Evaluation of An Orifice Debris Sensor

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COASTAL ZONE AND ESTUARINE STUDIES

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BACKGROUND

Submerged orifices are an important feature of state-of-the-art fingerling protection facilities being installed at certain low-head dams on the Columbia and Snake Rivers. Some systems require up to 60 orifices. One problem with the orifices is the tendency for debris to accumulate across their entrances. This debris can cause damage to fish that must pass through the orifice to reach the safety of a bypass channel. Because the orifices are submerged, they cannot be easily inspected. Timely elimination of debris requires constant surveillance at great expense. This research and development program was initiated to develop a method of automatically detecting debris when it begins to accumulate at the entrance to any orifice.

Earlier studies demonstrated that electronic load cells (strain gauges) would detect debris (Jensen and Long 1983). The objective of the studies under the current contract is to verify that the Orifice Debris Sensor (ODS) can reliably detect small quantities of debris over the broad range of hydraulic conditions likely to be encountered at dams.

METHODS

Table 1 lists and defines the series of tests which were originally scheduled for completion under this contract using the ODS shown in Figure 1. This ODS is constructed of two circular load cell arrays mounted together. Both the front and rear units are affected by flow through the orifice, but only the front unit

Table 1.--Test descriptions for calibration and evaluation of double-ring, load cell debris detectors.

Test no.	Test objective	Test condition: Orifice valve	Test condition: Turbine operation	Test condition: Hydraulic head	Test condition: Gatewell flow pattern	Debris
Test no. 1	Equalize voltage output of two rings.	closed	off	arbitrary	zero	absent
Test no. 2	Equalize voltage output of both rings by changing gain	open	off	maximum	zero	absent
Test no. 3	Compare relative voltage output of two rings over entire range of hydraulic heads. Adjust to equalize.	open	off	maximum to minimum	zero	absent
Test no. 4	Determine effect of flow pattern on voltage output of two rings.	open	full-load	maximum	standard	absent
Test no. 5	(same as no. 4)	open	full-load	variable	standard	absent
Test no. 6	(same as no. 4)	open	variable	variable	standard	absent
Test no. 7	(same as no. 4)	open	variable	variable	abnormal	absent
Test no. 8	Measure amount of debris required to trigger alarm	(select worst condition from Tests 4 through 7)				one or more 1/4" dowels
Test no. 9	(same as no. 7)	(select standard conditions)				one or more 1/4" dowels
Test no. 10	(same as no. 8)	(select conditions in concert with CofE personnel)				naturally occurring debris

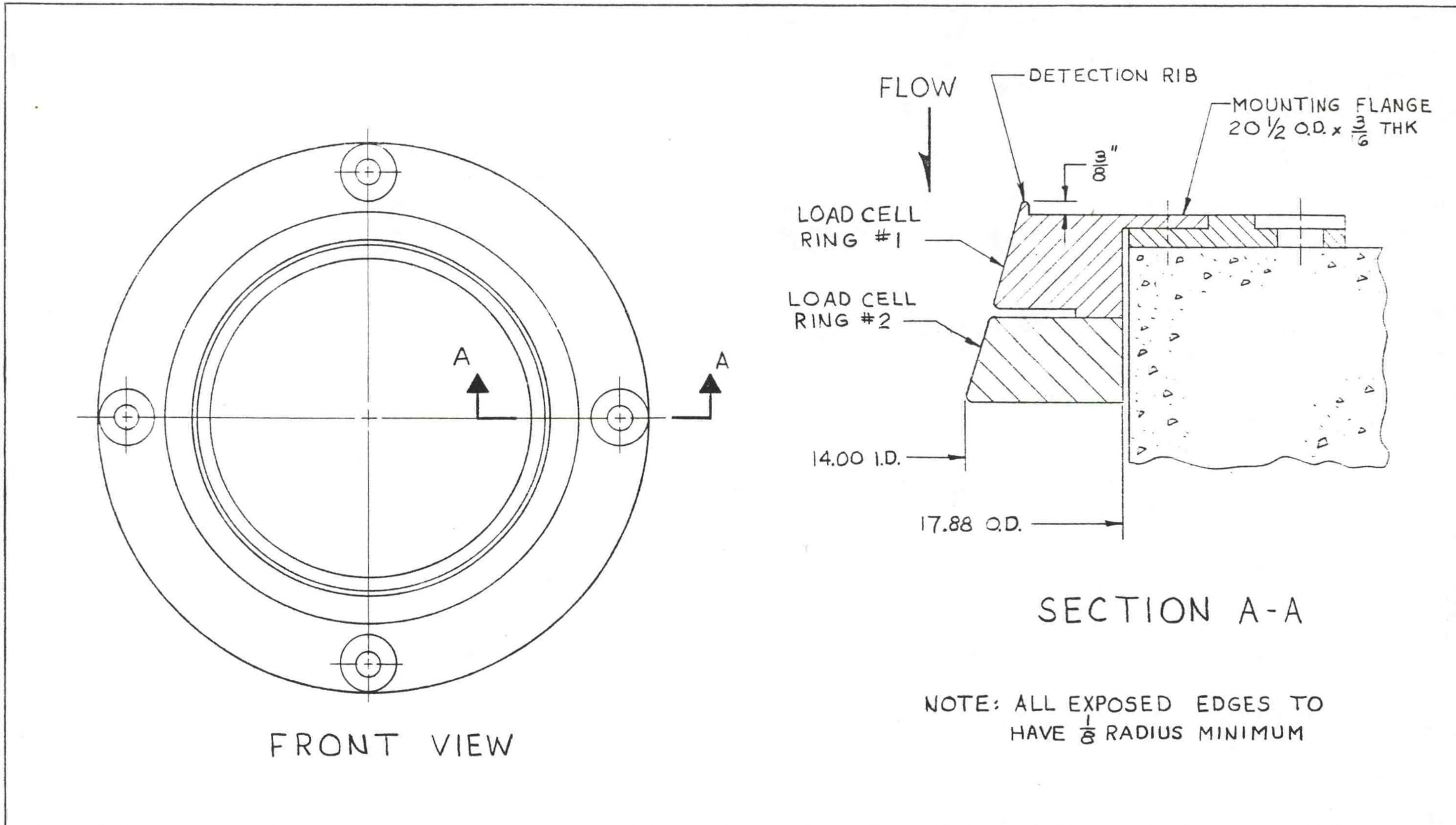

Figure 1.--Double-ring Orifice Debris Sensor - initial design.

is affected by debris which may impinge across its face. The rear unit thus serves as a reference to indicate how much of the signal from the front unit is attributable to the flow; an increase in signal above this reference level indicates the presence of debris. Early test results prompted modification of the ODS design, and Tests 8 through 10 were not completed, but will be part of a subsequent study.

Orifice debris sensors (Fig. 1) were installed in the gatewells of Units 7A and 9C of the first powerhouse at Bonneville Dam during the spring of 1984. Initial testing showed good sensitivity and the ability to detect the presence of debris. The range of the preamplifiers, however, was not sufficient to cover the range of conditions which were encountered during initial tests.

The ODS on Unit 9C was removed, and the electronics modified to provide an adequate range of output signal. The ODS was reinstalled and tested. Signal levels were of sufficient amplitude for recording, and preliminary tests were made using this circuitry. Both rings responded well, but the rear ring appeared to be located within the vena contracta and had insufficient contact with the flows to respond properly to changes in flow conditions. The rear ring was also seriously affected by pulsations, especially at higher velocities, apparently caused by eddy formation and resulting turbulence downstream from the ODS.

The throat contours of the ODS were redesigned (Fig. 2) so that separation of the water mass from the ODS' inner surfaces

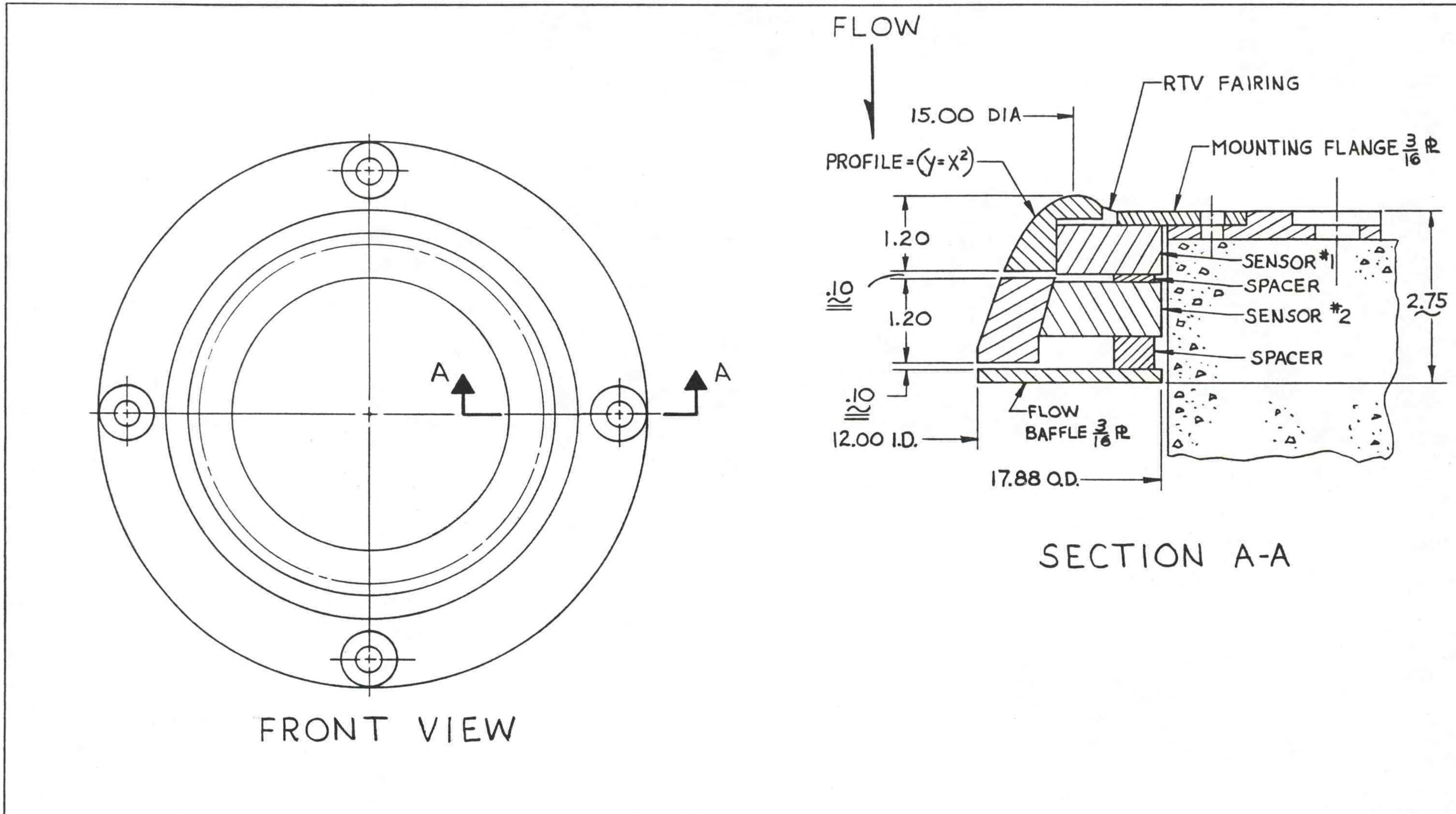

Figure 2.--Double-ring Orifice Debris Sensor with modified throat profile and flow baffle.

would be minimized. In addition, a downstream baffle was added to eliminate the eddy turbulence effects. Meanwhile, the 14-inch diameter orifices originally installed at the Bonneville Dam First Powerhouse were found to pass more water than desired. To solve this problem, the inside diameter of the ODS was reduced to 12 inches to conform to anticipated changes to be made to the rest of the orifices. In flume tests at Pasco, Washington, the modified ODS performed as expected within the narrow range of hydraulic conditions available.

The modified ODS was then installed in Unit 9C at Bonneville Dam for testing over a wider range of head, flow, debris, and turbulence conditions. Debris sensing ability was excellent, and debris and non-debris conditions were readily distinguished throughout the extended head range. The flow baffle behind the rear ring significantly reduced the effects of the downstream eddy turbulence, and the rear ring responded much better to changes in flow.

Simulation of the effects of turbine-caused turbulence was attempted by using compressed air injected several feet below the water surface. A turbulent condition similar to that found during turbine operation was created, and produced very erratic ODS output signals. Later testing, however, indicated that this occurred because a siphon tube on the downstream side of the orifice was used to create the head difference. During normal operation, the head difference would occur because of the difference in water levels in the forebay and in the downstream migrant channel (DSM). The siphon tube arrangement used for testing could produce the same net head difference, but did not maintain a submerged condition on the downstream side of the orifice. Under normal operation the downstream side of the orifice would always be submerged. However, with the siphon in place, the tube downstream of the orifice plate did not always remain filled with water, and the changes in discharge condition between water-filled and air-filled created dramatic changes in output signal. By maintaining the discharge tube in a water-filled state, as would occur under normal operating conditions, the fluctuations caused by the turbulence were reduced to levels which were within an acceptable range.

Although the system was very effective in detecting debris, in long-term tests the baseline signal from the rear ring tended to change or drift. This baseline drift was unexpected and not readily explained. Such drift would not be of concern if it were characteristic of the design and occurred the same in both rings, as it could then be compensated for electronically. It is not a normal occurrence in an installation of this type, however, and in this instance it was of particular concern, since the purpose of the rear ring was to provide a reference. Field tests of the electronics revealed no obvious reason for the drift, so the system was removed and tested further in the laboratory. Since the problem still existed, the ring circuitry was removed and a new bridge circuit installed. The best guess as to the cause of the anomaly is that the epoxy sealant did not cure properly and caused a stress due to uneven bonding of the strain gauges.

The rewired ODS was again installed in Unit 9C, and the test series was repeated. Output signals were stable and reliable, and the ODS functioned as expected. Figure 3 shows the difference in signal produced under non-debris and debris conditions, for several heads. No significant changes attributable to turbulence or turbine load were noted.

A single-ring ODS design was developed based on information obtained from these tests (Fig.4). It is designed so as to be minimally affected by changes in flows, and therefore eliminates the need for a secondary ring to provide flow reference information. Simplicity of operation and substantially reduced costs make this design desirable. Construction and testing of the single-ring ODS will be carried out under another contract.

CONCLUSIONS AND RECOMMENDATIONS

1. The ODS is effective in identifying the presence of debris on gatewell orifices. It can provide the information necessary to initiate, either by alerting operating personnel or activating automated systems, corrective action to remove accumulated debris from the orifices.

2. With the present throat contour design, both rings of the ODS are not affected identically under the full range of flows encountered, indicating that the design could be improved. The present design will work well as long as the flows do not exceed the limited range for which it has been calibrated.

3. Information obtained during this study provided the basis for the design of a simplified single-ring ODS. This single-ring design is such that it is not significantly

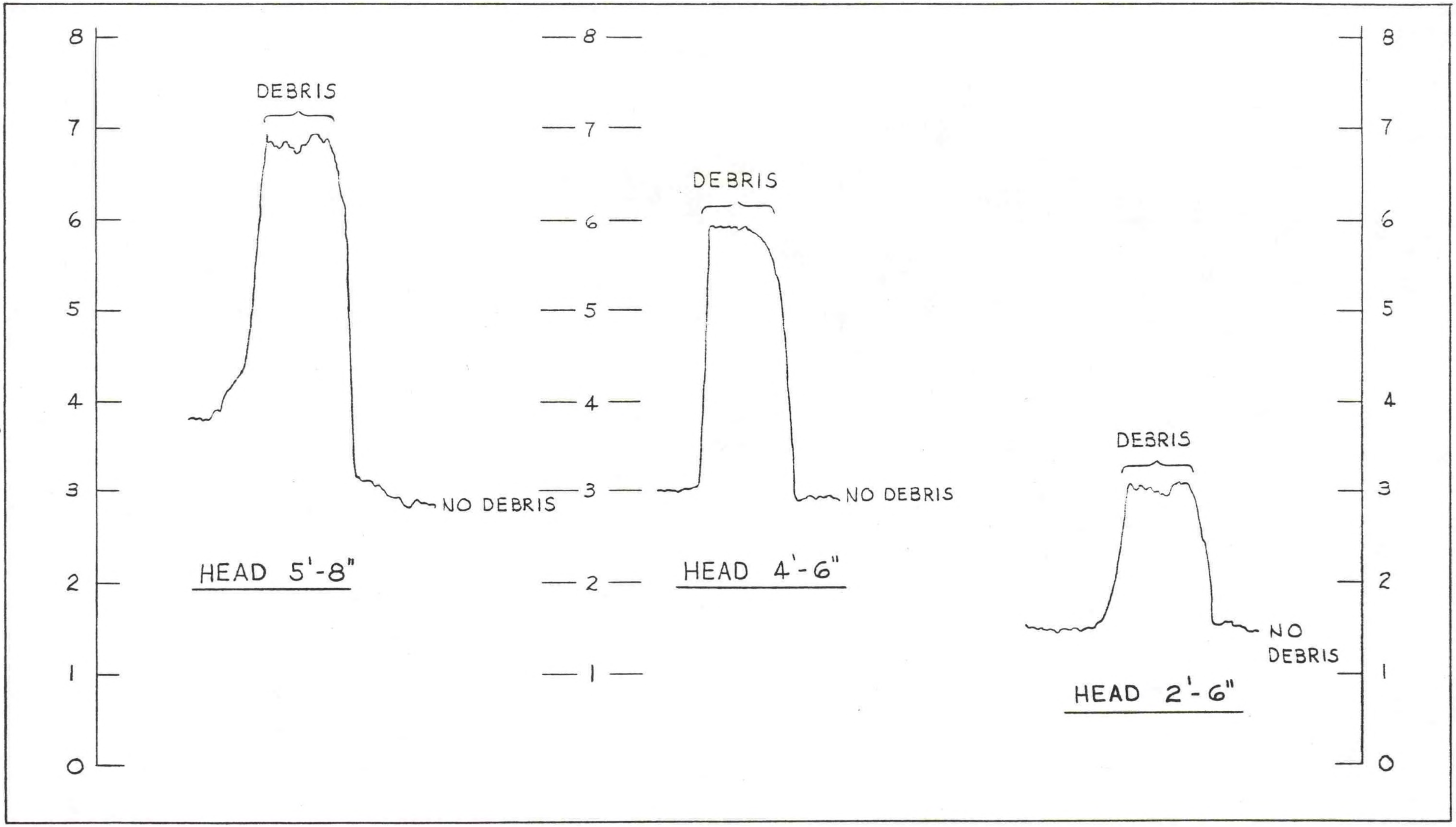

Figure 3.--Comparison of Orifice Debris Sensor signal levels produced under various heads.

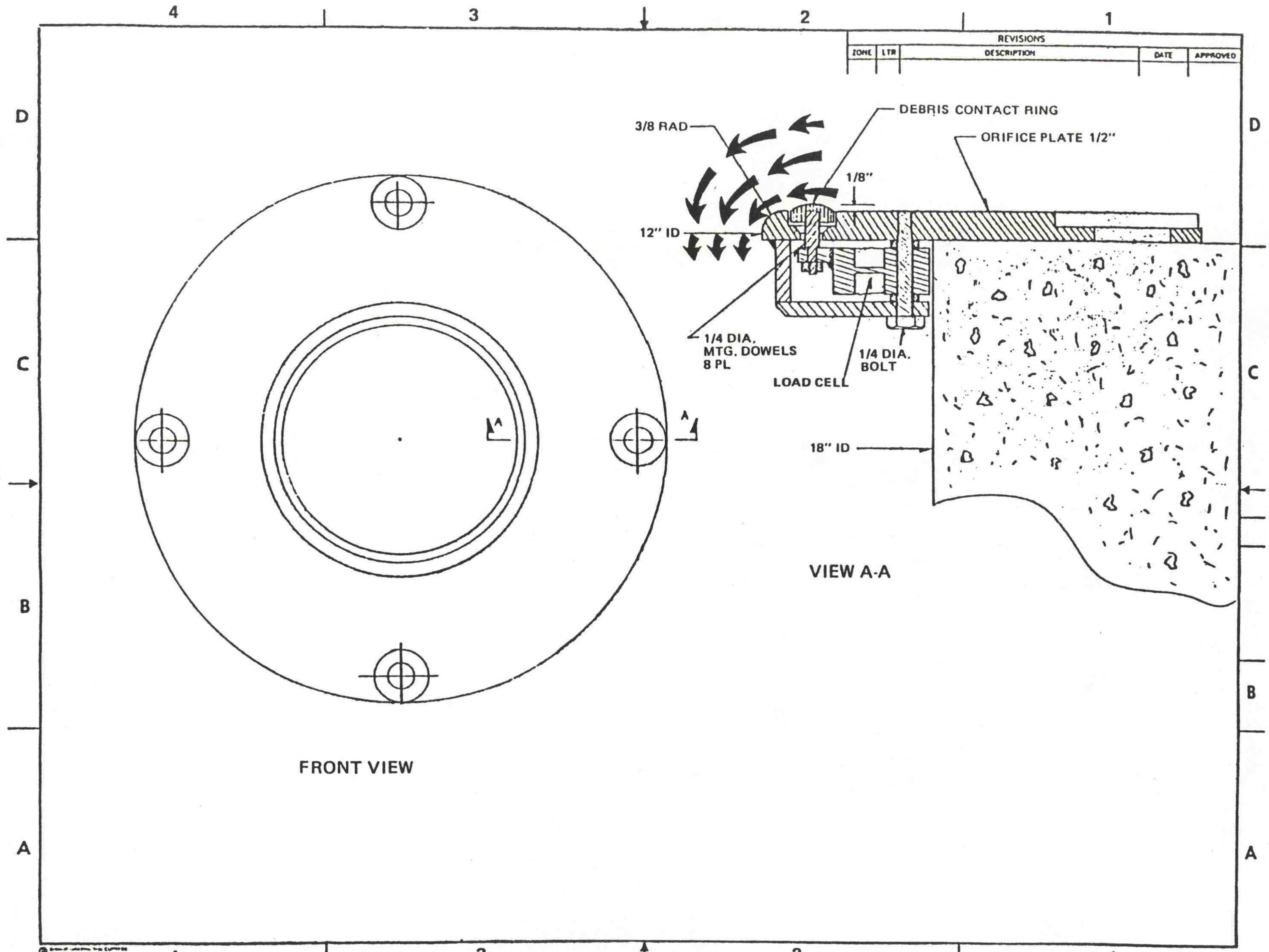

Figure 4.--Improved orifice detection system design.

influenced by flows, and therefore can provide the same information regarding the presence of debris without the necessity for a second reference ring. Costs are greatly reduced, and operation is much simpler. Construction and testing of the single-ring ODS will be conducted as part of a further study.

LITERATURE CITED

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1983. Development of a method for detecting debris at the entrance to submerged orifices. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest and Alaska Fish. Cent., Seattle, Wash. 16 p. (Report to U.S. Army Corps of Engineers, Contract DACW57-83-F-0369.)