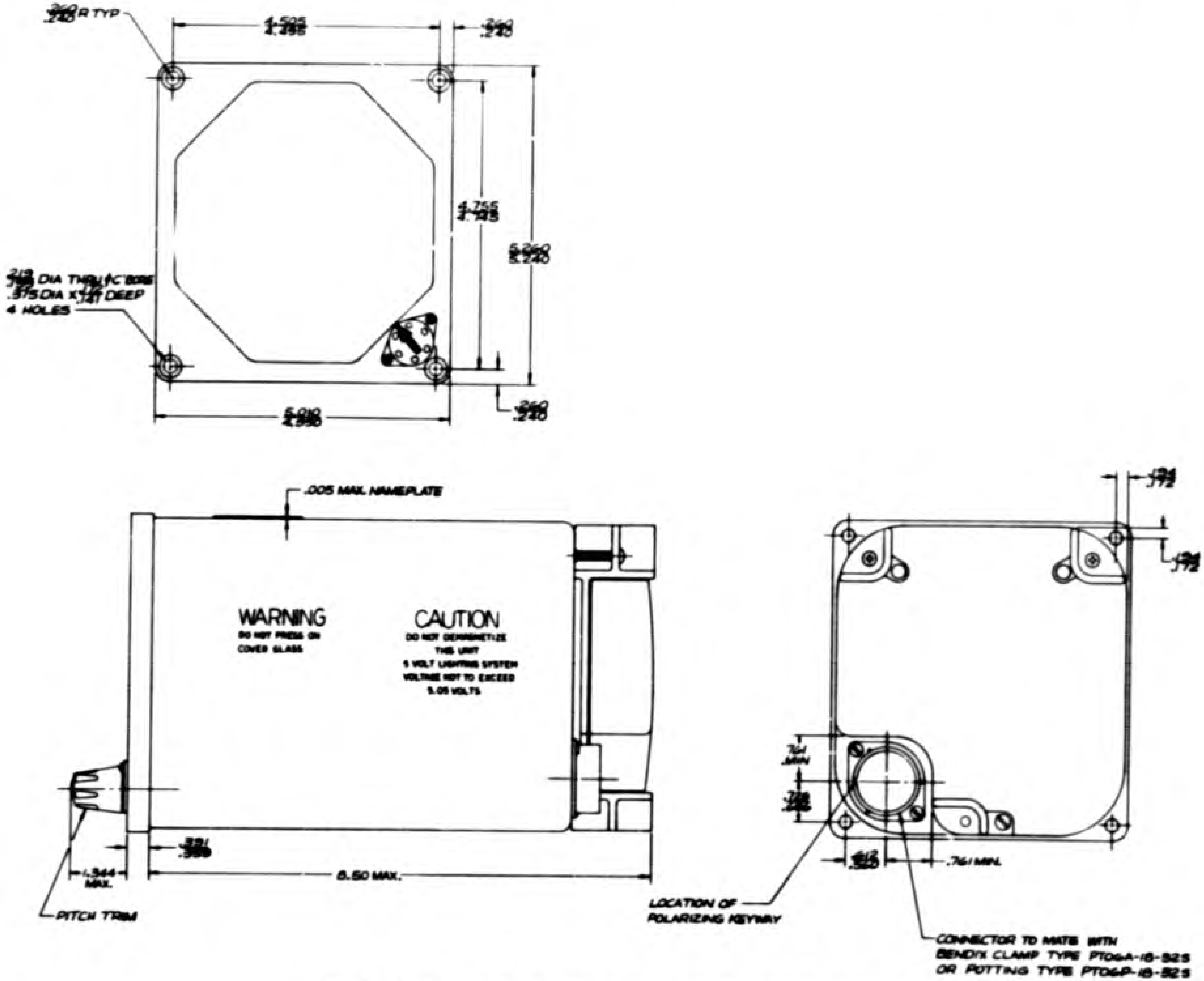
The amplifier schematic block diagram for the Model 4058Y is shown in Figure 20. This amplifier drives the three functions of pitch, roll, and flight path angle and supplies the power necessary for the basic instrument. A peak sampling method of error detection with subsequent error amplification is utilized in the Model 4058Y. Derived rate feedback furnishes information to stabilize the DC servo mechanisms under all operating conditions. This circuit is very similar to the one utilized in the Model 4076K horizontal situation indicator.

Horizontal Situation Indicator (Model 4076K)

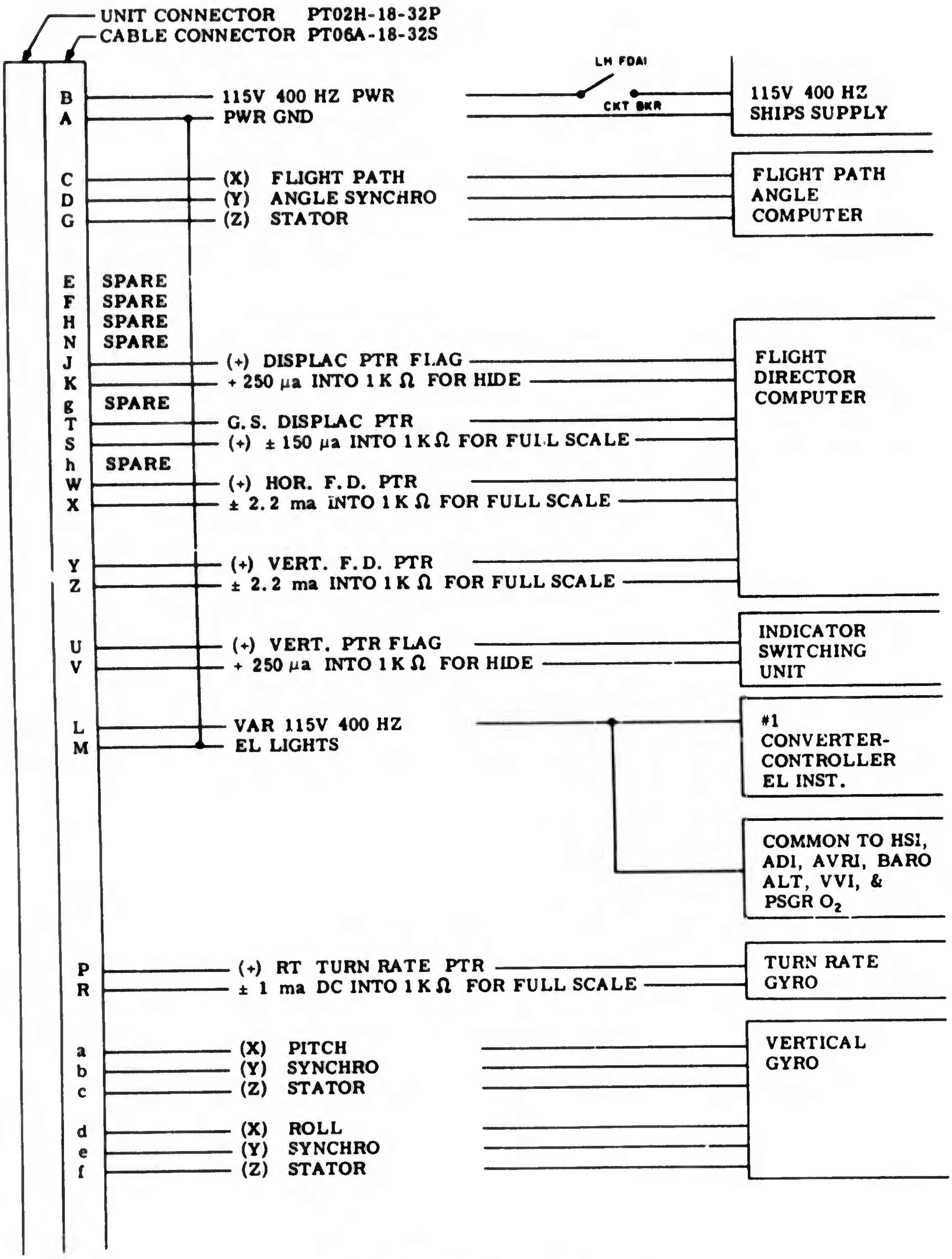
This display provides the pilot with azimuth information, selected heading, selected course deviation, ADF bearing, and distance to Tacan stations. This basic information is supplemented with the warning flags associated with course deviation and the directional gyro as well as DME warnings and to-from flags on the course card for Tacan operation. Knobs located at the bottom of the display provide course set features and heading set features. The display is that of a conventional Air Force AQU-4 horizontal situation indicator. As such, it provided little or no problems in integrating into the T-39 panel since the AQU-4 is standard in the T-39.

Electroluminescent lamps are utilized to illuminate the HSI. The display is wedge lighted in the same manner as the attitude director indicator discussed earlier. EL lamps are placed along the top periphery of the display wedge and provide lighting throughout the front of the instrument. A typical HSI EL lighting wedge is shown with the lamps installed in Figure 21.

This display also utilizes the DC servos as the drive element for all servo displays. Figure 22 shows the mechanism of the horizontal situation indicator. A semi-gearless approach is used to mechanize

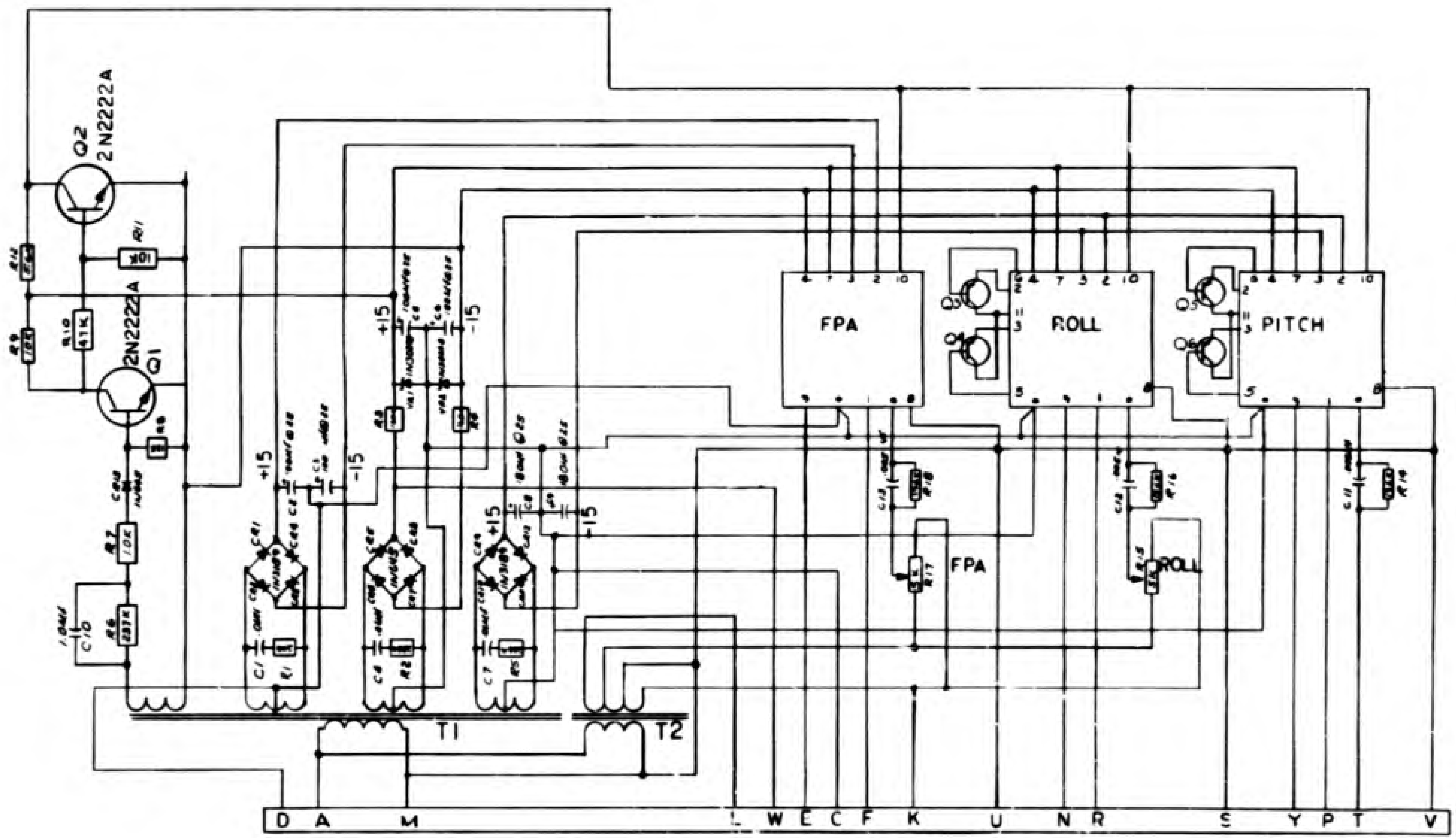



MODEL 4058Y ADI INSTALLATION DATA DIMENSIONS
FIGURE 18

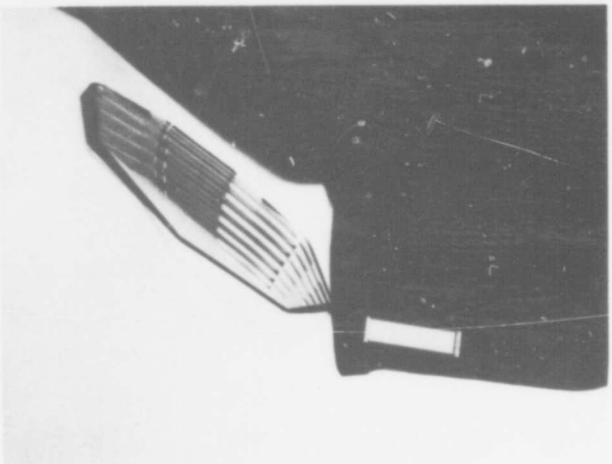



MODEL 4058Y ADI INPUTS

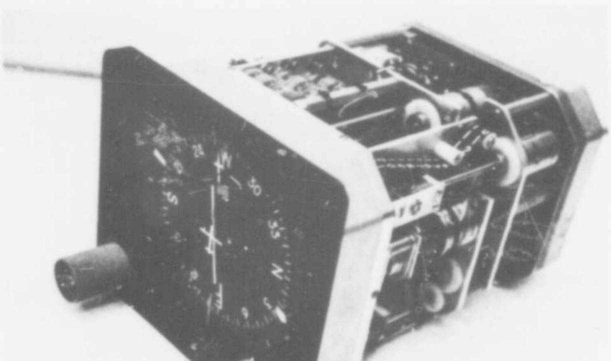
FIGURE 19




MODEL 4058Y ADI AMPLIFIER BLOCK DIAGRAM
FIGURE 20



HSI EL LIGHTING WEDGE
FIGURE 21



MODEL 4076K HSI MECHANISM
FIGURE 22

this display. This resulted in a reduced number of gears from that required by the AQU-4 AC servo unit. Table III compares the number of gears in each type of mechanization. This reduced gear number construction retains most of the benefits of DC torquer drive with the course and heading set select functions on the front of the instrument. These require differentials, and it is impossible to retain a completely gearless construction and still have the course and heading set functions on the front of the HSI.

A block diagram schematic of the Model 4076K horizontal situation indicator is shown in Figure 23. The unit includes internal amplifiers very similar in construction to those used on the attitude director indicator discussed earlier. The peak sampling method of error determination is utilized for signal feedback. The servo displays in the horizontal situation indicator are azimuth, course, heading, and ADF bearing. The Model 4076K is shorter by 2.5 inches than its AQU-4 conventional counterpart; this is shown in the installation data drawing in Figure 24. The pin assignment chart for the HSI is shown in Figure 25.

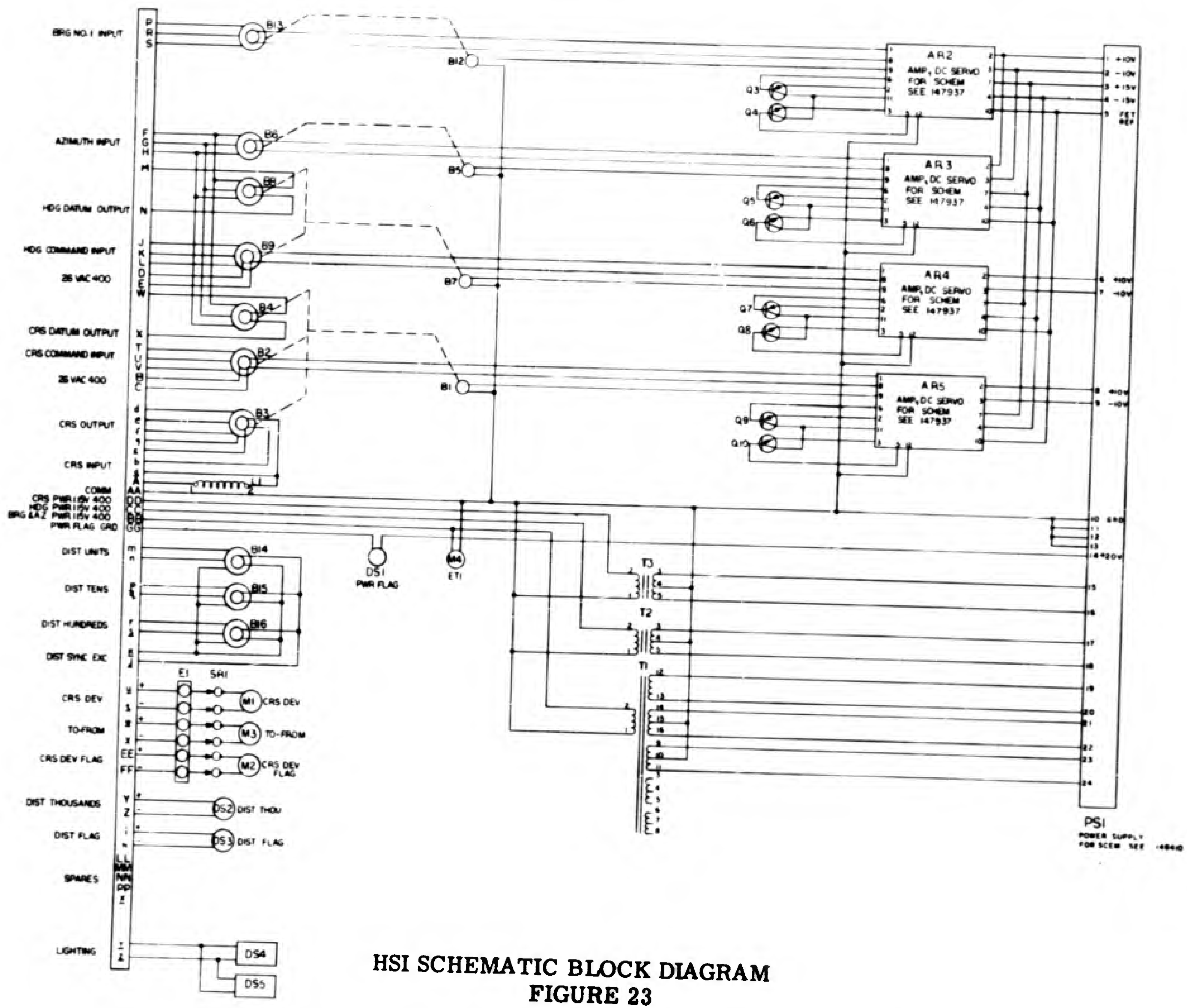
The display definition chart in Figure 11, gives the pertinent display details of both the attitude director indicator and the horizontal situation indicator.

## Altitude/Vertical Velocity Indicator

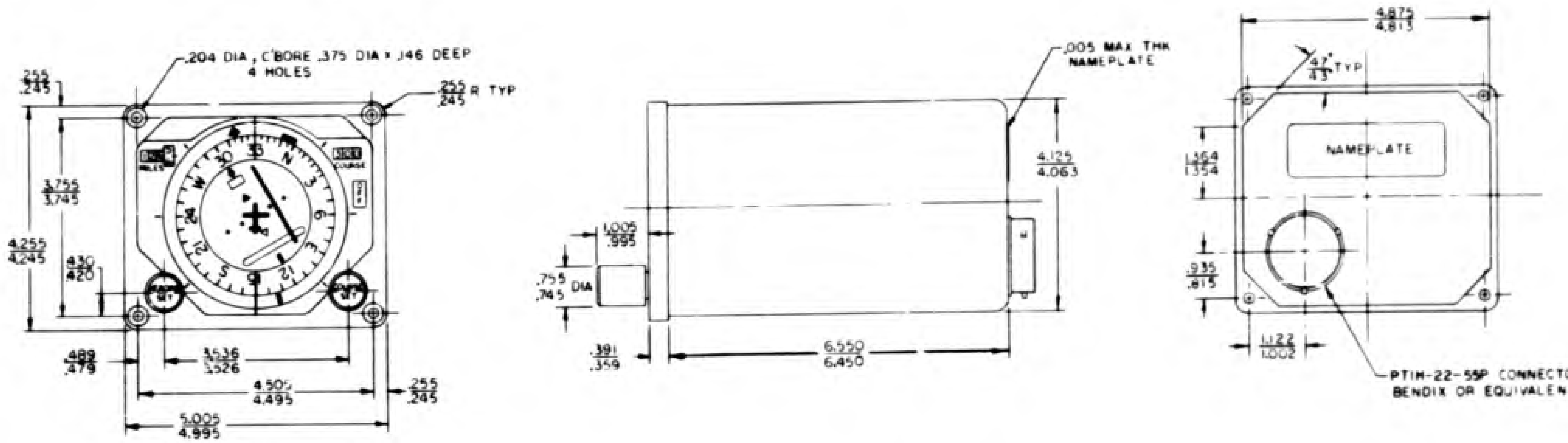
This display (shown in Figure 26) provides the pilot with instantaneous vertical velocity during all modes of operation and with radar altitude information during the landing portion of the mission. Altitude/vertical velocity is displayed from 0 to ± 20,000 fpm by the moving pointer with a "▷" shaped marker on the left side of the unit. The pointer moves from 0 to + 2,000 or -3,000 ft. per minute. At these two points it will lock into position, and the number tape in the window immediately to the right of the pointer will begin to move and will move for the remainder of the vertical velocity scale. The altitude portion of the display is located on the right of the display. It is the white moving tape column. At 1,000 ft. radar altitude it moves all the way into view, exposing a white column extending from the center of the lubber line to a point near the lower edge of the right side of the window. As altitude decreases towards zero, this display moves nonlinearly until at 50 feet radar altitude when the white-black intersection is adjacent to the number 1 on the vertical velocity scale. At 25 feet altitude, the column is adjacent to the number 0.5 on the vertical velocity scale. Thus this display provides not quantitative radar altitude information but rather qualitative indications consisting mostly of altitude rate to the ground. This display is used primarily during the landing mission.

TABLE III
COMPARISON OF HSI PARAMETERS

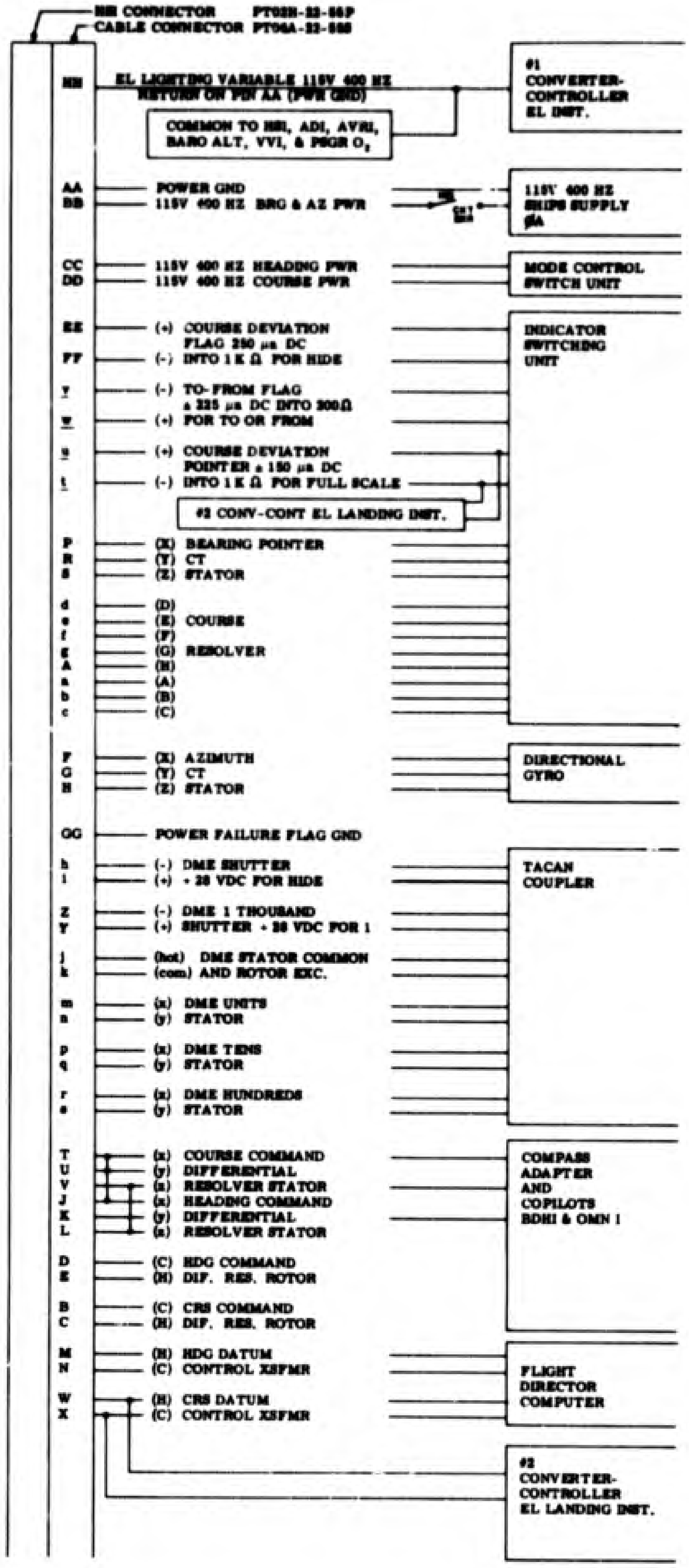
| Parameter | AQU-4 | 4076K |
| --- | --- | --- |
| Case Size | 4-1/4 x 5 x 9 | 4-1/4 x 5 x 6-1/2 |
| Hdg. Set | Knob | Knob |
| Course Set | Knob | Knob |
| Amp-Power Supply | Internal | Internal |
| Type Mech. | AC Servo | DC Servo |
| Type Const. | ≈ 90 Gears | ≈ 40 Gears |
| Power Comsumption | 55 VA | 10 VA |
| Lighting | White/Red | White EL |
| Compass Card | 3.125 Dia. | 3.0 Dia. |
| Command Hdg. | Manual or Servo | Manual or Servo |
| Command Course | Manual or Servo | Manual or Servo |
| Course Dev. | Yes | Yes |
| Dev. Fail | Yes | Yes |
| To-From | Yes | Yes |
| Bearing Pointers | Yes | Yes |
| Power Failure Flag | Yes | Yes |



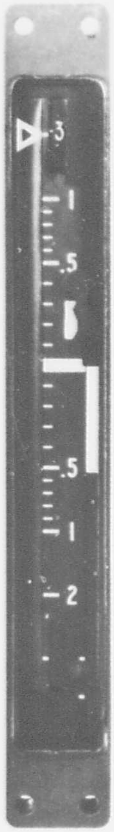

HSI SCHEMATIC BLOCK DIAGRAM
FIGURE 23




MODEL 4076K HSI INSTALLATION DATA
FIGURE 24




MODEL 4076K HSI INPUTS
FIGURE 25

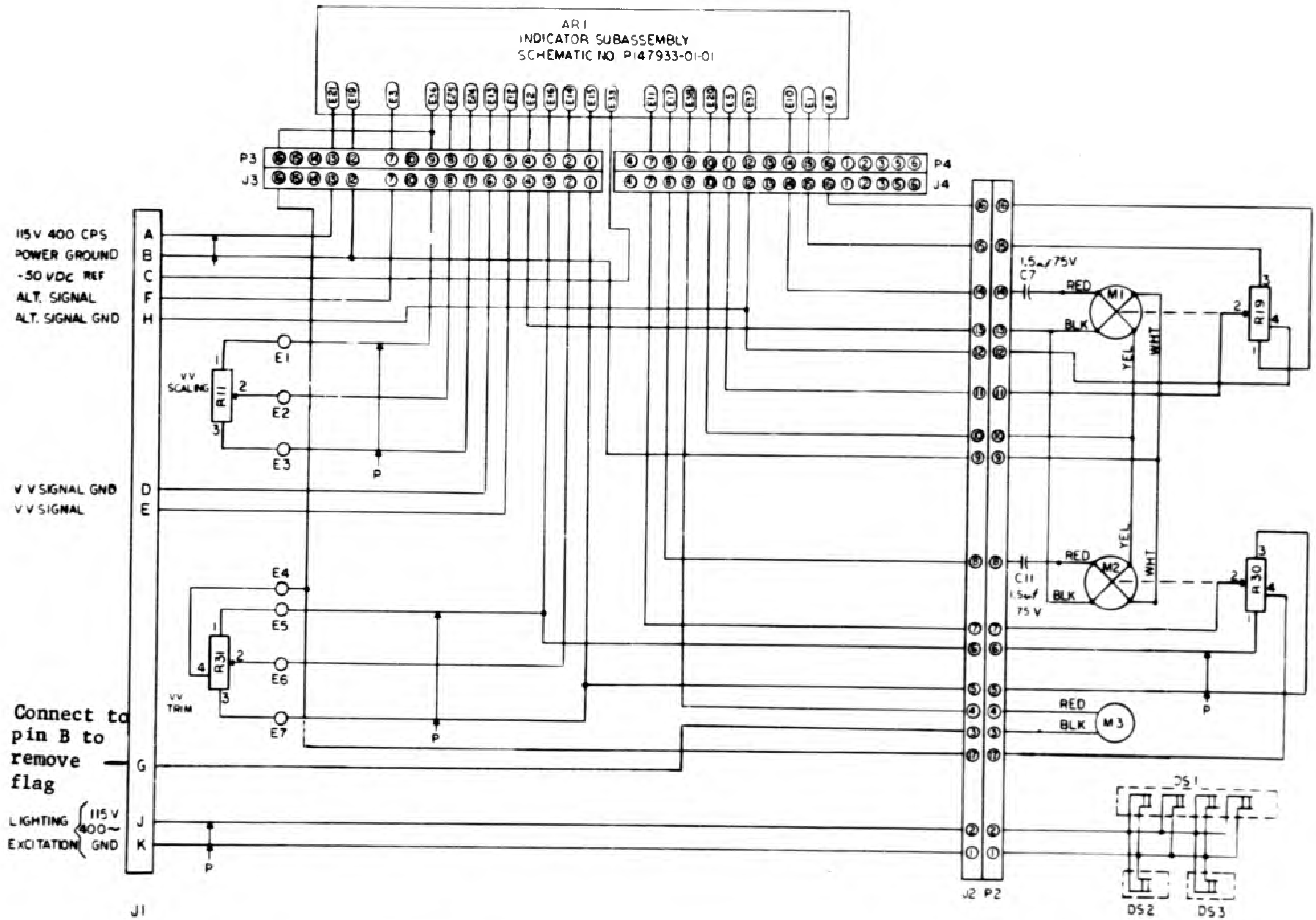



MODEL 7725E ALTITUDE/VERTICAL VELOCITY INDICATOR
FIGURE 26

This unit is transilluminated by electroluminescent lamps located behind the display scale. These lamps transmit light up through the display scale, where it renders the scale visible under night operating conditions. The light is also piped out through the plastic scale to both the lighted ▷ shaped marker and the radar altitude column.

A block diagram schematic of the Model 7725E Altitude/Vertical Velocity Indicator is shown in Figure 27.

This unit includes follow-up amplifiers mounted within the indicator proper. It is unique because of its narrowness (one inch) and because of the locking feature of the vertical velocity pointer as it moves up and locks into position beside the vertical velocity tape window.




MODEL 7725E ALTITUDE/VERTICAL VELOCITY INDICATOR BLOCK DIAGRAM
FIGURE 27

The AVVI subassemblies are shown in Figure 28. This unit is similar in size and construction to other Model 7725 Altitude Vertical Velocity Indicators provided by LSI for use on the PIFAX program. As indicated in the pin allocation chart shown in Figure 29, it is not wired interchangeable with these units. Provisions were made on this unit so that the warning flag could be operated by external inputs and thus provide additional warning capability for the display. Other areas of difference were in the pin assignments allotted to the electroluminescent lamp excitation. It is not,therefore, recommended that these units be used interchangeably with other units provided to the Air Force for use on the PIFAX program.

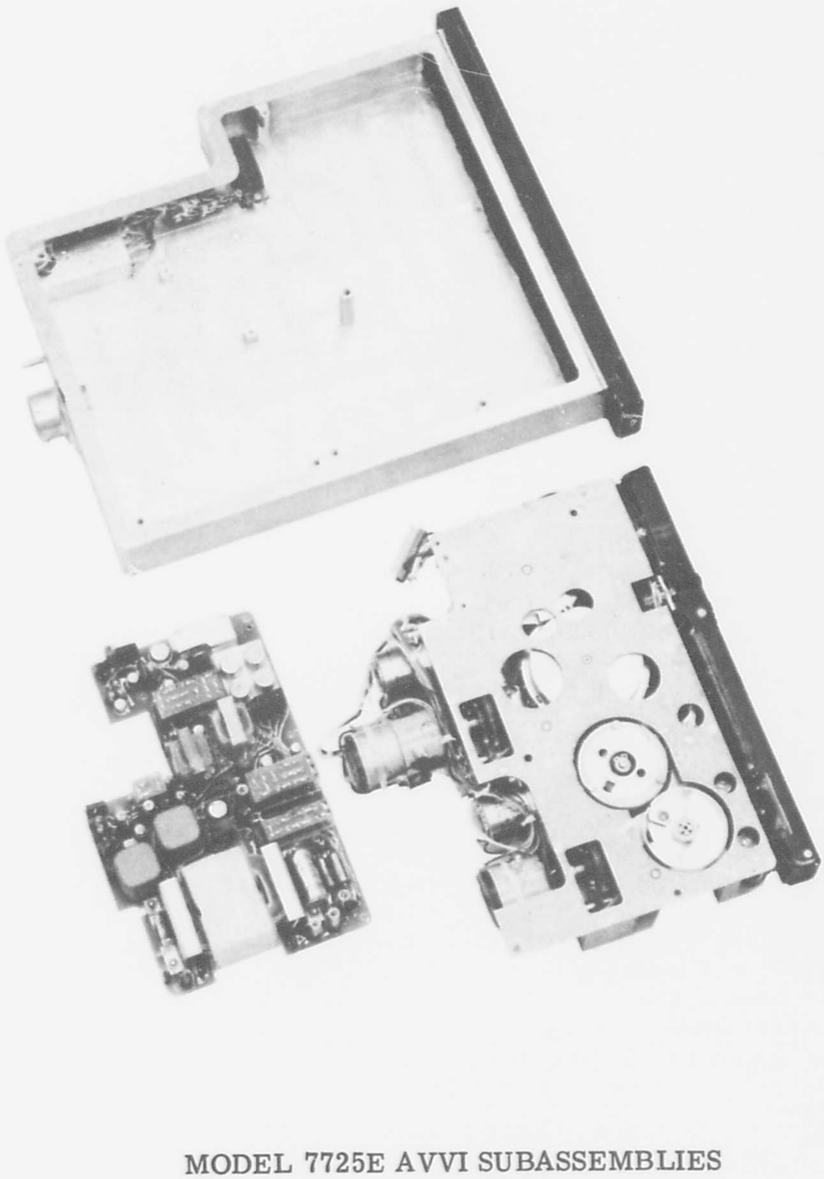
## Air Data Displays

Other units in the flight instrument group are the altimeter, the airspeed indicator, and the vertical velocity indicator. These are round dial instruments and have been purchased from standard aircraft Air Force suppliers and modified to include the electroluminescent wedge lighting. These displays are pitot-static driven and operate from conventional aircraft inputs. The electroluminescent light wedge replaces a lighting wedge that did provide red illumination to the displays. This wedge is very similar in construction to the wedges utilized on the horizontal situation indicator and the attitude director indicator. Lamps are mounted at the top and upper corners of the wedge in these displays to provide uniformity while lighting over the display surface. A typical instrument lighting wedge for the round dial assemblies is shown in Figure 30. Installation data drawings for each of the round dial instruments are shown in Figure 31, 32, and 33 of this report.

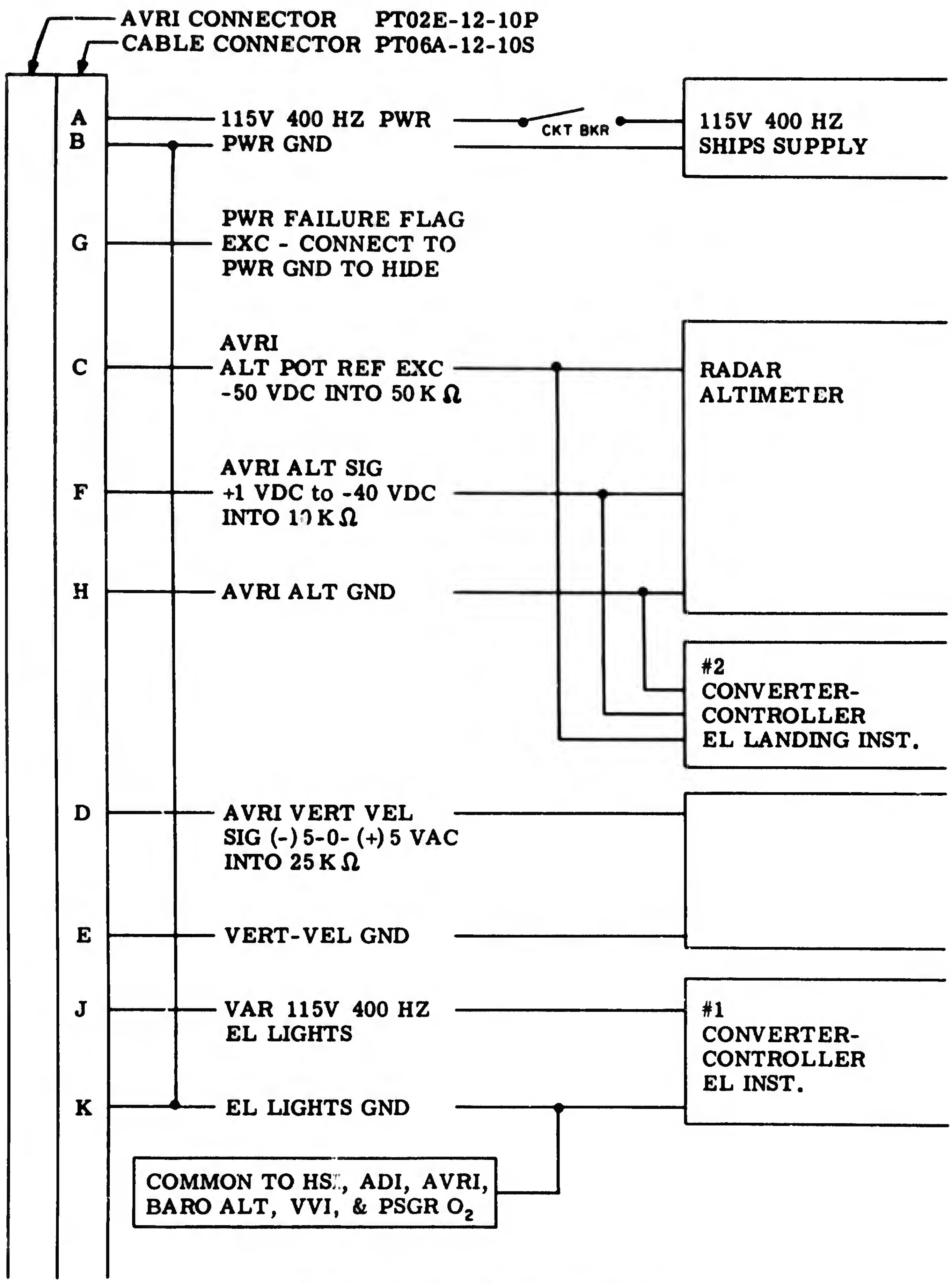
The schematics showing pin allocations for these units are shown in Figure 34, 35, and 36.

Lighted panels include the passenger oxygen panel, the radio call panel, and the course select panel. A typical lighted panel is shown in Figure 37.

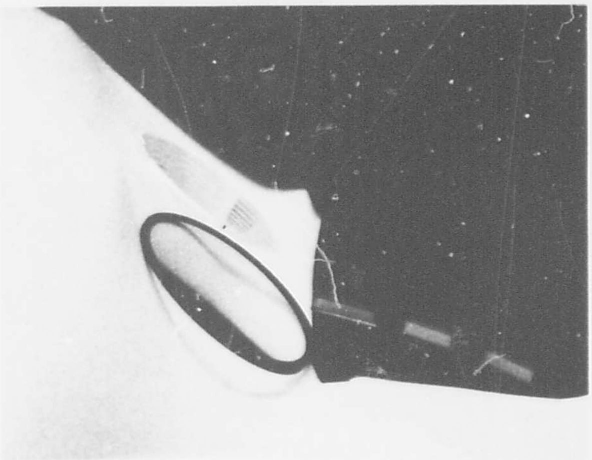
These panels utilize discrete electroluminescent lamps similar to those used on the attitude indicator and horizontal situation indicator for display illumination. As such, these lamps are mounted behind the areas to be lighted and transmit light up through the plastic for display illumination. Illumination of these displays is difficult since light is not piped readily through the plastic. A better method of constructing these displays would have been to utilize a large EL lamp mounted directly behind the overall panel, which would supply uniform lighting to all letters, legends, and nomenclature. If desired, switches could then be outlined and legends associated with the switch could have their own individual lamps -- which would provide light for that legend.



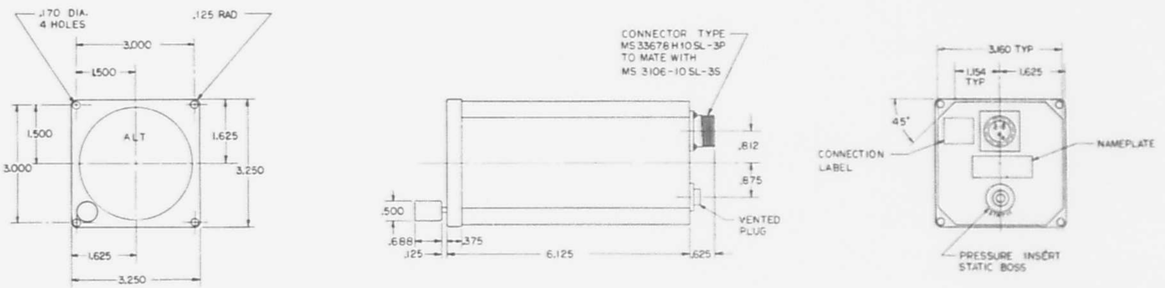
MODEL 7725E AVVI SUBASSEMBLIES
FIGURE 28



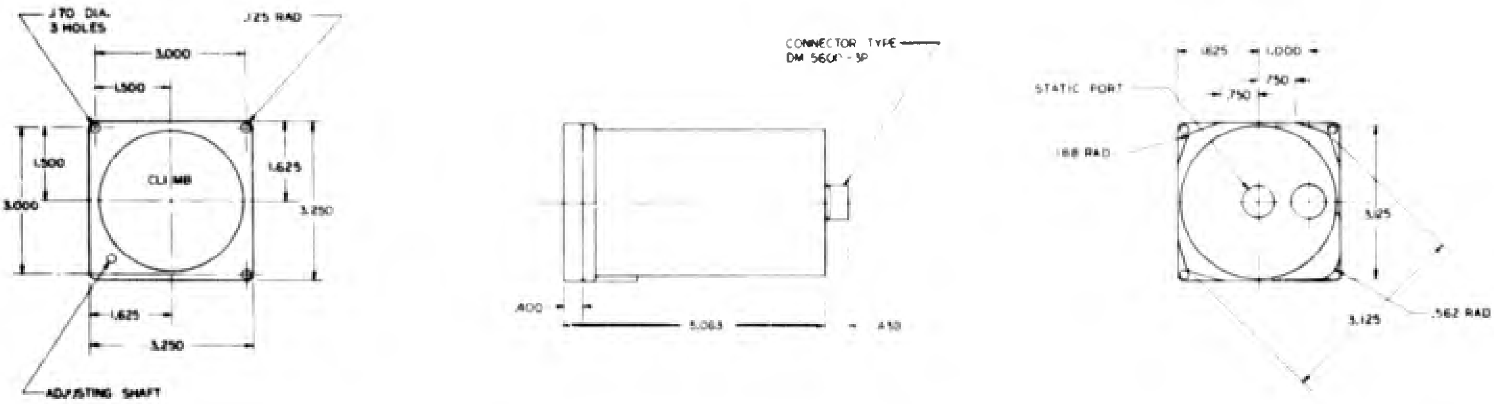

MODEL 7725E AVVI INPUTS
FIGURE 29



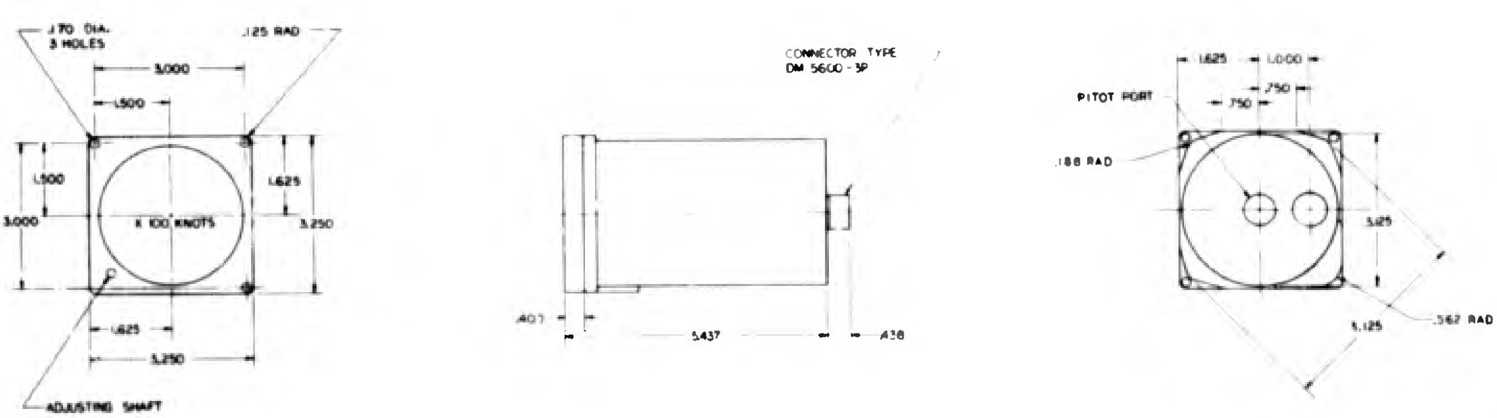
EL LIGHTING ASSEMBLY FOR THE INDICATED AIRSPEED, ALTITUDE AND VERTICAL VELOCITY INDICATORS
FIGURE 30




ALTIMETER INSTALLATION DATA
FIGURE 31



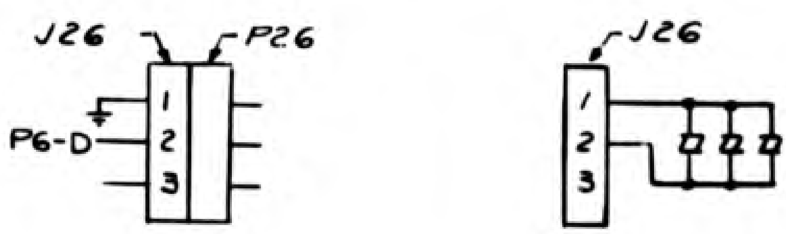

VERTICAL VELOCITY INSTALLATION DATA
FIGURE 32



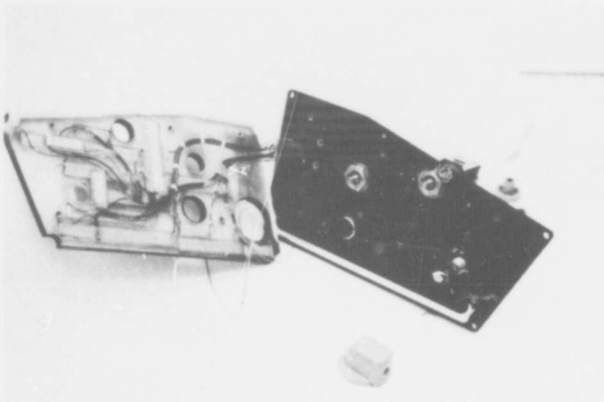

INDICATED AIRSPEED INSTALLATION DATA
FIGURE 33


ALTITUDE INDICATOR SCHEMATIC
FIGURE 34


VERTICAL VELOCITY INDICATOR SCHEMATIC
FIGURE 35




INDICATED AIRSPEED INDICATOR SCHEMATIC
FIGURE 36



TYPICAL LIGHTED PANEL
FIGURE 37

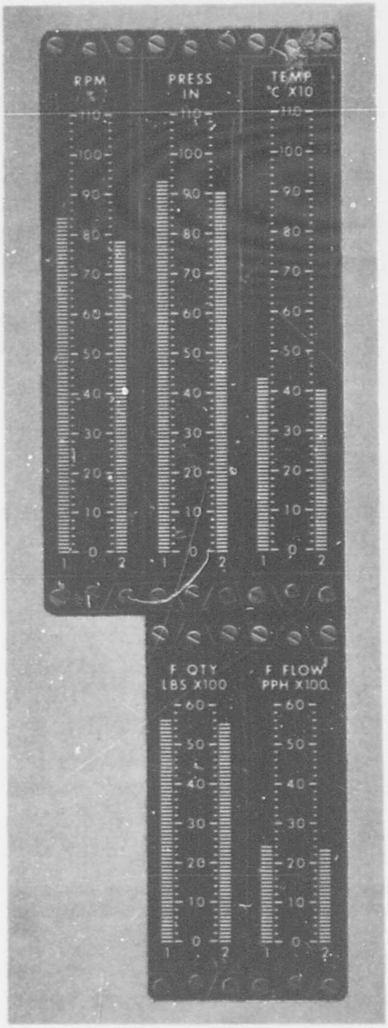
## ENGINE INSTRUMENT SUBSYSTEM

### Display Description

The engine displays for the T-39 consist of five vertical scale EL bar graphs. These displays are:

Thrust (ETP)
Exhaust Gas Temperature (EGT)
Engine RPM (RPM)
Fuel Flow
Fuel Quantity

They are shown in Figure 38. There are two basic display formats - - a four-inch display, and a six-inch display. Each unit contains a display for two engines. This display shares a single set of display markings or legends. The moving column bar graph is the dynamic element in each display and is identified by the numeral 1 and 2 beneath




EL ENGINE DISPLAY
FIGURE 38

the left and right column respectively. The displays are identical except for scale length. The display lamps are characterized by changing a back lighted legend panel located at the top of each lamp.

Each lamp assembly is interchangeable with another lamp assembly of the same length. Figure 39 illustrates the construction of this "plug in" interchangeable lamp. The lamp subassembly is hermetically sealed for maximum display life. This was accomplished by designing a metal back-plate with glass to metal sealed feedthrough terminals for each separate display circuit. The printed wiring board inside the lamp subassembly provides the circuit path between these feedthroughs and the conductive rubber snails that are in contact with the lamp substrate. A snail locater board spaces the lamp substrate and circuit board and locates the snails with respect to each. This group of components -- substrate, snails, locater board, and printed wiring board -- are soldered into the metal case providing the required glass to metal hermetic seal.

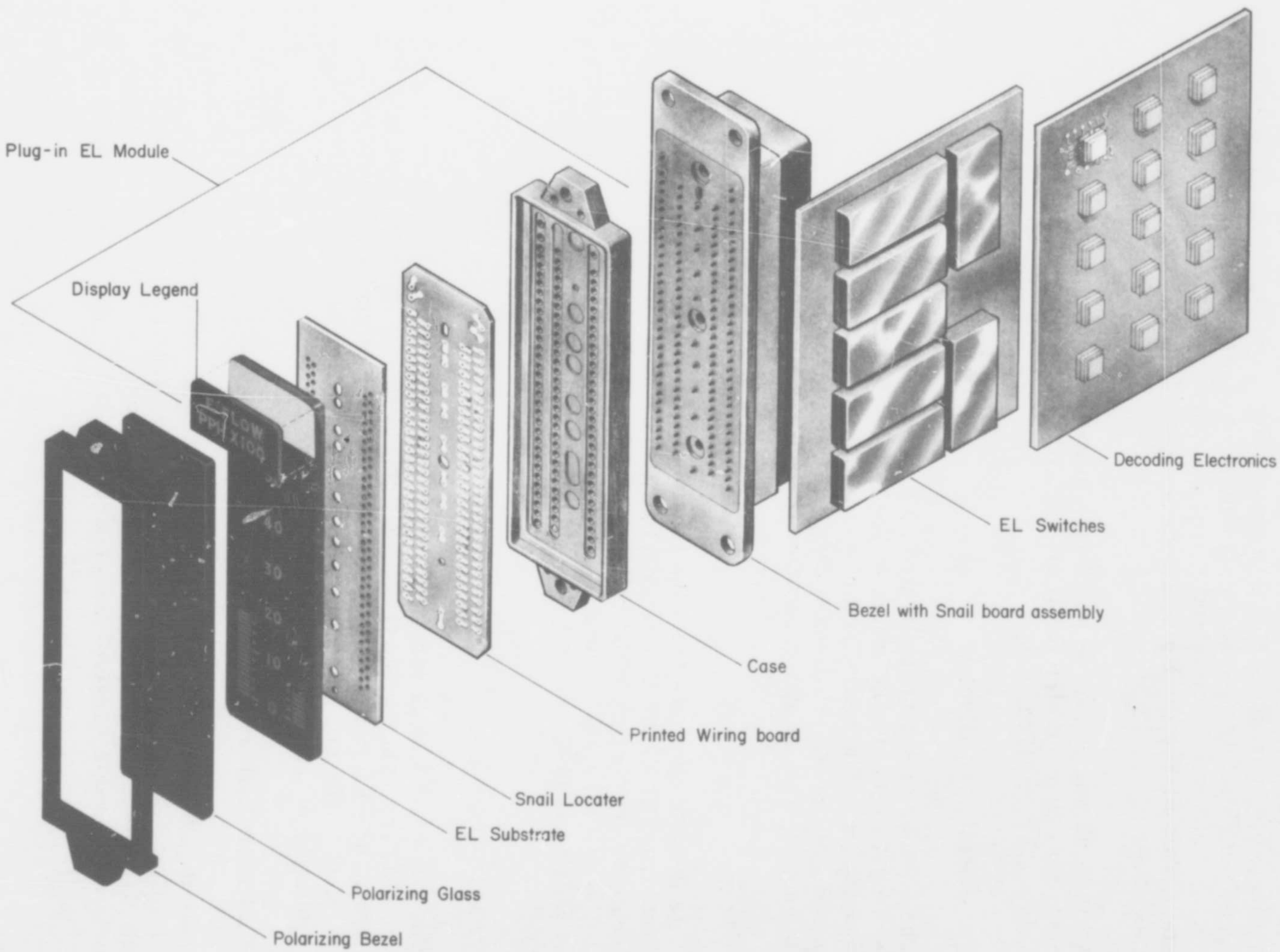
The entire lamp assembly mates to the electronics module with two screws. Electrical contact between the lamp and the electronics module is made through the compressible conductive rubber snails located in the front of the electronics module.

An area electrode behind the legend of each display causes a rectangular area to be illuminated. The "display legend" film which is held in place by the polarizing bezel can be changed to identify each display.

Splitting the rear electrode for the fixed scale information allows LSI to turn "on" only that portion of the scale utilized by that specific display, e.g., the full scale (0-110) is lighted for the RPM display whereas only part (0-84) is lighted for the ETP display. The amount of scale to be illuminated is determined in the electronics module.

The display electronics of the four-inch and six-inch displays are identical except for the larger number of display driver modules required in the six-inch unit to accommodate the additional display length.

The electronics modules for all engine displays are similar except that the primary aircraft display modules have been built utilizing only those display drive modules necessary for the associated display. A spare electronics module containing the maximum number of display drivers is provided and is interchangeable in any of the six-inch display stations. A similar spare module is provided for the four-inch stations.




EL INSTRUMENT CONSTRUCTION
FIGURE 39

Two of these engine displays (EGT and RPM) illustrate the use of the limit cue line mechanization. The red line limit for the parameter is annunciated by a lighted segment at the critical RPM (104%) or temperature (670°C). When the engine condition exceeds the limit line, the whole lighted portion of that bar graph blinks, annunciating an "over speed" or "over temperature" condition in that engine. The lighted segment changes to unlighted as the parameter moves beyond the limit line. This allows the limit line to be denoted even though it has been exceeded.

A slight wiring change is necessary in the spare display electronics module to characterize the limit line output of the spare module to either EGT or RPM.

Pressure (ETP) Display

The number of segments lighted on this segmented bar graph is proportional to the displacement of the exhaust total pressure synchro transducer. The scale factor is one inch of mercury pressure change per EL segment. Full scale range of this display is 85 inches of mercury. The indicator contains the ETP scale for each engine.

EGT

This display operates from the thermocouple input of exhaust gas temperature. The readouts are EL bar graphs which are proportional in length to the change in DC voltage from the thermocouple. The scale is linear with a scale factor of 10°C per segment. The full scale range of EGT is 1000°C. This indicator contains the EGT scales for each engine.

RPM Display

The input transducer for this display is a tachometer which provides a variable frequency proportional to percent RPM. The readouts for the display are EL bar graphs with a scale factor of one percent RPM per segment. The full scale range is 110 percent RPM. Two scales are contained in the one indicator.

Fuel Flow Display

This display operates from a synchro transducer and indicates rate of fuel flow. The readouts are also EL bar graphs proportional to the displacement of the synchro. The scale factor is 100 lbs per segment with a full scale range of 5000 pounds per hour. A single display provides readouts for both engines.

Fuel Quantity Display

This display operates from the rebalance potentiometers of the round dial instruments. The readouts are EL bar graphs which follow the round dial instruments. The scale is linear with a scale factor of 100 lbs per segment. Full scale range of the display is 4000 lbs.

This display operates in conjunction with the fuel quantity switch located to its left on the panel. When the switch is in the TOTAL position, each display shows the amount of fuel in the corresponding wing tanks, plus one-half the fuel in the auxiliary tank. When the switch is in the LH IND-AUX, RH IND-R WING, the indicators display the quantity of fuel remaining in the described tanks.

Display Decoding

The conversion of a binary-coded signal to an analog bar graph display is shown by Figure 40.

The binary-coded signal is split into two subwords to reduce the number of gates required for the decoding. A three-bit decoder decodes the first three bits into eight lines. This information is further changed to a bar graph configuration.

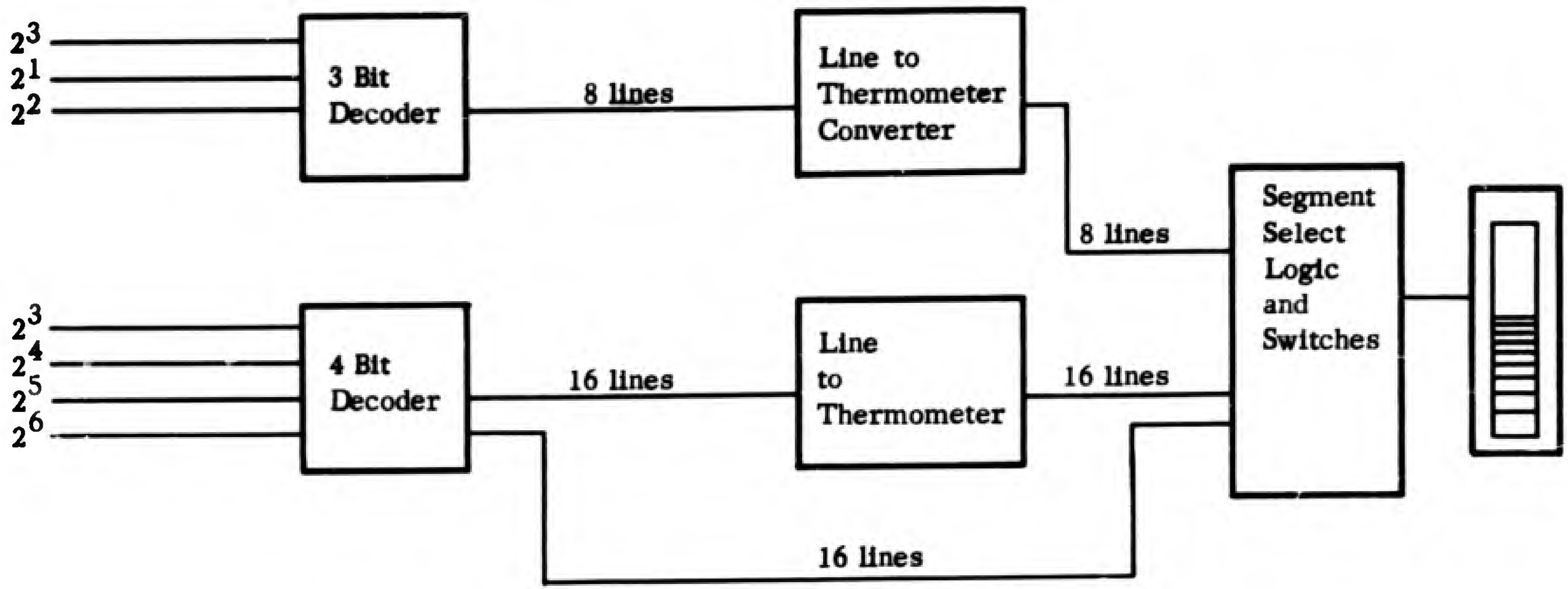
A four-bit decoder decodes the remaining four bits. These are decoded into a 16-line output plus a 16-element bar graph configuration.

The outputs from the three-bit decoding and the two systems of four-bit decoding are then combined to form the logic necessary for the final switching of the EL segments. This combining is done with DTL logic gates.

The final switching of the EL segments is accomplished using silicon controlled rectifiers (SCR) as the bilateral switch. These SCR's are easily controlled by the low level DC voltage from the DTL logic.

Electroluminescent Lamp Selection

One of the original goals of the program was to provide solid-state displays which would present clear and unambiguous flight control information under all ambient lighting conditions. The emphasis for the engine instrument system was, therefore, to make as bright a lamp as possible to meet the high ambient viewing conditions.




DISPLAY DECODING
FIGURE 40

Preliminary thought was given to using a scan selection technique to switch the EL lamp. Some tests of brightness vs. duty cycle were taken and it was found that the brightness would not be sufficient to meet the brightness requirements that were established by the flight tests.

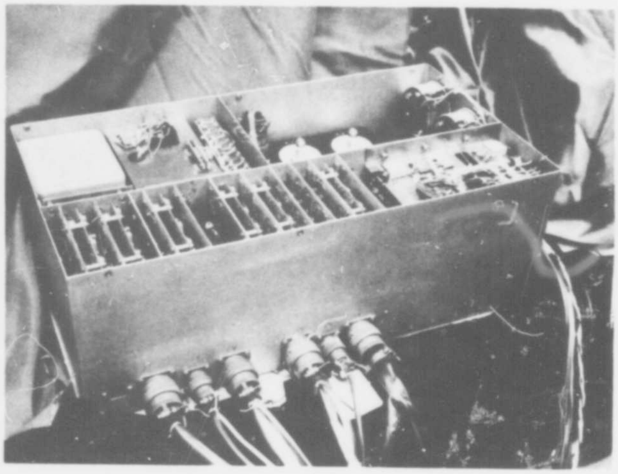
It was, therefore, concluded that an 800-cycle excitation voltage would be used to meet the brightness requirements. It was also determined that a constant brightness technique would be used, in which the voltage would start out at a value which is required to obtain 17 foot lamberts which is the required brightness determined by flight test. As aging of the lamps took place an increase in the exciting voltage would be allowed until the rated voltage minus a safety factor for the SCR's was reached. At this point in time the lamps would be replaced.

Results of life testing were shown by Figure 9. Tests were run at both 400 Hz and 800 Hz. It can be seen that the expected life for the engine lamps is 1000 hours when operated at their maximum brightness at 800 Hz at room temperature. Under actual operating conditions, the situation will be quite different. Since many of the flight tests will be run to evaluate low ambient situations, the life could be expected to be much longer than the 1000 hours. On the other hand, the ambient temperature will be higher in some instances than the +25°C under which the lab tests were run. It is anticipated that the two conditions will cancel so that the expected life will be 1000 hours.

## Conversion Techniques

It was originally planned to use a multiplex technique when converting the analog inputs to the digital outputs required for the EL displays. This approach was investigated but flight safety considerations dictated that individual parallel channel conversion techniques would be necessary. Therefore, a modification of the multiplex technique was utilized. Identical A-to-D converters were used, preceded by buffers to condition the input signal. An exception to this was the synchro conversions. The cost of the synchro-to-DC conversions was prohibitive on this program, hence it was decided to use a mechanical conversion for synchro to digital. All conversions for the engine instruments are accomplished in the Model 6360A converter shown in Figure 41. This unit size is 9" x 12" x 22".

The method of conversion for the individual channels is discussed in detail in the following sections.



ENGINE INSTRUMENT SYSTEM CONVERTER
FIGURE 41

## ETP Conversion

As was previously indicated, a mechanical conversion was selected to perform the analog-to-digital conversion. An "integrated" servo package called a Torqusyn and produced by the Vernitron Corporation was purchased for this conversion. This package contains a high efficiency DC torquer directly coupled to a synchro control transformer. Included in the package are all of the necessary electronics for driving the DC torquer. To complete the conversion to digital, a shaft angle encoder is geared to the Torqusyn. A single turn, self select type encoder is used and has output lines compatible with diode-transistor logic (DTL).

## Fuel Flow Conversion

This conversion was obtained using a device similar to that used for EPT. The only difference is in the gearing to shaft angle encoder, to allow differences in scale factor requirements.

EGT Display

Conversion for the EGT Display requires converting the DC voltage from the thermocouple to a binary coded digital equivalent. This is shown by Figure 42.

Special chromel alumel input wires are brought into the converter and go directly to a solid state cold junction compensator which tracks the temperature changes of the cold junction.

The output from the compensator then goes to the chopper-stabilized buffer amplifier. This special low drift amplifier raises the low level voltage to a voltage which is compatible with the analog-to-digital converter.

The A-to-D converter converts the DC voltage to a binary coded digital signal. Operation of the A-to-D converter is discussed in Paragraph 4.3.6.

RPM Display

Conversion for the RPM Display requires changing the variable frequency from the tachometer to a binary coded digital output. A block diagram of this conversion is shown by Figure 43.

The output from the tachometer is fed into a frequency-to-voltage converter. This converter uses a saturated core technique to provide a DC voltage which is proportional to the frequency of the input but yet is not affected by the changing amplitude of the input signal.

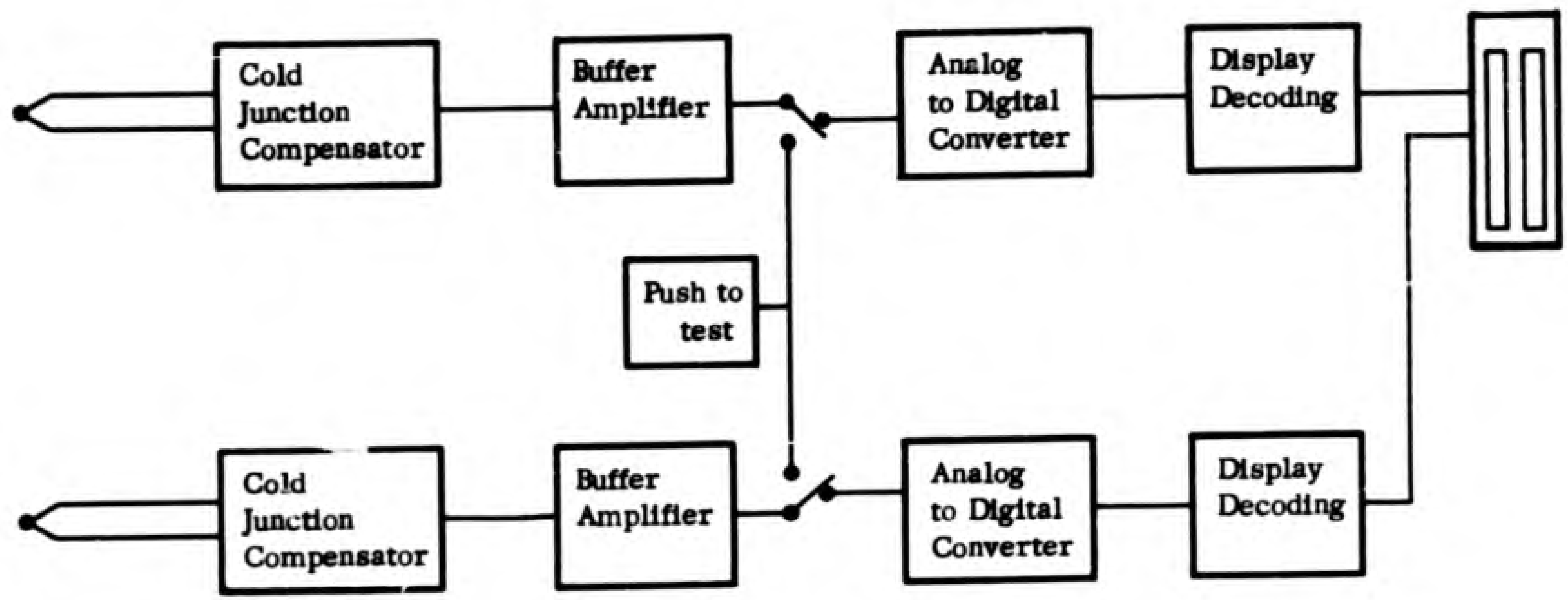
The DC voltage from the frequency converter is fed into a buffer amplifier which provides the proper impedance and voltage magnitude to interface with the A-to-D converter.

The output from the buffer is fed into a push-to-test relay. Under normal conditions the signal goes directly to the A-to-D converter while under test conditions a test signal provides the input for the A-to-D converter.

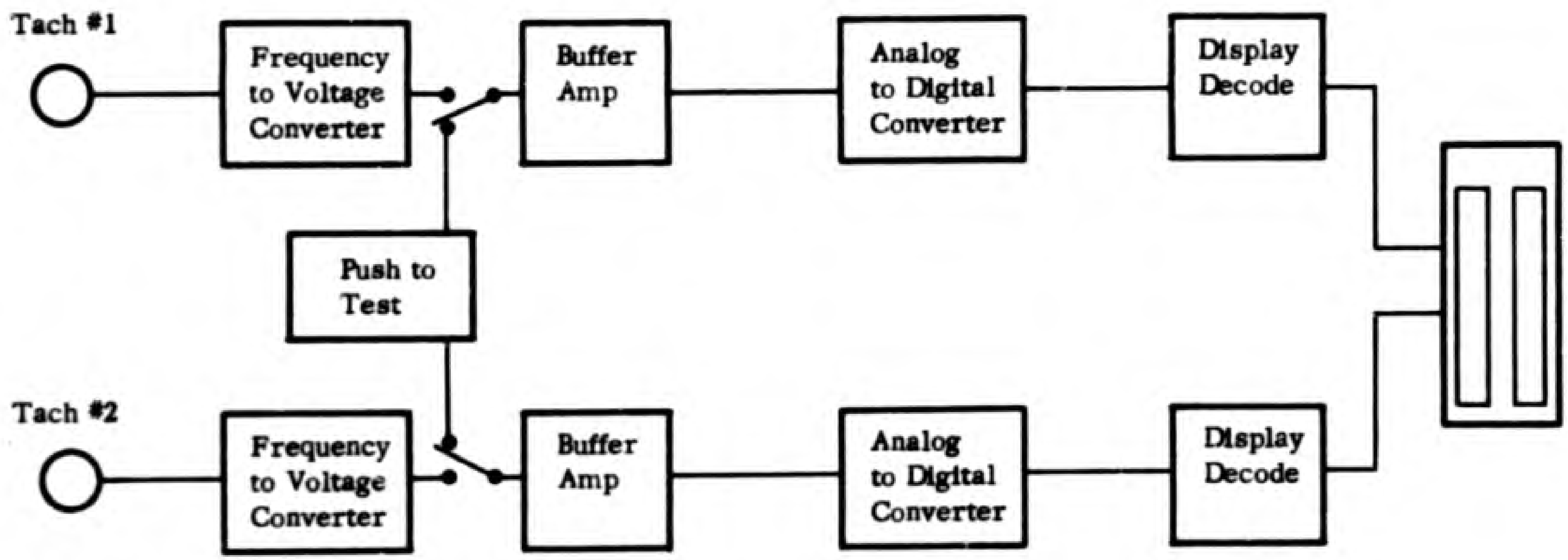
The A-to-D converter converts the DC voltage to a binary coded digital signal. This converter is discussed in detail in a later section.

Fuel Quantity Display

The input signal for the fuel quantity display is an AC signal from the round dial fuel quantity indicator. This signal is fed into a rectifier which converts the signal to a DC voltage which is fed through a buffer




EGT BLOCK DIAGRAM
FIGURE 42




RPM BLOCK DIAGRAM
FIGURE 43

amplifier into the analog-to-digital converter. The A-to-D converts the DC voltage to the binary coded number necessary to drive the EL display. (This conversion is shown in Figure 44.)

Since the input signal is a function of the AC line excitation, it is necessary to track this line value for accuracy considerations. In this application, tracking is accomplished by rectifying the AC line and using this voltage to supply the comparator reference for the A-to-D converter. As the digital output is proportional to this voltage, the desired tracking is accomplished.

Analog-to-Digital Conversion System

The analog-to-digital converter uses a basic successive approximation method of conversion to convert the analog voltage. The basic system is shown by the block diagram in Figure 45.

The analog voltage input signal is compared to the output of the analog-to-digital converter. If an error signal exists, it is detected and amplified by the comparator whose output drives the control logic. The control logic switches the analog-to-digital converter which reduces the error by the most significant bit. The cycle is repeated until the error is less than the system resolution. Each approximation requires one bit time.

The parallel output is obtained by using field effect transistor buffers and diode transistor logic. This output feeds directly into the display conversion logic which was described earlier.

Power Supply

The power supply for the engine instrument system is shown by Figure 46. A listing of the required supplies and their current ratings is listed below:

Analog-to-Digital Conversion

| No. Required | Voltage | Current | Description |
|---|---|---|---|
| 1 | + 5 VDC | 510 ma | Used for the DTL logic. |
| 2 | +20 VDC | 85 ma | Isolated supply for the RPM tach conversion. |
| 1 | +15 VDC | 17 ma | Used for the operational amplifier. |
| 1 | -15 VDC | 145 ma | Used for the operational amplifier. |

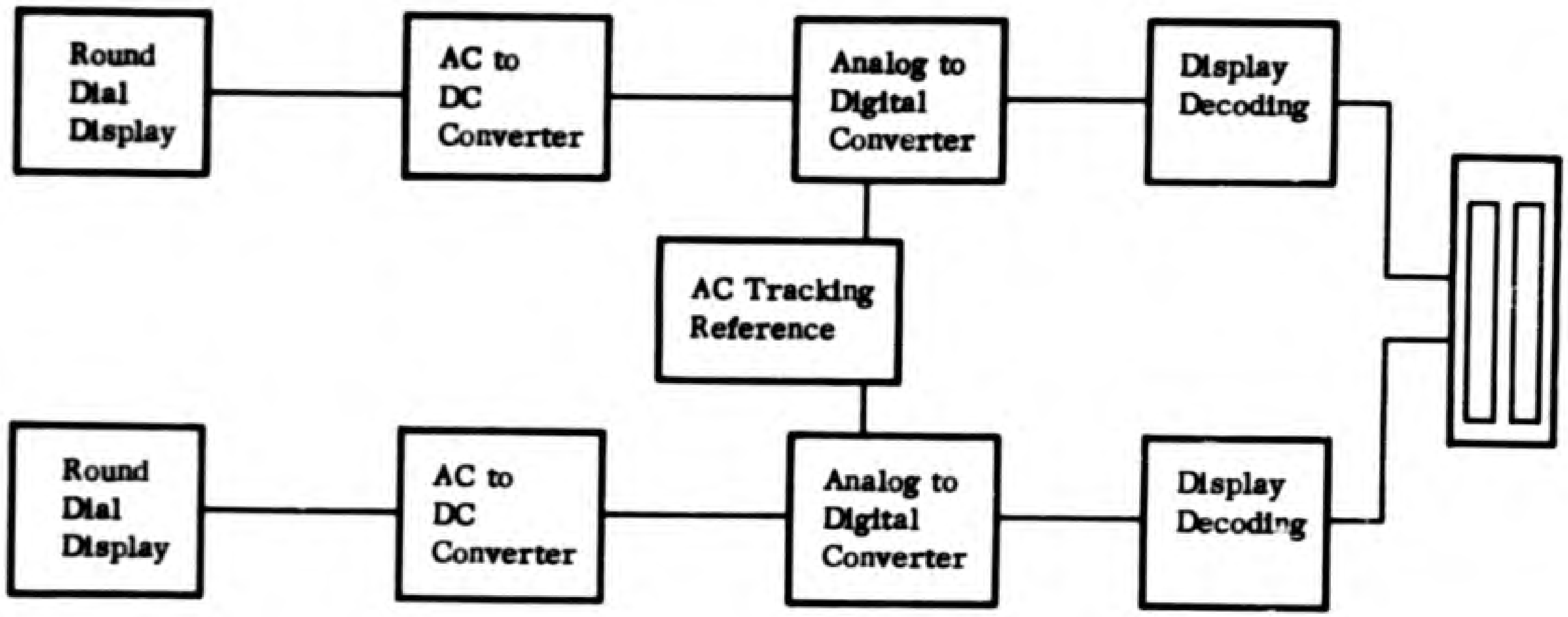
| | | | |
|---|---|---|---|
| 1 | -27 VDC | 36 ma | Used for the MOS switches. |
| 1 | -5.5 VDC | 8 ma | Used as a reference voltage for the SC-100 converter. |

## Display Conversion

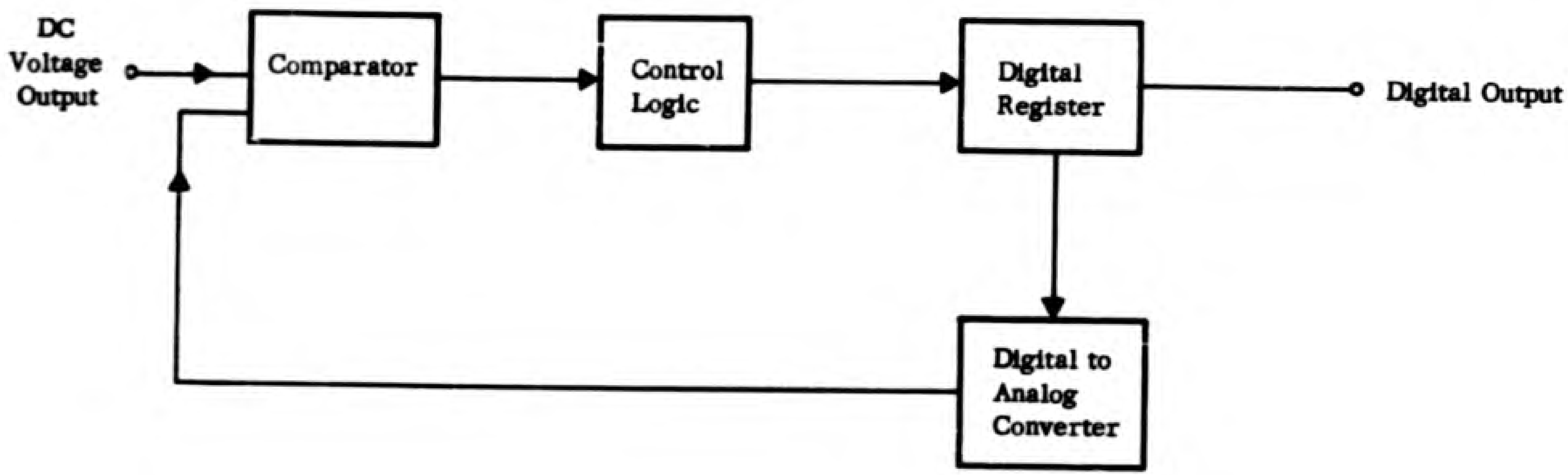
| No. Required | Voltage | Current | Description |
|---|---|---|---|
| 1 | 5 VDC | 4A | Used for the DTL logic. |
| 1 | 28 VDC | | |

## Lamp Excitation

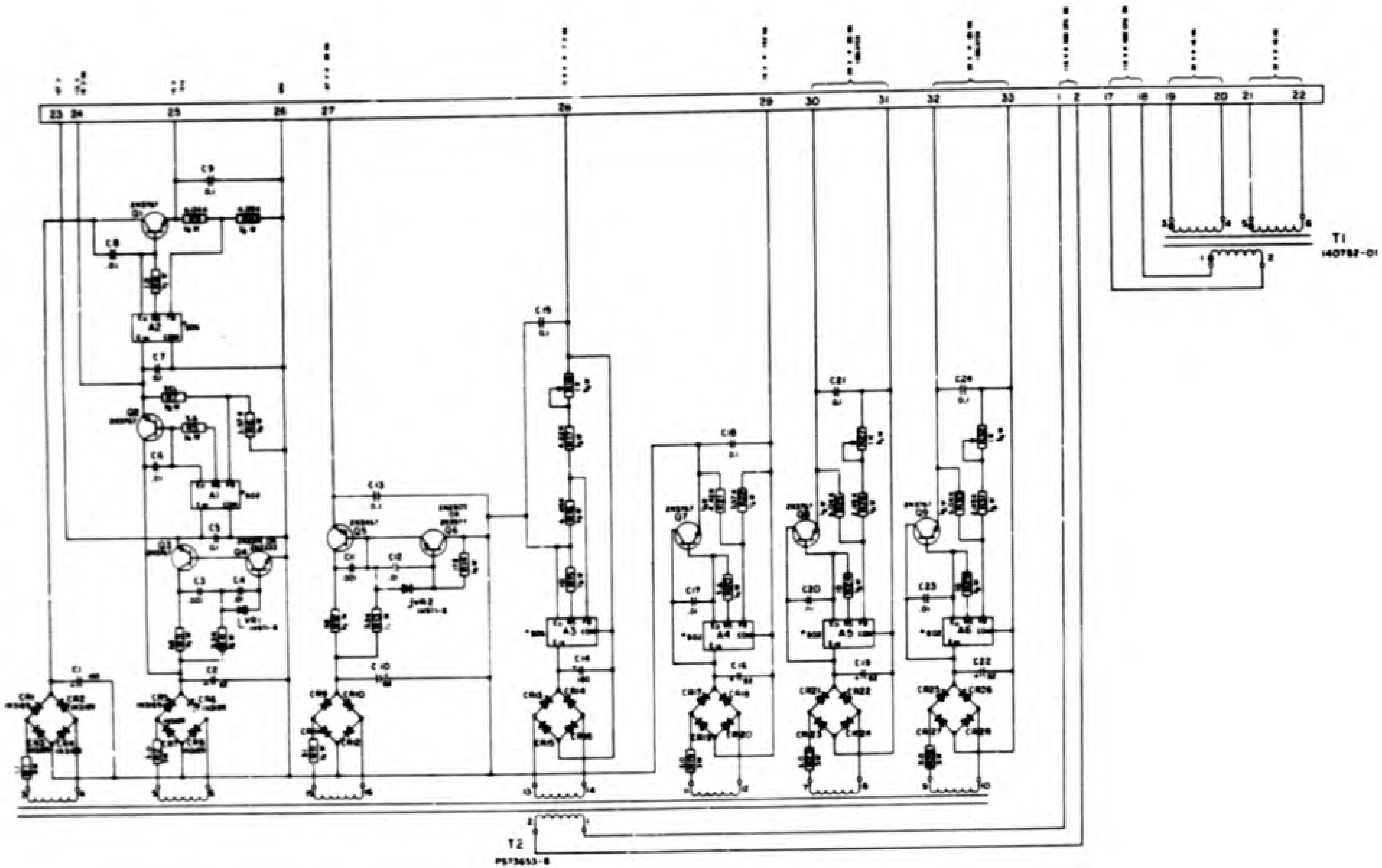
| No. Required | Voltage | Current | Description |
|---|---|---|---|
| 1 | 800 Hz | 250V rms max. | Used for light emitting displays. |




FUEL QUANTITY BLOCK DIAGRAM
FIGURE 44




ANALOG-TO-DIGITAL CONVERTER BLOCK DIAGRAM
FIGURE 45




POWER SUPPLY SCHEMATIC
FIGURE 46

## LANDING INSTRUMENT SUBSYSTEM

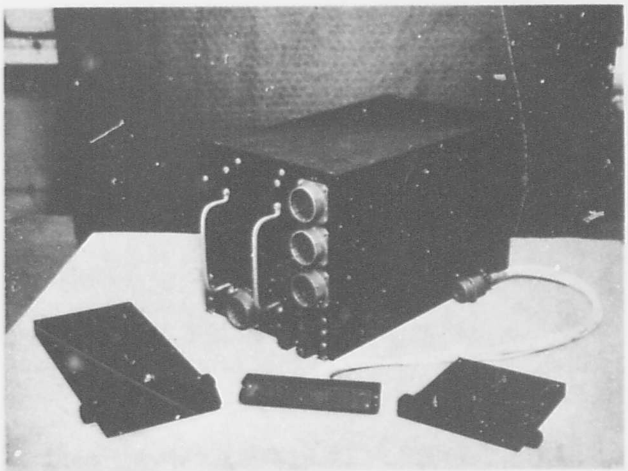
### General

The Landing Instrument Subsystem consists of a landing sequence indicator (LSI Model 8703D), a speed error indicator (LSI Model 2717C), a runway displacement indicator (LSI Model 2716C), and a converter (LSI Model 8360H). A power module and a test box are also provided.

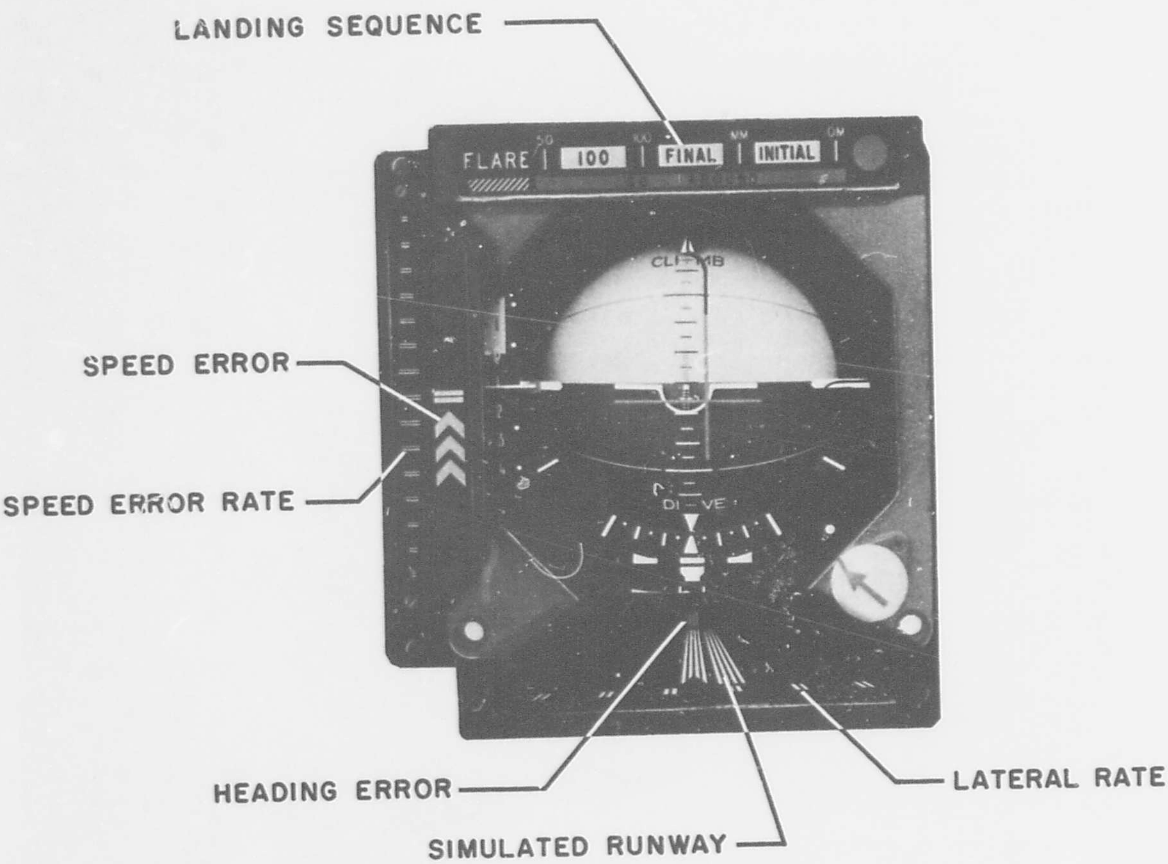
All units of the subsystem are completely solid state; the indicators are mechanized utilizing the latest techniques in electroluminescence.

The subsystem provides landing information to the pilot in formats which utilize certain of the unique advantages of electroluminescence (EL).

The three indicators are grouped around the attitude director indicator and overlap the bezel to minimize pilot scan area during approach and landing. (See Figure 48.)



LANDING INSTRUMENT SUBSYSTEM
FIGURE 47




LANDING INDICATORS GROUPING
FIGURE 48

## Display Philosophy

The program objective was to develop an experimental display panel capable of presenting clear and unambiguous flight control information under all lighting conditions through the use of advanced solid state and electromechanical display techniques.

This objective was applied to the landing displays utilizing several novel presentations of flight control information.

Landing Sequence Indicator (Model 8703D)

The landing sequence indicator, shown in Figure 49, provides annunciator type information of aircraft progress during approach and landing. Information sequentially moves from right to left. The amber flashing dot at the far right advises the pilot that additional information has been added to the display. Information displayed includes:

a. Checkpoints

    OM (Outer Marker)
    MM (Middle Marker)
    100 (100 ft. altitude)
    50 (50 ft. altitude)
    ////////// (touchdown)

b. Autopilot Gain Status

    Initial
    Final
    100


LANDING SEQUENCE INDICATOR
FIGURE 49

c. Action Command

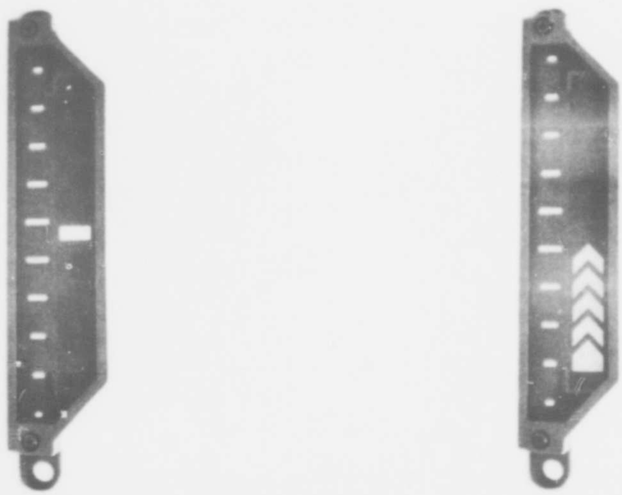
Flare
Go Around

All legends are green except the flashing dot and "GO AROUND" which are amber.

The landing sequence indicator utilizes LSI high-contrast electroluminescence to insure readability and minimize panel clutter in the off state.

Speed Error Indicator (Model 2717C)

The speed error indicator provides under and overspeed information to the pilot as an aid in controlling a preset nominal approach speed.



On Speed

Under Speed

SPEED ERROR INDICATOR
FIGURE 50

The display presents a green rectangular bar to indicate an "on speed" condition. If the aircraft deviates ±2 knots from the nominal speed, the green bar is extinguished and amber pointers appear. The pointers indicate the direction of speed correction necessary and amount necessary by a scaling of two knots per pointer. A total of five pointers is available in either direction (underspeed or overspeed).

To the immediate left of this speed error scale is a presentation of speed error rate. This rate is displayed as a series of equally spaced moving bars. Their rate of movement up or down provides an indication of the rate of speed change. This vernier of speed error rate should enable the pilot to maintain a tighter control loop around approach speed. Its rate is adjustable in the control electronics.

The entire display has been designed as peripheral data for use when the pilot's center of attention is focused on precise control of the flight director in the ADI; a rather bold simple presentation without numerals or legends utilizing color and motion was adopted.

The speed error indicator uses high contrast and polarizing light control techniques.

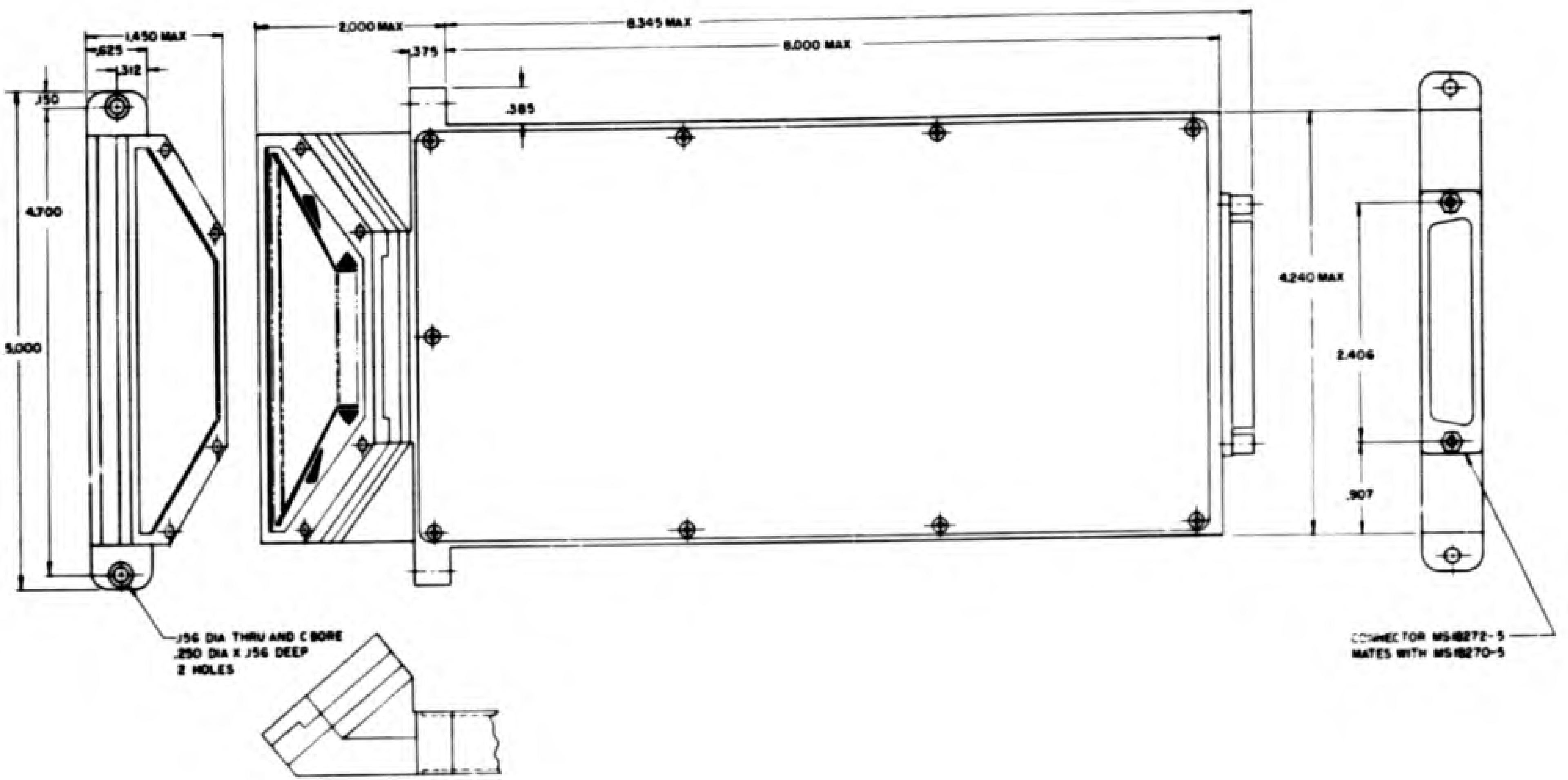
Runway Displacement Indicator (Model 2716C)

The runway displacement indicator presents a simulated runway, lateral rate analog, and heading error. The installation data on this unit is given in Figure 51.

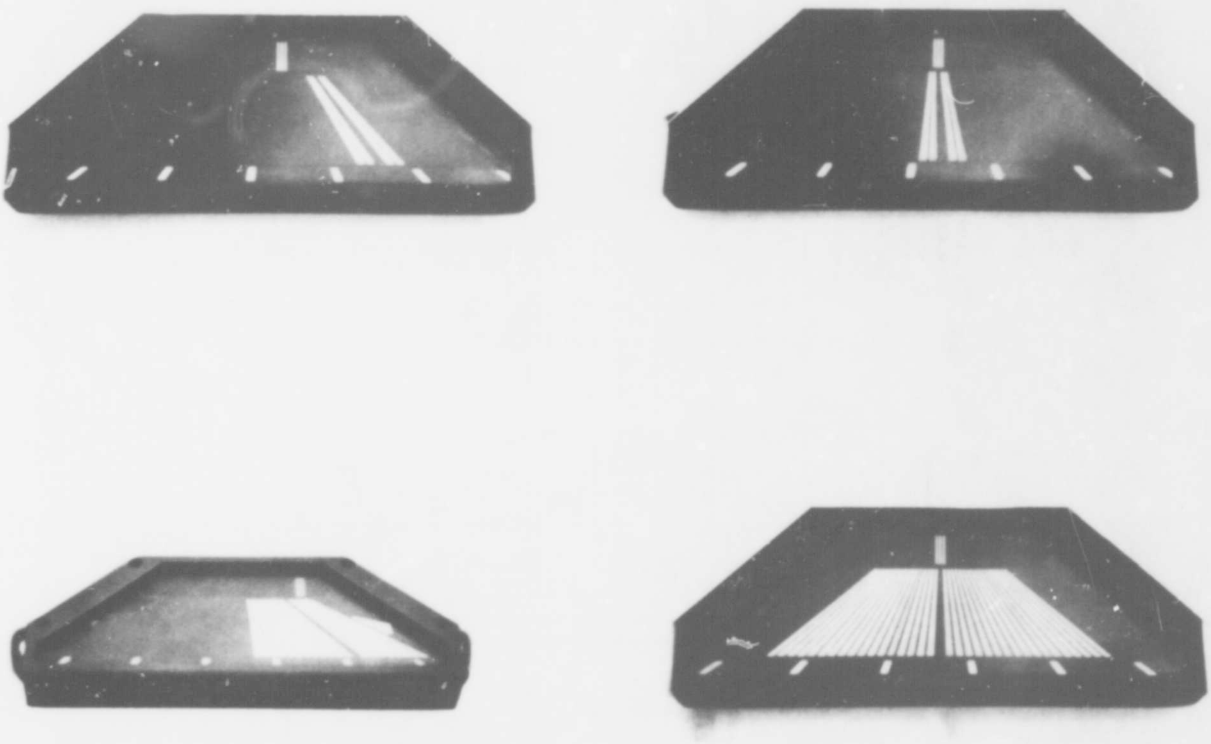
The simulated runway, shown in several conditions in Figure 52, provides information concerning aircraft alignment with the runway as indicated by the localizer. The lighted portion represents only the center half (75 ft.) of the runway width and is considered as an acceptable gate for lateral alignment. A blanked segment representing the runway centerline is provided to assist alignment control. The center of the display is located on the vertical centerline of the conventional T scan for flight control information.

The runway display simulates a real world approach by causing the runway to expand in width as distance to touchdown decreases. This expansion is variable in the control electronics to allow pilot reaction evaluation. Excessive lateral deviation is indicated by illumination of off scale pointers.

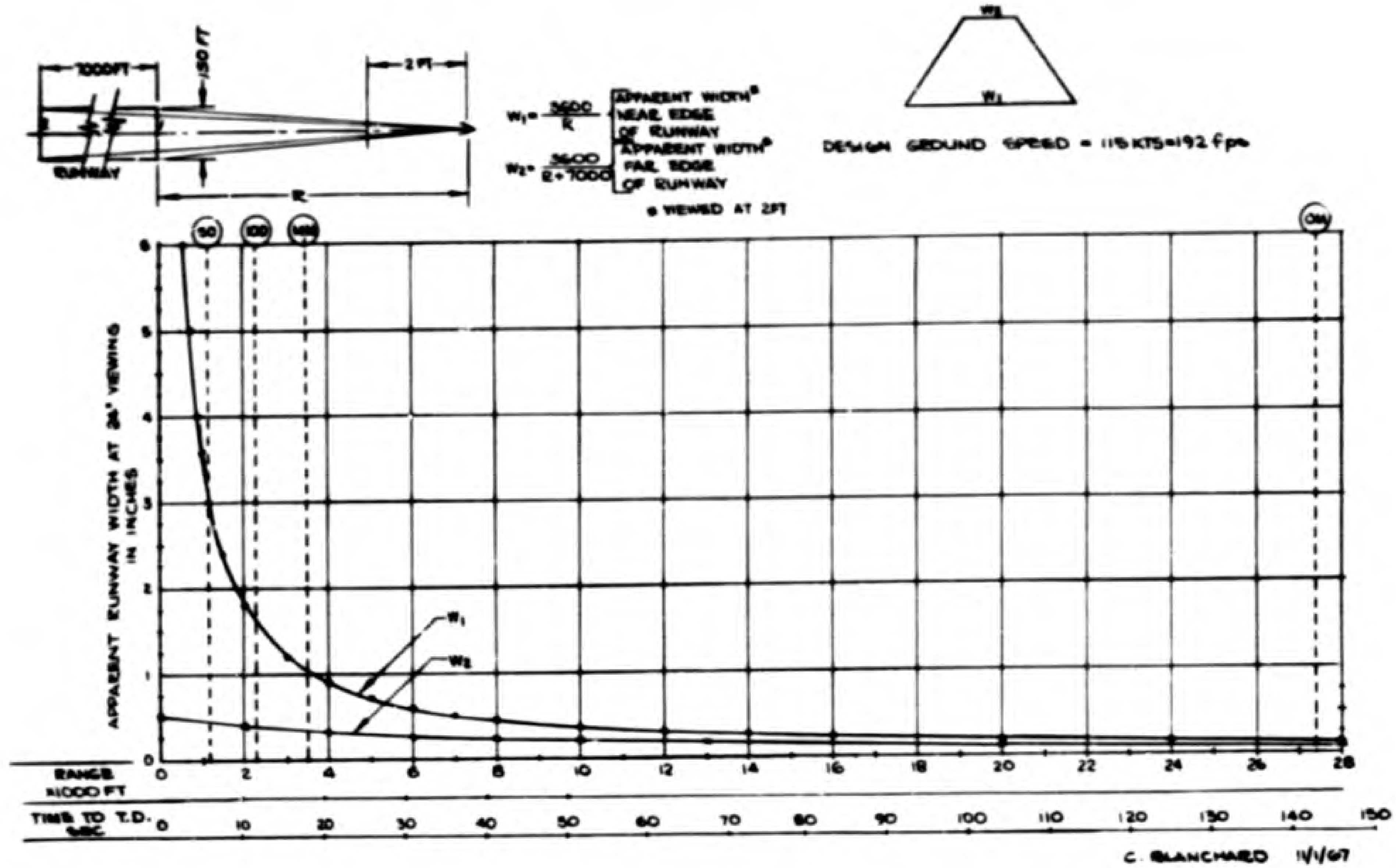
Display format analysis centered around evaluation of runway expansion. Figure 53 shows apparent runway width vs range to touchdown. The apparent runway width is at a viewing distance of 24 inches. This




RUNWAY DISPLACEMENT INDICATOR INSTALLATION DATA
FIGURE 51



RUNWAY DISPLACEMENT INDICATOR
FIGURE 52




APPARENT RUNWAY WIDTH VS. RANGE TO TOUCHDOWN
FIGURE 53

analysis shows the function to be nonlinear as experience would expect. It is observed that the function $W_1$ changes quite rapidly after the middle marker (MM). Analysis of the PINS simulated runway display has pointed up the desirability of an off-segment centerline and the need for good quickening in the rate field.

To assist the pilot in maintaining a tight control loop around lateral displacement, a segmented rate field is provided below the simulated runway. Its operation indicates lateral motion as a vernier of the runway lateral movement. Its rate is adjustable in the control electronics.

Both the runway and its associated vernier rate field are green.

Heading error is presented directly above the runway as an amber moving pointer. The angle displayed is the angle between aircraft heading and the heading set on the horizontal situation indicator. If runway heading is set on the HSI, the heading error will present aircraft crab angle.

Scaling is such that it presents an extension of the HSI compass card angular change. Placing this parameter near the ADI provides peripheral data of crab angle during the landing and decrab maneuvers. The decrab pointer is amber to emphasize the decrab requirement prior to touchdown.

The face of the runway displacement indicator is tilted 60 degrees from vertical. This eliminates specular reflections from the cockpit and increases the effective display area by a factor of two.

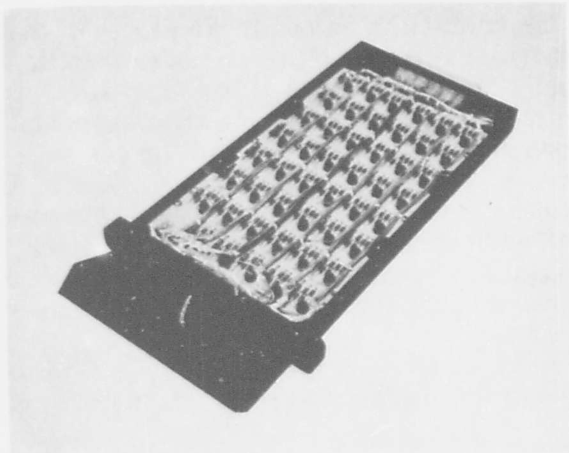
High contrast and polarizing techniques are also used to control readability.

Figure 54 shows the indicator with the top access plate removed.

## Mechanization Philosophy

The Landing Instrument Subsystem has been mechanized utilizing complete solid-state control circuitry and display media.

All input signal processing, data conversion, timing, logic, and control requirements are performed within the remote converter (Model 8360H). All control signals are converted to an optimum digital format and transmitted to the indicators along with necessary power for high voltage switching. The actual high voltage is controlled within each indicator. This insures a minimum EMI problem and makes maintenance and modification easiest.



RUNWAY DISPLACEMENT INDICATOR WITH
UPPER ACCESS PLATE REMOVED
FIGURE 54

The indicator drive electronics consists mainly of high voltage silicon controlled rectifiers (SCR) and steering diodes. No potted modules are used and each discrete component is individually replaceable. This philosophy is in contrast to that utilized on the engine instruments and is purposely done to allow evaluation of each concept under real world flight line conditions.

The Landing Instrument Converter, Model 8360H, contains eighteen 4-1/2 x 5 inch plug-in circuit boards. (See Figure 55.)

Operations within the converter are functionally divided and accomplished on a board-by-board basis. (See Figure 56.)

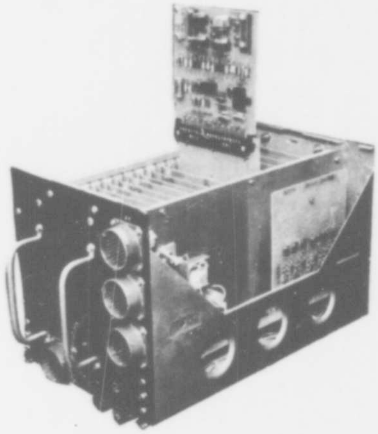
Each board is removable and can be serviced easily by using the incorporated card extender.

All variable parameters are adjustable via potentiometers located at the upper end of the associated circuit board.

Four connectors provide electrical access to and from the converter:

J1 - Connection to the runway displacement indicator

J2 - Connection to the landing sequence indicator and speed error indicator



CONVERTER WITH CARD EXTENDED
FIGURE 55

J3 - Connection to aircraft signal and power or test unit

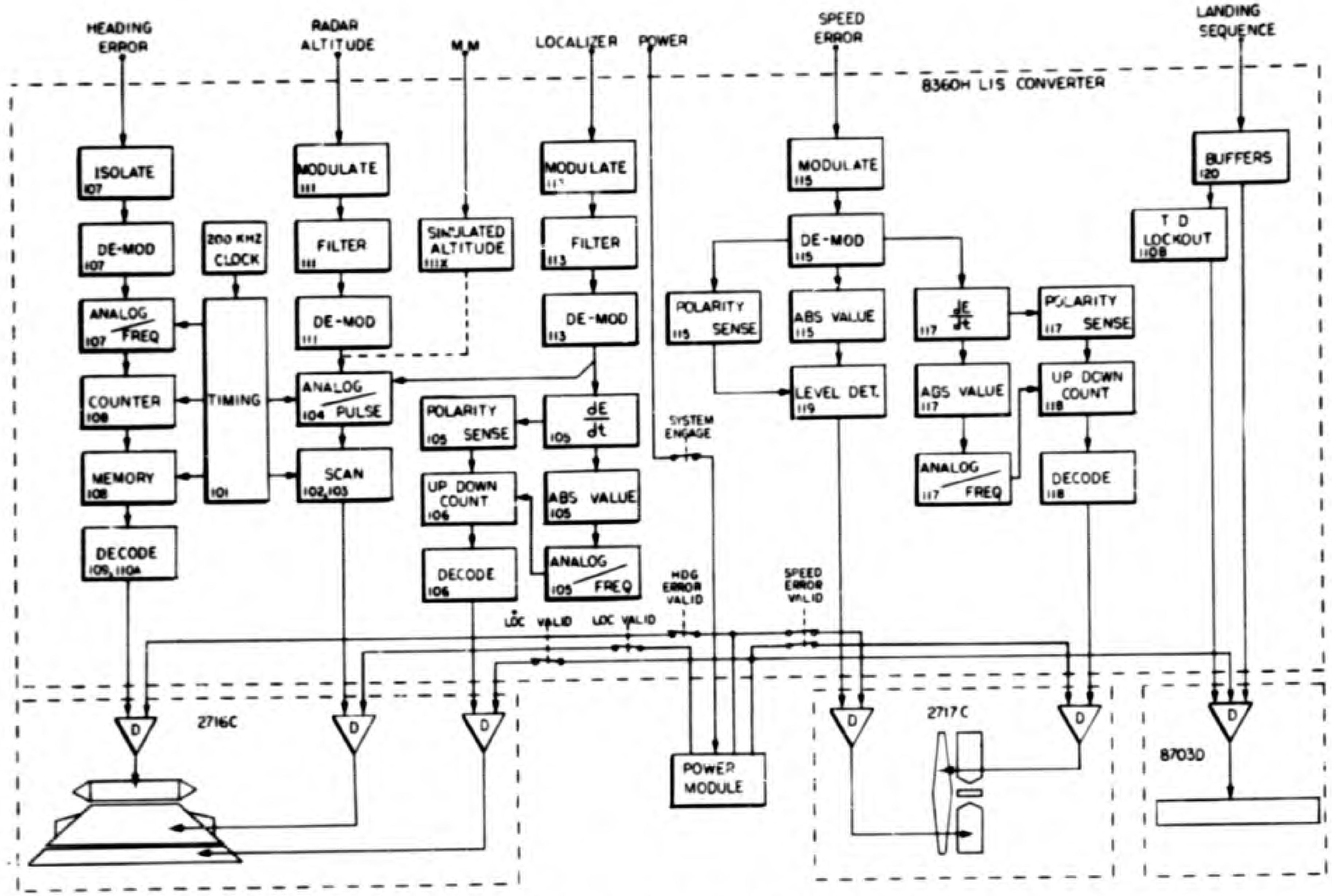
J26 - Connection (input to and output from) to power module.

The converter is a short three-quarter ATR (7.500" W x 7.625 x 12.563) including dust cover.

The solid-state components used are widely accepted and well suited to the requirements. Commonly used semiconductors include:

MC1530 and MC1531 operational amplifier
MC848 DTL flip flop
MC832 DTL gate
2N2222 npn switching transistor
2N3977 pnp chopper transistor
C3DX20 silicon controlled rectifier
1N4154 logic diode

The converter utilizes a 200 kHz basic clock crystal oscillator as a reference for internal digital conversions and signal processing. Although the Landing Instrument Subsystem receives several analog inputs, they are eventually converted to digital and the system can be considered to be basically digital.




EL LANDING INSTRUMENTS SUBSYSTEM BLOCK DIAGRAM
FIGURE 56

The digital format is described as:

Basic clock frequency 200 kHz

Logic Levels:

| | |
|---|---|
| Logical "1" | 5 VDC ± 0.5 VDC |
| Logical "0" | 0 VDC + 0.5 VDC |

The system can sustain power interruption without loss of memory or synchronism.

## Functional Operation

The development of the Landing Instrument Subsystem utilizing electroluminescence (EL) as a direct reading display device was guided by the combined experience of the Air Force Flight Dynamics Laboratory and the Instrument Division of Lear Siegler, Inc.

Special concern was given to minimizing the known disadvantages of EL and exploiting its unique advantages.

The primary disadvantage considered was the brightness-life-temperature characteristic. An excitation frequency of 800 kHz was chosen for each parameter except the simulated runway. Better lamp life should be achieved by utilizing a constant brightness-variable voltage philosophy.

The unique physical arrangement of the overlapped instrument bezels combined with cooler running DC-servoed ADI and HSI should place the EL lamps in a lower thermal environment.

Because the landing instruments are utilized during a small portion of the total flight profile, inhibiting lamp operation during the irrelevant portions of flight will greatly extend lamp calendar life.

To exploit some of the advantages of EL, the landing displays were conceived as peripheral displays providing information as near to the center of the ADI as practical. Because of the flexible format possible with EL, it was possible to lap the ADI bezel. This is a panel area which was previously lost to displaying data even though it was prime "real estate".

The simplicity of mechanizing an EL rate field lead to the use of two (speed error rate and lateral rate) in the system.

Because EL is one of the few true area light sources, it serves as an excellent media for annunciator type data. Therefore, a landing sequence display was incorporated to good advantage.

The simulated runway allows a good demonstration of the unique advantages of EL. It would be impossible to duplicate this function in the space allotted employing electromechanical or even cathode ray tube techniques.

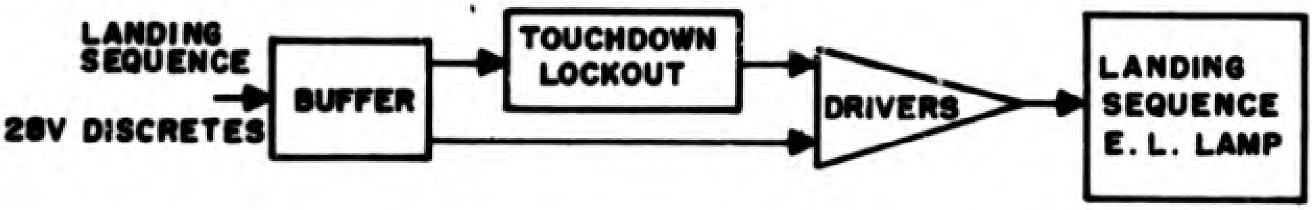
Other known advantages of EL utilized in the system are spectral uniformity, and reduction in size, weight, and power requirements.

The three indicators present six basic display parameters. The functional operation of each parameter from signal source to display element is discussed in the following paragraphs:

Landing Sequence (See Figure 57.)

The Landing Sequence parameters are:

Flasher
Outer Marker
Middle Marker
100 feet altitude
50 feet altitude
Flare
Touchdown
Initial (Autopilot)
Final (Autopilot)
100 feet (Autopilot)
Go Around




LANDING SEQUENCE FLOW DIAGRAM
FIGURE 57

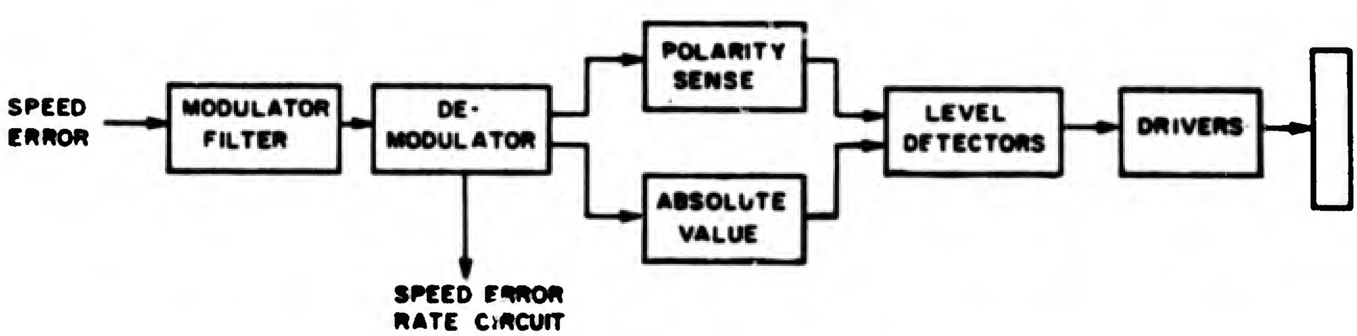
Each parameter receives a 28 VDC discrete signal from either the autopilot or the flight director mode selector. The signal is buffered to compatible logic and is transmitted to the indicator. The indicator receives the logic signal and switches the appropriate EL segment.

The indicator utilizes a common gate cathode-driven SCR configuration. Signal buffering is done in the converter on circuit board No. 120 (shown in Figure 56).

A special interlock circuit on board No. 110B insures that the touchdown display portion (cross hatched lines) of the lamp will not be energized continuously during irrelevant periods such as powered maintenance or testing. This is accomplished by requiring a flare command to precede the touchdown signal to validate it.

Speed Error (See Figure 58.)

The input signal for speed error is a bipolar DC voltage with a scale factor of 100 millivolts per knot. The signal is generated as angle of attack error but can be considered as speed error during approach and landing. The signal is received and processed on boards No. 115 and No. 119. The input signal is modulated for isolation, filtered, and demodulated. It is then split in two branches. One branch is sensed for polarity and the other is made single polarity via the absolute value circuit. The absolute DC value is then sensed for magnitude by five discrete level detectors. Each detector provides a logic level output to the indicator equivalent to two knots of speed error. A potentiometer is provided on board No. 115 to vary this scale factor. The polarity detector provides an overspeed/underspeed signal to the indicator.




SPEED ERROR SIGNAL FLOW DIAGRAM
FIGURE 58

If the speed error signal magnitude is not large enough to trip the least significant detector, its inverted output is sent to the indicator as a logic level indicating an "on speed" condition.

The indicator includes logic to sample the forementioned inputs and switch the appropriate SCR drivers to illuminate the desired EL segments.

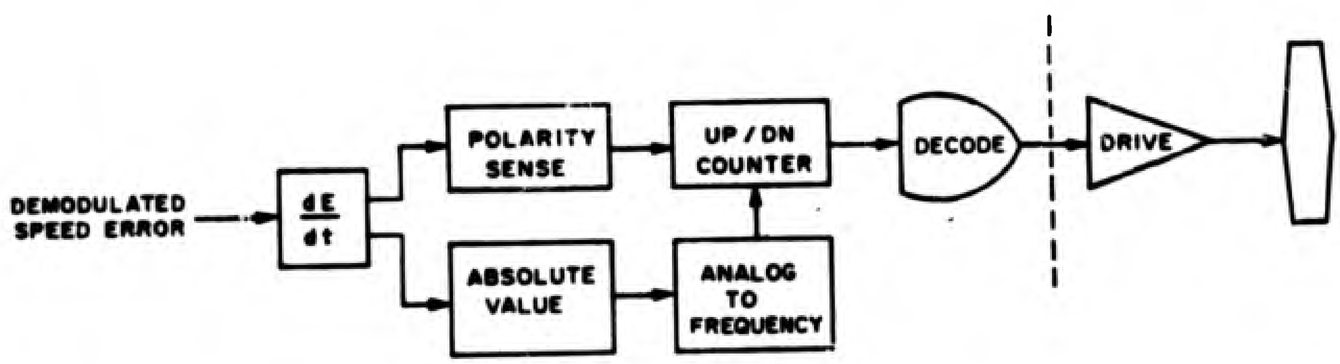
Speed Error Rate (See Figure 59.)

Speed error rate is a derived function which uses the demodulated, filtered, isolated speed error signal as its source.

The signal processing is done on circuit boards No. 117 and No. 118.

The DC speed error signal is first differentiated to provide a DC value of rate. The rate signal is then split with one branch sensed for polarity and the other made singular polarity.

The scaling of this section is adjustable via the potentiometer on board No. 115. The DC rate magnitude signal is next converted to a pulse train with frequency a function of DC input. This pulse train is accumulated in a three-stage up/down counter. The counter direction is controlled by the polarity sensing circuit. As an input rate signal is processed, the counter accumulates zero through seven and continues to count over. This binary count is decoded to a decimal one out of eight format. The eight lines are sent to the indicator as input discrete signals.




SPEED ERROR RATE FLOW DIAGRAM
FIGURE 59

Inside the indicator each input signal line controls one SCR high voltage driver. Each driver is connected to every eighth EL segment in the rate field. Only one SCR with its associated EL segments is energized at a given time. As the SCR's are sequenced, the EL rate field appears to be moving thereby achieving the desired display.

Simulated Runway

The simulated runway offered the most difficult problems of display generation. It also offered the most promising opportunity to demonstrate the capabilities of electroluminescence in solving unique display problems.

Initial design investigation showed that conventional signal control and matrix selection schemes were not well suited to solving this requirement. The use of diode selection matrix would have resulted in an impractical amount of electronic complexity.

Concurrently, LSI was developing a technique of EL display generation utilizing a scanning technique. This basic scanning technique enables use of an analog input signal to generate a variety of display formats on an electroluminescent segmented array.

Basically, this technique sequentially pulses the segments in an EL array with high voltage excitation. By performing this scan cycle continuously, each EL segment will appear to emit a steady light. The fundamental scanning relationship is given by:

Scan Period = Pulse width x number of segments.

The integrated light output will be a function of several parameters including:

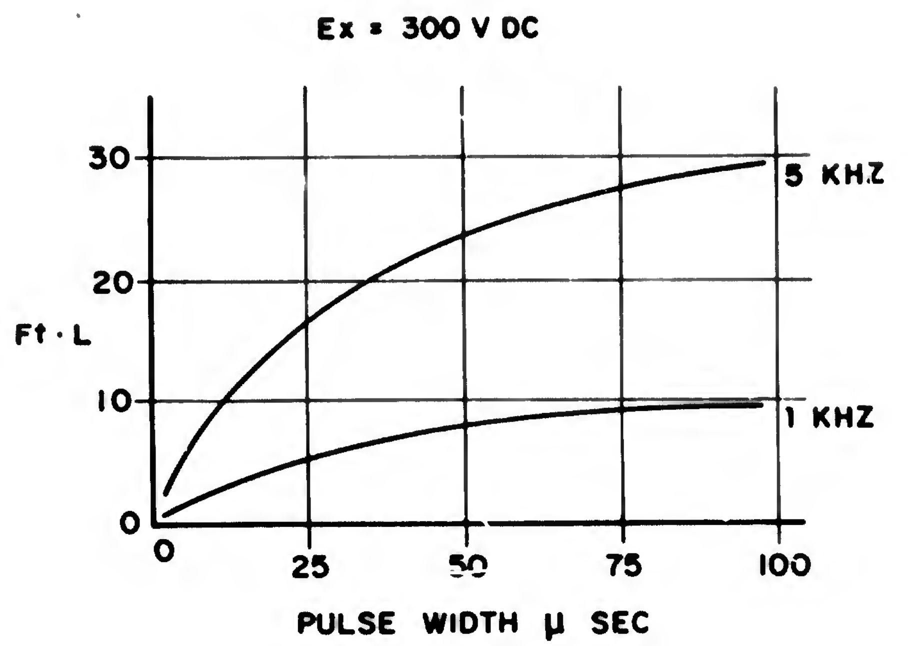
Waveshape $\frac{de}{dt}$

Pulse width

Voltage

Pulse repetition rate

Typical values are shown in Figure 60.



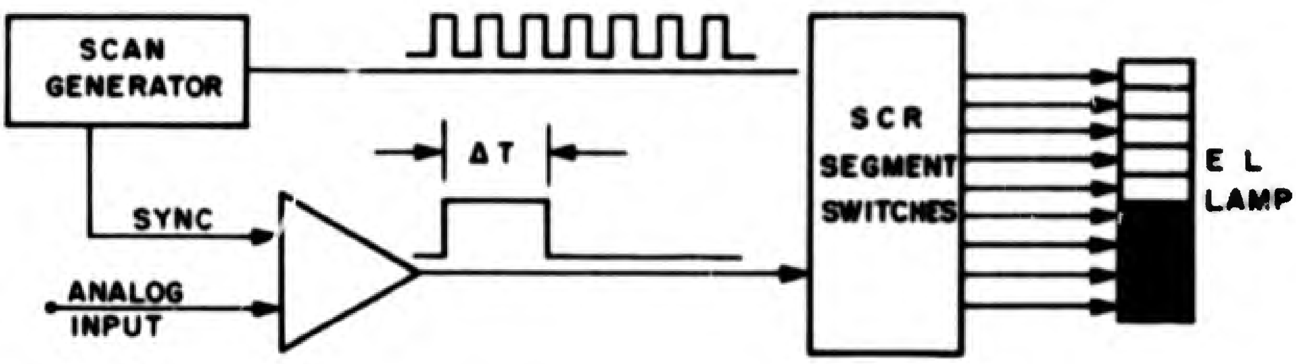

TYPICAL PULSE WIDTH/BRIGHTNESS CURVE
FIGURE 60

It is, furthermore, possible to illuminate only a portion of the segments by enabling some switches and inhibiting the rest. This function can be implemented in a much simpler fashion by enabling all the switches for a portion of the scan cycle and inhibiting them for the remainder. This eliminates individual logic control from the input signal to each switch. The input signal and output EL switches now become related through the time domain resulting in a greatly simplified control situation.

An enable pulse can be generated from the input analog signal which, if kept synchronous with the scan cycle, can accomplish the desired effect (see Figure 61).

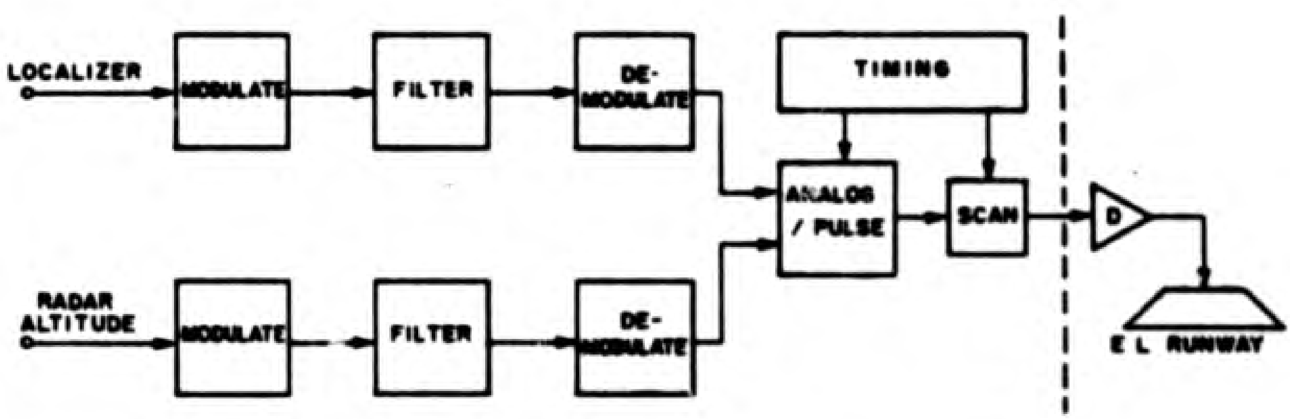
Therefore scanning allows a relatively simple control technique which eliminates conventional A/D conversions and matrix selection.

This basic principle can be expanded by varying the time occurrence and width of the scan enable pulse.




SCAN CONTROL OF EL SEGMENT
FIGURE 61

To mechanize the simulated runway, lateral position was allowed to be controlled by an analog localizer input signal while runway width was controlled by an analog altitude signal. These two basic input signals are utilized in a modified scanning approach to fulfill the runway display requirement.




LOCALIZER-ALTITUDE SIGNAL FLOW DIAGRAM
FIGURE 62

The raw localizer and radar altitude signals are each modulated for isolation, filtered, and demodulated prior to control processing. The localizer basic signal is ±75 millivolts per dot deviation. Potentiometers for gain and filter control are available on board No. 113. The altitude input is scaled at -40 millivolts per foot. The range extends to 1000 feet. Similar gain and filter control potentiometers are available for altitude on board No. 111.

An alternate altitude signal is available by replacing board No. 111 with board No. 111X. This alternate board generates a simulated decreasing altitude signal as a function of time. It is initiated by the middle marker signal. Rate of altitude change and nonlinearity of that change are adjustable by potentiometers located on board No. 111X. Boards No. 111 and No. 111X are interchangeable.

After preliminary signal conditioning, localizer and altitude are available as DC analog inputs to be used in the modified scan control circuit. Figure 63 shows the signal timing diagram.

The basic scan period is 480 microseconds. The runway is composed of 47 segments utilizing 48 timing pulses of 5 microseconds each. One pulse per scan cycle is dumped. An odd number is required to allow one segment to be in the geometric vertical centerline of the display. The display is scanned once during the first half (240 microseconds) of each period and blanked during the second half. This eliminates fringing of adjacent scan periods. The 47 scan pulses are generated by matrix gating 6 "address" pulses and 8 "line" pulses. Basic timing is accomplished on board No. 101.

To convert the input analog localizer signal to a synchronous pulse, signal No. 104-3* is generated. The continuous comparison of the ramp and analog voltage result in signal No. 104-4. Next, this signal is synchronized (104-2) or made to change states during the nearest clock state change. This eliminates partially illuminated EL segments.

When signal 104-2 falls to logic zero, this indicates the center of the runway to be generated.

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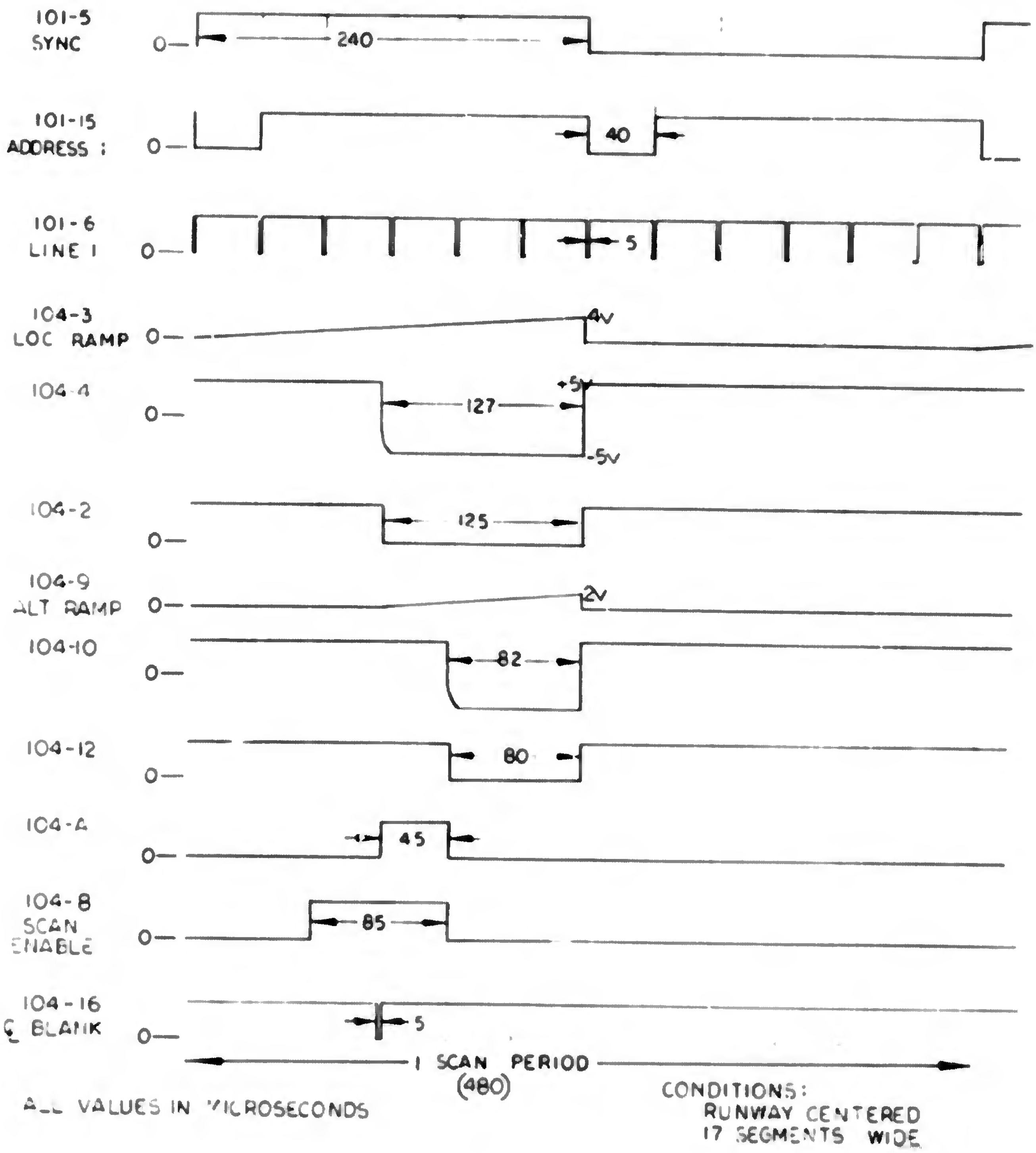
* Signal numbers indicate first the circuit board number (104) and then the test point connector pin on that board. (3)




**SIGNAL TIMING DIAGRAM**
**FIGURE 63**

At that time a second ramp is initiated (signal 104-9) which is used to compare against the altitude signal. Pulse signal 104-10 results and is synchronized to signal 104-12. Signals 104-2 and 104-12 are gated to produce signal 104-A. Signal 104-A represents the scan enable time period necessary to generate the right half of the runway.

This signal time period will contain a specific number of scan pulses depending on the altitude signal. This number of scan pulses will equal the number of illuminated EL segments to the right of the runway blanked centerline.

This same number of pulses is counted, multiplied by two, and subtracted from 96. This operation places the time at which the left outer edge of the runway begins on the following scan period.

Therefore, during a given scan period:

a. The center of the runway to be generated is located

b. The number of segments which compose the right half of the runway is determined

c. The time or number of pulses to arrive at the left edge of the runway in the next scan period is computed.

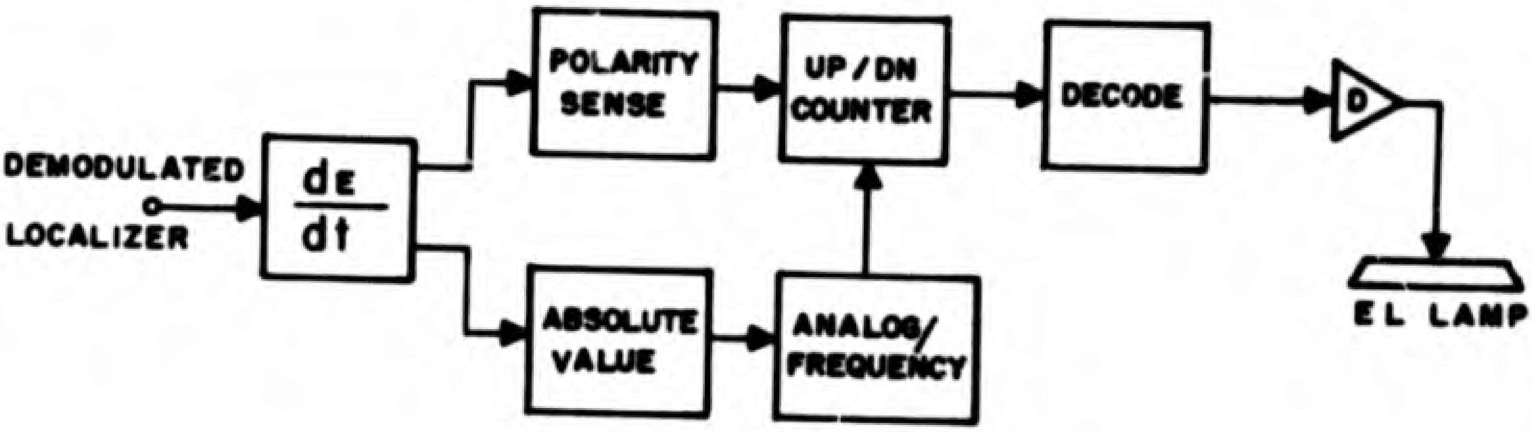
This data is then combined into signal 104-8 which represents the total runway position-in-time and width-in-time. Signal 104-16 represents the signal timing period which coincides with the centerline of the runway and is used as a blanking pulse.

The actual enabling and inhibiting (blanking) of the scan sequence is done by controlling the address drivers on board No. 103. Therefore, a modified version of the scanning technique was employed to generate the simulated runway.

Gain potentiometers are located on board No. 104.

Lateral Rate

Lateral rate, like speed error rate, is a derived function and is accomplished on boards No. 105 and No. 106. Its flow diagram is shown in Figure 64.




LATERAL RATE FLOW DIAGRAM
FIGURE 64

Heading Error

The signal source for heading error is a differential synchro in the HSI scaled at 300 millivolts per degree. The phasing indicates the direction of heading error.

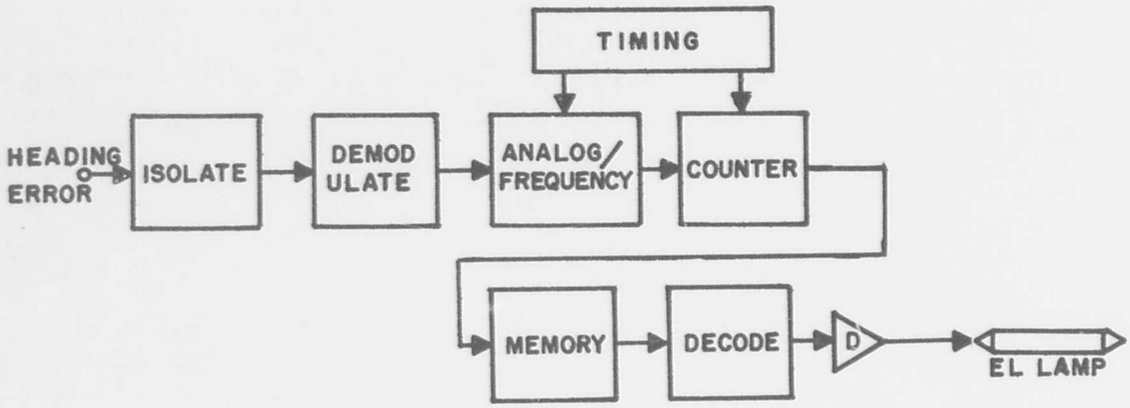
As shown in Figure 65, the input signal (400 Hz) is first transformed, isolated, and then demodulated on board No. 107.

This analog DC signal is then compared to an internal ramp resulting in a pulse of varying width. This varying width pulse is then used to gate a number of clock counts. This number is proportional to pulse width and is counted on board No. 108. The binary number is then parallel dumped into a flip-flop memory register where it is decoded on boards No. 109 and No. 110A. The computation is updated at a 2 kHz rate. The decoding utilizes a 6 x 8 matrix signal transfer to the indicator. This reduces the wires between units from 48 to 14.

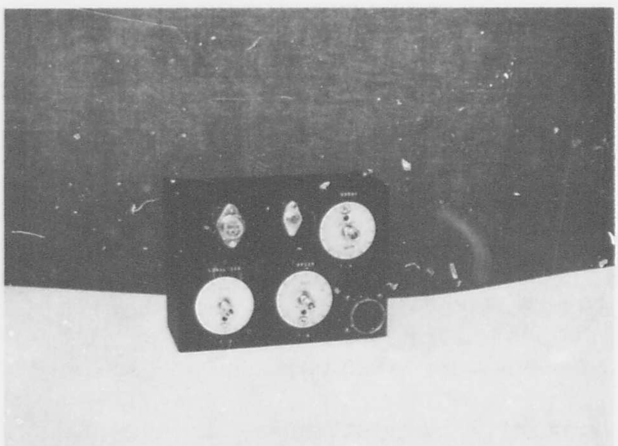
Inside the indicator the 6 x 8 selection matrix selects the SCR driver to be energized. The SCR gating is such that whatever segment is energized, the two adjacent segments will likewise be driven. This results in a moving pointer display three segments wide.

Power Control

Power requirements for the Landing Instrument Subsystem are met by the power supply module, shown in Figure 66.




HEADING ERROR FLOW DIAGRAM
FIGURE 65



POWER SUPPLY MODULE
FIGURE 66

Power input to the module is 115 volts 400 Hz via the converter. It converts this input power to ±6 volts DC fixed, 300 volts DC variable, and two sources of 250 volts AC 800 Hz variable. All output power is routed back through the converter for consumption and distribution to the indicators.

The ±6 volts is used to supply the converter signal processing. The 300 volts DC is routed through the converter relay board to supply excitation for the simulated runway. One of the 250 volts 800 Hz (labeled "green") is routed through the relay board to the landing sequence display, speed error rate, speed error "on speed" bar, and localizer rate. The second 250 volts 800 Hz (labeled "amber") is routed through the relay board to the speed error and heading error displays.

The relay board controls excitation voltage to the displays and allows remote switching. Four 28 VDC discrete input signals received in the converter control this switching.

- Localizer valid
- Speed valid
- Localizer rate valid
- Heading error valid

Each of the three high voltage excitation supplies can be adjusted for balance on the power module. A master level control of the 115 volt 400 Hz power to the module allows simultaneous dimming of all landing instruments.

The power module is normally located in the engine instrument converter but is supplied electrically from the landing instrument converter and can be physically removed easily for testing or demonstration.

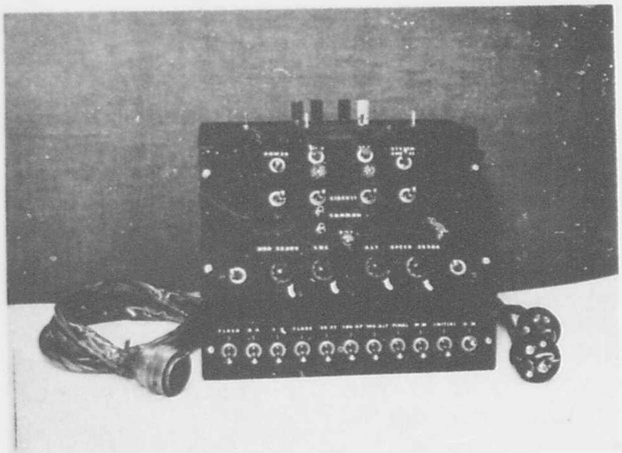
Fusing is provided on the landing instrument converter near the external connectors.

Test Unit

To facilitate testing, modification, and demonstration, the test unit shown in Figure 67 has been supplied.

The unit requires input power of 115 volts, 400 Hz, single phase and 28 VDC. It has a single output connector which mates with J3 on the converter.

The test unit supplies a simulated signal for each parameter and function in the Landing Instrument Subsystem and is readily controlled from the front panel of the unit.



TEST UNIT
FIGURE 67

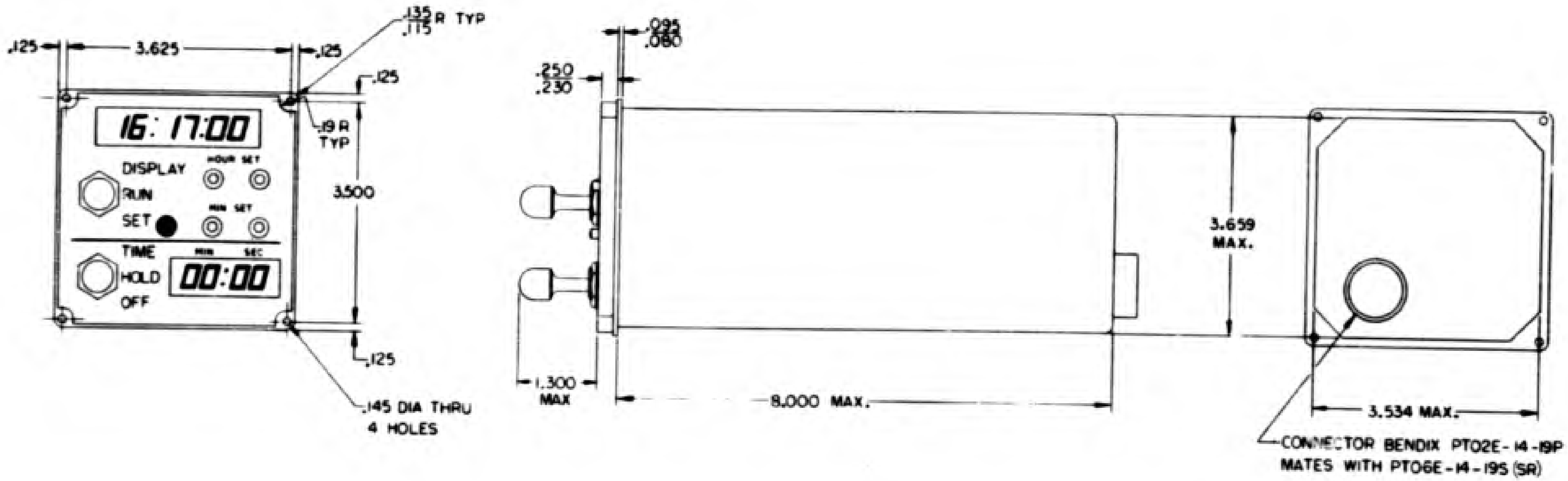
## Solid State Clock

### Functional Description

The solid-state clock, shown in Figure 68, consists of two separate timing systems that display real time and event time. Both displays consist of seven-stroke numeric characters. Real time is displayed in hours, minutes and seconds by the top set of characters. Event time is displayed in minutes and seconds up to one hour by the bottom set of characters.

The time base for both systems is an Accutron Model TE-11 battery-operated cycle timer. This unit provides one pulse per second with an accuracy of ± 2 second per day.

The function switch for the real time contains RUN, DISPLAY and SET positions. In the RUN position real time is being accumulated but the seven-stroke EL segments are not lighted. The display is lighted and time is accumulated when the switch is in the DISPLAY position. When the switch is in the SET position the seconds are




SOLID-STATE CLOCK INSTALLATION DATA
FIGURE 68

automatically to zero. In this position the display can be set to the desired time by activating the individual buttons for the minutes and hours.

The function switch for the event timer contains TIME HOLD and OFF positions. In the TIME position, the event time is being accumulated. In the HOLD position, the counters are stopped and the value is displayed. In the OFF position, the display is turned OFF and the counters are reset to zero.

Display Electronics Real Time Display

The block diagram for the real time display is shown by Figure 69. The 1 Hz pulse from the timer logic is fed to the first control gate. This pulse is then accumulated in the units 0 - 9 counter. Every 10th pulse is passed on to the next control gate and hence to the next counter. This is propagated on to the next counters to obtain minutes and hours.

When the function switch is placed in the SET position, the seconds digits are reset to zero and the other digits can be updated by pushing the individual set buttons. These will be updated at a 1 Hz rate as long as the button is depressed.

The counters are made up from an integrated circuit diode matrix and a flip flop for each counter. The control gates are made up of integrated circuit logic gates.

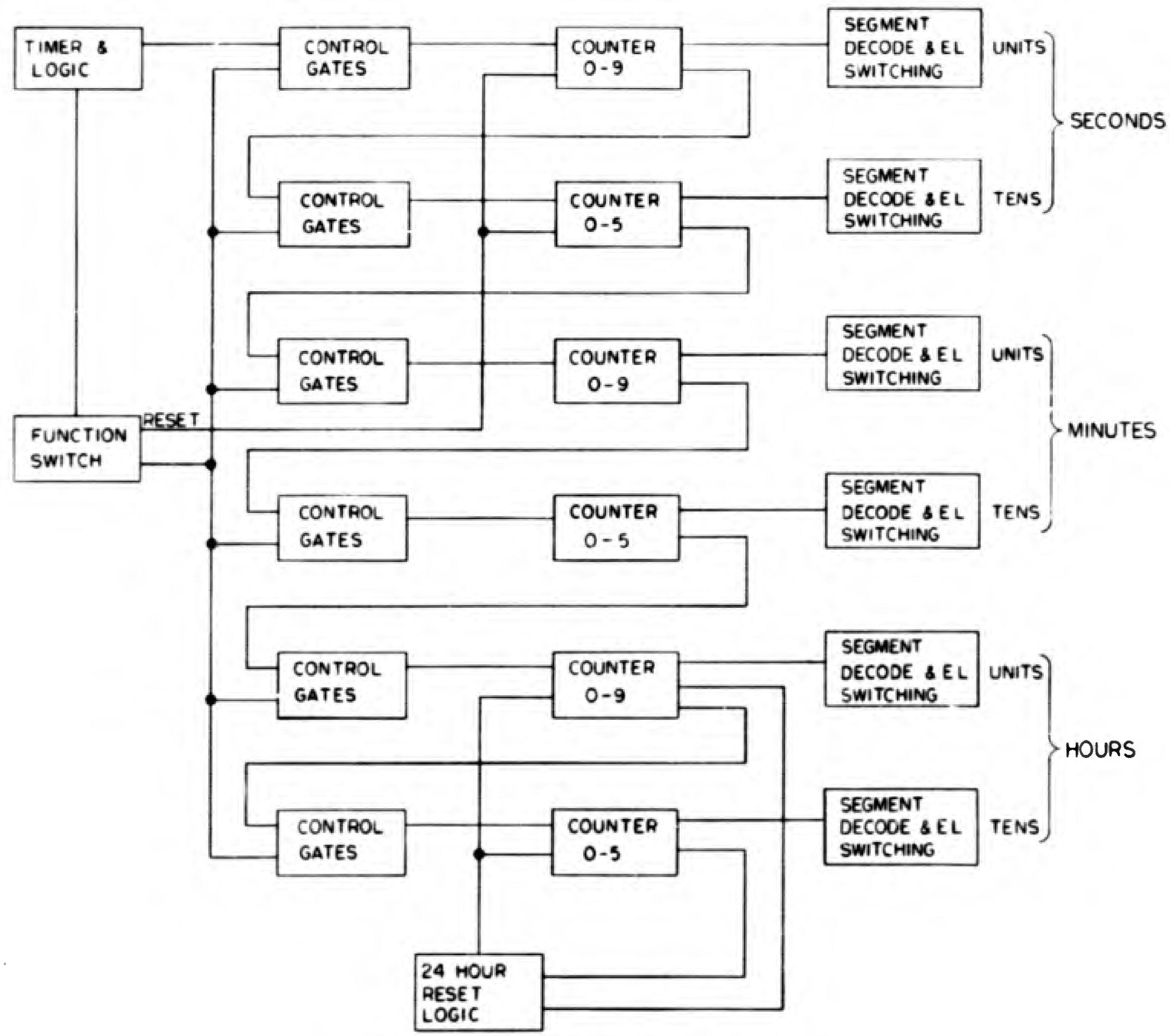
The outputs of the counters are decoded to 7 segment information by a diode matrix. These decoders drive silicon controlled rectifiers which are used to switch the AC excitation to the EL segments.

Display Electronics Event Timer

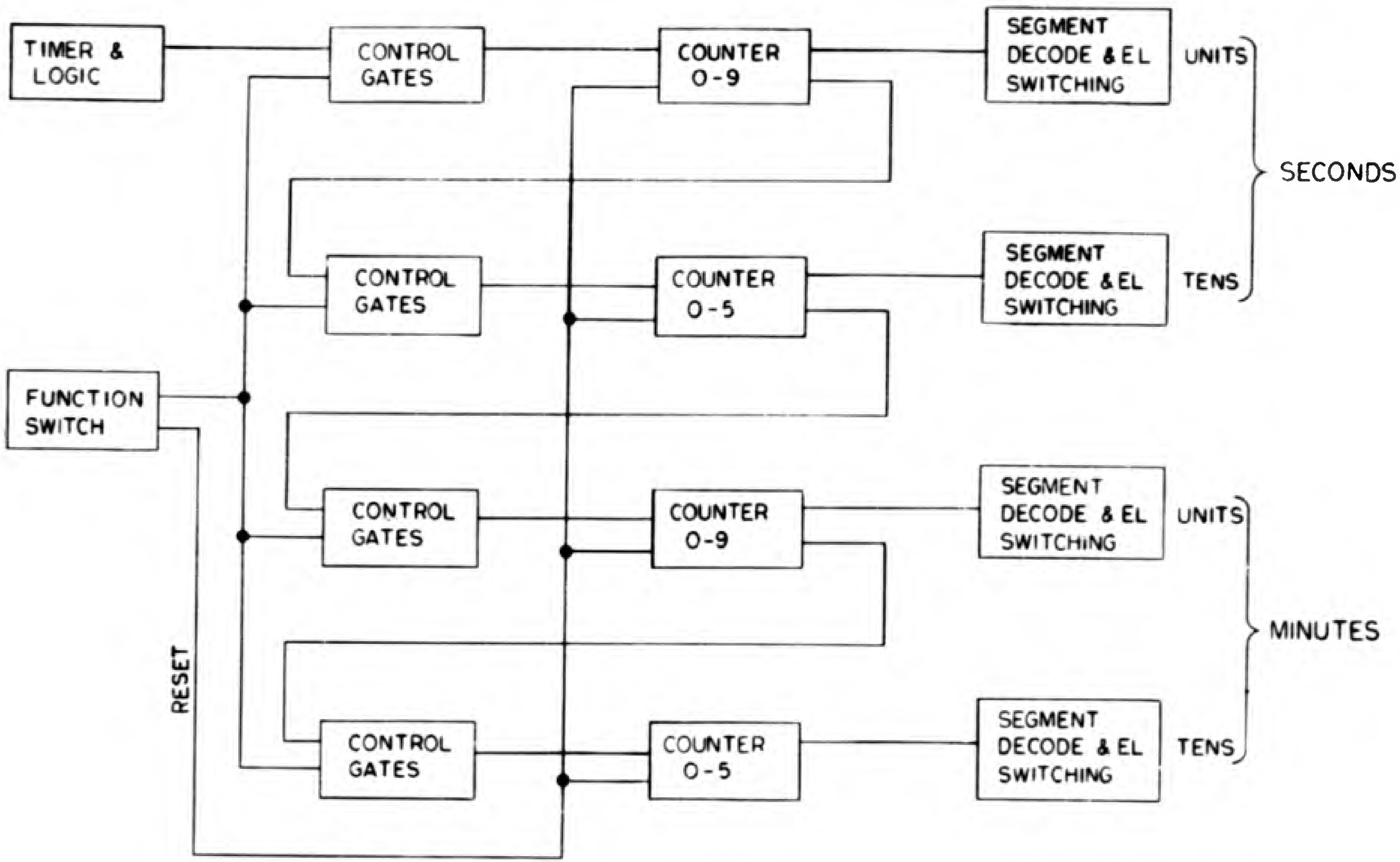
The block diagram for the event timer is shown by Figure 70. The 1 Hz pulse from the timer logic is fed to the first control gate. This pulse is accumulated in the units 0 - 9 counter. Every 10th count is propagated on to the next counter, etc, to obtain 60 seconds and 60 minutes.

When the function switch is placed in the OFF position, the counters are reset to zero.

This timer uses counters and decoders identical to those used in the real time display.




REAL TIME DISPLAY BLOCK DIAGRAM
FIGURE 69



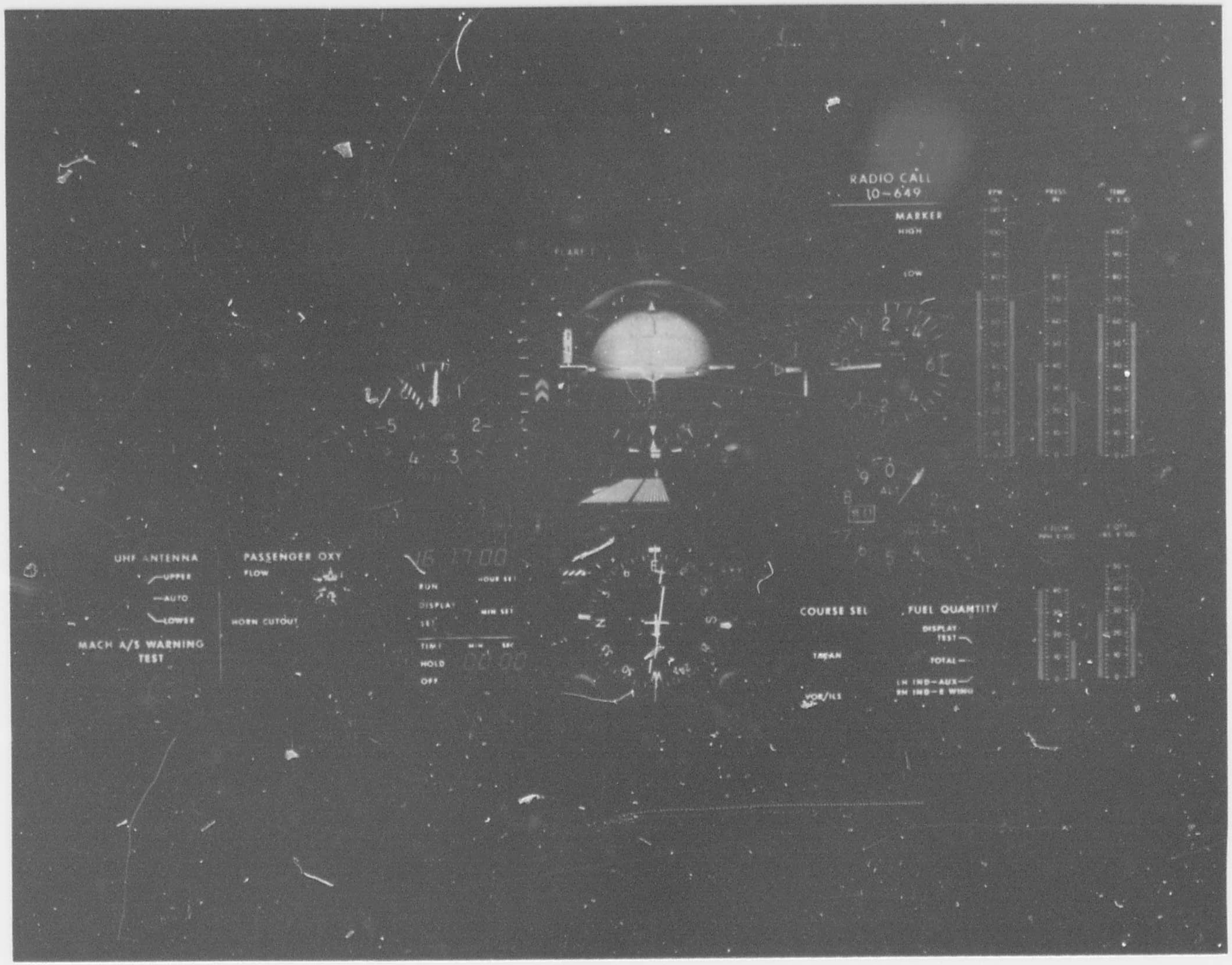

EVENT TIMER BLOCK DIAGRAM
FIGURE 70

# SECTION V

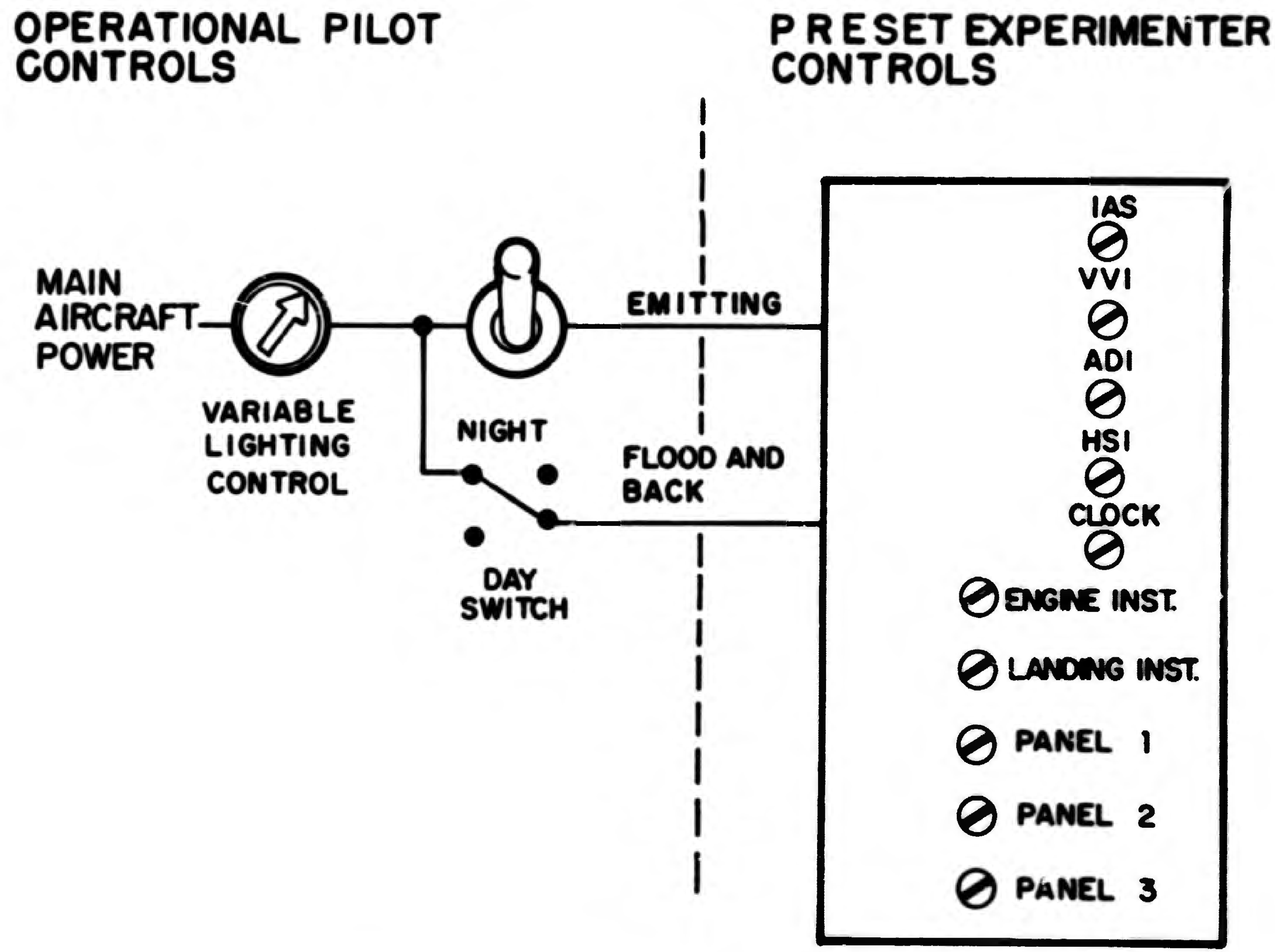
# SUMMARY

This report has described the effort expended by LSI to design and build an EL instrument group for the T-39. This panel is designed to serve as a tool for panel lighting evaluation under flight test conditions. Figure 71 shows the panel under night lighting conditions.

The panel lighting controls have been designed to afford maximum light control during the evaluation. The lighting control philosophy is shown schematically in Figure 72. A master dimming control is provided for pilot inputs so the pilot can raise or lower the overall panel illumination. A day/night switch enables the pilot to turn "off" all panel lighting except the emitting displays for daylight operation. Individual trimming controls for each display will enable the experimenter to "set up" any panel lighting situation he desires to evaluate.




T-39 PANEL LIGHTED
FIGURE 71




LIGHTING CONTROL PHILOSOPHY
FIGURE 72

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13. ABSTRACT

This report describes ~~in detail~~ the work expended by the Instrument Division of Lear Siegler, Inc. to design and develop an experimental electroluminescent display panel. This panel includes all displays necessary for the pilot to operate the aircraft. The format for the display was derived from the PIFAX program. The displays are grouped in three categories:

(a) Light Reflecting or flood lighted - This category includes all the mechanical, EL, wedge lighted displays

(b) Transilluminated or back lighted - This category includes all the EL backlighted panels and displays

(c) Light Emitting - This category includes all the solid state electroluminescent displays that utilize high contrast for light reflectance control

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| 14. KEY WORDS | LINK A ROLE | LINK A WT | LINK B ROLE | LINK B WT | LINK C ROLE | LINK C WT |
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| High Contrast | | | | | | |
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