12 METER MILLIMETER WAVE TELESCOPE
MEMO No. 249

# RECOMMENDATIONS FOR FEED LEG VENTILATION

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## 1 Introduction

The effects of heating of the feed legs can be quite severe unless steps are taken to minimise it. The legs are currently insulated and ventilated by small fans at the upper end of the feed legs. However the fans are rather small (30-40 CFM) which is probably insufficient to cause effective heat transfer. This note summarises some calculations of the thermal behaviour and recommends a better ventilation scheme.

## 2 Effect of Temperature Differential in Legs

It is difficult to calculate analytically what the effect of feed leg heating is on the surface figure and pointing of the telescope. To obtain at least an order of magnitude estimate some approximations need to be used. If one of the legs is heated more than the others by an amount $\Delta T$ then the leg will expand by a relative amount

$$\Delta \ell = \Delta T \alpha_{steel} \tag{1}$$

where $\alpha_{steel}$ is the thermal expansion coefficient of steel ($12 \times 10^{-6}$ $C^{-1}$). The effect of this will be to push on the primary backing structure and the secondary mirror support. This will cause an astigmatic distortion of the primary and a pointing shift. Numerically, $\Delta \ell$ is about 70 µm $C^{-1}$, and that the astigmatic surface error will be of order $\Delta \ell/2$ = 35µm. The pointing shift is difficult to calculate, but I estimate a value of about 2 arcsec $C^{-1}$.

It would appear that the thermal differential between feed legs should be kept down to the level of about 1 C, if possible.

## 3 Thermal Calculations

To get an idea of the amount of cooling required for the legs consider that one broad side of a leg (area 1.4 $m^{-2}$) is fully illuminated by the sun. Assuming a solar flux of 1 kW $m^{2}$ and an emissivity of 0.1 gives a total heat input to the leg of $Q$ = 140 W. The volume of the leg is about $v$ = 0.18 $m^{-3}$, so that the mass of air inside the leg is about 0.17 kg. If the air is heated at a rate $Q$ then the time it takes to warm by 1 C is of order

$$t = \frac{c_p m}{Q} \tag{2}$$

where $c_p$ is the specific heat of air, giving a time of about 1.2 s. The flow rate should therefore be greater than about 5 m $s^{-1}$ (150 l $s^{-1}$, 300 CFM). The current fans produce a flow of about a tenth of this.

Efficient cooling of the feed legs also requires that the flow inside be turbulent. The transition from laminar to turbulent flow occurs when the Reynolds Number is between about $2 \times 10^3$ and $2 \times 10^4$. For the feed legs this translates to a flow velocity of 0.25 - 2.5 m $s^{-1}$, so that the above velocity is in the turbulent regime.

To try to obtain a better estimate of the flow rate, a model was set up which included solar heating, re-radiation by the feed leg, external natural convection, and forced internal convection. It also allows for a layer of insulation on the feed legs. There is some uncertainty in choosing some of the parameters such as the emissivity of the surface and the fraction of the heat which radiates to the sky and the ground but some reasonable guesses were made. The main heat transfer mechanisms appear to be solar heating, natural convection from the outside, and forced convection on the inside. Radiation from the outside to the sky and ground is a smaller component. Figure 1 shows the estimated feed leg temperature as a function of the internal flow rate for different R-values of insulation[1]. It appears that better cooling than we have now could be obtained with a larger flow rate even if the insulation is removed. A velocity of around 10 m $s^{-1}$ is required. At this rate the pressure drop along the tube will be a few tenths of an inch of water, though there will also be flow resistance at the intake and outlet which I have not estimated.

## 4 Recommendations

I would recommend that larger blowers be installed on the feed legs with a minimum capacity of 600 CFM at a pressure of 1 IWG (inches of water gauge). The air should preferably be circulated from the rear of the backing structure and the blowers should force the air up from the lower end of the feed legs. Suitable blowers are commercially available and could be either mounted on the feed leg with a duct on the input to suck air from the back, or mounted behind the primary and connected to the feed leg with ducting.

It appears that the blowers may be sufficient without insulating the feed legs. To be on the safe side the blowers should be installed and tested in time to order insulation if that is found to be necessary. The feed legs should probably be re-painted if no insulation is used.

**Distribution**

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[1]The R-value is the insulation resistance in $ft^2$ s °F $Btu^{-1}$. 1 $ft^2$ s °F $Btu^{-1}$ = 0.176 $m^2$ s K $J^{-1}$.

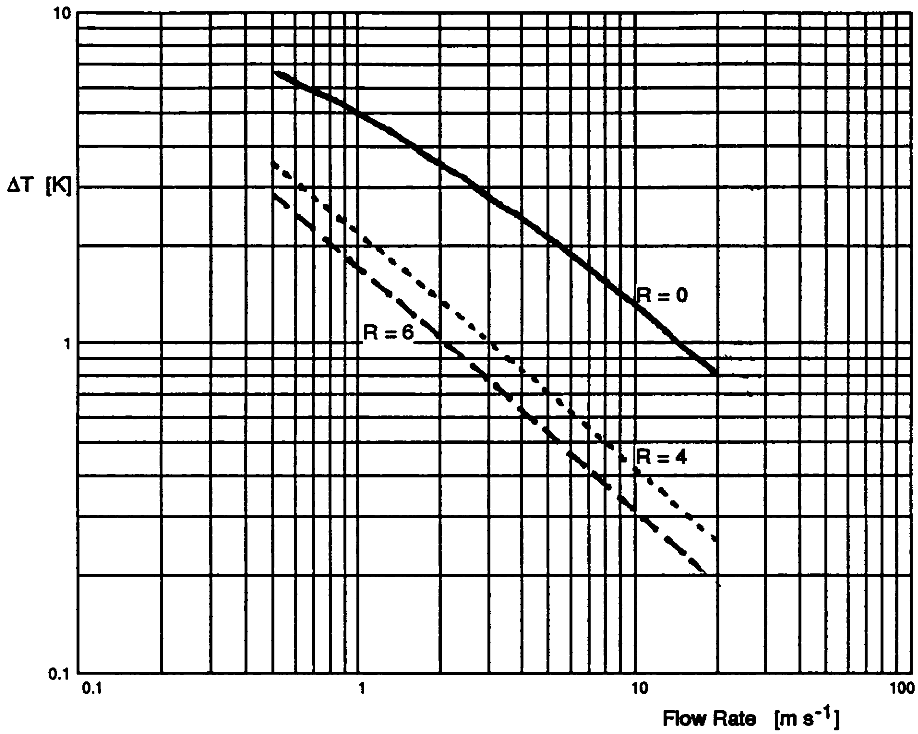


**Figure 1** Temperature difference between feed leg and ambient for different air flow rates and insulation values.