DEVELOPMENT AND TESTING OF A

SINGLE-RING ORIFICE DEBRIS SENSOR

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BACKGROUND

Fingerling salmon and trout migrating down the Snake and Columbia River systems must pass a number of low-head dams (Fig. 1). A high rate of mortality may occur as the fish pass through the turbines and the large populations of predators in the tailraces (Long et al. 1968). The discovery that the migrating fingerlings naturally concentrate near the ceilings of turbine intakes and in the gatewells of the turbines has led to efforts to utilize this tendency as a means for increasing fingerling survival (Long 1968; Long and Krcma 1969). As a result, traveling screens are now in use to divert fish out of turbine intakes and into the gatewells where they are permitted to exit through an orifice into a fish bypass (Fig. 2). A collection system at the terminal end of the bypass provides the means to concentrate the fish for trucking or barging around the remaining dams, or the fish may simply be released into the river downstream from the dam (Matthews et al. 1977).

The orifices that permit fish to pass from the gatewells to the bypass have been refined from the 6-inch diameters of early studies to the current standard of 12- or 14-inch diameters. The smaller diameters frequently plugged with debris and were not as effective in passing fish. The orifices are generally submerged 6 to 10 feet below the gatewell water surface and have a differential head of 2 to 4 feet of water across the orifice. Even with the larger diameter, though, the orifices sometimes collect debris across their entrances that can injure fish. Although turbine intakes are protected by trashracks which exclude large debris, considerable small debris enters the intakes and then the gatewells. Sticks frequently hang up at the entrances to the gatewell orifices and form a base upon which other materials may accumulate. When fingerlings are trapped by the velocity of the water flowing

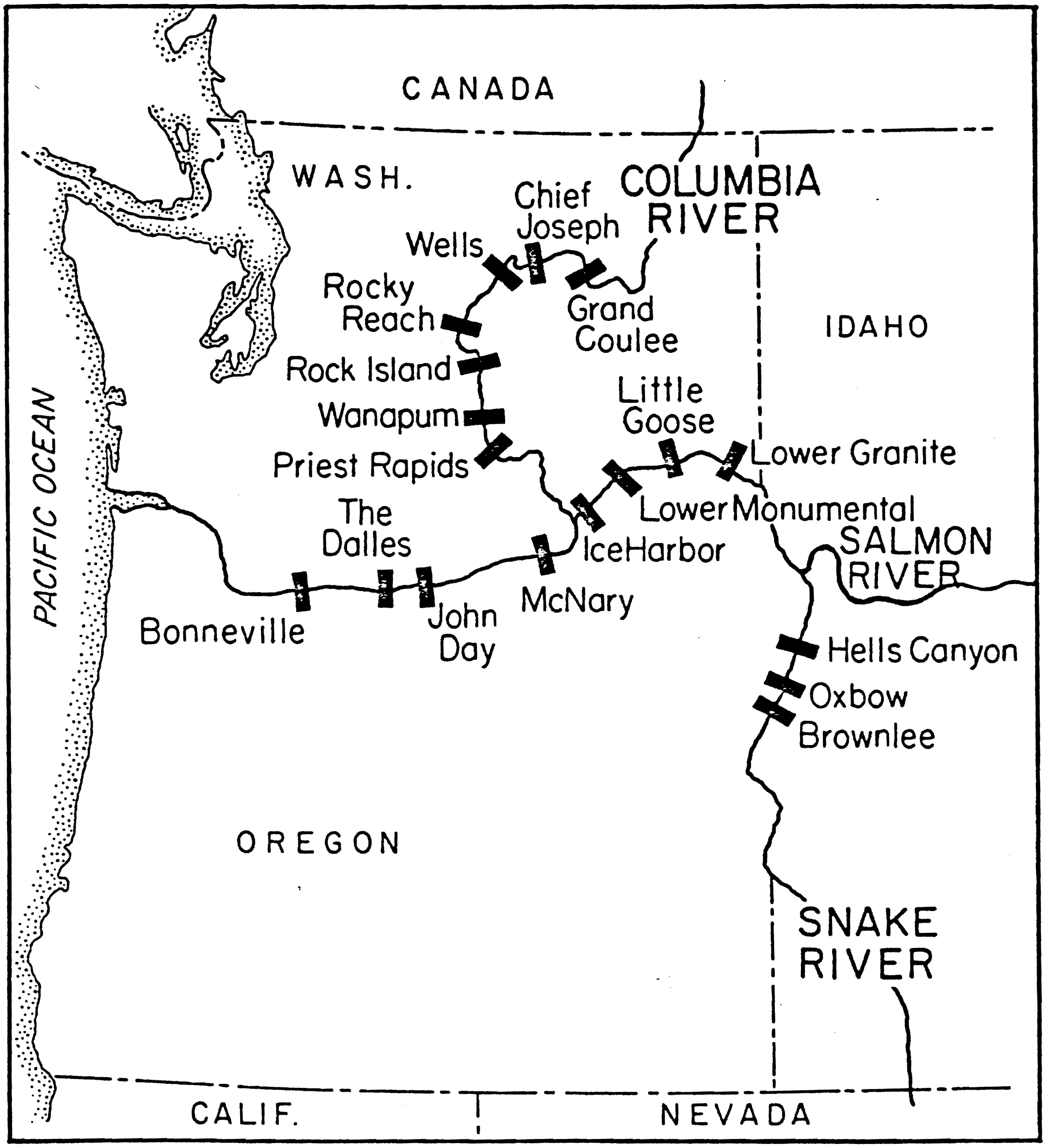

Figure 1.--Upriver stocks of fingerling salmon and steelhead trout must pass numerous dams on their migration to the Pacific Ocean.

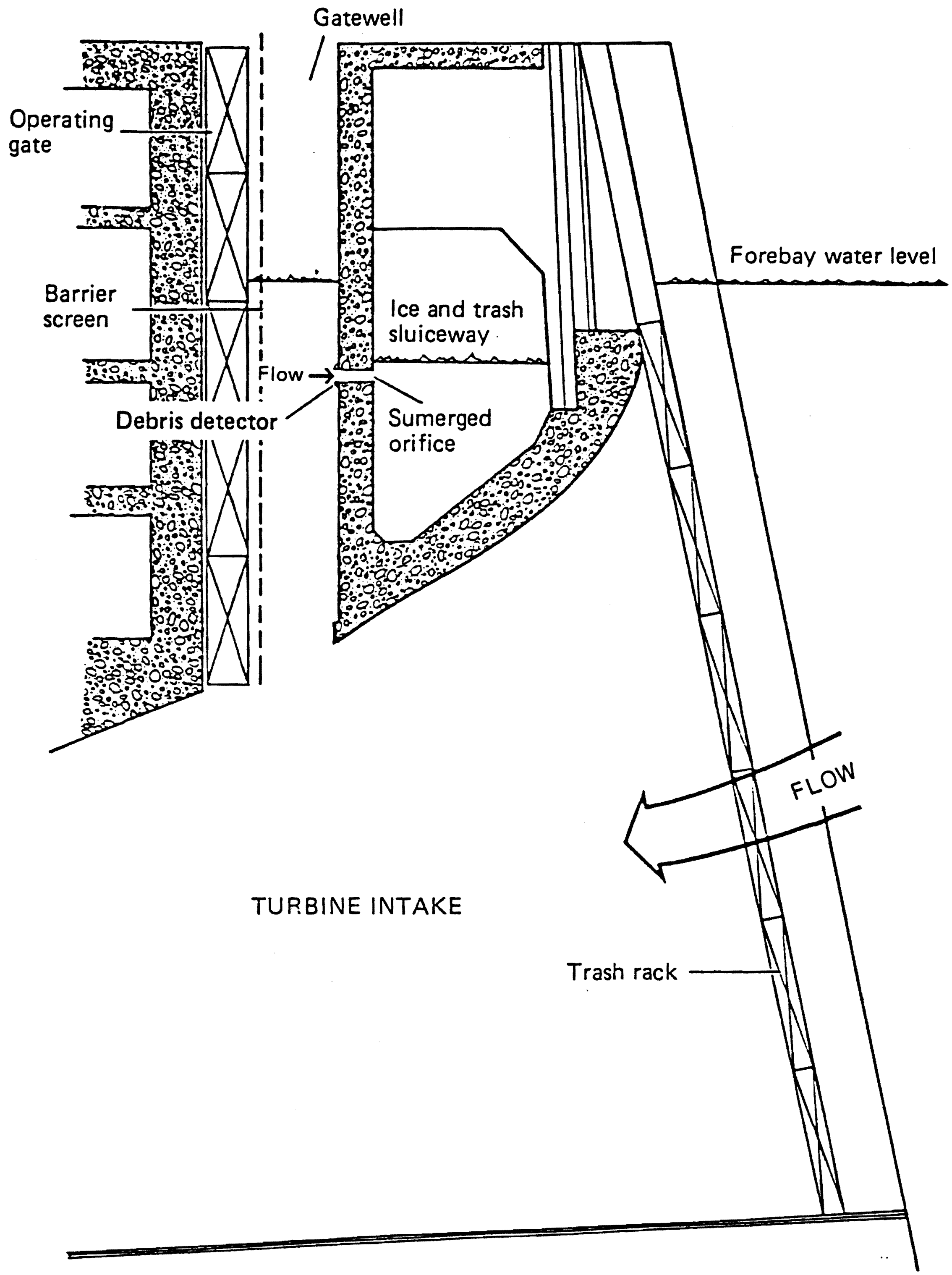

Figure 2.-- Transverse cross section through typical turbine intake of first powerhouse at Bonneville Dam showing location of submerged orifice and debris detector in gatewell.

into the orifices, they cannot avoid contact with the debris and are often descaled or otherwise injured.

At most dams, such as Bonneville and John Day, no simple method exists for determining when the orifices begin accumulating debris because both the entrance and exit of the orifices are submerged and cannot be readily seen. Underwater television or divers must be used to inspect the orifices for accumulated debris and to verify that the debris has been cleared after flushing. Since such inspections are only feasible on a periodic basis, debris may accumulate for a considerable time before it is removed.

A strain-gauge type of sensor system was developed for use in detecting the presence of debris on gatewell orifices. This system was installed and tested at Bonneville Dam during 1983 by the National Marine Fisheries Service (Jensen and Long 1983). It proved to be capable of detecting debris as small as 1/4 inch in diameter which impinged across the orifice.

The 1983, studies showed that a debris-detection system was possible and provided much information regarding those areas which required further investigation. This information was used to develop a double-ring Orifice Debris Sensor (ODS) which was studied during 1984 in tests conducted at the First Powerhouse of Bonneville Dam (Jensen 1985). The double-ring ODS proved to be capable of distinguishing between the presence and absence of debris over a range of test conditions, but the two rings were affected differently by changes in flow caused by fluctuations in head across the orifice.

An improved design was developed from information obtained during testing of the earlier designs. It consists of a single sensor ring mounted in an orifice plate (Fig. 3). The debris contact ring is set back from the orifice lip where it is not in contact with the main flow through the orifice. In the earlier designs it was was necessary to use a second ring to identify what

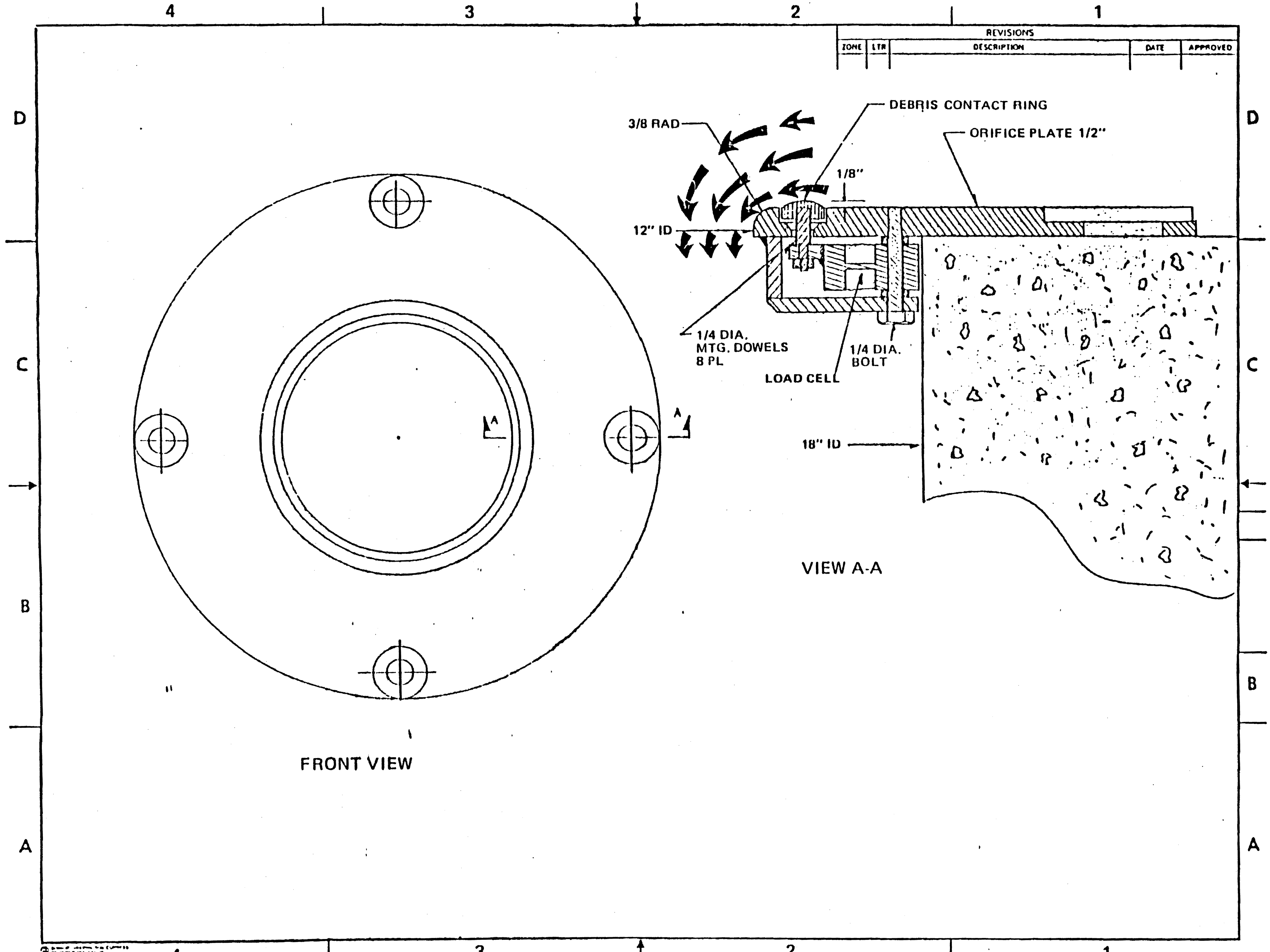

Figure 3.--Improved orifice detection system design.

part of the overall signal was attributable to flow and what was due to debris on the front ring. By minimizing the flow contact with the debris sensor ring, the necessity for the second ring was eliminated. Removing the flow effects, which produced a large part of the overall signal, makes a larger range of signals available for study and permits clearer differentiation between debris and non-debris conditions. This report summarizes results from testing of this improved ODS in 1985.

METHODS

Under the current contract, an ODS of the new design was constructed and installed on the orifice of Gatewell 7A of the First Powerhouse at Bonneville Dam. The signal conditioning and amplifying electronics used were the same as previous designs except that the preamplifier was mounted in the ODS itself. The load cell system was also the same as used in earlier versions, but the contact ring was independent, rather than being attached directly to the load cell systems as before. The area surrounding the load cells was filled with silicone gel, and a silicone sealant was used to seal around the contact ring and in the metal-to-metal joints.

When the ODS was installed, it responded well and worked properly, but after a short period of operation, it ceased functioning. Upon removal and disassembly, it was found that traces of water had seeped into the load cells and caused the failure. After several attempts to seal the unit with the silicone materials were unsuccessful, the decision was made to return to the practice of encapsulating the unit with a polysulfide potting compound. The silicone material was desired as it is quite flexible and can be readily removed should changes be necessary, but it did not provide an adequate bond under the severe environmental conditions to which it was subjected.

The polysulfide-potted ODS was installed and functioned properly, but was damaged when a heavy caisson struck it and overloaded the load cells. The ODS had been designed to withstand excess loads, but this was far in excess of expectations. Because of the possibility of future occurrences of similar nature, several possible design modifications were investigated.

The final design selected utilizes leaf springs to isolate the contact ring from the load cells. The contact ring is thereby permitted a larger range of movement than the load cells can accommodate, and the spring will only transmit a limited amount of force to the load cells. Since it is only necessary to indicate the presence of debris and not measure the total amount present, this method serves very well. More sensitive load cells may be used without risk of overloading them, and construction is simpler because no critical overload stop adjustments are required. The maximum amount of force transmitted to the load cell can be readily controlled by selecting springs which have an appropriate spring constant.

RESULTS

The isolated contact ring design ODS was installed and tested in Turbine 7A of the Bonneville First Powerhouse. Figure 4 shows the signal output by the ODS system under a variety of conditions. The system functioned well in all cases and provided an excellent indication of the presence of debris. Effects of flow on the basic signal level were negligible, and the level of extraneous electronic noise was very low. Debris as small as 3/16 inch in diameter was detectable, and debris as large as a two-by-four was easily handled. Flushing with air to remove impinged debris had no adverse effects on the ODS, nor did turbulence created by introduction of compressed air into the water in the gatewell.

Differences in turbine loads did not appear to have significant effect on the ODS (Fig. 4). The major factor influencing the output of the ODS, other than debris itself, appeared to be the submergence of the ODS. The change in submergence is related to changes in forebay level. It was expected that net head would be more influential, as the head would affect the flow through the orifice, but this design does not appear to be greatly affected by the flow. Should it be desired to install the ODS in a location which is subject to wide fluctuations in submergence, it might be desirable to include a compensating pressure sensor to cancel the pressure effects.

The ODS was left in continuous operation for a period of several weeks with no degradation of signal quality. The polysulfide sealant creates a small hysteresis effect due to its stiffness, but as Figure 4 shows, the hysteresis is not sufficient to interfere with the detection capability of the ODS. One of the older double-ring models of the ODS was still functioning well several months after installation.

CONCLUSIONS AND RECOMMENDATIONS

The current single-ring ODS design shows decided advantages over earlier designs. Flow effects are minimized and do not adversely influence the signal baseline or add to the electronic noise level. The single ring eliminates the necessity for duplication of the load cells and associated electronics for the reference ring which has no purpose other than to balance the effects of flow. The ODS functions well, having sufficient sensitivity to detect the smallest debris likely to present a problem and sufficient strength to withstand the impact of large debris. The signals produced are of ample clarity and definition to readily identify the presence of debris without significant false positive indications.

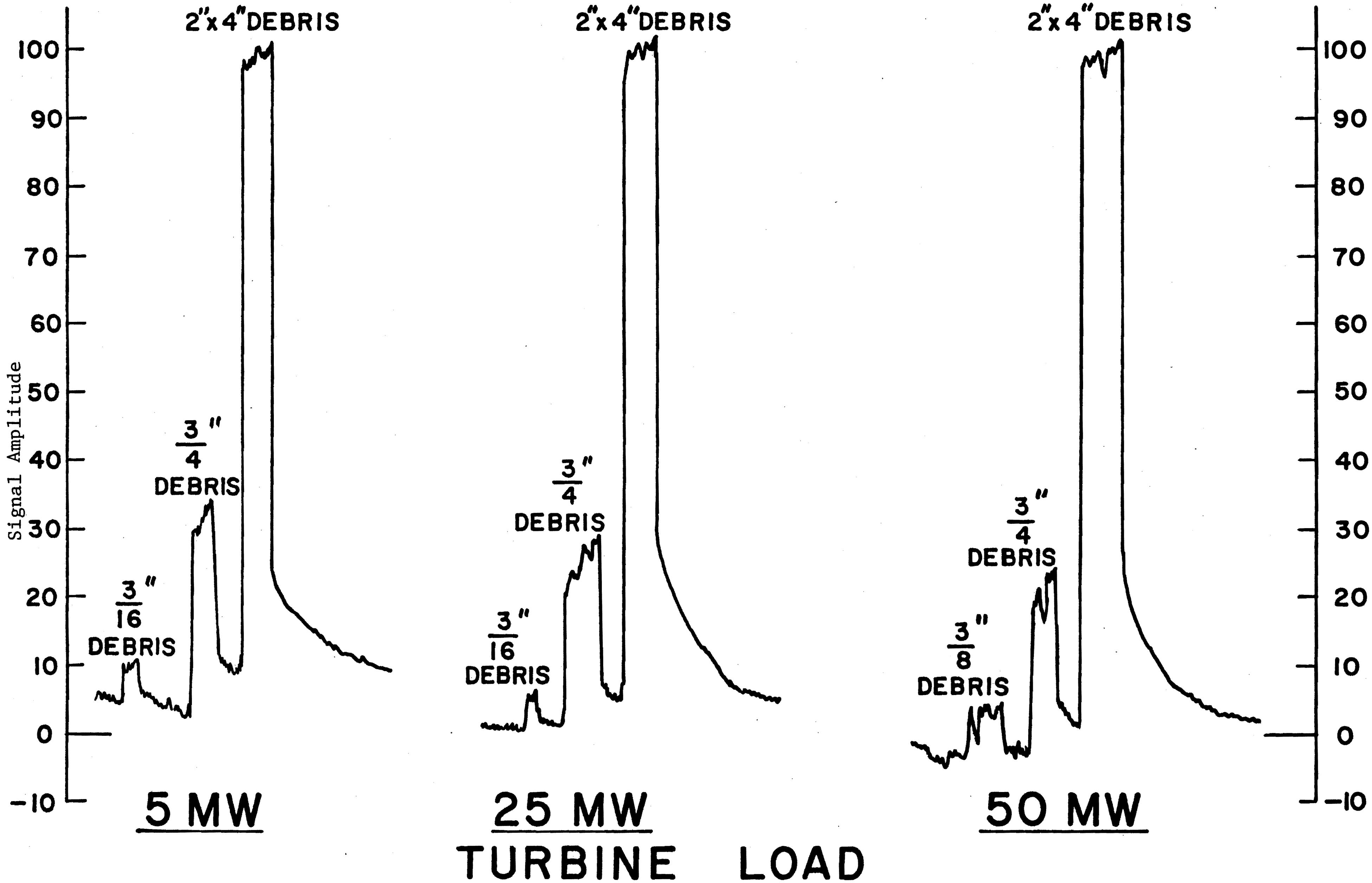

Figure 4.--Orifice Debris Sensor signals produced under various debris/turbine load conditions.

Minor improvements might be made in the exact dimensions and placement of the contact ring, as they are not necessarily optimal, but are fully functional in their current configuration. Some improvement is also possible in the sealing of the unit to eliminate hysteresis caused by the inelasticity of the polysulfide sealant. The slight barometric effect observed can be compensated for electronically, or might be eliminated by use of other sealant materials.

The current ODS design is, in our opinion, suitable for field use in its present configuration. It is fully capable of distinguishing between the presence and absence of debris impinged across the face of the fingerling bypass orifice and appears able to withstand the environmental conditions which are expected to be present.

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APPENDIX

Suggested Items to be Considered in Specifications

Suggested Items to be Considered in Specifications

No sharp edges around orifice.

Contact ring should be sealed to prevent debris, silt, etc. from collecting behind ring. Be aware that the back side of the contact ring must be vented or other means of pressure compensation provided.

Constant submersion of up to 15 feet.

Differential head across orifice of 6 to 10 feet.

Temperature range 35° to 70° Fahrenheit.

Load capacity of 100 pounds uniform load.

Overload protection: Must have mechancial stops to mechanically limit any point load on the contract ring which is in excess of 15 pounds. Unit must be capable of withstanding point loads of up to 100 pounds or a total uniform load of 300 pounds without zero shift or mechanical degradation.

Output signal of at least 5 millivolts per pound of load.

Resolution of 5 pounds of force on contact ring with orifice velocity of 34 feet/sec (5 feet headloss).

Material of construction: Type 304 stainless steel.

Waterproof signal cable 25 feet long x 5/8 inch maximum OD including protective hose. NEMA 4 junction box 6x6x4 of stainless steel with suitable termination for signal cable.

Signal conditioning unit:

Regulated excitation to ring sensors.

Provide zero balance and span adjustment controls for each channel.

Provide output suitable for use with multiplexed analog input to a microcomputer.

Microcomputer and software appropriate to handle data storage, reduction, and analysis.