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TRAVEL REPORT

Code : D-1530A

Date: August 2, 1983

To : Chief, Division of Research

From : Henry T. Falvey

Subject: Review of TVA Intake Gate Closure Studies

1. **Travel period (dates):** May 31, 1983 to June 2, 1983.

2. **Places or offices visited:** TVA Hydraulic Laboratory, Norris, Tennessee.

3. **Purpose of trip (include reference to correspondence prompting travel):** To review TVA's hydraulic downpull testing program. Reference: Report of telephone call to Henry T. Falvey from Svein Vigander, dated May 23, 1983.

4. **Synopsis of trip:** I flew to Knoxville on May 31 and rented an automobile to drive to Norris. I was met in Norris by Svein Vigander. He briefed me on the problem and what was expected during my visit. The next day, I met with Ely Driver, Branch Chief of the Hydraulic Laboratory and his assistant, Bill Waldrop. Following a tour of the labs, I met with Ted Fain, the principal investigator of the project. He showed me the model. We discussed his investigation and analysis. The following day, I had concluding discussions with Vigander and Driver. I returned to Knoxville and flew back to Denver.

5. Conclusions: My conclusions and observations are contained in the review report to the Tennessee Valley Authority, see attachment.

Henry T. Falvey

Attachment

Copy to: D-1500
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REVIEW OF THE TENNESSEE VALLEY AUTHORITY INTAKE BULKHEAD GATE CLOSURE STUDIES

by

Henry T. Falvey

Introduction

Several of the TVA (Tennessee Valley Authority) powerplants are supplied with vertical bulkhead gates located in the turbine intake. The primary purpose of the gates is to dewater the units. Therefore, the gates are normally lowered under no-flow conditions. However, if the wicket gates become inoperable, the gates provide a means to stop the flow under emergency conditions. The most extreme condition would be with the wicket gates fully open and the turbine at runaway speed. The gates must be designed to close under this emergency condition.

The intake to the turbine normally consists of three bays. To reduce the size and capacity of the lifting crane, each bay is sealed by two or three gates instead of one.

Each gate is picked up and lowered by a lifting beam. The lifting beam is connected to the gate by a linkage mechanism. The link is designed so that the beam must travel downward about 2 inches toward the gate before the gate is released. The lifting beam is supported by a cable. Ideally the cable should always be under tension and the beam should move toward the seated gate. However, before the gate is seated a tension should exist between the gate and the lifting beam to prevent premature release. Achieving these goals depends upon the interaction of the gate and beam weights, the functional forces on the gate and the beam, and the hydrodynamic forces on the gate and the beam.

The Problem

In 1961, hydraulic model studies on the Melton Hill Project were used to develop the gate shape and gate slot dimensions to obtain a satisfactory range of hydrodynamic downpull forces 1/. In 1965, hydraulic model studies were used to develop the lifting beam geometry for the Nickajack Project 2/. This intake uses two gates for the closure in each bay. The same year, field

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1/ Tennessee Valley Authority, Division of Water Control Planning, Hydraulic Data Branch, Hydraulic Operations and Tests Section, Melton Hill Project, Turbine Intake Studies, Advance Report No. 10, Norris Tennessee, August 1961.

2/ Tennessee Valley Authority, Division of Water Control Planning, Engineering Laboratory, Nickajack Project, Turbine Intake Gate Studies, Advance Report No. 23, Report No. 44-31, Norris, Tennessee, August 1965.

tests were conducted on the Melton Hill Turbine intake gates 3/. These studies showed a good agreement with the corresponding data from model studies. However, the lifting beam would not disengage from the lower and middle gates. In addition, the top gates failed to close by 3 to 4 inches. It was felt that Reynolds number effects or failure to perfectly simulate the elastic properties of the gate and lifting beam were reasons for the lack of model prototype conformance.

To investigate the problem, the present model studies were begun. Due to the critical nature of the problem and the familiarity of all the investigators with the studies it was decided to have an outside observer review the direction, instrumentation, and analysis of the investigation. This report summarizes the findings of the review.

Summary of the Review

On the evening of May 31, I was briefed by S. Vigander about the nature of the problem. The next morning, June 1, I met with Ely Driver, Bill Waldrop, and Svein Vigander to discuss administrative details. This was followed by a tour of the TVA laboratory by Vigander. After the tour, I met with T. Fain who carefully explained the model, the instrumentation, the method of operation, the data acquisition system, the computer program, and demonstrated the operation of all closure modes. On the following day, June 2, I discussed the analysis with Fain and Vigander.

The following are my observations:

The data acquisition system is excellent and the ease of controlling the model and reducing the data is very impressive. The test program which was outlined seems adequate to obtain a solution if one exists.

The problem of scaling model results to prototype values is critical. The biggest unknown is the coefficient of friction both in the model and in the prototype. Efforts to measure or infer the coefficient from direct observations should be increased. It should be possible to measure the model coefficient by taking measurements while the gate is being lowered and then while the gate is being raised. The friction force is given by

$$F_g = \frac{L_D - L_U}{2}$$

where L_D = Link load with downward motion

L_U = Link load with upward motion

F_g = Friction force on wheeled gate

3/ Tennessee Valley Authority, Division of Water Control Planning, Engineering Laboratory, Prototype Tests of Forces on Melton Hill Turbine Intake Gates, Melton Hill Project, Advance Report No. 14, Norris, Tennessee, April 1975, Report No. 36-31.

Since the normal force is measured for each gate position, the friction factor μ can be determined in situ.

Similarly, the beam friction can be obtained from

$$F_b = \frac{C_D - L_D - C_U + L_U}{2}$$

where C_D = Crane load down

C_U = Crane load up

Similar measurements could be made in the prototype. The normal force in the prototype can probably be inferred by scaling up the model values. A direct measurement would be better; however, the cost is probably prohibitive.

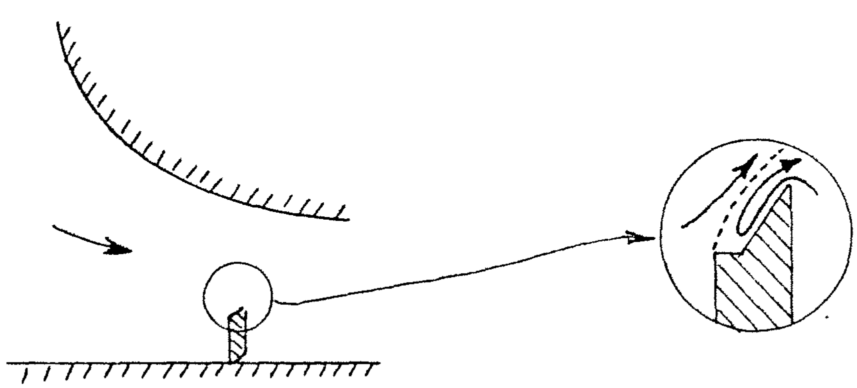
The computer program should be modified to allow measurements to be taken in both the ascending and descending modes. It should be possible to obtain a much better resolution of the data. Presently about 25 points (gate openings) are being observed. This number could be increased to something on the order of 200 without too much trouble. This recommendation is not essential to the program, but would be worthwhile to create a better presentation of the data and to more fully utilize the potential of the computer data acquisition system.

If the friction factor is determined as indicated above, it should be possible to calculate dimensionless hydraulic downpull coefficients. These would aid in determining the sensitivity of the final design to variation of discharge.

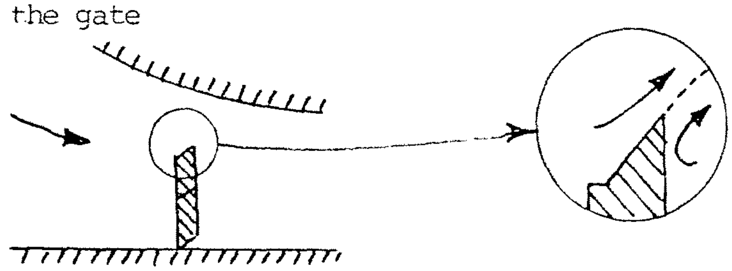
The following comments are concerned with items of lesser importance:

Leakage around the measuring gate. - The normal force measuring system allows the gate to deflect 1/8 to 1/4 inch downstream. This causes excessive leakage and misalinement of the measuring gate with a fixed gate at small separations between the two. Some tests should be repeated with the normal force measuring bars blocked which will reduce the space between the gate and the slot, thus reducing the leakage. The tests would measure the crane and link forces as before and the results compared with those having large amounts of leakage.

Approach flow conditions. - The flow lines were observed to separate from the leading edge of the lowest installed gate



With two gates installed, the separation was from the downstream edge of the gate



This effect could probably be best investigated using boundary element computations. The gate motion can be assumed to be slow enough to approximate quasi-steady state conditions.

The failure of the upper gates to close completely may be due to the increased friction of the gate seals. Perhaps the geometry of the lower lip of only the upper gates should be changed to increase the hydraulic downpull forces.

To more completely define the problem it would be advisable to measure pressures on the upper and lower lips of the gates. These should then be transformed into pressure coefficients. This may aid in predicting the gates' performance at higher discharges and other installations.

Severe vibration of the lifting beam was observed as the top of the middle gate just cleared the top flow surface when the gate was being lowered. If this occurred in the prototype, premature release of the gate might be experienced.

Finally, the recommended skirt and angle on the top of the lifting beam should be coordinated with the designers. It may not be practical to leave the downstream end of the ramp open as it is in the model. Closure of the end of the ramp could affect the hydraulic downpull forces on the lifting beam.

Conclusions

No significant deficiencies in the conduct of the model study nor its analysis were discovered. The present methods should lead to a satisfactory solution. I feel the most probable reason for the lack of agreement between the model and the prototype performance is the inability to accurately scale the friction forces.