Department of Energy
Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208 - 3621

July 3, 1986

In reply refer to: EPG

Doug -
For your review, comment, and any other enclosures you may desire to have sent. A similar letter will go to PGE for their Bull Run plant.

Mr. Jim Turner
Research Director
Idaho Power Company
P.O. Box 70
Boise, ID 83707

Dear Mr. Turner:

The purpose of this letter is to inquire as to your company's interest in a formal cooperative Research, Development, and Demonstration (RD&D) project with the Bonneville Power Administration (BPA). Specifically, BPA proposes to fund the purchase of a Kaplan turbine "optimizer" or index test box from the Woodward Governor Company and its installation at your Cascade hydroelectric plant. Your company's obligation would be to evaluate the accuracy of the optimizer and the ease or degree of difficulty in its field use. If the evaluation is successful, you would have the option of receiving title to the equipment.

Current fiscal year funding is available for this project. Total hardware costs are expected to be in the $40,000 to $50,000 range. However, future year funding for such RD&D projects has not yet been defined. Consequently, we are simultaneously contacting several companies to ascertain not only their level of interest, but also their ability to negotiate and execute a cooperative agreement before the end of the current fiscal year.

As you are aware, the efficiency of any Kaplan turbine is a critical function of the blade angle relative to both wicket gate opening and to net head. A field efficiency test known as an "index" test can be performed on the prototype to determine this optimum relation. However, when done in the conventional manner, this test is quite labor intensive. If a way could be found to reduce the labor intensive nature of index testing, a considerable amount of extremely low-cost, additional electrical energy potentially could be generated. Additional benefits available from optimizing the efficiency of Kaplan turbines include a decrease in the mortality of downstream migrants and increased machine life from reduced vibration and cavitation.

Woodward Governor Company has recently developed an on-line, Kaplan turbine optimizer which may be retrofitted on their Type 2 electronic 3-D cams used with electronic governors with load feedback. This new system is "plugged into" the existing governor by a simple replacement of the A/D interface

was then used to interpolate for the exact point of peak efficiency to be marked on Graph 1, rather than simply noting the particular data point with the highest efficiency. This second procedure provides up to 2 percent increase in the accuracy of identifying the blade angle at peak efficiency.

As to the best manner to graphically present this data, I do like the gate opening versus blade angle with efficiency contour overlay method of Don Sachs'. An additional use of Graph 2 is to obtain the loci of these isoefficiency contours to overlay on Graph 1. It is also informative on Graph 1 to show both the "as found" cam as well as the optimum cam.

One additional feature that probably would help demonstrate the value of this efficiency optimization would be an auxiliary plot of power versus efficiency increase between the "as found" and optimum cams as shown on the upper left of Graph 1. Again, Graph 2 may be utilized to obtain this plot. It is noted, however, that for this particular data, the plots of efficiency versus blade angle on Graph 2 show significant variations of several percent for the peak values. From this, it appears that, although a data set may be consistent within itself, they are not consistent one to another.

There are several possible explanations for this, the most likely being changes in some data or instrumentation calibration. Due to this variation, uniform isoefficiency contours could not be determined and plotted on Graph 1. This does demonstrate the need for a consistent test setup with constant or compensating calibrations. Even with these variations, however, the auxiliary plot on Graph 1 still shows the efficiency of this particular turbine- generator can be increased an average of 0.6 percent by shifting to the optimum cam.

It is observed on Graph 1 that half of the constant power data sets were all taken with 5 MW of full power. This certainly demonstrates the repeatability of your optimizer's solution but also points out the need for the tested unit to be operated uniformly over its full power range to accurately define the complete optimum blade-to-gate cam.

It is noted that for each data set, the power is not held exactly constant, but has a little variation. As near as can be determined, however, this did not appear to particularly effect the accuracy of the solution. On the other hand, some of the constant power, blade-to-gate, curves on Graph 1 show abrupt changes in curvatures. This is interpreted to be due to hysteresis in the blade control circuit. In other words, on this test your optimizer was instrumented to record where the governor was telling the blades to go rather than where the blades actually were. This undoubtedly caused some of the error in locating the peak efficiency points to define the optimum cam curve as well as the variations in the auxiliary plot of efficiency increase versus power.

Presumably, if you instrumented off the indicating surface of the blade servo rod (inner oil pipe) in the oil head or even the blade restoring cable, these constant power curves would exhibit a more uniform curvature and the errors would be reduced. In fact, if your instrumented off either one as well as keeping your present instrumentation, your optimizer could also be used to diagnose the mechanical hysteresis in the turbine blade positioning control. It is of interest to note that on this particular generating unit most of the sudden changes in curvature in blade position occur between 60 and 65 percent gate opening. This could indicate some kind of a "rough spot" in the positioning control.

Since Don Sachs apparently only indexed this unit at 75 foot head, I am sure he would appreciate receiving these results of the optimum blade-to-gate relation for 82.5 feet.

In view of the foregoing, we continue to maintain our interest in testing and demonstrating your optimizer here in the Pacific Northwest as part of our hydro system efficiency improvement program.

Sincerely,

Lee H. Sheldon

Lee H. Sheldon
Mechanical Engineer

Enclosure