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FILM DENSITY ANALYZERS FOR INFRARED INVESTIGATIONS

January 1968

Prepared by the U. S. Geological Survey for the National Aeronautics and Space Administration (NASA) under NASA Work Order No. T-65754-G

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON, D.C. 20242

Interagency Report
NASA-94
January 1968

Mr. Robert Porter
Acting Program Chief,
Earth Resources Survey
Code SAR - NASA Headquarters
Washington, D.C. 20546

Dear Mr. Porter:

Transmitted herewith is one copy of:

INTERAGENCY REPORT NASA-94

FILM DENSITY ANALYZERS FOR

INFRARED INVESTIGATIONS*

by

Robert M. Turner**

and

George R. Boynton**

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Sincerely yours,

William A. Fischer
Research Coordinator
Earth Orbiter Program

*Work performed under NASA Work Order No. T-65754-G
**U.S. Geological Survey, Washington, D.C.

UNITED STATES
DEPARTMENT OF THE INTERIOR
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This report is preliminary and has not been edited or reviewed for conformity with U. S. Geological Survey standards.

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PREFACE

This analytical report by members of the Geological Survey Infrared Laboratory was the result of work conducted in support of infrared instrument investigations funded by the NASA Manned Spacecraft Center, Houston, Texas. These investigations are primarily directed toward infrared imaging scanner systems but also include ancillary ground monitoring, data handling and interpretation equipment. Their purpose is intended to support other Applications Program tasks by providing background information on instrumentation and techniques of operation and interpretation. The infrared image was provided by the United States Air Force.

INTRODUCTION

Images produced by infrared scanners at the present state-of-the art are not quantitative. However it is highly desirable to have some means of objectively assessing image density, which in turn is related to terrain radiance. Recording microdensitometry is a useful technique for this purpose.

This report describes some of the modifications that have been made to a Joyce-Loebl Microdensitometer-Isodensitracer (MDT-IDT) to adapt it to our special needs. We have also examined briefly the Tech/Ops image quantizer and an example of the results is given.

THE JOYCE-LOEBL MDT-IDT

The Joyce-Loebl MDT-IDT is used primarily to analyze images generated by an aerial infrared scanner (fig. 1). The MDT-IDT produces a map of the IR film density, wherein density levels are indicated by appropriate symbols, either space, dot, or dash (fig. 2). It is convenient to consider the boundaries of density levels as contour lines. The MDT-IDT offers several advantages in image analysis. It quantizes density levels and variations in level by direct comparison against a standard density wedge. This avoids the usual errors connected with subjective visual comparisons and allows accurate correlation of density over wide areas. Moreover, by proper choice of contour interval, small scale variations in density can be enhanced. These maps are easily reproduced as illustrations or slides, avoiding problems of tonal value distortion in reproduction, or in viewing, the original film. As a derivative of the original imagery, it allows an unclassified presentation of data that might otherwise be classified.

The following discussion assumes that the reader has some working knowledge of the Joyce-Loebl MDT-IDT.

The IDT color attachment

The MDT-IDT in conventional operation generates a black and white map using only three symbols -- space, dot and dash. Where density gradients are steep or rapidly changing, we found the 3-mode black and white map difficult to interpret. An attachment was developed which divides the density range into seven color-coded divisions[1/] (fig. 3). The system employs seven lights (one for each division) placed along the path of the microdensitometer pen (figures 2,3,4). A photocell attached to the microdensitometer pen allows the isodensitracer to record only when the photocell is in the light path. Using the number 12 pen encoder (commutator) provided with the instrument, the full scale range gives 21 different density increments (seven major divisons each with a space, dot and dash pen mode). In order to give each major density division a color, it is necessary to make a separate run over the entire area for each division. When one run is completed, that light is turned off, the neighboring one turned on, and the next run is made, and so on. The biggest problem which arises is to keep the datum constant since it will take up to seven times longer to obtain the complete density map.

Construction of the IDT color attachment

The color attachment consists of (a) a bank of lights (placed along the path of the MDT pen); (b) a photocell (attached to the MDT

1/ A four-color IDT is now available commercially.

pen arm and scanning the lights); (c) a relay (which is controlled by the photocell and which allows the IDT circuit to print the dot or dash corresponding to the commutator position); and (d) a power supply for the light compartments, photocell, and relay (fig. 4).

The light bank is a box, fabricated from 1/16" aluminum, with a length equal to the full traverse of the MDT recording pen arm. The box is divided into seven compartments (fig. 5). The width of each compartment matches that of a major density division (2.75 cm.); the compartment opening corresponds to the dash and dot modes (1.84 cm.) and the compartment divider to the space mode (0.919 cm.). The dividers are aluminum strips cut 0.9 cm. wide and epoxied over the compartment separators. Since the dividers coincide with the space modes, they can be made slightly narrower than the mode width. This allows some adjustment to align the compartments with the corresponding mode positions.

Inside each light compartment are two lamps (Sylvania 120 PSB in socket BO 151). For each compartment there is a separate lamp switch mounted on top of the chassis.

The photocell is an RCA type 7412 oriented with the sensing element vertical and placed in a cylindrical housing. The housing end is masked to form a vertical slit which coincides with the photocell element (fig. 6). In our prototype we used a section of ballpoint pen case, with a slitted bakelite disc glued on the end. The photocell is mounted on the MDT recording pen arm (by a "Dial-lite" spring clip) so that it scans successive lamp compartments as the pen moves. The separation between the photocell and the light bank should be as small as possible to prevent the photocell from seeing light spillover from adjacent compartments and to reduce sensitivity to ambient light.

The power supply voltage to the photocell and relay is adjusted so that the relay closes when the lamps are lit. This voltage will range from 20-30 volts (fig. 7).

The power supply and photocell relay are mounted above the light bank on the same chassis. The control switches on top include the individual compartment light switches, a main switch for all compartments, and a switch (DPST) to bypass the photocell relay and allow normal IDT operation (printing all modes).

The mounting bracket is bolted to the MDT by means of the head housing bolts along the left side (fig. 4). The bracket holes are oversize slotted to allow movement of the light bank for proper alignment.

Recording procedures

The general procedure for making a color isodensity recording is as follows:

The MDT and IDT are turned on (following the instruction manual) except for the pen drive switch on the IDT. The mode switch ("auto-normal") on the IDT console must be in the "normal" position. The pen drive is not turned on until the commencement of zeroing operations. Warm-up time must be at least one hour to minimize zero drift of the instrument during actual recording operations.

During this time the sample is placed in the sample tray and oriented as desired. With normal photographic transparencies the orientation is not critical, but for transparencies with raster lines (e.g. IR images) the lines should be perpendicular to, or at 45° to, the direction of table travel. The 45° orientation allows the MDT to integrate the raster lines to produce a smoother record but some loss of detail results. Usually the shape of the desired sample area and the required resolution favor the perpendicular orientation.

The selection of the scanning aperture size must consider several factors: the spacing, density and contrast of raster lines or emulsion grain, the IDT scan line spacing (which depends on magnification and resolution) and the required sample resolution. Integration of pronounced grain or raster lines requires larger apertures with resulting loss in spatial resolution. Here some compromise must be made.

The ratio arm setting is selected on the basis of the magnification desired and the size of the sample area. This setting determines the relative travel of the sample and recording tables (table 1).

IDT recordings of larger sample areas can be made as a series of separate, overlapping records which are then pieced together as a mosaic This method usually does not prove practical for magnifications over 10X owing to inaccuracies caused by cumulative errors that make matching difficult.

The scan line interval must be chosen so that the ratio of the sample scan interval to the recording scan interval is the same as to the ratio arm setting. This gives equal magnification perpendicular to the scan lines as well as parallel to them. The sample scan interval should be adjusted relative to the aperture size so as to give sufficient scan overlap to insure lateral scan integration comparable to that in the direction of the scan lines. Overlap should be on the order of 25% to 50%.

The specimen drive is then disengaged and the density range of the desired sample area is determined by measuring the greatest and least densities of the film. The reference wedge with the least slope that will allow these densities to be reproduced will give the greatest detail. If great detail of a small portion of the film density graident is wanted (for example, low contrast anomalies against a high contrast background) a wedge is selected to reproduce that smaller density range. Density values outside of this range will consequently not be reproduced.

Table 1. Relative table travel

Ratio Arm Setting	Maximum Scanned Length		Maximum Scanned Width	
	Sample Table	Recording Table	Sample Table	Recording Tabl
1	10 in.	10 in.	8 in.	8 in.
2	5 "	"	4 "	"
5	2 "	"	1.6 "	"
10	1 "	"	0.8 "	"
25	0.4 "	"	0.32 "	"
50	0.2 "	"	0.16 "	"

The reference light beam and specimen light beam must be matched in intensity. The intensity of the specimen light beam depends on the effective scanning aperture and the background density of the sample. The reference light beam is adjusted by the insertion or removal of neutral density filters. In the case of large specimen apertures and/or extremely low specimen densities, a neutral density filter may be required in the specimen light beam. The "Pen Zero" control is then used to bring the MDT recording pen on scale so that the lowest density is on scale at some low value. If several records are to be made which must have the same relative density values, the sample is shifted to one side and a standard film reference with a density close to that of the least dense area of the sample is inserted into the sample light beam. The pen zero is then manually set to the closest point (in the lowest division of the samples density range) where there is a change in pen mode. This value is recorded on a sheet of MDT profile paper to be used as a zero point check. The sample is replaced and checked to make sure the greatest and least density values desired are still on scale.

The first line of the sample is then run as an MDT profile on a second sheet of MDT paper. This MDT profile will serve as the zero line profile to be rechecked at the beginning of each color run. Use of this zero line profile offers several advantages. Reproducibility of the zero line profile depends directly on the constancy of mechanical linkages as well as electrical factors and gives positive evidence of any shifting of the sample, linkages or electrical balance. The length of the zero trace minimizes any errors caused by pen tracking error. Use of the sample zero line instead of the film reference avoids excessive sample manipulation and thus minimizes chances of linkage shifts. In practice, several copies of the zero line profile are made so that a copy can be retraced for comparison before each run and one copy can be filed with the finished recording. The major color divisions may be recorded in any sequence. It is sometimes helpful to record first the density divisions containing the critical areas to make sure the contour interval and position chosen accentuate the desired features. Since the contour intervals are fixed by the MDT reference wedge, the position of the contour lines (as indicated by the "break points" of mode change) relative to the density gradients of the sample are variable by means of the pen zero control (another advantage to having the zero line profile). Any shift of the pen zero control cancels the previous alignment of the standard film reference with a point of change in pen mode. It is difficult to find a new standard film reference which corresponds to the new mode change point. It is better to draw a new MDT zero line profile to be used in zeroing operations. The displacement of the new zero line profile shows exactly the amount of pen zero shift and allows the original setting to be recovered if desired.

Each major density division is then run with its separate light and color. At the start of each color run the zero line profile is drawn and compared with the original profile. Any zero drift is corrected and the first IDT lines are run as specified for alignment check. Electronic shifting of the zero point shows as a vertical displacement of the entire zero line profile, and can be corrected by adjusting the pen zero control.

The IDT table is then inserted and the table stop adjusted to limit table travel to the scan length desired. The sample and recording tables are set at their starting points, a pen of the desired color is inserted in the recording pen carriage, and the first several lines are run with all the division control lights on, so that the complete density range of the lines are recorded. These lines serve as an additional check for alignment of succeeding runs. If the detail recorded along these lines is too complex, only one or two lights are turned on to give clearly defined patterns for checking alignment. The same lights must be used each time alignment is checked.

The complete run is then made with only the desired density division light on and the corresponding color pen installed. Red is usually used for the density corresponding to the highest temperatures. The complete recording will be a contoured density map of the sample with color-coded density increments. It is helpful to make MDT traverses to provide profiles through important areas of the recording. These can be correlated to the IDT recordings by reporting the scan line number as shown by the sample table counter.

THE TECH/OPS IMAGE QUANTIZER

Isodensity maps have also been made with the Tech/Ops Inc. image quantizer. This is a facsimile recording-type machine with specimen film and recording paper attached to a rotating drum. A light beam, either reflected or transmitted, is detected by a photomultiplier. Recording is by an electrical signal impressed on a stylus in contact with sensitized recording paper.

The image quantizer has four density modes which are printed as white, light grey, dark grey and black. The total density range and density increments are adjustable by steps. The minimum scanning aperture of 100, lack of magnification, and the single color printing make it somewhat inflexible for our purpose. However, it has the distinct advantage of rapid recording. An isodensity map of Balayan Bay, Philippines made by the image quantizer is shown in figure 8.

Figure 1. Infrared image of Balayan Bay, Luzon Island, Philippines.

Figure 2. IDT black and white density map of figure 1.

Figure 3 IDT color density map of figure 1.

To acquire color copies of figure 3 (IDT color density map of infrared image of Balayan Bay, Luzon Island, Philippines), requests should be made to the U.S. Geological Survey Library in Washington, D.C. The reader will be provided with inner negatives for printing and with names of color processing firms equipped to produce quality prints.

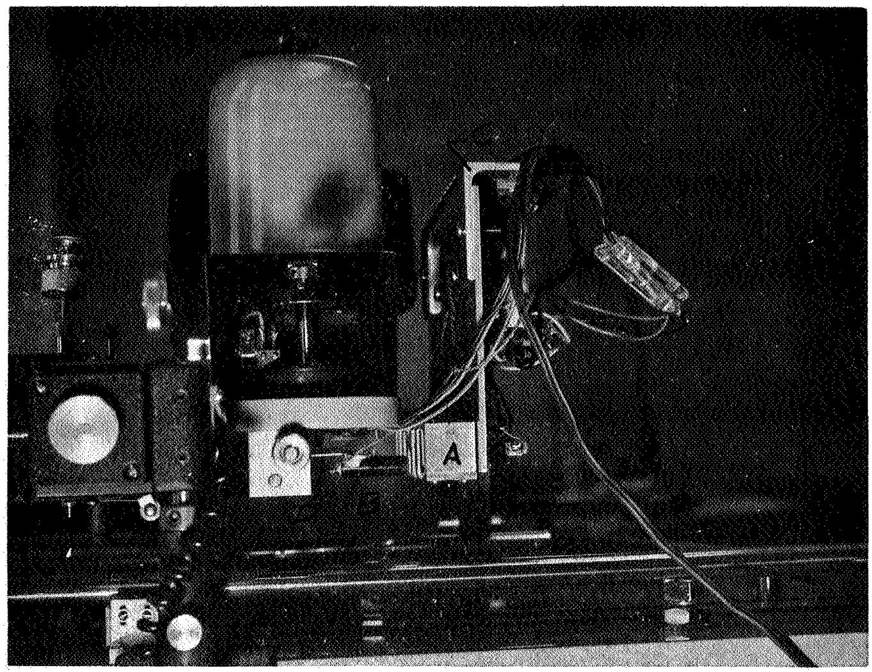

Figure 4A Rear view of MDT showing color attachment:

A - light compartments

B - photocell housing

C - chassis

D - "dial-lite" spring clip attachment to recording pen arm

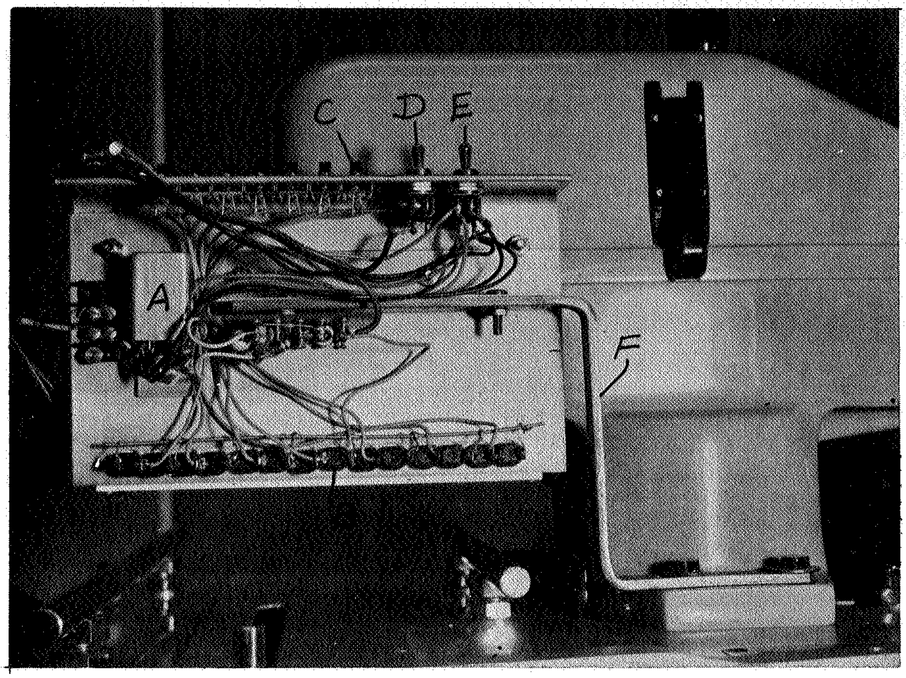

Figure 4B Side view of MDT showing color attachment:

A - photocell relay

B - lamp socket

C - light compartment switch

D - main light switch

E - photocell circuit bypass switch

F - mounting bracket

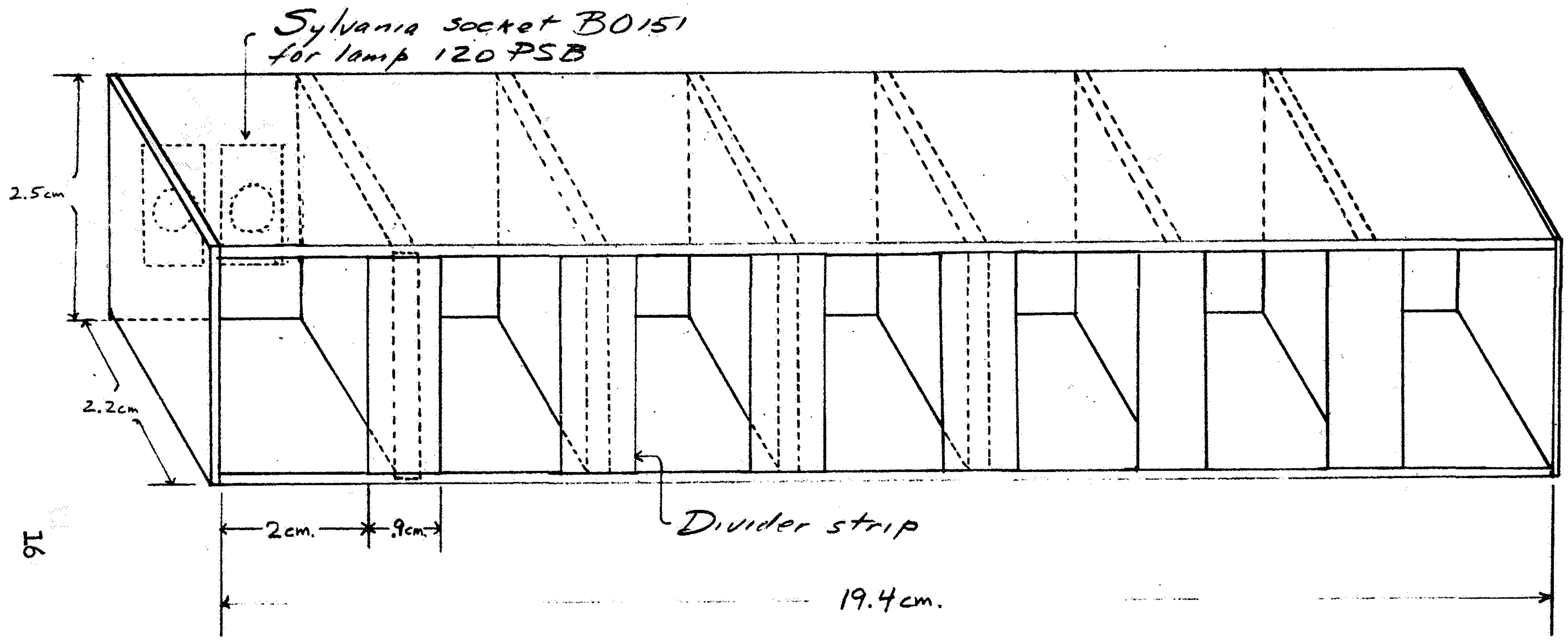

Fig. 5 Details of light compartment

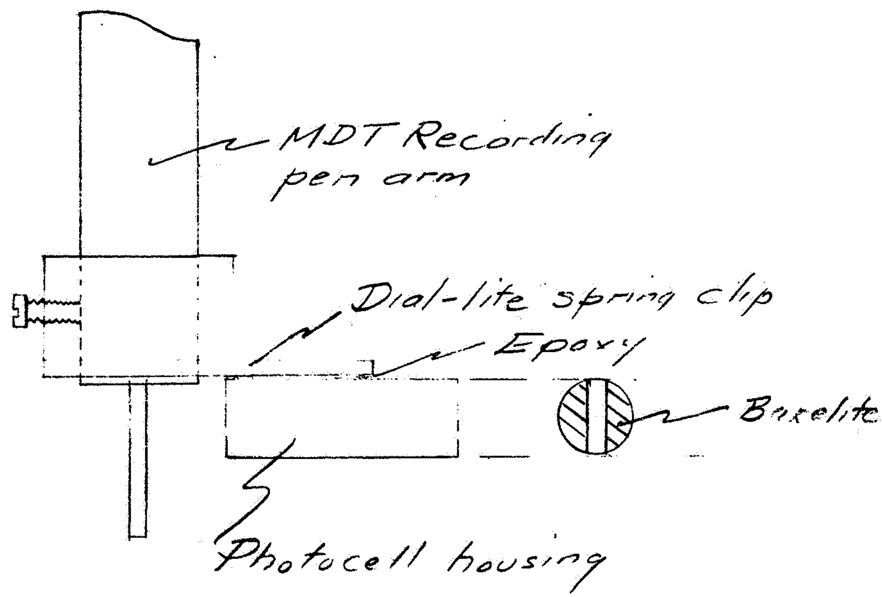

Fig. 6. Details of photocell housing
and attachment

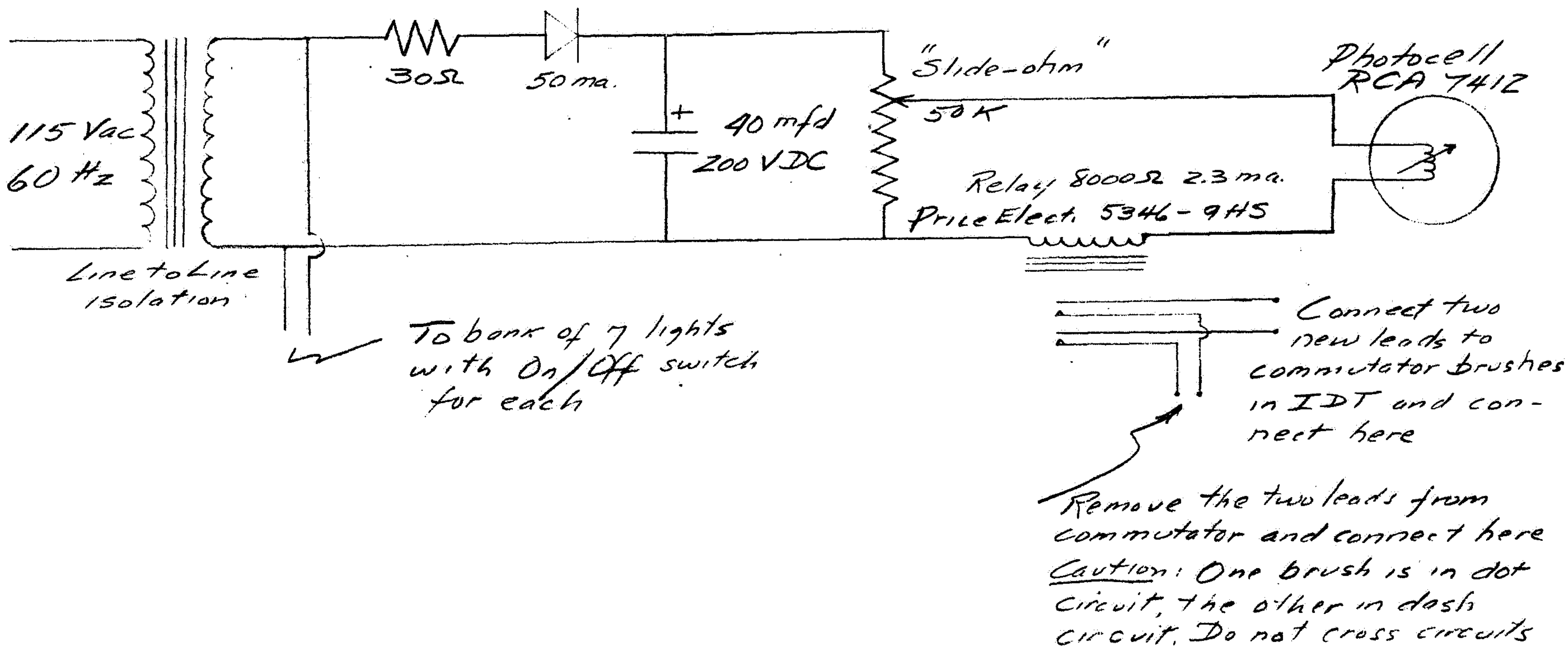

Fig. 7. Wiring diagram

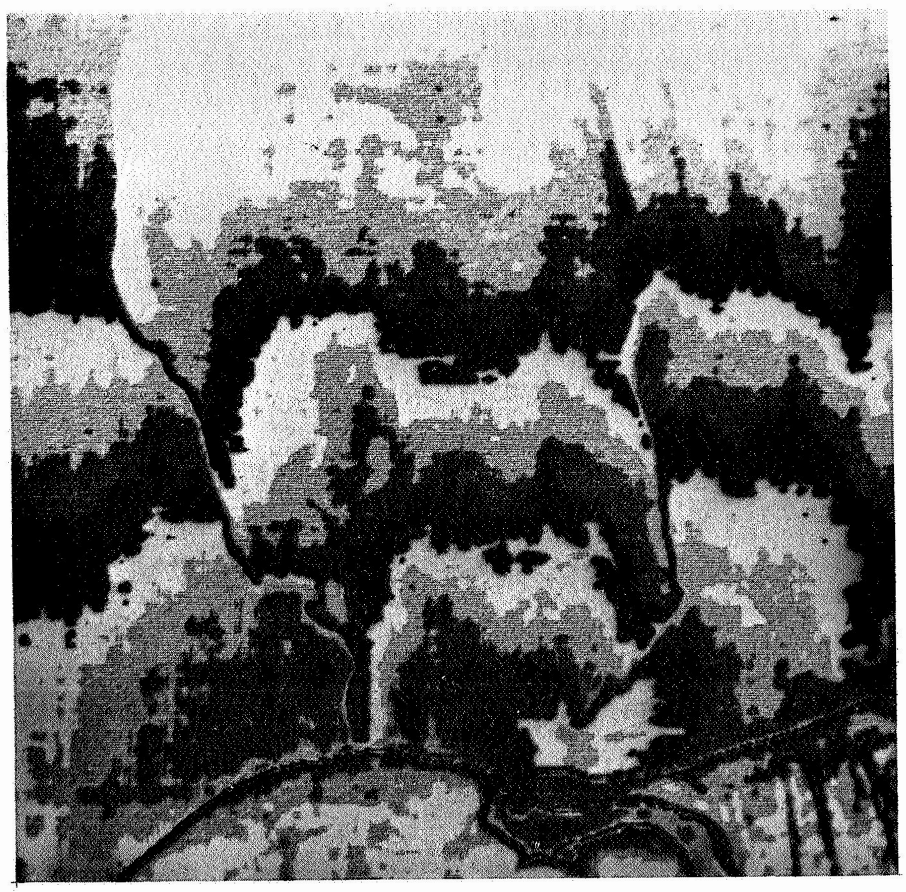

Figure 8. Tech/Ops density map of figure 1.