Department of Commerce

BUREAU OF STANDARDS

WASHINGTON

ADDRESS REPLY TO
BUREAU OF STANDARDS
LBT:HJE:MRC

IN YOUR REPLY
REFER TO FILE NO.
VI-5/VIII-2

Subject: Extensometer for High Temperature
Tension Tests.

Replying to your letter of , there is enclosed herewith copy of our letter circular No. 238, in which is described the Martens' extensometer with Tuckerman optical lever system for high temperature tension tests.

Respectfully,

George K. Burgess

George K. Burgess, Director.

Enclosure:
Letter Circular 238.

LBT:HJF:MPC

DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
WASHINGTON

Letter Circular 238

November 11, 1927.

MARTENS' EXTENSOMETER WITH TUCKERMAN OPTICAL LEVER SYSTEM FOR HIGH TEMPERATURE TENSION TESTS

The accompanying blue prints are working drawings of the extensometer for high temperature tension tests and the optical lever system now used at the Bureau of Standards.

The construction of the optical lever system can be materially improved in many details, and a new design is at present being developed. It will, however, be some time before the new design is completed and tested sufficiently to warrant its description.

The gage proper can readily be constructed by an instrument maker from the drawings, without further explanation. The proper functioning of the optical lever system depends upon the careful observance of certain precautions in construction and assembly which are described below.

The Tuckerman Optical Lever consists of an autocollimator and a quadruple mirror system.

Prism.

Three of these mirrors are in practice combined in a single glass prism (31). The two roof surfaces of the prism are mirrors which are essential to its working. Because of

the small aperture of the prism, these surfaces must be very accurately worked, and to avoid a disturbing double image the angle between them must be very close to 90°.

In addition to reflection, at the roof surfaces, the light suffers refraction at the two end surfaces of the prism. If these are not properly oriented an additional deviation of the rays is produced. If large enough, this deviation will make the proper pointing of the autocollimator more difficult and unless considerable care is used may lead to inaccuracies in the use of the instrument. As a result of a study of this system during five years of continual use, the tolerances given have been specified. If these tolerances are met, the prism gives satisfactory definition and can introduce no appreciable error into the measurements.

The "Flash Surface" is merely an auxiliary mirror which aids the operator in properly pointing the autocollimator. It therefore, does not need to be particularly accurately surfaced.

Theoretically, no silvering should be needed, but the roof surfaces are not easily accessible for cleaning and a small amount of grease or other dirt destroys their property of total reflection. Experience has shown that, although slightly diminishing the light, the silvering is preferable.

Lozenge (34).

In the first optical strain gages constructed at the Bureau of Standards, a 45° prism was used for the fourth mirror surface. Plane glass mirrors and prisms are still used in other applications of the optical lever systems, but in the strain gages they have been replaced by an optical surface worked on the face of the stellite lozenge (34). This has the advantage of placing the plane of the mirror accurately parallel to the axis of rotation of the lozenge which forms the lever of the system, without the necessity of careful adjustment. This polished surface of the lozenge must be accurately plane and worked to a fine surface if satisfactory definition is to be obtained.

Since the diagonal of the lozenge (34) forms the lever arm of the system this dimension should be accurately known and preferably be adjusted to a standard length. If more than one gage is read by the same autocollimator, the diagonals of the lozenges must be the same within the limits of error allowed, or else a separate calibration correction must be used with each gage. In the gages used the diagonal is adjusted to 0.200"±.0002".

Autocollimator.

The essential parts of the autocollimator are the objective lens (36), the reticule (33), the illuminating prism (32), and the eyepiece (35).

For the objective (36), a good quality range finder lens was selected having an aperture of F/5. After building the

instrument it was found that although the lens was otherwise satisfactory there was enough spherical aberration and coma present to introduce errors of about 1/3 per cent in the readings if the full aperture was used. For this reason the objective lens diaphragm (14) was added, stopping the lens down to about F/10. This made the shift of the image imperceptible. It is doubtful if any telescope lenses are available commercially which are sufficiently highly corrected to allow the use of an aperture greater than this without introducing noticeable errors. Any high quality telescope lens of approximately 25 cm. focal length should be satisfactory when sufficiently stopped down. The lens chosen should be stopped down by trial until no noticeable shift of the image occurs when the autocollimator is displaced sidewise.

Reticule.

The reticules (33) are photographic reductions on lantern slides of an accurately drawn large scale diagram. The film is protected by cementing on a cover glass with Canada balsam and the reticule is then edged to size.

In measuring angular changes the calibration depends upon the ratio of distance on the reticule to the focal length of the objective lens. For this reason the diagram should be accurately drawn and care taken to see that the photographic reduction is proportional over the whole scale. If this be

done a single calibration factor will apply to the whole scale. Otherwise, individual corrections will have to be determined for each reading.

Illuminating Prism.

This need not be particularly accurate. It is only necessary that the fine ground surface be sufficiently diffusing to secure uniform illumination.

Eye Piece.

Any good eye piece of about 15 diameters magnification and an apparent field of view of about 45° will do provided its working space is great enough to admit the illuminating prism between it and the reticule.

Adjustment of Autocollimator.

Adjust the reticule adjustment Lock Ring (19) so that when the reticule cell (20) is screwed tight, it just clears the face of the illuminating prism (32). Screw tight and seal with warm wax. Any displacement later will change the calibration of the instrument.

Place the reticule in its cell and turn until the "eared circle" with the fiduciary mark lies under the illuminating prism. Put in the Retaining Ring (21) and screw in the Retaining Ring (22) until the reticule does not rattle. Do not use too much force, the reticule is easily broken.

Slide the illuminating prism in until its edge just covers the eared circular opening. Tighten up the prism

mount (23) and seal the prism in place with warm wax. A shift of the prism in use will interfere with the illumination.

Assemble the eye piece end of the autocollimator screwing (17) and (18) up tight. (17) is preferably sealed to (12) with warm wax, or locked with a lock screw.

Screw the objective assembly into the autocollimator tube until the instrument is in focus, testing carefully by parallax on an "infinitely distant" object. Seal it in place with warm wax. Any displacement later will change the calibration of the instrument.

If the autocollimator is properly assembled according to these instructions, its calibration will not be altered by any proper use. Recalibration of instruments in use for over a year has shown no change.

Adjustment of the Mirror System.

Clamp the extensometer on the specimen. Set the lozenges in the notches in (6) and (7) with the mirror face outward and towards the prism (31). Point the autocollimator approximately perpendicular to the face of the prism (31). Rock the prism (31) until the proper stationary image (an image which does not move as the autocollimator is turned) of the fiduciary mark and vernier is seen. By tilting and twisting the autocollimator and rocking the prism (31) adjust so that the flash image is parallel to and near the stationary image and the stationary image is central on the scale. Rock the prism to a suitable

[illegible]

[illegible]

[illegible]

initial reading. The instrument is now in adjustment. (Note. There are two stationary images, only one of which can be seen at a time. The reading of the"tension image" increases when the specimen in stretched. The reading of the "compression image" increases when the specimen is compressed. A slight tilt of the prism (31) will carry either one of these images behind the illuminating prism and bring the other into view.)

Calibration.

The extension measured is given by:

$$Le = E = \frac{rd}{2f}$$

where L = the gage length

e = the relative extension (or compression)

E = the total extension

r = the difference in reading on the reticule (in cm)

f = the focal length of the objective (in cm)

d = the length of the diagonal of the lozenge

To calibrate the autocollimator alone, r may be measured (on a micrometer microscope) and f may be measured (on a nodal slide) before assembly of the instrument.

It is easier, however, to calibrate the assembled autocollimator by mounting it on a spectrometer table and sighting on a distant object. The angle of rotation (in radians) of the spectrometer table is equal to $\frac{r}{f}$.

Finally, the combination of lozenge and autocollimator may be calibrated as a unit by mounting the lozenge in a gage on a sensitive precise micrometer and reading corresponding values of E and r. An interferometer micrometer is convenient for the purpose

Precautions for Use at High Temperatures.

When the described equipment is used for high temperature tests, certain precautions should be observed. The suspension clamps (8)(9), comparison strips (5)(6), lock nuts (2)(4) and adapters (1)(3) which are partly or wholly within the heating unit during tests should be made of metals which will withstand the effects of the high temperatures encountered. The materials used in Bureau extensometers which have given satisfactory service in tests up to about 1400°F (760°C) comprise forged nickel-chromium-iron alloys. Two typical compositions are given herewith (approximate type compositions).

Carbon,	0.20	0.20
Manganese,	0.80	0.80
Nickel,	20.0	20.0
Chromium,	7.0	14.0
Copper,	1.0	1.0
Silicon,	1.3	1.3

These are cited merely to illustrate the type of material which has been used successfully. Satisfactory performance within the temperature range cited can be expected from a majority of the "heat resisting" alloys available industrially. However, the choice is limited by the necessity of at least moderately easy working and machining. After hot working (forging), the alloys

[illegible]

[illegible] ripe [illegible]

[illegible] cos [illegible]

[illegible] (1) [illegible] (1)(2) [illegible] con [illegible]

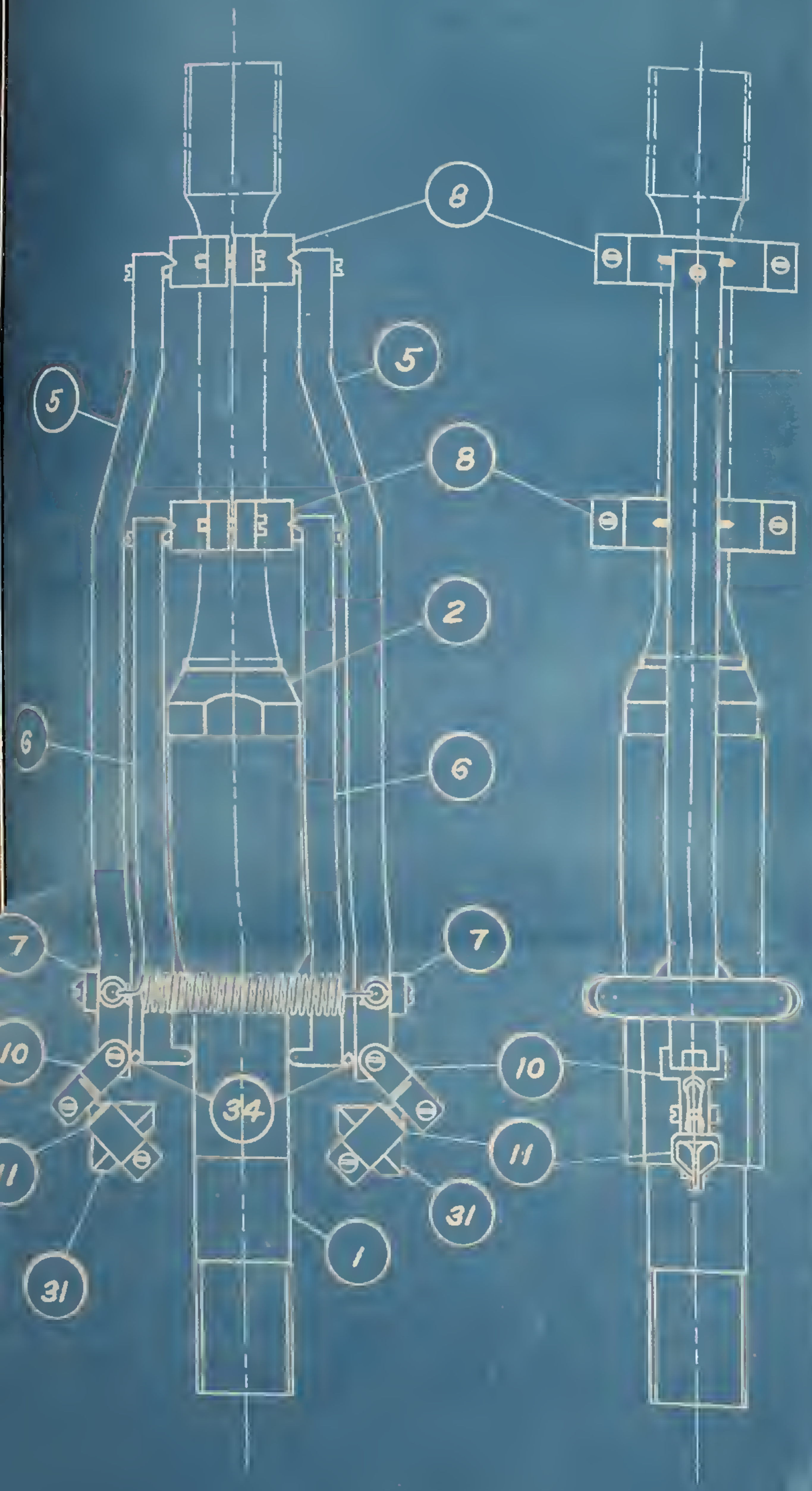
[illegible]

should be annealed so as to avoid dimensional changes on subsequent heatings for tests.

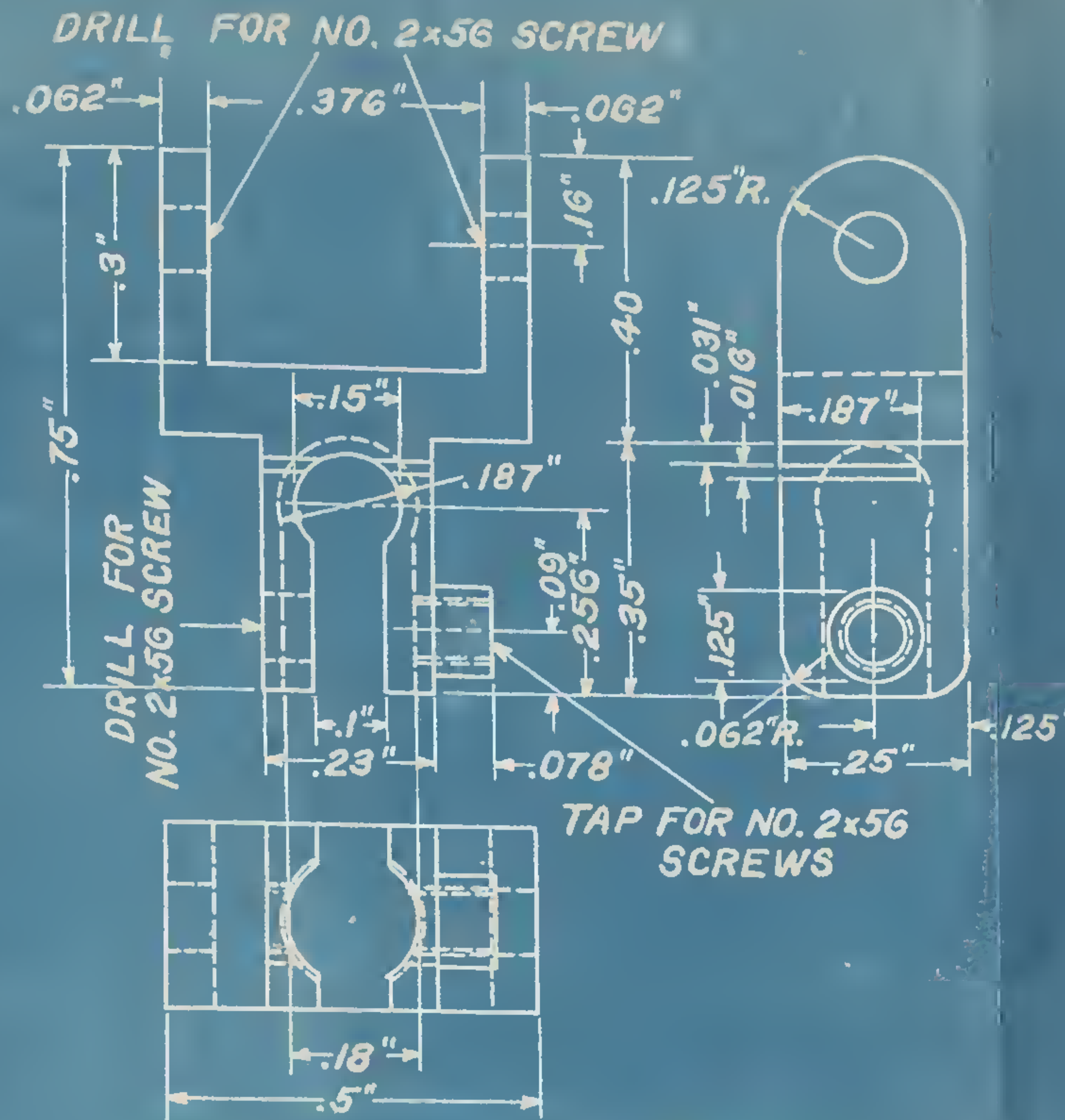
If, as in the Bureau equipment, the lower end of the heating furnace extends to within a short distance of the lower end of the comparison strips (5)(6), it is desirable to protect the lozenges (34) and prisms (31). This has been done at the Bureau by directing a gentle current of cold air over these parts and keeping this air current constant from the start of heating to the removal of equipment from the heating furnace (entire test interval). If some such precautions are not taken, the lozenges (34) and prisms (31) will become too hot and, aside from the danger of ruining these parts, difficulties will be encountered in handling adjustments of the optical system and distorted images may be obtained.

Note that two sets of adapters (1)(3), two lock nuts (2)(4) and two sets of suspension clamps (8) and (9) are shown on the attached drawings, one set for use with 0.505-inch diameter test specimens and the other for 0.250-inch diameter specimens.

Typical results obtained on metals at high temperatures with the described equipment are given in Technologic Papers, No. 362, entitled Creep in Five Steels at Different Temperatures, by H. J. French, H. C. Cross and A. A. Peterson. This is obtainable for 15 cents (stamps not accepted) only from the Superintendent of Documents, Government Printing Office, Washington, D. C.



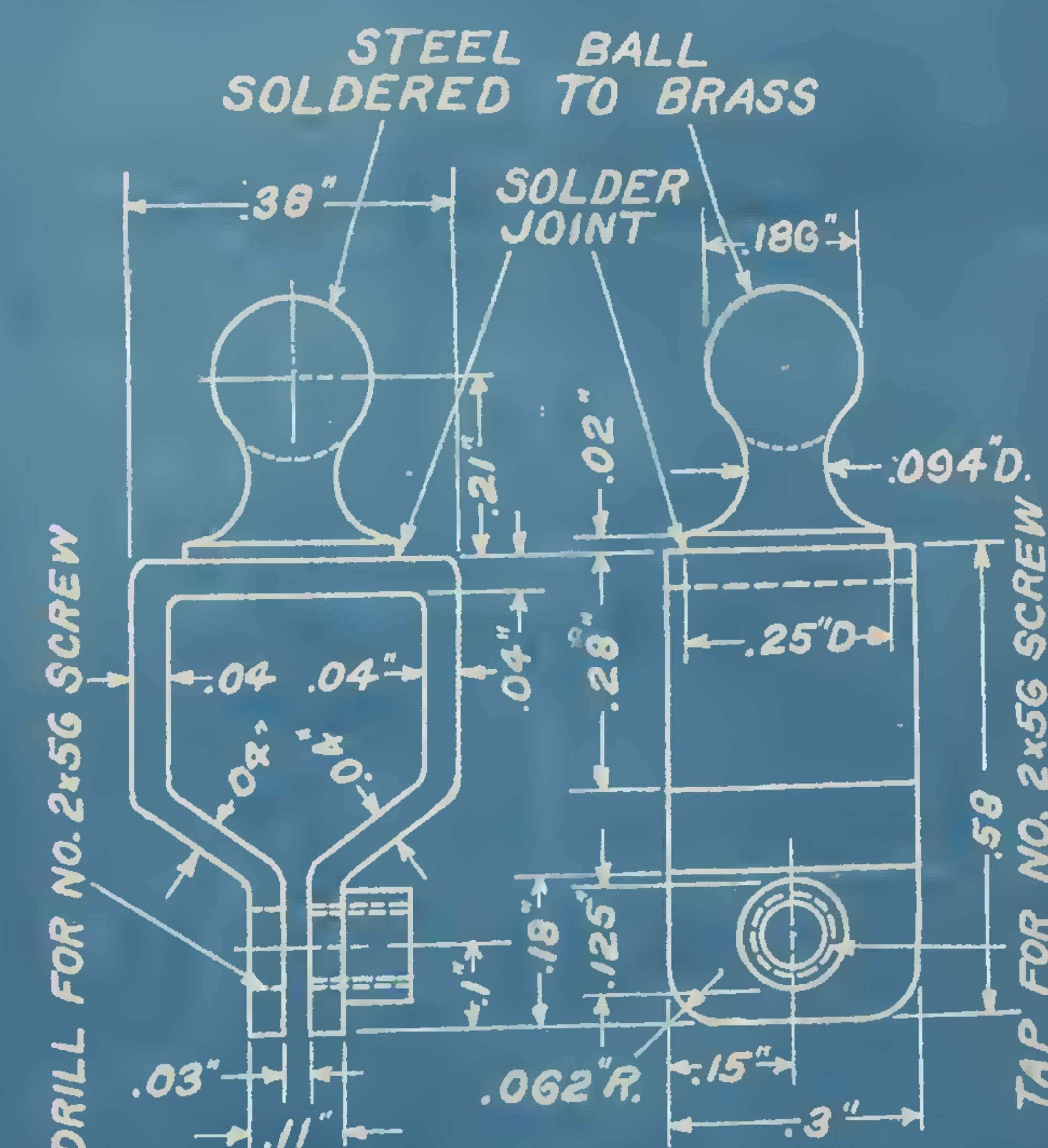
ASSEMBLY



PRISM HOLDER ATTACHMENT (10)

TWO – BRASS

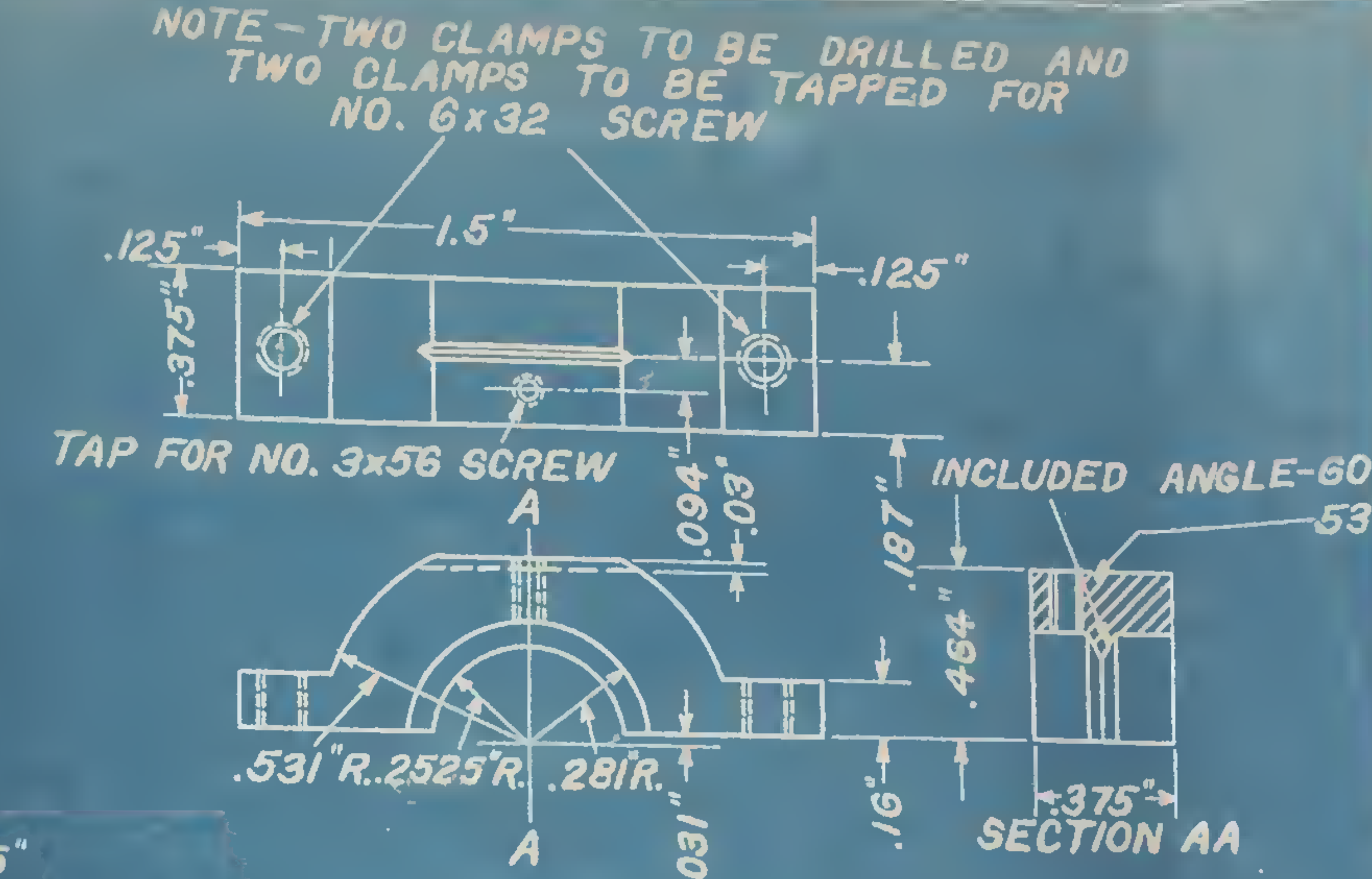
2-2x56 FILLISTER HEAD MACHINE SCREWS, .312" LONG



PRISM HOLDER (11)

TWO – BRASS

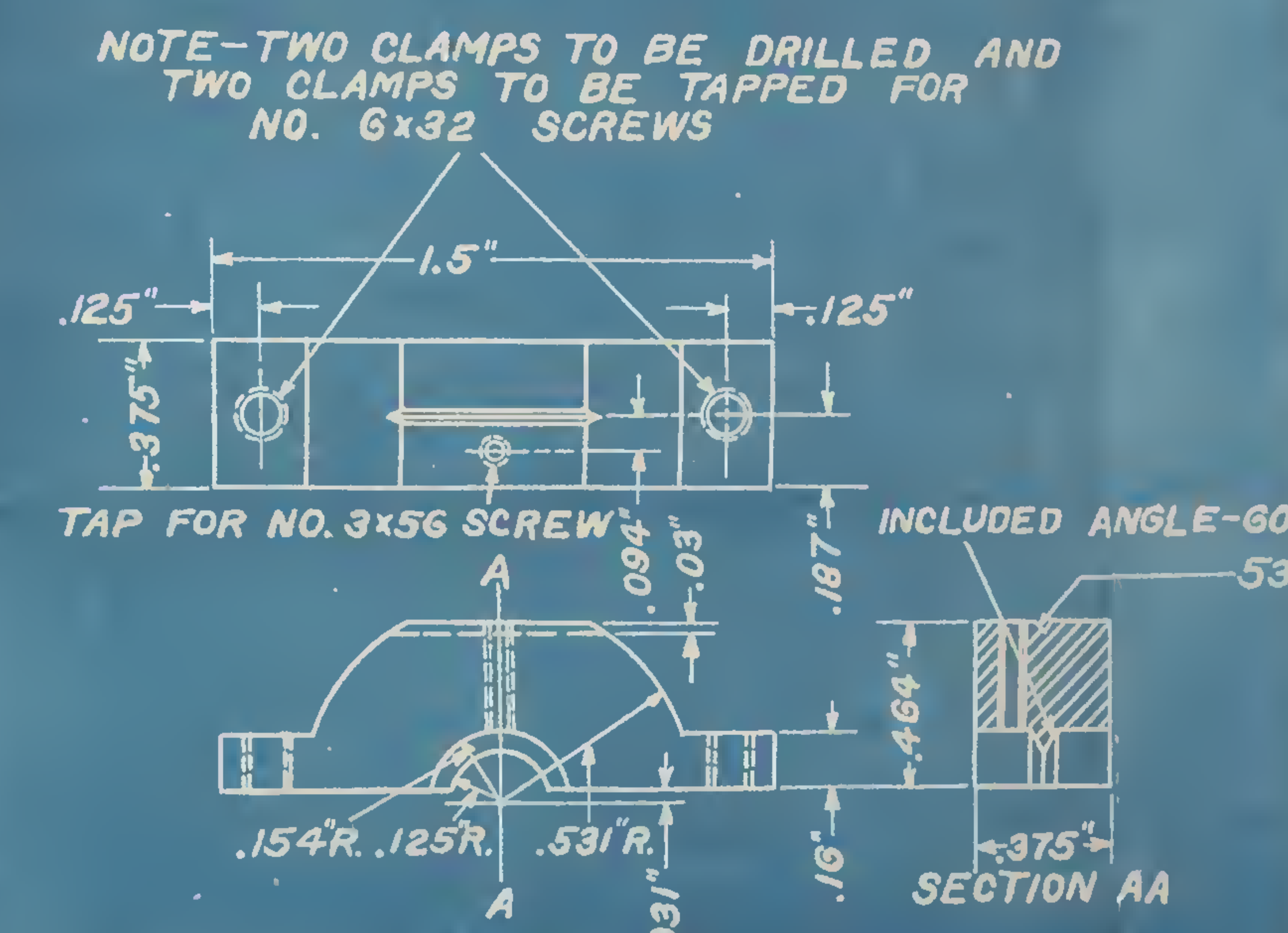
2-2x56 FILLISTER HEAD MACHINE SCREWS, .218" LONG



SUSPENSION CLAMP FOR .505" D. SPECIMEN (8)

FOUR – STEEL

4-3x56 FILLISTER HEAD MACHINE SCREWS, .5" LONG
4-6x32 FILLISTER HEAD MACHINE SCREWS, .437" LONG



SUSPENSION CLAMP FOR .250" D. SPECIMEN (9)

FOUR – STEEL

4-3x56 FILLISTER HEAD MACHINE SCREWS, .5" LONG
4-6x32 FILLISTER HEAD MACHINE SCREWS, .437" LONG

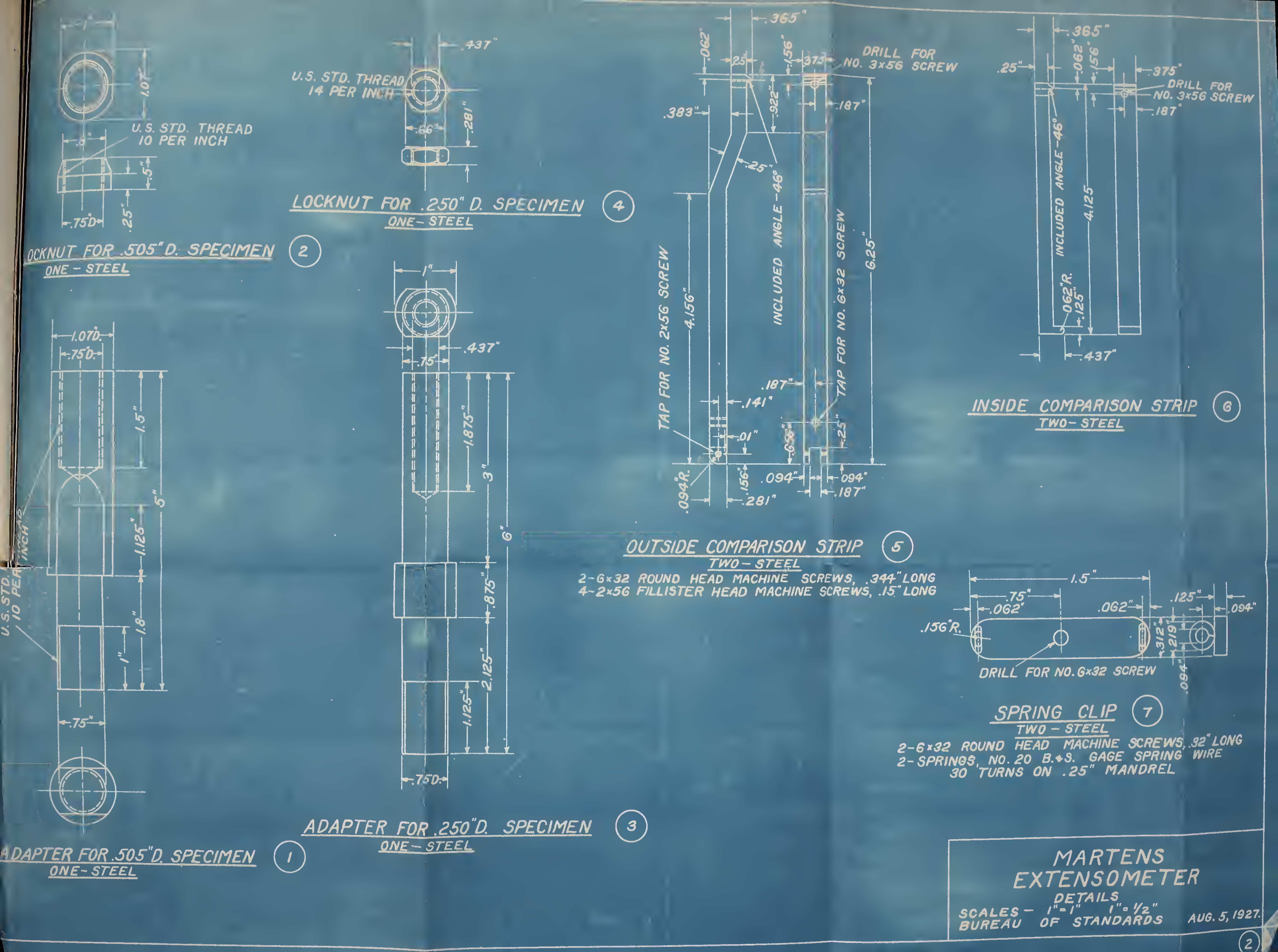
MARTENS EXTENSOMETER

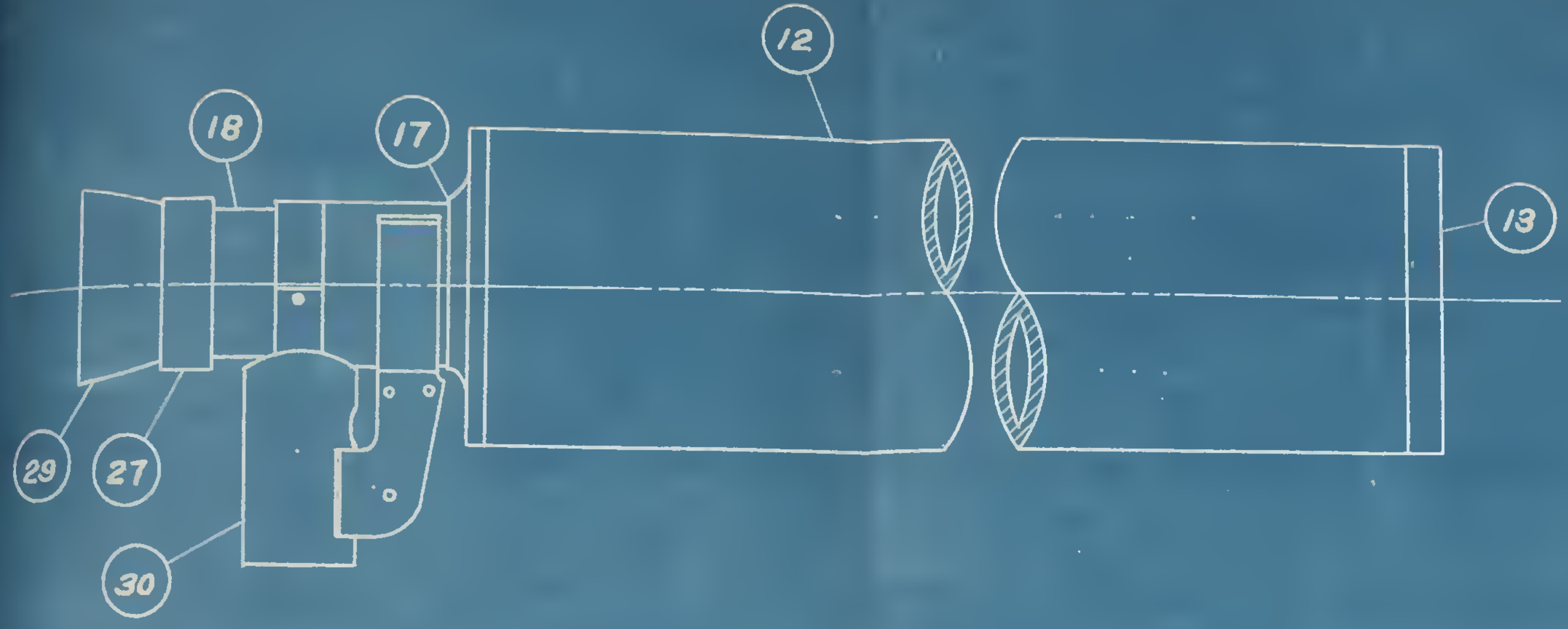
ASSEMBLY & DETAILS

SCALES – 1" = 1", 1" = 1/2", 1" = 1/4"

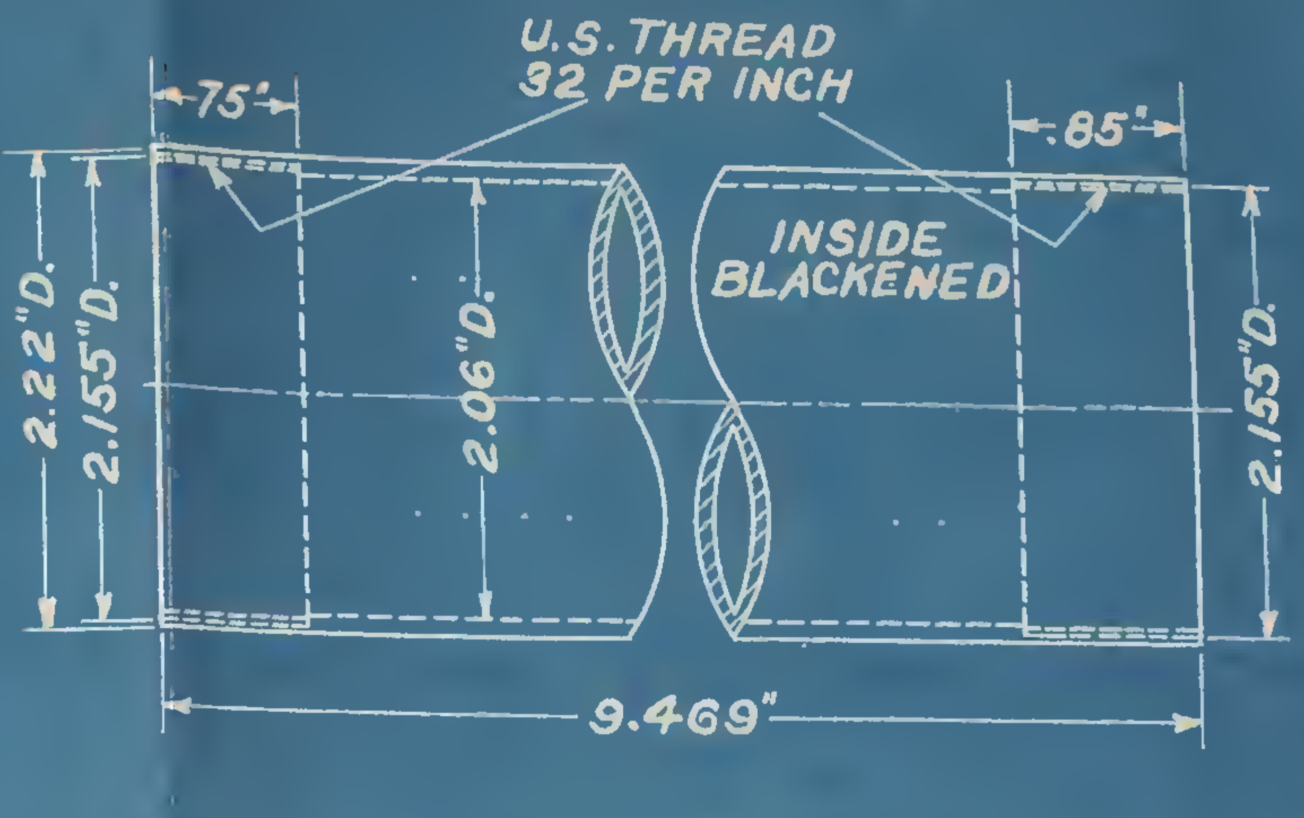
BUREAU OF STANDARDS AUG. 5, 1927.

(1)


LOCKNUT FOR .505" D. SPECIMEN (2)
ONE - STEEL
U.S. STD. THREAD 10 PER INCH
LOCKNUT FOR .250" D. SPECIMEN (4)
ONE - STEEL
U.S. STD. THREAD 14 PER INCH
ADAPTER FOR .505" D. SPECIMEN (1)
ONE - STEEL
ADAPTER FOR .250" D. SPECIMEN (3)
ONE - STEEL
OUTSIDE COMPARISON STRIP (5)
TWO - STEEL
2-6x32 ROUND HEAD MACHINE SCREWS, .344" LONG
4-2x56 FILLISTER HEAD MACHINE SCREWS, .15" LONG
DRILL FOR NO. 3x56 SCREW
TAP FOR NO. 2x56 SCREW
TAP FOR NO. 6x32 SCREW
INCLUDED ANGLE - 46°
INSIDE COMPARISON STRIP (6)
TWO - STEEL
SPRING CLIP (7)
TWO - STEEL
DRILL FOR NO. 6x32 SCREW
2-6x32 ROUND HEAD MACHINE SCREWS, .32" LONG
2-SPRINGS, NO. 20 B.&S. GAGE SPRING WIRE
30 TURNS ON .25" MANDREL
MARTENS
EXTENSOMETER
DETAILS
SCALES - 1"=1" 1"=1/2"
BUREAU OF STANDARDS
AUG. 5, 1927.
2

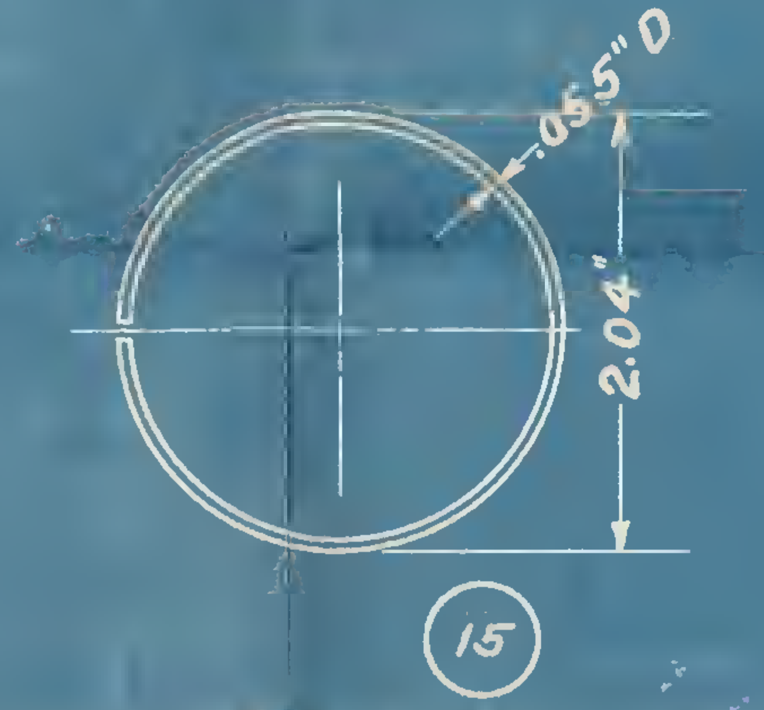


AUTOCOLLIMATOR ASSEMBLY



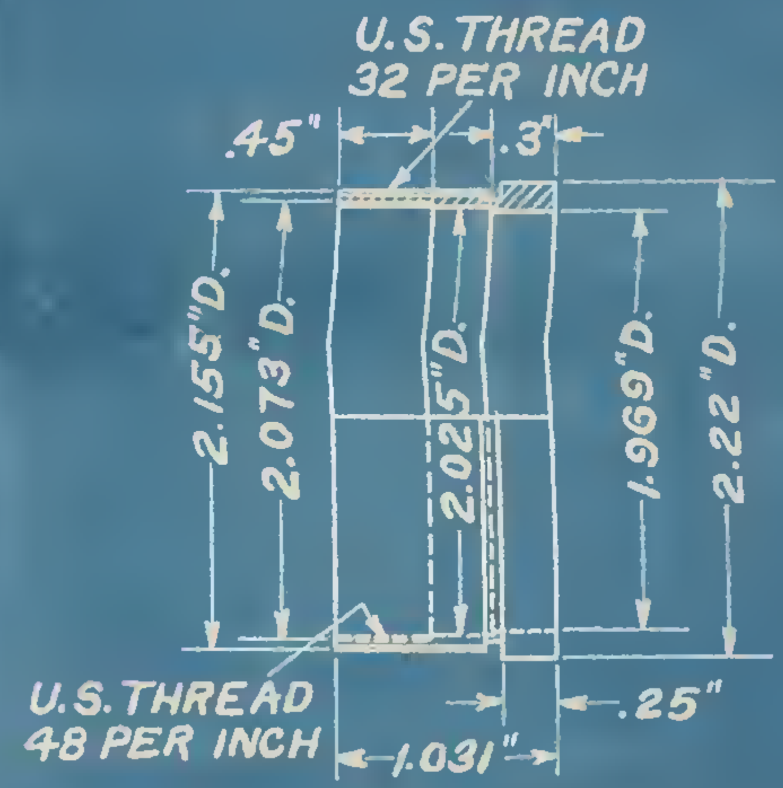
AUTOCOLLIMATOR TUBE (12)
ONE – JAPANNED BRASS

OBJECTIVE LENS SCREW RETAINING RING (16)
ONE – JAPANNED BRASS

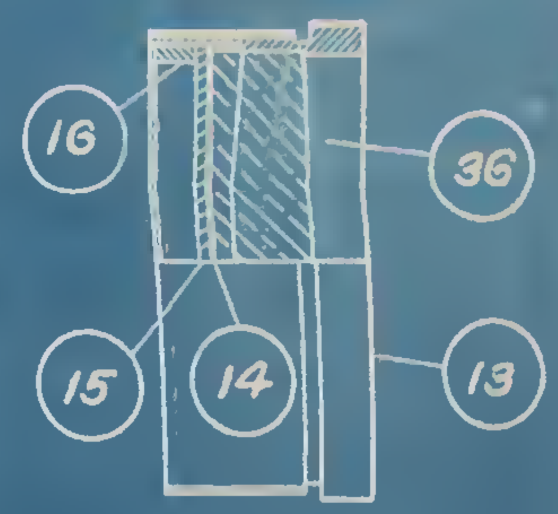


OBJECTIVE LENS SLIP RETAINING RING
ONE – BRASS

(14)
OBJECTIVE LENS DIAPHRAGM
ONE – JAPANNED BRASS .013" THICK

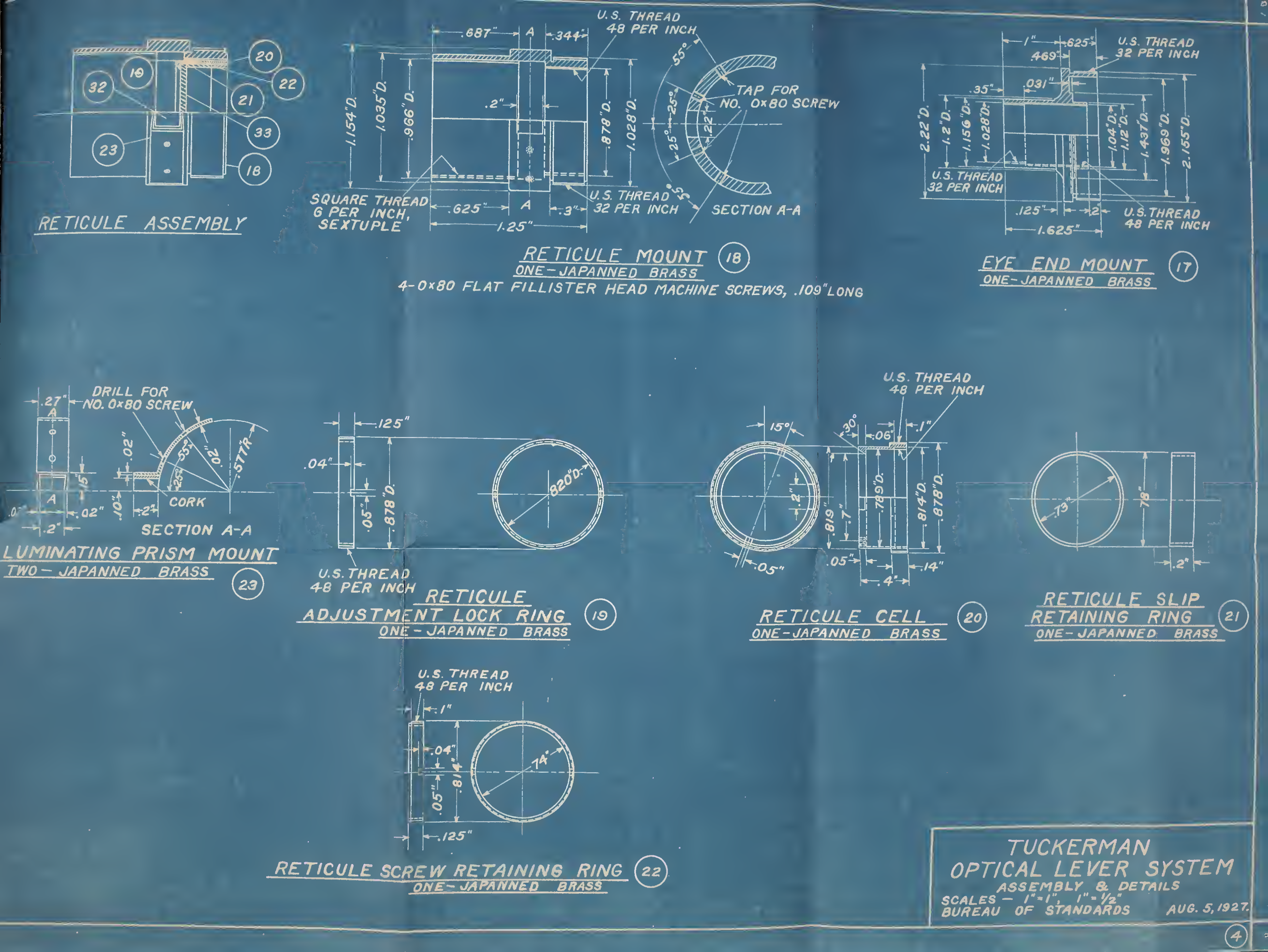


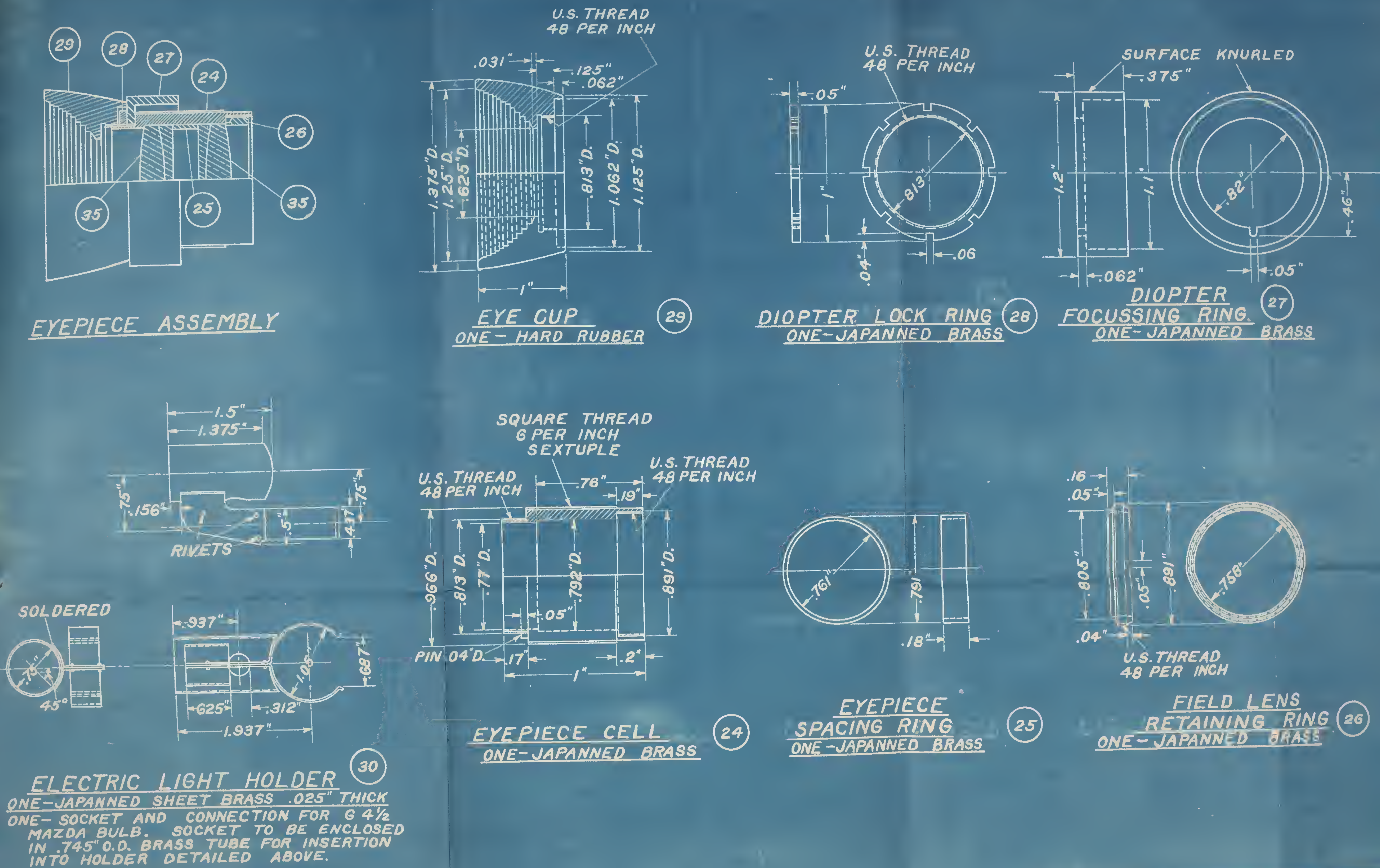
OBJECTIVE LENS CELL (13)
ONE – JAPANNED BRASS



OBJECTIVE ASSEMBLY

TUCKERMAN
OPTICAL LEVER SYSTEM
ASSEMBLY & DETAILS
SCALE – 1" = 1"
BUREAU OF STANDARDS AUG. 5, 1927.


RETICULE ASSEMBLY
20
22
19
32
21
33
23
18
U.S. THREAD 48 PER INCH
.687"
A
.344"
1.154"D.
1.035"D.
.966"D.
.2"
.878"D.
1.028"D.
SQUARE THREAD 6 PER INCH, SEXTUPLE
.625"
A
.3"
U.S. THREAD 32 PER INCH
1.25"
55°
25°
25°
25°
.22"
55°
TAP FOR NO. 0×80 SCREW
SECTION A-A
RETICULE MOUNT (18)
ONE-JAPANNED BRASS
4-0×80 FLAT FILLISTER HEAD MACHINE SCREWS, .109" LONG
1"
.625"
.469"
U.S. THREAD 32 PER INCH
.35"
.031"
2.22"D.
1.2"D.
1.156"D.
1.028"D.
1.04"D.
1.12"D.
1.437"D.
1.969"D.
2.155"D.
U.S. THREAD 32 PER INCH
.125"
.2"
U.S. THREAD 48 PER INCH
1.625"
EYE END MOUNT (17)
ONE-JAPANNED BRASS
.27"
A
DRILL FOR NO. 0×80 SCREW
.02"
.15"
55°
.02"
.577R
25°
A
CORK
.02"
.10"
.2"
.2"
SECTION A-A
LUMINATING PRISM MOUNT
TWO-JAPANNED BRASS (23)
.125"
.04"
.05"
.878"D.
.820"D.
U.S. THREAD 48 PER INCH
RETICULE ADJUSTMENT LOCK RING (19)
ONE-JAPANNED BRASS
U.S. THREAD 48 PER INCH
15°
30°
.06"
.1"
.2"
.819
.7"
.789"D.
.814"D.
.878"D.
.05"
.05"
.4"
.14"
RETICULE CELL (20)
ONE-JAPANNED BRASS
.73"
.78"
.2"
RETICULE SLIP RETAINING RING (21)
ONE-JAPANNED BRASS
U.S. THREAD 48 PER INCH
.1"
.04"
.814"
.05"
.74"
.125"
RETICULE SCREW RETAINING RING (22)
ONE-JAPANNED BRASS
TUCKERMAN
OPTICAL LEVER SYSTEM
ASSEMBLY & DETAILS
SCALES – 1"=1", 1"=1/2"
BUREAU OF STANDARDS AUG. 5, 1927.
4



TUCKERMAN
OPTICAL LEVER SYSTEM
ASSEMBLY & DETAILS
SCALES — 1" = 1", 1" = ½"
BUREAU OF STANDARDS AUG. 5, 1927.

TELESCOPE EYEPIECE (35)

ONE - OPTICAL GLASS

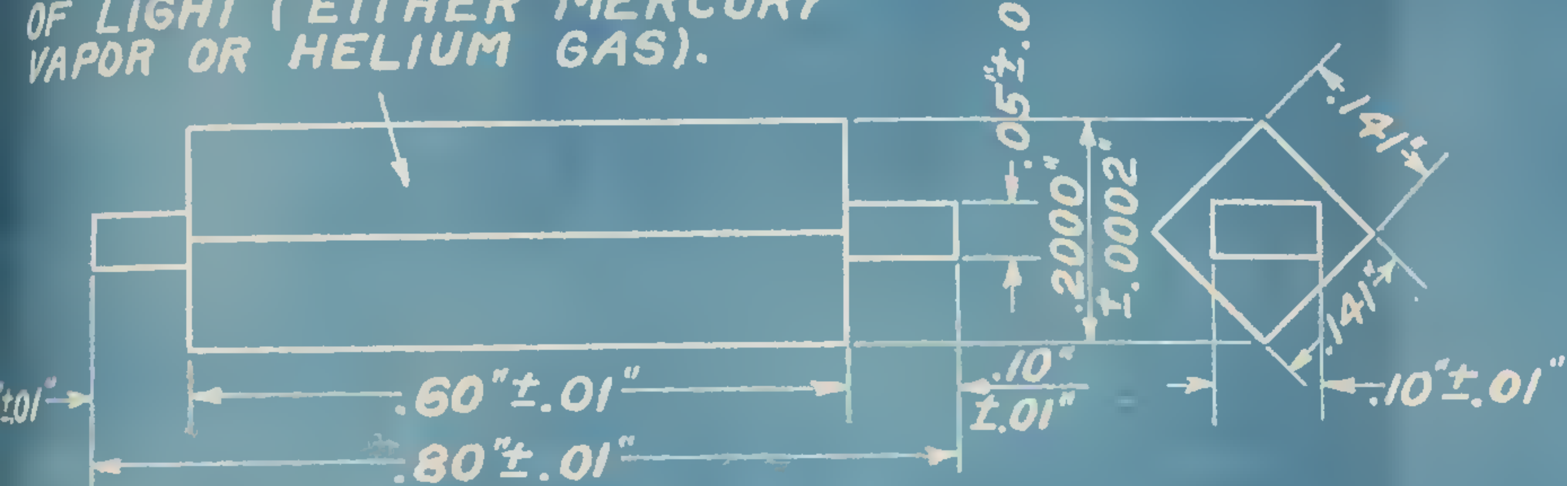
THIS EYEPIECE HAS A MAGNIFICATION OF ABOUT 15 DIAMETERS AND A FIELD OF VIEW OF APPROXIMATELY 45°.

TELESCOPE OBJECTIVE (36)

ONE - OPTICAL GLASS

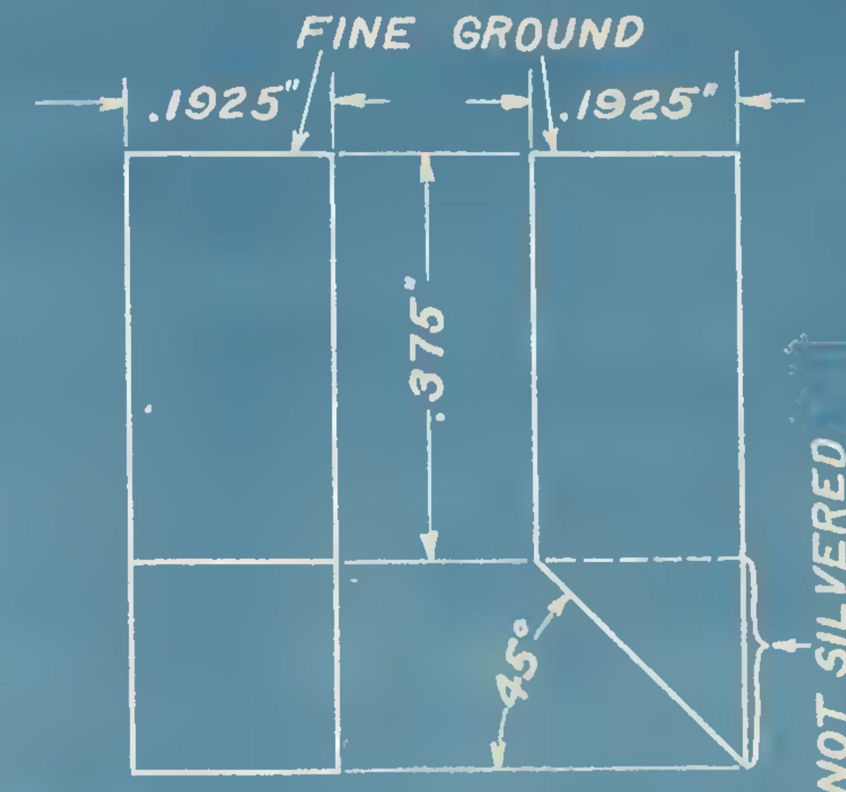
THIS OBJECTIVE IS AN ACHROMATIC DOUBLET OF ABOUT 25 CM. (9.84 IN.) FOCAL LENGTH, STOPPED TO APPROXIMATELY F/10 AND WELL CORRECTED FOR SPHERICAL ABERRATION AND COMA.

NOTE: CROSS HATCHED AREA TO BE BLACKENED



LOZENGE (34)

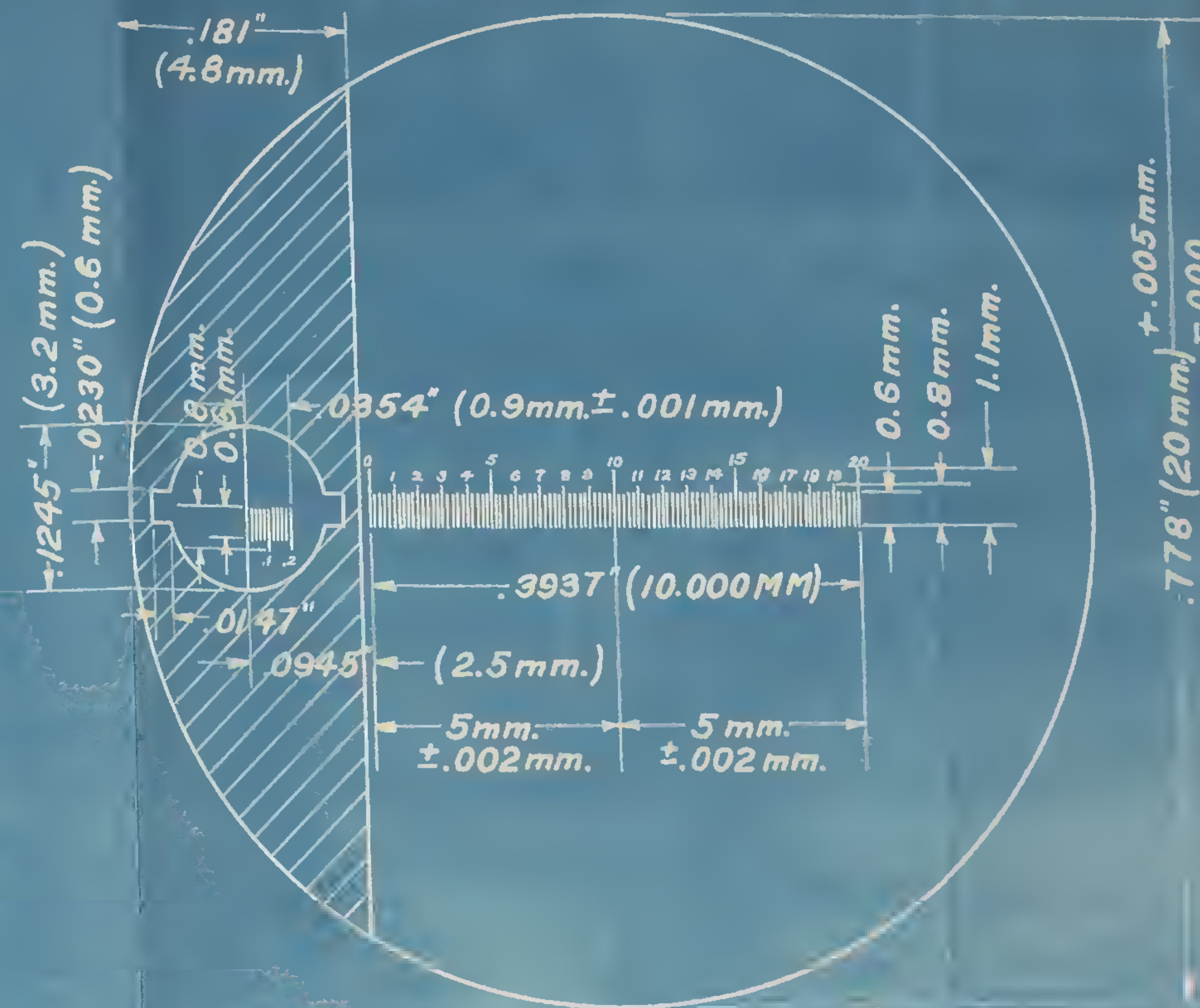
TWO - STELLITE



ILLUMINATING PRISM (32)

ONE - OPTICAL GLASS

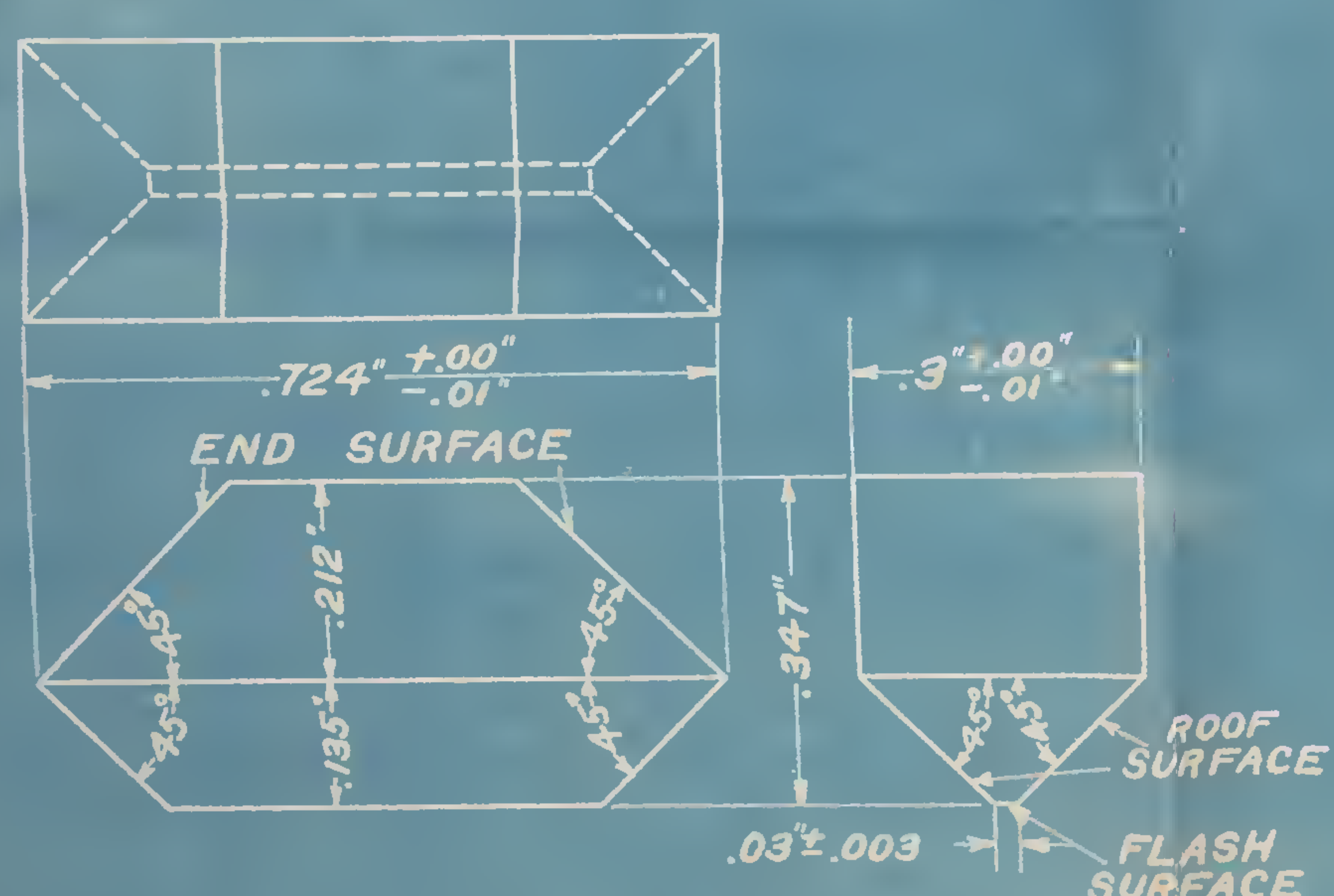
ALL SURFACES POLISHED AND SILVERED EXCEPT AS INDICATED



AUTOCOLLIMATOR RETICULE (33)

ONE - GLASS .043" THICK

MAXIMUM RANGE 0.025 RADIANS EQUIVALENT TO 0.0025 INCHES PER INCH WITH A 0.2 INCH LOZENGE OVER A 2 INCH GAGE LENGTH. FIDUCIARY LINE AND LINES ON VERNIER .015 MM. ±.001 MM. WIDE. LINES ON MAIN SCALE .01 MM. ±.001 MM. WIDE. DISTANCE FROM CENTER TO CENTER OF ADJACENT LINES ON MAIN SCALE 0.1 MM. ±.001 MM.



ROOF PRISM (31)

TWO - OPTICAL GLASS

NOTE: END, ROOF, AND FLASH SURFACES TO BE GROUND AND POLISHED TO AN OPTICAL SURFACE. ALL OTHER SURFACES TO BE FINE GROUND. END AND ROOF SURFACES TO BE ACCURATE PLANE SURFACES. ROOF SURFACE ANGLE TO BE 90° WITHIN THE TOLERANCE OF 2 SECONDS OF ARC. END SURFACES TO BE SO CORRECTED THAT THE AUTO-COLLIMATED IMAGES REFLECTED FROM THESE SURFACES COINCIDE WITHIN 30 SECONDS OF ARC. ROOF AND FLASH SURFACES TO BE SILVERED.

TUCKERMAN
OPTICAL LEVER SYSTEM
DETAILS
SCALES - 1" = 1/5", 1" = 1/8"
BUREAU OF STANDARDS AUG. 5, 1927.