TESTS OF STEEL DECK GRATING FOR VORTEX SUPPRESSION ON CLOSED CONDUIT SPILLWAYS

By

WENDELL RUDOLPH GWINN

Bachelor of Civil Engineering
Clemson Agricultural College
Clemson, South Carolina
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TESTS OF STEEL DECK GRATING FOR VORTEX SUPPRESSION ON CLOSED CONDUIT SPILLWAYS

Thesis Approved:

Roger L. Flanders
Thesis Adviser

Quintin B. Graves

Robert T MacVicar
Dean of the Graduate School

PREFACE

The presence of a vortex at the entrance to a closed conduit spillway can reduce the discharge capacity for the structure. The proper installation of an anti-vortex device is just as important as choosing the proper size of the conduit to be used. Wooden decks have been used in the past by the Soil Conservation Service, USDA, on the small flood retention dams. The design engineers wanted a material that would have a longer life to keep the cost of the closed conduit spillway within reasonable limits. Steel deck grating was suggested for this use, however there was doubt if the grating would prevent the vortex. A full scale test was needed to determine the effectiveness of the steel deck grating.

The tests were performed at the Stillwater Outdoor Hydraulic Laboratory using the test facilities and materials of the USDA, Agriculture Research Service, Stillwater, Oklahoma. Indebtedness is acknowledged to Mr. W. O. Ree, Project Supervisor for his valuable guidance of the tests and analysis. The author wishes to thank Professors Roger L. Flanders, and Quintin B. Graves of the School of Civil Engineering, Oklahoma State University for their valuable guidance, and assistance in the preparation of this thesis.

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CHAPTER I

THE PROBLEM

Circulation or the presence of a vortex at the entrance of a closed conduit spillway reduces the rate of flow. Anti-vortex devices in the past have been built of wood and other types of materials. Tests of a riveted steel deck grating anti-vortex device used on a drop inlet entrance are presented in this report.

Description of Entrance

The drop inlet tested is the entrance to a 24-inch diameter closed conduit spillway. This spillway had been built on the Stillwater Outdoor Hydraulic Laboratory grounds about seven years earlier and was available for these tests. The spillway consists of an eight-foot high riser entrance structure, 108.3 feet of 24-inch concrete tongue-and-groove pipe, and a 24-inch corrugated metal bituminous-coated pipe elbow having an 84-degree deflection. The slope of the concrete pipe is 0.0185. A description of the structure appears in a report by Mr. Fred W. Blaisdell.[1] The drop inlet entrance was subsequently rebuilt for

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[1] Fred W. Blaisdell, Hydraulics of Closed Conduit Spillways, Part IX, Field Tests, St. Anthony Falls Hydraulic Laboratory, Technical Paper No. 19, Series B (Minneapolis, Minn., March, 1958), pp. 20-30.

the trash guard tests reported in Research Report Number 313.[2] Figure 1-A shows the revised entrance. The steel deck grating was installed on this entrance as shown on Figure 1-B. The other revision to the original spillway was to remove all of the corrugated pipe line. This was done to obtain a higher discharge through the structure, and to increase the opportunity for vortex activity.

The Anti-Vortex Deck Grating

The deck grating used in these tests was a riveted industrial type grating with 1" x 1/8" bearing bars, 3/4" x 1/8" spacer bars bent to form a diamond shape, 1" clear opening and a rivet spacing of seven inches. Its principal features and dimensions are shown on Figure 1-B.

A photograph of the completed anti-vortex deck grating is shown on Figure 2.

The Experimental Apparatus and Technique

The discharge rate was measured by a modified four-foot Parshall Flume at the entrance to the forebay. Corrections for leakage from the earth forebay were based on leakage tests made at times throughout the tests period. These leakage rates were small, being on the order of 0.04 cubic feet per second. The error in discharge rate determination was less than one percent. The pressures at two levels within the riser were measured with Prandtl-type pressure tubes

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[2] W. O. Ree and W. R. Gwinn, "Tests of a Closed Conduit Spillway Debris Guard and Anti-Vortex Baffle" (unpub. Research Report No. 313, Watershed Technology Research Branch, Soil and Water Conservation Research Division, Agricultural Research Service, USDA, Beltsville, Maryland, October, 1958).

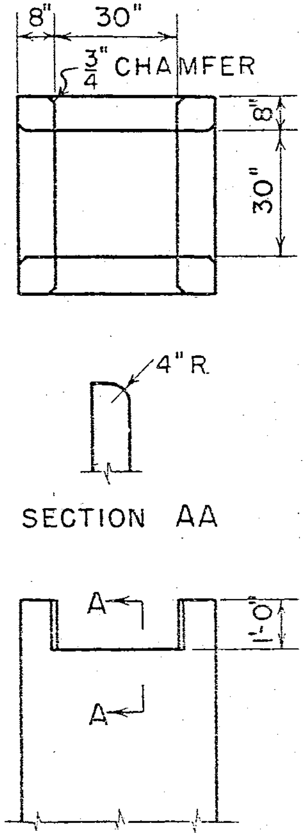

FIG. 1-A

DROP INLET ENTRANCE

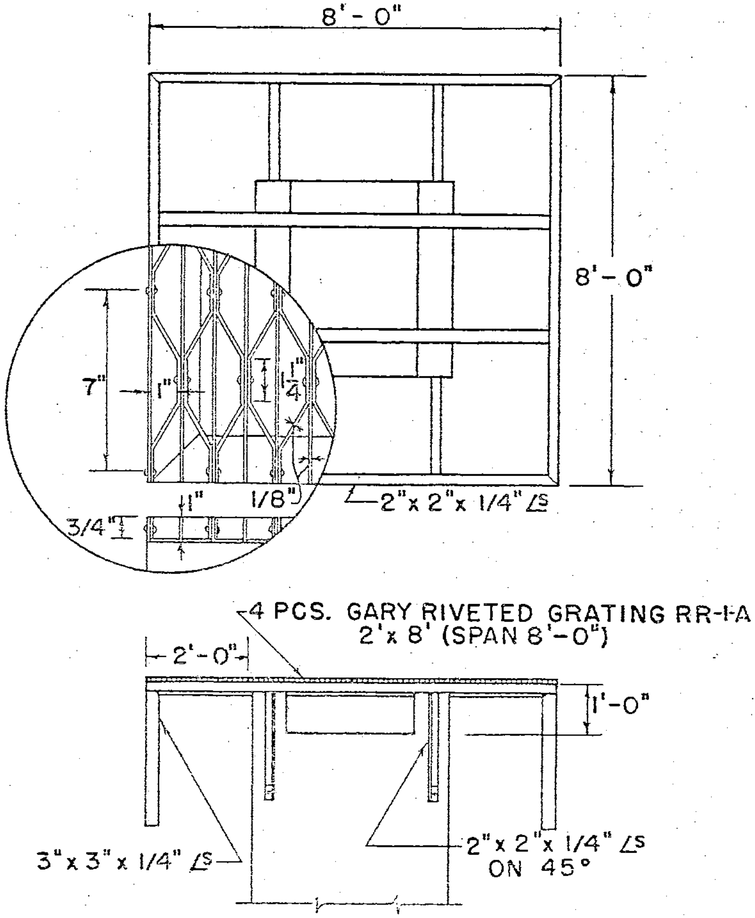

FIG. 1-B

ANTI-VORTEX DECK

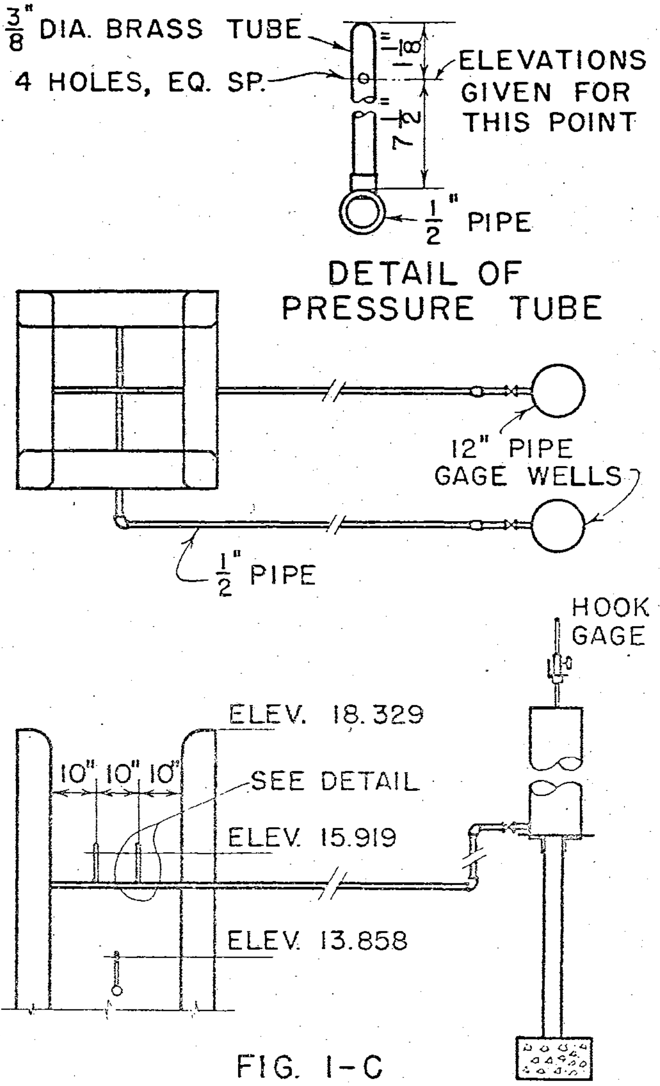

FIG. 1-C

GAGE ARRANGEMENT

Figure 2. The steel deck grating. The water supply facilities are in the background.

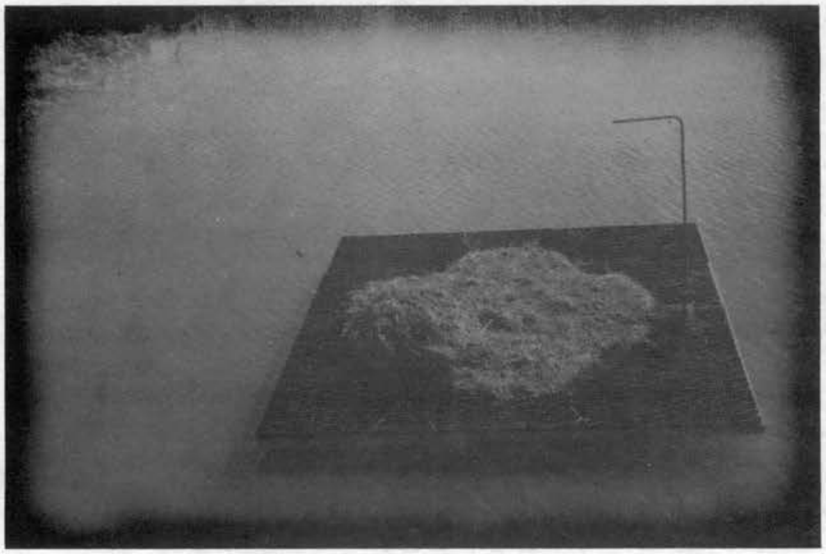

Figure 3. Typical trash collection on steel grating.

connected to 12-inch diameter gage wells. A third well was connected directly to the reservoir. Hook gages measured the water surface elevation in the wells. The whole assembly was supported by a steel frame resting on concrete bases. Careful zero checks showed a variation of only 0.003 foot over a two month period. Details of construction are shown on Figure 1-C.

All water surface elevations and pressures were read to the nearest 1/1000 of a foot. Ten readings taken at ten-second intervals were recorded for each gage with as many as four repeats to obtain reliable averages.

The Tests

Tests were made on three different entrance conditions: No anti-vortex device, a steel deck grating, and a solid plate deck. Figures 4, 5, and 6 show these entrance conditions with a head of 1.2 feet over the crest. Tests on an entrance with no anti-vortex deck and one with a solid plate were necessary to evaluate the effectiveness of the steel grating.

<u>Tests with no Anti-Vortex Device</u>: The tests of the entrance with no anti-vortex device were necessary to obtain the vortex potential of the structure. The reduction in discharge due to vortex activity was another question that was of interest. The size of the vortex core ranged from zero to as large as 19 inches in diameter. Visual observations of vortex size were made over a 30-minute test period for four different water surface elevations. Size classifications were established for four classes, with average core diameters of 0, 3, 8, and 15 inches in each respective class. Additional tests were made in the

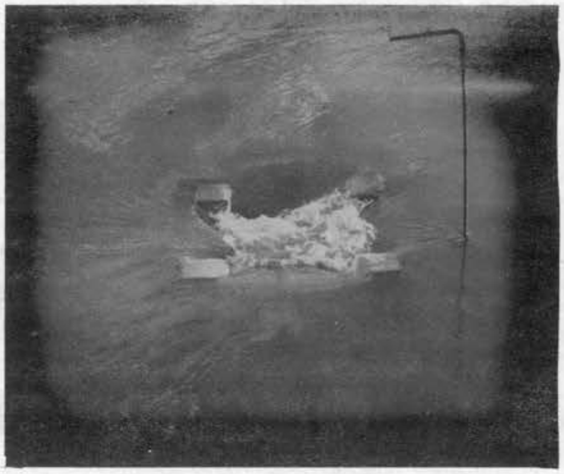

Figure 4. The drop inlet with no anti-vortex deck. Weir head equals 1.2 feet.

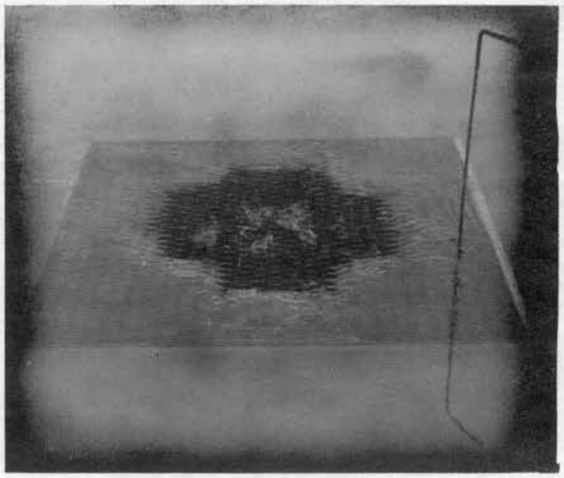

Figure 5. The steel deck grating with a weir head of 1.2 feet.

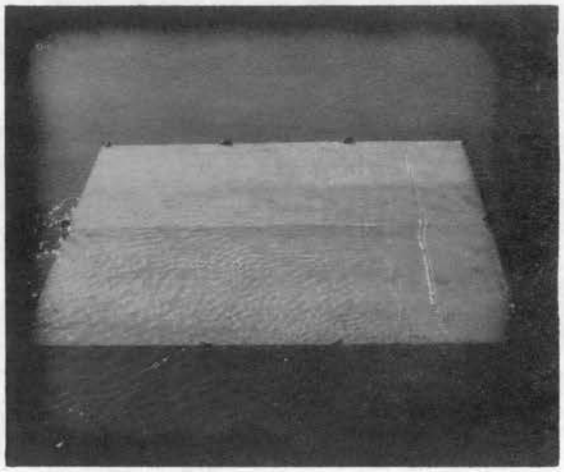

Figure 6. Two sheets of 5/8" plywood were added to eliminate vortex activity and form a solid plate over the entrance. Weir head equals 1.2 feet.

weir control range and in the transition from weir to pipe control.

Tests with Steel Deck Grating: The next step in the testing program was to install the steel deck grating to control the vortex. Tests only in the pipe control range were necessary for this series. In the initial tests the grass and trash from the supply canal would collect on the center area of the grating. As a result, a seal was formed over the center area and became a positive anti-vortex device. Figure 3 is an example of the way the trash collected on the steel grating. A floating trash guard was placed completely around the entrance and far enough away to prevent any interference with the flow pattern. A plywood cover was used before and after each test to keep the trash collection to a minimum. A small amount of grass clippings collected during each test. The steel grating was cleared before each test.

Tests with Solid Plate Anti-Vortex Device: The steel grating did not completely stop the vortex for all tests. Therefore, it was necessary to test a no-vortex series. This was accomplished by using two sheets of 5/8" x 4' x 8' plywood to form a solid plate over the riser. These sheets were mounted on the same frame that was used for the steel grating.

Analysis

The hydraulic characteristics of the drop inlet entrance were evaluated quantitatively by calculating various coefficients. Entrance loss coefficients for pipe control flows were calculated by the formula:

$$K_e = \frac{h - h_v}{h_v}$$

Where K_e is the entrance loss coefficient.

h is the difference (in feet) between the water surface elevation in the reservoir and the elevation of the hydraulic grade line at the measuring point within the riser.

h_v is the velocity head (in feet) of the flow in the riser and is equal to $V^2/2g$, where V is mean velocity (in feet per second) in the cross-section of the riser. The quantity 2g equals 64.3 (in feet per second per second).

Coefficients for weir control flows were calculated by the formula:

$$Q = C\,L\,h_w^{3/2}$$

Where Q is the discharge (in cubic feet per second).

C is the weir coefficient.

L is the total weir length (the sum of the four openings in feet).

h_w is the head (in feet) over the lip of the inlet crest.

CHAPTER II

REVIEW OF THE LITERATURE

The Prevention of Vortices

D. F. Denny and G. A. Young: The prevention of vortices and swirl at intakes to pipe-lines and tunnels are reported by Mr. Denny and Mr. Young.[3] A series of experiments in simple sump layouts were conducted to study the factors influencing the formation of air-entraining vortices. The shapes and dispositions of various intakes ranging in diameter from 7/8 inch to 30 inches were studied in sumps ranging in width from 6 inches to 8 feet. Mr. Denny and Mr. Young write:

> In most cases the development of an air-entraining vortex proceeded as follows. When the intake was well submerged and intake velocity low the vortex appeared first as a small dimple in the free water surface, which gradually became deeper; air bubbles would occasionally break away from the bottom of this hole and be carried into the intake as a chain of bubbles. At higher intake velocities the chain of bubbles became a continuous air core extending into the intake. With large submergence of the intake the vortex was located some distance from the pipe and was very stable, quickly reforming if the water surface was disturbed. With small submergence the vortex formed closer to the intake and was less stable in position.

The majority of the data are presented in terms of the critical submergence of the intake. Critical submergence is a measure of the depth of water above the intake where the flow changes from a vortex-

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[3] D. F. Denny and G. A. Young, "The Prevention of Vortices and Swirl at Intakes," Transactions of the Seventh General Meeting of the International Association of Hydraulic Research, Vol. 1, Paper C1 (L.N.E.C., Lisbon, 1957), pp. C1-1 - C1-10.

forming condition to a vortex-free condition.

The effect of the boundaries of the approaching flow played an important part in determining the strength of air-entraining vortices. Rotation in the water supplying the intake is created by asymmetry and solid boundaries or the boundaries between the flow entering the intake and flow entering another intake close by. Tests in this report show that any solid boundary that is closer than 10 diameters of the intake will effect the strength of a vortex. The authors state the shape of the intake has little effect on vortex formation. The behavior of upward facing and downward facing vertical intakes are very much alike.

Many factors that influence vortices also influence swirl in the same manner. Measured swirl angles in the pipe did not exceed 5° in the absence of air-entraining vortices. Guide vanes or fins attached either to the outside or inside of the intake were not effective in reducing the entrainment of air through a vortex.

The authors conclusions were:

1. Air-entraining vortices and swirling flow at the intake both arise from rotation in the water supplying the intake, the magnitude of which depends on the position of the intake relative to the direction and boundaries of the approaching flow.

2. In extreme cases over 10% of the flow entering the intake consists of air and swirl angles up to 40° can be realised.

3. Severity of both air-entraining vortices and swirling flow is diminished by (a) reducing the strength of the rotational flow in the approaching water; (b) increasing the area of the intake; (c) increasing the depth of water; (d)sitting vertical or slightly sloping walls close to the intake.

4. The only remedies that are equally satisfactory for both troubles, are guide vanes. Floating rafts and baffles may prevent vortices but leave swirl unaffected. Vanes in the intakes can reduce swirl but do not prevent air-entrainment.

5. For intakes up to 3 ft. diameter, scale models larger than 1/16 scale are capable of providing accurate quantitative data provided velocities in the model are equal to those in the prototype. It is also probable that smaller models than this give adequately reliable data, but the limit is not known; fortunately models tend to err on the safe side. The laws applying to intakes larger than 3 ft. are also not completely

understood. Air-entrainment is usually accompanied by loud noise and by vibration of the less rigid parts of the system, so that it is unlikely to occur unnoticed. If no air-entrainment is apparent, swirling flow is unlikely to be significant.

Fred W. Blaisdell: The prevention of a vortex was accomplished by use of vertical anti-vortex wall and dike.[4] The dimensions of the structure are given in terms of the diameter of the pipe (D). The riser was a 1.25D square inlet with a 5D height. The crest was square and flush with the floor of the approaching flow. The anti-vortex wall was placed on the downstream edge of the crest with a width of 3D and a height of 2D. The dike was placed on the downstream side of the anti-vortex wall and at the same height of the wall. The dike served to cut off circulation around the inlet. The pipe controlled the flow above a H/D (head above crest divided by the diameter of the pipe) of 1.2. With the dike and anti-vortex wall in place the circulation was prevented except for high heads where the wall was submerged. Using this series as a base of comparison, the discharge was reduced 13% with only the anti-vortex wall in place and a H/D of 1.2. The discharge was reduced 39% due to vortex formation when no protection was provided and a H/D of 1.2 was reached. Mr. Blaisdell writes:

> This group of tests shows that anti-vortex walls are needed and should be used on all drop inlets.
>
> Vortices, which may vary in intensity, make it impossible to predict the flow through the spillway in addition to causing a reduction in the flow through the spillway. The former deficiency is probably more serious than the latter. The only reliable solution is to eliminate vortices or to reduce their effect to negligible proportions.

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[4] Fred W. Blaisdell, Hydraulics of Closed Conduit Spillways, Part V and VII, St. Anthony Falls Hydraulic Laboratory, Technical Paper No. 18, Series B (Minneapolis, Minn., March 1958), pp. 24-35 and p. 43.

Mr. Blaisdell describes tests of anti-vortex walls and devices on a circular drop inlet.[5] The riser for these test was round in shape and had a 1.25D (where D is the pipe diameter) inside dimension and a 2D height. The crests were flush with the approach floor and included both rounded and sharp edged on the inside edge of the riser. A circular solid plate deck with a diameter of 4.25D and a thickness of 2/9 D proved to be the most satisfactory of any of the types reported in the circular drop inlet tests. The circular cover was supported by three piers 2/9 D in thickness, .75D in height, and 1.24D in length. These piers were placed tangent to the outside edge of the cover and 120° from center to center.

A splitter wall was second best in preventing the vortex. This wall was 2/9 D in thickness and extended across the widest portion of the riser and into the retention dam downstream of the intake. The 2D height of the wall above the crest was necessary to prevent a reduction in discharge due to vortex or circulation.

A tangent anti-vortex wall proved third best in prevention of vortex activity. This wall had a .33D thickness and was placed tangent to the inside radius of the riser and on the downstream side of the riser and parallel to the retention dam. This wall was 3.5D long and had a height of 2D. This height was necessary to prevent vortex reduction in discharge.

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[5] Fred W. Blaisdell, Hydraulics of Closed Conduit Spillways, Part VI and VII, St. Anthony Falls Hydraulic Laboratory, Technical Paper No. 18 Series B (Minneapolis, Minn., March 1958), pp 36-43.

Mr. Blaisdell writes:

To summarize the results of these tests on vortex inhibitors, it may be said, on the basis of performance, that the cover, the splitter, and the tangent anti-vortex devices are recommended in that order. However, the difference between the performance of these types of vortex inhibitors is so small that the governing consideration should be cost of construction. While the tests reported here have permitted a description of the performance of various types of vortex inhibitors, they were not extensive enough to definitely determine their optimum size.

A splitter placed inside the riser and flush with the floor and crest worked unsatisfactorily as a vortex inhibitor and its use was not recommended.

No anti-vortex device at all was used for one series of tests. The spillway performance was satisfactory as long as the control of the flow was by the inlet weir. Vortices formed when the control changed to pipe flow and produced reductions as large as 44% as comparied with a no vortex condition. The discharge was not effected by vortices for heads larger than 7D.

Vortex effect on Orifice Discharge

C. J. Posey and Hsieh-ching Hsu: Experiments concerning the reduction in discharge rate through a horizontal circular orifice are reported by Mr. Posey and Mr. Hsu.[6] The orifice was in the floor of a circular tank. The vortices were formed by admitting water radially or tangentially in different proportions to give the variations in the strength desired. The average tangential component of the velocity (tangent θ) determined the size of the vortex. The following is a summary of the data copied from their paper:

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[6] C. J. Posey and Hsieh-ching Hsu, "How the Vortex Affects Orifice Discharge," Engineering News-Record, March 9, 1950, p. 30.

% Reduction of Discharge	Tangent θ
10	19
20	41
30	70
40	110
50	190
60	310
70	900
75	2500

As seen from the above data the flow through an orifice with a vortex could be as small as one fourth the flow which would pass through the orifice if there were no vortex present.

Loss of Head for Trash Racks

Wolmar Fellenius and Erik G. W. Lindquist: The loss of head in protecting racks at hydro-electric power plants was measured by Mr. Fellenius and Mr. Lindquist.[7] Eleven different types of racks were tested to determine the influence of the shape, spacing, and slope of the racks on the loss of head. The spacing and cross section of the bars were tested at full scale. The head loss varied as the square of the velocity downstream of the rack. The head loss varied at the 2.15 power of the area ratio. The ratio is the ratio of the area obstructed by the bar thickness to the total area in the plane of the racks.

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[7] Wolmar Fellenius and Erik G. W. Lindquist, "Loss of Head in Protecting Racks at Hydraulic Power Plants", Hydraulic Laboratory Practice, The American Society of Mechanical Engineers, (New York, 1929), pp. 533-538.

Mr. Fellenius and Mr. Lindquist write:

The results for rectangular sections with sharp corners and for rectangular and trapezoidal sections with rounded corners follow the curve of sin α, while the loss for tapered sections varies as $\sin^{3/2}\alpha$.

These results lead to the formulas:

(1) Rectangular cross section with sharp corners and rectangular and trapezoidal sections with slightly rounded corners.

$$\Delta h = \mu \sin \alpha \, \psi^2 \, v_1{}^2/2g$$

(2) Tapered sections

$$\Delta h = \mu \sin^{3/2}\alpha \, \psi^2 \, v_1{}^2/2g$$

in which

Δh = head loss in meters or feet

α = angle with horizontal

ψ = area ratio including area of lateral bracing

v_1 = water velocity in feet or meters per second before the racks were installed.

g = acceleration due to gravity (m. per sec. per sec. or ft. per sec. per sec.)

μ = coefficient depending on shape (see following table).

The values of the coefficient μ for different types of racks were found to be the following:

Type	μ	Thickness (mm.)	Width (mm.)	Clear Spacing (mm.)	ψ Area Ratio	Section Shape	Corners
A	7.1	6.2	62.4	19.2	.271	Rectangular	Sharp
B	6.1	6.5	50.0	19.8	.283	Rectangular	Rounded
C	6.1	6.5	71.0	19.7	.283	Rectangular	Rounded
D	6.2	6.6	76.5	19.7	.273	Rectangular	Sharp
E	5.6	7.8	50.3	19.8	.303	Rectangular	Rounded
F	4.5	7.3 & 5.6	58.2	19.9	.299	Trapezoidal	Rounded
G	2.6	8.1	50.0	19.9	.308	Tapered	
H	3.4	9.2	61.0	19.5	.336	Tapered	
J rough	2.7	7.3	70.0	19.5	.299	Tapered	
J smooth	2.4						
K	1.0	1.5	43.5	19.0	.100	Rectangular	Rounded
L	6.5	6.0	59.0	18.5	.273	Rectangular	Rounded

Summary of the Literature

None of the literature available contained any information on use of a steel deck grating for the suppression of vortices on closed conduit spillways. Except for those cases where the vortex was initiated by the experimenter, the vortex formation and effect on discharge was unpredictable.

The additional head loss produced by the steel grating might be estimated using data furnished by Mr. Fellenius and Mr. Lindquist.

$\alpha = 90^\circ$

$\psi = .21$

$v_1 =$ estimated 5 ft./sec.

$g = 32.16$ ft./sec./sec.

$\mu =$ estimated 7

$$\text{Head loss in feet} = 7 \sin 90^\circ (.21)^2 (5)^2/64.3$$
$$= .12$$

This amount of head loss would be small as compared with other losses within the closed conduit spillway.

Tests on a full scale structure were necessary to determine the effectiveness of the steel grating in suppressing the vortex at the inlet to a closed conduit spillway.

CHAPTER III

RESULTS

A vortex formed for part of the time in all pipe-controled tests of the drop inlet without an anti-vortex device in place. The size of the vortex fluctuated from zero to a core diameter of approximately 19 inches. Figure 15 shows the estimate of the percent of time over a 30-minute test period that each of four different size classifications occurred. The maximum vortex activity occurred at a head (h_w) of 2.8 feet above the inlet crest.

The steel deck grating was very satisfactory in reducing vortex activity even with trash removed from the center. A small vortex formed for h_w smaller than three feet. The size did not fluctuate during the test. Figure 7, 8, 9, 10, 11, 12, 13, and 14 are photographs for comparison of the maximum vortex size for four different water levels. It was evident that if the supply flow contained any trash, the vortex would carry this to the center of the grating and deposit it on the high-velocity area of the grating. This in turn would form a seal and prevent vortex activity.

A preliminary study showed that the addition of the deck grating resulted in a small increase in the discharge capacity of the entrance. Since the grating did not completely eliminate the vortex, it was not possible to establish the relative magnitude of the increase in terms of the maximum increase possible. To make this determination, tests on

COMPARISONS OF SURFACE FLOW CONDITIONS

WITHOUT ANTI-VORTEX

WITH STEEL DECK GRATING

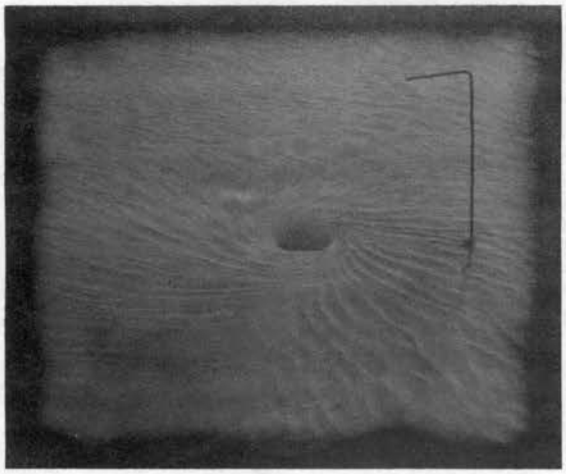

Figure 7
h_w = 1.66 ft. Q = 43.50 c.f.s.

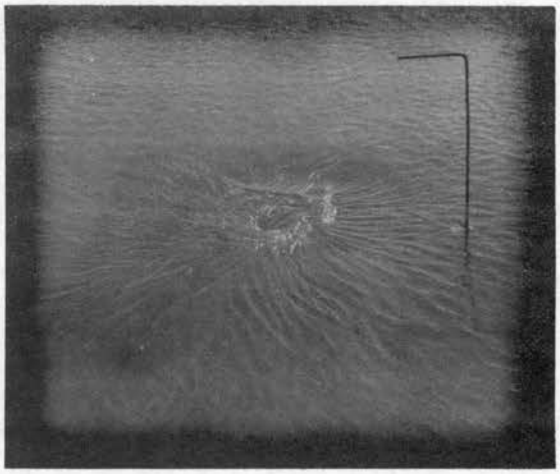

Figure 8
h_w = 1.73 ft. Q = 44.20 c.f.s.

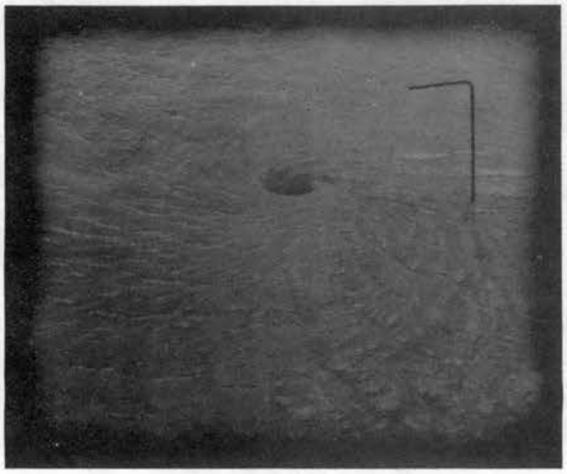

Figure 9
h_w = 2.83 ft. Q = 45.50 c.f.s.

Figure 10
h_w = 2.67 ft. Q = 45.80 c.f.s.

COMPARISONS OF SURFACE FLOW CONDITIONS

WITHOUT ANTI-VORTEX DECK

WITH STEEL DECK GRATING

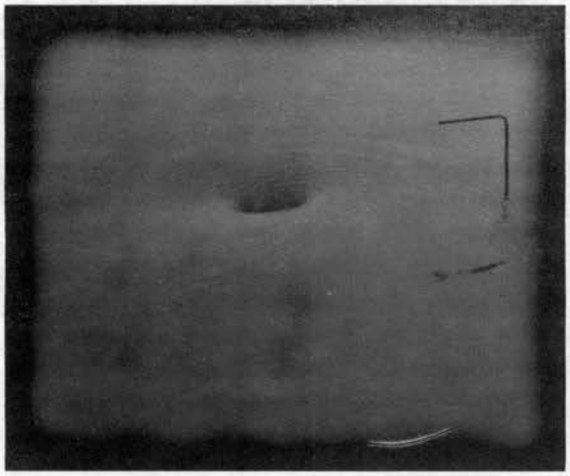

Figure 11
h_w = 3.60 ft. Q = 47.24 c.f.s.

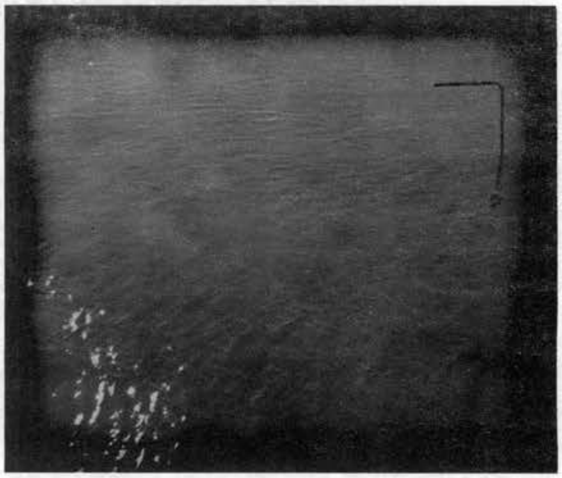

Figure 12
h_w = 3.75 ft. Q = 47.48 c.f.s.

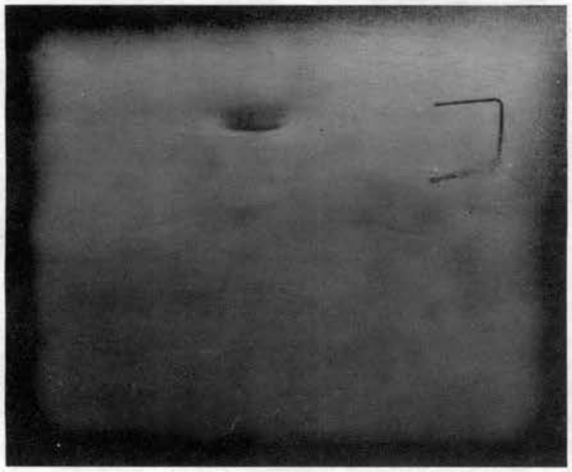

Figure 13
h_w = 4.36 ft. Q = 48.53 c.f.s.

Figure 14
h_w = 4.03 ft. Q = 48.40 c.f.s.

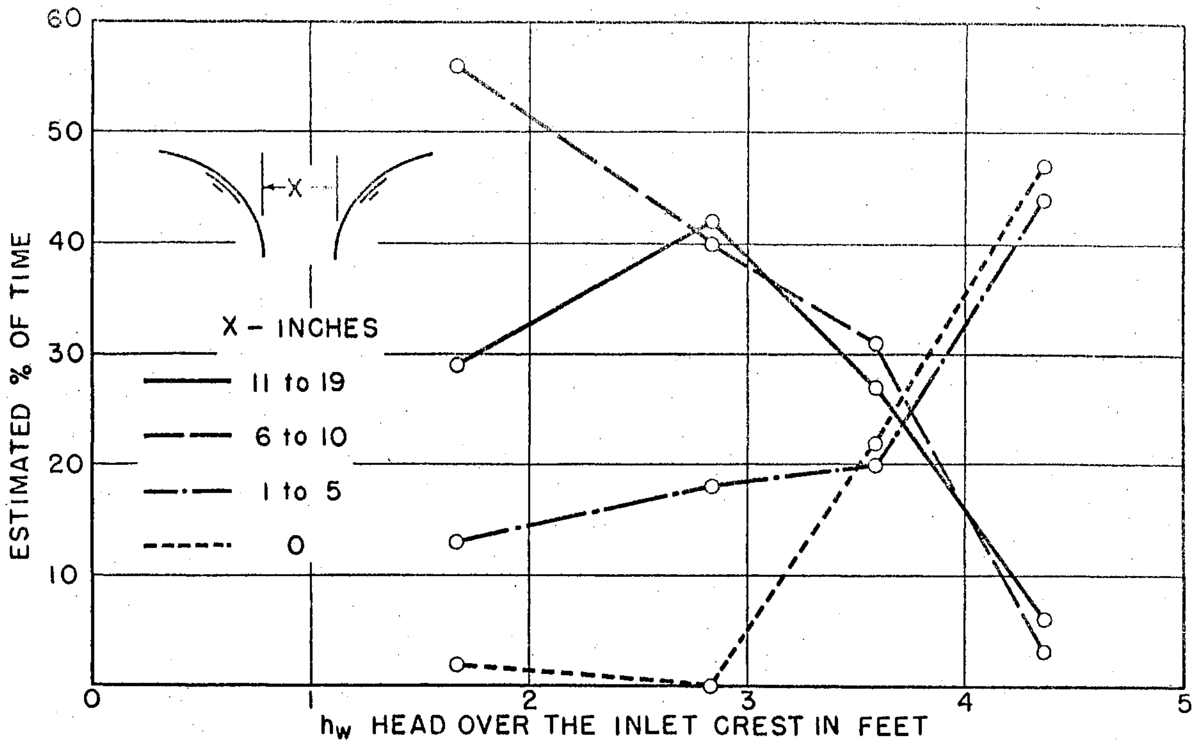

FIG. 15 FLUCTUATIONS IN SIZE OF VORTEX WITH NO ANTI-VORTEX DECK

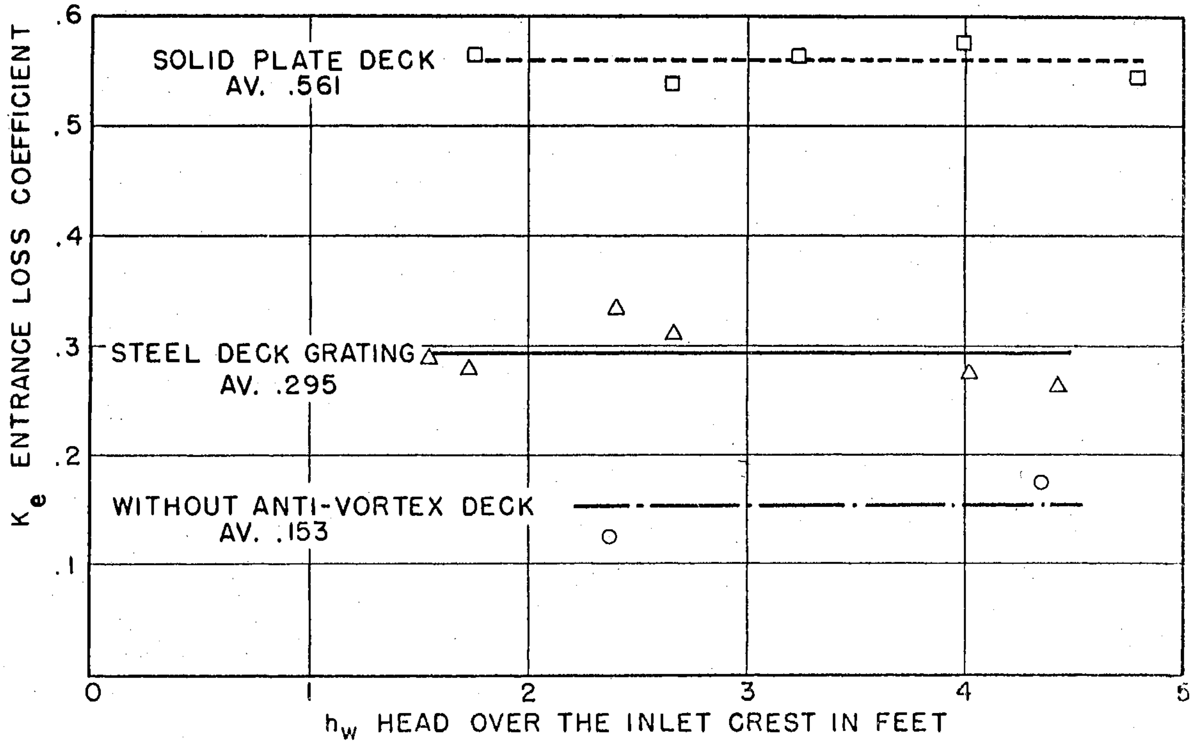

FIG. 16 ENTRANCE LOSS COEFFICIENTS FOR LOSSES ABOVE ELEVATION 13.858

a vortex-free flow condition were needed. This was achieved by placing a solid deck on top of the grating. No vorticies formed during the tests with the solid plate in place and a vortex-free calibration was made.

A direct comparison of the head-discharge curves for the three different entrances would not reveal the effect of vortex activity on the discharge. Each of the entrances had a different loss coefficient and this tended to obscure the effect of vorticity on the discharge rate. Therefore, a method of analysis was used that presumably resulted in a valid comparison. The first step in this procedure was the determination of the entrance loss coefficients. These coefficients were evaluated for each entrance form for a no-vortex condition and are presented on Figure 16. There were only two test points for the drop inlet with no anti-vortex device. Periods long enough to obtain a no-vortex measurement were rare and had to be selected from a portion of the test period. All test points for the steel grating are presented, except, for two of the tests where the large trash collection on the center of the grating gave higher values of K_e. A summary of these values are as follows:

Without anti-vortex device	average $K_e = 0.153$
Steel deck grating	average $K_e = 0.295$
Solid plate deck	average $K_e = 0.561$

Using the average value of K_e the entrance loss head, h_L, for each test discharge was computed by the formula $h_L = K_e h_v$. This head loss was subtracted from the total head on the pipe, h_p, (where h_p is the water surface elevation in the forebay minus the center line elevation of pipe at outlet).

Plotting discharge against $(h_p - h_L)^{\frac{1}{2}}$ produces a straight line on rectangular co-ordinate paper. The results of the three series of tests are presented on Figure 17. A least squares fit of the points gave the following formulas:

No anti-vortex device $Q = -1.163 + 13.438\ (h_p - h_L)^{\frac{1}{2}}$
Steel deck grating $Q = 0.876 + 13.077\ (h_p - h_L)^{\frac{1}{2}}$
Solid plate deck $Q = -3.482 + 14.328\ (h_p - h_L)^{\frac{1}{2}}$

The data for the above formulas were for values of $(h_p - h_L)^{\frac{1}{2}}$ between 3.3 and 3.7. The vortex action with no anti-vortex device produced an average reduction in discharge of 1.7 percent over the solid plate with no vortex. The steel grating gave discharges higher than the solid plate for the lower range of head and smaller values of discharge for the higher ranges of $(h_p - h_L)^{\frac{1}{2}}$. The average discharge over the complete range was the same as the solid plate. Therefore, for this particular structure the open steel deck grating was as effective as the solid plate deck in preventing discharge reduction by vortex activity. The small vortices observed with the steel grating did not appreciable effect the discharge rate.

Weir flow was obtained at higher heads than for the previous experiment because of the removal of the corrugated pipe. A plotting of the weir coefficients, Figure 18, showed that the coefficient continued to increase with head. The flattening of the curve at a value of C of 3.7 is due to the transition from weir to pipe flow and not due to the coefficient actually becoming constant at this head.

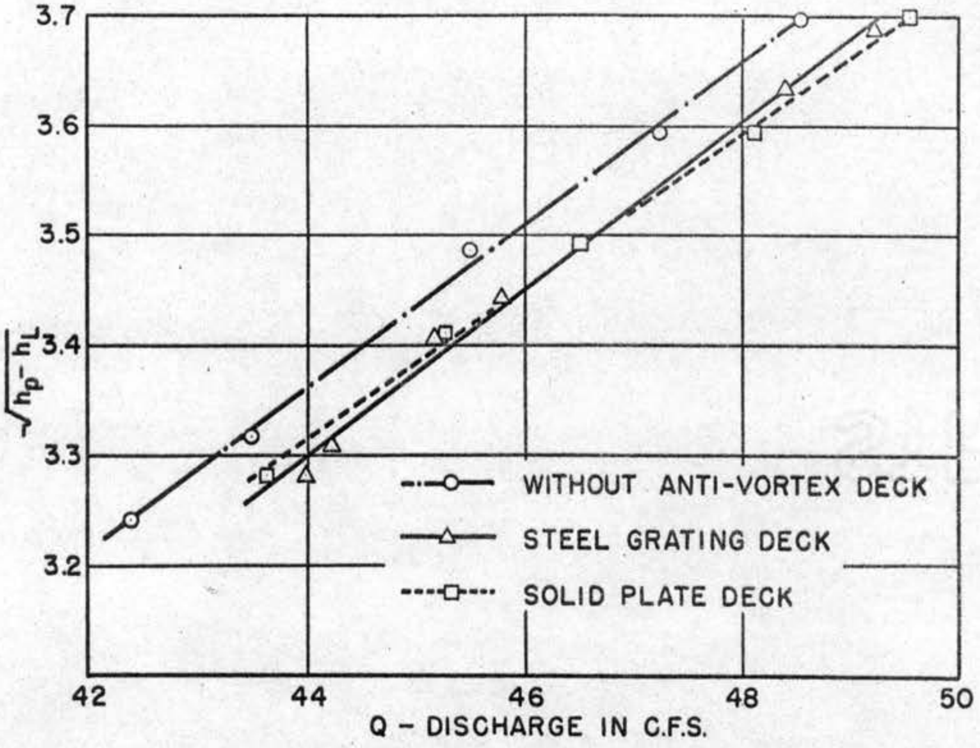

FIG. 17 REDUCTION IN DISCHARGE DUE TO VORTEX

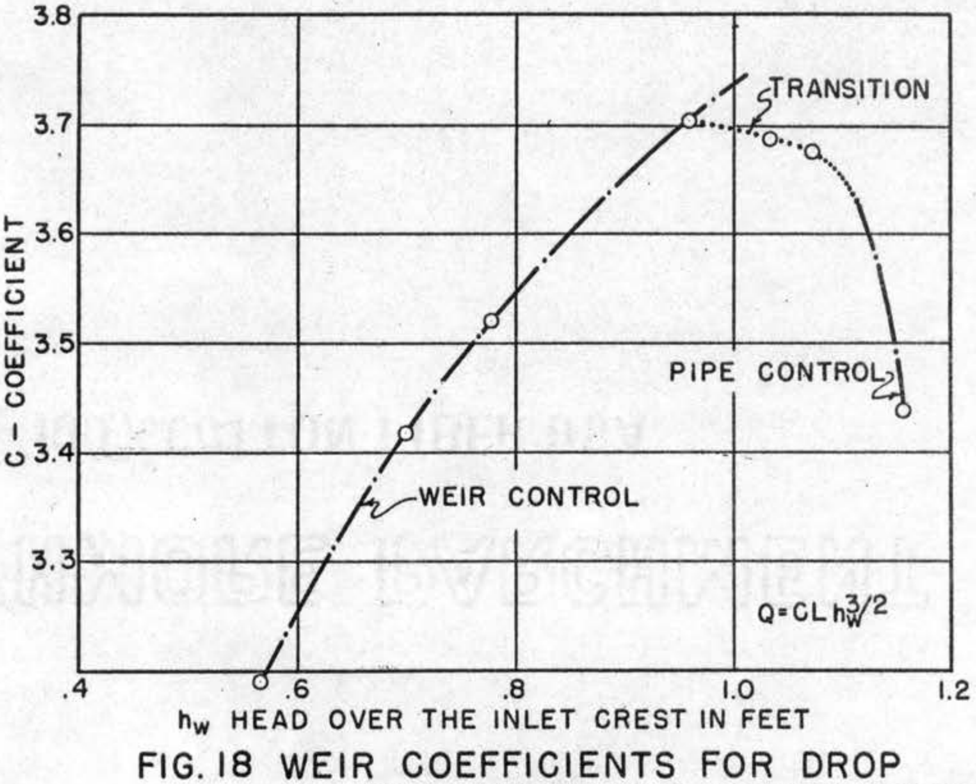

FIG. 18 WEIR COEFFICIENTS FOR DROP INLET WITHOUT ANTI-VORTEX DECK

CHAPTER IV

INTERPRETATION OF RESULTS

The process of vortex formation is complex and there are many questions that still remain unanswered. The vortices formed without the anti-vortex deck were not air-entraining and therefore produced small reductions in discharge. Mr. Blaisdell reports that air-entraining vortices can produce extreme reductions in the discharge of a closed conduit spillway.[8] Boundaries of the approaching flow play an important part of determining the strength and the amount of air entrained by a vortex.[9] The riser height was large enough to give an unrestricted approach to all sides of the crest. The magnitude of the velocity in the intake has a large influence on the formation of vortices and swirl at the intake.[9] The control of the flow changed from the weir to pipe before the velocities became very large in the intake or riser. The reductions in discharge due to vorticity were not produced by air-entrainment or bulking of the flow. The reductions produced by the vortices were due to swirl action within the pipe.

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[8] Fred W. Blaisdell, Hydraulics of Closed Conduit Spillways, Part VII, St. Anthony Falls Hydraulic Laboratory, Technical Paper No. 18, Series B, (Minneapolis, Minn., March, 1958), pp. 42-50.

[9] D. F. Denny and G. A. J. Young, "The Prevention of Vortices and Swirl at Intakes," Transactions of the Seventh General Meeting of the International Association of Hydraulic Research, Vol. 1 Paper C1, (L.N.E.C., Lisbon, 1957), pp. C1-1 - C1-10.

The steel deck grating acted as guide vanes to break up the rotation of the vortex and thus to prevent swirl in the riser and the pipe of the structure. Trash in the supply flow will collect on the high velocity areas of the grating and tend to form a solid plate over the riser. The results of this action will be to reduce the possibility of a air-entraining vortex for the structure. The structural supports of the steel deck grating should be designed to carry the additional load of the trash accumulations.

The results of these tests show that under some conditions there is no need of a anti-vortex device. The reduction in discharge due to vortex was not enough to justify the additional expense of a anti-vortex deck. The vortex potential of the structure was probably reduced by the corner piers used to support the anti-vortex deck. These acted as guide vanes and helped reduce the rotation of the flow for the no anti-vortex test condition.

A stable head-discharge rating was obtained for all three test conditions. To insure that a stable rating is obtained in a design requires the anti-vortex deck be placed a minimum distance above the lip of the crest. This minimum distance should not be less than the head on the lip of the crest where full pipe control will be in effect. This will also reduce the possibility of an over load condition due to trash collection or a solid plate.

The approach area should be large with no boundary characteristics that produce rotation of the flow. Placing the riser too close to the surface of the ground or side of the dam will confine the approach flow and increase the vortex potential of the structure.

Suggestions for Future Study

The majority of studies to date have been conducted on small scale models where the boundary flow conditions tend to increase vortex activity. The need for future study of vortex activity is in the field of large structures. These structures should be relatively free of boundary conditions that produce rotation of the flow. Information on discharge rate, intake velocity and other measurements where the air-entraining vortex initially forms in the closed conduit spillway are needed. This data will help the designer to determine the need of a anti-vortex device.

There are many factors concerning the dimensions of the riser and their relationship to vortex formation that remain unanswered. Some of these are height, shape, position on the retention dam, and the depth of sediment.

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VITA

Wendell Rudolph Gwinn

Candidate for the Degree of

Master of Science

Thesis: TESTS OF STEEL DECK GRATING FOR VORTEX SUPPRESSION ON CLOSED CONDUIT SPILLWAYS

Major Field: Civil Engineering

Biographical:

Personal Data: Born near Pauline, South Carolina, September 2, 1926, the son of Enoch W. and Ila W. Gwinn.

Education: Attended grade school in Roebuck, South Carolina; graduated from Roebuck High School in 1943; received the Bachelor of Civil Engineering from the Clemson Agricultural College, with a major in Civil Engineering, in August, 1948; completed requirements for the Master of Science in May, 1959.

Professional Experience: Conducted model studies, prototype check tests as a Hydraulic Engineer for the Tennessee Valley Authority Hydraulic Laboratory from September, 1948 to July 1955; Planned and estimated Hydro-electric projects for the Project Planning Branch of the Tennessee Valley Authority in Knoxville, Tennessee from July, 1955 to December, 1955; Assistant Project Supervisor for the Stillwater Hydraulic Laboratory, USDA, Agriculture Research Service, Stillwater, Oklahoma from January, 1956 to the present; Member of The American Society of Civil Engineers; Member of the honor society of Phi Kappa Phi.