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Control of flow by gates and valves †

by

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Discussion

The following contributions were received in writing.

Mr D. F. Campbell (Partner, James Williamson & Partners, Glasgow) stated that the Morgan air valve described in § 60 marked a big advance in the complex problem of securing satisfactory de-priming of siphon spillways. Where large reservoirs were served by such siphons the mouth of the air inlet, which might be the siphon tube itself or a separate duct led to the crown, was normally uncovered slowly as the reservoir level dropped and the undesirable condition of partial air/water flow, which arose until an adequate opening for admission of air was exposed, might cause alarming vibrations.

143. If the mouth of the air inlet was made small the entrance velocity would be such that the surface level in the vicinity would be appreciably below reservoir level. On first introduction of air the diminution of flow in the siphon and loss of suction in the air inlet would result in the mouth being covered again before de-priming was complete. The result was an objectionable hunting condition which might continue for many hours until the reservoir level dropped sufficiently to complete the de-priming operation.

144. If the mouth of the air inlet was made large with a view to minimizing the difference between reservoir level and the level adjacent to the mouth of the air inlet it would be found that as the mouth was uncovered air was admitted sluggishly in gulps or bubbles which travelled at a rate not much different to that of the inflowing water. A partial-flow condition was again established and although vibrations might be less severe the de-priming operation would be lengthy and uncomfortable.

145. Between those two extremes a compromise might be sought, but the undesirable partial-flow condition would not be eradicated.

146. The Morgan air valve, drawing its supply from free air, ensured a continuous flow of air once the valve was open. It was designed to avoid conditions of partial flow in the siphon as much as possible, although if that should occur it would be of a reasonably steady pattern devoid of excessive vibrations.

147. The valve had been designed with only one moving part and from the emphasis placed on that feature, if from nothing else, it was apparent that the elimination of all moving parts would be advantageous. In cold weather moving parts had to be kept operative by applying some degree of heat. It could be disastrous if the valve was to jam open, rendering the siphon incapable of priming during floods for which it had been designed to cater. Normally the small amount of winter heating required for a Morgan air valve would be of no consequence compared to the great advantage of its adoption.

148. In the design of two siphon spillways, each of 1,200-cusec capacity, for Lubreoch Dam in the North of Scotland Hydro-Electric Board's Breadalbane project an attempt was being made to eliminate all moving parts. The arrangement was shown diagrammatically in Fig. 34.

† Proc. Instn civ. Engrs, vol. 7, p. 537 (July 1957).

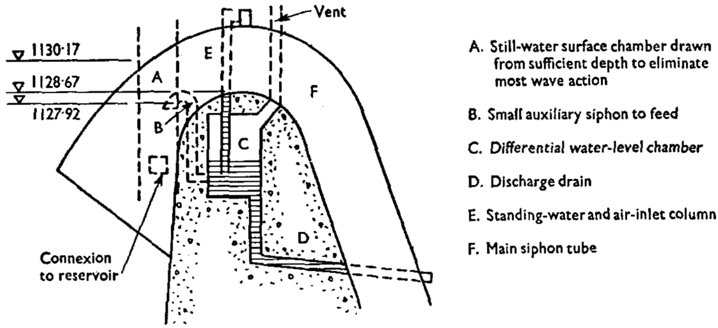

Fig. 34.

149. The level in the differential water-level chamber C was maintained sufficiently high to cover the mouth of the standing-water column tube E until falling reservoir level caused the auxiliary siphon B to de-prime. The chamber was then drained rapidly to drain D, giving a positive and continuous uncovering of the mouth of the tube E. Most of the water in the water column then passed over into the main siphon tube F and the supply of air was sufficient to de-prime the main siphon positively and almost instantaneously. An adequate air column followed, as it were, the broken water column in the main siphon to give smooth de-priming conditions.

150. The priming cycle was evident from the Figure and began after the primed auxiliary siphon built up sufficient head in the differential level chamber to cover the mouth of the air inlet. To Professor Naylor in his book entitled "Siphon spillways"[18] was due the idea of the air inlet which supported a water column rather than contributing to the main siphon flow continuously, but as sketched in that book the mouth of the upstand would suffer from the defects previously mentioned.

151. It might interest the Author to know that at the Lubreoch Dam siphons, in the event of the prototypes performing less satisfactorily than predictions from model tests indicated, provision would be made for flanges on the air inlets to which, if necessary, air valves of the Morgan type could be connected.

Mr D. H. Broadbent (Switzerland) agreed that the normal spring-loaded relief valve did not operate satisfactorily, but a type of spring-loaded valve had been developed in France with a very useful pressure-discharge characteristic.

153. The valve consisted of a simple orifice closed by a flat plate which was kept seated by a spring. No guides were used, and the disk was kept central by the well-known self-centering effect of a jet.

154. The advantages of the valve arose from the fact that there were no mechanical moving parts; it had low inertia and was almost completely watertight; it was compact and there was little pressure rise between just open and fully open discharge.

155. Butterfly valves (§ 30) had been used successfully in France as energy dispersers by making the disk flat sided. For full-flow guard valves, the disk was made lens shaped for less head loss, and pivoted off centre to ensure tight closure.

156. The Howell Bunger patents for the hollow jet valve (Fig. 18) had now run out and at least two variations had been developed, one by the English Electric Company and the other by the Ets Neyrpic.

157. The latter gave a very much wider angle of spread of the dispersed jet.

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[18] A. H. Naylor, "Siphon spillways". Ed Arnold & Co., London, 1935.

158. Maximum corrosion took place near the edge of the cone, but the tips were made of cladded steel and replaceable in the Neyrpic valve.

159. To overcome erosion in the stilling basin, it was now the practice to fit a hood to the valve to redirect the flow. The hood, of course, reduced the coefficient of discharge (from about 0·85 to 0·82) and had associated aeration problems.

160. Mr Broadbent understood that for a given span and depth of opening, a radial gate (Figs 29 and 30) weighed more than say, a Stoney gate ($\times 1\frac{3}{4}$) and that that and the civil engineering associated with the massive abutments, especially if a counterbalance was used, made the total cost of the installation more than with the other type ($\times 1\frac{1}{4}$).

161. An important addition to the drum gate (Fig. 31) was the fish-belly flap.

162. In designing the gate itself there was an economic length/diameter ratio and for a given span the design diameter might be less than the head required, so the flap had been added.

163. That type of barrage was used extensively on German rivers, and the Author's remark about intelligent operation of the double leaf gate held good for the drum gate with flaps.

164. Caterpillar gates were out of favour for the moment, because of jamming of roller trains and breaking of links. As with any chain, the strength of the weakest link was the strength of the chain, and to ensure uniformity of links and rollers on one Mr Broadbent had seen recently being made, the links and rollers were cut from one piece of material after it had been suitably heat-treated and samples tested.

165. Data of that gate were:—

For San Esteban. Head: 67 m. Sections: 5 m $\times$ 8 m in six parts. Total weight: 62 tons; lowest part 10 tons. Rollers: 13% chrome steel. Links: 13% chrome steel.

The roller paths had rubber behind them to permit slight rocking movements.

166. The Survey Table of the hydro-electric schemes with the positions of gates and valves was very interesting.

The Author, in reply, stated that Mr Campbell had made the point that the elimination of all moving parts in an air valve would be advantageous. That was so, but in the case of the air valve described in § 60 the one moving part had been designed so that the spindle needed only be loose fitting in the bushes and all points of contact had efficient self-draining surfaces. No heating had been provided and only one minor case of a valve sticking because of ice had been recorded. That had been some years before and was most probably an isolated case of insufficient greasing.

168. Mr Campbell's attempts to develop an air valve without moving parts was very interesting and the Author could see no reason why it should not give satisfactory performance, though possibly with rather wider limits of "make and break" than could be tolerated at Laggan dam.

169. It was interesting to have Mr Broadbent's comments on Continental practice, though his experience of cost and weight of radial gates was not borne out in Britain when all factors were taken into account. A very thorough comparison had been carried out between radial and vertical-lift gates before taking the decision to install the intake gate shown in Fig. 29. It had shown that the cost of the gates and associated civil works and plant was virtually the same for radial and fixed-wheel gates, and somewhat less than Stoney or caterpillar gates. The gate openings were 1,290 sq. ft for the radial gate and 915 sq. ft for the vertical-lift gates, the former having the advantage of being approximately square while the latter were restricted to somewhere near the ideal 2:1 height/width ratio required for such gates. The much more restricted opening presented by the vertical-lift gates increased the hydraulic problem at the intake and involved training works to ensure a smooth entry. The area could be increased by providing two gates, but apart from the considerable increase in cost due to duplication of special machined parts, that would introduce an intermediate pier which would be undesirable.

170. When the comparison was carried a step further to include operation and maintenance of the gates, and the complete figures were calculated on a basis of annual cost,

radial gates were found to be more economical (1:1·06). It had also been estimated that the radial gate showed an overall saving in weight of approximately 10%.

171. Mr Edgington and Mr Thornton had both mentioned the importance of an adequate air-vent system at the downstream side of a gate. The Author agreed that the air ducts should be of generous dimension and it was usual to make them as large as the adjacent pier would allow. It did not appear to be a matter of a correct ratio of air-vent area to conduit area, but rather of a minimum ratio. In that respect a graph published by the Bureau of Reclamation (see reference 9a) provided a guide. It is summarized in Table 2.

TABLE 2.—AIR-DUCT AREA AS A PERCENTAGE OF VALVE OR GATE AREA

Head: feet	Diameter of gate: inches					
	24	48	72	96	120	144
500	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$
300	2	2	2	2	2	2
100	1	1	1	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$
20	—	—	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$

172. When a 5-ft-8-in. × 10-ft vertical-lift gate was tested in America under a 90-ft head it was found to draw a maximum of 166 cu. ft of free air per second. If the air duct were dimensioned from the above-mentioned graph it would give an air velocity of the order of 250 ft/sec, which is a reasonable maximum.