OBSERVING WITH THE 36-FT MILLIMETER-WAVE TELESCOPE

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On May 31 through June 11 we carried out observations of several galactic radio sources and of Jupiter and Mars for calibration purposes, at 3 and 9 mm wavelength. The following reports our experiences with the 36-ft antenna, dome, and receivers, with the intent of describing observing procedures, pointing out those that we found best, and making a few minor suggestions for improvements. We include considerable descriptive material which we hope will be useful for prospective observers.

I. GENERAL DESCRIPTION

Telescope

The Alt-Az telescope is steered by a direct-drive system; that is, one with no gear reductions, thus avoiding the problem of backlash, or of pointing errors due to errors in gear rotations. The reflector is moved and positioned by large servo controlled torque motors mounted, two on the elevation axis, and one on the azimuth axis. The reflector is supported by radial rigid backup structures and rotates on precision anti-friction bearings. Such a system is necessary for the accuracy in pointing needed at these wavelengths (HPBW ≃ $1'.5$ at 3 mm, $0'.5$ at 1 mm). It has the disadvantage that a large amount of torque is needed from the driving motors to move the telescope, and cannot be obtained under wind loading in many cases. Thus for some ranges of A and E, especially low E, the telescope cannot be driven, nor track, in winds as low as 10 mph. Within our observing period of eleven nights, there were four nights when sources south of Decl. $\sim$0 could not be observed, and sources south of $\sim$+25° could be observed only with greatly reduced efficiency; at 3 mm a significant portion of data taken in the southern hemisphere when there was light wind has to be discarded because the telescope, although able to track, is often blown off source by a HPBW or more. This problem is less severe at 9 mm where the HPBW is $\sim$4ʹ.5 but at 1 mm we expect that observations will have to be conducted in virtually windless conditions. During our observing period, the wind usually came up just after sunset, and increased until typically 3 or 4 a.m. before dying down.

The focal length is 28 ft 10 inches. The dish is supported by an elevation-over-azimuth axis mount. The surface of the dish is milled aluminum, with tolerance specification of a few thousandths of an inch. The efficiency of the dish at 9 and 3 mm appears to meet requirements (see below). The feed support structure consists of two I-beams mounted in a plane of constant azimuth, and restrained from lateral movement by two guy wires under 85 lb. tension. There is some evidence that winds can cause significant lateral movement of the feed, since it was observed on occasion that dips in the output while observing Jupiter correlated with wind gusts which however did not move the dish itself, as indicated by instruments reading error angles in both A and E for the dish. The support wires cannot be tightened for greater stability without distorting the dish, since they are secured directly to its surface. It is less likely but possible that these effects could also be caused by dish flexure.

Limits: Mechanical: $15° \leq E \leq 90°$, none in A

Electrical: $18°46' \leq E \leq 89°$, A must lie outside $90° \pm 2°$.

The electrical limits can be overridden by controls on the main console.

The 90° limit in A is optimum in that few sources will require tracking through this range in A. However the limit on azimuth drive rate is 18°/min which means that the azimuth is unable to follow when tracking a source within ∿5° of the zenith. Thus sources with $28° \lesssim \delta \lesssim 37°$ cannot be observed within $\sim \pm 20^m$ of the meridian.

Runaways: During runaways, which occur on the average once per day, and usually while changing position, or under wind gusting, the computer loses control of the telescope, and the electrical limits are no longer recognized. Most runaways are in A, and if they pass through A = 90°, may wrap up and tear loose the cabling. Observers must be alert to hit the brakes quickly upon noting a runaway; the brakes can stop a runaway within 10° in A, when there is no wind. Although the system automatically shuts off power and applies brakes upon passing through mechanical limits, fast runaways make this an unsafe contingency to rely on.

Dome: The dome is a 95-foot hemispherical structure with 40-foot wide aperture running through the entire center portion of the hemispherical surface. The dome is rotated in azimuth by four motor reducer units driving large track tires which ride on the sidewall structure of the dome foundation.

Since the dome structure plays a dominant role whenever one observes through it, we summarize it here (see photographs). Two large arch beams shaped in the form of large 40-ft radial arches, provide a sufficiently rigid structure to maintain a uniform 40-ft wide gap through the center of the dome surface.

The arches are held in place by a rib-hoop-base truss structure which extends up ∿15 ft from the base but does not extend into the aperture section. At lowest elevation this portion would be seen by the bottom ∿1/3 of the dish. The vertical ribs are of 3" standard pipe and continue the vertical web structure of the base truss up to tie points on the arch beam. The ribs are ∿8 feet apart at the base, tapering to ∿2 feet at the top. Then, there are six hoops of 4" standard pipe, three on each side of the 40-ft arch beam gap, which interconnect structurally the ends of the arch beam and the rib network. Hoops are ∿14 feet apart. Seen by the dish, these dimensions make for less metal per unit area of dome on the sides, perpendicular to the aperture, and at elevation ∿50° than anywhere else.

Within the aperture, with door closed, there are three different sections, each covering ∿1/3 the aperture area. The fixed roof area is the area into which the folding door and a portion of the rigid door can retract. It is never seen by the telescope. The rigid door covers the bottom third when closed, and consists of six 40-ft long rectangular (cross-section) truss units interconnected by angle iron web structure. The space between each unit is about three unit widths. The angle subtended by one unit is ∿2.5°.

Finally, the folding door section consists of thirteen 40-ft long triangular (cross-section) truss units interconnected with a vinyl-coated nylon cover. This covers the top section when closed.

Receivers

a) 9.5 mm. Figure 1 shows the front end of the 9.5 mm receiver. The noise temperature is nominally 1120 °K double sideband. The Klystron center frequency is 31.4 GHz (9.55 mm wavelength). The bandwidth to 3db points is 400 MHz. Switching rate is 50 cps load switching or beam switching; changeover in switching mode is accomplished by a panel switch, with only a rebalancing required of the standard NRAO receiver, which serves as backend. The noise tube calibration is 15.0 °K and is phased to produce a deflection in the same direction as the signal, unlike the case of the 3 mm receiver.

b) 3.5 mm. This front end is similar to the 9.5 mm front end in having a balanced mixer, but has a mechanical rather than ferrite switch. The mechanical inertia means the switching cycle has to be delayed and its mark space ratio changed relative to that of the backend; this requires a rather delicate set of electrical adjustments each time the 3.5 mm box is mounted, which on occasion prove difficult to perform. In addition, the size of the noise calibration depends on the phase alignment. Receiver specifications are:

$\nu_{L.O.}$ = 85.0 GHz

T_S = 3000 °K double sideband

I.F. = 1.0 - 2.0 GHz

Switching frequencies: 2 Hz, 5 Hz, 90 Hz (load switching only)

T_{cal} = 13.9 °K with 90 Hz load switching and reference perfectly phased.

No blanking is required in any of the switching modes.

Feeds

Signal and reference feeds are horn type, mounted 9' apart in elevation at 9 mm wavelength, and 3' apart in elevation at 3 mm wavelength. On the meridian, the signal feed is north on the sky. The box is designed to rotate under computer control during observations so as to maintain the feed separation along a line of constant R.A. or decl., as desired. This facility is not at present operational, due to mechanical difficulties. Also, the present elaborate pointing corrections in the DDP are valid only for the box oriented as described above.

Data Acquisition

a) Scans, in which the telescope is driven through the source, are recorded on magnetic tape; the observer specifies start and end positions and box size (similar to 140-ft programs) which determines the integration time per data point. Sampling rate is 20 pulses per sidereal second.

b) On-off's: These may be recorded on and processed from magnetic tape under existing programs only if a so-called "short scan" is run, e.g., perhaps a scan at very slow rate ($\sim 0''.1$/sec) so that in the desired "on" time, the telescope moves only a small fraction of the beamwidth.

Alternately, on-off's may be recorded on printed or punched paper tape from a Beckman counter which is driven by a voltage to frequency converter run off the PSD output. The count time may be set from $0^{s}.1$ upwards.

Software

a) On-line: No data reduction of any kind is done in the DDP 116. At most, the DDP stores the data points taken during a scan (defined as once forward and back through a source) before writing it on tape. 250 boxes per scan is maximum capacity. The DDP does coordinate conversions, pointing corrections, and refraction, and correct feed positioning. Thumb switch and card input can be used to control telescope position. Besides the 7-track CDC tape unit, the DDP also communicates with a teletypewriter, through which limited comments can be put on tape by the observer, and on which the observer can have printed out the data which is going on tape. Since the latter occurs at a very slow rate and the computer cannot control the telescope during this time, an observer can monitor his data only at the cost of considerable observing time. In general, it is a problem for the observer to ascertain whether he has taken good data; there is no way to determine, for instance, that the analogue outputs represent the digital information. Further, faulty tapes and tape unit operation were not found to be uncommon. In particular, unlike the DDP on-line operations at Green Bank, the 36-ft DDP does not check the written tape records for parity errors and correct them if it finds them.

Computer control of the telescope seems generally efficient. Runaways very rarely occur unless sudden wind loading exceeds computer correction rate. The computer relinguishes control of the dish during read in of a new position via thumb switches, but runaways can be prevented here by removing the telescope from computer control during read in. It is necessary to have the nixie display control switch in position for displaying R.A. and decl. when entering new positions in these coordinates; if this is not done, it is usual that the existing position data in the DDP is clobbered upon trying to enter the new position, with resulting telescope runaway.

Positions to date must be entered; the DDP does not at the moment do precession. However, besides telescope pointing errors, data on mount and feed sag, and refraction, exist in the operating system and need not be considered by the observer. It is found, however, that position errors up to 45" exist; once determined, these are constant over the entire sky, and are entered as "offsets" in the actual observing. The DDP program allows on-offs to be performed conveniently by displacing from α_o, δ_o in either Az. or El. To offset in R.A. and decl. requires repeated entering via the thumb switches of the α,δ of the on and off positions. It would be a convenience to the operator to have at least another set of thumb switches to retain both on and off positions.

b) Off-line: Three programs developed by J. Schraml exist for reducing scan type data.

i) The first program copies the telescope tape (with 16 bits per word) onto a second tape (with 18 bits per word and a density of 556 bits per inch). This produces a Fortran-readable tape for the CDC 6400. The program prints out position, LST, scan rate, number of boxes, value of data in each box, encoder information, etc., for each subscan within each scan. This output may then be edited and the edit instructions entered via cards into the second program.

ii) The second program allows stacking of the subscans and gives a plot of antenna temperature vs. position for the scan.

iii) The third program copies the Fortran readable tape and gives an index of the data on the tape.

These programs are not documented (although listings exist) and an observer must rely upon verbal instruction by J. Schraml for their use. This situation poses obvious potential difficulties. At best, some trial and error seemed inevitable for inexperienced users. One observer error which seems to occur often is failure to write an EOF on the telescope tape; this results in some difficulty in using that tape in the first program.

An understandable problem at present is lack of flexibility in the reduction programs; it is hard to combine data taken inhomogeneously, as for example, if scan lengths are different, or if one wants to shift and invert part of a scan before averaging it with the rest.

We would conclude that a full reduction of the data cannot likely be done at Tucson with the existing programs in the typically short time an out-of-town observer has to spend there; most observers apparently carry through only preliminary reduction with Program II, and write an output tape which they take home and interface with their own computer. The NRAO Computer Division has programs for converting the data into a form compatible with the System 360.

II. OBSERVATIONAL PARAMETERS

The telescope was used during both day and night during the period May 31 to June 11. The dome was kept open for varying lengths of times after sunrise with the sun falling on the feed support up to four hours on some days, but never on the dish. Extensive measurements were made on the effect of the dome when closed, to assess what types of observations may be done when the dome is closed. During the observing period the weather was excellent. Even at 9 mm one appears to need a good photometric night to do optimum work; even slightly bad seeing shows up as noticeable fluctuation at 9 mm (p - p equivalent to $\sim$5 f.u. (beam switching) when the repeatability of photometric measurements was $\sim$2%).

Aperture Efficiency

The mean antenna temperature of Jupiter (average radius = 17".86) at 9.5 mm was 2.20 °K (see Figure 2) while for the single night June 9 it was 6.69 °K at 3.5 mm, averaged over 15 on-off's of 1^m integration each. To calculate the aperture efficiency η_A when Jupiter is considered a uniform disk of brightness temperature 140 °K at both frequencies, we use (see Mezger et al., NRAO Internal Report "Radio Tests of the 140-ft Telescope in the Wavelength Range 11 to 0.95 cm"):

$$T_A = T_B \frac{A\eta_A}{\lambda^2} \; 1.133 \left(\frac{\theta_A}{\text{rad}}\right)^2 \{1 - \exp\,[-R_p{}^2/(0.6\ \theta_A)^2]\}.$$

This formula assumes the taper is Gaussian; θ_A is the (circular) beam width at half power, A is the geometric area of the dish, R_p is the planetary radius. We measure θ_A(9.5 mm) = 4!05, θ_A(3.5 mm) = 1!52. These beamwidths are derived from

$$\theta_A = \sqrt{\theta_{obs}{}^2 - 1/2(\ln 2)(2\ R_p)^2}$$

which applies when the extended source is a uniform disk of radius R_p, so long as $2\ R_p < \theta_A$. We find

$$\eta_A\ (9.5\ \text{mm}) = 0.640$$

$$\eta_A\ (3.5\ \text{mm}) = 0.284$$

At 9.5 mm there was no noticeable decrease in efficiency (i.e., T_A) on nights following days when the feed support was heated by the sun for up to four hours. The 3 mm tests also followed such a day, but η_A is about the same as measured last summer by Buhl (0.30). For DR 21 we measure T_A = 0.385; assuming it is a point source of strength 19.0 f.u. at 9.5 mm (Mezger et al. 1967) gives η_A(9.5 mm) = 0.595. Terzian (1969) derived a mean η_A = 0.47 also using DR 21. The arguments given below concerning the beam efficiency suggest that $\eta_A = 0.47$ is probably correct, and that the nominal value of 15 °K for the noise tube calibration used in the present observations was in error.

Beam Efficiency η_B

η_B cannot generally be measured directly, since it requires a uniform source of size equal to the separation of first nulls of the antenna pattern. It can be calculated from η_A by using (Kraus, "Radio Astronomy"):

$$\eta_B = \frac{A\Omega_m}{k_o\lambda^2}\,\eta_A \approx \frac{1.133\,\theta_A{}^2\,A}{k_o\lambda^2}\,\eta_A$$

where the main beam solid angle $\Omega_m = 1.133\,\theta_A{}^2$ for a Gaussian illumination. k_o, the ohmic loss factor has value $0 \le k_o \le 1$ with the value unity corresponding to a lossless antenna. k_o appears in the denominator to compensate for a value of η_A which is smaller the smaller k_o is; η_B does not depend on k_o to a good approximation since k_o affects the magnitude but not the θ,ϕ dependence of the antenna pattern. Without further information we take $k_o = 1$ and find $\eta_B = 1.71\,\eta_A$ at 3.5 mm and $\eta_B = 1.65\,\eta_A$ at 9.5 mm. This gives

$$\eta_B\ (3.5\text{ mm}) = 0.474.$$

For η_B (9.5 mm) we get a value > 1, indicating an error in the value of η_A. It appears that the noise tube calibration, nominally 15 °K at 9.5 mm, must be in error. If we take $\eta_A = 0.47$ (Terzian 1969) we find $k_o \geq 0.776$, corresponding to $\eta_B \leq 1.0$. k_o is probably very close to 1 at 9.5 mm.

Dome Effects

a) Attenuation: An average of four observations of Jupiter on different days with dome open and closed gave an average attenuation factor of 1.565 $\pm$ 0.06, or 1.96 db. For DR 21 the average of two observations on different days was 1.384 $\pm$ 0.08, or 1.43 db. The difference is not explained, although the Jupiter values were observed in early evening when the dome fabric is typically at least 60° F cooler.

b) Variations: When the dome is closed, as the telescope tracks, the pattern of metal trusses and ribs changes in the beam and causes variations in the switched and total power outputs. Tests were conducted by slewing the telescope slowly in elevation while tracking the dome aperture in azimuth, with the aperture closed and open. There are no measurable variations greater than $\sim$0.1 °K ($\sim$6 f.u.) when the dome is open, and these seem to be caused by atmospherics rather than dome contributions entering the sidelobes. We note that although the aperture width is only 40 feet, or 4 feet wider than the dish, and that one edge of the dish looks through the dome even when the aperture is fully open, there appears to be no measurable attenuation; the aperture must be closed to cover about one-fourth of the dish before noticeable attenuation occurs.

When the aperture is closed, and the telescope is slewed in elevation at the rate of 88' per minute we measure variations while beam switching that are as large as 0.75 °K or $\sim$45 f.u. These variations can occur in a change of as little as 10' in elevation (at El $\approx$ 49°) and are very respectable. Variations when load switching may be as much as ten times greater. Under these conditions, mapping of extended sources by scanning techniques is impossible; on-off observations for detection-type projects are possible if beam switching is used, but the sensitivity will be limited to probably $\gtrsim$ 10 f.u. unless accurate calibration of the dome structure is made.

Regarding the latter technique, Ori A was observed in beamswitching mode over an interval covering the range $17° \leq El \leq 53°$ on a single day, T_A being measured by a series of on-off-cal observations each of 1^m duration. In this way dome variations would be eliminated which occur over smaller intervals of elevation than covered in about 3^m. The result, shown in Figure 3, indicates that maximum variations of $\sim$ 0.4 °K in T_A, or 24 f.u., still persist. For comparison, ΔT_{p-p} due to noise is shown.

<u>Atmospheric Attenuation</u>

Extinction was measured at 9.5 mm by observing Mars between the elevations 31° and 20° and DR 21 between 21° and 17°. Writing the extinction law as

$$\ln T_A = \ln T_{out} + K \sec z$$

where Z is zenith angle, T_{out} is antenna temperature outside the atmosphere, we find the following results.

Source	T_{out}	K	% at Zenith	Time of Observation	Temp. (°F)
Mars	.0575	-0.2054	18.5	0315	51°
DR 21	0.461	-0.279	24.4	-	Wide range

The percent extinction at the zenith should not depend on temperature but K should increase roughly as T^2 assuming extinction is due to the water line. Both K and the zenith extinction for DR 21 are unreliable since the value of K was probably changing during the interval of observation which occurred over more than one day and while the atmosphere was warming rapidly during the day when the low elevation range was observed. Zenith extinction at 9 mm is usually taken to be $\sim$15%. These circumstances make it clear that a lot of time must be devoted to deriving reliable extinction curves.

Focus

At 9.5 mm the focus curve is broad (see Figure 4) and somewhat asymmetric about the focal point. It is neither dependent on temperature to any measurable degree over the range 50° to 85° F nor on elevation. It is also independent of whether the dome is open or closed. The flatness of the focus indicates that at 9 mm the dish is behaving in accordance with geometric optics.

Thermal expansion of the feed legs after being illuminated by the sun for up to four hours is apparently insignificant, since no changes in focus at 9 mm are found when the legs are so illuminated and when they are not.

Some aspects of the focusing have not been well-studied. It is not known if there are secondary focal points. Also, pointing changes slightly when the dome is closed, indicating a refractive effect; however there is no apparent corresponding change in focus. Finally, at 3.5 mm Buhl (1968) measures a very large change in focus (up to 2.5 cm) when the sun shines on the dish for only 40 minutes (surface dish temperature not measured) while we find no focus change greater than 0.2 cm over a dish temperature range from 45° to 85°. We conclude that differential expansion produces the large effect under solar illumination, that uniform heating has only a very small effect, and that the dish temperature can change uniformly with a rate up to $\sim$10° per hour when not illuminated by the sun.

Pointing

The pointing problems mentioned in previous reports before pointing corrections were incorporated into the DDP, no longer exist. At night, we find pointing corrections between -10" and -20" in elevation, zero in azimuth, need to be applied independent of source position. The corrections seem to increase with higher dish temperature and indicate a small difference in expansion of the two feed legs. In the daytime with dome closed, corrections are -30" to -50" in elevation, and 0" to +20" in azimuth; the change from nighttime corrections seems to be caused mainly by the dome rather than by higher temperatures during the day.

Beam Shape and Beamwidth

At 9 mm and with the dome open we measure HPBW (azimuth) $\approx 4\overset{'}{.}1$, HPBW (elevation) $\approx 4\overset{'}{.}0$. The difference seems real, and since the effect of shadowing by the feed legs would actually be to narrow the beam in azimuth, the measured widths simply reflect the particular asymmetries in taper that are used with the TRG rectangular horn feeds. With dome closed we find HPBW (azimuth) = $3\overset{'}{.}84$, HPBW (elevation) = $4\overset{'}{.}83$. The uncertainties in these values suggest no significant difference in azimuth when the dome is closed, but the increase in elevation HPBW seems real.

System Sensitivity

9.5 mm. With a time constant of 1^s, bandwidth of 400 MHz, and measured $T_S \approx 1150$ °K, close to the minimal double-sideband value, we expect $\Delta T_{p-p} \approx 0.40$ °K for an ideal system. From analogue records estimated over intervals not greater than 1^m we find $\Delta T_{p-p} \approx 1.0$ to 1.5 times greater than theoretical. From digital measures taken over 20^m on the Beckman counter with time constant of 1^m, we find $\Delta T_{p-p} \approx 1$ to 10 times theoretical. Other observers have also found noise in excess of theoretical, by factors of typically five times.

Excess noise by analogue methods apparently must be attributed to atmospheric fluctuations or short-term gain fluctuations. An increase in noise measured digitally may be due to a) a factor of 1.5 to 2.0 increase due to the heating cycle of the front end box, which has periods between 1 and 10 minutes. b) non-linear voltage-to-frequency characteristic for the counter near zero voltage, which occurs if improper bias is used. We feel that it is much safer to record on-off observations on magnetic tape using the slow-scan technique described previously, than to rely on the digital counters.

3.5 mm. Observed noise (analogue) does not exceed expected noise by more than 20%; noise measured digitally has the same problems as mentioned above.

At both frequencies we find the same noise in load switching and beam switching configurations.

III CONCLUSIONS AND RECOMMENDATIONS

As a user facility, the 36-ft system is somewhat less streamlined than the 140-ft or 300-ft but the training period needed for the average observer is no longer. The fraction of time spent in useful observing is somewhat less than at Green Bank facilities, but we do not feel that the problems lie mainly with the telescope, receivers, or computer. They lie instead with the following points, which we recommend as improvements. The first point we feel is much the most important, while the others are not necessarily listed in order of importance.

1. New dome aperture covering: The inability of the telescope to track in even modest winds (5 to 10 mph) when at low elevation and toward

the south, costs considerable observing time (on 3 nights out of 10 we had to relinquish prime sources completely, while on another 3 nights tracking was poor, even for a 4' beam; at 3 mm at least half the time we tried to observe in the southern hemisphere was effectively lost due to being blown off source). During our observing period wind exceeded operable limits for a few hours every night after sunset for declinations south of $\sim$10°. In addition, the present dome aperture covering has been shown to preclude all but the crudest observations when the dome is closed, while at least at 9 mm it appears that some useful observations could otherwise be done in the daytime.

Both of these problems can be solved by covering the aperture with a permanent stiffened mylar covering, which is virtually lossless, and which avoids use of metallic trusses and ribs.

2. Dome tracking control: The photocell sensors at present do not work well in daylight. Shielding them from diffuse light should help. The stability of the associated electronics should also be checked: on some days it is almost impossible to keep the dome tracking properly, and runaways are frequent, spoiling the observations.

3. Temperature Control in Dome: Typical day-night temperature variations (up to 40 °F) do not seem to degrade observations at 9 mm beyond changing pointing corrections. However a very sizable temperature gradient can be set up over the dish when at lower elevations due to buildup of hot air at the top of the dome during the day. There was some indication that this affected beamshape slightly even at 9 mm, and can be

expected to have significant effect at 3 mm and shortward. Fans or air conditioning should be installed in the dome to equalize temperatures.

4. Feed rotator: The mechanical drive for rotating the feed tends to bind at present and is not in use. It can be computer controlled. Rotation relative to celestial coordinates of the electric vector and position angle of feed separation (when beam switching) may introduce systematic errors when following a source for an extended time. The rotator drive should be made operational as soon as possible.

5. Servo and drive system: Time constants and rate feedback do not seem optimized on the drive system, or else need continual readjustment. As a result, even small changes in telescope position (as in on-off's) often cause a very poorly damped oscillation as the telescope seeks the new position, with potential runaway. The amplifier and SCR circuiting should be reworked to provide better gain stability and more optimum time constants and rate feedback. There is also indication that the tracking rate at slower scan rates (<10"/sec) is not reliably uniform, so that position finding or slow scans are untrustworthy.

6. Emergency Systems: Normal runaways in azimuth can usually be spotted and corrected before hitting limit switches and are usually not too fast for the brakes to stop quickly. Runaways at low elevations caused by wind may be much faster and exceed the brake capacity. An audio warning device should be installed to sound whenever the rate

exceeds a preset value. And the present emergency elevation slew, which rapidly takes the telescope to stow elevation in case of dangerous wind, should be made more accessible. Presently one must locate a special key, insert it in an inaccessible lock under the console, then activate the slew drive before corrective action occurs.

7. Computer: The computer still poses several problems, of which we point out the following:

   a) Errors occur in on-line processing. Examples encountered are:

      i) The DDP often drops a bit in the position indication, although the telescope is still set at the desired position. But at the same time the data in box number 16 is always clobbered, at least when a total of 50 boxes is used in a scan, as in our case. This error occurred on several days with several different tapes in use, although only one source was involved (which did not lie near the zenith).

      ii) Cal scans using the noise tube must be numbered 999 or else they are irretrievably lost in further data processing with the present programs. Frequently, although read in by card as 999, the scan number was not recorded as 999; when this occurred, the subscan numbering sequence was also incorrectly recorded, preventing further processing of some of the data.

      iii) Several other inexplicable mismanagements of data also occurred, such as failure to write scan labels, mislabeling of subscan indices, etc. In addition, unaccountable failure to write data on the tape occurred on occasion, including one 2-hour stretch which was not recorded.

While these on-line problems remain, it is not possible to take completely homogeneous data, which creates difficulty in further processing with the present set of programs. However we believe that it would be very difficult to write sufficiently flexible follow-up reduction programs to incorporate all the DDP errors which are presently possible.

b) The tape drive appears to need more maintenance; it seems to wear out tapes rather rapidly, and either it or the DDP produce many more errors in writing than are found with the Green Bank on-line systems.

c) If possible the DDP should be programmed to read what it has written and check for writing errors, as do the Green Bank DDP's.

8. <u>3mm Receiver</u>: A couple of minor problems are: a) The front end switch drive can be difficult to adjust at times, requiring a critical delay and mark space ratio. Neil Albaugh is presently working on the problem. b) The noise tube has opposite phase to that of the signal, hence deflects in the opposite direction. This increases the dynamic range over which the Beckman counter must operate, and makes it difficult to avoid saturation on the high end or non-linearities on the low end.

9. <u>Backup Equipment</u>: Without a lot of expenditures, it is probably not possible to have a supply of spare parts comparable to that at Green Bank. However, for benefit of future observers we point out that a few key parts, such as klystrons, and drive servo system components, typically cannot be replaced at once upon failure. Observers should check in advance what the probable remaining lifetime of such equipment is (especially 3 mm kylstrons!) and plan accordingly.

10. Useful studies to be done: Further understanding of the focusing, especially under extreme temperature conditions and at the shorter wavelengths is needed. A study of the statistics of atmospheric fluctuations would be very useful. Reliable extinction data is needed. Careful calibration of the system under load and beam switching is needed, there being indication that beam switching gives higher T_A's for small sources, by $\sim$10%. When the paramp front ends are available, more calibration sources should be decided upon which are too weak for use with the present systems.

Some streamlining and generalization of existing data reduction programs would be very desirable, but the need for documentation of the existing ones is even more urgent. Apparently many observers do not even try to use the present system of programs or the magnetic tape facility. Documentation and distribution of this system along the lines of the 400 channel A/C system might well alter this situation.

APPENDIX

In Figures 5 to 7 we present additional data on the behavior of the telescope taken by Kellermann and by Schraml. These data apply to the 3 mm wavelength region, which was not adequately calibrated during our observing period owing to klystron failure.

Figure 5: This graph shows the antenna temperature measured on Jupiter on two successive days. The first day (·) followed observations of the sun. The second day (x) did not. It appears that at least five hours are required for the dish to cool off.

Figure 6: The graph shows the antenna temperature T_A of Jupiter and corresponding aperture efficiency. The T_A's have been corrected for extinction and changing apparent size (to a standard diameter of 30"). The 4.3 mm points have been adjusted to 3.4 mm by assuming that Jupiter radiates as a blackbody. The efficiencies are calculated on an assumed disk temperature of 150 °K. All measurements are made without direct sunlight on the dish. The air temperature measurements for the 4.3 mm points are taken in the dome at the time of the radio measurements. Similar temperature measurements were not generally made at 3.4 mm, and the quoted values are the mean of the extreme daily temperature recorded on top of the mountain. These appear to be within a few degrees of the temperature in the dome. While this may account for some of the scatter in measured T_A at the same temperature, the bulk of the scatter is not attributable to this, and is consistent with the experience of other observers that there is a large and not well understood variation in the efficiency at $\sim$3 mm at different times.

Figure 7: Distribution of maximum wind velocity on top of Kitt Peak for roughly a one-month period in June and July, 1968. No records are kept at the 36-ft site but the wind distribution seems qualitatively similar. That is, maximum winds occur on clear days around sunset and sunrise. Difficulty in tracking is encountered when the wind reaches 5 to 15 mph, and 20 mph is the danger point when the telescope dome must be closed.

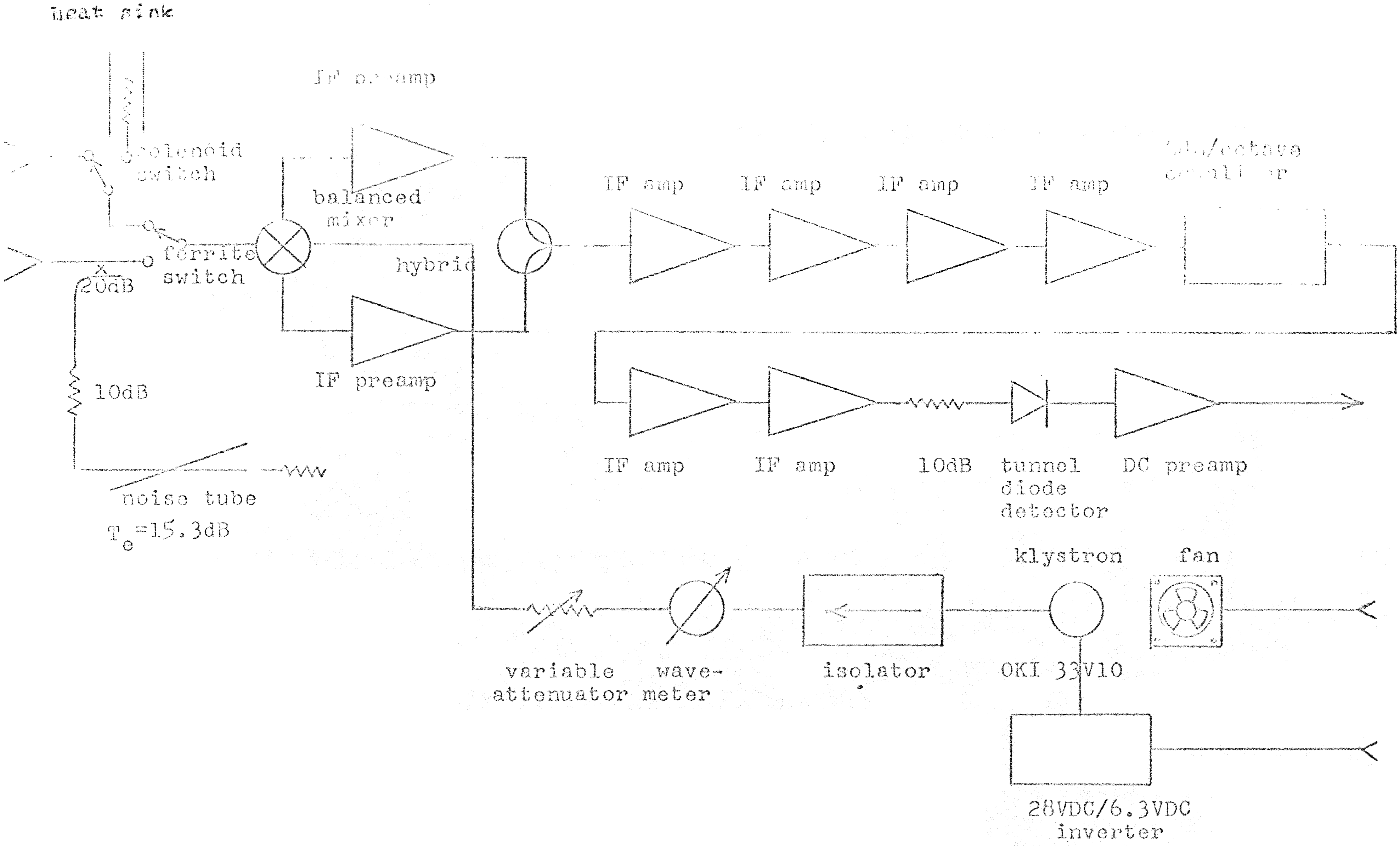


Figure 1

BLOCK DIAGRAM 9.5MM (31.4 GHz) RADIOMETER

FRONT-END

T_s= 1120 °K   B=400 MHz

5 Sept., '68 Albaugh

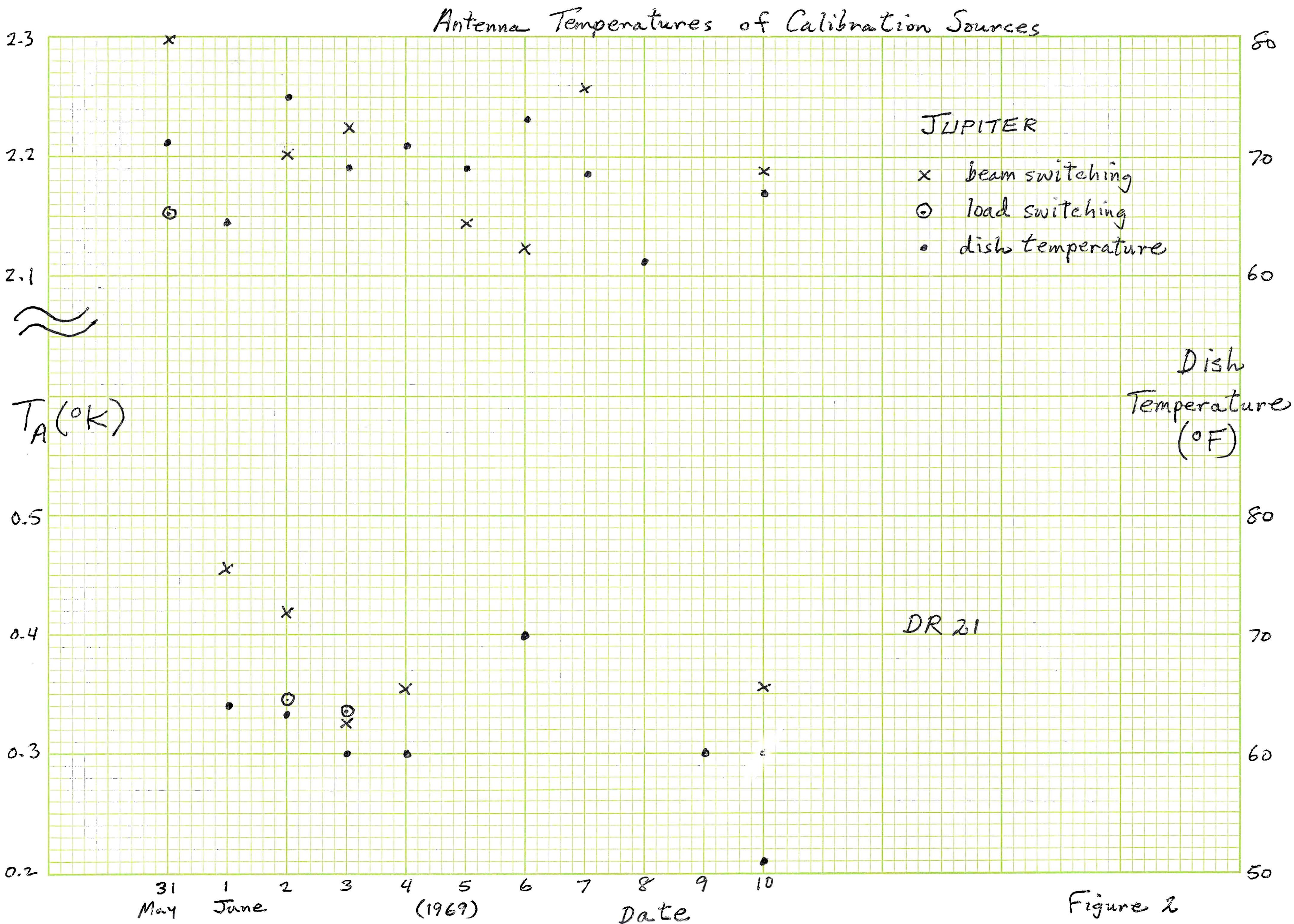

Antenna Temperatures of Calibration Sources
JUPITER
x beam switching
⊙ load switching
• dish temperature
DR 21
T_A (°K)
Dish Temperature (°F)
2.3
2.2
2.1
0.5
0.4
0.3
0.2
80
70
60
80
70
60
50
31 May
1 June
2
3
4
5
6
7
8
9
10
(1969)
Date

Figure 2

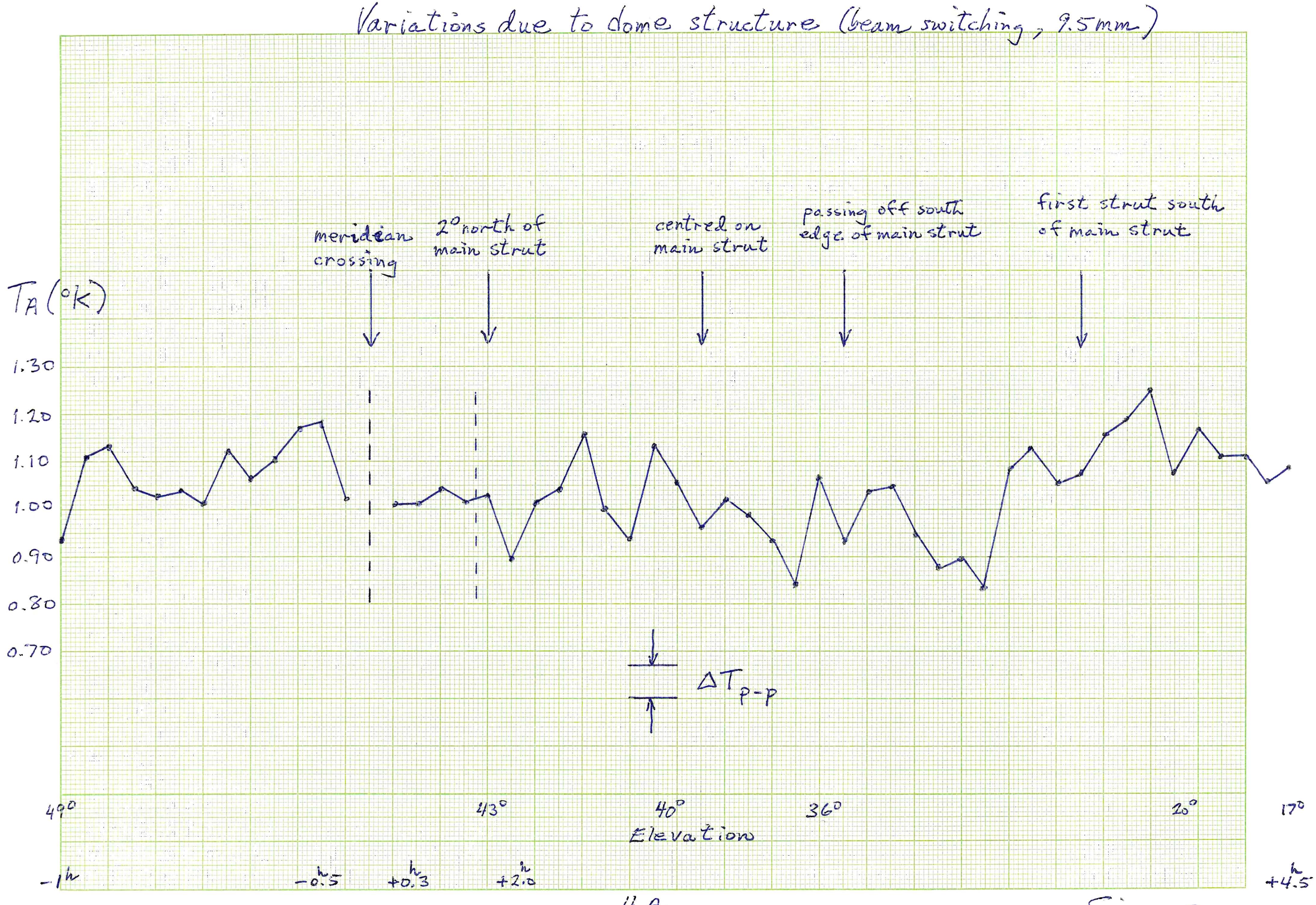
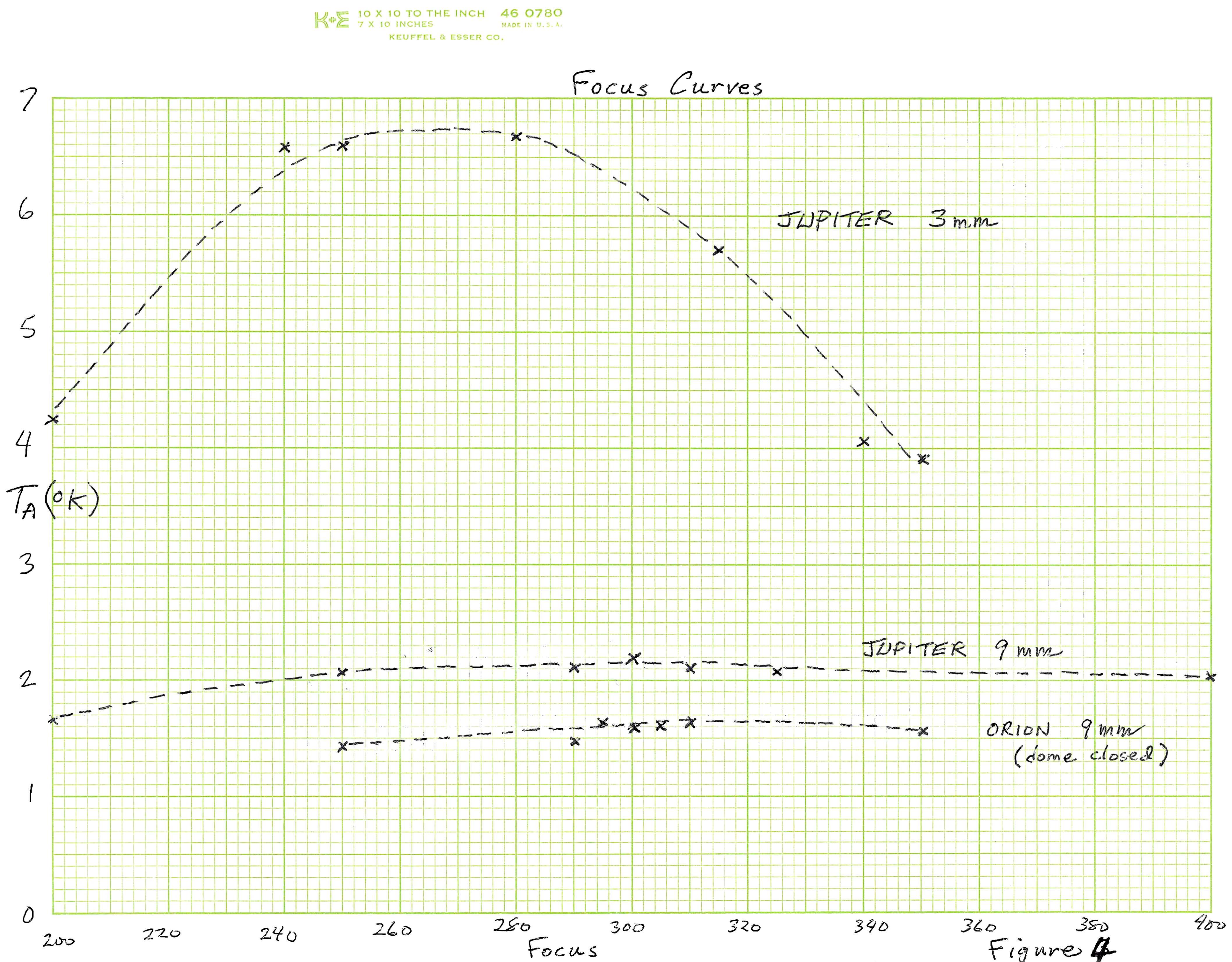

Variations due to dome structure (beam switching, 9.5mm)
meridean crossing
2° north of main strut
centred on main strut
passing off south edge of main strut
first strut south of main strut
T_A (°K)
1.30
1.20
1.10
1.00
0.90
0.80
0.70
ΔT_{p-p}
49°
43°
40°
36°
20°
17°
Elevation
-1^h
-0.5^h
$+0.3^h$
$+2.0^h$
$+4.5^h$
H.A.

Figure 3



K+E 10 X 10 TO THE INCH 46 0780
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.
Focus Curves
JUPITER 3mm
JUPITER 9mm
ORION 9mm
(dome closed)
T_A (°K)
7
6
5
4
3
2
1
0
200
220
240
260
280
300
320
340
360
380
400
Focus

Figure 4

Thermal Time Constant (3.4 mm observations)

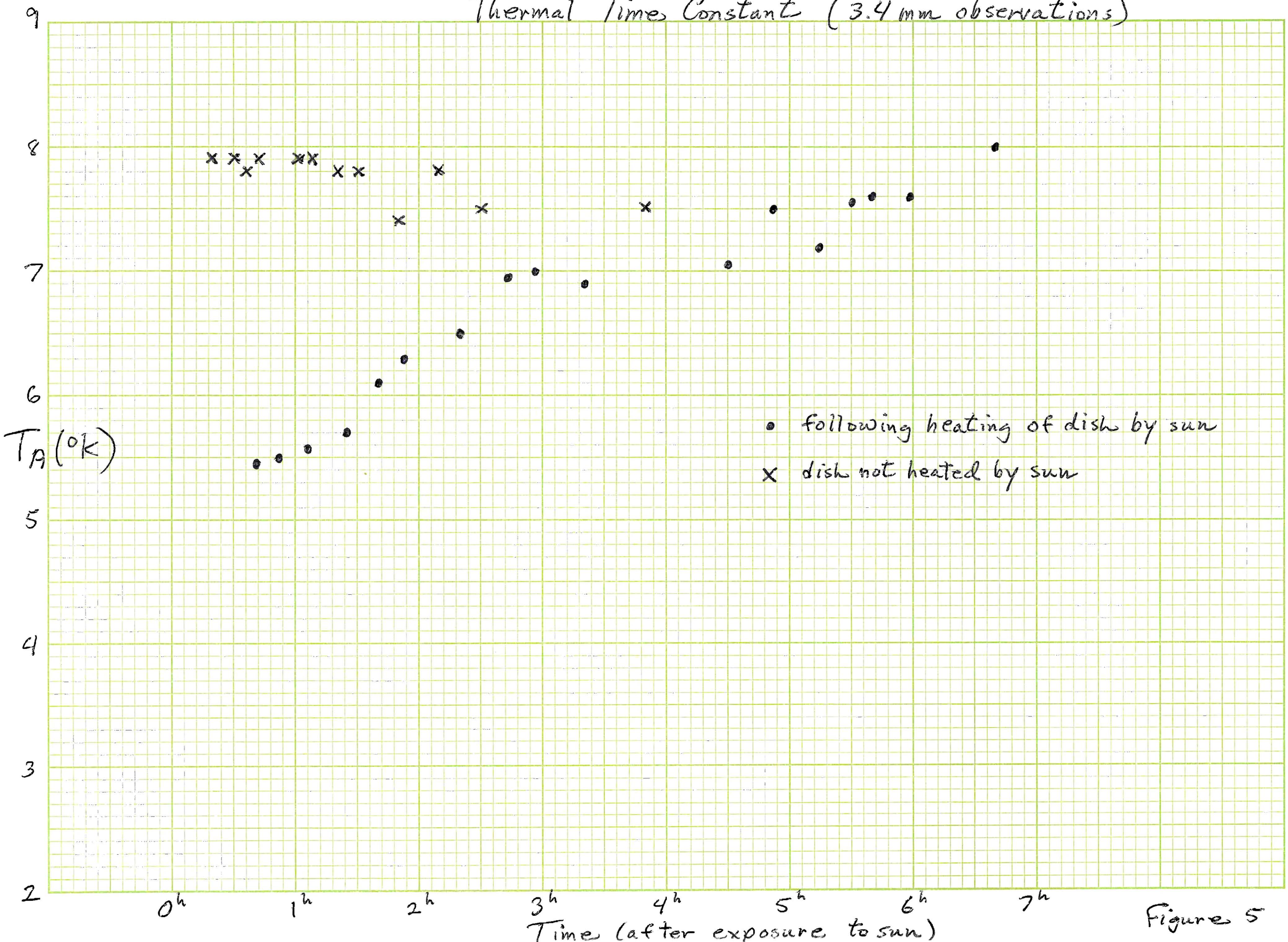


Figure 5

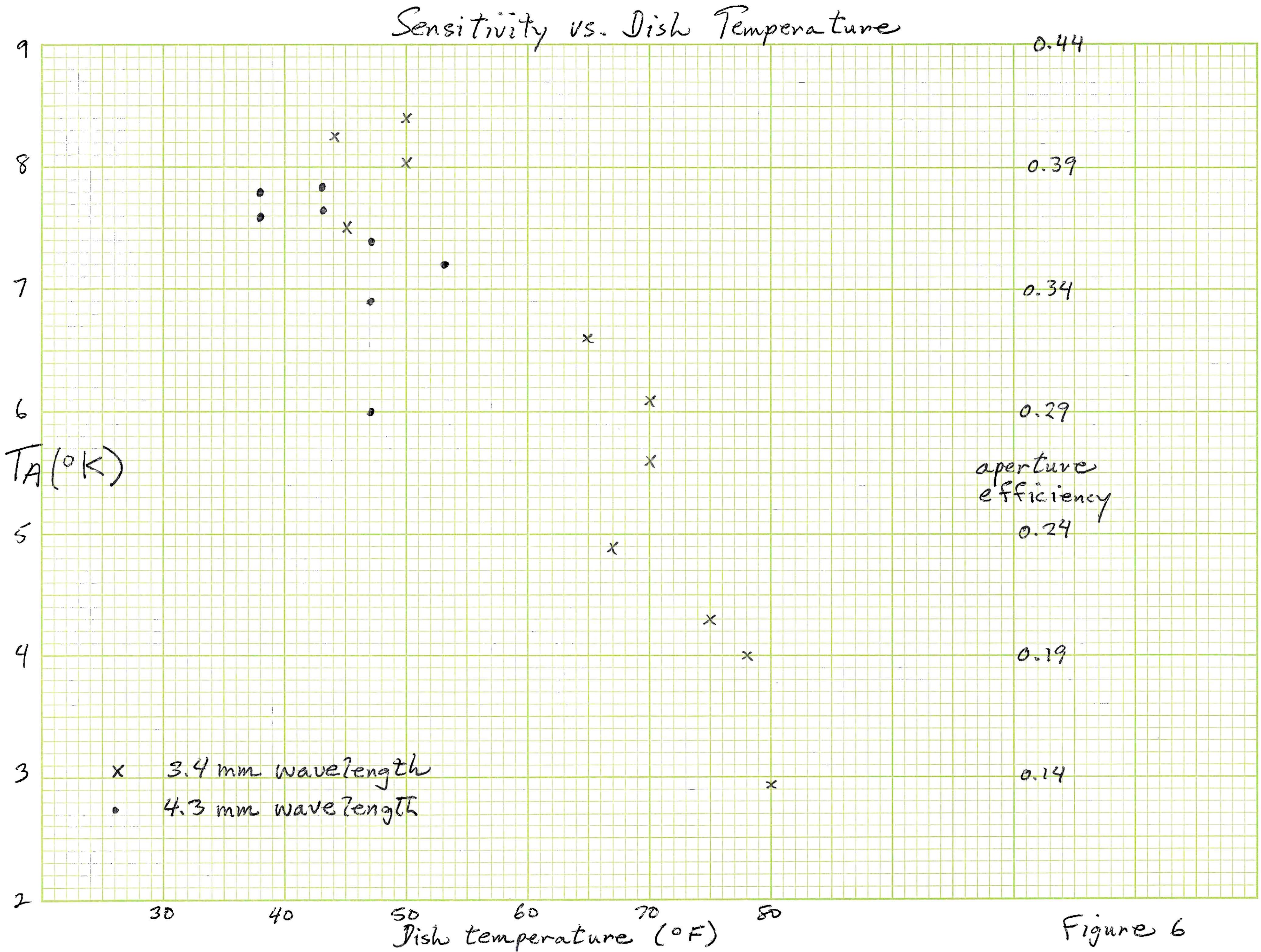

Sensitivity vs. Dish Temperature
9
8
7
6
5
4
3
2
TA (°K)
0.44
0.39
0.34
0.29
aperture efficiency
0.24
0.19
0.14
× 3.4 mm wavelength
• 4.3 mm wavelength
30
40
50
60
70
80
Dish temperature (°F)

Figure 6

Wind on Kitt Peak

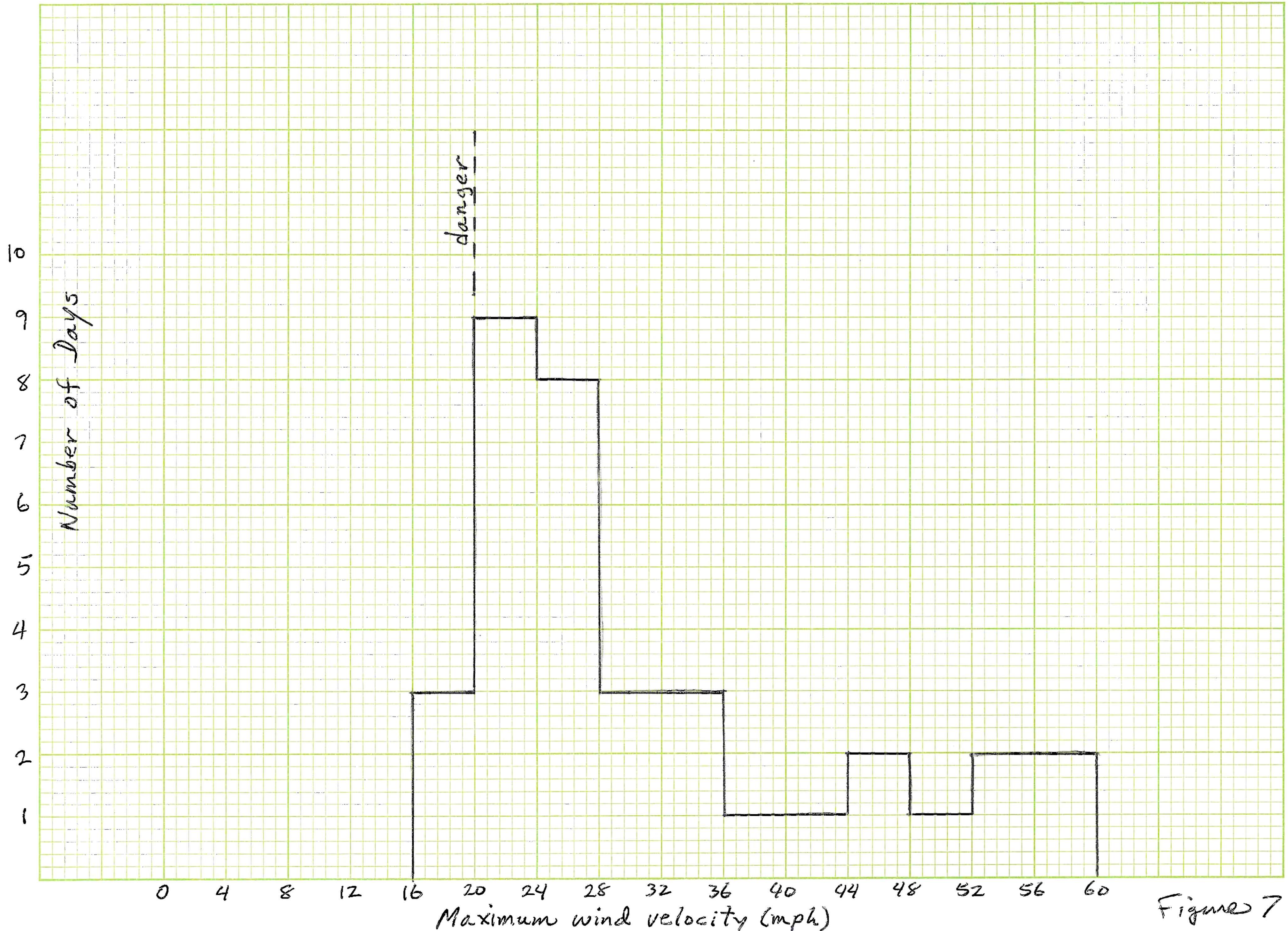


Figure 7

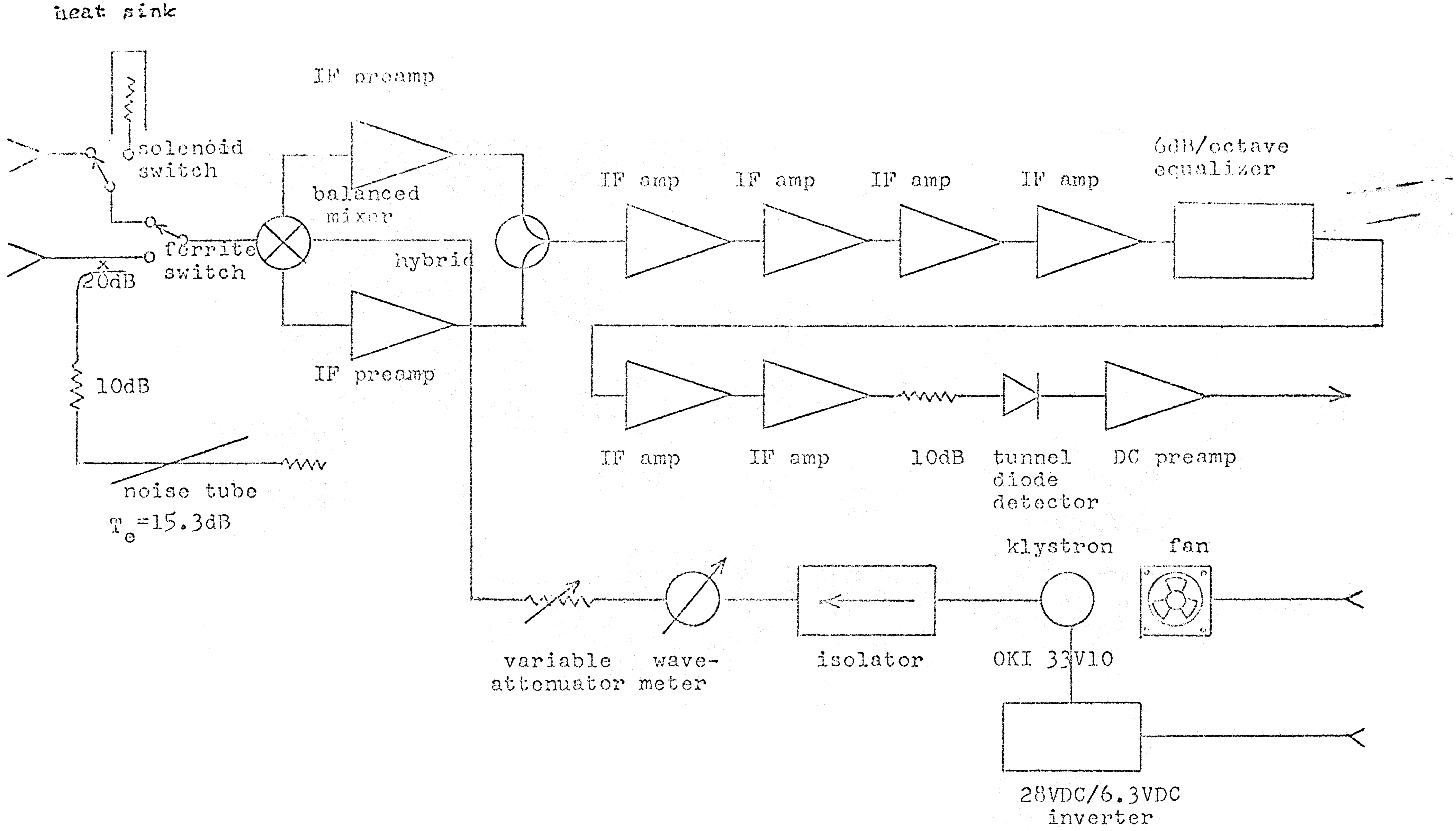


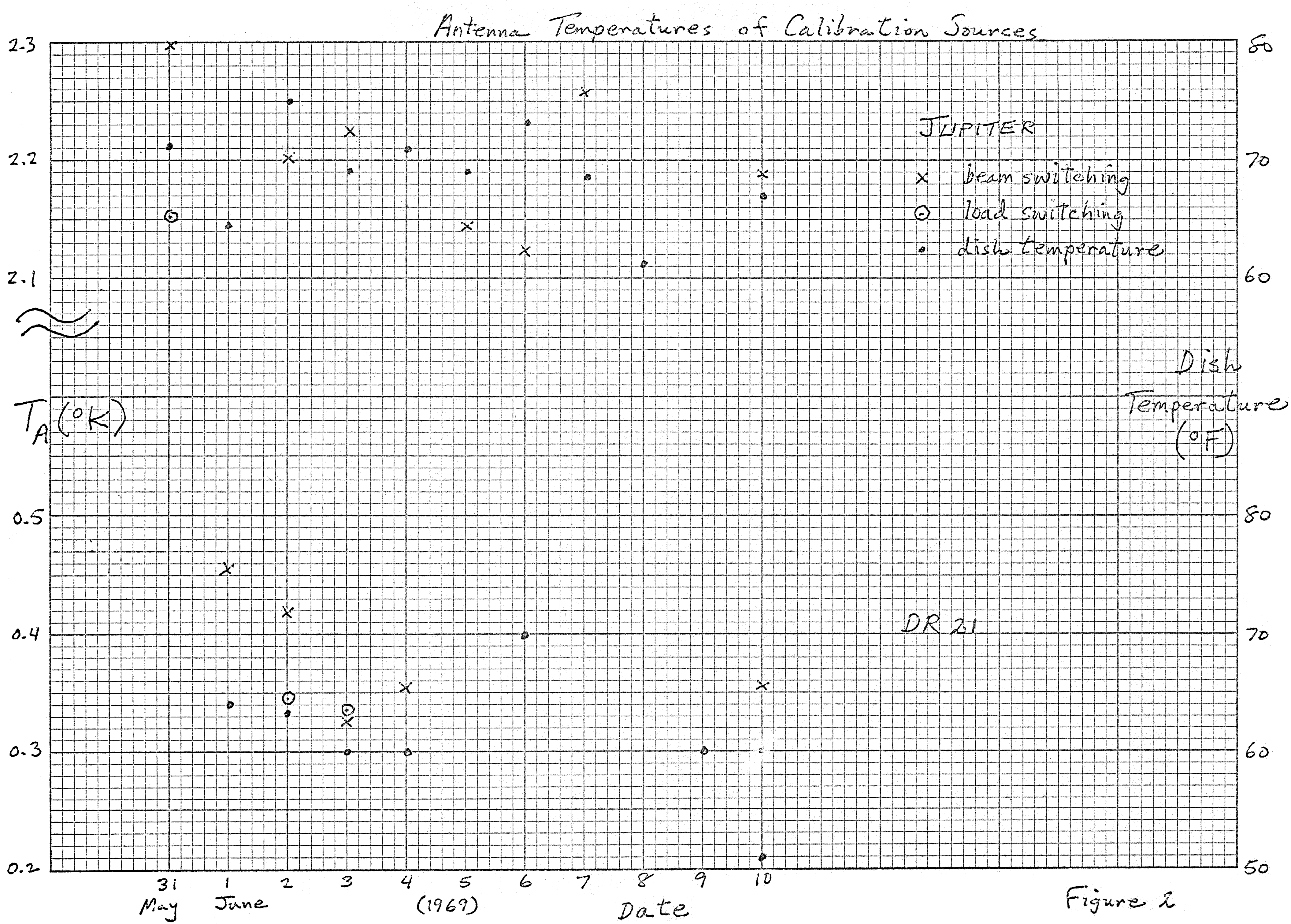
Figure 1

BLOCK DIAGRAM 9.5MM (31.4 GHz) RADIOMETER

FRONT-END

T_s= 1120 °K B=400 MHz

5 Sept., '68 Albaugh



Antenna Temperatures of Calibration Sources
JUPITER
beam switching
load switching
dish temperature
DR 21
T_A (°K)
Dish Temperature (°F)
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31 May
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2
3
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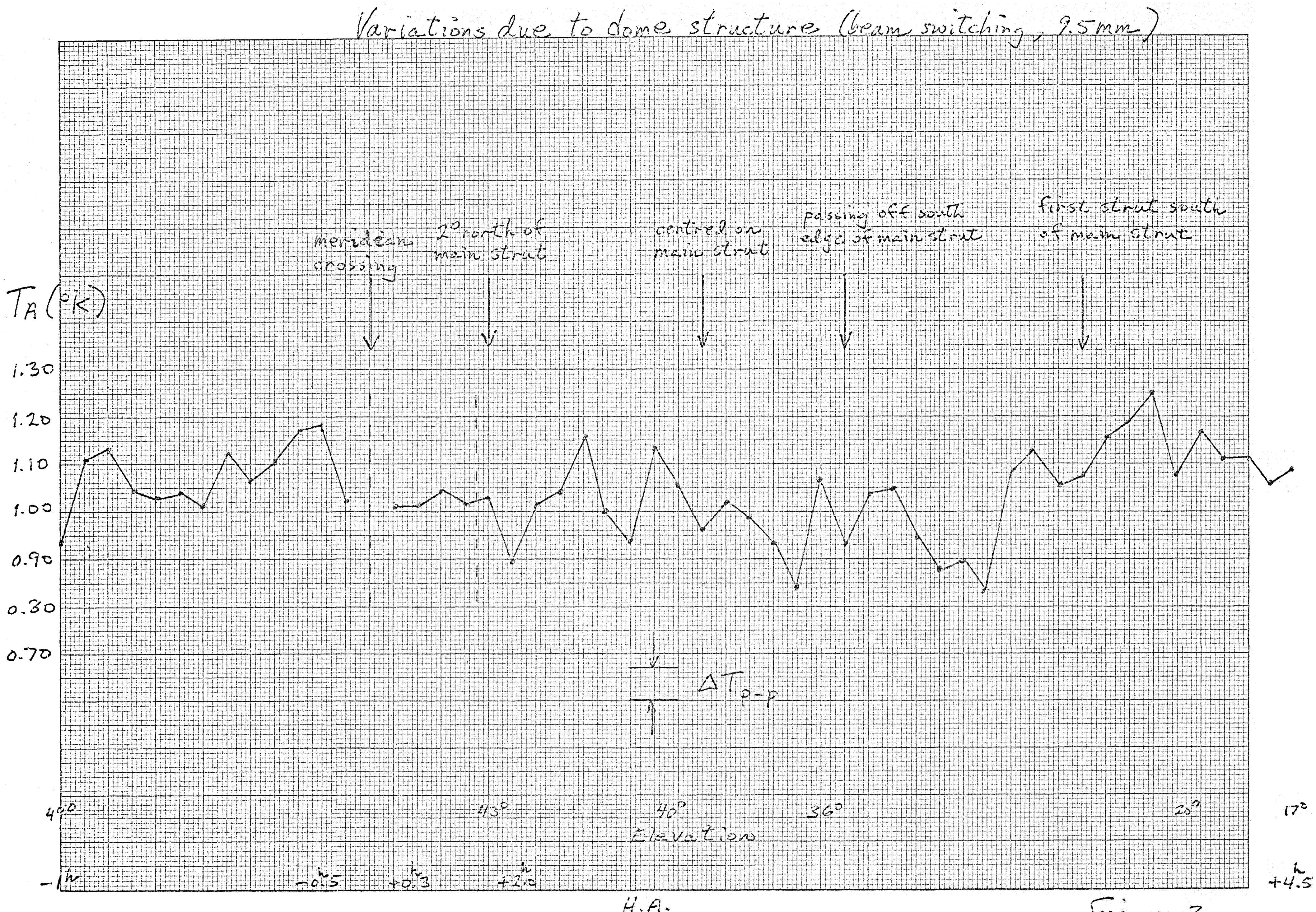
5
6
7
8
9
10
(1969)
Date

Figure 2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ΔT_{p-p}
40°
43°
40°
36°
20°
17°
Elevation
-1h
-0.5h
+0.3h
+2.0h
+4.5h
H.A.

Figure 3

Focus Curves

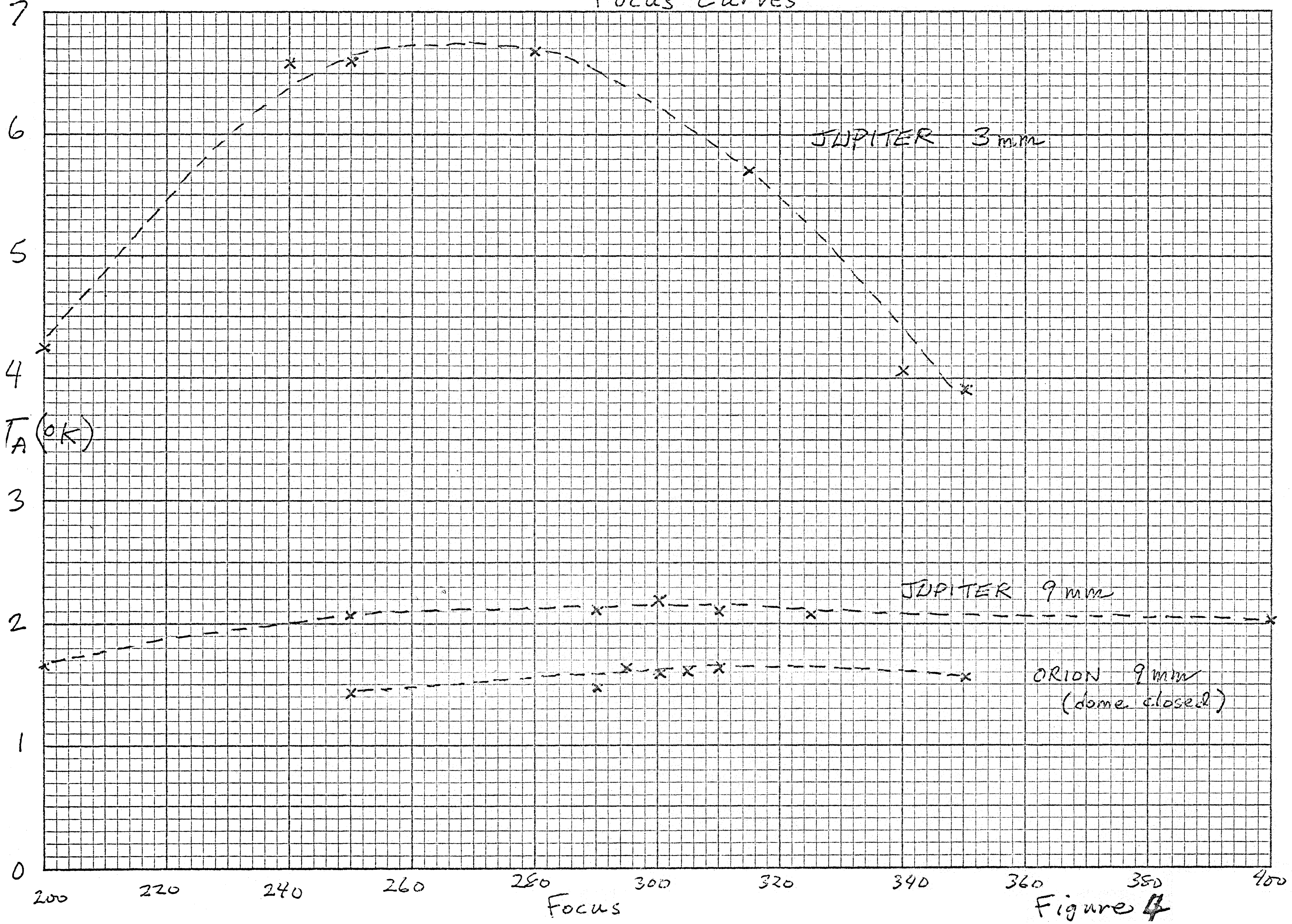

Figure 4

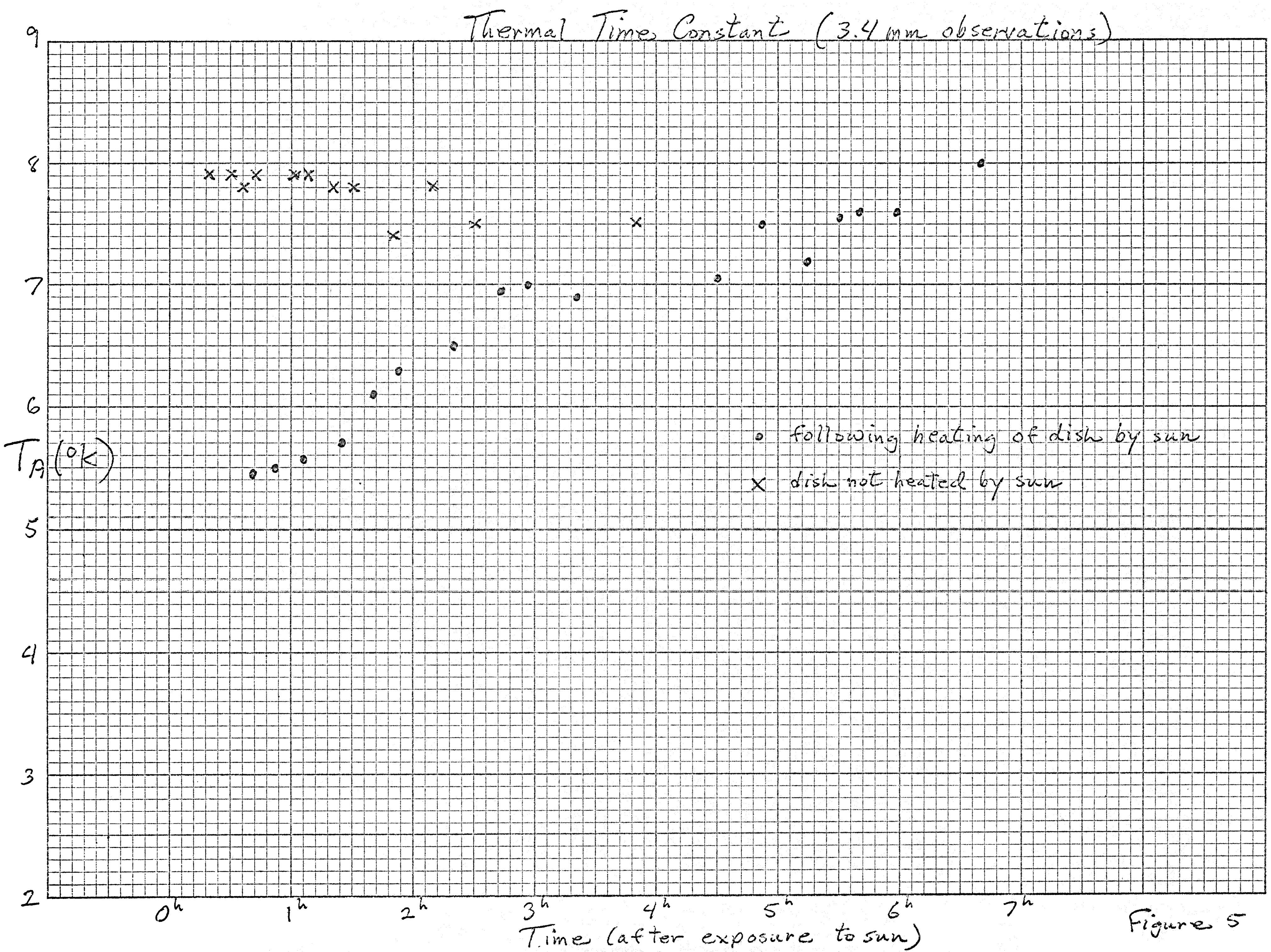
Thermal Time Constant (3.4 mm observations)
9
8
7
6
5
4
3
2
T_A (°K)
0h
1h
2h
3h
4h
5h
6h
7h
Time (after exposure to sun)
following heating of dish by sun
dish not heated by sun

Figure 5

Sensitivity vs. Dish Temperature

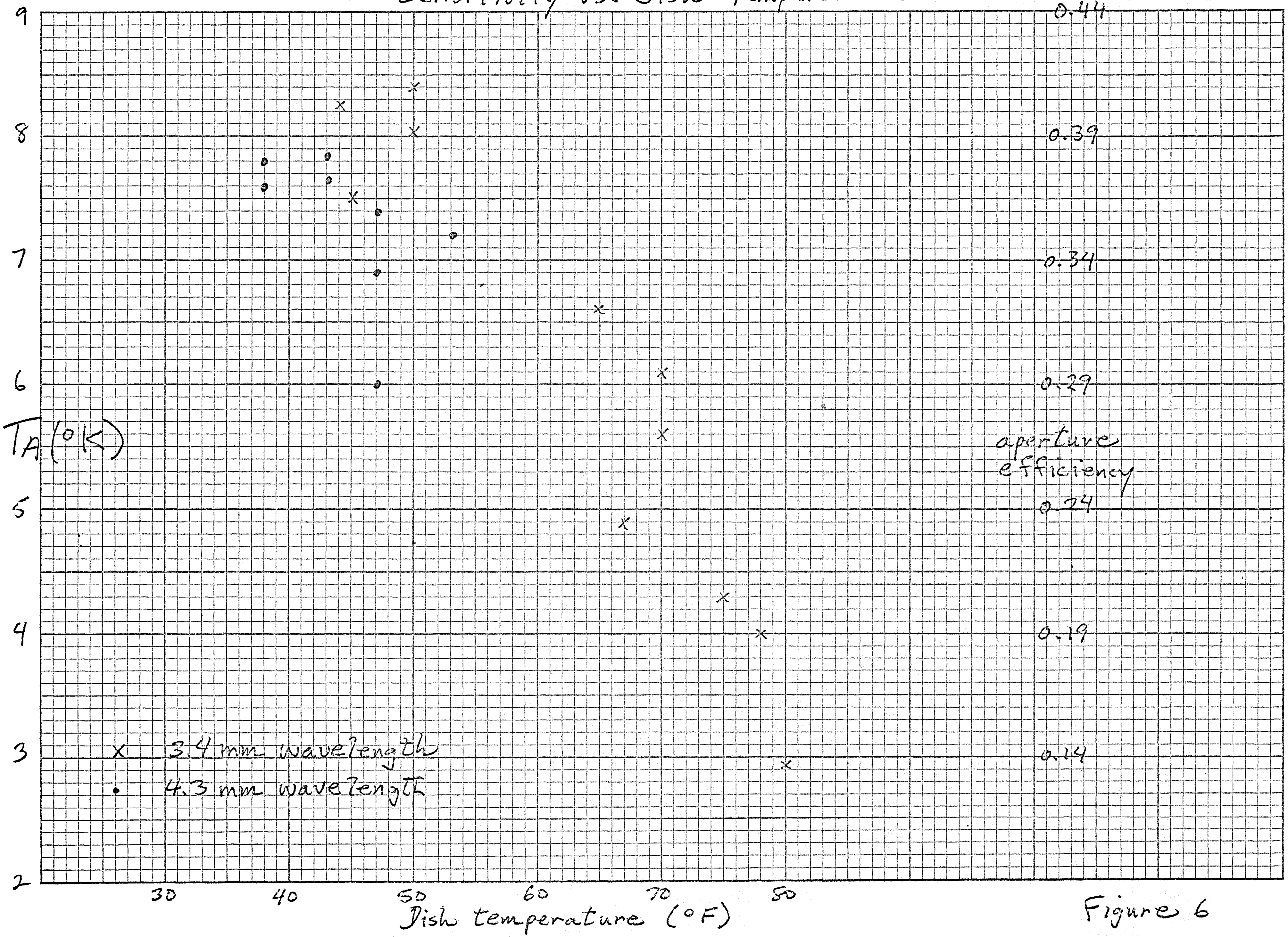

Figure 6

Wind on Kitt Peak

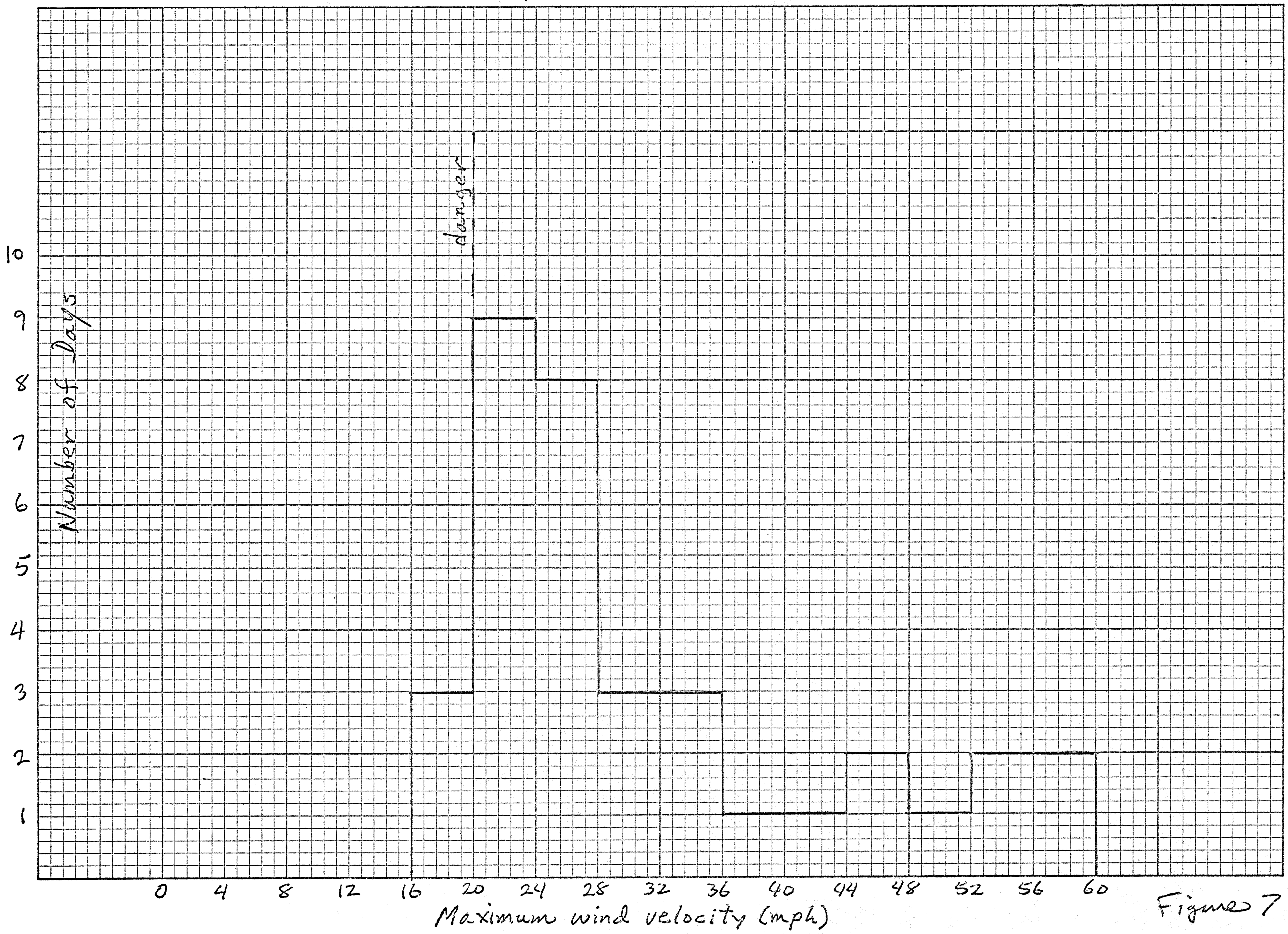

Figure 7