TECHNICAL INFORMATION ON A RECTILINEAR SCANNER FOR DETERMINATION OF BONE MINERAL CONTEN

by

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In a previous report (1) the operation of a recently constructed rectilinear scanner for use in the photon absorptiometric determination of bone mineral content was discussed. With this scanner an area of 15 cm x 15 cm can be scanned in a raster pattern with a scanning speed of 2 mm/sec in the "y-direction". Stepping increments in the "x-direction" can be 0.71, 1.38, 2.71, 5.38 or 10.73 mm in length at a speed of 0.62 mm/sec. The stepping motor can also be operated continuously at either 0.62 or 1.25 mm/sec for bringing the scanner to the desired scanning site. A photo of the completed scanner is shown in Figure 1.

This report includes the mechanical drawings and electronic schematics which were used to construct the scanner and the electronic control system. A set of these drawings has also been sent to the Division of Technical Information of the U.S. Atomic Energy Commission. Also included in this report are some technical notes describing those drawings and explaining the details of construction and some suggestions for improvement of the original system.

Construction Drawings

Figures 2 and 3 are isometric projections of completed sections of the scanner. The support roller for the scanning assembly referred to in Figure 3 was added to counteract the torque loading of the ball-bushings due to the detector assembly. This torque produced an unsteady scanning motion, which was markedly improved by the addition of the support roller. In what follows that part of the scanner shown in Figure 3 will be termed the linear scanning system (LSS).

The scanner base plate is shown in Figure 4. The dowel pins referred to were found to be unnecessary and were not used. Also shown in Figure 4 is the lead screw for moving the LSS during the stepping operation. The ends of the screw on each side of the threaded section were machined to mate with the ball-bearings used to support the screw in the scanner end plates.

The LSS is supported by the lead screw and the guide rod, which are fastened to the scanner end plates (Figure 5). Similarly the source and detector system moves along guide rods supported by the scanning platform end plates (Figure 6). Since this pair of guide rods must be parallel as well as the lead screw and guide rod supporting the LSS, both pairs of end plates must be machined as a set. The dowel pins referred to in these drawings were also found to be unnecessary.

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The carriers to which the LSS are attached are shown in Figures 7 and 8. The carrier in Figure 7 has been designed to house a 1/2-inch I.D. ball-bushing, while that in Figure 8 houses the lead nuts (also shown in Figure 8), which are threaded onto the lead screw and pressed into the carrier. A similar set of carriers for the source and detector system are drawn in Figure 9. These house 3/8-inch I.D. ball-bushings.

The platform which attaches the LSS to the stepping mechanism is shown in Figure 10. The scan motor, drive belt pulleys, and idler are also mounted on this plate.

Electrical Schematics

Figure 11 is the schematic of the power supply for the scanner. Since this is a hybrid control system consisting of relays, discrete electronics, and integrated circuits, many voltage levels were required.

Automatic control of the scanning and stepping operations during a measurement is achieved with the electronics diagrammed in Figures 12, 13, 14 and 15. The circled numbers, e.g. (5) refer to the pin number on the plug which connects the control system to the scanner. Relays GR1 and GR2 are DPDT general relays with 5000 ohm coil resistance and 2.8 mADC activating current. Relays LR1, LR2, LR3 and LR4 are 6PDT latch relays with latch coil resistance of 200 ohms and reset coil resistance of 275 ohms. The operating voltage of these relays is 26.5 VDC.

The truth table for the J-K flip-flops (Figure 12) is as follows (2):

t_n		t_{n+1}	
S	C	Q	$\bar{Q}$
1	1	Q_n	$\bar{Q}_n$
1	0	1	0
0	1	0	1
0	0	$\bar{Q}_n$	Q_n

where t_n is the time period prior to the negative transition of the clock pulse at T (terminal 2) and Q_n is the state of the Q output (terminal 10) in the period t_n. In this application the flip-flops are operated with the S and C inputs grounded such that the Q output alternates between 1 and 0 after each negative transition of the clock pulse.

The following is the sequence of operations that occurs assuming that the scanner is just completing a scan in the forward direction.

1. The scanner activates the Front Scan Limit Switches (FSLS)#1 and #2 (Figure 13).
   a. FSLS #1 energizes the latch coil of LR1 reversing the direction of the scan motor (Figure 14).
   b. FSLS #2 energizes GR1 which then energizes the latch coil of LR2.

2. Contacts on LR2

   a. Remove the 110 VAC from the scanning motor and apply DC for dynamic braking (Figure 14).

   b. Remove the DC braking from the stepping motor and apply 110 VAC (Figure 15).

   c. Remove the 3 VDC from the C_D input of the flip-flops enabling them to begin timing, clocked by the Schmitt Trigger connected to the T input of the first flip-flop (Figure 12).

3. When the Q output of the flip-flop selected by the "Step-Length" switch changes from the 0 to the 1 state, GR2 is energized (Figure 12).

4. GR2 energizes the reset coil of LR2, thus reversing all of the conditions established in step 2, resetting the Q outputs of the flip-flops to the 0 state, and beginning the next linear scan in the reverse direction.

When the scanner contacts the Rear Scan Limit Switches all of the above operations are the same except that stated in 1a. In this case it is the reset coil of LR1 which is activated.

<u>Suggested Improvements</u>

In the process of making this system operable it has become apparent that the major improvement which could be made in the existing control system is the replacement of the relays with solid state switching devices. The transients produced in the coils and contacts of the relays interfered with the I.C. timing circuit. Reliable operation has been obtained by connecting capacitors across most of these coils and contacts to quiet their operation. In the course of evolution of this control system GR1 and GR2 have become "vestigial organs" in that they merely activate other relays. These can (and will) be eliminated, improving the noise problem somewhat.

The versatility of the entire system could be significantly enhanced by replacing the hysteresis synchronous motors used for both scanning and stepping with step motors. These motors, with their control systems, would increase the flexibility of the system by allowing a greater range of scanning speeds and stepping increments.

REFERENCES

1. Sandrik, J.M., Mazess, R.B., Vought, C.E. and Cameron, J.R.; Rectilinear Scanner for Determination of Bone Mineral Content, U.S. Atomic Energy Commission Report COO-1422-96 (June, 1971).

2. Motorola Semiconductors Products, Inc.; The Integrated Circuit Data Book (August, 1968).

ACKNOWLEDGEMENTS

I wish to thank Orlando Canto who prepared the mechanical drawings and electrical schematics.

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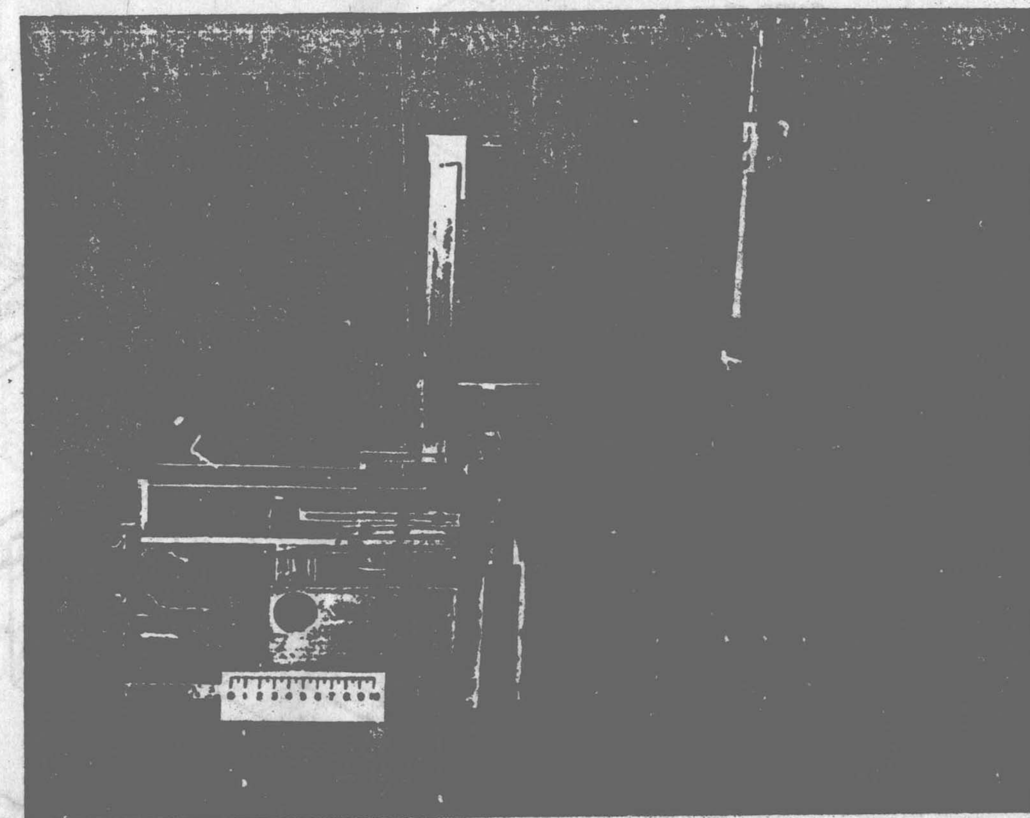


Fig. 1. Photograph of the assembled rectilinear scanner with its control panel. The range of the scanner is 15 cm square. It has a scanning speed of 2 mm/sec and five step lengths, which are selected from the control panel. Scale is in cm.

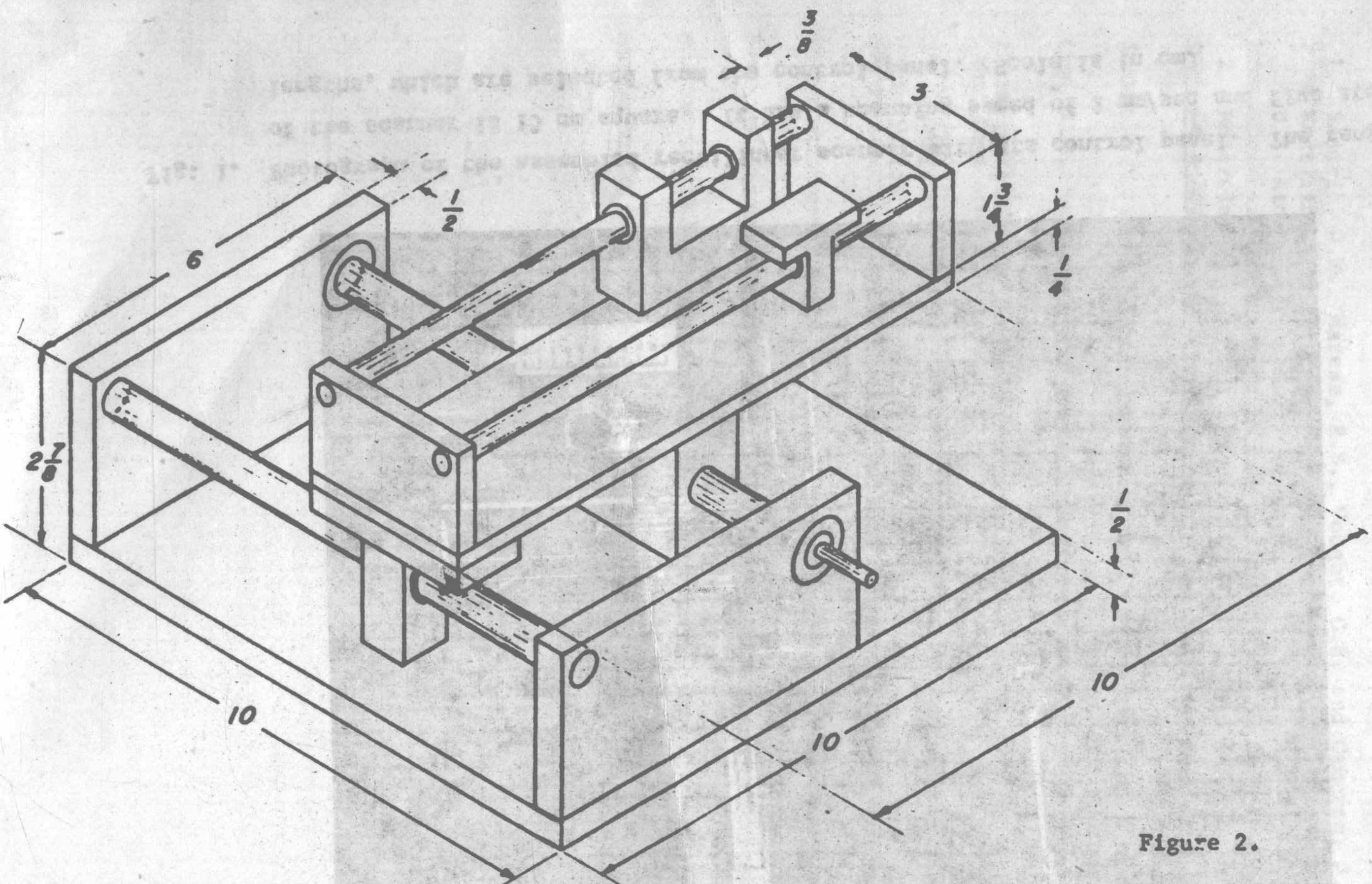


Figure 2.

X–Y SCANNER

PLATES MADE OF ALUMINUM. GUIDE RODS
60 C ROCKWELL STAINLESS STEEL. LEAD
SCREW 14MM × 1 1/2 MM PITCH STAINLESS STEEL
ALL DIMENSIONS IN INCHES. SCALE 1/2" = 1"

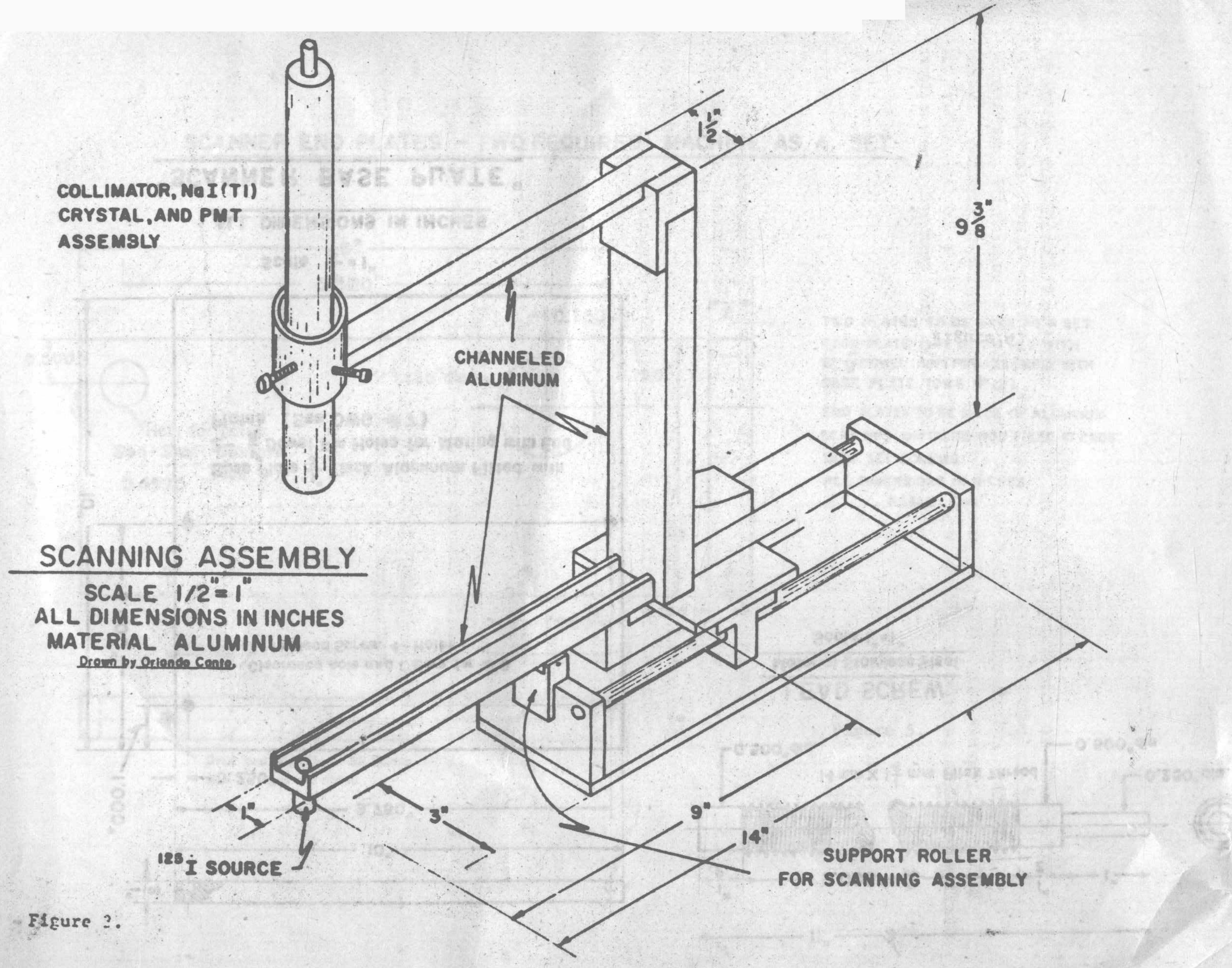
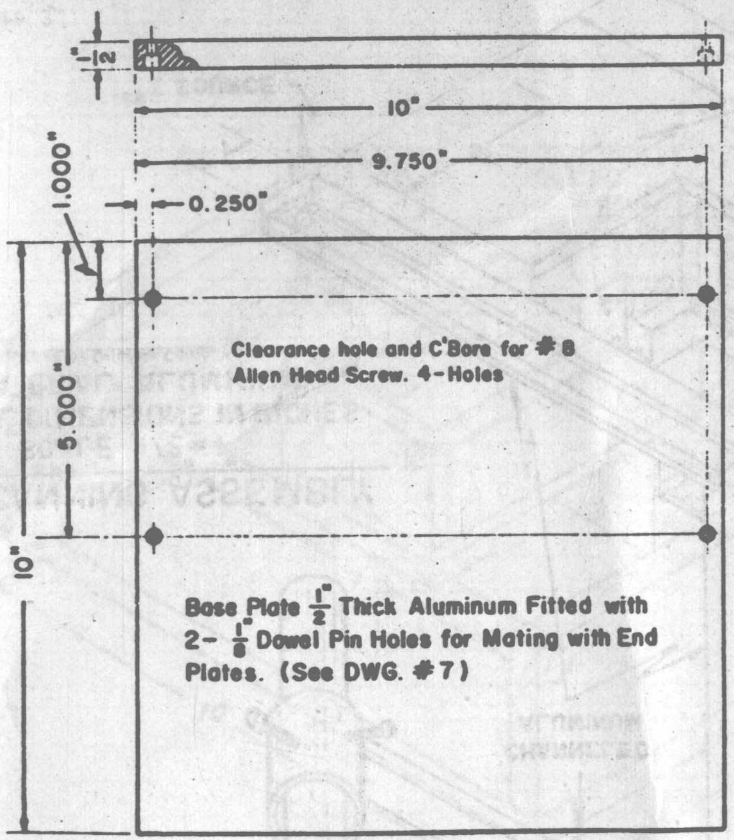

COLLIMATOR, NaI(Tl)
CRYSTAL, AND PMT
ASSEMBLY
CHANNELED
ALUMINUM
SCANNING ASSEMBLY
SCALE 1/2" = 1"
ALL DIMENSIONS IN INCHES
MATERIAL ALUMINUM
Drawn by Orlando Conte.
1 1/2"
9 3/8"
1"
3"
9"
14"
125I SOURCE
SUPPORT ROLLER
FOR SCANNING ASSEMBLY

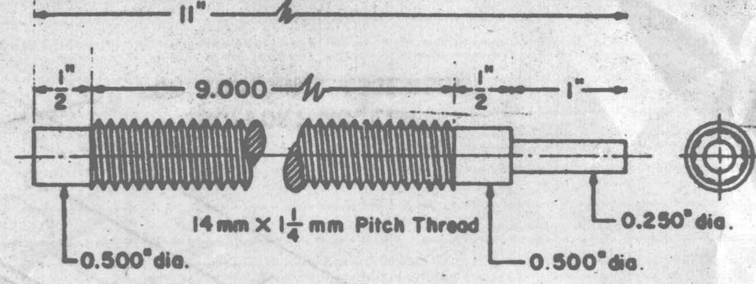
Figure 2.



Scale $\frac{1}{2}" = 1"$

ALL DIMENSIONS IN INCHES

"SCANNER BASE PLATE"



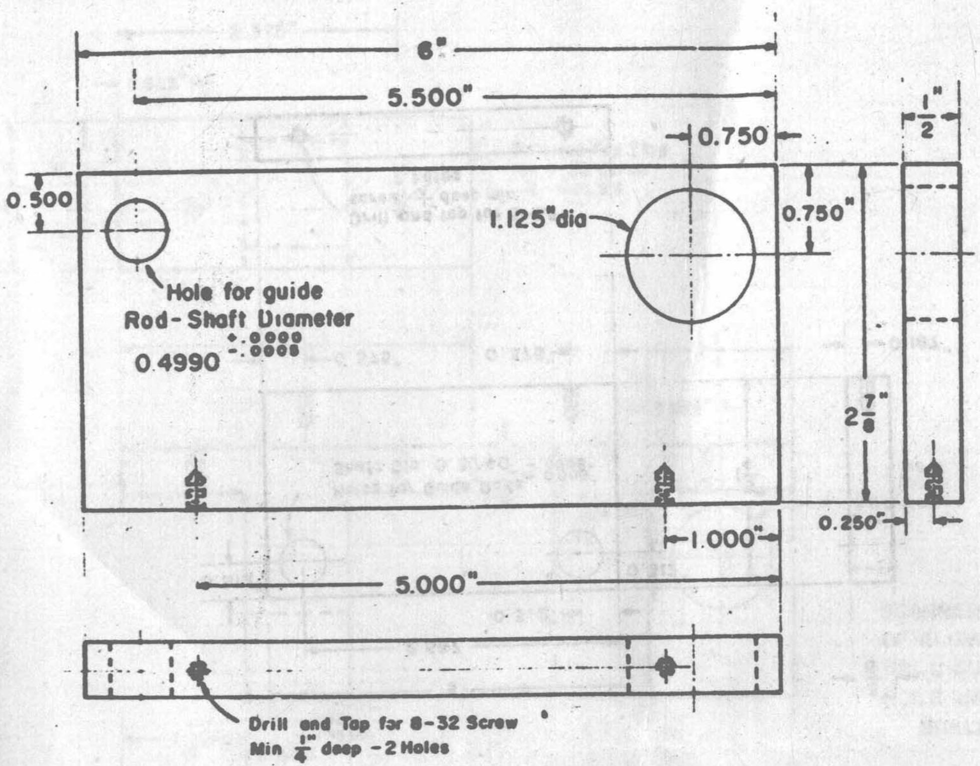
LEAD SCREW

Material Stainless Steel

Scale 1"=1"

Figure 4.

SCANNER END PLATES – TWO REQUIRED: MACHINE AS A SET

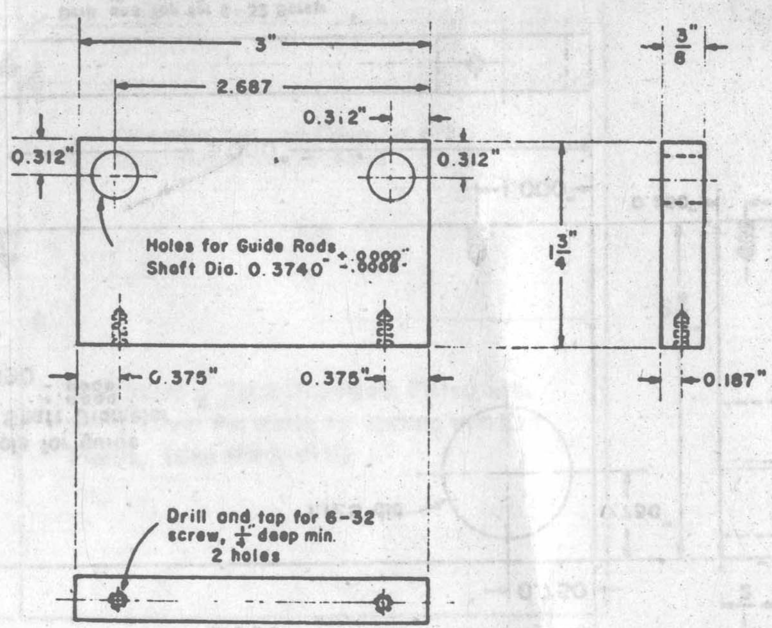


TWO PLATES TO BE MADE AS A SET.
EACH PLATE IS TO BE FITTED WITH 2 1/8" DOWEL PINS FOR ASSEMBLY WITH BASE PLATE. (DWG. # 12)

END PLATES TO BE MADE OF ALUMINUM.
BEARINGS and GUIDE ROD FIXED AT ENDS WITH SET SCREWS.
ALL DIMENSIONS IN INCHES
SCALE 1" = 1"

Figure 5.

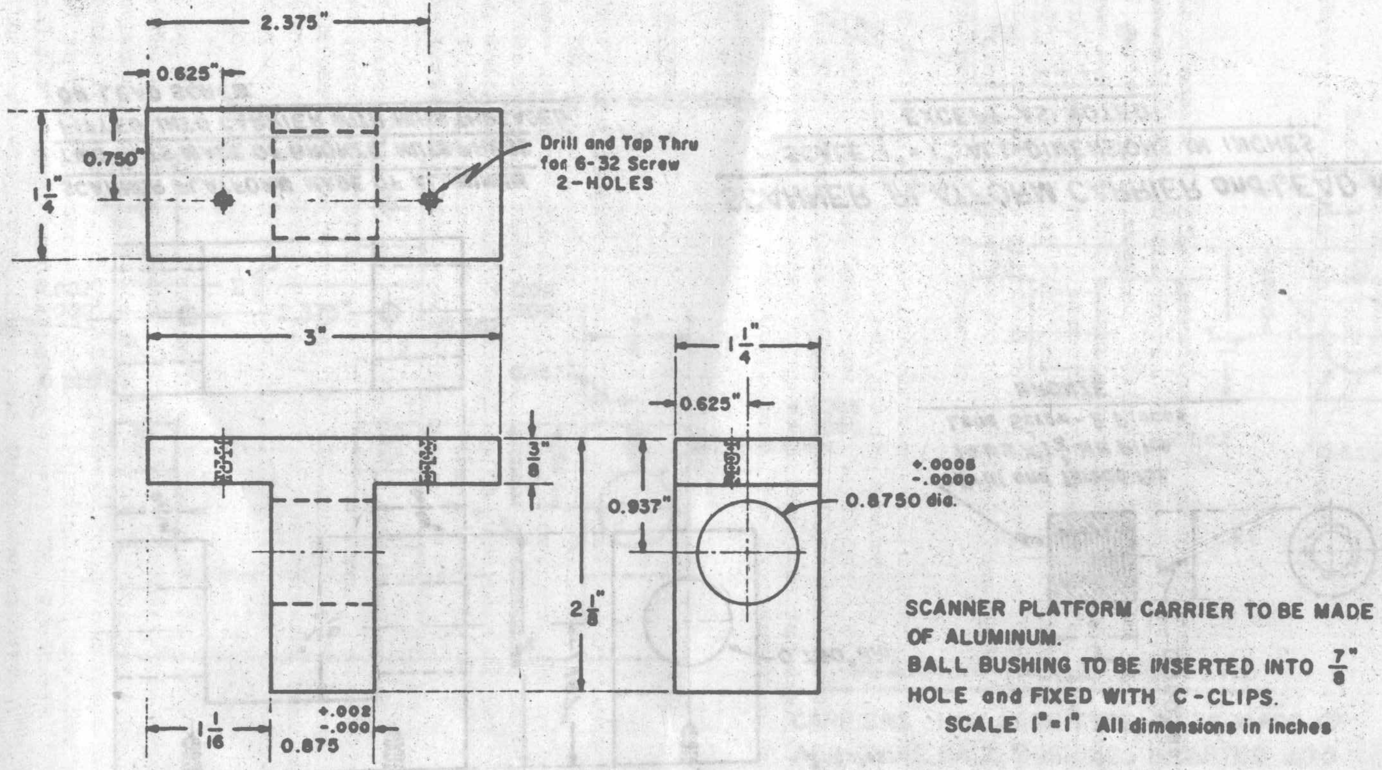
SCANNING PLATFORM END PLATES, 2 REQUIRED MACHINE AS A SET



END PLATES TO BE MADE OF ALUMINUM
EACH END PLATE IS TO BE FITTED WITH 2- $\frac{1}{8}$" DOWEL PINS FOR ASSEMBLY TO SCANNER PLATFORM. (DWG # 11)
GUIDE RODS FIXED TO END PLATES BY SET SCREWS.
ALL DIMENSIONS IN INCHES.

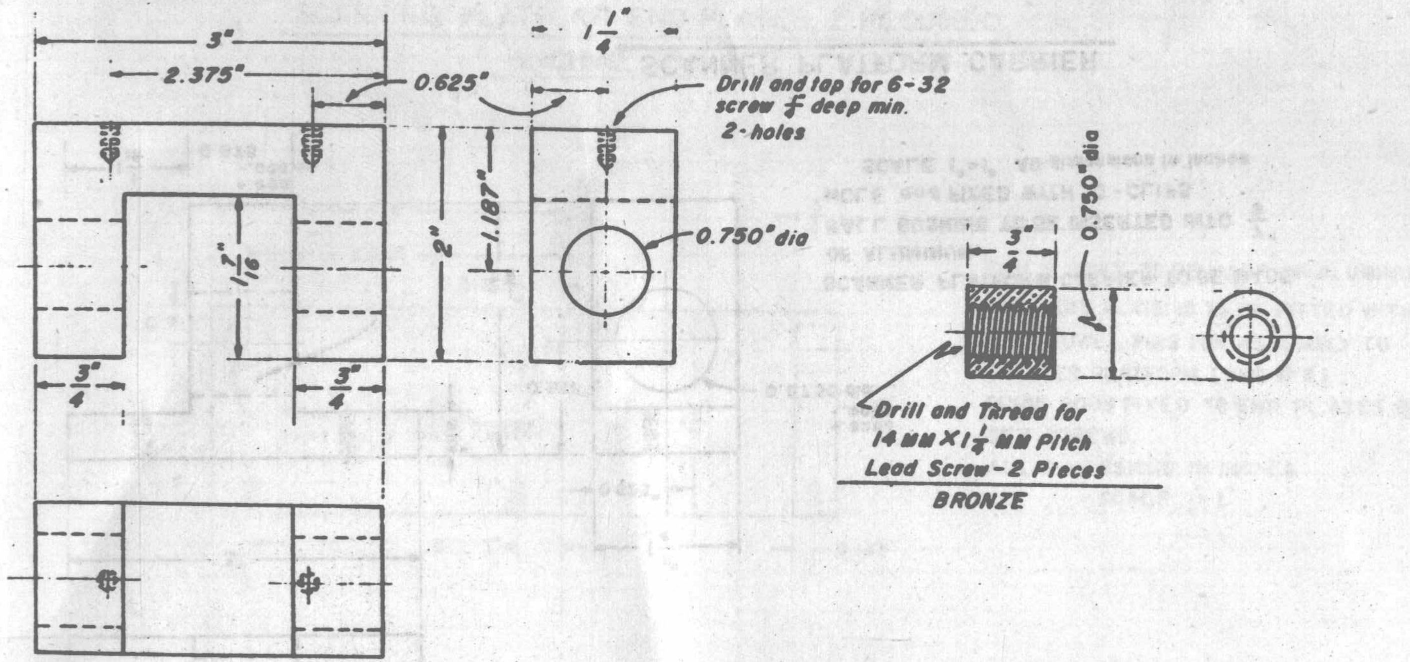
SCALE 1"= 1"

Figure 6.



SCANNER PLATFORM CARRIER

Figure 7.

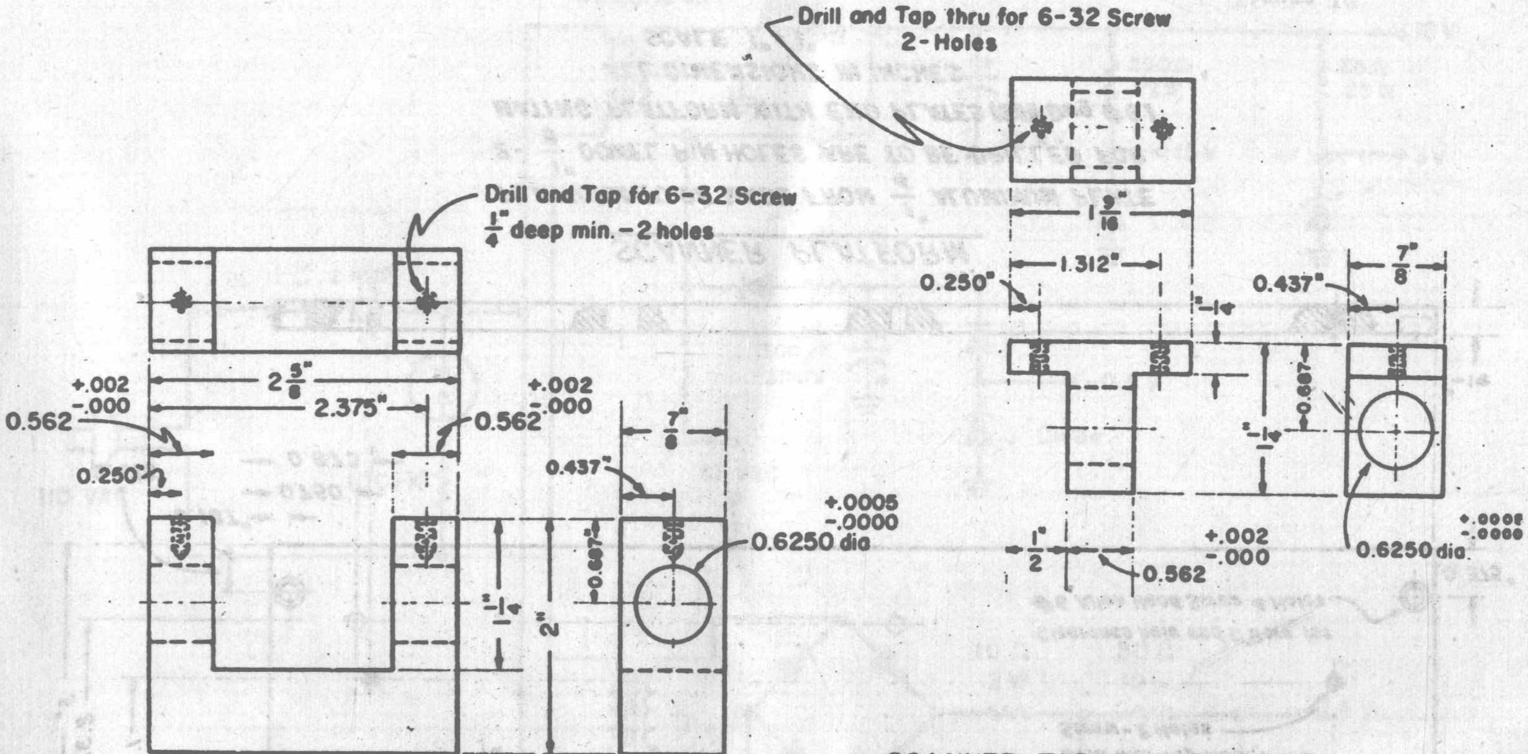


SCANNER PLATFORM MADE OF ALUMINUM
TWO NUTS MADE OF BRONZE. NUTS PRESS
FITTED INTO CARRIER WITH NUTS THREADED
ON LEAD SCREW.

SCANNER PLATFORM CARRIER and LEAD NUTS

SCALE 1" = 1", ALL DIMENSIONS IN INCHES
EXCEPT AS NOTED

Figure 8.



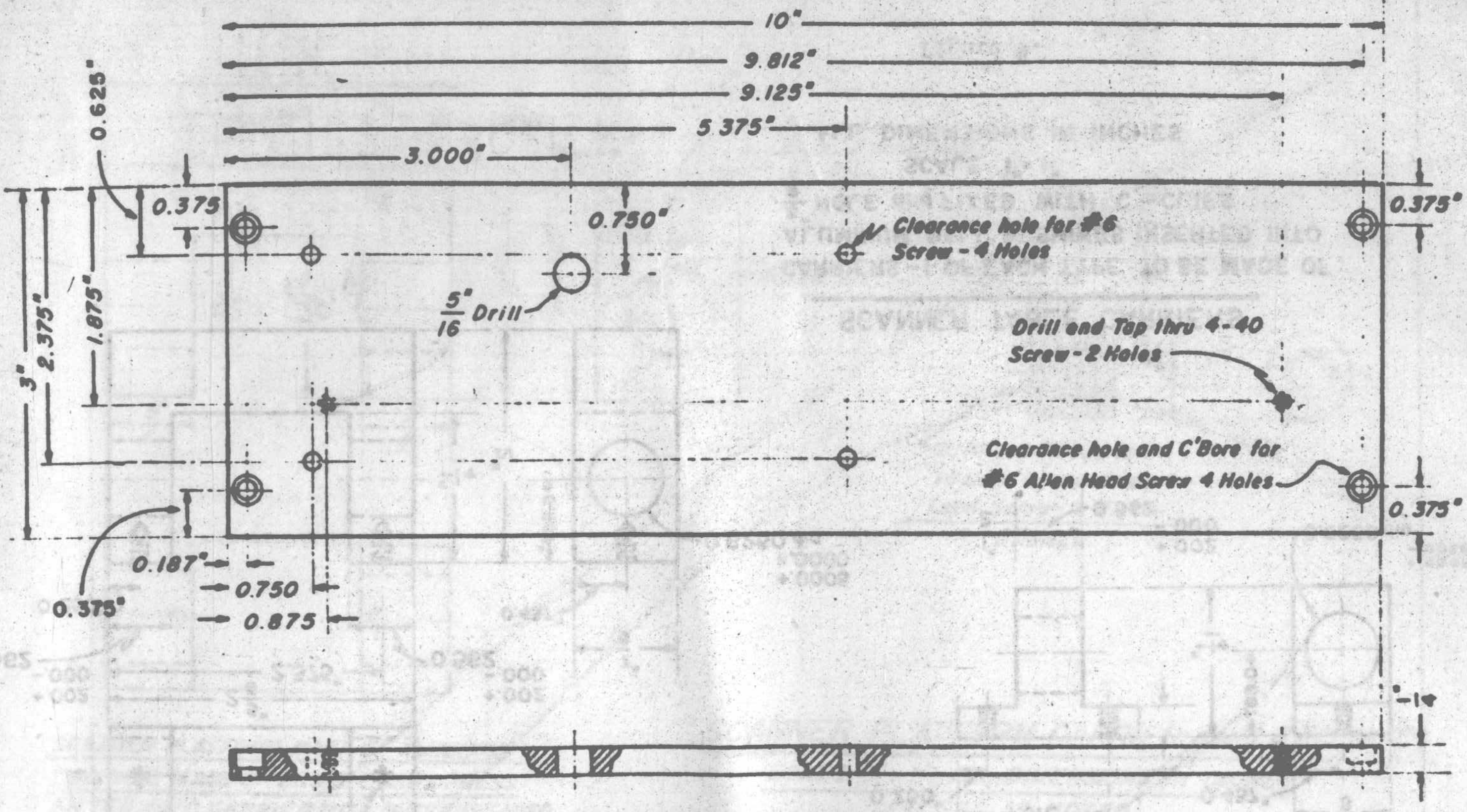
SCANNER TABLE CARRIERS

CARRIERS - 1 OF EACH TYPE TO BE MADE OF ALUMINUM. BALL BUSHINGS INSERTED INTO 5/8" HOLE and FIXED WITH C-CLIPS

SCALE 1" = 1"

ALL DIMENSIONS IN INCHES

Figure 9.



SCANNER PLATFORM

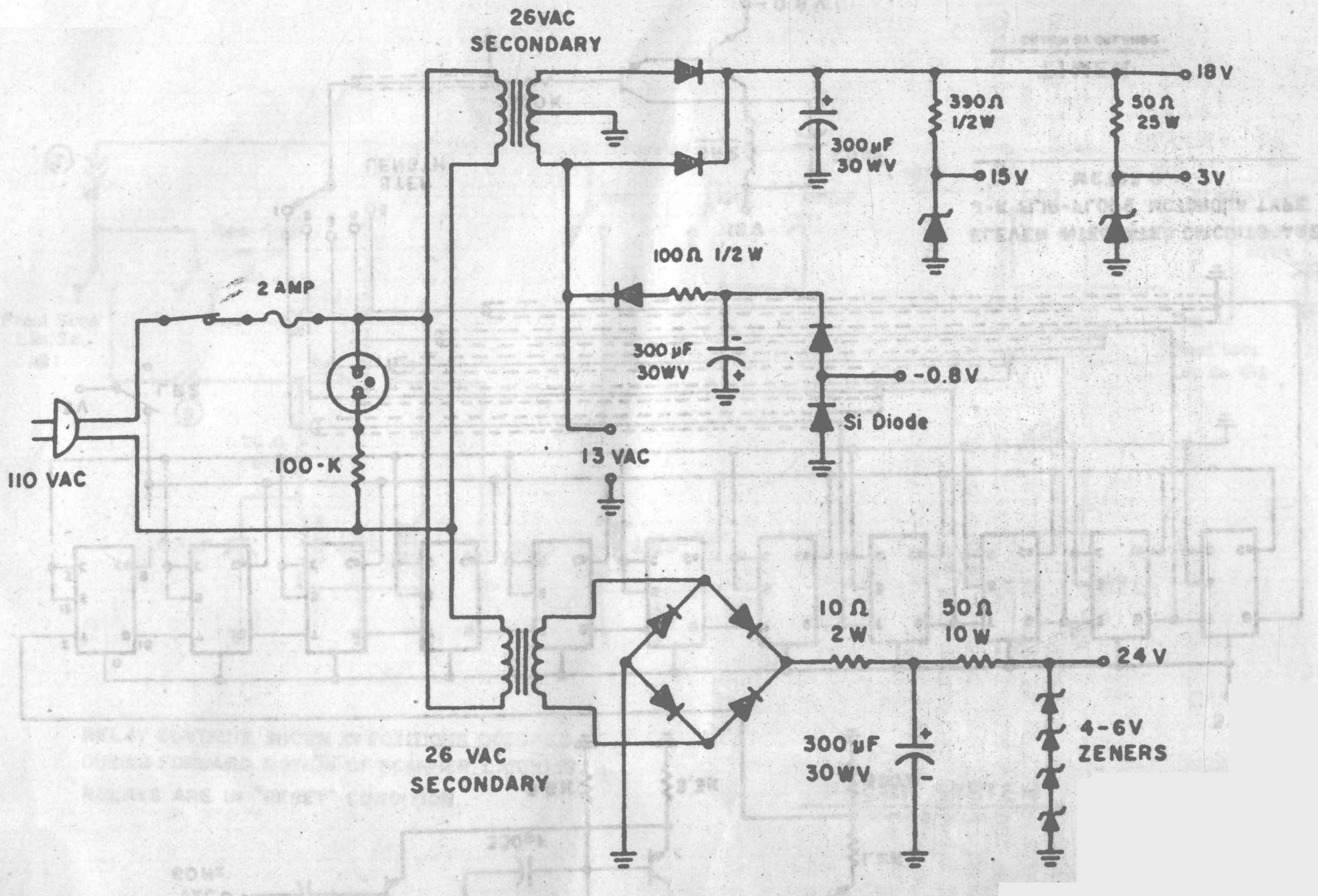
PLATFORM TO BE MADE FROM $\frac{1}{4}$" ALUMINUM PLATE

2- $\frac{1}{8}$" DOWEL PIN HOLES ARE TO BE DRILLED FOR MATING PLATFORM WITH END PLATES (See Dwg. #6)

ALL DIMENSIONS IN INCHES

SCALE 1" = 1"

Figure 10.



POWER SUPPLY

DRAWN BY ORLANDO

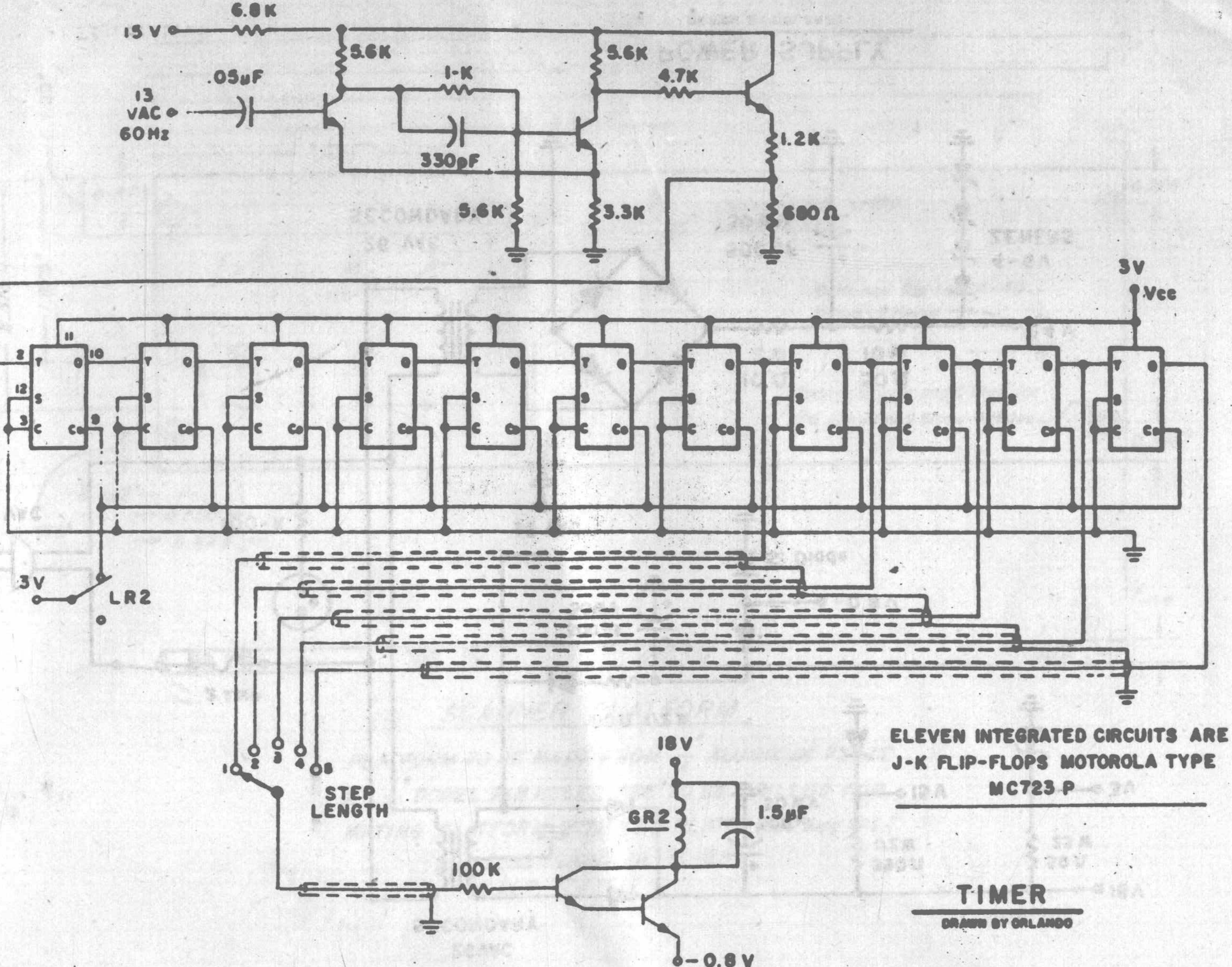

15 V
6.8K
5.6K
.05µF
13
VAC
60 Hz
1-K
330pF
5.6K
3.3K
4.7K
1.2K
680 Ω
3V
Vcc
T
Q
S
C
Co
2
11
10
12
3
9
3V
LR2
1
2
3
4
8
STEP
LENGTH
18V
GR2
1.5µF
100K
-0.8V
ELEVEN INTEGRATED CIRCUITS ARE
J-K FLIP-FLOPS MOTOROLA TYPE
MC723 P
TIMER
DRAWN BY ORLANDO

Figure 12.