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From: Jon Hagen, Sr. Staff Engineer, Cornell University, Arecibo Observatory
Date: 1-23-01
Subject: **Hydraulic Damper System**

The Arecibo radio telescope in Puerto Rico contains what are essentially two self-powered cars running on an inclined cog railway without counterweights. They can descend at controlled speeds by virtue of dynamic braking provided by their electrical drive system. However, there is no back-up service brake system or velocity damper to avoid a catastrophic runaway condition in the event of drive system failures. A possible solution is described below. If deemed feasible, we intend to issue an RFP to qualified hydraulic engineering firms.

Our Present System

The radio telescope contains two moving antenna platforms which are like self-powered cars on a cog railroad. One car weighs 33,000 lbs. The other weighs 190,000 lbs. The cars travel along a 40-degree circular arc like the bottom of a sextant. This track has a radius of curvature of 435 ft. Each car stays on its own side of the arc and travels between the bottom the arc (zero degrees), up to a maximum angle (20 degrees), where it has gained a height of 26 ft.

The Problem: No backup service brakes

The cars are fitted with electric drive motors (8 motors on the heavier car, 2 motors on the lighter car). Each motor has a planetary gear box driving a spur gear that engages the rack gear along the center of the track. The maximum operating speed along the track is 3.8 inches/sec. When the cars move downhill, the electronic drive system causes the motors to operate as generators to provide dynamic braking. The energy is dissipated in a resistor bank. Each motor is also fitted with a small disk brake. These disk brakes serve as parking brakes, but have very little surface area or heat capacity and can not be expected to bring the cars to an emergency stop near the top of the track if the downhill velocity exceeds the maximum operating speed.

The drive system is partially failsafe: the disk brakes are applied by spring pressure; during operation they are released by electrical solenoids. Thus, in the event of a sudden clean power failure (a common occurrence) the brakes engage. More complicated failures can easily be imagined in which the drive system computer keeps the disk brakes released, thinking, incorrectly, that braking current is flowing in the motors. The result would be a disastrous runaway condition.

A Possible Solution

We hope to install a totally passive safety system, somewhat like the hydraulic dampers used in door closers. It would consist of hydraulic pumps (possibly simple gear pumps): one pump coupled to each electric motor. When moving downhill, each pump would force oil through an orifice to provide a damping force. Radiators would be provided to dissipate the heat. If released, the car would accelerate up to the velocity where the total damping force equaled the gravitational force. The orifices would be sized so that, at the top of the hill, this velocity would equal our maximum operating velocity. When the car is not near the top of the hill, some force from the electrical drive system would be necessary in order to move down hill at the nominal maximum velocity, but this would be acceptable. When the car is moving up hill, check valves would bypass the orifices in order to eliminate the hydraulic damping. This totally passive damper system would require no electrical power, control, fault detection, or triggering. Oil temperature monitors and/or differential pressure monitors would confirm that each damper pump is doing its job.

Technical Specifications
With the car at the top of the track, each motor (Kollmorgen B-606) supplies 18.7 ft lbs of torque to counteract gravity. At nominal maximum speed, the motors turn at 1269 rpm. This is equivalent to a power of 18.7 ft lbs x 2π x 1269/min = 149081 ft lbs/min = 4.66 hp, which must be dissipated when moving downhill. In the current system, this power is dissipated in the resistor bank. With the proposed damper, this power would heat the hydraulic fluid and be dissipated by radiators. Each pump/orifice combination should therefore require 4.51 hp when turning at 1269 rpm. To allow for wind loading, the pumps might be sized at about 7 hp. The pumps would presumably have to operate without cavitation with the input side at atmospheric pressure.

<u>CALCULATIONS</u>

pinion pitch diameter: .2667m (Vertex Vol 1, p16) = 0 .875 ft = 2 x 0.4375 ft
rack gear pitch diameter 840.9375 ft (Vertex Vol 1, p16)
planetary box gear ratio: 190.07 (Vertex Vol 1, p16)

Calculate motor speed at slew (2.5 deg/min)

Motor speed = 190.07 x (840.9375 ft / 0.875 ft) x (2.5 deg/min) / (360 deg/rev)

= **1269 rev/min**

Wt. of Gregorian: assume 190,000 lbs

Calculate torque against gravity per Greg. motor at 20 deg:

Torque = 190,000 lbs /8motors x sin 20 deg x .4375 ft / 190.07

= **18.7 ft lbs**

(Page 1-7 of Vertex Vol II states (max) brake torque as 35 ft lbs.

Calculate power to move uphill at 2.5 deg/min when at 20 deg elevation (w/o friction)

Power = 2 pi x Torque x rpm = 2 x 3.14 x 18.7 ft lbs x 1269

= 149100 ft lbs/min = **4.51 hp**