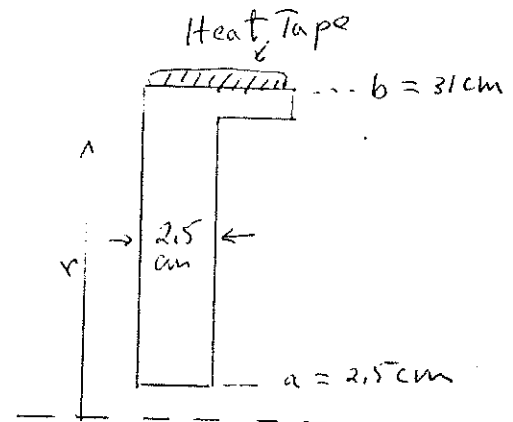
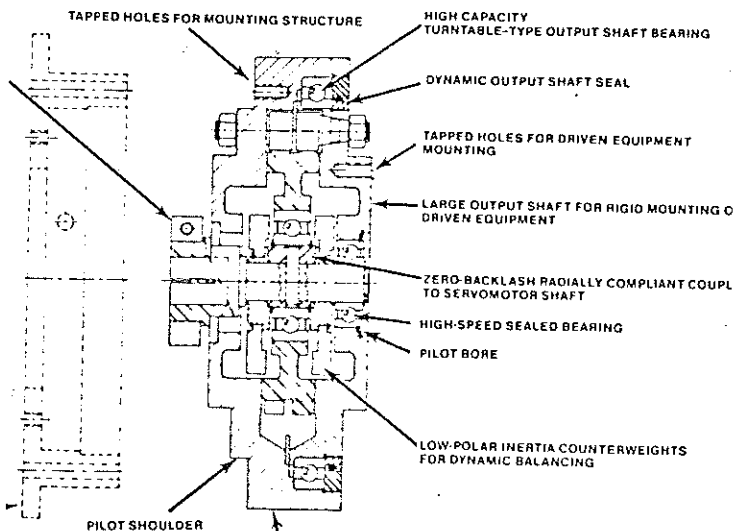


Several greases made by different oil companies are recommended by Rotek, the manufacturer of our azimuth bearings. A telephone call to Texaco revealed that their grease which is recommended for the bearing, Multifak EP 2, operates over the temperature range $-30^{\circ}\text{F} < T < 300^{\circ}\text{F}$. -30°F is lower than any temperature that we get at Hat Creek, as far as I know, and so it appears that we do not need to heat the bearing. I'll double check that with Rotek. Most greases don't go this low in temperature. The difficulty that we had before with the Whitaker antenna was probably due to the use of a higher temperature grease.

On the other hand, the manufacturer of the Dojen speed reducers clearly states that $+32^{\circ}\text{F}$ is the lower operating temperature for the reducer. These units will have to be heated. It looks as though it will be straightforward. Here is an estimate of the expected temperature rise that we should get with a 400 watt tape on the outer diameter of the reducer that we are using.

The figure below shows a cross-section of one of these units. It is a rotary actuator with an excentric cam at the input, a double cam between the input cam and the output shaft, and a large diameter output shaft. The sketch on the right shows the heat flow model that I am using for the outer casing. The double cam and output shaft will be (relatively slowly) heated through the grease and rollers.



We wrap a 400 watt heat tape around the outer perimeter of the two foot diameter case of the reducer. With the assumption that all the heat flows into the top of the 5cm thick outer plate of the reducer, the power density is 0.8 watts/cm^2 . The outer radius of the reducer is 31 cm. To make the estimate definite, we make the conservative assumption that the temperature of the input shaft of radius 2.5 cm remains at the ambient temperature. The steady state temperature rise as a function of radius for this simple model is given by:

$$T(r) = [b H_0/k] \ln(r/a)$$

b is the outer radius, 31 cm; H_0 is the input power density, 0.8 watts cm^2 ; a is the inner radius, 5 cm; and k is the thermal conductivity

of the steel, $0.46 \text{ watts/cm}^0\text{K}$.

The temperature rise at the outer radius, 31 cm, is a toasty 136K! Note that the output bearing is close to the outer radius. The innermost bearing is at a radius of about 5 cm where the rise is still 31K. It appears that the 400 watt heat tape will raise the unit temperature high enough for even the coldest weather. Insulation around the unit will be necessary to keep radiation and convection from stealing the heat away. The heat flow path is rather long for this unit, about 31 cm, and this will require over an hour to get the temperature of the steel case up to within 90% of the steady state value. Also, the heating of the interior of the unit and the output shaft will have to be through the grease and the rollers. Because the grease has a low thermal conductivity and the rollers touch at small cross section, it will take some time to warm up the entire unit after the heat has been turned on. We will need to make some test measurements to get more firm numbers. It appears that we will need to leave this unit on during power outages.

SUMMARY

There probably is no need to heat the azimuth bearing during even the coldest weather. The Dojen speed reducers will have to be heated, and it appears that 400 watt (or possibly smaller) heater tapes and insulation will be adequate. The time for heating the reducers is rather long, and we will need to leave their heaters connected to the emergency generator during power outages.