VLBA ACQUISITION MEMO # 290

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12 February 1992

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To: VLBA Data Acquisition Group

From: Hans F. Hinteregger
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Subject: Configuration of tape path for thin tape and high speed

I. Introduction

Described here are modifications to the Metrum 96 tape drive which we have found necessary to insure that properly manufactured thin (16 or 13 μm) tapes will not be significantly damaged by a drive operating indefinitely at speeds up to 320 ips.

Two drives with "quick fix" implementations of these modifications have been used almost continuously for more than ten weeks to "qualify" tapes for VLBI by passing a bidirectional high-tension/low-speed (15" H_2O vacuum, 67.5 ips) pack-without-bumps test before and after shuttling for at least 2 weeks (~1400passes) at 7", 270 ips. No debris build-up in the tape-paths was ever observed in that time even when tapes with a damaged (burred) edge were run. This is a good indication that the edge "melt-down" problem has been reliably solved.

Further optimization of the tape path to reduce edge pressure to increase tolerance of tape edge non-idealities (such as chisel-shapedness) and asperities may be possible in the future.

II. Melt-down Prevention: Selection of Edge Bearing Materials

The material selected originally only for its resistance to wear, a fine-grained, 99.6% pure, polished alumina, has been found empirically to be quite satisfactory for the inside edge bearing points. Sapphire (single crystal Al_2O_3) and SiC (harder and more thermally conductive) were both prone to wear scratching. Wear scratches are not innocuous, they seem to 'seed' debris build-up. CVD, chemical vapor deposited diamond, is not fully evaluated but may have a similar (unexplained) susceptibility to scratching. Deposits on the dark surfaces of SiC and CVD are hard to see whereas the white alumina provides good contrast. But the alumina recently used by Metrum for "hard-point"-equipped VLBA drives is a coarse-grained variety which stains easily and could therefore be confusing to an operator trained to be on guard for adherent debris build-up -- a sure cause of catastrophic tape edge damage (melt-down) at high speeds. The coarse-grained material appears however to be no more susceptible to debris build-up or scratching than the fine-grained variety. A quote for the proper fine-grained alumina plates has been obtained from Coors and we suggest that the coarse-grained plates be replaced.

A copper tape surface was found to be reliable for the outer tape edge bearings on the vacuum door. For unknown reasons, alumina or sapphire-faced experimental doors occasionally show debris build-up. Copper faced doors never have. The copper surface on the outer edge bearing wears only slowly because of lower contact pressure than in the case of the inner edge bearings and because the operating point of the loop moves and distributes contact over a much larger area. Retaping is easy and quick. It should be obvious when it is needed, probably no more than once per year in full-time operation.

III. Prevention of Edge Scrape and Foldover: Geometry Modifications

These modifications serve to insure, first, that sliding contact of the tape edges takes place only at the 6 design points and not at any other points especially sharp discontinuities such as at the end of an alumina plate, the end of the vacuum door, or where the tape enters or leaves the precision plate near the I/O roller.

Second, the I/O roller sleeve is modified (or made from scratch) to keep the tape from climbing the flange and folding over at slow speeds (during stop/start) without requiring unrealistically tight reel-to-tape path alignment.

Without the first modification, shaving of the tape edge can take place. This typically fouls the drive with excessive loose debris, but hard deposits and edge melt-down have also been observed. Without the second provision, local edge damage may occur at stop/start. Systematic damage at all but the highest operating speed is likely with the special deeply-grooved "non-slip" I/O roller sleeves that were mistakenly specified for new VLBA recorders.

I/O Roller and Sleeve

The flange of the I/O roller (without sleeve) is set 4 ± 1 mils above the precision plate. Metrum's new standard rollers are not adjustable and sets this distance to 1.0 ± 0.3 mils by design. A 3 mil shim washer with ~1/2" OD and 1/8" ID is required between the precision plate and this roller. (We have cut these by hand with scissors and a safety razor from plastic shim stock.) Honeywell's old standard roller (no longer made) is directly adjustable to the new standoff distance. The span of tape between roller and a full 14" reel is 5" long and that between roller and outside edge of the precision plate is 5/8"; thus the inner edge of the tape at the top of the pack can be displaced at least 24 mils inward with respect to the roller flange (which is at least 3 mils above the precision plate) before it touches the edge of the precision plate. For Metrum's 0.7 mil minimum standoff distance a 6 mil displacement of the tape pack is sufficient to produce the undesired contact.

The length of the tape-bearing sleeve (between flanges) has been increased from 1.001/1.000 to 1.011/1.009. With a bearing radius of r = .375", the tape wraps up to 140° for a surface bearing length of 0.92". A maximum width .999" tape will just touch both 1.009" minimally separated flanges (at diagonally opposite points) if it is wrapped at a helical angle corresponding to ±10 mils in the 1.2" span from flange edge entry to exit. Projecting this 8.3 mil/inch angle to the top of the tape pack about 4.8 inches downstream, we see that a tape edge displacement at that point of 50 mils outward from the inner flange or inward from the outer flange can be tolerated. The Metrum standard version allows only an unrealistically small ±5 mil displacement of the tape pack to reach the same binding condition where buckling (climbing of the flange and foldover of the tape edge) easily occurs.

It is important that the tape slide freely or fly on the roller sleeve so as not to resist the slightly helical wrapping that accommodates unavoidable tape pack misalignment. Honeywell's original smooth grooveless roller sleeves were OK in this respect, but the new standard grooved

sleeves and especially the deeply grooved VLBA version are not, and unlike the former, cannot be modified to conform to the new specification. Coating the outside polished aluminum surface of the sleeve with "Nedox SF-2R" (a teflon impregnated nickel coating) may reduce friction further but is as yet untried.

Vacuum Spacer and Door Modification

The inner tape edge bearing points are raised with respect to the precision plate and the sharp leading edges of the bearing plates. This is done by tapering and possibly recessing that part of the bottom surface of the vacuum spacer (E-casting) to which the bearing plates are clamped as shown in the drawing 6310-102. For a slope of 2 mils/inch, the bearing point is 3.8 mils above the leading edge of the alumina bearing plate which is 1.9" to the left.

Since the operating point of the loop moves about 0.1" from full to empty reel this slope produces a proportional 5 µm, end-to-end interchange tracking shift with respect to a conventionally configured (zero-slope) drive. Loop jitter is much smaller and the 2 mil/inch bearing slope probably introduces less than 1 µm tracking noise. This should be verified. Quick-fix prototypes have been operating satisfactorily with 1 and 3 mil/inch slopes, bracketing the proposed 2 mil/inch slope. If the jitter-induced tracking noise is larger than expected the slope could be reduced, but probably not much below 1 mil/inch.

The entire front surface of the vacuum spacer is also tapered (as it turns out, with the same 2 mil/inch slope) to provide a minimum clearance of 5 mils (8 mils nominal) between door and the outer edge of the tape at the end of the vacuum spacer, and a clearance of 4.5 ± 1.5 mils (6 mils maximum) between the alumina bearing plate and the bottom edge of the tape at the vertex of the loop (where the tape is in contact with the door). The latter clearance could be reduced to 4 mils maximum if useful to reduce edge pressure.

A new door (drawing 6310-103) or a similarly modified Metrum door (cut-off flush with the end of vacuum spacer) is required to positively prevent contact between the outer edge of the tape and the portion of the original door just beyond the vacuum spacer in the case where the tape contacts the outer roller flange. An outer-flange-contact angle of 2.8 ± 0.7 mil/inch implies up to 3.5 mils interference with an unmodified door. If an unmodified door is used, it can be made safe for the tape by applying 2 layers of copper tape in the area over the vacuum spacer. We advise against the use of the unmodified door because anomalous mechanical behavior of the tape near the I/O roller cannot be observed by a vigilant operator or trouble-shooter. Experimental doors with a teflon-impregnated nickel coating, "Nedox SF-2R", a possible substitute for the use of copper tape have not yet been tested.

IV. Reel Alignment

Recently delivered drives have reel tables set so that the inner surface of the inner flange of a self-packing reel is typically 10 mils below the precision plate (14 mils below the roller flange). Much larger misalignments have been observed on some older, heavily used drives whose supply reel tables have gradually slipped inward under the continual hammering of heavy tape mounts. (Note however, that the most recent version of the reel table is simplified -- it no longer has an adjustable clamp mechanism -- and supposedly cannot slip on the motor shaft). Only the factory-set mounting pads on the deck plate are supposed to control height of the reel table and to keep the reel flanges parallel to the precision plate.

Our proposed modifications have, so far, been tested only with reel tables set so that the inner self-packing reel flange is in the same plane as the inner roller flange to within ±5 mils.

Non self-packing take-up reels have been used in most tests (to observe the tendency of most thin tapes to pack against one flange). Thus we have observed that an inward pack misalignment of at least 15 mils is clearly tolerated. Clearly **not** tolerated was an inward displacement of the tape pack of about 70 mils which was recently encountered. (A D1-K tape returned from Bonn somehow had packed so that it flexed the inner flange about 65 mils.) In this case with an additional supply reel table misalignment of 6 mils, the inner tape edge immediately folded over during load. When the tape was flipped, it wound from the take-up side without trouble with a net displacement of the outer pack edge of about 47 mils outward from the outer (roller sleeve) flange. This behavior is consistent with the prediction that pack edge displacement of up to 50 mils at a distance of 5" from the flange contact point should be tolerated without binding and the consequent foldover. Some additional testing of extreme misalignment tolerances seems warranted nevertheless.

It is desirable to set the reel table height so that the tape is guided entirely by the flanges of a self-packing reel and not normally by the I/O roller flanges. The inner flange of a self-packing reel should therefore be 10 mils above the precision plate to center the tape between the roller flanges. This is equivalent to setting the inner flange of a non-self-packing reel flush with the precision plate.

To check and set reel table height use a depth micrometer (or even the back end of a vernier caliper), a standard metal reel with the outer flange removed, and, if necessary, some shim stock. Compare the height of the reel flange near the hub with that of the precision plate. Select shim stock to the nearest 5 mil thickness increment to make these heights equal. Slip one piece, preferably with a hole for the screw, between each of the three pads on the deck-plate and the reel motor mounting flange.

We assume here that mounting pads in the deck plate have been properly set at the factory to make the mounting surface of the reel motor adequately parallel to the precision plate. To check for gross angular misalignment, place a long straight edge on the precision plate (with obstacles such as the vacuum spacer removed) so that it overlaps the single flange of the height-setup-reel and look for a significant variation in the air gap along the chord. A 10 mil difference between the gap at the beginning and at the end of a chord tangent to the hub is noticeable and tolerable. The factory alignment should be much better and larger angular misalignments should be corrected.

V. Caveat

Some further refinements of the tape path geometry may be possible to ensure even gentler handling of the tape edge. These include the possibility of recessing the angled hard-point mounting surface up to 6 mils (at which point the tape would run nominally parallel to the precision plate and centered between the I/O roller flanges from hard point to reel hub), reducing the nominal hard point slope to perhaps as little as 1 mil/inch, and reducing the separation of inner and outer edge bearing points by as much as 2 mils. The effectiveness and value of these possible refinements is not yet clear.

VI. Quick-Fix

The quick-fix implementation uses the standard 1.002/1.003" thick Metrum vacuum spacer modified only with the addition of the six hard-point mounting holes shown in Haystack drawing 6310-102 or Metrum drawing 16827013. It also requires the standard hard-point components: 2 alumina bearing plates (Metrum #16827012-001 or direct from Coors), 2 bearing clamp plates (#16827014-002) and a new precision plate with the hard point insert cavity (#16827011) or similarly modified old precision plate (not recommended).

The bottom of the vacuum spacer is taped up as shown in the attached xerox. Two layers of "zebra tape" (3 mils/per layer) serve to stand the vacuum spacer 6 mils off the precision plate. The four 1"-long, 6 mil thick areas of tape at the end of the vacuum spacer legs are just long enough to force the left edges of the bearing plates into the same plane as the precision plate; no tape under the right edge implies a slope of at least 2 mils/inch and the inch-long one-layer (3 mil) taped sections yields a slope of no more than (actually close to) 3 mils/inch.

The 2 mil/inch slope of the door is most easily produced by using 2 staggered layers of 3 mil thick copper tape as shown in the xerox; the one- and two-layer sections begin 1.5" and 3" to the left of the door hinge respectively. The door must be firmly seated against the vacuum spacer at the hinge end and the desired 15 mil spacing at the latch end can be enforced with a pad of that thickness in each corner (not shown).

VII. Upgrade Procedure

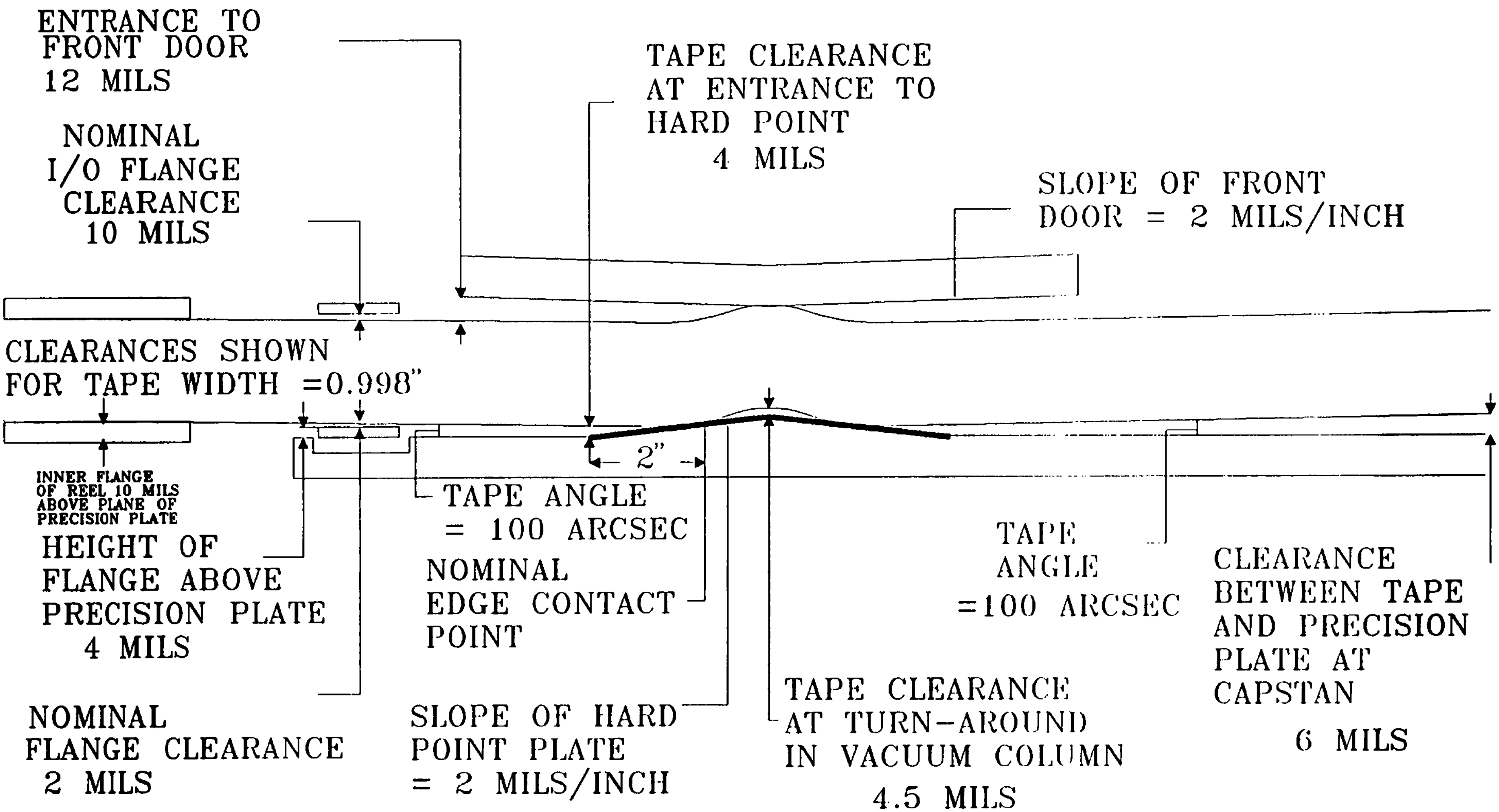
a. Quick-fix

1] Install new precision plate.
2] Apply tape to E-casting - see Fig. 6.
3] Install new or modified I/O sleeves with shims - see Fig. 2.
4] Apply copper tape to (preferably cut-off) front door - see Fig. 7.
5] Check and set alignments to conform to Fig. 1 and text.

b. Upgrade

1] Install new precision plate.
2] Install new E-casting - see Fig. 3 and Fig. 4.
3] Install new I/O sleeves with shims - see Fig. 2.
4] Install new or cut-off front door with single layer of copper tape - see Fig. 5.
5] Check and set alignments to conform to Fig. 1 and text.

Attachments: (7)
Figures 1 - 7



TAPE PATH IS SHOWN FOLDED OUT ABOUT THE CENTER OF THE LOOP TURN-AROUND
NOT DRAWN TO SCALE

FIGURE 1. NOMINAL TAPE CLEARANCES

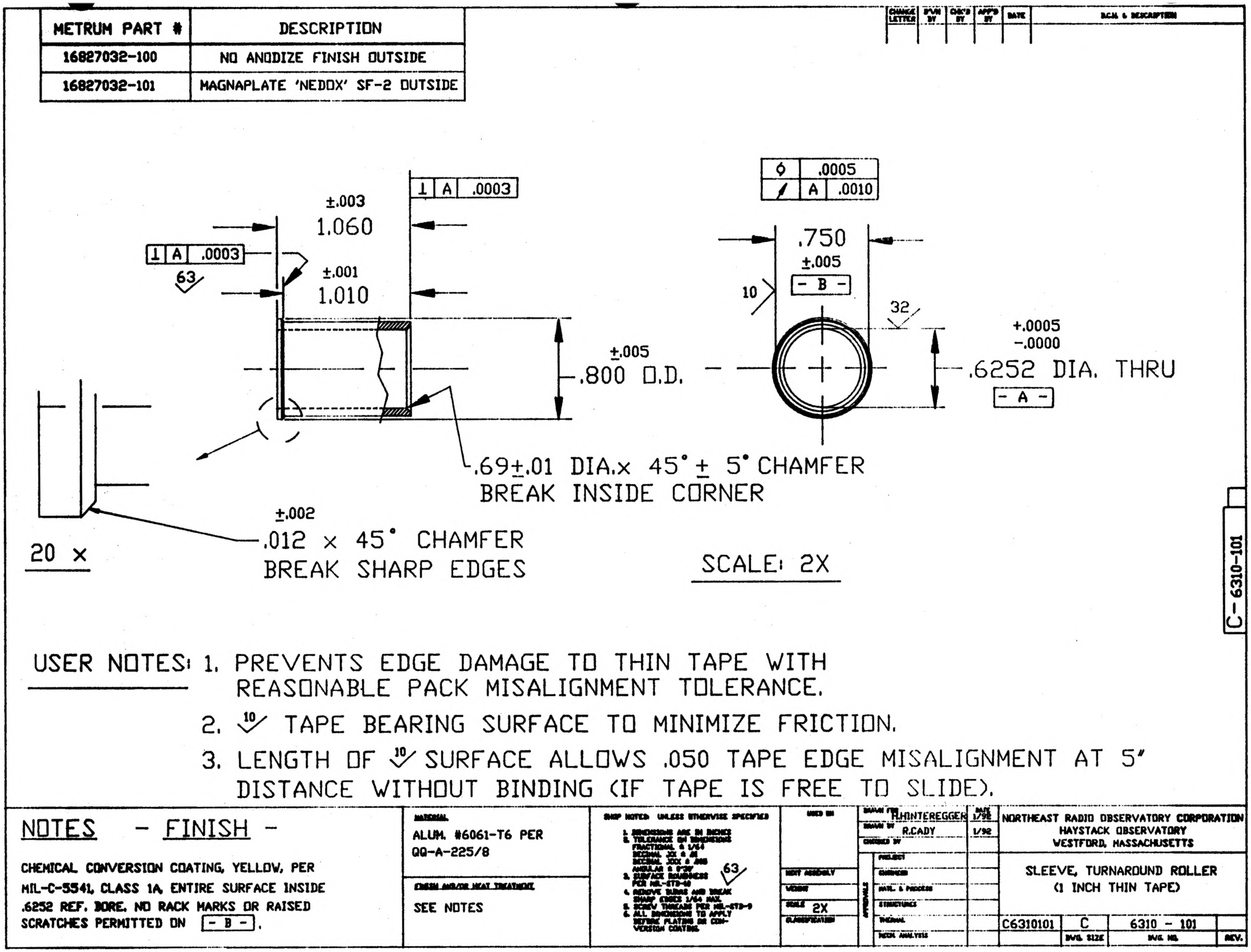
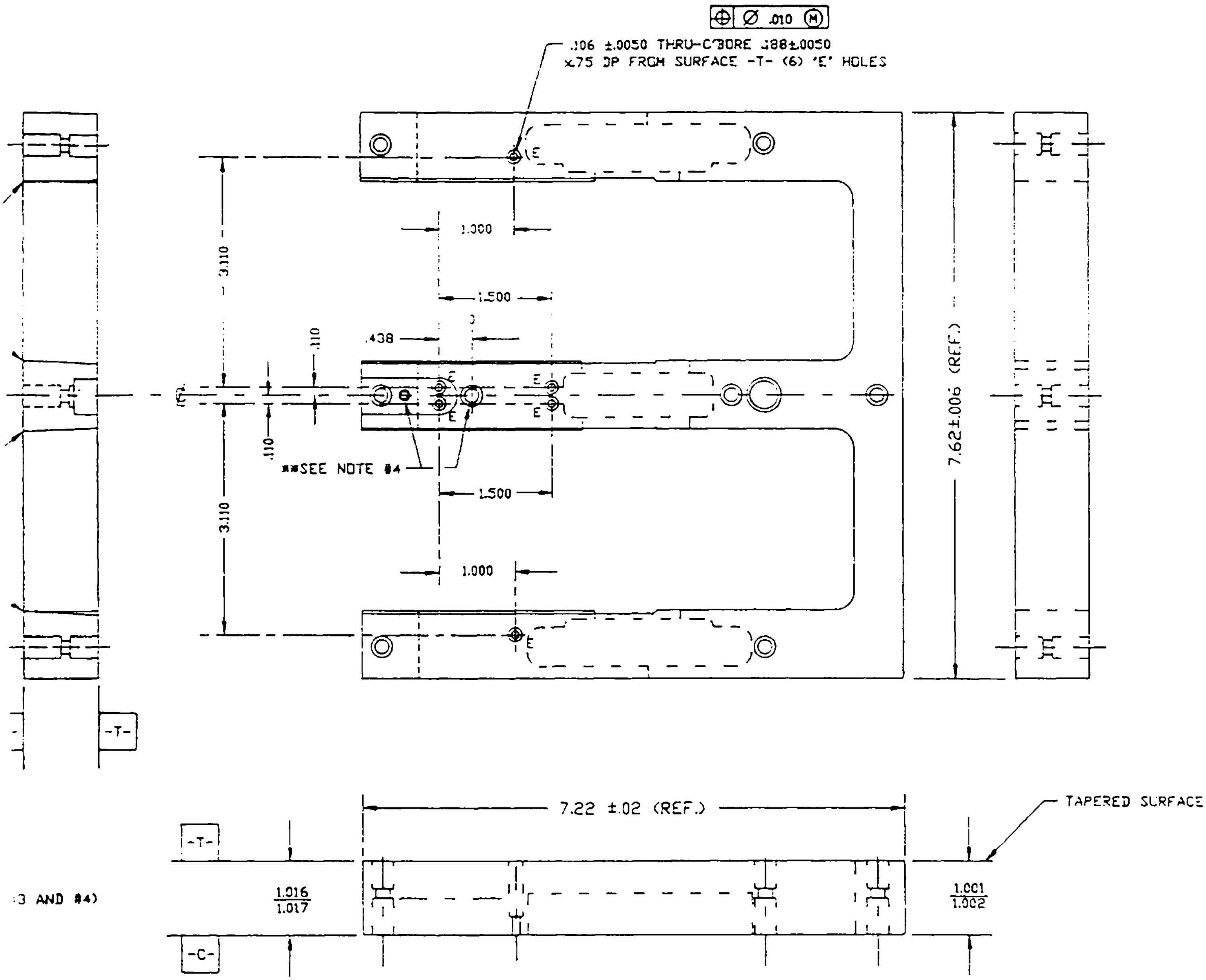

METRUM PART #
DESCRIPTION
16827032-100
NO ANODIZE FINISH OUTSIDE
16827032-101
MAGNAPLATE 'NEDOX' SF-2 OUTSIDE
⊥ A .0003
±.003
1.060
63
±.001
1.010
±.005
.800 O.D.
.69±.01 DIA.x 45° ± 5° CHAMFER
BREAK INSIDE CORNER
±.002
.012 × 45° CHAMFER
BREAK SHARP EDGES
20 ×
.0005
A .0010
.750
±.005
- B -
10
32
+.0005
-.0000
.6252 DIA. THRU
- A -
SCALE: 2X
C-6310-101
USER NOTES: 1. PREVENTS EDGE DAMAGE TO THIN TAPE WITH REASONABLE PACK MISALIGNMENT TOLERANCE.
2. 10 TAPE BEARING SURFACE TO MINIMIZE FRICTION.
3. LENGTH OF 10 SURFACE ALLOWS .050 TAPE EDGE MISALIGNMENT AT 5" DISTANCE WITHOUT BINDING (IF TAPE IS FREE TO SLIDE).
NOTES - FINISH -
CHEMICAL CONVERSION COATING, YELLOW, PER MIL-C-5541, CLASS 1A, ENTIRE SURFACE INSIDE .6252 REF. BORE. NO RACK MARKS OR RAISED SCRATCHES PERMITTED ON - B -.
ALUM. #6061-T6 PER QQ-A-225/8
SEE NOTES
63
H.HINTEREGGER 1/92
R.CADY 1/92
SCALE 2X
NORTHEAST RADIO OBSERVATORY CORPORATION
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS
SLEEVE, TURNAROUND ROLLER
(1 INCH THIN TAPE)
C6310101
C
6310 - 101
DWG. SIZE
DWG. NO.
REV.

FIGURE 2.

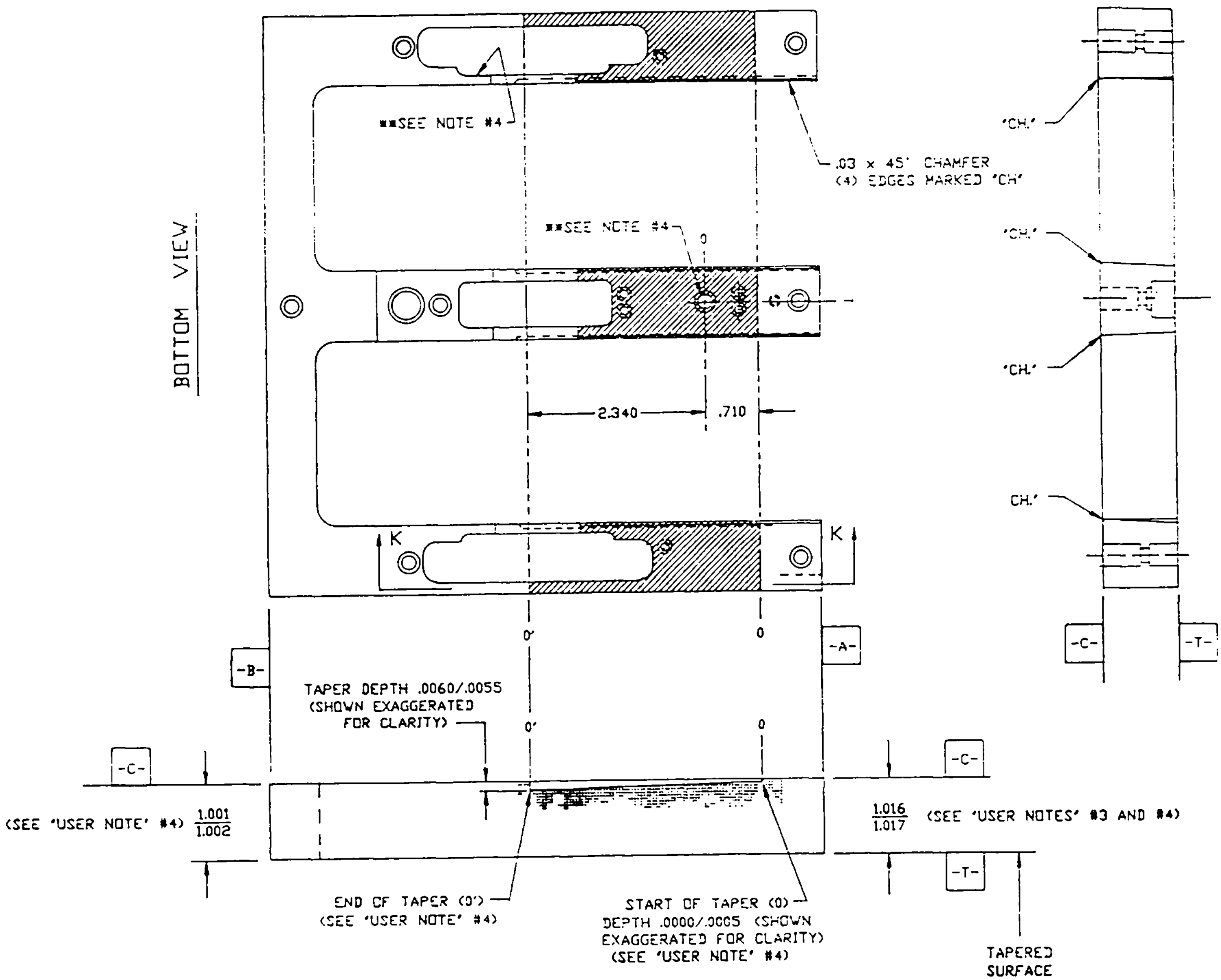


USER NOTES:

- * THIS MODIFICATION SERVES VLBA AND MARK IV (HIGH SPEED, THIN TAPE) VERSIONS OF METRUM 96 TAPE TRANSPORT.

1. ADDED 'E' HOLES SERVE TO MOUNT INNER TAPE EDGE BEARINGS (HARD POINTS) ON ALUMINA PLATES.
2. TAPERED SURFACES ADDED TO PREVENT DAMAGE TO THIN TAPE AT HIGH SPEED.
3. REQUIRES A THICKER VERSION OF STANDARD VACUUM SPACER.
4. PRELIMINARY: THICKNESS INCREASE AND CORRESPONDING RECESS OF SHADED TAPERED AREAS OF UP TO .006 MAY BE SPECIFIED IN APPROVED MODIFICATION.

MATERIAL: ALUMINUM ALLOY 6061-T651 PER QQ-A-250/11 - SEE 'METRUM' DWG.#16785050,SH.1 OF 1 FOR PRELIMINARY MACHINING DATA	63	SCALE FULL	RHINTEBERGER 1/92; R. LCADY 1/92
FINISH AND/OR HEAT TREATMENT: SEE NOTE #3			NORTHEAST RADIO OBSERVATORY CORPORATION HAYSTACK OBSERVATO WESTFORD, MASSACHUSE
			MODIFICATION OF VACUUM SPA R
			D6310102 | D | 6310-102



TYPICAL SECTION K-K

REPRESENTS SIMILAR TAPER AREAS ON ALL (3) LEGS OF VACUUM COLUUM SPACER

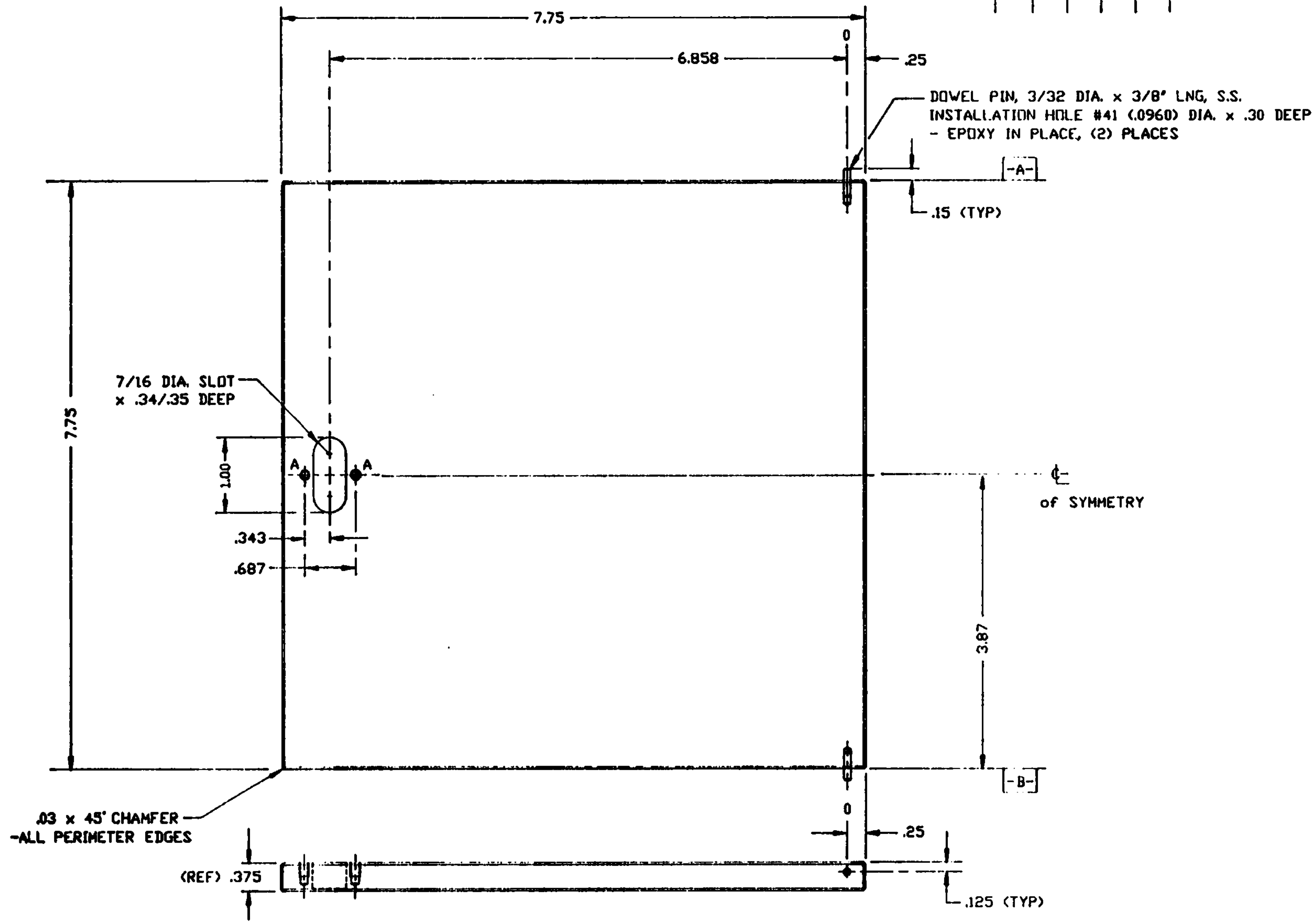
NOTE: HOLE REPRESENTATIONS OMITTED FOR CLARITY.

FIGURE 4.

NOTES

1. SHADED AREA ▨ REPRESENTS TAPER ZONE.
2. SURFACES -A- AND -B- ⊥ TO SURFACE -C-
3. FINISH COATING
   ITEM 1 - GLASS BEAD IMPACT BLASTING
   ITEM 2 - UNLESS OTHERWISE NOTED: 'NEDOX' SF2R COATING .0005/.0007 ALL SURFACES.
4. MASK (2) HOLES AND (8) SURFACES AS INDICATED PRIOR TO FINISH COATINGS.

CHANGE LETTER	DWN BY	CHK'D BY	APP'D BY	DATE	ECN & DESCRIPTION



C-6310-103

NOTES

1. FINISH COATING:

   ITEM 1 - GLASS BEAD IMPACT BLASTING

   ITEM 2 - UNLESS OTHERWISE NOTED: 'NEDOX' SF2R COATING .0005/.0007 ALL SURFACES ** MASK 'A' HOLES

MATERIAL

AL. ALLOY 6061-T651, TYPE 200 WROUGHT TOOL PLATE PER QQ-A-250/11, .375 THICK STOCK

FINISH AND/OR HEAT TREATMENT

SEE NOTE #1

SHOP NOTES: UNLESS OTHERWISE SPECIFIED
1. DIMENSIONS ARE IN INCHES
2. TOLERANCE ON DIMENSIONS FRACTIONAL ± 1/64 DECIMAL .XX ± .01 DECIMAL .XXX ± .005 ANGULAR ± 0°30'
3. SURFACE ROUGHNESS PER MIL-STD-10 63
4. REMOVE BURRS AND BREAK SHARP EDGES 1/64 MAX.
5. SCREW THREADS PER MIL-STD-9
6. ALL DIMENSIONS TO APPLY BEFORE PLATING OR CONVERSION COATING

USED ON	
NEXT ASSEMBLY	
WEIGHT	
SCALE	FULL
CLASSIFICATION	

		DATE
DRAWN FOR	H.UNTEREGGER	1/92
DRAWN BY	R.J.CADY	1/92
CHECKED BY		
APPROVALS: PROJECT		
ENGINEER		
MATL. & PROCESS		
STRUCTURES		
THERMAL		
RESCH. ANALYSIS		

NORTHEAST RADIO OBSERVATORY CORPORATION
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS

SQUARE VACUUM DOOR

	DWG. SIZE	DWG. NO.	REV.
C6310103	C	6310-103	

[redacted]RE [redacted]

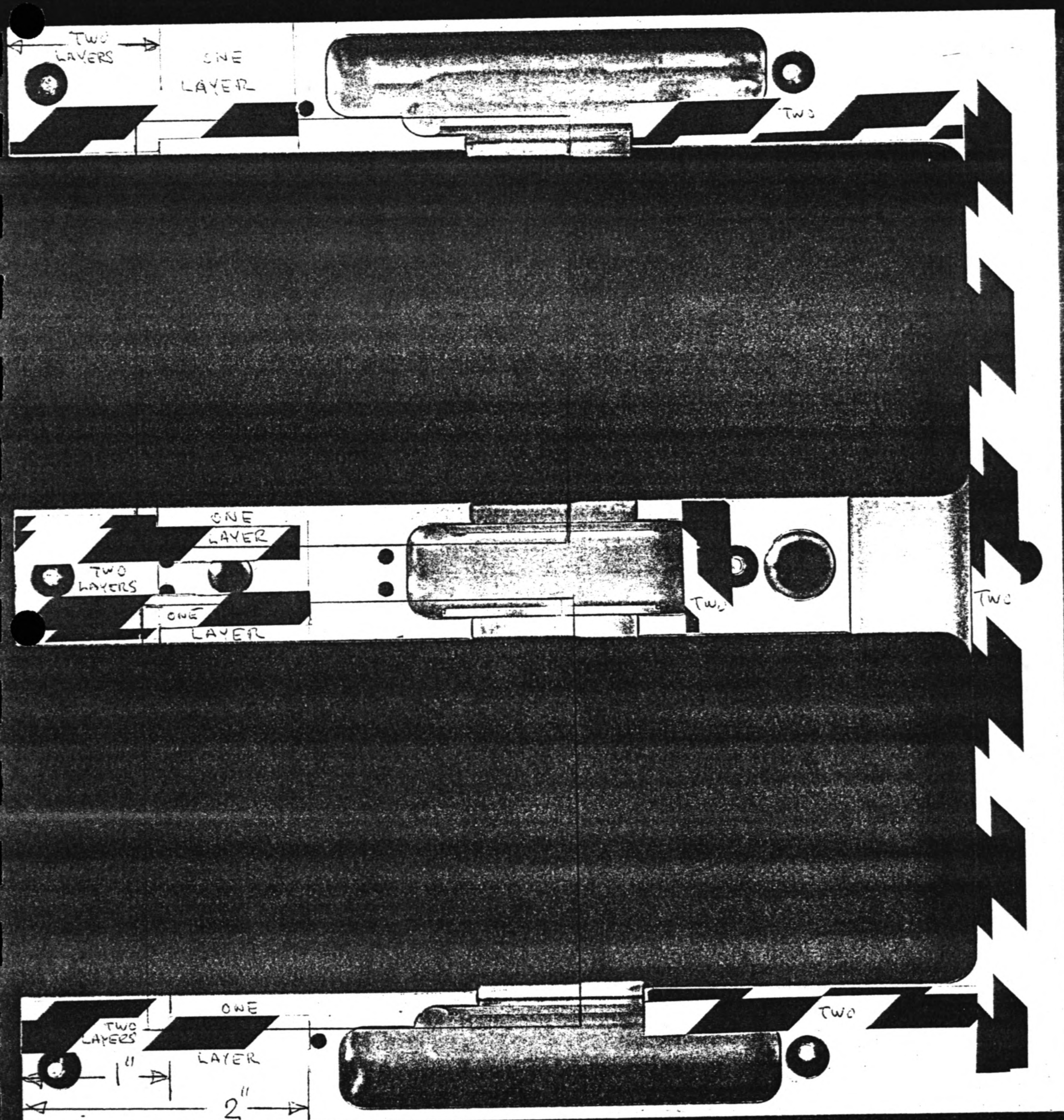

TWO LAYERS
ONE LAYER
TWO
ONE LAYER
TWO LAYERS
ONE LAYER
TWO
TWO
TWO LAYERS
ONE LAYER
TWO
1"
2"

FIGURE 6.

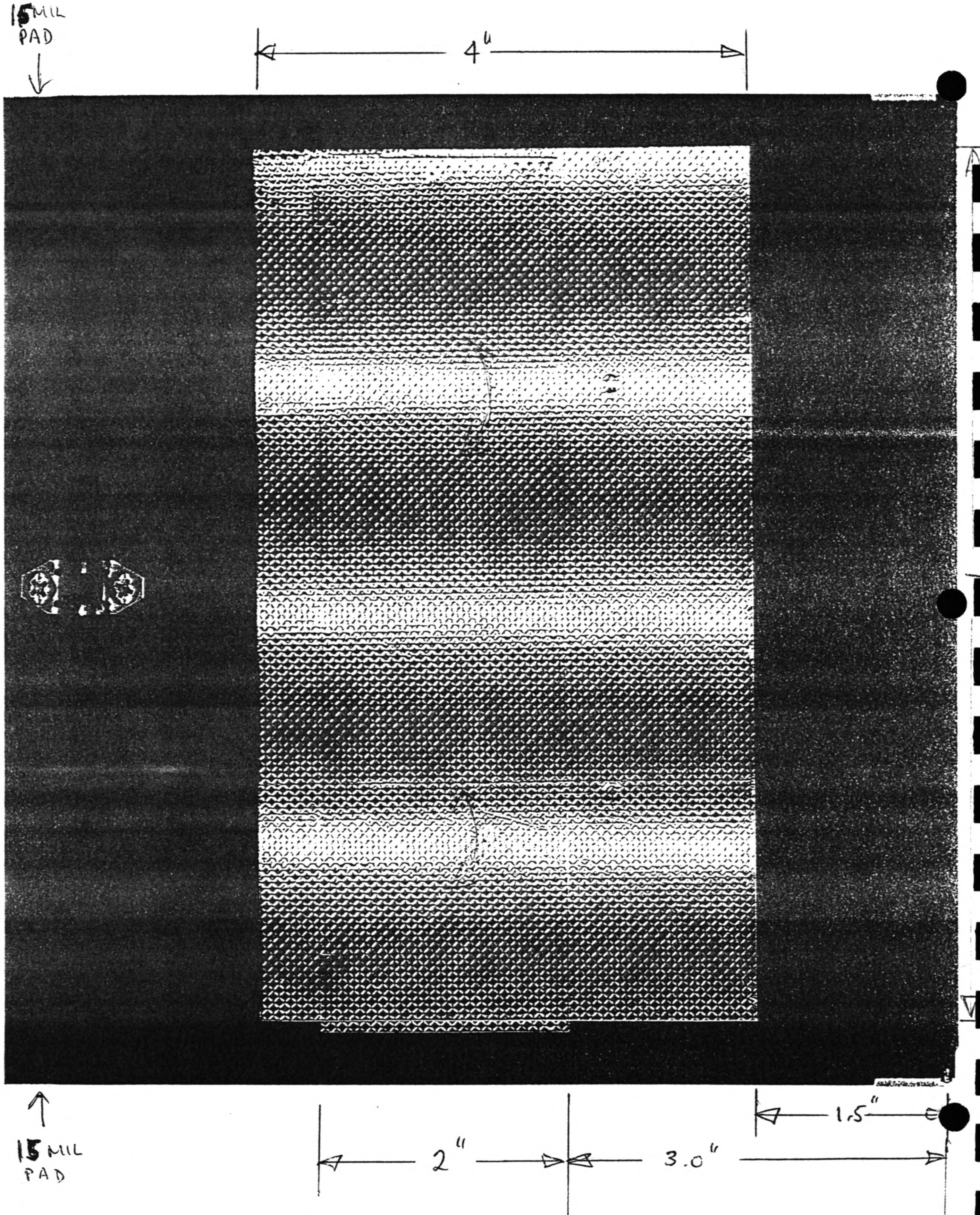


FIGURE 7.