STATINTL

SPECIAL HANDLING

FILM DATA READER

PR-09

8 MARCH 1965

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LIST OF ILLUSTRATIONS

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SECTION 1

INTRODUCTION

1.1 GENERAL

This proposal has been prepared to describe an automatic reading equipment intended for the purpose of reading recorded auxiliary digital data from photographic film. The equipment will be capable of reading both positive and negative film records at high rates, and will handle films ranging from 35 millimeter to 9-1/2 inches in width, and rolls up to 1000 feet in length.

The reader will be designed for maximum flexibility by the adoption of a new approach to this problem. The approach described is made possible by two unique advancements in the fields of recording auxiliary data on film and microelectronic photoresponsive devices. The major advantages derived is the economy and the multi-purpose flexibility of the Universal Data Block Reader described herein. These two achievements have resulted

[redacted]

The output of the Universal Data Block Reader will be ~~either punched card or~~ magnetic tape, at the customers option. Either one will be suitable for input to a digital computer or other data processing systems.

1.2 BACKGROUND

When a large number of bits of digitally coded data are recorded on film as a contact area array of dots, it has been conventional to use a serial form of dot exposing equipment. This method is exemplified by a miniature cathode ray tube. The spot of illumination of such a tube is swept by deflecting voltages while the intensity is controlled by the data being written. Because the function of positioning of the dots in the compact array and that of exposure of the dots are controlled by the single device (the CRT) it is inherently a serial laydown device. In such a device drift and non-uniformities, which cannot be avoided, result in extreme lack of regularity of the geometry of the resultant compact flock of dots. The problem of reading a compact array of dots such as recorded by a miniature cathode ray tube is, therefore, extremely complex since the entire data block must be swept and read in order to reconstruct the geometry of the original data block. Thus an area scanning device is required in the reader.

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In order to overcome the problem of poor data block geometry, which has been threatening to limit severly the exploitation of photography enchanced with digitally coded auxiliary data, [redacted] has perfected an all solid state auxiliary film data recording system. This system consists of a very compact micro-electronic solid state array of individually controllable light sources. All of the light sources are fabricated within a single silicon crystal using diffusion and other fabrication techniques common to the semiconductor industry. This fabrication process produces light sources which are extremely uniform in performance and are almost perfectly spaced in a desired geometric pattern. The exposure is in near contact resulting in a data block whose geometry is very close to the recording array.

The major advantage is the simplification of the reader task when the designer of the reader can rely upon the perfection of the geometry of the data block. The reader will be much more compact and the film transport mechanically simpler when compared to conventional area scanning readers. This represents one of the advancements made possible through the efforts of personnel of the [redacted] Divisions named above.

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[redacted]

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The second advancement offered in the proposed Universal Data Block Reader is made possible by another family of microelectronic devices created by [redacted] which are complementary to the solid state recording devices. In conventional film data readers, the functions of photoresponsivity (to produce changes in an electrical signal in response to spots of light and dark areas on the film) and positioning are combined in a cumbersome serial system. This system takes the form of a fly-spot scanning beam which serially sweeps the film which is interposed between the beam and a photomultiplier tube placed on the reverse side of the film. The flying spot selects the area to be scanned, while the photomultiplier reads only the spot being illuminated by the beam at any instant.

The Universal Data Block Reader will use instead, a linear array of photodiodes to combine the functions of spot selection and photosensitivity. This represents a vast simplification in that the actual elements which must be placed in proximity to the film being read are reduced in size, do not require high voltage accelerating anodes and highly stable sweep voltages. The device to be used is a single monolithic silicon crystal structure. The spacing of the diodes of the linear array is extremely accurate and known.

Therefore, the linear array presents at the output of each diode the exact pattern of dark and light spots passing over the linear array axis. Each diode is individually wired and its signal is preamplified by an individual amplifier. The diode array, therefore, scans and measures the data block being read and provides the required photosensitivity.

These two advancements are, therefore, complementary to one another. Since the position of the dots with respect to one another and with respect to the indexing columns and rows within the data block are known and held to very close tolerances, a single basic logic control is sufficient to determine which outputs of the reading array shall be used as the data block passes over the linear array of photodiodes.

This proposal recognizes that the new solid state recording method will come into general use on film records to be used by the offeree. A number of expected general arrangements of film data formats are accomodated within the scope of the capabilities offered by the Universal Data Block Reader. The approach utilizes as many common devices and circuits as is economical for the formats listed, with the desired degree of flexibility to accept films of widely varying digital recording formats and positioning within the film.

SECTION 2

PROBLEM STATEMENT

2.1 GENERAL REQUIREMENTS

It is required that an automatic film reader be available which is capable of reading auxiliary data blocks as laid down on photographic film by the various camera systems currently in use. The film reader will, therefore, be capable of accepting 35 mm, 5 inch, 70 mm, or 9-1/2 inch films. It is permissible to utilize more than one read head for the various films provided that the method of interchange of the heads is simple and of a plug-in nature. The reader will locate the data block, read the data and either record it on a magnetic tape in IBM format or present it to an IBM punch for recording on cards. Should the output be punched cards, the reader will contain all of the necessary drive and control circuitry for operating the IBM punch.

2.2 DATA BLOCK SPECIFICATIONS

The film reader shall be capable of reading four types of data blocks as outlined below. Dot size and density variations will be in accordance with MIL-STD-782-A " Tactical Reconnaissance Data Marking ".

2.2.1 Type A

The data block will consist of one file of dots located between the picture areas. The file will contain a maximum of 30 dots. The uppermost position of the file will always contain a dot and shall be designated the index dot. This dot will indicate the beginning of the data block. Dot spacing and block location will be in accordance with Figures 1 and 2.

2.2.2 Type B

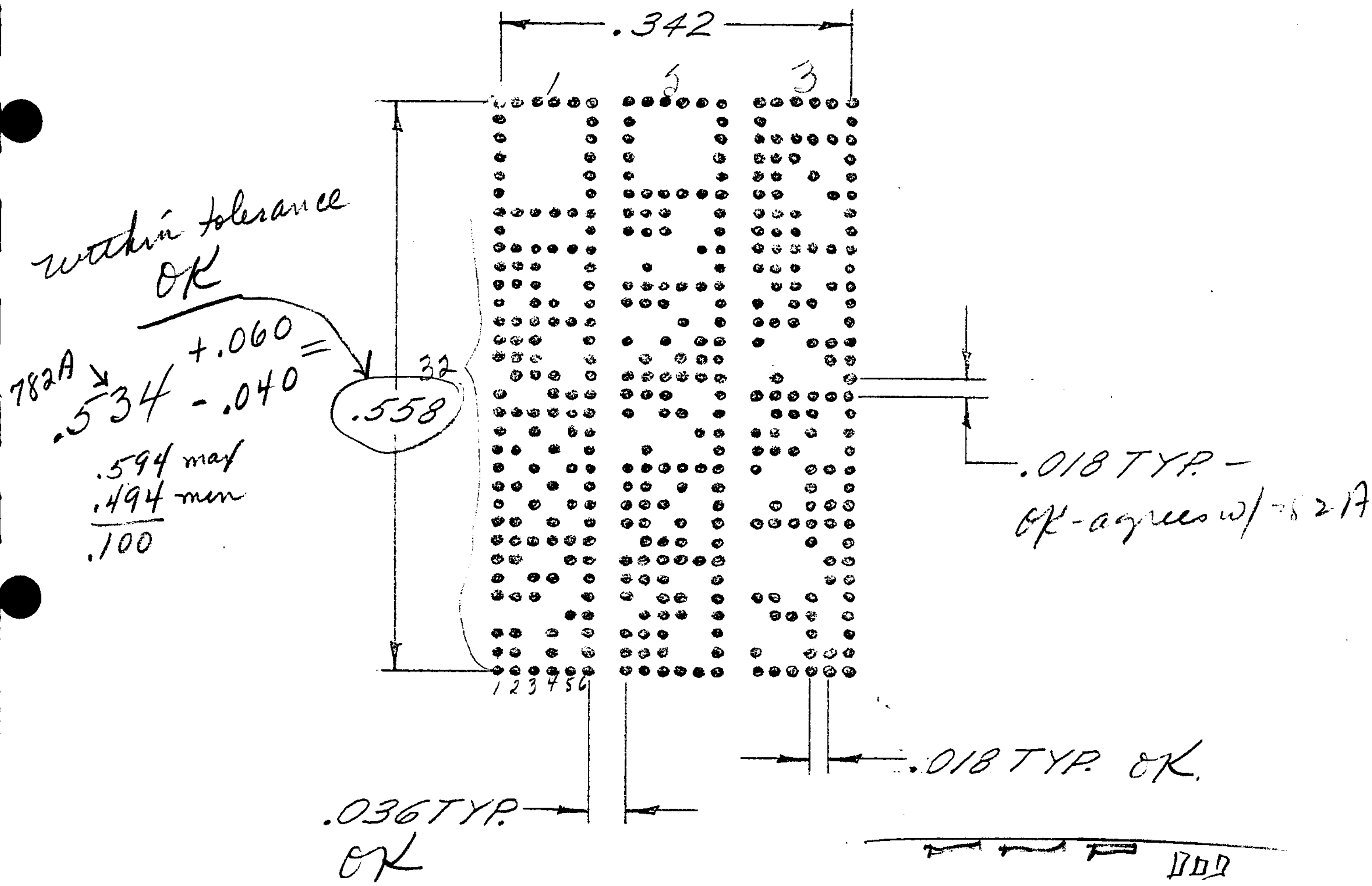
The data block will consist of three rows of dots located in the upper margin between the picture area and the edge of the film. Row number one will be an index row and will contain precisely 32 dots. Rows 2 and 3 may contain any number of dots up to a maximum of 32 with the exception that position number one shall always be a dot and will be designated an index dot. Dot spacing and block location will be in accordance with Figures 3 and 4.

2.2.3 Type C

The data block will consist of 3 columns of data, 6 files per column, 32 dots per file. The format will be in accordance with MIL-STD-782-A. However, all references to spacing and location of dots in MIL-STD-782-A

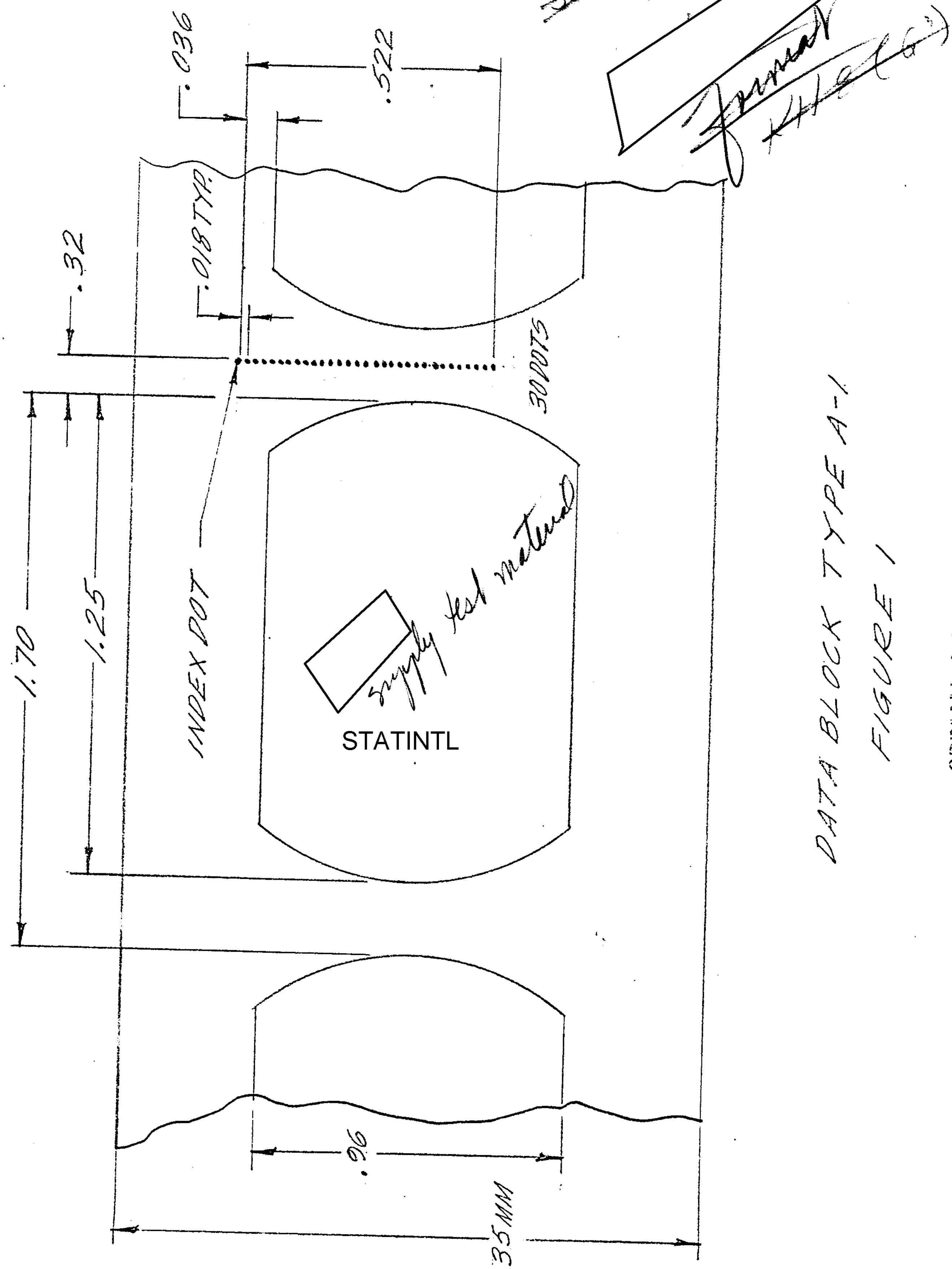
NOTE: ALL TOLERANCES ARE ± .000125
NON ACCUMULATIVE

Will not need cathode ray tube recording (RF4B, RF4C)

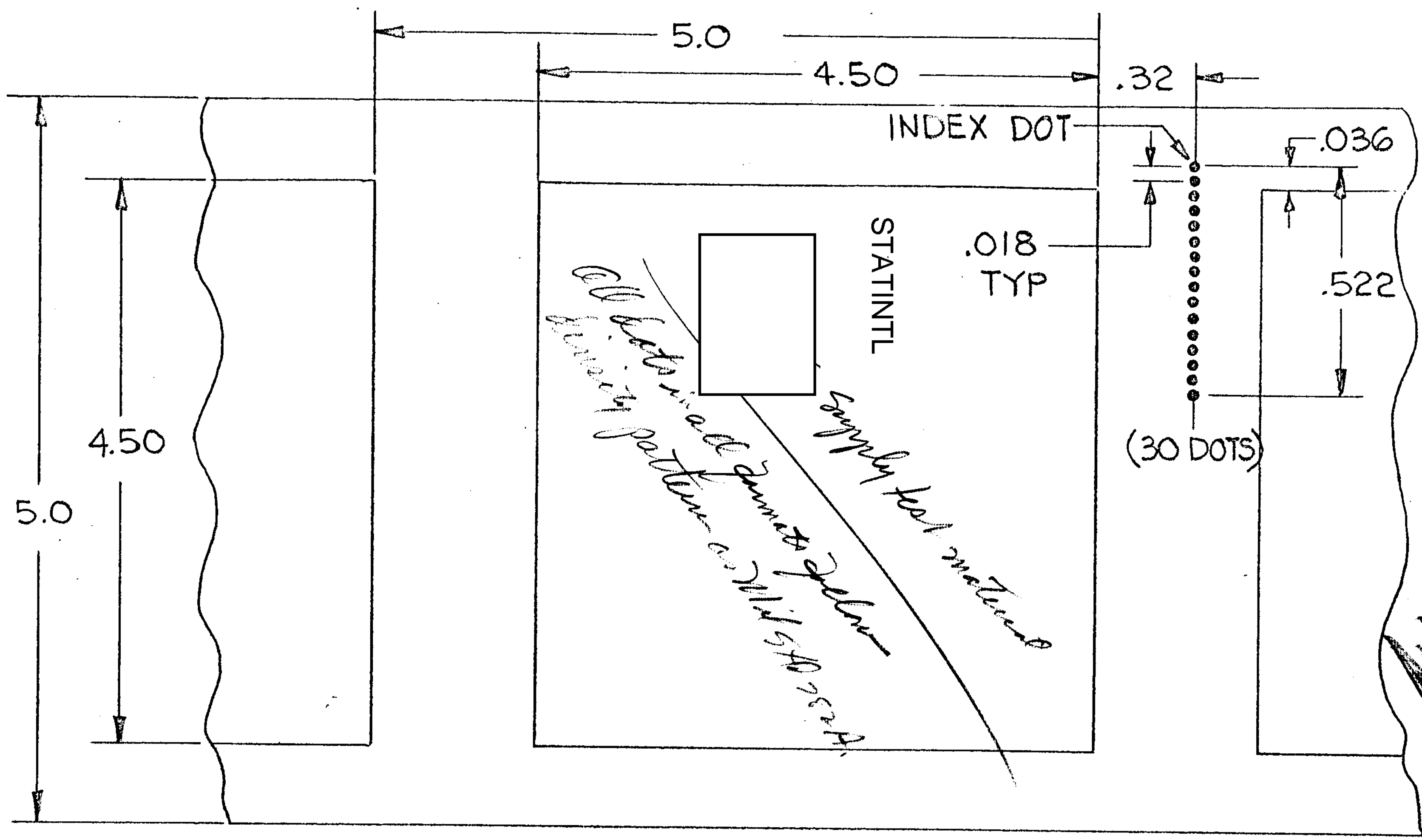


DATA BLOCK TYPE C

FIGURE 5



DATA BLOCK TYPE A-1
FIGURE 1



DATA BLOCK TYPE A-2
FIGURE 2

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G³ Sys – Same Data Block, except bars instead 60x20w w/28u sep.

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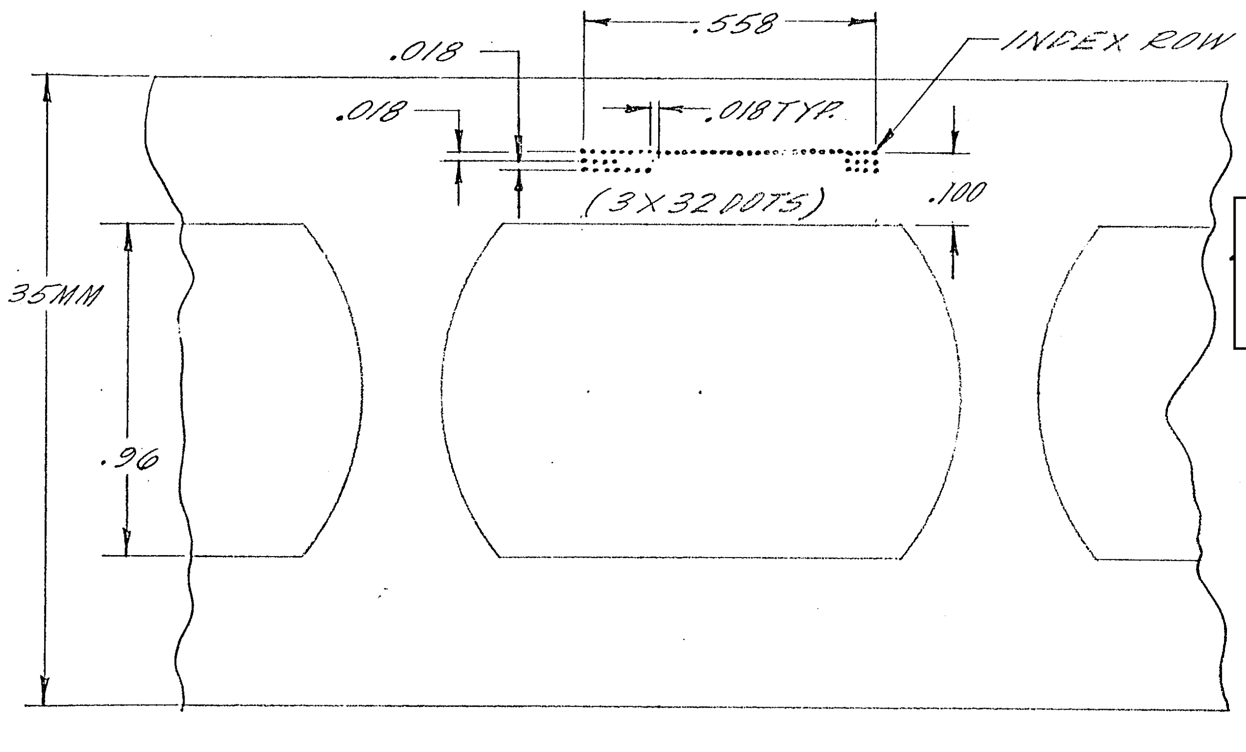

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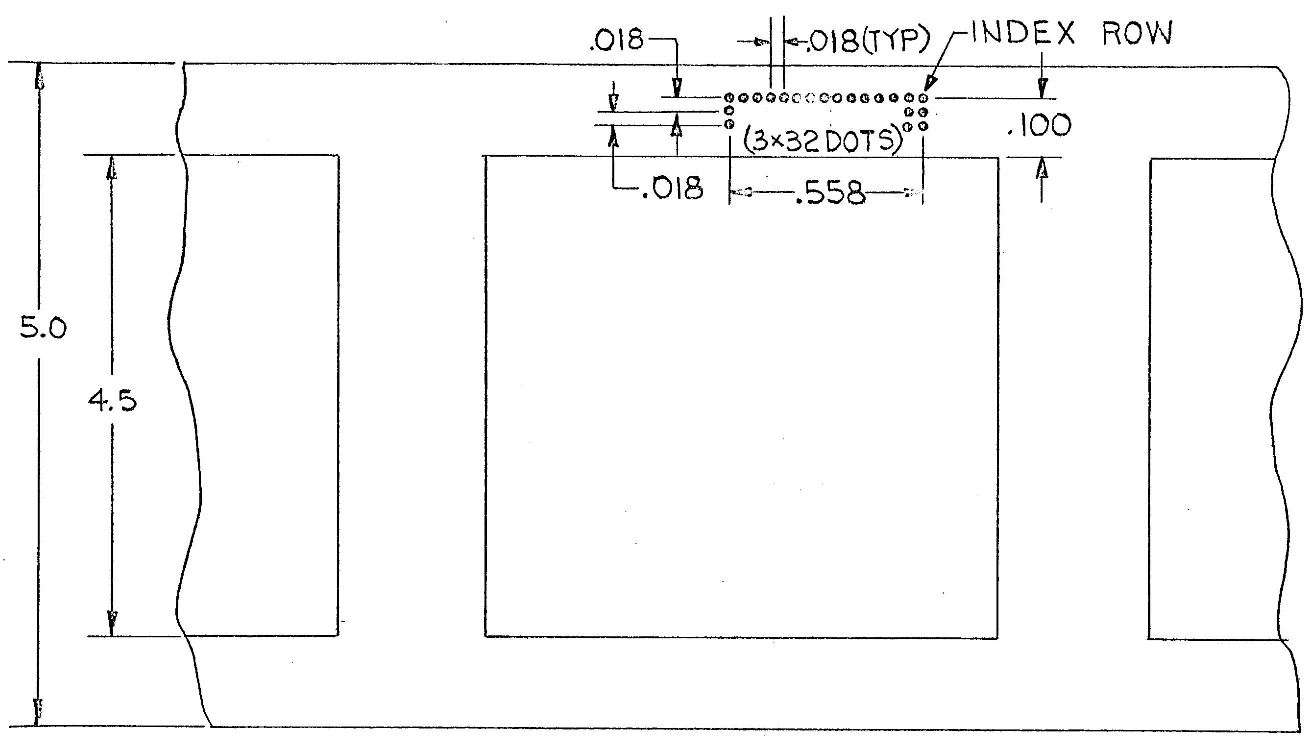
DATA BLOCK TYPE B-1

FIGURE 3

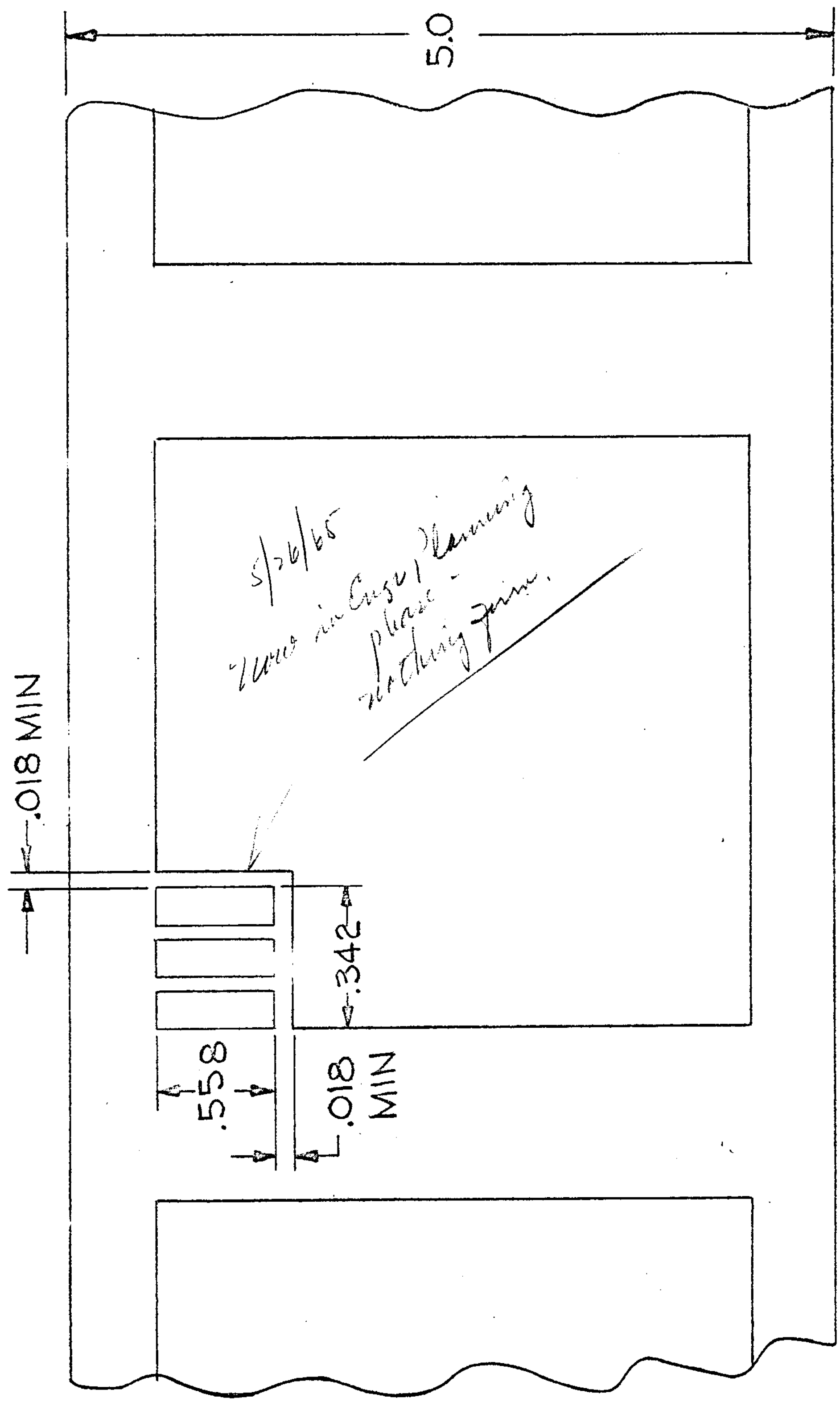


DATA BLOCK TYPE B-2
FIGURE 4

shall not pertain to this specification. Dot spacing and data block location will be in accordance with Figures 5, 6, 7 and 8.

2.2.4 Type D

The data block will consist of 5 rows of rectangular bars located in the margin between the picture area and the edge of the film. Row number one will be an index row and will contain approximately 42 rectangular bars. Rows 2, 3, 4 and 5 will be approximately twice the width of the index bars.



DATA BLOCK TYPE C-I
FIGURE 6

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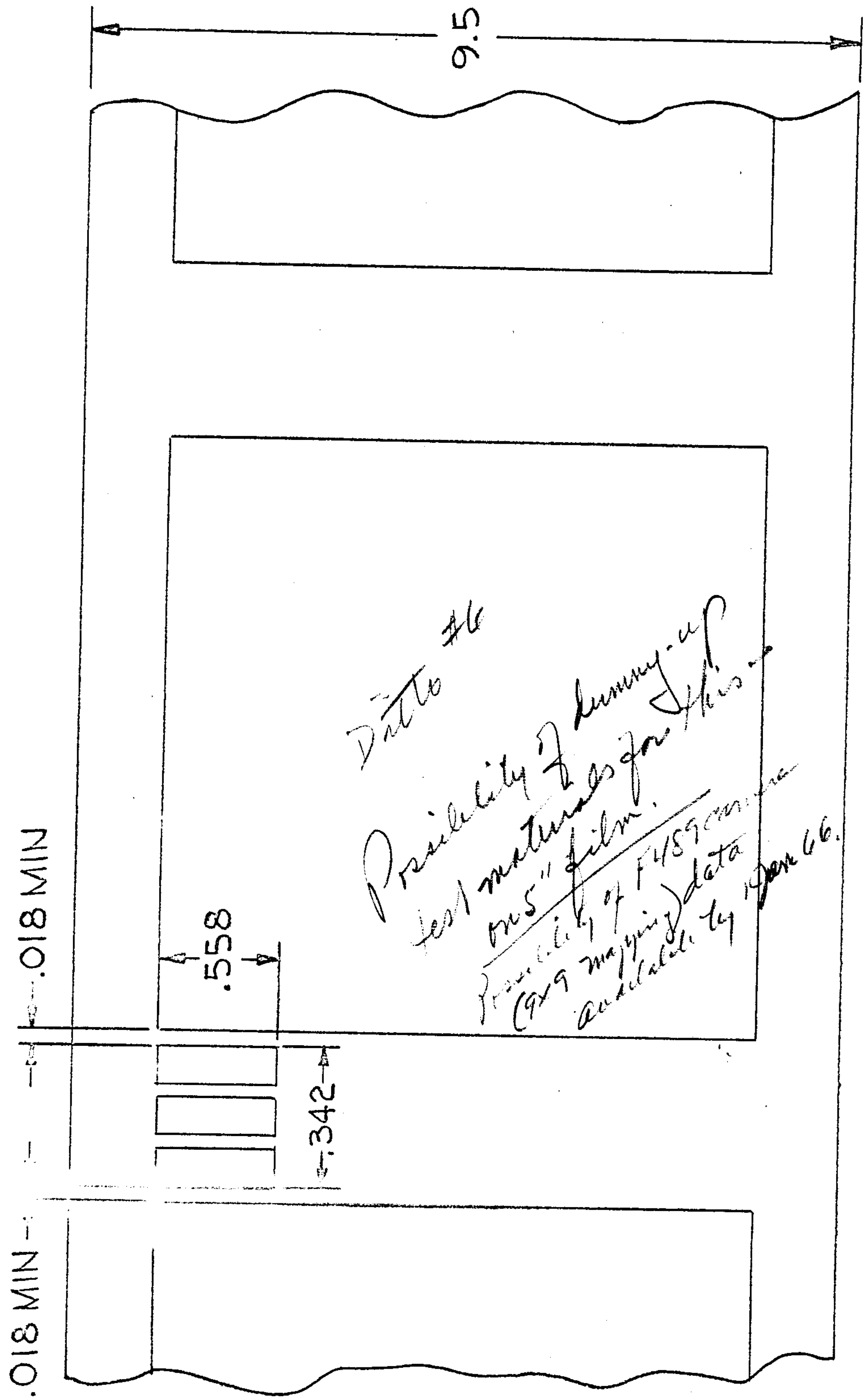

DATA BLOCK TYPE C-2
FIGURE 7

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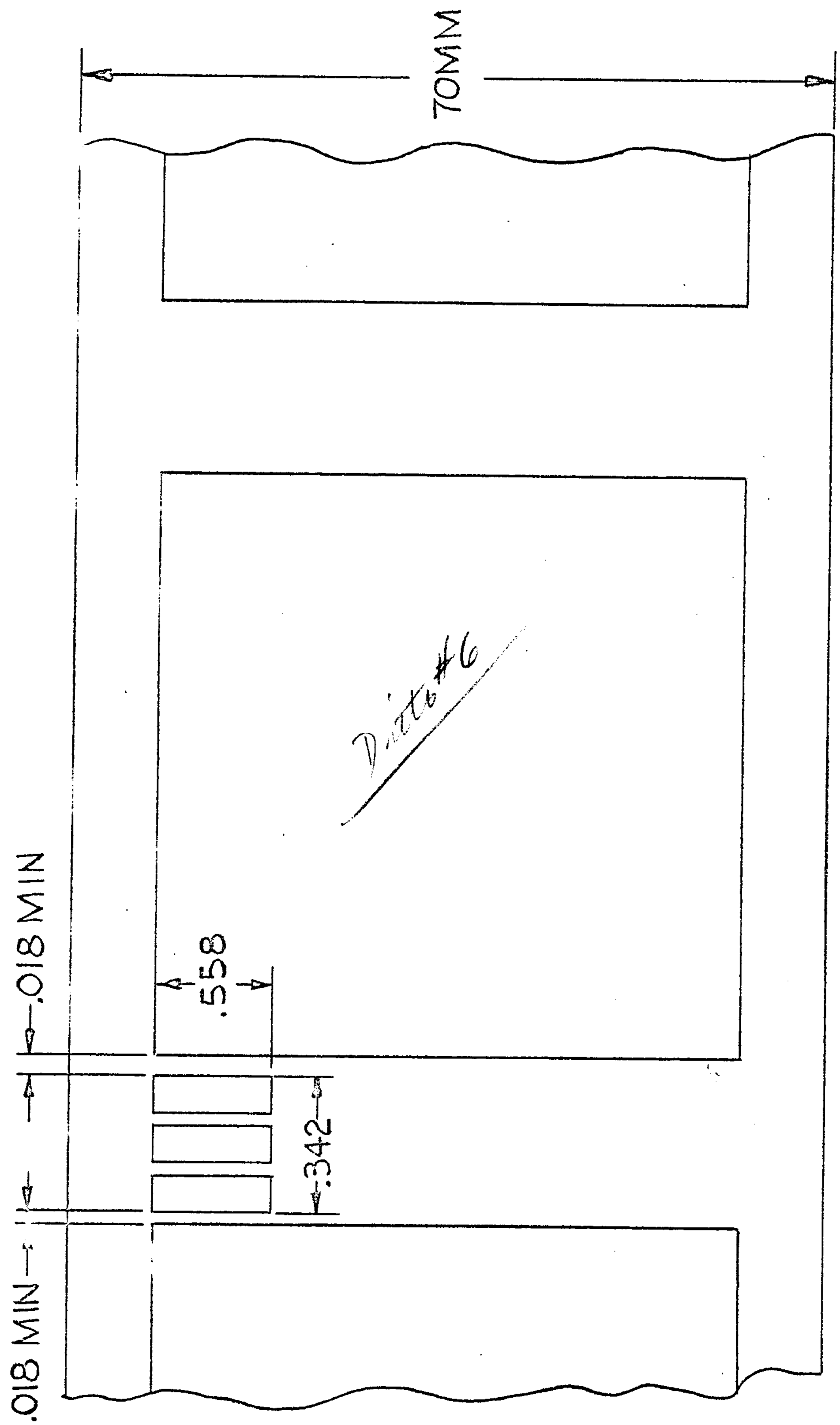

DATA BLOCK TYPE C-3
FIGURE 8

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SECTION 3

FUNCTIONAL SPECIFICATION

all 35 thru 9 1/2.

3.1 FILM SIZE

The data block reader shall accept 35 mm, 70 mm, 5 inch and 9-1/2 inch film.

3.2 CAPACITY

1000 feet maximum, each type.

3.3 FILM SPEED

The film transport shall carry the film at a constant velocity of 60 feet per minute.

3.4 DATA FORMAT

The Data Block Reader shall be capable of locating and reading each of the data blocks as outlined in paragraphs 2.2.1, 2.2.2, 2.2.3 and 2.2.4.

3.5 OUTPUT

3.5.1 ~~Option A~~

The data block reader will supply all of the necessary voltages and command signals required to operate an IBM 514 Model 2 card punch. Cards shall be prepared on a row basis, 2 computer words per row. Data will be punched in the format read from the film, with the exception of type C where the BCD excess three code will be converted to 8421 BCD.

3.5.2 Option B

The data block reader will record the information read from the film on magnetic tape at a packing density of 556 bits per inch. The tape format shall be IBM compatable (6 bits plus parity per character) for direct entry into an IBM computer via an IBM tape recorder. The data will be recorded in the format read from the film on a character basis, with the exception of type C where the BCD excess three code will be converted to 8421 BCD.

3.6 ENVIRONMENT

The unit shall be capable of operating in a laboratory environment whose temperature will be 75°F ± 20°F.

3.7 POWER

The unit shall operate from a power source of 115 V A.C., 60 cycles, single phase.

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SECTION 4

SYSTEM DESCRIPTION

4.1 INTRODUCTION

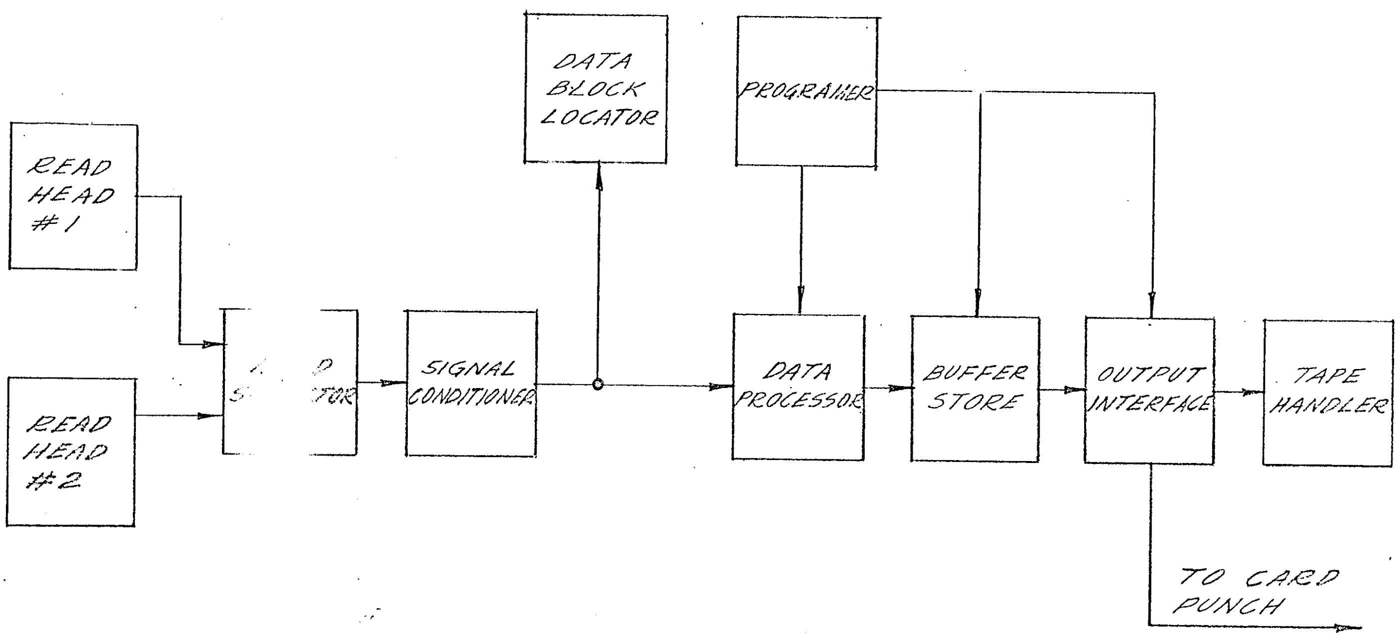
There are three general problems associated with continuous data block readers. The first is that of distinguishing the data block from the picture area when the two are in line with each other. The second is the correction necessary due to the change in position of the data brought about by the film wander and skew in both the camera and the data block reader. The third is the distinguishing of a dot from its background area even though the peak density and the background fog are both independent variables with no relationship to each other.

In most conventional film data block readers these problems are met by physically moving a spot of light across the film and utilizing complex computational techniques for character recognition and wander correction. All use photo-responsive devices, such as photomultiplier tubes, to provide the required signal sensitivity. Movement of the light spot is achieved either by means of mechanical motion or electronically by controlling the beam of a cathode ray tube (flying spot scanner).

The system proposed herein deviates from the conventional in that an array of microphotodiodes will be employed to continuously map the area of the film in question. The only mechanical motion involved is that of a normal transport which reels the film at a constant rate. Film wander is accounted for by making the mapping area larger than the combined wander that can occur in both the camera and the data block reader. Separation of the data block from the picture is accomplished by a separate sensing element which preceeds the read head. The mapping operation occurs only after the sensing element signals the read electronics that the picture has passed and the head is now looking at the area between the picture frames. Signal improvement is achieved by employing integrated circuit techniques in manufacturing the read head and utilizing the uniformity of the signal response of the various diodes.

4.2 GENERAL APPROACH

Figure 9 is a general block diagram of the Universal Data Block Reader. It will be noted that the reader has two heads coupled to one set of electronics. Head number one will be used in conjunction with types A, B and C data blocks. Head number two will be used to read the type D.



BLOCK DIAGRAM
UNIVERSAL DATA BLOCK READER

FIGURE 9

[redacted]

The operator will decide which type of data block is to be read and connect the proper head by means of a selector switch. After loading the film, he will align the read head by means of two magnified hair lines, so that it is oriented in the same direction as the record head was in the camera. This adjustment eliminates the need for accurate positioning of the record head in the camera. He then presses the read button and all functions from that point are automatic.

The data block locator senses that the head is looking at an area between the picture frames. A command is sent to the programmer and the area between the frames is read. After reading the data and arranging it in its proper form, it is stored prior to its transmission to the recording section. The purpose of the storage is to hold the data long enough to perform the recording operation. The output will be in either punch card or magnetic tape, dependent upon customer preference. Should magnetic tape be selected, the unit will contain the required tape transport. Should punched card be selected, the unit will contain the necessary control and drive circuits to operate an IBM 514 Model 2 card punch. However, [redacted] will not supply the punch.

4.3 FILM READER

4.3.1 Film Transport

The film transport system (Figure 10), is designed to accept perforated or unperforated roll film up to 1000 feet in length and in widths of 35 mm, 70 mm, 5 inch and 9-1/2 inch. Film is transported at a constant 60 ft. per minute rate for all sizes. The transport may be driven in reverse for rewind.

The main elements of the film transport system are the supply spool, programmed torquer, supply guide roller, synchronous motor, glass capstan and pressure rollers, take-up guide roller, take-up drive slip clutch and take-up spool.

The synchronous motor drives the glass capstan with its pressure rollers, metering film from the supply spool through the supply guide roller and over the glass capstan. The take-up spool is over-driven by the synchronous motor through the take-up slip clutch to maintain a taut film path from the glass capstan through the take-up roller to the take-up spool.

A constant tension is applied to the film on the supply side of the glass capstan by the programmed torquer on the supply spool. The torquer is

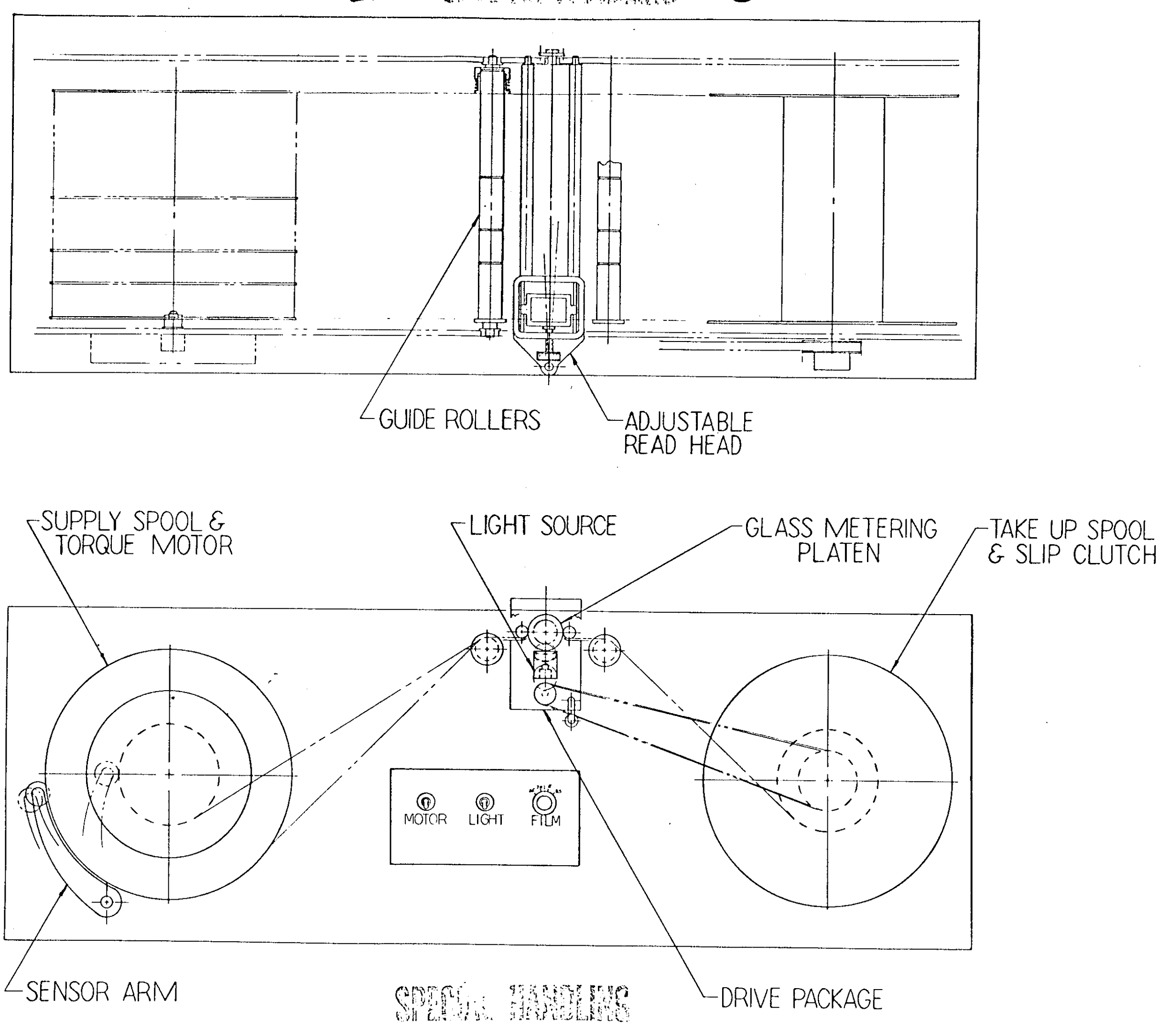


FIGURE 10. TRANSPORT DIAGRAM - UNIVERSAL DATA BLOCK READER

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programmed by a follower arm riding on the supply spool film diameter. In this manner the synchronous motor sees a relatively uniform load once it is up to speed. This assures an accurate uniform film speed for data read-out.

The read head is located above the glass capstan. The supply and take-up guide roller on either side of the capstan edge guide the film in the read-out path by means of an axially spring loaded flange. The spring loaded flange on the guide roller is positioned in any one of four detents to accomodate any one of the four film widths which may be used. The film is illuminated through the glass capstan by a tungsten lamp and a cylindrical condenser lens under the capstan.

For rewind, the synchronous motor is reversed and the torquer over-drives the supply spool to maintain a taut film path. A drag brake is provided on the take-up spool to prevent overspooling.

The reading photodiode array is mounted on the upper arm of a pivoted assembly straddling the glass capstan at the data side of the film. The pivot enables an initial manual setting to compensate for static skew misalignment which is limited to 3° either side of the perpendicular to the guiding edge.

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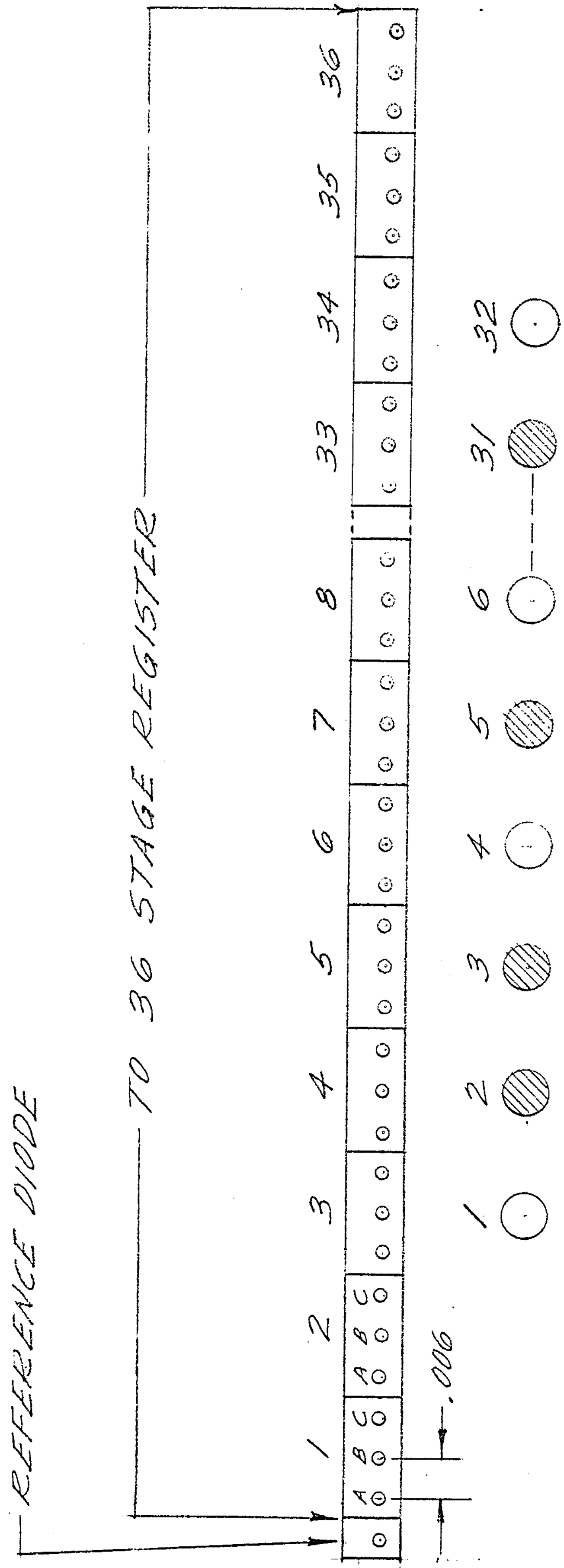
Variations in the skew due to the dynamics of recording are assumed to be within .0025 per inch throughout the entire roll. Dynamic skewing in the reader loop will be held to .001 in. per in. The total dynamic skew of .0035 in. per in. will be accommodated by the photodiode array without requiring motion of the array. The light source together with its cylindrical focusing lens must adjust concurrently with the photodiode array, and so is mounted on the lower arm of the yoke. Both light source and photodiode array will be adjusted linearly along their respective yoke arms by means of a common lead screw to accommodate variations in distance of the data block from the guiding film edge. This will be an initial manual setting with dynamic variations compensated by the electronic reading technique described elsewhere in this proposal. Both the manual skew adjustment and edge distance setting will be facilitated by providing a suitable magnifier and reticle either in place of or adjacent to the photodiode array, and providing suitable illumination for viewing by the operator. These settings should not have to be made more frequently than once at the beginning of each film roll, and possibly less frequently if the conditions are identical between similar recording devices.



PHOTODIODE ARRAY

FIGURE 11

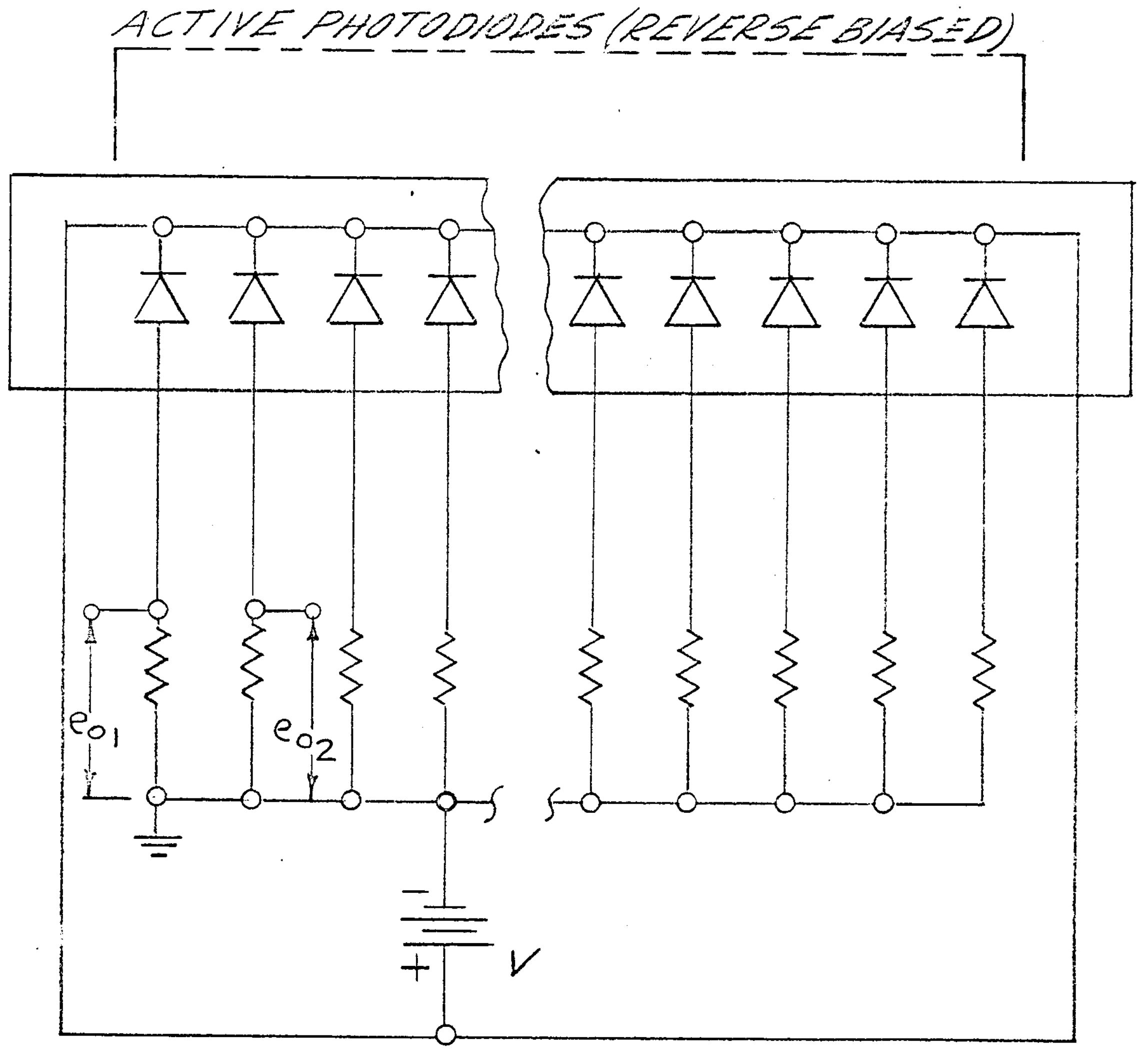
[redacted]

4.3.2 Read Head

The read head consists of an array of silicon photodiodes spaced 0.006 inches apart, see Figure 11. These diodes are photoresponsive devices which are reverse biased and connected to a load resistor, see Figure 12. As the diode is illuminated, photons are absorbed causing the release of current carriers. These carriers are transported across the junction causing a current to flow. Each diode, therefore, acts as a current generator whose output is a function of the light incident on it.

4.3.3 Signal Conditioning

The major problem in detecting the presence of a digital bit, or dot recorded on film is that the background as seen by the diode is foggy, not clear. This foggy background also produces a signal which must be considered as noise. Normally, the output of the read amplifier is connected to some form of biased switch whereby the bias is set above the noise level so that only the true information is amplified. The flog in the film, is not a constant, but varies over the length of the film from roll to roll. The bias, however, is a constant and must be set for the highest level of noise that may be encountered. Therefore, the allowable information window becomes very small and it is possible to lose some data. To avoid this, [redacted] has developed a method where-



SCHEMATIC DIAGRAM
PHOTODIODE ARRAY

FIGURE 12

STATINTL

by the fog signal is subtracted from the head output. The resulting signal to noise ratio is strictly a function of the strength of the information signal relative to the electrical noise in the amplifier.

Through the development of integrated circuits by our Semiconductor Division, it was found that those transistors made on the same silicon chip or wafer had very close characteristics. The same holds true for photo-diodes. If instead of comparing the output of the read amplifier to a fixed bias level, the output of a diode on the same substrate, which is looking at the background only, is subtracted from it, the difference will be the information plus the variation in dark currents of the diodes. Since the diodes are on the same silicon chip, their dark currents will be almost identical. This subtraction is actually made in a difference amplifier whose output is then connected to a switch which is biased to inhibit noise on the voltage lines. The net effect is a read amplifier whose detection reference is dynamically compensated for variations in fog levels.

4.4 LOGIC SECTION

The function of the Logic Section is to accept the signals as received from the read head, recognize when the data has been read, store the data for the

[redacted]

output operation and feed the output media under command of the programmer. To minimize cost and increase reliability this section of the machine will be constructed of [redacted] commercial grade micrologic elements where possible.

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4.4.1 Head Selector

The assignment of the appropriate photodiode array in the read head is dictated by the data format. Data Block types A, B and C share the same photodiode array, since they contain codes of the same dot size, shape and spacing. Data Block type D utilizes a second array, with its photodiodes spaced to coincide with the bit spacing of the type D code.

The operator, by manually setting the format selector switch, will cause the head selector to connect the proper photodiode array to the reader's electronics. This setting is maintained until a reel of a different type is loaded into the reader.

4.4.2 Data Block Locator

As the film is transported, all variations in density patterns are sensed by the read head. These variations may be caused by either the digital data or the photographic frame itself. Therefore, a discrimination process is established, which enables the reader to read the digital data, and ignore all other prographic data. Depending on the data block type, the reader may utilize any of two techniques for the location of the data. The setting of the format selector switch will determine which method is to be employed.

4.4.2.1 Data Block Types B and D

In these types, the digital data is recorded in the horizontal margin and is not intermixed with the frame patterns. Therefore, the area between data blocks is of an even density. However, due to the unavoidable film

.03125 = ± 1/32

wander of ±.030", the read head has to be at least .060" wider than the data block. Consequently, part of the head may cover a portion of the picture area. Thus, a dark pattern in the lower portion of the read head does not necessarily consitute digital data.

The locating of block types B and D is performed by searching for the first bit of the index row. Since the nominal distance from the edge of the film to the index or clock bits is known, a portion of the head .030" wide on either side of this position is assigned as a search window during the locating mode. The first dot detection by this window will establish the beginning of the block and switch the reader out of the locating mode and into the read mode. The unit will automatically switch back to the locating mode after the block reading has been completed.

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4.4.2.2 Data Block Types A and C

In these types, the data is recorded vertically in the interframe space. The gap between data blocks is of variable density and therefore, the locating method described previously is insufficient. Since data blocks type A and C are always preceded by a uniform density area which under worst case conditions (type C-1) is at least .018" wide. The locating procedure will be inhibitted until this area is found.

The locating procedure for types A and C is accomplished in two steps. First, the uniform density area is found, and then the index bit of the data block is located.

To detect the uniform density area, a split photodiode array is mounted .010" behind the reading array. The length and the vertical position of this array is such, that with maximum film wander in either direction part of it will always scan the picture area and the other part will always scan the margin. When the sensing array is over the picture area the two sections will always have different outputs. However, when the array is positioned over the inter-frame area, the outputs will be identical. At this time the reading array will also be in the uniform density area since it preceeds the sensing array by .010". The fact that the two outputs are identical will be detected and used to switch the unit over to the data block location routine. This routine will be identical to that outlined in paragraph 4.3.2.1 for types B and D.

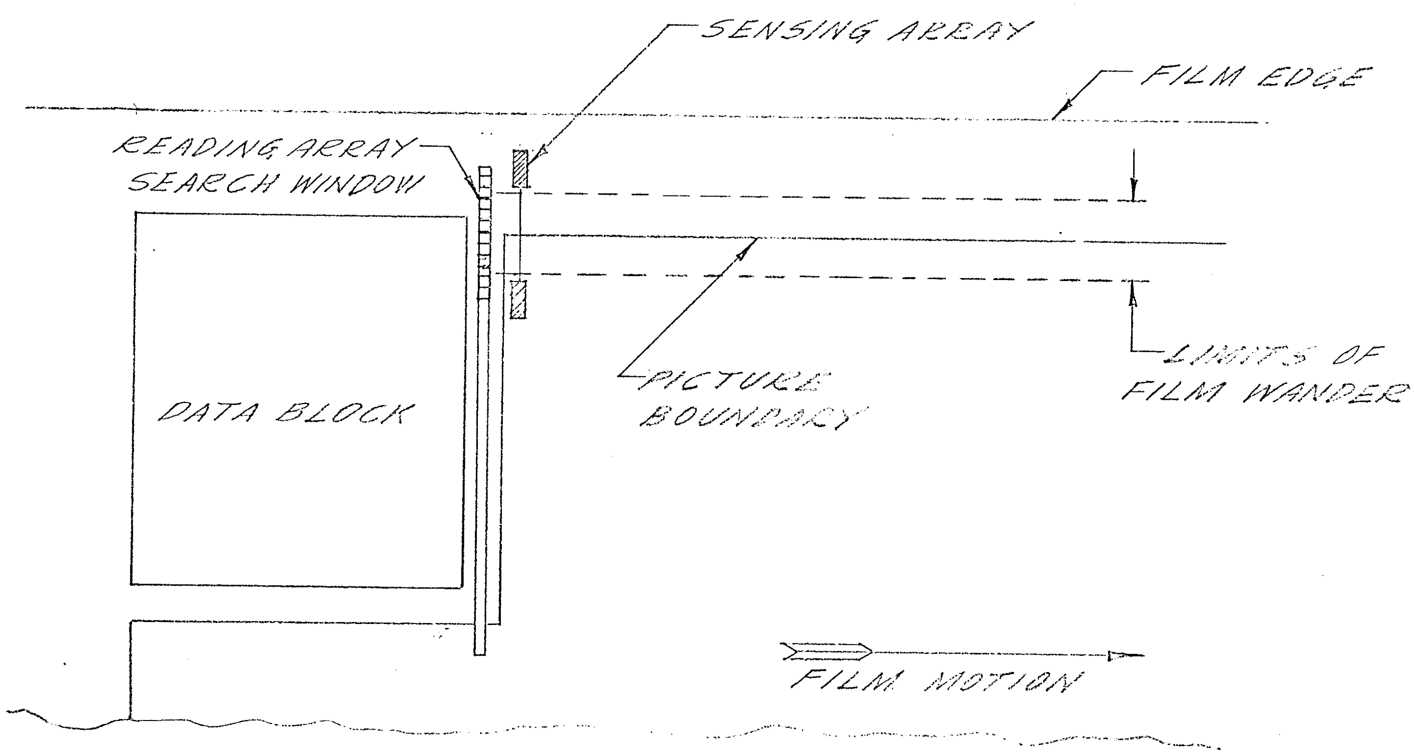
Figure 13 shows the relationship between the sensing array, the search window and the film format. Data Block type C-1 is shown in this example.

4.4.3 Data Processor

Once the data block is located, the reading head will provide the reader electronics with electrical signals corresponding to the data pattern. These signals, are forwarded as outputs of the individual elements of the photodiode array and have to be segregated and organized before they can represent the coded data.

The analysis and organization of the head output patterns will take advantage of the fact that the recorded data has a fixed geometry and that the tolerance between the silicon light pulsers which recorded the data and the photodiodes in the read head can be kept under .0003".

As shown in Figure 11, the photodiodes in the read head are spaced .006" apart, while the recorded bit spacing is on an .018" pitch. Each bit spacing



BLOCK LOCATING ARRAYS

FIGURE 13

is, therefore, covered by three diodes. The diodes are grouped in three sets - A, B and C, creating three separate heads physically interlaced with each other. Due to film wander, the distance of the index bit from the edge of the film is a variable, and therefore it may be read by any one of the diodes of the three groups. Because of the accurate matching of the read and record heads, once a diode from a particular group in the search window detects an index bit, the remaining diodes of that group will read the other corresponding bits.

The read head consists of 108 diodes (36 bits x 3 diodes/bit), while the maximum data block contains 32 bits, requiring only 96 diodes. The remaining 12 diodes cover an additional .072" of film, insuring coverage of the block under maximum film wander condtions. However, since the head is wider than the data, the index bit will not necessarily be encountered by the first bit position of the head (diodes A1, B1, C1). Actually , it could be detected by any of the first 12 diodes (A1, B1, C1 through A4, B4, C4). The data is, therefore, transferred into a register, where it is shifted in the direction of the index bit until the first stage of register contains a dot. By definition, the index bit is always the first dot recorded in every line of data. The shifting operation, therefore, always places the index bit in position "1" of the shift register, which in turn places the data bits in positions 2 through 32. Figure

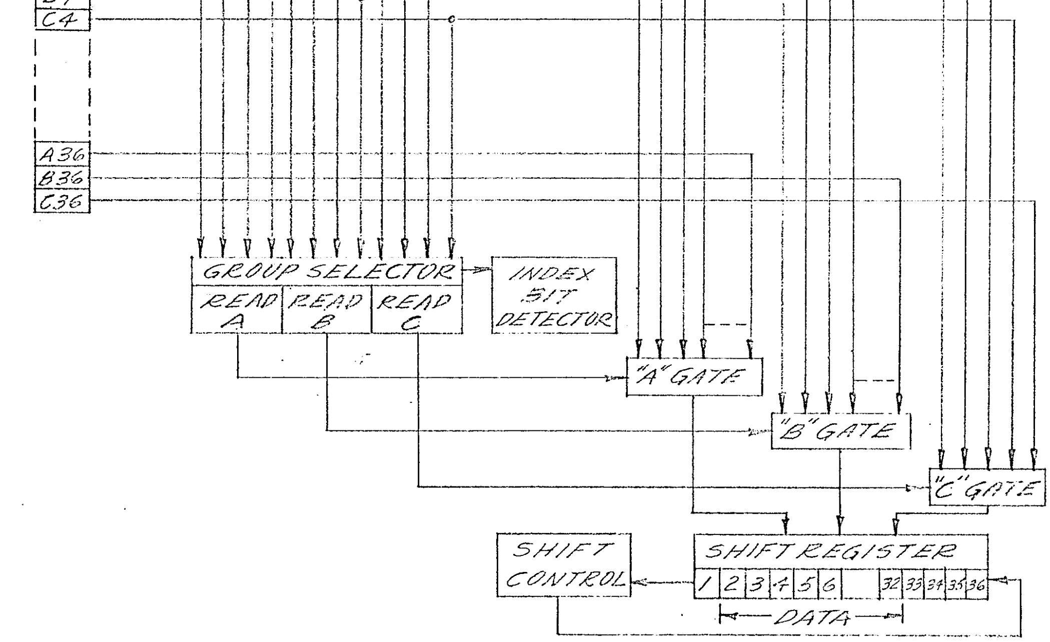
14 shows in block form the selection of the proper photodiode set, and the data flow from the read head into the shift register.

4.4.4 Buffer Store

The bits within the data block are recorded in a small area, while the blocks throughout the film are scattered. As a result, the data within the block is retrieved during 10% of the time, whereas no reading is performed 90% of the time. The buffer store will accept the data at the fast retrieval speeds, and forward it to the output device at lower speeds during the inter-block gap period. This enables efficient utilization of medium speed output devices, as opposed to 10% utilization of very high speed output devices which would be required without the buffer store.

The data will be transferred from the shift register into the buffer store one line at a time under control of the programmer. During the transfer the data will be rearranged to conform with the format of the output device. The required amount of storage will vary according to the type of output device used with the reader, and designed to accomodate the outputing of the largest block read by the system, namely block type C.

If the output is selected to be punched cards, the storage will contain 780 bits. For magnetic tape, only 380 bits of storage are required.



LOGIC DIAGRAM-DATA ORGINIZATION

FIGURE 16

4.4.5 Programmer

The programmer is the control section for the entire operation. Since four different data types are to be read, the programmer will contain four different wired programs. Selection of the proper program will be automatically made when the operator depresses the format selector switch on the control panel. The control functions which the programmer provides, include, control of the wander correction logic, transferring the data from the input register to the buffer store, formatting the data in the store, sequencing the data onto the output lines, signalling the output recorder that the information is present and supplying the output media with any special command required for format and control (end of record, inter-record, card advance, etc.).

4.5 OUTPUT

Two options are proposed for the reader's output. The system will be designed to operate with one option only, as chosen by the customer.

[illegible] [illegible]

Under this option the output medium will be punched cards. Two computer words will be punched in every row of the card. The data will be punched in the

[redacted]

format read from the film, except in the case of block type C where the BCD excess three code will be translated into 8421 BCD. Wherever parity exists in the data block format, it will be checked when the data is transferred from the buffer store to the punch drivers, but will not be punched on the card.

The output equipment used will be an IBM 514 Model 2 card punch, which is capable of punching 100 cards per minute. The card punch will not be supplied as part of this system. All necessary electronic interface equipment will be supplied by [redacted]

4.5.2 Option B - Magnetic Tape

Under this option the output medium will be magnetic tape. The data will be recorded on 1/2" magnetic tape at a packing density of 556 bits per inch.

[redacted]

BCD excess three code will be translated into 8421 BCD. The parity bits required by the tape format will be generated for all data block types. The original parity bits will be used for validation of the reading process, then stripped out of the code, and a new parity bit generated to conform with the magnetic tape format.

The tape recorder used will be a Cook Electric Model 150 incremental recorder or equivalent. The tape reel will be 10-1/2 inches in diameter with hubs compatible with IBM equipment.

SPECIAL HANDLING
Approved For Release 2002/06/17 : CIA-RDP78B04747A001500040012-9