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TEXAS INSTRUMENTS INCORPORATED
Apparatus Division
P. O. Box 6015
Dallas, Texas 75222

PROPOSAL [redacted]
SD-5 INFRARED SYSTEM

Proposal No. C126-CP65
Part 1

July 29, 1965

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PROPOSAL TO DESIGN AND DEVELOP D-5 INFRARED SYSTEM

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SECTION I
INTRODUCTION

Texas Instruments has, in the past two years, substantially advanced all phases of infrared sensor systems technology. The AN/AAS-18 program advanced state-of-the-art V/H capability to 2.6 radians per second in addition to other advances. The D series of systems developed a truly "hands off" electronic system, 0.5 milliradian angular resolution (with good NET) and developed a temperature control system to combat a hostile environment. The AN/AAS-10 infrared system proved the techniques necessary for multichannel recording. Only through a combination of these advanced techniques is a D-5 Infrared Reconnaissance System feasible.

The D-5 Infrared Reconnaissance System reflects design constraints which have been determined through approximately 75 man-years of infrared system design accumulated at Texas Instruments in the past two years. Typical of the constraints are the maximum scanner speed of 6000 rpm, video bandwidth of 650 kc, and a scan angle of 140°. Having applied a great deal of experience to the preliminary design of this system, we are confident of our ability to deliver the proposed system - maximum V/H of 1.2 radians per second, angular resolution of 1.0 milliradian, and NET of 0.5°C - within six months after receipt of order.

It is important to realize the versatility of the D-5 IRRS, which is modular in concept. With minor changes, the same D-5 system could have maximum V/H of 0.33 radian per second, 0.5 milliradian angular resolution and NET of approximately 1.0°C. The basic system will be supplied in one or the other configuration and the change-over kit will be auxiliary equipment.

	D-5 "A"	D-5 "B"
V/H max	1.2 sec^{-1}	0.33 sec^{-1}
$\Delta\theta$	1.0 mr	0.5 mr
NET	0.5°C	1.0°C

With the exception of Table 2-1, this proposal specifically describes the D-5 "A" configuration since it represents the more difficult design situation. The numbers will change for the "B" configuration but the techniques apply equally to either configuration discussed.

SECTION II

SYSTEM DESCRIPTION

A. PERFORMANCE AND PHYSICAL CHARACTERISTICS

Determination of the maximum velocity-to-height (V/H) ratio for contiguous mapping requires examination of the parametric relationships between the scan mirror rotational speed (f lines per second), the number of detector elements (n), and the angular resolution of each detector element ($\Delta\theta$). The equality expressing contiguity of scan lines is:

$$V/H_{max} = nf\Delta\theta .$$

In addition, the relationship between optical area (A_o), focal length (F), bandwidth (Δf), detectivity of the detector (D^*), atmospheric and optical transmissions (τ_a and τ_o), and angular resolution ($\Delta\theta$) must be recognized in order to provide the required noise equivalent temperature (NET). This relationship is expressed as

$$NET = kF(\Delta f)^{1/2}/A_o D^* \tau_a \tau_o (\Delta\theta)$$

where

$$k = \pi/4\epsilon\sigma T^3 \; (T = 300° \; K).$$

Bandwidth is related to rpm by

$$\Delta f = 2\pi(rpm)/60\,(\Delta\theta).$$

The proposed compromise between the requirements defined by the parametric equations and the system complexity, size, weight, and power considerations is listed in Table 2-1. With these parametric definitions, the NET will be approximately 0.50°C for the 1-milliradian mercury-doped germanium (Hg:Ge) detector.

B. FUNCTIONAL DESCRIPTION

The proposed system is illustrated in Figure 2-1. Major subsystems design characteristics and functions are described in the following paragraphs.

1. Optical System

The transverse scanning motion of the all-reflective, modified Cassegrainian optical system is provided by rotating a rectangular scan mirror about an axis parallel to the aircraft heading. Each side of the four-sided scan mirror is approximately 8 by 2.5 inches. The mirror will be driven by a motor at 6000 rpm to generate 400 scans per second.

This rotating element scans a total field of view of 140 degrees, centered about the aircraft ground track.

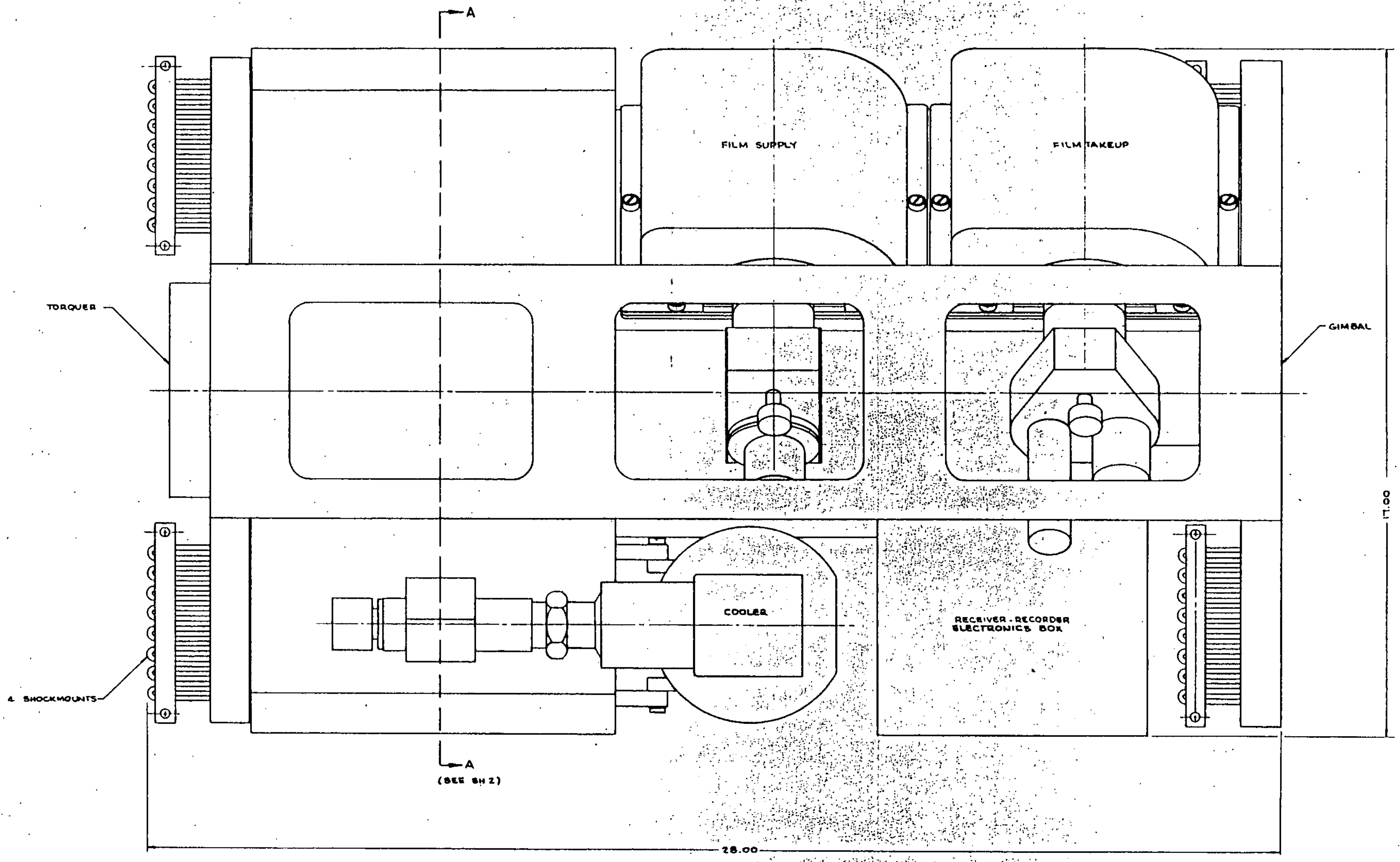

Figure 2-1. Proposed D-5 Infrared System
(Sheet 1 of 3)

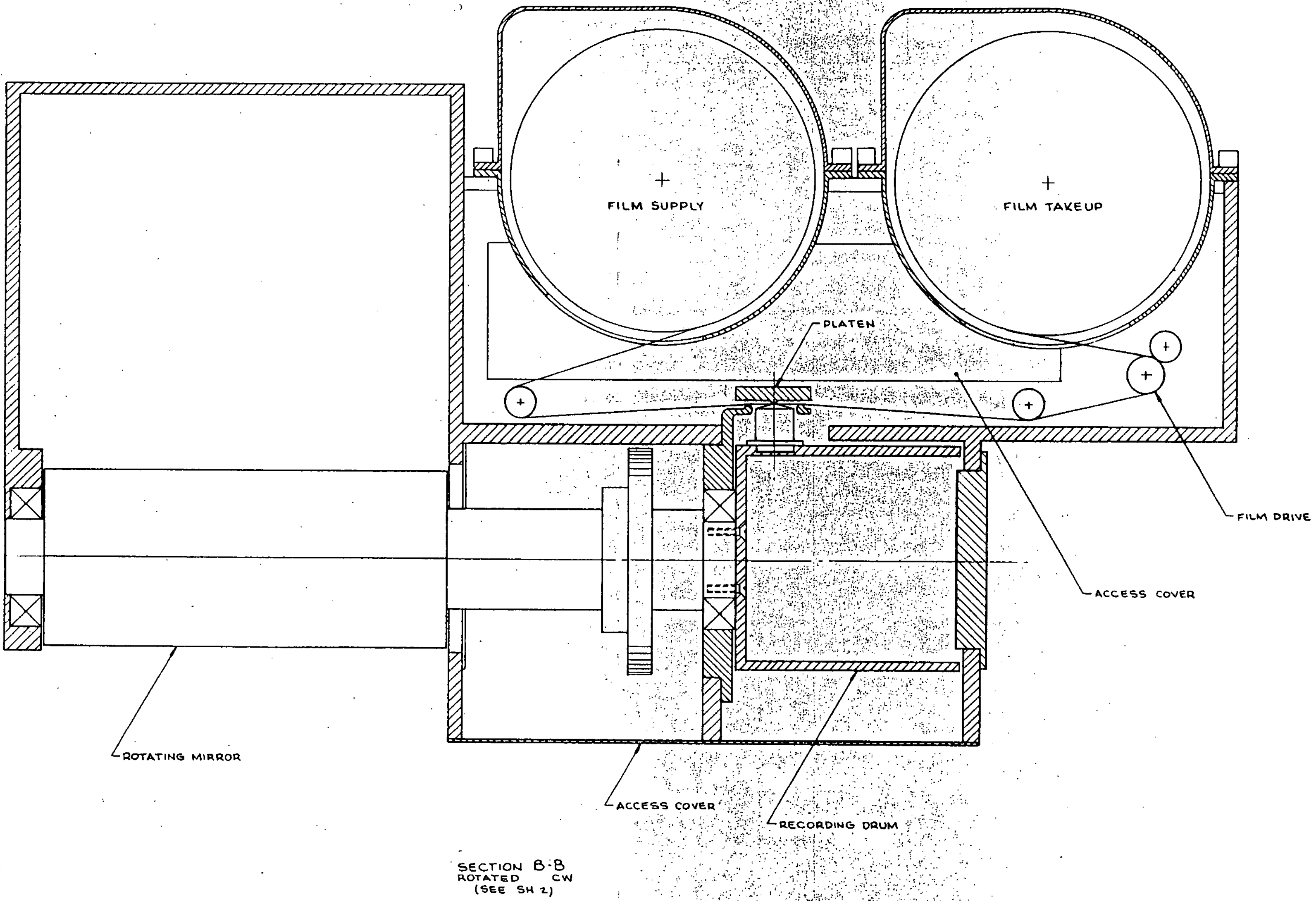

Figure 2-1. Proposed D-5 Infrared System
(Sheet 2 of 3)

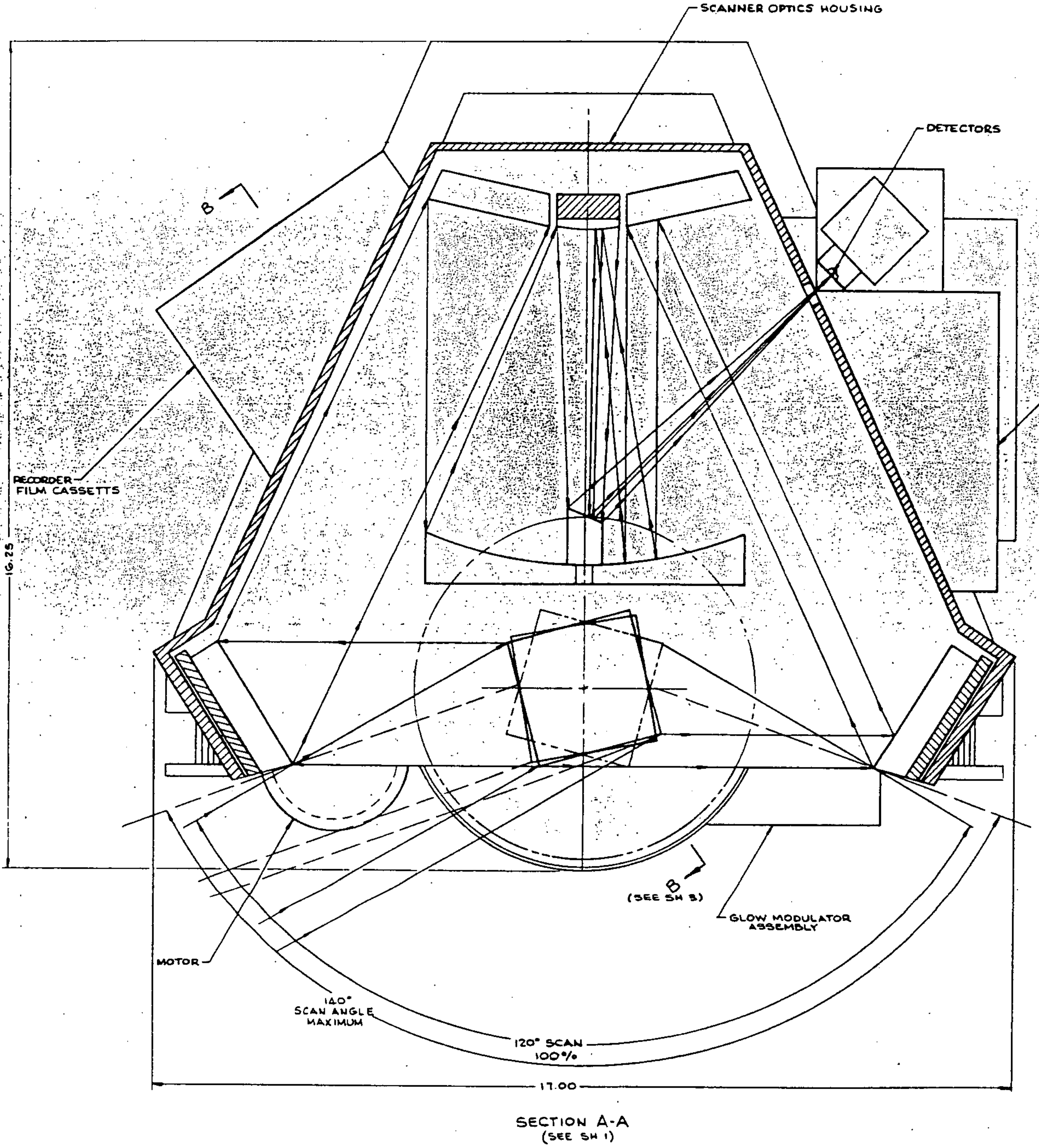

Figure 2-1. Proposed D-5 Infrared System
(Sheet 3 of 3)

Table 2-1. Performance and Physical Characteristics of D-5 IR Reconnaissance System

	Configuration "A"	Configuration "B"
Angular resolution ($\Delta\theta$)	1 milliradian	0.5
Total scan angle	140 degrees (±70 degrees from nadir)	140 degrees (t70)
V/H range	0.02 to 1.2 seconds^{-1}	0.02 to 0.33 second^{-1}
Noise equivalent temperature (NET)	0.5°C (Hg:Ge detector array)	1.0°C (Hg:Ge detector array)
Scan rate	6000 rpm	3000 rpm
Bandwidth	628 kilocycles	628 kilocycles
Detector	One-three-element array of Hg:Ge detectors	Same
Stabilization	Roll gimballed, ±10 degrees	Same
Size	Length: 28 inches	Same
	Width: 17 inches	Same
	Height: 16.25 inches	Same
Power	300 watts, 28 volts dc; 2200 volt-amperes, 115 volts, 3 phase, 400 cps	Same
Weight	Approximately 150 pounds	Same
Recording	Panoramic recording on a 5-inch photographic film strip, 4-inch format, 250-foot supply	Same
Auxiliary data	Time Data	Same

Flat relay mirrors reflect the radiation to the primary focusing element, an ellipsoidal mirror. This mirror, with a secondary spherical mirror, produces a 25-inch effective focal length optical system with an unobscured collecting aperture of approximately 140 square centimeters and has an optical resolution capability of 0.3 milliradian. The proposed optical system is illustrated in Figure 2-2.

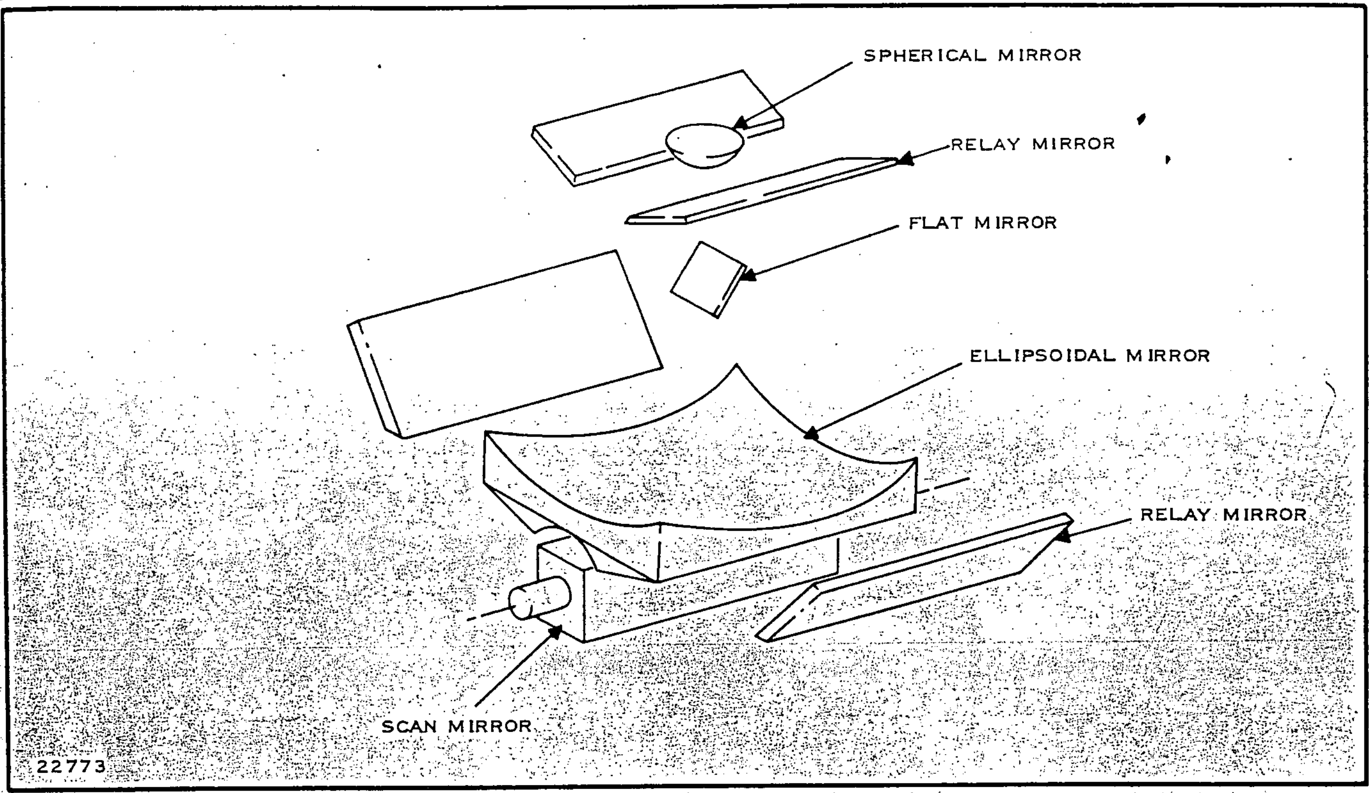

Figure 2-2. Scanner Optical System

2. Detectors and Cryogenic Refrigerator

The spectral region of interest for the proposed system is 8 to 14 microns. Mercury-doped germanium (Ge:Hg) is the optimum operational detector in this spectral region.

The Ge:Hg detector is a single-crystal, extrinsic, photoconductive device. It is a bulk absorber of 2 to 14 micron energy. A metal plate with a small aperture in it normally defines the sensitive area of the detector. Another aperture is placed a short distance in front of the detector to shield the sensitive area from radiation outside the useful field of view.

The sensitive area of the detector is then placed near the focal point of the optics system such that it subtends an angle

$$\Delta\theta = \frac{\Delta X'}{F}$$

where $\Delta X'$ is the length of one side of the square sensitive area and F is the focal length of the scanning optical system.

The number of detectors to be used in this application was determined by two factors. First, according to the equations, system rps is inversely proportional to the number of detectors, n. Therefore, the centrifugal acceleration of the rotating optics is proportional to n^2. To minimize dynamic misalignment and distortion of the optical components, a three-element array is best for the D-5 system.

The detectors in the array can be exactly contiguous (or tangent) when the array is canted perpendicular to the linear axis of the detector array. By locating the detector heatsink between the rows of Ge:Hg detectors, good isolation of optical and electrical crosstalk is maintained. Also, there is additional room for surface contacts and lead wires. Detector arrays in this configuration have been built and flight proven by Texas Instruments.

A North American Phillips closed-cycle cooler similar to that proven on the AN/AAS-18 and used on the D-3, D-4 systems is proposed.

3. Electronics

The electronics will be identical to the D-3, D-4 electronics except for those minor changes required by the additional bandwidth requirements of the D-5 system. A simplified block diagram showing the signal flow is shown in Figure 2-3. The function of the preamplifier is to provide the initial gain and good noise characteristics. The automatic leveling circuit provides additional gain and also compensates for "background changes" in the incoming video. The video compensation circuit corrects for atmospheric and scanner induced "humps" in the video. The automatic gain control circuit compensates for infrared background changes and also for "apparent background changes" such as a change caused by temperature variations of the scanner or detector itself. The video compression circuit is a nonlinear amplifier used to extend the dynamic range of the infrared system. The glow modulator driver provides the light output for exposing the film.

a. System Parameters

The bandwidth for a particular system depends on various parameters, among them resolution, scan rate, and field of view. In general:

$$BW = \frac{2\pi N}{\theta}$$

Where BW = Needed electronic bandwidth (cps)

N = Effective scan speed in revolutions per second

θ = Resolution in radians

This equation supposes that the electronics is the limiting link in setting resolution. In general, this is not true because resolution depends on the optical resolution, the detector field stop, the electronics bandwidth, and the recording spot size. Basically, the effective resolution on the film is the mathematical convolution of the impulse responses of all the parts of the electro-optical system. Here the electronics has an impulse response associated with its bandwidth.

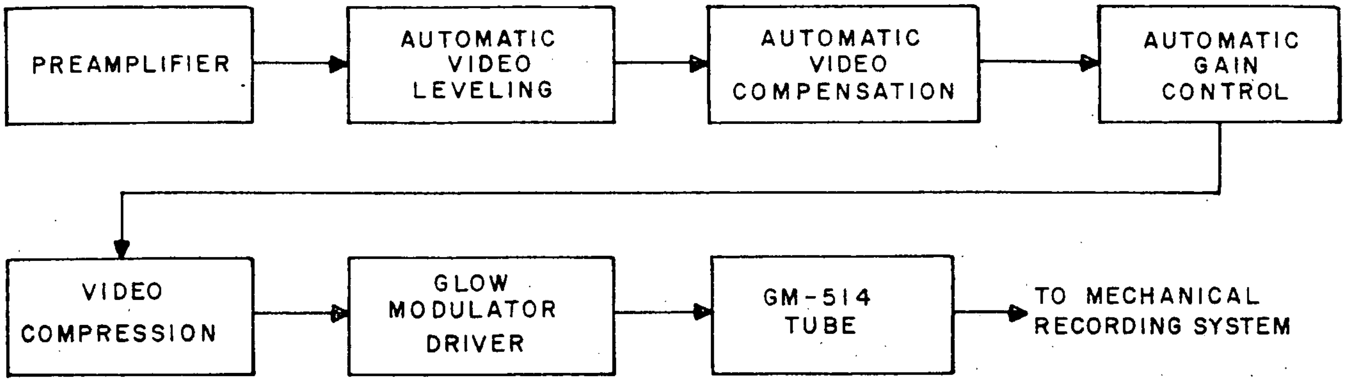

Figure 2-3. Simplified Signal Flow, Block Diagram

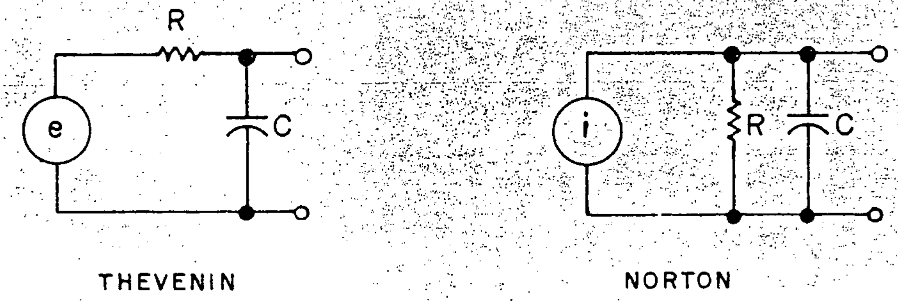

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Figure 2-4. Simplified Equivalent Circuits for IR Detector

This says that the electronics bandwidth, no matter how great, will always have an effect on system resolution. It is only a question of when it becomes appreciable. A value slightly larger than that given in the equation is found to be adequate.

b. Preamplifier

The purpose of the preamplifier is to obtain the best noise characteristics from the infrared system. It does this in two ways. First, by making maximum use of the detector parameters; second, by providing sufficient gain to make shielding and noise characteristics of the following stages less severe.

A simplified equivalent circuit for an infrared detector is given in Figure 2-4. If we assume that the equivalent current or voltage generator faithfully reproduces the information scanned (or that its frequency response is ideal), we still note that the frequency response at the output is limited by the R and C of the equivalent circuit. This problem can be overcome in several ways. One is loading by a resistor R1. While the original 3-db frequency was $\frac{1}{2\pi RC}$, it is now $1/2\pi R'C$, where $R' = RR1/R + R1$.

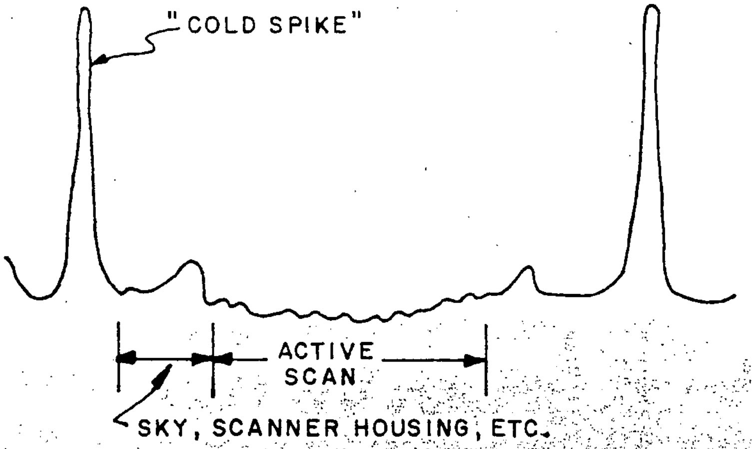

Figure 2-5. Typical Preamplifier Output Waveform.

Another approach is to run the signal into a high impedance amplifier and to shape the response by "peaking" later on. While either approach is satisfactory and has certain noise advantages, the peaking approach is highly dependent on detector parameters (C and R) and can result in a system with peculiar frequency response characteristics.

All this has neglected the noise output of the detector itself. So long as the equivalent noise of the preamplifier is much below the detector noise, the preamplifier does not appreciably detract from the system performance. This was found to be the case with the RS-7 scanner, and the noise figure of the preamplifier, as defined by

$$N_f = 20 \log_{10} \frac{S/N \text{ in}}{S/N \text{ out}}$$

was found to be less than 1 db. Therefore, the system was found to be nearly "detector noise limited."

c. Automatic Leveling Circuit

In general, ground information of interest is the relative radiance of objects, not their absolute radiance as in a normal photograph. In ordinary photography this background change is taken care of by changing the exposure. To accomplish exposure control in the infrared mapping system, the system must be effectively "A-C coupled" from preamplifier to film.

However, another problem arises. The video information appearing at the preamplifier output appears as shown in Figure 2-5. The scanner looks at the ground only during the active portion of the scan. Part of the other time it looks at the casting or at the detector itself. If this waveform were fed directly into a light-modulating amplifier, then the average light output would have to be constant, because it is an ac coupled video system. Any

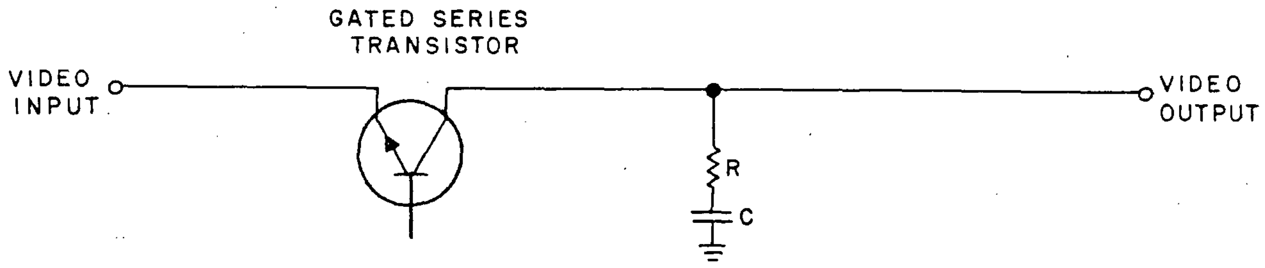

Figure 2-6. Simplified Leveling Circuit

Figure 2-7. Leveling Circuit Waveforms

changes in the waveform, representing changes in casting temperature, ground temperature, etc., would shift the exposure during the actual video time. What is needed is a "leveling circuit" which senses incoming radiation only during the active video time and disregards all information outside the field of view. The circuit shown in Figure 2-6 performs this function and was used during the test of this video processing scheme. The series transistor is turned "on" only during the active scan period and is off the remainder of the time. A simple analysis shows that the output point is tied directly to the input waveform during the active scan and left free to return to the voltage on C during the unwanted portion of the scan. But RC forms an integrator and C is charged to the average level of the video during the active portion. Therefore, the output waveform is returned to its average level over the field view. The circuit performs much like an automatic exposure control on a camera.

Similar in function to several circuits used with other infrared systems, this circuit has the advantage of being much simpler. It does not need adjustment, is much more stable, and can accept a much greater range of signals than other circuits. A typical output waveform is shown in Figure 2-7.

d. Automatic Video Compensation

"Humps" which occasionally appear in the video are believed to be caused by the air through which the infrared radiation must pass. Energy received from the edges of the scan has to pass through a longer distance of cold air than energy arriving at the center of the scan. As expected, an

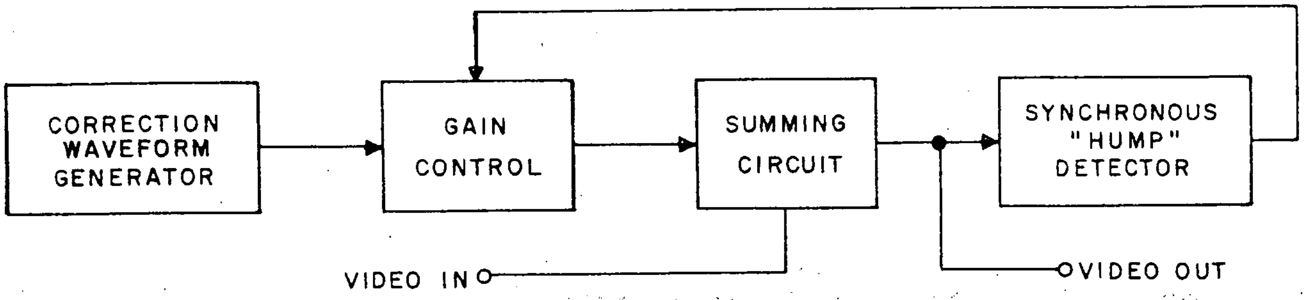

Figure 2-8. Automatic Video Compensation Block Diagram

increase in altitude is found to aggravate the condition. Because of the limited dynamic range of any recording system, and because this hump does not represent true infrared information but rather a manufactured side-effect, a means was desired to remove this "hump" from the video.

Figure 2-8 is a simplified block diagram of the scheme used to construct the D-3, D-4 automatic video compensation circuit. A correction waveform similar in shape to the expected hump characteristics is generated. A controlled amount of this correction waveform is summed into the video until a "hump detector" is at zero. This hump detector is a gated sampling circuit which analyzes the average value of the video at the center of the scan and compares it with the average value at the edges. The response of this system is made as long as it is possible to make a system using small electrolytic capacitors and still maintain temperature stability. Its time constant is on the order of about 4 seconds.

e. Automatic Gain Control

Just like an automatic leveling control is needed to take care of slow background changes, an automatic gain control is needed to correct for slow changes in the peak-to-peak amplitude of the signal. These changes can be due to many factors, among them atmospheric attenuation, day-to-day changes, changes in the detector caused by changes in the operating temperature of the cryogenic cooler, or simply by the type of terrain being mapped. The automatic gain control senses the signal component of the video information in a range of frequencies and adjusts the gain correspondingly. It has the capability of correcting for approximately a 30-db range of input signals. Its response is fairly long, being approximately 4 seconds. A shorter response time than this was found to have an adverse effect on small, sharp targets.

Automatic video compensation precedes the automatic gain control. Failure to do this would result in gain controlling a possible hump, which is not really video information but system generated-effect.

f. Video Compression

This circuit is basically a nonlinear amplifier and limiter. Shaping of its input-output characteristics is done with diodes breaking at preset points.

Video compression has two main advantages. First, it prevents the following amplifiers from saturating on large signals by providing a form of gradual, controlled "saturation." Also, it keeps the film operating in its proper dynamic range. Secondly, the gain can be increased considerably, bringing out less pronounced targets without the usual adverse effects caused by too much gain. It tends to make the video system less critical to gain or signal content changes in the video.

4. Recorder

a. Proposed Recording Method

The recording method best suited for displaying the multichannel video data of the D-5 infrared system is shown in Figure 2-9.

The recording system consists of a set of modulators (recording light sources), driven by the video chain of the detector array. A set of modulators is composed of three individual modulators, each of which represents one channel of video information. Consider, for the moment, operation of the modulator set. The modulated light flux from the three sources passes through the exposure control filter and a set of compensation slits on a rotating drum to flood the entrance of a stationary fiber optic assembly.

This light is transmitted through the fiber optic to the exit end which is mounted at the center of rotation of the compensation drum. The fiber bundle is so constructed that the light emerging is confined in a 90-degree cone. The exit end of the tapered fiber optic is imaged on the photographic film by a microscope objective which is mounted on the rotating drum. There are four of these objectives mounted at 90-degree intervals around the periphery of the drum. These four microscope objectives correspond to the four sides of the scan motor shaft so that the recording objectives rotate in precise unison with the scan mirror.

The film is formed into a circular arc by a platten and, as the drum rotates, the three individual images expose three parallel lines across the full recording width of the film. The exit end of the fiber optics is so designed that each of the respective images is contiguous with the adjacent image.

There are several pecularities of the multichannel recorders that are not found in single-channel devices. One of these is transferring information from three separate light sources through the processing optics and arranging these sources on the film so that they appear contiguous. This is accomplished with a three-channel, tapered, fiber-optic assembly that rearranges the sources such that their images correspond to the detector array configuration.

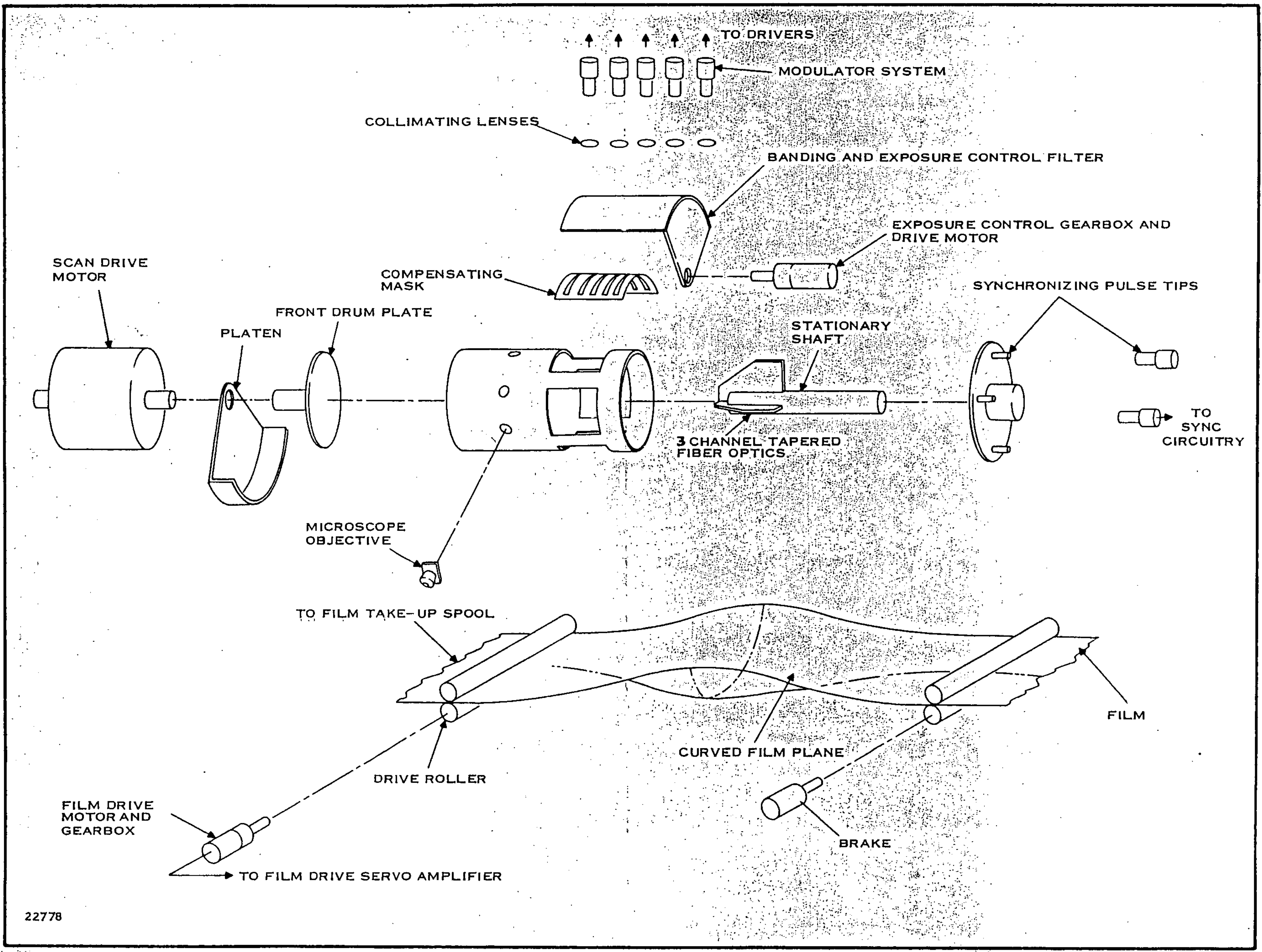

Figure 2-9. Recorder Optics

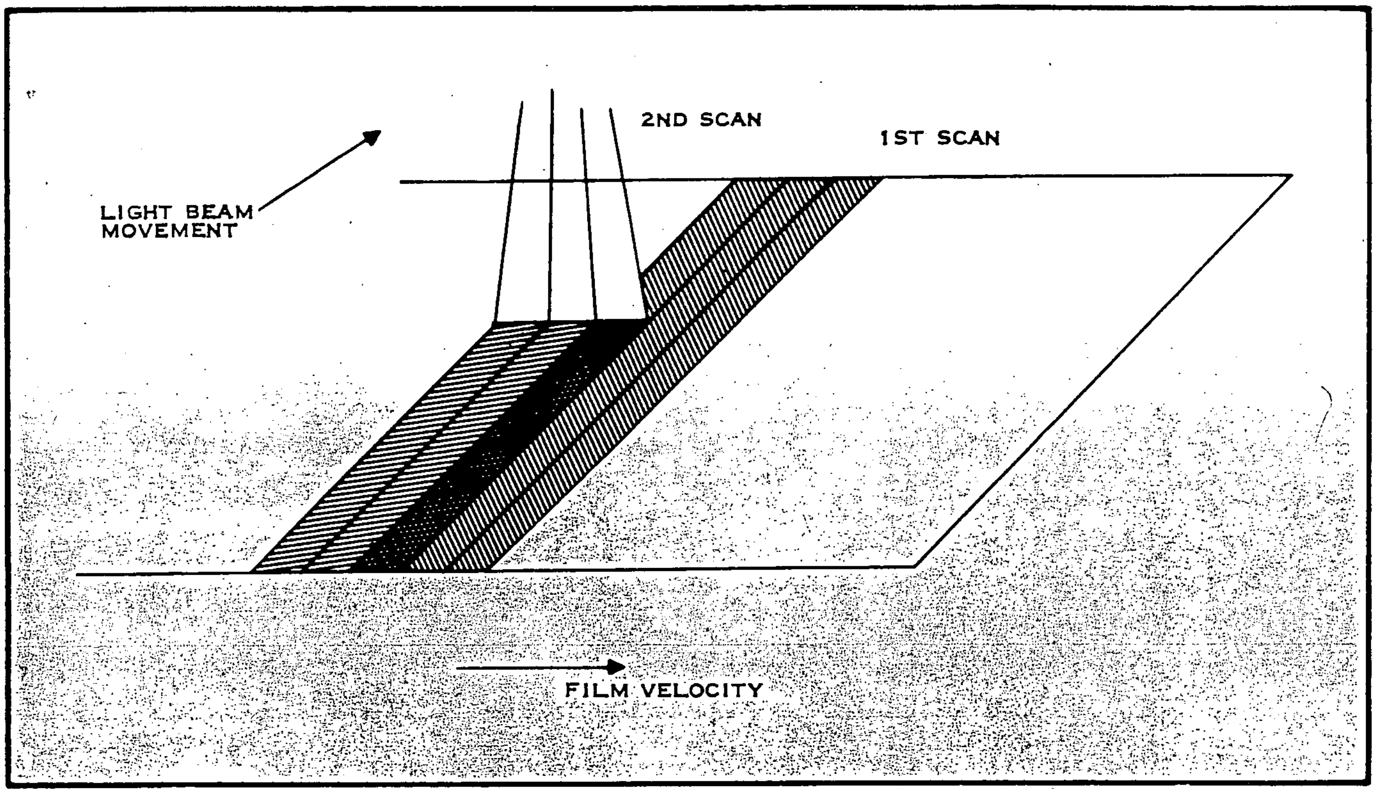

Figure 2-10. Schematic of Three-Channel Recorder Trace on Film

Another problem inherent in three-channel recording systems is that of banding. Banding is primarily an exposure control problem. Figure 2-10 illustrates the basis of the problem. Two successive scans by a three-channel recorder that is pulling film at a rate below maximum V/H are illustrated. In this condition, the exposed emulsion from the first scan does not move sufficiently far to be missed completely by the second scan. In this case, the last channel of the first scan is over-lapped by the first channel of the second scan, thereby creating a band that has twice the exposure of the surrounding area. This overexposure will be repeated periodically. Essentially the problem is one of channel-to-channel, rather than line-to-line, overscanning.

FAR effect is another serious multichannel problem in wide-angle scanners. This problem concerns the ability of the recorder to reproduce information at larger scan angles and will be discussed in detail shortly.

These are the problems associated with multichannel recording systems that are different from those of single-channel systems. Unfortunately, all problems suffered by single-channel recorders are shared equally with their multichannel counterparts. Accuracy in alignment, sufficient light, jitter, maintainability, and reliability are a few of the common problems.

b. Recorder Component Operation

(1) Collimating Lens System

The purpose of the lens system is to provide collimated light to the fiber-optics system. This is necessary because of the extremely narrow acceptance angle of the tapered-fiber bundle. Also, the parallel light will cast a sharper shadow through the compensation mask.

(2) Compensating Mask

The purpose of the mask is to allow selective illumination of the entrance end of the fiber bundle. Starting from zero-scan angle, the mask illuminates progressively larger areas of the fiber while the illuminated area of the fiber translates across the fiber end. This translation rate depends on the video-channel number and is symmetrical about the center channel.

(3) Tapered Fiber-Optics Bundle

The fiber-optics bundle provides a means of transmitting the video modulated light from several separated sources and combining it so that it appears to come from sources adjacent to each other. This bundle is an aligned tapered-fiber bundle. The alignment provides the means of reimaging the compensation mask in the object plane of the objectives, and the taper provides a wide angle of divergence at the exit end of the bundle so that the objective is constantly illuminated throughout the entire recording angle.

(4) Microscope Objectives

The microscope objectives focus the light energy from the fiber bundle to the film plane. Since the fiber-bundle end is on the axis of the rotating optics, the objective is in focus throughout the entire recording scan.

(5) Modulators

A cold-cathode glow discharge tube is proposed as the recording light source. This current-controlled light modulation device has been proved in a series of infrared line scan systems (RS-7, RS-9 and the D series) and is currently used as the recording light source in the AN/AAS-10 (XE-1) multichannel system.

(6) Film Drive

The range of the V/H ratio requires a film drive system with a 60:1 dynamic range. This capability can be provided by incorporating a slightly modified AN/AAS-18 film drive subsystem. This system is described here.

The servosystem is essentially an amplifier and motor generator regulator loop that uses the input voltage from the V/H servosystem relative to a reference voltage to achieve linear speed control. Figure 2-11 is

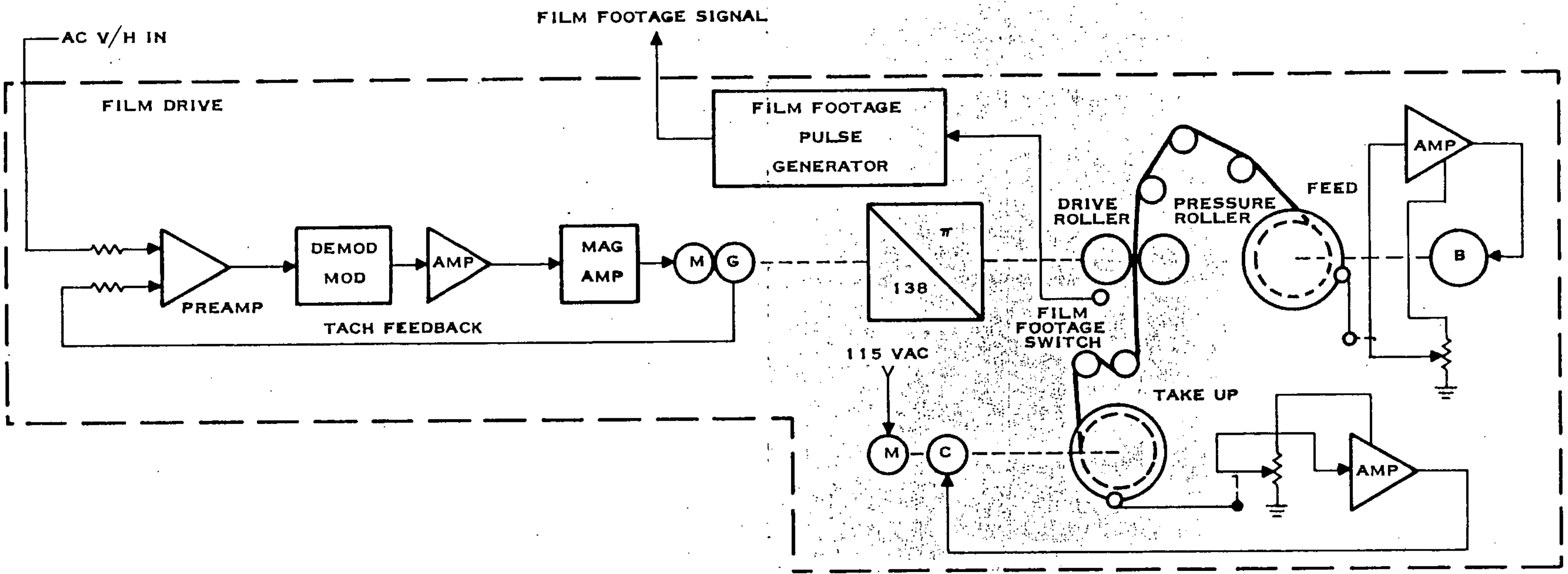

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Figure 2-11. Film Drive Block Diagram

the block diagram of the system. An ac amplifier is connected to the control phase of a two-phase servomotor. The motor shaft is connected to a generator whose output is a 400-cps voltage with an amplitude that is proportional to speed. The generator output (opposite in phase to the V/H input) is fed to the amplifier where it is compared to the V/H input to produce an error signal. This error signal is amplified to drive the servomotor. The V/H input and generator feedback signal (opposite in phase) are fed to a preamplifier, and the error is amplified to a level sufficient to drive a phase-sensitive demodulator. The demodulator output contains a dc component which represents the in-phase error component and an ac component which represents the quadrature component. The ac component is eliminated by a resistor-capacitor filter so that it will not saturate the amplifier. The filtered dc output is reconverted to 400 cps by a chopper, and this signal is amplified in the driver circuits. This output is fed to another demodulator which converts it to a dc signal to control the magnetic amplifier. The filtered dc output is reconverted to 400 cps by a chopper and this signal is amplified in the driver circuits. This output is fed to another demodulator which converts it to a dc signal to control the magnetic amplifier. The magnetic amplifier is connected directly to the control phase of the film drive motor. The voltage gain from the preamplifier to the modulator output is 20. The combined driver-magnetic amplifier voltage gain is approximately 500k, giving an overall voltage gain of approximately 10,000. The film drive motor turns a roller which causes the film to move through the magazine. So that film tension may be maintained in the magazine, the film supply reel is restrained by a brake and the take-up reel is driven by the take-up motor. The film drive motor is coupled to the take-up reel shaft by a magnetic particle clutch. The film supply reel and brake are restrained by a magnetic particle clutch (coupled to the brake). The torques on the two reels are varied with the amount of film on each reel by mechanical arms that sense the diameter of the spool and film and control the amplifier input to the magnetic clutch and brake.

(7) Auxiliary Data

In a manner similar to that used on the D-3 and D-4, time data will be printed on one margin of the film.

c. FAR Effect Compensation

The fixed-axis resolution (FAR) effect is a problem associated with any line scan system which scans a flat object plane at a constant angular rate. This effect arises from the fact that, as the resolution cone scans farther from the line of flight, the ground area viewed increases. In single-line scanners, this effect manifests itself as the familiar "bow-tie" degradation.

In the conventional system, this effect can be tolerated because the limited degradation it produces does not compromise the value of the imagery. This is not true when a multichannel capability is required, in which case the FAR effect produces ambiguous and distorted imagery. A solution to the FAR effect must be provided in the multichannel system if it is to produce useful imagery.

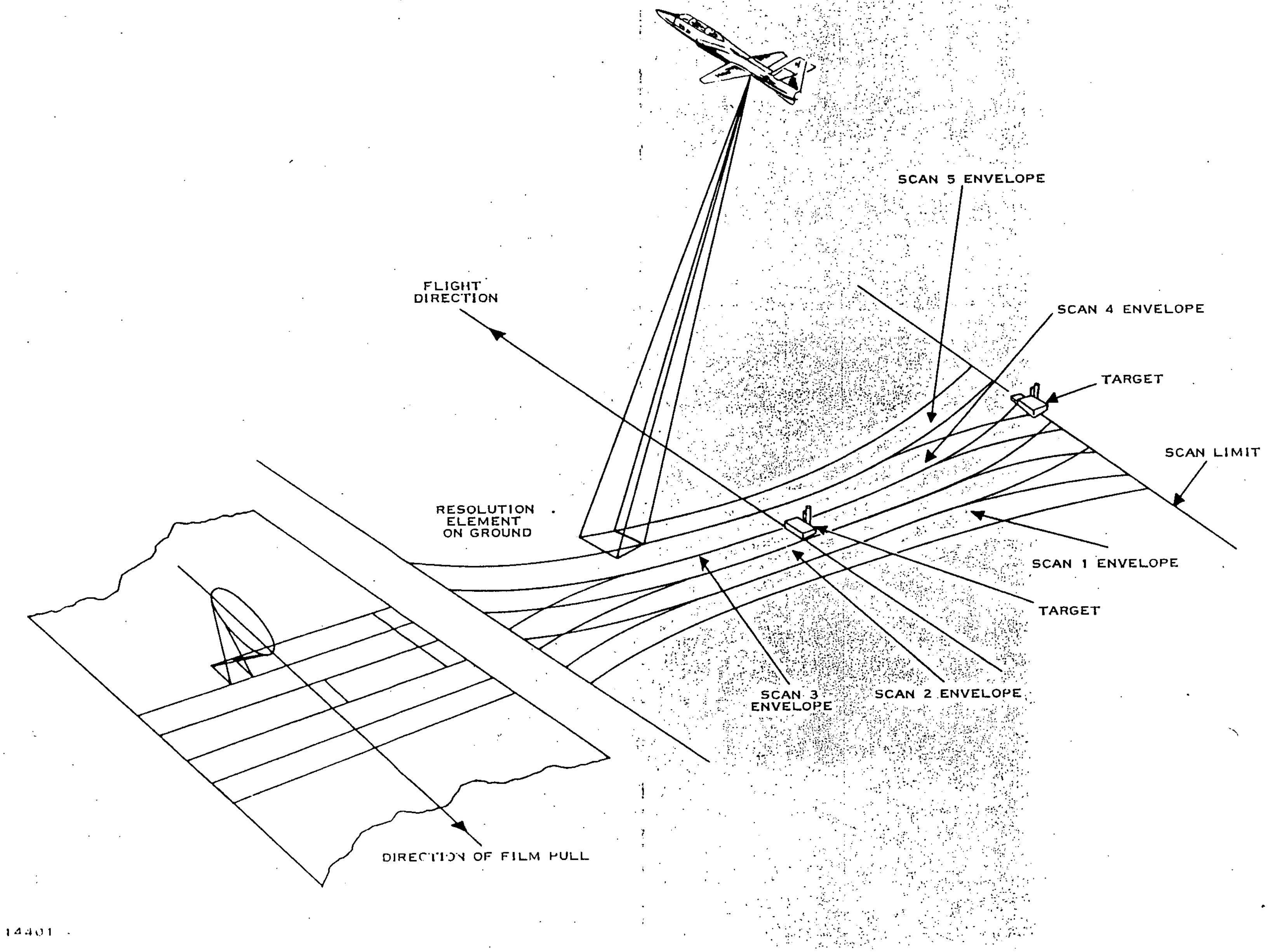

Figure 2-12. Printout Illustrating Bow-Tie Distortion

The recording system described here has been designed to eliminate this effect. Flight tests have proved that it does eliminate it.

FAR effect is a problem associated with a multichannel, wide-angle line recorder. Its solution is concerned with preserving the resolution capability of the recording system at scan angles greater than 50 degrees off the nadir.

Before discussing FAR effect, it may be illuminating to refer to single-channel scanning-recording relationships to supply some background to the problem. Figure 2-12 illustrates a single-channel line scanner mapping a section of terrain where one target is on the flight line and another is off at the limit of ground scan. To the left of this is a schematic representation of a recorder imaging the information on film. Note that the scan pattern on the ground is not a straight, constant-width line. This condition exists because, as the resolution element on the ground scans farther from the flight line, its width increases, although the angular resolution of the scanner remains constant. The width of the resolution element as a function of scan angle can be found to be

$$d = \Delta\theta \cdot h \cdot \sec\theta$$

where

d is the width

h is the aircraft altitude

$\Delta\theta$ is the angular resolution of the scanner

θ is the scan angle.

Hence, for a 140-degree full field of view, the width of the ground resolution element along the direction of flight at the scan limit is three times the width at the flight line. The recorder does not exhibit bow-tie distortion because the film is formed in an arc of a circle and the recording optics rotate inside this arc. When the light source is imaged on the film, the spot image remains constant size through the entire scan angle, since the source remains constant size and the optics remain a constant distance from the film. This results in a straight, constant-width line across the film for each scan.

As the aircraft moves over the target complex, the scanner "sees" the target on the flight line on the third illustrated scan. This information is transmitted to the recorder, which images a dot on the film at the proper place. On the same scan, the scanner also sees another target at the scan limit since it also falls between the same envelope lines.

The recorder puts a dot on the edge of the film to represent the target. The aircraft and film both move forward one resolution element before the next scan. The next scan does not include the target on the flight line but does include the scan limit target. This target still sends a signal to the detector and the recorder, which puts a second dot adjacent to the first dot. On the next scan, the target is still in the field of view of the detector and another dot is imaged by the recorder. If another scan were made, it would be found that the scan limit target is finally out of the field of view of the scanner.

Returning to the diagram, note that the target on the scan limit was recorded three times and appears to be larger than the target directly below the aircraft. This is not caused by some deficiency in the system, but by the fact that the ground resolution at the scan limit is three times larger than at the nadir because the target is three times farther away. Also of interest is that the target, although enlarged, is placed properly.

Multichannel systems are somewhat different. The following paragraphs discuss the design solutions effected in the AN/AAS-10. Similar methods applied to three-channel operation will be used on the D-5. Figure 2-13 illustrates an AN/AAS-10 five-channel scanner flying a similar target complex as before. Also shown is the five-channel recorder. The scan pattern of the multichannel system is considerably different from that of the single-channel system. The center channel exhibits bow-tie distortion as did the the single-channel system; however, the other four channels perform differently. The ground resolution in the flight direction of each channel at the scan limit is still three times larger than at the nadir, but at large scan angles the outside channels are "pushed" out from the center channel. Since each detector is scanning contiguous to the detectors on each side of itself, no detector during any one scan looks at terrain covered by another detector. Therefore, as the center channel grows, it pushes the inner edge of the next channel outward. As that channel grows in size, it must push the outer edge of its envelope out still farther. This results in the scan pattern illustrated. As the first scan is made, channel 1 sees the target somewhat in front of the aircraft. The recorder receives the signal and puts a dot on the film edge for channel 1. On the next scan, the aircraft and film have moved forward five resolution elements, and the aircraft is abreast of the target which is seen by channel 3. The recorder dutifully records the target at the edge under channel 3. On the next scan, the target is seen by channel 5, which is looking somewhat behind the aircraft. Again, the recorder performs its function perfectly, leaving a dot at the edge under channel 5. Now, for one target, there are three targets separated by two resolution elements each. Obviously, this is not a true representation. When the aircraft is flying at a V/H such that it moves forward only one resolution element per scan, the recorder shows the target to be 15 times as large as the target actually is. When the aircraft moves one resolution element, the film moves one resolution element. It takes 15 scans before the target is removed from the field of view of all detectors. On 15 successive scans, the recorder puts a target on the film, seldom putting it at the same place. One small burning outhouse at the scan limit would almost give the appearance of a forest fire on the film.

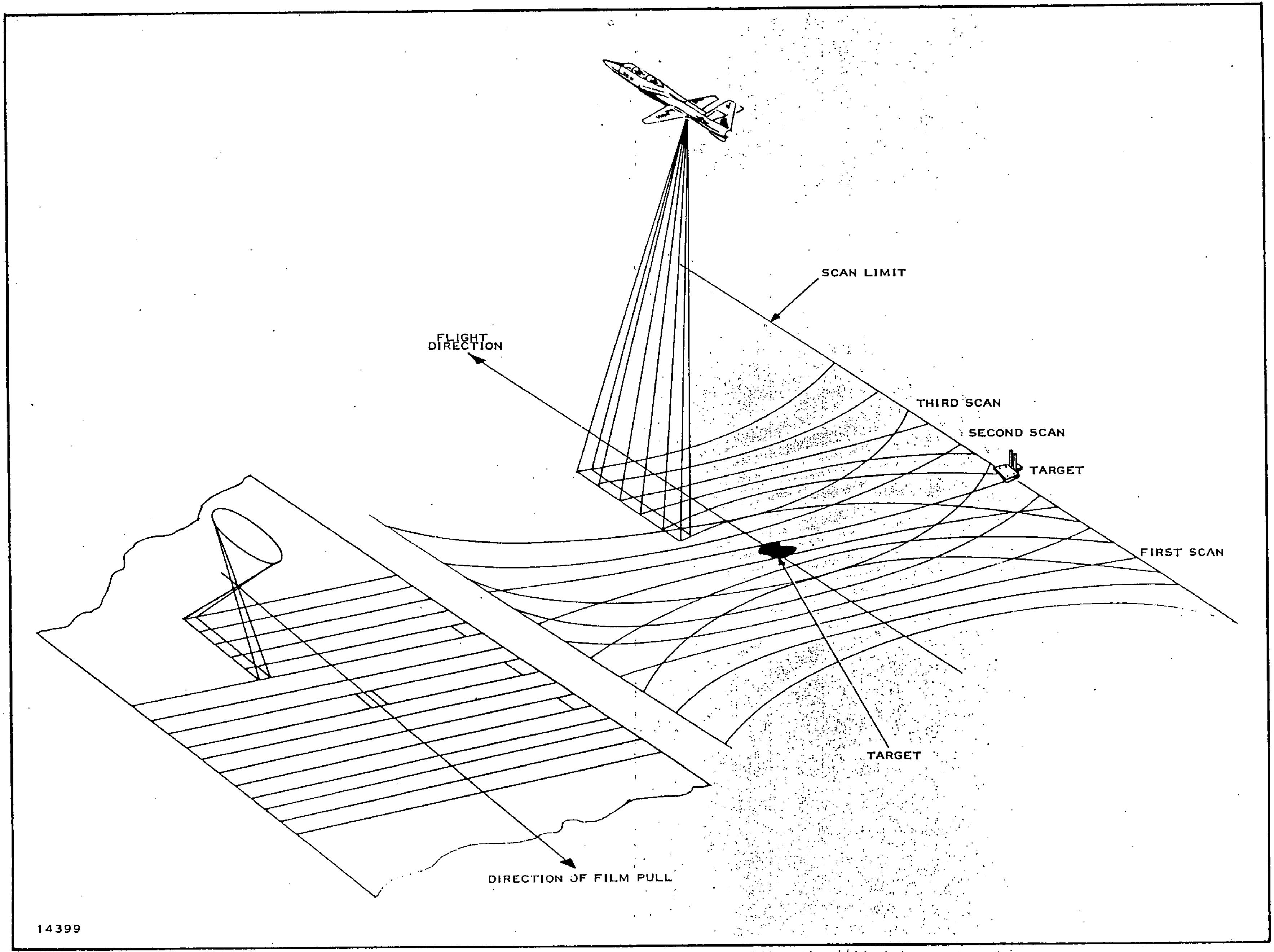

Figure 2-13. Printout Without FAR Effect Correction

Correction of this problem is possible. Figure 2-14 illustrates the method of solution. In this figure, the same scanning pattern is employed, but the recording pattern is drastically altered. Instead of recording with straight, constant-width lines, each channel on the film duplicates the pattern of that channel on the ground. As the resolution element on the ground grows, the spot image of the channel on the film grows at the same rate. As the outer channels are pushed out on the ground, the outer images on the film are pushed out at the same rate. In this way, there is a one-to-one correspondence between channel location on the film and channel location on the ground.

When the aircraft scans the first time, the target is seen by channel 1 and recorded on film. However, the channel 1 image has been shoved out considerably, and the dot is displaced considerably from where it was placed in the five-channel recorder illustrated in Figure 2-13. On the second scan, channel 3 sees the target, and it is recorded as shown. With this method each recorded target is placed on top of the previously recorded target. The target is recorded three times larger than it actually is but its location is accurate. This was the same case with the single-channel recorder.

One undesirable feature of this method is the overscanning at large scan angles. As can be seen, the target has been scanned three times, hence the exposure in that area is three times that experienced by the target in the center of the map that has been scanned once. If no correction were made, the result would be a map covered with shaded, overexposed areas. The most straightforward correction is to keep FAR effect correction but eliminate the overscanned areas.

Figure 2-15 illustrates the method of accomplishing this. The straightforward method was used and the overscanning areas were lopped off. Now, instead of each channel expanding over into a different scan area, they are constrained to expand between two lines. These lines define the total line width recorded each scan. At the V/H shown (contiguous), there is no overscanning between channels or scans. (The exposure problem at lower V/H ranges will be dealt with later.) FAR effect correction is maintained since only one target prints out. This indicates the recorder is not limiting the resolution throughout the scan.

All that remains is to design a device that records in this manner. The necessary components are the recorder drum, microscope objectives, compensation mask, and fiber optic assembly.

The recorder drum is an aluminum cylinder with mounting fixtures for the four microscope objectives and four compensation masks. The microscope objectives mount to the exterior surface toward one end of the drum. The compensation mask mounts on the interior surface at the other end. The drum assembly, microscope objectives, and compensation masks are the only recording components that rotate. All other components, particularly the fiber optic assembly, are held rigidly and firmly. The microscope objectives

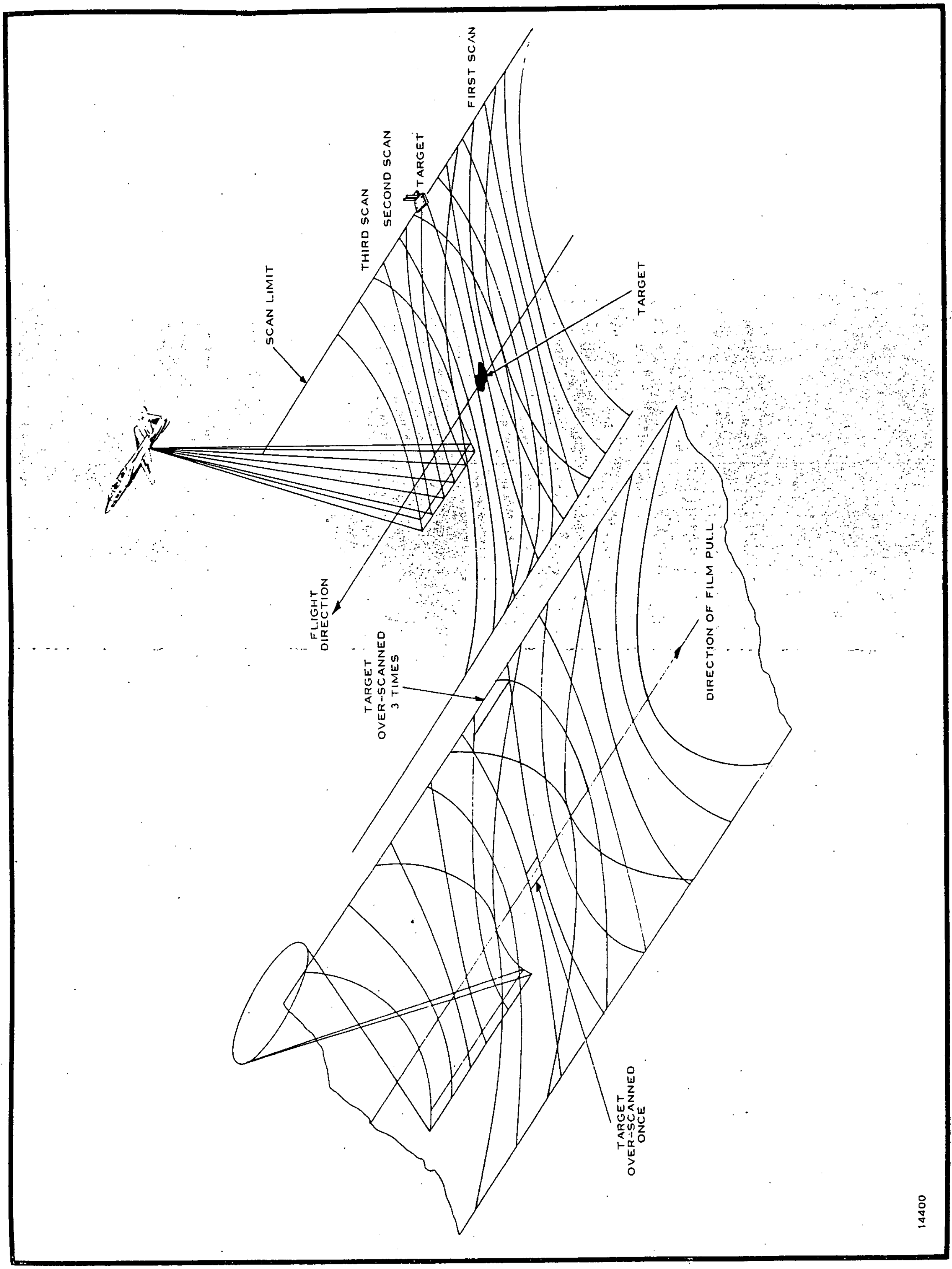

Figure 2-14. Target Printout With FAR Effect Correction

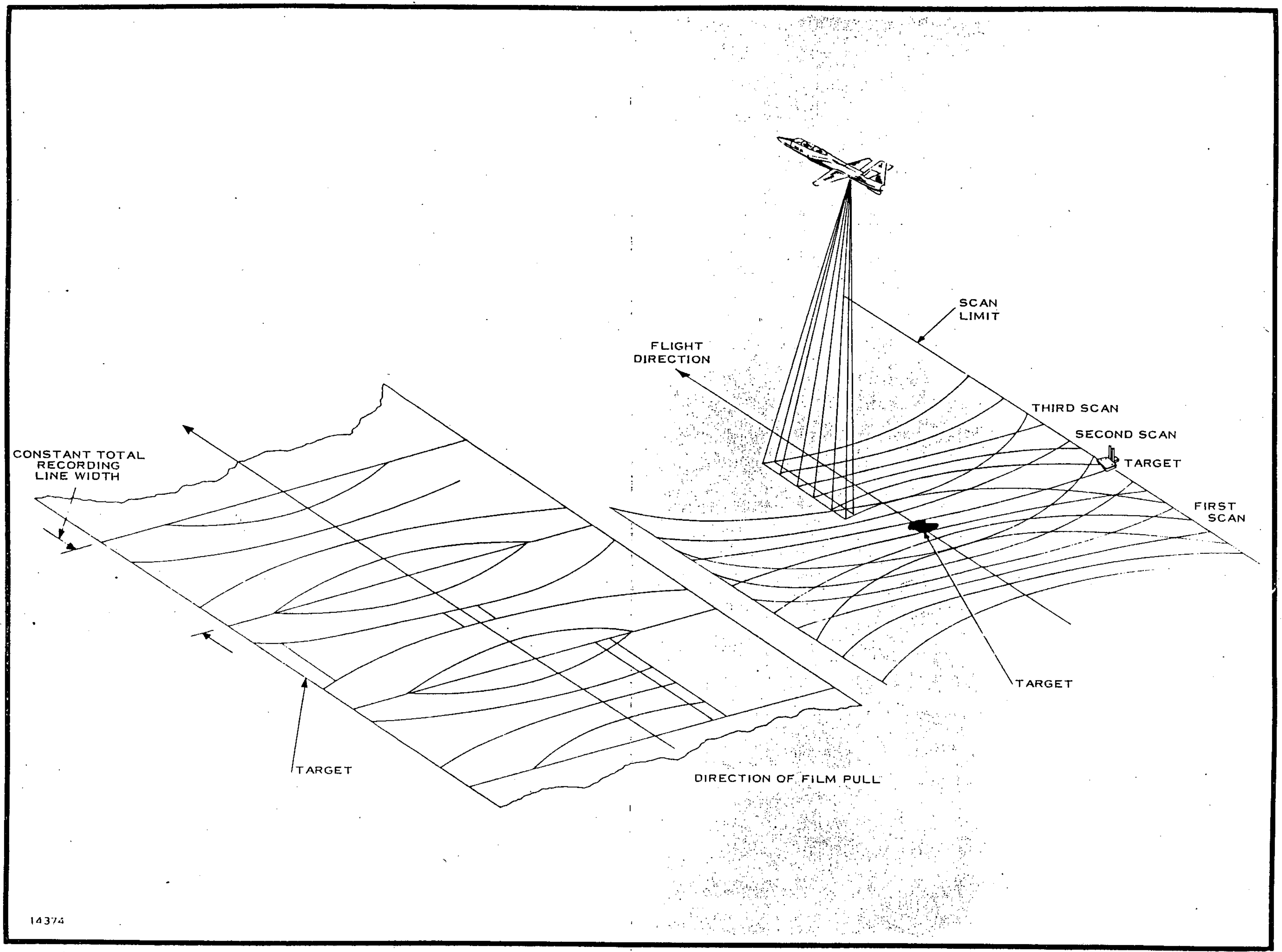

Figure 2-15. Target Printout With FAR Effect Correction and Constant Line Width Recording

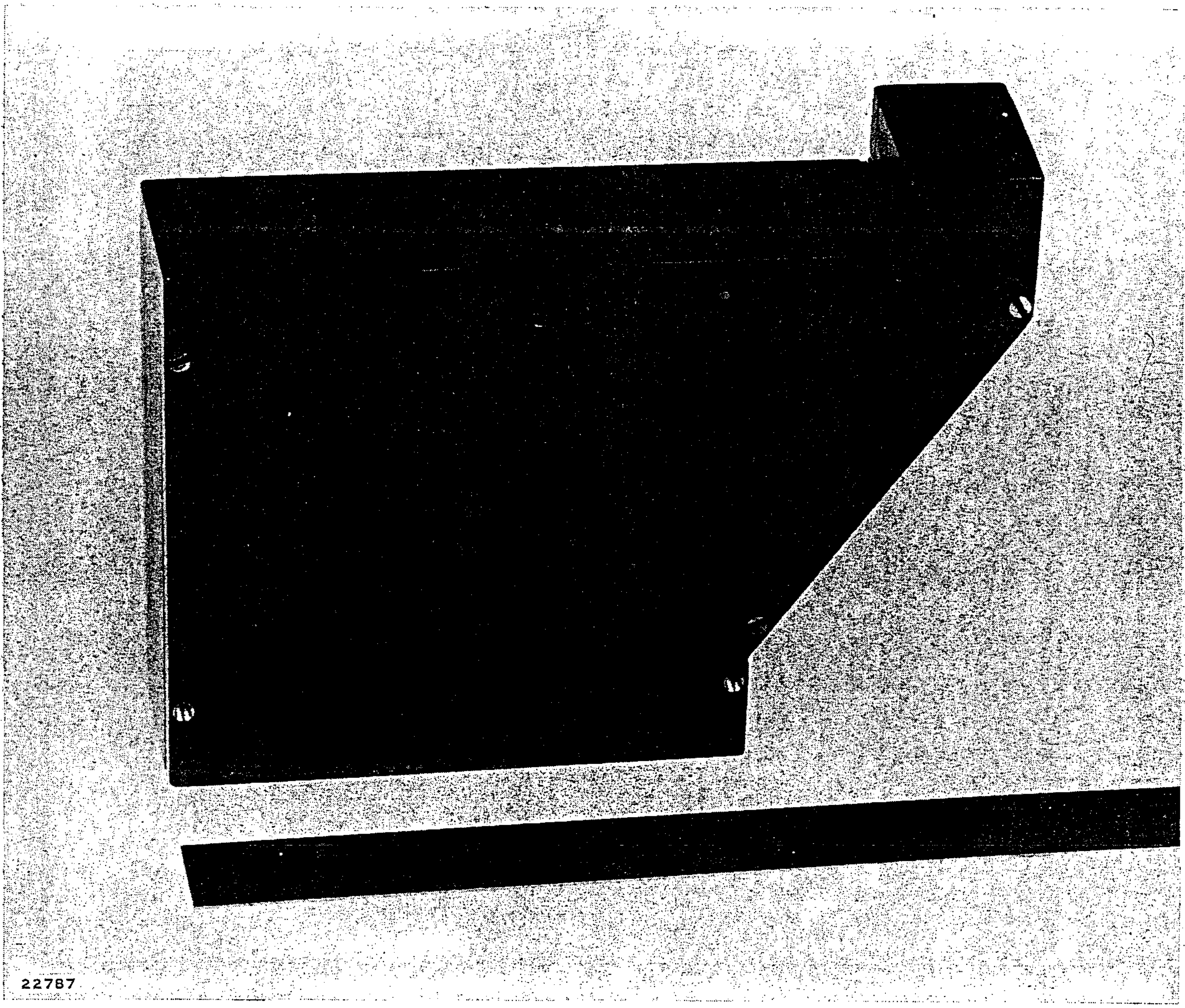

Figure 2-16. Oblique View of Fiber Optic Assembly

image the exit end of the fiber optic on the film, the compensation mask covers the entrance end of the fiber optic in a manner to yield the correct scan pattern. These components will be taken up in detail later.

The fiber optic assembly is the heart of the recording system. Figures 2-16, 2-17, and 2-18 are three views of the AN/AAS-10 fiber optic assembly. Basically, it consists of five aligned fiber optic bundles of different cross sections that are tapered 5:1 from entrance end (large end) to exit end. The optic assembly mounts to a shaft inside the drum. The shaft exits the drum through the back drum plate and is held rigidly by the recorder housing. The optic is designed such that when mounted in the drum, the exit is on the axis of rotation of the drum in the plane of rotation of the objectives, the entrance end is very close to the compensation mask, and the individual channel

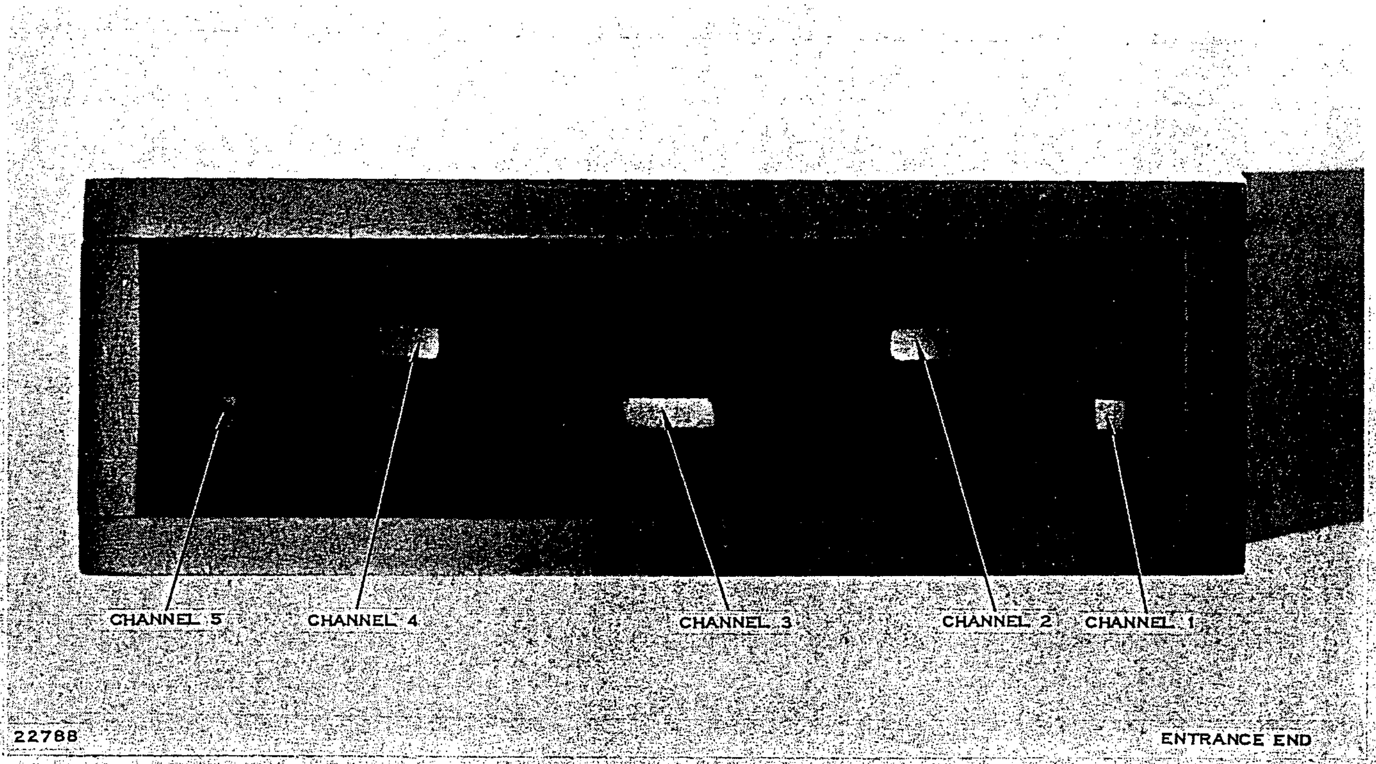

Figure 2-17. Entrance End of Fiber Optic Assembly

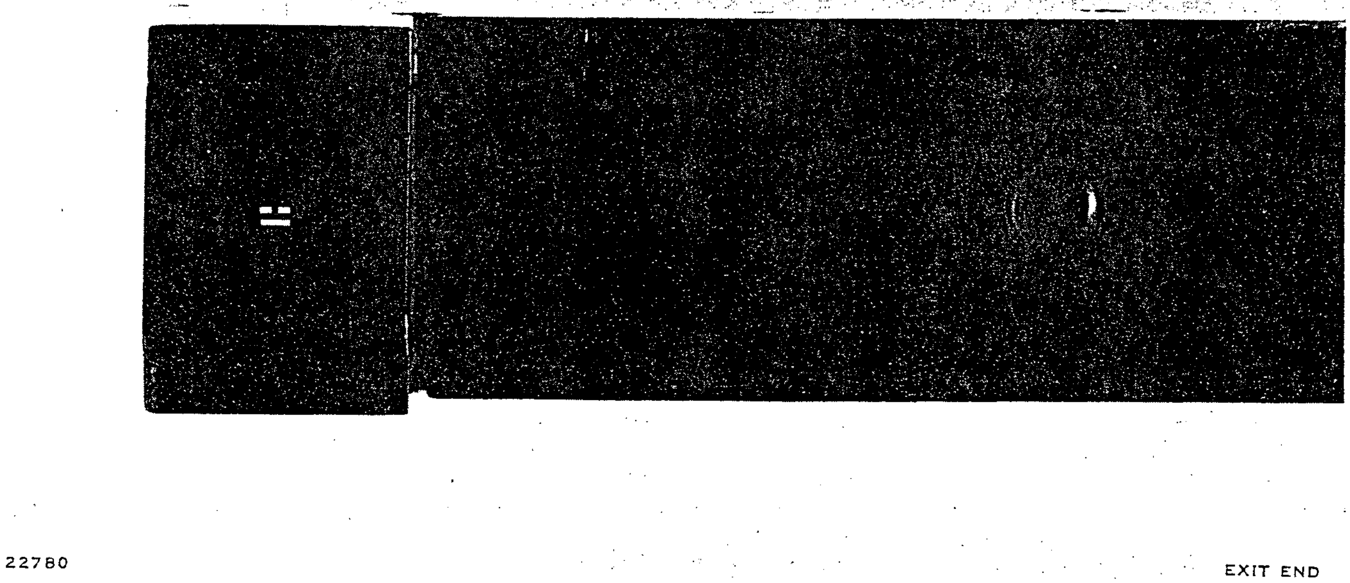

Figure 2-18. Exit End of Fiber Optic Assembly

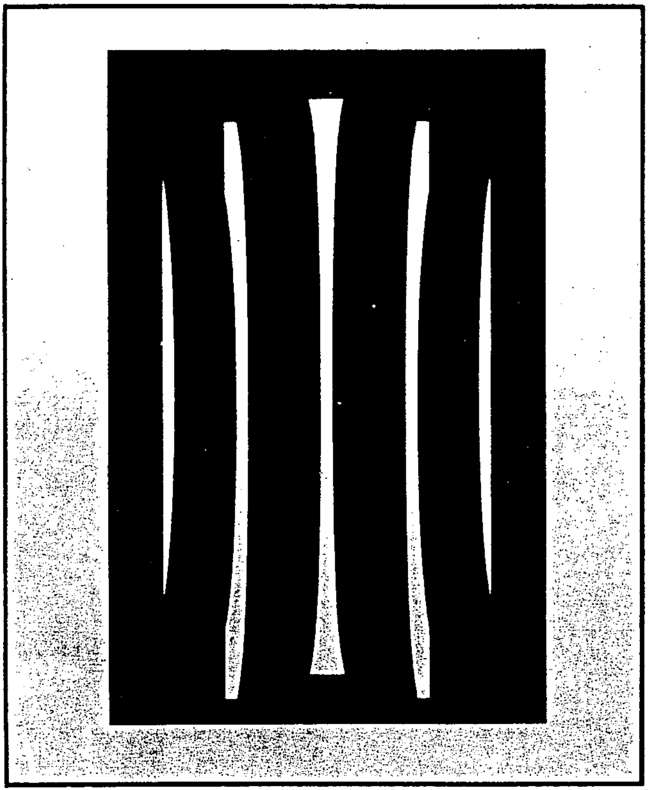

Figure 2-19. AN/AAS-10 Compensation Mask

bundles are coincident with the compensation mask slits. With the exit end on the axis of rotation, the microscope objectives are maintained at a constant distance from the exit end which serves as an object for the objective. This allows the objectives to image the exit end on the circular film plane and stay in focus throughout the entire recording angle. As mentioned before, the fiber optic also allows several separate light sources to be reorganized such that each source appears to be contiguous. The taper in the fibers accomplishes two objectives. The taper allows light entering at a small cone angle to be dispensed through a large cone angle, thus allowing light to enter the microscope objective throughout the recording angle. Second, the small size required of each channel at the exit end (approximately 0.014 inch square) would be difficult to work with at the entrance end where other functions such as FAR effect compensation and banding control are taking place. The image transmitting ability of the fiber optic allows compensation for FAR effect and banding to be accomplished. FAR effect is achieved by transmitting an image of the compensation mask to the exit end. The same is true of the banding filter. The technical details of the fiber optic are discussed later.

The AN/AAS-10 compensation mask is shown in Figure 2-19. The white areas are slits and the rest is opaque. The mask is photo-etched from 0.006-inch-thick steel and then mounted to a curved bracket which conforms to the inside diameter of the drum. Of interest is the slit pattern. This is the same pattern as shown necessary in Figure 2-15 for the recording traces, the only difference being that each channel pattern is now separated. This is accomplished by imaging the separated patterns on the entrance ends of the fiber optics, transmitting this to the exit end where the patterns are again put adjacent to each other, and imaging this on the film.

Figure 2-20 is an illustration showing the sequence of events through one scan that allows proper recorder channel traces for FAR effect correction. The top figure shows the mask fiber optic orientation when the angle of scan is zero. Note that channel 3 fiber optic element is three times as large as either channel 1 or channel 5's element. Channel 2 and channel 4 are twice as large as channel 1 and channel 5. However, at zero scan, the mask

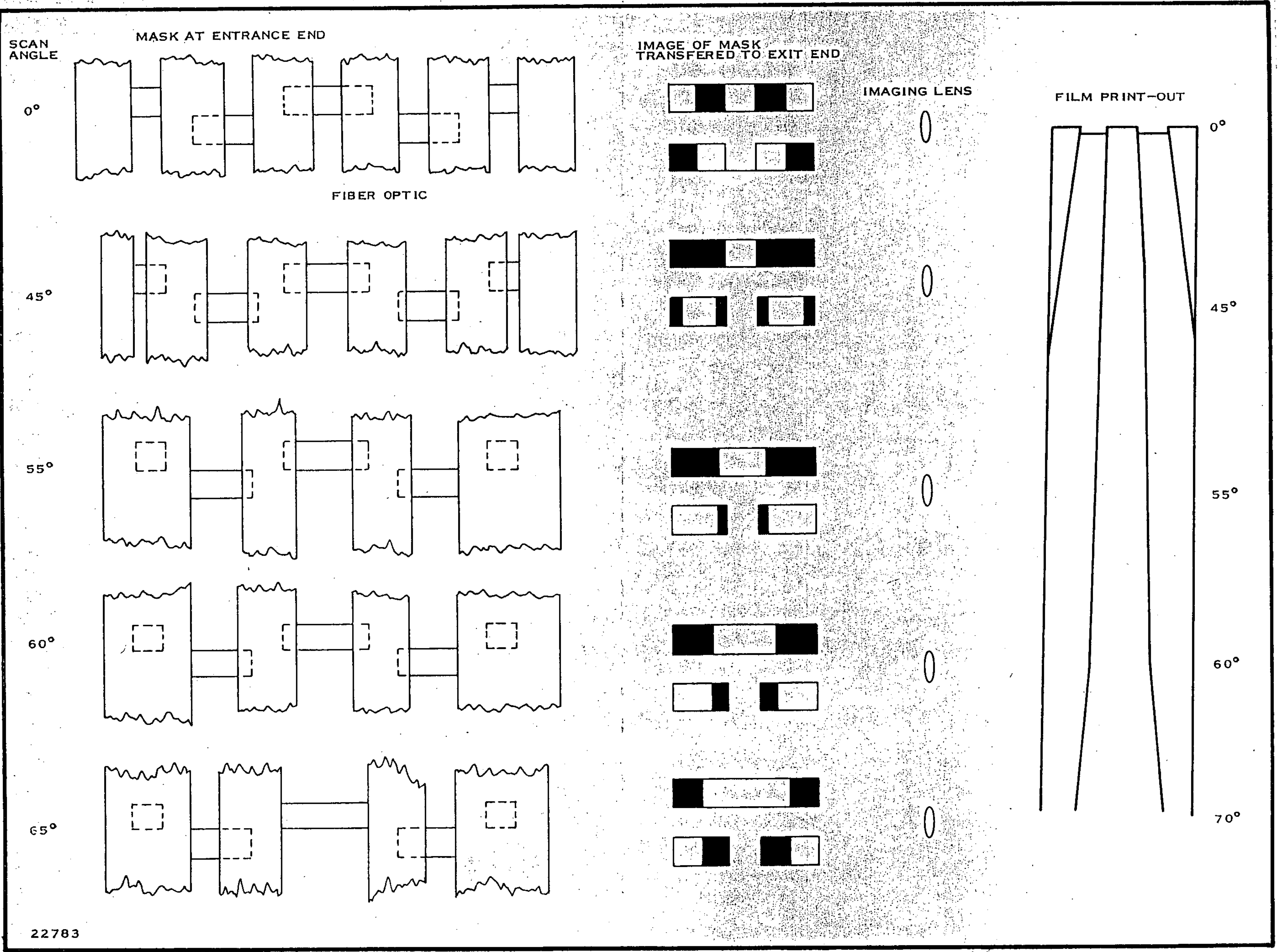

Figure 2-20. Compensation Mask Operation

has allowed channel 1 and channel 5 to be completely open. The outside ends of channel 2 and channel 4 are masked off as is the outside end of channel 3. At this position, each channel has the same amount of area capable of being illuminated. The light impinging on the open areas is transmitted to the exit end as shown to the right (Figure 2-20). The two far outside channels (channel 1 and channel 5) are on each side of the middle channel (channel 3). Channel 2 and channel 4 are below. The light areas of the array are the areas of each channel that are not masked off. Hence, there are five small, square, equally sized light areas whose edges are adjacent but offset. This is imaged on the film by the microscope objective which leaves a spacing of squares on the film. The lines on the schematic of the film represent the edges of the various light areas. The next sequence shows the mask as it has rotated past the fiber optic to where it corresponds to a scan angle of 45 degrees. Here, channel 3 has opened up slightly on each side. The inside edges of channel 2 and channel 4 have been covered up by an amount equal to the amount of opening of channel 3. However, channel 2 and channel 4 have opened up more area to the outside edges of the fiber optic, and they are of equal size to channel 3. Channel 1 and channel 5 have been closed considerably. This image is then transmitted to the exit end as shown. As before, the edges of each channel are contiguous, but their relative position and size in the array have changed. This is imaged on the film, and the recording pattern begins to emerge. On the other three scan angles, the same thing is happening. As the microscope objective rotates past the film and the FAR effect compensation mask rotates past the film and the FAR effect compensation mask rotates past the entrance end of the fiber optic the proper recording pattern is "wiped" on the film. This method is completely satisfactory in that only the microscope objective and compensation mask move and then only in a smooth rotational motion. All other components are held stationary. Once the compensation mask is adjusted to the proper location with respect to the fiber optic, no further maintenance or adjustment is necessary to keep the FAR effect compensation system operating. Figure 2-21 is a section of a map made during an AN/AAS-10 flight test. The area shown in the map is Carswell AFB in Fort Worth, Texas. The mapping aircraft altitude is 10,000 feet above the ground. The section shown is between 60 and 70 degrees off the nadir. The distance to the parked aircraft on the map is approximately 5-1/2 miles. At this distance, the ground resolution on the direction of flight is 15 feet. Examination of the map reveals the swept wings, tail assemblies, and other details of the aircraft. This degree of resolution and detail would be impossible at this large scan angle without FAR effect correction. Examination of other maps made in the course of the AN/AAS-10 program reveals that FAR effect correction does nothing to deteriorate any portion of the map but does indeed enhance the information at the edge.

Figure 2-21. Infrared Map of Carswell Air Force Base

d. Recorder Resolution

In general, there are four major factors that determine the resolution of a recorder of this type. These are:

Angle alignment

Track alignment

Focus

Jitter.

The first two are concerned with the location of each microscope objective with all other objectives. The third is concerned with the location of all objectives with respect to the film, and the last is concerned with the short-term phase difference between the scan mirror and the recording objectives.

Angle alignment places each microscope objective precisely 90 degrees from each adjacent objective. This is required because the scan mirror will be looking at the same point on the ground every 90 degrees of its rotation. If the scanner detects two targets 1.0 milliradian apart, one objective will record these targets with 1.0 milliradian separating them. When the scanner rotates exactly 90 degrees, it can see these same targets again. If the objective that records for that mirror face pair is out of alignment, 1.0 milliradian, it will displace the location of the targets that amount. Hence, it will record between the two targets already recorded, and only one large target can be discerned. This would ruin the recorder resolution in the direction of scan.

The recorder can be aligned easily to 0.1 milliradian in angle and, with extra patience, to 0.05 milliradian. This degree of alignment is important because all other factors such as film resolution, slight variation in focus, etc., tend to decrease the ultimate resolution of any recorder. The additional error of as much as 0.4 milliradian in angle alignment would preclude the resolution of 1.0-milliradian targets.

Track alignment places each microscope objective such that, if the film did not move, each objective would place its image on film directly on top of the previously recorded image. Error in track deteriorates recorder resolution along the direction of flight. Alignment of track can be made with at least as much accuracy as the angle alignment and is considerably easier to achieve.

Other than static track alignment (moving each objective into alignment relative to the drum) precautions have been taken to ensure that the drum does not move along its axis relative to the film. The drum support bearings are preloaded, thereby removing their axial play.

Focus in the multichannel recorder is the most critical of all adjustments. It affects resolution in both scan and flight directions. Because of the necessity of gathering as much light as possible, an objective with a high numerical aperture was used. This type of lens has a very small depth of focus (distance film can be away from lens image plane and still be in adequate focus). Figure 2-22 schematically illustrates the problem. It can be seen that

$$x = 2\Delta S'(\tan \theta) + x'$$

where

x is the defocused spot size

x' is the desired image size

θ is the half angle of the light out of the lens

$\Delta S'$ is the distance the film plane is removed from the image plane.

For the objective system anticipated, $\tan \theta = 0.88$ and x is about 0.0008 inch; therefore, for x to be twice the size of x', the film plane need only be displaced 0.0005 inch. This means, assuming the film is formed in a perfect circle, that each objective must be adjusted radially on the drum so that all are the proper distance from the film within ±0.0003 inch to ensure 1.0-milliradian resolution.

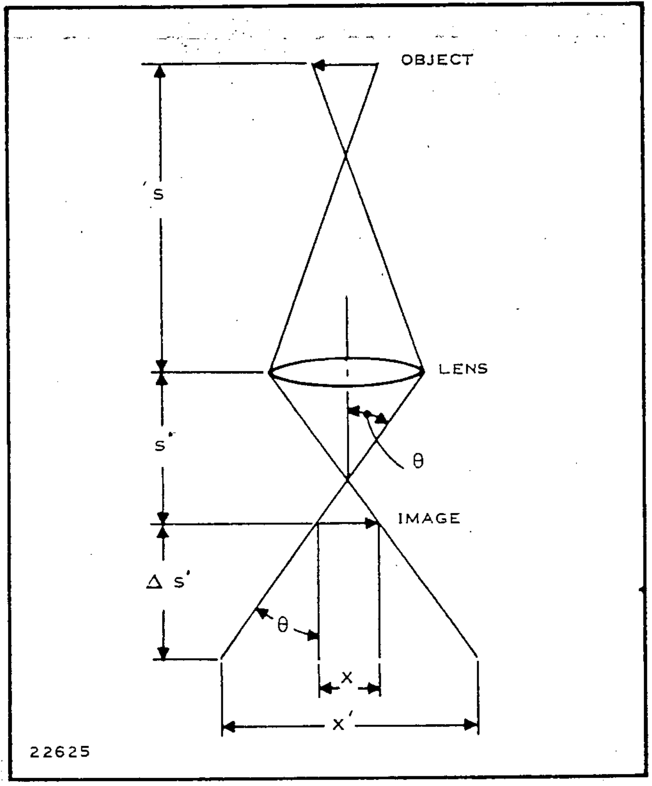

Figure 2-22. Focal Depth of Microscope Objective

It is comparatively easy to perform this adjustment, but it is difficult to maintain the film plane location, with this accuracy throughout the recording angle. Any buckle or dimpling of the film would ruin resolution. If the film plane were out of concentricity with axis of rotation of the microscope objectives of only one small area of the map will be in focus.

This problem was solved in the D-series equipments by machining the inner and outer platen as a single unit. The final process includes machining the film-forming surfaces of each platen, concentric to the mounting base of the inner platen. This mounting base is then located in the drum bearing base of the recorder. In this way, the film plane is referenced to the axis of spin of the microscope objectives which ensures that the film surface is concentric with the axis of rotation.

Many systems of this type have been plagued with the problem of jitter. This problem arises when the scan mirror and recorder are allowed to move relative to each other during a scan. It manifests itself as a variable angle alignment error, and the resolution along the direction of scan can be no better than the maximum play between the two components. To be able to resolve 1.0 milliradian, the jitter must be maintained less than ±40 seconds of arc. The system uses a fitted coupling as shown in Figure 2-23. This coupling has a precision semicylinder base that fits both shafts very snugly and allows no lateral play. The caps are drawn down on each shaft flat,

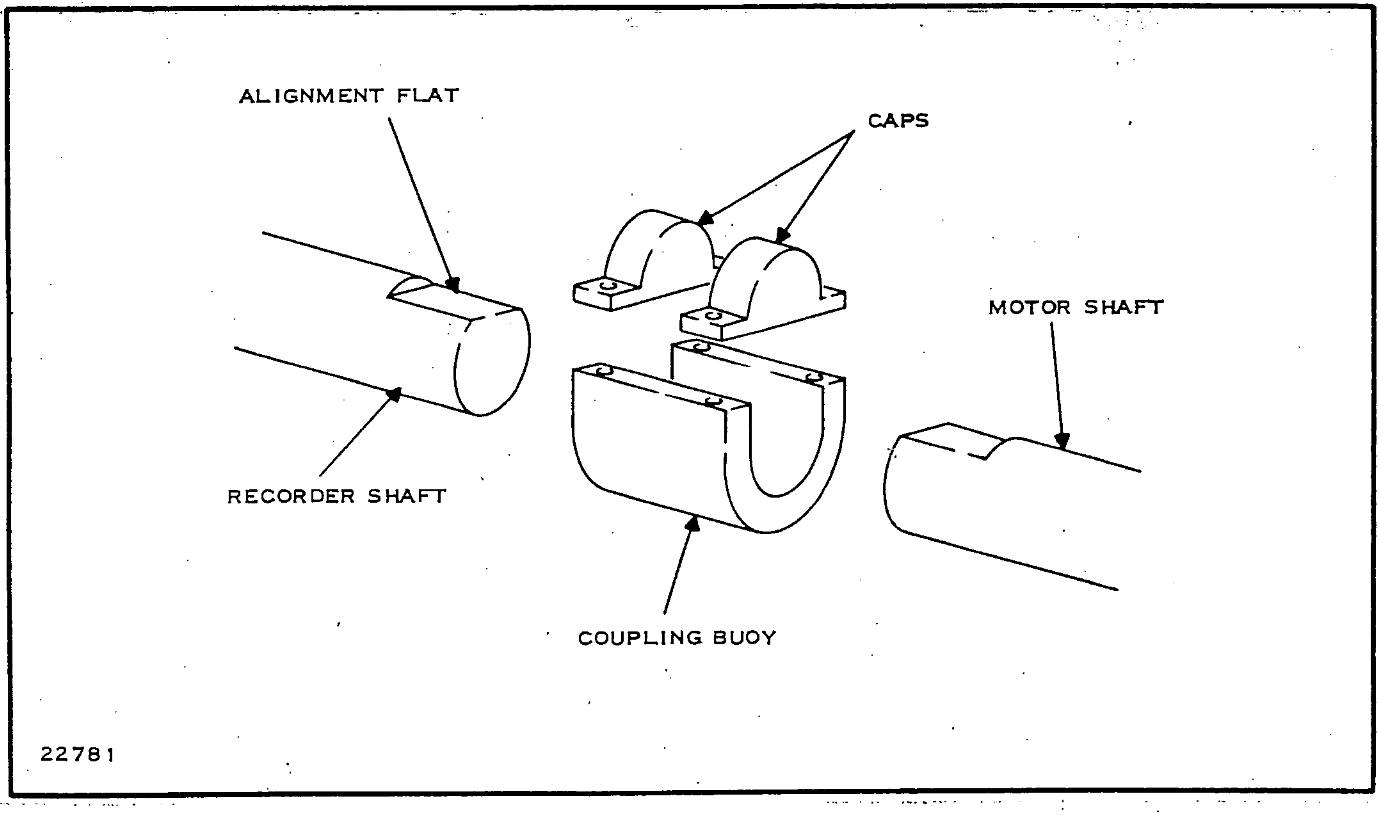

Figure 2-23. Motor-Recorder Coupling to Eliminate Jitter

thereby aligning each flat and retaining the shafts. The recorder drum shaft is coupled to one end of the motor shaft and the scan mirror to the other end of the motor shaft. This, in effect, creates one solid shaft from scan mirror to recorder drum and limits angular jitter to torsion in the shafts. High precision ball bearings are used in the shaft line to reduce radial jitter. All bearing bores are line bored to reduce wear and to permit assembly.

e. Photographic Film

No less important than any other component in the system is the photographic film used. The film used in the system depends on the light source used - glow tube or gallium arsenide diodes. For glow tube use, Tri-X film is desirable because of its high photographic speed and reasonable resolution. Its sensitivity closely matches the spectral output of the glow modulator tube. Tri-X is capable of resolving between 50 and 90 line pairs per millimeter, depending on processing. This is adequate for the system requirements.

Tri-X film can be purchased in either the acetate or polyester base. The polyester base is superior in strength, thickness, and base density to the acetate base.

The use of an infrared emitting diode as a light source necessitates Kodak high speed infrared film. This film is quite sensitive to the spectral output of the diode when the diode is cooled to liquid nitrogen temperature. This infrared film has resolution comparable to Tri-X and exhibits good storage characteristics.

At this time, Kodak only supplies the polyester base infrared film in special orders of large quantities.

f. Automatic Exposure Control

The purpose of an exposure control is to ensure that the film does not vary in darkness over the entire V/H range. This is necessary because at low V/H ranges overscanning of the map occurs in the recorder. For instance, at a V/H of 0.1 radian per second, each area of the map is scanned by the recorder spot 10 times. At V/H = 0.02 radian per second, the overscanning factor is 50. Obviously, this level of exposure difference requires compensation.

As mentioned before, multichannel recorders have two exposure control problems:

Banding - Overexposure on one area of the film but not on others due to overscanning of one channel by another

Gross overexposure - Overexposure on all areas of the film due to many overscans.

Each of these problems has a V/H range where they are objectionable. Banding is a problem from V/H = 1 radian per second to V/H = 0.25 radian per second. Gross overexposure is objectionable from V/H = 0.25 down to zero.

The automatic exposure control developed for the AN/AAS-10 system will be utilized in the D-5 recorder.

g. Banding Filter

With FAR effect correction incorporated in the system, banding control is difficult. Figure 2-24 shows the FAR effect scan pattern (5 channel AN/AAS-10) on the film at a V/H of 1 radian per second. Three scans are illustrated. Note that no area is overscanned at this V/H, and banding control is not necessary. If the V/H is decreased to 0.8 radian per second, the film pull rate will be decreased by one channel width per scan. Figure 2-25 illustrates the result of this reduction as found in the AN/AAS-10.

There is now a band across the full width of the film. This band is one channel width wide. The pattern is not as simple as if only channel 1 and channel 5 were overscanning each other. There are four separate areas of overscan where one channel is overscanning some other channel. If, for instance, only channel 1 and channel 5 were attenuated 50 percent, this would cause the cigar-shaped area in the center to have proper exposure, but the areas where channel 2, channel 5, channel 4, and channel 1 are overscanning would be over exposed by 50 percent. Also, the area where channel 2 and channel 4 overscan would be overexposed by 100 percent. A solution to this would be to attenuate channel 2 and channel 4 50 percent. This would eliminate overexposure in the area overscanning, but in the areas where channel 2 and channel 4 are not overscanning, a 50-percent underexposed area would result. This indicates that not only is it necessary to attenuate certain channels, but also parts of certain channels, and this attenuation must be a function of scan angle.

Figure 2-26 shows the result of decreasing the V/H to 0.6 radian per second. A more complicated overscan pattern results. Now, instead of four different overscan areas, there are six.

Figure 2-27 is a flat view of the banding control filter. Each vertical line accommodates one channel and is placed between the glow modulator and the entrance end of the tapered fiber optic. This allows the light coming through the banding filter to cast a shadow image of the banding filter on the entrance end of the tapered fiber optic. The quantity of light reaching the fiber optic is a function of the transmission through the banding filter. The numbers on the right indicate that the area of the filter that will cast its shadow image of the banding filter on the fiber optic and that particular V/H. If, for instance, the V/H were 0.8 radian per second, the area lying on the 0.8 line would be shadow imaged on the fiber optic.

Figure 2-28 illustrates the banding control action of the banding filter, compensation mask, and fiber optic. The top set shows the compensation mask position at a scan angle of zero and an overscan pattern at the right corresponding to V/H = 1. As mentioned before, there is no overscanning at V/H = 1 radian per second; therefore, the edges of scan 1, 2, and 3

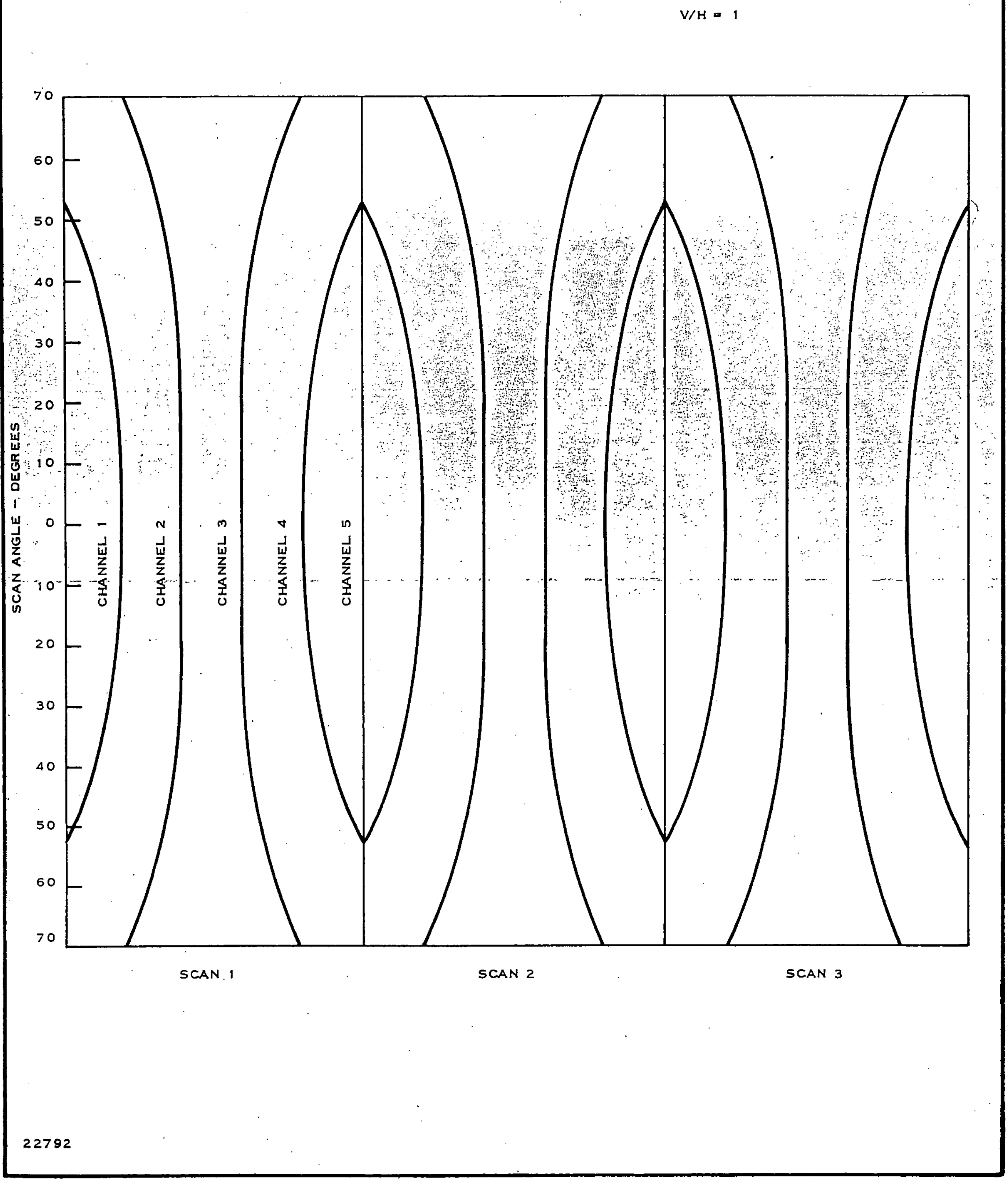

Figure 2-24. Scan Pattern

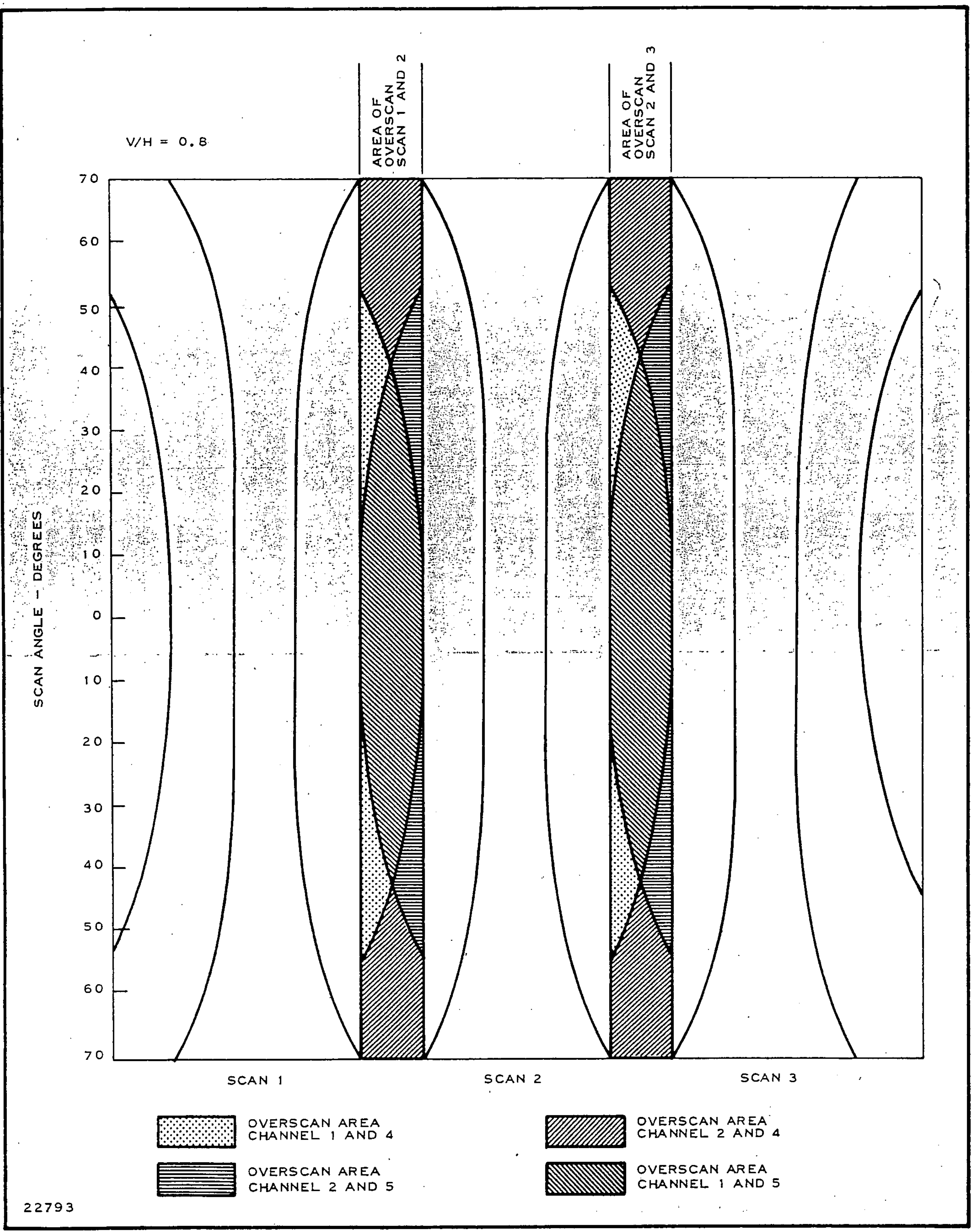

Figure 2-25. Banding Versus Scan Angle with V/H Decreased to 0.8 Rad/Sec

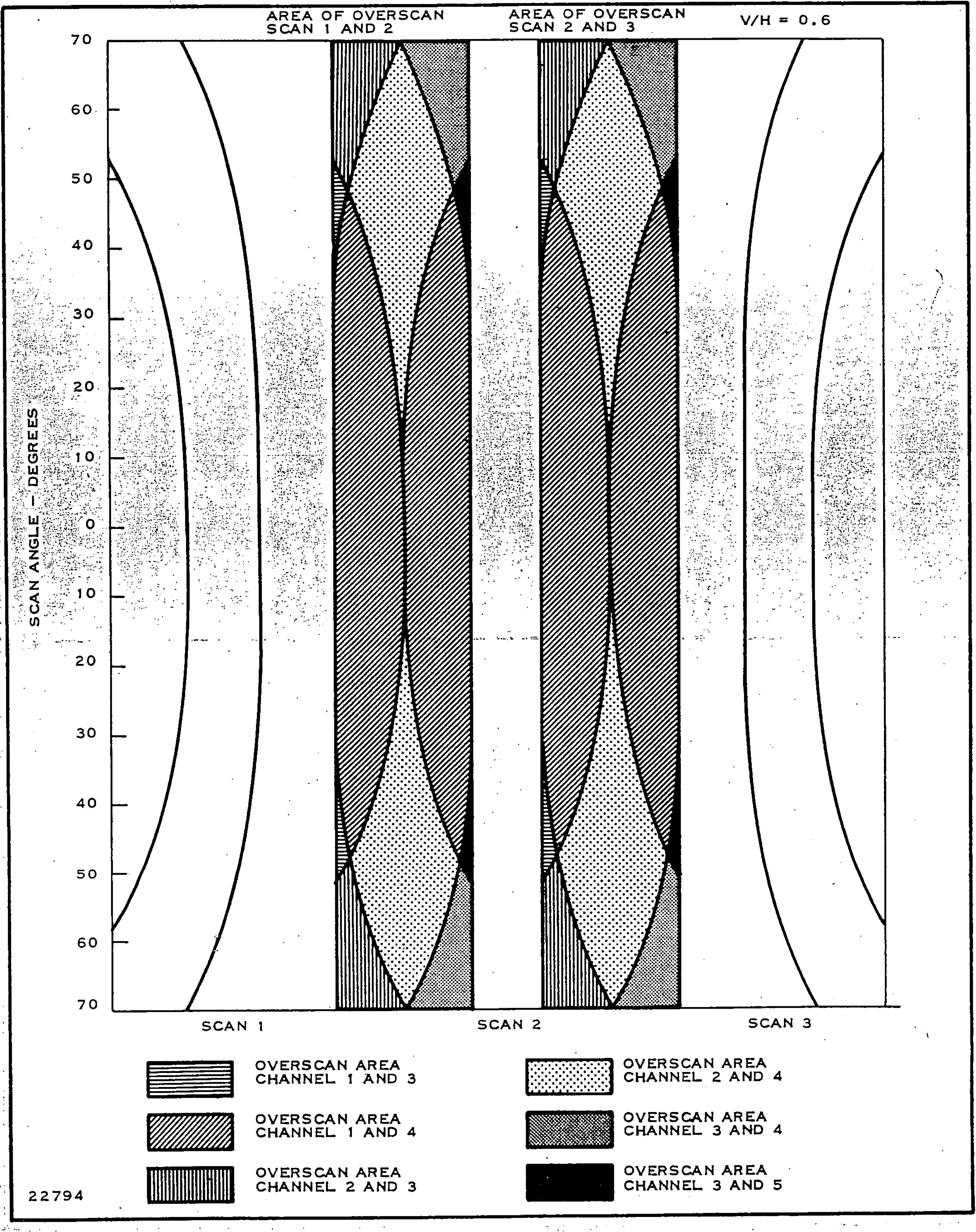

Figure 2-26. Banding Versus Scan Angle with V/H Decreased to 0.6 Radian Per Second

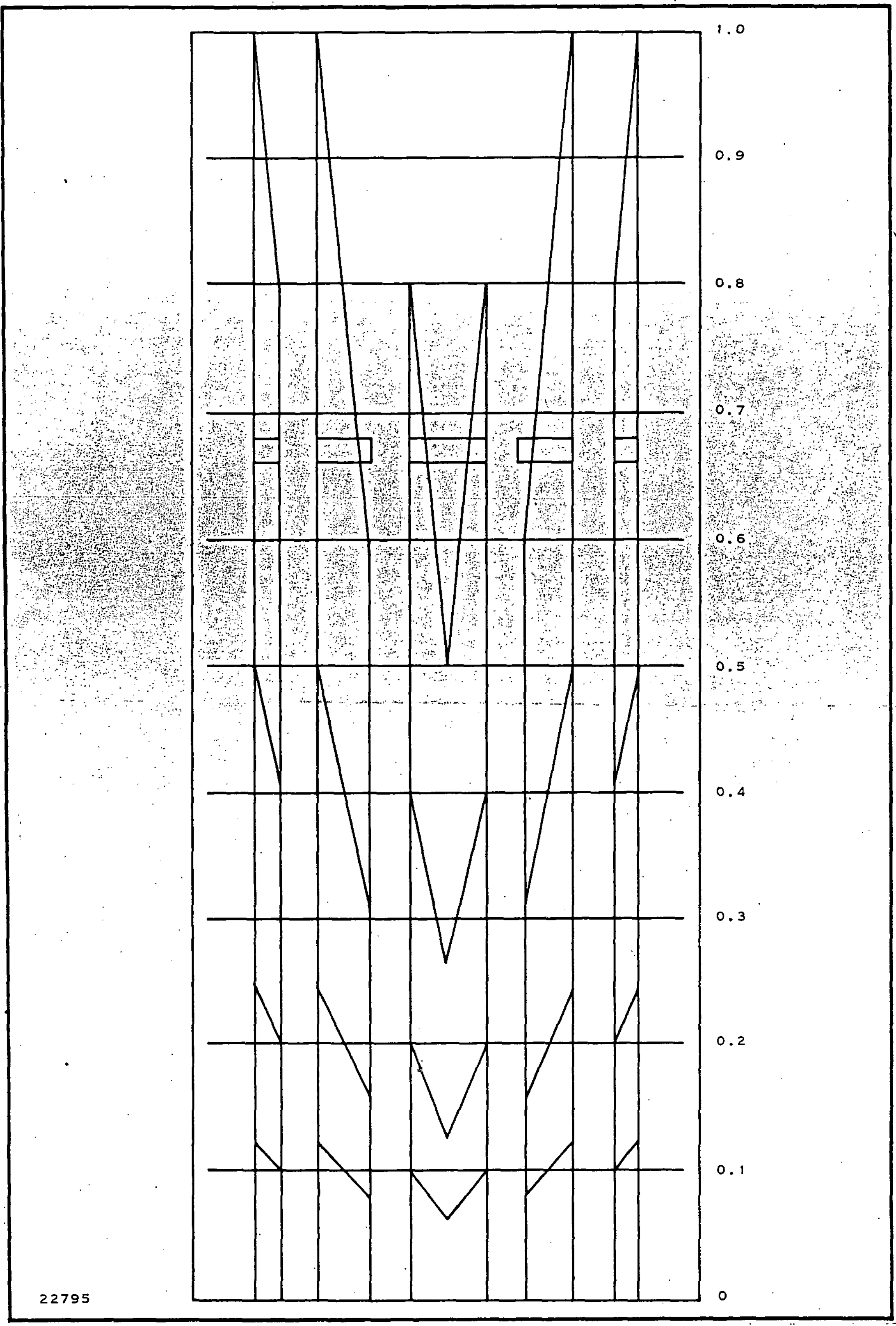

Figure 2-27. Flat View of Banding Filter

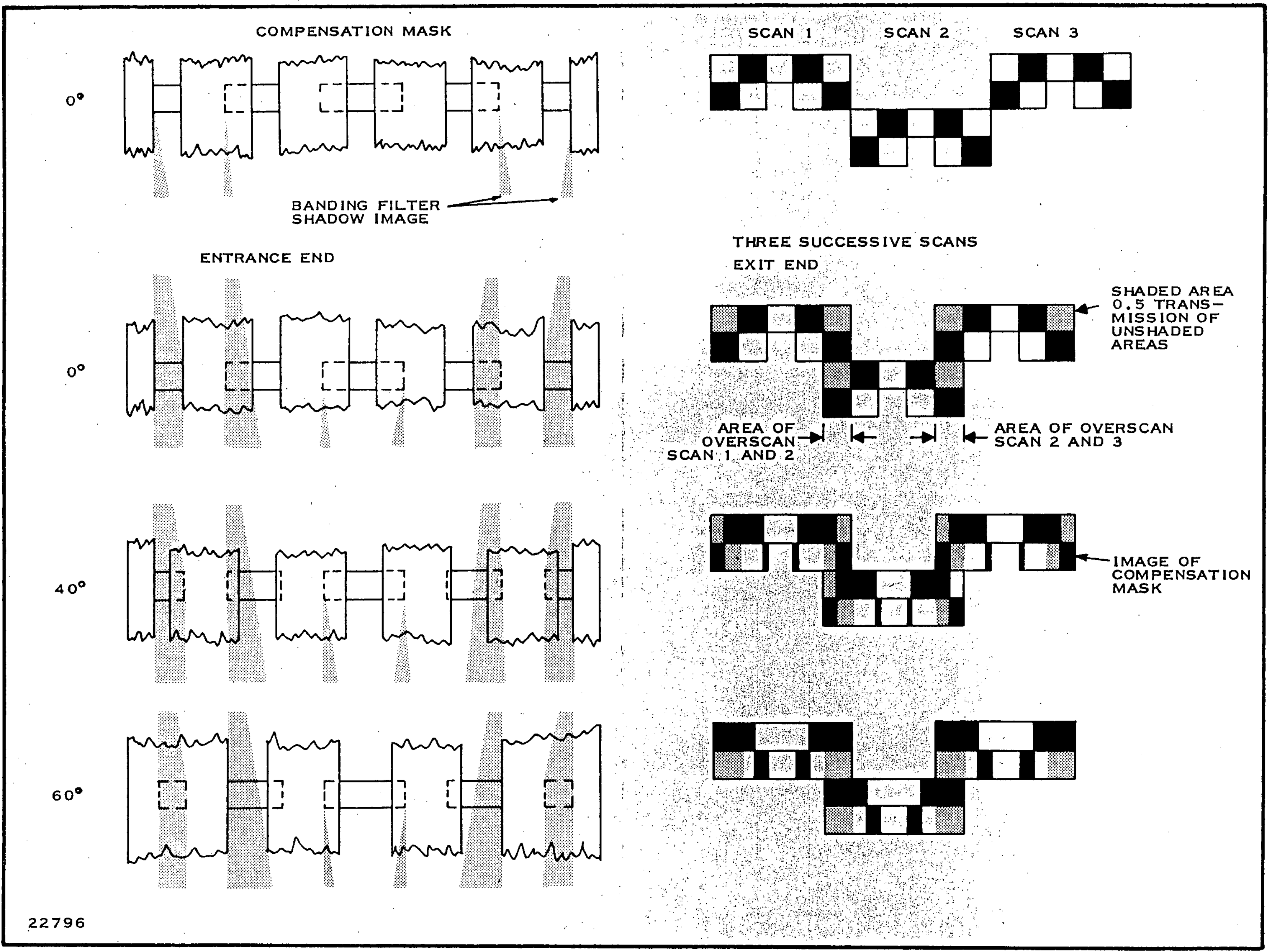

Figure 2-28. Banding Filter Operation at V/H = 0.8 Radian Per Second

are contiguous. The white areas are light emitting, and black areas are masked off by the fiber optic. If the exit end pattern were "wiped" down the illustration, each emitting area would be an equally exposed line the full width of the three scan widths. The shaded areas on the entrance end are the shadow image of the banding filter. It can be seen that no shaded area covers a section of the fiber optic, even if the compensation mask were not present.

The second drawing shows the compensation mask positioned for zero-scan angle; however, the V/H is now 0.8 radian per second. The banding filter has positioned itself such that the shaded areas have moved up the transmission of the shaded areas 50 percent. The exit end images now have an area of overscan shown at the right. Notice that the shaded entrance end area of channel 1 and channel 5 is transmitted to the exit end which is represented there by a shaded area. The light exiting from the shaded areas is half that exiting from the white areas. If this exit image were wiped down the illustration, the exposure in the area of overscan would be unified since at this scan angle, channel 1 and channel 5 are exactly overscanning each other, and their light output is down 50 percent. The sum of their outputs is 0.5 + 0.5 = 1. The light areas still expose unity; hence, there would not be an overexposed area at zero-scan angle. Refering back to Figure 2-25, note that at zero-scan angle, it is only necessary to attenuate channel 1 and channel 5. The next figure shows the compensation mask at 40 degrees scan angle and the same V/H. The mask has opened up the entrance ends of channel 2, channel 3, and channel 4, but the shadow image of the banding filter attenuates part of the entrance area of channel 2 and channel 4. Referring to the exit and image at the right, it can be seen that the area of channel 2 that overscans an area of channel 5 is only emitting 50 percent, and the same is true of channel 5. Therefore, the sum of channel 2 and channel 5 exposure is unity. The same is true of channel 1 and channel 4, channel 3 not being affected at all since the banding filter does not shade any part of its entrance end. The next drawing shows the compensation mask at 60 degrees of scan. Here, channel 1 and channel 5 have disappeared behind the mask. The exit end image shows that where channel 2 and channel 4 overscan, the emission is 50 percent and the sum of their exposure is unity.

This operation holds true throughout the scan angle. When one channel starts to overscan another channel, the area of the entrance end that corresponds to the overscanning area of the exit end is shadowed by the banding filter. This allows parts of channels to be attenuated as required while the compensation mask provides the angular transmission control.

The banding filter at V/H of 0.6 radian continues operating on the entrance end light, preventing banding down past V/H = 0.1 radian per second. At this point, each channel is being overscanned so many times that banding is negligible.

At a V/H of 0.1, the gross overexposure control takes over and begins to aperture the entrance ends simultaneously by blocking the light.

This exposure control method eliminates both banding and gross overexposure with one simple mechanical device driven by a conventional position servoloop. No complicated alignment or adjustment is required. The techniques required for design of banding filters is considered by Texas Instruments to be state of the art. The system designed for the AN/AAS-10 will be utilized in the D-5 IRRS.

5. Stabilization

The recommended stabilization system for the RA-5C infrared system will be for roll correction only.

High-quality maps have been made on the AN/UAS-5(XE-1), RS-9, AN/AAS-18, and other systems built by Texas Instruments using roll-axis stabilization only.

The proposed system will be similar to that developed for the RS-9 and presently being designed for the D-3 infrared system and will use a roll gimbal to mass stabilize the scanner-recorder. Gearless motors or torquers will be used to overcome the friction of the bearings in the roll gimbal since they do not add additional coupling between the platform and the aircraft. Disturbances to the platform will be limited by the friction in the bearings and, hence, will be independent of the amplitude of the aircraft motion.

The size, weight, and power requirements are based on the stabilization provisions described here; a three-axis stabilization system will necessitate increases in these system characteristics.

6. Control Panel

The preliminary control panel layout for the D-5 infrared system is shown in Figure 2-29. The panel will be an edge-lite panel in accordance with appropriate military specifications.

Critical system functions are monitored on a go, no-go basis during the normal aircraft system check and also during operation.

C. SYSTEM CALCULATIONS

The following analysis is conducted to determine the system resolution parameters.

To achieve contiguous scanning, we must consider the V/H equation for a four-sided scan mirror which is

$$V/H = 4nf(\Delta\theta),$$

where

V/H is the maximum velocity-to-height ratio in radians per second

n is the number of detectors

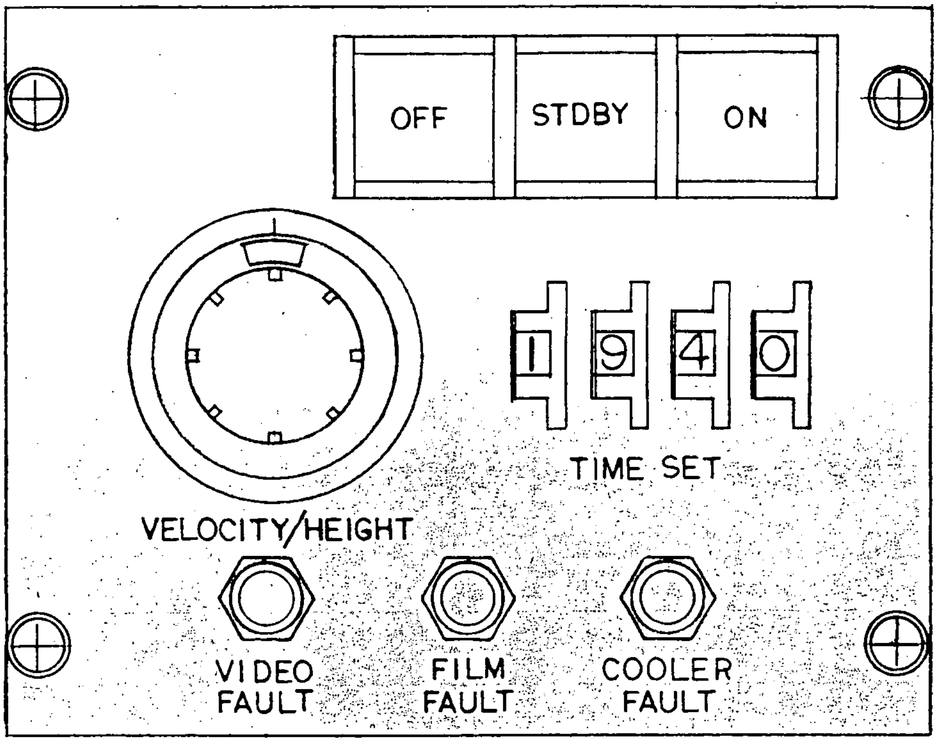

Figure 2-29. Preliminary Control Panel Layout

f is the number of scans per second

$\Delta\theta$ is the angular resolution in radians per scan.

Therefore, the scan speed is given by:

$$f = \frac{V/H}{4n\Delta\theta} .$$

For V/H = 1.2 radians per second, three detectors, and 1-milliradian angular resolution, f is calculated as:

$$f = \frac{1.2}{(4)(3)(1 \times 10^{-3})}$$

$$f = \frac{2.4 \times 10^{3}}{2.0 \times 10^{1}}$$

$$f = 100 \text{ rps or } 6000 \text{ rpm.}$$

The electronic bandwidth (3 decibels) can be determined from the scan speed and angular resolution. With optical doubling, the electronic bandwidth is defined by:

$$\Delta f = \frac{2\pi(f')}{60\ (\Delta\theta)}\ ,$$

where

Δf is the electronic bandwidth in cps

f' is the scan speed in rpm

$\Delta\theta$ is the angular resolution in radians per scan.

For a scan speed of 6000 rpm and angular resolution of 1 milliradian, the value for Δf is calculated as:

$$\Delta f = \frac{2\pi(6000)}{60(1 \times 10^{-3})}$$

$$\Delta f \sim 628 \text{ kilocycles.}$$

The corresponding noise bandwidth used in the D* and NET calculations is $\pi/2$ times the 3-decibel bandwidth or, for this case approximately 1.0 megacycle.

Stefan Boltzmann's equation for the power emitted by a ground target with a given radiating temperature (T) and emissivity (ϵ) is given by:

$$P = \frac{\epsilon\sigma T^4 A_t A_o \tau_o \tau_a}{\pi H^2}\ ,$$

where

P is the radiated power in watts

ϵ is the target emissivity

σ is Stefan Boltzmann's constant

T is the radiating temperature in degrees Kelvin

A_t is the area of the ground target in square centimeters

A_o is the effective area of the optical aperture

τ_o is the optical transmission efficiency

τ_a is the atmospheric transmission factor

H is the distance between the infrared system and the ground target.

For a square field stop or detector, the area for a ground target is expressed by

$$A_t = H^2(\Delta\theta)^2\ .$$

Therefore,

$$P = \frac{\epsilon\sigma T^4 A_o (\Delta\theta)^2 \tau_o \tau_a}{\pi}.$$

The differential power is given by:

$$\Delta P = \frac{4\epsilon\sigma T^3 A_o (\Delta\ )^2 \tau_o \tau_a (\Delta T)}{\pi}$$

for a signal-to-noise ratio of one, $\Delta P = \mathrm{NEP}$, and $\Delta T = \mathrm{NET}$, where NEP is the noise equivalent power measured in watts and NET is the noise equivalent temperature measured in degrees centigrade. A figure of merit for detectivity can be expressed as

$$D^* = \frac{(A_D \cdot \Delta f)^{1/2}}{\mathrm{NEP}},$$

but the area of the detector $A_D = \frac{\pi}{4} F^2 (\Delta\theta)$, where F is the optical focal length.

The selected parameters for the 8- to 14-micron wavelength region are:

$F = 63$ centimeters

$\Delta f = 1.0$ megacycles (noise bandwidth)

$\epsilon = 1$ (by specification)

$\sigma = 5.67 \times 10^{-12}$ watt per square centimeter-degrees Kelvin^4

$T = 300°K$

$D^* = 9.3 \times 10^9$ cm-cps 1/2-watt^{-1} (Hg:Ge detector array)

$A_o = 140$ cm^2

$\Delta\theta = 1 \times 10^{-3}$ radian

$\tau_a = 1$ (by specification)

$\tau_o = 0.7$

yielding an effective NET of approximately 0.5°C.

SECTION III

MAINTAINABILITY

The D-5 Infrared Reconnaissance System will be designed to facilitate maintenance for both flight line (hangar deck) and shop personnel. It is suggested that the flight line personnel limit their maintenance duties to the isolation and replacement of defective line-replaceable units (LRU's). The self-test features incorporated into the control panel will provide the go, no-go equipment status.

Defective LRU's removed from aircraft will be repaired by trained technicians using shop equipment. Again, the line maintenance concept is to isolate and replace, rather than to isolate and repair.

SECTION IV
RELIABILITY

The program proposed here will take full advantage of the formal reliability assurance programs in effect at Texas Instruments. The effectiveness of this program is evidenced in the results of the AN/AAS-18 reliability tests.

The AN/AAS-18 was subjected to reliability demonstration tests for 788 hours and 35 minutes, during which time six relevant failures occurred. Four of these failures were associated with the closed-cycle cooling system. The other two were attributed to the remainder of the system. The last 393 hours of the test were conducted without a relevant failure. The AN/AAS-18 has demonstrated a mean-time-between-failure (MTBF) of 131 hours. This figure will, of course, be improved as the cryogenic system's reliability limiting shortcomings are eliminated.

Texas Instruments recognizes the importance of the "reliability in design" philosophy; this philosophy will be reflected in the design approach and component selection and will be carried through the entire development effort. Particular emphasis will be placed on the utilization of designs and techniques found on previous D-series Infrared Reconnaissance Systems. In those instances where techniques not used on previous D-series systems are required, only proven design techniques will be utilized.

SECTION V

PROGRAM SCHEDULE

The design and fabrication of the D-5 Infrared System will be accomplished in the Special Projects branch of the Electronic and Optical Systems department of Texas Instruments. The program is envisioned as a 9-month effort.

Figure 5-1 shows the progression of work.

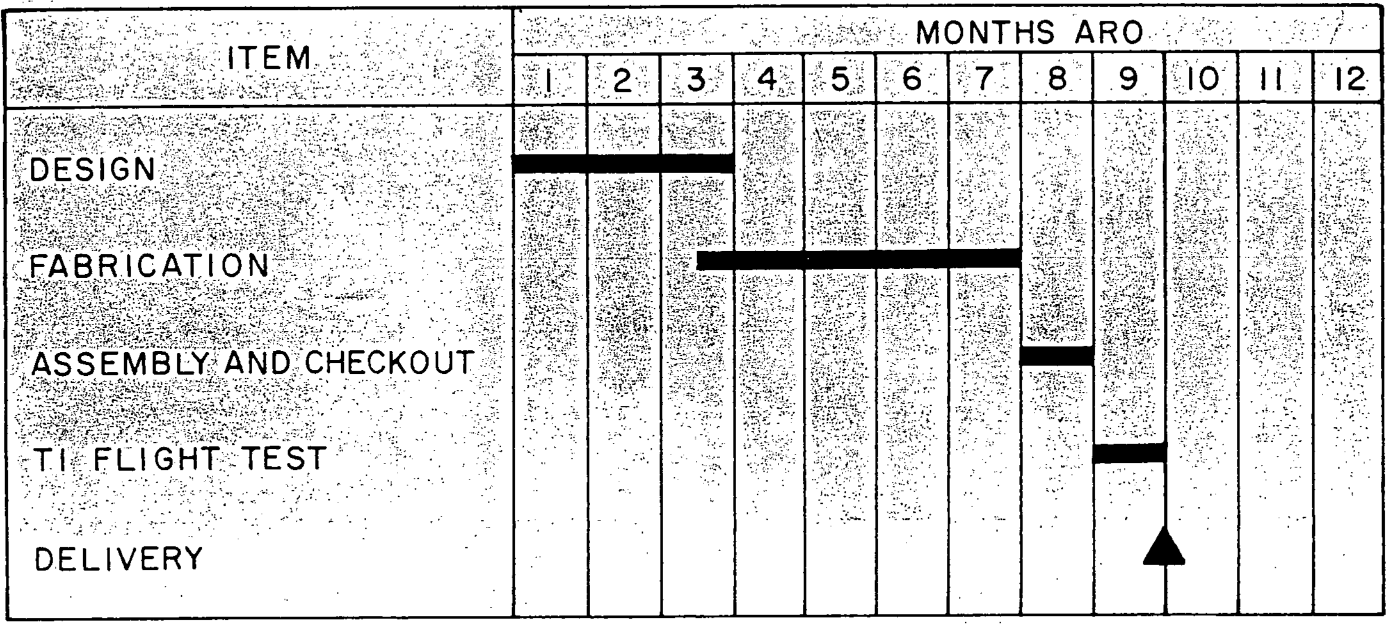

Figure 5-1. D-5 Program Schedule

While this schedule is the most desirable, delivery of the first unit could be accomplished in 6 months ARO if need be.

SECTION VI

SUMMARY

Texas Instruments is uniquely qualified to perform the work proposed herein within the suggested time schedule and at a minimum cost to the purchaser. The reconnaissance system proposed,is a basic infrared reconnaissance system, modular in concept and easily adapted to many mission profiles. If it were desirable, a simultaneous two-spectrum (3 to 5 microns and 8 to 14 microns) detection capability could be designed into the D-5 IRRS without changing the basic package size. This is an example of the versatility of the D-5 system. The D-5 Infrared Reconnaissance System will be a very reliable "hands-off operation" infrared reconnaissance system having capabilities consistent with advanced state-of-the-art techniques plus unique modular design permitting simple adaptation to a variety of configurations.

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