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CRYOGENIC AIRBORNE INTERFEROMETER

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Franklin
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22 December 1976

Final Report
February 1973 through October 1976

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This report gives a comprehensive account of the development of a cryogenically-cooled interferometer, suitable for use in a balloon at altitude and at LN temperature. The instrument has been designed to operate in the spectral region from 2 to 14 microns, and is the so-called cat's-eye optical configuration.

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INTRODUCTION

This account attempts to discuss the design requirements for the construction of an interferometer spectrometer having a resolution of greater than 0.1 cm^{-1} for operation in the near infrared region (2 - 14 microns) (nano meters) and being capable of performing to this resolution at both ambient temperature and at 77° K (L/N temperature).

These requirements impose very severe design problems in regard to materials selection and materials handling. Machine tolerances have to be pushed to the extreme of the state of the arts, and these tolerances must be maintained through abnormally large temperature excursions. Many of the pieces have to be held to flatnesses of 50×10^{-6} inch per 5 inches, and similar tolerances have to be held for parallelism. Fortunately, absolute dimension can be met with normal machine tolerances in many instances by the use of careful design techniques.

TECHNICAL REPORT SUMMARY

Design and fabricate a high resolution liquid nitrogen interferometer spectrometer suitable for use in the laboratory and in a balloon borne package, for the purpose of making measurements in the spectral region of two (2) to fourteen (14) microns of an extended source having a temperature of approximately 200° K.

Of fundamental importance is that the design concept should be such as to make it possible for the instrument to stay in substantial alignment after having been cooled to the liquid nitrogen in a suitable cryogenic enclosure. This has made it mandatory that very close attention be given to the choice of materials and to fabrication techniques.

As one of the important and critical elements in the optical configuration, the beamsplitter mount received considerable attention. Because of the dissimilar materials interface requirement and the consequent thermal expansion problem, we have settled on a modification of the spring loaded mount which we previously designed and used to good advantage.

The instrument has been fabricated almost entirely from A-2 steel. This is a material with which we have had considerable experience and success.

PRELIMINARY RESEARCH AND INVESTIGATION

The primary requirement under this contract was to design an interferometer which would be capable of operation in a liquid nitrogen temperature environment and would be capable of producing a resolution of 0.1 cm^{-1} in the 4 to 15 micron spectral region. It was decided at the outset, that a 2 inch aperture instrument would be suitable to the anticipated mission. This instrument was to be furnished with a suitable laser fringe monitoring system and a white light monitoring system. We started our design considerations by studying all of the various interferometric configurations which appeared to be applicable to our requirements. Our studies brought us to a consideration of two systems. The first system that we considered was a straightforward interferometer on which we have had considerable working experience. IDEALAB had previously designed and built a one (1) inch aperture 2 cm optical path difference instrument for operation at approximately 10 degrees Kelvin and in a vibrational environment produced by a sounding rocket. This instrument was produced under the auspices of DNA and ARPA contracts and was intended for the measurement of Class II aura and Class III aura. The total system was integrated into a cryogenic package by Honeywell Radiation Labs and further incorporated into a payload configuration for rocket flight. To quote the "HIRIS EXPERIMENT", AFGL-OP-TM-02 Report; "The interferometer appears to have worked extremely well during all phases of the flight; therefore, excellent first-of-its-kind data were obtained not only during the vertical viewing time but at all other aspects as well. Emission spectra of the atmospheric species CO_2 at 2325 cm^{-1} (4.3 u m) and 667 cm^{-1} (15 u m), O_3 at 1042 cm^{-1} (9.6 u m) and NO at 1786 cm^{-1} (5.6 u m) were obtained with resolution of two wave members." From this previous experience we hoped to gain sufficient information to point the direction in which we should proceed in attempting to build the instrument required under this contract. It should be pointed out that the contract required a two (2) inch aperture instrument and a resolution of better than 0.1 cm^{-1}. After having reviewed all of the information we had obtained from our previous experience we decided that it would be appropriate to investigate the possibility of using a cat's eye configuration for this mission. The necessity for a substantial increase in path length and aperture requirements were major factors in promoting this judgement. We therefore embarked upon an in-depth study of the optical properties of this system. The endeavor resulted in a FORTRAN IV programmed ray trace of the optical configuration. This program made no simplifying assumptions and was accomplished in double precision. We initially wrote the program in BASIC, but the results were unacceptable. The degree of precision we could get produced graphical errors in the plotted outputs that were intolerable. The FORTRAN program solved this problem.

What we were desirious of determining was what the effects of movement of the small mirror in the system vis-a-vis the large mirror would have on the wave front distortion. The program was therefore set up in such a fashion as to make it possible to move the small mirror in respect to the large mirror in any direction and determine what the effect of this would be on the wave front. In most cases (all cases so far as know) studies of this kind have attacked the problem of determining the best location of the small mirror in respect to the large mirror when it is assumed to be precisely on the optical axis of the system. As it turns out, the best place to place this mirror, as demonstrated by Consienier and others, is at the circle of least confusion of the large mirror. This is not altogether surprising. However, these studies do not demonstrate what the effect would be on the system wave front if the small mirror were to be moved longitudinally away from the optical axis. In the normal course of events, it is certainly fair to make the on-axis assumption, there being no reason to believe that, once adjusted for the position, the adjustment would not be maintained. In our case such an assumption would be inappropriate, since we are involved in a system which has to undergo substantial temperature change. This temperature change, in turn, can produce undesirable thermal distortions with the possibility of effecting the geometry of the optical components vis-a-vis each other. Since it is essentially impossible to anticipate, to the degree necessary, how these effects will manifest themselves, it is only prudent to consider all reasonable possibilities. We needed this information not only for its own sake, but in order to make a valid comparison of it with the conventional Michelson interferometer. We should note that the conventional Michelson system is comprised of a beamsplitter, a fixed mirror, and a movable mirror. It is very well known that a basic problem of such a system is that of moving the movable mirror in a very precise and accurate way, without tilt, as we say. On the other hand, the benefit to be derived from the cat's-eye system is that somewhat less precision is required of the moving mirror cat's-eye portion, in order to be able to maintain as high a contrast function as is the case with the simple Michelson moving its movable mirror with substantially no tilt. However, this is only true if the elements of the cat's-eye configuration are maintained in a certain geometry in respect to each other. One system has the defect of being relatively more complex in terms of its optics (the cat's-eye system) and consequently capable of going out of adjustment, and the important and beneficial characteristic of being relatively tilt immune. The other, the Michelson, has a very simple optical configuration, a plus; but it is very critical in regard to tilt, a minus.

We wished to determine through our ray trace analysis the sensitivity of alignment of the cat's-eye optical components. In addition to this, we also wished to determine a set of practical parameters in terms of the focal lengths of the large and small mirrors in the cat's-eye system. This information was necessary in order to be able to have some idea as to how large, or better still how small, maintaining a 2 inch aperture, we could afford to make the system and accomplish a minimum of distortion of wave front as it passes through the system. The results of these investigations showed that we could build a configuration of sufficiently small dimensions as to be acceptable. Further, it also demonstrated that by choosing the focal lengths of the two optical components wisely, we appeared to be able to arrive at a design which was not unduly sensitive to the exact placement of each mirror in respect to the other.

The analysis of the cat's-eye optical system compares a set of twenty or more equally spaced rays on a diameter of the system aperture to the optical path length of the central ray, and determines the optical path difference. This optical path difference is then plotted as a function of distance from the central ray. The result is a plot of wave front distortion as a function of distance from the optical axis. Just how this works is best understood by studying the enclosed graphs which show on each individual graph the wave front distortion as a function of position of the large and small mirrors when one graph is compared to the other. We were sufficiently impressed with the results of this study to feel that for a two-inch aperture interferometer having a total optical path difference in excess of 10 cm, we would be well advised to go with the cat's-eye system. To date, all of the data that's been taken and all of the observations that we have been able to make on the system would tend to confirm the validity of this decision.

During this period of time we also considered the possibility of adapting the system to utilize field widening techniques. It appeared at the outset to be a valid line of endeavor since the instrument would be required to view extended sources. We did not, however, get deeply into this matter, before it became abundantly clear to us that because of material considerations and the general state of the art, plus prohibitive cost factors, that we would have to abandon this area of study.

BASE DESIGN CONFIGURATION

The base mounting plate of the interferometer is an extremely important element in the total interferometric configuration. It has to be so designed as to support the various optical and mechanical elements of the interferometer in their correct position in respect to one another and at the same time it has to be able to maintain this geometry through the required temperature excursion. In particular, this base plate must support the fixed cat's-eye mounting configuration, the beamsplitter mounting configuration, the movable cat's-eye configuration and the linear motor configuration. All of these elements must be mounted to the base plate and the method of mounting must be such as to induce essentially no stress or strain into any of the support members. In order to accomplish these requirements, the base casting was first of all designed in a box-like configuration having ribs placed under all of the optical support members, a modified egg crate or honey comb type construction. This construction would, it was hoped, provide rigidity in the mounting plate and at the same time reduce its weight and thermal capacity and preserve the integrity of the geometry of the total interferometric system. After this fundamental design philosophy had been structured, preliminary mechanical drawings were worked up. These drawings were sent to a number of different foundries for pricing and comments. Finding someone who could cast the base plate proved to be no small task. Finally, we were able to locate one concern who represented that they could pour the casting if we were willing to make certain modifications to our design drawing. The gist of their requested changes meant increasing all dimensions in order to insure, after the required machining, a sound casting. We were very agreeable. The casting as we received it from the foundry appeared to be very sound and so machining on it was started. The size of the casting as received was such as to require at least 25% of all the material from all of the exposed surfaces be removed. This was to insure that we would be able to eliminate all casting blow holes, imperfections that might be in the casting. This turned out to be a long and tedious process. However, it was a satisfying one in that when the casting was completely rough machined, we found it to be, in every respect, sound. We sent the casting out to have it magna fluxed in order to inspect for any structural defects and found that the casting was in excellent condition. After this inspection process was completed, additional machining was done on it to bring it to near print size and it was again sent out to be reannealed and magna fluxed a second time. Both of these processes produced successful results. The final standard machining was done to bring the piece to exact print size. We then subjected the casting to a liquid nitrogen bath. This is a rather horrendous procedure. The thermal shock to the piece is maximized and the net result is a reasonable confidence that there will, at least, be no catastrophic failure as a result of lowering the temperature to liquid nitrogen in the normal way. When the piece had ceased to cause the liquid nitrogen to boil for a half hour period, it was brought back to room temperature using infrared lamps. We then checked for any distortion. This was done by placing the piece on a granite slab and checking for dimensional changes and warpage by comparison to similar data taken before the immersion into the liquid nitrogen bath. No distortions were evidenced by this procedure, and we proceeded to have the mounting pads for the optical components hand scraped to bring them to a flatness and parallelism, all surfaces to all other surfaces, of at least 50×10^{-6} inches per 6 inches. The casting was again subjected to the liquid nitrogen dip process, and tested again for any distortions. It passed this test and was then ready for mounting of the optical components.

CAT'S EYE TUBES

The design of the cat's eye tube configuration was predicated on the information achieved by the geometric ray trace to which we have already made mention. The study of the ray trace determined the focal lengths of the small and large mirrors. A suitable mechanical mounting arrangement had to be developed in order to be able to place these two mirrors on precisely the same optical axis and separate them by the required distance. At the outset it was decided to use what essentially amounts to a telescope type mounting arrangement. The main mounting fixture, the tube, required for this type of arrangement had of necessity to be made from A-2 steel. This meant starting from a solid piece of material sawed from billet stock and then turned and bored and reamed to the exact size required. Special support jigs and fixtures were needed to bore lightening holes in the moving cat's-eye tube, while at the same time causing no deformation to its geometry. The reason for doing this was to lower the weight for better dynamic performance. It was only done to the moving tube.

The end cap was designed to spring load the main (large) mirror up against a shoulder accurately machined to a given depth in the tube. This was required in order to know precisely where the front surface of the mirror, when mounted, would be in respect to the back surface of the mirror mount fixture.

ELECTRICAL FIXTURES

The cat's-eye supporting fixture, used in conjunction with the slide-way carriage system, is fitted to support the movable slugs in the positional transducer and the moving magnet employed in the tachometer. A mounting plate fixture carrying the positional transducer and the tachometer coil is located directly below the slide-way carriage system. This mounting plate is arranged so that it can be moved a small distance back and forth in the direction of the slide motion in order to be able to achieve precise centering of the positional transducer's electrical center with the mechanical center of the movable slide carriage. Provisions have also been made on this structure to mount a subsidiary fiducial determining device to accomplish the necessary logic for coherent addition of interferograms.

SERVO CONTROL

The servo system used to control the slide motion, is a modified type 2 system, having positional and rate feedback. The operation of the electronics is as follows:

A logic system develops a step function E=u(t) upon command. This command may originate from a computer, a simple toggle switch or it may be internally generated by a comparitor system which recognizes the slide motion and points as a function of the output of the linear positional transducer.

The step function E=u(t) is integrated by a precision analog integration system. The output of this integrator is a ramp function, the rate of rise of which is a function of the time constant of the integrator and the value of E. The value of E is continuously adjustable by means of a ten turn pot. This pot is known as the velocity pot. If further adjustability is required, it can be accomplished by changing the RC time constant of the precision integrator. The ramp voltage, thus generated, is the command signal to which the servo must respond.

At start up, the system logic forces the slide to the HOLD position as determined by the output voltage of the positional transducer and a comparitor circuit. At this point the positional transducer is disconnected from the feedback circuit by the action of sweep status signal and is replaced by what amounts to an F.M. to D.C. converter whose output is integrated. The input signal to this part of the system is the output from the laser monitoring system. The result is a ramp output from the integrator, which is an accurate measure of the position of the moving mirror cat's eye slide system. If this signal does not match exactly the sample command signal previously described, the error signal, which is the difference between these two signals, forces the power amplifier either to increase or decrease its output or change its polarity to correct for the error condition. The result of this is that the drive motor is constantly adjusting its force output in an attempt to correct for any changes in frictional profile or input load functions such as vibrations, acoustical forces, etc.

This position feedback system just described works quite well for the low frequency response of the system. However, it is inadequate to handle the higher frequencies to which the system may be exposed. Consequently we have added rate feedback in two forms. The first method utilizes a conventional magnetic rate generator. This system generates a voltage in accordance with the equation:

$$E = N \frac{d\varphi}{dt} = K \frac{dx}{dt}$$

where $N d\varphi = K dx$

In other words, the time rate of change of the flux is equal, to within a proportionality constant, to the velocity of the moving mirror slide. This system exhibits some deviation from the above, because of flux leakage. This, and the inherent time constant of the LR relationship of the tachometer coil make it desirable to introduce another feedback mechanism which will compensate for these drawbacks.

Such a system is a phase-lock loop. This system uses the output from the laser monitoring system and acts in the conventional fashion to stabilize this frequency by generating a signal proportional to the laser frequency. This signal is fed back in the same fashion as the tachometer signal. One might wonder why the necessity for the tachometer signal using the magnet circuit? The principal reason is that the phase-lock loop system is sensitive to frequency only, and not to direction of motion, whereas the tachometer is.

Thus:

A) They complement each other nicely, and

B) the dynamic range (capture range) of the phase-lock loop is relatively small, whereas the capture range of the magnetic tachometer is, if the term is appropriate, essentially infinite.

Under fly-back conditions the sweep status signal disconnects the F.M. to D.C. system and reconnects the position transducer system, which then commands the slide to move to the hold position, which is determined by the setting of the resolution pot. The resolution pot determines at what point the voltage from the positional transducer will fire a comparitor system whose output forces the system into the HOLD position where it stays awaiting another START command. This completes a data taking cycle. The unit can also be placed in a continuous mode where the same signal from the comparitors, which produces a HOLD command, generates a START command, keeping the unit in a state of continuously scanning. Finally, a manual override to the command signal generated in the form of a potentiometer adjustable output voltage can be used to manually position the slide mechanism. This is a useful feature when making tests for optical alignment of the instrument.

RAPID-STEPPING SCHEME STUDY

Introduction

One of the advantages that the technique of Fourier spectroscopy can realize, is obtained by multiplexing the observation of all spectral elements in a single interferogram measurement. This multiplex advantage comes into a full effect only when the scintillation noise in the measurement is well suppressed. Three schemes are commonly used at present for suppression of the scintillation noise. They are the scheme of (1) ratio-recording, (2) internal modulation, and (3) rapid scanning. The first scheme works on the principle of amplitude cancellation, while the second and third work on that of frequency discrimination. It has been proven that these three schemes work reasonably well for this purpose. No conclusion has been reached at present to answering the question of which of the frequency discrimination schemes, the internal modulation or the rapid scanning, has overall better characteristics. The primary concern of the present study does not fall into examination of this question. The study conducted for this report is to examine the scheme of rapid-stepping, by which either the scheme of the internal modulation or of the rapid scanning can be implemented without making any fundamental design change.

Basic Design Problem of the Rapid-Stepping Scheme

Generally speaking, the servo-control scheme which accommodates the step-and-hold drive of the cat's eye interferometer, can be divided into two parts. The servo-controlled motion of the entire cat's eye assembly can be made to have a slow response, while a control with a fast response can be built to achieve a fine positional adjustment of the secondary mirror which is very small and light. By combining these two motor systems, the overall drive can attain the servo control characteristics necessary for the rapid-stepping. The mechanical structure of the cat's eye interferometer would exhibit no basic weakness toward implementing the rapid-stepping movement.

Phase-Modulated Signal

The control system for the step-and-hold drive would be found convenient to use if it has the following specifications:

(1) The position accuracy during the holding period is a value much smaller than the reference laser wavelength.

(2) The stepping distance may take any value, not limited to some exact multiples of the reference laser wavelength.

(3) Both the stepping and holding period are controlled under the same servo logic. That is to

say, the interferometer appears to step by holding action when the positioning servo error is large. The error becomes small, as the interferometer approaches the null position. No distinctive difference exists in the servo action between the stepping and the holding period.

The present study is to search the logic scheme which accommodates the servo action specified above. The error signal in such a scheme generates a certain quantity which varies linearly with the error distance all the way even beyond a single fringe distance of the reference line. The minimum resolution element contained in the error signal must be much finer than a single fringe distance.

Several schemes have been built already for accomplishing such a servo-controlled action. These servo logics are essentially constructed on the phase modulated sinusoidal signal with a certain high carrier frequency (or single sideband modulated signal). This signal can be expressed by

$$s = A \cos 2\pi(ft - \varphi)$$

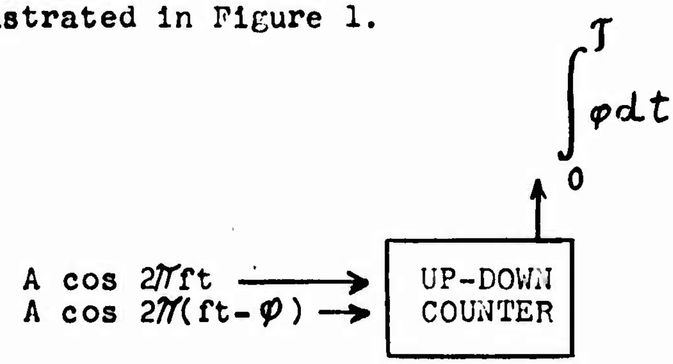
where f is the carrier frequency, and φ is the phase, varying linearly with the servo error (including the $\pm$ sign). Incidentally, the ordinary interference fringe signal belongs to a special form of this signal given by

$$f = 0$$

and

$$\varphi = \sigma x \qquad .$$

The simplest electronic circuit which is commercially readily available for extracting the phase information φ from the phase modulated signal, $A \cos 2\pi(ft-\varphi)$, is the up-down counter. Its usage is illustrated in Figure 1.



Reset at t=0

Figure 1

PMSS Systems Already in Use

1. Two-line method.

This method uses two laser lines of slightly different frequencies which are excited from a single plasma tube. Their frequency difference is fixed. When a detector observes these two lines, it generates the difference frequency f at its output. The system is designed in such a way that two lines strike different arms of the interferometer, one spectral line to a fixed arm and another to a movable arm. Now the line striking the movable arm has its optical frequency shifted by v/c, in addition to the constant difference f, if the optical path is changed at a rate of v. Therefore the detector which sees these two lines returned from the interferometer, registers instantaneously a new value for the difference frequency given by f(+ v/c). In other words, the PMSS is generated, given by

$$s = A \cos 2\pi (ft + v/c) \quad .$$

When the movable arm is moving at a speed of λ/sec., the frequency shift is exactly 1 Hz. Thus the resolution unit is 1λ. The Up-Down counter shown in Figure 1 does not register a change of 1 count at its output unless the movable arm moves more than the distance of 1λ.

The method, therefore, can detect the movement not only in distance but also in direction. For our application, it is important that both laser lines are well stabilized. The stabilization of the difference frequency only is not sufficient. This system inherently fails to monitor the path difference change much smaller than 1λ. The method is in principle insensitive to the intensity fluctuation contained in these two laser lines.

2. Polarimetric Method

This method uses a single laser line. The optical circuit is built in such a way that the plane of polarization at the output of the interferometer rotates linearly with the optical path difference. This output which is linearly polarized, is rotated by a spinning halfwave plate (at the spinning frequency of f) to generate the PMSS.

3. Interferometer Modulation Method

This method also uses a single laser line. The interferometer path difference is modulated at a frequency f. Two signals which are in quadrature relation to each other, are generated

$$s_1 = A \cos 2\pi ft \cos\varphi \quad ,$$

and

$$s_2 = A \sin 2\pi ft \sin\varphi \quad .$$

They are then combined to form the PMSS.

The Method Studied

The method adopted for the present study is to use the intensity information obtainable in the interference fringe signal. The phase angle φ within a complete fringe cycle is determined from two signals which are in quadrature. The interferometer path difference is modulated by a high frequency. The intensity fringe signal is synchronously detected for generation of the two quadrature signals. Several circuits for normalizing their amplitude and for removal of their bias offset are necessary for generating the signals given by

$$s_1 = A \cos \varphi$$

and

$$s_2 = A \sin \varphi \; .$$

Change of the phase φ can be detected as shown in Table I. Therefore the interferometer drive direction is known all the time.

TABLE I

Determination of Interferometer Drive Deflection

s_1	s_2	Δs_1	v
+	+	+	+
+	+	-	-
+	-	-	+
+	-	+	-
-	-	-	+
-	-	+	-
-	+	+	+
-	+	-	-

Signals s_1 and s_2

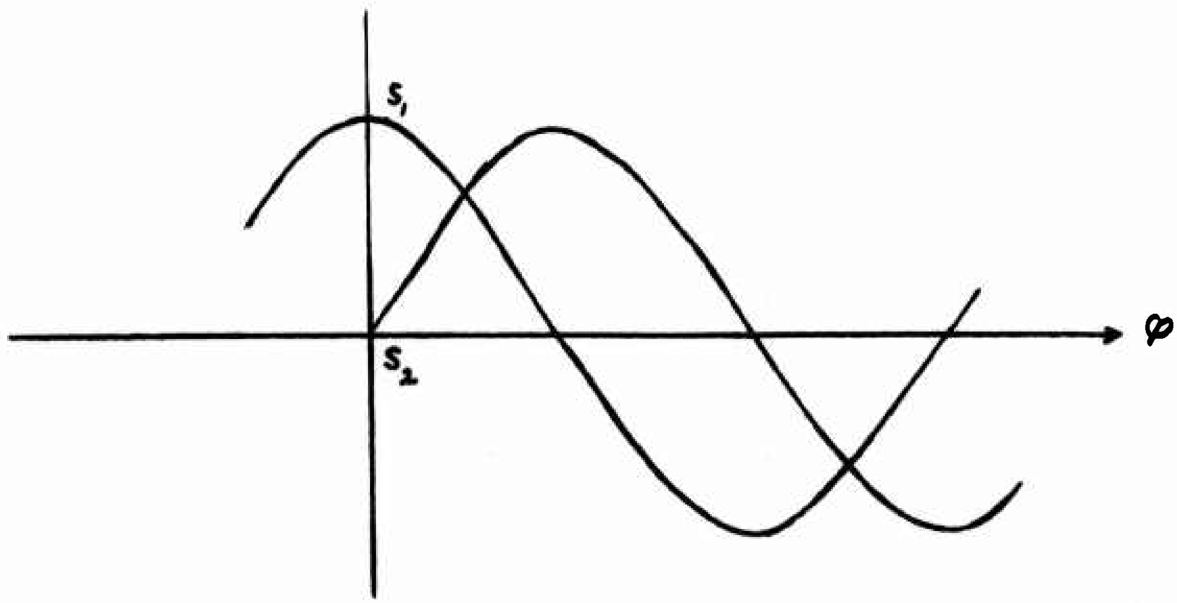


FIGURE 2

After these two quadrature signals are generated, the phase angle φ can be detected using voltage detectors. The PMSS is generated using the digital logic. The system is structured as shown in the block diagram of Figure 3.

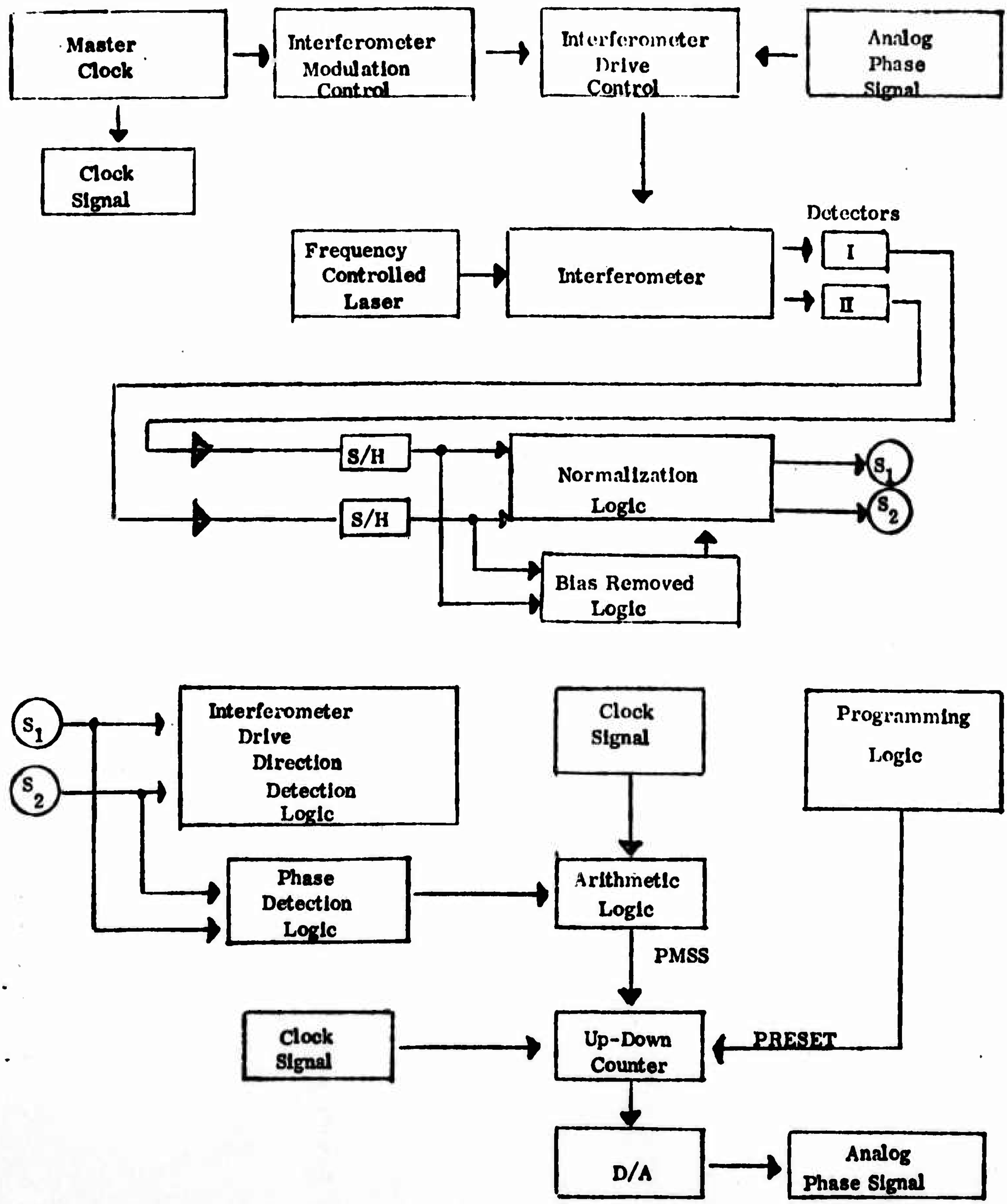
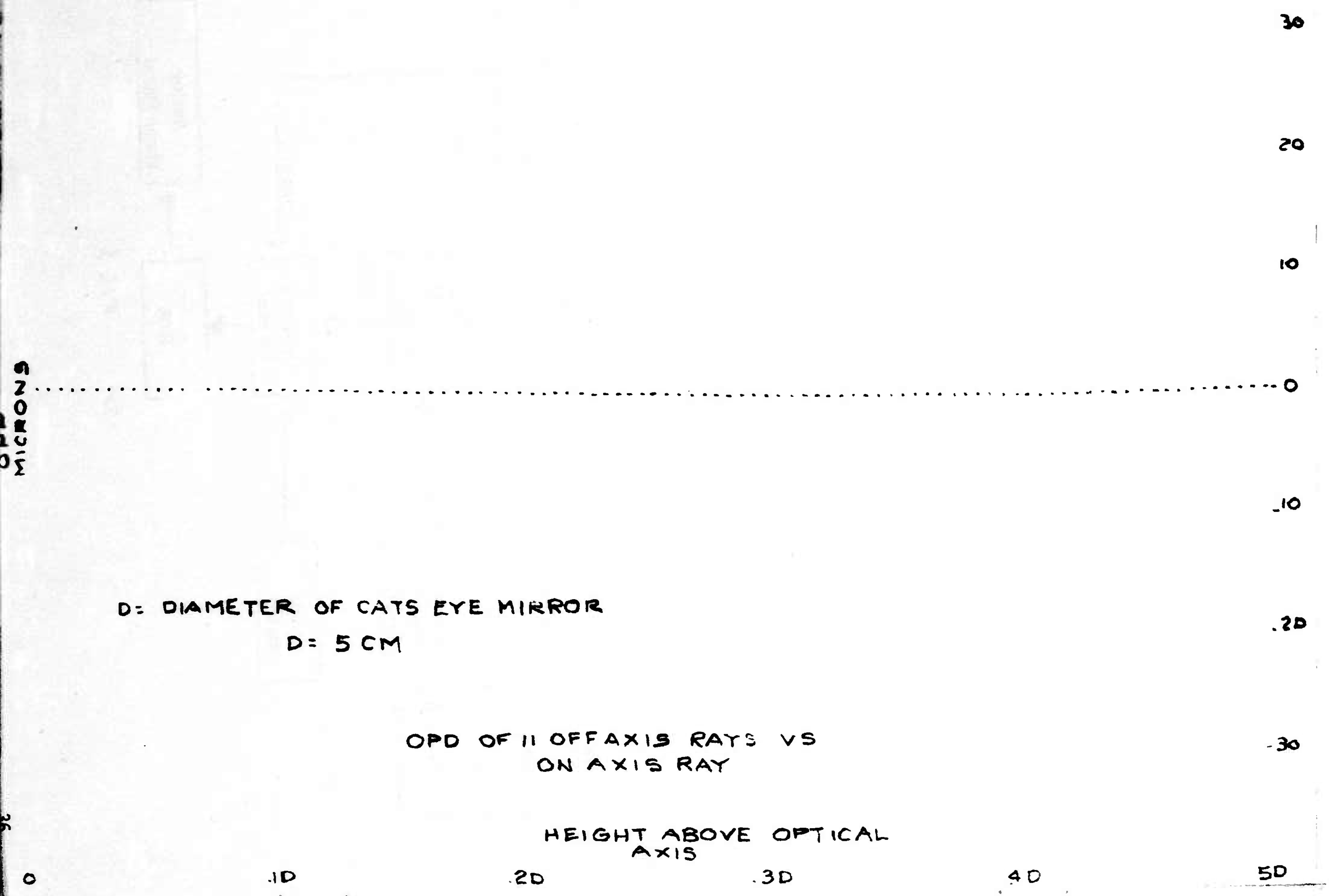

Master Clock
Interferometer Modulation Control
Interferometer Drive Control
Analog Phase Signal
Clock Signal
Detectors
Frequency Controlled Laser
Interferometer
I
II
S/H
S/H
Normalization Logic
S_1
S_2
Bias Removed Logic
S_1
S_2
Interferometer Drive Direction Detection Logic
Clock Signal
Programming Logic
Phase Detection Logic
Arithmetic Logic
PMSS
Clock Signal
Up-Down Counter
PRESET
D/A
Analog Phase Signal

FIG 3

GRAPH #1



OPD MICRONS
30
20
10
0
-10
-20
-30
D= DIAMETER OF CATS EYE MIRROR
D= 5 CM
OPD OF 11 OFFAXIS RAYS VS
ON AXIS RAY
HEIGHT ABOVE OPTICAL
AXIS
0
.1D
.2D
.3D
.4D
.5D

GRAPH #1

SYSTEM SCALE FACTOR = 1

POSITION OF REF. LINE = 0

RADIUS OF CURVATURE OF CONCAVE MIRROR = 40

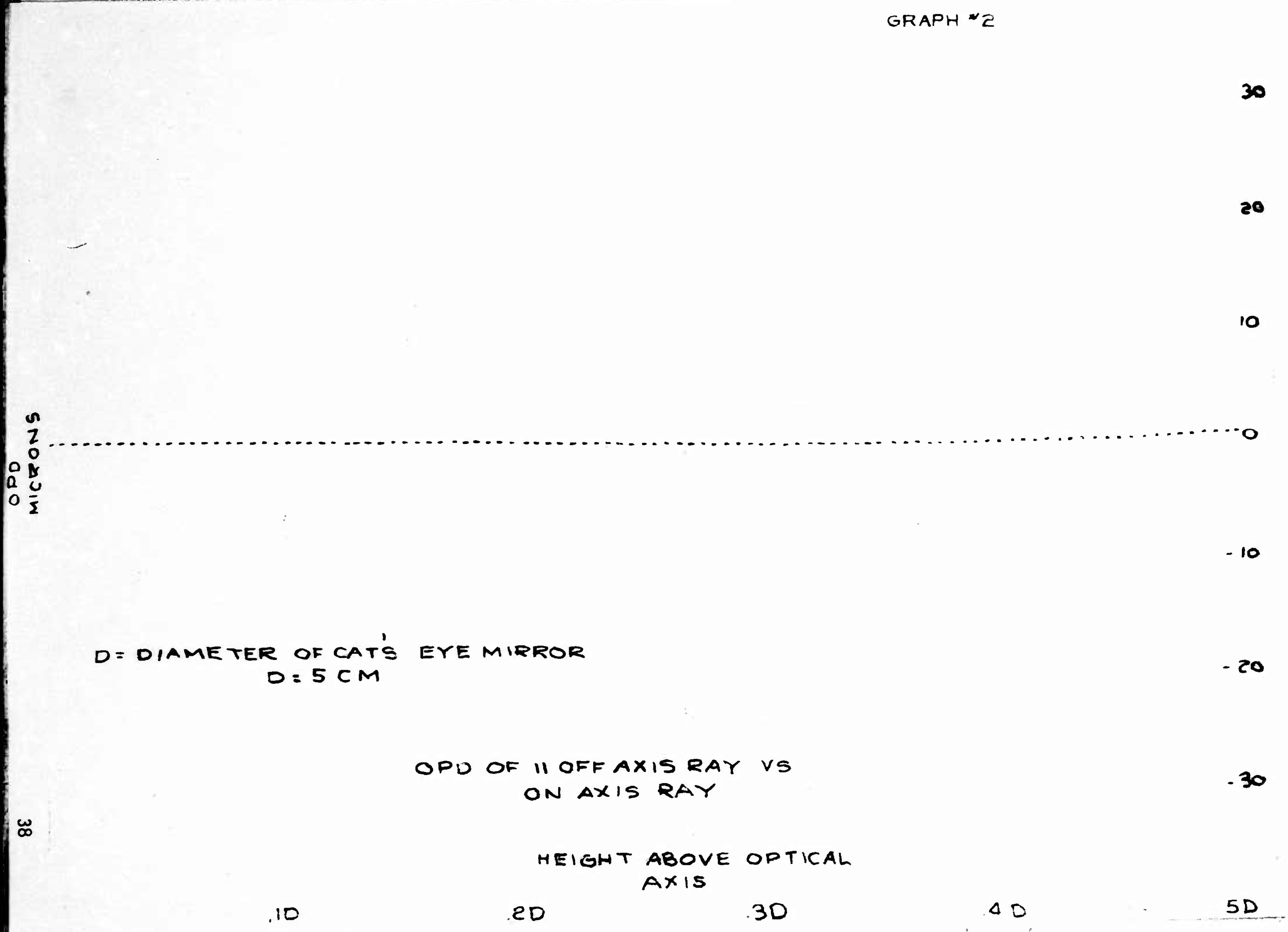
RADIUS OF CURVATURE OF CONVEX MIRROR = 20.02

X DISPLACEMENT OF CONVEX MIRROR = 0

Y DISPLACEMENT OF CONVEX MIRROR = 0

DIAMETER OF CONCAVE MIRROR = 5.00

NUMBER OF POINTS DESIRED = 100


GRAPH #2
30
20
10
0
- 10
- 20
- 30
OPD MICRONS
D = DIAMETER OF CAT'S EYE MIRROR
D = 5 CM
OPD OF 11 OFF AXIS RAY VS
ON AXIS RAY
HEIGHT ABOVE OPTICAL
AXIS
.1D
.2D
.3D
.4D
.5D

GRAPH #2

SYSTEM SCALE FACTOR = 1

POSITION OF REF. LINE = 0

RADIUS OF CURVATURE OF CONCAVE MIRROR = 40

RADIUS OF CURVATURE OF CONVEX MIRROR = 20.02

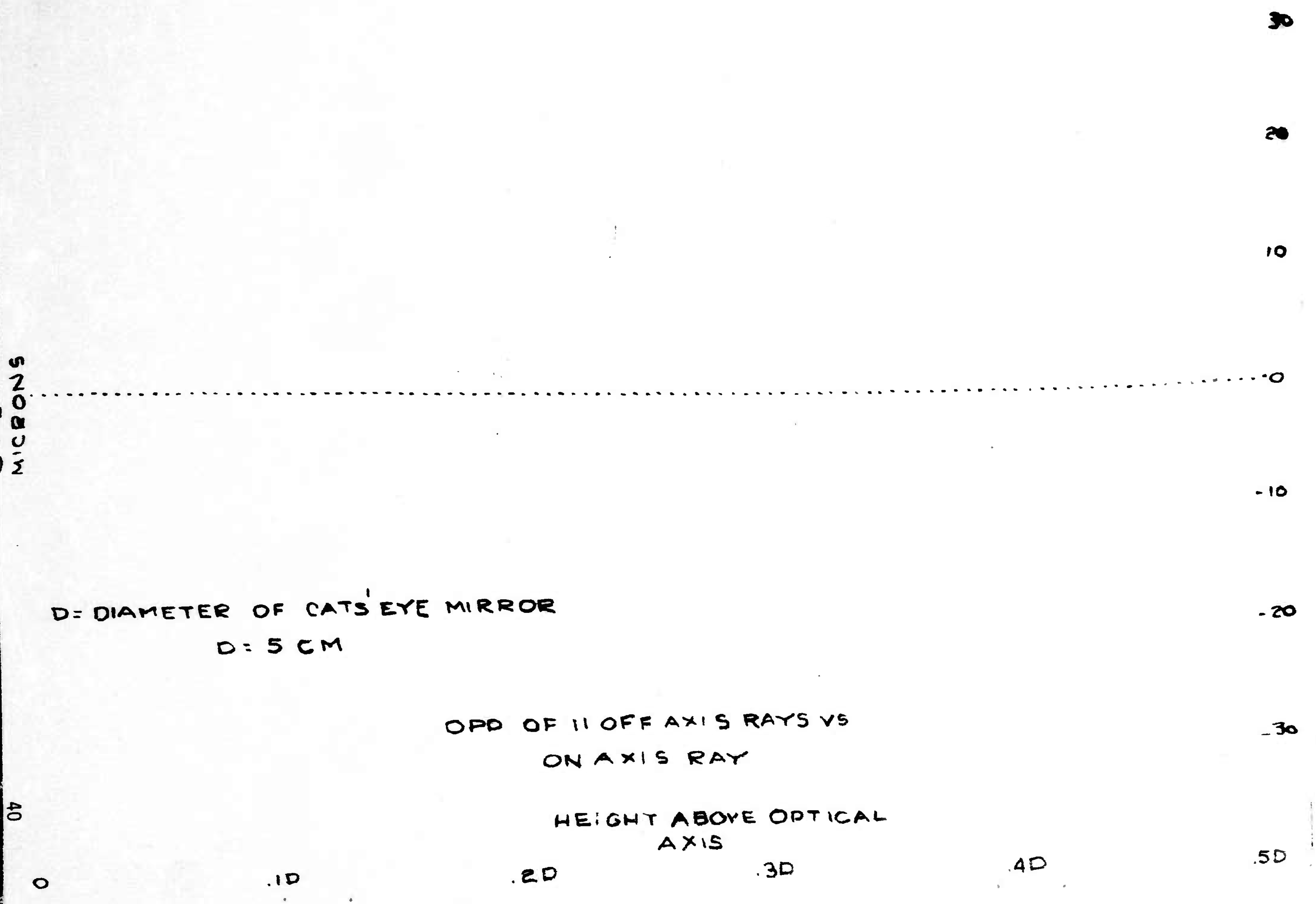
X DISPLACEMENT OF CONVEX MIRROR = 0

Y DISPLACEMENT OF CONVEX MIRROR = .0002

DIAMETER OF CONCAVE MIRROR = 5.0

NUMBER OF POINTS DESIRED = 100

GRAPH #3


30
20
10
0
-10
-20
-30
MICRONS
D= DIAMETER OF CATS' EYE MIRROR
D = 5 CM
OPD OF 11 OFF AXIS RAYS VS
ON AXIS RAY
HEIGHT ABOVE OPTICAL
AXIS
0
.1D
.2D
.3D
.4D
.5D

GRAPH #3

SYSTEM SCALE FACTOR = 1

POSITION OF REF. LINE = 0

RADIUS OF CURVATURE OF CONCAVE MIRROR = 40

RADIUS OF CURVATURE OF CONVEX MIRROR = 20.02

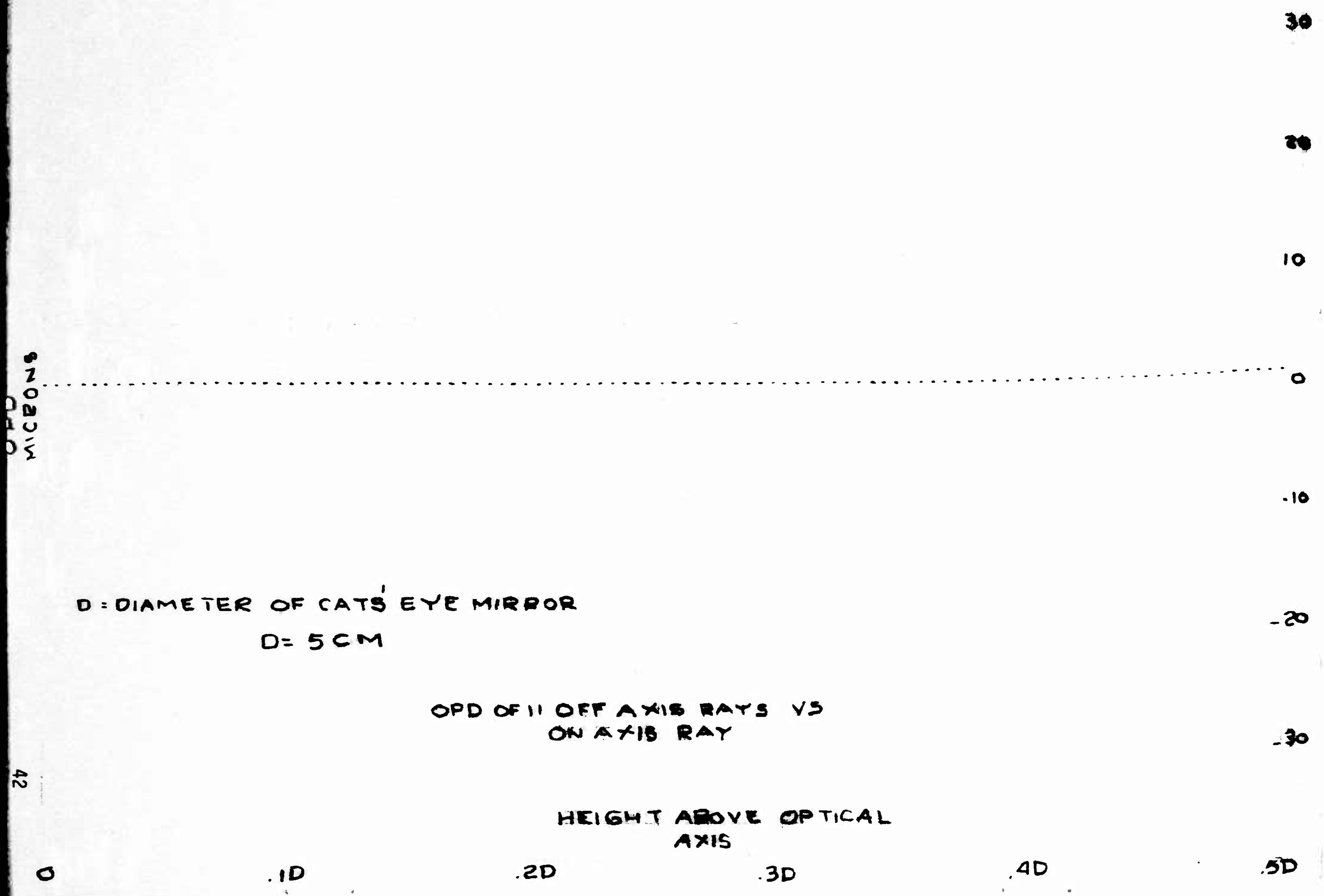
X DISPLACEMENT OF CONVEX MIRROR = 0

Y DISPLACEMENT OF CONVEX MIRROR = -.0002

DIAMETER OF CONCAVE MIRROR = 5.0

NUMBER OF POINTS DESIRED = 100

GRAPH #4



30
20
10
0
-10
-20
-30
OPD MICRONS
D = DIAMETER OF CATS' EYE MIRROR
D = 5 CM
OPD OF 11 OFF AXIS RAYS VS ON AXIS RAY
HEIGHT ABOVE OPTICAL AXIS
0
.1D
.2D
.3D
.4D
.5D

GRAPH #4

SYSTEM SCALE FACTOR = 1

POSITION OF REF. LINE = 0

RADIUS OF CURVATURE OF CONCAVE MIRROR = 40

RADIUS OF CURVATURE OF CONVEX MIRROR = 20.02

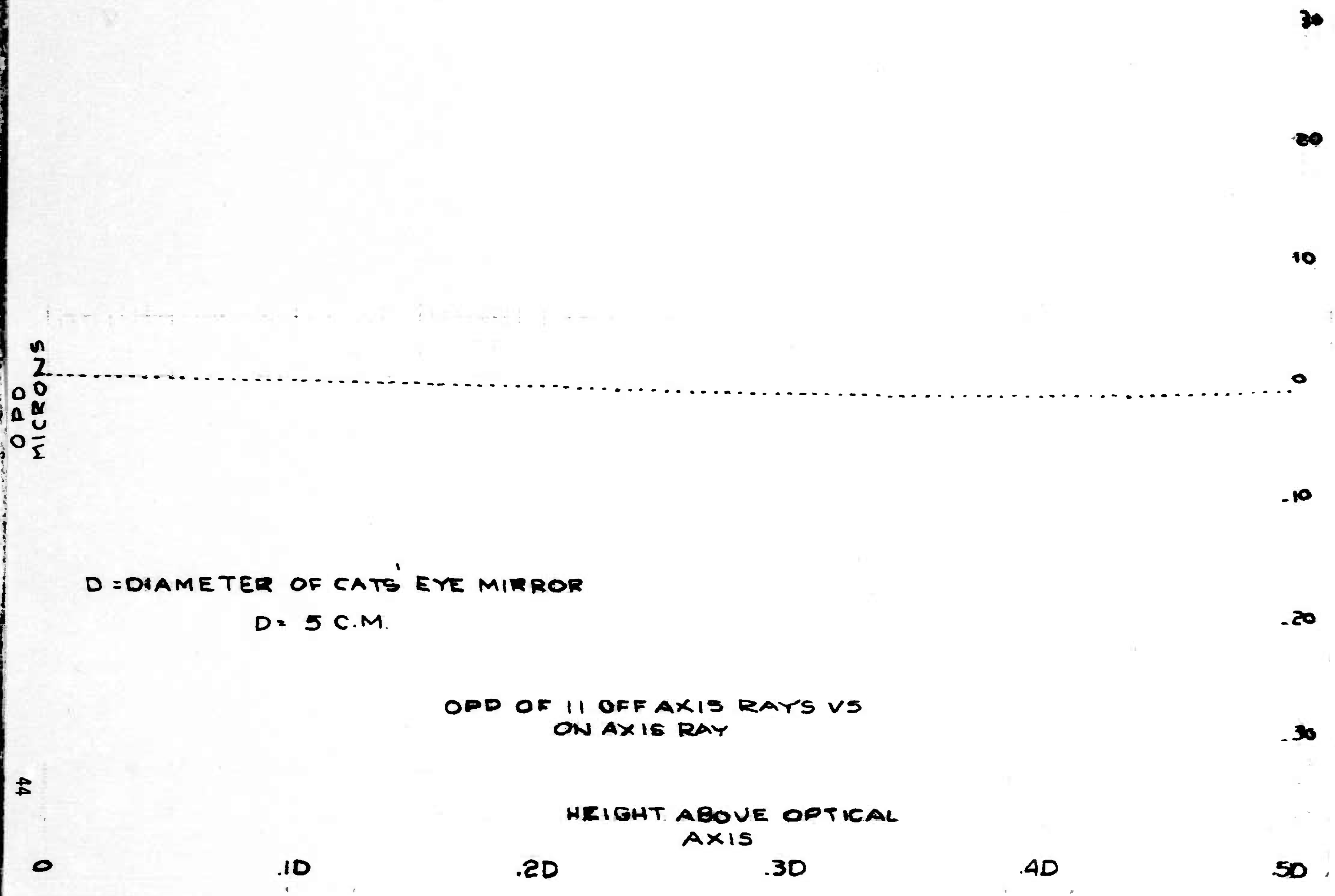
X DISPLACEMENT OF CONVEX MIRROR = 0

Y DISPLACEMENT OF CONVEX MIRROR = .0004

DIAMETER OF CONCAVE MIRROR = 5.0

NUMBER OF POINTS DESIRED = 100

GRAPH #5



OPD MICRONS
30
20
10
0
-10
-20
-30
D = DIAMETER OF CATS' EYE MIRROR
D = 5 C.M.
OPD OF 11 OFF AXIS RAYS VS ON AXIS RAY
HEIGHT ABOVE OPTICAL AXIS
0
.1D
.2D
.3D
.4D
.5D

GRAPH #5

SYSTEM SCALE FACTOR = 1

POSITION OF REF. LINE = 0

RADIUS OF CURVATURE OF CONCAVE MIRROR = 40

RADIUS OF CURVATURE OF CONVEX MIRROR = 20.02

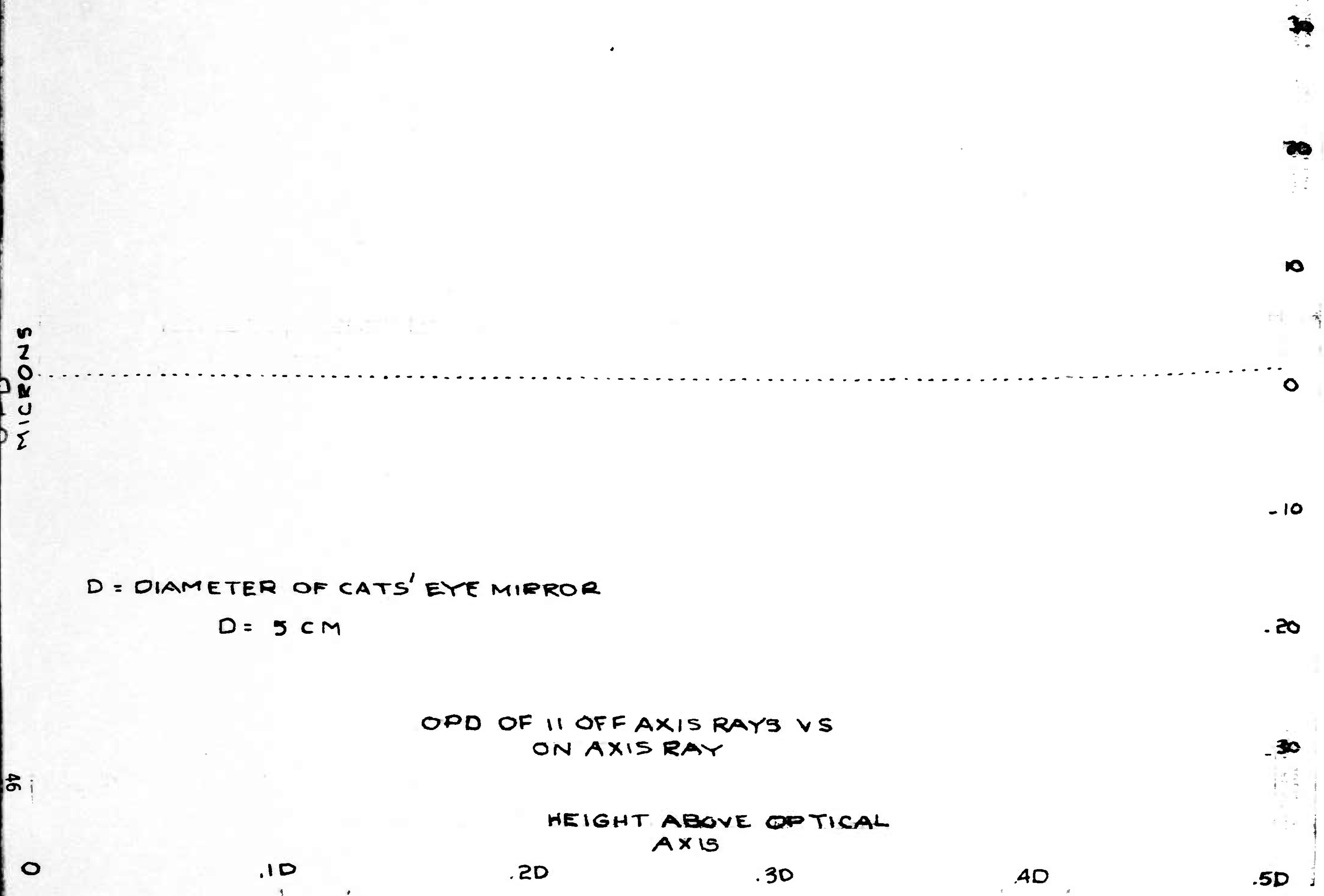
X DISPLACEMENT OF CONVEX MIRROR = 0

Y DISPLACEMENT OF CONVEX MIRROR = -.0004

DIAMETER OF CONCAVE MIRROR = 5.0

NUMBER OF POINTS DESIRED = 100

GRAPH #6


30
20
10
0
-10
.20
.30
OPD MICRONS
D = DIAMETER OF CATS' EYE MIRROR
D = 5 CM
OPD OF 11 OFF AXIS RAYS VS
ON AXIS RAY
HEIGHT ABOVE OPTICAL
AXIS
0
.1D
.2D
.3D
.4D
.5D

GRAPH #6

SYSTEM SCALE FACTOR = 1

POSITION OF REF. LINE = 0

RADIUS OF CURVATURE OF CONCAVE MIRROR = 40

RADIUS OF CURVATURE OF CONVEX MIRROR = 20.02

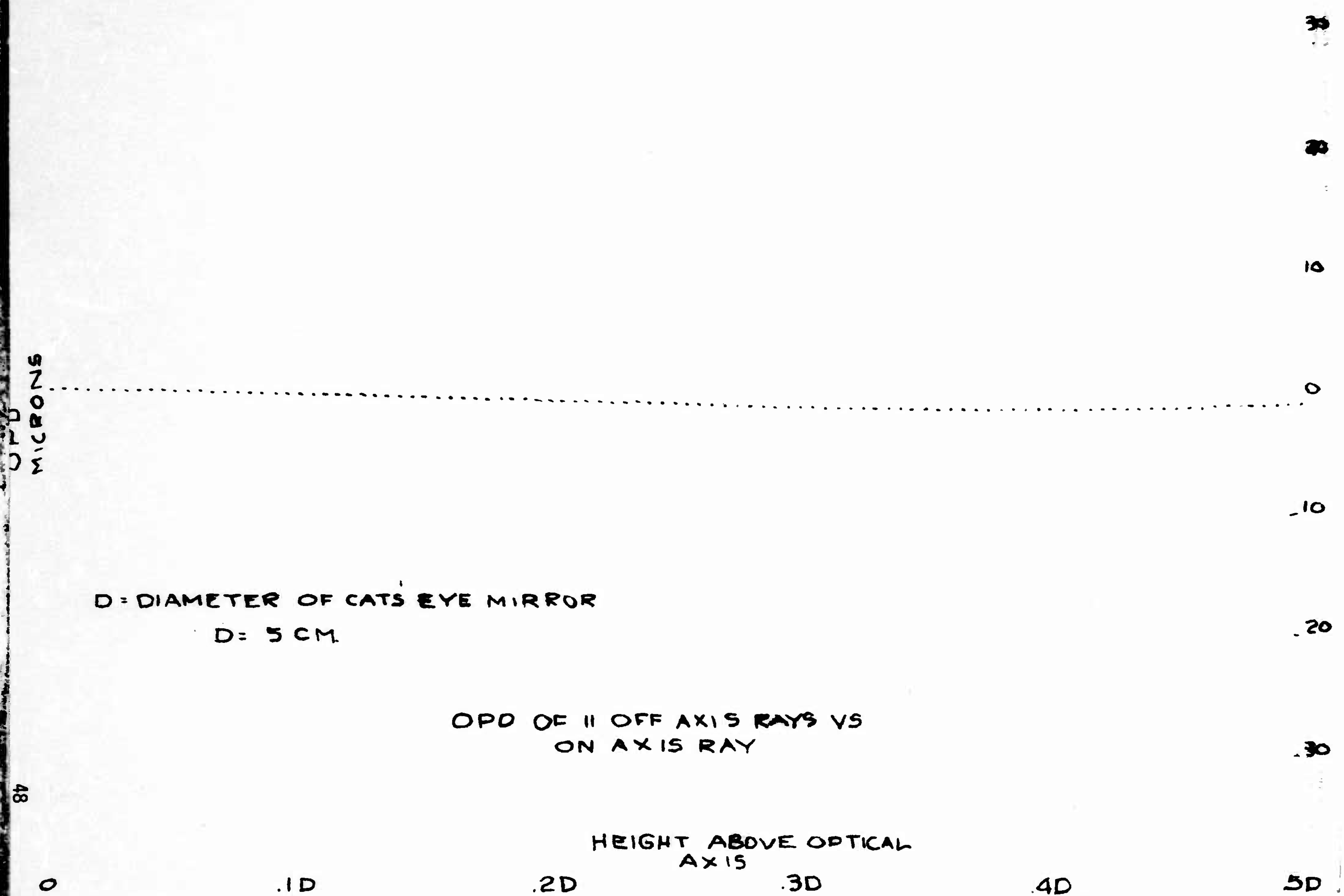
X DISPLACEMENT OF CONVEX MIRROR = 0

Y DISPLACEMENT OF CONVEX MIRROR = .0006

DIAMETER OF CONCAVE MIRROR = 5.0

NUMBER OF POINTS DESIRED = 100

GRAPH #7



OPD MICRONS
30
20
10
0
-10
-20
-30
D = DIAMETER OF CATS EYE MIRROR
D = 5 CM
OPD OF 11 OFF AXIS RAYS VS ON AXIS RAY
HEIGHT ABOVE OPTICAL AXIS
0
.1D
.2D
.3D
.4D
.5D

GRAPH #7

SYSTEM SCALE FACTOR = 1

POSITION OF REF. LINE = 0

RADIUS OF CURVATURE OF CONCAVE MIRROR = 40

RADIUS OF CURVATURE OF CONVEX MIRROR = 20.02

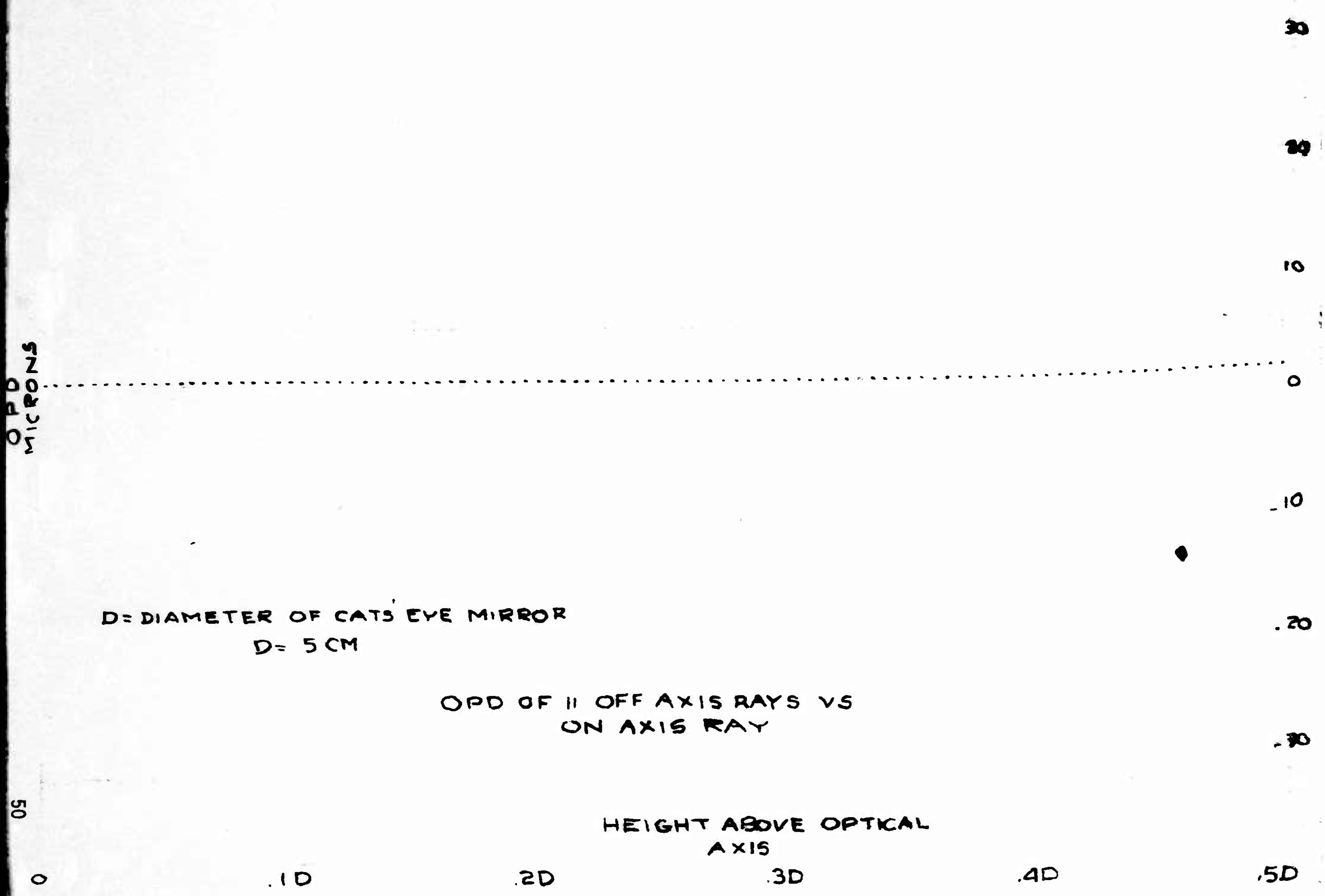
X DISPLACEMENT OF CONVEX MIRROR = 0

Y DISPLACEMENT OF CONVEX MIRROR = -.0006

DIAMETER OF CONCAVE MIRROR = 5.0

NUMBER OF POINTS DESIRED = 100

GRAPH # 8


OPD MICRONS
30
20
10
0
-.10
-.20
-.30
D= DIAMETER OF CATS EYE MIRROR
D= 5 CM
OPD OF 11 OFF AXIS RAYS VS
ON AXIS RAY
HEIGHT ABOVE OPTICAL
AXIS
0
.1D
.2D
.3D
.4D
.5D

GRAPH #8

SYSTEM SCALE FACTOR = 1

POSITION OF REF. LINE = 0

RADIUS OF CURVATURE OF CONCAVE MIRROR = 40

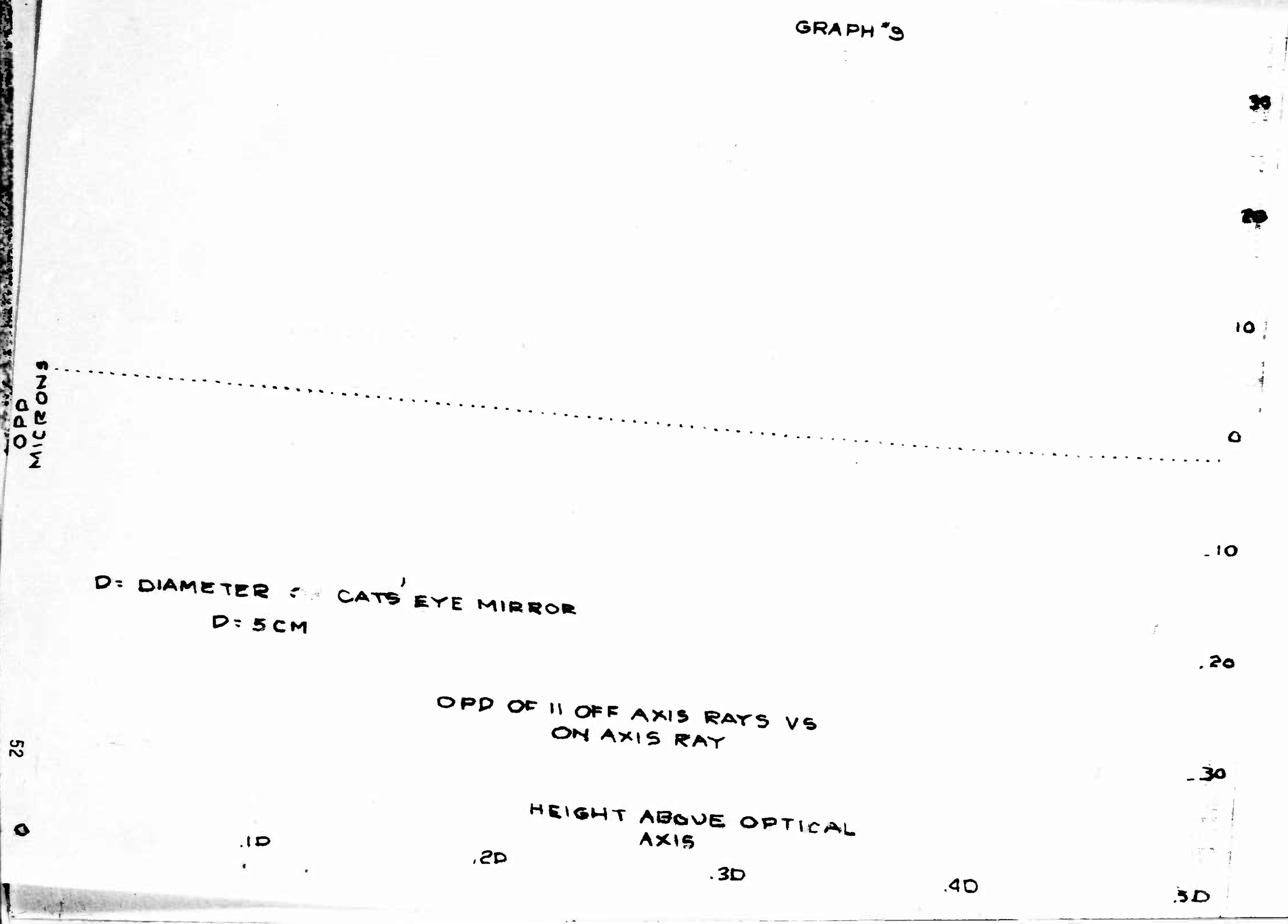
RADIUS OF CURVATURE OF CONVEX MIRROR = 20.02

X DISPLACEMENT OF CONVEX MIRROR = 0

Y DISPLACEMENT OF CONVEX MIRROR = .0008

DIAMETER OF CONCAVE MIRROR = 5.0

NUMBER OF POINTS DESIRED = 100


GRAPH #9
30
20
10
0
-.10
.20
-.30
OPD
MICRONS
D = DIAMETER OF CATS' EYE MIRROR
D = 5CM
OPD OF 11 OFF AXIS RAYS VS
ON AXIS RAY
HEIGHT ABOVE OPTICAL
AXIS
0
.1D
.2D
.3D
.4D
.5D

GRAPH #9

SYSTEM SCALE FACTOR = 1

POSITION OF REF. LINE = 0

RADIUS OF CURVATURE OF CONCAVE MIRROR = 40

RADIUS OF CURVATURE OF CONVEX MIRROR = 20.02

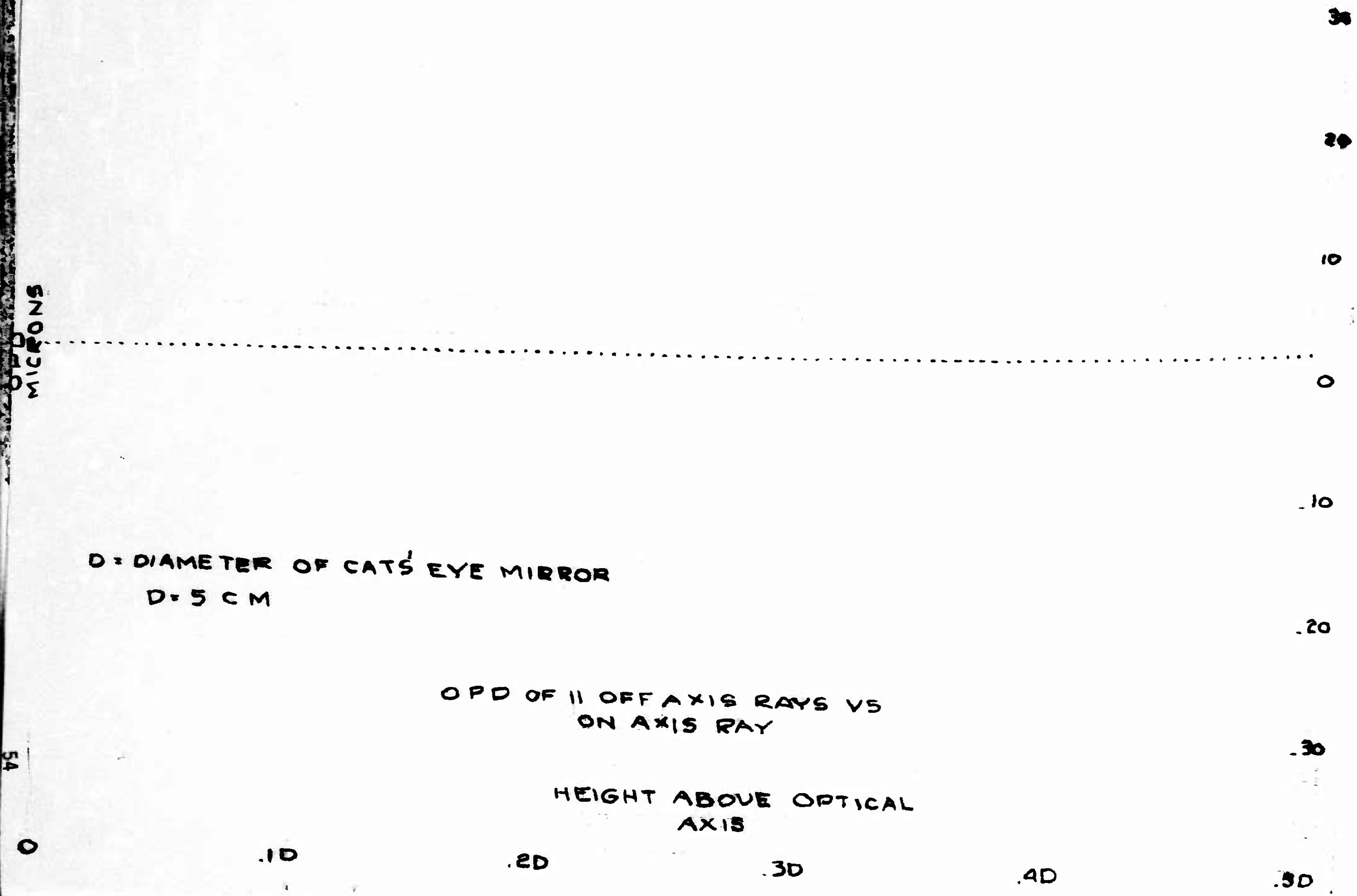
X DISPLACEMENT OF CONVEX MIRROR = 0

Y DISPLACEMENT OF CONVEX MIRROR = -.0008

DIAMETER OF CONCAVE MIRROR = 5.0

NUMBER OF POINTS DESIRED = 100

GRAPH #10


OPD MICRONS
30
20
10
0
-.10
-.20
-.30
D = DIAMETER OF CATS' EYE MIRROR
D = 5 CM
OPD OF 11 OFF AXIS RAYS VS ON AXIS RAY
HEIGHT ABOVE OPTICAL AXIS
0
.1D
.2D
.3D
.4D
.5D

GRAPH #10

SYSTEM SCALE FACTOR = 1

POSITION OF REF. LINE = 0

RADIUS OF CURVATURE OF CONCAVE MIRROR = 40

RADIUS OF CURVATURE OF CONVEX MIRROR = 20.02

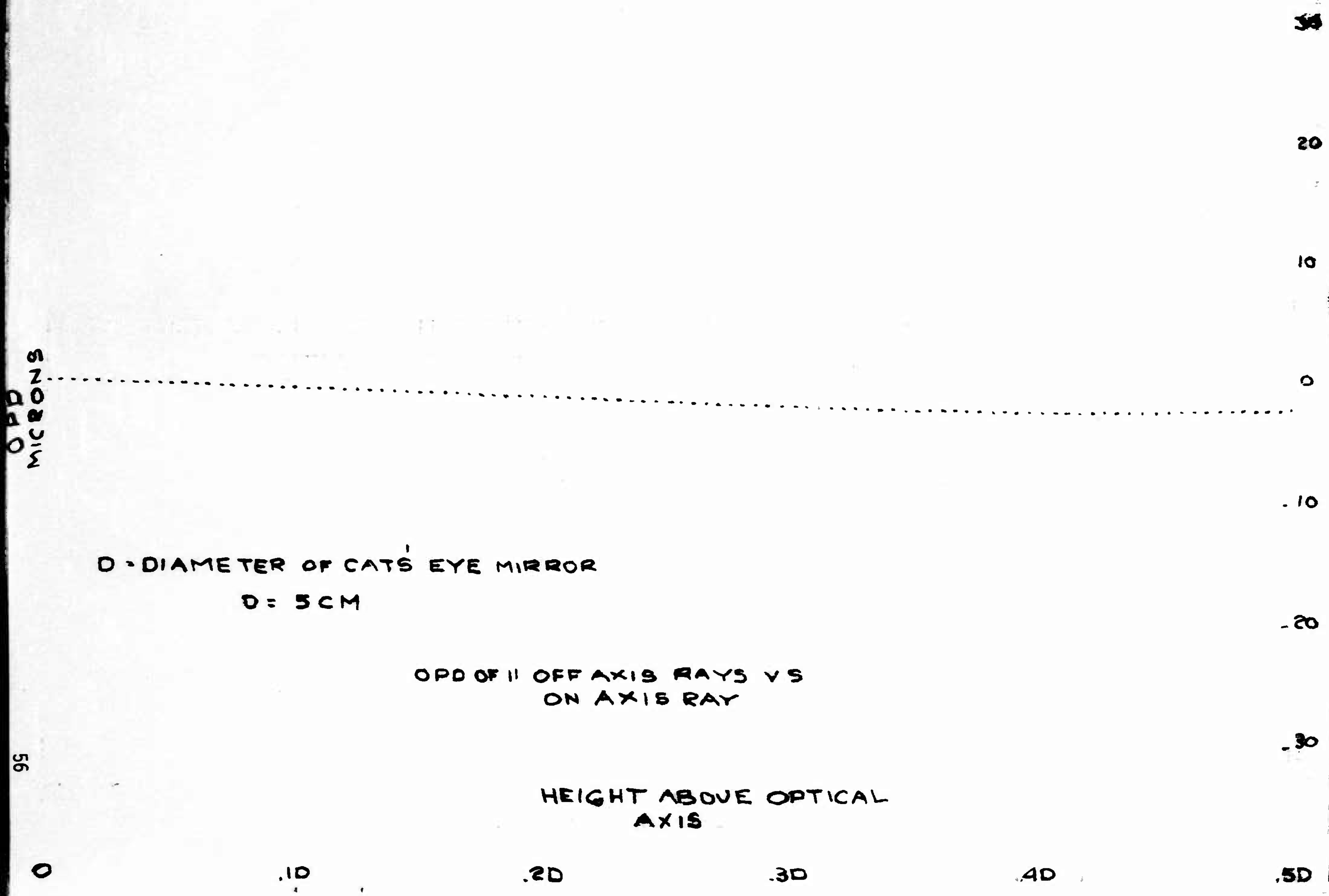
X DISPLACEMENT OF CONVEX MIRROR = 0

Y DISPLACEMENT OF CONVEX MIRROR = .001

DIAMETER OF CONCAVE MIRROR = 5.0

NUMBER OF POINTS DESIRED = 100

GRAPH #11



OPD MICRONS
30
20
10
0
-.10
-.20
-.30
D - DIAMETER OF CAT'S EYE MIRROR
D = 5CM
OPD OF 11 OFF AXIS RAYS VS ON AXIS RAY
HEIGHT ABOVE OPTICAL AXIS
0
.1D
.2D
.3D
.4D
.5D

GRAPH #11

SYSTEM SCALE FACTOR = 1

POSITION OF REF. LINE = 0

RADIUS OF CURVATURE OF CONCAVE MIRROR = 40

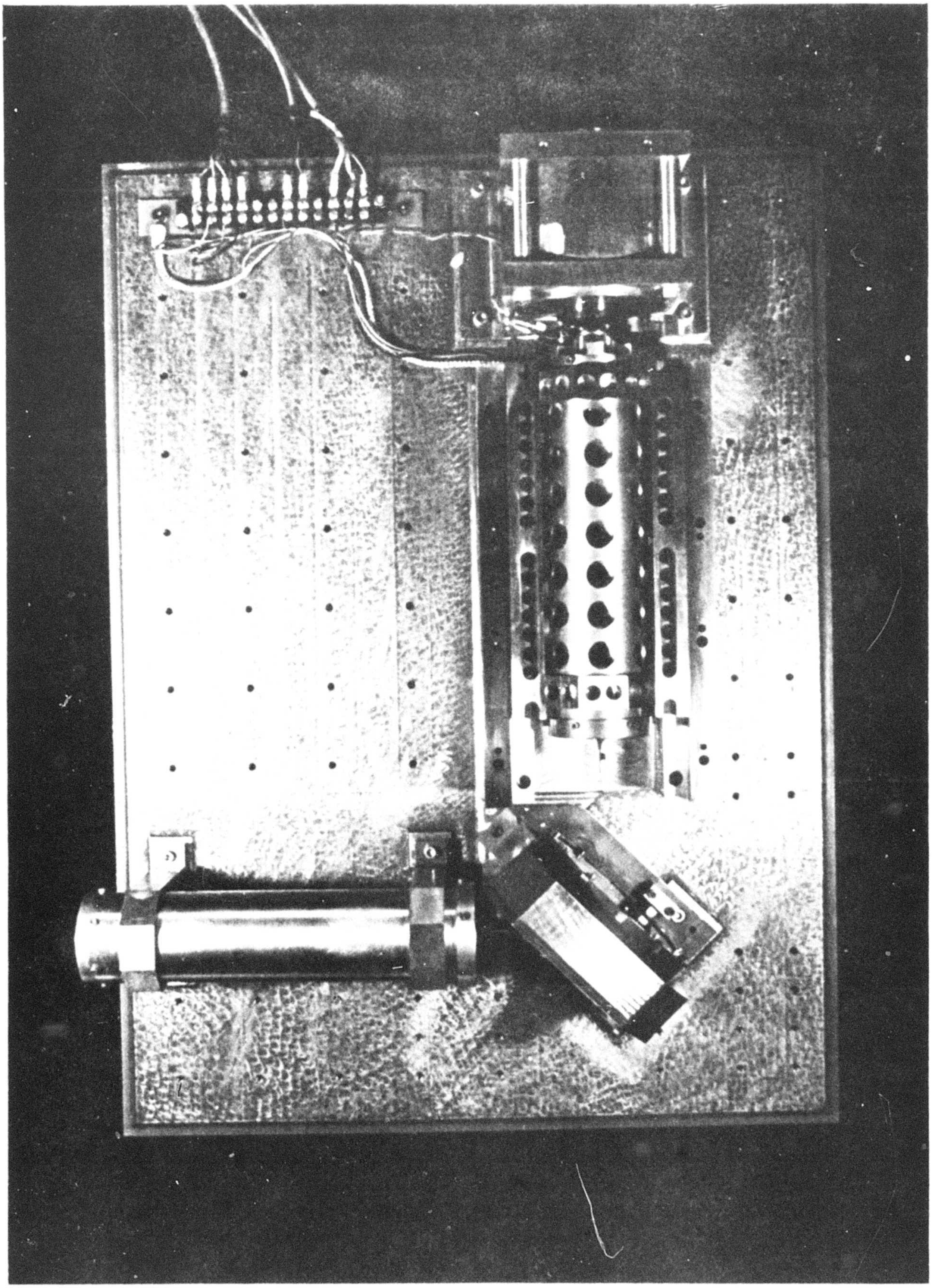
RADIUS OF CURVATURE OF CONVEX MIRROR = 20.02

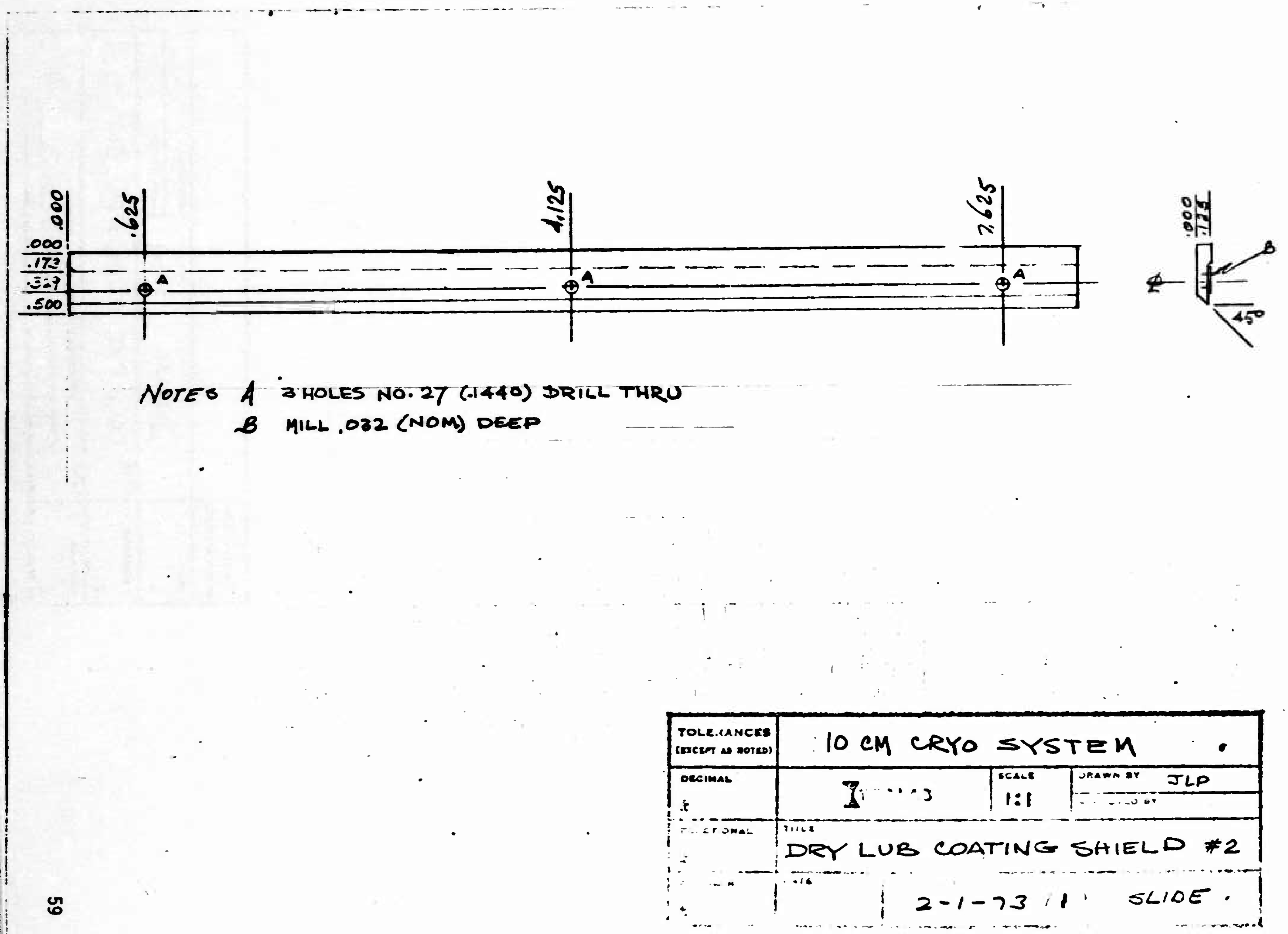
X DISPLACEMENT OF CONVEX MIRROR = 0

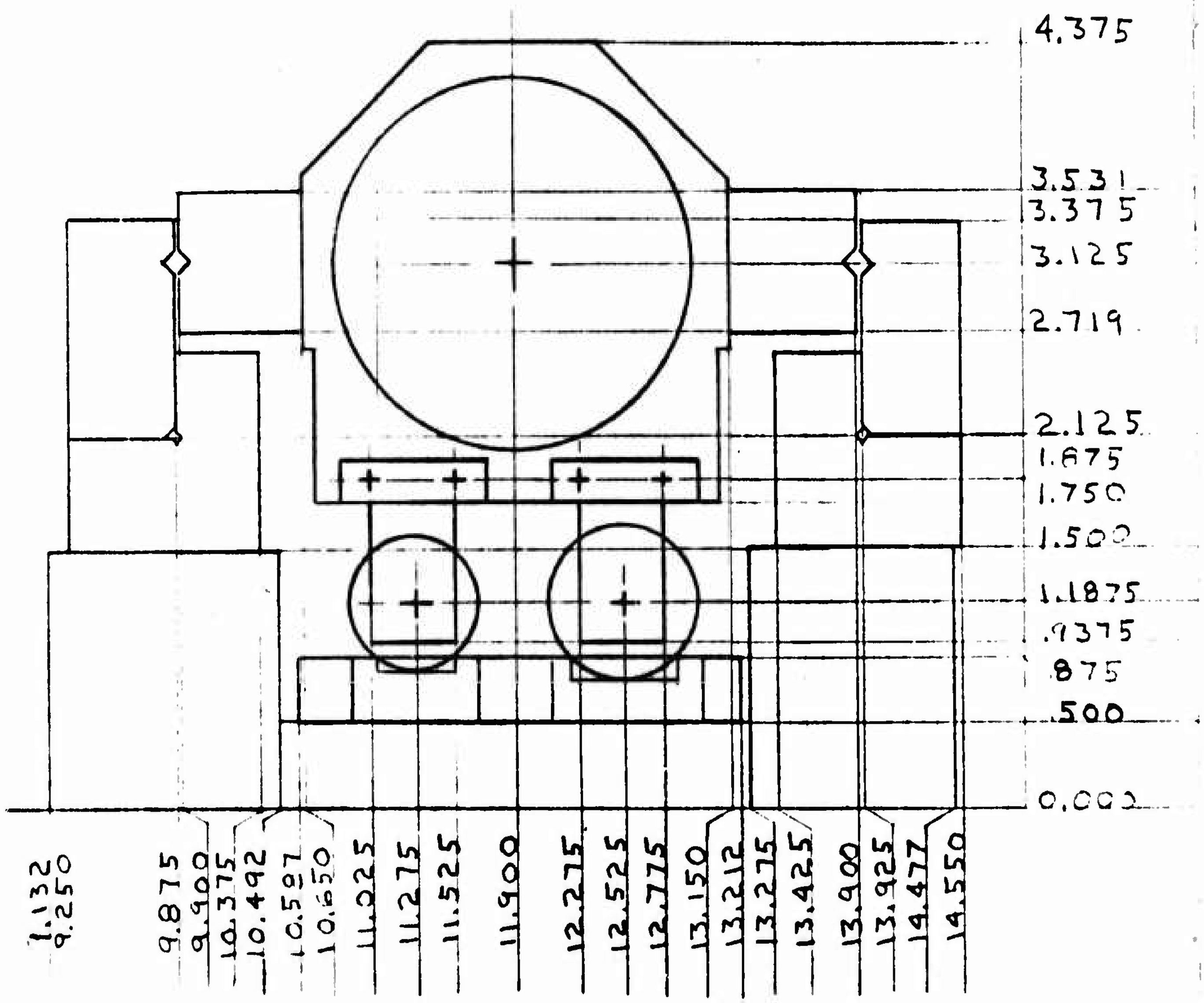
Y DISPLACEMENT OF CONVEX MIRROR = -.001

DIAMETER OF CONCAVE MIRROR = 5.0

NUMBER OF POINTS DESIRED = 100

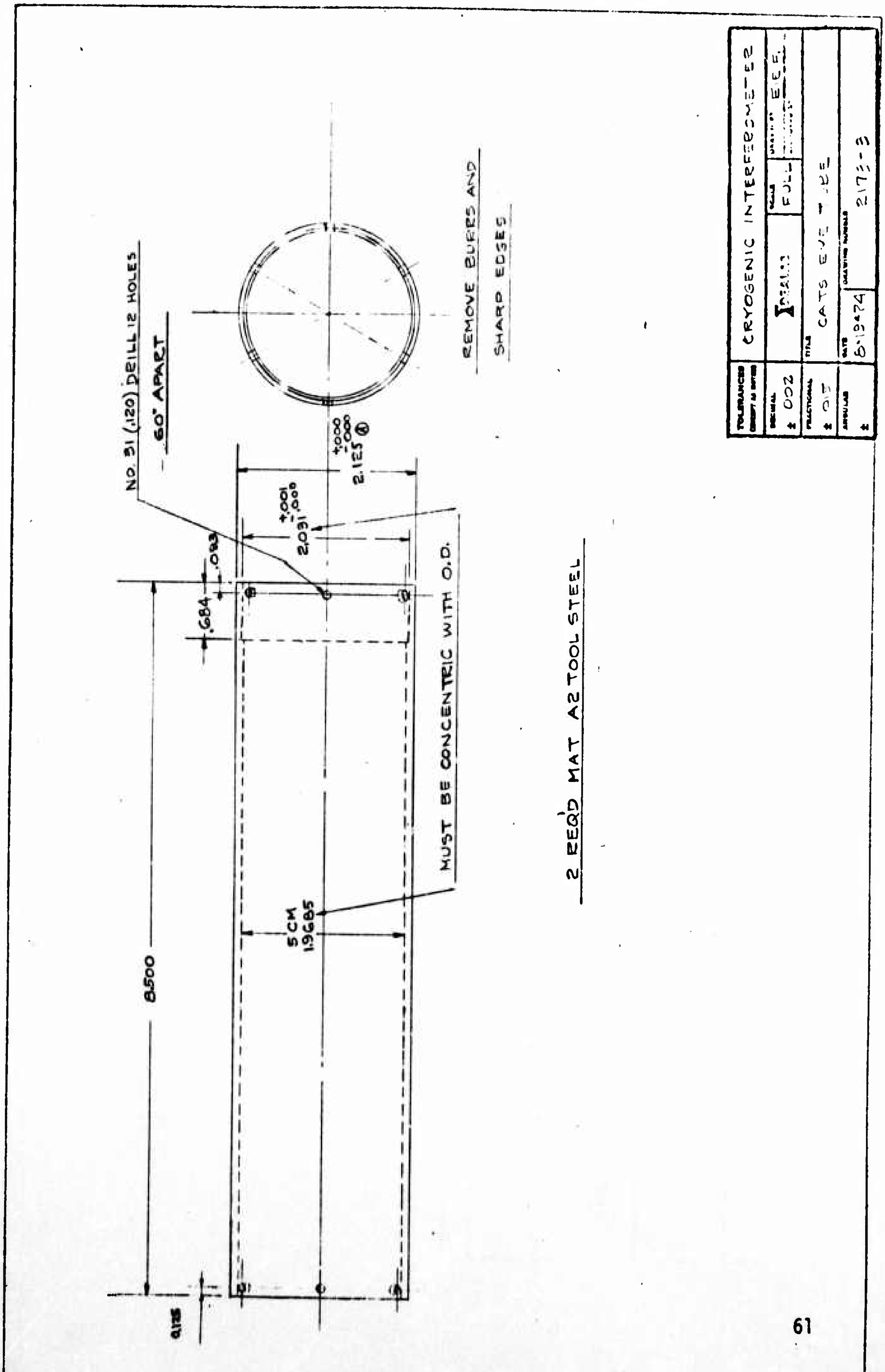


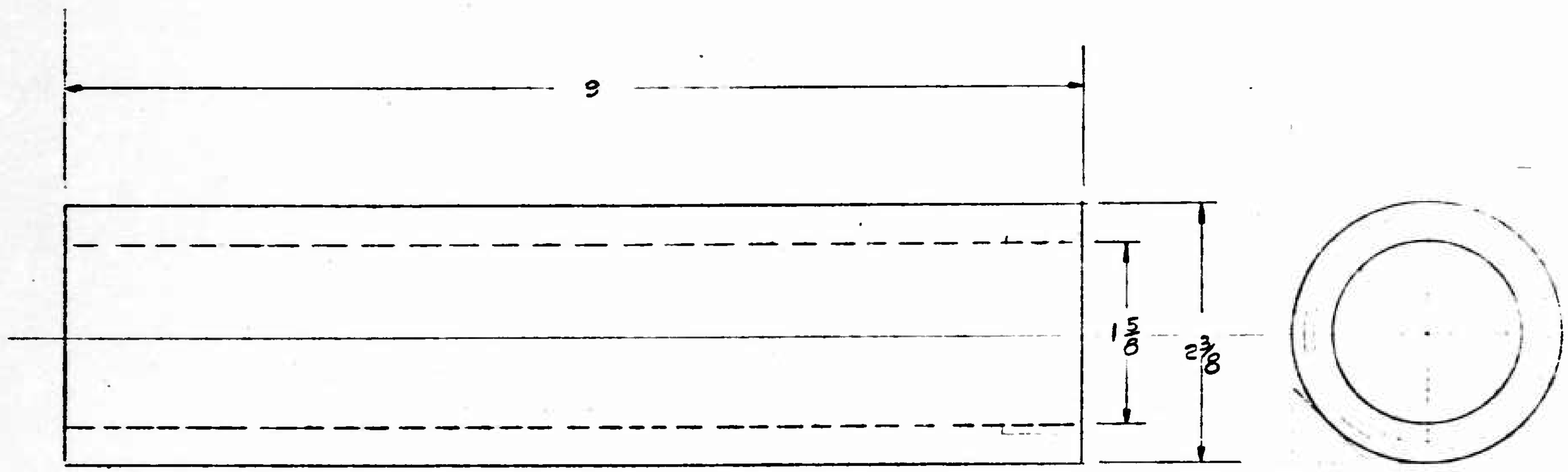

.000
.000
.173
.327
.500
.625
4.125
7.625
A
A
A
.000
.125
B
45°
NOTES A 3 HOLES NO. 27 (.1440) DRILL THRU
B MILL .032 (NOM) DEEP
TOLERANCES (EXCEPT AS NOTED)
DECIMAL
10 CM CRYO SYSTEM
SCALE
1:1
DRAWN BY
JLP
TITLE
DRY LUB COATING SHIELD #2
2-1-73
SLIDE



TOLERANCES (EXCEPT AS NOTED)			
DEC'L ±	IDEALAB	SCALE 1=1	DRAWN BY ELP / APPROVED BY
FRACTIONAL ±	TITLE CATS EYE TUBE HOLDER		
ANGULAR ±	DATE 7-2-75	DRAWING NUMBER 2173-2A	

60


NO. 31 (.120) DRILL 12 HOLES
60° APART
REMOVE BURRS AND SHARP EDGES
MUST BE CONCENTRIC WITH O.D.
2 REQ'D MAT A2 TOOL STEEL
8.500
.684
.093
2.031 +.001 -.000
2.125 +.000 -.000
5 CM
1.9685
0.125
TOLERANCES
± .002
CRYOGENIC INTERFEROMETER
FULL



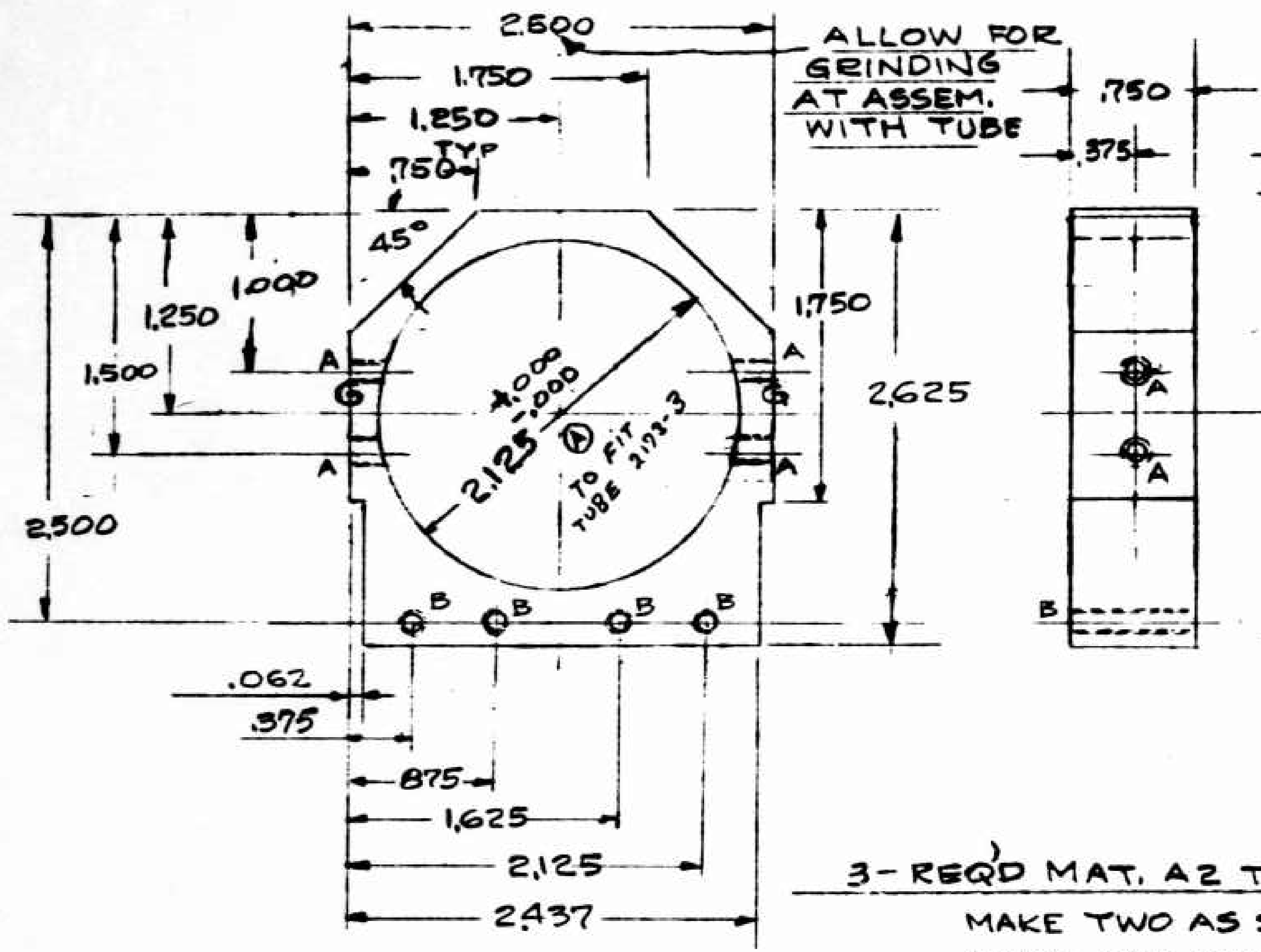
2 REQD MAT. A2 TOOL STEEL CASTING (AIR-HDN)

ANALYSIS -	CARBON	1.00 %
	MANGANESE -	.60 %
	CHROMIUM	5.25 %
	MOLYBDENUM	1.10 %
	VANADIUM	.25 %

NOTE

FINISHED PIECE - I.D. 1.9685 O.D. 2.125 x 8.500

TOLERANCES (EXCEPT AS NOTED)	• CRYOGENIC INTERFEROMETER		
DECIMAL ±.002	IDEALAB	SCALE FULL	DRAWN BY E.E.F. / APPROVED BY
FRACTIONAL ± 1/64	TITLE CATS EYE TUBE		
ANGULAR ±	DATE 12-13-73	DRAWING NUMBER 2173-3-	



NOTE -
A - 4 HOLES 6-32 TAP THRU
B - 4 HOLES 4-40 TAP THRD
ON TWO ONLY

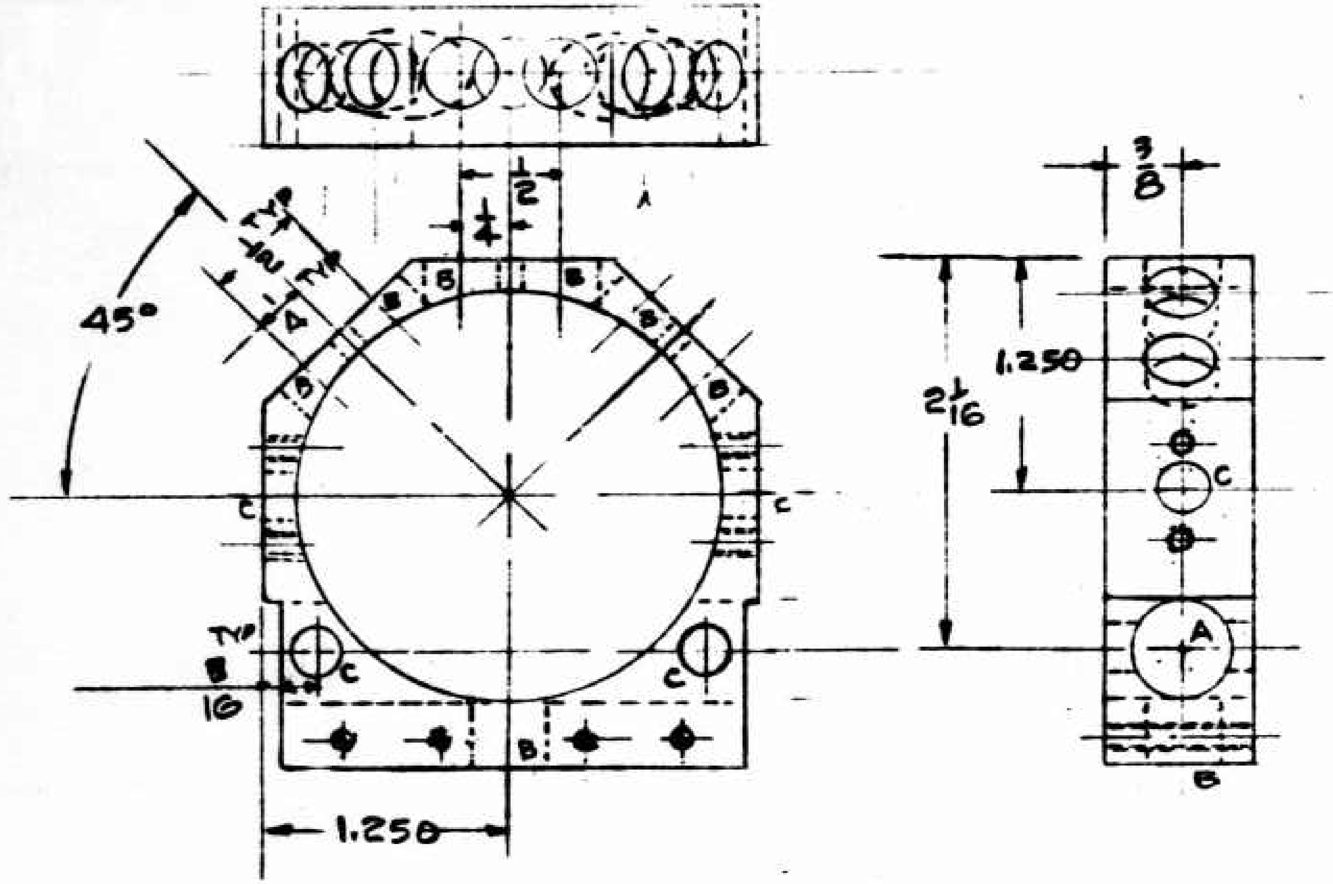
REMOVE BURRS AND
BREAK ALL SHARP
EDGES

3 - REQ'D MAT. A2 TOOL STEEL
MAKE TWO AS SHOWN
MAKE ONE WITHOUT "B" HOLES 2½ LONG

SEE DRAWING 2173-4A
FOR LIGHTENING HOLE
SCHEDUDLE

CHANGE (A) WAS -.002

TOLERANCES (EXCEPT AS NOTED)	CRYOGENIC INTERFEROMETER		
DECIMAL ± .002	[illegible]	SCALE FULL	DRAWN BY E.E.F
FRACTIONAL ± .015	TITLE CATS EYE TUBE HOLDER		
ANGULAR ± 0°-30'	DATE 4-22-74	DRAWING NUMBER 2173-4	



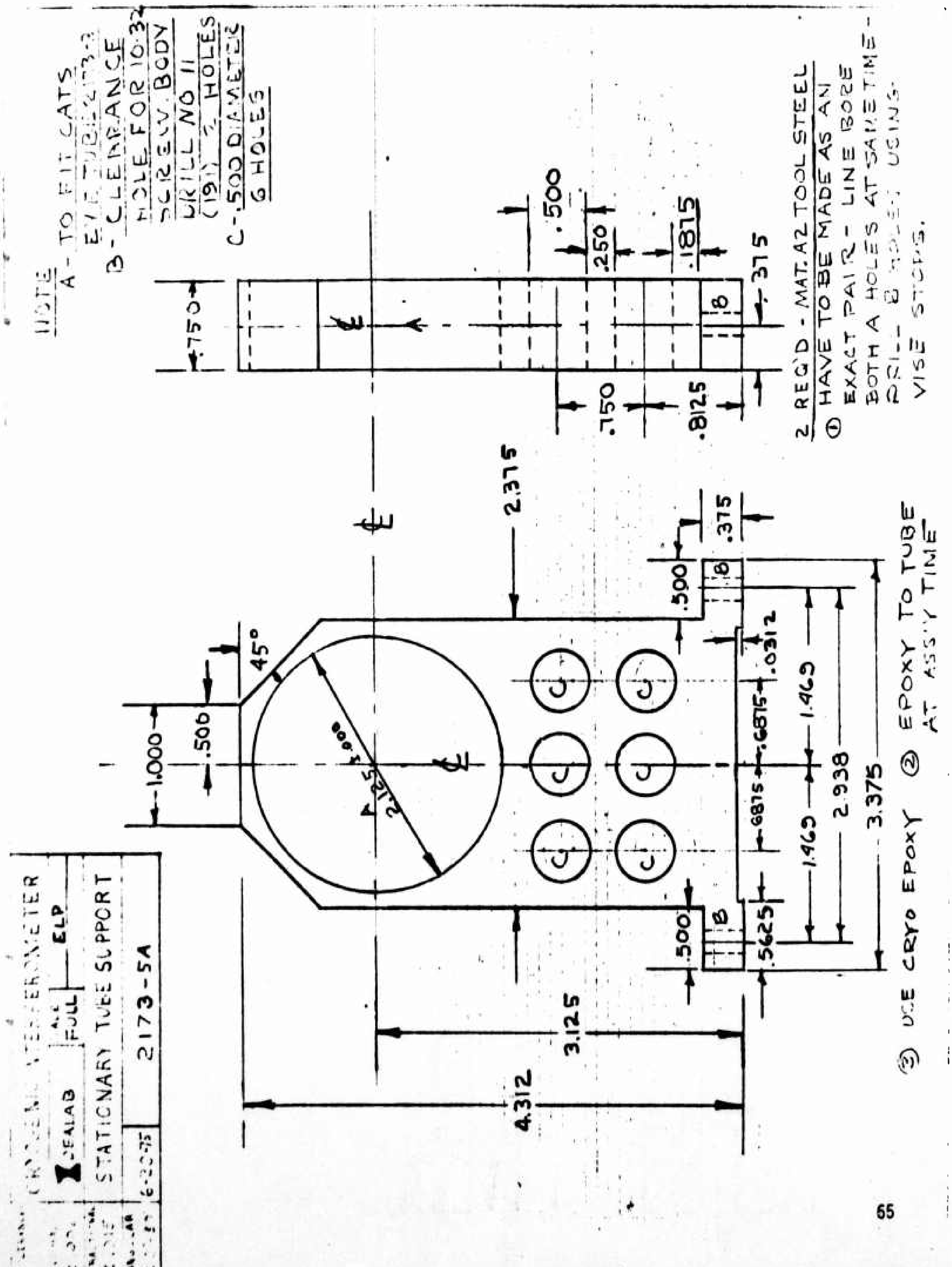
NOTE -

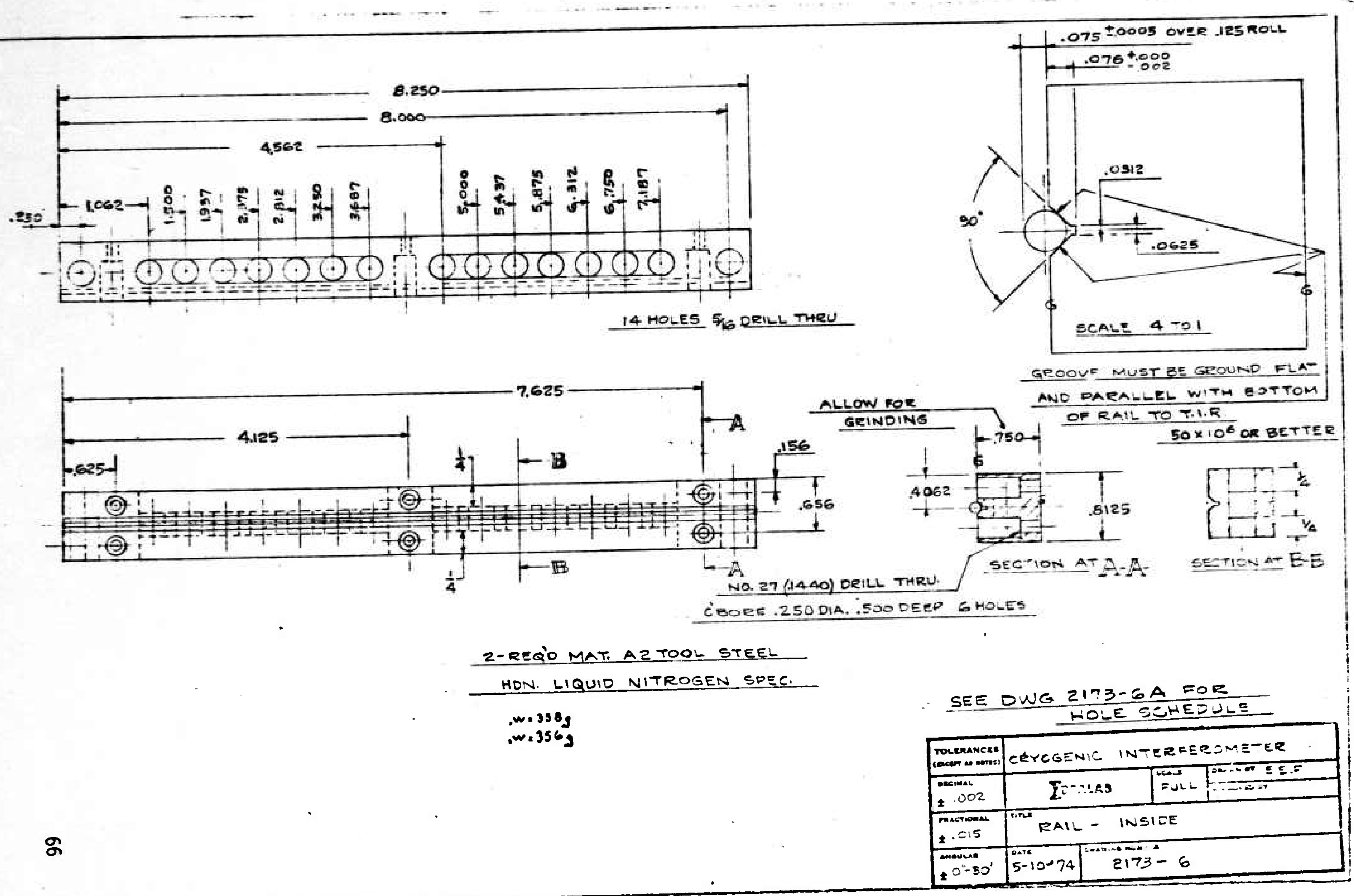
A - 1 HOLE 1/2 THRU.

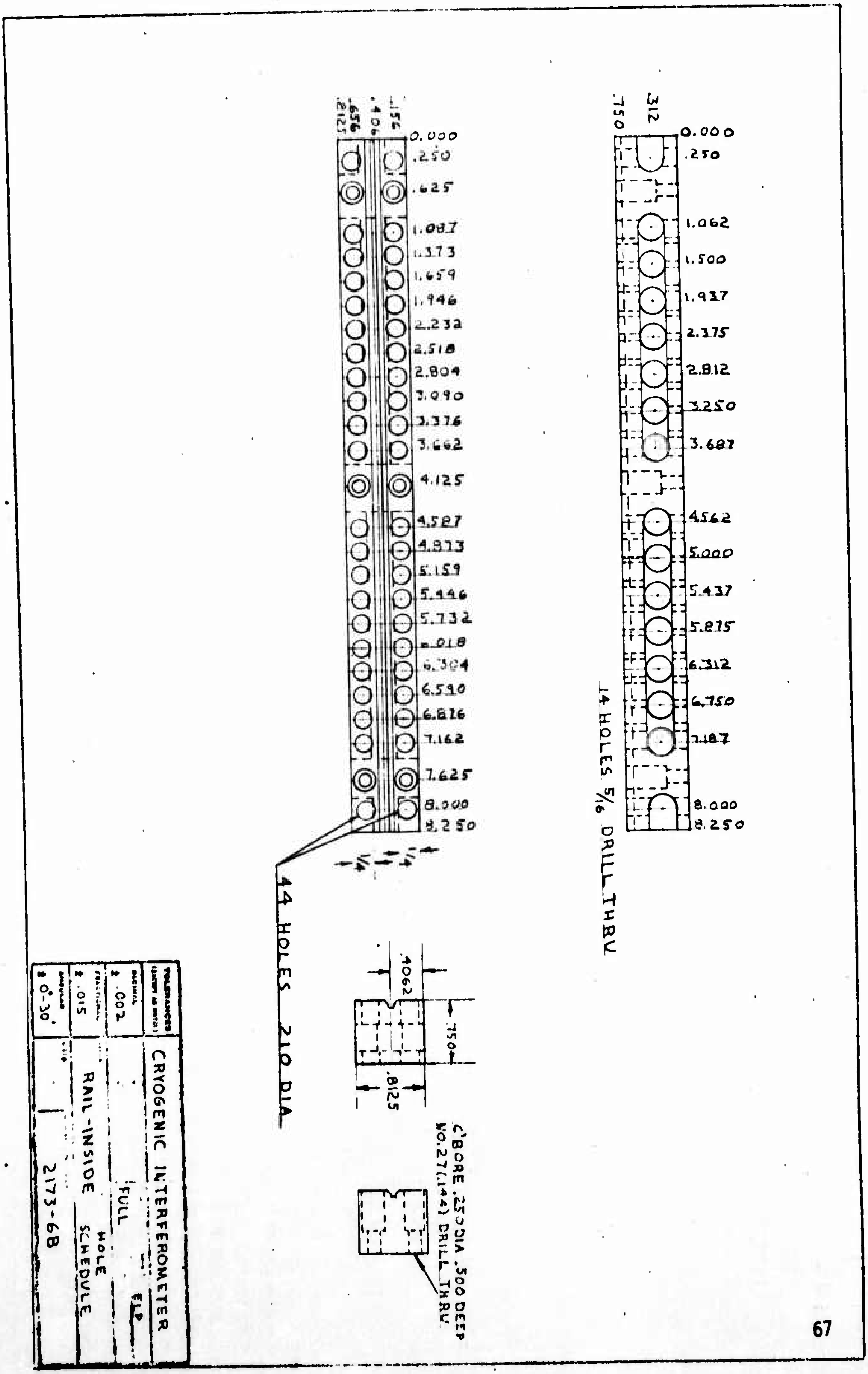
B - 7 HOLES 3/8 DRILL INTO 2.123 HOLE

C - 4 HOLES 1/4 DRILL " " "

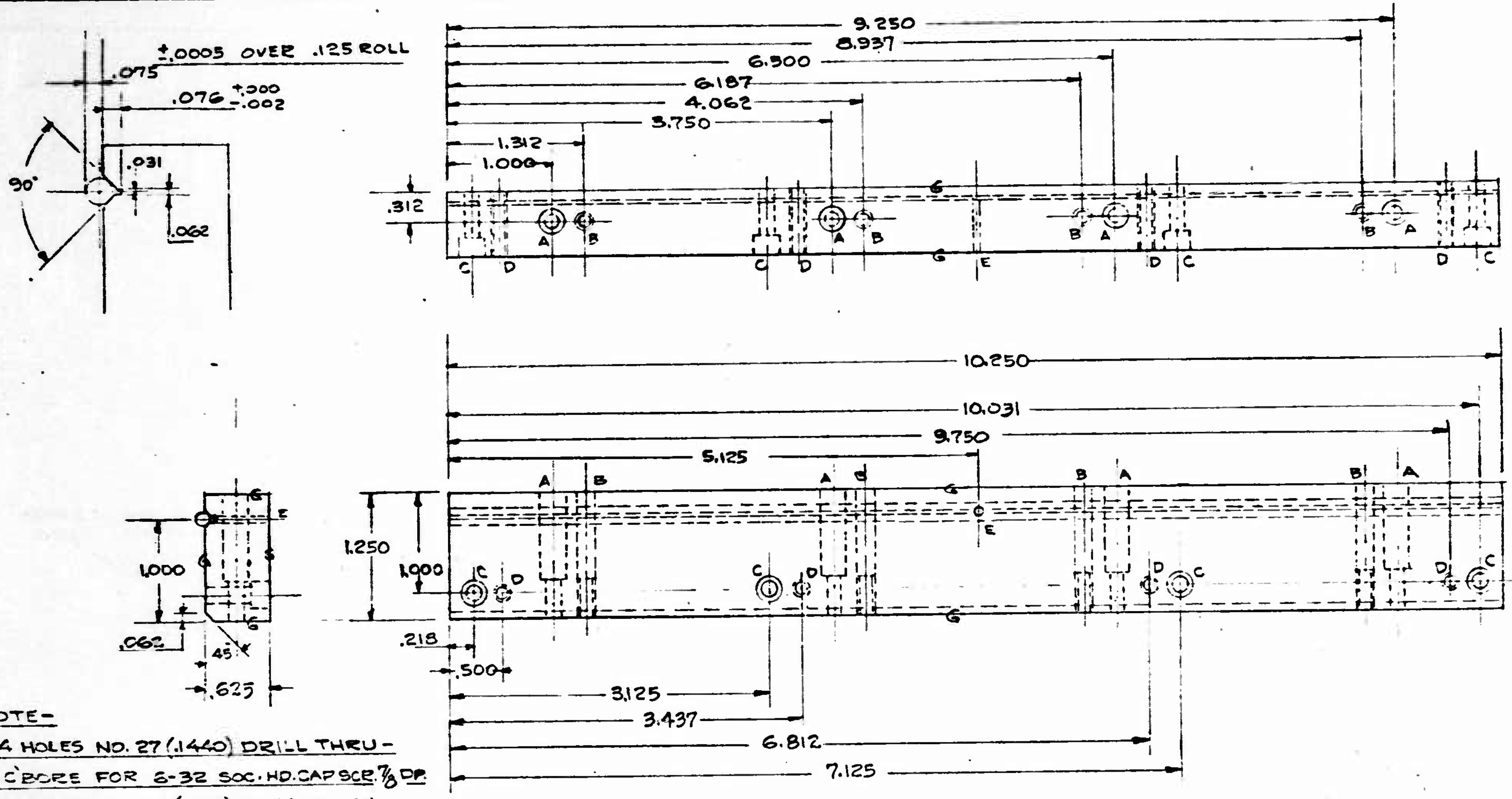
TOLERANCES (EXCEPT AS NOTED)	CRYOGENIC INTERFEROMETER		
DECIMAL ± .002	IDEALAB	FULL	EEF
FRACTIONAL ± .015	CATS EYE TUBE HOLDER LIGHTENING HOLE SCHEDULE		
ANGULAR ± 0°-30'	1-15-75	2173-4A	


SEALAB
FULL
ELP
STATIONARY TUBE SUPPORT
2173-5A
NOTE
A - TO FIT CATS EYE TUBE 2173-3
B - CLEARANCE HOLE FOR 10-32 SCREW. BODY DRILL NO 11 (.191) 2 HOLES
C - .500 DIAMETER 6 HOLES
2 REQ'D - MAT. A2 TOOL STEEL
① HAVE TO BE MADE AS AN EXACT PAIR - LINE BORE BOTH A HOLES AT SAME TIME - DRILL B HOLES USING VISE STOPS.
② EPOXY TO TUBE AT ASS'Y TIME
③ USE CRYO EPOXY
.750
.500
.250
.1875
.375
.8125
2.375
.0312
1.469
.6875
2.938
3.375
1.000
45°
2.125
.5625
3.125
4.312


8.250
8.000
4.562
.250
1.062
1.500
1.937
2.375
2.812
3.250
3.687
5.000
5.437
5.875
6.312
6.750
7.187
14 HOLES 5/16 DRILL THRU
.075 ±.0005 OVER .125 ROLL
.076 +.000 -.002
.0312
.0625
90°
SCALE 4 TO 1
GROOVE MUST BE GROUND FLAT
AND PARALLEL WITH BOTTOM
OF RAIL TO T.I.R
50 x 10⁶ OR BETTER
7.625
4.125
.625
.156
.656
ALLOW FOR
GRINDING
.750
.4062
.5125
SECTION AT A-A
SECTION AT B-B
NO. 27 (.1440) DRILL THRU.
C'BORE .250 DIA. .500 DEEP 6 HOLES
2-REQ'D MAT. A2 TOOL STEEL
HDN. LIQUID NITROGEN SPEC.
W=358g
W=356g
SEE DWG 2173-6A FOR
HOLE SCHEDULE
TOLERANCES (EXCEPT AS NOTED)
DECIMAL ± .002
FRACTIONAL ± .015
ANGULAR ± 0°-30'
CRYOGENIC INTERFEROMETER
SCALE FULL
DRAWN BY E.S.F
TITLE RAIL - INSIDE
DATE 5-10-74
DRAWING NUMBER 2173 - 6



14 HOLES 5/16 DRILL THRU
14 HOLES .210 DIA
C'BORE .250 DIA .500 DEEP NO.27(.144) DRILL THRU
.4062
.750
.8125
TOLERANCES
.002
.015
0°-30'
CRYOGENIC INTERFEROMETER
FULL
ELP
RAIL-INSIDE HOLE SCHEDULE
2173-6B



NOTE-

A- 4 HOLES NO. 27 (.1440) DRILL THRU - C'BORE FOR 6-32 SOC. HD. CAP SCR. 7/8 DP.

B- 4 HOLES NO. 33 (.1130) DRILL THRU. REDRILL NO. 27 (.1440) DRILL 7/8 DEEP - TAP 6-40 THRU

C- 4 HOLES - DRILL & C'BORE FOR 6-32 SOC. HD. CAP SCR

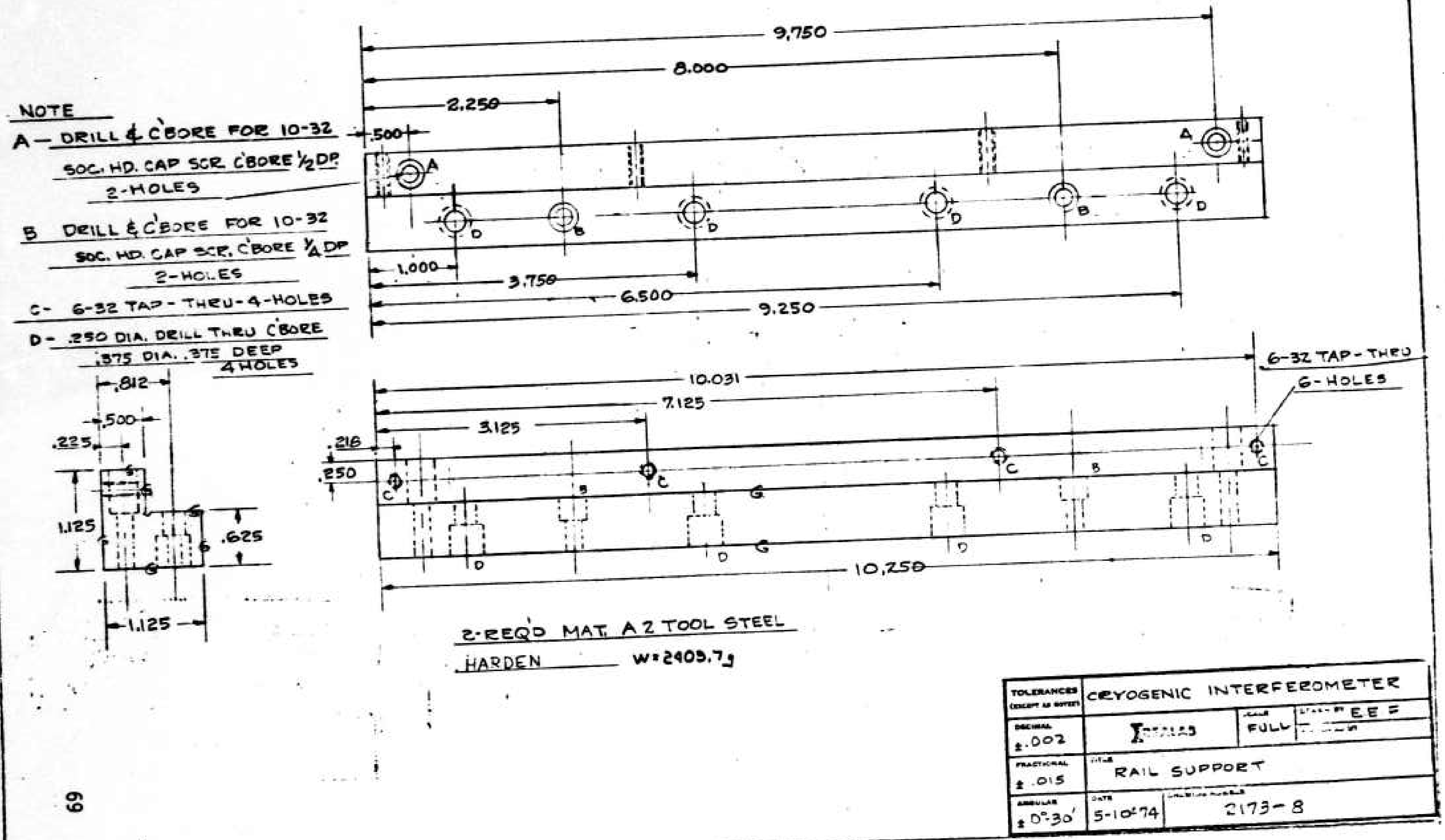
D 4 HOLES - TAP 6-40 THRU

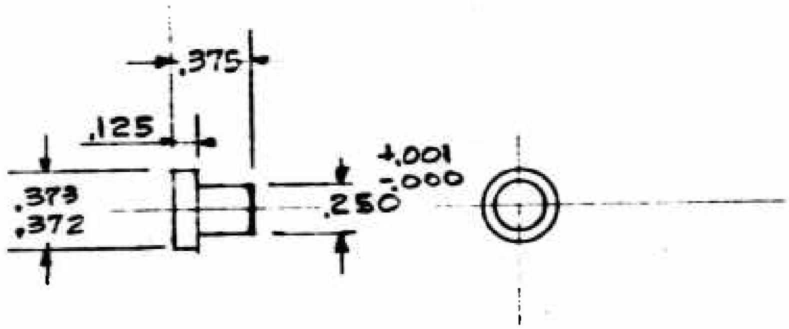
E- 1 HOLE NO 52 .0635 DRILL THRU

W: 989 g
W: 991.5 g

2-REQ'D MAT. A2 TOOL STEEL
HDN. LIQUID INTROGEN SPEC

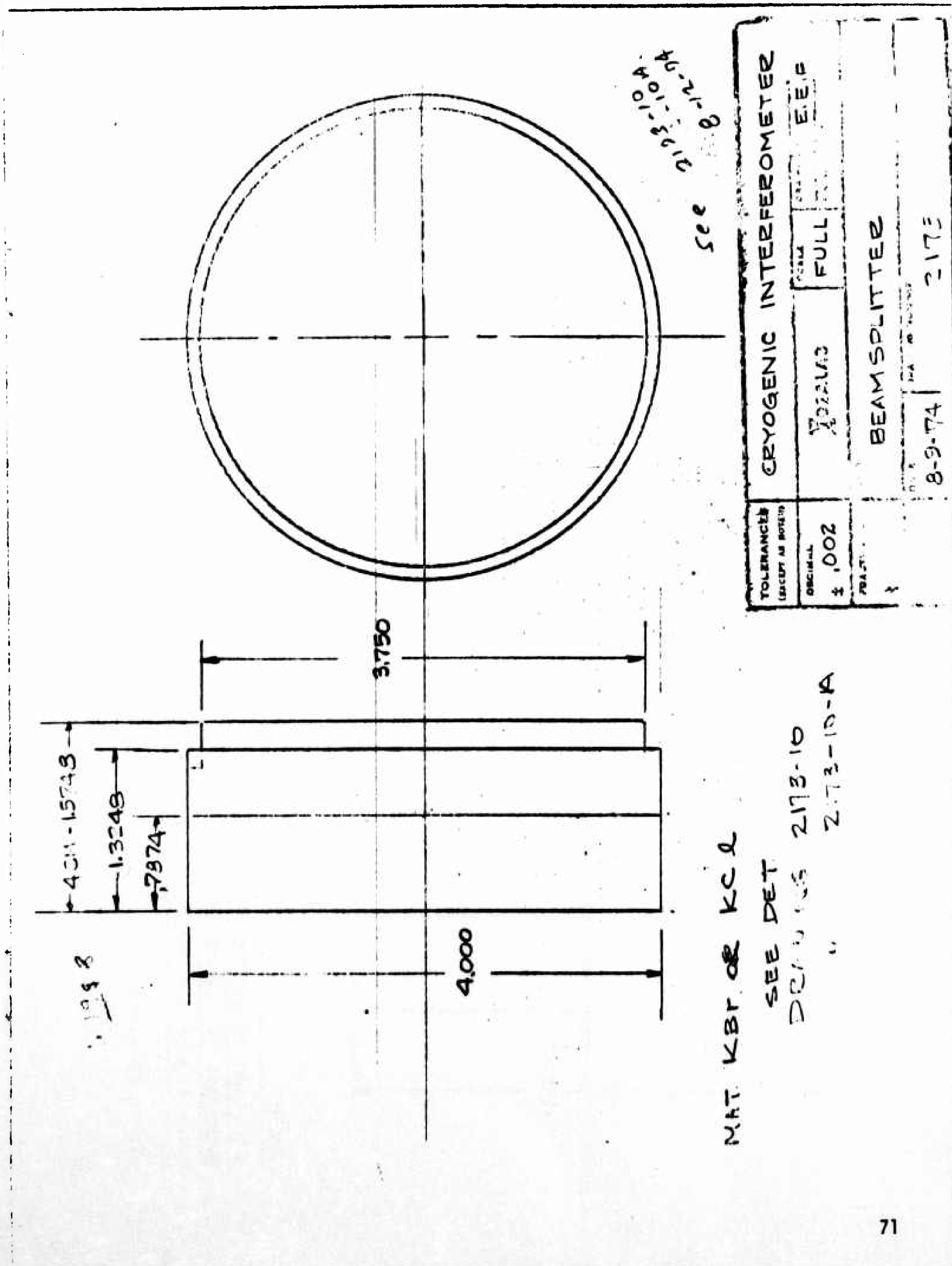
TOLERANCES (EXCEPT AS NOTED)	CRYOGENIC INTERFEROMETER		
DECIMAL ± .002	IDEALAB	SCALE FULL	DRAWN BY EEF
FRACTIONAL ± .015	TITLE RAIL - OUTSIDE		
ANGULAR ± 0°30'	DATE 8-5-74	DRAWING NUMBER 2173-7	

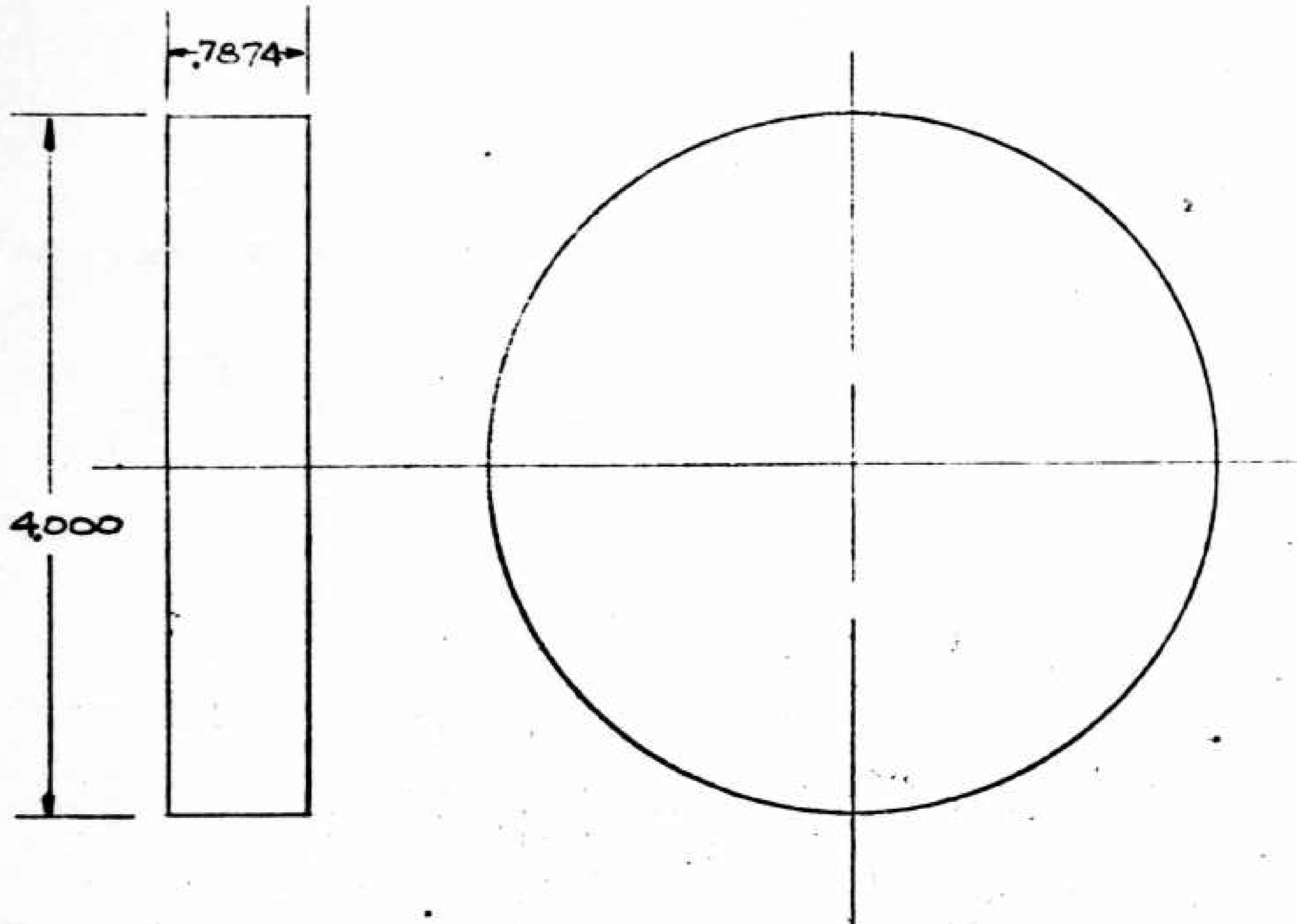

NOTE
A — DRILL & C'BORE FOR 10-32
SOC. HD. CAP SCR. C'BORE 1/2 DP.
2-HOLES
B DRILL & C'BORE FOR 10-32
SOC. HD. CAP SCR. C'BORE 1/4 DP
2-HOLES
C- 6-32 TAP - THRU - 4-HOLES
D - .250 DIA. DRILL THRU C'BORE
.375 DIA. .375 DEEP
4 HOLES
9.750
8.000
2.250
.500
1.000
3.750
6.500
9.250
6-32 TAP - THRU
6-HOLES
10.031
7.125
3.125
.216
.250
10.250
.812
.500
.225
1.125
.625
1.125
2-REQ'D MAT. A2 TOOL STEEL
HARDEN
W=2405.7g
TOLERANCES (EXCEPT AS NOTED)
DECIMAL ±.002
FRACTIONAL ±.015
ANGULAR ±0°30'
CRYOGENIC INTERFEROMETER
SCALE FULL
TITLE RAIL SUPPORT
DATE 5-10-74
2173-8



8 REQ'D MAT. A2 TOOL STEEL

TOLERANCES (EXCEPT AS NOTED)	CRYOGENIC INTERFEROMETER		
DECIMAL ± .002	[illegible]	SCALE FULL	DRAWN BY E.E.F
FRACTIONS ± .015	RAIL SUPPORT PLUG		
[illegible]	DATE 8-9-74	DRAWING NUMBER 2173-9	

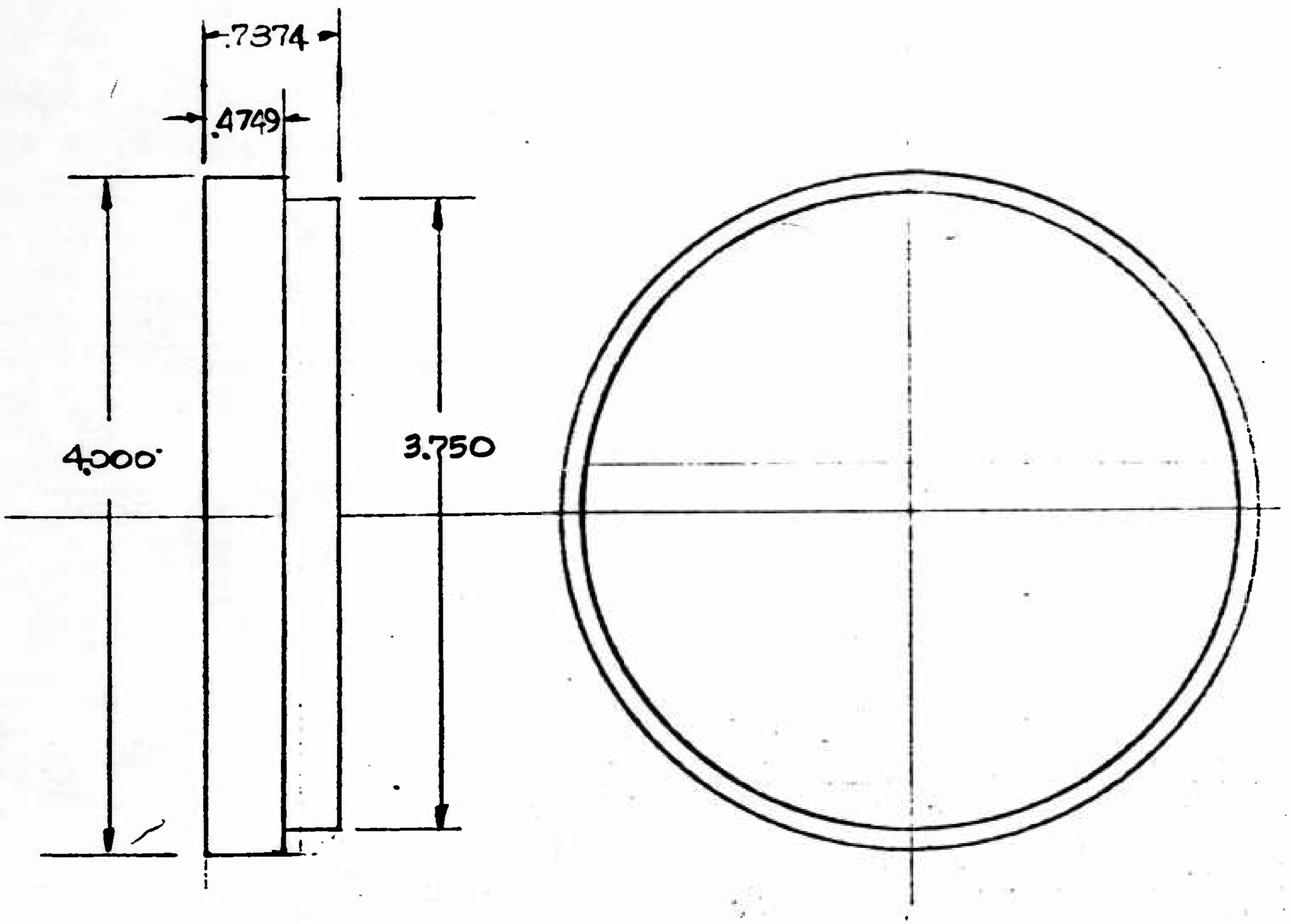

CRYOGENIC INTERFEROMETER
BEAMSPLITTER
TOLERANCES
DECIMAL
±.002
FULL
8-9-74
2173
3.750
4.000
.7374
MAT. KBr or KCl
SEE DET
2173-10
2173-10-A



MAT.
POLISH FLAT TO 1/2 WAVE
SODIUM D AND PARALLEL
TO 1 SEC. OF ARC OR BETTER

To be an exact matched pair in thickness.

TOLERANCES (EXCEPT AS NOTED)	CRYOGENIC INTERFEROMETER		
± .002		FULL	E.E.F.
	BEAMSPLITTER		
	3-12-74	2173-10	



MAT.

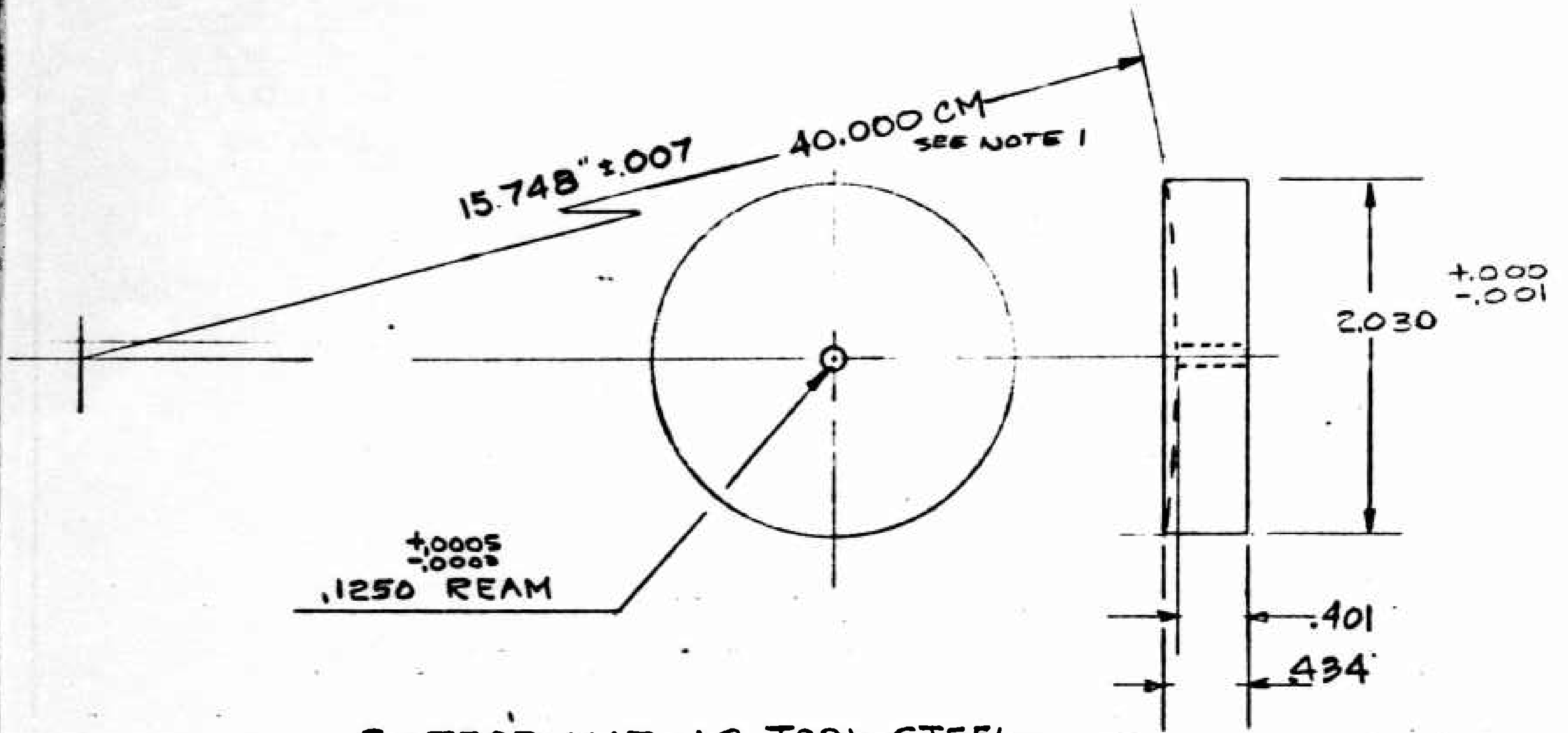
POLISH FLAT TO ½ WAVE
SODIUM D AND PARALLEL
TO 1 SEC. OF ARC OR BETTER

To be an exact matched pair in thickness.

TOLERANCES	CRYOGENIC INTERFEROMETER		
.002		FULL	EEF
	BEAMSPLITTER		
	8-12-74	2173-10A	

MTL.: CERVIT, QUARTZ, OR FINE ANNEALED PYREX.

2 PCS REQUIRED
SPHERICITY AND MATCH TO WITHIN 1/10 WAVE (.0000023")



2 - REQD MAT. ~~A2 TOOL STEEL~~

HDN. LIQUID NITROGEN SPEC.

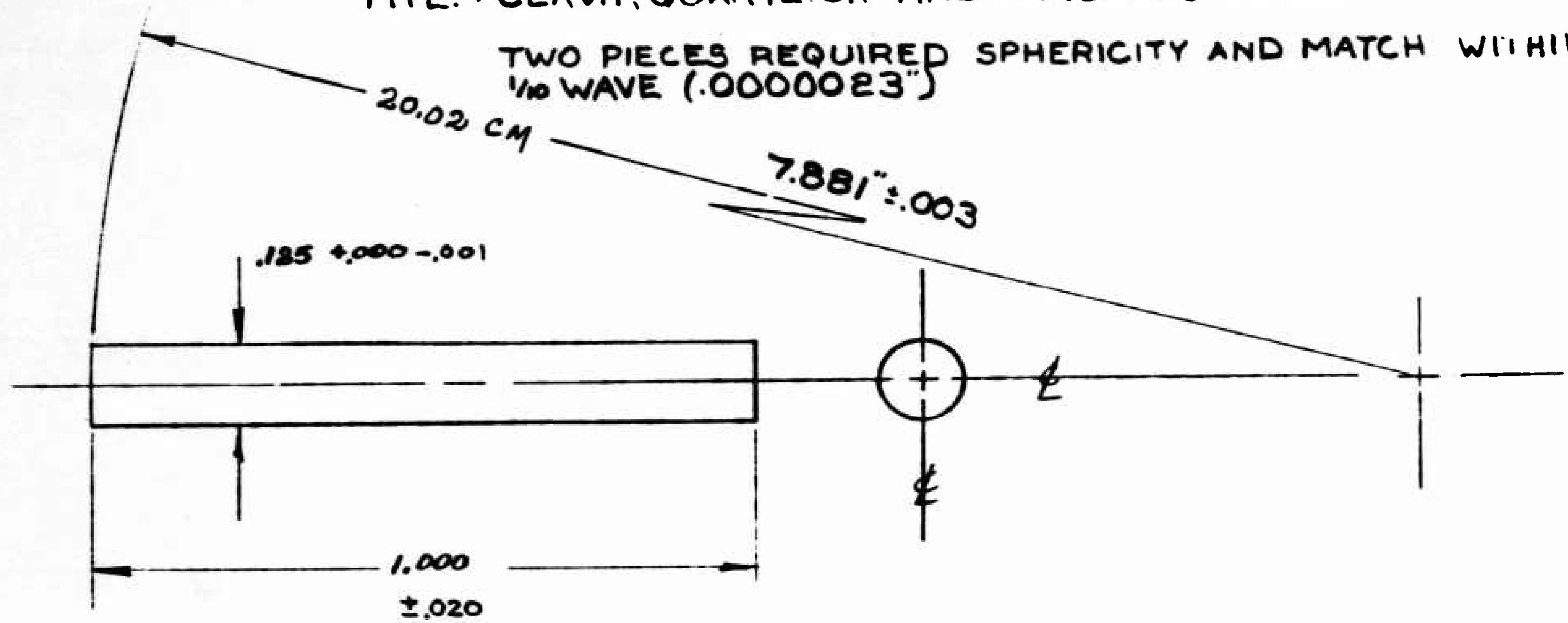
NOTE

1. ALL DIMENSIONS IN INCHES
EXCEPT RADIUS OF CURVATURE

TOLERANCES (EXCEPT AS NOTED)	CRYOGENIC INTERFEROMETER		
DECIMAL ± .002	[illegible]	SCALE FULL	DRAWN BY E.E.F
FRACTIONAL ±	TITLE MIRROR CONCAVE		
ANGULAR ±	DATE 3-19-7[illegible]	DRAWING NUMBER 2173-11	

MTL. : CERVIT, QUARTZ OR FINE ANNEALED PYREX

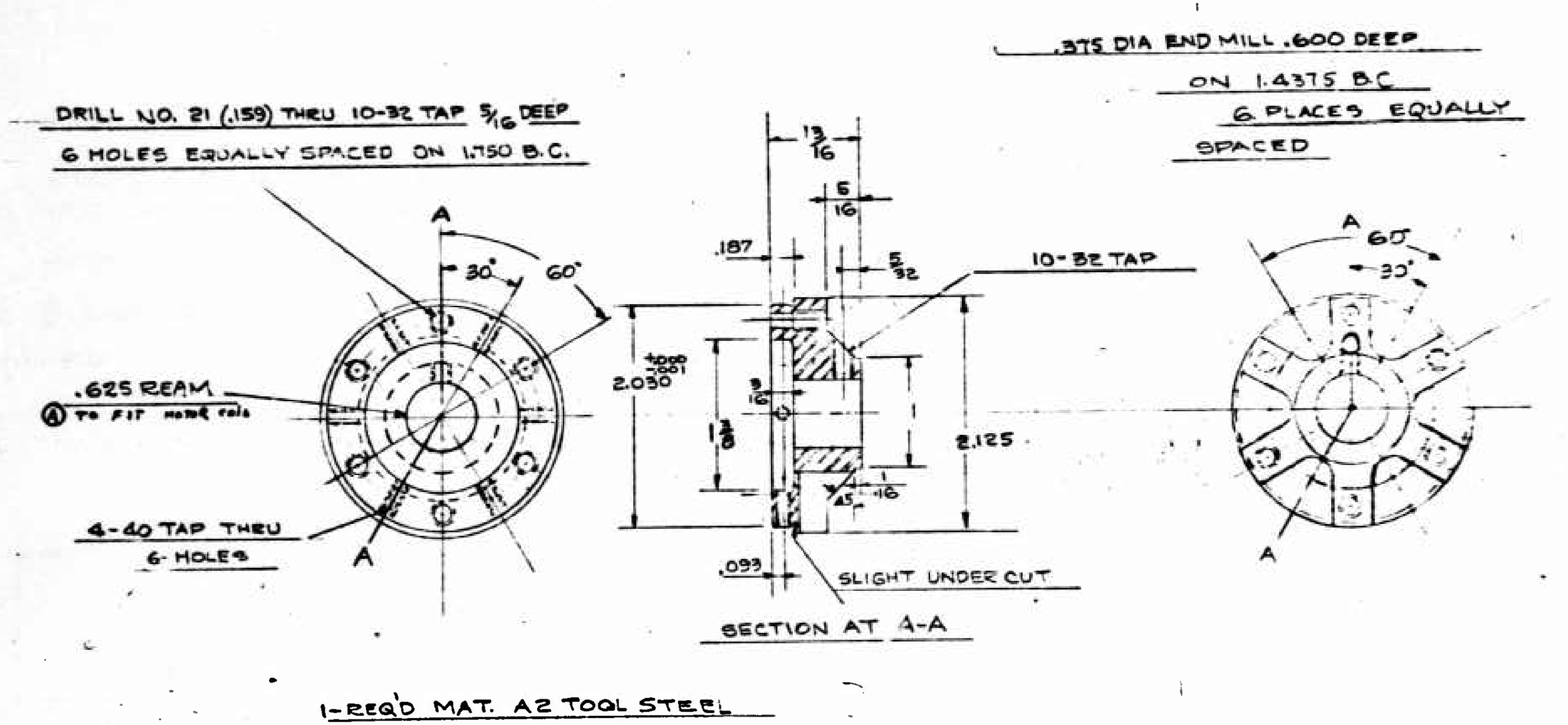
TWO PIECES REQUIRED SPHERICITY AND MATCH WITHIN 1/10 WAVE (.0000023")



Notes

1. 2 REQ'D ~~MAT A-2 TOOL STEEL~~
2. HDN. L/N SPEC.
3. ALL DIMENSIONS IN INCHES EXCEPT RADIUS OF CIRVERTURE

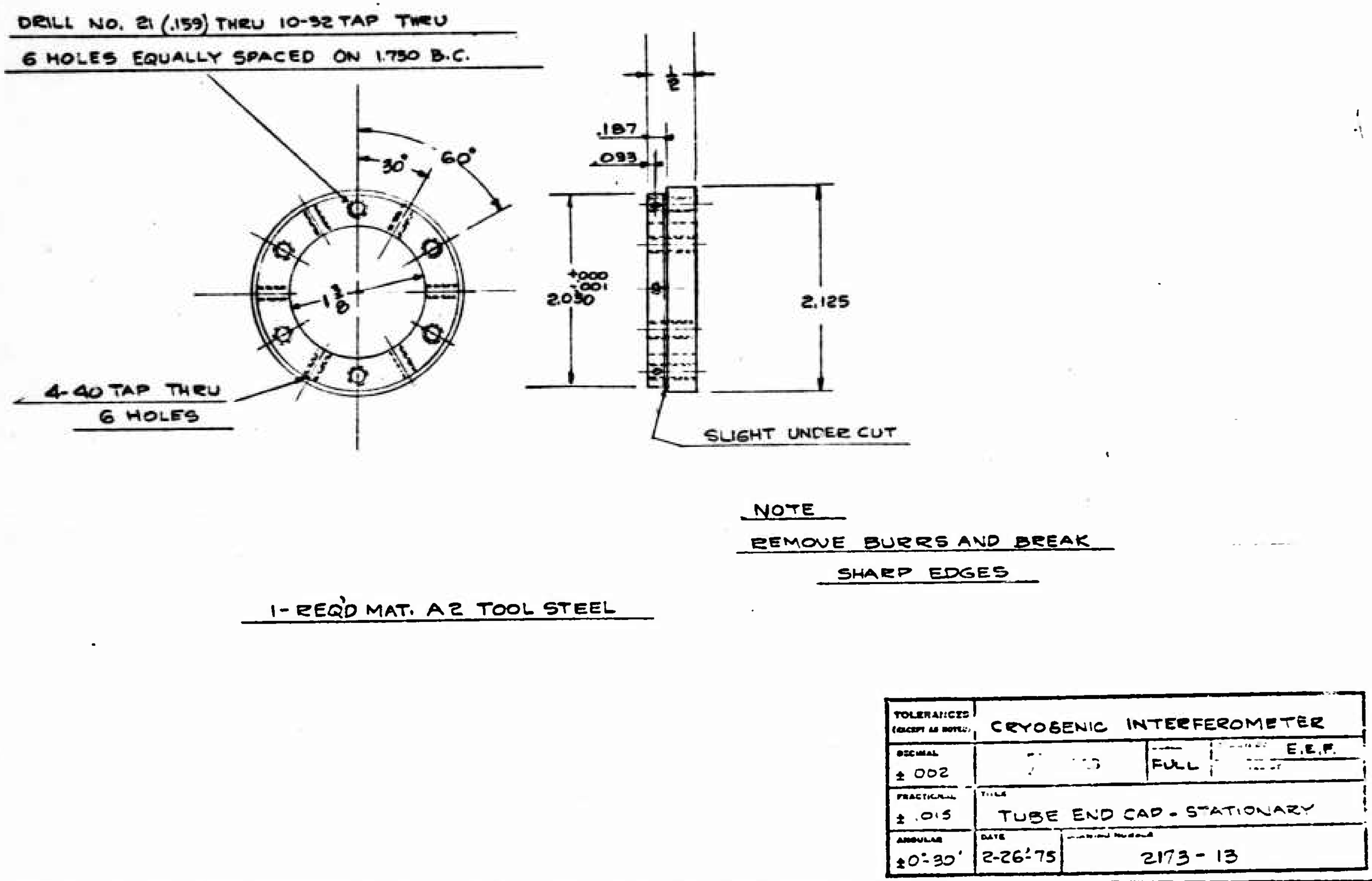
TOLERANCES (EXCEPT AS NOTED)	CRYOGENIC INTERFEROMETER		
DECIMAL ± .002	IDEALAB	4 TO 1	JLP
FRACTIONAL ±	MIRROR CONVEX		
ANGULAR ±	DATE 3-26-75	2173-11A	

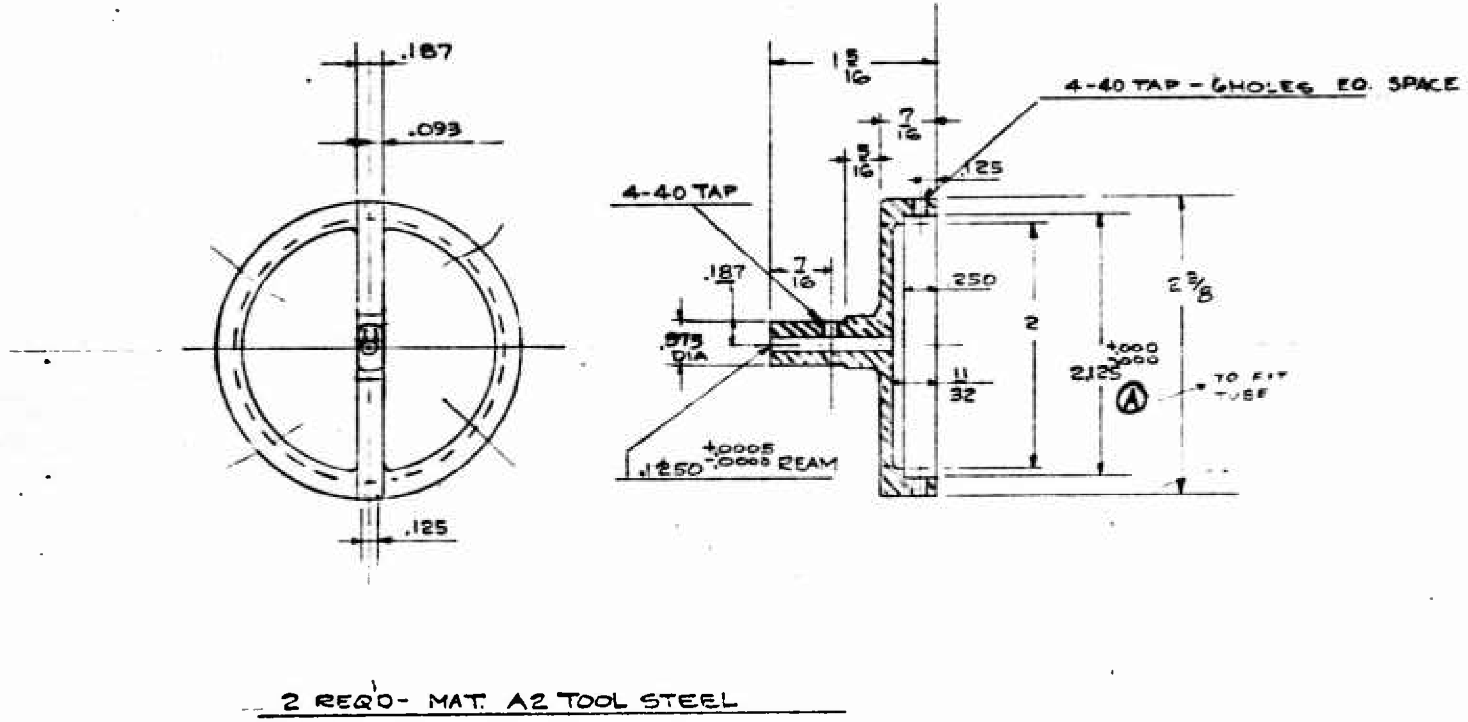


CHANGE

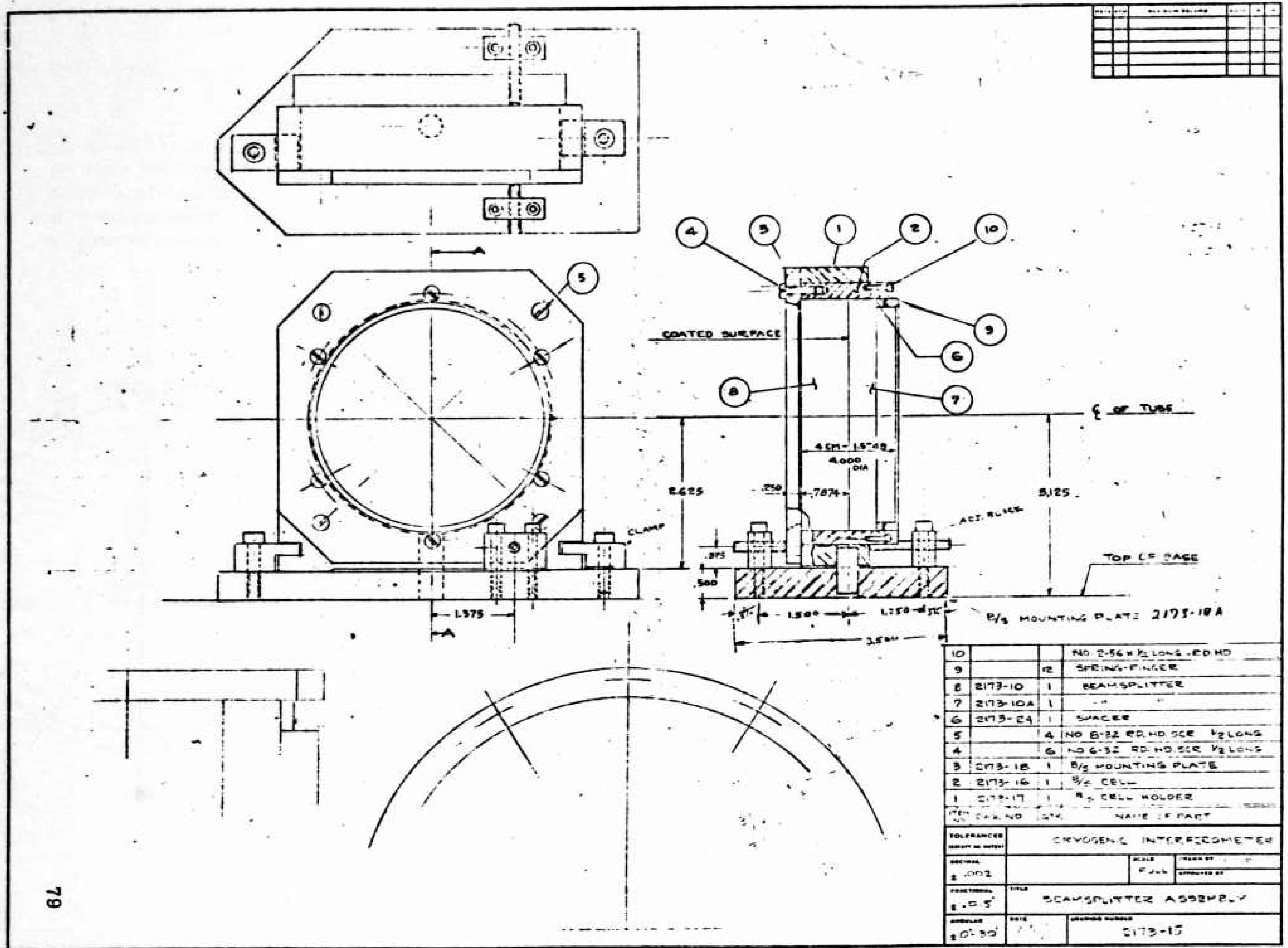
(A) TO FIT MOTOR coil

TOLERANCES (EXCEPT AS NOTED)	CRYOGENIC INTERFEROMETER		
DECIMAL ± .002	IDEALAB	SCALE FULL	DRAWN BY EEF
FRACTIONAL ± .015	TITLE TUBE END CAP - MOTOR END		
ANGULAR ± 0°-30'	DATE 8-27-74	DRAWING NUMBER 2173-12	


DRILL NO. 21 (.159) THRU 10-32 TAP THRU
6 HOLES EQUALLY SPACED ON 1.750 B.C.
30°
60°
1 3/8
4-40 TAP THRU
6 HOLES
1/2
.187
.093
+.000 -.001
2.030
2.125
SLIGHT UNDER CUT
NOTE
REMOVE BURRS AND BREAK
SHARP EDGES
1-REQ'D MAT. A2 TOOL STEEL
TOLERANCES (EXCEPT AS NOTED)
DECIMAL ± .002
FRACTIONAL ± .015
ANGULAR ± 0°-30'
CRYOGENIC INTERFEROMETER
FULL
E.E.F.
TITLE
TUBE END CAP - STATIONARY
DATE
2-26-75
2173 - 13

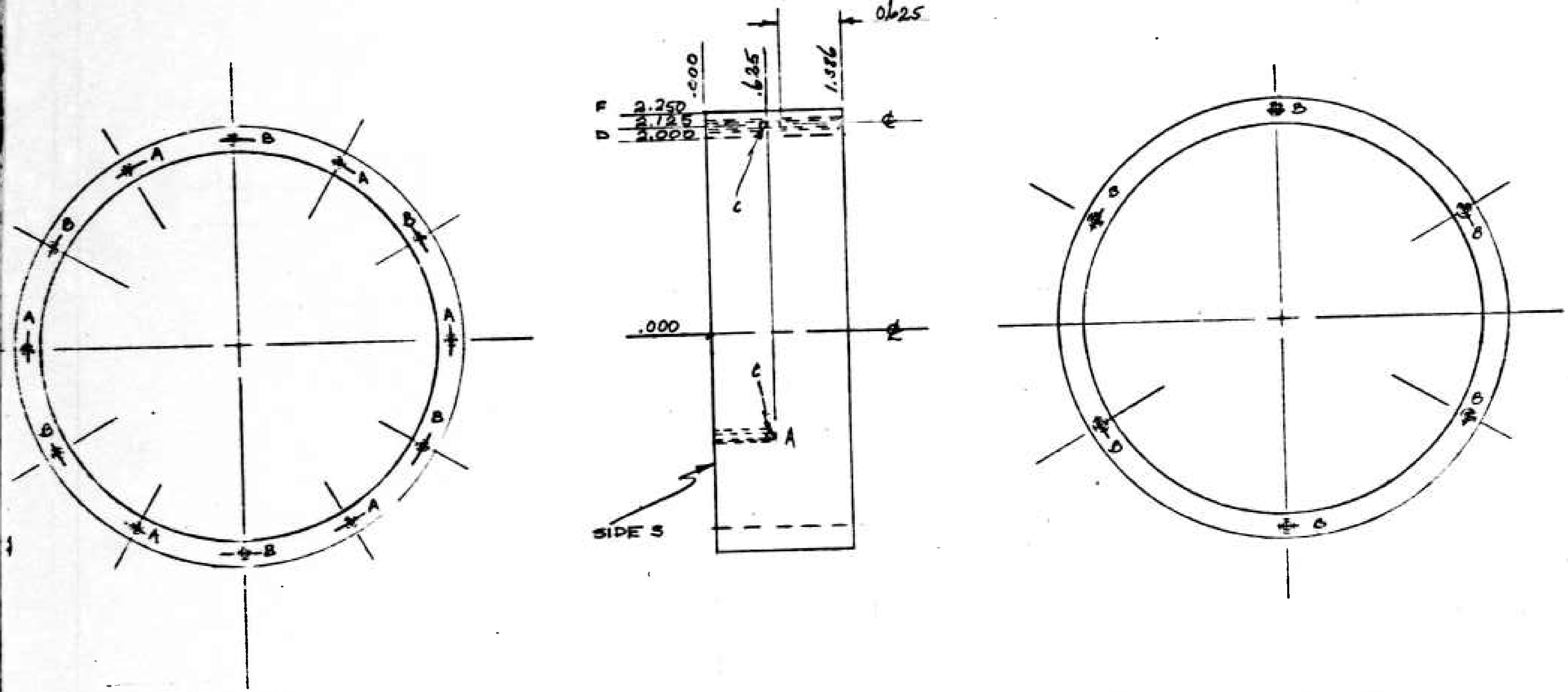


TOLERANCES (EXCEPT AS NOTED)	CRYOGENIC INTERFEROMETR		
DECIMAL ± .002	IDEALAB	SCALE	DRAWN BY EEF
FRACTIONAL ± 1/64	TITLE TUBE END MIRROR SUPPORT		
ANGULAR ±	DATE 3-4-74	DRAWING NUMBER 2173-14	



ITEM NO	DWG NO	QTY	NAME OF PART
10			NO 2-56 x ½ LONG RD HD
9		12	SPRING-FINGER
8	2173-10	1	BEAMSPLITTER
7	2173-10A	1	"
6	2173-24	1	SPACER
5		4	NO 8-32 RD HD SCR ½ LONG
4		6	NO 6-32 RD HD SCR ½ LONG
3	2173-18	1	B/S MOUNTING PLATE
2	2173-16	1	B/S CELL
1	2173-17	1	B/S CELL HOLDER

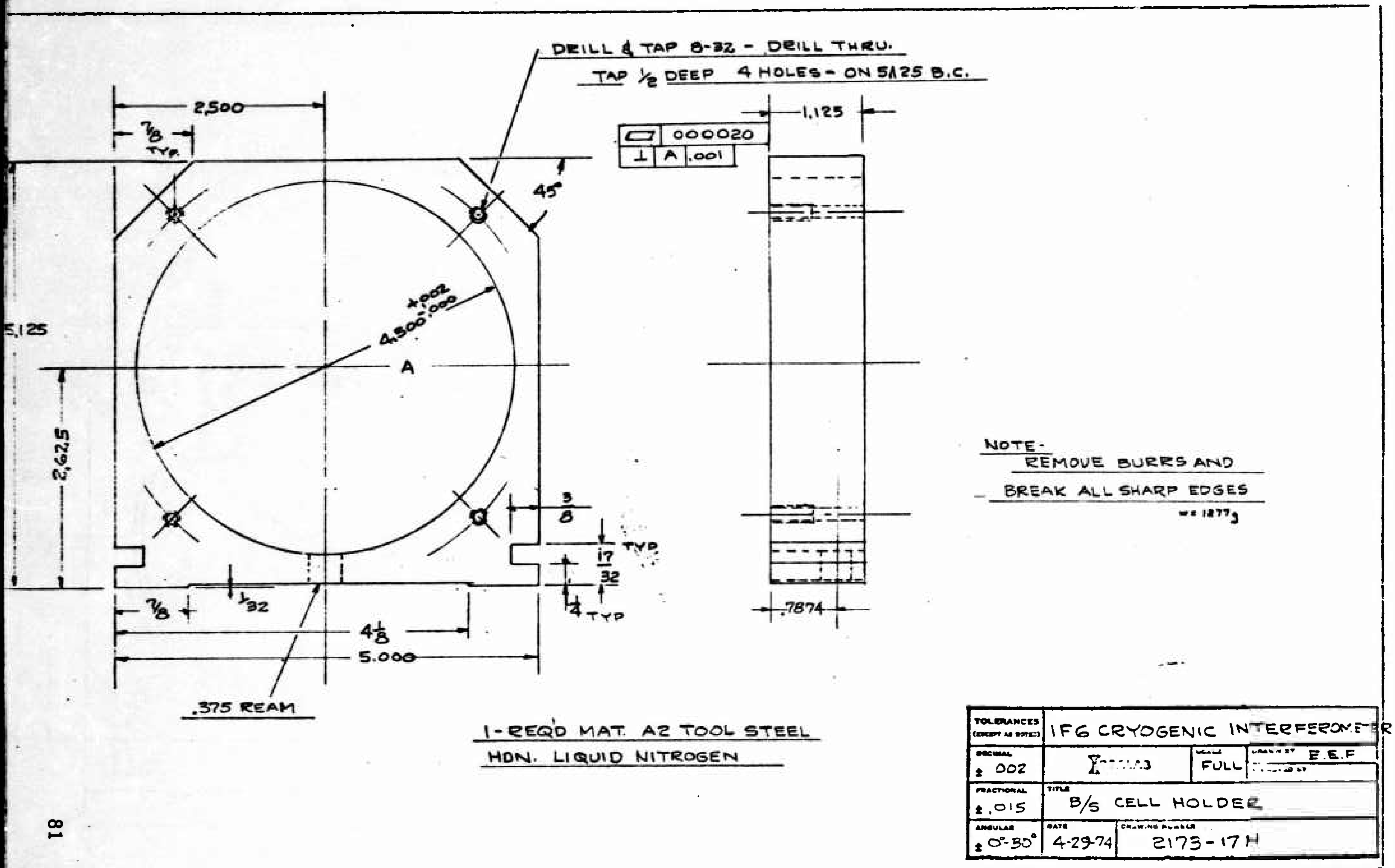
TOLERANCES	CRYOGENIC INTERFEROMETER
DECIMAL ± .002	SCALE FULL
FRACTIONAL ± .005	TITLE BEAMSPLITTER ASSEMBLY
ANGULAR ± 0°-30'	DRAWING NUMBER 2173-15

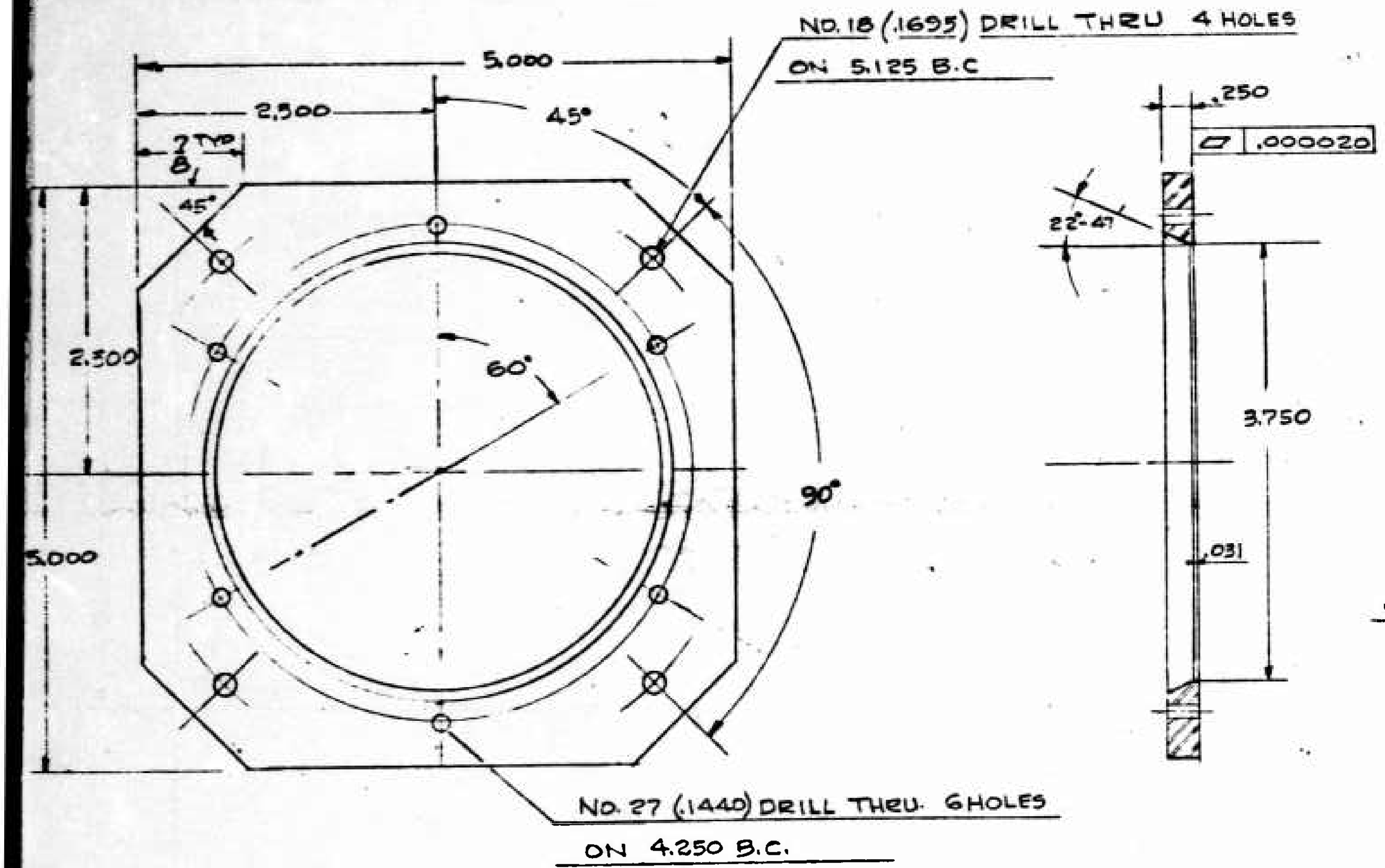


A 6 HOLES DRILL { TAP 6-40 - .625 DEEP AS SHOWN
B 6 HOLES DRILL { TAP 6-40 - .625 DEEP ON BOTH SIDES
C VENT ALL HOLES - 1/16 DRILL 12 PLACES - 1/2" DOWN ON SIDES
D 2.000 NOMINAL - TO BE BORE FOR B/S FIT
E LEAVE .005+ ON THICKNESS FOR GRINDING
F +.000-.004

MATERIAL A-2 STEEL
W=560.2 g

TOLERANCES (EXCEPT AS NOTED)	10 CM CRYO INTERFEROMETER		
DECIMAL ±	ΣDEALERS	SCALE	DRAWN BY JLP / APPROVED BY JLP
FRACTIONAL ± .020	TITLE BEAMSPLITTER CELL		
ANGULAR ± [illegible]°	DATE 4-22-76	DRAWING NUMBER 2173-16A	


DRILL & TAP 8-32 - DRILL THRU.
TAP ½ DEEP 4 HOLES - ON 5.125 B.C.
2.500
7/8 TYP.
45°
+.002 4.500 -.000
A
5.125
2.625
3/8
17/32 TYP
1/4 TYP
1/32
7/8
4 1/8
5.000
.375 REAM
000020
⊥ A .001
1.125
.7874
1-REQ'D MAT. A2 TOOL STEEL
HDN. LIQUID NITROGEN
NOTE-
REMOVE BURRS AND
BREAK ALL SHARP EDGES
TOLERANCES (EXCEPT AS NOTED)
DECIMAL ± .002
FRACTIONAL ± .015
ANGULAR ± 0°-30'
IFG CRYOGENIC INTERFEROMETER
SCALE FULL
DRAWN BY E.E.F
TITLE B/S CELL HOLDER
DATE 4-29-74
DRAWING NUMBER 2173-17H



NOTE

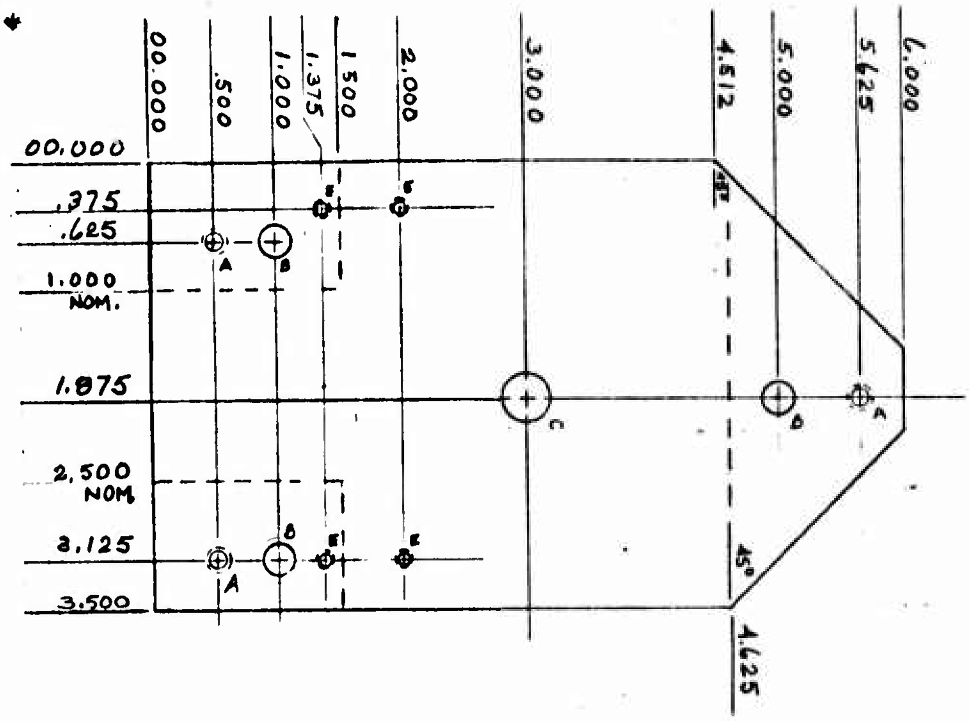
REMOVE BURRS AND

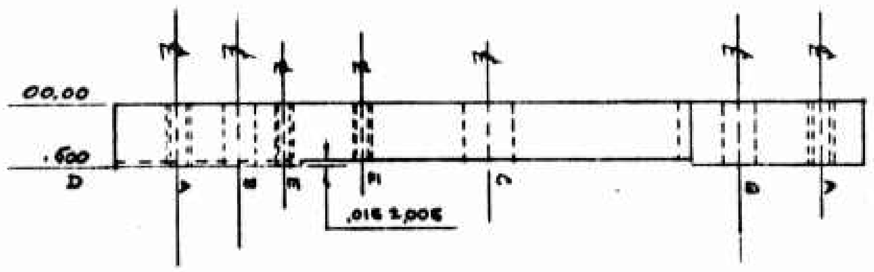
BREAK ALL SHARP EDGES

1-REQ'D MAT. A2 TOOL STEEL

HON. LIQUID NITROGEN

TOLERANCES (EXCEPT AS NOTED)	CRYOGENIC INTERFEROMETER		
DECIMAL ± .002		SCALE FULL	DRAWN BY E E F
FRACTIONAL ± .015	TITLE B/S MOUNTING PLATE		
ANGULAR ± 0° 30'	DATE 4-30-74	DRAWING NUMBER 2173-18	





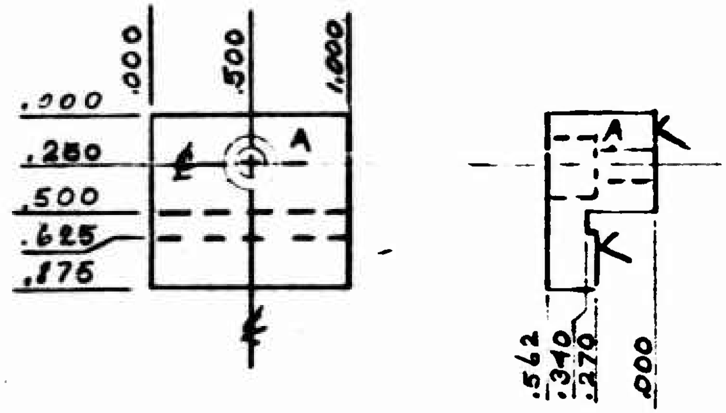
Notes

- A DRILL & TAP 3 HOLES 8-32
- B DRILL 3 CL. HOLES FOR 1/4-20 BOLT
- C DRILL & REAM FOR 3/8 DOWEL
- D ALLOW 0.012" FOR FINISH GRINDING
- E DRILL & TAP 4 HOLES 6-32

SEE REFERENCE PRINT FOR MORE NOTES.

MATERIAL A-2 STEEL W=1264.6g
HARDEN

TOLERANCES (EXCEPT AS NOTED)	2-1-73 10 CM CRYO		
DECIMAL ±	Tie-ALAB	SCALE FULL	DRAWN BY TLP
FRACTIONAL ±	TITLE B/S ASSY MOUNTING PLATE		
ANGULAR ±	DATE MAY 5, '75	DRAWING NUMBER 2173-18 A	



NOTES

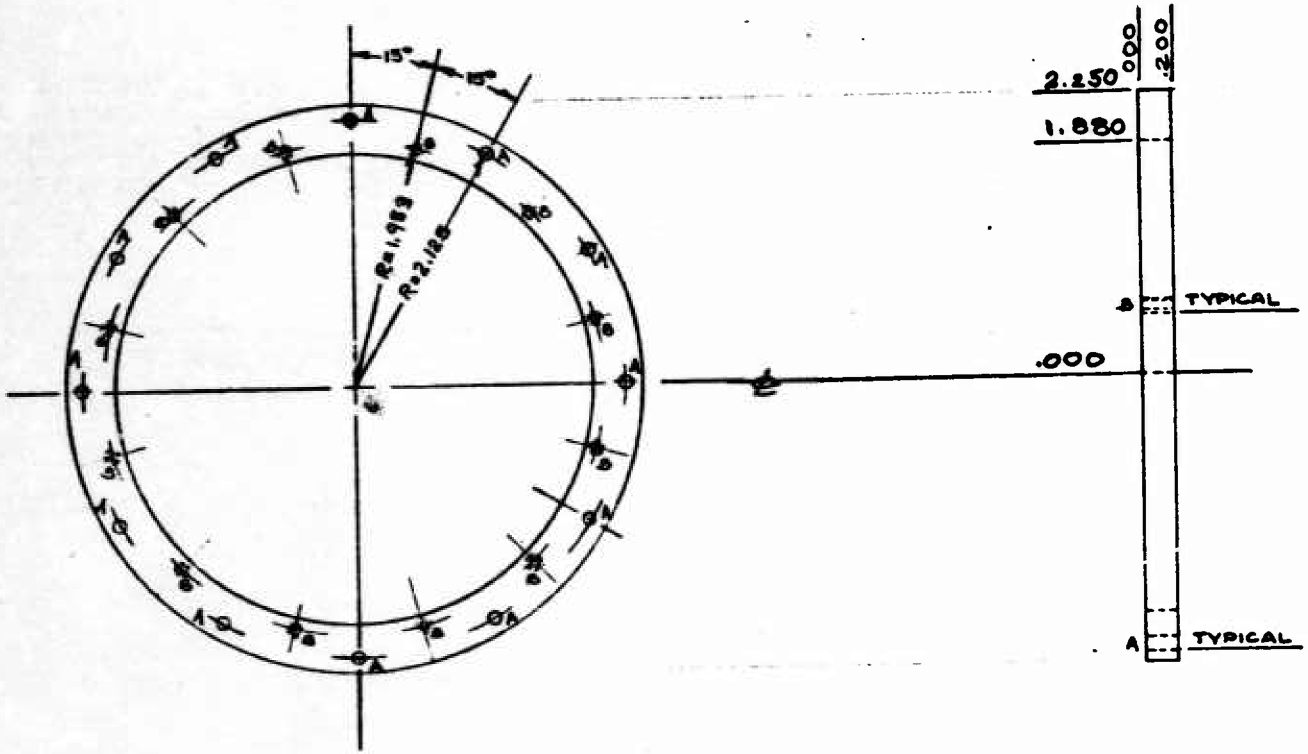
A. DRILL AND C/BORE FOR 8-32

B. ✓ SURFACES WILL BE GROUND TO FIT AT ASSEMBLEY TIME

MATERIAL A2 STEEL

2 REQUIRED

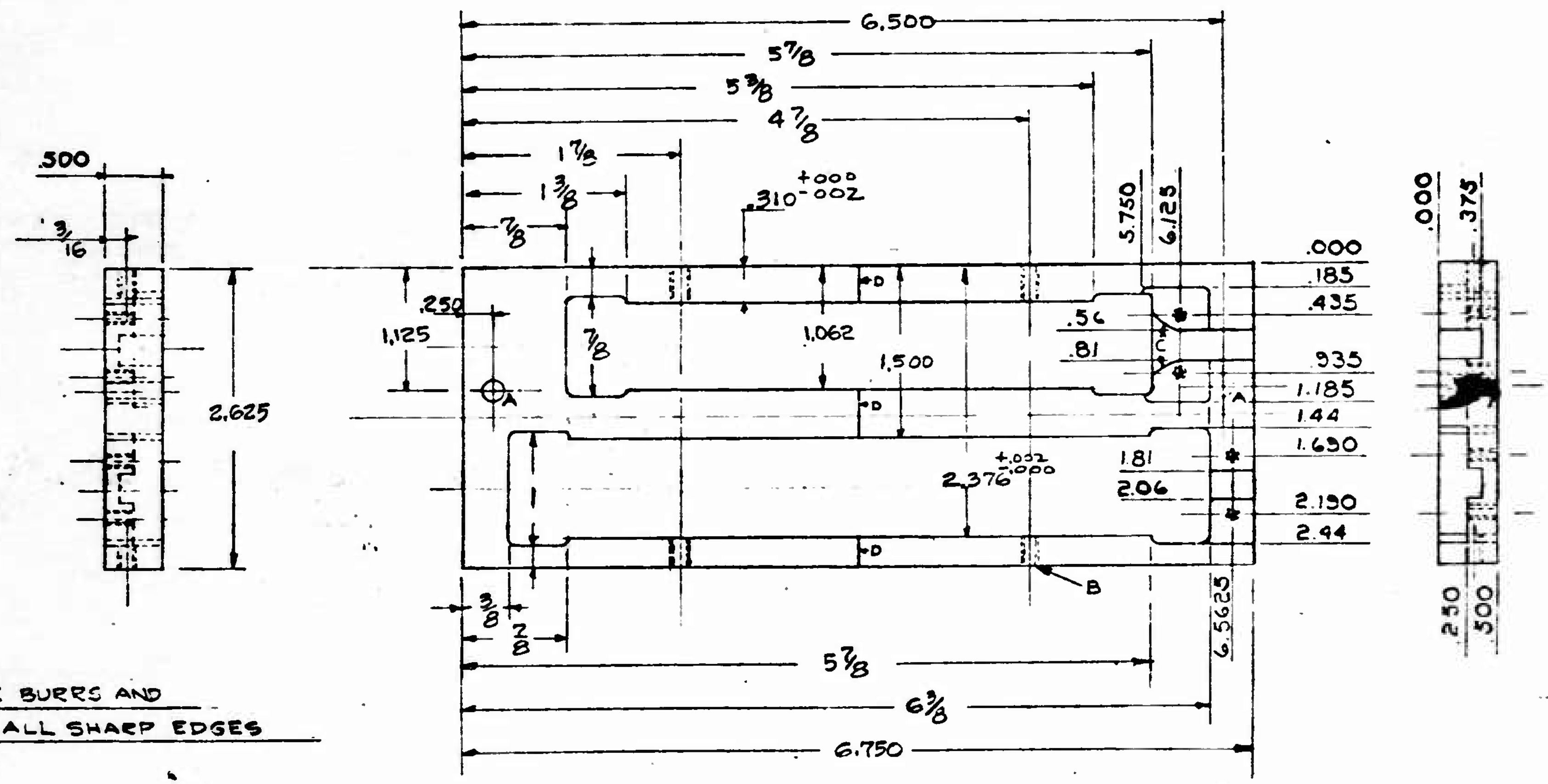
TOLERANCES (EXCEPT AS NOTED)	10 CM CRYO UNIT		
DECIMAL ± .002	LAB	SCALE	DRAWN BY JLP
FRACTIONAL ±	HOLD DOWN CLAMPS B/S		
±	75 JUNE 12	2-1-73 — 19	



NOTES
A 12 HOLES EQUALLY SPACED ON 2.125 RAD. BC - DRILL CL FOR 6-40 SCREWS
B 12 HOLES EQUALLY SPACED ON 1.953 RAD. BC - DRILL { TAP FOR 6-40 (.116)
w: 189.35 g

MATERIAL A-2 STEEL

TOLERANCES (EXCEPT AS NOTED)	10 CM CRYO INTERFROMETER
DECIMAL ±	SCALE FULL
FRACTIONAL ±	TITLE B/S SPRING RING
ANGULAR ±	DATE 4-28-76 DRAWING NUMBER 2173-20



REMOVE BURRS AND

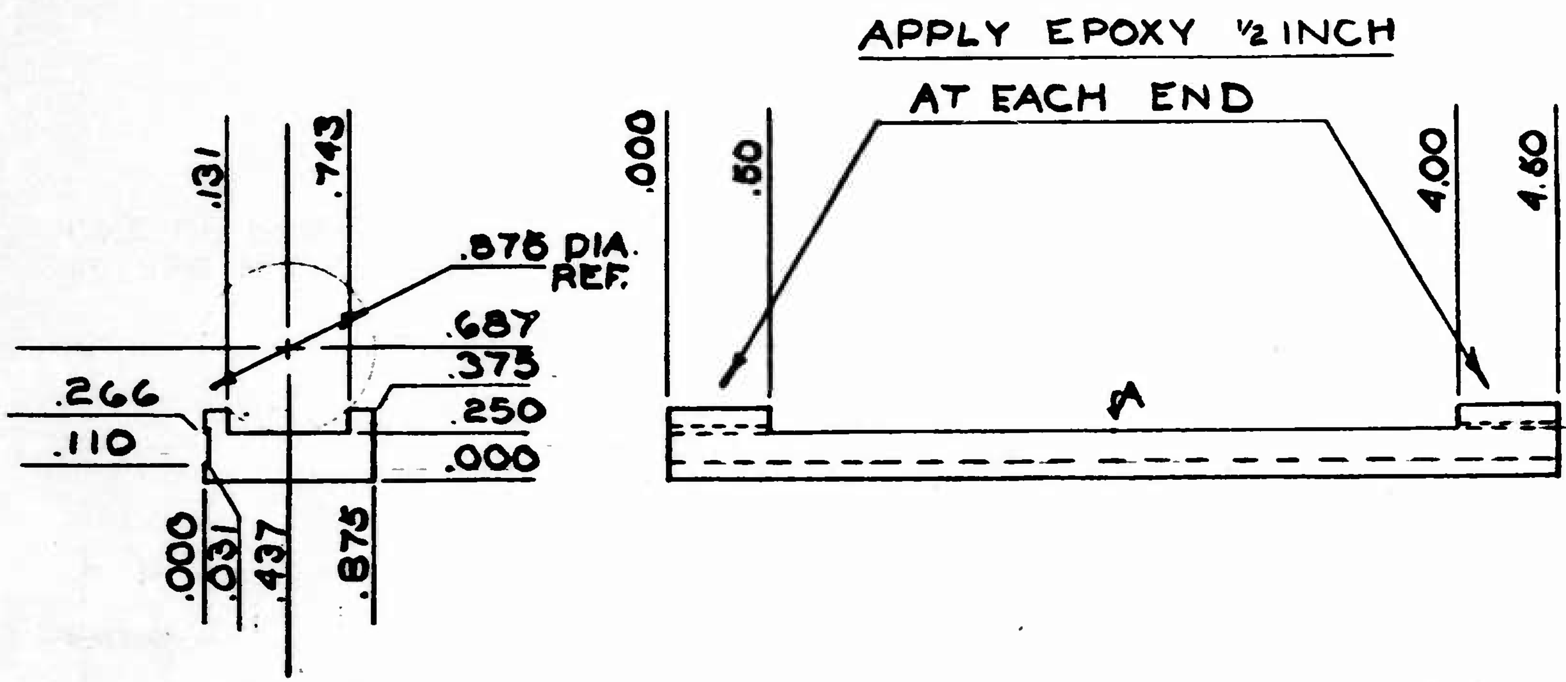
BREAK ALL SHARP EDGES

1-REQ'D MAT. A2 TOOL STEEL

NOTES:

A 2 HOLES NO.7 (.201) DRILL
B 8 HOLES #6-32 TAP THRU
C HAND MILLED
D SCRIBE A LINE HALF WAY TO LINE UP PARTS

TOLERANCES (EXCEPT AS NOTED)			
DECIMAL ± .002	CRYOGENIC INTERFEROMETER		
FRACTIONAL ± 1/64	[illegible]	SCALE FULL	DRAWN BY E.E.F
ANGULAR ± 0°-30'	TITLE TACH. & TRANSDUCER CRADLE		
	DATE 9-16-74	DRAWING NUMBER 2173 - 21	



NOTES

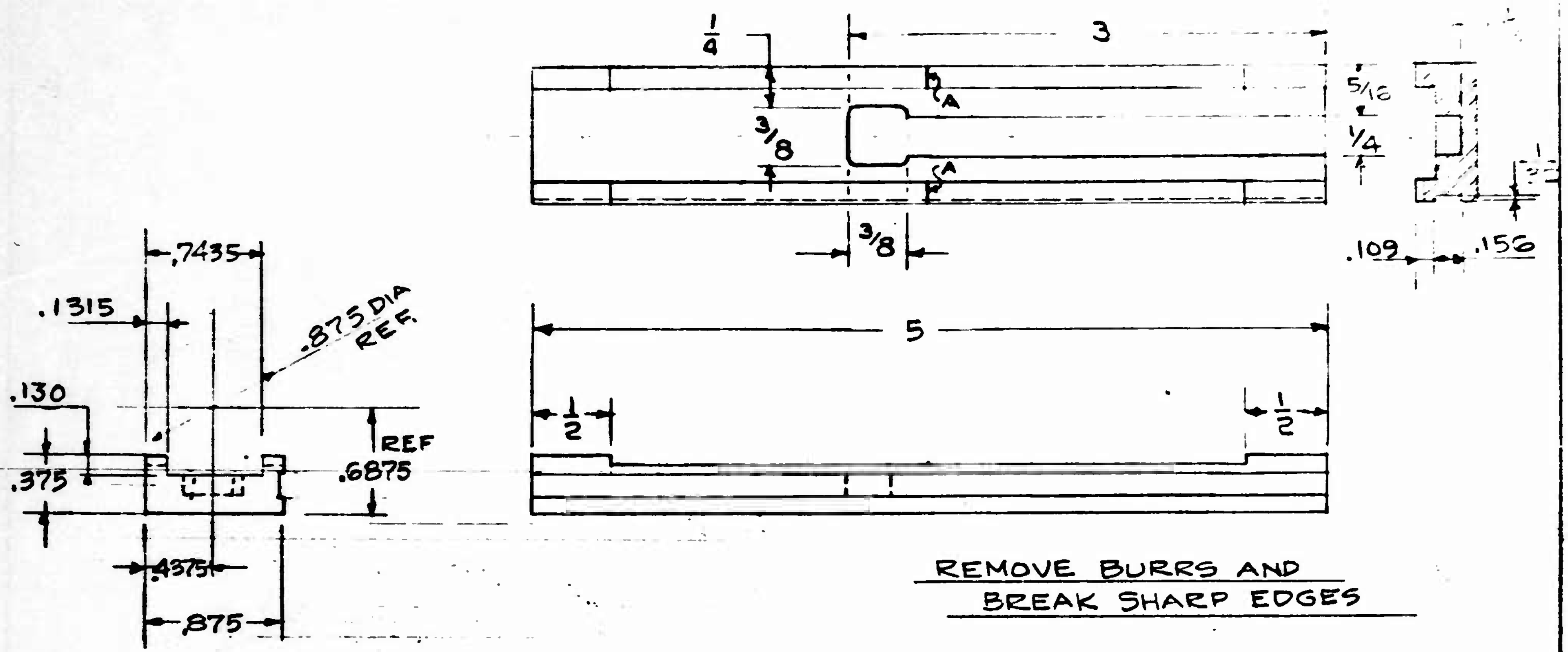
A SCRIBE A LINE HALF WAY TO LINE UP PARTS

REMOVE BURRS & BREAK EDGES

TWO PLACE DIM. TOL. ±.01

MTL. A2 TOOL STEEL 1 REQ

TOLERANCES (EXCEPT AS NOTED)	CRYO INTERFEROMETER	
DECIMAL ±	FULL	RS
FRACTIONAL ±	TRANSDUCER HOLDER	
ANGULAR ±	2/3/77	2173-22



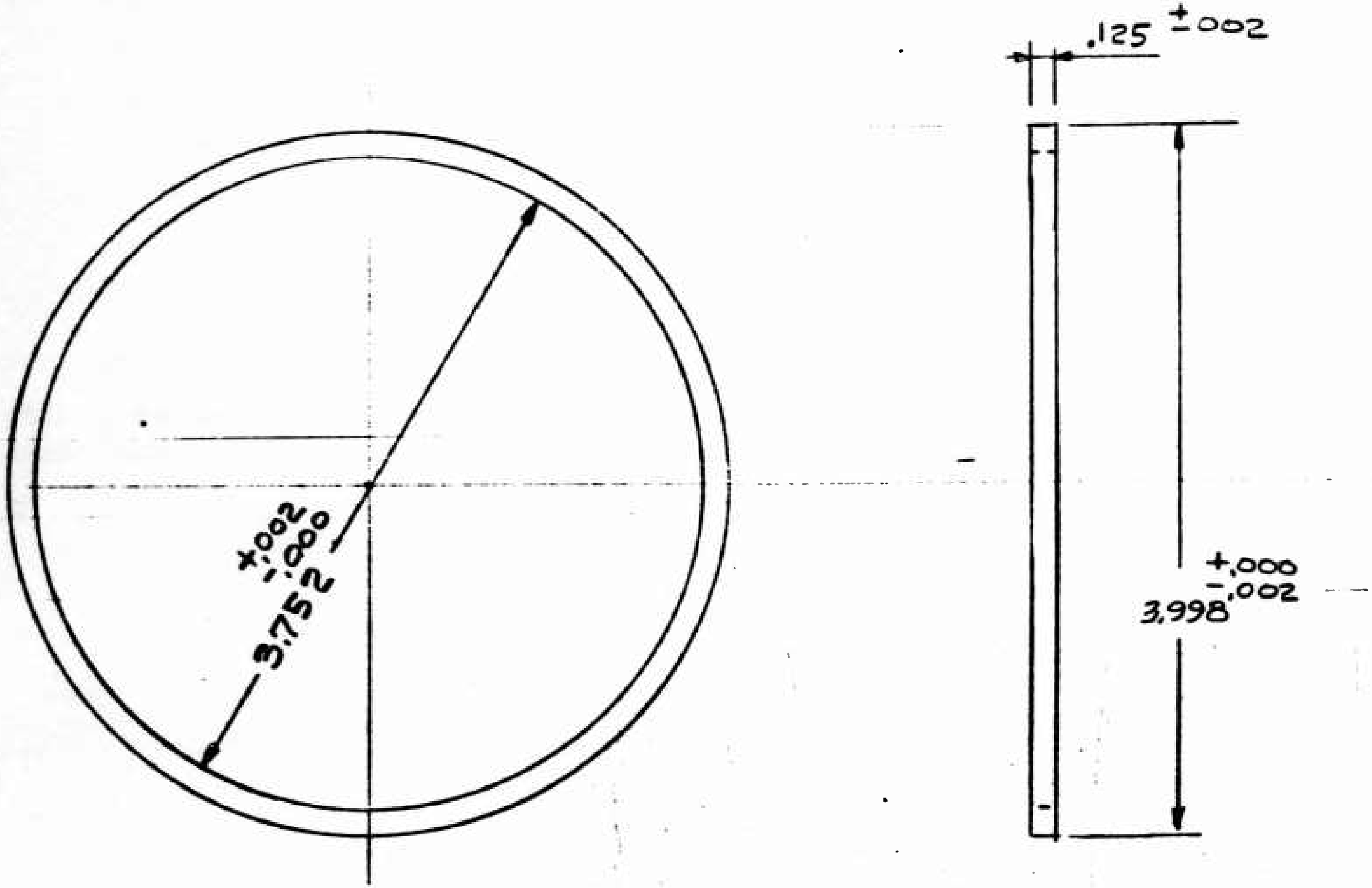
REMOVE BURRS AND
BREAK SHARP EDGES

1-REQ'D MAT. A2 TOOL STEEL

NOTES

A SCRIBE A LINE HALF WAY TO LINE UP PARTS

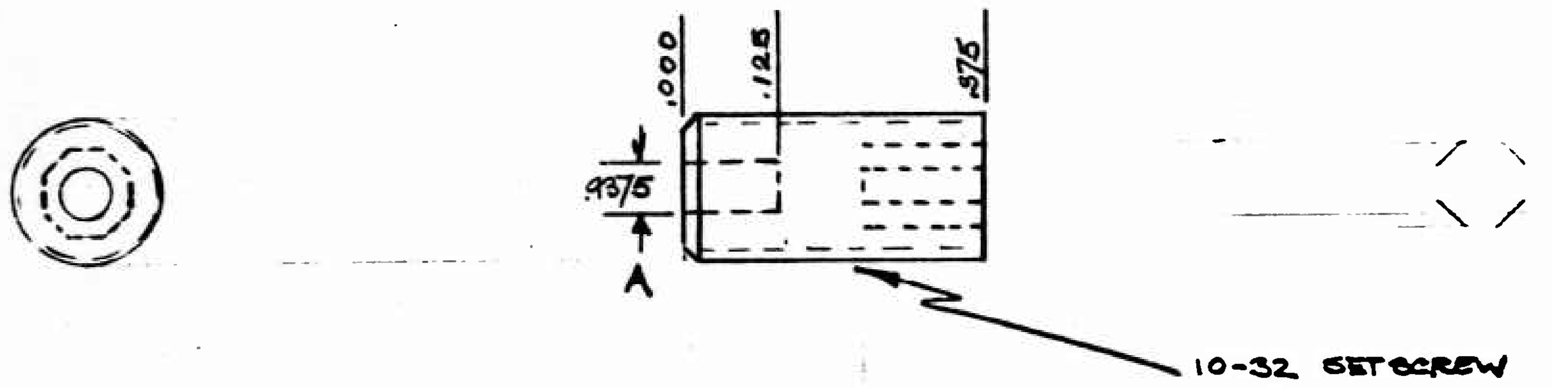
TOLERANCES (EXCEPT AS NOTED)	CRYOGENIC INTERFEROMETER		
DECIMAL ± .002	[illegible]	FULL	DRAWN BY E.E.F.
± 1/64	TACHOMETER HOLDER		
ANGULAR ± 0°30'	DATE 3-17-74	2173-23	



1-REQD MAT. A2 TOOL STEEL

TOLERANCES	CRYOGENIC INTERFEROMETER
	IDEALAB E.E.F
	SPACER B/S
	3-11-75 2173-24

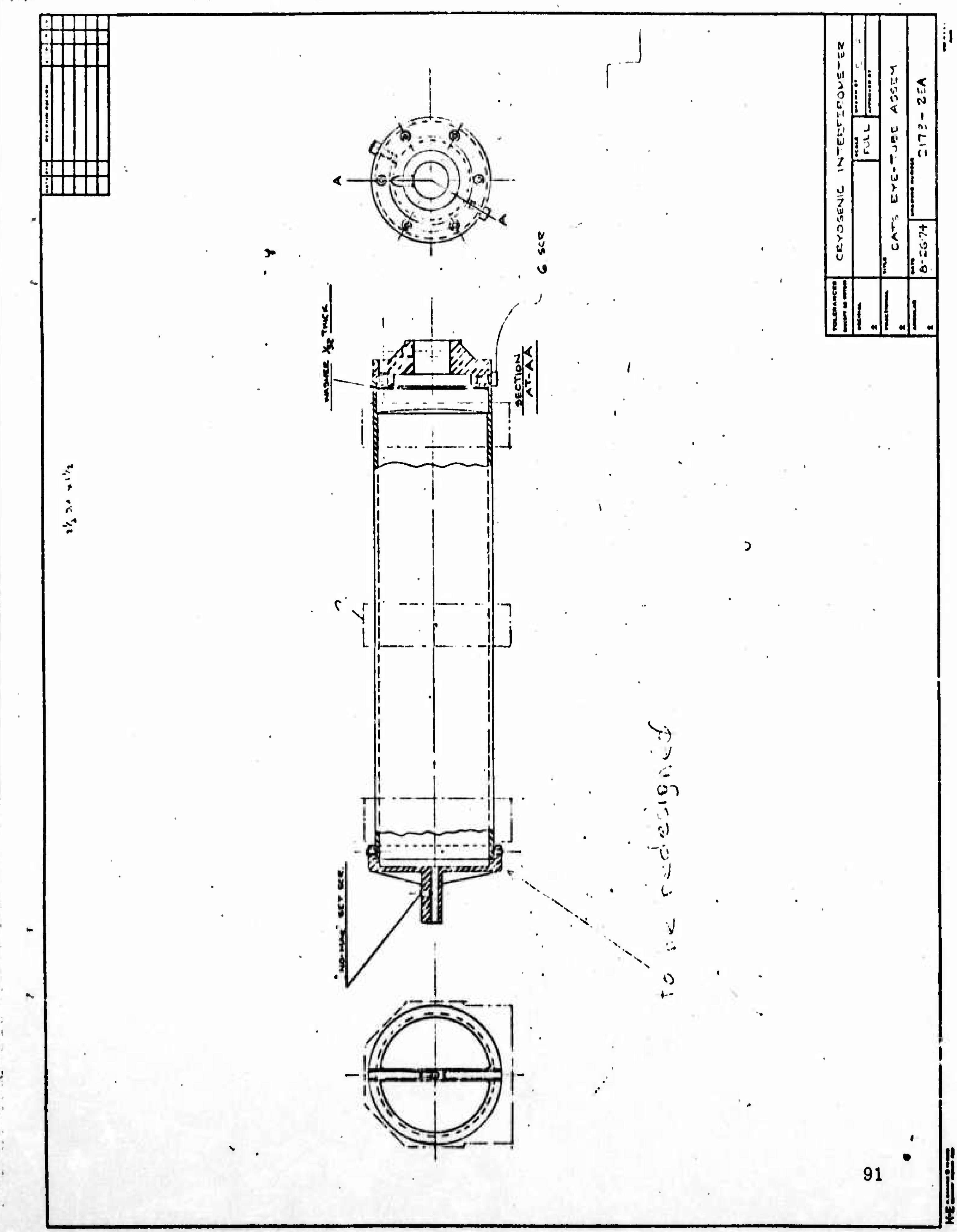
SPRING LEE
C1-0128-3 SS
STAINLESS STEEL
FREE LENGTH .025
RATE 11 lbs/IN.
SOLID HEIGHT .093



NOTE:

1. THESE SET SCREW HAVE TO BE ANNEALED BEFOR DRILLING
2. DRILL 1 HOLE AS SHOWN

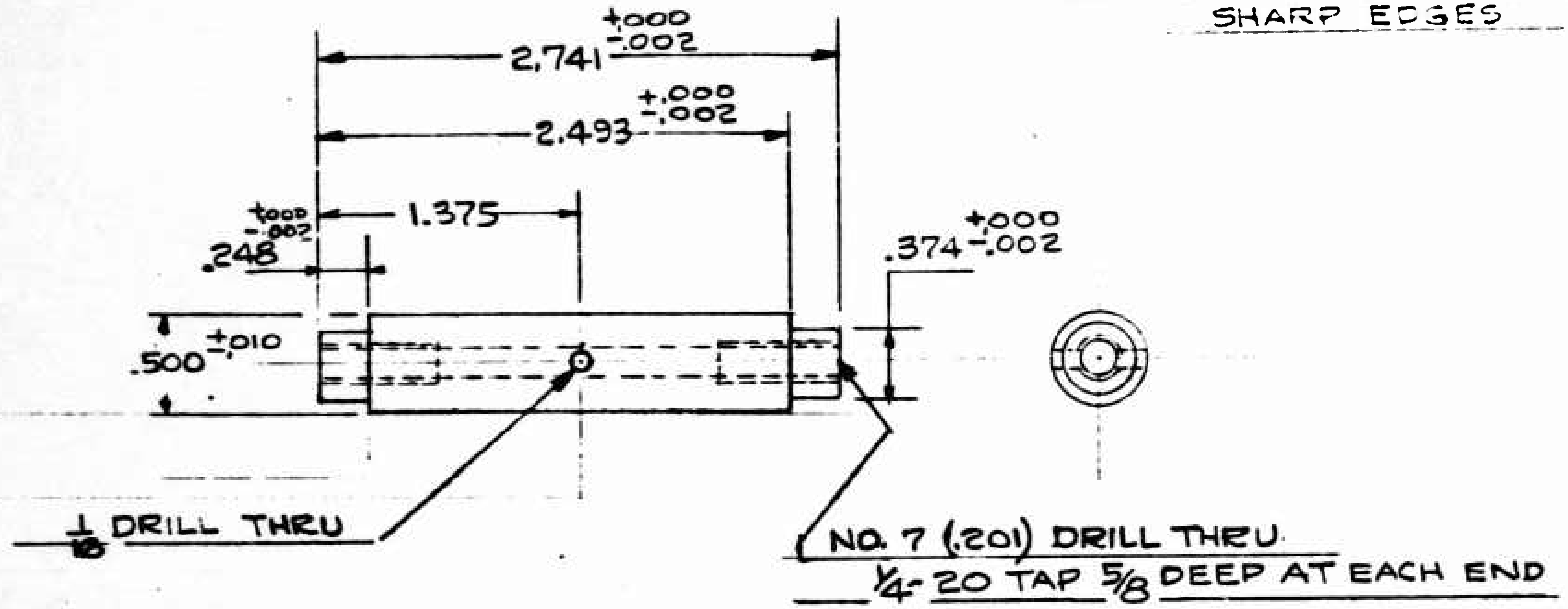
TOLERANCES (EXCEPT AS NOTED)	10 CM CRYO UNIT		
DECIMAL ±	ΣCSALAB	SCALE 4:1	DRAWN BY JAP / APPROVED BY
FRACTIONAL ±	TITLE SPRING PUSHER SET SCREW		
ANGULAR ± °	DATE	DRAWING NUMBER 2173-25	



CRYOGENIC INTERFEROMETER
FULL
CAT'S EYE-TUBE ASSEM
8-26-74
2173-2EA
WASHER 1/32 THICK
SECTION AT-AA
6 SCR
"NO-MAR" SET SCR

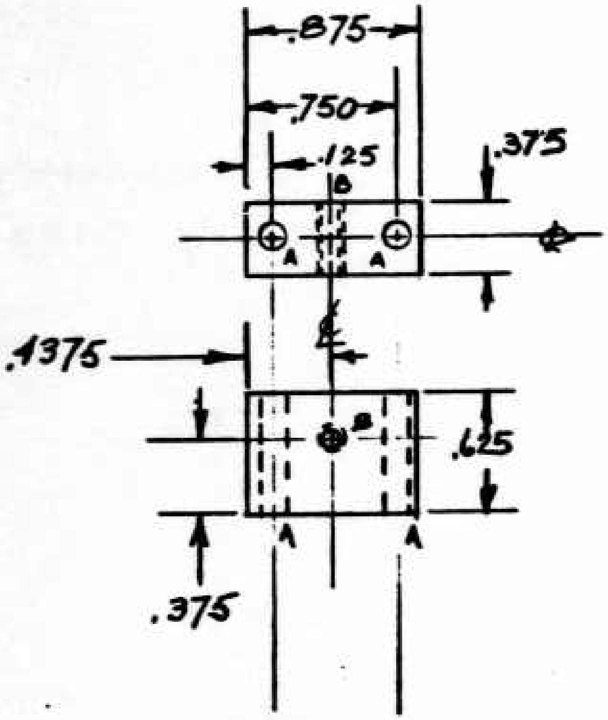
NOTE -

REMOVE BURRS & BREAK SHARP EDGES



4 REQD MAT. 304 STAINLESS STEEL

TOLERANCES (EXCEPT AS NOTED)	CRYOGENIC INTERFEROMETER		
DECIMAL ± .002	[illegible]	SCALE FULL	DRAWN BY E.E.F / APPROVED BY
FRACTIONAL ± .015	TITLE MOTOR SEPARATOR		
ANGULAR ±	DATE 4-3-73	DRAWING NUMBER 2173-26	



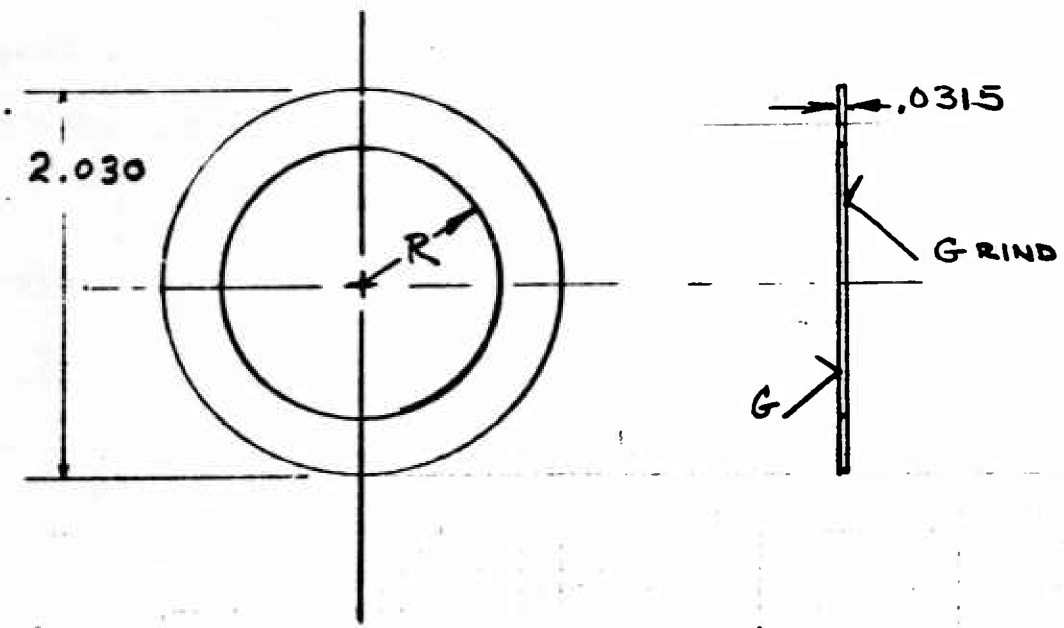
NOTE A 2 HOLES DRILL CL. FOR 6-32

B 1 HOLE DRILL & TAP FOR 1/4-28

C MATERIAL A-2 STEEL

TOLERANCES (EXCEPT AS NOTED)	10CM CRYO 2-1-73		
DECIMAL ± .001		SCALE FULL	DRAWN BY JLP
FRACTIONAL ±	B/S ADJUSTMENT FIXTURE		
ANGULAR ±	DATE MAY 6,75	2-1-73 - 27	

	10 CM CRYO		2173
002	IDEALAB	1:1	DH JLD
	MIRROR WASHER		
OCT. 21, 75	2173-28		



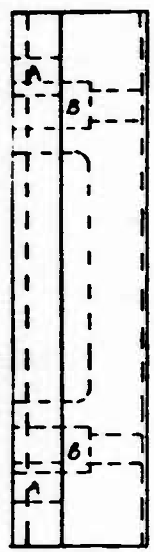
MATERIAL A-2 STEEL
2 REQUIRED

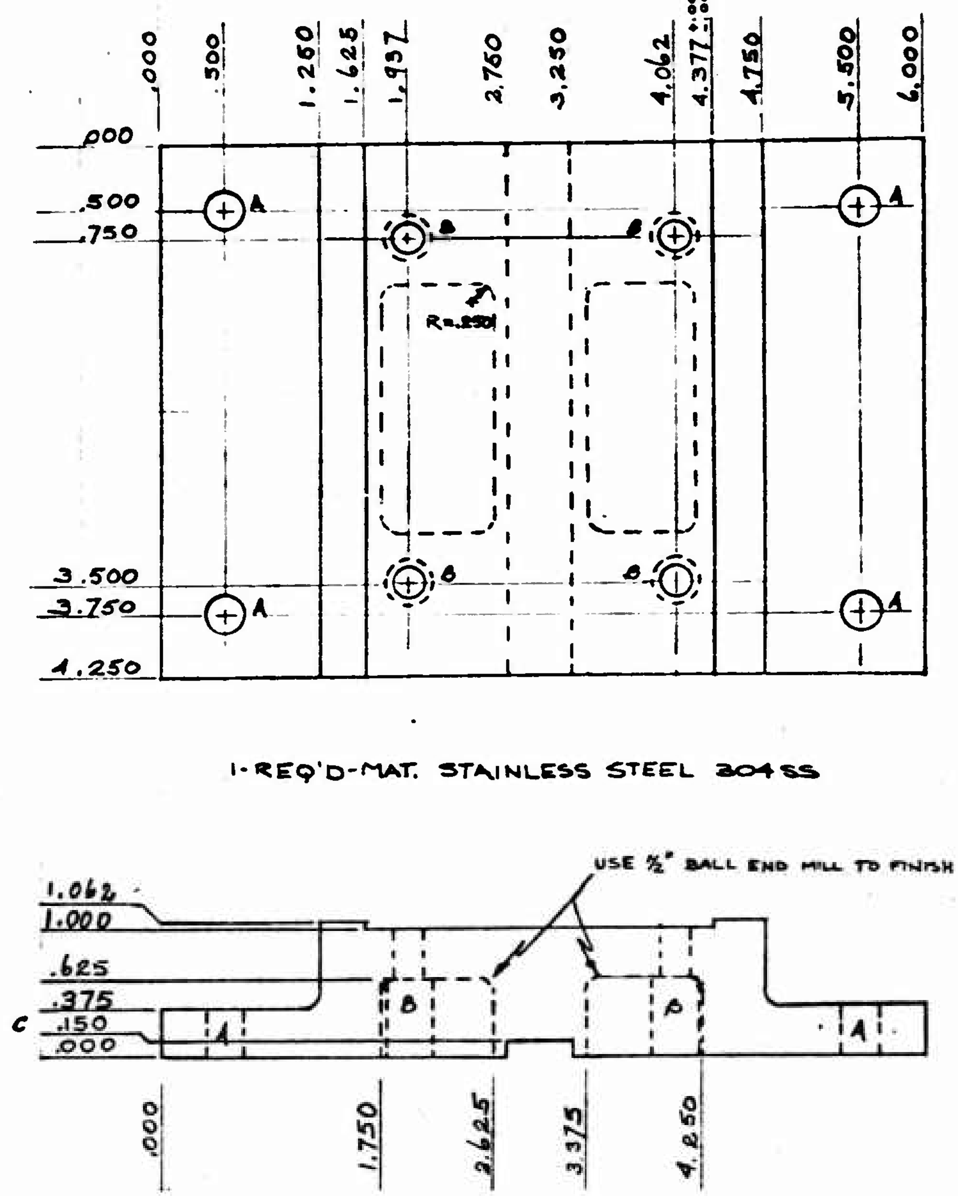
R = .6875

NOTES:

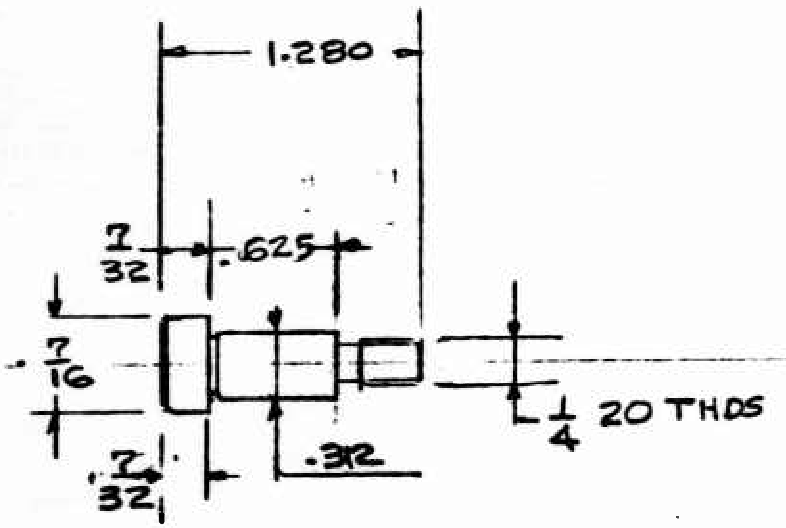
A. 4 HOLES - H DRILL

B. 4 HOLES DRILL & C'BORE FOR ¼ SOC. HD. SCREW





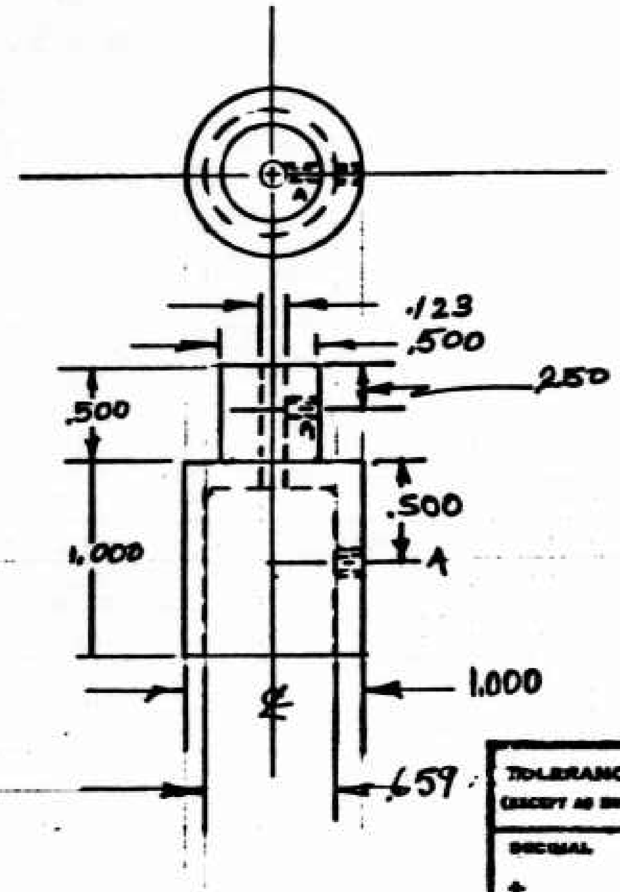
TOLERANCES	CRYOGENIC INTERFEROMETER		
DECIMAL ± .002		SCALE 1:1	DRAWN BY JLP / APPROVED BY
FRACTIONAL ±	TITLE MOTOR BASE		
ANGULAR ±	DATE 6/9/75	DRAWING NUMBER 2173-29A	



4-REQD. SHOULDER SCR NO. CL 21-SS

PURCHASE FROM HOWELL MACDUFF & CO.
69 SHREWSBURY ST.
BOYLSTON, MASS 01505

TOLERANCES	CRYOGENIC INTERFEROMETER
±	E.E.F
±	MOTOR BASE BOLTS
ANGULAR ±	2-20-75 2173-30

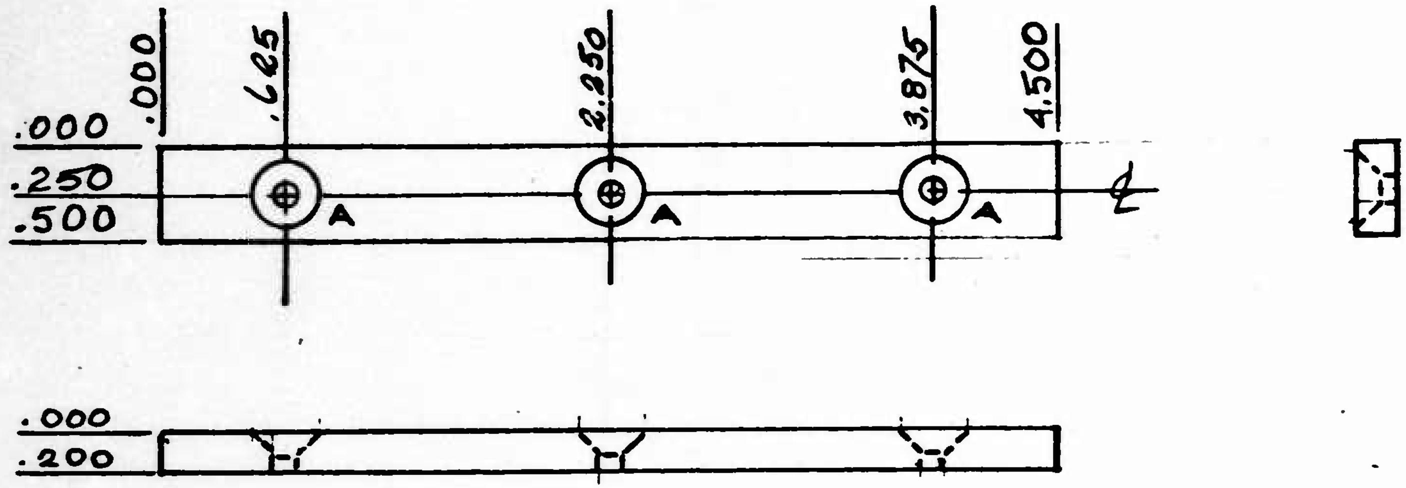


NOTES

MATERIAL Al.

A 2 HOLES 4-40

TOLERANCES (EXCEPT AS NOTED)	10 CM CRYO UNIT		
DECIMAL ±	[illegible]	SCALE FULL	DRAWN BY JLP / APPROVED BY
FRACTIONAL ±	TITLE LIGHT PIPE HOLDER		
ANGULAR ±	DATE JUNE 17,75	DRAWING NUMBER 2-1-73 – 31	



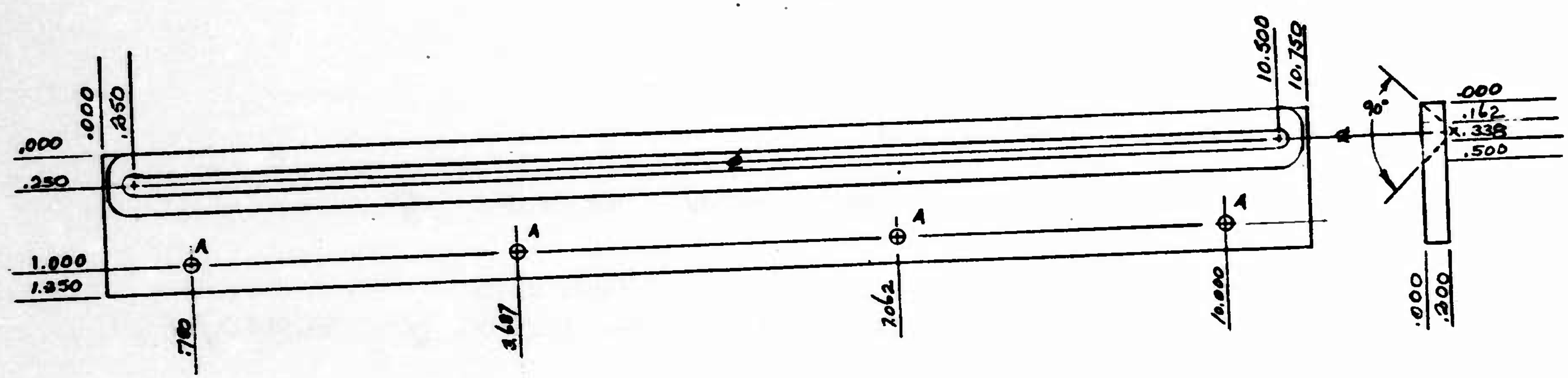
NOTES

A. 3 HOLE - DRILL & COUNTER SINK FOR 10-32 FLAT HEAD SCREWS

1. MATERIAL A-2 STEEL

2. 1 REQUIRED

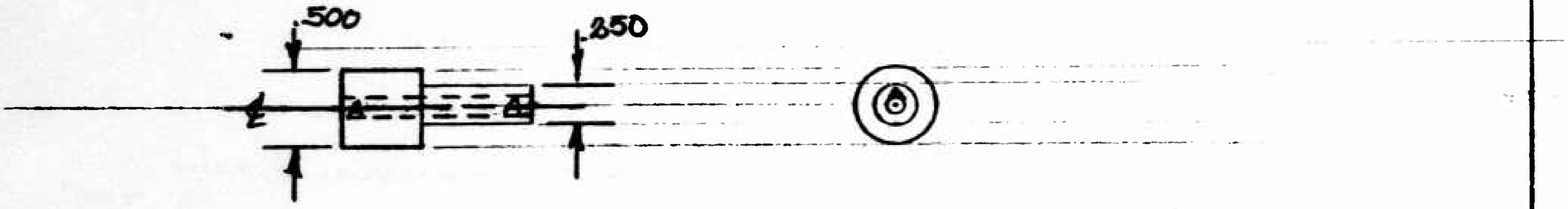
TOLERANCES (EXCEPT AS NOTED)	10 CM CRYO		2-1-73
DECIMAL ±	IDEALAB	SCALE	DRAWN BY JLP / APPROVED BY
FRACTIONAL ±	TITLE MOTOR BASE KEY		
ANGULAR ±	DATE 11-13-75	DRAWING NUMBER 2173-32	



MATERIAL Al

NOTES: A 4 HOLES DRILL CL FOR 6-40 SCREWS

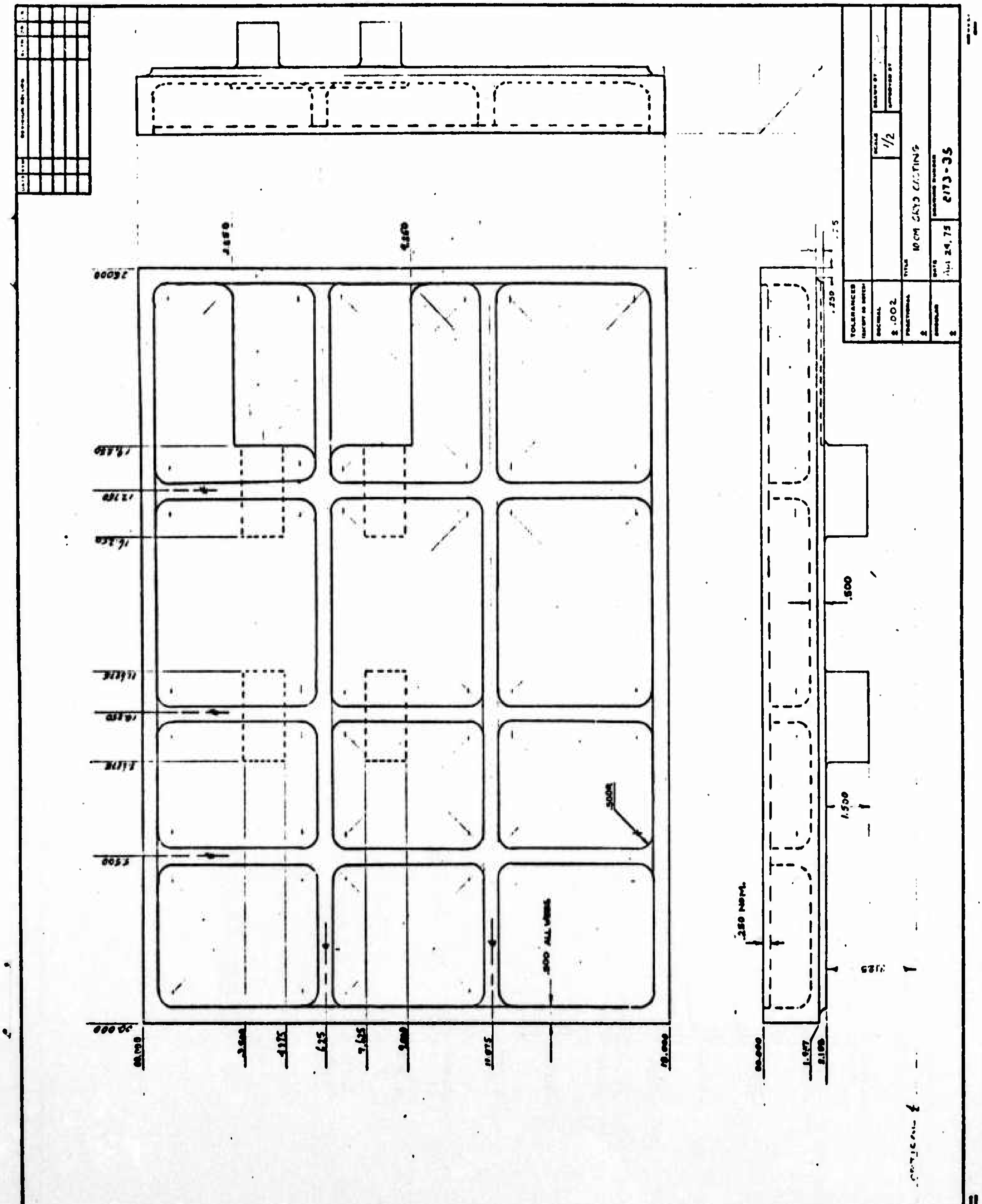
TOLERANCES (EXCEPT AS NOTED)	10 CM CRYO SYSTEM		
DECIMAL ± .002		SCALE	DRAWN BY JLP
FRACTIONAL ±	TITLE DRY LUB. COATING SHIELD #1		
ANGULAR ±	DATE	DRAWING NUMBER 2-1-73-33 (RAILS)	

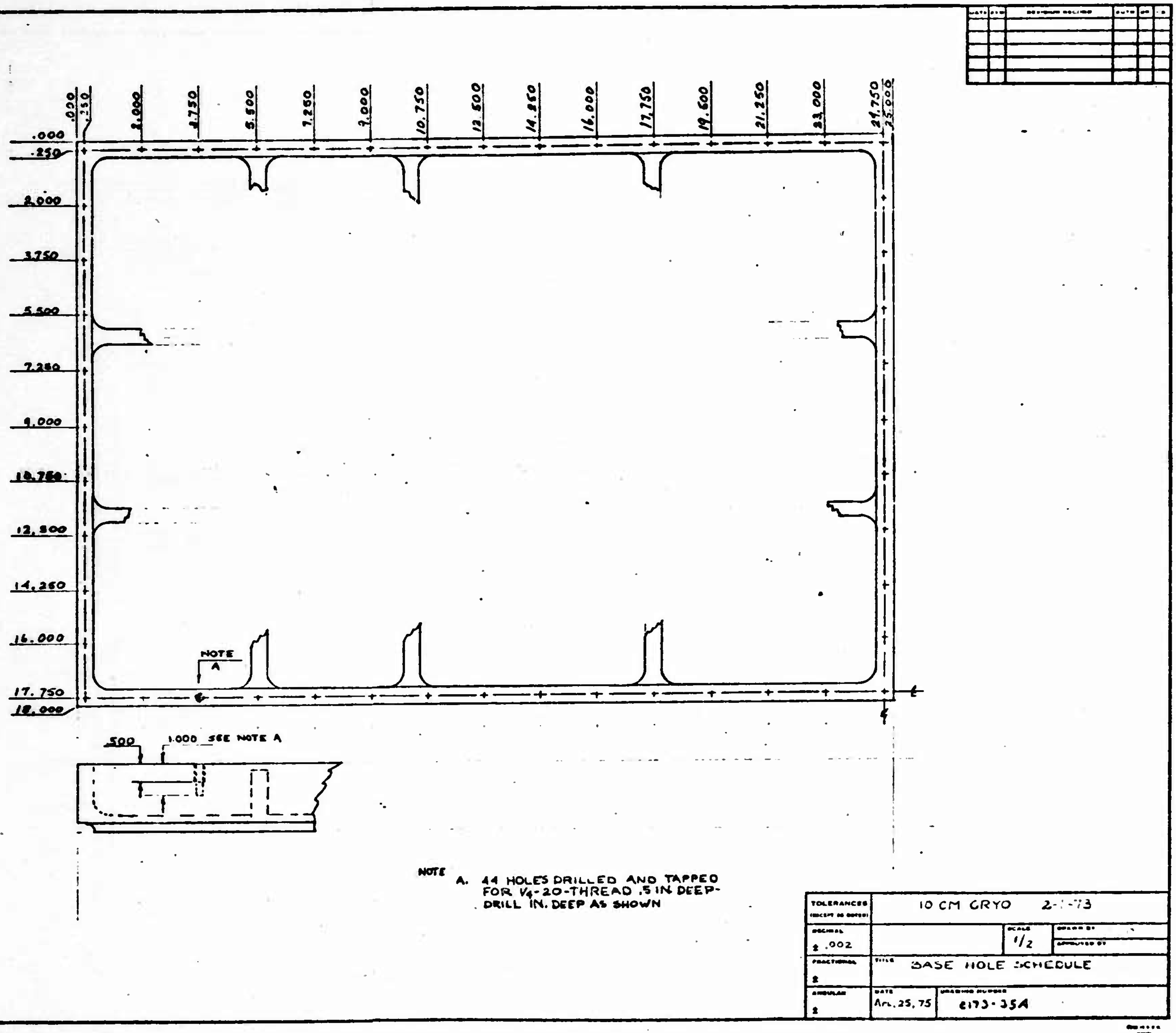


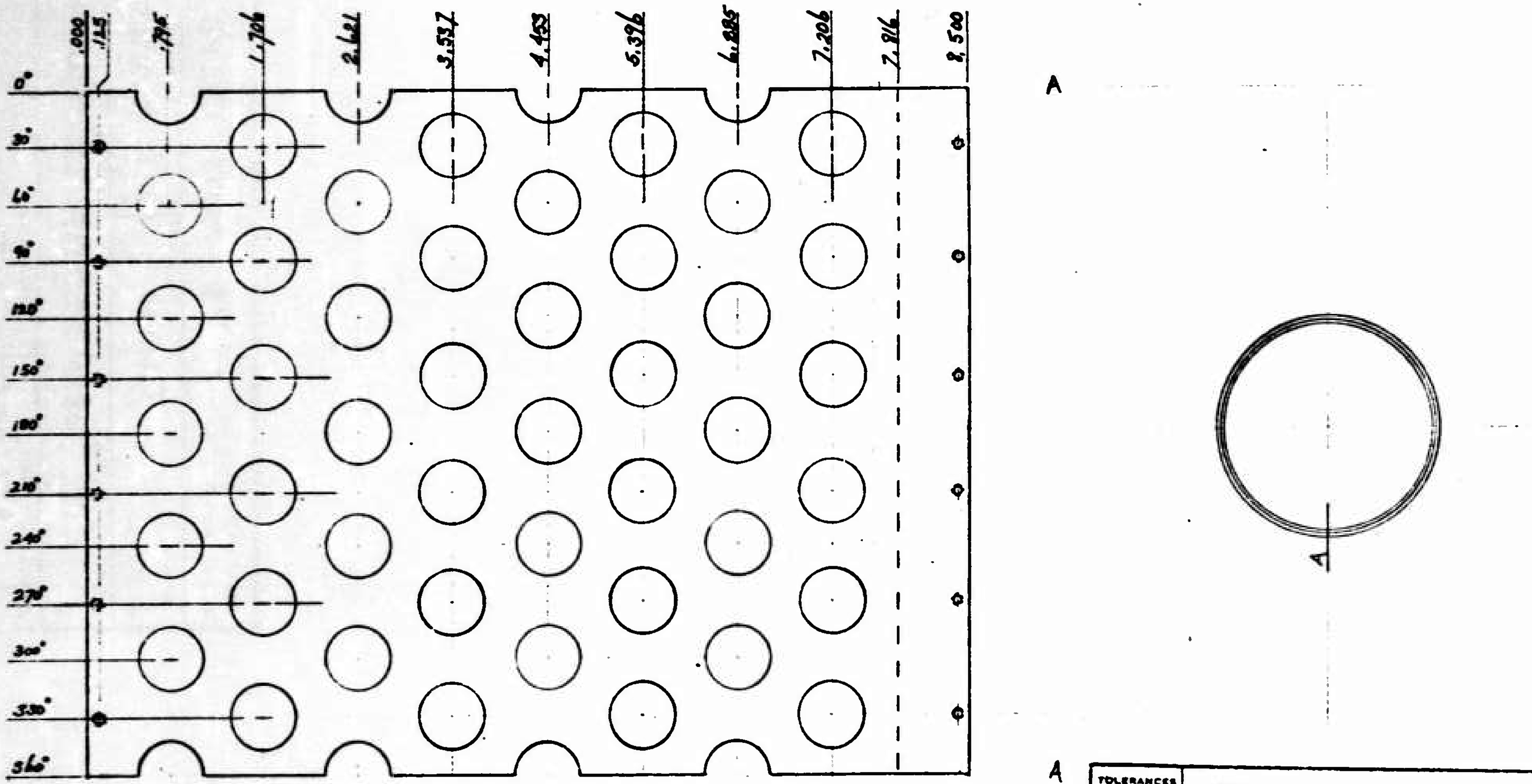
NOTES A DRILL THRU WITH # 28 DRILL (.140 DIA.)

B MATERIAL - MILD STEEL

TOLERANCES (EXCEPT AS NOTED)	10 CM CRYO UNIT		
DECIMAL ±	IDEALAB	SCALE 1:1	DRAWN BY JAP APPROVED BY
FRACTIONAL ±	TITLE PUNCH GUIDE BUSHING		
ANGULAR ±	DATE	DRAWING NUMBER 2173-34	

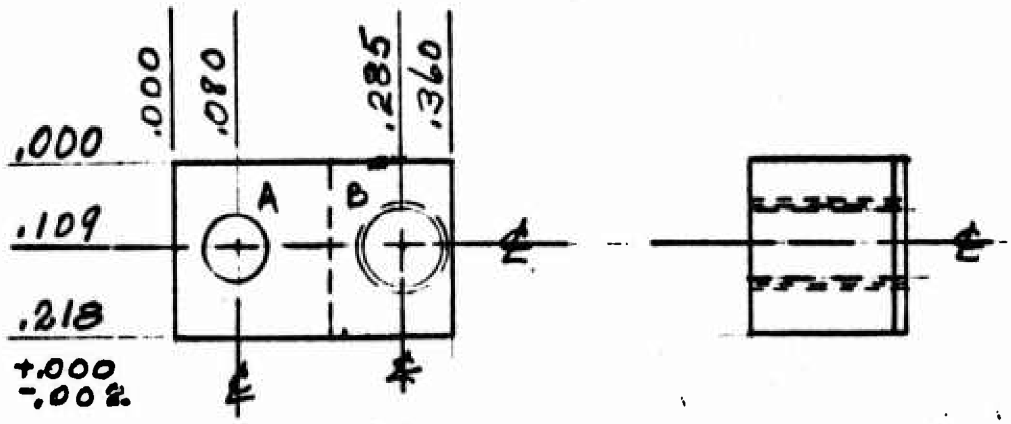

TOLERANCES
1/2
2173-35
.500
1.500
.250 NOM.

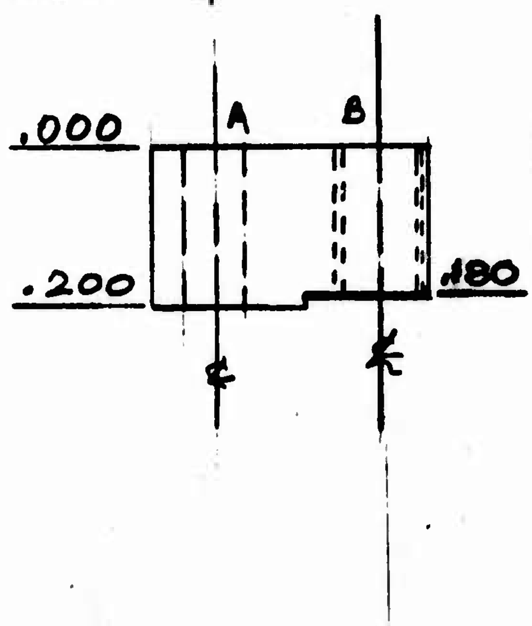

.000
.250
2.000
3.750
5.500
7.250
9.000
10.750
12.500
14.250
16.000
17.750
18.000
3.000
4.750
19.600
21.250
23.000
24.750
25.000
NOTE A
.500
1.000 SEE NOTE A
NOTE A. 44 HOLES DRILLED AND TAPPED FOR 1/4-20-THREAD .5 IN DEEP-DRILL IN. DEEP AS SHOWN
TOLERANCES
10 CM CRYO 2-1-73
± .002
1/2
BASE HOLE SCHEDULE
Ap. 25, 75
8173-35A



NOTES A 48 HOLES-DRILL THRU AND BREAK EDGES .625 DRILL

TOLERANCES (EXCEPT AS NOTED)	CRYOGENIC INTERFEROMETER
DECIMAL ± .005	SCALE 1:1 · DRAWN BY JLP · APPROVED BY
FRACTIONAL ±	TITLE CATS EYE TUBE HOLE SCHEDULE
ANGULAR ±	DATE MAY 4,75 · DRAWING NUMBER 2-:-73 36





NOTES

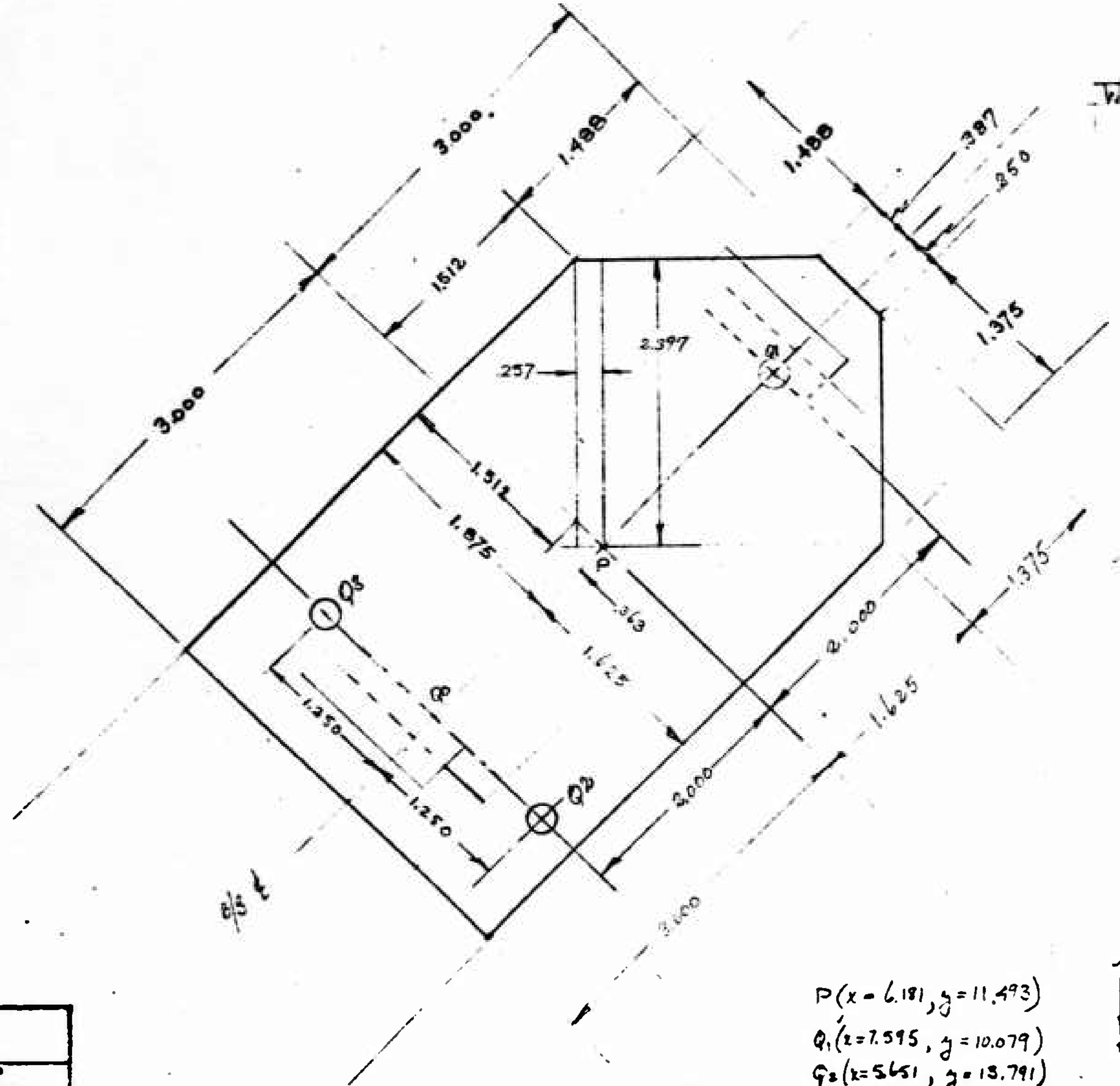
A 1 HOLE #44 DRILL

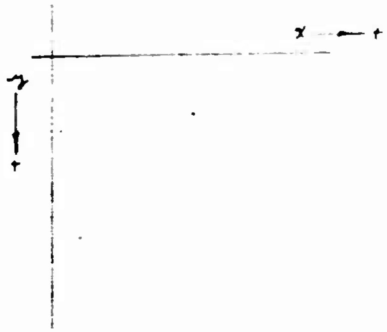
B DRILL & TAP 6-40

TOLERANCES (EXCEPT AS NOTED)	'2-1-73 10CM CRYO		
DECIMAL ±.002	IDEALAB	SCALE 4:1	DRAWN BY JLP APPROVED BY
FRACTIONAL ±	TITLE BEAMSPLITTER CRYSTAL RETAINER		
ANGULAR ±	DATE 1/29/75	DRAWING NUMBER 2173-37	

WERK SHEET

B/S MOUNTING PLATE





P(x = 6.181, y = 11.493)

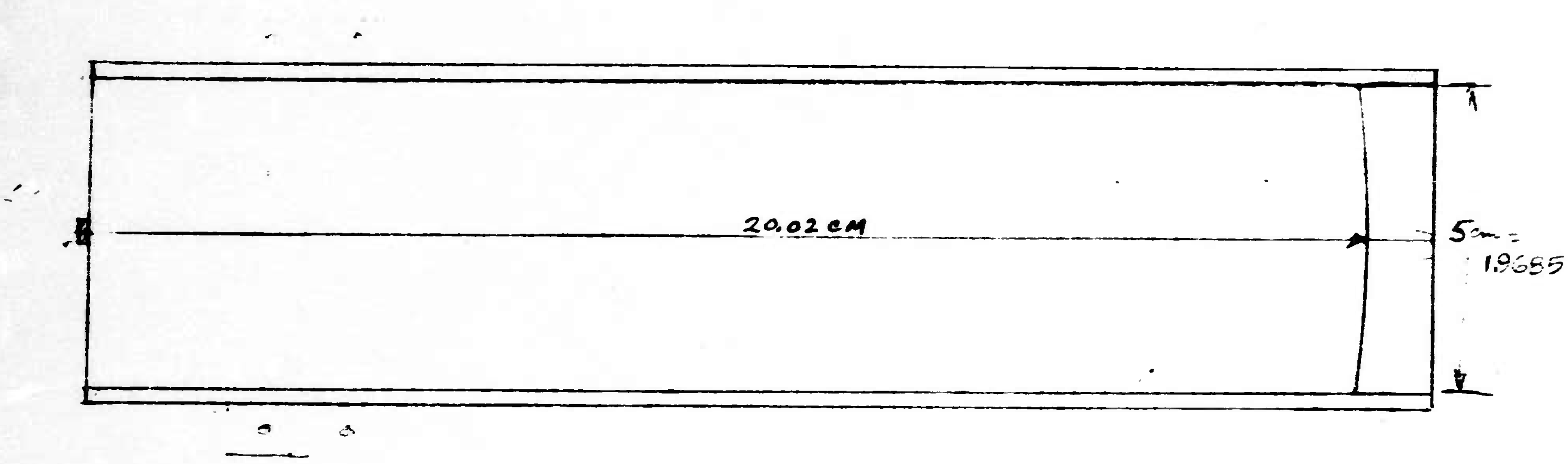
Q1(x = 7.595, y = 10.079)

Q2(x = 5.651, y = 13.791)

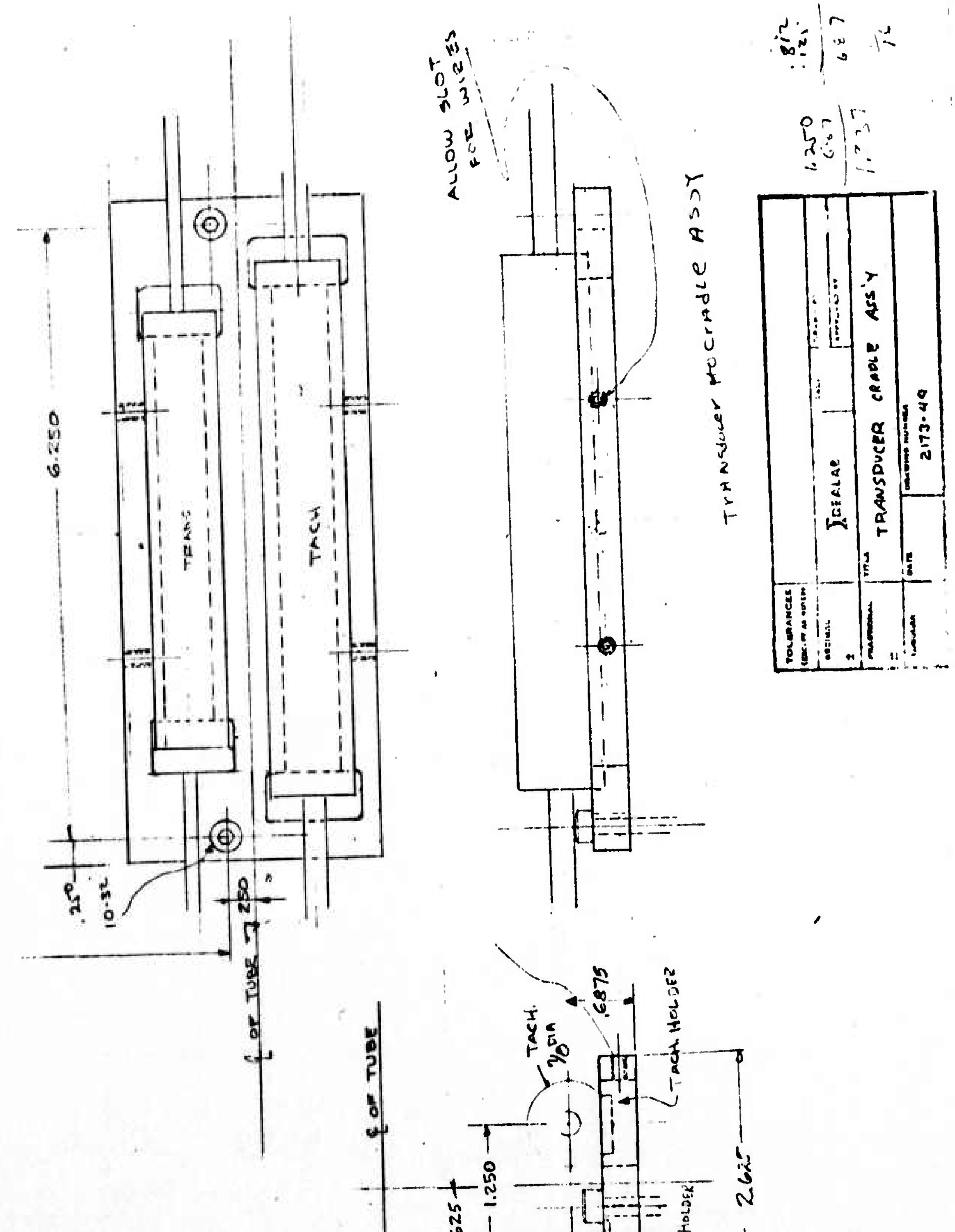
Q3(x = 3.883, y = 12.023)

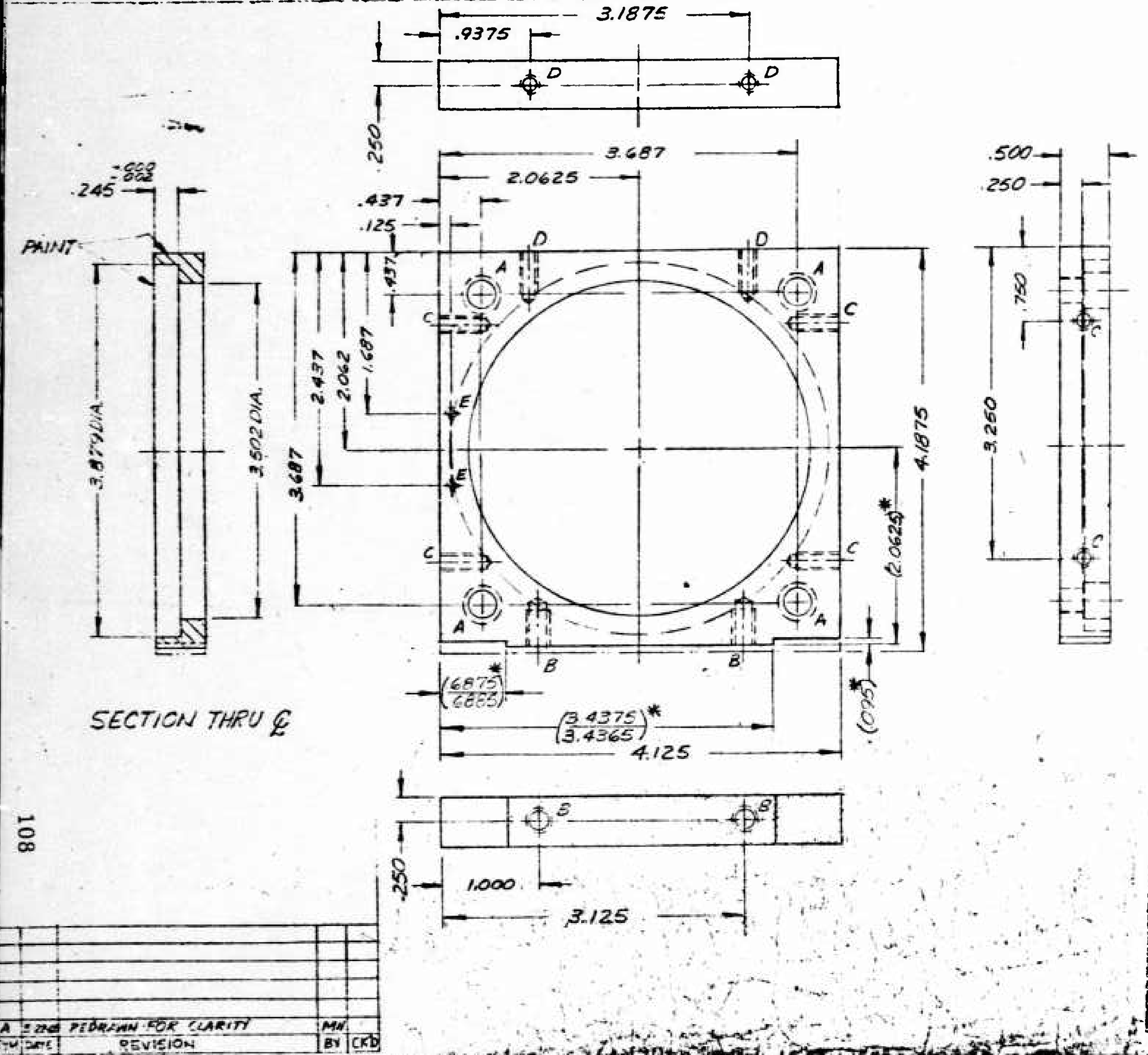
May 1, 1975 JLP

TOLERANCES			
	IDEALAB	SCALE	DRAWN BY JLP / APPROVED BY
	TITLE B/S MOUNTING PLATE		
	DATE 5/1/75	DRAWING NUMBER 2173-42	



TOLERANCES (EXCEPT AS NOTED)	CATS EYE Tube
±	TOLALAB
	CATS EYE TUBE
	2173-43

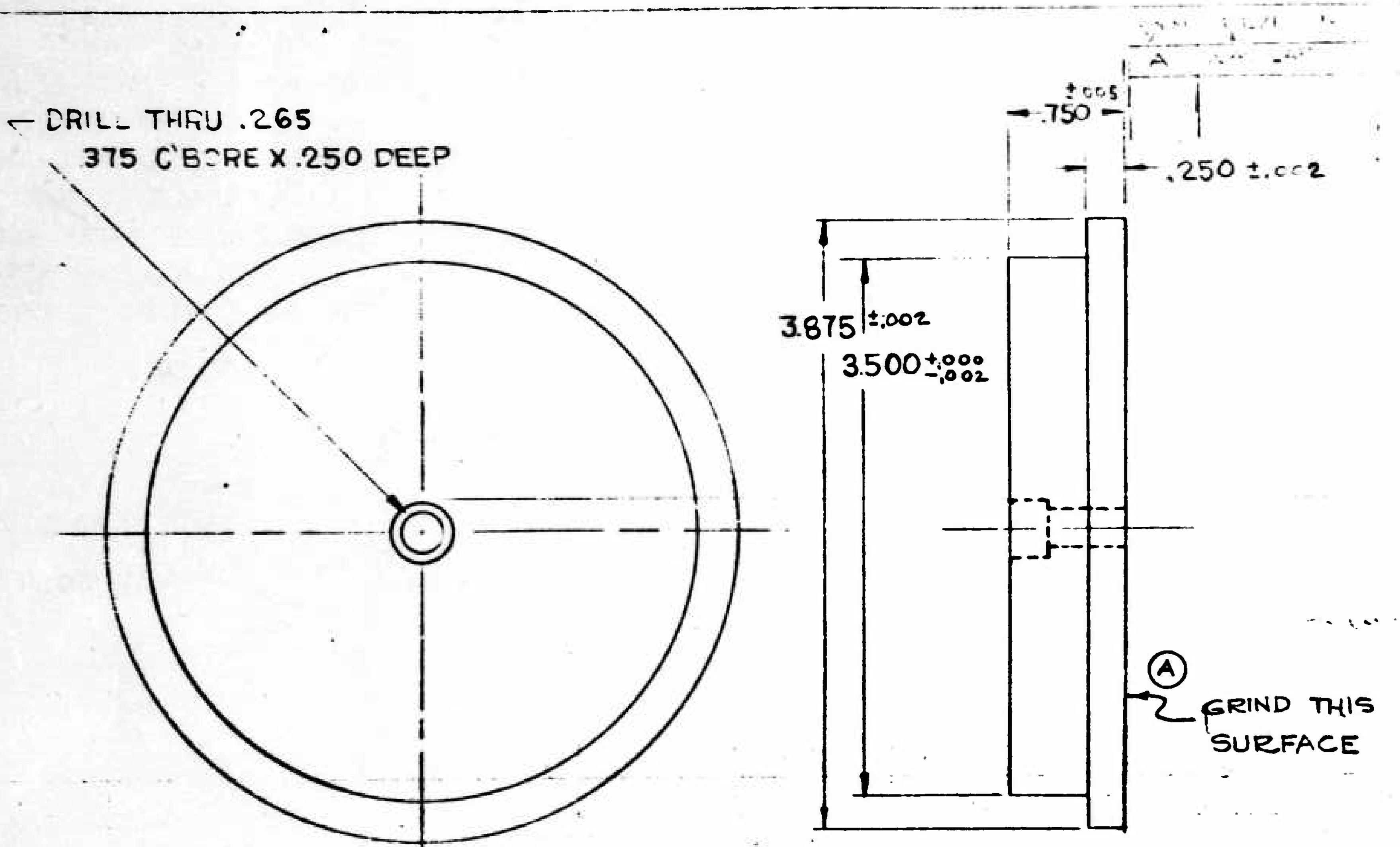

6.250
TRANS
TACH
.250
10-32
.250
℄ OF TUBE
ALLOW SLOT FOR WIRES
TRANSDUCER CRADLE ASS'Y
2173-49
TOLERANCES
.6875
TACH HOLDER
TRANS. HOLDER
1.250
.625
1.9375
2.625



NOTES

1. MATERIAL: ALUM. 921T OR CC 70
2. QTY (2)-(1) FRONT SUPPORT AS SHOWN WITHOUT HOLES NOTED "D" AND (1) BACK SUPPORT IF3-3 WITHOUT HOLES NOTED "E"
3. REMOVE BURRS & SHARP EDGES
4. PAINT NOTED SURFACE AFTER ASS'Y FLAT BLK ENAMEL MASK ALL OTHER SURFACES
5. ( )* DIM'S TO BE MACHINED AFTER ASSEMBLY OF MOTOR
6. NOTED "A" (4-HOLES) .266 DIA THRU ⌀.375 C'BORE .250 DP.
7. NOTED "B" (2-HOLES) DR & TAP FOR 1/4-20 X .250 LG HELI-COIL INSERT
8. NOTED "C" (4-HOLES) [illegible]
9. NOTED "D" (2-HOLES) #10-32 THD X .375 DP IN BACK SUPPORT ONLY
10. NOTED "E" (2-HOLES) #4-40 THD X .187 DP IN FRONT SUPPORT ONLY

TOLERANCES (UNLESS NOTED)			
DECIMAL ±.002	DICALAB	FULL	MCMAHKINS
FRACTIONAL ±1/64	MOTOR SUPPORT		
ANGULAR ±0°30'	5-22-68	IF3-7 & IF3-8	

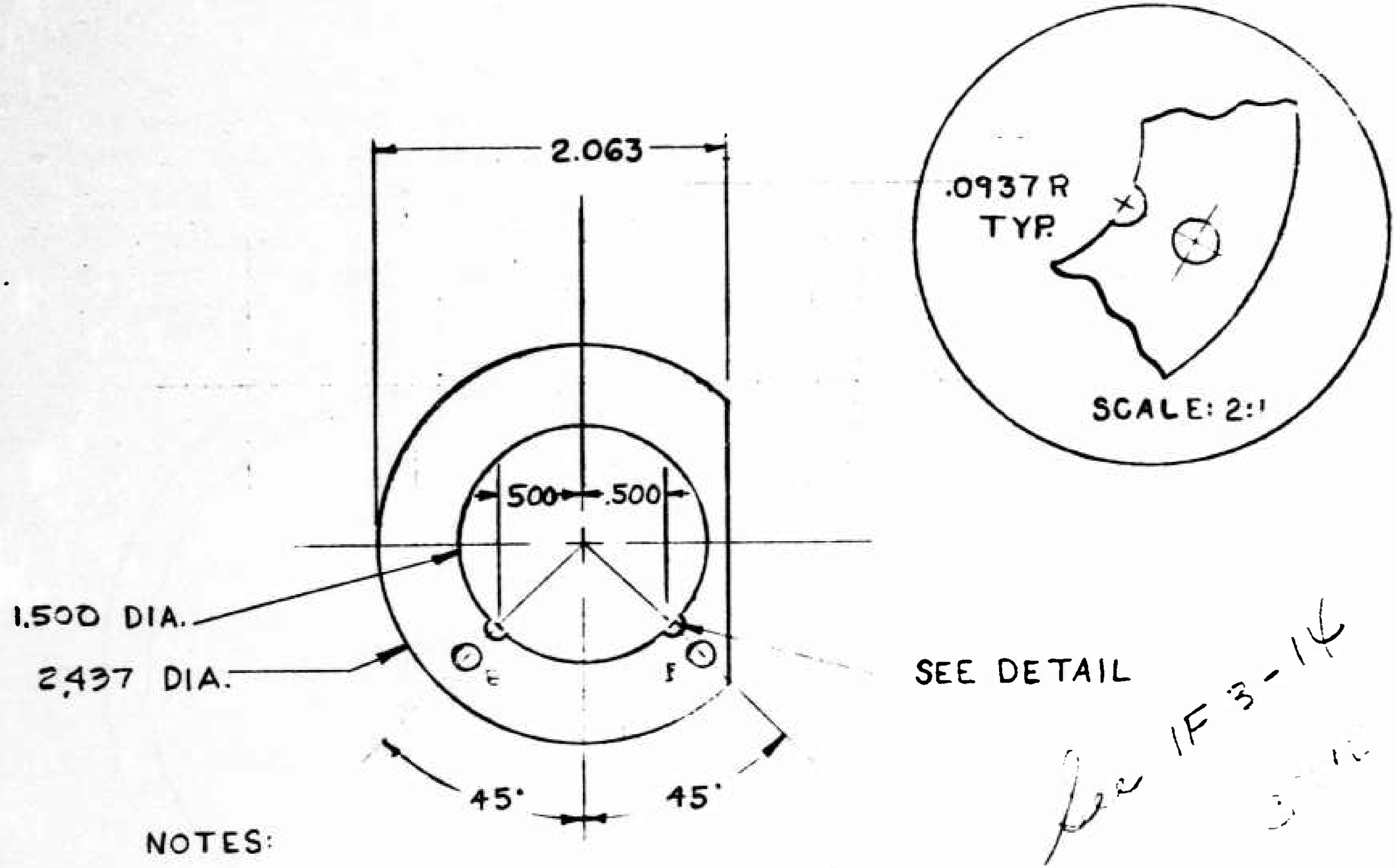


NOTES

1. MATERIAL: ARMCO MAGNETIC INGOT IRON
2. QUANTITY (1)
3. REMOVE BURR & BREAK SHARP CORNERS
4. PAINT AFTER ASSEMBLY EXPOSED SURFACES FLAT BLACK ENAMEL

TOLERANCES (EXCEPT AS NOTED)	IF3- INTERFEROMETER		
±.002	[illegible]	SCALE FULL	DRAWN BY [illegible]
	MOTOR BACK PIECE		
	[illegible]	IF3-9	

FIRST DRAWING [illegible]



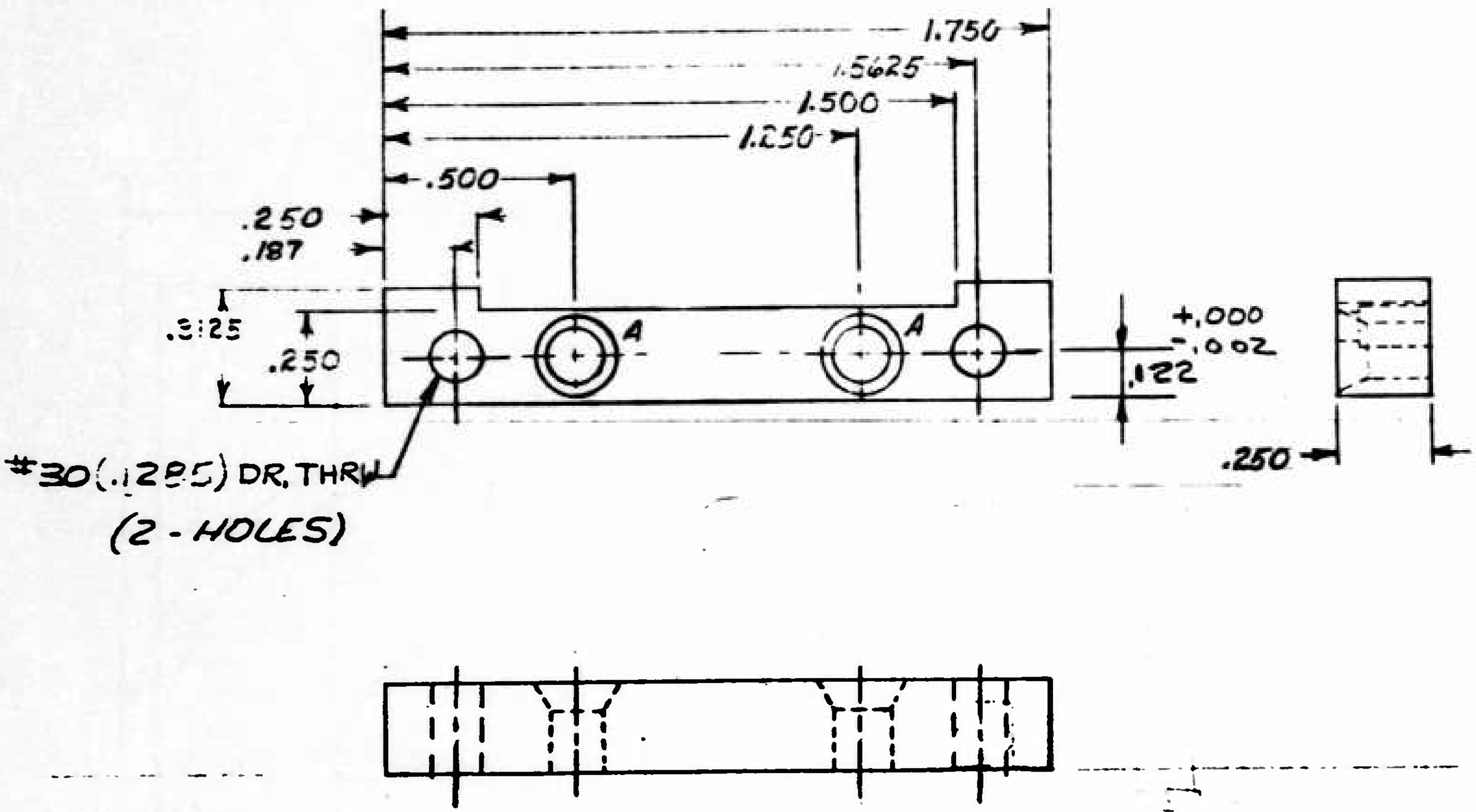
NOTES:

1. MAT. .0625 TH'K ALUM.
2. QUANTITY: (1)
3. "E" (2 HOLES) - #29 DRILL THRU. ON .980 B.C.
4. REMOVE BURRS & BREAK SHARP EDGES
5. FINISH - BLACK ANOD

[illegible]			
.002		FULL	[illegible]
1/64	MOTOR COIL TERMINAL MTG RING		
0°30'	4/11/68	1F6-12	

915??-017

INTERFEROMETER



NOTES:

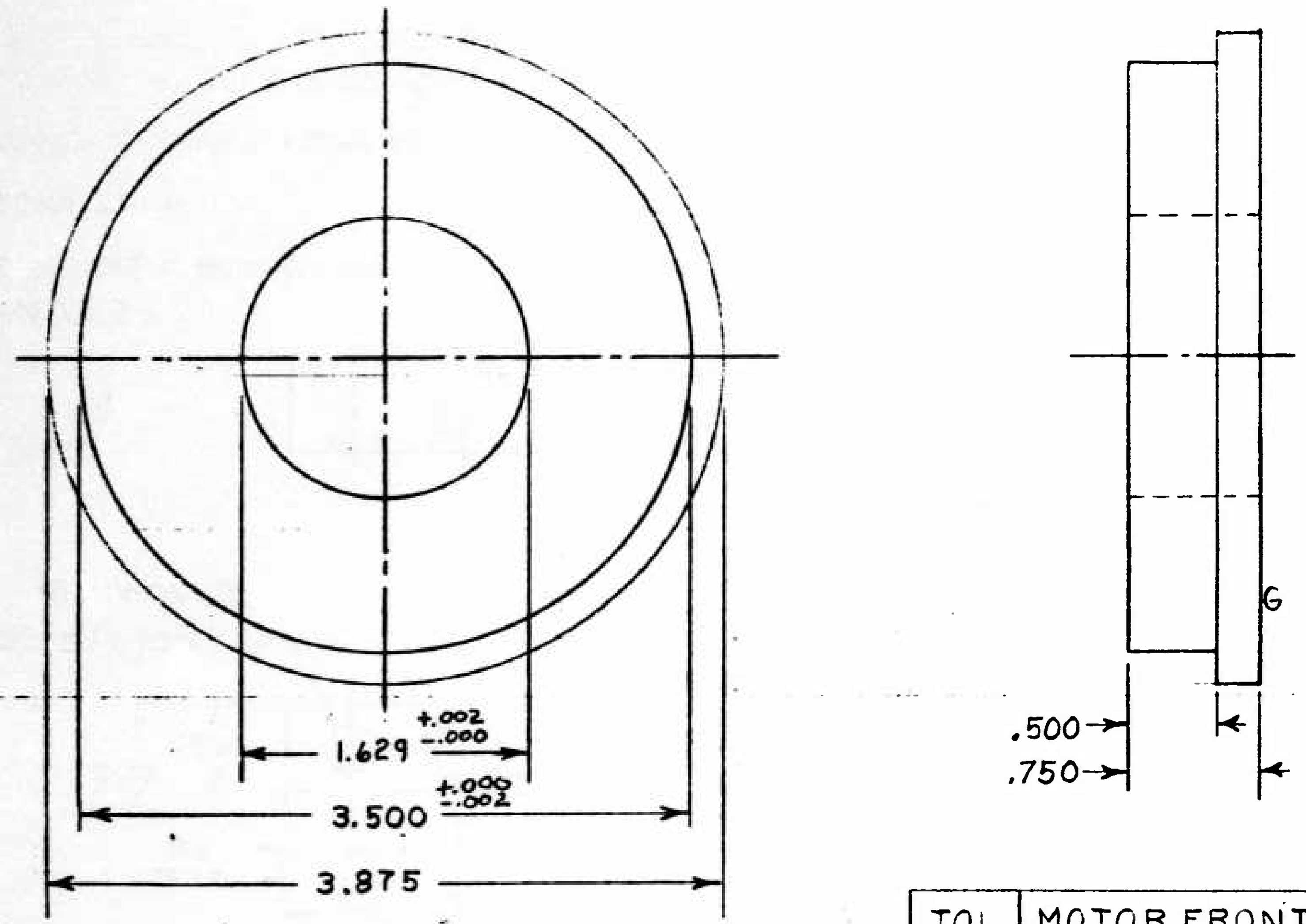
1. MATERIAL: ALUMINUM

2. QUANTITY (1)

3. REMOVE BURRS & BREAK SHARP EDGES

4. NOTED "A" (2-HOLES) #31 (.1200) DRILL THRU & 82° C'SINK .250 DIA.

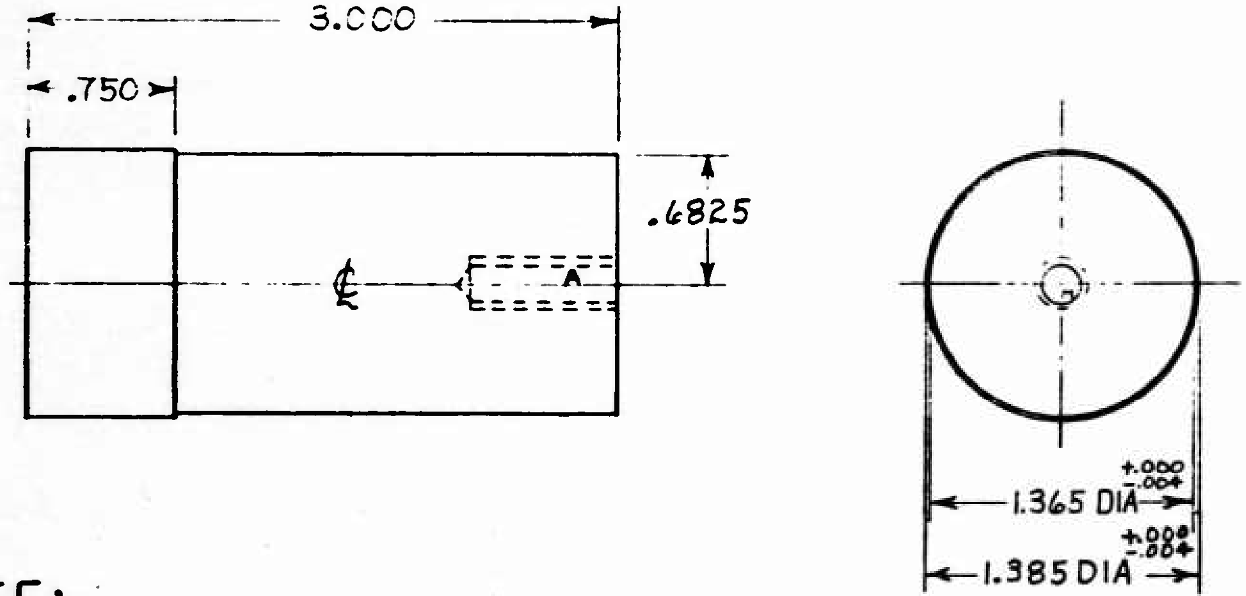
TOL.	MOTOR TERMINAL BLK.	
±.002	DATE NOV-1, 1967	IDEALAB
	DRAWN BY STEVE KENT	SCALE 2" = 1"
	DRAW. No. No. IFB-13	



TOL	MOTOR FRONT PIECE	
±.002	DATE NOV 9, 1967	DR BY S. KENT
	X DEALA3	SCALE FULL
	DRAWING No 1F-C-3	MATERIAL ARMCO

S-567-D-13

D13

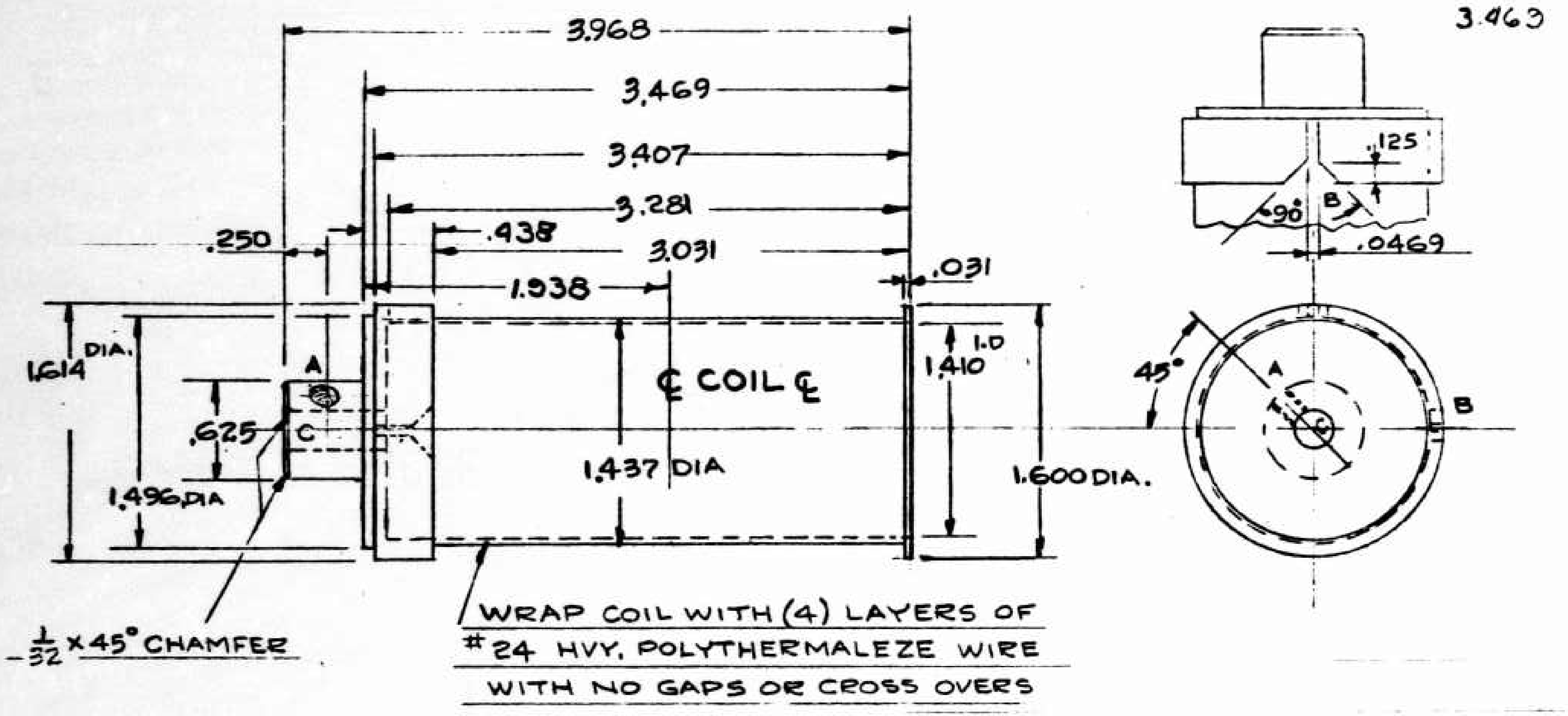


NOTE:

1. "A" HOLE (1) REQ'D DRILL + TAP FOR $\frac{1}{4}$-20 $\frac{3}{4}$" DP.

TOL	MOTOR POLE PIECE	
	DATE NOV 10, 1967	DR BY S. KENT
	I DEALAB	SCALE FULL
	DRAWING No. 1F [illegible]	MATERIAL ARMCO

91567-D14



NOTES

A - TAP FOR 6-32 SET SCR

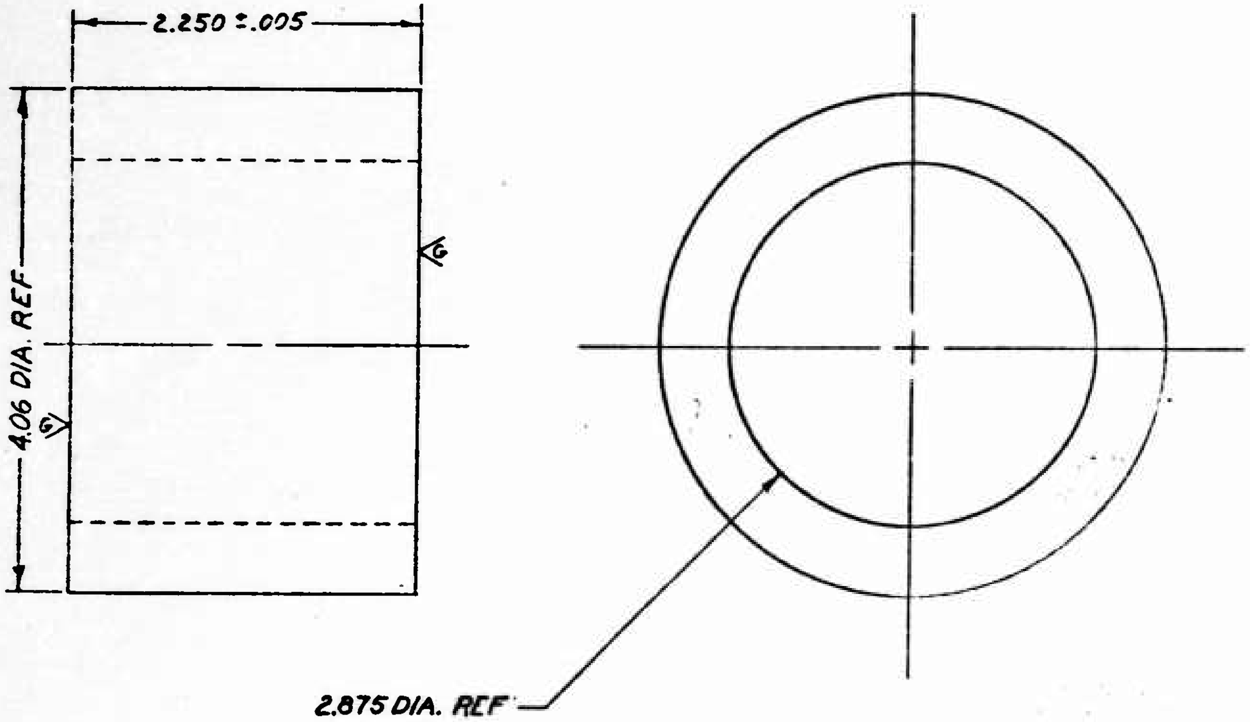
B - SLOT .0469 FLUSH WITH 1.437 DIA. FLARED AS SHOWN 2 SLOTS 90° APART

C - HOLE .2500 $^{+.0005}_{-.0000}$

D - ROUND & BREAK ALL EDGES

1-REQ'D MAT. ALUM.

TOLERANCES	IFG INTERFEROMETER		
DECIMAL ± .002		SCALE FULL SIZE	E.E.F
FRACTIONAL ± 1/64	MOTOR COIL FORM		
ANGULAR ±0°-30'	4-3-70	IF-G-11	



NOTES

MATERIAL: CRUCIBLE STEEL R-224 ALNICO V MAGNET (UNMAGNETIZED), 2 EPOXIED TOGETHER & GROUND TO FINISHED THICKNESS PER MAGNET.

PURCHASE PART

TOLERANCES (EXCEPT AS NOTED)	1F6 INTERFEROMETER		
DECIMAL ±.002	INCHES	FULL	ERF
FRACTIONAL ±1/64	MOTOR MAGNET		
±0°30'	8-22-68	1F-6-13	

41168-D21

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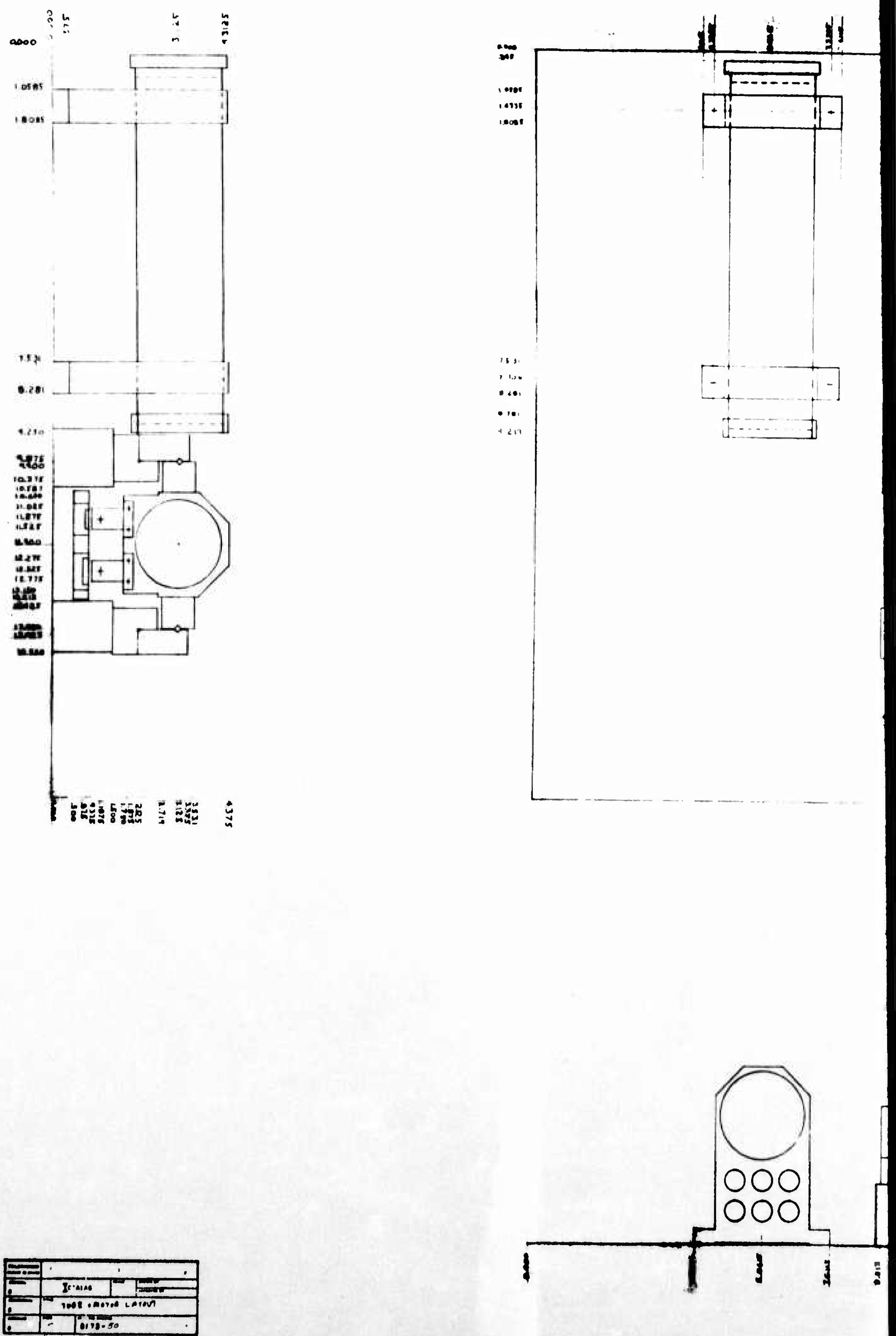
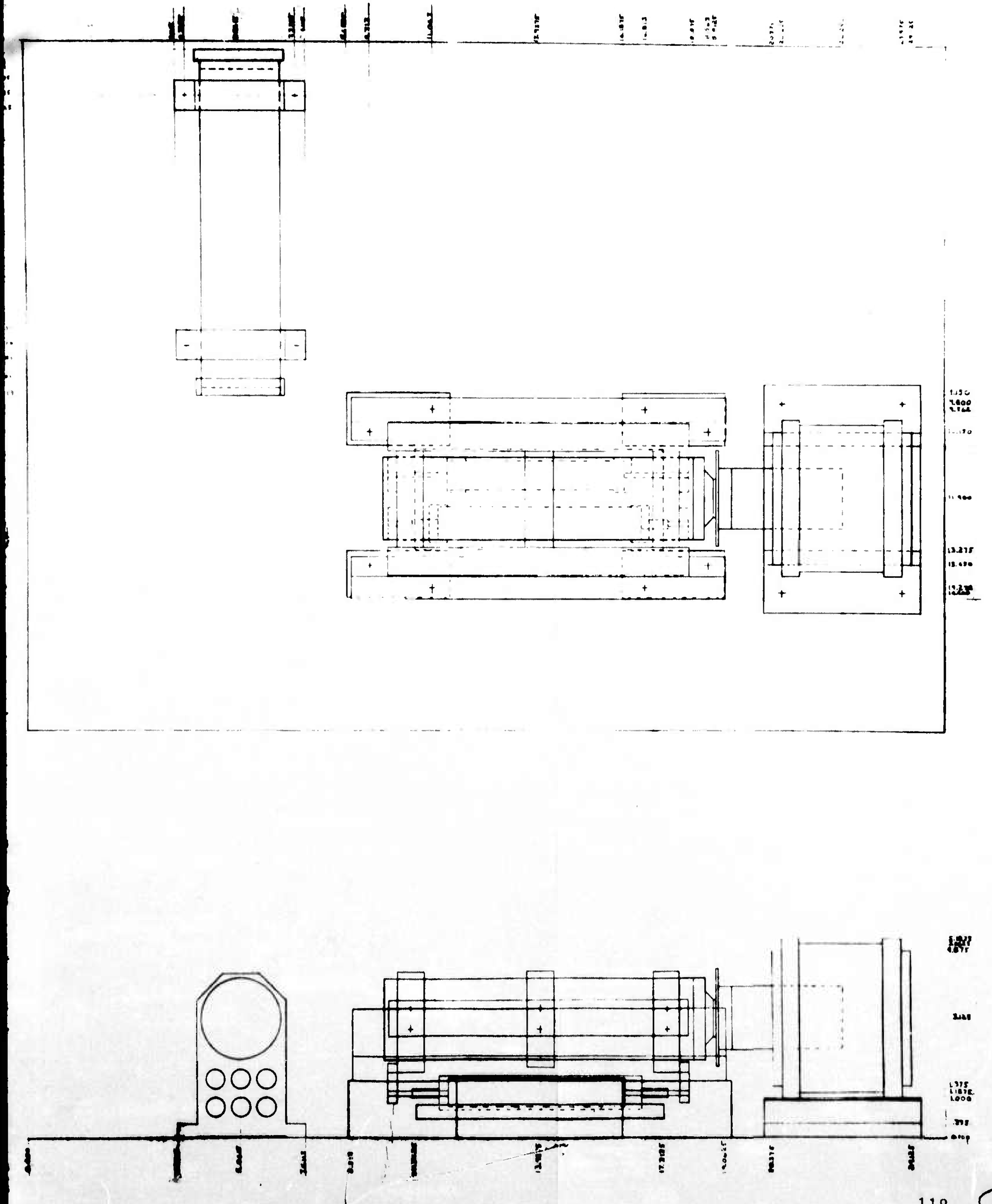
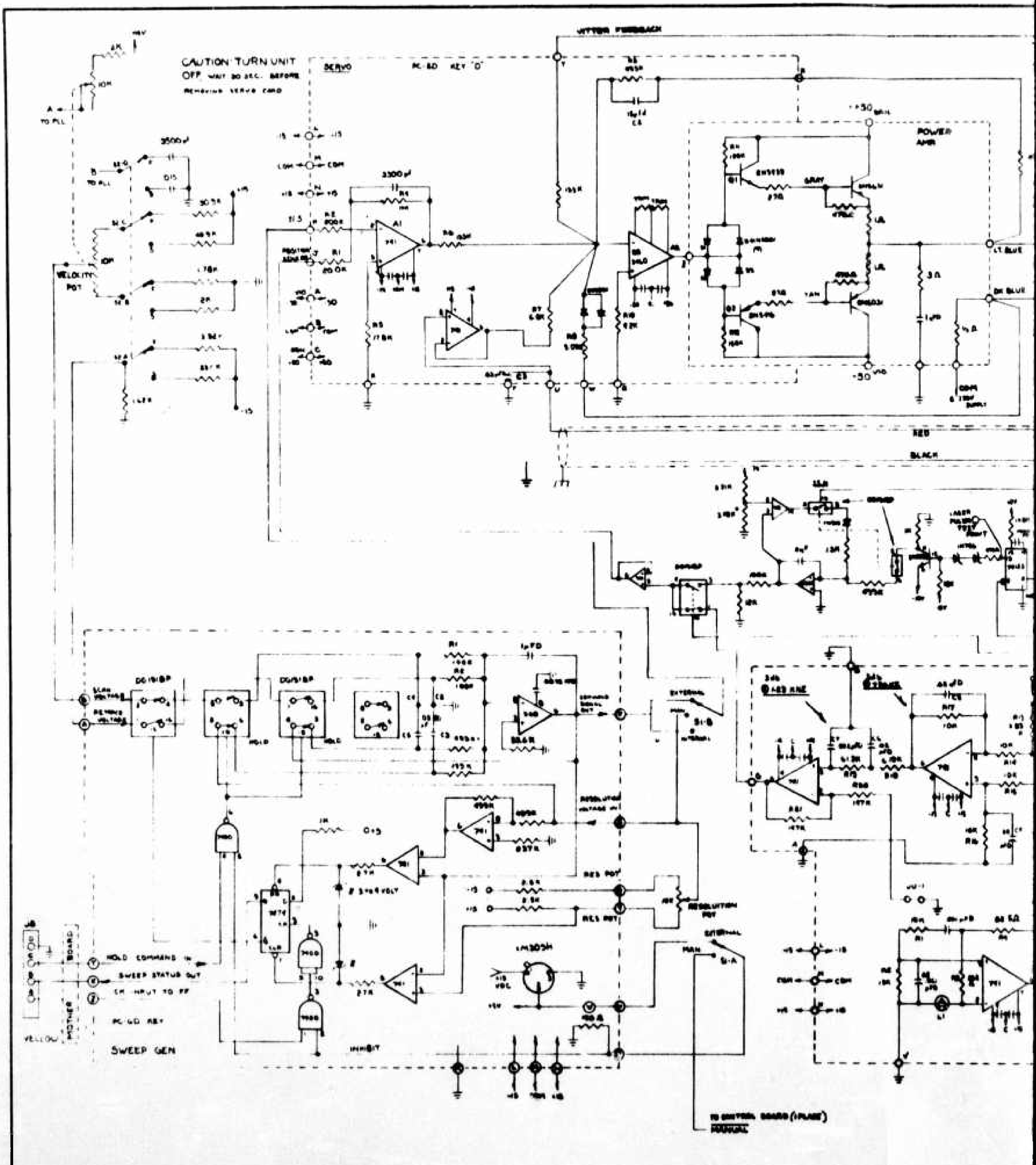
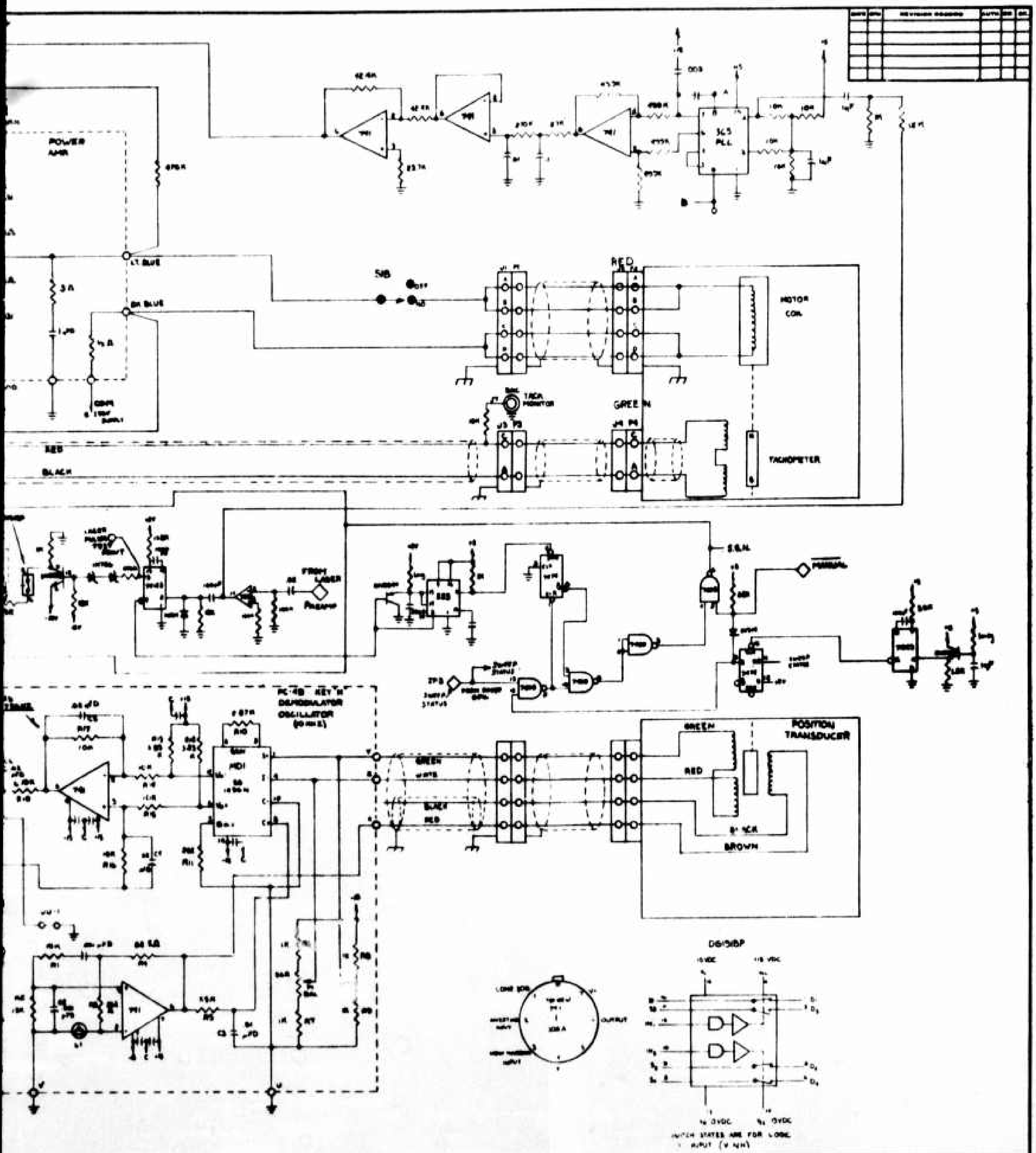





CAUTION: TURN UNIT
SERVO
POWER AMP
VELOCITY POT
TO PLL
RED
BLACK
LT BLUE
DK BLUE
HOLD COMMAND IN
SWEEP STATUS OUT
SWEEP GEN
RESOLUTION POT
EXTERNAL
MAN
INHIBIT
LM309H
YELLOW
MOTHER BOARD



TOLERANCES	IF3 INTERFEROMETER		
DECIMAL		SCALE	DRAWN BY RS
			APPROVED BY
FRACTIONAL	TITLE 8173 CONTROL UNIT		
ANGULAR	DATE 10/6/76	DRAWING NUMBER 8173 - IF3	

2

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