National Radio Astronomy Observatory

Charlottesville, Virginia

VLA ELECTRONICS MEMORANDUM NO. 145

VLA CIRCULAR WAVEGUIDE SYSTEM

Read Predmore

September 25, 1974

I. Coupling Joints

A. Comparison of Japanese Joints

All use precision threads (1.5 or 2.0 mm pitch) on the waveguide. All use rubber rings (trapezoidal or circular cross-section) for a pressure seal with a teflon disk between the rubber ring and packing nut. The packing nuts are precision machined (±.001") and are important in meeting the 0.001 radian tilt specification.

1) Fujikura (supplied 1250 meters)

a) Use a 7" coupling sleeve with straight threads that are machined on a numerical lathe.

b) Most difficult waveguide to assemble in Green Bank. Could be an extreme problem in field. The assembly problems are due to:

i) very tight tolerances on threads (.003" allowance) with a tighter than class 3 fit;

ii) slight scratches across tops of threads, probably from handling during the coating process;

iii) wire edge on leading part of threads since the threads were not chamfered.

c) Recommend silicon grease for pressure seal and molybdenum disulfide (available from Dow Corning) for thread lubrication.

2) Furukawa (supplied 200 meters)

a) Use a 5" coupling sleeve with tapered threads that are not automatically machined.

b) Easiest of the three waveguides to assemble in Green Bank.

c) Recommended M_OS_2 dry lubricant. Their rubber rings appear to be deteriorating from the use of machine oil or rust preventive in the Green Bank test run.

3) Sumitomo (supplied 200 meters)

a) Eight inch long coupling sleeve, machined on numerical lathe with straight threads.

b) Field installation possible without jig by careful handling. Two joints of twenty were jammed during the test burial of 100 meters at the VLA site.

c) Offset alignment comes from smooth surfaces at the ends of the waveguide and inside the coupling sleeve and not just from the threads.

B. Recommendations

1) Use "mouse" to measure all three types of joints to determine their actual tolerances.

2) This November, when the gages and dies are ready, test the assembly of Fujikura waveguide at the site (not buried). This will give us more information in specifying a joint design for the 1975 waveguide order.

3) Determine how Furukawa can get away with a short coupling sleeve and a relaxed thread tightness and still meet offset and tilt specs.

4) Re-evaluate the waveguide system to see if the offset and tilt specs can be relaxed slightly.

II. Schedule of Waveguide Tests

A. Green Bank tests this October:

1) Attenuation measurements on Fujikura waveguide.

2) Mouse measurements on all three types of joints.

3) Mouse test on 50 meters of waveguide to prepare for test of 100 meters of buried waveguide at site.

B. Continuing tests at Green Bank:

1) Tests of rectangular to circular couplers.

2) Tests of antenna waveguide system before it is installed on the first two antennas.

C. VLA Site tests:

1) RF attenuation and mouse measurements of 100 meters of buried waveguide this fall.

2) Trial assembly of Fujikura waveguide this fall.

3) RF attenuation and mouse measurements of Fujikura waveguide as it is installed in March-April 1975.

III. Manhole Design

A. Overall System

We plan to use a 4x6 ft. concrete manhole for the first fourteen (14) (out to C9) or fifteen (15) (out to B5) antenna locations on each arm of the VLA. The last nine (9) or ten (10) antenna stations on each arm will require a manhole at least 4x12 feet. In addition, the outer reaches of the VLA waveguide system will require eight (8) to ten (10) 4x6 ft. manholes per arm to break the waveguide into sections approximately one (1) kilometer long for maintenance and test purposes. Drawing B13320M3 shows the details of a 4x6 ft. manhole.

Two special manholes will be required at the wye center to route the waveguide runs coming from the control building out along the west, north and south arms. Drawings B13320P2 and P1 show the waveguide runs at the wye center and a detail of the special manhole for rotating the west arm waveguide direction 162 degrees to run from the wye center to the control building.

B. Coupler Reinforcing Brackets

For the 40" coupler used near the wye center, we plan to incorporate the reinforcing brackets, which transmit the waveguide tension and compression, into the coupler mechanical design. The dummy couplers which will be placed in the manholes during the installation of the 1250 meters of waveguide will be straight pieces of 60 mm waveguide with butt flanges on them. A hydraulic jack will be used to force apart the waveguides on each side of the dummy coupler when the final coupler is installed.

IV. Installation of Circular Waveguide

Since Forrest Wells and Emory Egler have done the trial installation of 100 meters at the site there is not much point in reviewing the trenching, assembly and backfilling procedure that they have devised. However, we would like to review some points in the inspection and testing of the waveguide as it is assembled and after it is installed.

A. Joint Assembly

1) Lubrication

The threads inside the coupling sleeves and on the waveguides and packing nuts must be lubricated with Molybdenum disulfide (M_oS_2) dry lubricate without the M_oS_2 getting inside the waveguide. The rubber rings should be lubricated with silicone vacuum grease before they are placed on the waveguide.

2) Assembly

After a packing nut, teflon ring and rubber ring are placed on the end of a waveguide, the coupling sleeve should be hand threaded onto the waveguide until the edge of the coupling sleeve lines up with the machined marking ring on the waveguide. Then the packing nut is tightened up and the adjoining waveguide is threaded into the coupling sleeve. When the waveguide stops, its marking ring needs to be checked.

The face to face mating of the two waveguides is extremely important for proper mechanical and electrical operation of the waveguide system.

After the mechanical alignment is assured the other O-ring and packing nut must be tightened to complete the pressure seal. Then the shrinkable sleeve is heated to weather proof the coupling sleeve.

B. Tests on Installed Waveguide

1) RF Attenuation Measurements

The waveguide test trailer will be installed just SW of the manhole for CW-9 with 20-30 meters between the trailer and the manhole and with the waveguide shutter in the CW-9 manhole. With an increased delay range and a 3-4 dB attenuation range in the waveguide test set, the entire 1250 meters of waveguide could be checked out from one spot as 100-200 meter lengths of the waveguide are assembled.

2) Internal Mechanical Measurements

When the waveguide installation between two manholes is completed (356 meters maximum for the first installation), the "mouse" should be run through that section to determine the mechanical deformations in the installed waveguide.

3) Leak Detection

Since the 12,000 joints in the waveguide system may leak, a test procedure has to be developed to inspect the waveguide for leaks as it is being installed and after it is in use.

4) Strain Gages

To check on the thermal stresses which will occur on a diurnal and yearly time scale, a few strain gages will be installed on the waveguide. These will not be continually monitored, but will be used for regular checks on the waveguide.

V. Waveguide Pressurization System

A. Function

The purpose of the pressurization system is to supply dry nitrogen to the entire run of 60mm waveguide and the 20mm runs from the manholes to the antenna vertex rooms. The pressure will be about 0.5 atmospheres gauge. The exclusion of water vapor and oxygen from the waveguide transmission system are important to its reliability and sensitivity. Water vapor would hasten any deterioration of the waveguide lining, and oxygen attenuates the RF signal at frequencies from 48.5 to 71 GHz[1], with the greatest attenuation at 60.4 GHz. Table 1 lists some oxygen absorption frequencies and the percentage of air that would increase the signal path loss by 3 dB in 21 km at that frequency. The design for the VLA waveguide system will be for less than 1% of oxygen in the waveguide.

B. Design

The pressurization system is currently being detailed with the following requirements in mind:

1) Oxygen content less than 1% when averaged over the 21 km run.

2) Total leak rate limited so that the total gas in one arm would be replaced in no less than 10 days.

3) No pressure windows will be used at each manhole. The total number of windows would be limited to about 5 in a 21 km run of 60mm waveguide to limit the ripple in the signal transmission curve to <0.05 dB in a 1 MHz band. From Table 1 up to 23% of air would be temporarily acceptable in an arm for an increased loss of 3 dB at 52 GHz (Channel 11).

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[1] E. E. Reber, R. L. Mitchell and C. J. Carter, Microwave Journal, Vol. 12, November 1969, p.75-81, "Oxygen Absorption in the Earth's Atmosphere."

TABLE I

Percentage of Air Which Increases Waveguide Loss
3 dB In 21 km Due To Oxygen Absorption

Frequency	ΔL (dB/km) for 100% Air	% Air for 3 dB Attenuation in 21 km
48.5	0.17	83
51.0	0.38	37
52.0	0.61	23
53.0	1.12	12.5
54.1	2.25	6.2
55.8	6.37	2.2
57.0	9.65	1.5
58.4	13.90	1.0
60.4	16.18	0.9
63.0	11.32	1.2
64.7	4.58	3.1
68.4	0.68	20.6
70.0	0.44	31.8
71.1	0.36	38.9

VI. Corrosion and Lightning Protection System

A design for the system is not being offered here, but several considerations for the design are suggested.

The zinc shielding ribbons and dielectric strength of the waveguide coating should provide good lightning protection for direct hits to the waveguide[2]. The main concern will probably be for lightning entering the waveguide via the 20mm waveguide runs from the manholes to the antenna station, the waveguide pressurization system, the waveguide runs inside the control building, or the manholes. For these reasons, the integration of the grounding for the 20mm waveguide runs, the manhole reinforcing bars, and the manhole covers is an important part of the system design. Also, the grounding of the 60mm waveguide system must be incorporated into the design.

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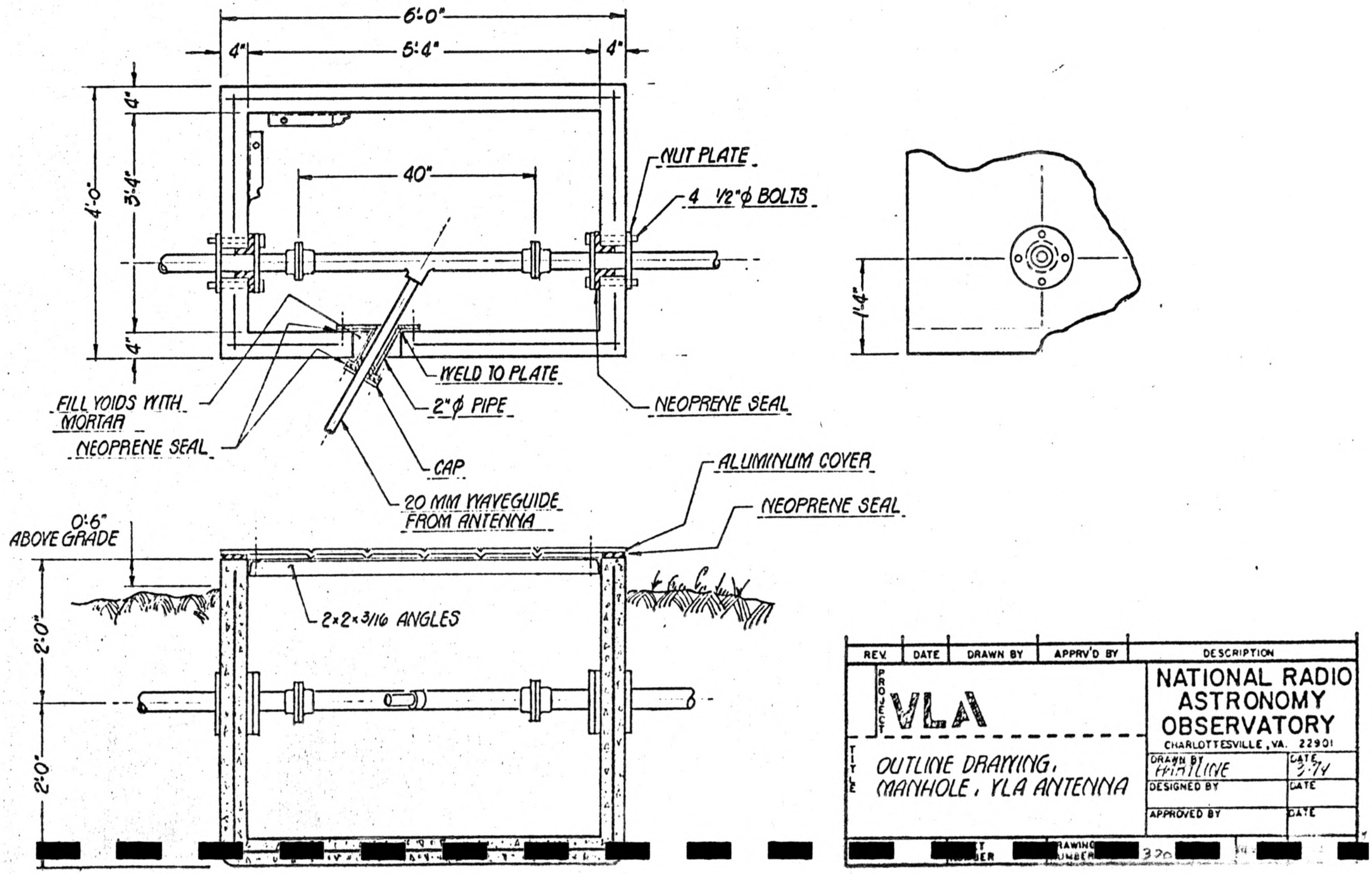
(2) E. D. Sunde, Earth Conduction Effects in Transmission Systems, p.317, 1968 Dover Publications, Inc., S1891, New York.


6'-0"
4"
5'-4"
4"
4'-0"
4"
3'-4"
4"
40"
NUT PLATE
4 1/2"ϕ BOLTS
1'-4"
WELD TO PLATE
2"ϕ PIPE
NEOPRENE SEAL
FILL VOIDS WITH MORTAR
NEOPRENE SEAL
CAP
20 MM WAVEGUIDE FROM ANTENNA
ALUMINUM COVER
NEOPRENE SEAL
0'-6" ABOVE GRADE
2x2x3/16 ANGLES
2'-0"
2'-0"
REV.
DATE
DRAWN BY
APPRV'D BY
DESCRIPTION
PROJECT
VLA
NATIONAL RADIO ASTRONOMY OBSERVATORY
CHARLOTTESVILLE, VA. 22901
TITLE
OUTLINE DRAWING, MANHOLE, VLA ANTENNA
DRAWN BY
DATE
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DESIGNED BY
DATE
APPROVED BY
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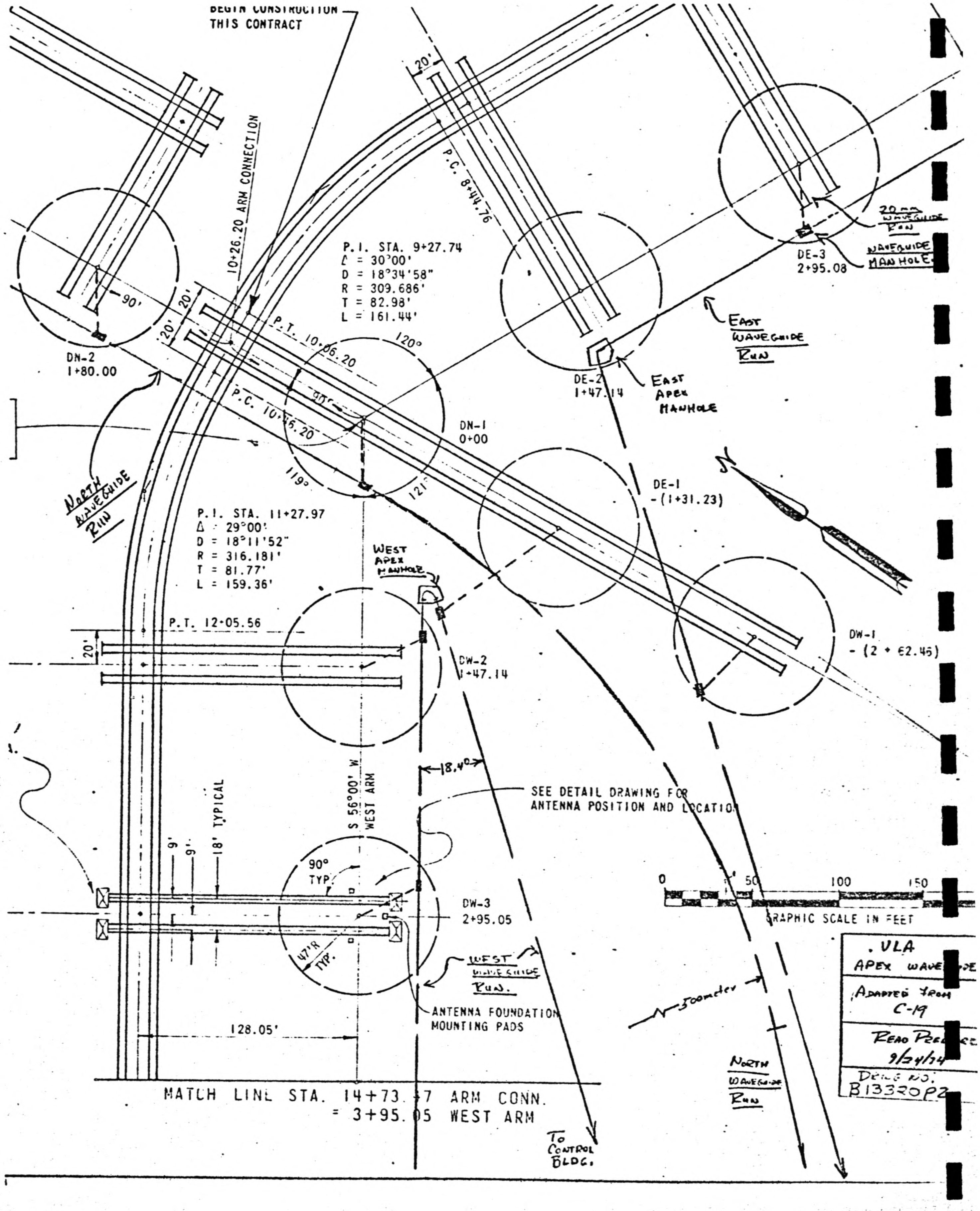
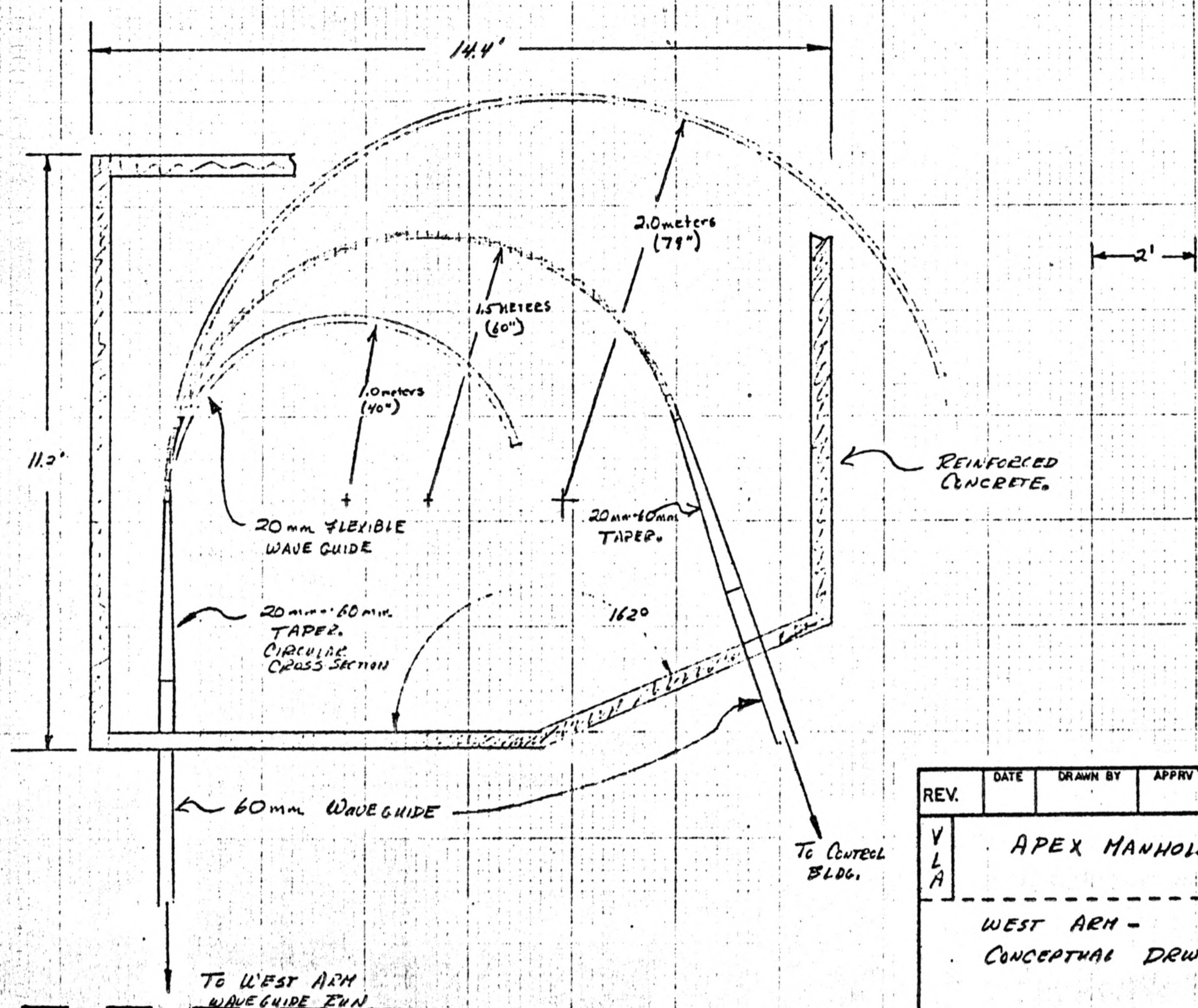


BEGIN CONSTRUCTION
THIS CONTRACT
10+26.20 ARM CONNECTION
20'
P.C. 8+44.76
P.I. STA. 9+27.74
Δ = 30°00'
D = 18°34'58"
R = 309.686'
T = 82.98'
L = 161.44'
20mm WAVEGUIDE RUN
WAVEGUIDE MANHOLE
DE-3
2+95.08
90'
20'
20'
DN-2
1+80.00
P.T. 10+06.20
120°
90°
P.C. 10+46.20
EAST WAVEGUIDE RUN
DE-2
1+47.14
EAST APEX MANHOLE
DN-1
0+00
NORTH WAVEGUIDE RUN
119°
121°
DE-1
-(1+31.23)
N
P.I. STA. 11+27.97
Δ = 29°00'
D = 18°11'52"
R = 316.181'
T = 81.77'
L = 159.36'
WEST APEX MANHOLE
P.T. 12+05.56
20'
DW-2
1+47.14
DW-1
-(2+62.46)
18.4°
S 56°00' W
WEST ARM
18' TYPICAL
9'
9'
SEE DETAIL DRAWING FOR
ANTENNA POSITION AND LOCATION
90°
TYP.
DW-3
2+95.05
47'R
TYP.
0
50
100
150
GRAPHIC SCALE IN FEET
VLA
APEX WAVEGUIDE
ADAPTED FROM
C-19
WEST WAVEGUIDE RUN.
ANTENNA FOUNDATION
MOUNTING PADS
300 meter
READ PRECE
9/24/74
DWG NO.
B13320P2
128.05'
NORTH WAVEGUIDE RUN
MATCH LINE STA. 14+73.57 ARM CONN.
= 3+95.05 WEST ARM
TO CONTROL BLDG.



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VLA

APEX MANHOLE

WEST ARM - CONCEPTUAL DRWG.

NATIONAL RADIO ASTRONOMY OBSERVATORY

CHARLOTTESVILLE, Va., 22901

DRAWN BY R. Preombe

DESIGNED BY R. Preombe

APPROVED BY

DATE 9/[redacted] SHEET [redacted] NUMBER [redacted] 1 D[redacted] NUMBER B[redacted] P1 [redacted]