Hydrostatic Bearing Pad Maximum Load and Overturning Conditions for the 70-Meter Antenna

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The maximum hydrostatic bearing loading is shown to be sufficiently small and the ratios of stabilizing to overturning moments are ample.

I. Introduction

A project has been established to increase the reflector diameters of the 64-m antennas to 70-m (Ref. 1). In order to evaluate the minimum film thickness of the hydrostatic bearing which supports the antenna weight, it is first necessary to have a good estimation of the maximum operational load on the most heavily loaded bearing pad. The most heavily loaded pad is the Number 3 pad, and this is identified in Figs. 1 and 2. It is also essential to know the stabilizing moment and overturning moment caused, respectively, by weight and wind loading.

II. Bearing Pad Load Calculation

The maximum reactions on the Number 3 pads of the 64- and 70-m antennas, caused by wind loading only, are[1] for the 64-m antenna.

$$R_{3_{64}} = 1.519\, q \frac{\pi}{4} D^2 \tag{1}$$

and for the 70-m antenna

$$R_{3_{72}} = 1.627\, q \frac{\pi}{4} D^2 \tag{2}$$

where

$q = 1/2\, \rho V^2$ = the dynamic pressure of the wind

ρ = the air density

V = the wind speed

These maximum reactions occur at an elevation angle of 5° and a wind azimuth of zero.

The measured weight loading on pad Number 3 of the 64-m antenna was 9,719,604 N(2,185,054 lb) and was obtained by measuring the pressure in hydraulic jacks when the alidade was raised for repair of the hydrostatic bearing runner in 1983. It is estimated that the 70-m reflector will add from 3,333,750

[1] See Table VI in *The effects of wind loading on the bearings and drives of the 64-m and 72-m antennas* (unpublished), by H. D. McGinness, 1984, Reorder No. 84-2, Jet Propulsion Laboratory, Pasadena, CA.

to 4,445,000 N (750,000 to 1,000,000 lb) to the weight reaction at Pad Number 3. The total reactions, R_{T3}, at the Number 3 pads, using one third the larger of the estimated increment for the 70-m antenna and a wind speed of 22.35 m/s (50 mph), are:

$$\begin{aligned} R_{\substack{T3\\64}} &= 9{,}719{,}604 + \left(\frac{1}{2}\right) 1.171\,(22.35)^2\,\frac{\pi}{4}\,(64)^2 \\ &= 10{,}660{,}000 \text{ N } (2{,}396{,}463 \text{ lb}) \end{aligned} \tag{3}$$

$$\begin{aligned} R_{\substack{T3\\72}} &= 11{,}202{,}343 + \left(\frac{1}{2}\right) 1.171\,(22.35)^2\,\frac{\pi}{4}\,(72)^2 \\ &= 12{,}392{,}533 \text{ N } (2{,}785{,}952 \text{ lb}) \end{aligned} \tag{4}$$

where 1.172 kg/m^3 is the air density 670 m above sea level. Thus, the Pad Number 3 loading of the 70-m antenna is (12392533/10,660,000) = 1.163 times that of the 64-m antenna pad. From elementary laminar flow through a slot theory, the film thickness, h, should vary inversely with the cube root of the load. When applied to the load factor 1.163

$$h_{72} = h_{64}\frac{1}{(1.163)^{1/3}} = 0.95\,h_{64} \tag{5}$$

A more accurate analysis taking account of the disposition of the pad recesses, and the deflection of the runner, produced a somewhat smaller value of h_{72}/h_{64}, namely 0.85, as the ratio of the film thicknesses at one corner of the pad.

III. Overturning Calculations

The ratio of stabilizing moment, M_s, to overturning moment, M_o, for two conditions may be obtained.[2]

During operation of the antenna the minimum ratio of stabilizing to overturning moment occurs at elevation angle 5° and wind azimuth zero. For this case the ratios of the two antennas are:

$$\left(\frac{M_s}{M_o}\right)_{64} = \frac{W_3}{1.516\,q\,\frac{\pi}{4}D^2} = \frac{W_3}{1.516\left(\frac{1}{2}\right)\rho V^2 D^2} \tag{6}$$

$$\left(\frac{M_s}{M_o}\right)_{72} = \frac{W_3}{1.612\,q\,\frac{\pi}{4}D^2} = \frac{W_3}{1.612\left(\frac{1}{2}\right)\rho V^2 D^2} \tag{7}$$

[2]See Table VI, H. D. McGinness, *op. cit.*

where W_3 is the weight loading on Pad Number 3 at zero wind. Evaluate Eqs. (6) and (7) for V = 31.29 m/s (70-mph) and obtain:

$$\frac{M_s}{M_o} = \frac{9{,}719{,}604}{1.516\left(\frac{1}{2}\right)1.171\,(31.29)^2\,\frac{\pi}{4}(64)^2} = 3.478 \tag{8}$$

$$\frac{M_s}{M_o} = \frac{11{,}202{,}343}{1.612\left(\frac{1}{2}\right)1.171\,(31.29)\frac{\pi}{4}(72)^2} = 2.979 \tag{9}$$

Overturning impends when M_s/M_o = 1. From Eqs. (8) and (9) the overturning wind speeds are:

$$V_{64} = \left[\frac{9{,}719{,}604}{1.516\,\frac{1}{2}\,1.171\,\frac{\pi}{4}(64)^2}\right]^{1/2} = 58.36 \text{ m/s } (131 \text{ mph}) \tag{10}$$

$$V_{72} = \left[\frac{11{,}202{,}343}{1.612\,\frac{1}{2}\,1.171\,\frac{\pi}{4}(72)^2}\right]^{1/2} = 54.00 \text{ m/s } (121 \text{ mph}) \tag{11}$$

At the stow position of elevation angle 90° and wind azimuth 180°, the M_s/M_o ratios are:

$$\left(\frac{M_s}{M_o}\right)_{64} = \frac{W_3}{1.079\left(\frac{1}{2}\right)\rho V^2 D^2} \tag{12}$$

$$\left(\frac{M_s}{M_o}\right)_{72} = \frac{W_3}{1.124\left(\frac{1}{2}\right)\rho V^2 D^2} \tag{13}$$

Evaluating Eqs. (12) and (13) for V = 44.7 m/s (100 mph) there are obtained:

$$\left(\frac{M_s}{M_o}\right)_{64} = \frac{9{,}719{,}604}{1.079\left(\frac{1}{2}\right)1.171\,(44.7)^2\,\frac{\pi}{4}(64)^2} = 2.394 \tag{14}$$

$$\left(\frac{M_s}{M_o}\right)_{72} = \frac{11{,}202{,}343}{1.124\left(\frac{1}{2}\right)1.171\,(44.7)^2\,\frac{\pi}{4}(72)^2} = 2.093 \tag{15}$$

Overturning impends when $M_s/M_o = 1$. From Eqs. (12) and (13) the overturning wind speeds for the two antennas at stow are:

$$V_{64} = \left[\frac{9{,}719{,}604}{1.079\left(\frac{1}{2}\right)1.171\,\frac{\pi}{4}(64)^2}\right]^{1/2} = 69.17 \text{ m/s } (155 \text{ mph}) \tag{16}$$

$$V_{72} = \left[\frac{11{,}202{,}343}{1.124\left(\frac{1}{2}\right)1.171\,\frac{\pi}{4}(72)^2}\right]^{1/2} = 64.67 \text{ m/s } (145 \text{ mph}) \tag{17}$$

IV. Conclusion

The minimum film thickness at Pad Number 3 corner of the 70-m antenna is not less than 0.85 times the corresponding thickness of the 64-m antenna and this is considered satisfactory. Additional pumping power for the hydrostatic bearing system is not required.

The stabilizing to overturning ratios, as given by Eqs. (9) and (15), namely 2.979 and 2.093, respectively, are deemed to be ample. The wind speed required to overturn at the worst operating attitude is 54 m/s (121 mph), whereas drive to stow will start at 22.35 m/s (50 mph). At stow the overturning wind speed is 64.67 m/s (145 mph), whereas survival specifications for the 64-m antenna was 53.64 m/s (120 mph).

Reference

1. McClure, D. H., and F. D. McLaughlin, 64-meter to 70-meter antenna extension, *TDA Progress Report 42-79*, Jet Propulsion Laboratory, Pasadena, CA, pp. 160-164.

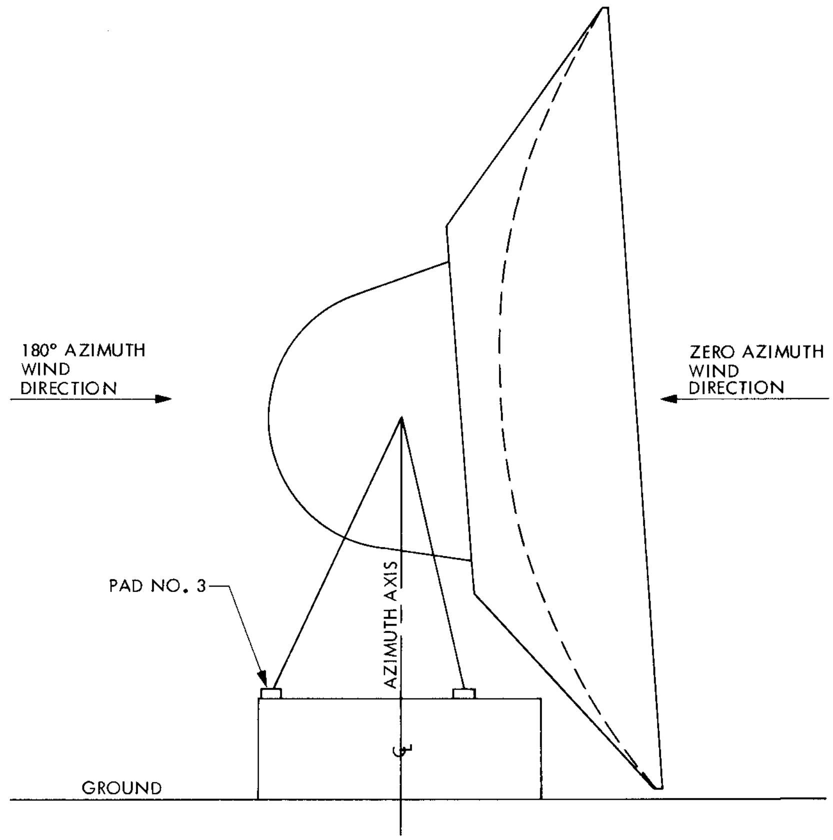

Fig. 1. Attitude of antenna for critical load on Pad 3 during operation, wind azimuth zero; critical overturning, wind azimuth 180°

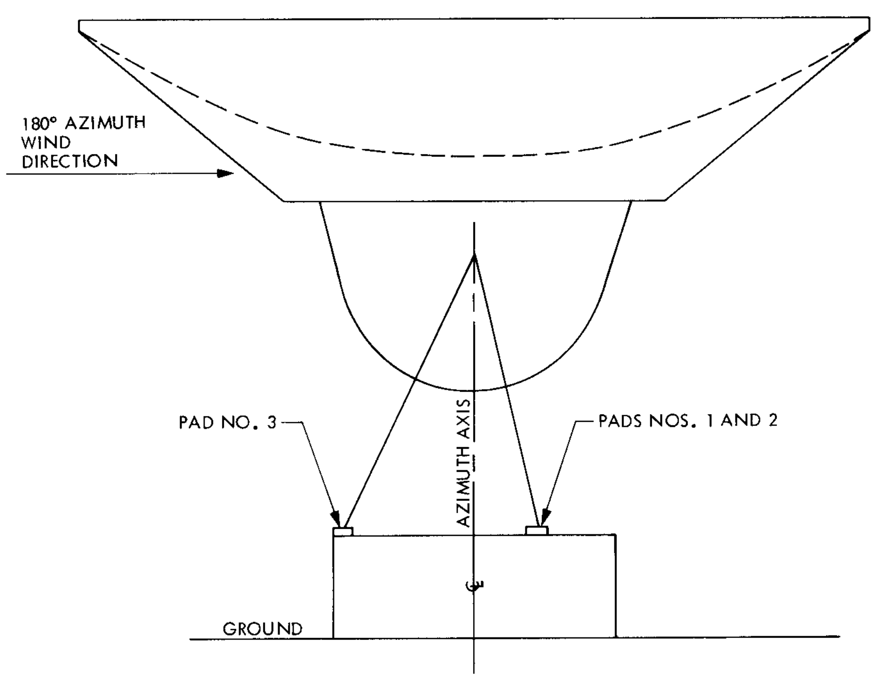

Fig. 2. Stow position of antenna; overturning critical at wind azimuth 180°