TRIP REPORT TO: CLARENCE CANNON DAM, MASON CITY, MO.
PURPOSE: Install index test box on their Kaplan unit.
DATES: April 26- May 4, 1985.
PERSONS MET: Dale Russell, John Stone, Lee Ratliff, John Hickam.
FROM: Doug Albright.

ABSTRACT

The purpose of this trip was to get some field data and practical experience at index testing of Kaplan turbines. This experience is to be used to prepare the index test box for a fully automated index test later this summer.

The index test box was tested for data collection capability, and its ability to determine steady state and uniqueness of collected data points. In addition, a test to provide correlated data with the official Corps of Engineers index test planned for later this summer was run. Burst samples of several start-no-loads and an orderly shutdown of the unit were taken to demonstrate dynamic recording capability.

The power plant Superintendant, Dale Russell, has requested a quote for installation of an Electronic 3-D cam and having an automated index test run on his Kaplan unit.

BACKGROUND

The index test box project goal is to develop an automated index test box which, in conjunction with a Woodward Electronic 3-D cam, will perform an index test on a Kaplan turbine during normal operation. Results of this test are intended to improve the operating profile in the electronic 3-D cam. Preliminary tasks to this goal are:

1. Prepare an instrumentation system to collect data on the turbine and generator.
2. Install this instrumentation on a Kaplan turbine-generator and acquire data to demonstrate the feasability of performing an automated index test with the generator on line, with power held constant by the governor.
3. Provide the hardware/software tools necessary to interface this data collection system to the existing 3-D cam prom surface generation system.
4. Perform an index test driven from the index test box, install the resulting prom chip in the electronic 3-D cam computer, and evaluate performance with the new surface.

The instrumentation system hardware consists of an Analog Devices uMAC-5000 Computer, an interface card to connect the computer to the 3-D cam signals of headwater, tailwater, gate and blade stroke, the watt transducer, plus a differential pressure transducer across the spiral case Winter-Kennedy taps.

System software is written to perform the tasks necessary to ascertain the "steady-stateness" of the data, compare collected data points against the array compiled in memory, and if unique, record the data point.

Testing of the data transfer interface from the index test box to the prom generation software resident on the Honeywell is presently underway.

METHOD

FIRST DAY

The Bikor power supply was connected to power both the Analog Devices 2B22L voltage to current converter for the watt transducer signal, and the 3-D cam interface card.

Generation level signal is taken across the center tap and test point L3 on the watt transducer amplifier panel of the governor. This signal is isolated and converted to a 4-20 ma. signal by the 2B22L.

Input signals of headwater and tailwater levels were connected to the interface card from terminal strip EE, pins 33, 34, and 35. These signals are converted to 4-20 ma. by the interface card.

A dual element potentiometer was installed, replacing the single element potentiometer used to indicate gate position to the Supervisory Control Unit.

Blade position signal was obtained using an improvised system consisting of 2 magnets, another dual element pot, a 7 ounce weight and some string.

SECOND DAY

At the request of the powerplant Superintendant, Dale Russell, the morning was spent working with Lee Ratliff troubleshooting the Supervisory Control Unit. This equipment is to provide remote operation of the Clarence Cannon facility from the powerhouse at Truman dam.

Once the problems with the SCU were corrected the calibration of the index test box was started.

Data was taken from the prints to get calibration values for headwater, tailwater, and power generation level.

Headwater has a range of 590-648 ft. a 58 foot span indicated by a voltage of 13.61 volts from the transmitter pot. Headwater level was 606 feet, represented by 5.8 volts, which is 27% of span.

Tailwater has a design span of 521-537 feet, a 16 foot span, indicated by a 13.61 volt span from the tailwater transmitter pot. This was found to be incorrect when the transmitter pot output was compared to the tailwater instrument in the control console. Due to the tailwater indicating pot being physically damaged by being turned past its stop when the tailwater level went below the design minimum of 521 feet last year, the pot position was rotated upon replacement to allow indication of tailwater below the disign value without breaking it again.

Present calibration of the tailwater indication system is still a 16 foot span, but the bottom is now at 515.5 feet. The effect of this is a nethead indication that is 4.5 feet less than the actual net head.

Calibration of the generation level across L3 and center tap output of the watt transducer amplifier is a 0 to 5.24 volt span for 0 to 31 MW, or 115% of a 28 MW unit. This signal was input to the strip chart recorder to provide a time record.

The differential pressure transducer was connected to the index box and checked for zero and operation. Operation was tested by opening the bleed valve on the low side, and checking for an output as the bypass valve across the transducer was closed.

A problem was found with the eprom chips taken along to store the programs in for execution. Five chips were found to be defective, presumably from static discharge. This prevented the entire set of programs from residing in the index box computer at the same time, and still leave enough space in memory to collect the burst samples.

In order to get around this problem, The software was re-arranged to allow testing of all modes of operation. The procedures for the correlation test, unique test, and an abbreviated burst sample test were placed in memory, with approx. 4800 bytes left for modifications of and additions to these procedures. The burst sample test was separated from the rest to allow room in ram for the 7x3000 array of integers to receive the data.

THIRD DAY

The first task of the day was to complete the software changes in preparation for starting the unit to speed-no-load to get calibration values for flow, gate and blade.
Five starts were made to allow measurement of outputs of blade, gate, flow, and test burst sample procedures.

Calibration values for the blade at angles of 33 and 8 degrees were obtained. Corresponding voltages from the indicator pot were 1.14 and 12.03 volts. For the purpose of these tests, these angles will be regarded as 0 and 100% of blade stroke, respectively.

Calibration of the gate indicator was only over 20% of stroke, because that is all the further it opened to get the turbine up to speed. Corresponding voltages were:

0% stroke = .04 volts.
20% stroke= 2.74 volts.

FOURTH DAY

All calibrations were re-checked, and the method for evaluating nethead from headwater and tailwater signals was worked out.

Calibration of headwater, tailwater, and gate stroke were still correct, but the blade pot's string had stretched to give approximately 8% shift.

Permission was granted to run the unit for a short time to get calibration values for power and flow.

The unit was started and put on line at 30% generation, or 10MW. At this level there was considerable surging of the generated power, and the signal from the Winter-Kennedy transducer was unusable due to noise. It was noticed that the differential pressure transducer signal went downscale when the unit was run. When tested with a 144 inch water column on the input to the transducer from the outer Winter-Kennedy tap, the input was indeed reversed. The plumbing was corrected and calibration set at 0-144 inches input for a 4-20 ma. output, which is converted to a 0 to 100% indication in the index box. The unit was run up to 65% generation where the power and flow were both much quieter and appeared to be usable.

Discussions of this noise problem with power house personnel indicated that the noise would not be a problem because index testing at lower than 65% is pointless. These two units are always run at 100-115% generation level, and no one is interested in performance below that level.

The command staff from the Corps of Engineers was through today, and were mildly interested in my work.

We have been given clearance to run the unit for 4 hours tomorrow morning, 2 hours at 100%, then 2 more hours at 65% generation level.

FIFTH DAY

The unit was started remote from Truman, and loaded to 100%. The index box rejected all data during the slew to full load, and once there, captured one set of data, then rejected all new sets due to similarity to the one that characterized operation at 100%.

Uniqueness was determined by comparing the collected values for nethead, gate and blade against the data compiled on disk.

The second two hour segment of generation was also run at 100% instead of the originally granted 65%, due to the amount of settling time required by the index box at each sample before it would take a data point. This settling time is set by the values of deviation limits input during calibration of the index box. Limit values for this first test were .080 for all input signals. Settling time is determined by how long it takes for noise on all signals to dissipate to a value below this limit. This default value was selected on the lab workbench as a best case for the development test system.

<u>RESULTS</u>

The first data point collected with the unit on line at 100% was:

nethead	tail	gate	blade	flow	power
65.58	32.10	65.90	42.02	20.25	87.53

The manual blade adjustment pin was inserted and the blade lifted (brought to a steeper angle) 4% higher:

65.45	33.21	66.92	45.66	19.46	85.48
65.35	33.99	68.56	45.68	20.09	86.13
65.26	34.77	70.17	45.69	20.19	86.72
65.10	36.16	71.34	45.69	20.63	86.96.

Time increments between these measurements are approximately 1 minute.

The decrease of power due to rotating the blade is corrected by the governor as it opens the gates to 71.34%. At this time the flow is at the higher value of 20.63% and the power is not quite all the way back to 87.5%. The flow indication is lower in the first sample after the movement of the blade, indicating the opposite of what was expected: for the flow to increase when the blade is rotated steeper.

When the unit stabilized at 71% gate, the flow is higher, as expected.

Again the blade was raised, this time to 48%:

nethead	tail	gate	blade	flow	power
64.73	39.17	73.34	48.20	20.33	85.33
64.68	39.50	74.45	48.25	20.37	85.54
64.61	40.14	76.30	48.24	20.97	86.07
64.54	40.71	77.80	48.24	21.16	86.34
64.44	41.54	79.22	48.37	21.14	86.52
64.35	42.30	80.32	48.38	21.53	86.54
64.30	42.74	81.41	48.37	21.56	86.30
64.24	43.18	82.55	48.37	21.70	86.19

The resulting power decrease is compensated for by the governor as it opens the gates to get power back up to the set-point. Water flow, after settling to the final value, also behaves as predicted, increasing with gate opening and having a higher value as the power returns to 87%.

The blade was then lowered 6% with resulting power increases as the blade rotates into the flow of water:

64.21	43.38	81.28	42.16	23.17	90.19
64.19	43.62	78.62	42.04	23.41	90.40
64.16	43.85	76.29	42.01	22.54	89.73
64.13	44.10	74.31	42.00	22.31	89.24
64.10	44.33	72.91	42.04	22.02	88.63
64.05	44.74	71.41	42.04	21.60	87.88
63.99	45.28	70.14	42.04	21.32	87.24

The gates closed to 70.14%, bringing power back to the setpoint of 87%. The blade was then lowered to the on-cam position and data re-checked:

63.81	46.75	67.34	39.96	21.21	87.00

Repeatability of blade position was 2%, which is .0024" rise on the cam follower.

The blade was then rotated to a below-cam position:

63.86	46.28	67.85	37.79	22.01	88.99

At first this point appears to show a power increase of 2% over the design cam position, just what we are looking for. The flow indication, however, does not make sense. The flow should decrease because the flatter blades provide increased resistance to flow.

It appears that the differential pressure across the spiral case is not only affected by water velocity, but also by changes in momentum of the water column.

NOTE

Due to the short period of operation available and difficulty with the manual blade positioning equipment, additional below cam data is not available from the uniqueness test. Additional below cam data is available from the correlation test, which is reduced to the same format as above, and evaluated in the same manner.

The unit was shut down to allow time to make changes to the test and evaluate test results. The second two hours at

100% generation level were utilized to check out the correlation data test, which records all of the values measured, and the results of all calculations on disk. The power setpoint is 2% lower than the first run. The average values were separated from this file to give this below-cam data.

This first point is on-cam for reference:

nethead	tail	gate	blade	flow	power
63.46	49.63	71.91	44.71	20.88	85.54

The blade is then lowered to 40% blade angle:

The resultant increase of power is compensated for by the govenor as it closes the gates to 66%.

63.37	50.27	67.91	40.51	20.74	86.22
63.38	50.26	66.95	40.47	20.69	85.87
63.37	50.27	65.91	40.74	20.62	85.37
63.35	50.45	66.28	40.22	20.64	85.73
63.35	50.46	66.20	40.22	20.18	85.73
63.28	50.97	66.58	40.47	20.47	85.85

CONCLUSIONS

The primary purpose of this trip was to determine the nature of the data, not to characterize the turbine. The four hours of running time provided did allow sufficient data collection to test operation of hardware/software prepared for this task.

The nature of the data was characterized for noise and abnormalities. The signals taken from the 3-D cam interface (headwater, tailwater, gate and blade stroke) and the power signal from the watt transducer were all as predicted. Water flow indicated by the Winter-Kennedy taps performs as expected in the steady-state, but when water column momentum is changing this differential pressure reflects these accelerations. This makes it imperative that the software be able to detect disturbances to the system, and wait appropriate time periods for things to settle out after them.

Unit sensetivity to changes of blade angle was characterized by observing power changes for small blade motions. Power deviation is significant for blade changes of .25%, which correlates to 1 step of an electronic 3-D cam.

This data indicates that normal governor action can be used to evaluate turbine performance with the unit on-line, the power held constant by the governor. The trickiest part is to identify steady-state operating conditions.

Tests completed:

1. Unique data test while the unit was in transition, and at steady state with blade position arbitrarily set by hand. These measurements were made both above and below the design cam surface.
2. Correlation data recording was done to provide data suitable for comparison with a manual index test by the conventional method.
3. Burst data was collected during the shut-down sequence, as well as 2 burst samples of speed-no-load.