The National Aeronautics and Space Administration
Research Grant NGR-05-020-115

"FIELD ANALYSIS OF TERRAIN"

FINAL REPORT

1 November 1967 - 31 October 1968

R.J.P. Lyon
Principal Investigator
School of Earth Sciences
Stanford University
Stanford, California

December 20, 1968

REMOTE SENSING LABORATORY
SCHOOL OF EARTH SCIENCES

STANFORD UNIVERSITY • STANFORD, CALIFORNIA

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FOUR REPORTS PRECEDE THIS COPY

This Fiscal Report presumes the prior existence of the First and Second Annual Reports issued 1 December 1966 and 10 December 1967, and the Semi-annual Reports issued 10 May 1966 and 15 May 1967. Material in those reports is not covered in this edition.

Contained in this report are the drawings and logic diagrams of the new Stanford Mobile Data System, and of the recently developed circular variable filter (CVF) spectrometer system. Monies from several sources were used for this construction, and this may be summarized as follows (through February 1968),

NASA Grants	- NGR-05-115-020 (this one)	63%
	- NGR-05-020-237	18%
NASA Cont.	- NAS9-7313	19%*

as well as equipment furnished GFE under NASA Cont. NAS2-3402(F).

(*considerably expanded lately to secure this documentation)

This support is gratefully acknowledged.

R.J.P. Lyon

R.J.P. Lyon
Principal Investigator
December 20, 1968

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I. PREAMBLE

This NASA step-funded grant to Stanford University was funded only for its first two years, but has been continued in force for the full 3 years to avoid changing the status of equipment furnished (GFE). These units are still in active use at Stanford on the same type of work, but under funding now originating from NASA/MSC Houston, Earth Resources Division.

The work is still continuing at this date under NASA Cont. NAS9-7313.

II. OBJECTIVE

This grant was made to test the feasibility of using infrared spectrometry <u>outside the laboratory</u> to identify and determine rocks and soils of geological significance. During the period of the grant the following objectives where achieved:

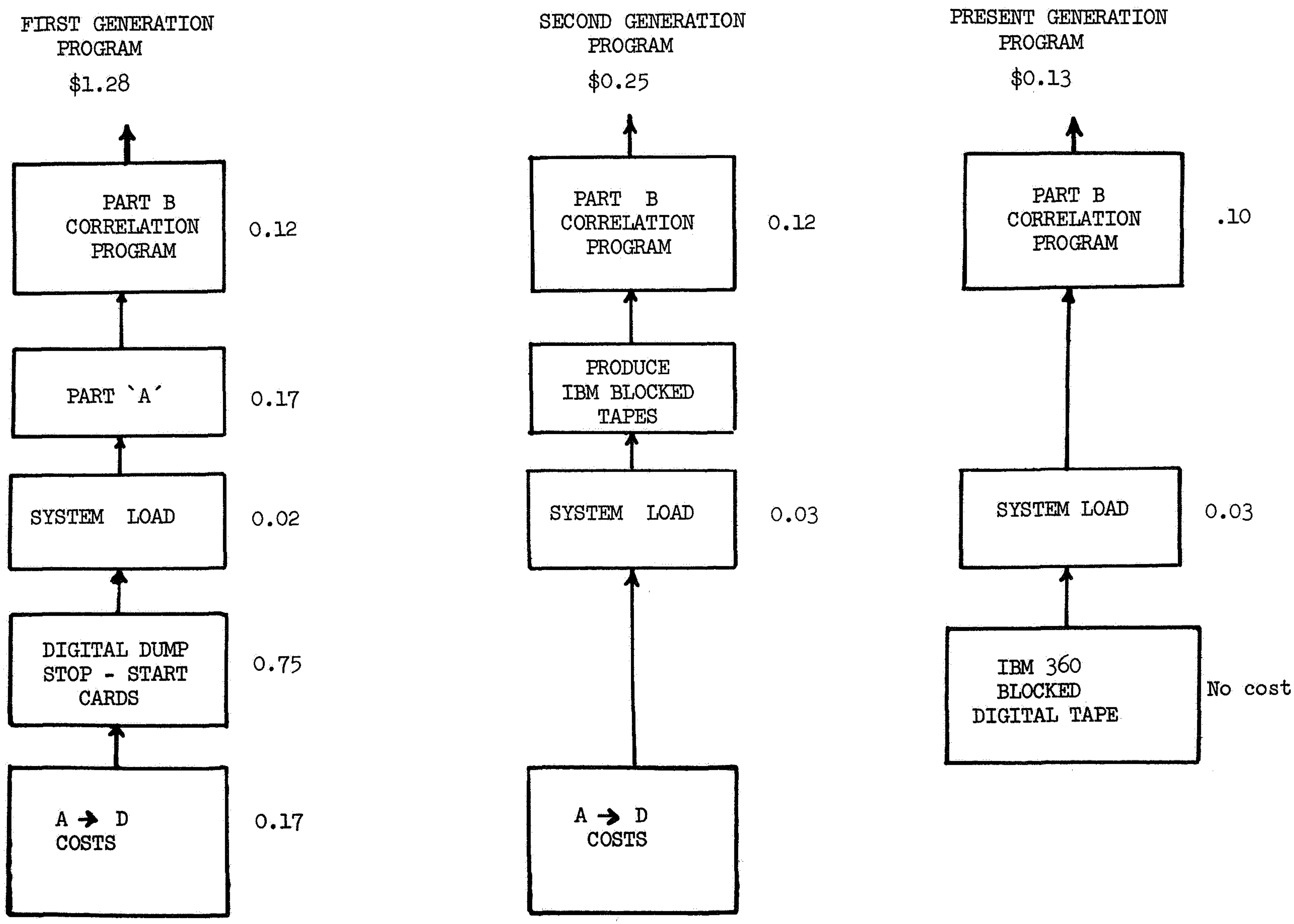
<u>Successfully</u>

1. Rock type materials of varying degrees of roughness particle size and porosity were observed with the spectrometer and diagnostic data identified.
2. The analog data system (which had caused so much delay and cost in data reduction) was replaced by a fully digital system. This step lowered the unit cost per reduced spectra from \$2.17 to 13¢, a factor of 17 . (Table I)
3. A new spectrometer was developed (from a basic design lent by W. Hovis NASA, GSFC) and now includes many advances in digital formatting to aid data reduction.

<u>Unsuccessfully</u>

1. The effect of the atmospheric path between the terrain and the experiment was identified, but it has not been possible to use these data in a corrective sense. To anyone familiar with the IR region this is no new statement. We have used horizontal path lengths of over 17,000 feet (in the Sierras) and vertical paths of 10,000 feet, in the airborne mode over Padre Island, Texas during periods of 90+% humidity. In both cases it was possible to determine the rock type.

TABLE 1


FIRST GENERATION PROGRAM
$1.28
PART B CORRELATION PROGRAM
0.12
PART `A´
0.17
SYSTEM LOAD
0.02
DIGITAL DUMP STOP - START CARDS
0.75
A → D COSTS
0.17
SECOND GENERATION PROGRAM
$0.25
PART B CORRELATION PROGRAM
0.12
PRODUCE IBM BLOCKED TAPES
SYSTEM LOAD
0.03
A → D COSTS
PRESENT GENERATION PROGRAM
$0.13
PART B CORRELATION PROGRAM
.10
SYSTEM LOAD
0.03
IBM 360 BLOCKED DIGITAL TAPE
No cost

III. SUMMARY

1. How are Rocks Classified?

Some of the prime objectives in the course of research carried out by geologists are to identify and classify rocks and soils, and to show their location on a suitable map. The geologist uses long-established rules and criteria to complete this work. For example, rocks are grouped into various classes and given a varietal name on the basis of such properties as rock texture and mineral composition. Three general (but genetic) groups of rocks are igneous, metamorphic, and sedimentary, each of which is characterized by a fairly unique texture. Varieties of rocks within these three general groups are based on the presence (or absence) and proportions of the constituent rock-forming minerals.

The advent of remote sensing of earth surface materials has brought about a rather unique problem for the geologist. The properties of rocks observed by the remote sensor are not necessarily texture and mineral composition *per se*, but such things as average reflectance, average emittance, surface temperature, etc. Because rocks are classically defined in terms of texture and mineral composition, the problem faced by the modern geologist is to redefine the criteria by which rocks are identified and classified in terms of the properties observed by a remote sensor.

Let us take an example to illustrate this point. Suppose an airborne infrared spectrometer is used to scan a terrain composed of granite, in an overflight. The spectrometer will yield a series of spectral emittances in the 8-13μ region taken at intervals along the flight line, each one corresponding to a patch of given size (typically $\approx$ 40 ft. square) on the ground. Assuming no *a priori* knowledge exists of the composition and texture of the rocks, then the spectra will provide the only criteria by which the rock may be identified. We would hope in this case that the spectra of the granitic rocks would be similar to other spectra taken of other rocks and known to be granites. If the flight line were to be extended to pass over an area in which basalts were exposed, another series of spectra would be produced of that section of the flight line. Hopefully, the basalt spectra would be similar to other spectra of rocks known to be basalts <u>and</u> different from the spectra of the granitic rocks.

The above description suggests a method by which the identification of rock type based on spectra alone can be made. A "library" of spectra of known rock types is produced under simulated field conditions. Spectra of unknown rocks are then compared statistically with the "library". The statistical comparison might take the form of a fitting procedure in which the unknown and known spectra are compared and the results might take the form of a correlation statistic. Spectra taken over a granitic terrain should correlate strongly with known granite spectra and poorly with known basalt spectra. This procedure has been used with success in the Stanford Remote Sensing Program (see Table II).

The above rock identification procedure is not the only one available. It is possible to mathematically determine the proportion of rock-forming minerals in the rock scanned from the spectra alone with a fair degree of accuracy. This method yields criteria which are exactly those used by the geologist to identify the rock. This method of identification of rock type from spectrum analysis has been used in the Stanford program previously and so far has met with limited success, principally because of the noisy quality of the spectra. Briefly, the method is based on the assumption that a rock spectrum is a linear combination of its component mineral spectra. Using this mathematical model, it is possible to obtain least squares estimates of individual weighted component mineral spectra. The calculated mineral spectra are then combined in various proportions by a least squared method to give an optimum "fit" to the rock spectrum. The statistically derived mineral composition of the rock is taken to be the various percentages of individual mineral spectra whose combined spectrum give the best "fit" to the original rock spectrum. This method of analysis has been performed on 22 "library"

TABLE II

Typical page of computer output showing analysis of field spectra of granite taken at a horizontal range of 15,000 ft.

STATISTICAL INFORMATION

708 GRANITE ACROSS VALLEY (15,000 FT)

LIBRARY SPECTRA CORRELATION COEFFICIENTS

	1st choice	2nd choice	3rd choice	4th choice	5th choice
Spectrum I	GNTRUF 91	PYXAPL 90	WLDTUF 88	QBSAND 82	OBSID4 82
Spectrum II	GNTRUF 86	PYXAPL 86	WLDTUF 81	QBSAND 78	OBSID4 72
Spectrum III	GNTRUF 67	QBSAND 67	PYXAPL 60	WLDTUF 58	OBSID4 41
Spectrum IV	PYXAPL 89	GNTRUF 88	WLDTUF 86	QBSAND 79	OBSID4 78
Spectrum V	PYXAPL 91	GNTRUF 91	WLDTUF 88	OBSID4 85	RYPMCE 82
Spectrum VI	QBSAND 72	GNTRUF 64	WLDTUF 58	PYXAPL 52	RYPMCE 46

GNTRUF = GRANITE ROUGH
PYXAPL = PYROXENE APLITE
WLDTUF = WELDED TUFF
QBSAND = QUARTZ BEACH SAND
OBSID4 = OBSIDUAN
RYPMCE = RHYOLITE PUMICE

rock samples for which both CIPW Norms (Normative Mineral Composition) and infrared spectra were available.

A third method of identification of rock types from infrared spectra is available to us at this time. This method involves the use of multiple linear discriminant analysis in discriminating between rock types and classifying each spectrum (rock) into one of several groups on spectral properties alone. A drawback of this system of analysis is that spectra (rocks) are classified into pre-assigned groups, the assignment of groups made before the statistical analysis. This is in no way a major constraint, but should be recognized. This can pre-suppose that the various types of rocks for which spectra were taken, were known in general before hand, possibly through geological ground analysis of the sites scanned. A test group of spectra from each of the pre-assigned groups is used as a basis for comparison with the spectra from unknown rocks. The computer program used in this analysis (BMD07M) treats each rock class as a square covariance matrix, the size (N) of the matrix depending upon the number of individual wavelengths judged to give the best classifying power. Each spectrum of an unknown rocks is then placed in N-dimensional space based on the N critical wavelengths by the computer program. The "Mahalanobis distance" from each individual rock spectrum to the center of gravity of each of the pre-assigned classes is then computed. The rock is then assigned to the class (rock type) that to which it is nearest, based on the Mahalanobis distance. The program also computes canonical variables, which are used as an aid in graphically showing the discriminating power of this type of analysis.

2. Details of Spectral Matching Technique

Having demonstrated that the types of rock present on a terrestrial surface do have differences in their spectra, the question arises as to what is the most accurate and sensitive method for discriminating between them. All such methods rely on performing some form of spectral matching or correlation with a library of reference spectra.

One system described by Hunt, Salisbury, and Reed* attempts to identify the rocks by an optical correlation process which produces a visual image as its output. In this process, the incoming radiation from the target rock is filtered by reflecting it from a polished reststrahlen plate of the reference material. If target and reference are the same, then a spectral match is obtained and this appears as a minimum in total reflected energy. From data published so far it does not appear that this method will be successful in discriminating anyting but highly dissimilar rocks. The necessarily slow nature of the matching process when a library of more than a few samples is required is also a disadvantage for spacecraft use. For rapid analysis of multiple spectra, computerized data reduction of each and every spectrum appears to be essential.

(a) CORRCO Program (Pearson's Product Moment Correlation Coefficient)

An example of the output of the Stanford program wherein successive target spectra were correlated with 19 reference spectra, using an IBM 7094, is shown in Table II. The spectra (taken in the field) were of a naturally occurring granite face near Tioga Pass over a horizontal pathlength about 5 km (15,000 ft). The computer printout in Table II shows the first five choices from the reference library along with their correlation coefficients. In this program only the ranking of choices is significant, the correlation coefficients losing their absolute value during computation. A complete discussion of the program is given in Stanford RSL Tech Report #67-1. The six spectra shown identify granite as the first choice in three cases, and the remainder identify it as the second choice with a compositionally similar rock as first choice.

(b) Percentage Mineral Composition Program

An alternative program performs analysis in terms of individual mineral spectra and calculates the percentage of minerals needed to produce the closest fit to the sample spectrum. Hence, one obtains the mineralogical

*Reference: Hunt, G.R., Salisbury, J.W. and Reed, J.W., "Rapid remote sensing by spectrum matching technique," J. Geophys. Res. 72, 705-719 (1967) composition (modal analysis) of the target rock. An example of this output is given in Fig. 1. where the spectra of the five commonly occurring major minerals shown were computed from a test set and used to produce the compositional analyses of the unknown rocks shown. There is nothing to stop the program from being extended to include other less abundant minerals, although rock classifications are based on these 5 major minerals. This technique provides a method for performing immediate semi-quantitative modal analyses, without the necessity of preparing thin sections and conducting laborious point counts.

(c) Adaptive Learning (Stepwise Discriminant) Program

A third program was generated to separate the target spectra into a small number of categories. The computer was given a "training set" of granite, andesite, and snow spectra and programmed to find some combination of variables which would best separate the given spectra. The preliminary output is plotted in Fig. 2 , and it can be seen that in most cases the differentiation is striking. Figure 3 shows a recent analysis of 242 ground spectra with 98% correct identification of rock types.

The canonical variables shown are of the form $a\ x\ (\lambda_1) + b\ (\lambda_2) + c\ x\ (\lambda_3)$...where $x\ (\lambda_1)$, $x(\lambda_2)$, $x(\lambda_3)$ etc., are the emissivities at wavelengths λ_1, λ_2, $\lambda_3 \ldots \lambda_N$. In this figure $N = 20$. The constants a, b, c... were calculated from this group of spectra. It can be seen that there is a region of indecision between the boundary of granite and andesite, both rocks having the same compositions but differing in crystal structure. This is also complicated by the noisy spectra used in the analysis. The boundaries shown are the bisectors of the mean values of the three groups. The main attraction to the program is its ability to handle large numbers of spectra economically.

After "training" on the first sets of spectra, the coefficients of the discriminant function can be used to process the rest of the flight data. The output format can be tailored to show a continuous progression of rock type decisions along the flight line (Table III).

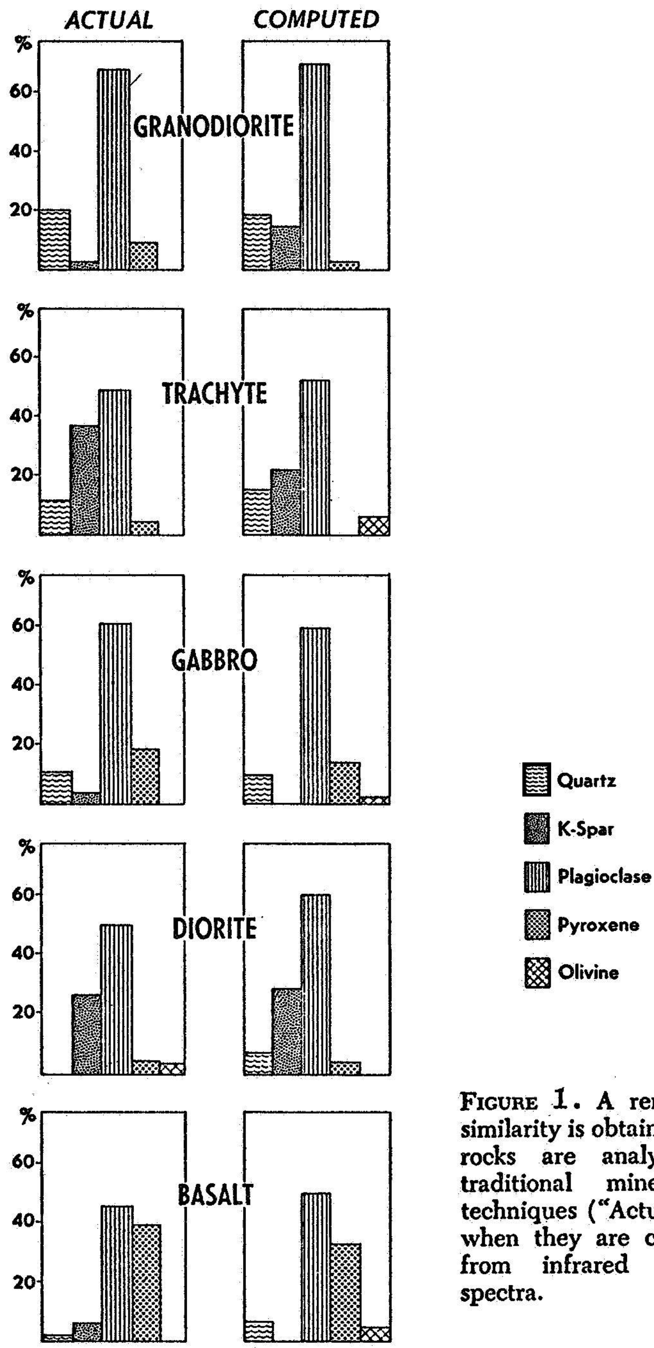


FIGURE 1. A remarkable similarity is obtained when rocks are analyzed by traditional mineralogical techniques ("Actual") and when they are computed from infrared emission spectra.

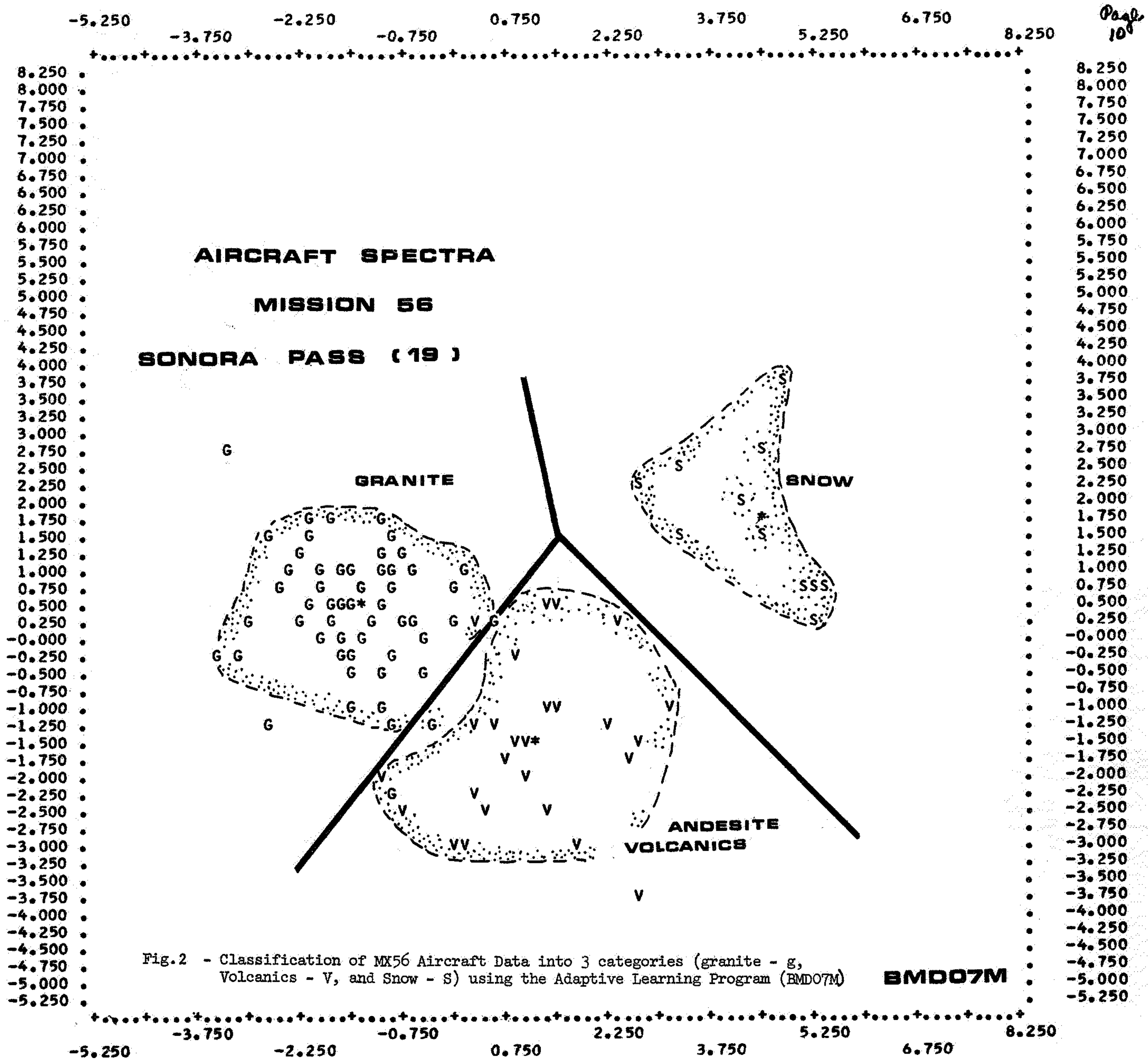
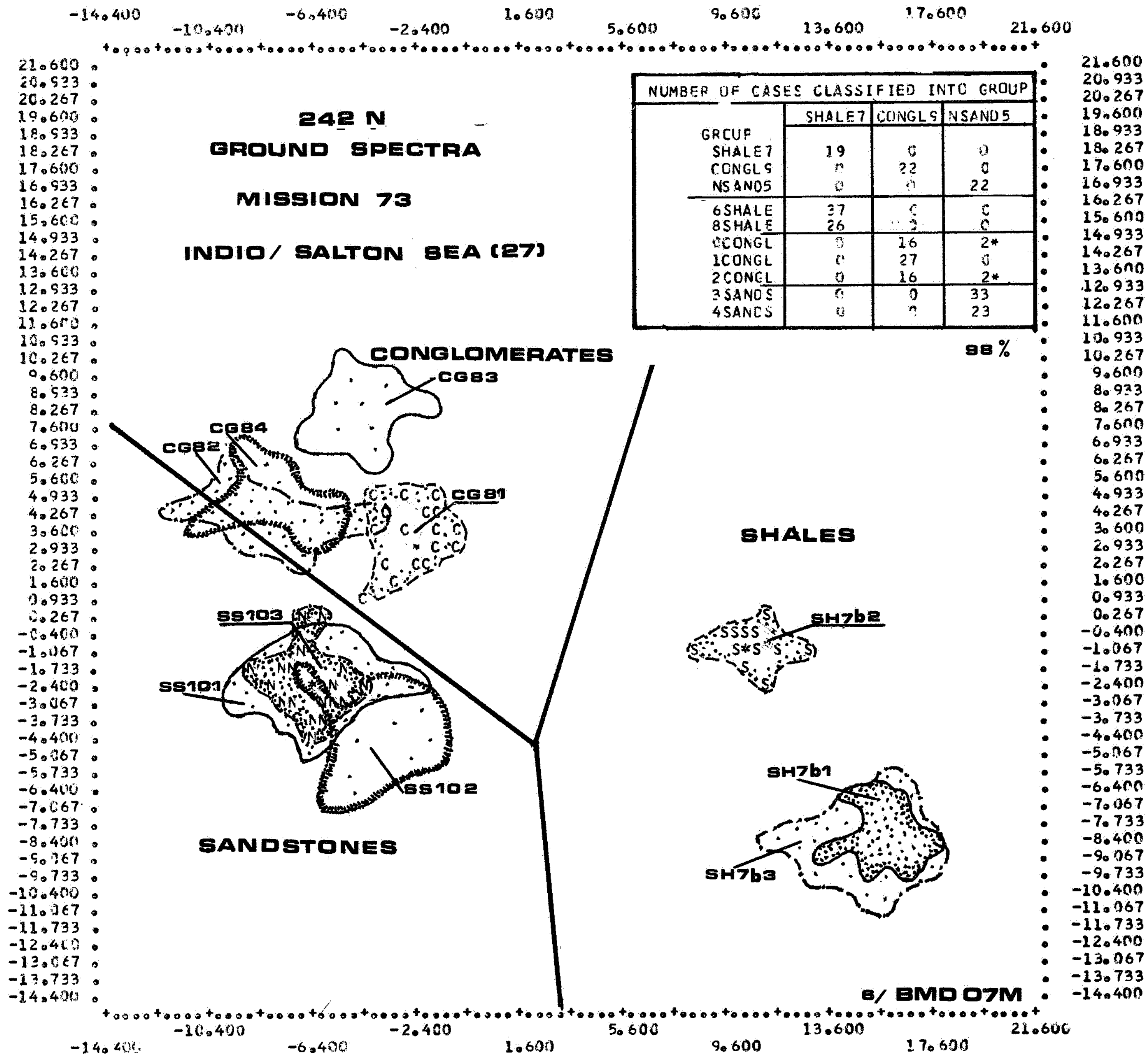


Fig.2 - Classification of MX56 Aircraft Data into 3 categories (granite - g, Volcanics - V, and Snow - S) using the Adaptive Learning Program (BMD07M)



NUMBER OF CASES CLASSIFIED INTO GROUP	SHALE7	CONGL9	NSAND5
GROUP			
SHALE7	19	0	0
CONGL9	0	22	0
NSAND5	0	0	22
6SHALE	37	0	0
8SHALE	26	0	0
0CONGL	0	16	2*
1CONGL	0	27	0
2CONGL	0	16	2*
3SANDS	0	0	33
4SANDS	0	0	23

FIGURE 3

TABLE III

Mission 56	Day 6	Line	Run	Site 19		Hrs	Min	Secs Msecs	Ground Truth	Probability %	Rock type	Probability %
56	6	19	1	19	0	17	21	7698	GR		GRANIT	91
56	6	19	1	19	0	17	21	8000	GR		GRANIT	76
56	6	19	1	19	0	17	21	8304	GR		GRANIT	78
56	6	19	1	19	0	17	21	8608	GR		GRANIT	87
56	6	19	1	19	0	17	21	8911	GR		GRANIT	78
56	6	19	1	19	0	17	21	9215	GR		GRANIT	91
56	6	19	1	19	0	17	21	9518	GR		VOLCAN	63
56	6	19	1	19	0	17	21	9822	GR		GRANIT	88
56	6	19	1	19	0	17	21	10126	GR		VOLCAN	75
56	6	19	1	19	0	17	21	10428	VO		GRANIT	84
56	6	19	1	19	0	17	21	10732	VO		VOLCAN	75
56	6	19	1	19	0	17	21	11035	VO		GRANIT	52
56	6	19	1	19	0	17	21	11339	VO		VOLCAN	72
56	6	19	1	19	0	17	21	11642	VO		VOLCAN	84
56	6	19	1	19	0	17	21	11946	VO		GRANIT	86
56	6	19	1	19	0	17	21	12250	VO		VOLCAN	67
56	6	19	1	19	0	17	21	12553	GR		VOLCAN	66
56	6	19	1	19	0	17	21	12856	GR		VOLCAN	58
56	6	19	1	19	0	17	21	13160	GR		GRANIT	65
56	6	19	1	19	0	17	21	13463	GR		GRANIT	68
56	6	19	1	19	0	17	21	13766	SN		SNOW	69
56	6	19	1	19	0	17	21	14070	SN		SNOW	100
56	6	19	1	19	0	17	21	14375	SN		SNOW	95
56	6	19	1	19	0	17	21	14677	SN		SNOW	100
56	6	19	1	19	0	17	21	14980	VO		SNOW	100
56	6	19	1	19	0	17	21	15284	SN		SNOW	95
56	6	19	1	19	0	17	21	15587	VO		VOLCAN	100
56	6	19	1	19	0	17	21	15891	SN		SNOW	44
56	6	12	2	19	0	17	23	35176	GR		GRANIT	79
56	6	12	2	19	0	17	23	35480	GR		GRANIT	99
56	6	12	2	19	0	17	23	35784	GR		GRANIT	86
56	6	12	2	19	0	17	23	36088	GR		GRANIT	96
56	6	12	2	19	0	17	23	36390	GR		VOLCAN	98

d. Nearest Neighbor Program

In this newly created program of ours the spectra, made of x points (x = 89 or 96), are placed into N dimensional space upon the selection of N data values (N = 10 in most cases). Again groups of training spectra are used with about 20 examples in each group. The newly incoming spectra are located into N space the the region searched for K-nearest neighbors (K = 5). The K nearest are ranked and a "vote" taken. The majority decision sets the classification for the new spectrum

Although quite new this program is already exciting our interest as a more precise method of classification than those we now use.

These programs and their results are described in greater detail in the Semi-annual and Annual reports of previous phases of this program.

Several figures have been prepared to show the relationship between the various sub-tasks of the study. In particular Figure 4 defines the interrelationships of MSC aircraft programs and the data pre-reduction activities of MSC/CAAD. The areas of mutual activities involving the University of Nevada groups are also outlined.

From the flow-diagram nature of these two figures (Fig. 4 and 5) the connection between the various activities should become clear.

Figure 5 is a status diagram of the analysis system, showing by stippling the areas presently "running" on the Stanford Computer. All spectra are now composed of 89 data values.

PROGRAM #1 CORRCO (Pearson product moment correlation) COMPLETED. Outputs flight line data

PROGRAM #2 BMD07M (Stepwise discriminant) Now fully ON-LINE (Figs. 2 and 3)

PROGRAM #3 PULSE (Version of #1). Temporarily shelved.

PROGRAM #4 NEIGHBOR. Very useful. Now ON-LINE.

STANFORD / U NEVADA / MSC RELATIONSHIP ON
INFRARED SPECTROMETER EXPERIMENT -- P 3A AIRCRAFT
STIPPLED AREAS NEED MUCH MORE ATTENTION

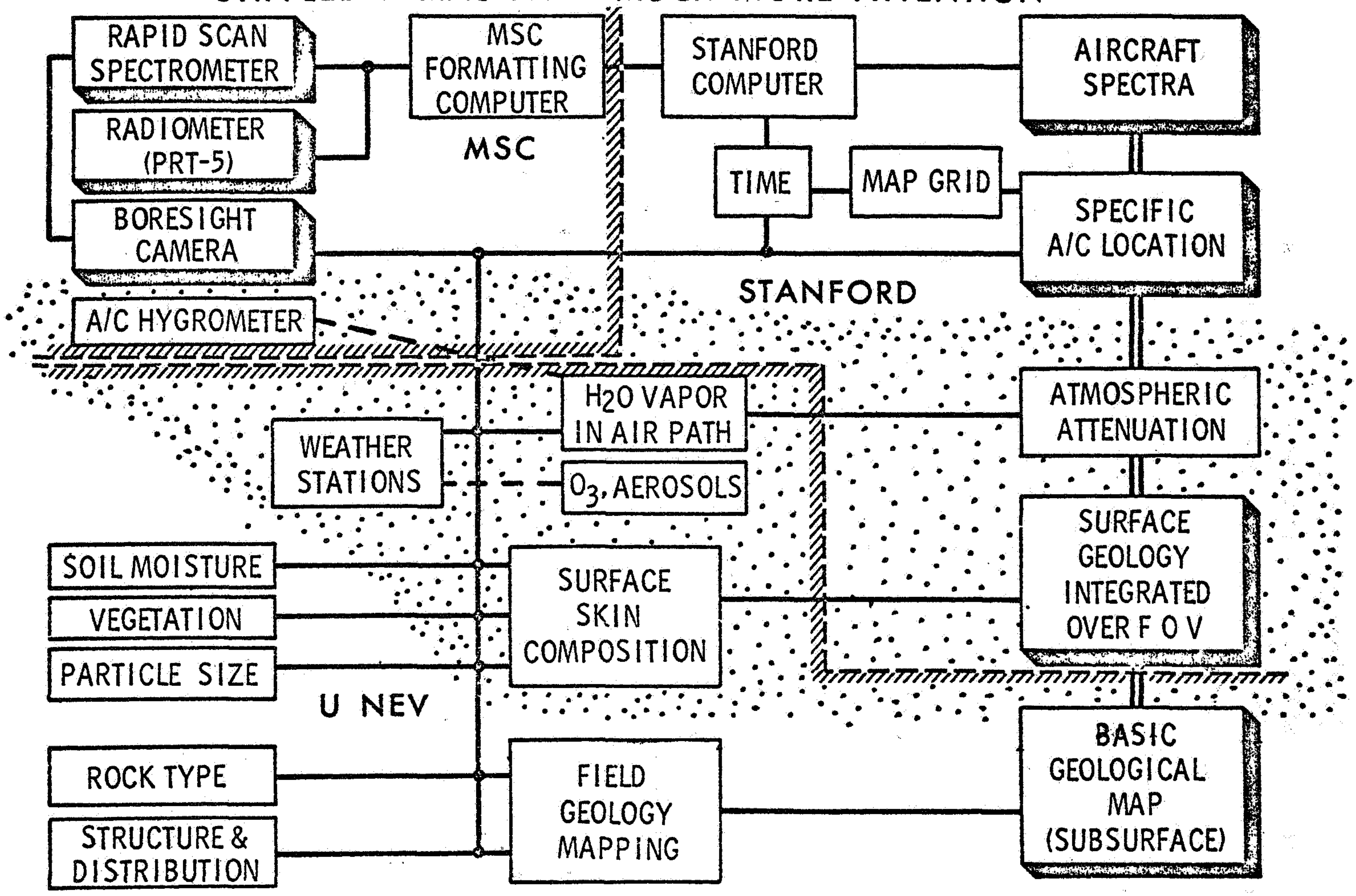


FIGURE 4

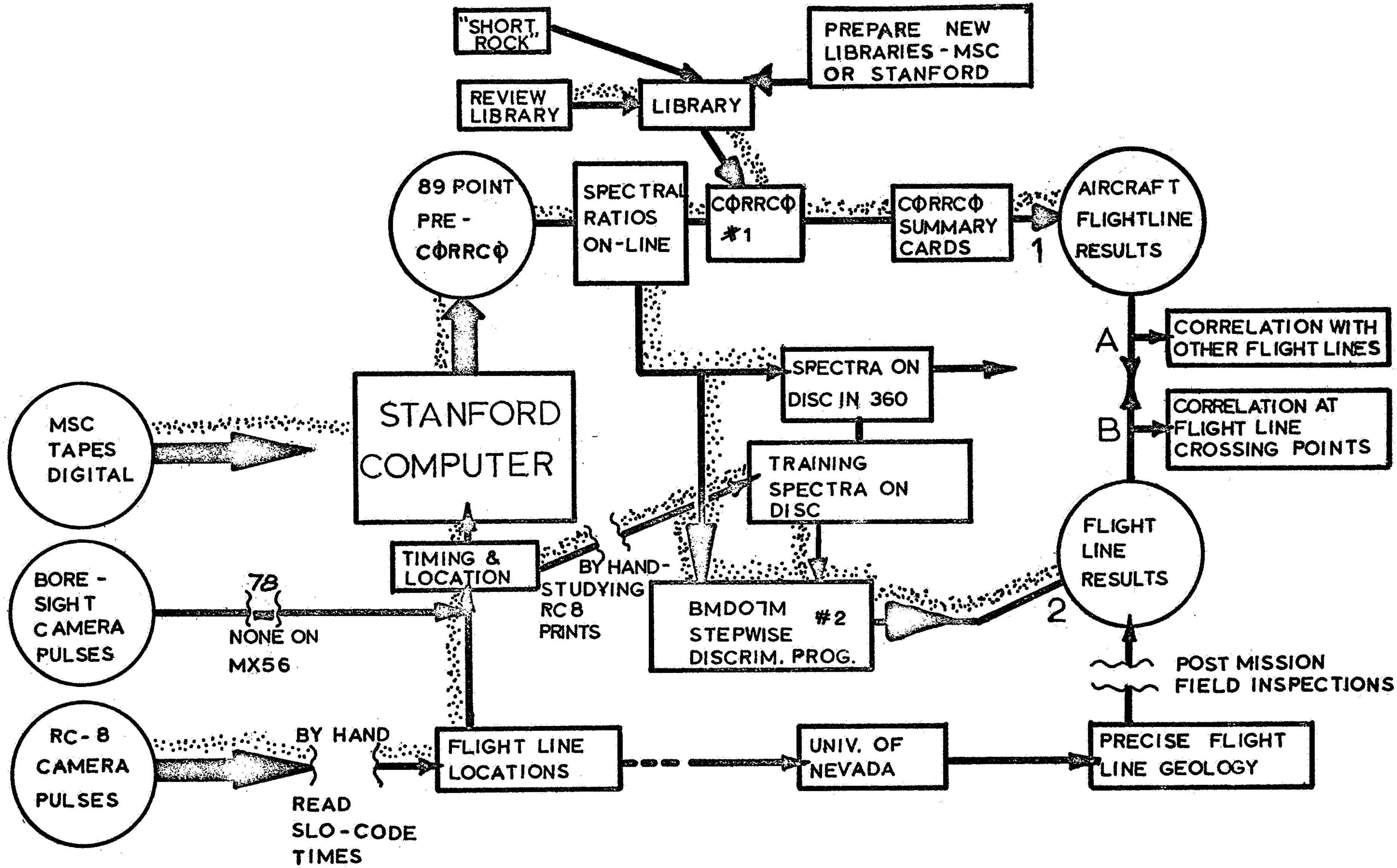


FIG. 5 STANFORD SPECTRAL DATA ANALYSIS SYSTEM

IV. RESULTS

1. Summary and Costs

Most of the results from this program have either been reported previously in the our preceding reports, or, they are still being reported in the "carry-on" contract NAS9-7313.

Two results can be identified as being significantly developed on this grant and are as yet unreported.

A. Circular Variable Filter Spectrometer (MARK I AND MARK II)

B. Digital Data Recording System.

These appear herein as Appendicies A and B.

A considerable amount of time and research effort have been expended in these two tasks. Up to 2/1/68 the costs were, for the spectrometer $24,423, and for the data system $6,189. A more detailed breakdown of these appear in Table A1 .

Construction, updating, and increasing the reliability of both of these systems is actively proceeding now under NAS9-7313.

V. ACKNOWLEDGMENTS

A program of this complexity in a new field of endeavor cannot proceed without the assistance of many persons. This help is often far out of line of the cost of that person to the program, and, at many times, it can be said that the advances made during the research would not have been achieved had that help not been given.

To single out persons at this point is difficult. We are initially very appreciative of the guidance of Dr. Peter C. Badgley, NASA Headquarters, without whom this project would not have begun. William Fischer of the USGS has continually come to our aid in ways too numerous to mention. Without NASA funding we would not have functioned. To Warren Hovis, NASA, Goddard Space Flight Center we owe the original (MARK I) CVF Spectrometer plans and our thanks. At Stanford I am indebted to many, of whom Dr. Roger Vickers, Research Physicist and Peter Gordon, machinist, of the School of Earth Sciences, stand out. Instruments and systems do not develop overnight-they come only after many days (and nights) of thought, worry and hard work. Roger's ideas

and concepts formed the digital data system logic and enabled us to move forward again out of a quagmire of data handling problems. Peter's machining abilities far outlie his title (for which model-maker would be a more true description) and the construction of an optical instrument from back-of-the envelope sketches is no mean feat.

To these men I am greatly in debt and most appreciative of their continual help.

APPENDIX A

CIRCULAR VARIABLE FILTER SPECTROMETER

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APPENDIX A

LIST OF ILLUSTRATIONS

APPENDIX A LIST OF ILLUSTRATIONS (CONT'D)

APPENDIX A

CIRCULAR VARIABLE FILTER SPECTROMETER

Most of the infrared spectral studies at Stanford have been performed with the SG-4 spectrometer system. Many have been the problems with this unit, but to single one out from the multitude it has been the non-reproducibility of the grating drives (and the attendant problems of relating radiance and wavelength) which caused us to seek a new unit.

Dr. Roger Vickers joined us in July 1966 and for the past 2 years has been developing a new spectrometer concept around the circular variable filter as the dispersive element. This is a rotating wheel (instead of a rocking grating) and has a constant (and forward) motion. This leads to constant wavelength versus angular rotation versus time graphs, but also permits better coding of the angular motion of the drive shaft. This development now gives us precise pulses by which to drive the A-D radiance samples.

The following description of the system is taken from a forthcoming paper by Vickers and Lyon.

1. The Stanford CVF Spectrometer

The data handling principles described in the foregoing reports have been incorporated at Stanford University into a new MARK II CVF spectrometer working in the 7-14μ region. This instrument is an upgraded design of one supplied to us by W. Hovis of NASA Goddard Space Flight Center (MARK I). This new unit is specially designed for measuring the emission spectra of naturally occurring terrestrial materials. The data system accompanying the spectrometer is also described in this section. Many of the mechanical features of this spectrometer were suggested by Mr. Peter Gordon of the School of Earth Sciences at Stanford who also is responsible for the detailed design and construction of the instrument.

The Optical Design

The optical layout was shown in Figure A2 . The telescope, which is a 4" Cassegrain obtained from the Barnes Engineering Co., has focal planes situated at F_1 and F_2. As can be seen from the figure, the second plane (F_2) is provided by reflection from the front surface of the chopper. This double-sided chopper also allows the detector to view alternately a reference blackbody at known temperature, and the target. This front surfaced chopper provides "simultaneous" visual viewing and infrared data acquisition.

The incoming infrared energy is then re-focussed by a KRS-5 relay lens on to the front surface of the filter wheel, beyond which it is imaged onto the detector*. The viewfinder at F_2 is relayed by a fiber optics bundle to a low power viewing microscope at the rear of the instrument. The operator can therefore "sight" roughly over the top of the spectrometer, and then locate the exact target area simply in the microscope viewer. This parallelism of line of sight and optical axis of the instrument is of very important practical significance in the field.

2. The Reference Blackbody

The blackbody reference used is a thermoelectric cooler coated with Minnesota Mining and Manufacturing's black paint. The cooler is in thermal contact with a substantial heat sink. A small thermistor bead is epoxied on the cool blackened side of the unit and has its output fed to an external digital thermometer for monitoring reference temperatures. The cooler is driven by a constant current source and stabilized at about 20°C below ambient. Some deposition of moisture on the face of the blackbody can occur at this temperature differential, but does not constitute a problem since water itself is a good blackbody in the 7-14μ region.

---

*Presently an immersed thermistor detector on loan from W. Hovis, NASA/GSFC.

A better blackbody can be made by epoxying a piece of aluminum honeycomb to the face of the cooler and spraying with 3M's matte black. However, this arrangement presents too high a thermal load for small cooling elements and cooling efficiency is impaired.

3. Mechanical Design

Figures A1 and A2 show the layout of the Stanford CVF spectrometer. A shaft encoder with a resolution of 10-bits (approximately 1000 pulses per revolution) is keyed on to the same shaft that drives the CVF. Thus any position of the filter wheel can be uniquely defined by a combination of bits from the encoder, or more simply by counting the number of pulses from the encoder's most rapidly-changing output from some arbitrary zero. The zero position is of course set to correspond to 0° on the filter wheel - the start of a spectrum.

Since the filter wheels are usually constructed to give two spectra per 360° of rotation, a 10-bit encoder allows up to 500 samples to be taken per spectrum. This appears adequate for the present state of the art which limits circular variable filters of this type to 1.0 to 1.5% resolution.

It was found in the early MARK I version of this instrument that many components in the electronics (batteries, detector, signal cables, etc.) were susceptible to interference from alternating magnetic fields. In this instrument therefore, both chopper and CVF drive motors are of the hysteresis synchronous type, chosen because of their low external magnetic field. A lamp-phototransistor combination detects the chopper frequency and provides a reference signal for the synchronous demodulator (Ithaco Model # 351) mounted at the rear of the spectrometer.

Detector bias is provided by batteries mounted away from any 60 cps fields. It was found during early design efforts that removal of 60 cps signals could be very difficult due to the high impedance of the detector. Consequently, in this spectrometer, all signal and bias leads were taken to a common ground at the input to the low noise amplifier. Also anodizing was avoided wherever possible since it leads to very poor grounding of components.

4. Stanford Data Handling System

The data flow from spectrometer to tape recorder is controlled by a series of simple logic circuits. A data flow diagram is given in Figure . Most of the diagram is self-explanatory. The two "write" instructions are used in driving the "data-gates" before being combined and fed into the tape recorder. A delay of 100 μsec is included to allow all the gates to open fully before the "write" operation takes place. In this system, the identification data is written during a gap in recording which is created by blanking out alternate 180° sectors of the wheel. The time that would have been occupied by the second spectrum is now used for writing identification data, thereby avoiding the use of large or high speed multiplexers. The multiplexer needed for this system has in fact only six channels.

Selection of the half of the filter wheel to be used is accomplished by gating the "write" instructions with a suitable output from the encoder. Another output, after suitable gating produces the "record gap" instruction. Thus the system records a sequence of:

Identification Data
First Spectrum
Record Gap
Identification Data
Second spectrum
Record Gap, etc.

At the end of a recording session a "file gap" can be entered manually which enables the computer to separate those data from spectra recorded the next day (for example).

In using this system, the first record on the tape in any data set is used as a means of identification for the whole group of spectra.

Various levels of sophistication are possible in identifying groups of spectra. In the Stanford system, the spectrum is identified by:

a)	the Tape Number	(recorded on the beginning of each tape)
b)	Spectra group number	(used in conjunction with field notes to identify the sample)
c)	Spectrum number	(denotes the spectrum within a given group)

By using these three numbers, any spectrum on a given tape should be capable of selection (or being by-passed) by the computer. In addition a number of temperatures essential to the reduction of our spectra are recorded during the identification sequence.

5. Other CVF Instruments

The instrument described here was developed primarily as a ground based unit for work on NASA's remote sensing program. An advanced CVF spectrometer was procured by NASA/MSC for use in the airborne phase of the same program. This instrument was built by Lockheed Missiles and Space Co., Sunnyvale, California, under the direction of Mr. Jere Patterson, and is capable of taking six spectra per second in the 6.5-13μ region. Its filter wheel is equipped with an edge-coding analogous to the shaft encoder used in the Stanford instrument. Although the data recording system presently used is analog, the computer processing performed by NASA/MSC closely approximates the philosophy described in this paper. This time the computer (and not the A-D converter) is instructed to pick out a digital sample from the spectrometer output every time a pulse from the CVF edge-coding appears.

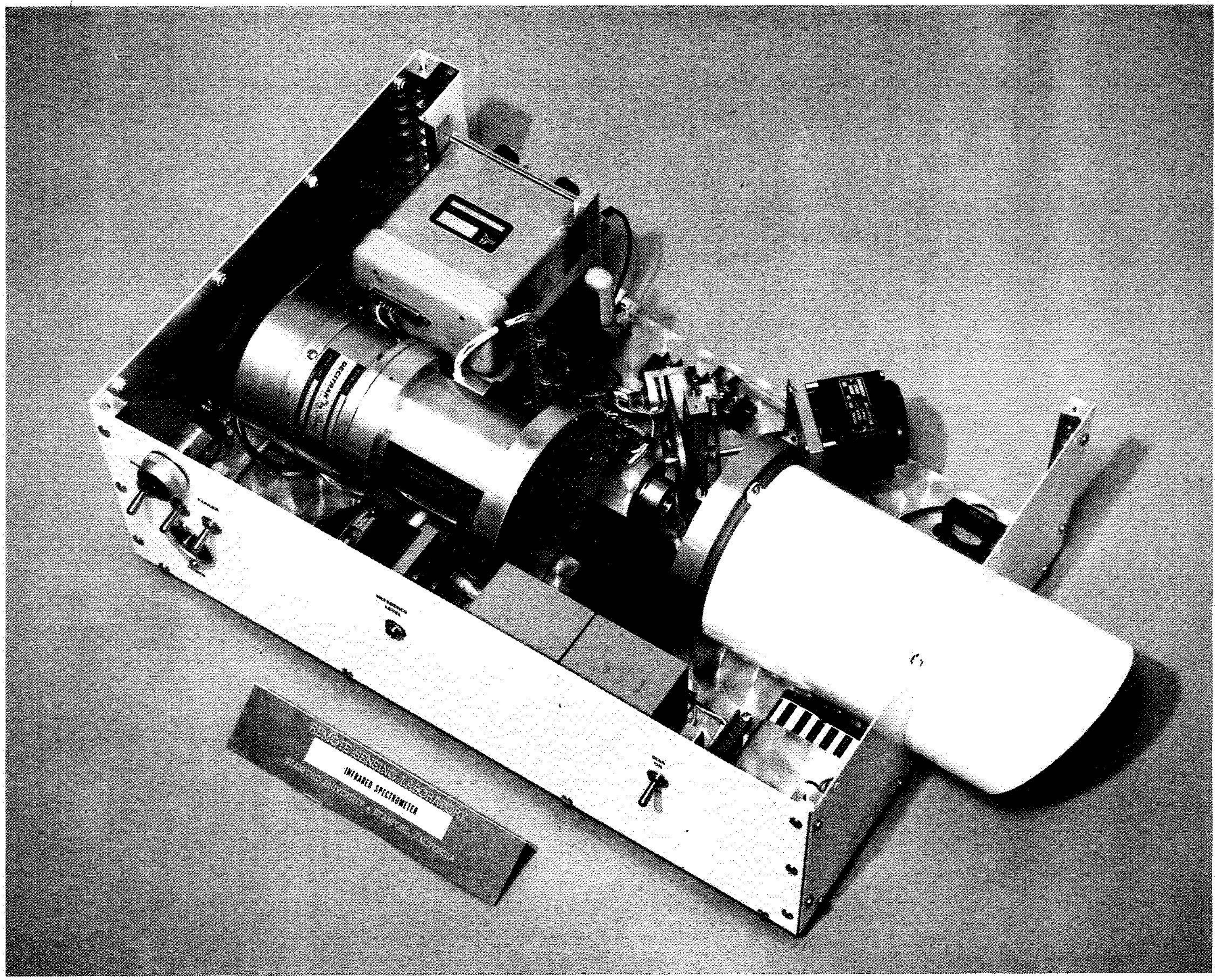
Prior to the development of this instrument, Hovis also flew a balloon and an airborne CVF spectrometer similar to our MARK I design, but the data handling system was a very simple analog recording.

CVF SPECTROMETER COSTS

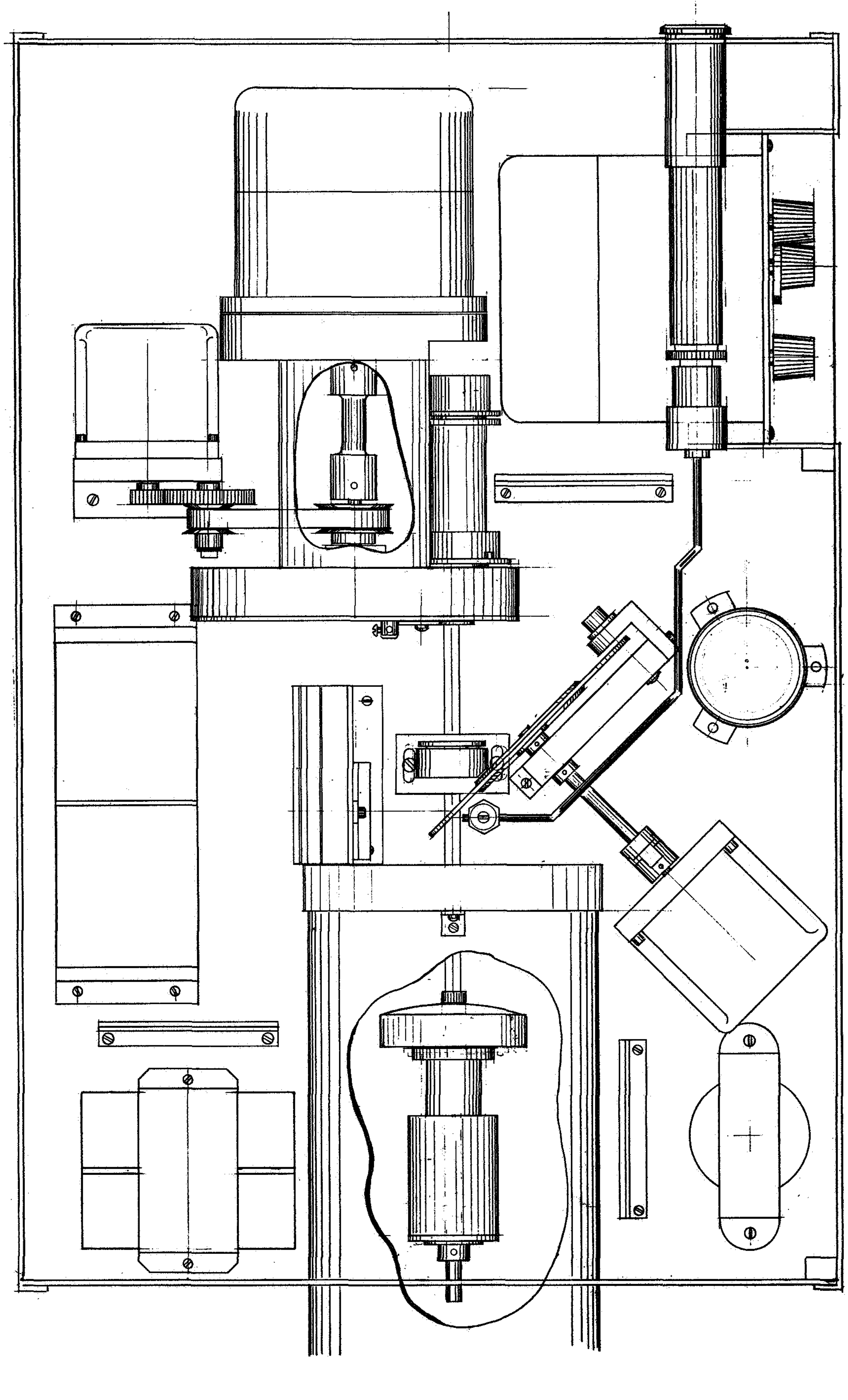
	NASA HDQ.GRANT		NASA HOUSTON		NASA HUNTSVILLE		TOTAL
HARDWARE							
Hardware	$12,803		-		$ 125		$ 12,928
Spare Detector	4,059		-		-		4,059
TOTAL HARDWARE	$16,862		-		$ 125		$ 16,987
	Man Mo.	$	Man Mo.	$	Man Mo.	$	
LABOR							
1. Professional Building, Repair, Main.	2.20	$1408	0.5	$ 643	0.75	$ 964	$ 3,015
2. Sub-Professional Building, Repair, Main.					1.75	1312	1,312
3. Clerical					0.2	100	100
LABOR	2.20	1408	0.5	643	2.70	2376	4,427
LABOR + OVERHEAD AND BENEFITS		2365		1080		3991	7,436
TOTALS TO 2/1/68		19,227		1080		4116	24,423
		(79%)		(3%)		(17%)	

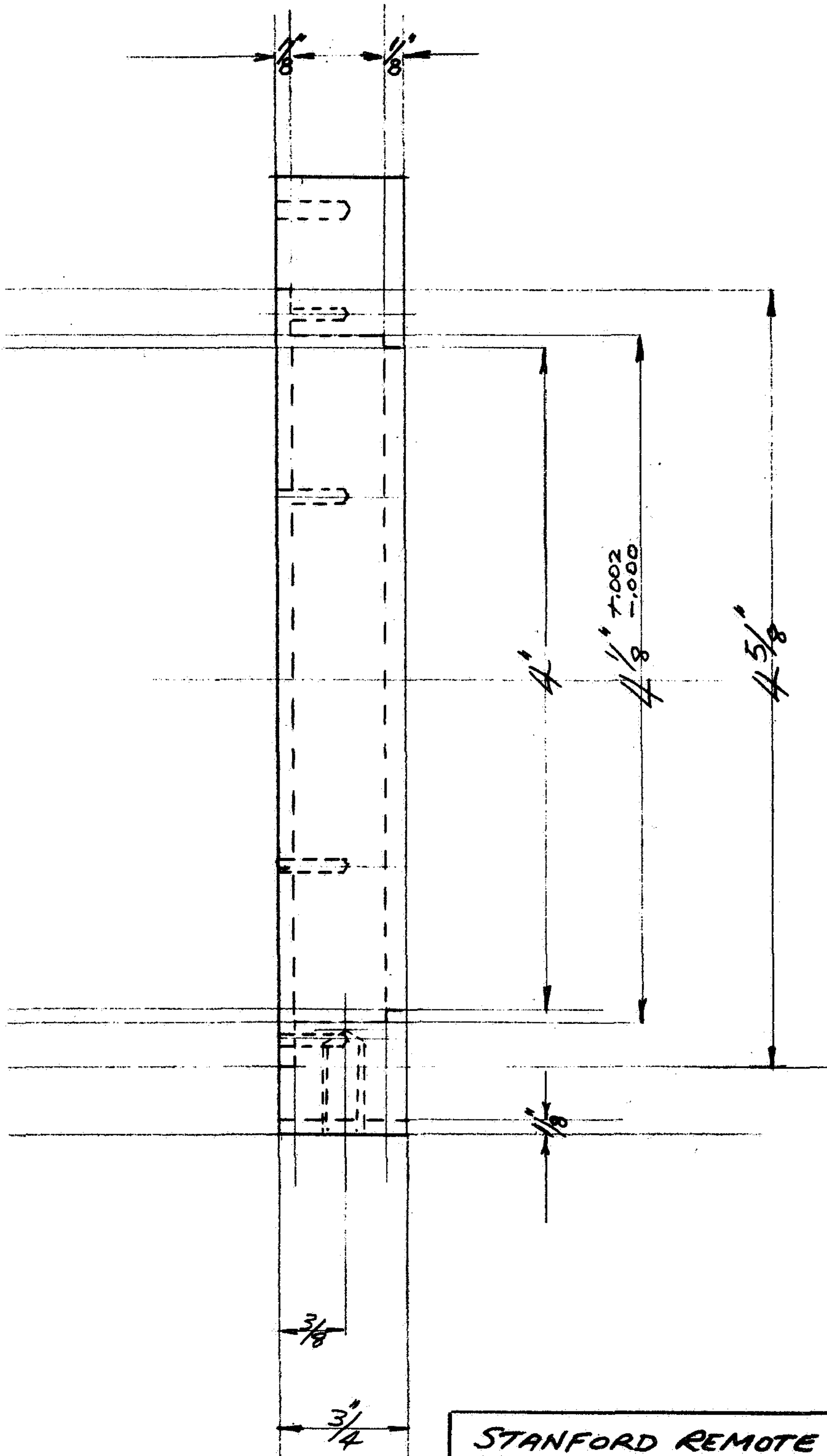
B. DIGITAL DATA SYSTEM COSTS

	NASA HDQ.Grant		NASA HOUSTON		NASA HUNTSVILLE		TOTAL
HARDWARE							
Hardware	-		-		$ 760		$ 760
Digital Recorder	-		3,964		-		3,964
	Man Mo.	$	Man Mo.	$	Man Mo.	$	
LABOR							
1. Professional Building, Repair, Main.	-		0.3	386	0.3	386	772
2. Sub-professional Building, Repair, Mian.	-		-		-		
3. Clerical	-		-		0.2	100	100
LABOR	-		0.3	386	0.5	486	872
LABOR + OVERHEAD AND BENEFITS				648		816	1,464
TOTALS TO 2/1/68				$4,612		$1,576	6,189
				(74%		(26%)	
GRAND TOTAL OF BOTH EFFORTS		$19,227		5,692		5692	30,612
		(63%)		(18.5%)		(18.5%)	

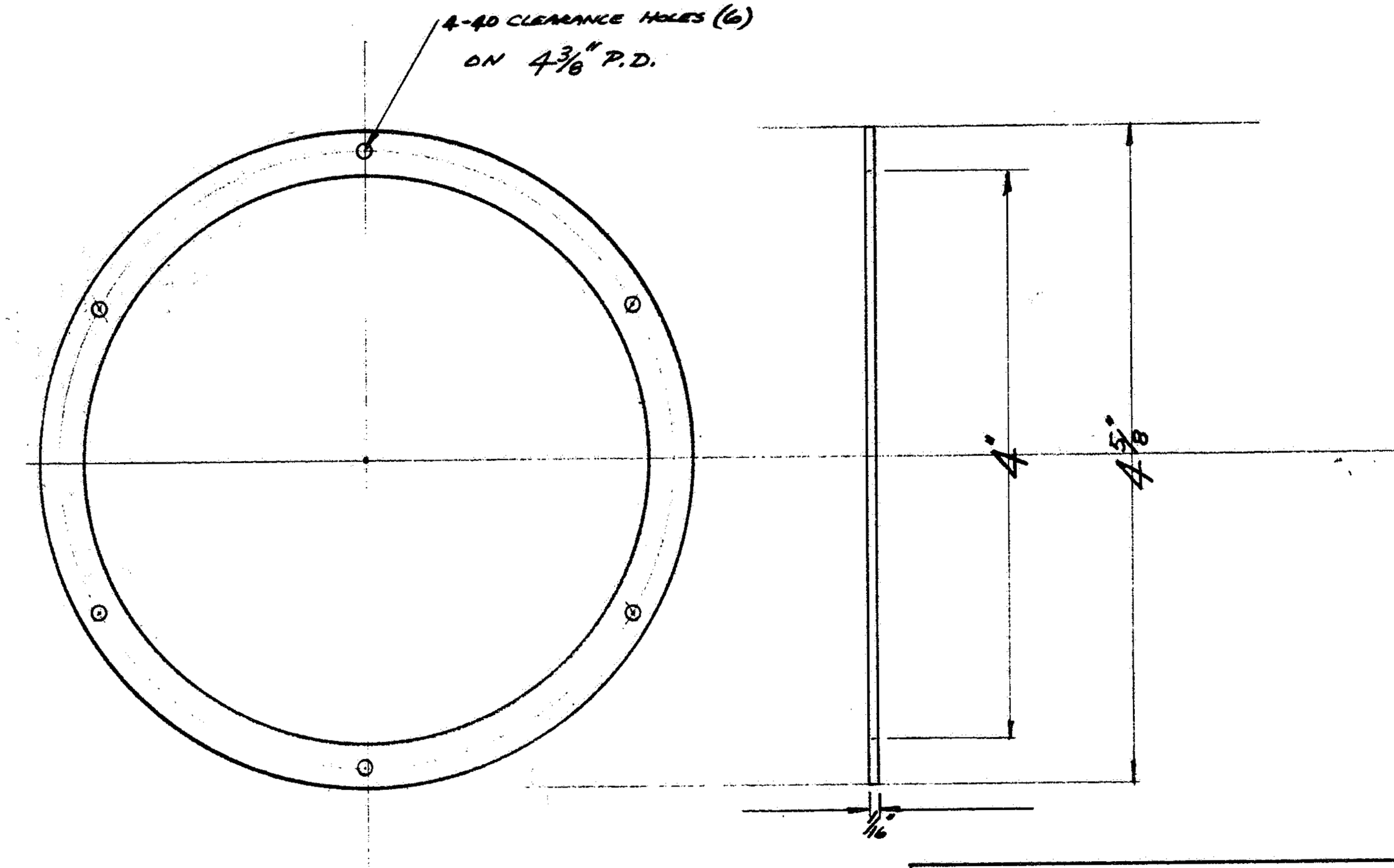


Stanford CVF Infrared Spectrometer

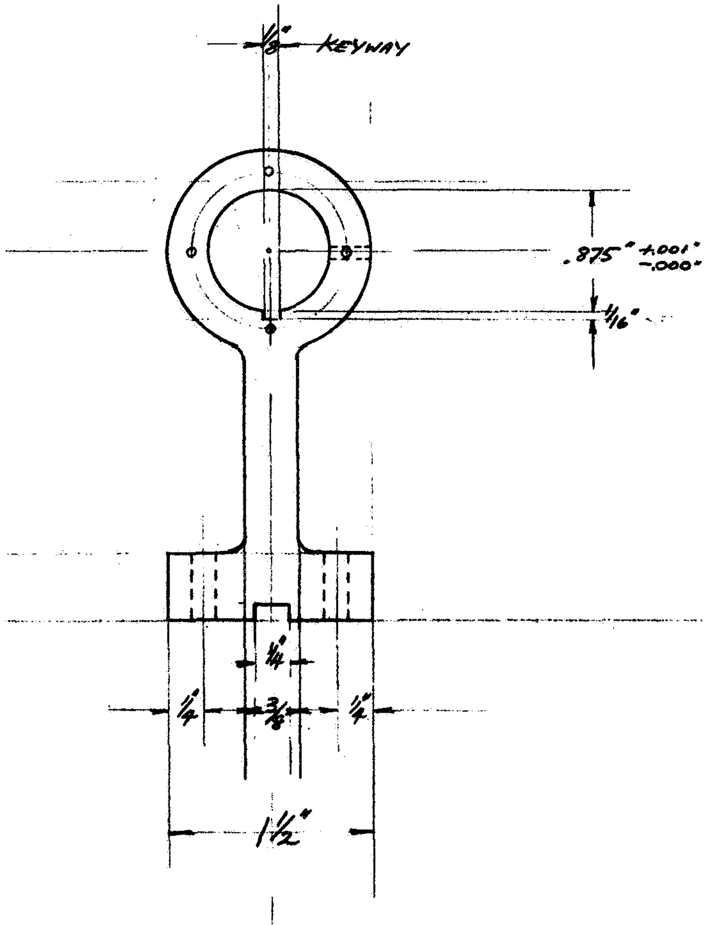




STANFORD REMOTE SENSING LAB	
MAT ALUM	PRIMARY MIRROR MOUNT
SCALE	TOLERANCES UNLESS STATED
DRAWN P. Gordon	FRACTIONAL ± 1/64"
4-26-68	DECIMAL ±.005
	NO REQ 1

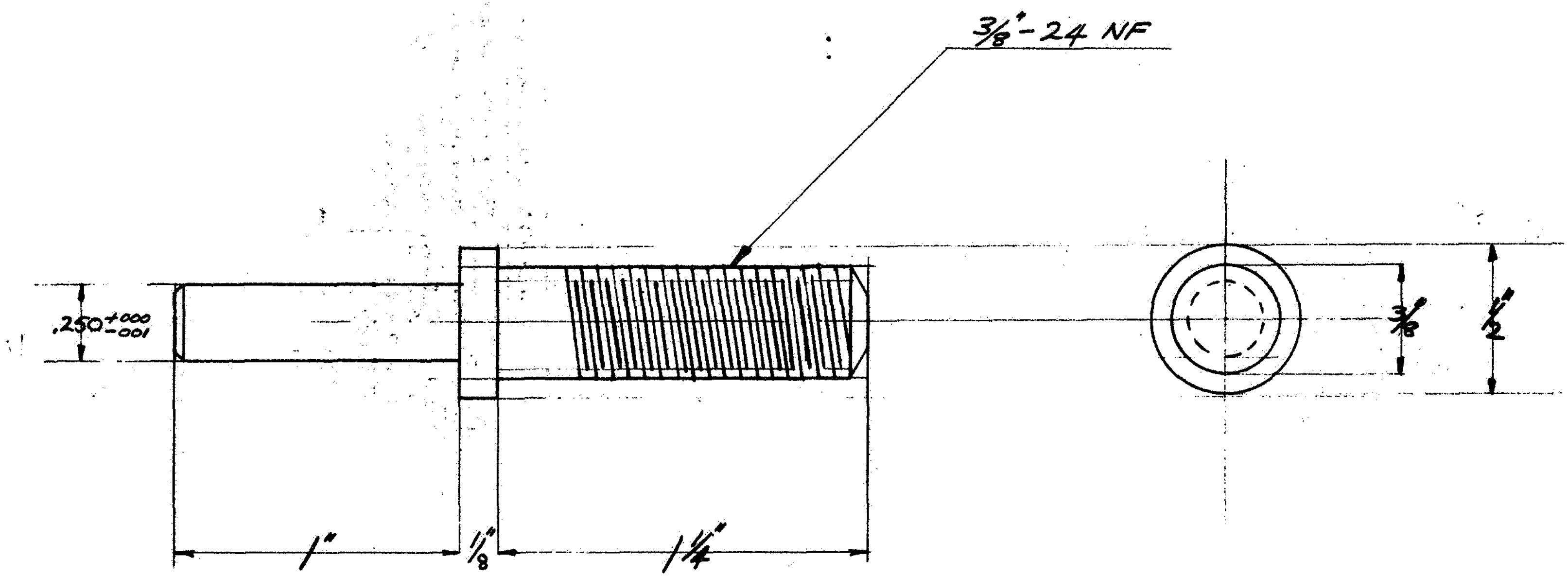


STANFORD REMOTE SENSING LAB	
MAT ALUM	PRIMARY MIRROR RET
SCALE FULL	TOLERANCES UNLESS STATED FRAC 1/64" DEC .005" ±
DRAWN P. Gordon	N° REQ 1
5-29-68	BREAK ALL SHARP EDGES

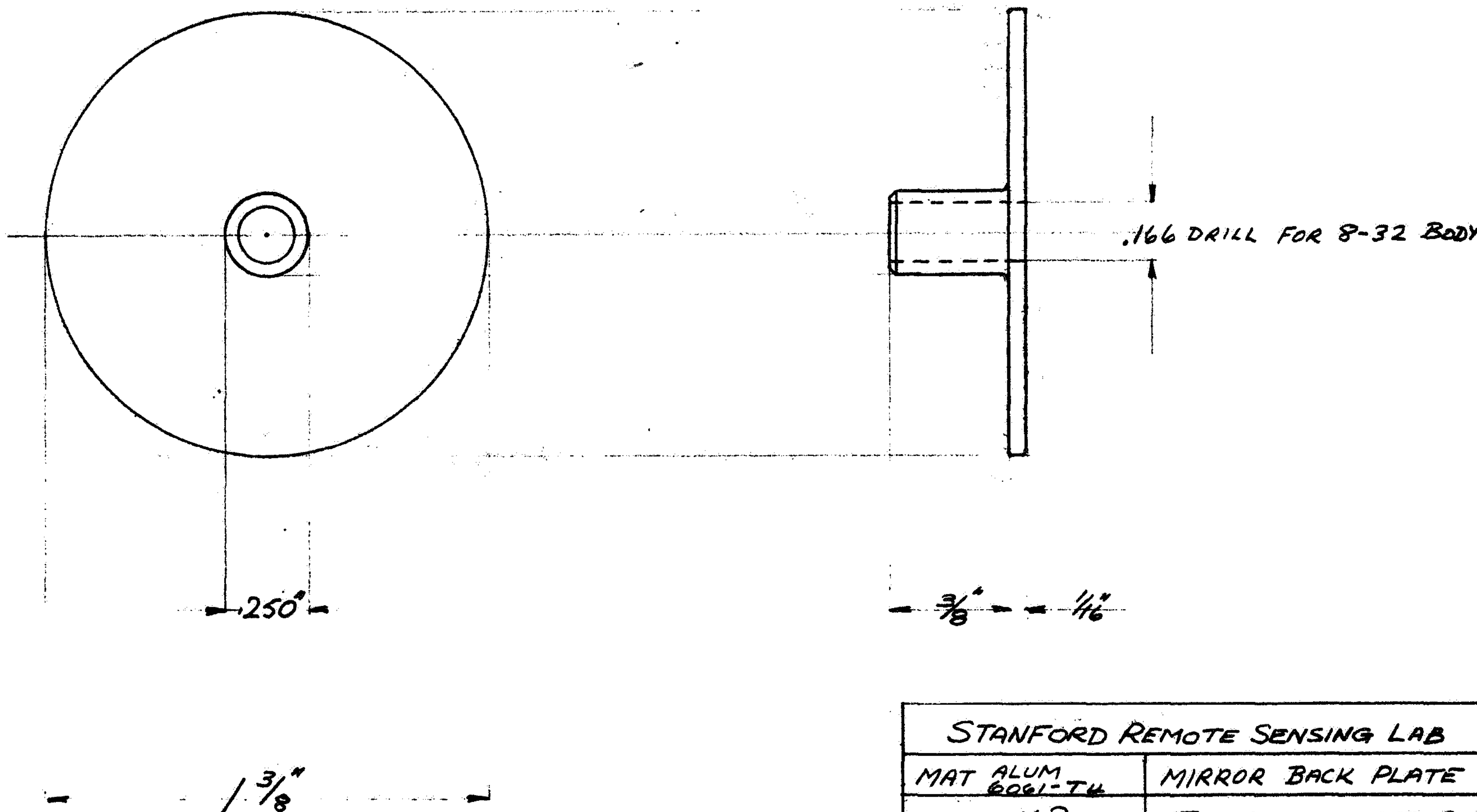


MAT ALUM 1 OFF

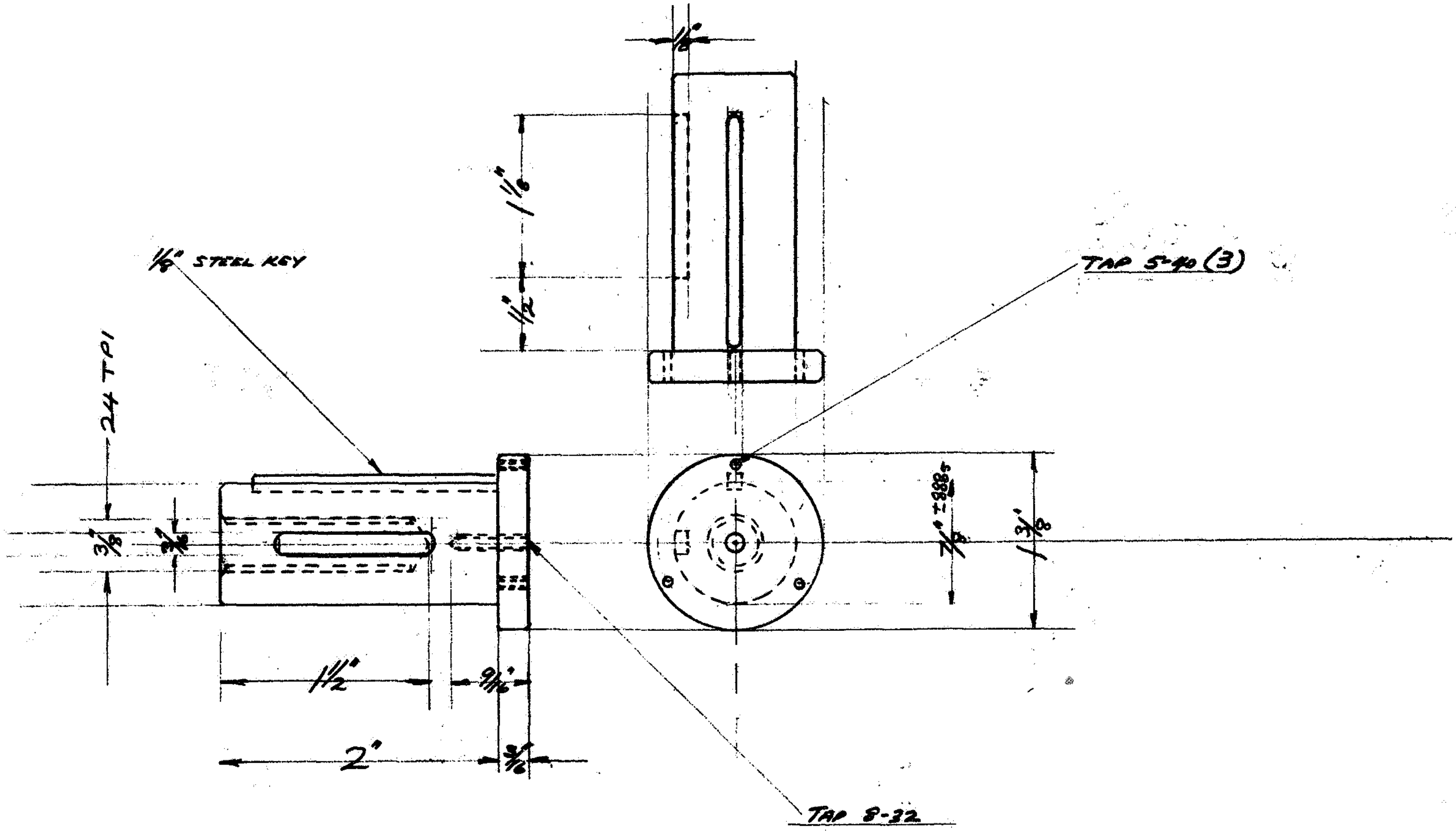
STANFORD REMOTE SENSING LAB	
MAT ALUM	SECONDARY MIRROR MOUNT
SCALE FULL	TOLERANCES UNLESS STATED
DRAWN P. Gordon	FRACTIONAL $\pm \frac{1}{64}$"
3-20-68	DECIMAL $\pm$.005
1 REQ	



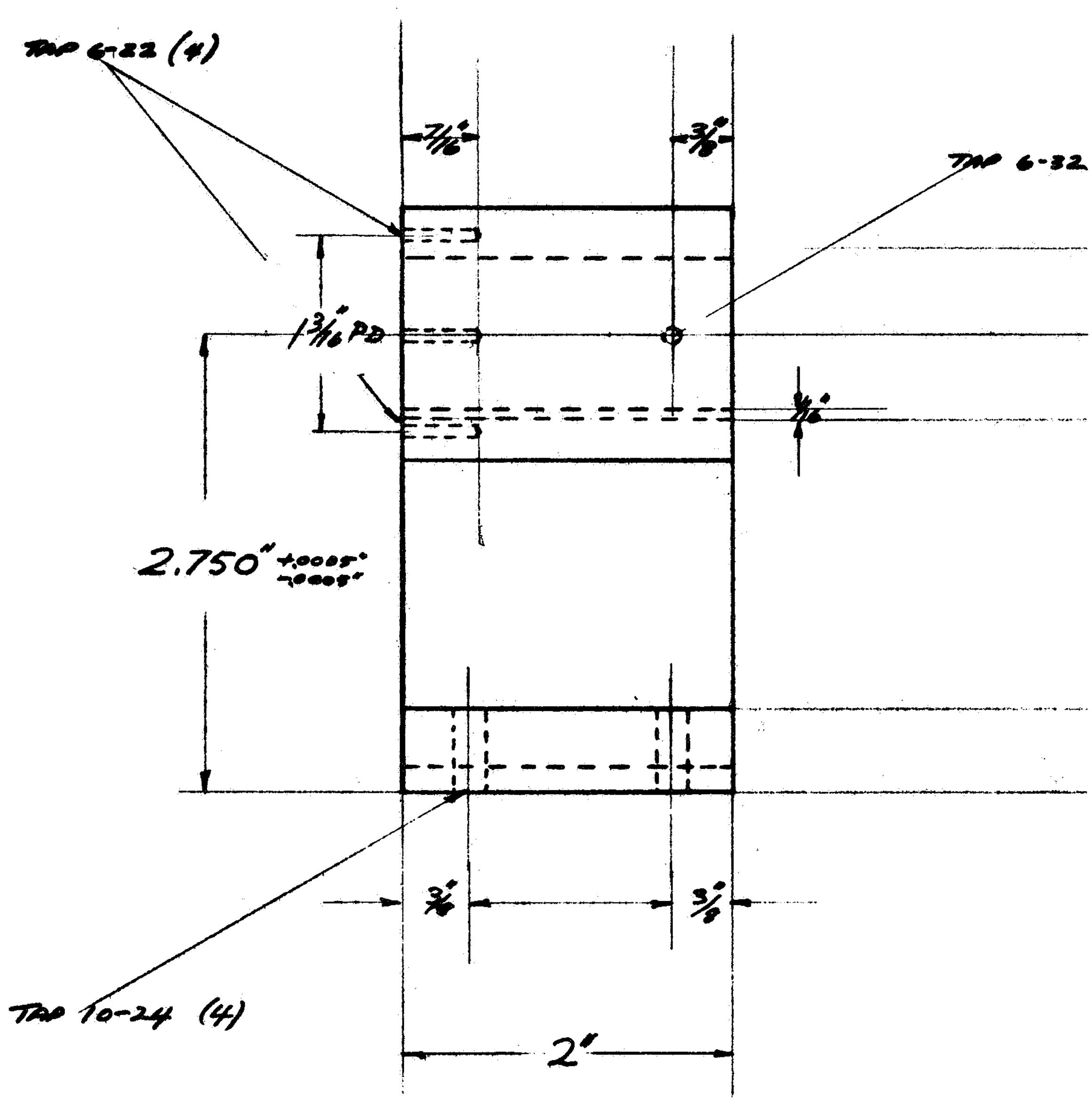
STANFORD REMOTE SENSING LAB	
MAT. C.R.S.	MIRROR ADJ. SCREW
SCALE X2	TOLERANCES UNLESS STATED
DR. P. GORDON	FRACTIONAL ± 1/64"
3-20-68	DECIMAL ± .005"



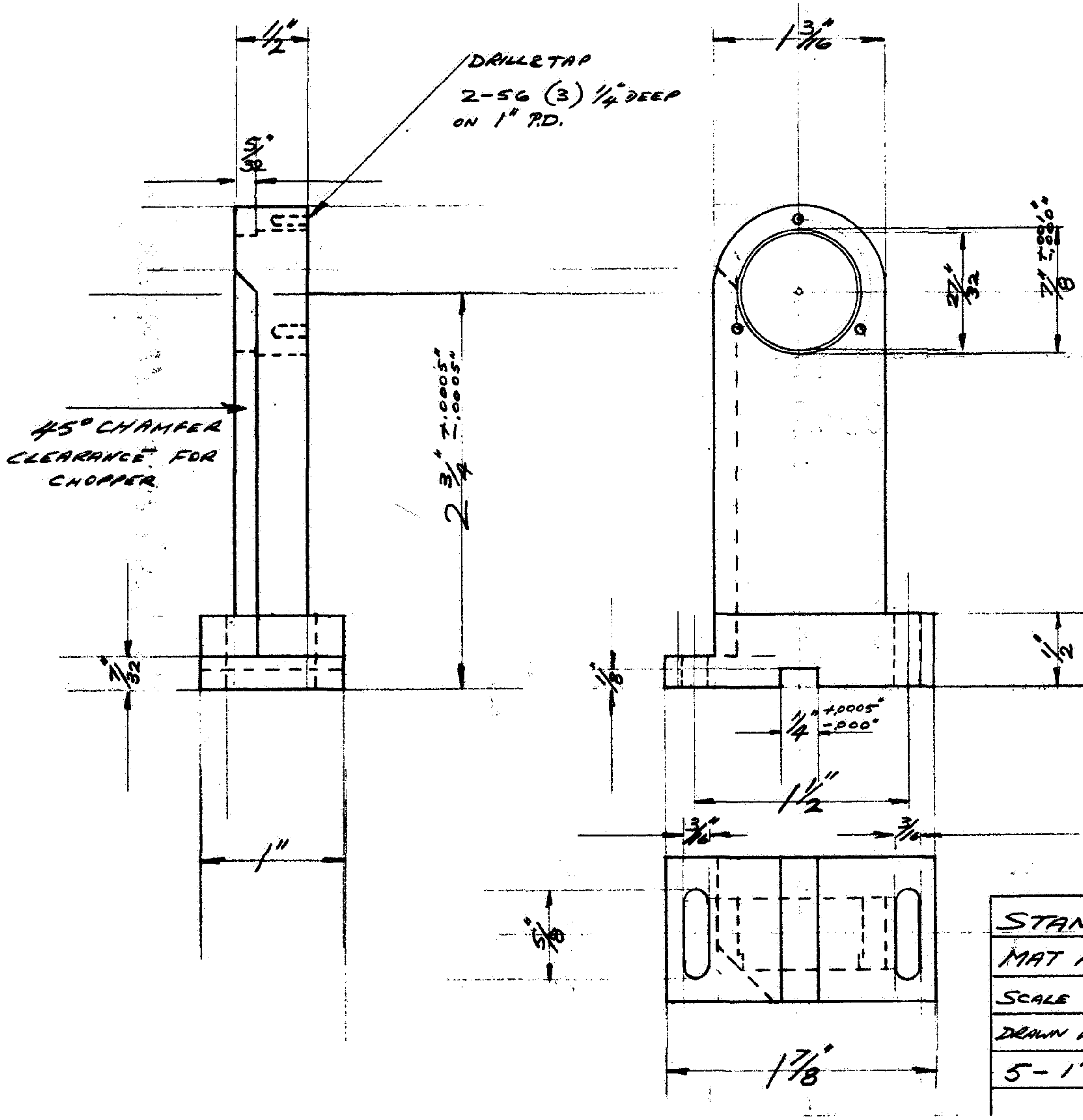
STANFORD REMOTE SENSING LAB	
MAT ALUM 6061-T6	MIRROR BACK PLATE
SCALE X 2	TOLERANCES UNLESS STATED
DRAWN P. Gordon	FRACTIONAL ± 1/64"
3-21-68	DECIMAL ±.005
	NO REQ 1



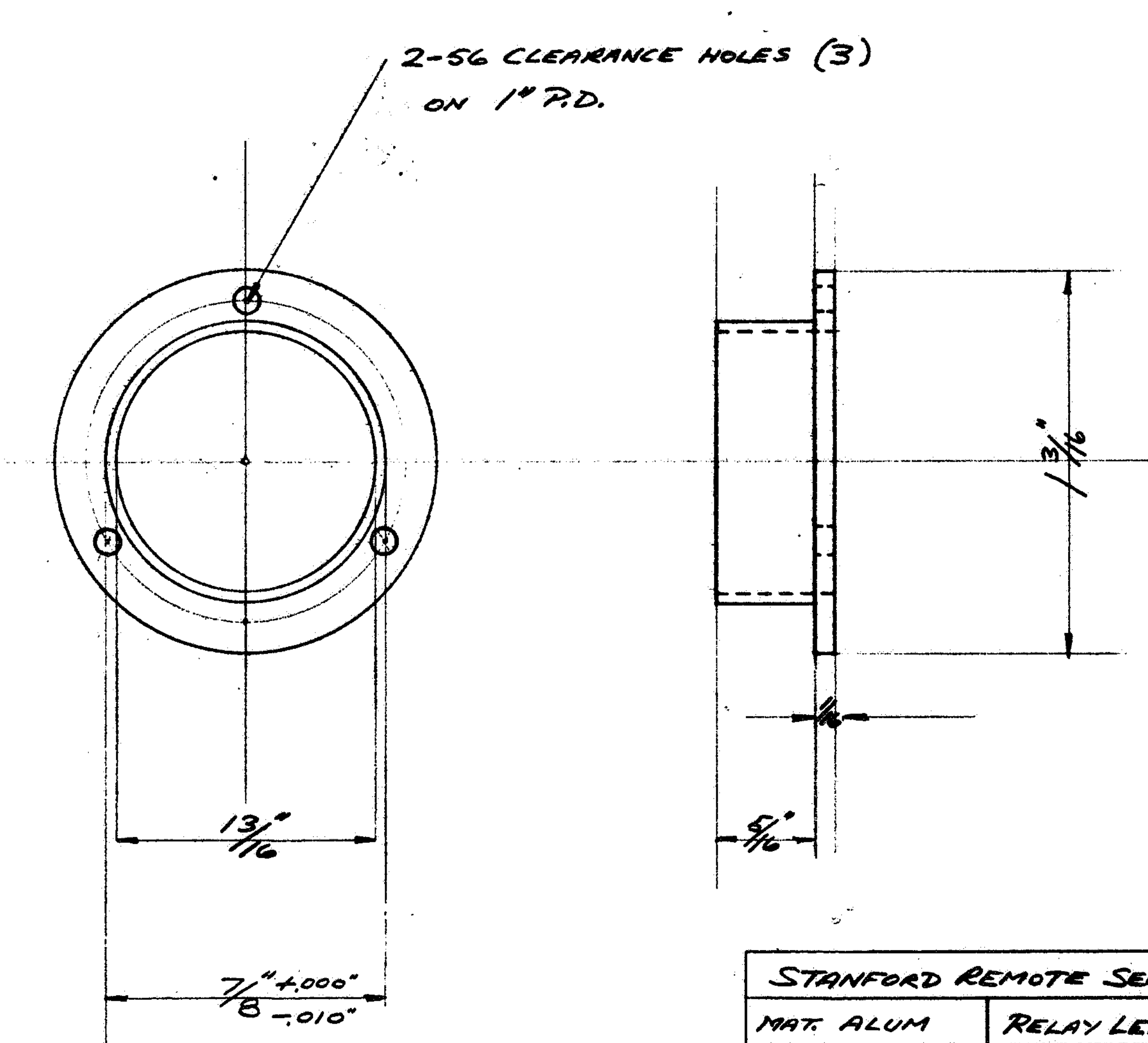
STANFORD REMOTE SENSING LAB	
MAT ALUM 6061-T4	MIRROR ARBOR
SCALE FULL	TOLERANCES UNLESS STATED
DRAWN [illegible]	FRACTIONAL 1/64"
3-20-68	DECIMAL .005
	N° REQUIRED 1



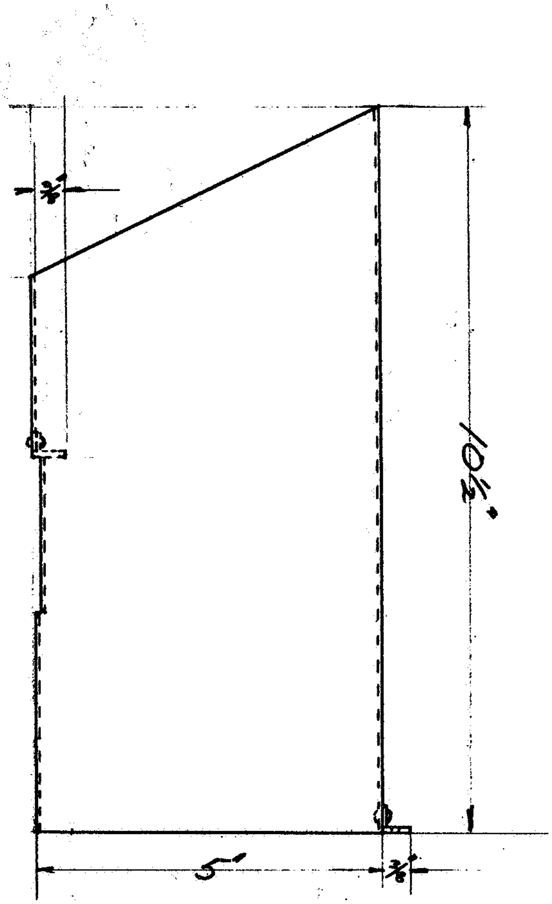
CONVEX MIRROR MOUNT



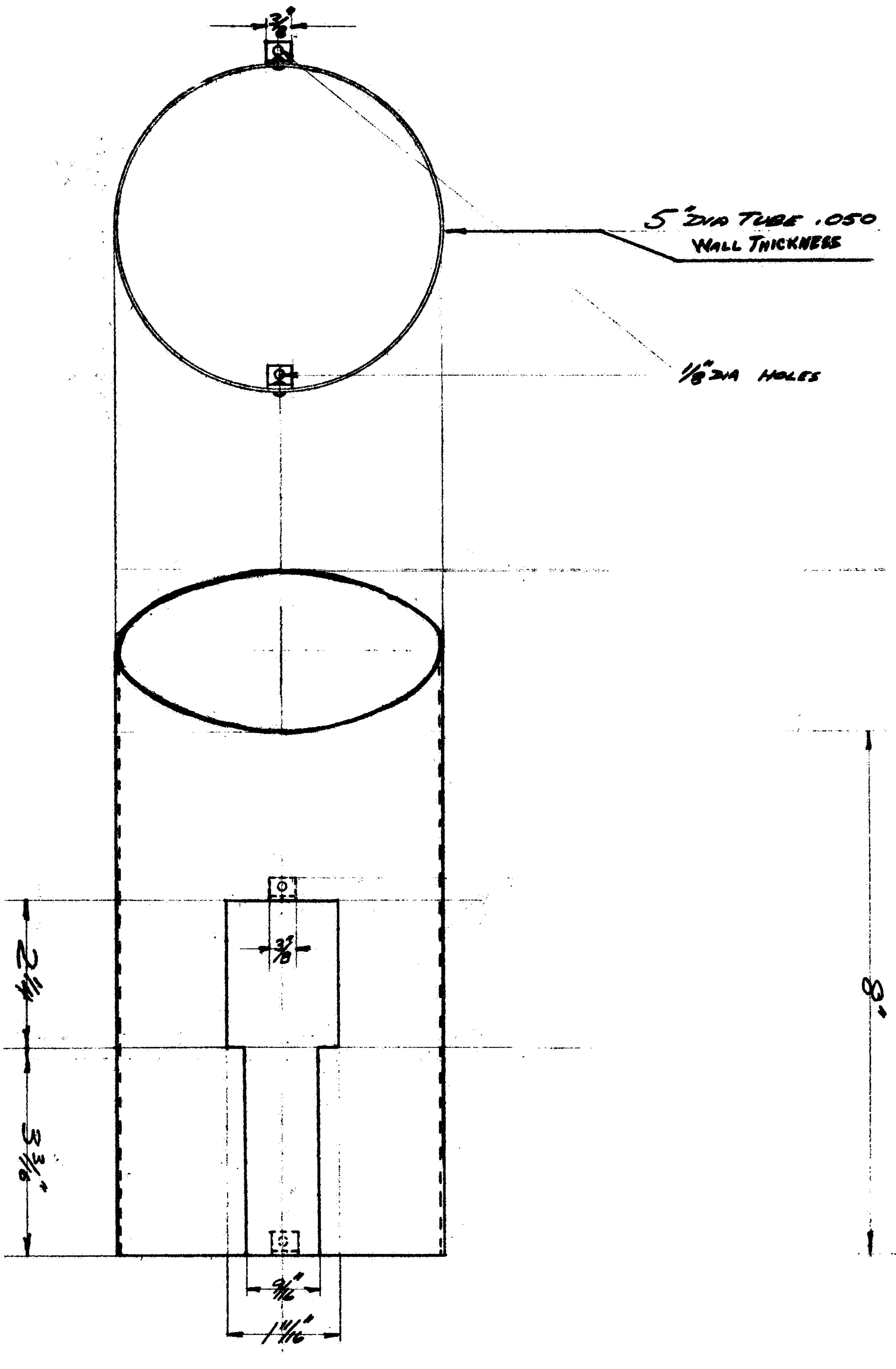
STANFORD REMOTE SENSING LAB	
MAT ALUM	RELAY LENS HOLDER
SCALE FULL	TOLERANCES UNLESS STATED FRAC ± 1/64" DEC .005"
DRAWN P. Gordon	N° REQ 1
5-17-68	



STANFORD REMOTE SENSING LAB	
MAT. ALUM	RELAY LENS RETAINER
SCALE X2	TOLERANCES UNLESS STATED FRAC ± 1/64" DEC. .005
DRAWN P. Gordon	N° REQ 1
5-17-68	BREAK SHARP EDGES

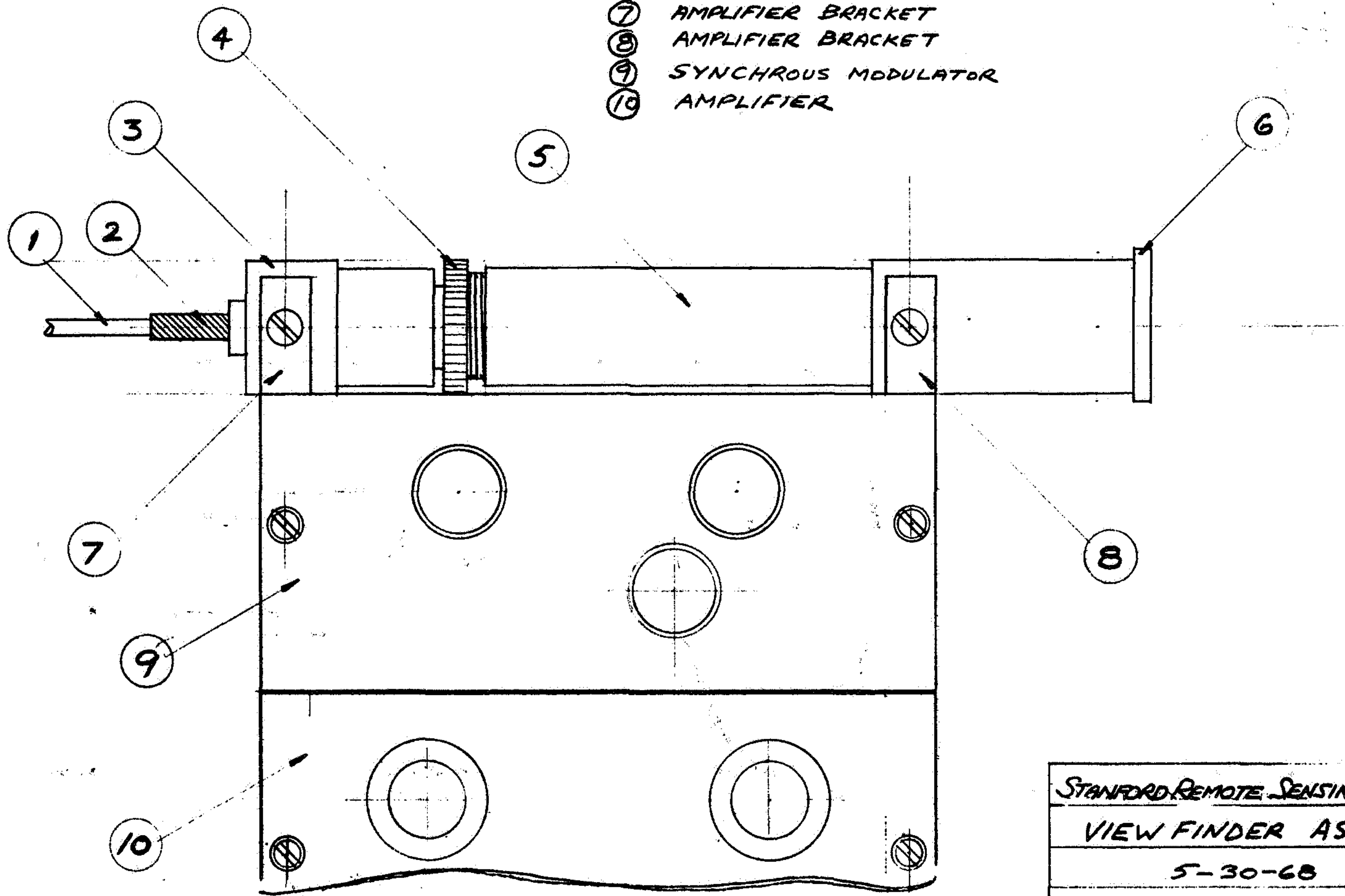


STANFORD REMOTE SENSING LAB	
MAT ALUM TUBE	LIGHT SHIELD
SCALE X 1/2	TOLERANCES UNLESS STATED
DRAWN P. Gordon	FRACTIONAL 1/64"
3-20-68	DECIMAL .005
1 REQ	

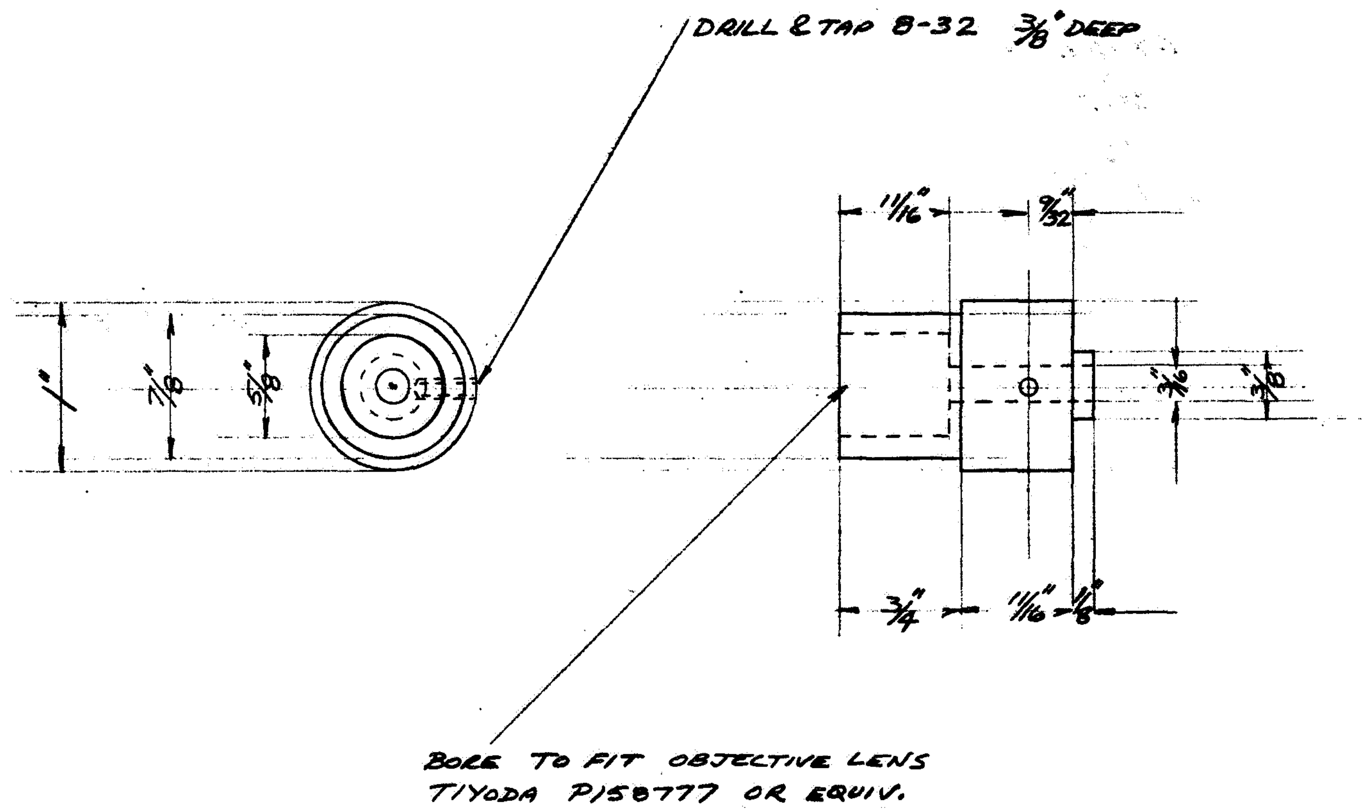


3/8"
5" DIA TUBE .050
WALL THICKNESS
1/8" DIA HOLES
3/8"
2 1/4"
3 3/16"
8"
9/16"
1 11/16"

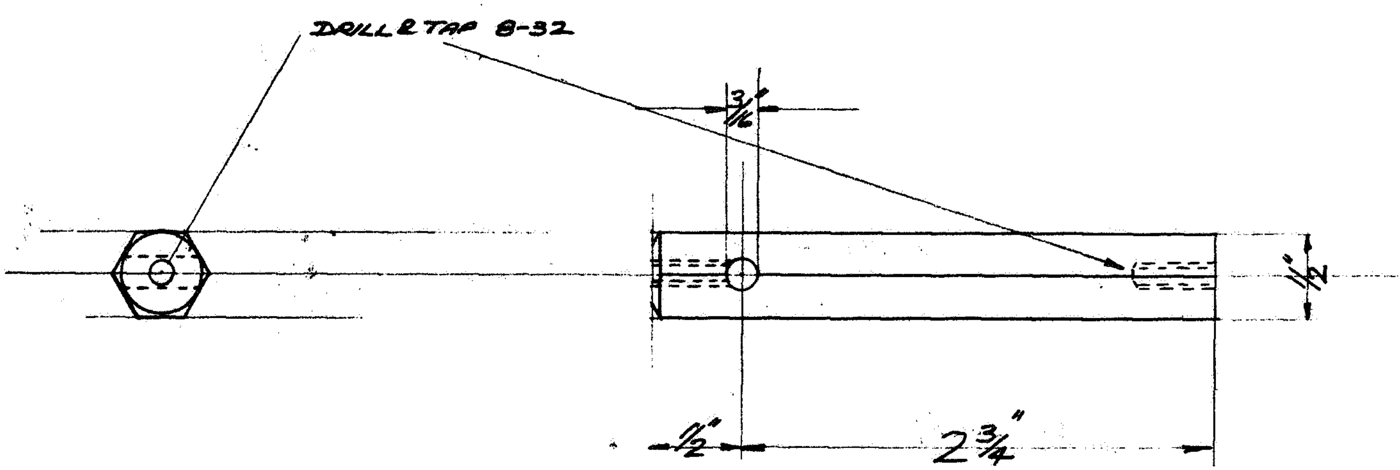
(1) LIGHT CONDUIT
(2) FIBRE SLEEVE
(3) LIGHT CONDUIT CONNECTOR
(4) OBJECTIVE LENS HOLDER
(5) VIEWFINDER TUBE
(6) EYE PIECE
(7) AMPLIFIER BRACKET
(8) AMPLIFIER BRACKET
(9) SYNCHROUS MODULATOR
(10) AMPLIFIER



STANFORD REMOTE SENSING LAB
VIEW FINDER ASSEM
5-30-68
DRAWN P. Gordon



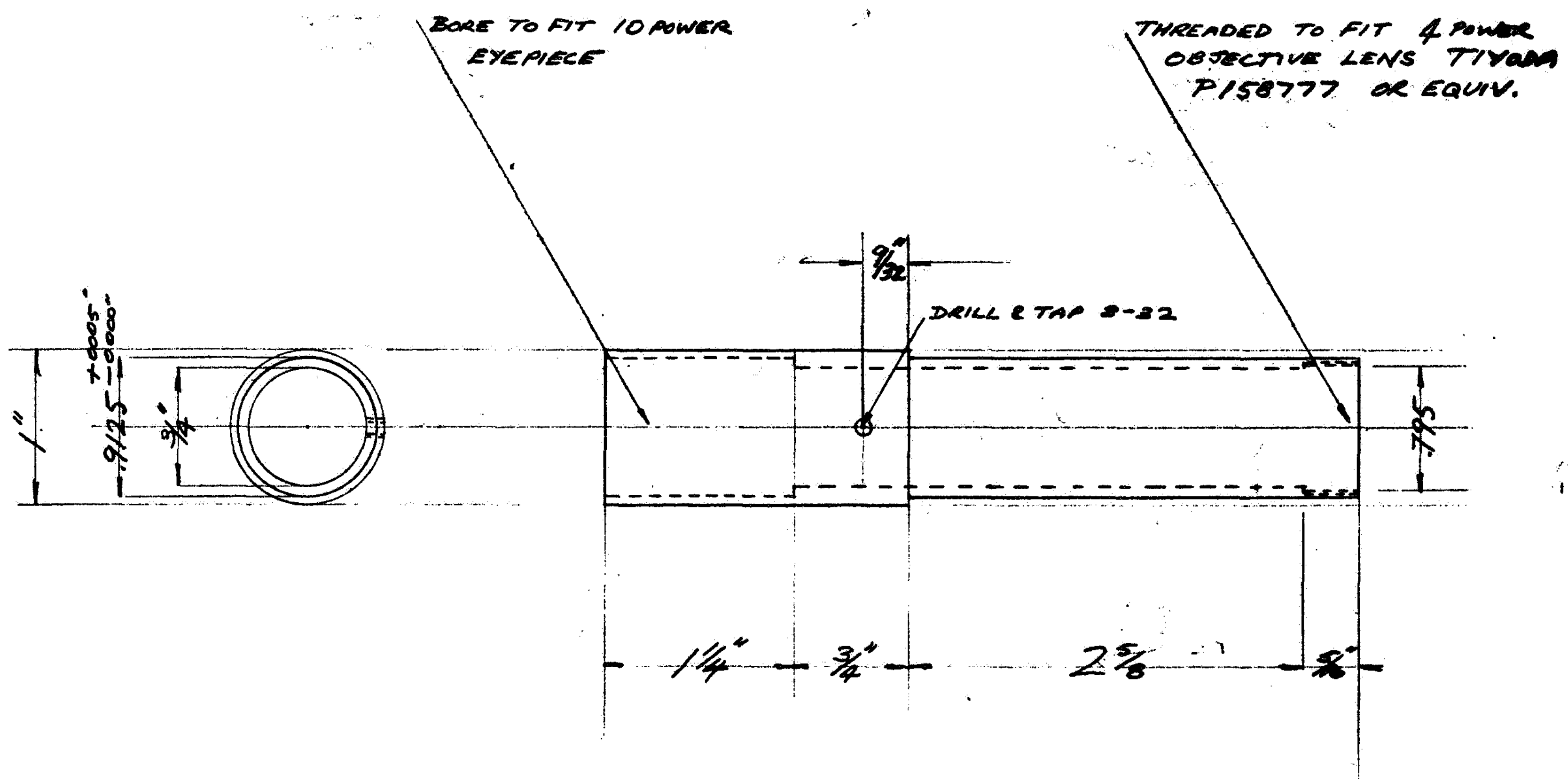
STANFORD REMOTE SENSING LAB	
MAT. ALUM	LIGHT CONDUIT CONN.
SCALE FULL	TOLERANCES UNLESS STATED FRAC 1/64" DEC .005" ±
DRAWN A. Gordon	N° REQ 1
5-30-68	BREAK ALL SHARP EDGES



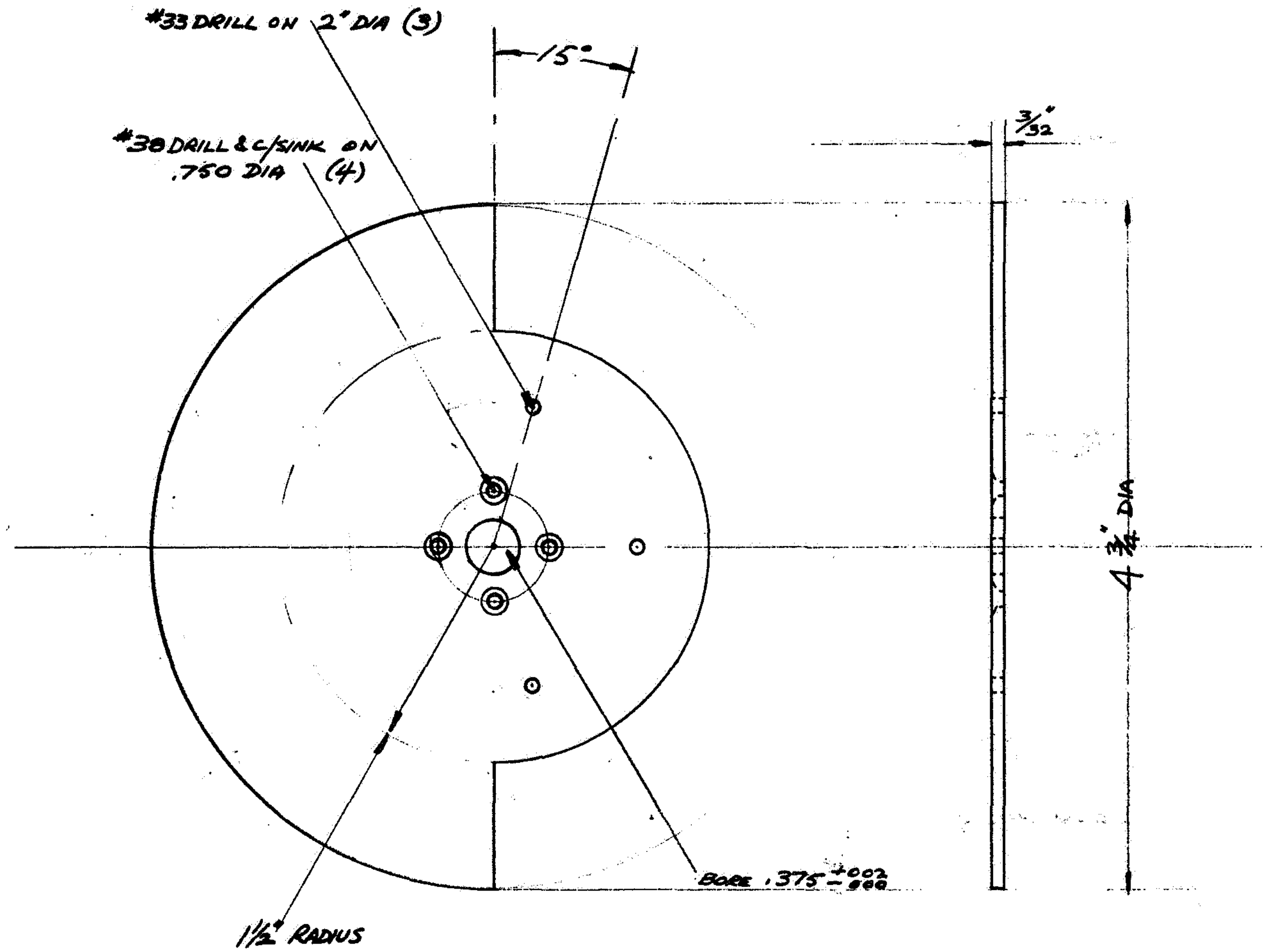
USE NYLON SCREW TO RETAIN LIGHT CONDUIT

STANFORD REMOTE SENSING LAB	
MAT ALUM HEX	LIGHT CONDUIT SUPP.
SCALE FULL	TOLERANCES UNLESS STATED FRAC 1/64" DEC .005 ±
DRAWN P. Gordon	N° REQ 1
5-29-68	BREAK SHARP EDGES

9

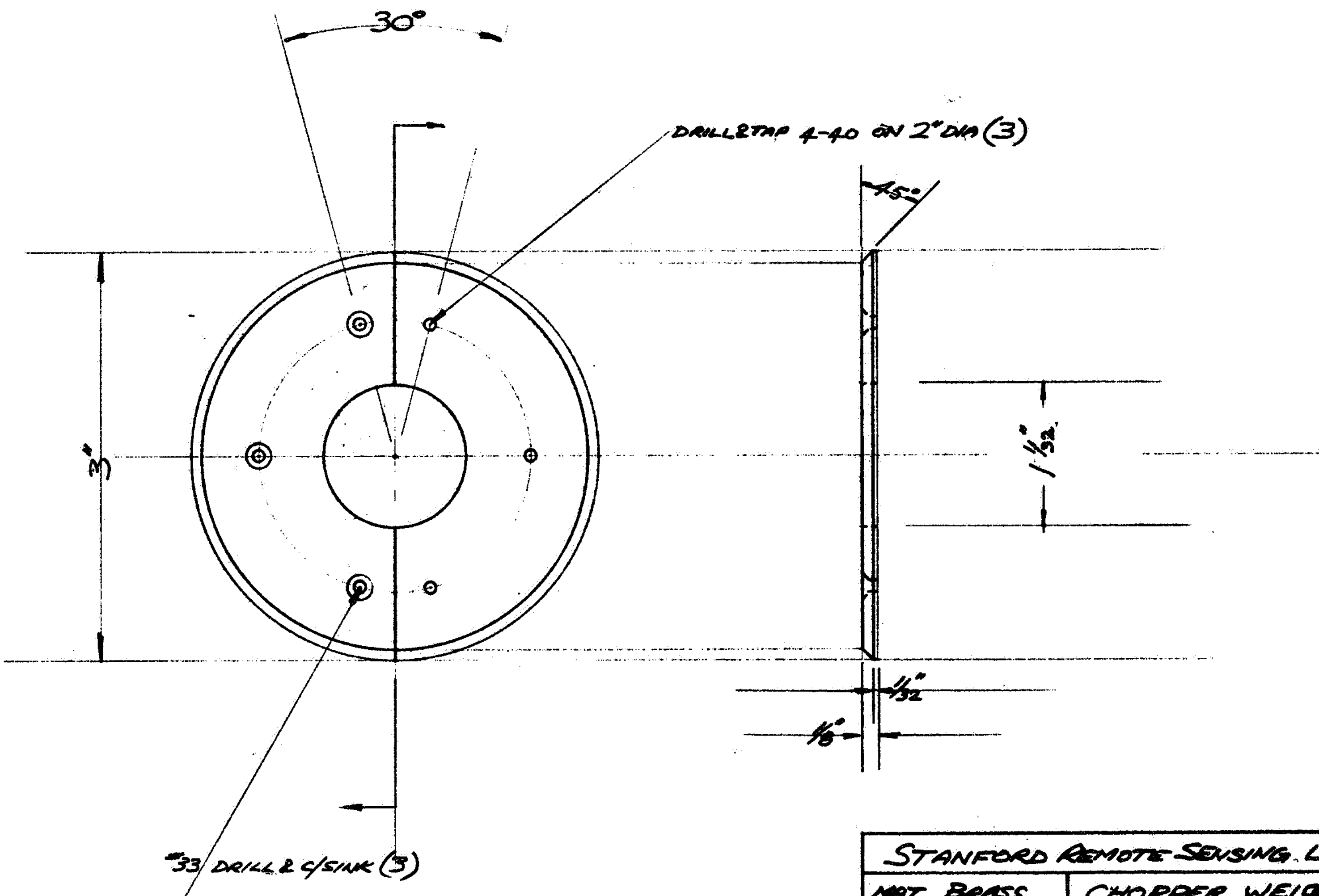


STANFORD REMOTE SENSING LAB	
MAT. BRASS TUBE	VIEWFINDER TUBE
SCALE FULL	TOLERANCES UNLESS STATED FRAC 1/64" DEC .005 ±
DRAWN P. Gordon	N° REQ 1
5-30-68	PAINT MATT BLACK INSIDE TUBE



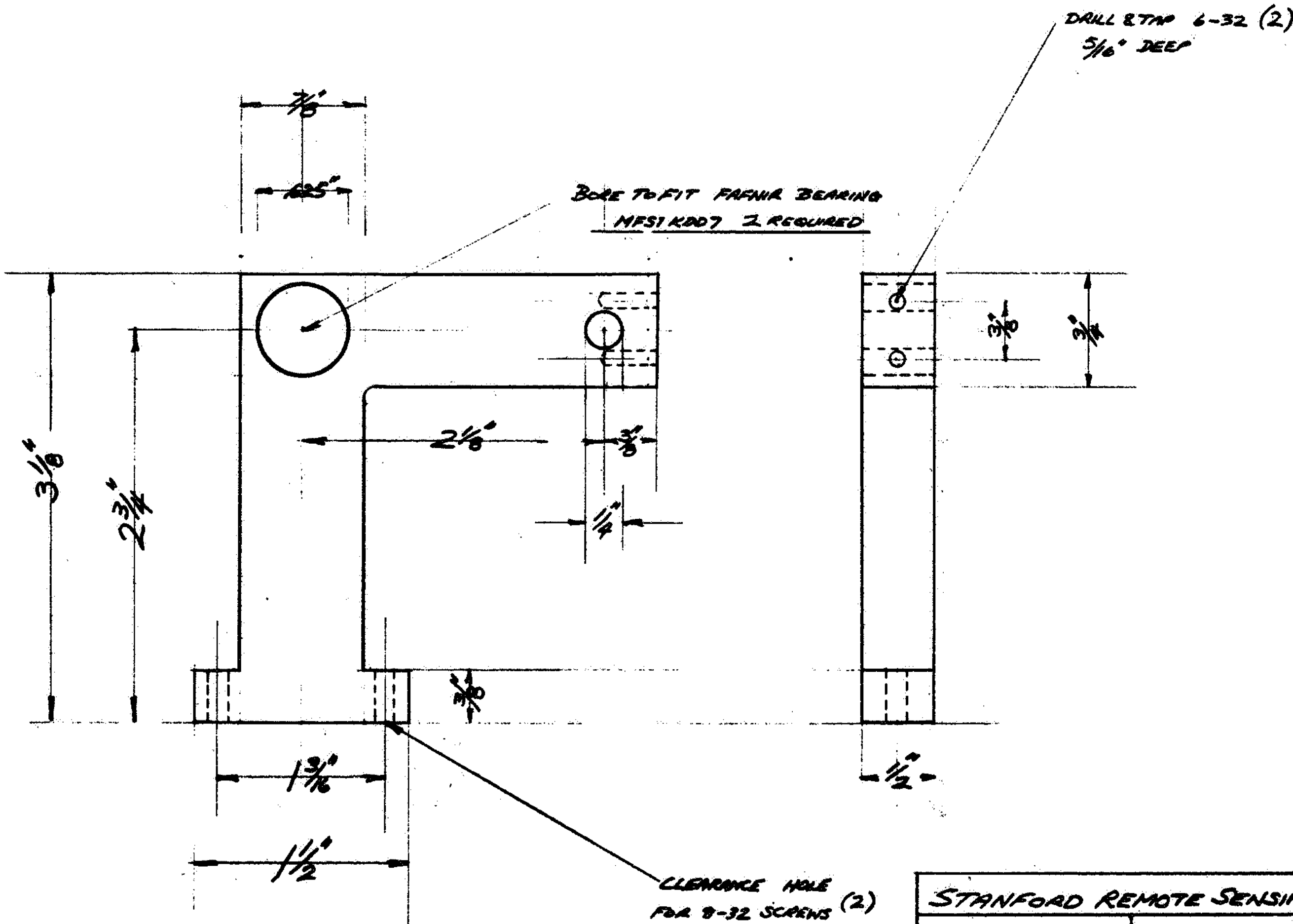
NOTE MUST BE FLAT & RUN TRUE WHEN ON HUB. POLISH EACH SIDE 32/ AND VACUUM DEPOSIT FRONT WITH GOLD REAR ALUMINUM

STANFORD REMOTE SENSING LAB	
MAT BRASS	CHOPPER
SCALE FULL	TOLERANCES UNLESS STATED FRAC 1/64" DEC .005 ±
DRAWN P. Gordon	N° REQ 1
5-30-68	

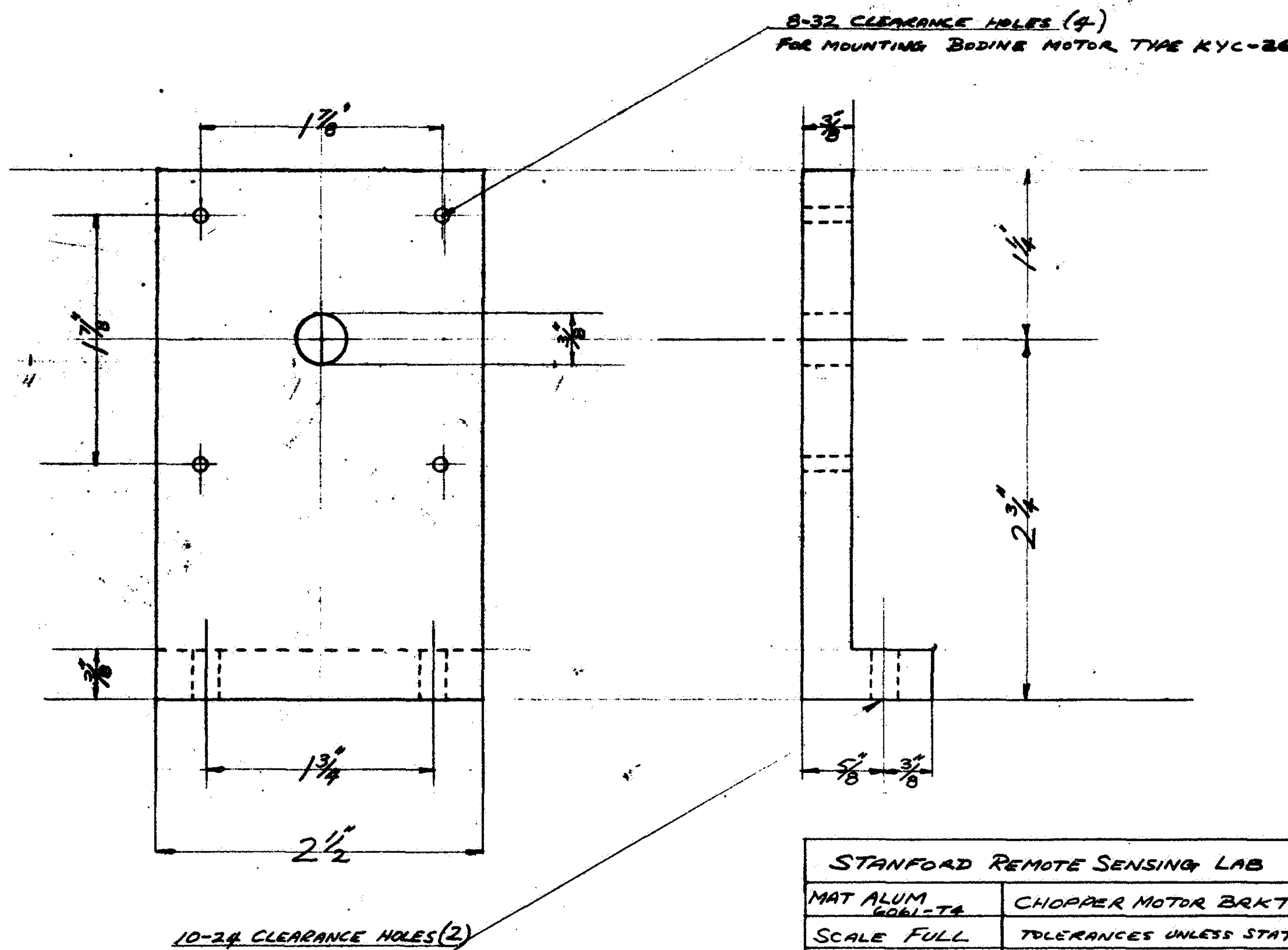


NOTE TO BE SPLIT AFTER MACHINING AND BALANCED BY SPOT DRILLING WHEN ASSEMBLED ON CHOPPER

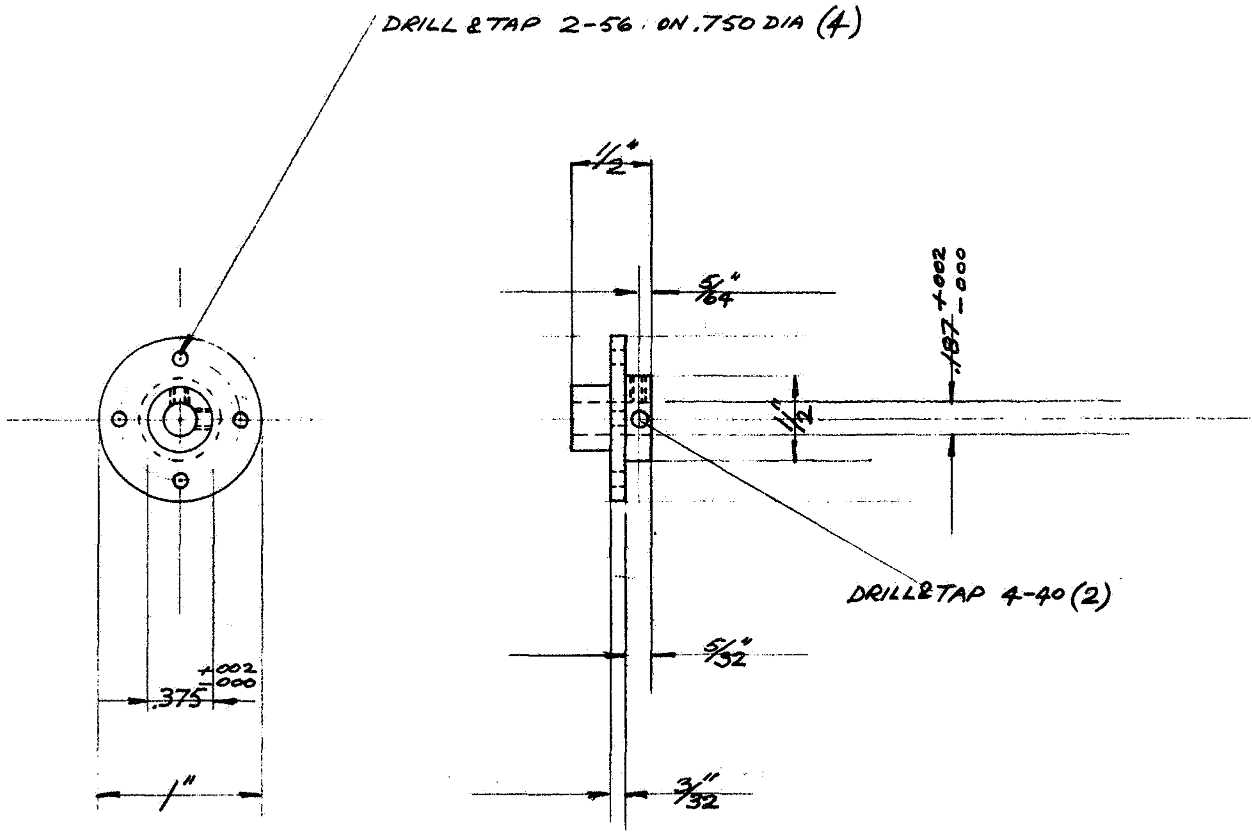
STANFORD REMOTE-SENSING LAB	
MAT BRASS	CHOPPER WEIGHT
SCALE FULL	TOLERANCES UNLESS STATED FRAC 1/64 DEC .005 ±
DRAWN P. Gordon	N° REQ 1
5-30-68	BREAK ALL SHARP EDGES



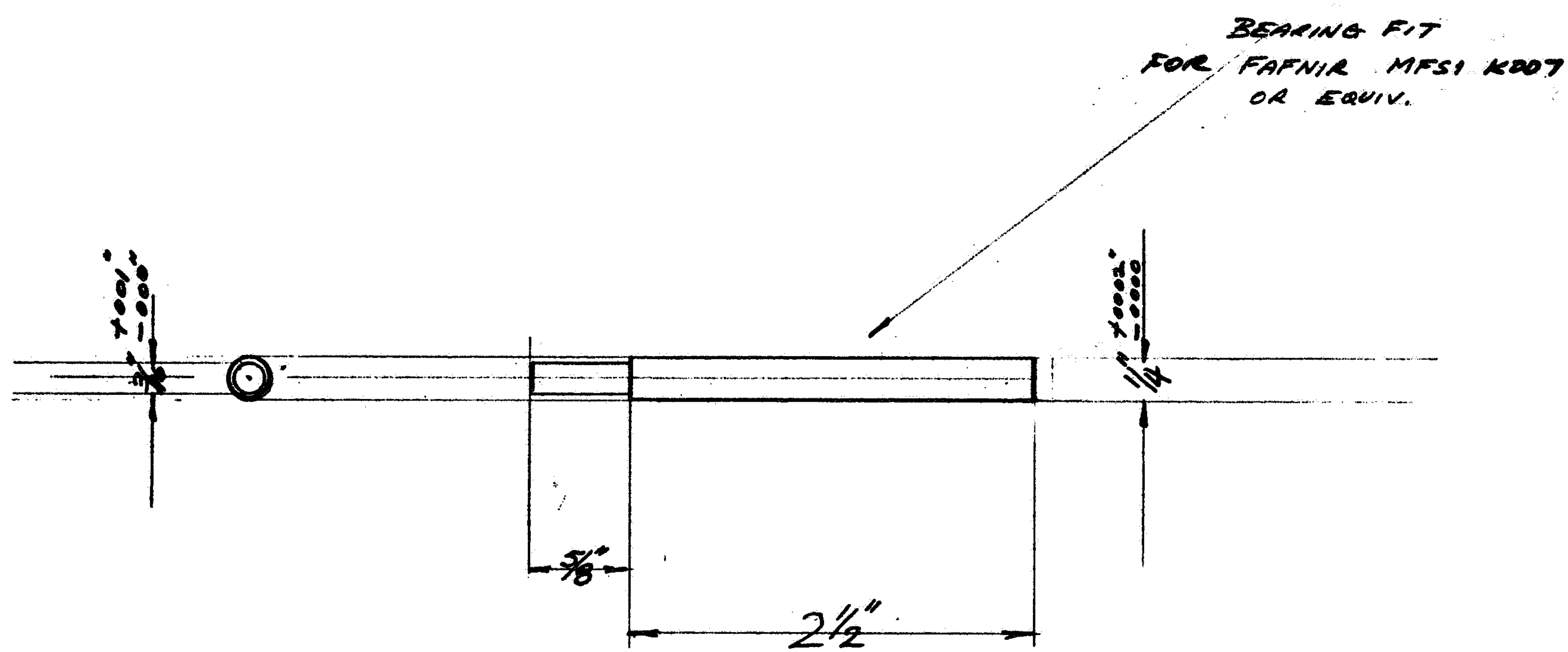
STANFORD REMOTE SENSING LAB	
MAT ALUM	CHOPPER BRKT.
SCALE FULL	TOLERANCES UNLESS STATED
DRAWN P. Gordon	FRACTIONAL ± 1/64
1 REQ	DECIMAL ±.005



STANFORD REMOTE SENSING LAB	
MAT ALUM 6061-T4	CHOPPER MOTOR BRKT
SCALE FULL	TOLERANCES UNLESS STATED
DRAWN P. Gordon	FRACTIONAL ± 1/64"
4-12-68	DECIMAL ± .005
	Nº REQ 1

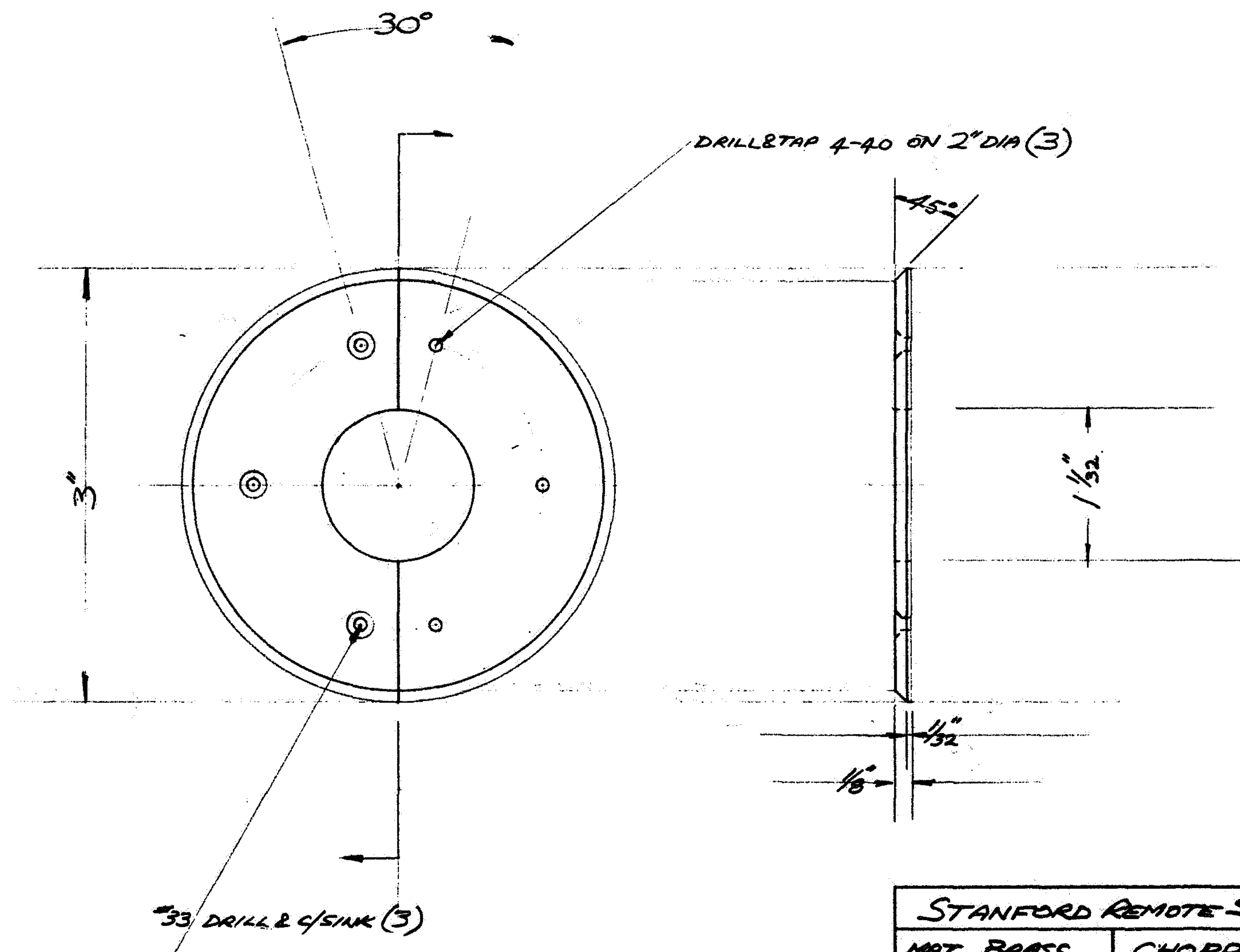


STANFORD REMOTE SENSING LAB	
MAT ALUM	CHOPPER HUB
SCALE FULL	TOLERANCES UNLESS STATED FRAC 1/64" DEC .005 ±
DRAWN P. Gordon	N° REQ 1
5-30-68	BREAK ALL SHARP EDGES



BOTH DIA. TO BE CONCENTRIC WITHIN .0005"

STANFORD REMOTE SENSING LAB	
MAT ALUM	CHOPPER SHAFT
SCALE FULL	TOLERANCES UNLESS STATED FRAC 1/64" DEC .005 ±
DRAWN P. Gordon	N° REQ 1
5-29-68	BREAK ALL SHARP EDGES



NOTE TO BE SPLIT AFTER MACHINING AND BALANCED BY SPOT DRILLING WHEN ASSEMBLED ON CHOPPER

STANFORD REMOTE SENSING LAB	
MAT BRASS	CHOPPER WEIGHT
SCALE FULL	TOLERANCES UNLESS STATED FRAC 1/64 DEC .005 ±
DRAWN P. Gordon	N° REQ 1
5-30-68	BREAK ALL SHARP EDGES

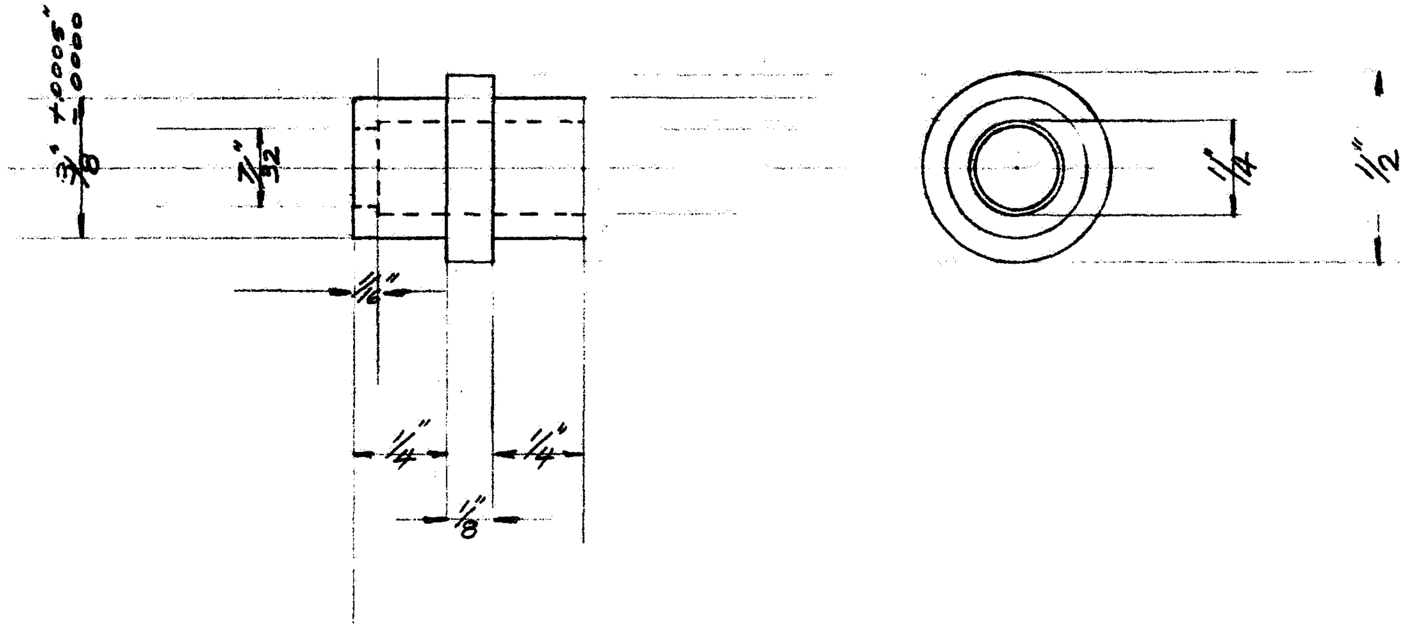
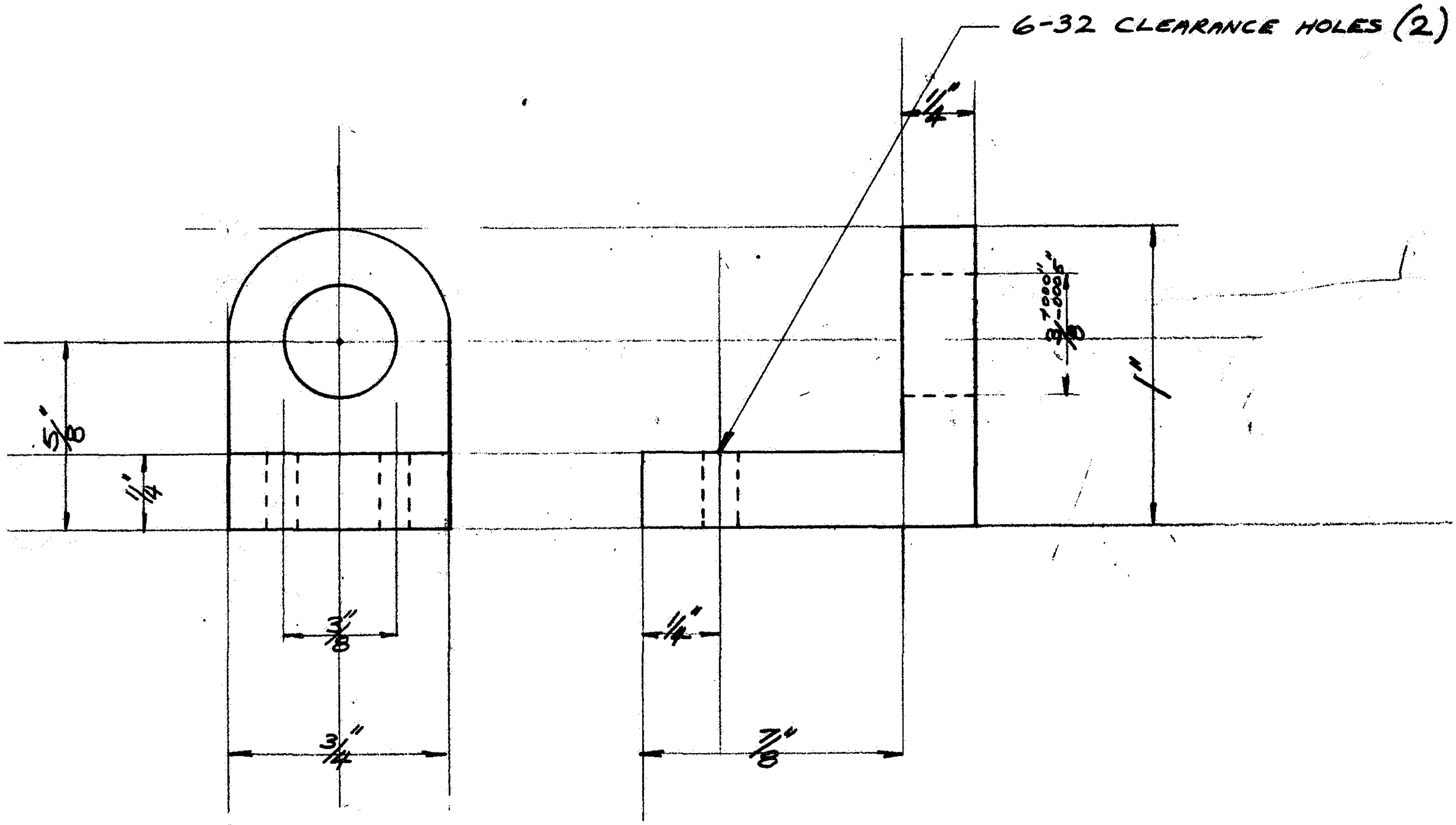


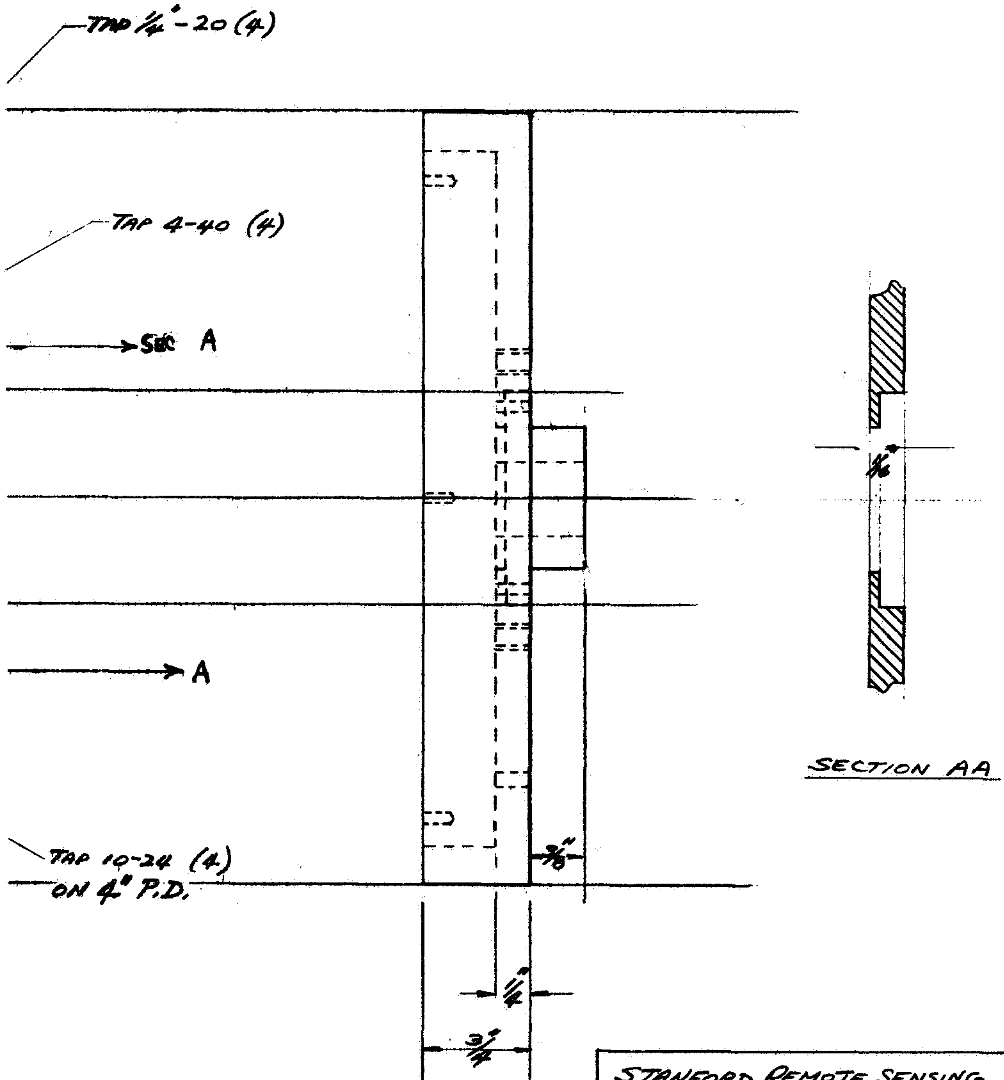
PHOTO TRANSISTOR P.T. L.S. 223

TO BE EPOXIED IN HOLDER

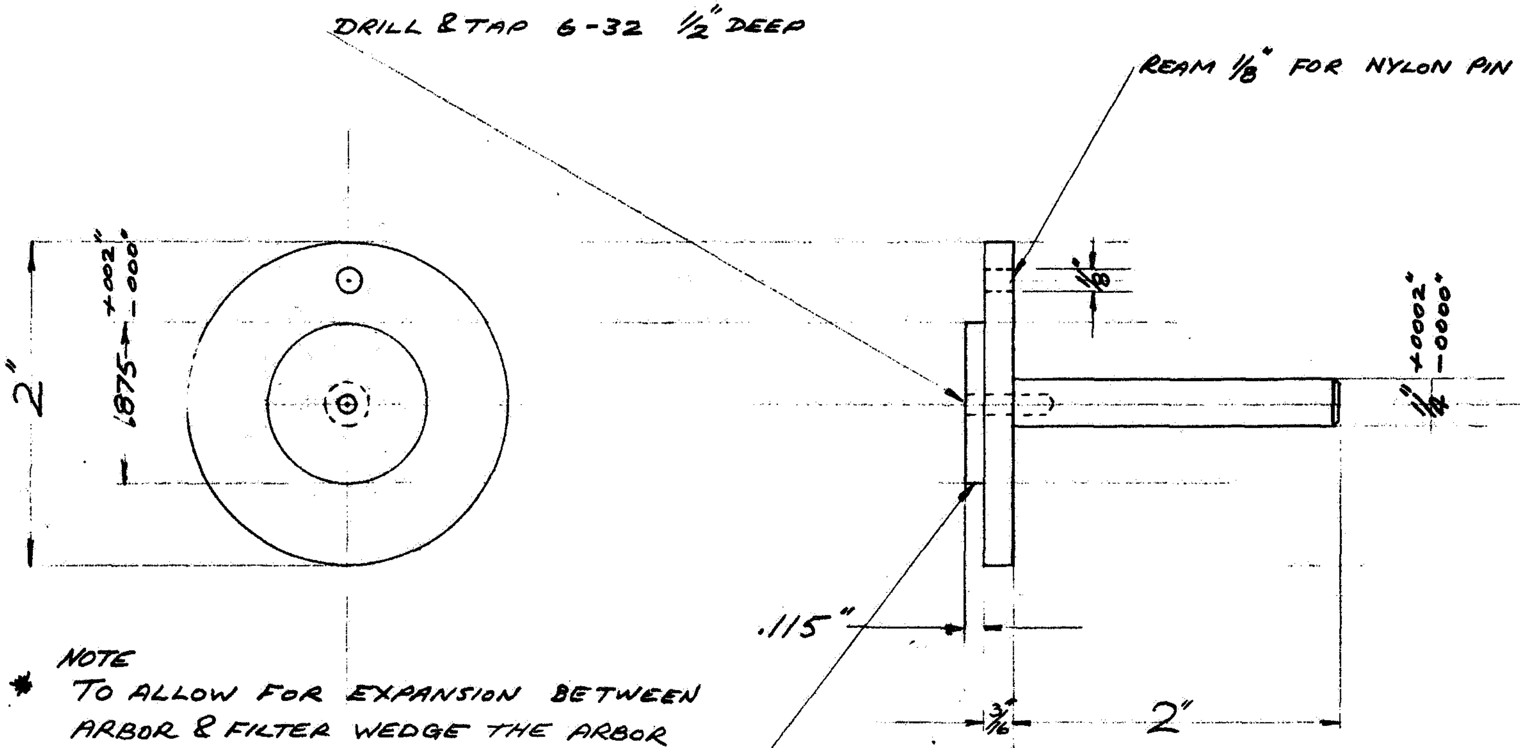
STANFORD REMOTE SENSING LAB	
MAT PHENOLIC	PHOTO TRANSISTOR MOUNT
SCALE X 2	TOLERANCES UNLESS STATED FRAC ± 1/64" DEC ±.005
DRAWN P. Gordon	N° REQ 1
5-24-68	



STANFORD REMOTE SENSING LAB	
MAT ALUM	PHOTO TRANSISTOR BRKT
SCALE X 2	TOLERANCES UNLESS STATED FRAC ± 1/64" DEC .005"
DRAWN P. Gordon	N° REQ 1
5-18-68	BREAK ALL SHARP EDGES



STANFORD REMOTE SENSING LAB	
MAT ALUM	FILTER WEDGE HOUSING
DRAWN P. Gordon	TOLERANCES UNLESS STATED
SCALE FULL	FRACTIONAL ± 1/64"
5-3-68	DECIMAL ± .002
	Nº REQ 1



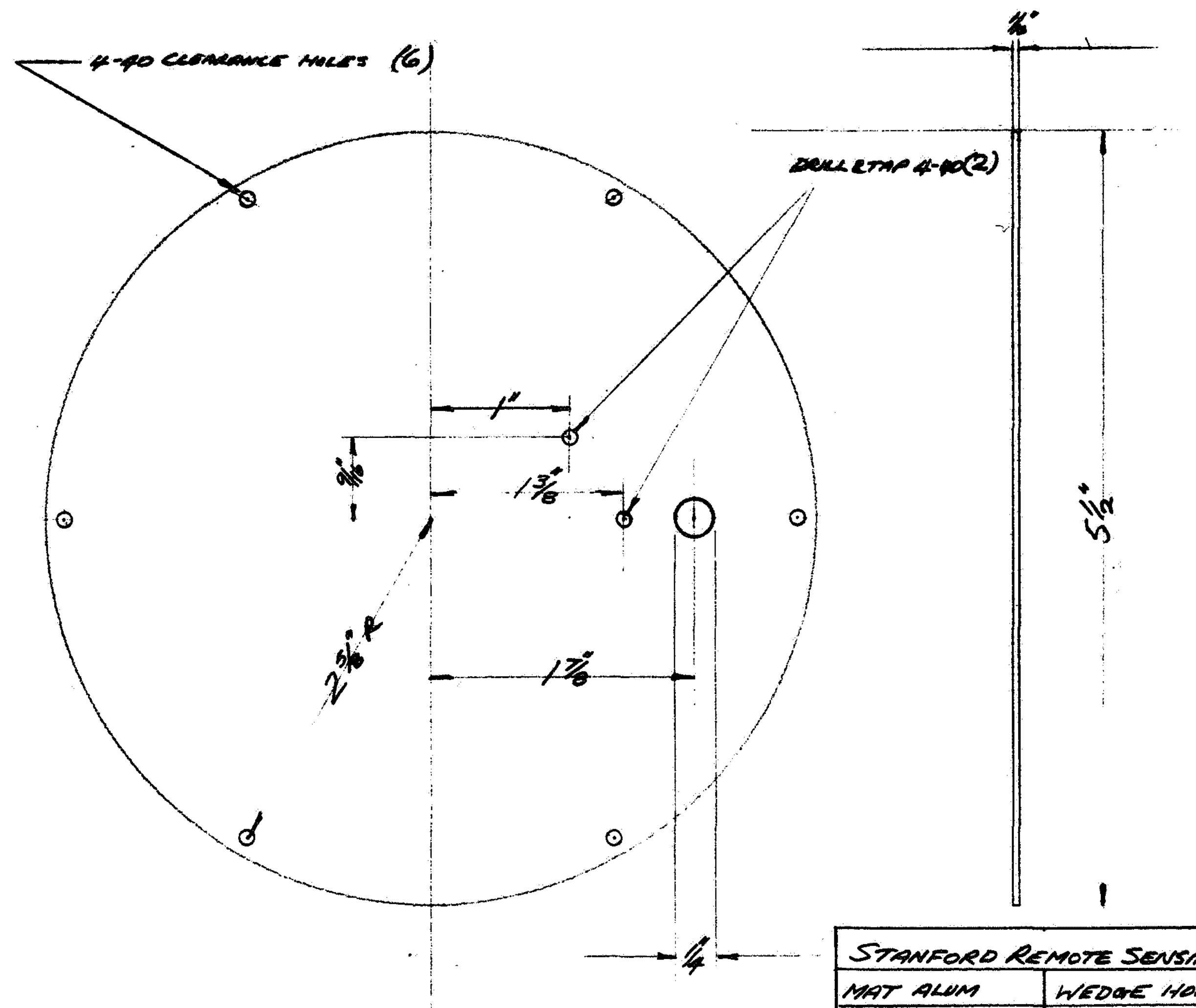
NOTE

* TO ALLOW FOR EXPANSION BETWEEN ARBOR & FILTER WEDGE THE ARBOR HAS BEEN MODIFIED.

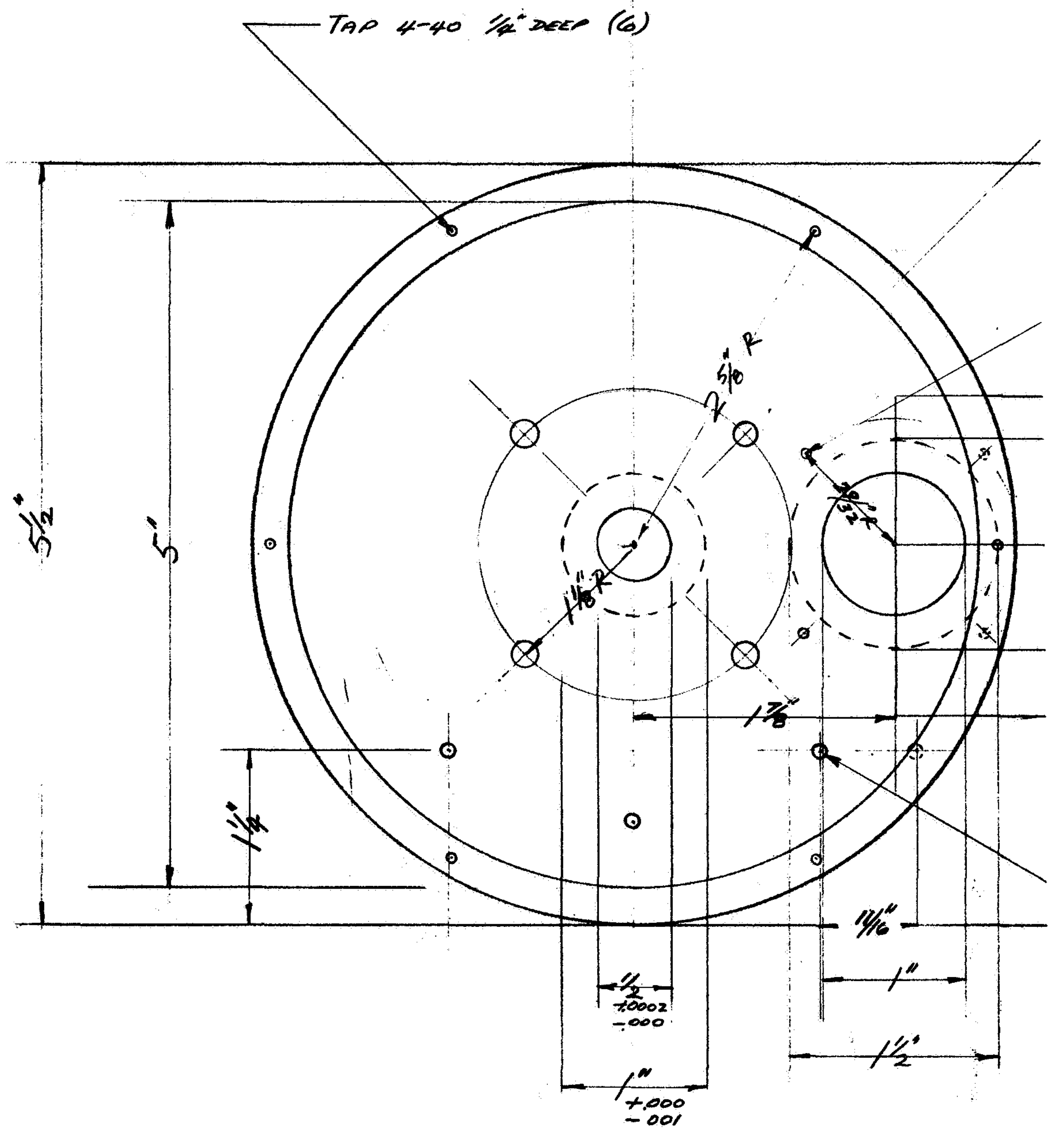
2 1/32" THICK NEOPRENE WASHERS ARE USED BETWEEN THE ARBOR, WEDGE & RETAINER AND A NYLON SLEEVE 1" O.D. 7/8" I.D. .100" THICK IS FITTED ON THE ARBOR HUB 6-14-68

TO BE CONCENTRIC WITH SHAFT

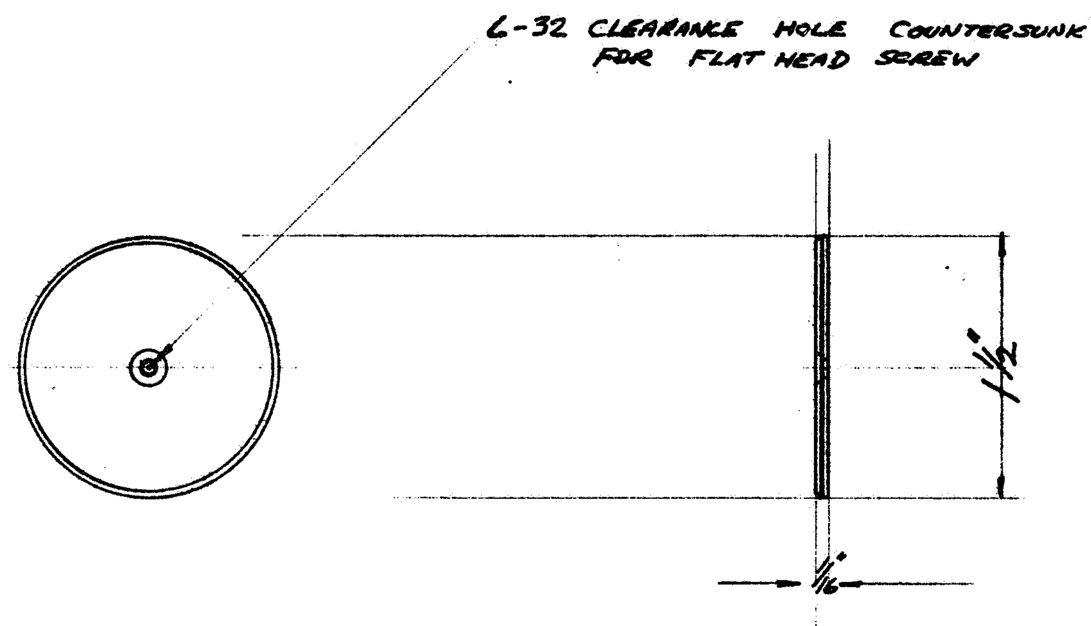
STANFORD REMOTE SENSING LAB	
MAT ALUM	FILTER WEDGE ARBOR
SCALE FULL	TOLERANCES UNLESS STATED FRAC 1/64" DEC ±.005"
DRAWN P. Gordon	Nº REQ 1
5-29-68	BREAK ALL SHARP EDGES



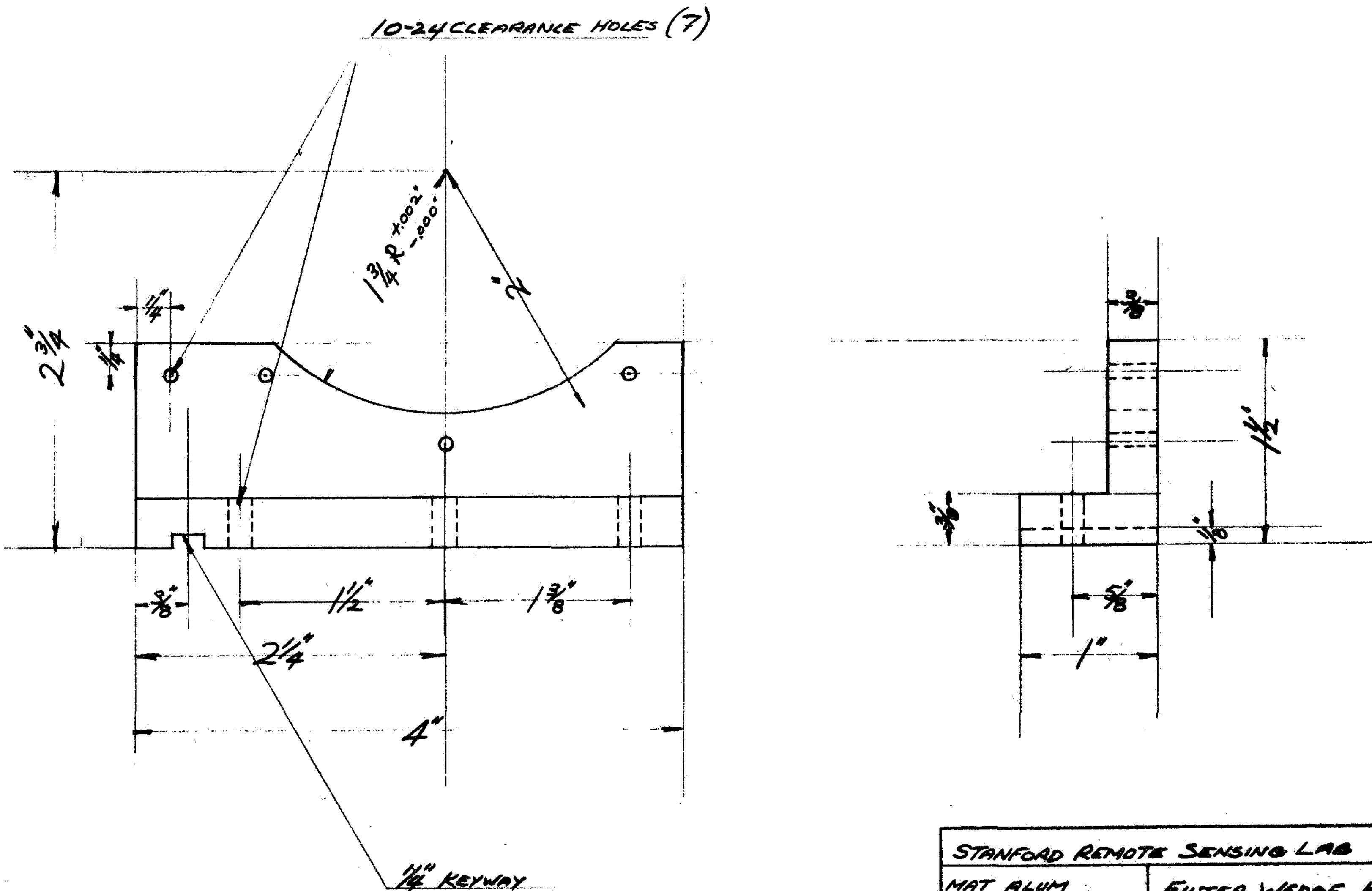
STANFORD REMOTE SENSING LAB	
MAT ALUM	WEDGE HOUSING COVER
DRAWN P. [illegible]	TOLERANCES UNLESS STATED FRAC 1/64 DEC .002
5-3-68	Nº REQ 1
SCALE FULL	



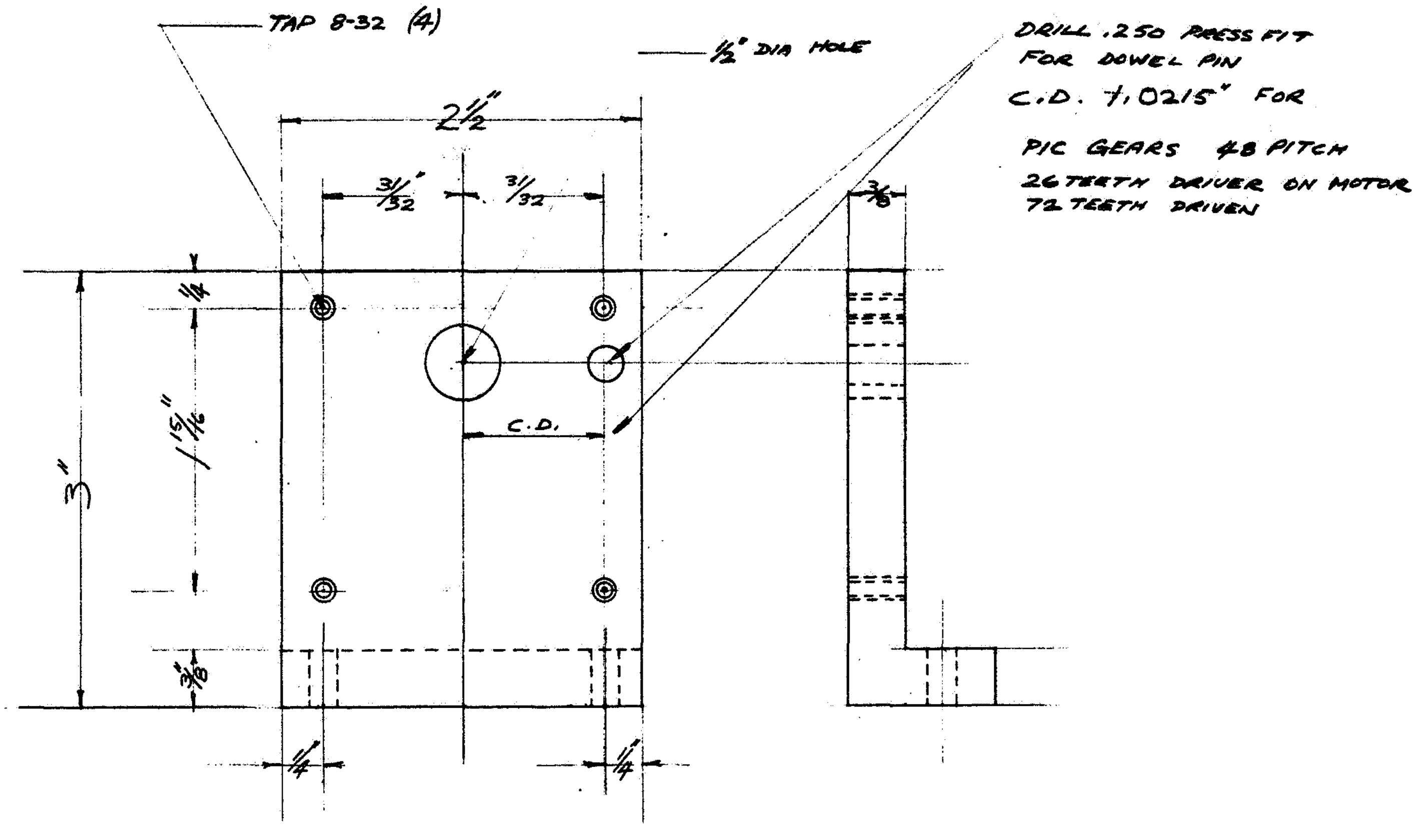
BEARINGS REQ (2) NEW HAMPSHIRE #SFR 188-PP-K58



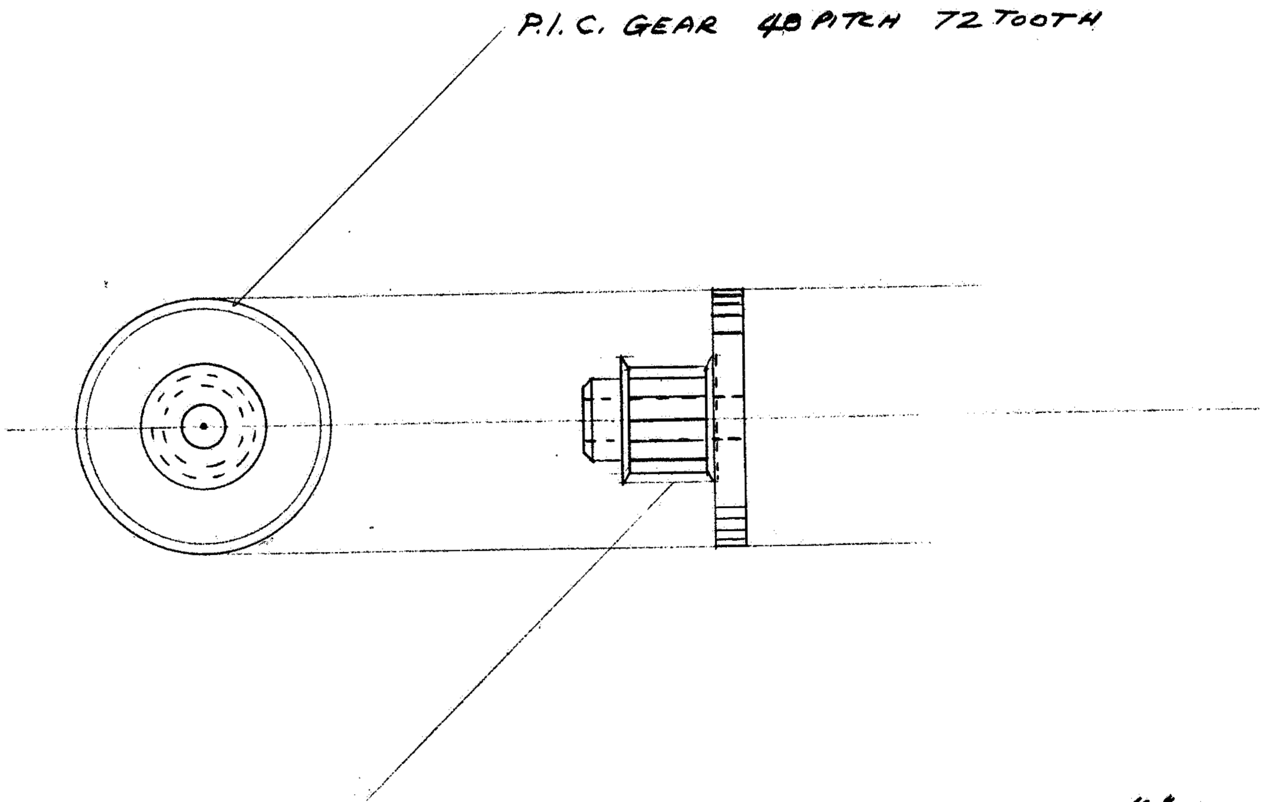
STANFORD REMOTE SENSING LAB	
MAT ALUM	FILTER WEDGE RET.
SCALE FULL	TOLERANCE UNLESS STATED FRAC 1/64" DEC ± .005
DRAWN P. Gordon	N° REQ 1
5-29-68	BREAK ALL SHARP EDGES



STANFORD REMOTE SENSING LAB	
MAT ALUM	FILTER WEDGE HSG. BRKT
DRAWN P. [illegible]	TOLERANCES UNLESS STATED
SCALE FULL	FRACTIONAL ± 1/64"
4-26-68	DECIMAL ±.002
	Nº REQ 1



STANFORD REMOTE SENSING LAB	
MAT ALUM	FILTER MOTOR BRACKET
SCALE FULL	TOLERANCES UNLESS STATED FRAC 1/64 DEC .002 ±
DRAWN P. Gordon	N° REQ 1
5-8-68	REMOVE ALL SHARP EDGES & BURRS

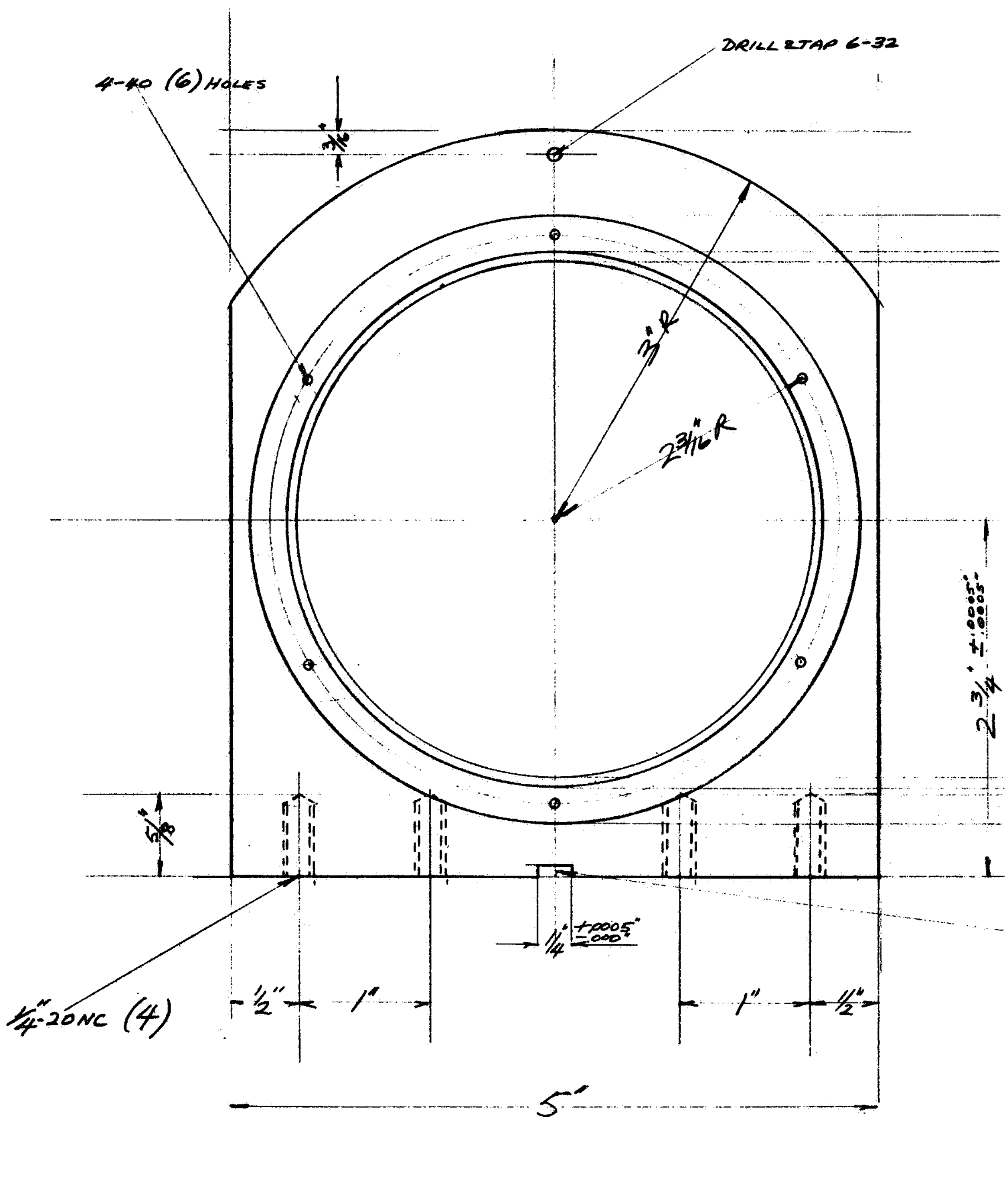


NOTE GEAR & PULLEY MUST BE CONCENTRIC

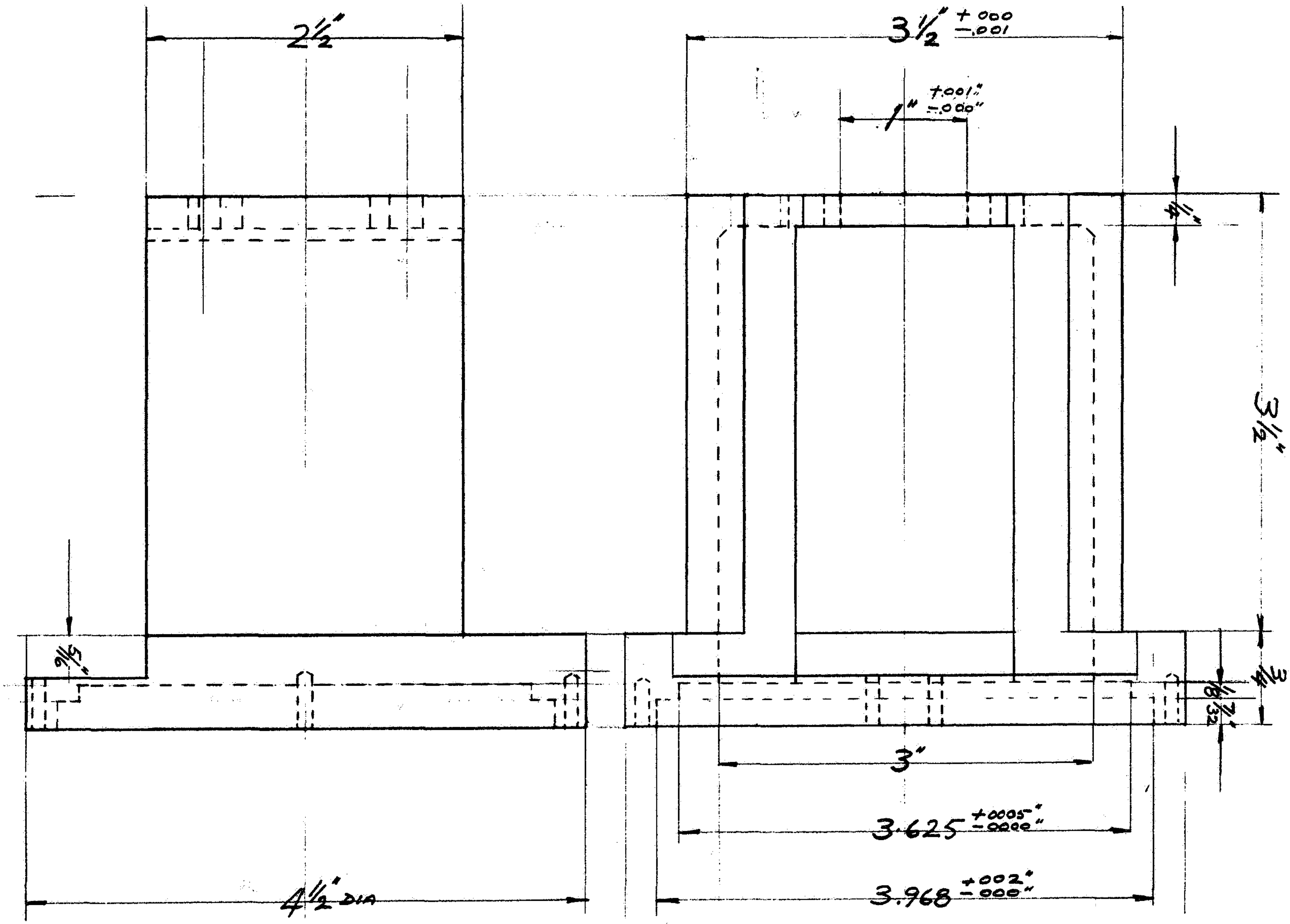
BELT N° XL037

DRIVEN COG 22 TOOTH

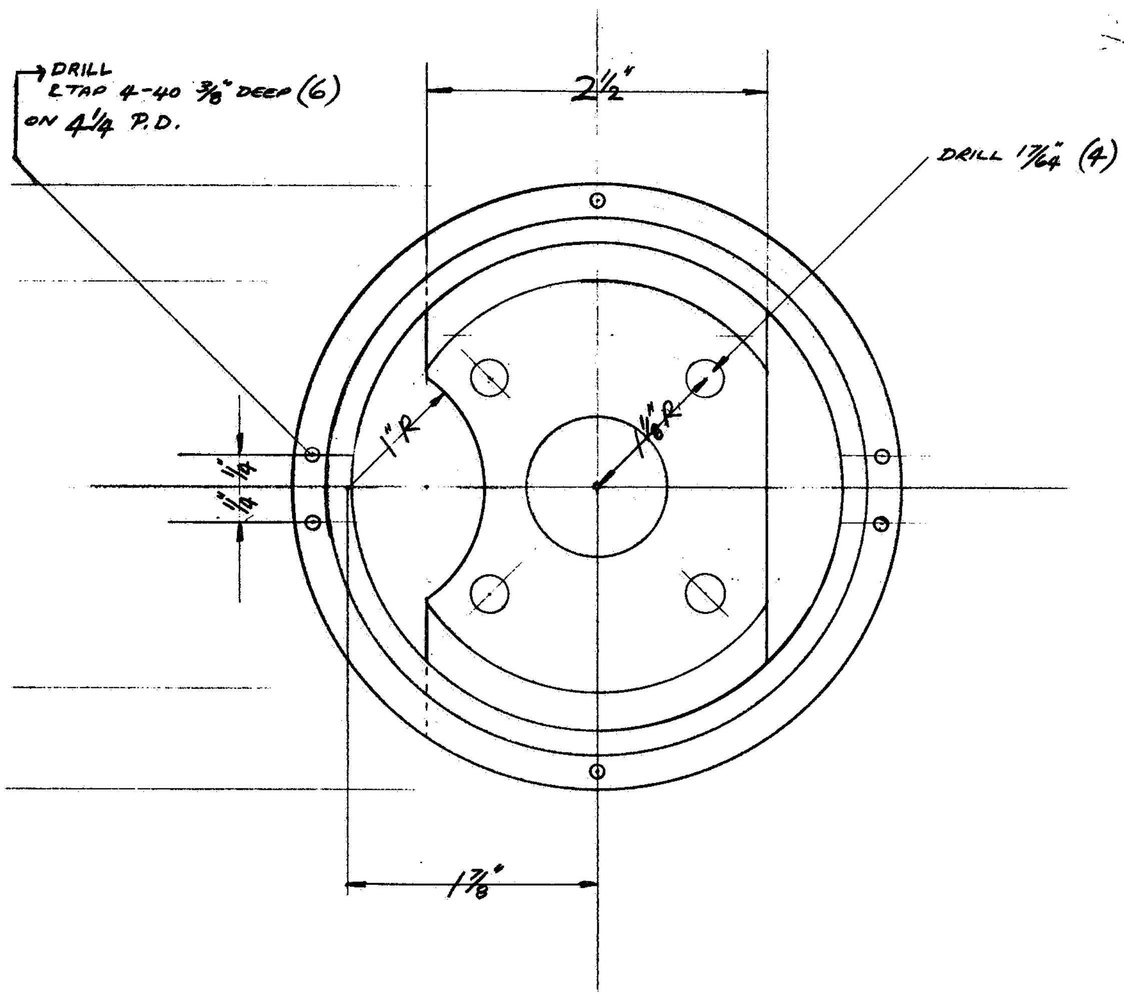
STANFORD REMOTE SENSING LAB	
MAT ALUM	REDUCTION GEAR
SCALE FULL	TOLERANCES UNLESS STATED FRAC 1/64 DEC .005 ±
DRAWN P. Gordon	N° REQ 1
6-14-68	



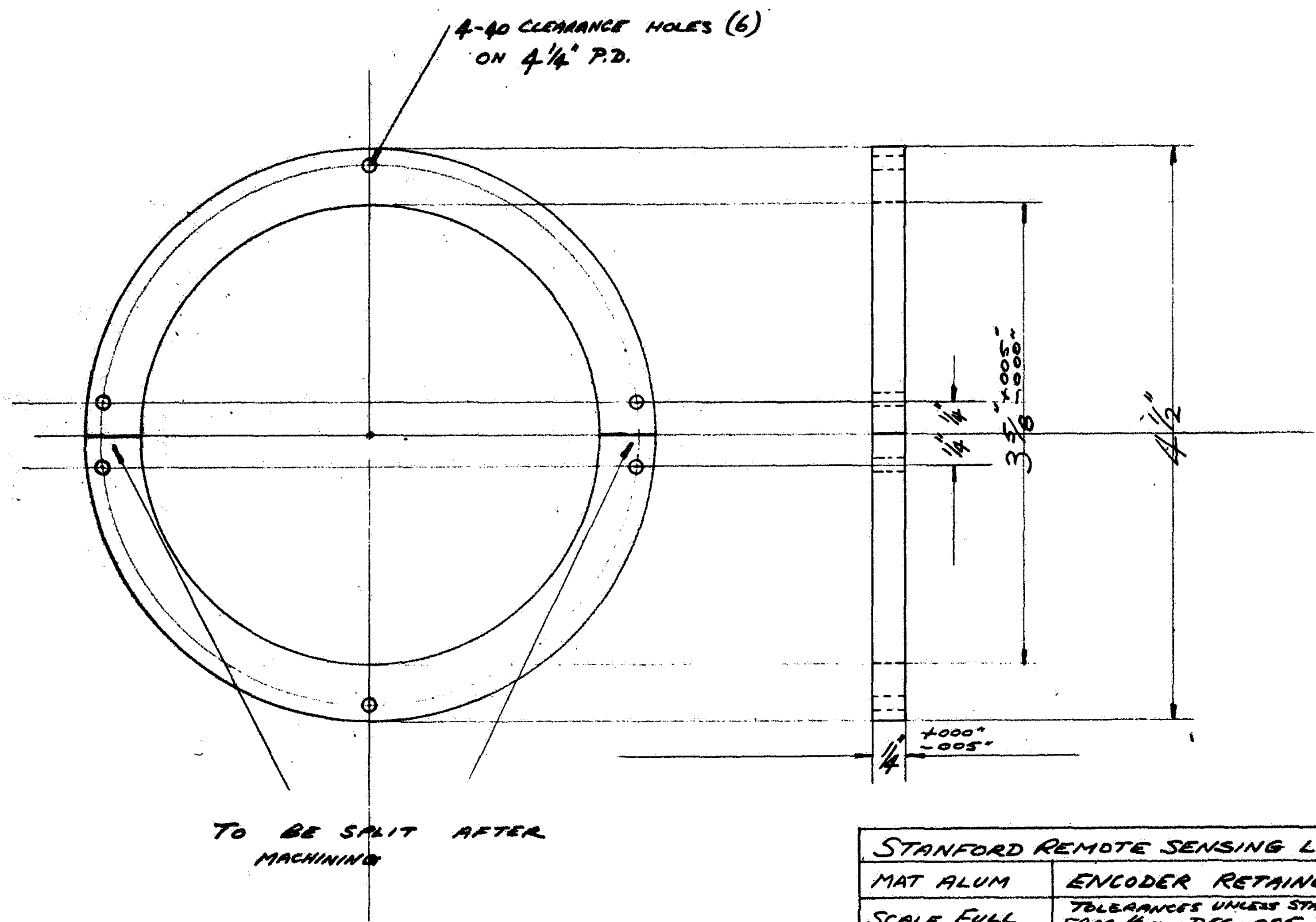
DRILL & TAP 6-32
4-40 (6) HOLES
3/16
3"R
2 3/16"R
2 3/4" ±.0005" -.0005"
5/8
1/4" +.0005" -.000"
1/4"-20NC (4)
1/2"
1"
1"
1/2"
5"



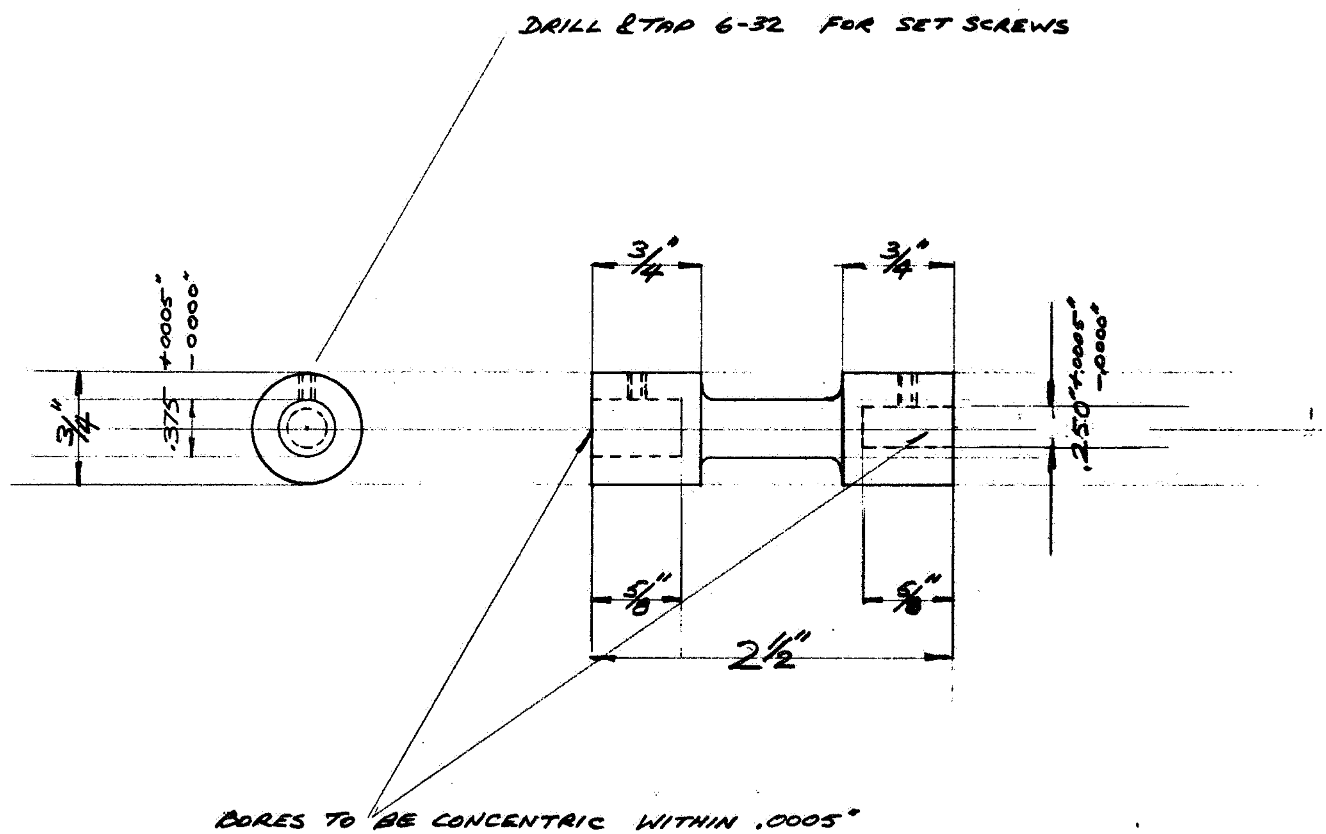
2½"
3½" +.000 −.001
1" +.001" −.000"
¼"
3½"
¾
⅛
7/32"
5/16"
3"
3.625 +.0005" −.0000"
3.968 +.002" −.000"
4½" DIA



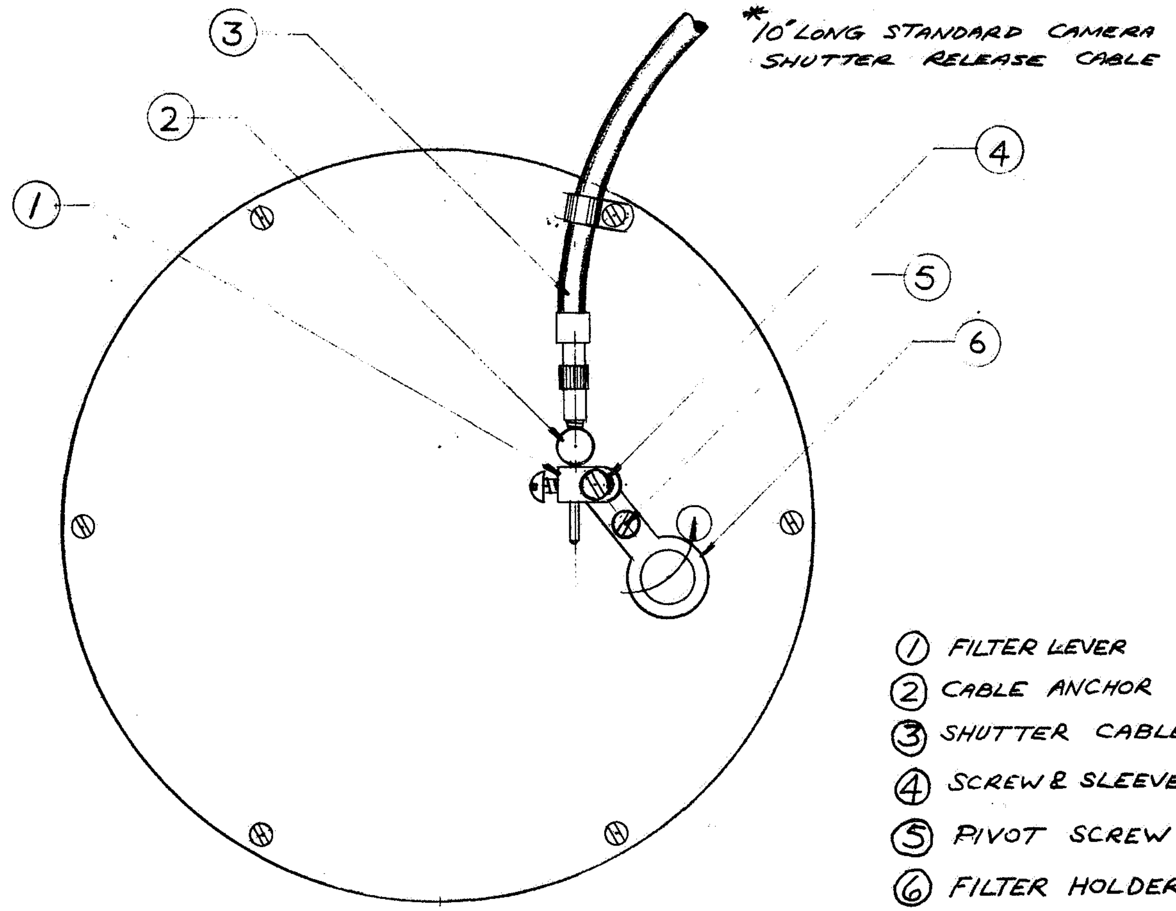
STANFORD REMOTE SENSING LAB	
MAT ALUM	SHAFT ENCODER MNT.
SCALE FULL	TOLERANCES UNLESS STATED FRAC 1/64" DEC ±.005
DRAWN P. Gordon	N° REQ. 1
5-24-68	BREAK ALL SHARP EDGES



STANFORD REMOTE SENSING LAB	
MAT ALUM	ENCODER RETAINER
SCALE FULL	TOLERANCES UNLESS STATED FRAC 1/64 . DEC .005 I
DRAWN P. Gordon	N° REQ 1
5-29-68	BREAK ALL SHARP EDGES



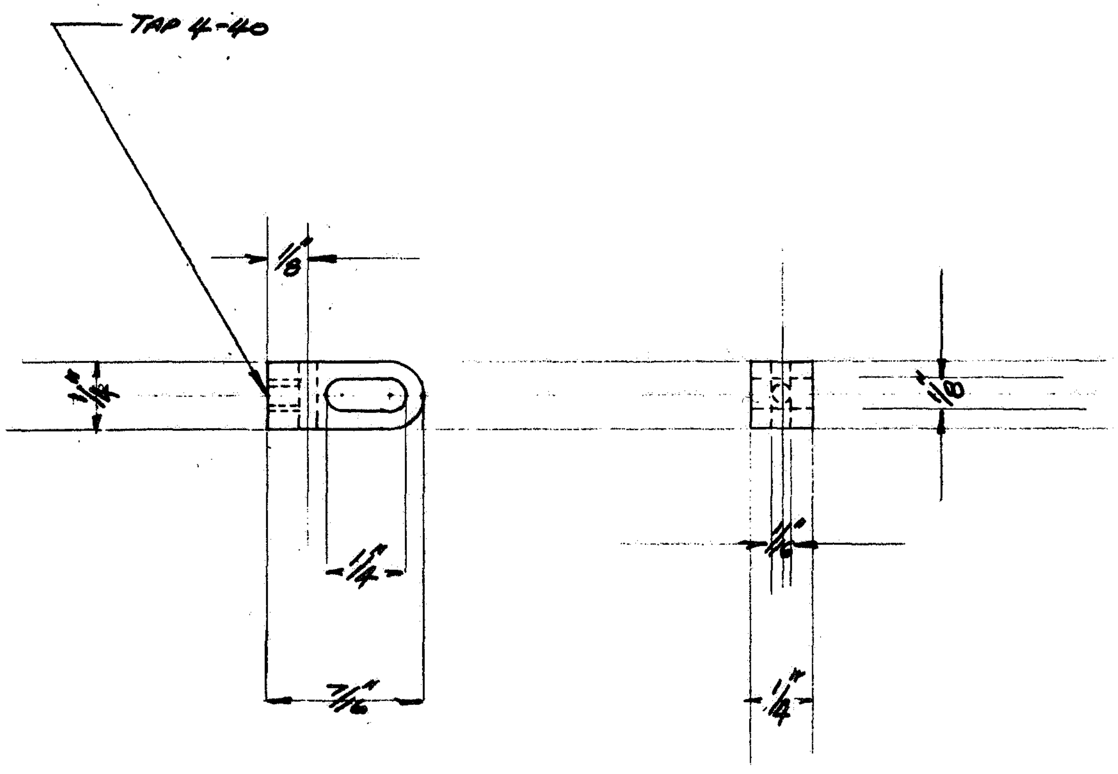
STANFORD REMOTE SENSING LAB	
MAT. ALUM	SHAFT ENCODER CPLNG
SCALE FULL	TOLERANCES UNLESS STATED FRAC ±1/64" DEC ±.005
DRAWN P. [illegible]	N° REQ 1
5-29-68	BREAK ALL SHARP EDGES



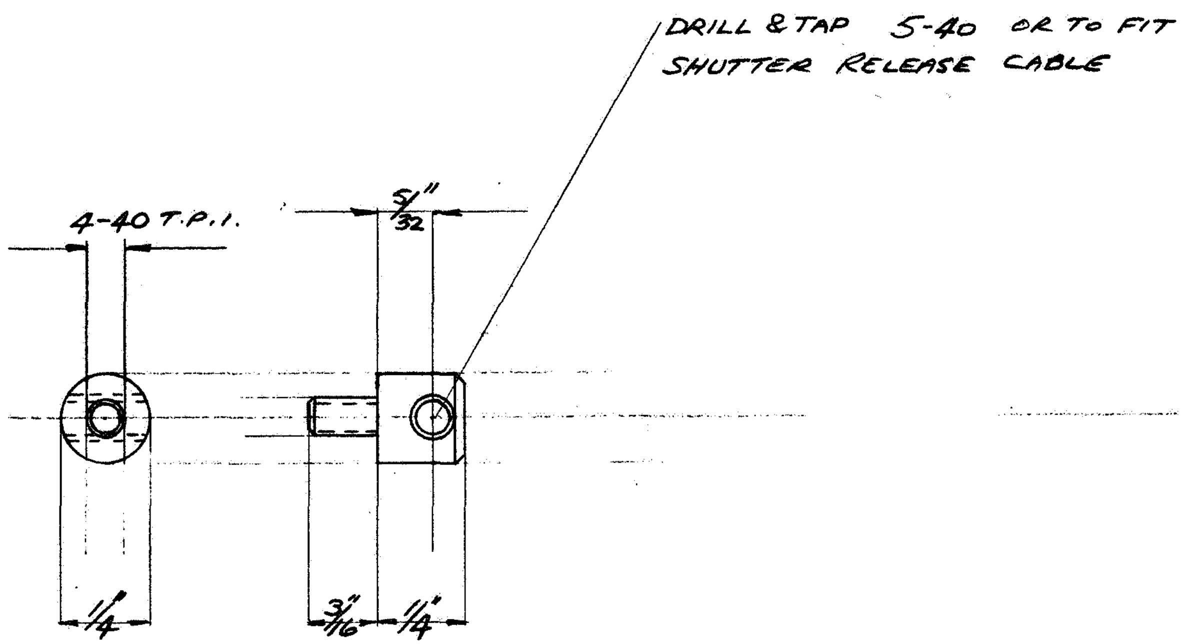
(1) FILTER LEVER
(2) CABLE ANCHOR
(3) SHUTTER CABLE*
(4) SCREW & SLEEVE
(5) PIVOT SCREW
(6) FILTER HOLDER

NOTE. NUT AT BACK OF PIVOT SCREW MUST NOT BE THICK ENOUGH TO FOUL FILTER WEDGE

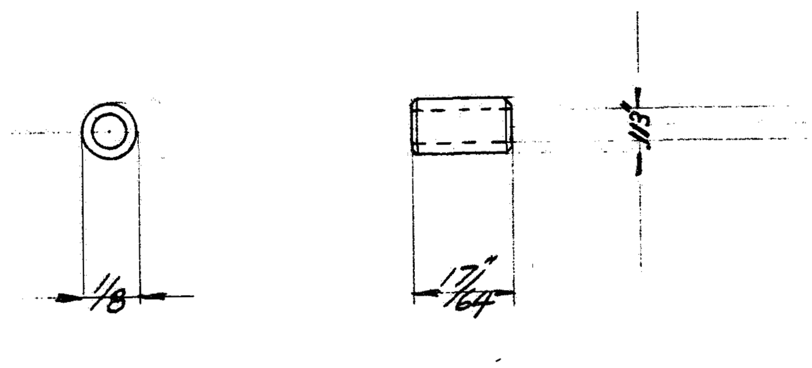
STANFORD REMOTE SENSING LAB
5-30-68
POLYSTYRENE FILTER ASSEMBLY
* AGC SHUTTER RELEASE CABLE 18"
DRAWN P. Gordon.



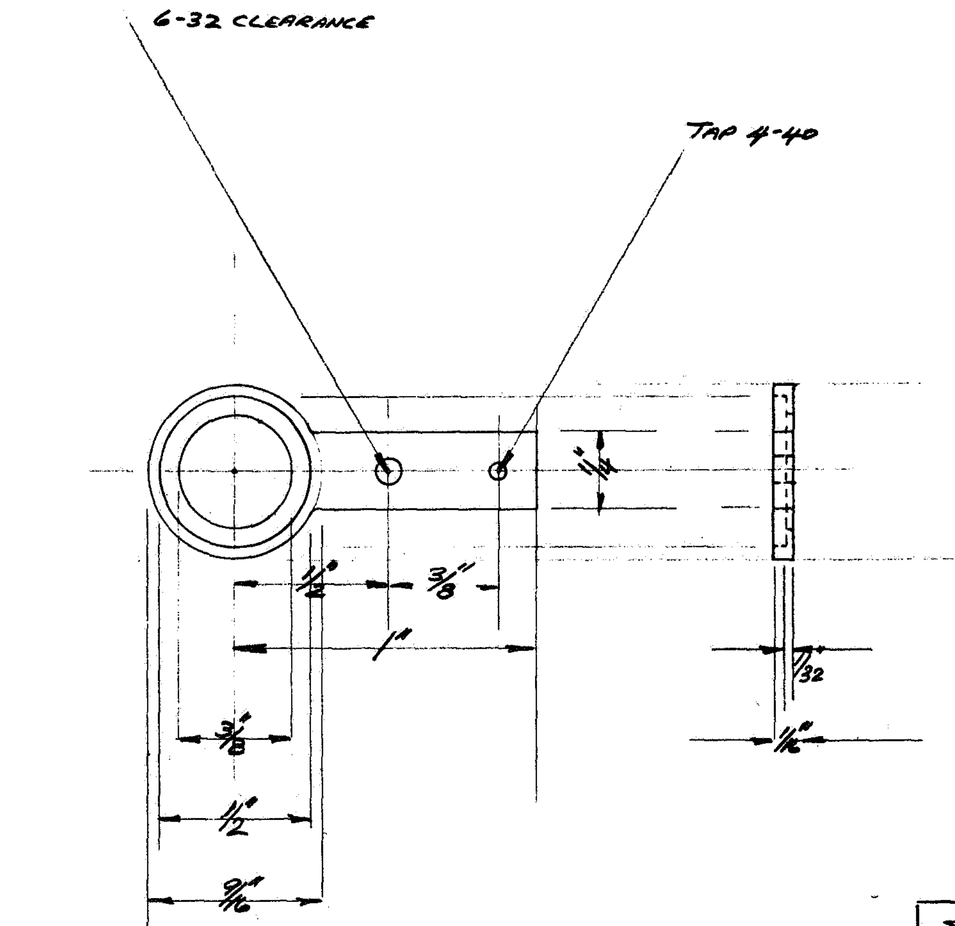
STANFORD REMOTE SENSING LAB	
MAT ALUM	FILTER LEVER
DRAWN P. Gordon	TOLERANCES UNLESS STATED FRAC 1/64 DEC .002 ±
5-3-68	Nº REQ 1
SCALE X2	



STANFORD REMOTE SENSING LAB	
MAT. ALUM	CABLE ANCHOR
SCALE X2	TOLERANCES UNLESS STATED FRAC 1/64" DEC .005"
DRAWN P. Gordon	N° REQ 1
5-30-68	BREAK ALL SHARP EDGES

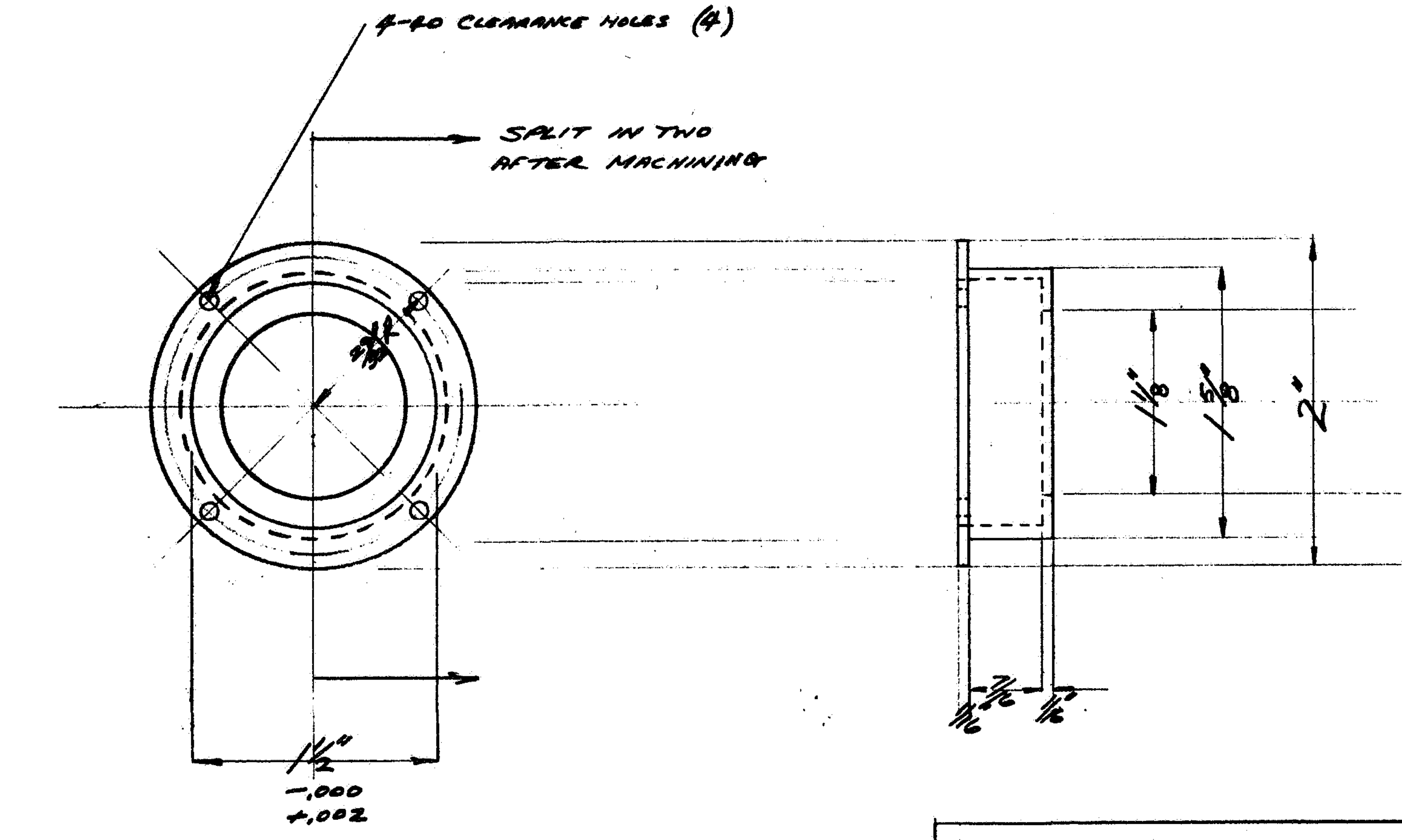


STANFORD REMOTE SENSING LAB	
MAT. C.R.S.	FILTER LEVER SLEEVE
SCALE X2	TOLERANCES UNLESS STATED FRAC 1/64" DEC. .005 ±
DRAWN P. Gordon	N° REQ 1
5-30-68	BREAK ALL SHARP EDGES



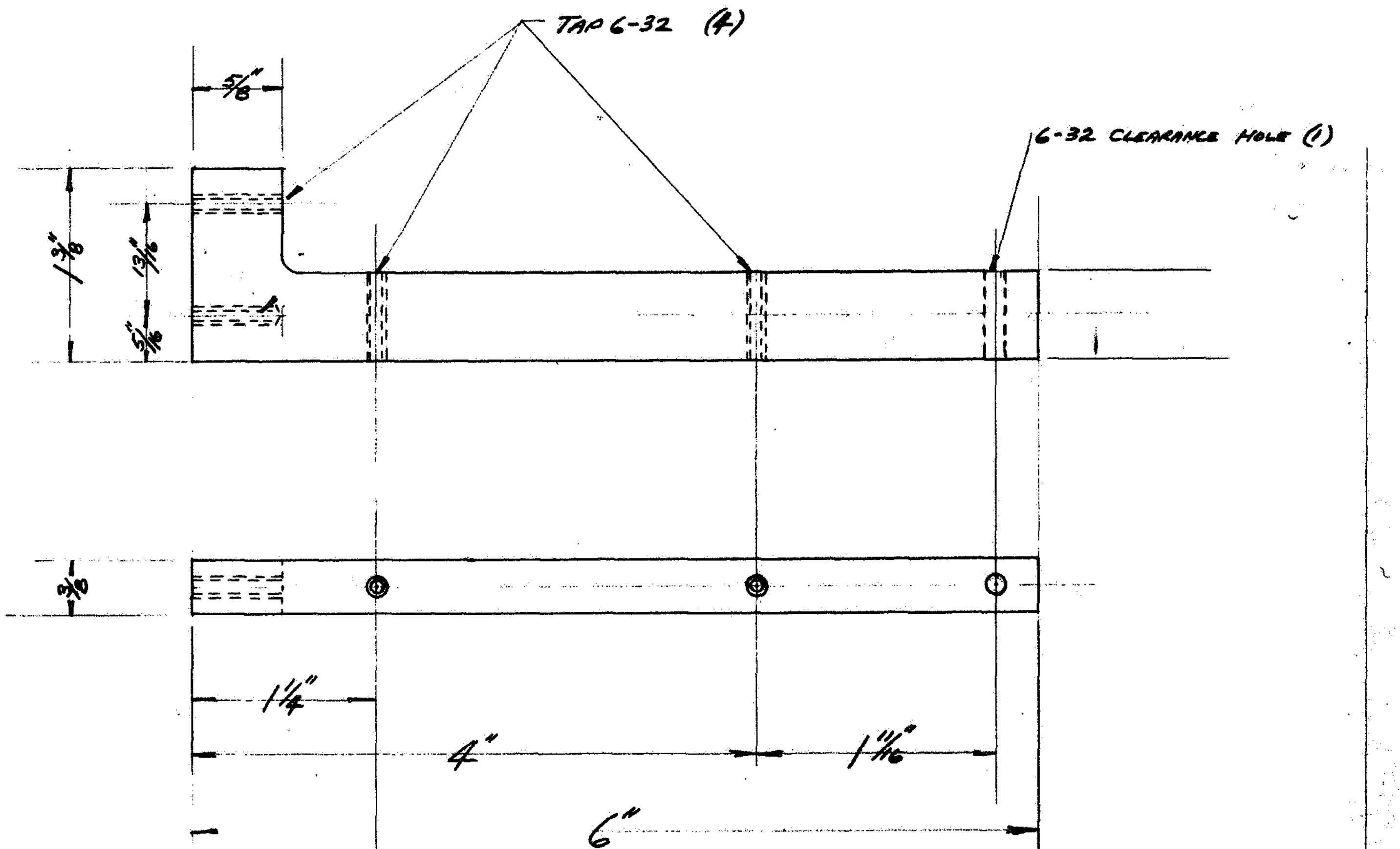
NOTE. 3/8" DIA POLYSTYRENE FILM TO BE GLUED OR EPOXIED INTO HOLDER

STANFORD REMOTE SENSING LAB	
MAT ALUM	FILTER HOLDER
DRAWN P. Gordon	TOLERANCES UNLESS STATED FRAC 1/64 DEC .002
5-3-68	Nº REQ 1
SCALE X2	BREAK ALL SHARP EDGES



TO BE SPLIT AFTER MACHINING

STANFORD REMOTE SENSING LAB	
MAT ALUM	DETECTOR RETAINER
DRAWN P. Gordon	TOLERANCES UNLESS STATED FRAC 1/64 DEC .002
SCALE FULL	N° REQ 1
5-3-68	



STANFORD REMOTE SENSING LAB	
MAT ALUM	AMPLIFIER BRACKET
SCALE FULL	TOLERANCES UNLESS STATED FRAC 1/64 DEC .002 ±
DRAWN [illegible]	N° REQ 2
5-7-68	

APPENDIX B

DIGITAL DATA RECORDING SYSTEM

I. FUNCTIONAL SPECS FOR DATA SYSTEM

Unit must perform the following functions:

a) Convert input (one channel) signal on command

Conversion rate =	10/sec to 100/sec	(SG-4)
	10/sec to 100/sec	(Stanford C.V.F.)
	650/sec	(NASA C.V.F.)

Conversion command will be a level change (zero crossing) on a 0V-10V square wave. In the case of the SG-4, this will be accompanied by contact noise from the brush that generates this signal.

b) At the end of each spectrum, generate "record gap" command (+10V pulse). End of spectrum is denoted by encoder pulse:
   Encoder Pulse (+5V) from SG-4 (with brush noise)
   Encoder Pulse (+10V) from Stanford C.V.F.
   Encoder Pulse (+5V) from NASA C.V.F.

c) Count spectra and display count.

d) Allow operator option to blank alternate spectra. Alternate spectra may be identified by
   Level Change (10V) on Stanford C.V.F.
   Ramp Voltage (-3V to -0.5V) on SG-4.
   Level Change (0-5V) on NASA C.V.F.

e) At beginning of each spectrum, read-in identification data (see later specs).

f) Required specs for A-D and Logic System

Resolution	10 bits + sign
Conversion Speed	At least 1000 samples/sec. (asynchronous)
Accuracy	0.1%
Temperature	0°C - 70°C
Humidity	0% - 80%
Altitude	0 - 50,000 ft.
Compatability	SG-4 Spectrometer
	Standard C.V.F. Spectrometer
	NASA/MSC C.V.F. Spectrometer
Power	115 VAC 50-400 HZ

g) Logic Board Specifications

1) Inputs to Recorder

Data Lines =	0V (=0) + 10V (=1)
	Data must be true 50μsec before writing
Write 1/P =	+ 10V pulses (>100μsec) Spacing >2mSec

Record Gap = + 10V pulse (> 100μsec)

2) <u>Logic Inputs</u>

Encoder Outputs = 0V - 10V pulses

Power = 10V @ 250 m amp.

Wavelength ramp (For SG-4 option) = -3V to - 0.5V (= unmodified SG-4 output)

3) <u>Logic Outputs</u>

Hold DVM = +5V level

Recorder Inputs as specified above

II. CIRCUIT DESIGN

1. Overall System Description

The SG-4, which is comprised of a grating spectrometer and associated control package, has been modified extensively to permit the use of a liquid helium cooled infrared detector. These modifications include relay optics ($8000), a Ge:Cu detector/dewar ($4500) along with mounting hardware and detector preamplifiers. The control electronics package modifications include the addition of a "sample and hold" circuit, a ramp generator, panel mounted meter for continuous indication of grating position and provisions to supply selected wavelength encoder outputs to timing and control logic. The digital voltmeter which is utilized as an A/D converter was also modified to accept an external command to hold BCD output registers during data transfer to the digital tape recorder write amplifiers. Figure B1 is an overall system diagram.

The process of recording spectral data is begun in the SG-4 spectrometer from which there are 4 separate outputs. The analog radiance signal is produced by the detector as the diffraction grating scans the incoming radiation in the band from 6.66 microns to 11.75 microns. This signal is routed to the digital voltmeter where it is digitized in BCD format, and also sent to the vertical deflection circuit of the oscilloscope. The ramp output, a voltage which varies from -3.0V at beginning of up-ramp to -0.5V at end of up-ramp, is applied to the control-and-timing logic and to the horizontal deflection circuit of the oscilloscope. There, in combination with the radiance analog signal, an "intensity versus wavelength" waveform is displayed for system monitoring (and photographic recording).

Two other outputs, both square wave, are produced by an encoder connected to the diffraction grating. One of the two outputs are 96 level changes (48 pulse square wave, 0 to +10V) during the ramp period. The other is two +10V level changes, one at the beginning and one at the end ramp (see Figure B2).

During one scan of the target spectrum there are 198 bytes (6 bits) of information placed on the tape. This comprises one record. Within each record there are 6 bytes of identification data (see App. B, Sect. V) and 192 bytes of spectral data. Defining a word as 2 bytes, it is seen that there are 96 words of spectral data, two for each of the 48 square wave pulses. Since the recorder has six data channels and since each A/D conversion produces a 12 bit BCD output, the digitized data is recorded as two consecutive bytes. Each two byte word is read and recombined by the computer. The correlation of a given data word with a wavelength is accomplished through counting the data as it is processed. A detailed description of the timing and control logic is given in Appendix B, Section V.

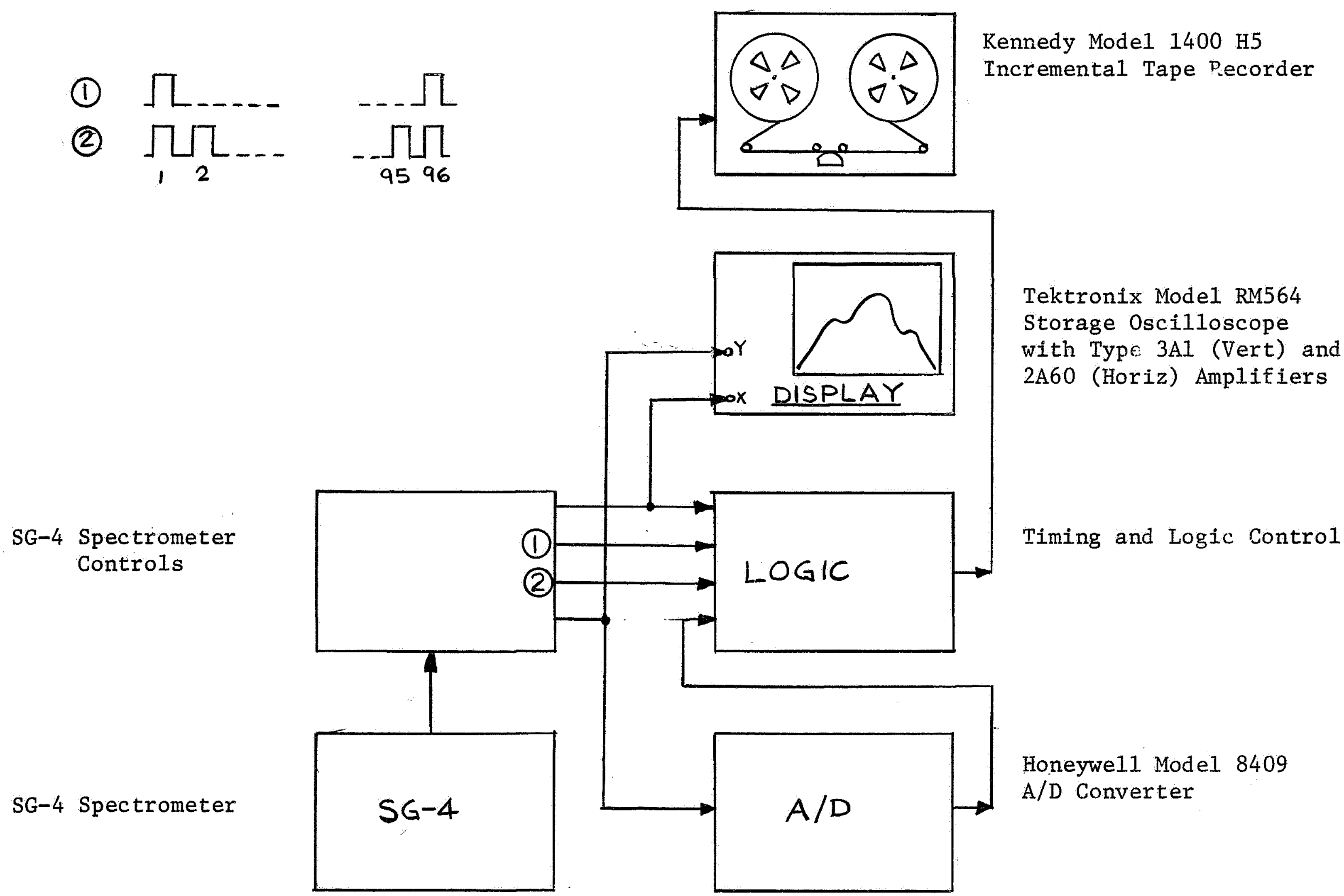


FIGURE B1--Systems Diagram

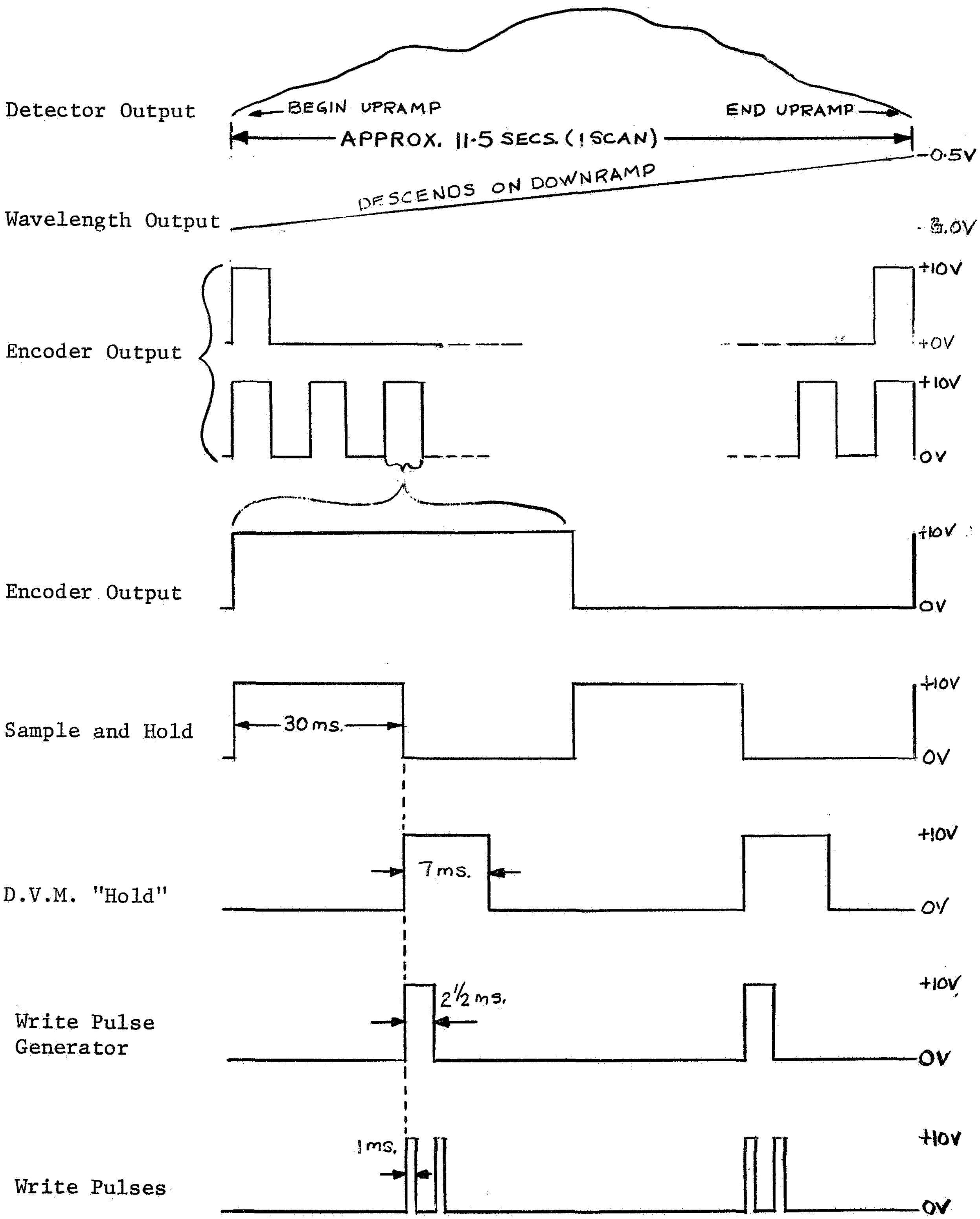


FIGURE B2 --Timing Diagram

2. Signal Channel

The radiance signal from the spectrometer is fed directly to the A-D converter, where it is continuously digitized at high speed. The output of the converter is held constant during a "write" period by the application of a +5V signal to an internal "hold" line. Prior to the output being held constraint, a "sample and hold" circuit is activated on the convertor input. The purpose of this is to allow the converter to come to equilibrium before holding the digital output.

The conversion cycle is initiated on board three, where a one-shot circuit generates the "sample and hold" instruction, and 30mSec later allows the recording sequence to start. The instruction for this is generated by a monostable on board two, and is presently 7mSec long. It emerges on pin 9 bd. 2. Two other monostables on the same board generated two "write" pulses (presently 2 1/2mSec apart) which are summed and fed to the Kennedy recorder. The timing of these two pulses is controlled by the two 50K preset potentiometers on board two. Summing is achieved on board four. The first two transistors on this board invert the pulse, the second two buffer and add, and the third two form a Schmitt Trigger which shapes the pulse.

The write pulses also have to be delayed 50μSec. in order to allow the Kennedy to accept the input data before writing. Delay is accomplished by the two 33K summing resistors and the associated 0.1 μf capacitor (board 4).

Before summing, the write pulses are fed to two gate drivers on board 9. Each driver supplies six gates (boards 8 and 7) with a strobe pulse connecting a data line with the tape recorder. Each of the Kennedy outputs is therefore connected to two data lines sequentially, thereby writing the first six and second six bits. The first byte contains the most significant bits, with the MSB next to the parity channel on tape.

3. Encoder Outputs

Two outputs are used from the encoders; one to denote "end of spectrum" and one (the 10th bit) to provide sampling instructions. Both outputs are buffered from the logic by a DC coupled multivibrator, whose time constant is set to be long enough to reject any brush noise from the encoder. These noise discriminators are on boards 9 and 1. Since the period of a spectrum also determines the time during which brush noise is generated, a fixed value of time discrimination will set a limit on the maximum spectral period. The values are adjusted by varying the two cross-coupling capacitors on each multivibrator. Presently, the values will permit spectra from 2 secs. to 11 secs. Indication that brush noise has occurred will be given by the computer printing out "total count error".

The encoder "end of spectrum" output triggers a bistable (on board five) and is gated with output from the bistable on board six (and gate). The resultant waveform is positive for each alternate spectrum but goes negative just before the grating reverses direction. This positive waveform gates ON the "write" generator by the gate on board one. (The signal is fed through three diodes simply to subtract 2V from the DC level).

The "ON" condition is synchronized to UP-RAMP spectra by biasing the bistable with a modified version of the SG-4 wavelength output. DOWN-RAMPS can be selected by reversing the switch on board six.

4. Write Instructions

Most of the write pulse generation has been described, but a few functions on board one remain. The encoder output (10th bit) only provides 48 pulses per spectrum. By using both +ve and -ve edges we can obtain 96 pulses. The first two transistors on board one form the monostable noise discrimination previously mentioned. The following pair take antiphase outputs from the monostable, differentiate them and add the result. The output of these two is therefore a positive pulse every time the encoder changes its level. These pulses can either be passed to pin 12 of board one, or shorted to ground, depending on the state of the gating circuit formed by the third transistor pair.

5. Location of Major Logic Units

Sample and Hold amplifier	Board 3
Timing generators	Board 2
Ramp selector	Board 6
A → D output "hold" generator	Board 2
"Write" generators	Board 2
Ramp synchronizing	Board 5
Kennedy "write" interface, and 50 μSec delay	Board 4

6. Identification Data

The identification data for each spectrum comprises six bytes of six bits each. The data is as follows:

1. Blackbody Indicator
2. Spectrum Group No.
3. Blackbody Temperature
4. Target Temperature
5. Spectrum Number
6. Zero byte for computer synchronizing.

The first four bytes are set by a series of handswitches. The spectrum number is provided by a six stage binary counter, and the zeros are set automatically on the sixth byte.

The logic for recording the I.D. data is located behind the switch panel on two boards. Because of their high current consumption, the integrated circuits used run off a separate 10V regulated power supply, and not from the Kennedy, as in the case of the rest of the logic.

The functions performed by the logic are:

a) Count record gaps = Spectrum No.;

b) Six bit shift register with write command generation

c) Gating the handswitch data.

"b" and "c" can be considered as a six-pole, six-way multiplex unit.

The only information required to follow through the operation of the shift register is that the flip flops trigger on a <u>negative</u> going signal, and the single shots trigger on a <u>positive</u> signal. The trailing edge of the Kennedy "gap in process" signal triggers the first single shot, and sets a "1" in the first shift register stage. This allows the first six switches (i.e., the first byte) to be gated through to the Kennedy inputs. After a delay of 2 mSec produced by the sequential firing of the other single shot units, the "1" is transferred to the second stage of the shift register. In the middle of this cycle, a "write" command is picked off and routed to the Kennedy. The cycling continues until the "1" arrives in shift register 6. The output of this element is also connected to a gate in the delay loop, and prevents more than six write pulses being generated.

The record gap signal is also used as the input to a six bit counter (spectrum number).

. Handswitch Table

HANDSWITCHES ARE IN GROUPS OF SIX. (SEE Fig.B3.)

SWITCH	1	BLACKBODY INDICATOR (ALL "1"s = BLACKBODY)
	2	SPECTRUM GROUP NO.
	3	BLACKBODY TEMP.
	4	TARGET TEMP.
	5	SPECTRUM COUNT
	6	ZEROS (COMPUTER ERROR DETECTION BYTE SET AUTOMATICALLY)

SWITCH CODING TABLE

DOWN = 0 UP = 1

SWITCH	DECIMAL NO.	TEMP.
000000	0	0°C
100000	1	3°C
010000	2	6°C
110000	3	9°C
001000	4	12°C
101000	5	15°C
011000	6	18°C
111000	7	21°C
000100	8	24°C
100100	9	27°C
010100	10	30°C
110100	11	33°C
001100	12	36°C
101100	13	39°C
011100	14	42°C
111100	15	45°C
000010	16	48°C
100010	17	51°C
010010	18	54°C
110010	19	57°C

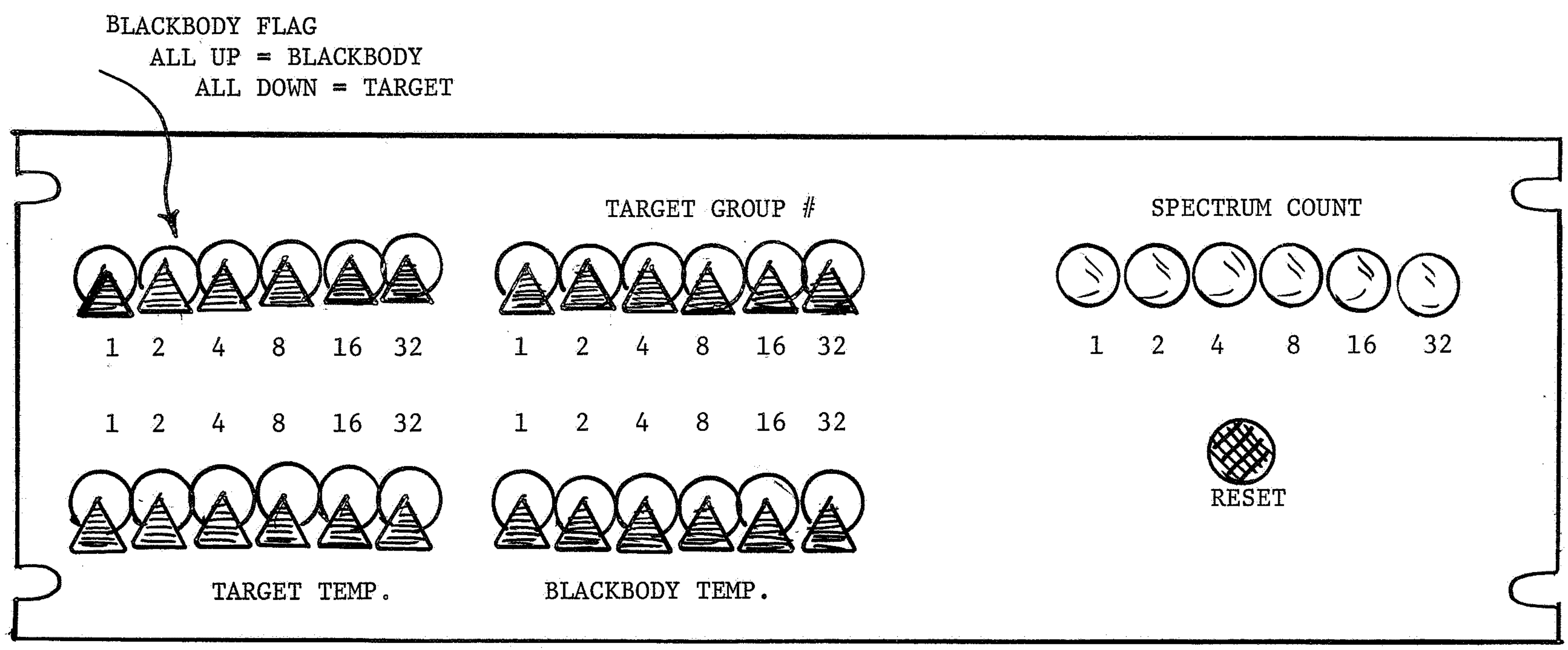


FIG. 3 HANDSWITCH PANEL

SWITCH	DECIMAL NO.	TEMP.
001010	20	60°C
101010	21	63°C
011010	22	66°C
111010	23	69°C
000110	24	72°C
100110	25	75°C
010110	26	78°C
110110	27	81°C
001110	28	84°C
101110	29	87°C
011110	30	90°C
111110	31	93°C
000001	32	96°C

etc.

III. OPERATIONAL GUIDES FOR EXISTING SYSTEM

1. Setting the Tape Number

The tape number is a three-digit decimal number recorded during the first day of any tape. It is set by adjusting the D.V.M. input until the desired number is displayed in the frontal panel, then by putting the D.V.M. in a "hold" condition. The D.V.M. input can be varied by

a) disconnecting the rear input cable and substituting a battery plus potentiometer in the front input. (5K or 10K will do)

OR

b) varying the SG-4 gain until the desired number is seen. Alternative 'b' is obviously quicker, but the operator must remember to reset the gain afterward to the previous value. This is a one time/tape operation.

Procedure:

1/ Point spectrometer at blackbody.
2/ Check viewfinder is out.
3/ Stop SG-4 scan (down ramp) at high point of spectrum.
4/ Adjust SG-4 gain to give desired number. (For two digit number, set D.V.M. on 100v range.)
5/ Put D.V.M. on "HOLD"

The first spectrum recorded will now consist of this number alone, followed by a record gap, followed by the I.D. data for the next spectrum.

2. Selecting Scan Speed

The Model 8409 D.V.M. presently (June 20) installed will not allow spectral speeds shorter than 8 seconds. This presently corresponds approximately to position 5 on the scan switch. The SG-4 presently scans from 2 to 10 seconds; the range can be changed as described in "SG-4 Modification I" note.

The Honeywell Model 85 (used at Indio) allows 1 second scan when operating at maximum speed.

3. Adjusting Sample and Hold Time

The logic boards contain one adjustment related to the particular D.V.M. used and hence to the scan speeds. This is the "sample and hold" time control; the only potentiometer on board three.

Procedure:

1/ Look up D.V.M. specs for "conversion time." Add 25% for a safety factor.

2/ Connect scope probe to pin 3, board 10.

3/ Set scope controls to 5v/cm and 5mSec/div. and Trigger = INT, FAST A.C., -ve.

4/ Adjust board three potentiometer until pulse is the desired length as in 1. If the control is turned to its extreme, oscillations will result. Should such extreme changes in timing be required, increase 1µf, then make the adjustment. As presently wired, the timing can be varied from 10mSec to 35mSec.

4. Selecting the SG-4 Gain

This must be done prior to the beginning of a recording session. The gain may be changed during the recording, but no provision exists for putting this information on tape. The SG-4 clips data at +7 Volts, therefore the maximum allowable voltage from the SG-4 must be set for less than this. A second constraint is that the D.V.M. is now (June 20, 1968) set to accept negative voltages and therefore has its range from +5v to -5v.

The output must not therefore exceed 5.00v. The hottest spectra will be those for a blackbody, therefore the set-up procedure is as follows:

1/ Point spectrometer at blackbody.
2/ Check that the viewfinder is out.
3/ Stop SG-4 scan on highest point of spectrum.
4/ Adjust gain until D.V.M. reads under 5.00v. If conditions are expected to get hotter, set at 4.00v. to allow for increased radiance levels later.
5/ Note gain-setting in field sheet.

5. Changing the Grating Setting and Encoder

The grating can be reset as required (see SG-4 manual), but the encoder must be reset also. If possible, the two should be marked before moving so that approximate realignment is possible.

Having found the approximate alignment, correct scope (with wave-length drive on X axis), as follows:

Use dual trace amplifier

Trace 1.	Pin 4	Board 1
Trace 2.	Pin 9	Board 5

Trace 2 should show a single level change at each end of the spectrum. Minute adjustments of the encoder position will affect this output greatly, it is an accurate adjustment. Trace one should show rapid level change with a high level at each end.

IV. OPERATIONAL CHECKLIST FOR EXISTING SYSTEM

1. ERASE TAPE

2. SET SWITCHES AS FOLLOWS

D.V.M.

	1/	POWER	= ON
	2/	DIGIT READINGS	= TAPE NUMBER (3#'s closest to ± sign fourth)
	3/	PRINT CONTROL	= HOLD
	4/	RANGE	= 10V (SENSITIVITY)
SG-4	5/	"AGC"	= "AGC"
	6/	SCAN	= OFF
	7/	GAIN	= VARIABLE (Reset After Tape # Operation)
	8/	SCAN SPEED	= #5 (12.5 sec. period or 25 sec. UP and DOWN ramp)
	9/	BANDWIDTH	= 12
	10/	FILTER	= #1 (POLY is #4)

Note down gain setting giving blackbody peak less than 5V.

O/SCOPE

3A1 CH2 to Kennedy Left. CH1 open. Both set on DC (top 5V/div., bottom IV/div.)

2A60 INPUT to Kennedy Right. Set on DC (set at 0.05V/div) SWITCH ON CH2

LOGIC

1/ WRITE = OFF

2/ POWER = ON

HANDSWITCHES

1/	BLACKBODY (TARGET)	= 111111 (All up)
2/	GROUP NUMBER	= 100000 (LEFT TO RIGHT)
3/	TEMPERATURE SWITCHES (2)	= AS SET-UP TABLE
4/	COUNTER	= PUSH RESET BUTTON

LOAD TAPE

PRESS "LOAD FORWARD"

(Tape reel rotates
File Gap marks end)

OPERATION

1. SG-4 SCAN = ON

   LET SG-4 RUN FOR AT LEAST TWO SPECTRA TO SYNCHRONIZE LOGIC WITH UP-RAMPS (NO KENNEDY SOUND)

2. STOP SCAN IN MIDDLE OF DOWN-RAMP

3. WRITE FIRST RECORD AS FOLLOWS

   1/ WRITE SWITCH = ON, RESET COUNTER

   2/ SCAN = ON

   3/ RECORD ONE "SPECTRUM"

   4/ SCAN = OFF

4. WRITE SECOND AND SUBSEQUENT SPECTRA AS FOLLOWS

   1/ D.V.M. PRINT CONTROL = TRACK

   2/ SCAN = ON

   3/ SET TEMPERATURES

   4/ AFTER THE RECORD GAP FOR THE LAST BUT ONE SPECTRUM HAS BEEN RECORDED, THE I.D. SWITCHES MUST BE SET UP FOR THE NEXT SAMPLE. (CHANGE BB SWITCH TO ALL DOWN)

      MOST IMPORTANT IS TO ADVANCE THE GROUP NUMBER BY ONE.

   5/ ADVANCE GROUP NUMBER BY 1

   6/ RESET COUNTER

   7/ RECORD LAST SPECTRUM

   8/ SCAN OFF

5. CHANGE TARGET

   1/ SCAN = ON

   2/ SET TEMPERATURES

   3/ AFTER THE RECORD GAP FOR THE LAST BUT ONE SPECTRUM HAS BEEN RECORDED, THE I.D. SWITCHES MUST BE SET UP FOR THE NEXT SAMPLE. (BB SWITCHS ALL DOWN)

      MOST IMPORTANT IS TO ADVANCE THE GROUP NUMBER BY ONE.

4/ ADVANCE GROUP NUMBER BY 1

5/ RESET COUNTER

6/ RECORD LAST SPECTRUM

7/ SCAN OFF; RETURN TO 5.

AT END OF RECORDING SESSION, TURN SCAN OFF AND WRITE I.D. OFF AND PRESS FILE GAP BUTTON ON THE KENNEDY THREE TIMES.

REWIND TAPE.

TURN ALL OFF.

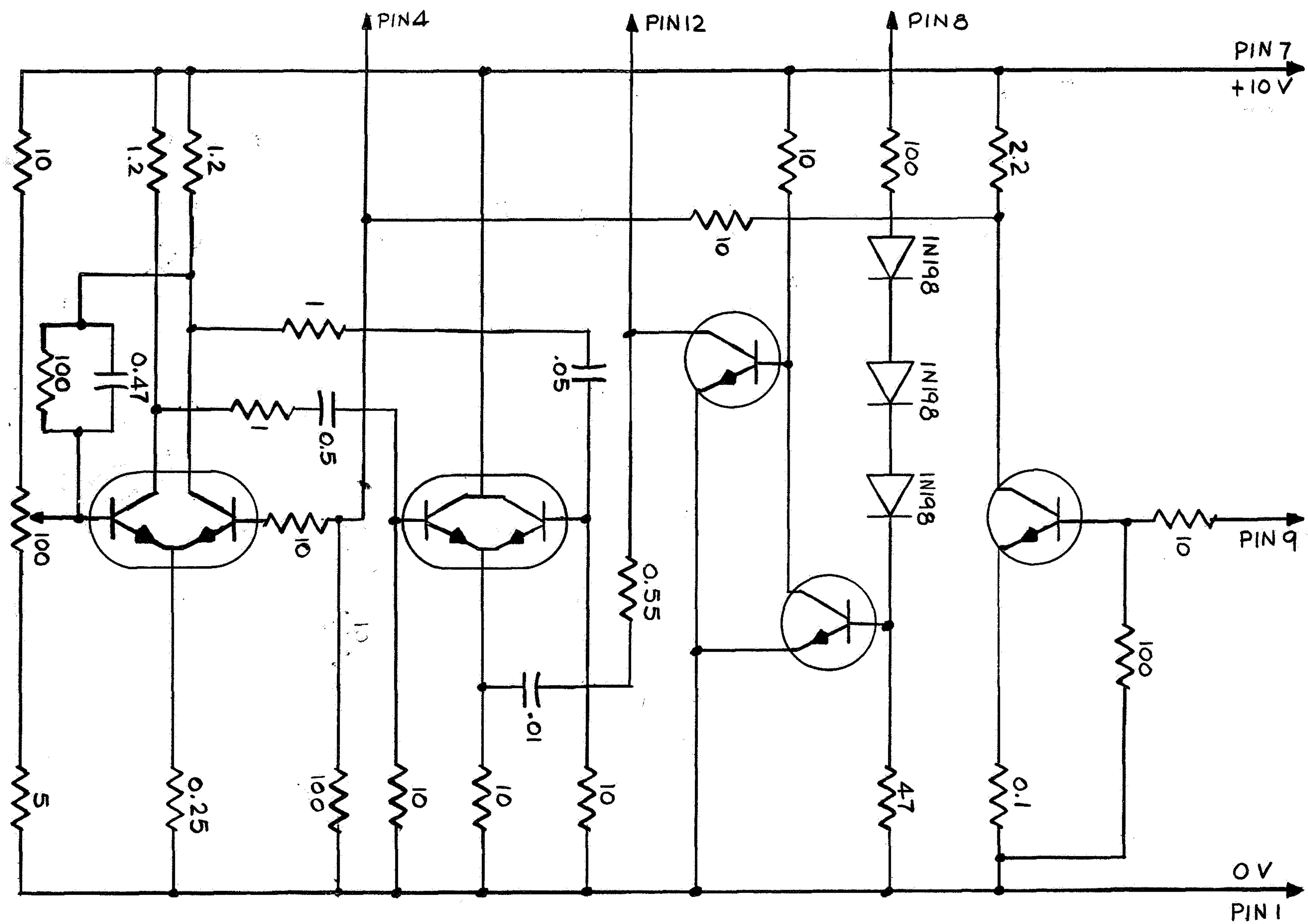
V. CIRCUITS

NOTES:

All transistors are 20V NPN switching types unless otherwise noted. (Type AMELCO 404)

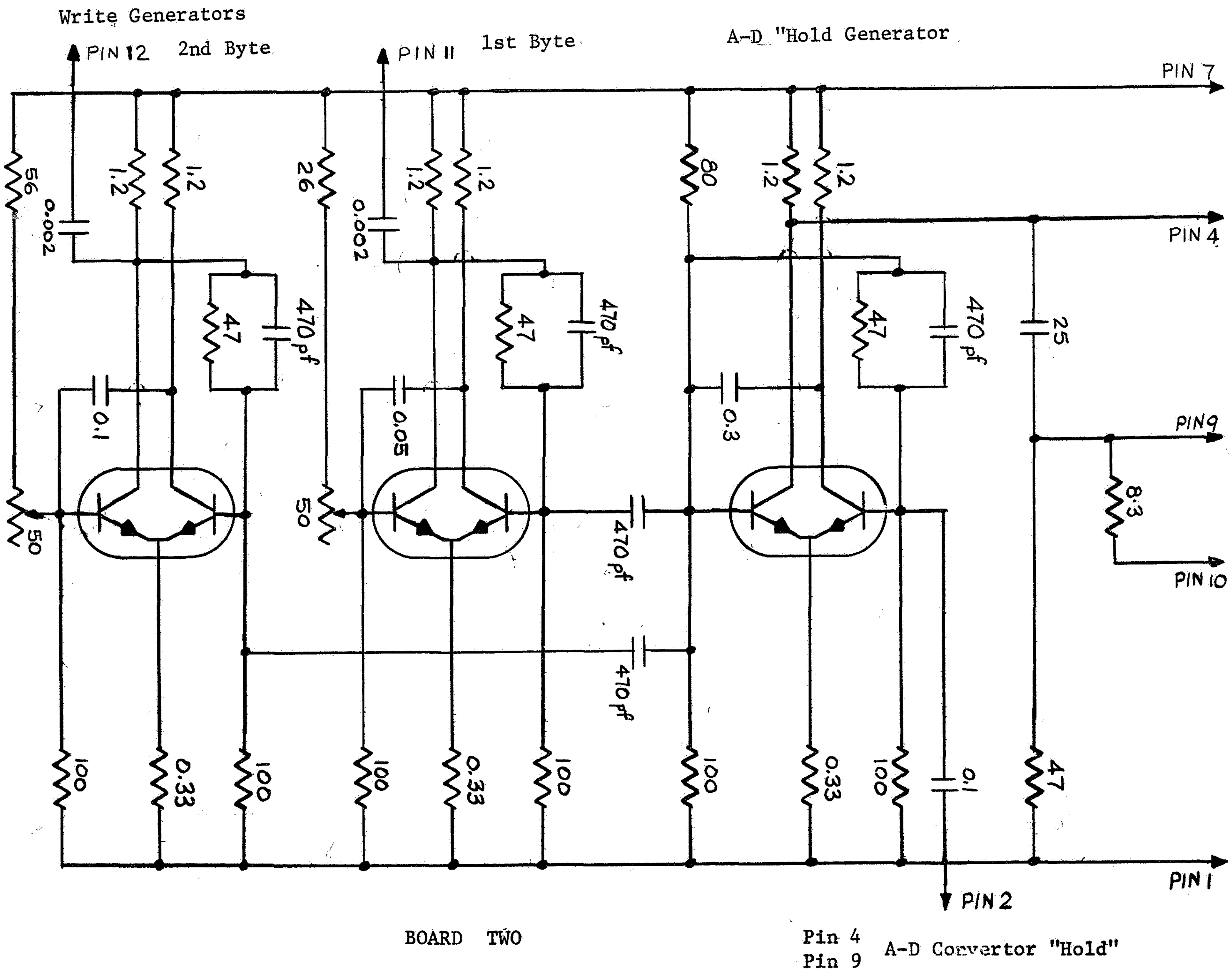
All resistors 1/4 W 10% (Marked in 1000 Ω units).

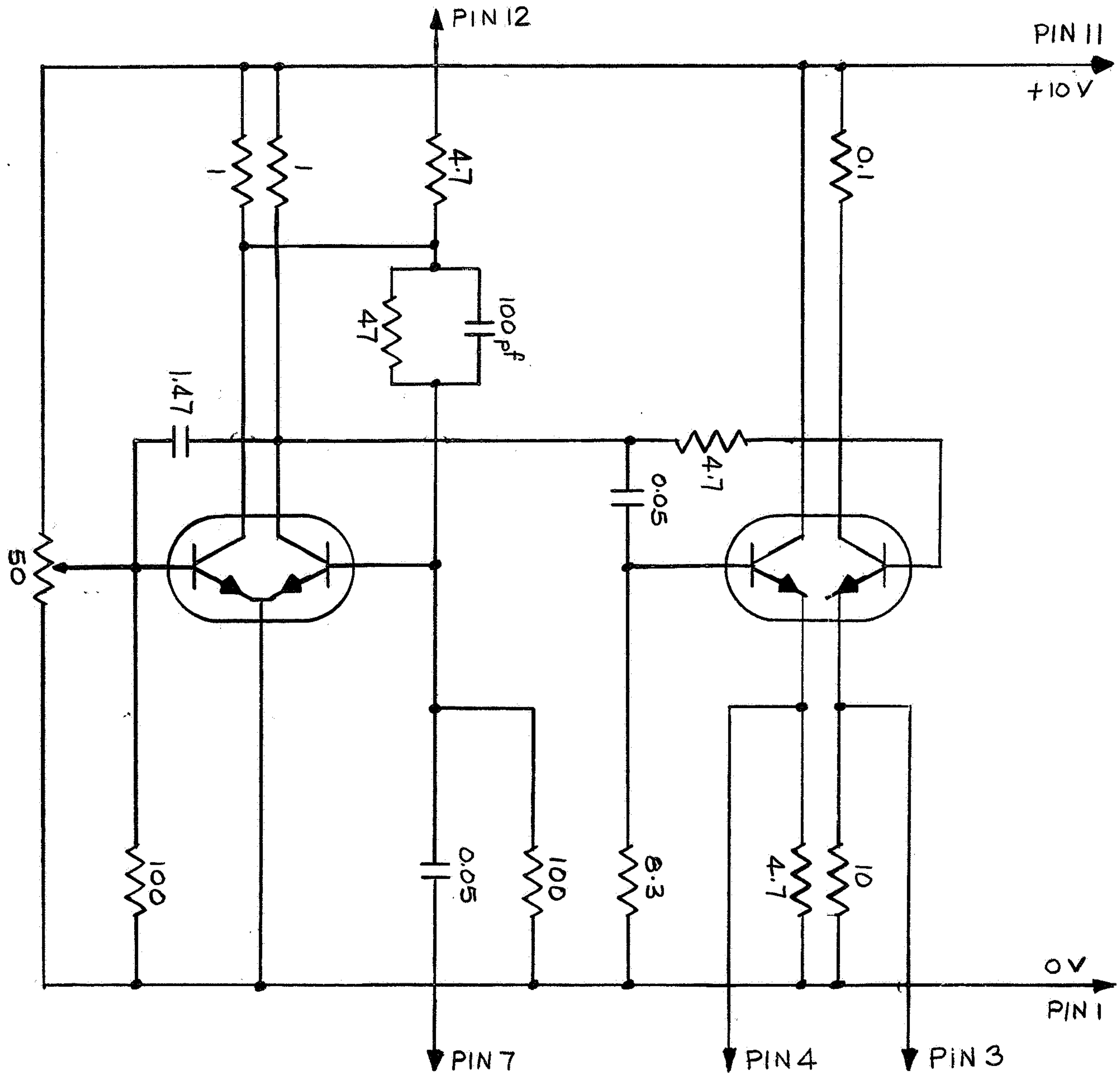
All Capacitors marked in μf.



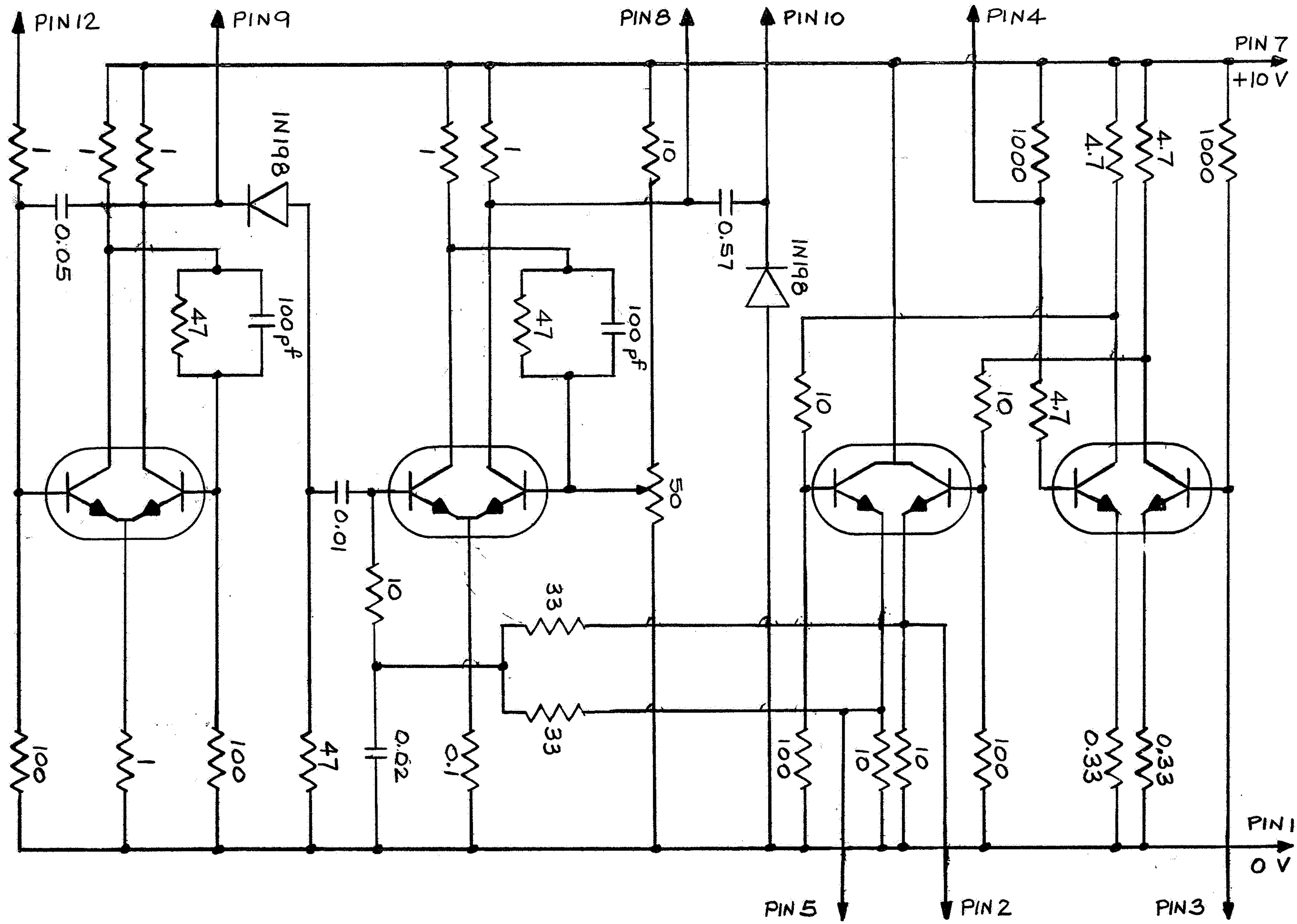
Pin 4 to Encoder 10th Bit
Pin 8 to Ramp Selector
Pin 12 to "Sample" Instruction Output

Board One


Write Generators
PIN 12
2nd Byte
PIN 11
1st Byte
A-D "Hold Generator
PIN 7
PIN 4
PIN 9
PIN 10
PIN 1
PIN 2
56
1.2
1.2
0.002
26
1.2
1.2
0.002
80
1.2
1.2
47
470 pf
47
470 pf
47
470 pf
25
0.1
0.05
0.3
8.3
50
50
470 pf
470 pf
100
0.33
100
100
0.33
100
100
0.33
100
0.1
47
BOARD TWO
Pin 4
Pin 9
A-D Convertor "Hold"



PIN 3 TO SAMPLE/HOLD RELAY BOARD THREE

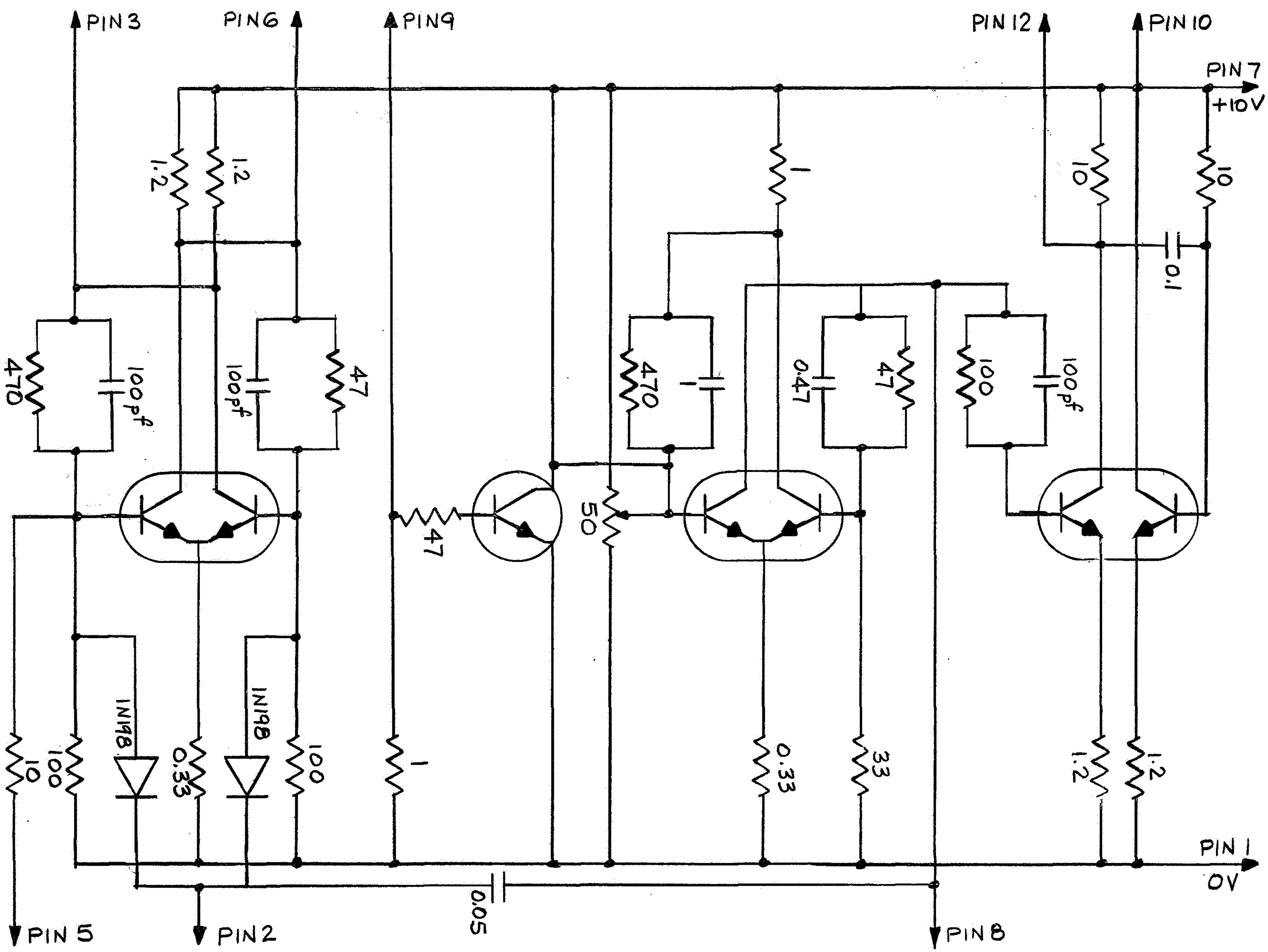


BOARD FOUR

Pin 10 to "Write" on Kennedy

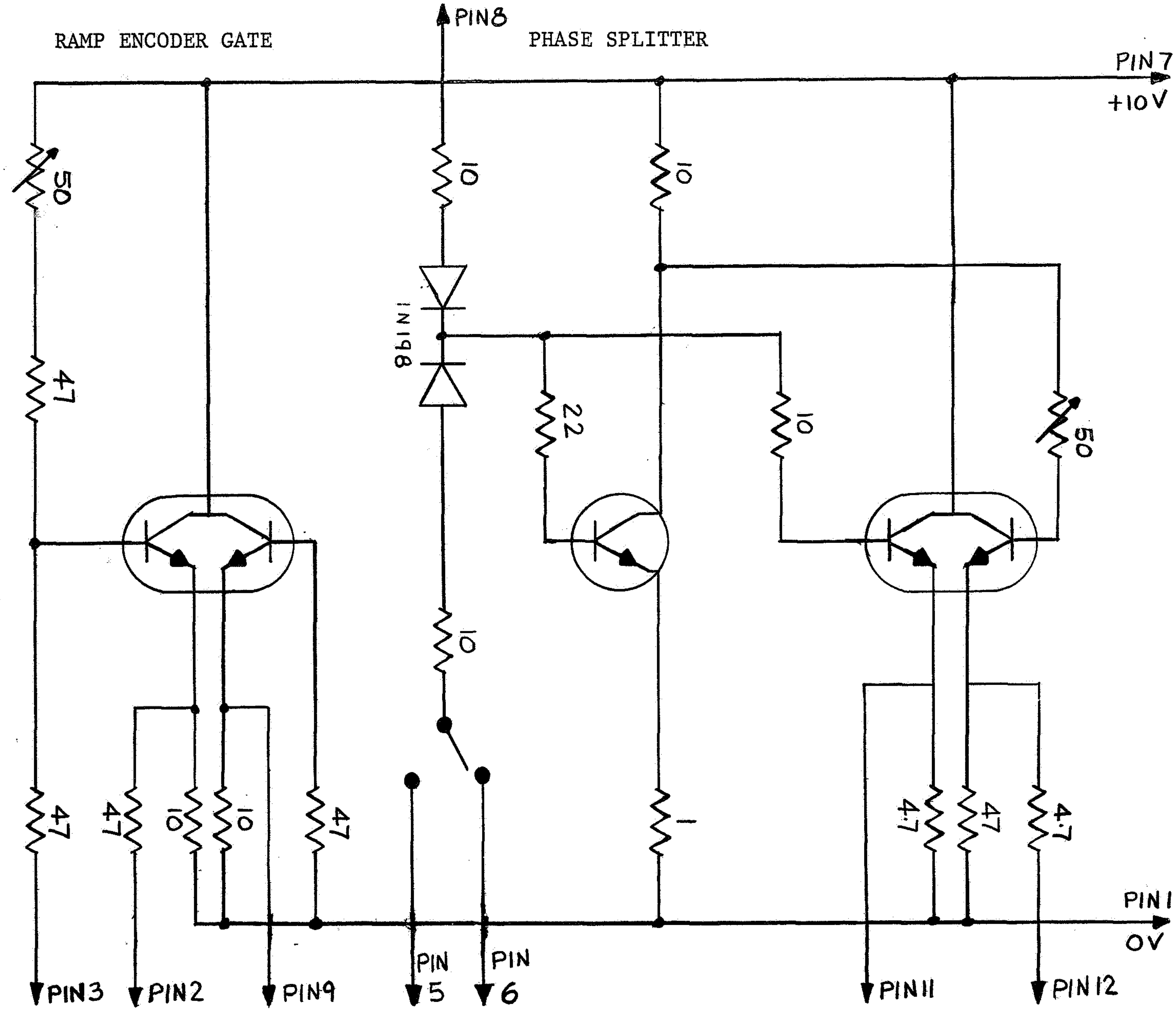
"Write" Pulse Generator
Shapers + 50µsec Delay

RAMP SELECTORS



BOARD FIVE

Pin 5 FROM MODIFIED WAVELENGTH OUTPUT
Pin 9 TO ENCODER "END OF SPECTRUM" OUTPUT

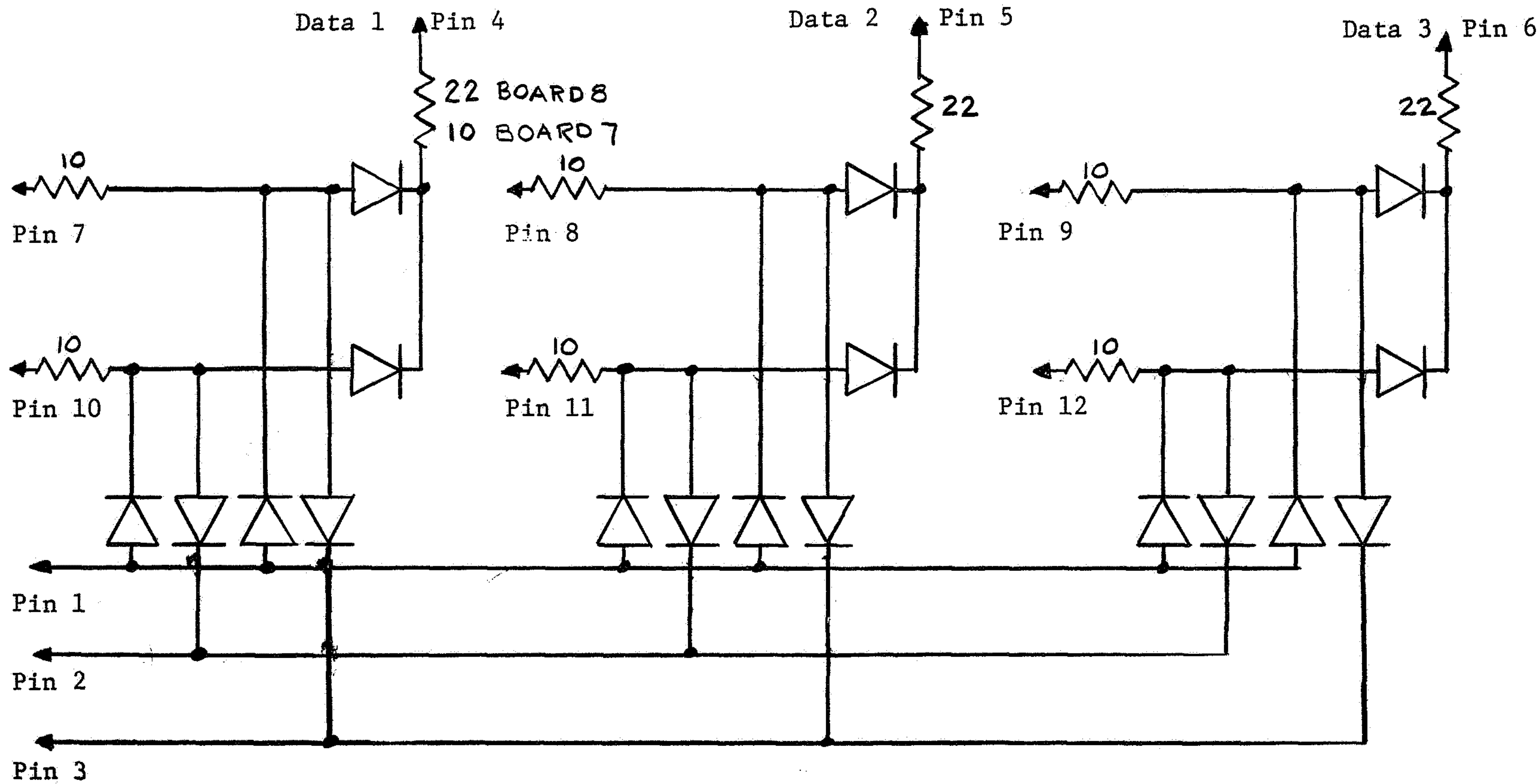

RAMP ENCODER GATE
PHASE SPLITTER
PIN8
PIN7
+10V
50
47
10
10
1N198
22
10
50
10
47
47
10
10
47
1
4.7
47
4.7
PIN1
0V
PIN3
PIN2
PIN9
PIN 5
PIN 6
PIN11
PIN12

BOARD SIX

7. BOARD SEVEN AND EIGHT

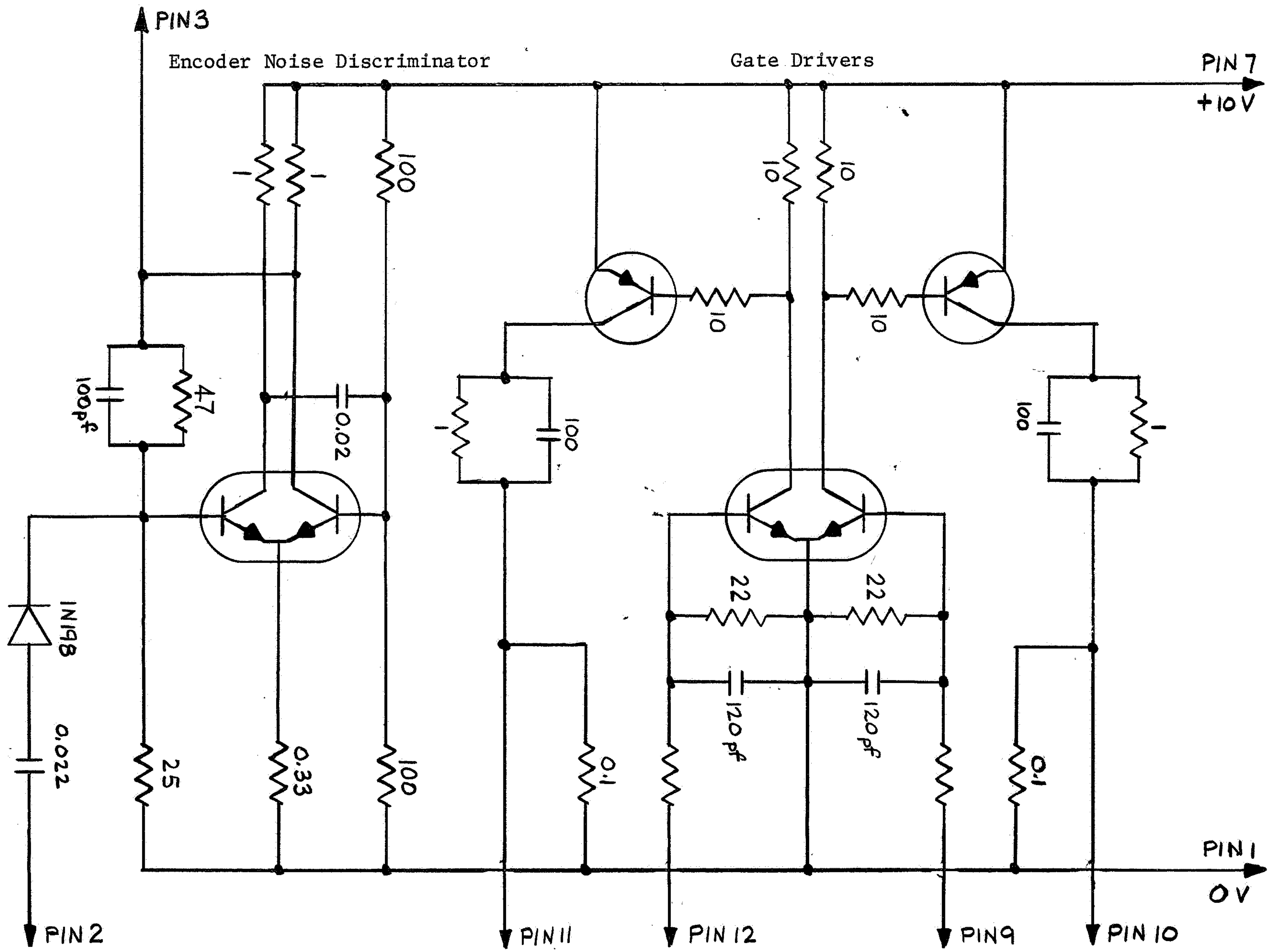
CONNECTIONS

SEVEN PIN			EIGHT PIN	
7	10^2 1	Write Together	7	10^2 2*
8	10^2 2		8	10^1 1
9	10^2 4		9	10^1 2
10	10^1 4	Write Together	10	10° 2
11	10^1 2*		11	10° 4
12	10° 1		12	10° 2*



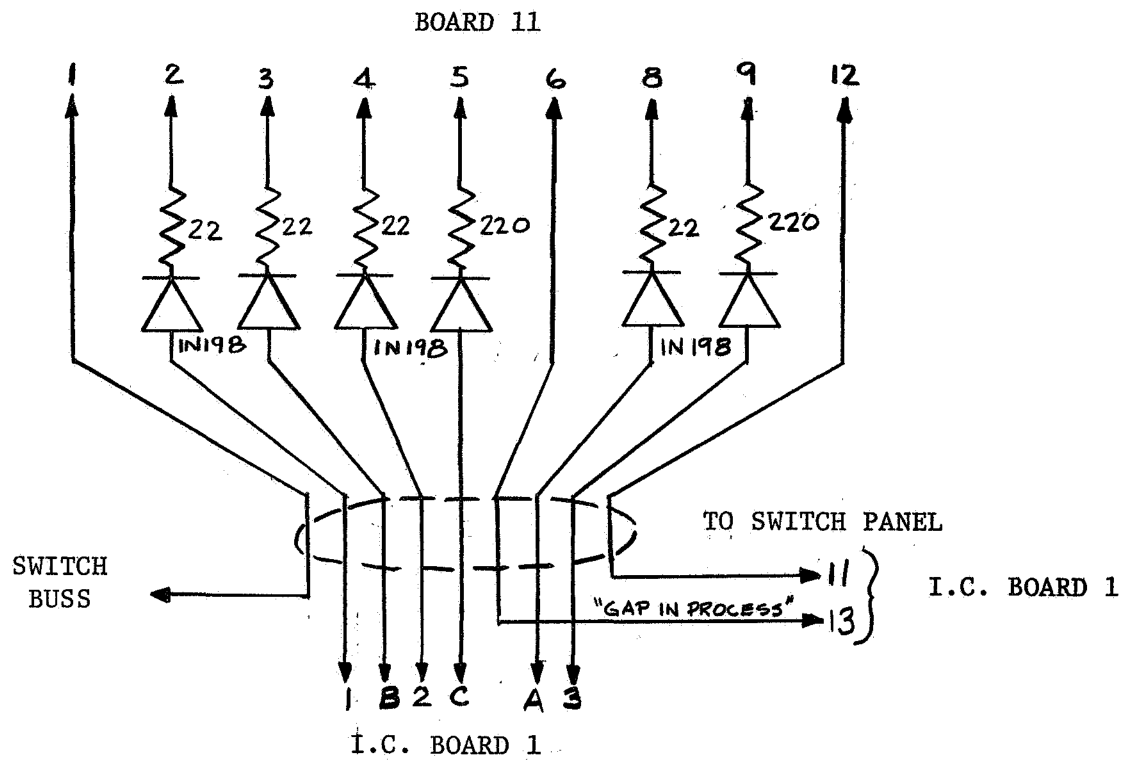
All diodes = IN341

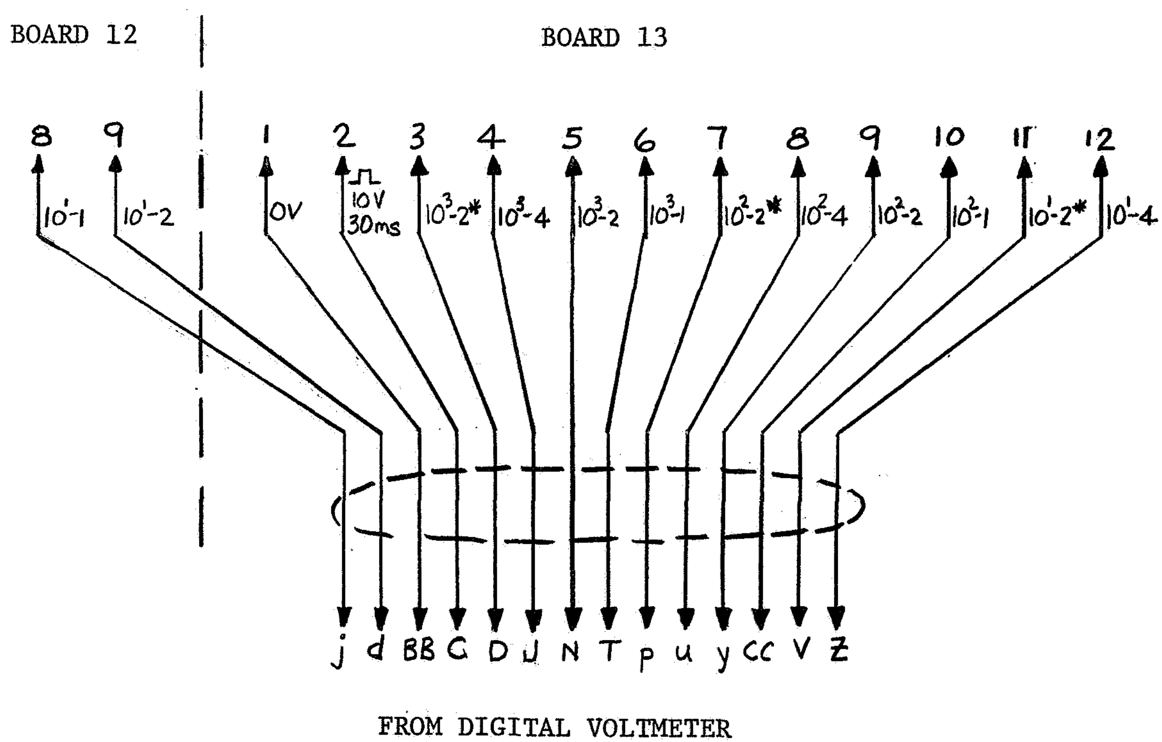
BOARDS SEVEN AND EIGHT



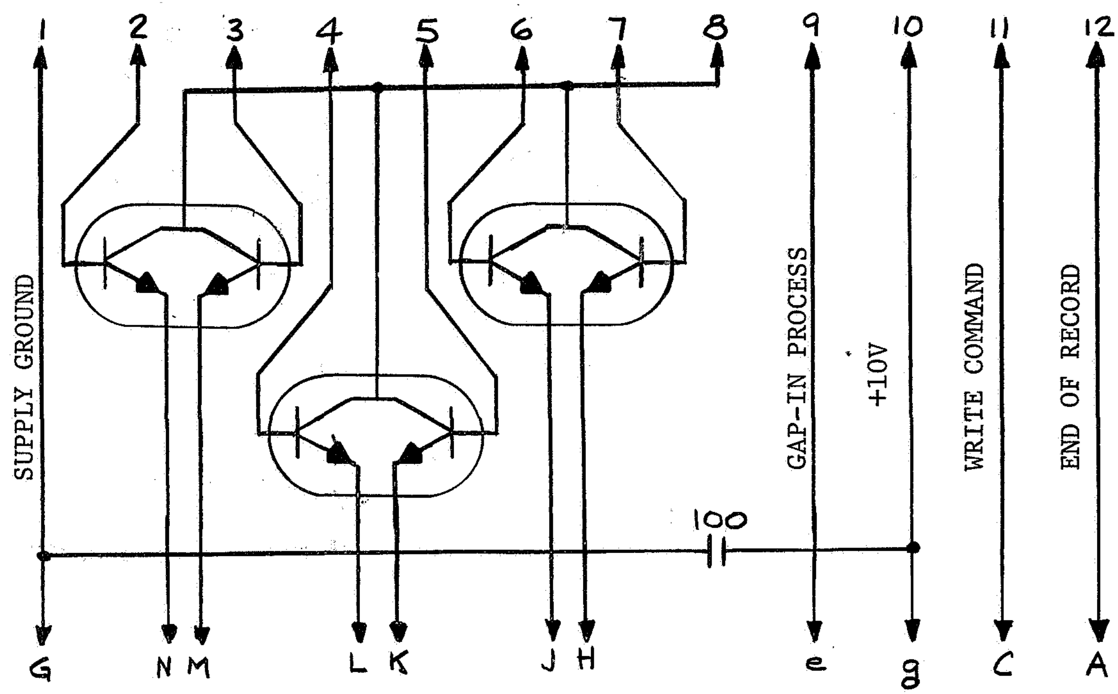
Pin 13 To "End of Record"

BOARD NINE


BOARD 11
1
2
3
4
5
6
8
9
12
22
22
22
220
22
220
IN198
IN198
IN 198
TO SWITCH PANEL
SWITCH BUSS
11
"GAP IN PROCESS"
13
I.C. BOARD 1
1 B 2 C A 3
I.C. BOARD 1

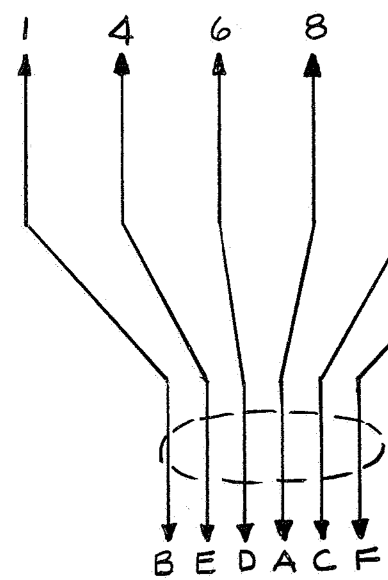

BOARD 12
BOARD 13
8 9
1 2 3 4 5 6 7 8 9 10 11 12
10⁻¹-1
10⁻¹-2
0V
10V 30ms
10⁻³-2*
10⁻³-4
10⁻³-2
10⁻³-1
10⁻²-2*
10⁻²-4
10⁻²-2
10⁻²-1
10⁻¹-2*
10⁻¹-4
j d BB G D J N T p u y CC V Z
FROM DIGITAL VOLTMETER

BOARD 14

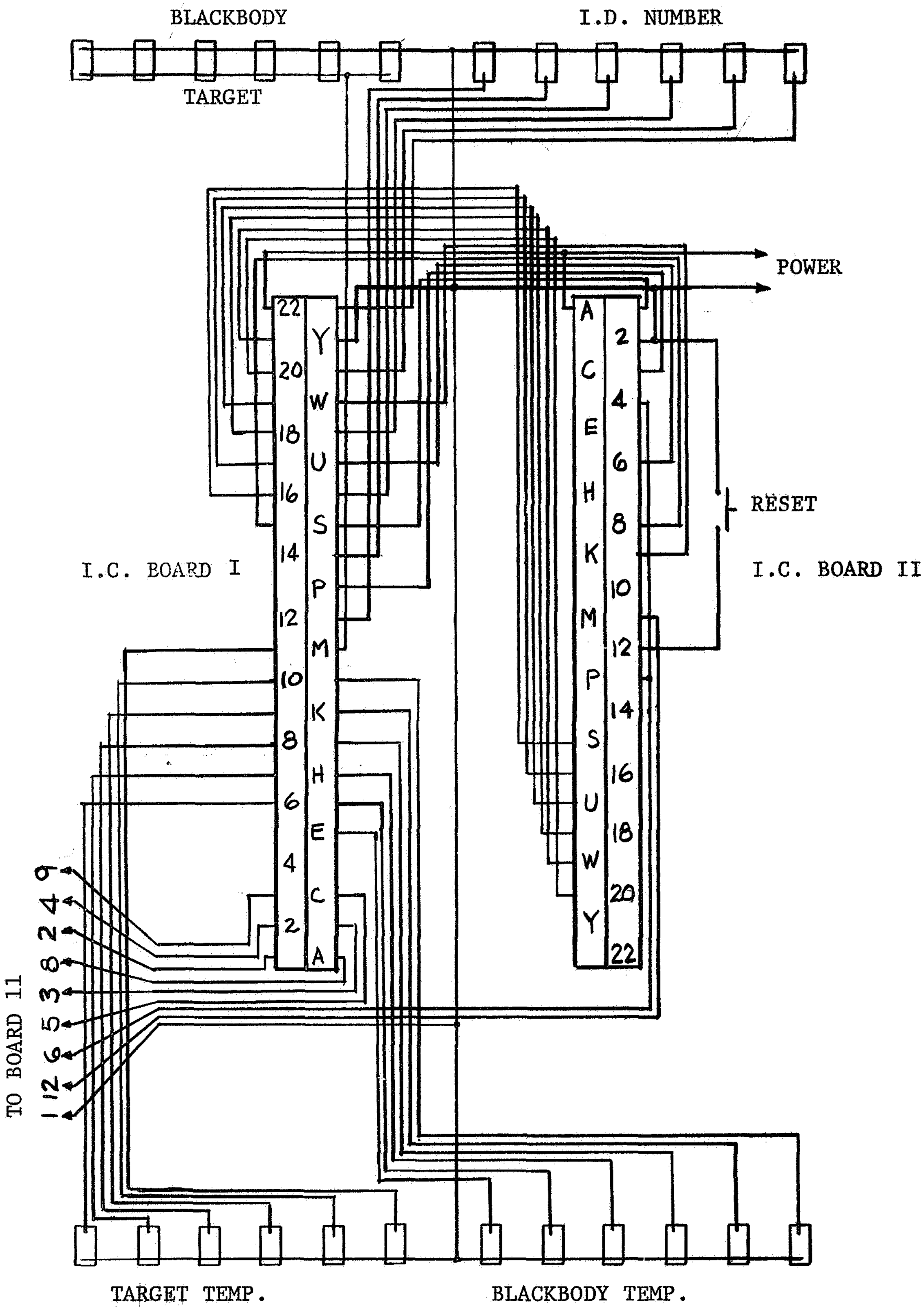


TO KENNEDY INPUT

BOARD 15



TO SG-4 OUTPUT



INTERCONNECTION DIAGRAM FOR SWITCH PANEL AND INTEGRATED CIRCUIT BOARDS

15. B.C.D. Decode Table

	4	2*	2	1
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	1	0
5	0	1	1	1
6	1	0	1	0
7	1	0	1	1
8	1	1	1	0
9	1	1	1	1

	8	4	2	1
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

Used on Indio Tapes Only

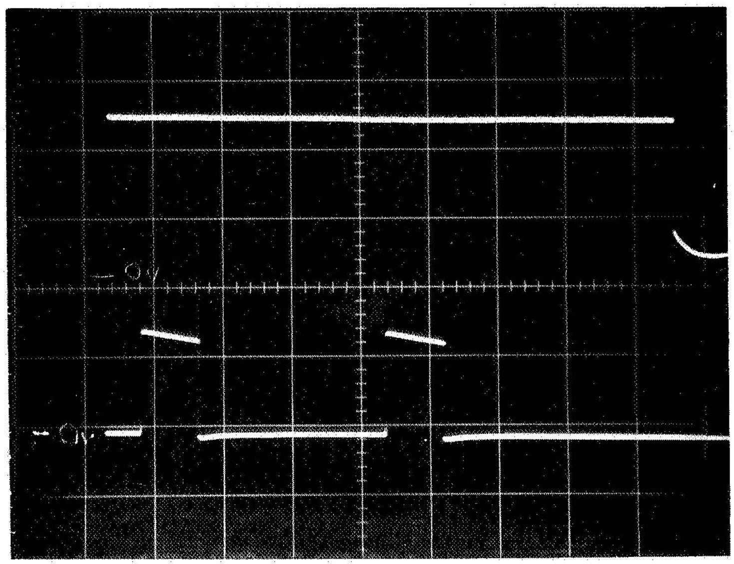
16. J808 (Connector on Back of D.V.M.)

Pin A Hold logic. +5-10v Hold 40µ sec. delay
+0-1/2 Track Use 47k series.

DIGIT	PIN
10° - 2*	B
- 4	F
- 2	L
- 1	R
10^1 - 2*	V
- 4	Z
- 2	d
- 1	j
10^2 - 2*	p
- 4	u
- 2	y
- 1	CC
10^3 - 2*	D
- 4	J
- 2	N
- 1	T

ground = BB
polarity = K

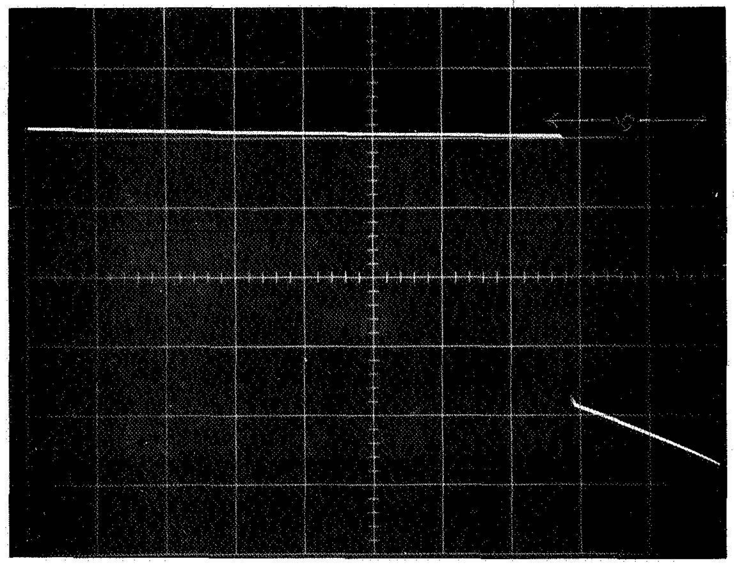
TEST POINT WAVEFORM 1. D.V.M. "HOLD"



	UPPER TRACE	LOWER TRACE
FUNCTION	D.V.M. 'HOLD'	KENNEDY WRITE PULSES
BOARD	TWO	FOUR
PIN	TEN	TEN
HORIZ. SCALE	1m Sec/Div	
VERTICAL	2v/cm	5v/cm

NOTES

TEST POINT WAVEFORM 2. "GATE" PULSE

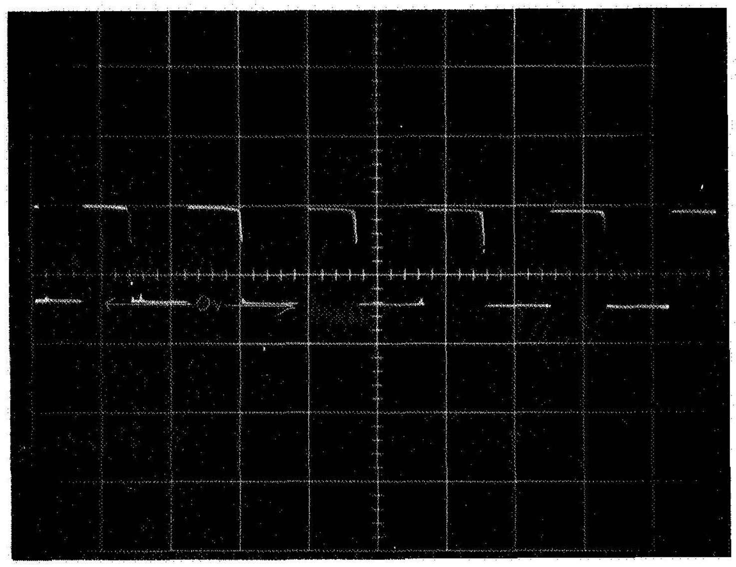


	UPPER TRACE	LOWER TRACE
FUNCTION	'GATE' PULSE	
BOARD	SEVEN & EIGHT	
PIN	THREE	
HORIZ. SCALE	1m Sec/Div	
VERTICAL SCALE	2v/cm	

NOTES

Later modifications have removed the droop at the tail of this pulse.

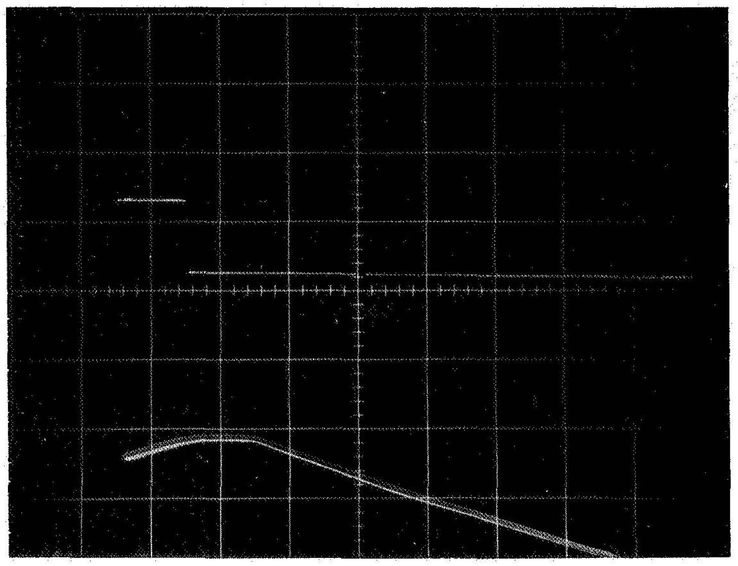
TEST POINT WAVEFORM 3. ENCODER 10th-BIT-OUTPUT



	UPPER TRACE	LOWER TRACE
FUNCTION	ENCODER 10th BIT OUTPUT	
BOARD	ONE	
PIN	FOUR	
HORIZ. SCALE	0.2Sec/Div	
VERTICAL SCALE	2v/cm	

NOTES

TEST POINT WAVEFORM 4. RAMP SELECTOR

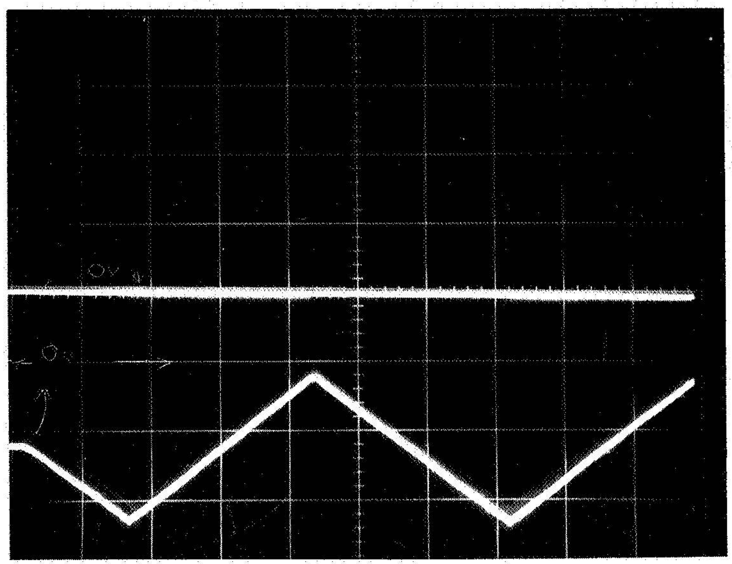


	UPPER TRACE	LOWER TRACE
FUNCTION	RAMP SELECTOR	SG4 WAVELENGTH
BOARD	ONE	
PIN	EIGHT	
HORIZ. SCALE	1 Sec/Div	
VERTICAL SCALE	5v/cm	0.5v/cm

NOTES

The lower level of the upper trace=unwanted ramp, **note that the** spectrometer turnaround is also rejected

TEST POINT WAVEFORM 5. WRITE IMPULSES
(SG-4 WAVELENGTH RAMP)



	UPPER TRACE	LOWER TRACE
FUNCTION	WRITE PULSES (FAINT)	SG4 WAVELENGTH RAMP
BOARD	FOUR	
PIN	TEN	
HORIZ. SCALE	2Sec/cm	
VERTICAL SCALE	5v/cm	1v/cm

NOTES

Ramp selector on 'up-ramp'.

February 1967
APPENDIX A

AMELCO

HIGH NOISE IMMUNITY LOGIC

300 SERIES

High Noise Immunity Logic (HNIL) is ideally suited for applications requiring maximum noise immunity and excellent line driving capability. A sixteen pin package and complex logic functions result in a minimum number of packages per system. Buffered outputs on all elements and 12 volt logic swings eliminate the necessity for interface circuitry in most applications. The Dual Buffer, with a 60 mA output, permits driving lamps and relays directly. A compatible set of interface circuitry is included in the family to permit interconnection with all forms of low level logic currently available.

QUAD 2 INPUT GATE	DUAL 5 INPUT EXPANDER
DUAL 5 INPUT GATE	DUAL ONE SHOT
DUAL 5 INPUT BUFFER	DUAL INPUT INTERFACE
DUAL EXCLUSIVE–OR FLIP-FLOP	DUAL OUTPUT INTERFACE

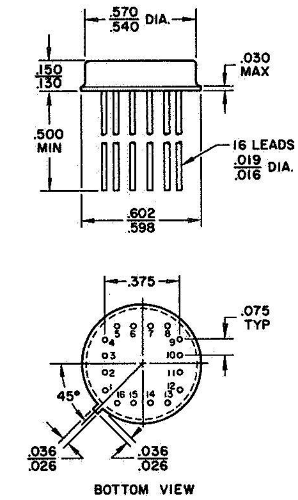
ELECTRICAL SPECIFICATIONS 25°C ($V_{CC} = +12V$)

Parameter	Symbol	Limit Min	Limit Typ	Limit Max	Units	Test Conditions
Output Voltage "One" State	V_{OH}	10.5	11.3		Volts	$V_{IN} = 4.8$ V
Output Voltage "Zero" State	V_{OL}		1.2	1.5	Volts	$V_{IN} = 6.5$ V, $I_{sink} = 8.5$ mA (60 mA for 301)
Input Current (1 Load)	I_{IN}		1.2	1.7	mA	$V_{IN} = 1.5$ V
Noise Immunity (Either State)	NI	3.3	4.2		Volts	
Fan Out	FO					
Gate		5	9			
Buffer		36	50			
Leakage Current	I_L		.1	1	μA	$V_{IN} = 12$ V, All other inputs grounded
Output Voltage "One" State Loaded	V_{OHL}	7	8		Volts	$I_O = -5.0$ mA, $V_{IN} = 4.8$ V
Propagation Delay (Gates)	T_{pd}		60		nsec	
Clock Rate (Flip Flop)			4		mc	

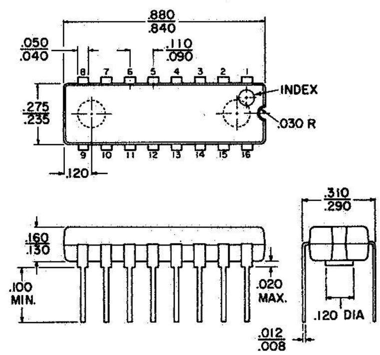
TEMPERATURE RANGE

	300 BG Series	300 CG Series	300 CJ Series
Storage	−65°C to +150°C	−65°C to +150°C	−55°C to +100°C
Operating	−55°C to +125°C	0°C to +100°C	0°C to +70°C

G package



J package



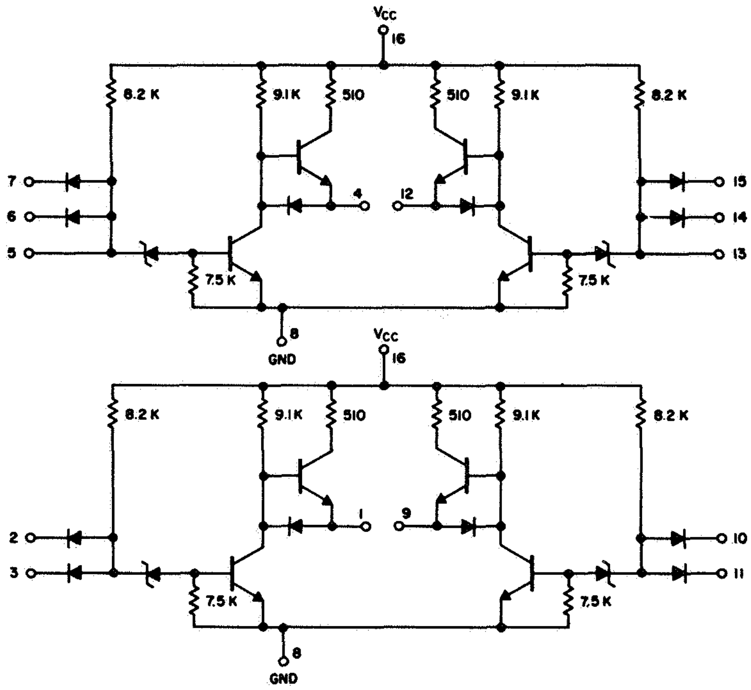
Complete part number designation consists of three digits and two letters, for example:

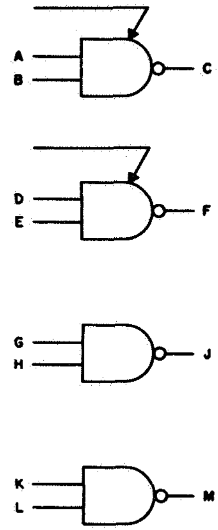
321 BG
- Package
- Temperature Range
- Circuit

B-42-

AMELCO SEMICONDUCTOR
DIVISION OF TELEDYNE, INC. / 1300 TERRA BELLA AVE., MOUNTAIN VIEW, CALIFORNIA
MAIL ADDRESS: P.O. BOX 1030, MOUNTAIN VIEW, CALIFORNIA • PHONE (415) 968-9241 • TWX: (415) 969-9112

Type 321 Quad 2 Input Gate

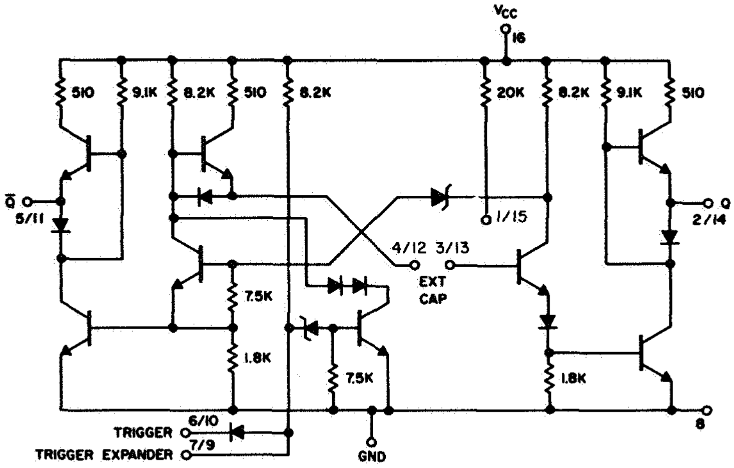


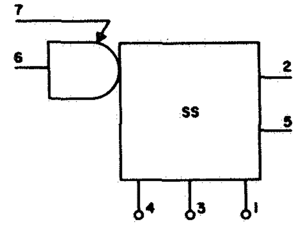


$C = \overline{A \cdot B}$
$F = \overline{D \cdot E}$
$J = \overline{G \cdot H}$
$M = \overline{K \cdot L}$

POWER DISSIPATION: 96 mw
LOADING FACTOR:
INPUT-1 LOAD
OUTPUT-6 INPUT LOADS

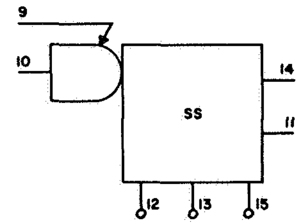
Type 342 Dual One Shot





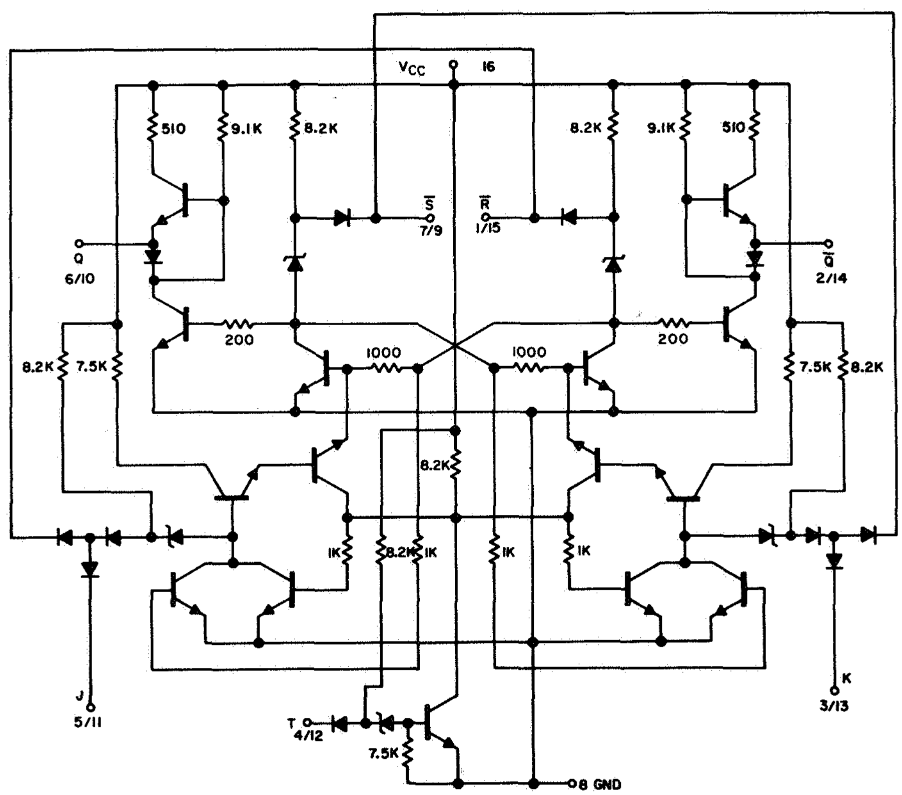
EXT. TIMING CONNECTIONS

POWER DISSIPATION: 100 mw
LOADING FACTOR:
INPUTS - 1 LOAD
OUTPUTS - 6 INPUT LOADS



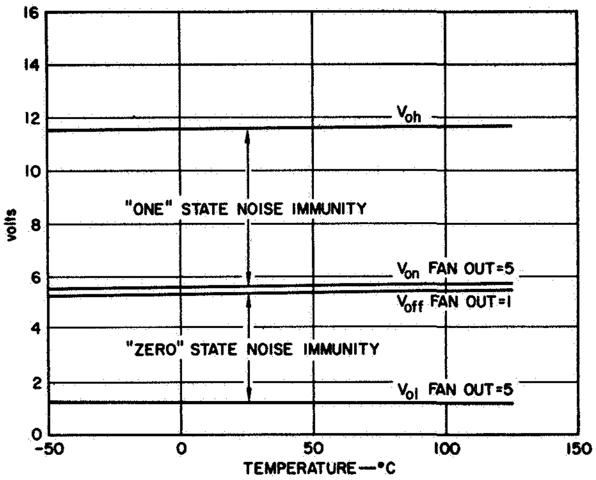
EXT. TIMING CONNECTIONS

Type 312 Dual JK Flip-Flop

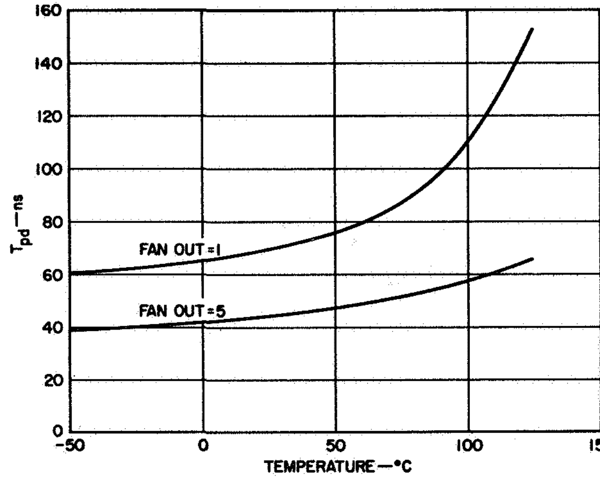


CHARACTERISTIC CURVES

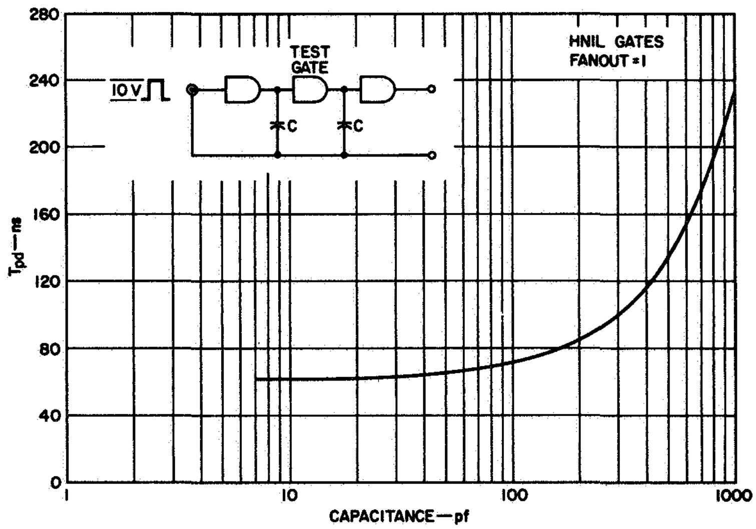
Noise Immunity vs. Temperature



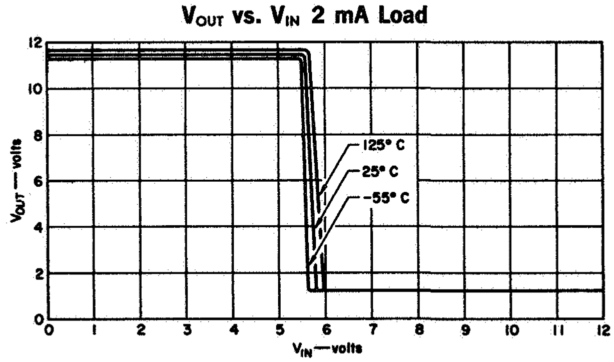
High Noise Immunity Gate T_{pd} vs. Temperature



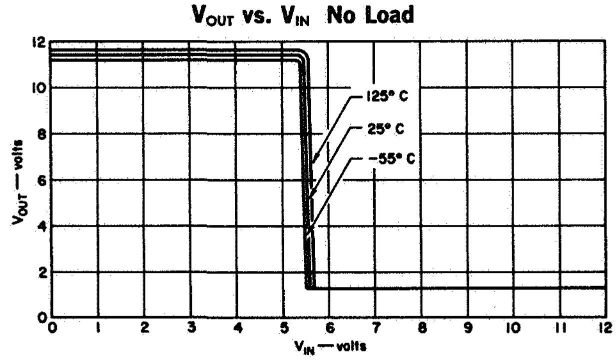
T_{pd} vs. Capacitive Loading



V_{OUT} vs. V_{IN} 2 mA Load

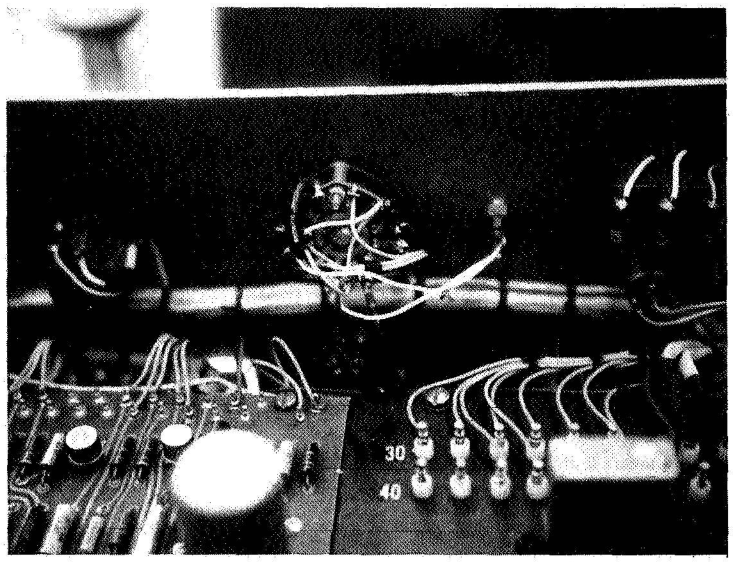


V_{OUT} vs. V_{IN} No Load

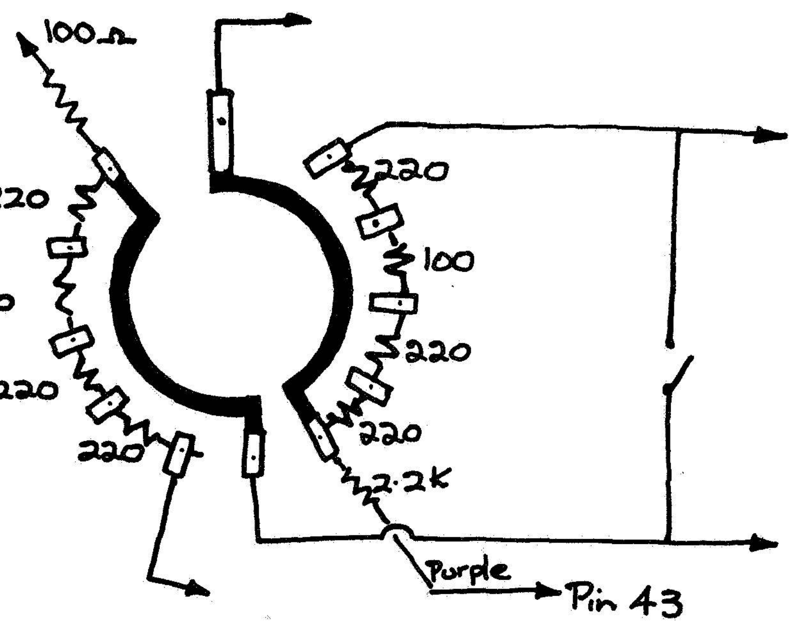


APPENDIX B SG4 CIRCUIT MODIFICATIONS

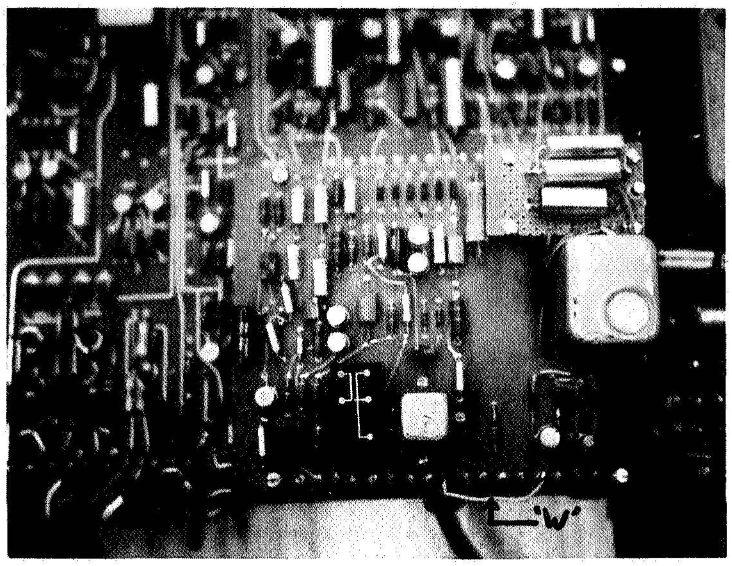
SG-4 MODIFICATIONS I



SCAN SPEED SWITCH - Used to be a two gang 1.5K potentiometer, and is now a 6 position switch, wired as follows:



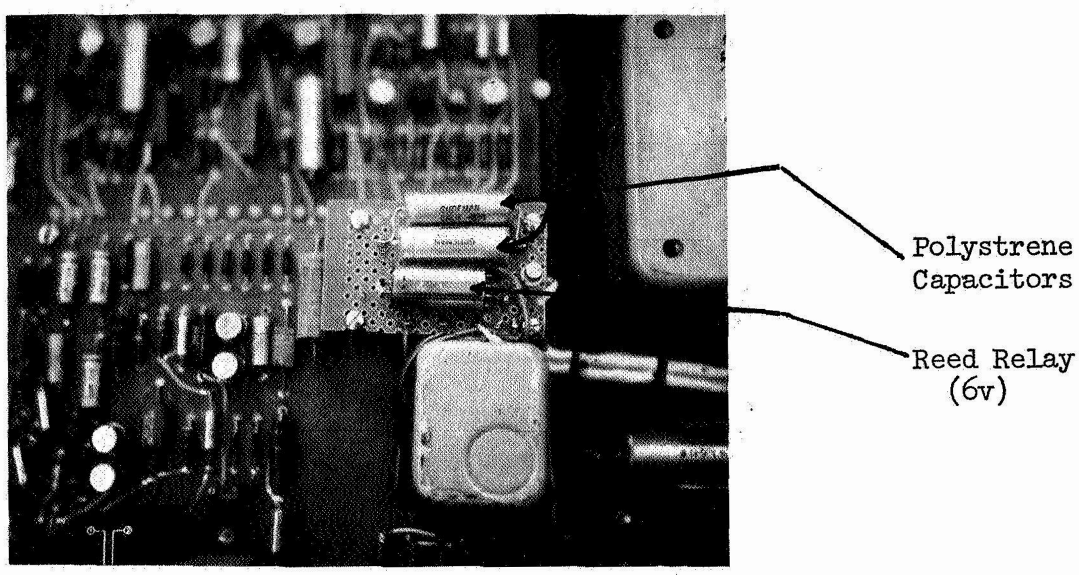
The overall speed is controlled by a resistor inside the sleeving (marked R on the photograph). 1K gives scans from 8 secs. 200Ω gives 2 secs to 11 secs.



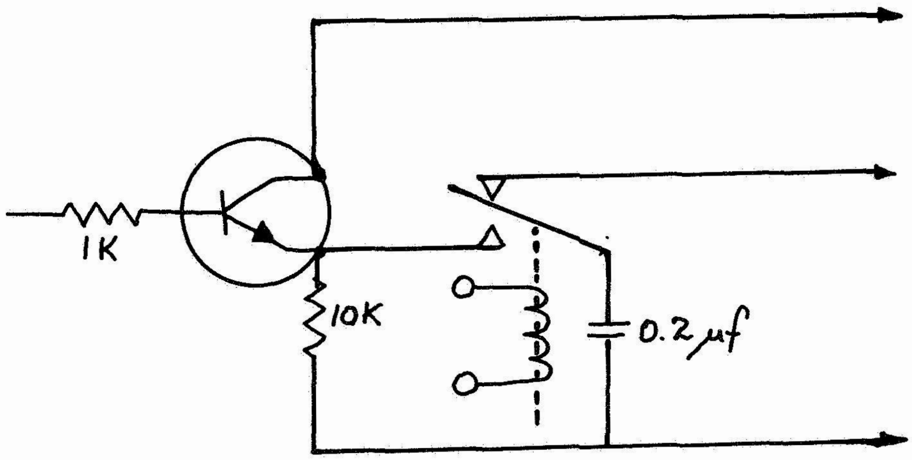
WAVELENGTH METER

The small edge meter on the front panel now displays the wavelength output. One side of the meter is grounded, the other goes via 22K to the wavelength output (yellow wire marked "W" on photograph).

SG-4 MODIFICATIONS III



SAMPLE AND HOLD AMPLIFIER



An extra emitter follower stage is wired onto the radiance output. The emitter charges up a low-loss polystyrene 0.2μf capacitor. On receiving a "hold" pulse the capacitor is connected directly to the A-D converter input line, and is disconnected from the emitter follower. Timing for the "hold" instruction is derived from Board 3 of the logic system. The relay used is a miniature reed type relay (see photograph). The transistor is any working NPN type (50V).