GBT Feed/Receiver Room Flange Center Locations

Measurements March 31-April 1, 1998

M.A. Goldman   March 23, 1999

Abstract: This note describes measurements of relative locations of the center reference locating holes on flanges which are templates for the feed mount flanges to the GBT feed/receiver room. The template flanges for six of the GBT feed mount flanges were bolted to their mating flanges on the turret of the receiver room. An optical plummet telescope set onto a 2-axis translation stage was mounted vertically below the center of the N7 flange template. Surveyor's optical targets were mounted in the central reference pin hole of each of the template flanges. The turret was rotated repeatedly and the turret detent engaged to set the flange position. The reproducibility of setting flange N7 was measured, and the relative locations of the other flanges were measured. The measurements are described and the results given below.

The note also discusses measurements to find the room's Gregorian focus, as built, with respect to the hard casters which define the turret's rotation. It also describes locating bushings which have been attached to the outside of the room's roof, for surveyor's targets which can serve as references for aligning the room with respect to the antenna structure.

Description of Feed/Receiver Room and Feed Template Flanges:

The feed turret 24", 36" and 48" opening drill templates for the Gregorian receiver feeds are specified in NRAO Green Bank GBT drawings C35220M023, M024, M025 respectively. Each template has through holes on a bolt circle, for attachment bolts, and two dowel pin holes on the flange periphery to define template orientation. The templates were modified by drilling and reaming three holes, one to locate the flange center and two colinear with that center hole, to define a line perpendicular to the line of centers of the dowel pin holes. Surveyors targets can be mounted in these holes to provide survey alignment reference points for the templates when mounted on the receiver room turret.

The feed/receiver room is specified in RSI drawing 121036, sheets 1-7. The turret geometry and motion are as follows. The turret is a disk of diameter 174 inches, which rolls along and is located by two steel cylindrical casters, C1 and C2 (the "hard" casters). The caster axes are parallel to one another and to the axis of the turret. The caster diameter is 6 inches. C1 and C2 are designed to be separated by $90\sqrt{2}$ inches from one another. Two other casters, C3 and C4 (the pre-load casters), press the turret against the hard casters, so that the turret rolls on C1 and C2. The four caster centers are designed to lie on a square of diagonal 180 inches. The turret rotation axis is designed to be 90 inches from each hard

caster axis. Each receiver feed axis is designed to lie 56 inches from the turret axis. (See Figures 1 to 3). When the room is installed on the antenna structure, the line of centers of the hard casters should lie parallel to the telescope elevation bearing.

We call the intersection point of a caster's axis with the common parting plane of the roof flanges the "center" of the caster. In this note we describe displacements by using a local room X_{hg}, Y_{hg}, Z_{hg} Cartesian coordinate system (Fig. 3). The Z_{hg}-axis is assumed to lie parallel to the line connecting the center points of casters C1 and C2, and also lies in the plane of the roof flanges, at $45\sqrt{2}$ inches distance from line C1-C2, and points towards the receiver room door. The X_{hg}-axis is assumed to lie in the plane of the roof flanges and perpendicularly bisects line segment C1-C2, and points from the room interior towards the sloping wall of the room. The Y_{hg}-axis is perpendicular to the plane of the roof flanges and points outward from the receiver roof. The coordinate origin point is defined by the aforementioned geometric criteria. Nominally, it lies on the turret's rotation axis. In reality there is no physical turret rotation axis (e.g. as defined by a bearing pair in a solid shaft); the turret rotation is defined by the tangency of its rim with the hard casters.

The design Gregorian focus point lies on the X_{hg}-axis at distance 56 inches from the local coordinate origin. The centers of the eight receiver flanges are designed to lie on a 56 inch radius circle centered at the coordinate origin. The ideal turret design is such that the turret rotates about the The Y_{hg}-axis to bring the receiver flange centers sequentially to the Gregorian focus position $(X_{hg}, Y_{hg}, Z_{hg})_{Gregorian\ focus} = (56", 0", 0")$.

At the time of measurement, the mating pin holes in the receiver room roof flanges had not been drilled and fixturing was not available for performing the aligning and drilling operations. The bolt hole fits on the templates to the roof flanges were, however, tight and the radial play was less than 0.2 mm. We shall adopt this value as a conservative estimate of the standard error of the template flange fit to the roof flange for location in the X_{hg} and Z_{hg} directions. It was intended that the optical plummet measurements be repeated after drilling and pinning of the roof flanges, schedule and labor permitting, but this was not accomplished and the present measurements are the only ones available to date.

Description of Measurements:

Measurements were made inside the GBT receiver room while it was on the ground at the GBT site, next to the antenna feed arm tip.

A Kern type OL zenith-nadir Optical Precision Plummet was set into a tribrach and mounted onto two crossed linear translation stages with metric micrometer motion and readout. This gave a plummet mounted on a 2-axis XY-translation mount. Each translation stage had a central hole, to allow a downward view through the mount. Adapter plates and wedge feet were fabricated to allow mounting of the plummet onto the tribrach and translation stages. This assembly was mounted onto a tripod stand. The plummet has two coaxial telescopes which can look up and down respectively, that is to zenith and nadir.

Optical survey targets were set into the center holes of templates N2, N3, N4, N5, N7,

N8. The flange for position N1 was not available. A target had not been installed in flange N6, but sighting to the flange center hole could be made fairly accurately by sighting to the hole center. The targets were Hubbs Machine & Manufacturing, Inc. (Cedar Hill, Missouri) type TSO Straight-On Theodolite Target. This cylindrical-symmetry target fits precisely into the reamed pin hole at the flange center.

The turret was rotated to bring flange N7 to Gregorian focus position. The plummet was levelled and centered directly below the center of the target on N7 (at Gregorian focus position). An additional survey target was centered on the floor beneath the plummet, so serve as a secondary position reference.

The turret was then rotated several times and repositioned to bring different flange center targets into view. Each time, the turret's detent mechanism was engaged, to lock the turret position. Transverse displacement components of the viewed target, from the initial N7 target position, were recorded. Before beginning these measurements, the N7 flange target was centered in the zenith telescope cross hairs; with flange and target stationary, the telescope was repeatedly displaced off target and re-sighted onto the target center, using the translation stage micrometers. The averages of the transverse position coordinates were computed, and used as position reference coordinates for the entire set of measurements. The coordinate measurement standard errors (0.024 mm parallel to the side walls of the room and 0.019 mm parallel to the front wall, for 7 sightings) were used as estimators of the accuracy of sighting onto a target. These target setting standard errors were small compared to the standard errors found subsequently for repeatability of target location when the turret was rotated, and to the offset of the different receiver template flange centers from the reference center location.

The measurement results give an indication of the setting repeatability of the flange centers and the relative offset (box offset) of the other receiver flange centers from the mean position of flange N7 (used as reference flange).

Measurement Results.

The observed translation stage micrometer readings (mm) when the target is centered in the telescope cross hair are given below. The micrometer zeros are arbitrary.

Viewed Target Center	Reading, X_{hg} Direction	Reading, Z_{hg} Direction
Floor	21.20	8.30
N7	20.20	10.70
N2	20.30	11.70
N3	20.00	10.80
N4	21.20	11.55
N5	20.10	11.20
N7	20.20	10.90
N8	19.55	11.15
N2	20.60	11.70
N3	20.20	11.05
N4	21.25	11.55
N5	20.20	11.20
N6	20.05	10.90
N7	20.40	10.70
N8	19.70	11.20

Viewed Target Center	Reading, X_{hg} Direction	Reading, Z_{hg} Direction
N2	20.55	11.75
N3	20.15	11.80
N4	21.25	11.55
N5	20.20	11.15
N6	20.95	11.05
N7	20.35	11.70
N8	19.60	11.20
N2	20.55	11.75
N3	20.15	10.80
N7	20.15	10.60
N3	20.20	10.70
N7	20.15	10.55

The mean reading for the X_{hg} micrometer, when observing the target center on template flange N7 was 20.24 mm, with measurement standard error $\sigma_{X_{hg}}(N7) = 0.11$ mm.

The mean reading for the Z_{hg} micrometer, when observing the target center on template flange N7 was 10.86 mm, with measurement standard error $\sigma_{Z_{hg}}(N7) = 0.43$ mm.

The measurement standard error of radius in setting N7 is computed to be $\sigma_R(N7) = \sqrt{(0.11)^2 + (0.43)^2}$ mm $= 0.44$ mm.

The mean displacement components (box offsets) measured for the template target centers relative to the mean position of the reference flange N7 are given in the following table.

| Template | $X_{hg}(Nj) - X_{hg}(N7)$ | $Z_{hg}(Nj) - Z_{hg}(N7)$ |
(Nj)	(mm)	(mm)
N2	-1.00	+1.35
N3	+0.45	-0.05
N4	+0.60	+0.85
N5	-0.05	+0.65
N6	0.20	+0.15
N7	0.00	0.00
N8	-0.50	-0.10

Location Of The Gregorian Focus:

A set of fixtures was fabricated to physically locate a surveyor's target inside the receiver room so that the target center was located at coordinates $X_{hg} = 56$", $Z_{hg} = 0$", $Y_{hg} \simeq -18.4$". This target is fixtured to be equidistant from the two hard caster centers and to be displaced $(45\sqrt{2} - 56)$ inches in the minus-X_{hg} direction from the line of hard caster centers. The fixtures are described, and their drawings are given, in GBT Archive Memo A0095, "*A Proposal For GBT Feed Arm Alignment*", M.A. Goldman, February 1998. The fixtures locate the target center directly below the desired location of the Gregorian focus point (as defined relative to the hard caster centers) when the roof flanges are horizontal.

The fixtures were used together with gauge blocks to measure the actual spacing between hard caster centers. The design spacing of the hard caster centers is $90\sqrt{2}$ inches. The measured value for the caster center spacing was smaller than the design value by 0.044 inches.

The optical plummet was sighted on this target, and its transverse displacement from the target in the template N7 was measured while the template was mounted on the receiver room roof. The room had not been levelled (and could not be levelled using available jacking equipment). The tilt of the room from level was measured and used to correct the measured transverse displacement components for the error caused by the departure of the room from level and the difference of vertical height (Y_{hg}) of the two targets. After making this correction it was found that the Z_{hg} coordinate at the center of template N7 was $(0.325-0.266)$ inch $= 0.059$ inch. That is, the N7 flange center (which is the Gregorian focus point for the room) was 0.059 inch from the plane bisecting the line segment C1-C2. That is, the flange center is too close to the room door by 1.5 mm. The standard error in the Z_{hg} coordinate of N7 center was found to be 0.43 mm.

Allowing a similar error for the location of the fixtured Gregorian flange target center, and an error of 0.2 mm because the template flange was bolted but not pinned to its mating roof flange, it is estimated that the center of template flange N7 is at $Z_{hg}(N7) = 1.5 \pm 0.7$ mm.

The radial coordinate of the center of template N7 is estimated to be $X_{hg}(N7) = 0.0 \pm 0.3$ mm.

Survey Target Bushings On The Receiver Room Roof:

The feed/receiver room must be aligned to the GBT antenna structure after erection onto its support shelf. To assist in the alignment of the room on the antenna, survey target fiducials are desirable. Locating bushings to take standard surveyor's targets were installed on top of the receiver room roof. Each bushing consists of a plate which is welded to a roof beam, and a slide piece containing the survey target locating hole. The slide piece can be moved in one direction along the plate and then locked in position with respect to the plate. Using a theodolite stationed on the receiver room roof, the direction of the line of casters (parallel to the Z_{hg} axis) and the perpendicular to this line (parallel to the X_{hg} axis) were transferred to targets placed in these bushings, and the bushing locating holes were then locked into place. This generated a set of four survey target bushings which, when standard survey targets are placed into them, form a cross whose arms are along the receiver house axes, and intersect at the mean center location of reference template flange N7, which is the reference position of the Gregorian focus for the receiver room feeds. The target configuration on the roof is indicated in Figs. 5 and 6.

The bushings are shown in Fig. 4. They consist of two parts. The lower part is a stainless steel slide plate (Fig. 7) which welds onto a steel channel beam on the receiver room roof. The upper part is an aluminum slide containing an 0.250 inch diameter bushing hole for the survey target. The slide bolts onto the slide plate with four 1/4-20 steel screws and lock washers, and is cemented after survey alignment to generate the target cross. Hubbs 45 degree theodolite targets were used during alignment of the target cross, but other targets can be used. A plastic protective cover plate is presently screwed over each slide bushing, and is to be removed before use.

Discussion:

When a receiver feed is rotated into Gregorian focus position, the feed's position is set by a solenoid-driven detent pin which engages the turret with respect to the room's roof structure. Ideally the detent pin should reproducibly lock the feed to the same location with respect to the receiver room structure each time that it is engaged. Here, the receiver room structure is the (supposedly) rigid set of roof beams which support the hard casters. The optical plummet measurements reported in this note gave the following results: the reference template center repeated radially (in the X_{hg} direction, perpendicular to the line of the hard casters) with a standard error of 0.43 mm, and repeated in the X_{hg} direction, perpendicular to the line of the hard casters, with a standard error of 0.11 mm. The template flanges were not weight-loaded by feeds or receivers during the measurements. When loaded, it is possible that the reproducibility of setting will be different.

The relative box offsets of the bolted reference template flanges are given in the second table in the section "Measurement Results." A standard error of 0.3 mm should accompany these offsets, due mainly to the estimated error of 0.2 mm in each bolted flange location.
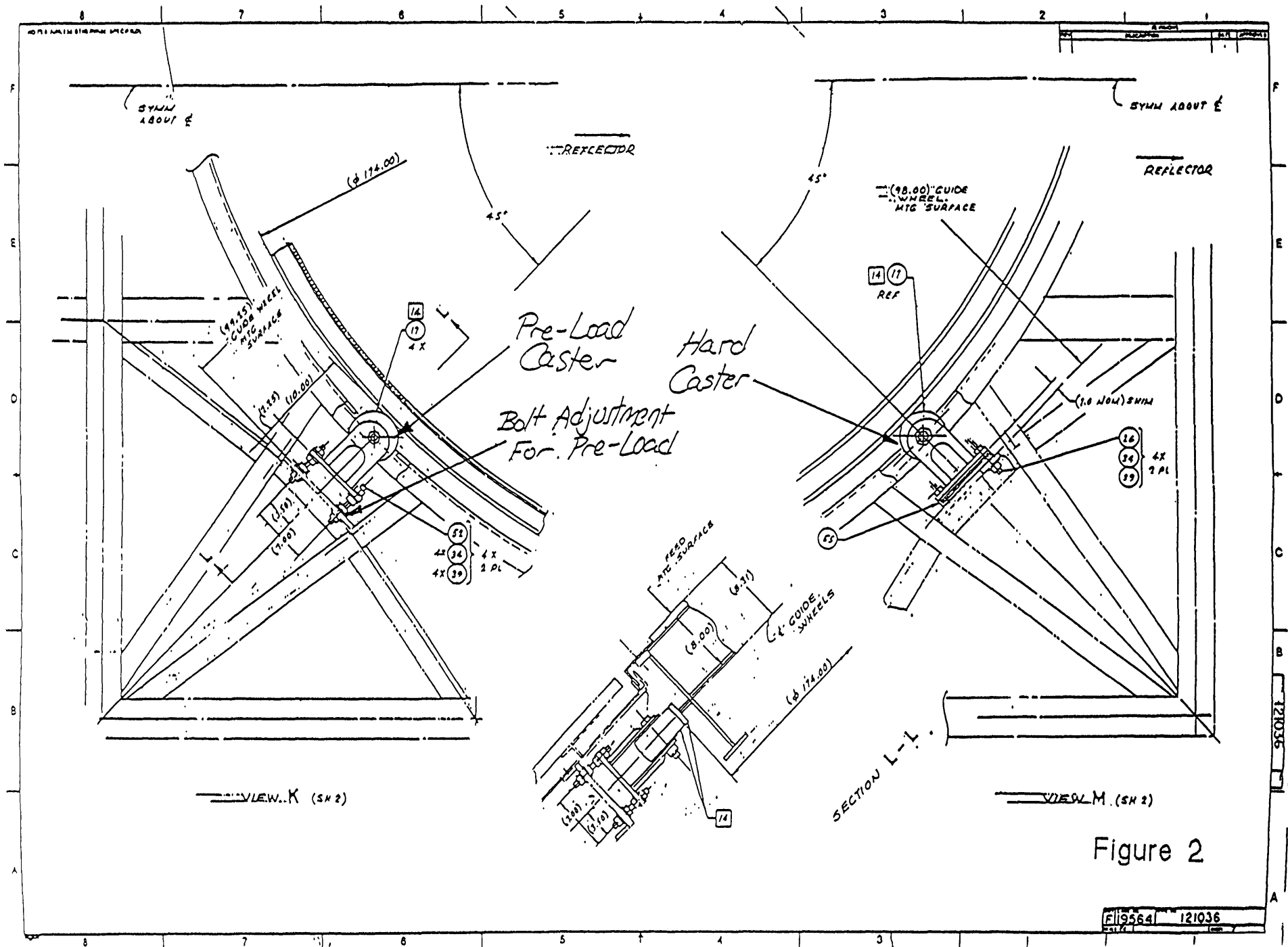
The measured spacing between the hard caster centers was 0.044" less than the design value of $90\sqrt{2}$ inches. The measured location of the room's mean Gregorian focus with respect to the hard casters appears to be within 2 mm of the design value in a direction parallel to the line of caster centers and within 1 mm perpendicular to the line of caster centers.

Four survey target bushings were provided on the receiver room roof to assist in setting the room into alignment with the GBT antenna structure after erection of the room onto the antenna. It may be desirable, before erection, to place targets into these bushings and measure the spacings between centers of each target pair. The set of 6 measured distances might provide additional survey measurement data in the case that total-station (theodolite plus electronic-distance-measurement) survey measurements are used to align the room with respect to the antenna.

I wish to acknowledge contributions and help by John Shelton and Todd Wright to making the measurements. The measurement data is recorded in computation notebook 43-648, GBT Receiver House Fiducialization, M.A. Goldman, March 9, 1998, Antenna Metrology.
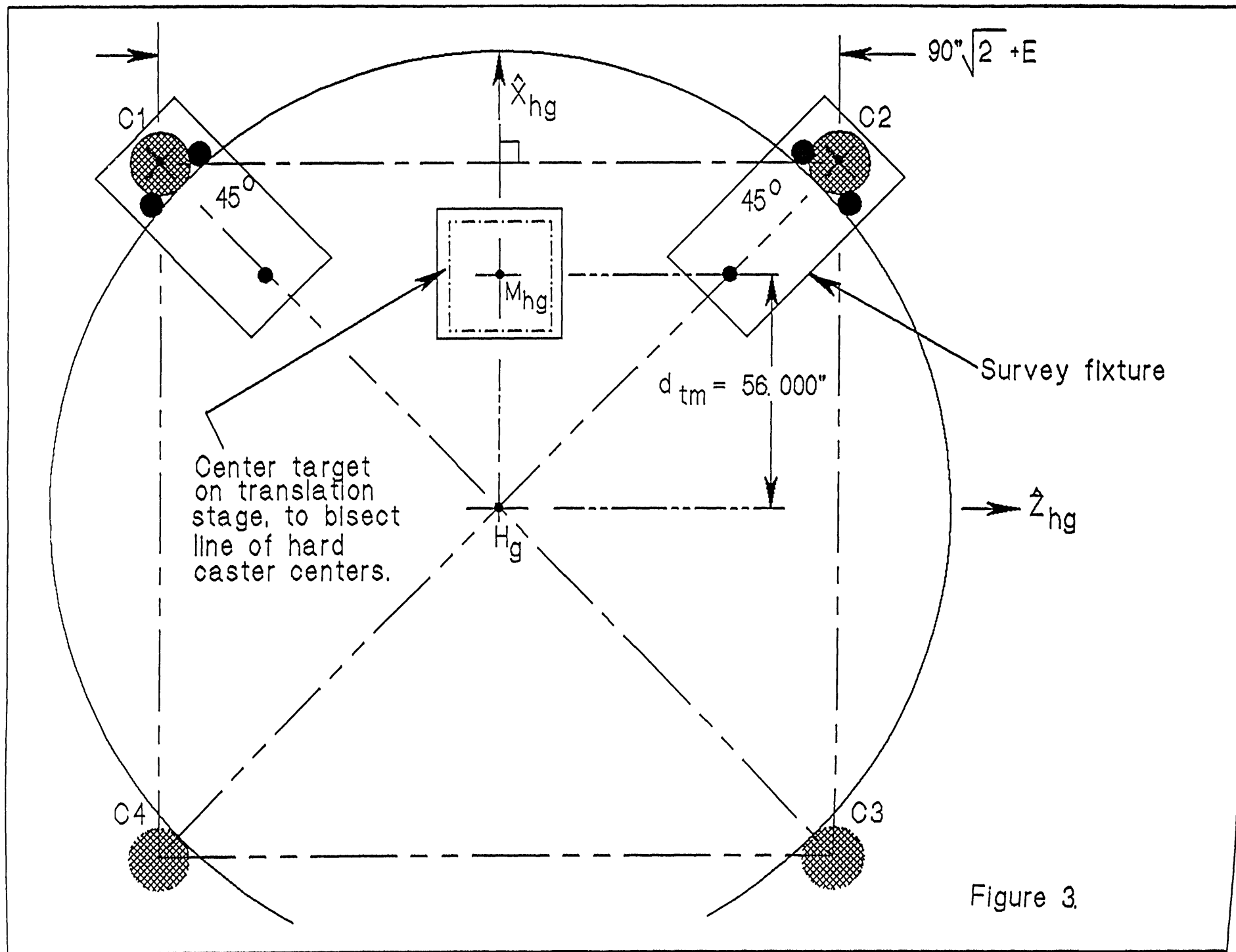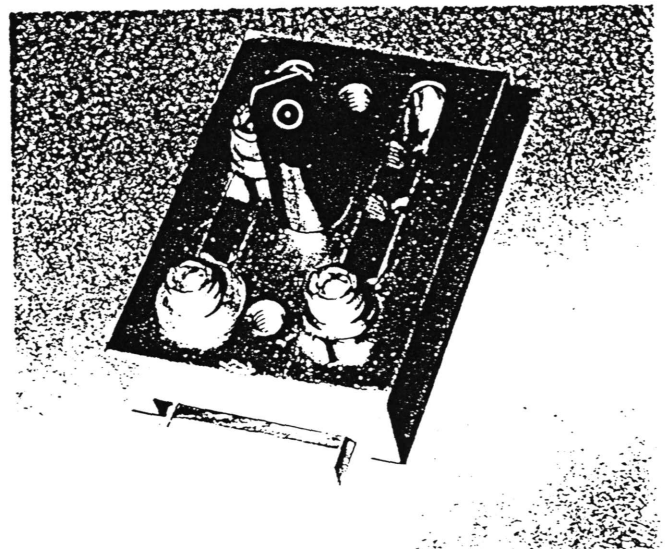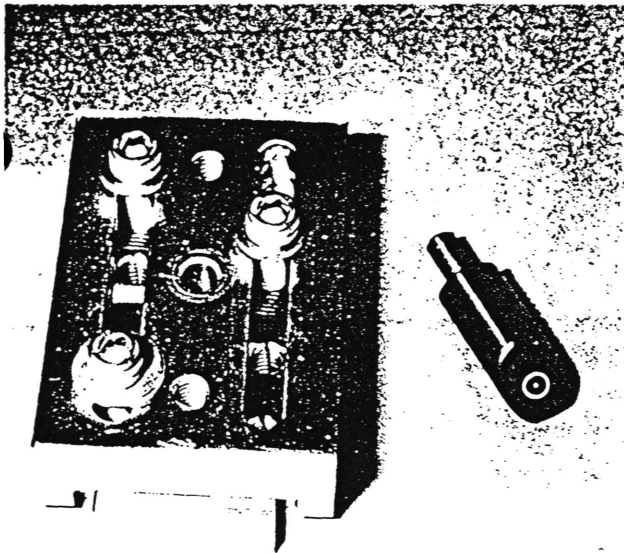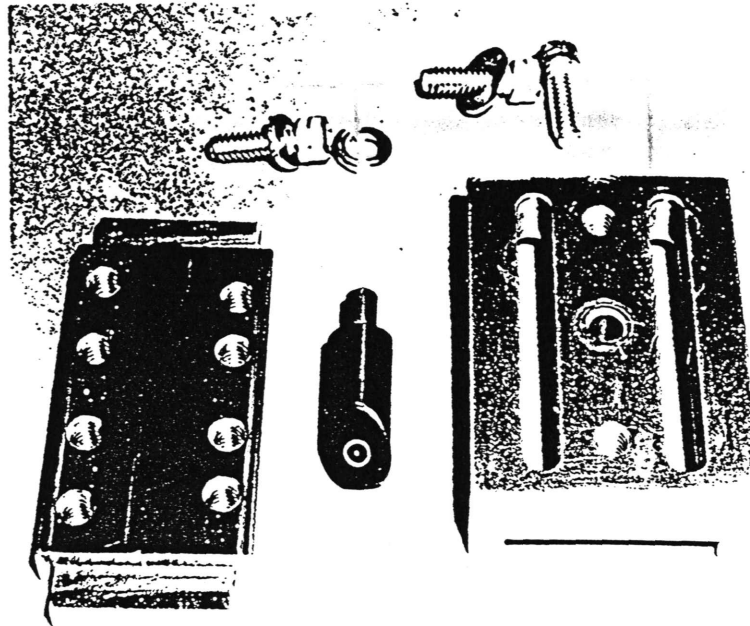
Figure 1

Pre-Load Caster

Hard Caster

Bolt Adjustment For Pre-Load

REFLECTOR

REFLECTOR

SYMM ABOUT ℄

SYMM ABOUT ℄

45°

45°

(φ 174.00)

(98.00) GUIDE WHEEL MTG SURFACE

(98.55) GUIDE WHEEL SURFACE

(1.0 NOM) SHIM

VIEW K (SH 2)

SECTION L-L

VIEW M (SH 2)

MTG SURFACE

FEED

4" GUIDE WHEELS

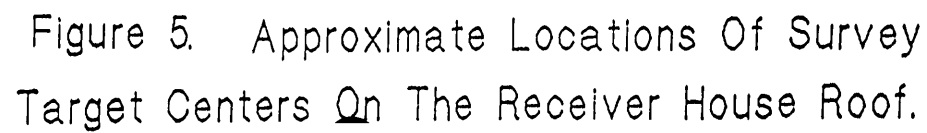(8.00)

(9.31)

(φ 174.00)

Figure 2

121036

Figure 3.

Figure 4.

Figure 5. Approximate Locations Of Survey
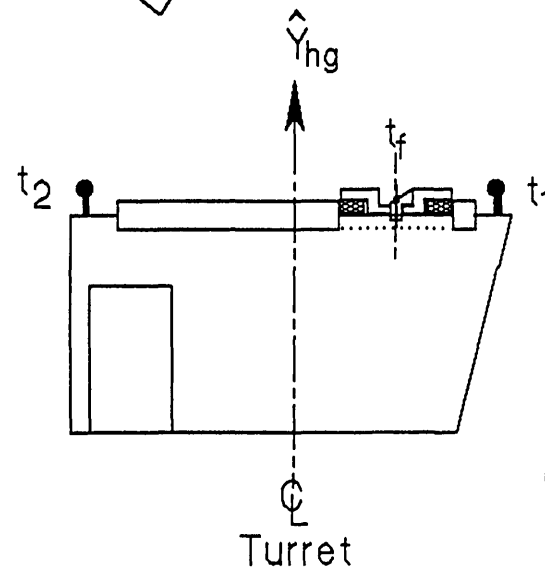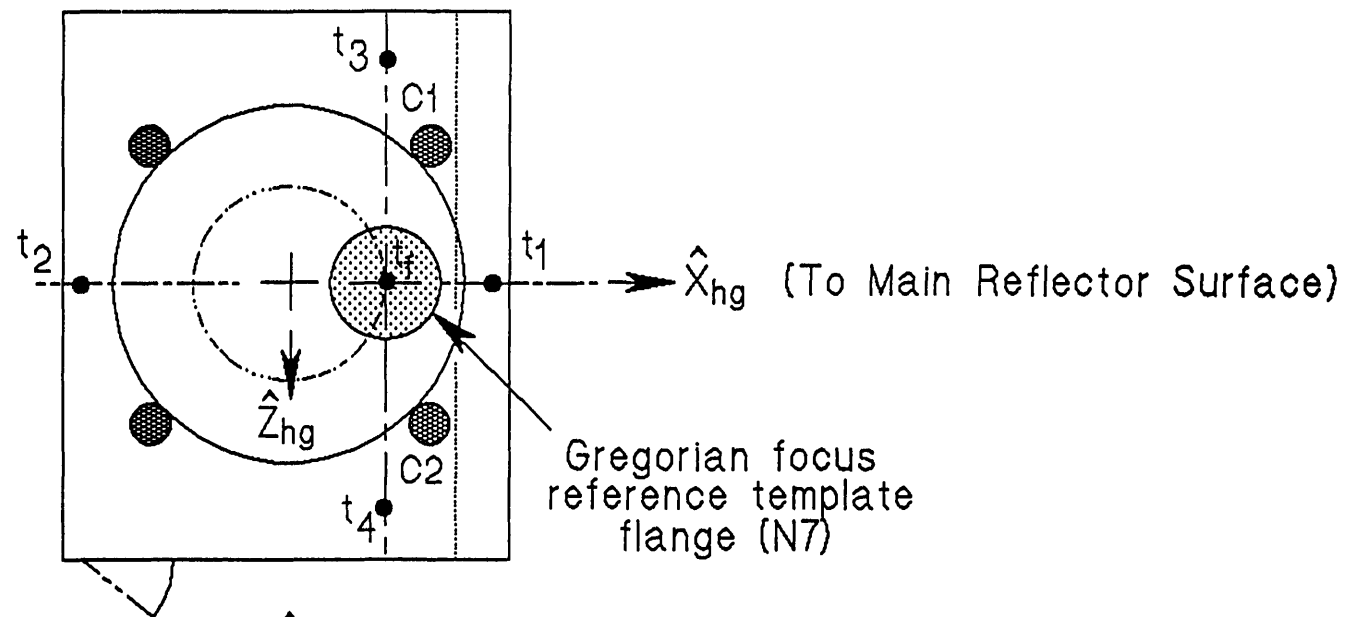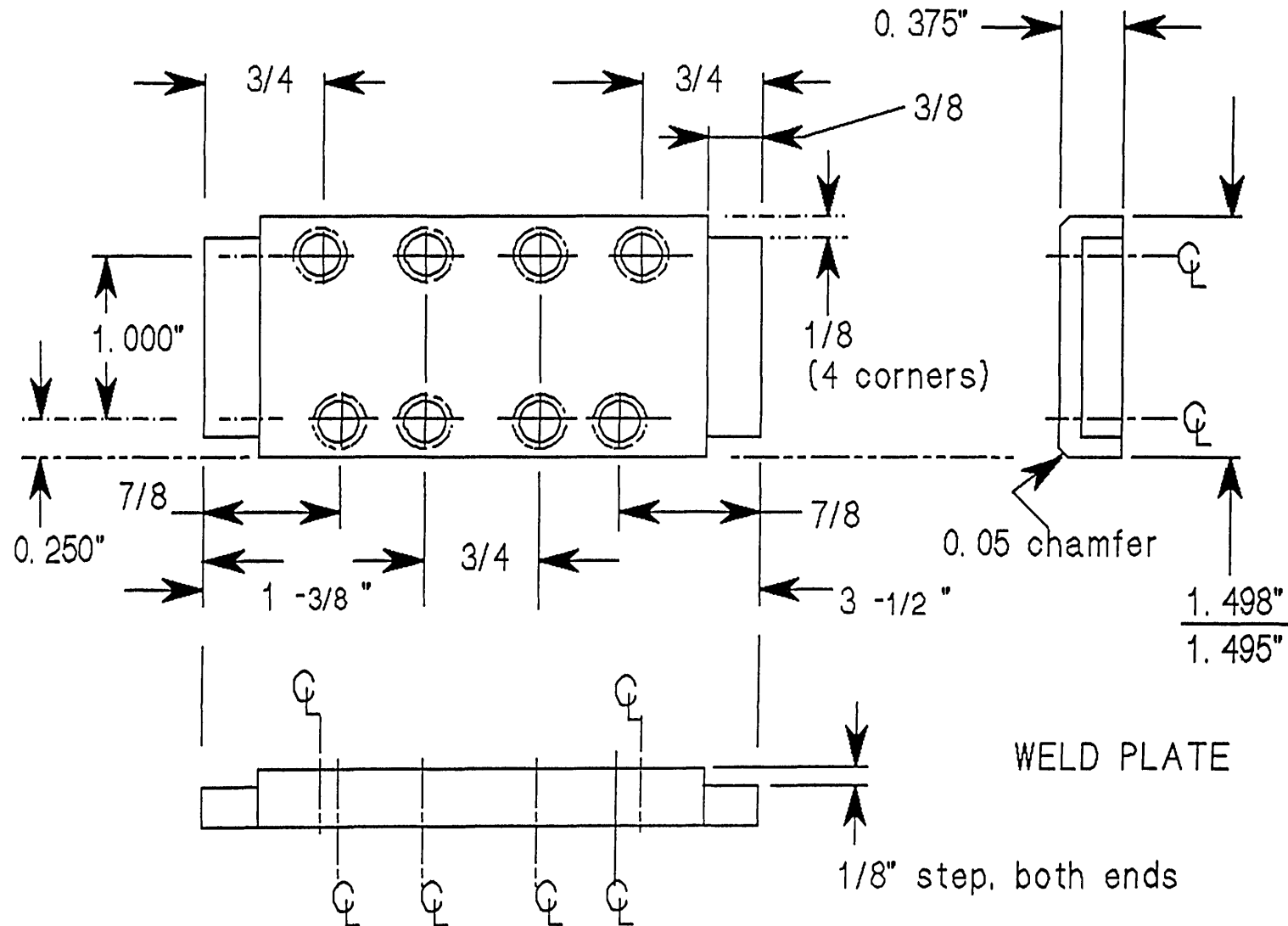Target Centers On The Receiver House Roof.

Figure 6. Locating The Feed/Receiver Room Using Roof Targets

1. Drill thru & tap 8 holes, 1/4-20 thread.

2. Make 4 of #304 stainless steel.

3. Tack welds at end corners only.

Figure 7.

Receiver House Alignment - Weld Plates

0. 375"

3/4   3/4

3/8

1.000"

1/8
(4 corners)

0. 250"

7/8   7/8

3/4

1 -3/8 "   3 -1/2 "

0. 05 chamfer

1. 498"
1. 495"

WELD PLATE

1/8" step, both ends

Drill thru & ream to 0.2500 dia.
for survey target sliding fit.

Drill thru & tap 1/4-20 thread, 2 places.

1/4"

1/4"

2.000"

0.240

1.000"

0.130

0.250"

1.506"
1.502

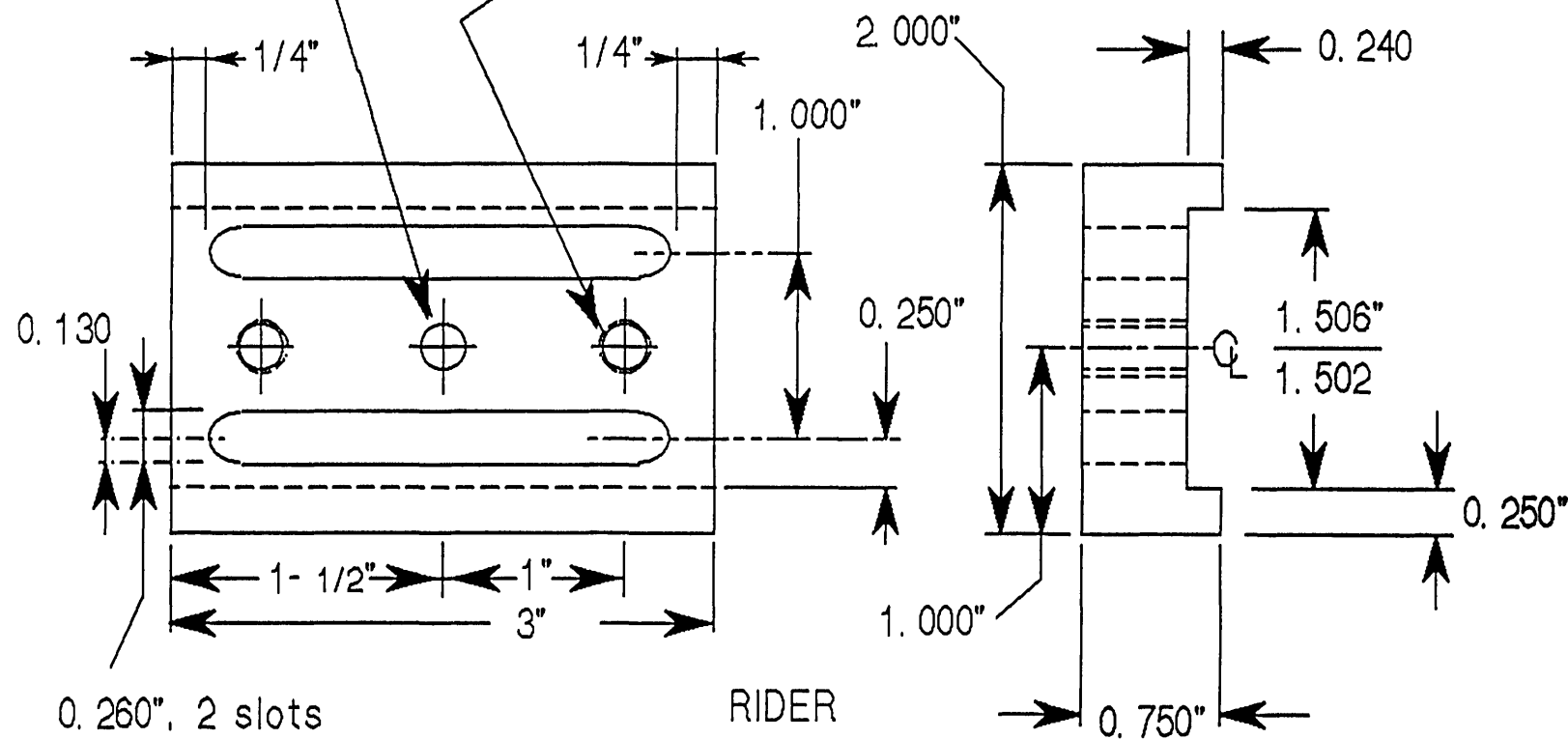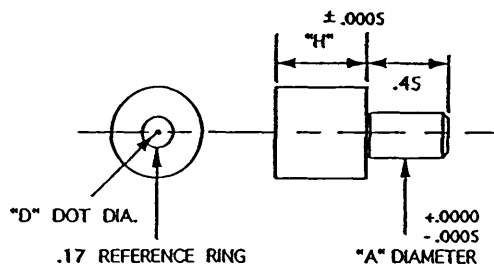0.250"

1-1/2"

1"

3"

0.260", 2 slots

RIDER

1.000"

0.750"

Figure 8. Receiver House Alignment - Weld Plates and Riders

1. Make 4 riders of aluminum.
2. Black anodize riders.
3. Tolerance +/-0.003" on 3-decimal dimensions unless specified otherwise.
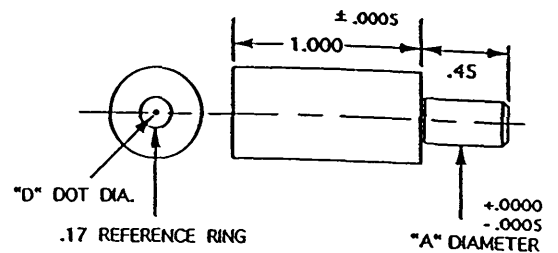
STRAIGHT-ON TARGET, THEODOLITE
Used with Computer-Aided Theodolite for targeting holes approximately in line with line of sight.

± .0005
"H"
.45

"D" DOT DIA.
.17 REFERENCE RING

+.0000
-.0005
"A" DIAMETER

DRAWING NUMBER
TSO

TO ORDER: SPECIFY PART NO. AS SHOWN
EXAMPLE: TSO-500-2500-020
"H"   "A"   "D"

± .0005
1.000
.45

"D" DOT DIA.
.17 REFERENCE RING

+.0000
-.0005
"A" DIAMETER

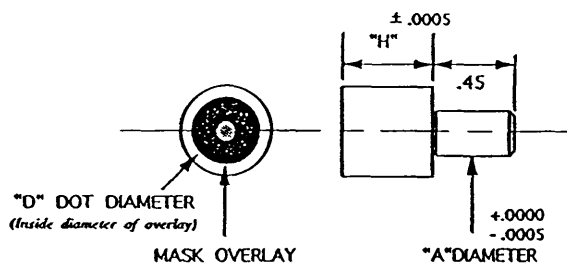| DRAWING NUMBER |
| --- |
| TSO-1.000 |

TO ORDER: SPECIFY PART NO. AS SHOWN
EXAMPLE: TSO-1.000-2500-020
"H"   "A"   "D"
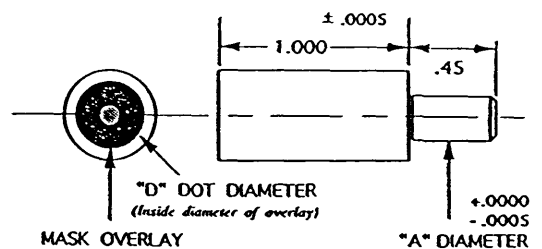
STRAIGHT-ON TARGET, RETRO-REFLECTIVE
Used with Photogrammetry or Motorized Theodolite for targeting holes approximately in line with line of sight.

± .0005
"H"
.45

"D" DOT DIAMETER
(Inside diameter of overlay)
MASK OVERLAY

+.0000
-.0005
"A" DIAMETER

DRAWING NUMBER
TSOR

TO ORDER: SPECIFY PART NO. AS SHOWN
EXAMPLE: TSOR-500-2500-125
"H"   "A"   "D"

± .0005
1.000
.45

"D" DOT DIAMETER
(Inside diameter of overlay)
MASK OVERLAY

+.0000
-.0005
"A" DIAMETER

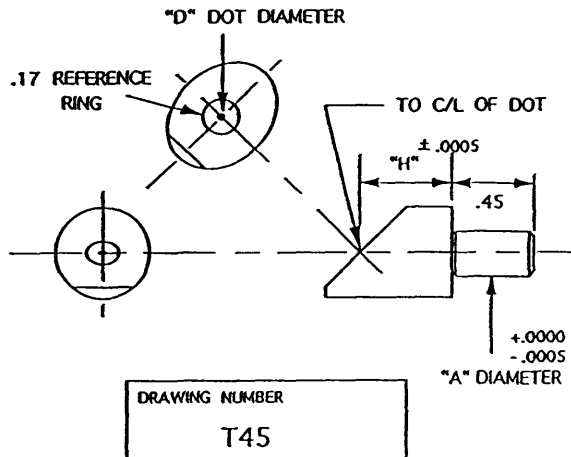| DRAWING NUMBER |
| --- |
| TSOR-1.000 |

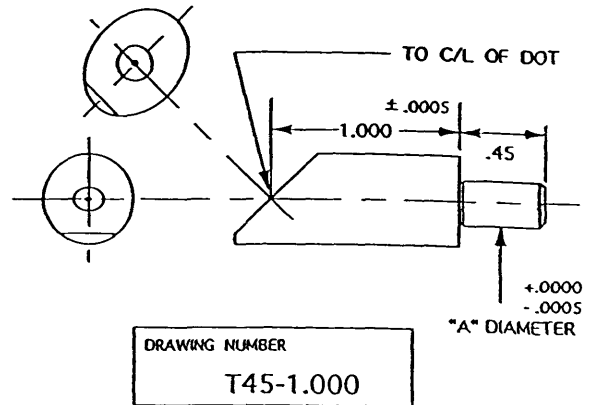TO ORDER: SPECIFY PART NO. AS SHOWN
EXAMPLE: TSOR-1.000-2500-125
"H"   "A"   "D"

45 DEGREE TARGET, THEODOLITE

Used with Computer-Aided Theodolite for targeting holes approximately 45 degrees to line of sight.

"D" DOT DIAMETER

.17 REFERENCE RING

TO C/L OF DOT

"H" ± .0005

.45

+.0000 -.0005 "A" DIAMETER

DRAWING NUMBER
T45

TO ORDER: SPECIFY PART NO. AS SHOWN
EXAMPLE: T45-500-2500-020
"H" "A" "D"

TO C/L OF DOT

± .0005
1.000
.45

+.0000 -.0005 "A" DIAMETER
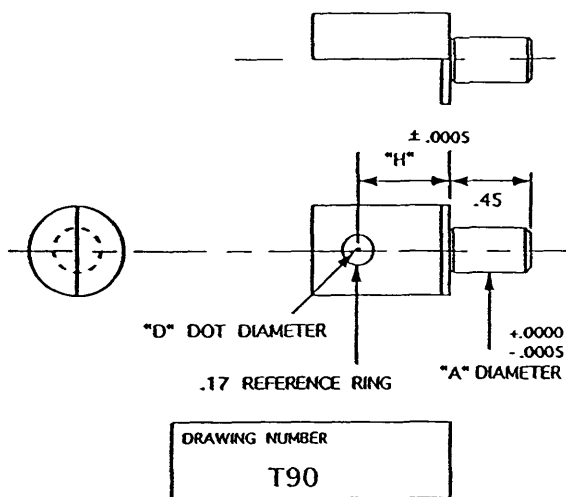
DRAWING NUMBER
T45-1.000

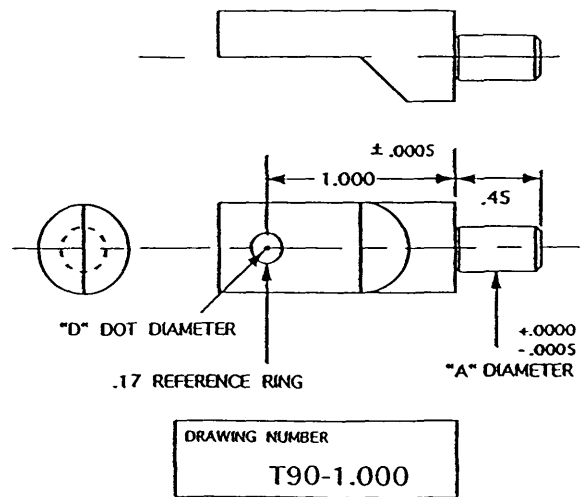**TO ORDER: SPECIFY PART NO. AS SHOWN**
EXAMPLE: T45-1.000-2500-020
"H" "A" "D"

90 DEGREE TARGET, THEODOLITE

Used with Computer-Aided Theodolite for targeting holes approximately 90 degree to line of sight.

± .0005
"H"

.45

"D" DOT DIAMETER

.17 REFERENCE RING

+.0000 -.0005 "A" DIAMETER

DRAWING NUMBER
T90

TO ORDER: SPECIFY PART NO. AS SHOWN
EXAMPLE: T90-500-2500-020
"H" "A" "D"

± .0005
1.000
.45

"D" DOT DIAMETER

.17 REFERENCE RING

+.0000 -.0005 "A" DIAMETER

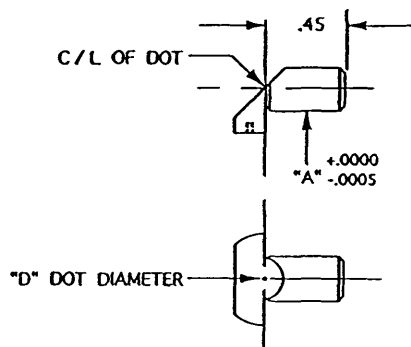| DRAWING NUMBER |
|---|
| T90-1.000 |

TO ORDER: SPECIFY PART NO. AS SHOWN
EXAMPLE: T90-1.000-2500-020
"H" "A" "D"

FLUSH MOUNT

Use a FM or FMR for targeting holes when a zero height value is required

.45

C/L OF DOT

"A" +.0000 -.0005

"D" DOT DIAMETER

SHANK SIZES AVAILABLE AT THIS TIME - "A"

.1250	.3750
.1285	.4375
.1875	.5000
.1935	.6250
.2188	.7500
.2480	1.0000
.2500	8mm
.2570	8.7mm
.3125	

"R" ALSO AVAILABLE IN RETRO-REFLECTIVE
(.1875 shank diameter and larger only)
Some dot diameter limitations apply.

DRAWING NUMBER
FM
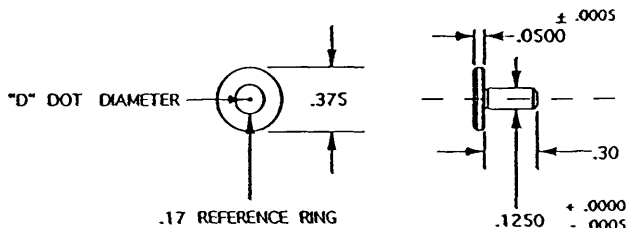
TO ORDER: SPECIFY PART NO. AS SHOWN
EXAMPLE: FM - 2500 - 020
FMR - 2500 - 125

"A"   "D"

TARGET, BUTTON

Used with Computer-Aided Theodolite for targeting .125 diameter tooling holes

Anything other than a .125 diameter shank or .050 height would be considered specials

± .0005

←.0500

"D" DOT DIAMETER   .375

.30

.17 REFERENCE RING

.1250 + .0000 - .0005

.1250 + .0000 - .0005

DRAWING NUMBER
TB

TO ORDER: SPECIFY PART NO. AS SHOWN
EXAMPLE: TB - .020

"D"