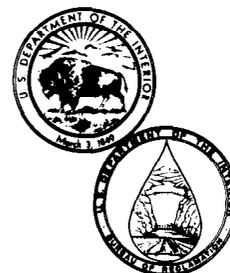REC-ERC-83-9

DISCHARGE ALGORITHMS FOR CANAL RADIAL GATES

December 1983

Engineering and Research Center

U. S. Department of the Interior

Bureau of Reclamation

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. REC-ERC-83-9	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE Discharge Algorithms For Canal Radial Gates		5. REPORT DATE December 1983
		6. PERFORMING ORGANIZATION CODE D-1531
7. AUTHOR(S) Clark P. Buyalski		8. PERFORMING ORGANIZATION REPORT NO. REC-ERC-83-9
9. PERFORMING ORGANIZATION NAME AND ADDRESS Bureau of Reclamation Engineering and Research Center Denver, Colorado 80225		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Same		13. TYPE OF REPORT AND PERIOD COVERED
		14. SPONSORING AGENCY CODE DIBR

15. SUPPLEMENTARY NOTES
Microfiche and/or hard copy available at the Engineering and Research Center, Denver, Colo. Ed: BDM

16. ABSTRACT

Discharge algorithms for canal radial gates that can be applied to manual and/or automatic flow regulation of prototype canals or to mathematical model simulation of canal systems were developed through an extensive research program. Existing methods do not adequately consider critical variations in gate geometry such as the horizontal angle of the gate lip (which is the function of the ratio of the gate radius to the pinion height) and the actual gate lip configuration (whether it is sharp or has a gate lip seal). Algorithms developed in this investigation accommodate a wide range of water level variations and the critical variations in geometry. They predict the discharge of the prototype very near to the true value with a high degree of confidence. A 1:6-scale, single-gate hydraulic model having a horizontal invert and a variable gate pinion height was used in the detailed study. The results are presented in accordance with Metzler's systematic method of illustrating the complete discharge characteristics of a radial gate. From the contoured data, which have conic curve characteristics, algorithms were developed that are functions of upstream and downstream water levels, gate opening, and ratio of the gate radius to the pinion height. The algorithms are based on a hard-rubber bar gate lip seal design (standard design used by Bureau of Reclamation). An adjustment is made for gates that have a music note gate lip seal (an older design used by the Bureau) and for gates which do not have a gate lip seal. The analytical development of the algorithms is summarized for free and submerged flow conditions. The study included a field verification test program. Comparison of the algorithm-predicted discharge is made to field prototype data for 13 different canal radial gate check structures to determine the range of accuracy. Practical application of the develped algorithms is presented in detail. Sufficient documentation for a computer program is provided as a basis for application by those who operate or simulate conveyance systems employing canal radial gate check structures.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS-- *canals/ *radial gates/ *check structures/ hydraulics/ water levels/ laboratory tests/ hydraulic models/ gate seals/ algorithms/ *discharge coefficients/ *discharge measurement/ free flow/ submerged flow/ computer programs/ field data

b. IDENTIFIERS-- Central Valley Project/ Columbia Basin Project/ Solano Project/ Tehama-Colusa Canal/ Coalinga Canal/ West Canal/ East Low Canal/ Putah South Canal/ San Luis Canal/ Friant-Kern Canal

c. COSATI Field/Group 13B   COWRR: 1313.1   SRIM: 50B

18. DISTRIBUTION STATEMENT *Available from the National Technical Information Service, Operations Division, 5285 Port Royal Road, Springfield, Virginia 22161.* (Microfiche and/or hard copy available from NTIS)	19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED	21. NO. OF PAGES 232
	20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. PRICE

REC-ERC-83-9

DISCHARGE ALGORITHMS FOR CANAL RADIAL GATES

by
Clark P. Buyalski

December 1983

Hydraulics Branch
Division of Research and Laboratory Services
Engineering and Research Center
Denver, Colorado

UNITED STATES DEPARTMENT OF THE INTERIOR   ★   BUREAU OF RECLAMATION

ACKNOWLEDGMENTS

CONTENTS

CONTENTS—Continued

CONTENTS—Continued

TABLES

Table

APPENDIX TABLES

CONTENTS—Continued

FIGURES

CONTENTS—Continued

CONTENTS—Continued

CONTENTS—Continued

CONTENTS—Continued

Figure

GLOSSARY

CC	Contraction coefficient
CD	Coefficient of discharge
CDA	Coefficient of discharge based on algorithms
CDM	Coefficient of discharge based on measured data
CFCDA	Correction factor for free flow coefficient of discharge based on algorithms
CSCDA	Correction factor for submerged flow coefficient of discharge based on algorithms
D	Directrix
DR	Transformed directrix
E	Eccentricity
ER	Transformed eccentricity
FCDA	Free flow coefficient of discharge based on algorithms
FD	Free flow directrix
FE	Free flow eccentricity
GAXCO	CC*GO
GC	Gravitational constant
GO	Gate opening
GOF	Free flow gate opening
GOS	Submerged flow gate opening
GW	Gate width
H	Head
HD	Downstream depth
HU	Upstream depth
PH	Pinion height
Q	Discharge
QFT	Free flow discharge
QST	Submerged flow gate opening
RAD	Gate arm radius
SCDA	Submerged flow coefficient of discharge based on algorithms

PURPOSE

An extensive research program was conducted to obtain a better definition of the discharge characteristics of canal radial gates, the way they are used to control flow and water levels in a canal system. Algorithms were developed to represent Metzler's[1,2][1] systematic method of illustrating the complete discharge characteristics of canal radial gates. This report presents the results of the investigation and the algorithms which accurately calculate the coefficient of discharge for submerged and free flow conditions. The results are expressed in a format suitable for practical application to operating canal systems.

SUMMARY

The objectives of the laboratory and field investigation program for canal radial gates were essentially achieved. A series of mathematical equations referred to as algorithms were developed that represent with accuracy the complete discharge characteristics. The algorithms accommodate a wide range of water levels and radial gate geometry normally encountered in the Bureau of Reclamation's design and construction of canal check gate structures.

The Hydraulic Laboratory test program was very detailed and extensive, with 2,647 test runs completed. Thirty-five piezometer measurements were taken for each run of nine different radial gate geometric configurations. The model was constructed to a 1:6 scale and consisted of a single radial gate, one-half gate pier, and a level invert extending upstream and downstream of the gate sill. The variables that were considered critical were the upstream and downstream water levels, the gate opening, and the pinion height. All were measured from the gate sill datum. The gate lip seal was varied by modeling three commonly used designs: (1) the hard rubber bar; (2) the music note seal; and (3) without a seal, resulting in a sharp edge configuration. The elements of gate geometry held constant were the gate sector radius, the gate width, the one-half pier, and the level invert.

Water levels and gate openings were varied to the maximum range of the laboratory model. The water levels ranged up to 1.5, and the gate openings to 1.2, times the pinion height. The pinion height distance was used as the geometric reference quantity and was adjusted by two (50-mm)

---

[1] Numbers in the brackets refer to entries in the bibliography.

2-in. increments, resulting in three values of the gate-radius-to-pinion-height ratio, RAD/PH— 1.373, 1.521, and 1.715. This range of RAD/PH ratios accommodates about 90 percent of the 128 existing check gate structures for 13 canal systems reviewed, which had an average ratio of 1.514. The algorithms developed from the laboratory data extend the range of gate-radius-to-pinion-height ratios to accommodate all canal radial gate check structures designed by the Bureau of Reclamation.

Several techniques for organizing the experimental data into a simple and usable format were explored. The initial analysis of the data confirmed that Metzler's concept for presenting the discharge coefficient family of curves provides the best scheme for developing algorithms and was closely followed. A contour mapping process of the submerged flow experimental data established an orderly and systematic family of discharge coefficient curves. The curves or contours have conic characteristics. Therefore, the general conic equation was adopted as the basic algorithm and could be fitted to each individual contour with extremely good accuracy. Additional algorithms vary the constants of the general conic equation as a function of the upstream and downstream water levels, gate opening, and radius-to-pinion-height ratio. The same basic approach was applied to the experimental data of the free-flow conditions, except the constants of the general conic equation are not dependent on the downstream water level. However, as each algorithm was constructed, the overall accuracy of the conic equation would decrease slightly.

The laboratory verification test program compared the predicted discharge coefficient calculated from the final series of algorithms to the experimental data of the submerged and free flow conditions. For the 2,647 test runs conducted, the statistical analysis indicated an average error of +0.36 percent and a standard deviation of ±4.9 percent.

An important phase of the investigation was the field verification test program. Thirteen canal radial gate prototype installations, 12 having a significant variation in geometry, were investigated. The objective was to establish the degree of accuracy that can be anticipated for practical application purposes.

Statistical analysis of 468 field test data points indicated that the algorithms predicted the discharge with an average error of +0.7 percent as compared to the field measurement of discharge. The standard deviation was ±4.9 percent. The comparison was normally distributed, linear, and unbiased. Therefore, the field verification test

program demonstrated that good accuracy can be anticipated when applying the algorithms to field prototype installations. The degree of accuracy was also established with a high degree of confidence since each field installation studied was accompanied by sufficient data acquired using high professional standards.

A computer program—developed for general use and application by operators of canal systems—was used in the field verification test program, with the required geometry of the 13 field prototype installations designated as checks No. 1 through 13. The program is dimensioned for 20 check structures, with capacity to print out a combination of 20 check structures and 40 flow condition alternatives by interactive computer terminal response, or it can be used to generate rating tables. The program length is 30,500 octal words and requires 65,500 octal words using the E&R Center's CDC (Control Data Corporation) CYBER 170/730 60-bit word computer system. The final algorithms are programmed and a test is included to determine if the flow condition is free or submerged.

The algorithms are much more complicated than originally anticipated; however, the complexity was necessary to achieve satisfactory accuracy in representing complete discharge characteristics for the wide range of water levels and radial gate geometry normally encountered at Bureau canal radial gate check structures. The program is easily adaptable to mathematical models used to simulate canal systems. In its present state, the computer program requires a relatively large computer; however, it is anticipated that the program can be adapted to minicomputers, microcomputers, desk calculators, and hand calculators if sufficient memory capacity is provided.

The general arrangement of this report is as follows:

- A summary of the conclusions reached is made first.
- The application of the discharge algorithms including their advantages, disadvantages, and limitations are highlighted.
- The background prompting this investigation and the laboratory test program and results are then discussed.
- The analytical development of the algorithms from contoured data which have conic characteristics is summarized, including the final series of algorithms which calculate the discharge coefficient for free and submerged flow conditions.
- A comparison of the algorithm-predicted discharge for laboratory and field data and the results is summarized.

- An important part of this report is the practical application of the developed discharge algorithms which is discussed at considerable length, including the presentation of preliminary equations that are necessary to interface the discharge algorithms to the canal system.
- Finally, sufficient documentation for the computer program is provided in appendix V to serve as a basis for application by those who operate or simulate conveyance systems employing canal radial gate check structures.

CONCLUSIONS

1. The discharge algorithms developed from a single-gate hydraulic laboratory 1:6 scale model are an accurate representation of the prototype canal radial gate check structure which may have one to five radial gates. The number of gates at the check structure does not affect the accuracy of the discharge algorithms.

2. The discharge algorithms are capable of predicting the true discharge of prototype radial gates in large or small canals as accurately as any measuring device or procedure currently available.

3. Statistical analysis of the comparison between the algorithm-predicted and the measured discharge has demonstrated: (a) the distribution of errors are normal, (b) the functional relationship is linear and unbiased, and (c) the algorithms predict the discharge near the true value.

4. Like any field measurement device or procedure for measuring flow in canal systems, the proper application of the discharge algorithms — including (a) resolution to ±2 mm (±0.005 ft) of measurement for the upstream and downstream water levels and the vertical distance of the gate opening, (b) calculation of the head losses that may occur between the water level measurement location and the radial gate, and (c) proper identification of the canal radial gate geometry— is essential to achieve a high degree of accuracy.

5. The radial gate lip configuration has a significant effect on the coefficient of discharge characteristics. The different gate lip seal designs investigated indicated the coefficient of discharge could vary from –10 to +12 percent (average range) when compared to the sharp edge. Even minor changes in the standard hard-rubber-bar gate lip seal design can cause significant variation, ranging from –8 to +13 percent. However, correction algorithms can be developed for different gate lip configurations and,

when applied, can achieve an overall average error near zero percent.

6. The discharge algorithms developed in this investigation, including correction algorithms for different gate lip configurations, apply only to canal radial gates designed by the Bureau of Reclamation.

7. The discharge algorithms developed in this investigation for predicting the discharge or gate opening are more complex than desired; however, practical application can be made by canal system operators through the use of the general use computer program included in this report. The canal operator can obtain solutions through an interactive computer terminal response feature or by developing rating tables.

8. The discharge algorithms are easily adaptable to mathematical models that simulate the entire canal system. They can also be adapted to microprocessor-based RTU's (remote terminal units) for continuous measurement and control of the radial gate discharge on a real time basis.

APPLICATION

Discharge algorithms for canal radial gates developed in this study should have extensive application. They have the potential for a high degree of accuracy when applied to the many radial gate check structures used to control and maintain flow and water levels on Bureau of Reclamation canal systems. Correct application of the discharge algorithms, however, is essential if a high degree of accuracy is to be achieved and maintained. Important factors that must be considered when making application of the discharge algorithms to the prototype canal radial gate are:

1. The discharge algorithms are limited to canal radial gates designed by the Bureau of Reclamation.

2. Accurate measurements are required for the upstream and downstream water levels and the vertical distance of the radial gate opening(s). These measurements should have a resolution of ±2 mm (±0.005 ft).

3. Head losses that occur between the upstream and downstream water level measurement locations and the radial gate(s) must be identified.

4. The geometry of the radial gate (including the exact configuration of the gate lip seal

design), the check structure, and the upstream and downstream canal sections must be correctly identified.

A general use computer program that solves the complex series of discharge algorithms for free and submerged flow conditions has been developed for the practical application of the algorithms. The required geometry is entered as data statements; then the computer program interfaces the variations of canal geometry upstream and downstream of the check structure through the energy balance equations, and includes a test to determine if the flow is free or submerged. The computer program description and listing are included in appendix V.

The general use computer program has an interactive terminal response feature. The watermaster can obtain the gate opening(s) by entering the upstream and downstream water elevations (or depth) and the total discharge, or the total discharge can be determined by entering the opening of each gate by interactive response with a computer terminal. The computer program can also provide a series of rating tables that can easily be used by the ditchrider.

Detailed information is provided in appendix IV on the discharge algorithms application procedures and the use of the computer program. Appendix IV also includes methods for accurately measuring the upstream and downstream water levels and the vertical distance of the gate opening, the proper identification of head losses, and other important criteria needed for successful application of the discharge algorithm. Examples are discussed in detail, including the development of the necessary parameters needed to generate a series of rating tables for the canal radial gate check structure. Anyone seriously interested in making a practical application should review appendix IV carefully before proceeding with the implementation of the discharge algorithms to their radial gate.

The general use program has other applications. With minor modifications, the program can easily be adapted to mathematical models simulating the entire canal system. The computer program, appendix V, could be used as a sub-routine having the following arguments:

1. Upstream depth, HU.
2. Downstream depth, HD.
3. Discharge, Q.
4. Gate opening(s)
5. The flag QORG is used to solve for the discharge when the gate opening is known or to solve for the gate opening when the discharge is known.

The general use computer program could be adapted to a microprocessor-based RTU (remote

terminal unit) located at the canal check structure. The RTU could then measure the discharge and provide an output to a continuous recorder and/or an encoder used in a remote monitoring system, or it could be used as a "Q" controller to automatically regulate the gate opening to maintain a discharge that has been "dialed in" locally or provided by the remote control system. The discharge algorithms, including the energy balance equations, would continuously calculate the gate opening for the desired discharge based on real time upstream and downstream water level measurement inputs. A comparator unit is required to raise or lower the gate whenever the calculated gate opening differs from the actual measured opening by more than a prescribed amount, which typically is about 0.03 m (0.1 ft).

However, it is important to realize that a "Q" controller controls the discharge and not the water levels. Control of the water levels must be accomplished by separate means. The ditchrider would increase or decrease the RTU discharge "dial-in" at each check structure to adjust the water levels to maintain a balanced canal operation. A steady-state mathematical model at the remote control center could be used to determine the desired discharge for each check structure that will maintain a balanced canal operation. The remote control system would then transmit the correct discharge to the check structure's RTU. Periodic update procedures are needed to eliminate the inevitable errors of measurement when using the RTU as a "Q" controller.

Extensive modifications of the general use computer program will probably be required for implementation of the RTU. If the discharge at the check structure is known to be always free or always submerged, the computer program could be greatly simplified by eliminating the test for free or submerged flow condition.

Using the discharge algorithms for "Q" controllers at all canal check structures would be difficult for a canal system that is operated in the conventional manner. The required discharge at each check structure, including adjustments for errors, would be difficult to obtain on an hourly basis by the ditchrider. However, for a remote supervisory control system, the task of controlling the canal discharge and water levels becomes relatively straightforward. The remote control system that monitors all the water levels, gate openings, and perhaps the canalside turnout discharges, and has a central computer system, can provide the RTU with the desired discharge on an hourly basis to maintain a balanced canal operation and provide quick corrections for emergencies or abnormal operations.

Advantages

The discharge algorithms accurately represent the complete discharge characteristics for the range of water levels and radial gate geometry normally encountered at canal radial gate check structures designed by the Bureau of Reclamation. As a result, a direct benefit is provided for canal operators who control canal systems manually or by remote manual/automatic control systems. The general computer program provides accurate gate openings or discharges for field operating personnel through the interactive terminal response feature or from a series of rating tables. The discharge algorithms are easily adaptable to mathematical models that simulate the entire canal system. They can also be adapted to microprocessor-based RTU's for continuous measurement and control of the radial gate discharge on a real time basis.

The discharge algorithms, correctly applied to canal radial gates, have the capability of being as accurate as any measuring device or procedure currently available for measuring the discharge in small or large canal systems. Thereby, the installation of costly Parshall flumes, weirs, acoustic velocity meters, and many canalside turnout meters could be eliminated, providing an economic benefit to many projects.

Disadvantages

The primary disadvantage of the discharge algorithms is their complexity. Many equations are necessary to represent the complete discharge characteristics of all the radial gates encountered in the Bureau of Reclamation canal systems. To solve the algorithms efficiently requires a computer program format. Certain skills are required to implement the algorithms and to use the computer program. A computer system must be available on demand when using the interactive computer terminal response feature. If computer services with high-speed printers are not available, they must either be purchased or rented to develop the series of rating tables.

Compared to just one measurement needed for the Parshall flume, the discharge algorithms require three accurate measurements: (1) upstream water level; (2) downstream water level; and (3) vertical distance of each radial gate opening. Head losses between the water level measurement locations and the radial gate must be correctly identified. For radial gate check structures that are not typical (such as one with a significant decrease in the downstream transition invert elevation, for example), special field tests may have to be conducted to develop the correct head loss coefficient.

Limitations

The discharge algorithms' high degree of accuracy is limited to canal radial gates having the characteristics of those designed by the Bureau of Reclamation:

● Canal invert through the check structure is flat and nearly horizontal from the upstream pier nose to the end of the pier downstream.
● Radius-to-pinion-height ratio has a range of about 1.2 to 1.7.
● Maximum water-level-to-pinion-height ratio is about 1.6.
● Gate faceplate is smooth.

The discharge algorithms are based on the hard-rubber-bar gate lip seal design (fig. 10a). Correction algorithms apply only to the music note gate lip design (fig. 10b) and to the combined hard-rubber-bar/music-note design, which is a replacement of the original music note design (fig. 10b, item M) with the hard-rubber bar (fig. 10a, item L). A correction algorithm has been developed for the sharp edge gate lip (radial gates without a gate lip seal) based on the laboratory model studies. However, the latter correction algorithm has not been verified for accuracy based on field data nor is it included in the general use computer program because canal radial gates without the gate lip seal are nearly nonexistent.

BACKGROUND

There is a need to define accurately the discharge coefficients of radial gates, the way radial gates are used to control flow and water levels in a canal system. Direct beneficiaries would be canal operators who control canal systems either manually or with remote manual/automatic supervisory control systems. Canal radial gates would have the potential of being used as standard measuring devices if a technique were available that establishes the correct discharge coefficients. This would eliminate the necessity of costly Parshall flumes, weirs, acoustic velocity meters, and many canalside turnout water meters, providing an economic benefit to the project [16].

Recent developments in automatic flow regulation schemes for canal systems require accurate definition of canal radial gate discharge coefficients. Examples of sophisticated control techniques are the predictor [3] and gate stroking [4] concepts. Successful implementation of these two methods of automatic control require accurate gate positioning as the canal flow changes to a new steady-state condition.

Variations in the upstream and downstream water levels and the gate geometry can significantly influence the discharge characteristics for
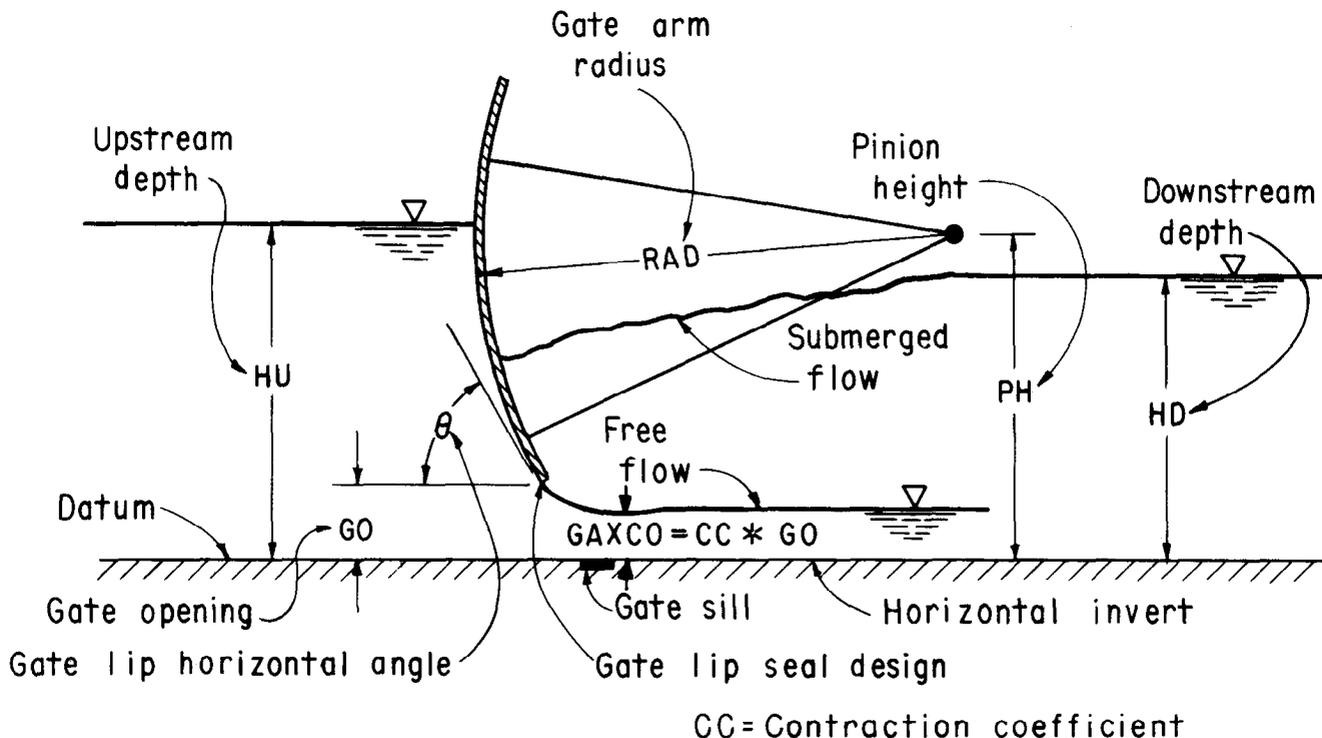
Figure 1.—Variables affecting discharge characteristics of canal radial gates.

any given radial gate. The two most critical elements of gate geometry are the horizontal angle of the gate lip between the gate face and the horizontal plane — a function of the gate sector radius to the pinion height ratio, and the configuration of the gate lip — whether it has a gate lip seal with hard-rubber-bar or music note design, or has no gate seal, resulting in a sharp edge profile. Figure 1 illustrates the variables that affect discharge characteristics of canal radial gates.

A literature review indicates that many experiments and analytical studies on underflow gates have been conducted to define discharge characteristics. Most of the investigations were concerned with vertical-lift sluice gates, spillway gates, etc., operating at free flow conditions. However, a few investigators [1, 5, 6, 7] studied flow under radial gates particularly in regard to the development of the discharge characteristics for the submerged flow conditions. The results are not completely applicable to canal radial gates for several reasons:

1. The range of geometry studied was too narrow compared to the designs encountered on the Bureau of Reclamation's canal systems.

2. The gate lip profile was usually sharp-edged and gate lip seal designs were not considered.

3. Results were not easily adaptable to actual operating canal radial gates or for mathematical model simulation of canal systems.

4. Field verification of discharge coefficients to determine their degree of accuracy when applied to the prototype was usually insufficient.

The canal radial gate is used to maintain upstream water levels and to regulate flows to downstream canal reaches as the demands by water users change on a monthly, daily, and hourly basis. Referring to figure 1, the upstream water level, HU, is held nearly constant at the maximum depth (for the maximum design discharge, Q) at all steady state flows. The purpose of maintaining maximum water levels upstream is to permit canalside turnouts to receive their maximum design delivery even when the canal flow is near zero. The maximum head differential, HU–HD, is typically about 0.9 m (3 ft) at zero flow conditions, or when the canal radial gate is closed. As the demands of the downstream canalside deliveries increase to the maximum canal design capacity, the head differential approaches zero, and the gate lip clears the water surface. The purpose of the relatively small head differential from zero to maximum discharge is to minimize water pressure differentials beneath the

canal lining, particularly when canal flow decreases. Lining failures can occur during operations if the canal flow is allowed to decrease rapidly. Therefore, flexibility of operation (the maximum allowable rate of change in canal flow on a daily basis) is enhanced when the head differential change is minimized.

The general equation for discharge through an underflow gate can be obtained from Bernoulli's equation and is expressed as:

$$Q = CD*GO*GW*\sqrt{2*GC*H} \qquad (1)$$

where:

$\quad$ Q = Discharge
$\quad$ CD = Coefficient of discharge
$\quad$ GO = Gate opening
$\quad$ GW = Gate width
$\quad$ GC = Gravitational constant
$\quad$ H = A definition of the head term

The definition of the head term, H, in equation (1) is critical to the development of the coefficient of discharge, CD. The coefficient of discharge could vary significantly and have different characteristics if the head term were to be defined as the head differential, H = HU–HD (fig. 1), as compared to being defined as the upstream depth, H = HU.

If the head term, H, is defined as the head differential, H = HU–HD, equation (1) becomes the well known "orifice" equation which is used frequently to measure discharge. However, applying the orifice equation to measure discharge through an underflow canal radial gate has its limitations. As the flow in the canal system increases and approaches the maximum designed capacity, the head differential, HU–HD, approaches zero (assuming the normal submerged flow conditions downstream). Since the terms GO and GW in equation (1) have maximum limits, CD becomes very large and would tend to approach infinity. Therefore, when equation (1) is used as the orifice equation, CD is: (1) nonlinear, (2) changes rapidly from low flow to high flow conditions, and (3) can be difficult to define when the flow through the gate structure approaches the maximum designed capacity.

A method for obtaining the coefficient of discharge characteristics using the orifice equation has been in use for a number of years, with limited success, for mathematical model simulation of canal systems. The procedure, developed by Shand [8, 9], involves the use of the U.S. Army Corps of Engineers Hydraulic Design Chart 320-3 [5] (fig. 2) to estimate the contraction coefficient, CC, as a function of the ratio of the gate opening to the upstream depth, GO/HU, and the gate lip horizontal angle, Θ (fig. 1). A steady-state

6

TOP OF CONDUIT

DEFINITION SKETCH

GATE OPENING (G₀) / CONDUIT HEIGHT (D)

$\dfrac{\text{GATE OPENING }(G_0)}{\text{CONDUIT HEIGHT }(D)}$

79°

74°

69°

64°

60°

52°

46°

$\beta=90°$ 80° 70° 60° 50° 45° 40° $\beta=30°$

1.0

0.8

0.6

0.4

0.2

0

0.60 0.65 0.70 0.75 0.80 0.85

DISCHARGE COEFFICIENT - C

BASIC EQUATION

$$Q = C\,G_0\,B\sqrt{2gH}$$

WHERE :

Q = DISCHARGE-CFS
C = DISCHARGE COEFFICIENT
G₀ = GATE OPENING-FT.
B = WIDTH OF GATE OPENING-FT.
H = ENERGY GRAD. ELEV.
   -(INVERT ELEV. + CG₀)

LEGEND

—— VON MISES
● GARRISON MODEL

TAINTER GATES IN CONDUITS
DISCHARGE COEFFICIENTS
HYDRAULIC DESIGN CHART 320-3

PREPARED BY U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, VICKSBURG, MISSISSIPPI

WES 8-60

Figure 2.—Corps of Engineers Hydraulic Design Chart 320-3.

7
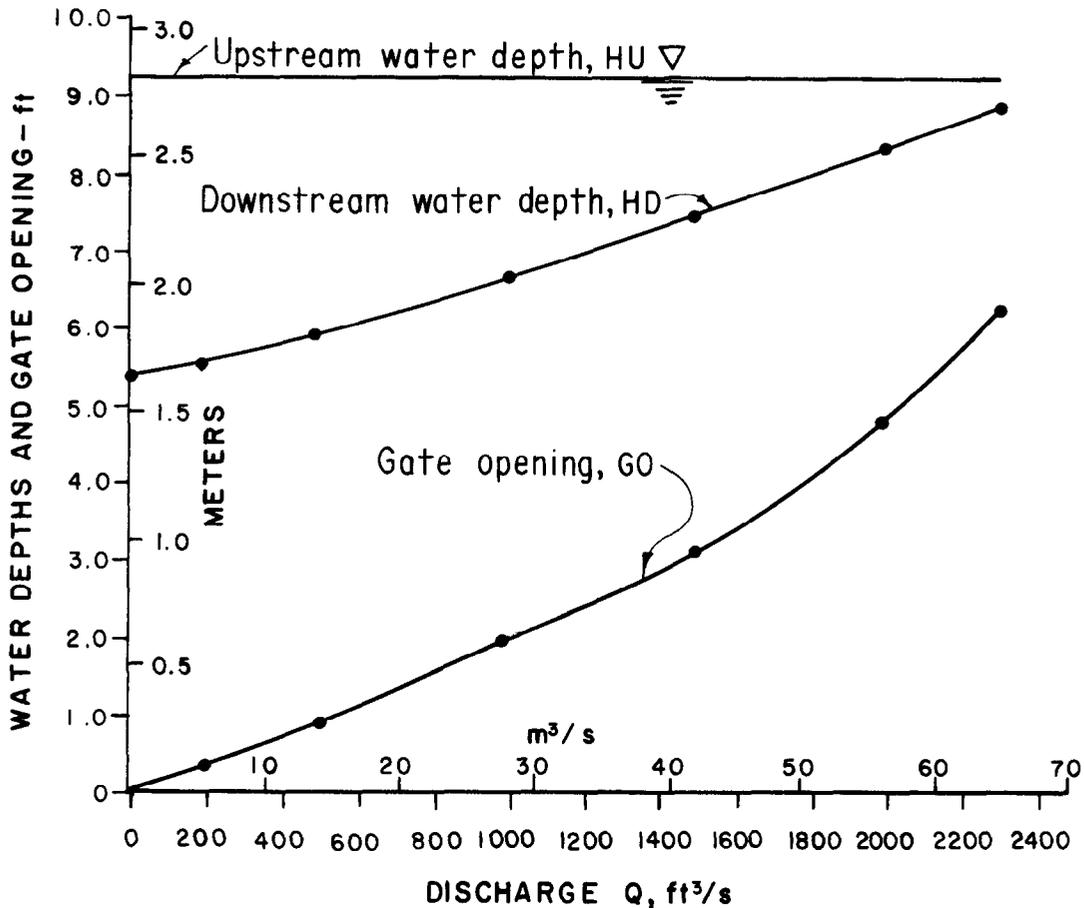
Figure 3.—Radial gate discharge characteristics—Tehama-Colusa Canal check No. 1.

mathematical model which simulates the check gate structure as the upstream boundary, and the downstream canal reach, was used to determine the downstream depth, HD, and the value of GAXCO (fig. 1) for selected steady-state discharges. Having determined the value of GAXCO, the gate opening, GO, is then calculated by dividing GAXCO by the corresponding value of CC.

The results of the above procedure can be observed with the Tehama-Colusa Canal check No. 1 (see fig. 3). Upstream depth, HU, is held constant for all steady-state discharges. Downstream depth, HD, is determined from backwater surface profiles of the downstream canal reach. It is assumed the water level at the downstream end will also be held constant for all steady-state discharges. Gate opening, GO, is determined based on the values of GAXCO and the contraction coefficient, CC. The coefficient of discharge, CD, is then determined from the orifice equation (1) using the data as shown in figure 3 with the total gate width, GW, for three radial gates equal to 12.8 m (42.0 ft). The results of the CD, calculations can be observed as the solid line in figure 4. Note in figure 4 that CD varies from a minimum

value of 0.73 at the low gate openings or low discharges to a high value of about 1.5 at the high gate openings or high discharges as the head differential, HU–HD, in figure 3 varies from its maximum to its minimum value.

The coefficient of discharge, as shown in figure 4, will provide satisfactory measurement of discharge through the radial gate for gate openings less than 60 percent, provided HU is held constant and HD always varies the same as the function of the discharge. However, if HD varies as little as ±5 percent from the rating curve for HD as shown in figure 3, caused by a change in the canal friction factor or a change in the operating depth of the downstream canal reach, CD can change significantly, causing a substantial error in the calculation of the discharge. Figure 4 demonstrates the change in CD when the downstream water depth varies ±5 percent shown by the upper and lower dashed lines. The error in CD will be about +8 to -1 percent at the low discharges to about +43 to -24 percent at the high discharges unless a new rating curve for CD is developed by repeating the procedure described above.

8
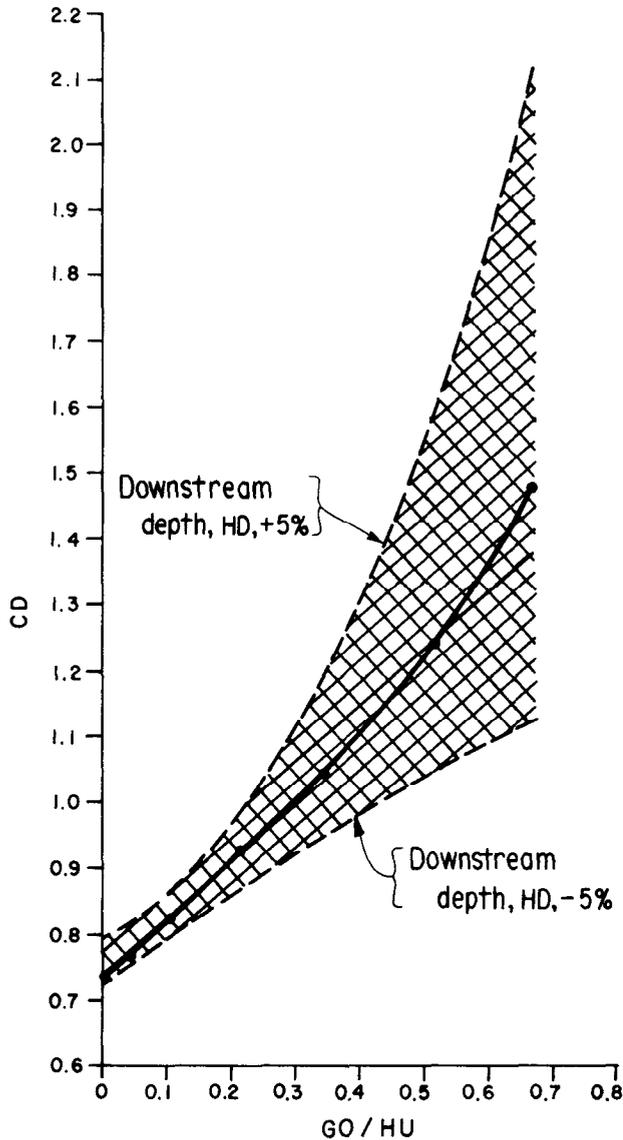
Figure 4.—Coefficient of discharge, CD, based on the orifice equation as a function of the gate opening to upstream water depth ratio, GO/HU—Tehama-Colusa Canal check No. 1.

Other methods for developing the coefficient of discharge based on the orifice equation were examined. For example, figure 5 demonstrates the relationship of the CD as a function of the head differential, $\Delta H = HU-HD$, and the ratio of the gate opening to the pinion height, GO/PH, using the hydraulic laboratory results from model No. 1. As can be observed in figure 5 (known as the "can of worms") applying the orifice equation to canal radial gates the way they are used to control flow and water levels in a canal system does not produce an orderly family of curves. It would be difficult to develop a series of mathematical equations for figure 5 that would represent the discharge characteristics with a high degree of accuracy.

Metzler's concept [1] defines the head term, H, in equation (1) as the upstream depth, HU measured from the gate sill to the upstream water surface. The coefficient of discharge, CD, calculated from equation (1) using HU for the head term, H, must still be associated with the downstream depth, HD, for submerged flow conditions. Figure 6 illustrates how this association can be achieved using the hydraulic laboratory data from model No. 1. Each data point is plotted with CD as the y-axis coordinate; HU/PH as the x-axis coordinate, the associated HD/PH is the z-axis coordinate. The three coordinates produce a "map" similar to a topographic map. (Variations in the water depths and gate geometry are greatly simplified using dimensional analysis employing the PH distance as the reference quantity [2]). A contour mapping process of the submerged flow experimental data established and orderly family of curves representing even values of the HD/PH, shown as the solid lines in figure 6. Examination of figure 6 confirmed that Metzler's concept provides the best scheme for presenting the discharge coefficient family of curves in an orderly and systematic way and was adopted for the development of the discharge algorithms.

The "map" (fig. 6), represents the flow characteristics for a wide range of water levels. However, only one radial gate geometry is represented: i.e., one gate lip seal design (in this example, the hard-rubber-bar design, fig. 10a); one gate opening, GO/PH = 0.200; and one gate arm radius, RAD/PH = 1.521. For each variation of gate geometry, a new map is required. Numerous maps were generated from experimental data. Subsequent paragraphs describe the hydraulic laboratory test program and the analytical development of the algorithms based on Metzler's concept.

LABORATORY TEST PROGRAM

General

The objective of the laboratory test program was to develop discharge algorithms from experimental data that would accurately describe the complete discharge characteristics of any Bureau of Reclamation canal radial check gate structure. Therefore, it was necessary to construct a laboratory model that would accurately represent any prototype canal radial gate. The Tehama-Colusa Canal check No. 1 was selected for two reasons: (1) the geometry of the radial gate is typical and (2) considerable field data are available to verify the laboratory test results (refer to app. IV).

The Tehama-Colusa Canal check No. 1 structure has three radial gates, each 4.27 m (14.0 ft) wide,

9
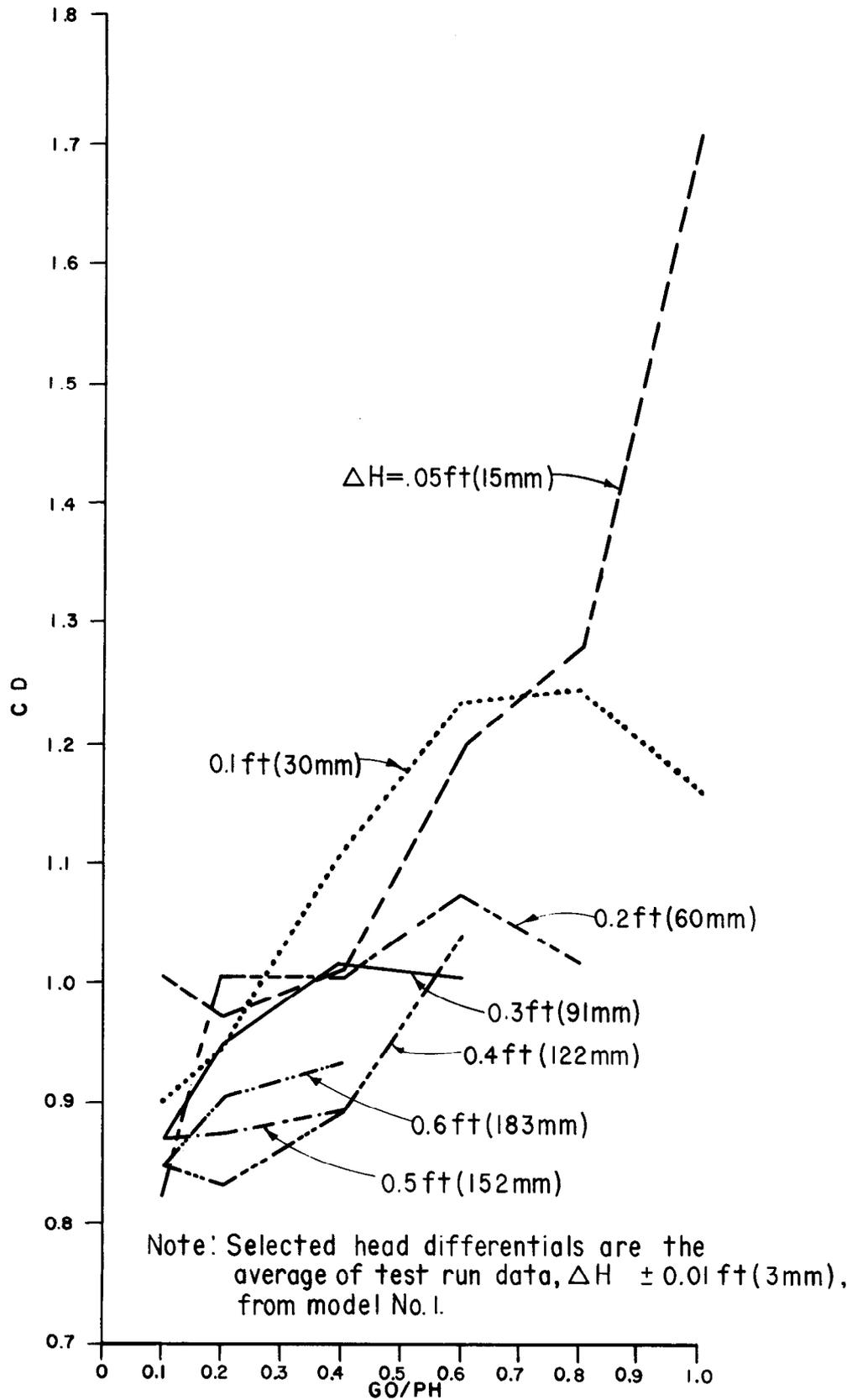
Figure 5.—Coefficient of discharge, CD, based on the orifice equation as a function of the head differential, ΔH = HU–HD and the ratio of the gate opening to pinion height, GO/PH.

10
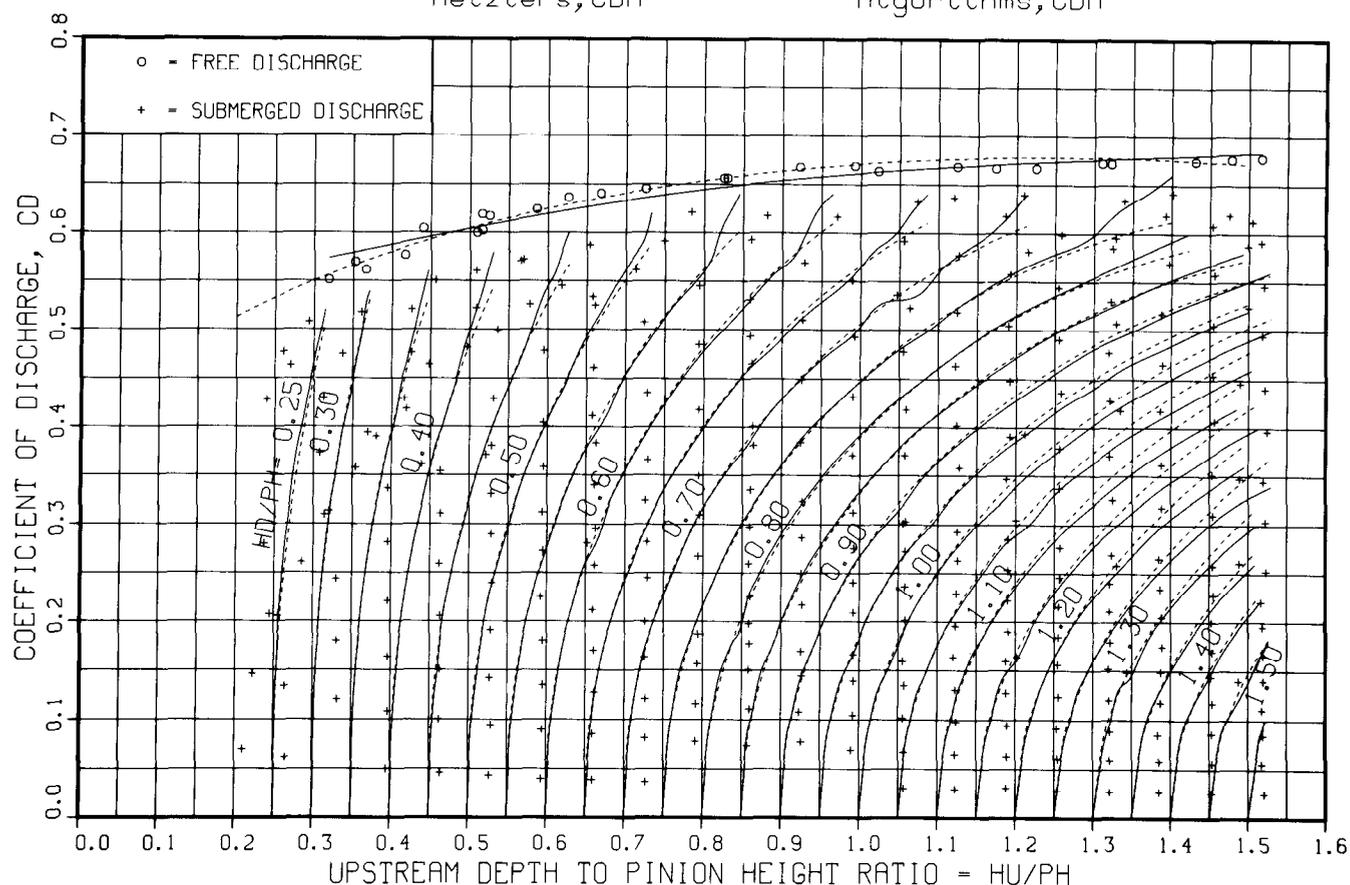
Figure 6.—Example of the coefficient of discharge, CD, for free and submerged flow conditions based on Metzler's concept.

separated by two 0.46 m (1.5 ft) wide piers. The gate arm radius is 4.20 m (13.77 ft) and the pinion height is 2.74 m (9.0 ft), resulting in a gate arm radius-to-pinion-height ratio of 1.530, very near the average value of 1.514 for the 13 canal systems reviewed. The gate lip seal is the standard hard-rubber-bar design and the invert through the check structure is horizontal.

It was decided that the complete discharge characteristics of the prototype multiradial gate check structure could be adequately defined by modeling just one radial gate in a rectangular flume. A scale of 1:6 was selected based on the Froude law of similarity that would provide the largest scale model that would not exceed the flow capacity of the laboratory water supply. The maximum laboratory water supply to the model was about 0.32 m³/s (11.3 ft³/s), which represents a prototype discharge of about 28.3 m³/s (1000 ft³/s). The 1:6 scale also provided an adequate definition of the model geometry of the gate-lip seal configuration.

Laboratory Model Description

The layout of the laboratory test facility is shown on figure 7. The 1:6 scale radial gate was placed in a 0.76-m (30-in) wide rectangular flume 3.05 m (10.0 ft) downstream from the laboratory water supply inlet. A half pier was constructed on the left side of the gate. On the right side, a Plexiglas window was placed for easy viewing of the model discharge as shown on figure 8. Figure 8 also illustrates the arrangement for raising and lowering the gate and for adjusting the gate pinion position. The model radial gate had rubber music note seals along the sides to prevent leakage.

A total of 35 piezometer taps were installed to measure water depths and pressures at selected locations as shown on figure 7. The upstream depth was measured at the HU location shown on figure 7 for all discharges. The HD1 location was used for the measurement of downstream depth

11

PLAN

Picker fence gate outlet

2-Downstream invert piezometer taps

3-Gate lip piezometer taps, GLL left, GLC center and, GLR right

0.76 m (2ft-6in)

0.05 m (2in) 0.71 m (2ft-4in)

Half pier (left side only)

2.08 m (6ft-10in)

0.59 m (2ft-3in)

P26 P29

4-Side wall piezometer taps

25-invert piezometer taps

1-Upstream invert top

FLOW

PROFILE

HD2

HD1

HU

8.46 m (27ft-9in)

5.49 m (18ft-0in)

0.76 m (2ft-6in)

3.05 m (10ft-0in)

Canal radial gate section

Plexiglas window (right side only)

P25

P1

Dimension reference line

1.22 m (4ft-0in)

3.12 m (10ft-3in)

Horizontal invert and datum

FLOW

25 invert piezometer taps of 50.8mm(2in)c. to c.

LEGEND

DIMENSION	DESCRIPTION
A = 702 mm (2.302 ft)	Gate arm radius
B = 529 mm (1.735 ft)	Horizontal distance
C = 409 mm (1.342 ft)	Pinion height (low)
D = 461 mm (1.513 ft)	Pinion height (middle)
E = 511 mm (1.677 ft)	Pinion height (high)
F = 152 mm (6 in)	4 side wall piezometer taps at 50.8mm(2in)c. to c.
G = 30.5 mm (0.1 ft)	Vertical distance to the 4 side wall piezometer taps
H = 305 mm (1.0 ft)	Horizontal distance
I =1219 mm (4.0 ft)	25 invert piezometer taps at 50.8mm(2in) c. to c.

Water supply inlet transition

Figure 7.—Layout of Hydraulic Laboratory 1:6 scale canal radial gate model test facility.

12
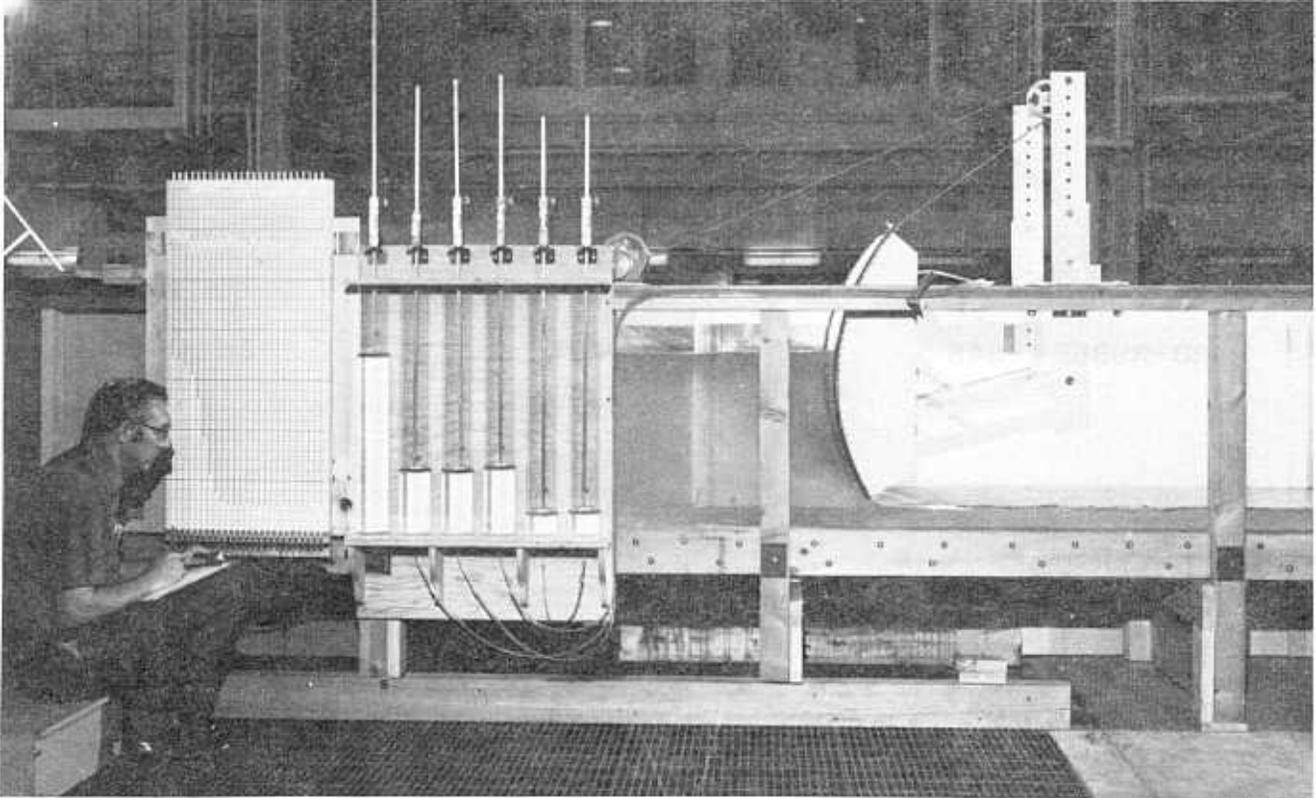
Figure 8.—View of Hydraulic Laboratory canal radial gate model, showing manometer and stilling well boards used to measure water pressure at selected points. P801-D-80379

under the free-flow condition, and the HD2 location for the measurement under the submerged-flow condition. Piezometer taps HU, HD1, and HD2 were connected to stilling wells having 102-mm (4-in) inside diameters as shown on figure 8.

Twenty-five piezometer taps, designated as P1 through P25, were installed on the invert of the flume along the centerline of the radial gate beginning 0.30 m (12 in) upstream of the reference line and spaced at 50.8-mm (2-in) centers downstream. Four piezometer taps were installed on the Plexiglas sidewall 30.5 mm (0.1 ft) above the flume invert beginning at the reference line and spaced at 50.8-mm (2-in) centers downstream and were designated as P26 through P29. Three piezometer taps were installed on the gate lip — two 0.22 m (8.5 in) left and right of the gate centerline and one on the centerline — and were designated as GLL, GLM, and GLR. Piezometer taps P1 through P29 were connected by flexible plastic tubing to 4.8-mm (3/16-in) inside-diameter glass tubes mounted on the manometer board shown in figure 8. The gate lip piezometer taps, GLL, GLM, and GLR, were connected to a separate manometer board (not shown on fig. 8) which had larger, 11.1-mm

(7/16-in) inside-diameter, glass tubes to provide additional damping characteristics for the dynamic pressure fluctuations experienced at these locations.

A gate valve located on the supply pipe (not shown on fig. 7) was used to control the discharge to the hydraulic model flume inlet. The discharges were measured by the laboratory northwest venturi bank employing visual readings of the mercury manometer for obtaining the head differential. Five venturi meter sizes were used—3, 4, 6, 8, and 12 inch—to accommodate accurate measurement of the radial gate model discharge, which ranged from about 2.8 L/s (0.1 ft³/s) to a maximum of about 0.33 m³/s (11.5 ft³/s).

A picket-fence type gate was used at the outlet of the flume to control the downstream depth for the submerged flow conditions.

The gate arm radius, RAD, was held constant for all the model studies. However, three different pinion heights, PH, were used, resulting in three different radius-to-pinion-height ratios, RAD/PH, of 1.373, 1.521, and 1.715. The radius-to-pinion-height ratio is a function of the gate lip horizontal angle, Θ, figure 1. These three values

13

HARD-RUBBER-BAR **MUSIC NOTE** **SHARP EDGE**

(a) Prototype

HARD-RUBBER-BAR **MUSIC NOTE** **SHARP EDGE**
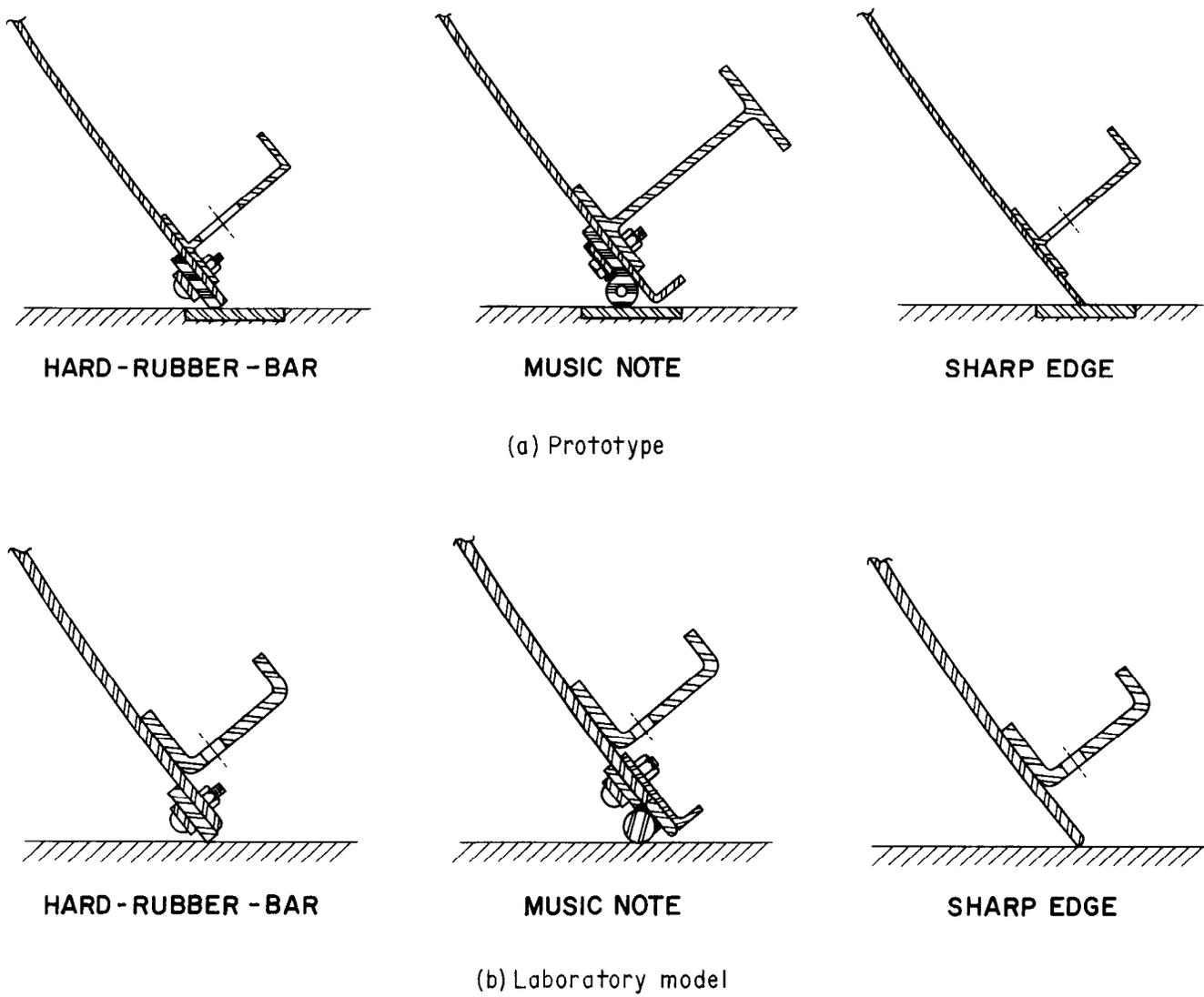
(b) Laboratory model

Figure 9.—Comparison of laboratory model and prototype designs for radial gate lip seal.

represent the low, mid, and high ranges of this critical variable as determined from the review of 13 different canal systems consisting of 128 radial gate check structures. The variation of the pinion height to obtain the three ratios was accomplished by changing the pinion height mounting frame (fig. 8) by ±50 mm (±2-in) increments from the midpinion height of 461 mm (1.513 ft).

Three different gate lip seal configurations were studied: (1) the standard hard-rubber-bar design; (2) the older music note design; and (3) the sharp edge, which is seldom used on canal systems designed by the Bureau of Reclamation. Figure 9 compares the prototype configurations of these three designs with the model designs used in the laboratory studies. Figure 10 shows the details of the hard-rubber-bar and music note gate lip seals as constructed for the radial gate model. Details

of the gate lip piezometer tap installation are also shown, along with "as-built" dimensions for both the model and the prototype gates, in metric and inch-pound units.

The sharp edge gate lip was achieved by simply removing the gate lip seal and filling in the screw holes with solder. The gate lip piezometer taps were left in the same location and were filed flush to the surface of the gate face plate.

Seven different gate openings were used in the model studies and were selected to obtain even ratios of gate opening (vertical distance) to pinion height, GO/PH: 0.1, 0.2, 0.4, 0.6, 0.8, 1.0, and 1.2. Therefore, for each of the three different pinion heights used in the laboratory test program, three different gate openings were required to maintain each of these ratios of GO/PH. The vertical distance for each selected gate opening was obtained by cutting Plexiglas

14

(a) Hard-rubber bar

DIMENSION	MODEL		PROTOTYPE	
	METRIC mm	INCH-POUND inches	METRIC mm	INCH-POUND inches
A	9.5	3/8	57.2	2 1/4
B	7.9	5/16	N/A	N/A
C	17.5	11/16	101.6	4
D	7.9	5/16	50.8	2
E	4.0	5/32	9.5	3/8
F	15.9	5/8	79.4	3 1/8
G	50.8	2	N/A	N/A
H	1.6 chamfer	1/16 chamfer	6.4 chamfer	1/4 chamfer
I	1.6	1/16	6.4	1/4
J	0.8	1/32	0	0
K	1.6	0.065 (16ga.)	9.5	3/8
L	2.9	0.113 (12ga.)	15.9	5/8
M	2.9	0.113 (12ga.)	6.4	1/4
N	2.9	0.113 (12ga.)	12.7	1/2
O	19.0	3/4	N/A	N/A
P	2.4 O.D.	3/32 O.D.	N/A	N/A
Q	6.4 O.D.	1/4 O.D.	N/A	N/A
R	3.2 x 12.7 rd. hd. mach. screws @ 25.4 mm c.to c.	1/8 x 1/2 rd. hd. mach screws @ 1 in. c. to c.	15.9 x 63.5 carriage bolts @ 152 mm c.to c.	5/8 x 2 1/2 carriage bolts @ 6 in. c. to c.
S	6.4 dia. @292mm c.to c.	1/4 dia. @11 1/2 in. c. to c.	76.2 dia @229mm c.to c.	3 dia @ 9 in. c.to c.
T	9.5	3/8	140	5 1/2

(b) Music note

DIMENSION	MODEL		PROTOTYPE	
	METRIC mm	INCH-POUND inches	METRIC mm	INCH-POUND inches
A	17.5	11/16	104.8	4 1/8
B	15.9	5/8	N/A	N/A
C	3.2	1/8	19.0	3/4
D	22.2	7/8	127.0	5
E	14.3	9/16	N/A	N/A
F	6.4	1/4	N/A	N/A
G	7.9	5/16	50.8	2
H	8.7	11/32	N/A	N/A
I	24.6	31/32	127.0	5
J	50.8	2	N/A	N/A
K	1.2	3/64	6.4	1/4
L	11.1	7/16	63.5	2 1/2
M	7.9 dia.	5/16 dia.	44.5 dia.	1 3/4 dia.
N	1.6	0.065 (16ga.)	6.4	1/4
O	1.6	0.065 (16ga.)	9.5	3/8
P	2.9	0.113(12ga.)	14.3	9/16
Q	2.9	0.113(12ga.)	6.4	1/4
R	2.9	0.113(12ga.)	12.7	1/2
S	19.0	3/4	N/A	N/A
T	2.4 O.D.	3/32 O.D.	N/A	N/A
U	6.4 O.D.	1/4 O.D.	N/A	N/A
V	3.2 x 12.7 rd. hd. mach. screws @ 25.4 mm c.to c.	1/8 x 1/2 rd. hd.mach screws @ 1 in. c. to c.	15.9 x 63.5 sq. hd. mach. bolts @ 152mm c.to c.	5/8 x 2 1/2 sq. hd. mach. bolts @ 6 in. c.to c.
W	6.4 dia. @ 292 mm c.to c.	1/4 dia. @11 1/2 in. c.to c.	None	None
X	9.5	3/8	N/A	N/A

Figure 10.—Details of the (a) hard-rubber-bar and (b) music note seal designs.

blocks to the proper dimension and cutting each block in half (vertical direction) so that two blocks of exactly the same dimension were formed. The blocks were then placed on the invert of the flume at about the one-fourth points of the gate width and the gate was lowered onto them. When a snug fit was obtained, the gate was clamped into this position on each side at the top of the flume and the blocks were removed. The gate remained in this position until the required series of test runs was completed. The vertical distance of the gate opening, therefore, was measured from the flume invert, or gate sill, to the lowest point of the gate lip configuration.

Table 1 lists the physical properties of the canal radial gate model by model number for the various geometric configurations used in the studies. Dimensions listed are the actual "as-built" dimensions.

Table 1. — *Physical properties of the canal radial gate model for various geometric configurations.*

Gate physical properties[1]	Hard-rubber-bar (see fig. 10a) Model No.						Music note (see fig. 10b) Model No.						Sharp edge (see fig. 9) Model No.					
Gate lip configuration	1		2		3		4		5		6		7		8		9	
	mm	(ft)	mm	(ft)	mm	(ft)	mm	(ft)	mm	(ft)	mm	(ft)	mm	(ft)	mm	(ft)	mm	(ft)
Pinion height, PH	461	(1.513)	511	(1.677)	409	(1.342)	409	(1.342)	461	(1.513)	511	(1.677)	409	(1.342)	461	(1.513)	511	(1.677)
Gate arm radius, RAD	702	(2.302)	702	(2.302)	702	(2.302)	702	(2.302)	702	(2.302)	702	(2.302)	702	(2.302)	702	(2.302)	702	(2.302)
Gate width, GW	711	(2.333)	711	(2.333)	711	(2.333)	711	(2.333)	711	(2.333)	711	(2.333)	711	(2.333)	711	(2.333)	711	(2.333)
Radius-to-pinion-height ratio, RAD/PH[2]	1.521		1.373		1.715		1.715		1.521		1.373		1.715		1.521		1.373	
Gate openings, GO																		
No. 1	46	(0.151)	51	(0.167)	40	(0.131)	40	(0.131)	46	(0.151)	51	(0.167)	40	(0.131)	46	(0.151)	51	(0.167)
No. 2	92	(0.302)	102	(0.336)	81	(0.266)	81	(0.266)	92	(0.302)	102	(0.336)	81	(0.266)	92	(0.302)	102	(0.336)
No. 3	185	(0.608)	204	(0.669)	162	(0.532)	162	(0.532)	185	(0.608)	204	(0.669)	162	(0.532)	185	(0.608)	204	(0.669)
No. 4	277	(0.909)	305	(1.001)	243	(0.797)	243	(0.797)	277	(0.909)	305	(1.001)	243	(0.797)	277	(0.909)	305	(1.001)
No. 5	370	(1.215)	407	(1.335)	325	(1.066)	325	(1.066)	370	(1.215)	407	(1.335)	325	(1.066)	370	(1.215)	407	(1.335)
No. 6	462	(1.516)	509	(1.670)	406	(1.332)	406	(1.332)	462	(1.516)	509	(1.670)	406	(1.332)	462	(1.516)	509	(1.670)
No. 7	554	(1.818)	611	(2.005)	487	(1.598)	[3]		[3]		[3]		[3]		[3]		[3]	
Gate-opening-to-pinion-height ratio, GO/PH[2]																		
No. 1	0.100		0.100		0.098		0.098		0.100		0.100		0.098		0.100		0.100	
No. 2	.200		.200		.198		.198		.200		.200		.198		.200		.200	
No. 3	.402		.399		.396		.396		.402		.399		.396		.402		.399	
No. 4	.601		.597		.594		.594		.601		.597		.594		.601		.597	
No. 5	.803		.796		.794		.794		.803		.796		.794		.803		.796	
No. 6	1.002		.996		.993		.993		1.002		.996		.993		1.002		.996	
No. 7	1.202		1.196		1.191		[3]		[3]		[3]		[3]		[3]		[3]	

[1] Refer to figure 1 for nomenclature.
[2] Ratio based on the measured values in inch-pound units.
[3] No test runs were made for this gate opening and model number.

The water depth or pressure at each of the 35 piezometer taps shown on figure 7 was measured with a single pressure transducer using a scanner valve arrangement that automatically sequenced each port connected to the piezometer taps to the pressure transducer. The pressure transducer was carefully calibrated and checked each day before a series of test runs were conducted to obtain a 1.000-volt readout on a digital voltmeter for 1.000 foot of water level change. The calibration procedure used a Lory-type gage which had a small stilling well attached on the sliding scale. The pressure transducer was placed about 150 mm (0.5 ft.) below the invert of the model flume to maintain a positive pressure at all flow conditions. The index of the pressure transducer referenced to the gate sill was obtained from two stilling wells connected to two ports of the scanner valve. The water level in each index stilling well was measured by visual readings of Lory-type pointer gages, (fig. 8) which were calibrated to read zero when the pointer was at the gate sill datum of the model flume. Because the wells were a closed system, only two visual readings of the pointer gages were necessary each day, mainly to account for the evaporation of the water inside the wells. Subtracting the transducer pressure reading from the pointer gage reading, the "index" or the pressure of the transducer could be accurately determined. Two index stilling wells were used to obtain the index at the beginning and the end of each test run and were then averaged, mainly to account for temperature drifts of the pressure transducer. Also, if a sudden shift or a change in calibration of the transducer occurred, it could be immediately detected and corrected before continuing with the test run series. Subtracting the average index reading from the pressure transducer readings would then provide water depths and pressures for each of the 35 piezometer taps referenced to the gate sill datum.

A timer was used to automatically sequence the scanner valve to each port of the 35 piezometer taps including the two index wells. At each port, an 8-second rest period was provided to allow for stabilization of the pressure. Then an 8-second integration period of the pressure reading began. At the end of the 8-second integration period, the pressure reading was displayed on the digital voltmeter and printed on a paper tape. After the reading was printed, the scanner valve was sequenced to the next port and the 8-second rest and integration periods would be repeated. Scanning a total of 37 ports took about 10 minutes to complete and constituted one test run. During the 10-minute period, an average reading of the mercury manometer measuring the head differential of the venturi meter in the laboratory water supply line was obtained. From calibration tables, the average discharge was determined and recorded on the test run data sheet.

The data for each test run were also recorded on coding forms in an I8, A8, or F8.2 format in the following sequential order:

First line:
  1. Test run number, I8 format
  2. Flow condition FREE or SUBM, A8 format
  3. Average discharge, F8.4
  4. Gate opening, F8.4
  5. Piezometer taps HU, HD1, and HD2, 3F8.4
  6. Piezometer taps GLL, GLM, GLR, 3F8.4

Second line:
  7. Piezometer taps P1 throuigh P10, 10F8.4

Third line:
  8. Piezometer taps P11 through 20, 10F8.4

Fourth line:
  9. Piezometer taps P21 through 29, 9F8.4
  10. Average index reading, F8.4

The test run number, item 1 above, was recorded directly onto (1) the code form, (2) the paper tape printout, and (3) the special laboratory test run data form. Discharge, gate opening, and index items 2, 3, and 10 were also recorded directly onto the coding form and the laboratory test run data forms. The 35 piezometer tap pressure readings, items 4 through 9, were transferred from the paper tape printout onto the coding forms. All the data recorded on the coding forms were then keypunched to provide punched card decks for analyzing the data by the use of special computer programs.

The punch card decks were separated by inserting a card at the beginning to identify the geometry variations giving the (1) gate opening, (2) pinion height, (3) gate arm radius, (4) the gate width, and (5) the model number (at a 4F8.4, I4 format) for each series of test runs.

All data collected in the laboratory test program are available in their original form and on punched cards. The laboratory test form also included a recording of the Lory-type pointer gage readings, which were made for each test run, of the upstream and downstream HU, HD1, and HD2 piezometer taps, for additional check of these measurements. The venturi meter used to measure the flow and the actual mercury manometer venturi head differential readings were also recorded on the laboratory test run data sheets, along with any special remarks as necessary.

17

Laboratory Test Procedure

The laboratory test program began with model No. 1 as listed in table 1, with the model hard-rubber-bar seal design as shown in figure 10a. The test procedure for collecting experimental data is summarized as follows:

1. The model radial gate was clamped into position (usually starting with the smallest gate opening) using the procedure described earlier.

2. Free flow condition tests were usually conducted first. The picket fence gate at the outlet of the model flume was removed for these tests.

   a. Discharge at the inlet to the flume was adjusted to obtain an upstream water depth that would just barely submerge the gate lip piezometer taps. When the stilling wells reached a steady state, the first test run was conducted according to the sequence described above.

   b. After the first test run sequence was completed, the discharge to the inlet of the flume was increased until the upstream water level increased by about 30 mm (0.1 ft.). After the stilling wells reached the new steady state, the second test run sequence began. During the settling time of the stilling wells, the data of the previous test run were recorded onto the coding forms.

   c. For each test run for the free flow conditions, the upstream depth was increased in increments of 30 mm (0.1 ft.) by increasing the inlet discharge. Test runs continued until the maximum upstream depth of the flume, about 0.7 m (2.4 ft.), or the maximum flow capacity of the laboratory water supply, about 0.33 m³/s (11.5 ft³/s), was reached. Free flow test runs for the first selected gate opening were then complete.

3. Next, the submerged flow condition test runs were conducted with the gate remaining clamped in the position established for the free flow condition.

   a. First the inlet discharge was adjusted to a preselected value, usually starting with the smallest discharge.

   b. Then a few of the picket fence slats were inserted at the outlet of the model flume until one of two conditions occurred: (1) the upstream depth just barely submerged the gate lip piezometer taps or (2) the toe of the downstream hydraulic jump submerged the vena contracta immediately downstream of the gate lip, which could be observed on the manometer board, figure 8. Submerged flow is defined in this investigation as when the vena contracta becomes submerged. The test run sequence was begun after the stilling wells reached a steady state.

   c. For the next test run, additional picket fence slats were inserted until the upstream depth increased by about 30 mm (0.1 ft.). The discharge was held nearly constant, requiring occasional minor adjustments to the inlet gate valve as the upstream water level was increased. The next test run sequence began after the new steady-state flow condition was established.

   d. Increase of the upstream water level by 30-mm (0.1-ft.) increments continued at the preselected constant discharge value for each test run until the maximum depth of the model flume was reached.

   e. Next, the discharge was changed to the next higher preselected value and steps 3a through 3d above were repeated. Preselected discharges were based on limiting the increase of the coefficient of discharge, CD, to a value of about 0.08 or less. Submerged flow test run series conducted at nearly constant discharge can be seen on figure 6 for the data designated by "+" as the test runs progress from left to right and at spaced increments of CD of 0.08 or less from the bottom to the top of the chart as the discharge increased to the preselected values.

   f. Test runs continued, repeating items 3a through 3e above, until the maximum preselected discharge was reached, and were limited to the maximum laboratory water supply capacity of 0.33 m³/s (11.5 ft³/s) for the larger gate openings. Test runs for the submerged flow conditions at the first preselected gate opening were then complete.

4. Next, the radial gate opening was changed to the second preselected value and test procedures 1 through 3 above were repeated.

5. Test runs continued, repeating the above procedures 1 through 4, until all of the seven preselected gate opening values were completed.

6. The model radial gate pinion height, PH, was then changed to the next preselected value and test procedures 1 through 5 were repeated for model No. 2 and then again for model No. 3. However, for models No. 2 and No. 3 the preselected discharges were based on a larger increment of CD (step 3e), about 0.25 or less. The number of test runs for submerged flow conditions was therefore decreased by a factor of

about 7 for models No. 2 and 3. The test procedure for the free flow conditions remained the same.

After the laboratory test data collection was completed for models No. 1, 2, and 3, the gate lip seal was changed from the hard-rubber-bar design, figure 10a, to the music note design, figure 10b. The test procedure, items 1 through 6 above, was repeated for models No. 4, 5, and 6. However, only one preselected discharge value for the submerged flow conditions was used, usually selected at the maximum or about two-thirds of the maximum discharge of the gate opening. At the gate-opening-to-pinion-height ratio, GO/PH, of 0.4 for model No. 4, three equally spaced preselected discharges were used. The number of submerged flow test runs was therefore reduced further by a factor of about 10 as compared to model No. 1. The free flow test procedure remained the same.

After the laboratory test program data collection was completed for models No. 4, 5 and 6, the music note gate lip seal was removed to form the sharp edge design. The test procedure, items 1 through 6 above, was again repeated for models No. 7, 8, and 9 using the preselected discharge values established for models No. 4, 5, and 6. This completed the collection of the experimental data for the radial gate model studies.

Laboratory Test Results

The next phase of the laboratory test program was preparing the collected experimental data for models No. 1 through 9 for analytical development of the discharge algorithms.

Data for the free and submerged flow conditions for each gate opening of models No. 1, 2, and 3 were plotted onto "maps" following Metzler's concept [1, 2] for systematically illustrating the complete discharge coefficient characteristics for canal radial gates. The coefficient of discharge, CD, was calculated from equation (1) using the laboratory measured upstream depth, HU, for the head term, H. Each data point was plotted with CD as the y-axis coordinate; the upstream depth ratio, HU/PH, as the x-axis coordinate; and the associated downstream depth ratio, HD/PH, as the z-axis coordinate. Variations in the water depths and gate geometry are greatly simplified, using dimensional analysis employing pinion height, PH, distance as the geometric reference quantity [2]. The three coordinates for the submerged flow data produce a map similar to a topographic map. A contour mapping process (using a library computer program developed for topography contour mapping purposes) established an orderly family of curves for the submerged flow experimental data representing

even values of the downstream depth ratio, HD/PH, shown as the solid lines in figure 6. Figure 6 is an example of a map developed from the laboratory test program. The solid line drawn through the free flow data is a best fit line using special library curve fitting computer programs.

The 21 maps, including figure 6, developed from the laboratory data for models No. 1, 2, and 3 are included in appendix I. The series of discharge algorithms developed in this investigation are based on the data from models No. 1, 2, and 3 having a gate lip with the standard hard-rubber-bar seal design. Not enough data were collected for models No. 4 through 9 to construct maps with contours for the submerged flow conditions; therefore, these maps are not included. Correction algorithms for the music note gate lip design are based on models No. 4, 5, and 6 data. Correction algorithms for the sharp edge are based on models No. 7, 8, and 9 data. A tabulation of all the laboratory data for models No. 1 through 9 is included in appendix II. Appendixes I and II also include the comparison between the coefficient of discharge based on laboratory data, CDM, and the coefficient of discharge based on the final algorithms, CDA.

The downstream depths, HD1 and HD2, measured in the laboratory model were adjusted to an equivalent depth for a rectangular channel having a width equal to the model gate width. This adjustment was necessary to eliminate the effect of the half pier used in the model studies (fig. 7), particularly for the downstream free flow conditions. The upstream depth, HU, however, was not adjusted.

In the development of coefficient of discharge characteristics based on Metzler's concept, it was only necessary to use the water depth measurements made at the piezometer tap locations HU, HD1, and HD2 (fig. 7). Therefore, the other water level and pressure measurements made at the piezometer taps P1 through P29 and at the gate lips GLL, GLM, and GLR were not used. However, the data were collected as a matter of convenience. These data will then be available for analysis at some future time, with the objective being to determine if the definition of the discharge characteristics of the canal radial gate can be further simplified by using another suitable pressure point of measurement. Perhaps one, or maybe two, of the three points of measurement required for the Metzler's concept could be eliminated, and still produce the same or even better results.

During the mapping process of the submerged flow data, the calculated x, y, and z coordinates of

19
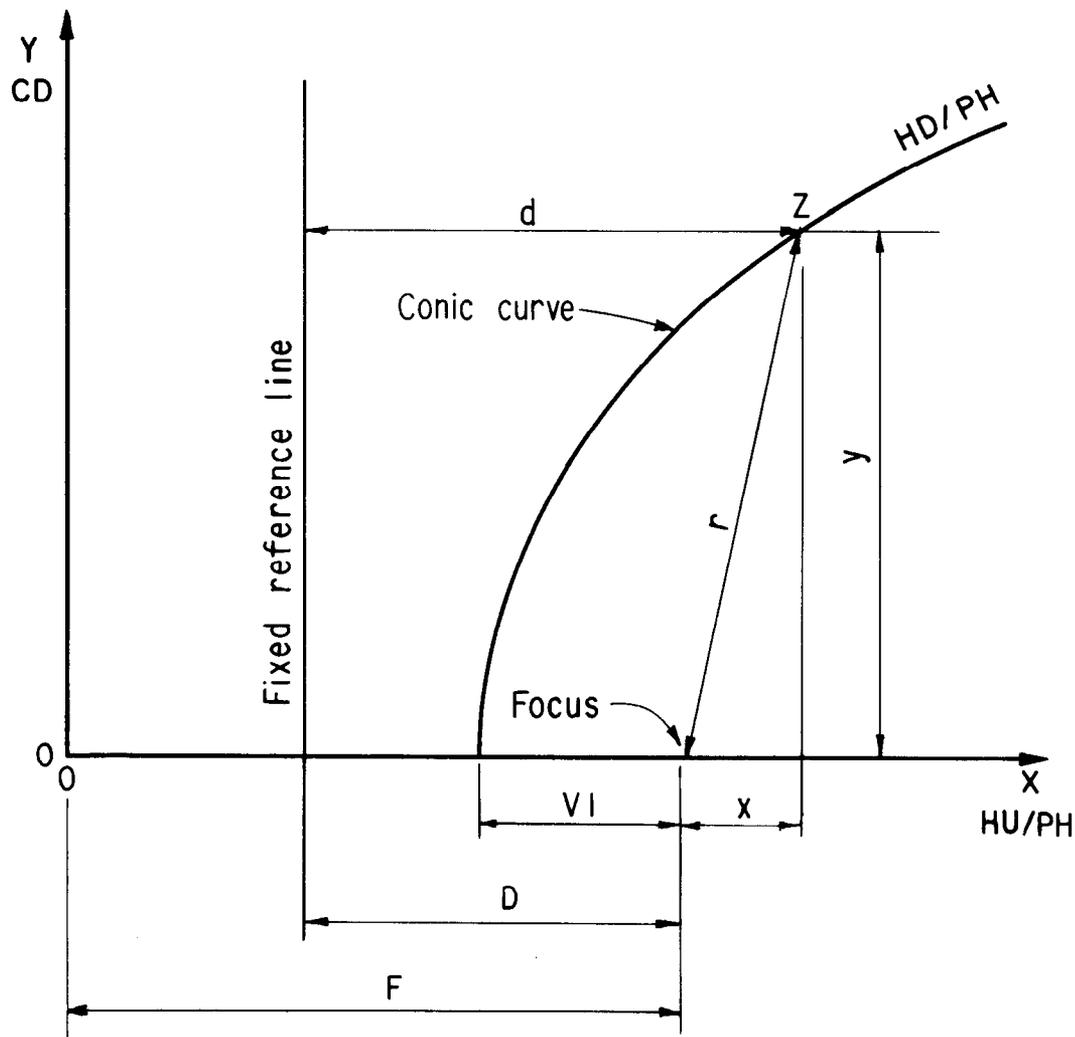
Figure 11.—Conic curve characteristics.

the selected even contours were stored on separate computer files for later use in the analytical development of the submerged flow algorithms which is discussed in the following paragraphs.

ANALYTICAL DEVELOPMENT OF ALGORITHMS

General

Results of an initial analysis of the submerged flow experimental data indicated the even contours of the downstream-depth-to-pinion-height ratio, HD/PH, have conic characteristics. Figure 11 illustrates a conic curve. By definition, a curve is conic when the ratio of the distance r to the distance d as the point Z moves along the curve remains constant. The constant ratio of r/d is called the eccentricity, E. The distance from a fixed reference line to the focus is called the

directrix, D, which also remains constant. With the major axis being the x-axis and the minor axis parallel to the y-axis of figure 11, the general expression of a conic curve can be derived:

$$x^2 + y^2 = E^2(D + x)^2 \qquad (2)$$

where:

x = the horizontal distance measured from the focus to the locus of point Z

y = the vertical distance measured from the focus to the locus of point Z

E = the eccentricity equal to the ratio of r/d and is constant

D = the directrix equal to the distance measured from the fixed referenced line to the focus and is constant

If:

E < 1, the conic is an ellipse
E = 1, the conic is a parabola
E > 1, the conic is a hyperbola

20
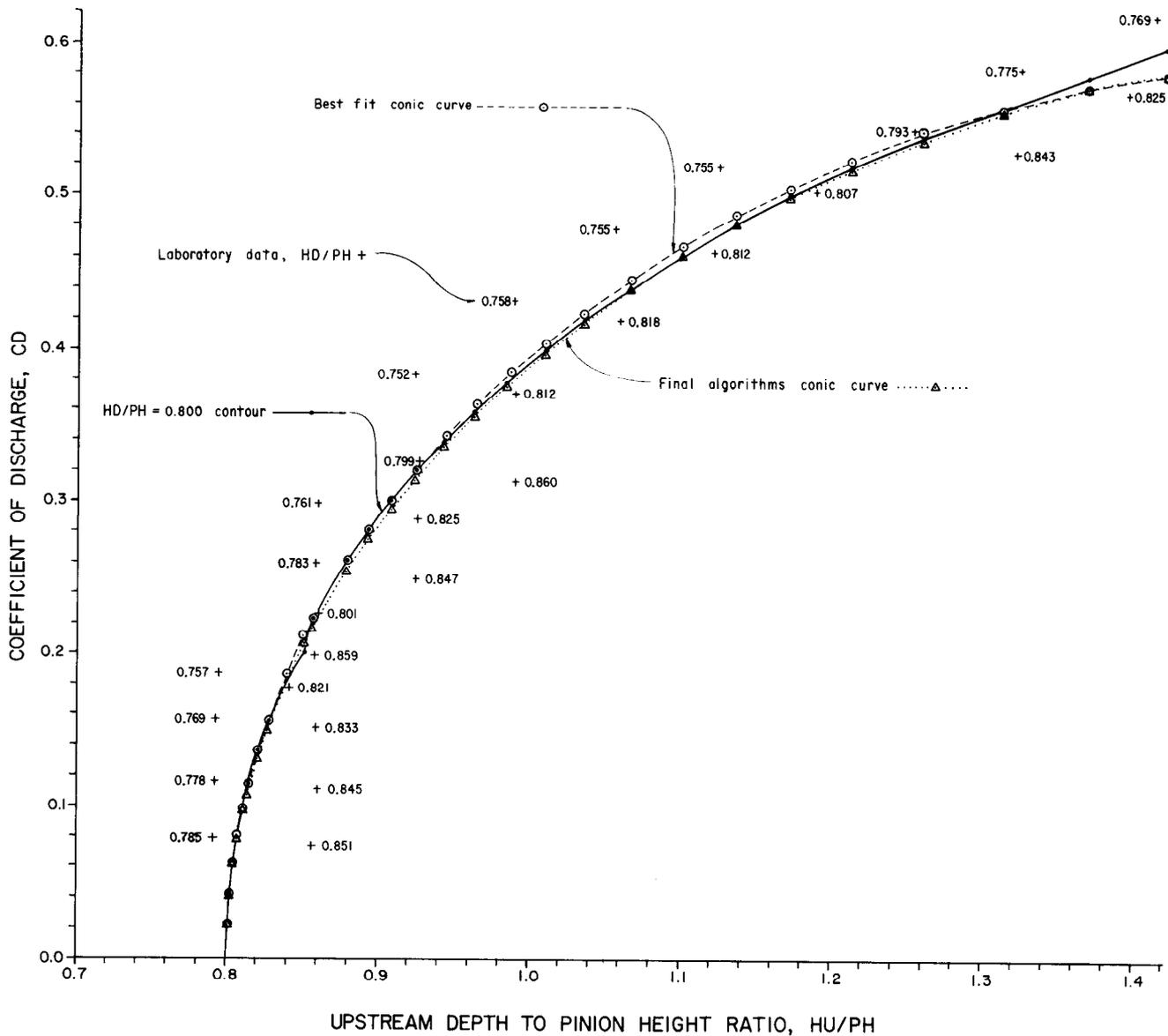
Figure 12—Illustration of the conic curve application to the submerged flow data at one even contour, HD/PH = 0.800, using model No. 1 data at GO/PH = 0.200 and data from table 2.

Applying the general conic equation (2) to the even contours of HD/PH for the submerged flow data in figure 6, y becomes the coefficient of discharge, CD, x becomes the upstream depth, HU/PH, and the focus (located on the HU/PH axis) is referenced to the origin by a distance F as shown in figure 11. Solving for CD, the general conic equation (2) becomes:

$$CD = \sqrt{E^2 * [D + (HU/PH - F)]^2 - (HU/PH - F)^2} \quad (3)$$

where:

$$F = HD/PH + \frac{E*D}{1.0 + E}$$

Figure 12 illustrates the application of the general conic equation (3) to one of the even submerged flow contours, HD/PH equal to 0.800, taken from figure 6 as an example. The laboratory submerged flow data (obtained from app. II, model No. 1) surrounding the even HD/PH = 0.800 contour are shown at the "+" points including the associated downstream depth, HD/PH, and are tabulated in table 2, columns 1 through 4, for easy reference. The model-calculated coefficient of discharge, CDM (col. 4), is based on equation (1), with the upstream depth, HU, equal to the head term H. Other physical properties for model No. 1 necessary to solve equation (1) can be found in table 1. Applying

21

Table 2. — *Data support for detailed analysis of the conic curve characteristics of the submerged flow data at one even contour, HD/PH = 0.800, using model No. 1 data at GO/PH = 0.200 (plotted on fig. 12)*

Laboratory data Appendix II, model No. 1 at GO/PH = 0.200				Contour data[2] HD/PH - 0.800		Best fit conic[3]	Devia-tion[4]	Final ALGO's [5]	Devia-tion[6]
Q col. 1	HU/PH col. 2	HD/PH col. 3	CDM[1] col. 4	HU/PH col. 5	CD col. 6	CD col. 7	Percent col. 8	CDA col. 9	Percent col. 10
1.280	0.859	0.808	0.198	0.8000	0.000	0.0000	0.00	[7]0.0000	0.00
.474	.857	.851	.074	.8005	.020	.0209	4.50	.0217	8.57
.481	.791	.785	.078	.8020	.040	.0423	5.75	.0420	4.88
.718	.792	.778	.116	.8042	.060	.0613	2.17	.0604	.63
.716	.860	.845	.111	.8071	.080	.0797	- .38	.0783	-2.18
.971	.859	.833	.151	.8110	.100	.0991	- .90	.0972	-2.83
.969	.793	.769	.156	.8154	.120	.1171	-2.42	.1148	-4.33
1.159	.794	.757	.187	.8201	.140	.1336	-4.57	.1309	-6.50
1.144	.859	.821	.177	.8281	.160	.1576	-1.50	.1543	-3.56
1.457	.861	.801	.226	.8392	.180	.1855	3.06	.1816	.89
1.672	.859	.783	.259	.8513	.200	.2114	5.70	.2070	3.50
1.669	.925	.847	.249	.8564	.220	.2212	.54	.2167	-1.50
1.915	.926	.825	.286	.8665	.240	.2395	- .21	.2346	-2.25
1.918	.859	.761	.298	.8786	.260	.2593	- .27	.2541	-2.27
2.165	.927	.799	.323	.8926	.280	.2801	.04	.2746	-1.93
2.163	.991	.860	.312	.9075	.300	.3003	.10	.2945	-1.83
2.577	.991	.812	.371	.9248	.320	.3217	.53	.3156	-1.38
2.567	.924	.752	.384	.9437	.340	.3429	.85	.3366	-1.00
2.989	.990	.758	.432	.9631	.360	.3629	.81	.3564	-1.00
2.995	1.059	.818	.419	.9850	.380	.3835	.92	.3768	- .84
3.414	1.122	.812	.463	1.0094	.400	.4044	1.10	.3977	- .58
3.414	1.056	.755	.478	1.0353	.420	.4246	1.10	.4179	- .50
3.828	1.190	.807	.504	1.0656	.440	.4461	1.39	.4394	- .14
3.823	1.124	.755	.518	1.0986	.460	.4670	1.52	.4606	.13
4.239	1.254	.793	.544	1.1318	.480	.4859	1.23	.4798	- .04
4.239	1.322	.843	.530	1.1683	.500	.5044	.88	.4988	- .24
4.680	1.397	.825	.569	1.2107	.520	.5232	.62	.5188	- .23
4.683	1.325	.775	.585	1.2608	.540	.5423	.43	.5384	- .30
5.078	1.393	.769	.619	1.3133	.560	.5588	- .21	.5562	- .68
5.100	1.453	.806	.608	1.3665	.580	.5722	-1.34	.5712	-1.52
5.519	1.512	.802	.645	1.4219	.600	.5830	-2.83	.5839	-2.68

[1]Calculated from equation (1) using HU for the head term H.
[2]Developed from contour mapping computer programs.
[3]Eccentricity, E = 0.6567, directrix, D = 0.6854, F = 1.0717 by trial and error and HD/PH from column 5 using equation (3).
[4][(col. 7 - col. 6)/col. 6]*100.0. Average deviation = +0.60 percent and the standard deviation = ±2.25 percent.
[5]Eccentricity, E = 0.7058, directrix, D = 0.6094, F = 1.0521 by final algorithms and HD/PH from column 5 using equation (3).
[6][(col. 9 - col. 6)/col. 6]*100.0. Average deviation = -0.70 percent, and the standard deviation = ±2.78 percent.
[7]Used F equal to 1.052149.

available library contour mapping computer programs to the laboratory data, the HU/PH and CD (x and y) coordinates were obtained for the even 0.800 HD/PH contour. The results are shown as the solid line on figure 12 and are tabulated in table 2 in columns 5 and 6.

By trial and error, using a specially developed program for this purpose, it was determined that an eccentricity, E, of 0.6567, a directrix, D, of 0.6854, with a distance, F, of 1.0717 would provide the best conic curve fit to the 0.800 HU/PH

contour. The best fit was based on achieving the smallest actual standard deviation between the conic fit and the contour data. Using the above best fit E, D, and F values in equation (3), CD was calculated (using the same values of HU/PH tabulated in column 5 for the even contour). The results are tabulated in column 7 and shown as the dashed line with circles at the plotted data points on figure 12.

Column 8 of table 2 is a calculation of the percent deviation between the contour and the best fit

22

conic curve data. A statistical analysis of the deviation yielded an average error of +0.60 percent and a standard deviation of ±2.25 percent, which was considered to be good. Further analysis indicated the conic curve could be fitted to each of the HD/PH contours for the submerged flow data with the same degree of accuracy, leading to the conclusion that all the contours have definite conic characteristics. Therefore, the general conic equation (3) was adopted as the basic algorithm to represent the submerged flow discharge characteristics of the canal radial gate check structures.

As a matter of interest at this point, the final algorithms, which will be discussed next, yielded an eccentricity, E, of 0.7058, a directrix, D, of 0.6094, with the distance, F, at HU/PH = 1.0521. Using these final E, D, and F values in equation (3), the coefficient of discharge CDA was calculated (using the same values of HU/PH tabulated in column 5, table 2). The results are tabulated in column 9 and shown as the dotted line with triangles at the plotted data points of figure 12. Column 10 lists the percent deviation between the contour and the final algorithm data. Statistical analysis of the deviation, column 10, produced an average error of –0.70 percent and a standard deviation of ±2.78 percent. The slightly larger error and standard deviation are caused by expressing the E and D values as a function of radius, RAD/PH, gate opening, GO/PH, and downstream depth, HD/PH, which reduce the resolution of the best fit conic curve.

Hard-Rubber-Bar Gate Lip Seal Design, Models No. 1, 2, and 3

Discharge algorithms for submerged and free flow conditions are based on the canal radial gate model with the hard-rubber-bar gate lip seal design, models No. 1, 2, and 3. Laboratory data used for the development of the algorithms are included in appendixes I and II and the physical properties are listed in table 1. Extensive trial and error processes were employed to obtain the best fit conic curves to the laboratory experimental data. No attempt is made in this report to describe the trial and error procedures used. However, the systematic development with sufficient data is presented to establish the basis for selecting the final series of algorithms. Straight-line functions were used to fit the parameters of the general conic equation 3 whenever possible. Conic curve functions were used to fit the parameters when substantial improvement in the accuracy was achieved. Also, heavier emphasis was placed on achieving a better fit for the normal range of the canal radial gate operations, which for example, would be the center area of the "map" shown on

figure 6. Therefore, the edges of the map would not necessarily have the minimal deviation that could have been achieved.

Submerged flow.—Analytical development of the algorithms began with the submerged flow conditions for model No. 1. Continuing with the use of figure 6 as an example, the best fit eccentricity, E, and directrix, D, for the conic curve equation (3) were determined for each of the downstream depth, HD/PH, contours by trial and error. The results are plotted on figure 13.

It was discovered that the directrix, D, on figure 13 could be transformed by the algorithm:

$$DR = \frac{1.0}{D^{0.7}}$$

which yields a good linear relationship as a function of the HD/PH contours as shown on figure 14. The transformed directrix, DR, could now be fitted with a straight line algorithm with minimal deviation. A new directrix, D, was calculated based on the algorithm:

$$D = \left(\frac{1.0}{DR}\right)^{1.429}$$

where: DR = AD*HD/PH + BD from figure 14.

The results are plotted on figure 15 as a function of the HD/PH contours. Using the new directrix, D, of figure 15, a new eccentricity, E, was determined for each HD/PH contour by trial and error. The new E is also plotted on figure 15 as a function of the HD/PH contours.

It was also discovered the new eccentricity, E, on figure 15 could be transformed by the algorithm:

$$ER = e^{E^2} * D$$

where: e = 2.7183

The transformed eccentricity, ER, provided a good linear relationship as a function of the directrix, D, as shown on figure 16 and it could also be fitted with a straight line algorithm with good accuracy. The new eccentricity, E, was calculated based on the algorithm:

$$E = \sqrt{\ln\left(\frac{ER}{D}\right)}$$

where: ER = AE*D + BE from figure 16.

The results are shown on figure 15 illustrating the best fit curve to the eccentricity, E, data points.

It was determined by trial and error that considerably less deviation of the conic curve fitting would
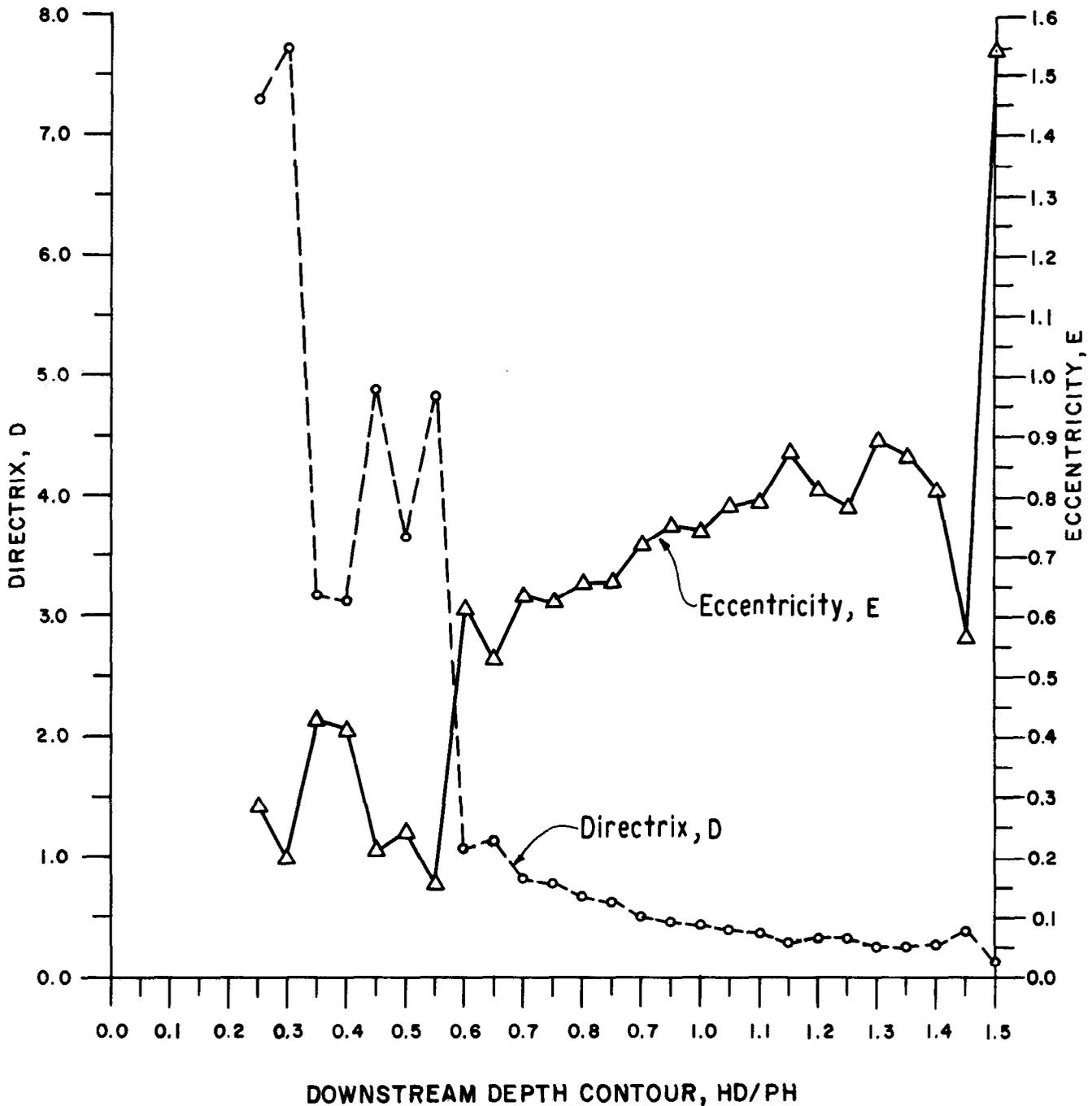
Figure 13.— Best fit eccentricity, E. and directrix, D, determined for the submerged flow downstream depth, HD/PH, contours of figure 6.

result if the focus (fig. 11) was shifted in the positive CD, or y-axis direction, particularly for the lower HD/PH contours. Figure 17 shows the shift of the focus distance, FY, as a function of the HD/PH contours, including best fit straight line and its algorithm. If the focus is shifted, an adjustment, FX, should also be made to the focal distance, F. The final selected algorithms to adjust the F distance by FX are included on figure 17.

At this point in the analytical development of the algorithms, the relationship of (1) the directrix, D, as a function of the HD/PH contours, (2) the eccentricity, E, as a function of the directrix, D, and (3) the focal adjustment FY as a function of the HD/PH contours has been established for the submerged flow conditions for one "map" or one gate opening (GO/PH equal to 0.200 using fig. 6 as an example). The next step determined the relationship of (1) the transformed directrix, DR,

24
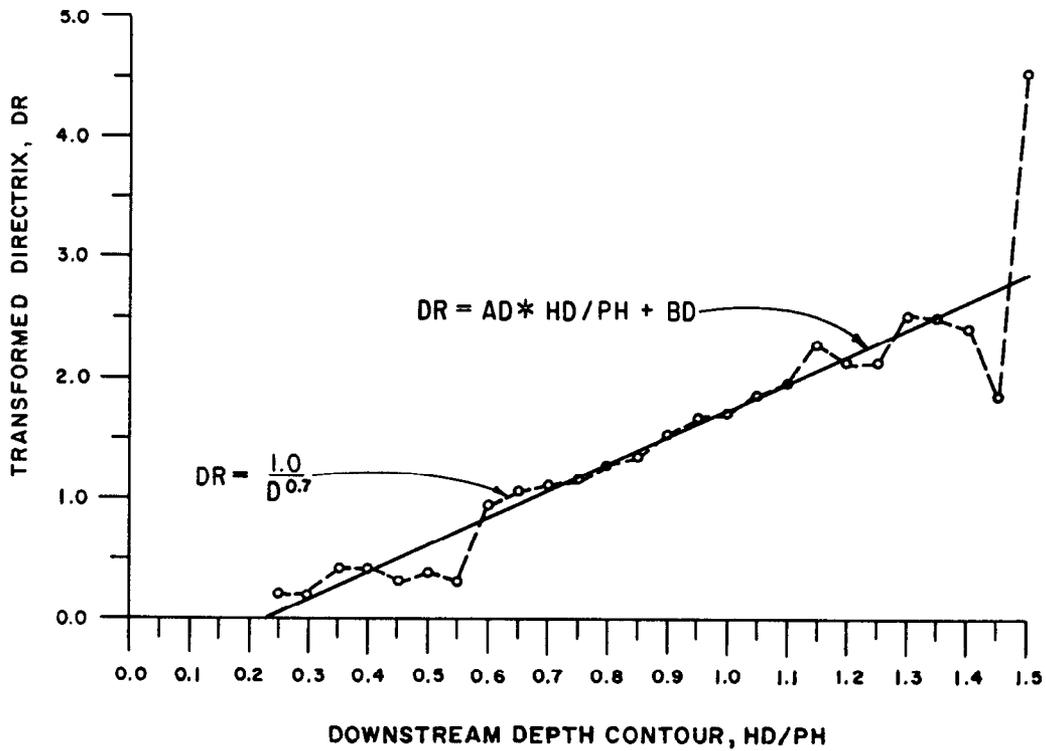
Figure 14.—Transformed directrix, DR, versus the submerged flow HD/PH contours, including the best fit straight line and algorithms.
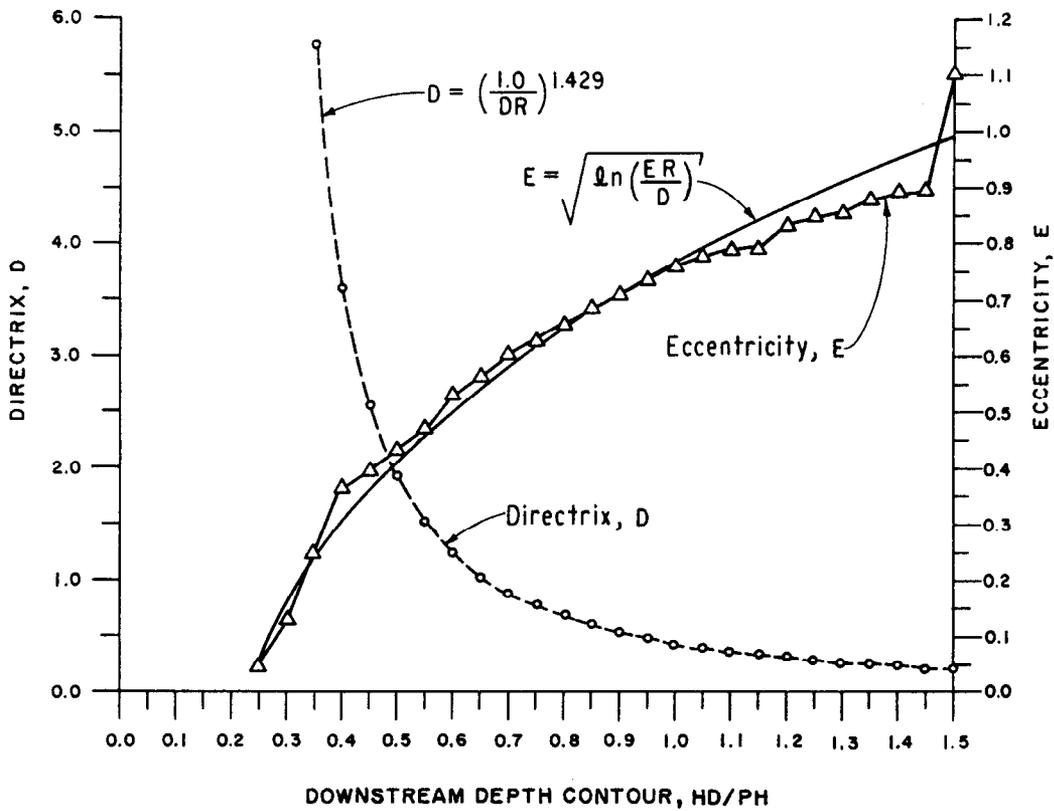
Figure 15.—Directrix, D, based on the transformed directrix, DR, of figure 14 and the new eccentricity, E, versus the submerged flow HD/PH contours, including the best fit eccentricity, E, curve and algorithms based on the transformed eccentricity, ER, of figure 16.

25
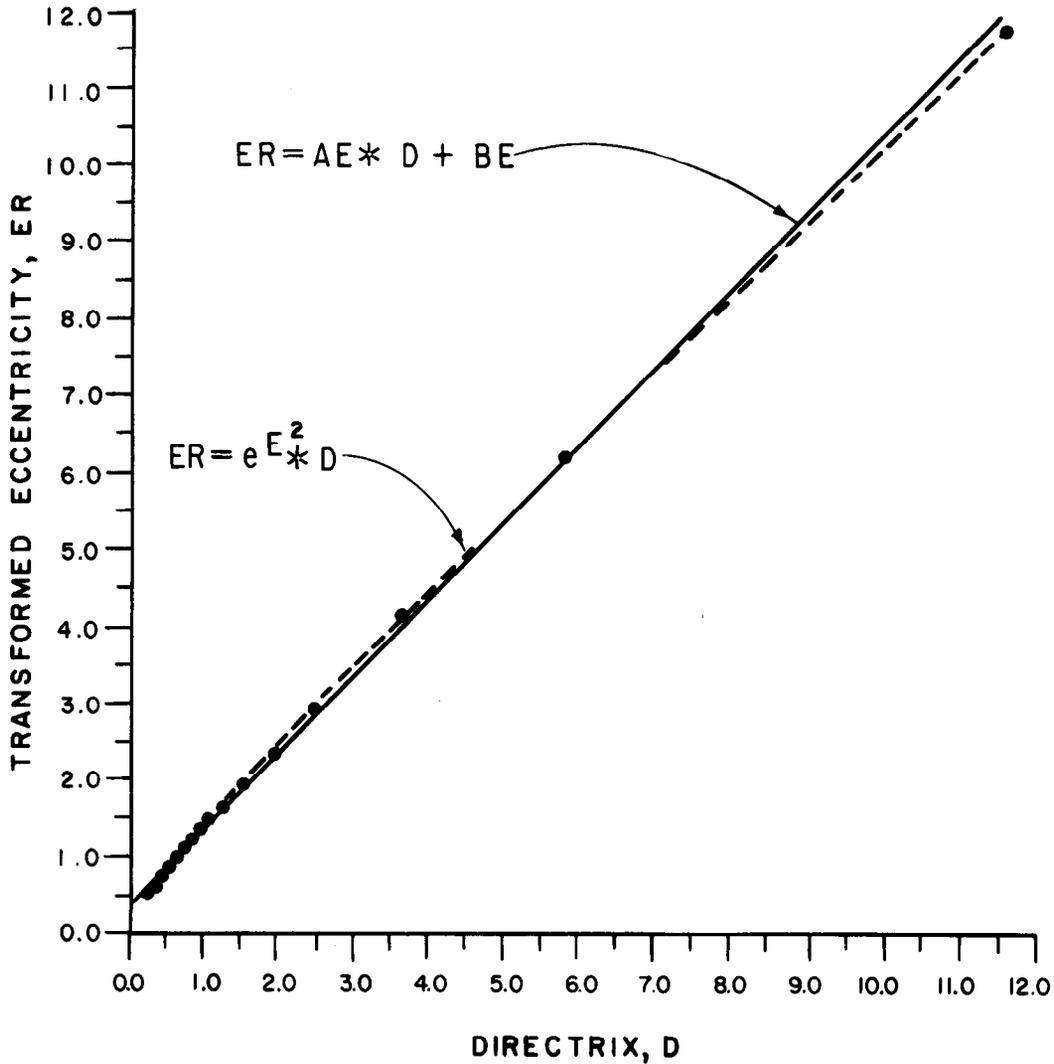
Figure 16.—Transformed eccentricity, ER, versus the directrix, D, for submerged flow, including the best fit straight line and algorithms.

parameters AD and BD (fig. 14), (2) the transformed eccentricity, ER, parameters AE and BE (fig. 16), and (3) the focus distance, FY, parameters AF and BF (fig. 17), as a function of the gate opening, GO/PH.

The results of the transformed directrix, DR, parameters AD and BD, the transformed eccentricity, ER, parameters AE and BE, and the focus distance parameters AF and BF are shown on figures 18, 19, and 20, respectively, as a function of GO/PH, including the selected best fit curves and their algorithms.

Up to this point, conic curves have been fitted to all of the submerged flow data for model No. 1 or for one radius-to-pinion-height ratio, RAD/PH, equal to 1.521. The entire process was repeated for models No. 2 and 3, which have RAD/PH

values of 1.373 and 1.715, respectively. Therefore, the relationship of (1) the directrix parameters ADA, ADB, BDA, and BDB (fig. 18), (2) the eccentricity parameters AEA, AEB, and BEK (fig. 19), and (3) the focus adjustment parameters AFA, AFB, BFA, and BFB (fig. 20) were determined as a function of RAD/PH. The results are shown on figures 21, 22, and 23, respectively, plotted as a function of RAD/PH, including the best fit curves and their algorithms.

Analytical development of the algorithms representing the submerged flow conditions for canal radial gates with the standard hard-rubber-bar gate lip seal design was at this point complete. The final series of algorithms are listed below in the order in which they are used to calculate the submerged flow coefficient of discharge:

26

Submerged Flow Algorithms	Figure No.

Directrix, D:

$$ADA = \frac{1.0}{11.98*RAD/PH-26.7} \qquad 21$$

$$ADB = \frac{-0.276}{RAD/PH} + 0.620 \qquad 21$$

$$AD = \frac{1.0}{ADA*GO/PH+ADB} \qquad 18$$

$$BDA = 0.025*RAD/PH -2.711 \qquad 21$$

$$BDB = -0.033*RAD/PH + 0.071 \qquad 21$$

$$BD = BDA*GO/PH + BDB \qquad 18$$

$$DR = AD*HD/PH + BD \qquad 14$$

$$D = \left(\frac{1.0}{DR}\right)^{1.429} \qquad 15$$

Eccentricity, E:

$$AEA = -0.019*RAD/PH + 0.060 \qquad 22$$

$$AEB = 0.0052*RAD/PH + 0.996 \qquad 22$$

$$AE = \frac{1.0}{AEA*GO/PH+AEB} \qquad 19$$

$$BEK = -0.293*RAD/PH + 0.320 \qquad 22$$

$$BE = \sqrt{\left[1.0 + \frac{(GO/PH-0.44)^2}{0.7}\right]*0.255} + BEK \qquad 19$$

$$ER = AE * D+BE \qquad 16$$

$$E = \sqrt{\ln\left(\frac{ER}{D}\right)} \qquad 15$$

Vector V1:

$$V1 = \frac{E*D}{1.0+E} \qquad 17$$

Focal Distance, FY:

$$AFA = \frac{-0.158}{RAD/PH} + 0.038 \qquad 23$$

$$AFB = -0.115*RAD/PH + 0.290 \qquad 23$$

$$AF = AFA*GO/PH+AFB \qquad 20$$

$$BFA = \frac{0.0445}{RAD/PH} -0.321 \qquad 23$$

$$BFB = \frac{-0.092}{RAD/PH} +0.155 \qquad 23$$

$$BF = \frac{BFA}{GO/PH} +BFB \qquad 20$$

$$FY = -AF*HD/PH+BF \qquad 17$$

$$IF\ FY<0.0,\ FY = 0.0\ and\ FX = 0.0 \qquad 17$$

$$IF\ FY>0.0,\ FX = \sqrt{V1^2 + FY^2} - V1 \qquad 17$$

The general conic algorithm for calculating the submerged flow coefficient of discharge is as follows:

$$SCDA = \sqrt{E^2*(D+VX)^2 - VX^2} + FY \qquad (4)$$

where: SCDA = the Submerged flow Coefficient of Discharge calculated by Algorithms

$$VX = HU/PH-(V1+HD/PH+FX)$$
equal to the horizontal x distance shown on figure 11

V1+HD/PH = the F distance shown on figure 11

To solve for the submerged discharge, QST, of the canal radial gate, the following algorithm is used when the gate opening is known:

$$QST = SCDA*GOS*GW*\sqrt{2*GC*HU} \qquad (5)$$

where:

GOS = submerged gate opening (vertical distance)
GW = gate width
GC = gravitational constant
HU = upstream depth measured from the gate sill datum to the water surface, figure 1

The same equation (5) is used to solve for the submerged gate opening, GOS, when the submerged discharge, QST, is known.

Free flow.—Because the application of the general conic equation (2) to the submerged conditions produced excellent results, its application to the free flow laboratory experimental data was continued. An initial analysis indicated conic curve fitting to the free flow data would achieve good results. The application of the general conic equation (2) is illustrated on figure 24 for the free flow data (again using fig. 6 as an example). The
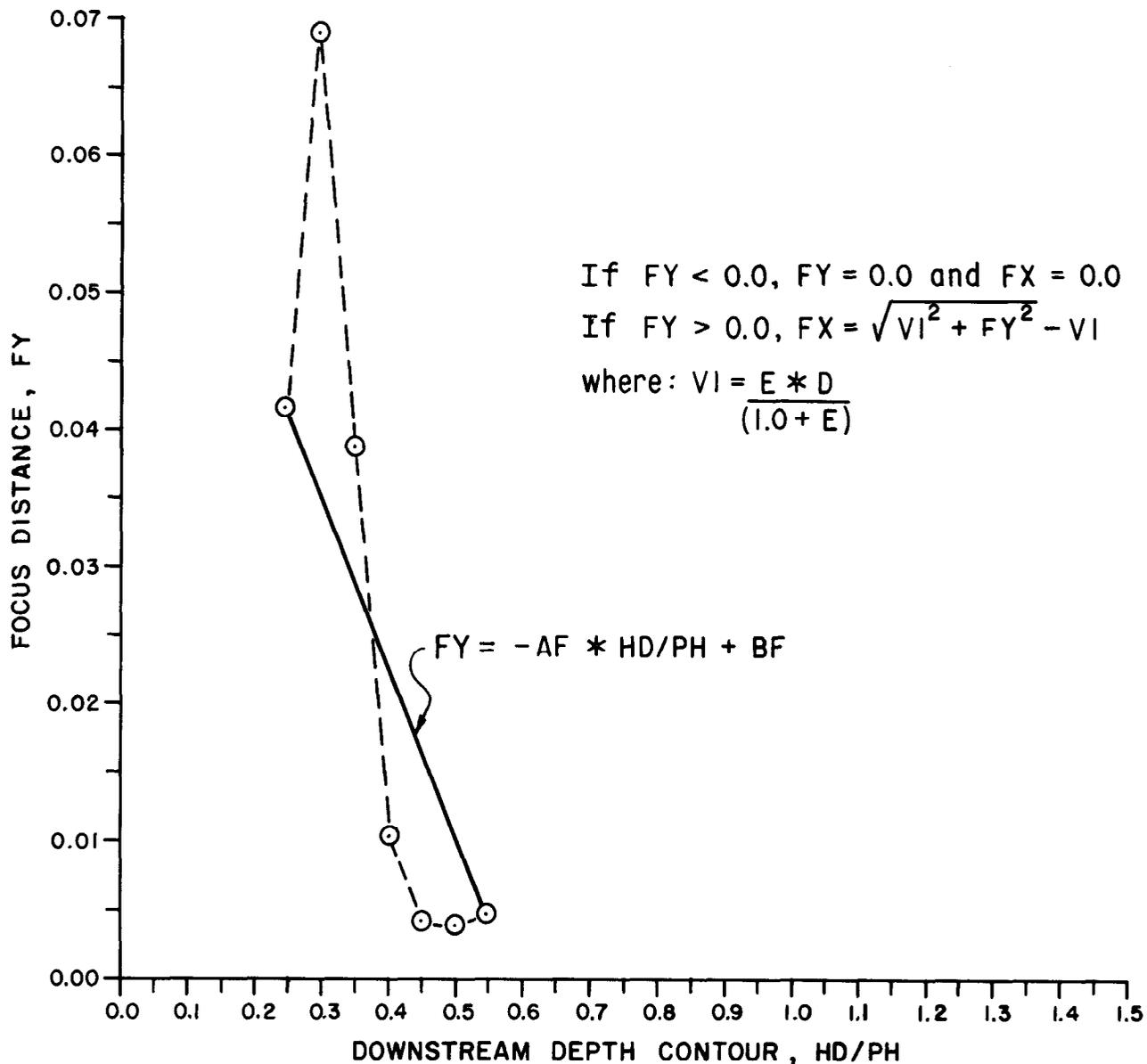
Figure 17.—Focus distance, FY, versus the submerged flow HD/PH contours, including the best fit straight line and algorithms.

The equations in the figure:

$$\text{If } FY < 0.0, \ FY = 0.0 \text{ and } FX = 0.0$$
$$\text{If } FY > 0.0, \ FX = \sqrt{VI^2 + FY^2} - VI$$
$$\text{where: } VI = \frac{E * D}{(1.0 + E)}$$

$$FY = -AF * HD/PH + BF$$

free flow data (obtained from app. II for model No. 1 at GO/PH = 0.200 and tabulated in cols. 1, 2, and 3 of table 3 for easy reference) is plotted in figure 24 at the circled points. The coefficient of discharge, CDM, column 3, was calculated using equation (1), with the upstream depth, HU, as the head term H.

The best fit conic to the free flow data points on figure 24 determined (by trial 'and error) the eccentricity, FE, and the directrix, FD, to be 0.949 and 0.1324, respectively, with the focus located at FX1 = 0.05 and FY1 = 0.28. The calculated best fit coefficient of discharge, CD, tabulated in column 4 of table 3 (using the above best fit values of FE, FD, FX1, and FY1 at the same laboratory data values of HU/PH tabulated in column

2) is based on the following general conic equation:

$$CD = \sqrt{FE^2*(FD+(HU/PH-FX1)\ )^2-(HU/PH-FX1)^2} + FY1 \qquad (6)$$

The best fit conic curve data columns 2 and 4 are plotted on figure 24 and are shown as the solid line, demonstrating a satisfactory curve fitting through the laboratory data points.

Statistical analysis of the percent deviation between the laboratory and best fit conic coefficient of discharges (cols. 3 and 4) tabulated in column 5 produced an average error of –0.14 percent and a standard deviation of ±1.17 percent. The small error and standard deviation

28

PARAMETER, AD

4.0

3.0

2.0

$$AD = \frac{1.0}{ADA * GO/PH + ADB}$$

1.0

0.0

$$BD = BDA * GO/PH + BDB$$

-1.0

PARAMETER, BD

-2.0

-3.0

-4.0

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2

GATE OPENING, GO/PH
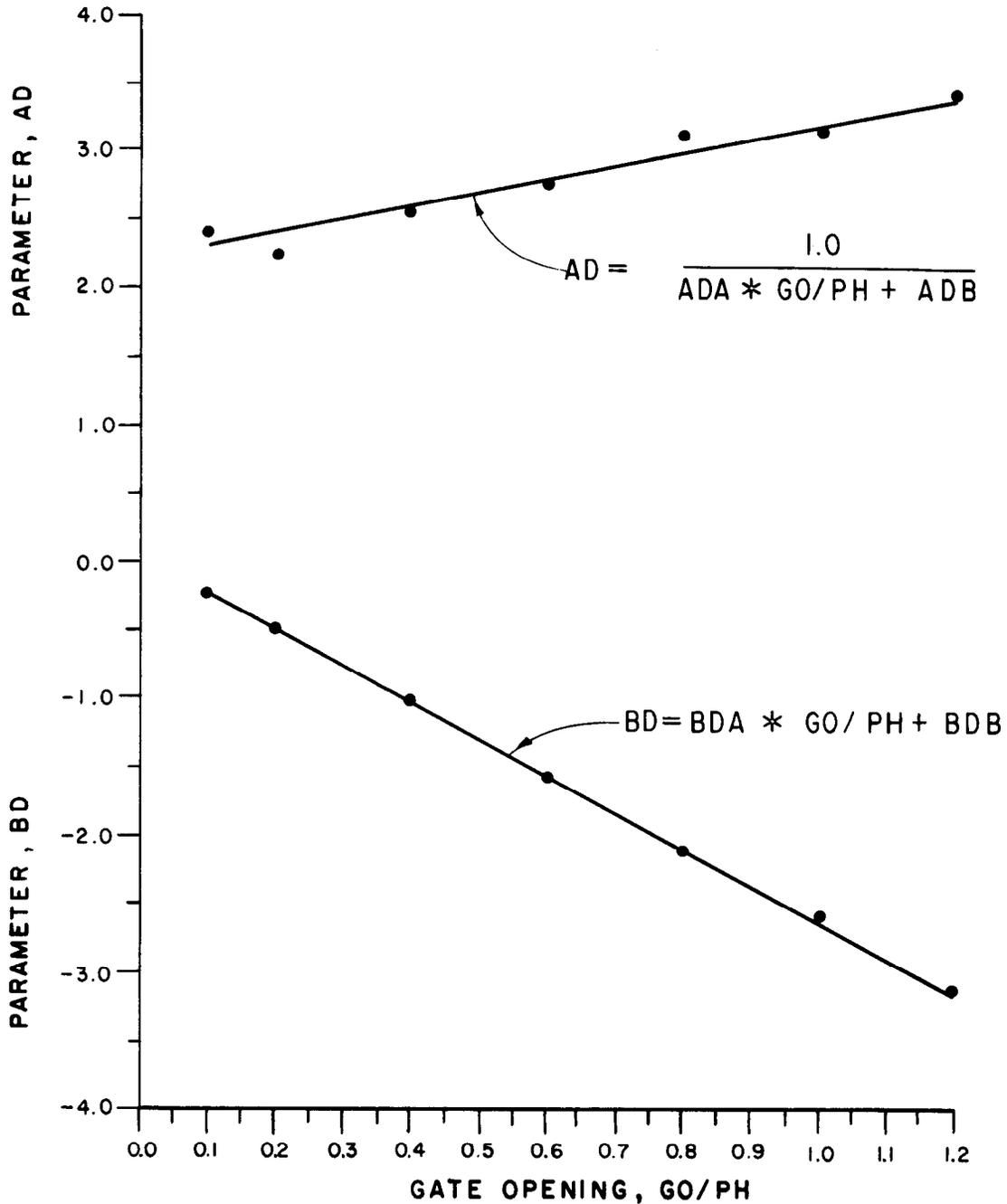
Figure 18.—The directrix parameters, AD and BD, versus the submerged flow GO/PH, including the best fit straight lines and algorithms.

were considered to be an indication that excellent agreement of conic curve fitting could be achieved.

As a matter of interest at this time, the final free flow algorithms calculated an eccentricity, FE, and a directrix, FD, of 0.950 and 0.1340, respectively, with FX1 = 0.011 and FY1 = 0.271. Using these values of FE, FD, FX1, and FY1 in equation (6) at the same laboratory values of HU/PH,

column 2, the calculated coefficient of discharge, CDA, is tabulated in column 6 of table 3. Statistical analysis of the percent deviation between the laboratory and the final algorithm coefficients of discharge, columns 3 and 6 and tabulated in column 7, produced an average error of +0.12 percent and a standard deviation of ±1.05 percent. The final algorithms resulted in a slightly better agreement than the best fit conic in this example. The conic curve produced by the final

29

$$AE = \frac{1.0}{AEA*GO/PH+AEB}$$

$$BE = \sqrt{\left[1.0+ \frac{(GO/PH-0.44)^2}{0.7}\right]*0.255} \ +BEK$$
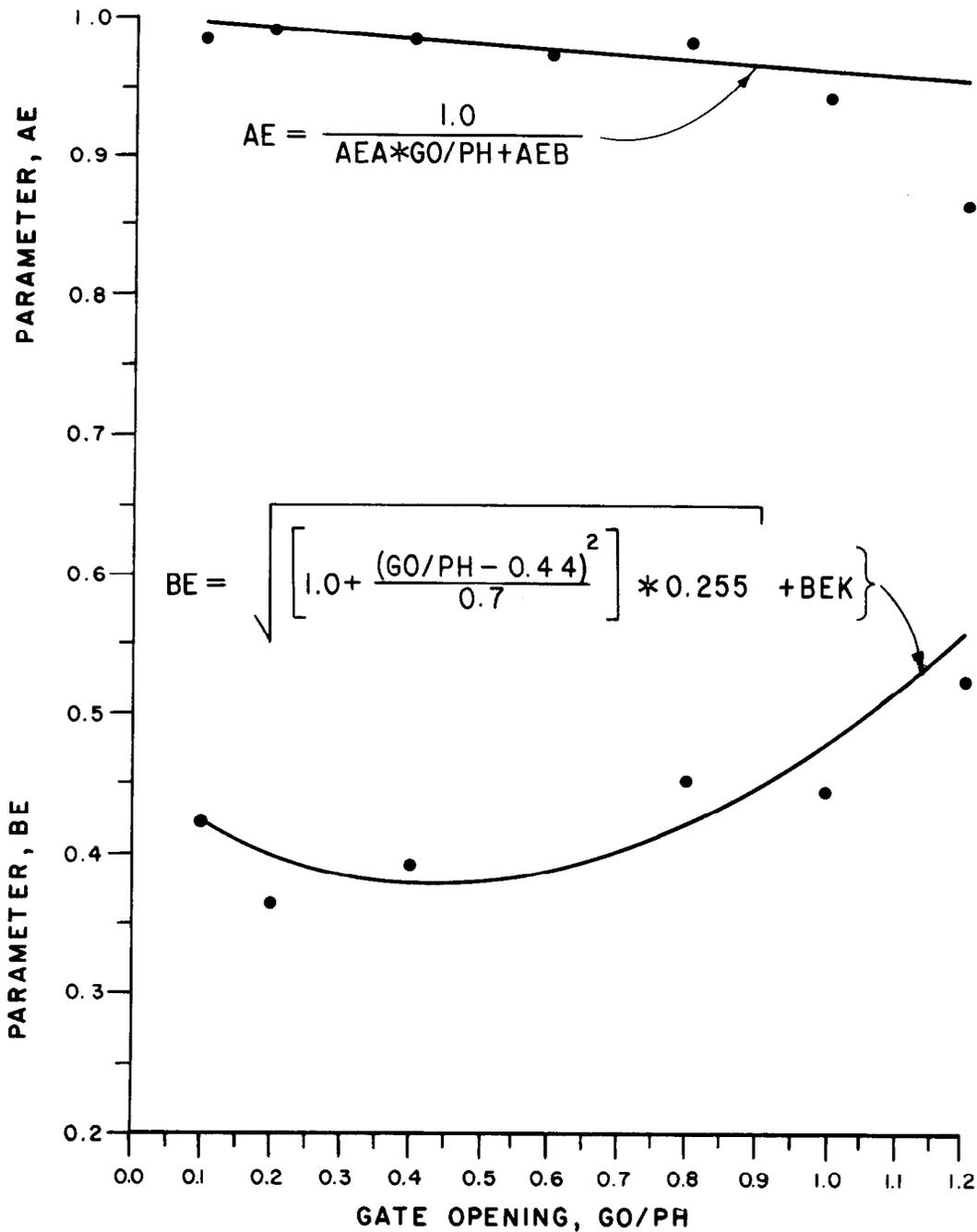
Figure 19.—Eccentricity parameters, AE and BE, versus the submerged flow GO/PH, including the best fit lines and algorithms.

algorithms (cols. 2 and 6, table 3) is not plotted in figure 24 because it is essentially the same as the solid line.

Figure 24 represents a best fit conic curve to the free flow data for GO/PH = 0.200 as a function of the upstream depth, HU/PH. The conic curve application to the free flow data is somewhat simplified because free flow of the radial gate is not controlled by the downstream depth, HD/PH.

Therefore, the next step is to determine the FE, FD, FX1, and FY1 for each of the gate openings, GO/PH, for model No. 1 by trial and error.

Results of the best fit FE and FD values are plotted in figure 25 as a function of GO/PH, showing the best fit curves and their algorithms. It should be noted the laboratory data for the free flow conditions are limited to GO/PH values of 0.1, 0.2, 0.4, and 0.6. The laboratory water supply capacity
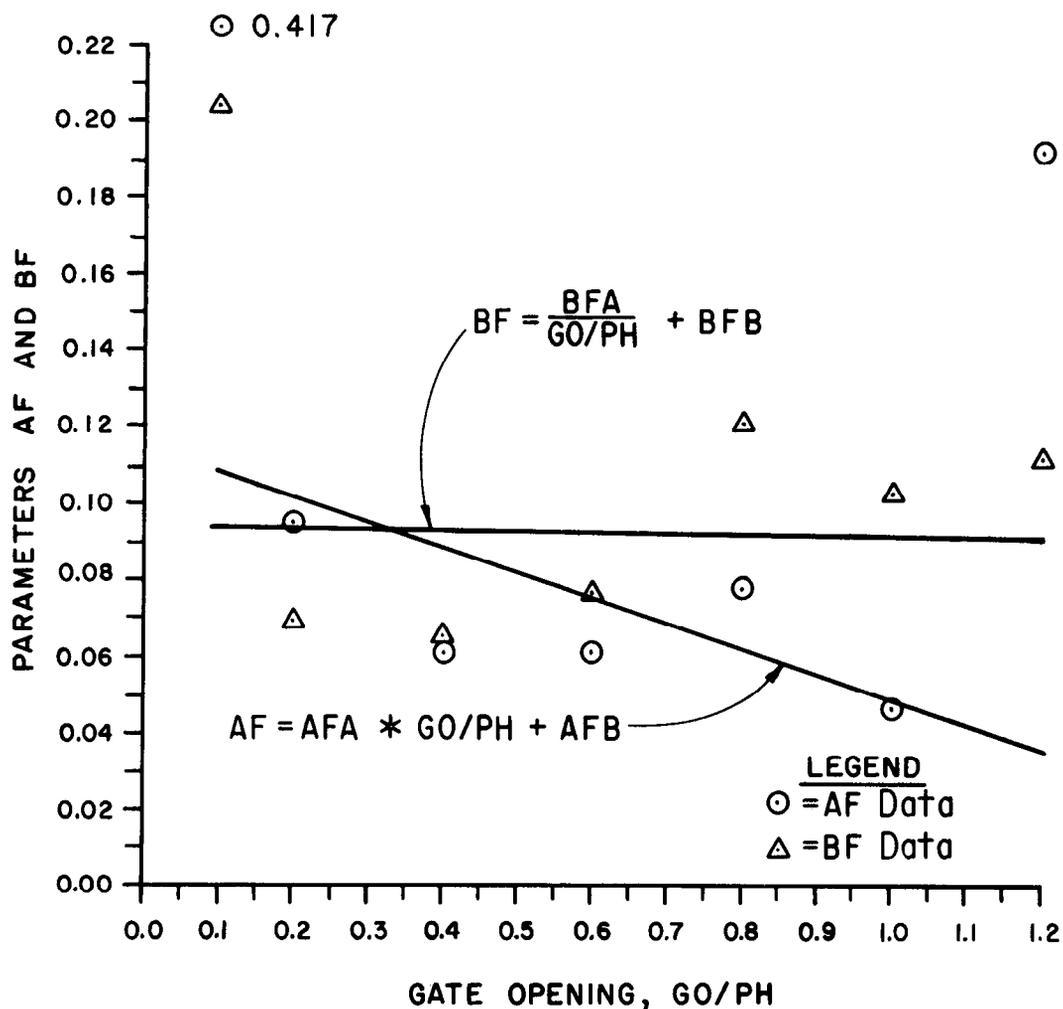
Figure 20.—Focal distance parameters, AF and BF, versus the submerged flow GO/PH, including the best fit straight lines and algorithms.

was not sufficient to obtain free flow conditions for GO/PH values of 0.8 and above. Results of the best fit FX1 and FY1 as a function of GO/PH are shown in figure 26. The best fit curves and their algorithms, however, are not the best fit for model No. 1, but represent the average fit for all the models No. 1, 2, and 3 data. The FX1 and FY1 values did not significantly change with the different RAD/PH values. Therefore, the results were averaged.

Up to this point the conic curves have been fitted to establish the relationship of the eccentricity, FE, and the directrix, FD, for all the data of model No. 1 for one radius-to-pinion-height ratio, RAD/PH, as a function of the gate opening, GO/PH. The entire process was repeated to determine the relationship of the eccentricity parameters AFE and BFE and the directrix

parameters AFD and BFD of figure 25 as a function of the RAD/PH for the data of models No. 2 and 3. The results, including the best fit curves and their algorithms, are shown on figures 27 and 28.

As mentioned above, it was not necessary to determine the relationship of the focus distances, FX1 and FY1, as a function of RAD/PH, thereby eliminating the need for four more algorithms.

Analytical development of the algorithms representing the free flow conditions for canal radial gates with the standard hard-rubber-bar gate lip seal design was at this point complete. The final series of algorithms are listed below in the order they are used to calculate the free flow coefficient of discharge:

31
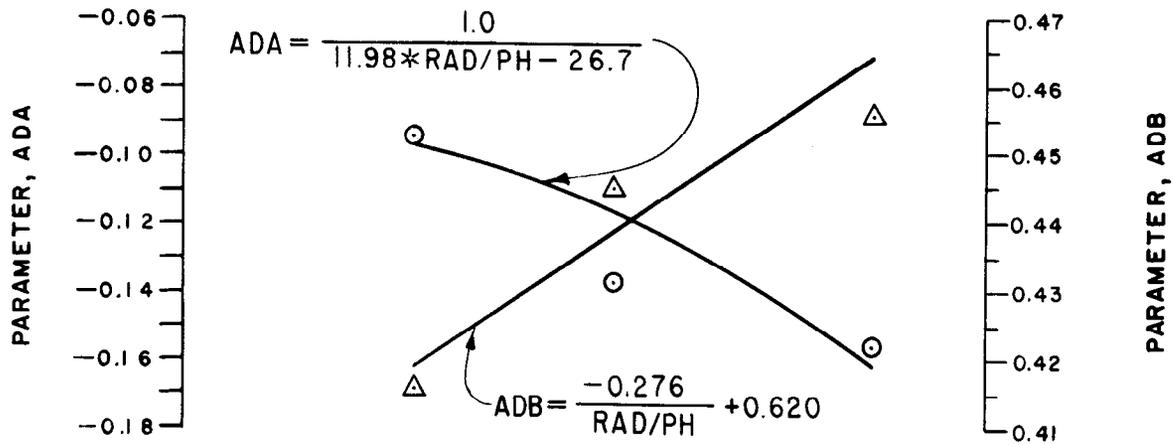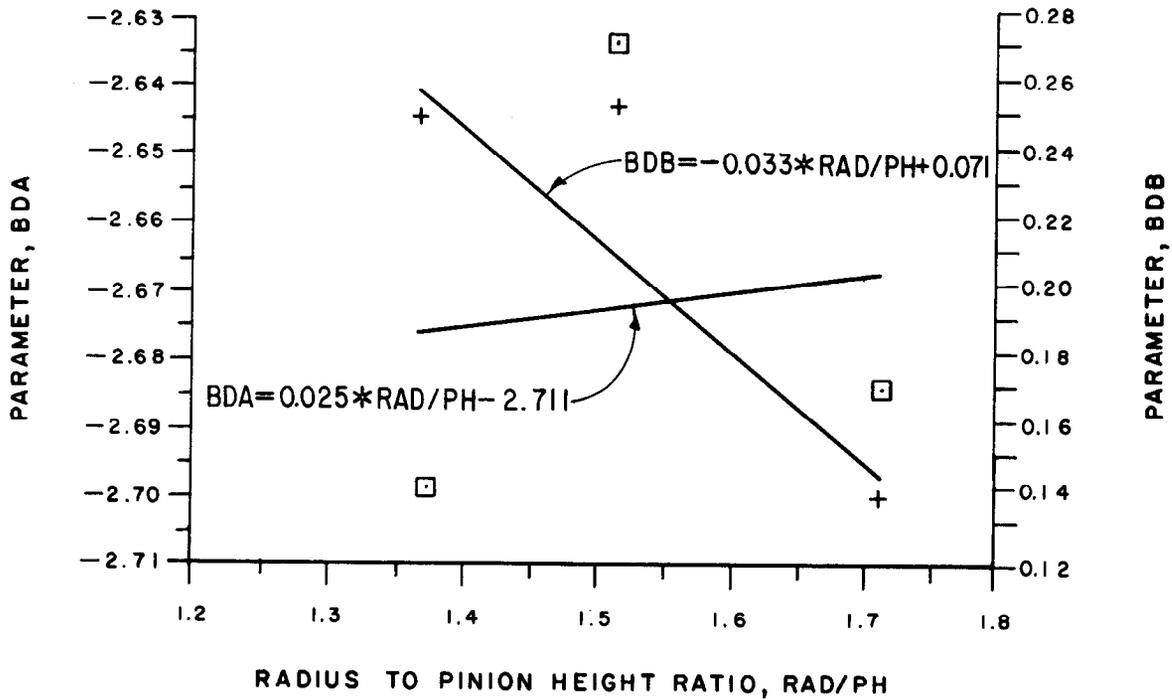
Figure 21.—Directrix parameters, ADA, ADB, BDA, and BDB, versus RAD/PH for submerged flow, including the best fit lines and algorithms.
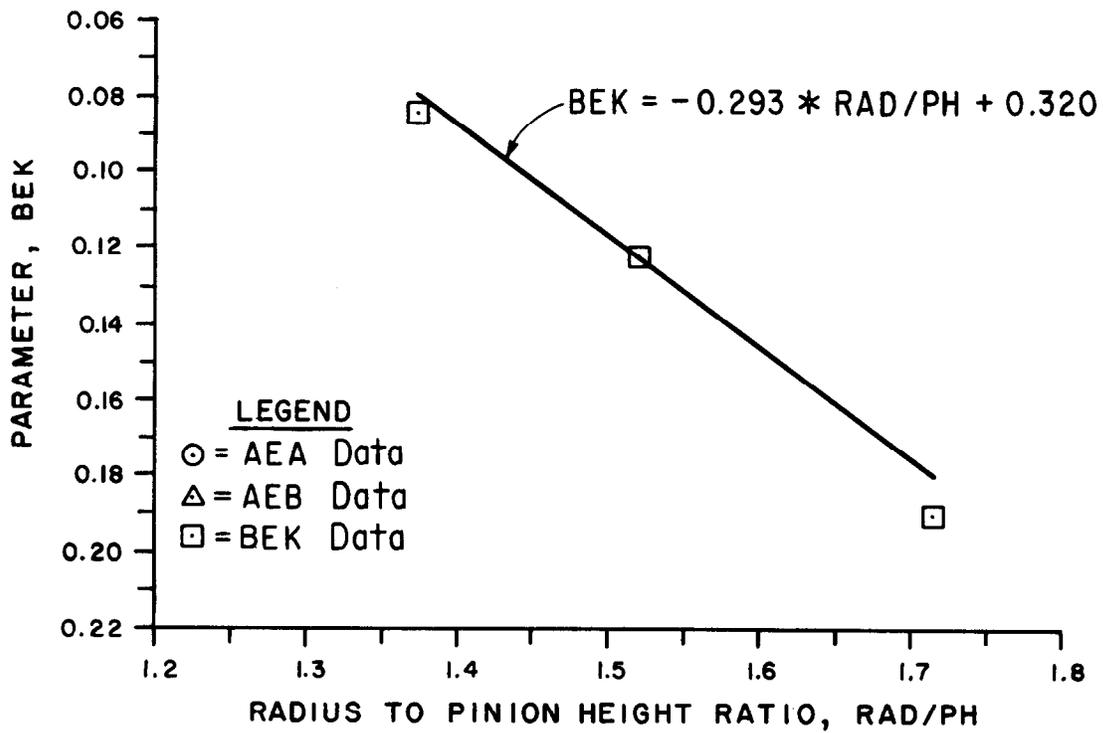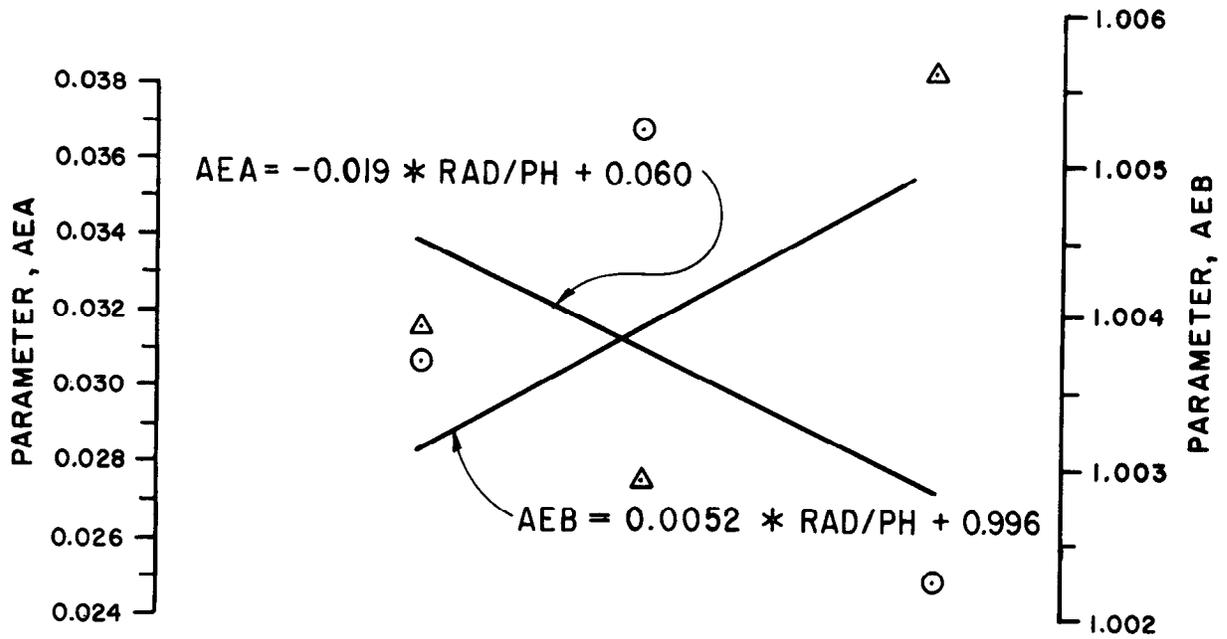
Figure 22.—Eccentricity parameters, AEA, AEB, and BEK, versus RAD/PH for submerged flow, including the best fit lines and algorithms.

Figure 23.—Focal distance parameters, AFA, AFB, BFA, and BFB, versus RAD/PH for submerged flow, including the best fit lines and algorithms.

The equations shown in the figure are:

$$AFA = \frac{-0.158}{RAD/PH} + 0.038$$

$$AFB = -0.115 * RAD/PH + 0.290$$

$$BFA = \frac{0.0445}{RAD/PH} - 0.321$$

$$BFB = \frac{-0.092}{RAD/PH} + 0.155$$
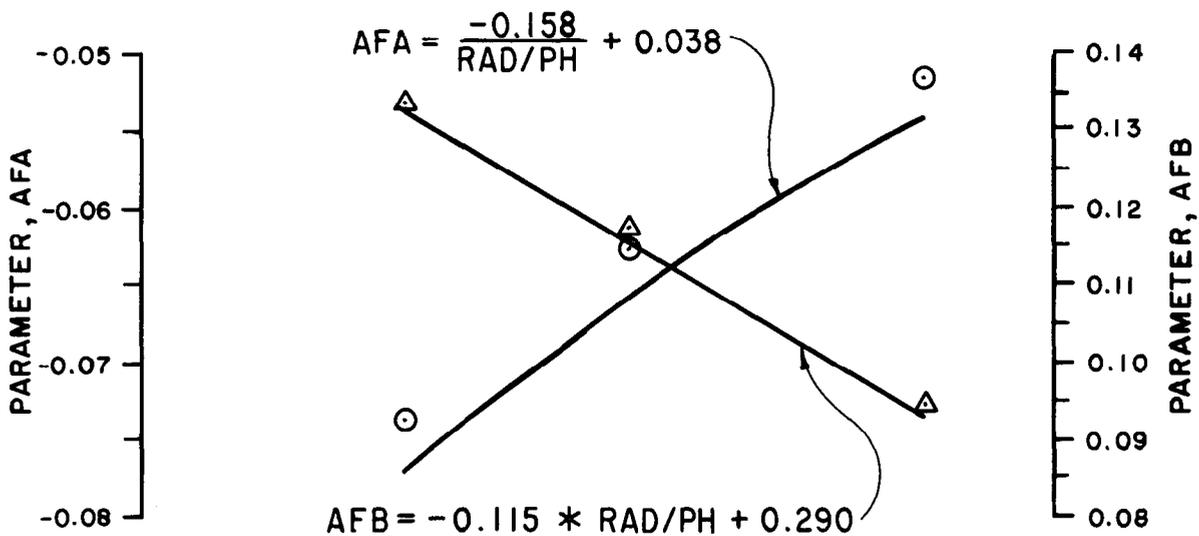
LEGEND
⊙ = AFA Data
△ = AFB Data
□ = BFA Data
+ = BFB Data
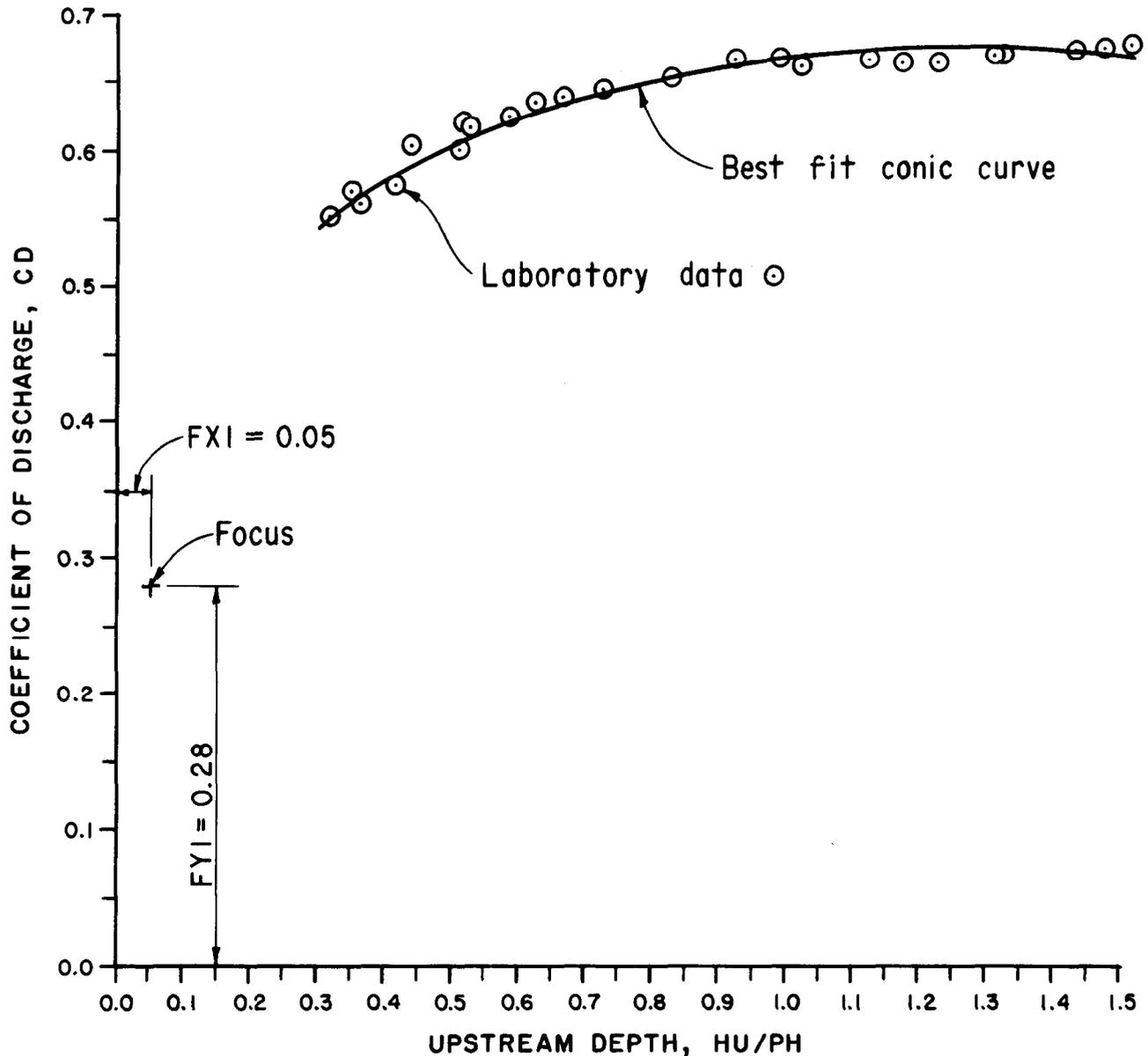
Figure 24.—Illustration of the conic curve application to the free flow data for one gate opening, GO/PH=0.200, using model No. 1 data and data from table 3.

Free Flow Algorithms	Figure No.

Eccentricity, FE:

$$AFE = \sqrt{(1.0+(RAD/PH-1.60)^2*31.2)*0.00212} \quad +0.901 \qquad 27$$

$$BFE = \sqrt{(1.0+(RAD/PH-1.635)^2*187.7)*0.00212} \quad -0.079 \qquad 27$$

$$FE = AFE - BFE*GO/PH \qquad 25$$

Directrix, FD:

$$AFD = 0.788 \quad - \sqrt{(1.0+(RAD/PH-1.619)^2*89.2)*0.04} \qquad 28$$

	Figure No.

$$BFD = 0.0534*RAD/PH + 0.0457 \qquad 28$$

$$FD = 0.472 - \sqrt{(1.0-(GO/PH-AFD)^2)*BFD} \qquad 25$$

Focal Distance, FX1:

IF GO/PH $\leq$ 0.277,
$$FX1 = 1.94*GO/PH - 0.377 \qquad 26$$

IF GO/PH $>$ 0.277,
$$FX1 = 0.180*GO/PH + 0.111 \qquad 26$$

Focal Distance, FY1:

$$FY1 = 0.309 - 0.192*GO/PH \qquad 26$$

35

Table 3. — Data support for detailed analysis of the conic curve application to the free flow data for one gate opening, GO/PH = 0.200, using model No. 1 data (plotted on fig. 24)

Q	Laboratory data Appendix II, model No. 1 at GO/PH = 0.200 HU/PH	CDM[1]	Best fit conic[2] CD	Devia- tion[3] percent	Final ALGO's[4] CDA	Devia- tion[5] percent
col. 1	col. 2	col. 3	col. 4	col. 5	col. 6	col. 7
2.360	0.352	0.570	0.5606	-1.65	0.5665	-0.61
3.100	.516	.619	.6046	-2.33	.6079	-1.79
3.650	.668	.640	.6338	-.97	.6357	-.67
4.170	.829	.656	.6558	-.30	.6568	.12
4.650	.992	.669	.6702	.18	.6706	.24
5.040	1.173	.667	.6778	1.62	.6780	1.65
5.370	1.310	.672	.6781	.91	.6783	.94
5.740	1.477	.677	.6720	-.74	.6726	-.65
5.807	1.516	.678	.6696	-1.24	.6702	-1.15
5.612	1.430	.675	.6745	-.07	.6749	-.01
5.374	1.322	.672	.6779	.88	.6781	.91
5.134	1.225	.667	.6785	1.72	.6786	1.74
4.930	1.124	.669	.6766	1.14	.6767	1.15
4.666	1.022	.663	.6720	1.36	.6723	1.40
4.459	.922	.668	.6649	-.46	.6655	-.37
4.144	.825	.656	.6554	-.09	.6563	.05
3.820	.725	.645	.6426	-.37	.6441	-.14
3.500	.626	.636	.6267	-1.46	.6289	-1.12
3.110	.525	.617	.6066	-1.69	.6087	-1.34
2.978	.510	.600	.6032	.53	.6066	1.10
2.163	.319	.551	.5497	-.24	.5564	.98

[1] Calculated from equation (1) using HU for the head term H.
[2] Eccentricity, FE = 0.949; directrix, FD = 0.1324; focus at HU/PH = FX1 = 0.05; and at CD = FY1 = 0.28 by trial and error using HU/PH from column 2 and equation (6).
[3] ((col. 4 - col. 3)/col. 3)*100.0 average deviation = -0.14 percent and the standard deviation = ±1.17 percent.
[4] Eccentricity, FE = 0.950; directrix, FD = 0.1340; focus at HU/PH = FX1 = 0.011 and at CD = 0.271 by final algorithms using HU/PH from column 2 and equation (6).
[5] ((col. 6 - col. 3)/col. 3)*100.0 average deviation = +0.12 percent and the standard deviation = ±1.05 percent.

The general conic equation for calculating the free flow coefficient of discharge is as follows:

$$FCDA = \sqrt{FE^2*(FD+FXV)^2 - FXV^2} + FY1 \qquad (7)$$

where:

FCDA = the Free flow Coefficient of Discharge calculated by Algorithms

FXV = HU/PH – FX1 equal to the horizontal x distance shown on figure 11

To solve for the free flow discharge, QFT, of the canal radial gate, the following algorithm is used when the gate opening is known:

$$QFT = FCDA*GOF*GW*\sqrt{2*GC*HU} \qquad (8)$$

where:

GOF = free flow gate opening (vertical distance)
GW = gate width
GC = gravitational constant

HU = upstream depth measured from the gate sill to the water surface, figure 1

The same equation (7) is used to solve for the free flow gate opening, GOF, when the free discharge, QFT, is known.

Summary

The analytical development of the free and submerged flow algorithms described above demonstrates the nonlinear characteristics of the coefficient of discharge as a function of the critical variables, HU/PH, HD/PH, GO/PH, and RAD/PH shown on figure 1. Application of the general conic equation (2) to Metzler's systematic way of representing the complete discharge characteristics provides an excellent technique to accurately repesent the nonlinear characteristics of the coefficient of discharge by a series of algorithms. The number of algorithms and their complexity are more than originally
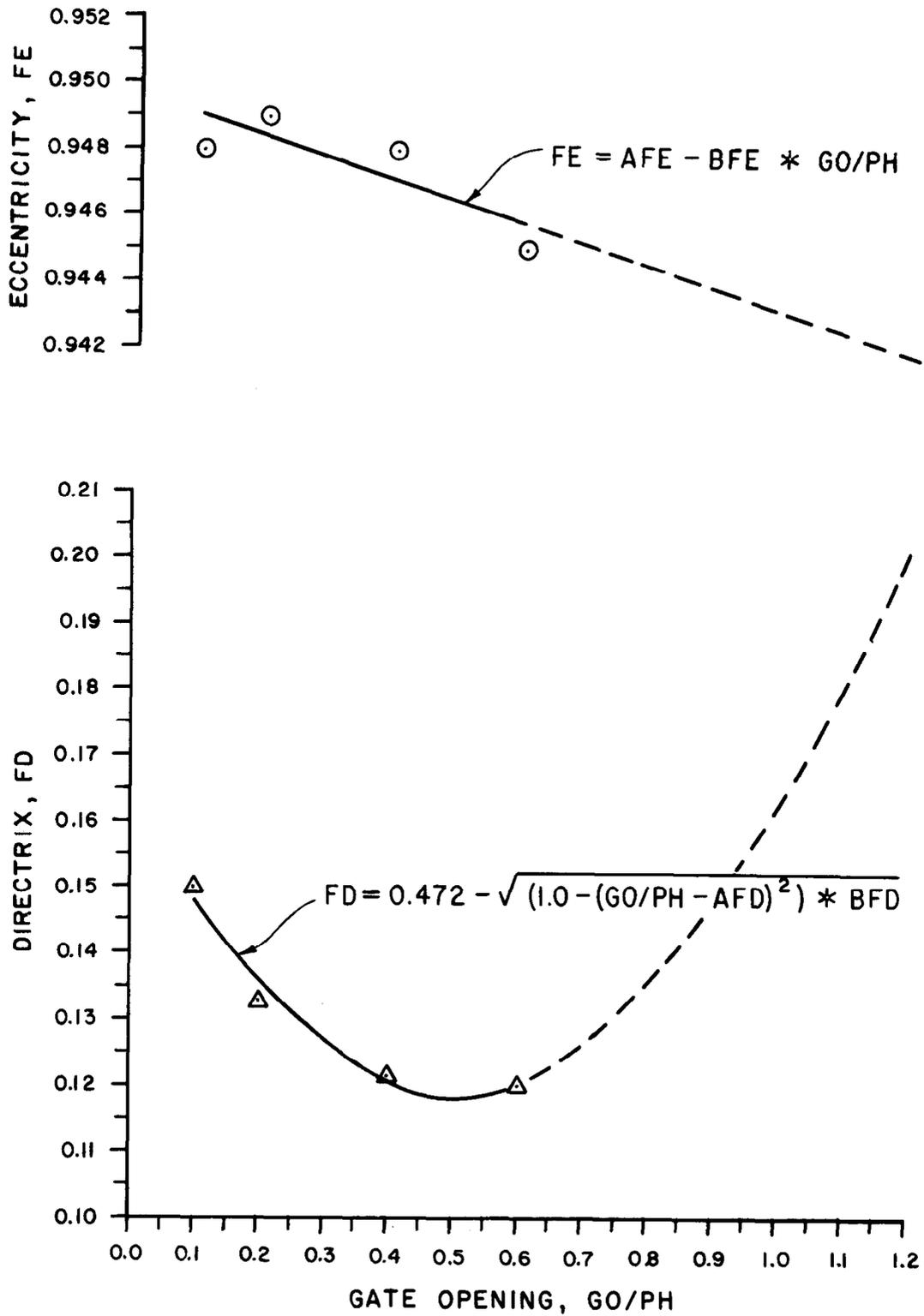
Figure 25.—Eccentricity, FE, and directrix, FD, versus the free flow GO/PH, including the best fit lines and algorithms.
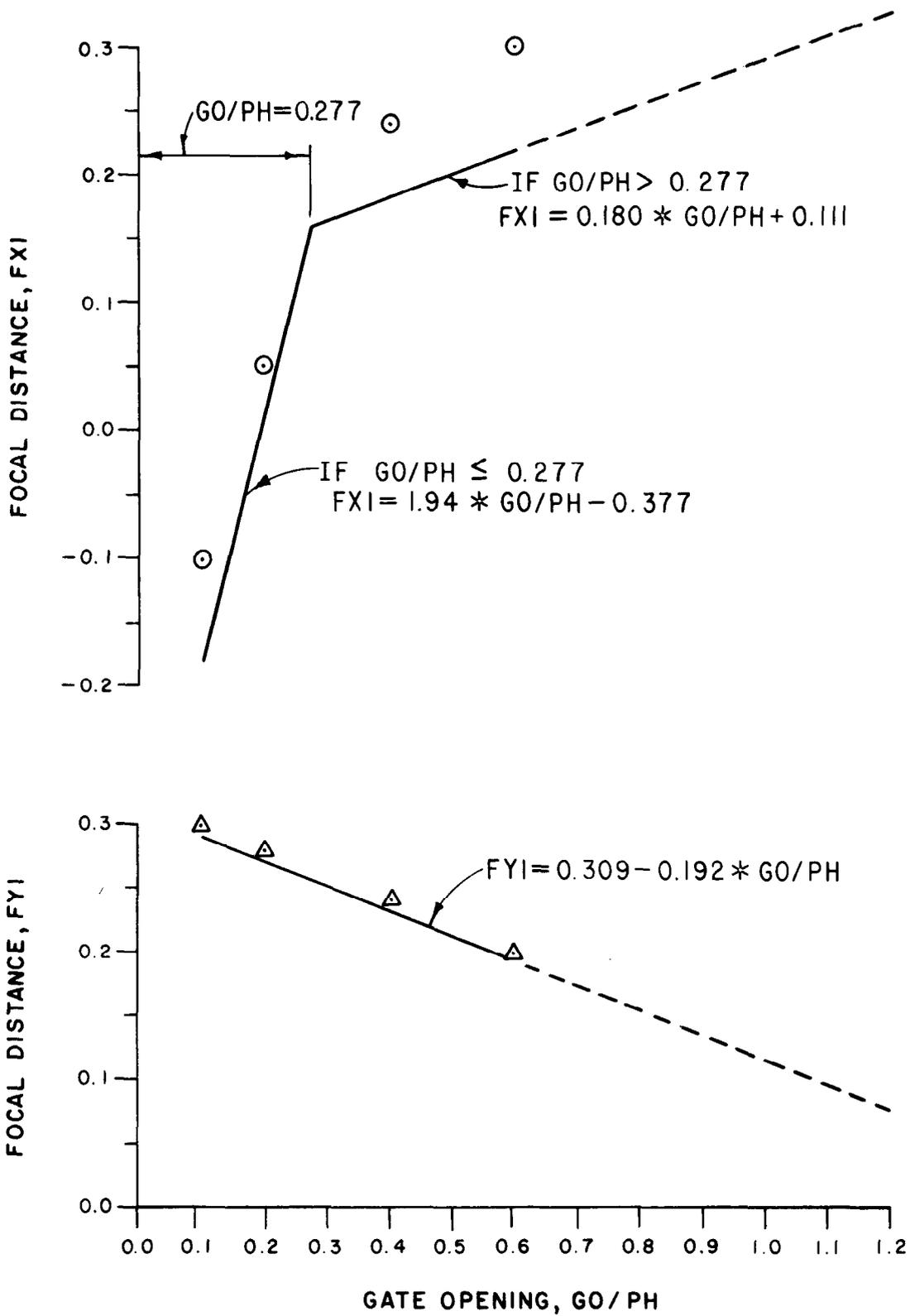
Figure 26.—Focal distances, FX1 and FY1, versus the free flow GO/PH, including the best fit lines and algorithms.

PARAMETER, AFE

0.980
0.975
0.970
0.965
0.960
0.955
0.950
0.945
0.940

PARAMETER, BFE

0.10
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04

$$AFE = \sqrt{(1.0+(RAD/PH-1.60)^2 * 31.2)*0.000212)+0.901}$$

$$BFE = \sqrt{(1.0+(RAD/PH-1.635)^2 * 187.7)*0.000212} - 0.079$$

RADIUS TO PINION HEIGHT RATIO, RAD/PH

1.2 1.3 1.4 1.5 1.6 1.7 1.8
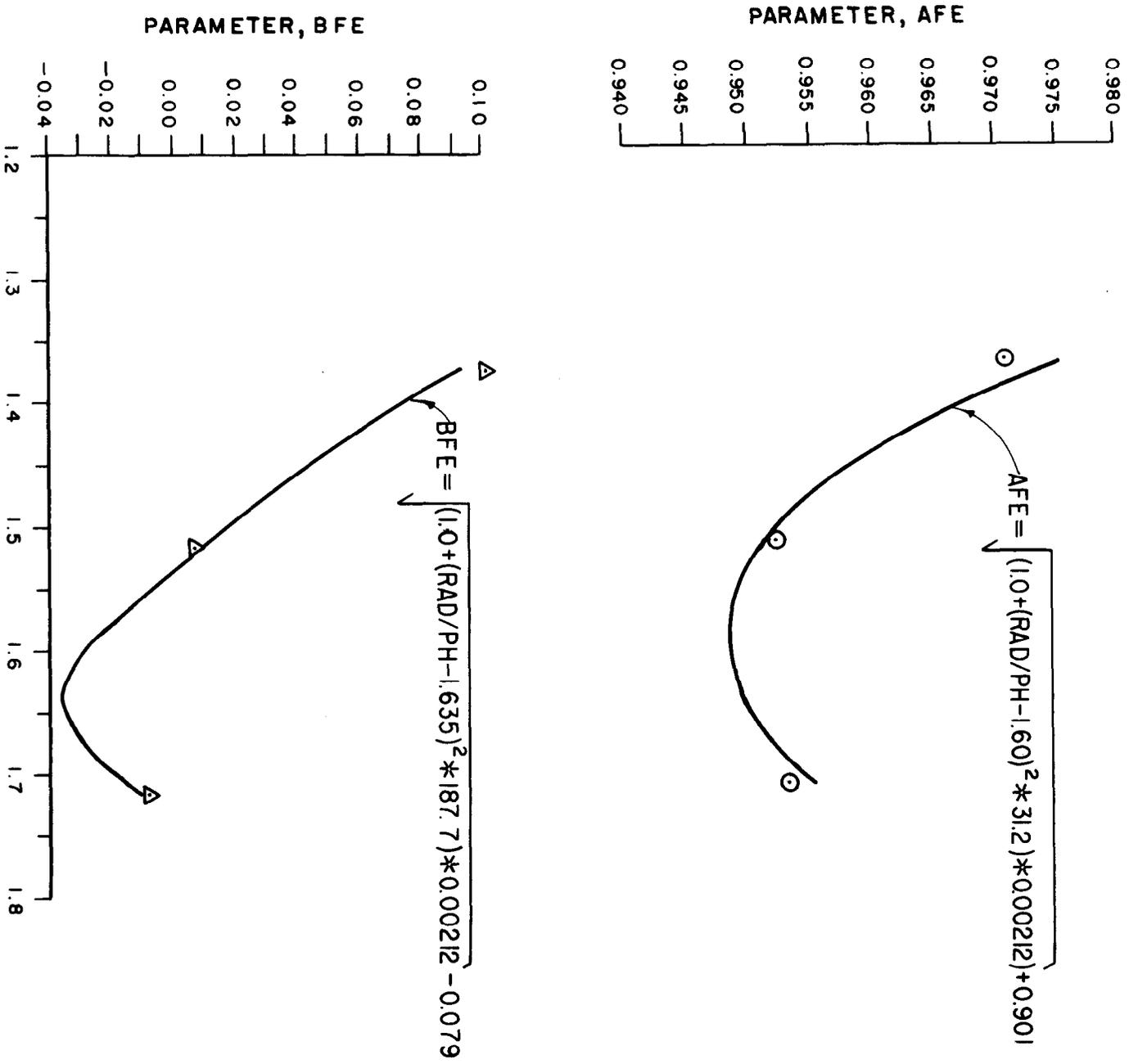
Figure 27.—Eccentricity parameters, AFE and BFE, versus RAD/PH for free flow, including the best fit lines and algorithms.

39
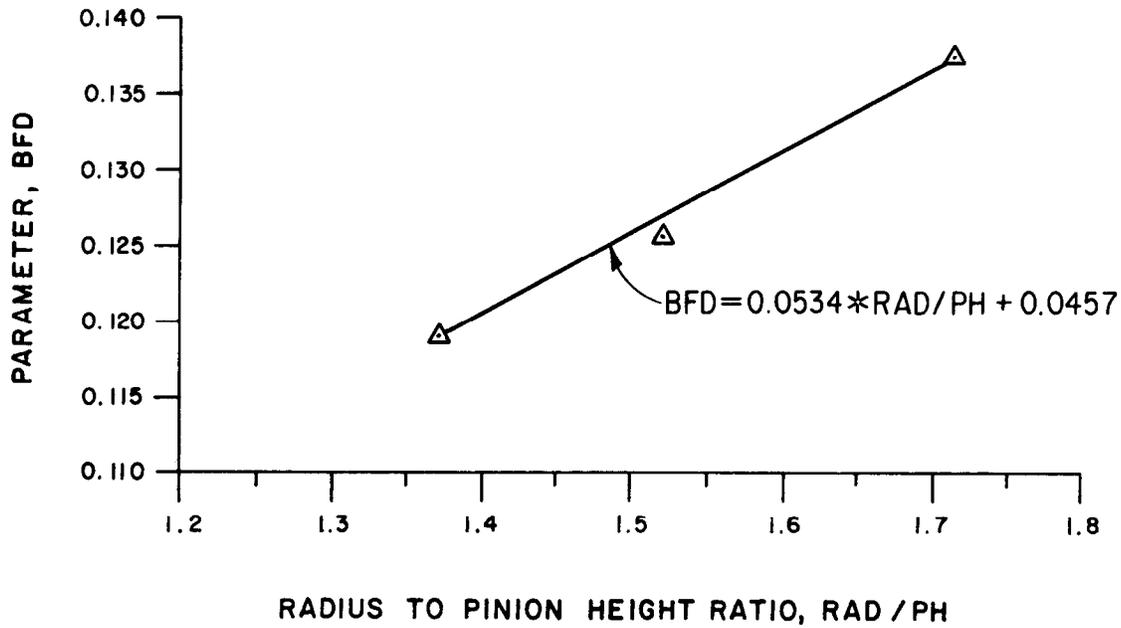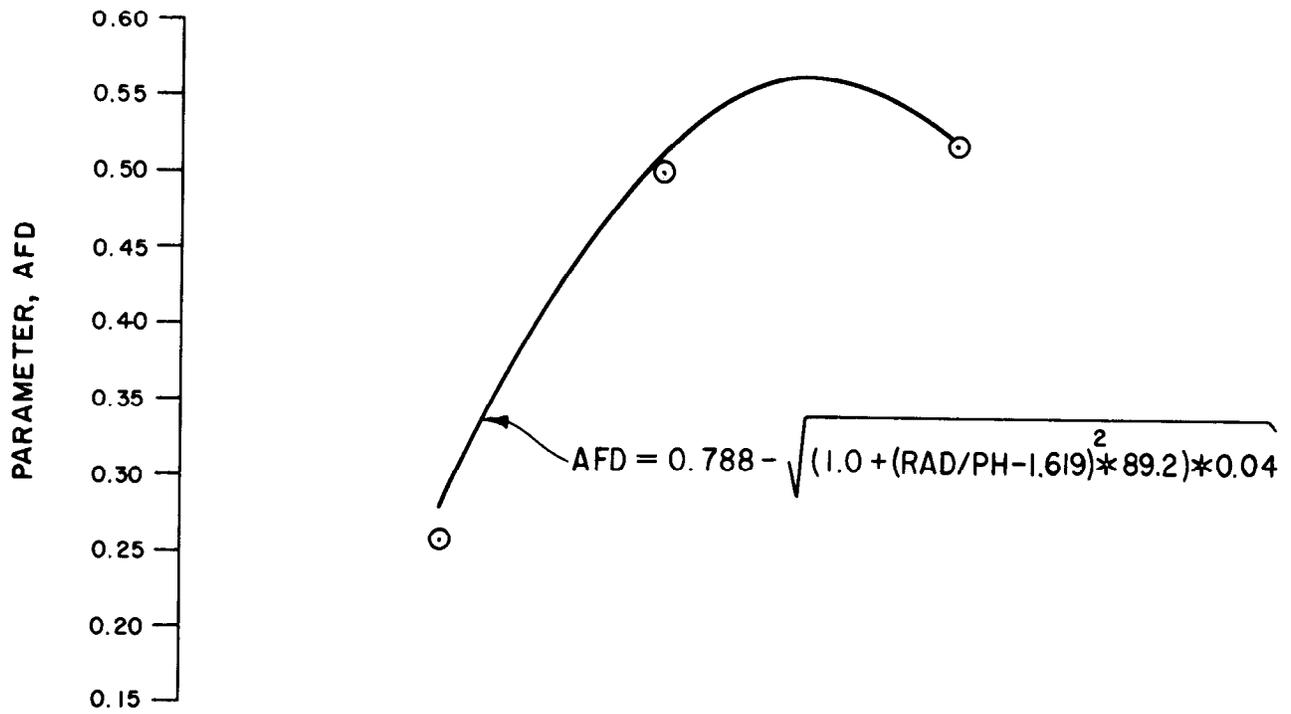
Figure 28.—Directrix parameters, AFD and BFD, versus RAD/PH for free flow, including the best fit lines and algorithms.

The equations shown in the figure are:

$$AFD = 0.788 - \sqrt{(1.0 + (RAD/PH - 1.619)^2 \ast 89.2) \ast 0.04}$$

$$BFD = 0.0534 \ast RAD/PH + 0.0457$$

40

desired. However, to achieve the desired degree of accuracy, the number of complex algorithms listed above was absolutely necessary.

The above algorithms were written in Fortran language for a general use computer program which is included in appendix V.

One other critical variable of the canal radial gate has yet to be represented by algorithms and that is the different gate lip seal designs. The technique developed to represent different gate lip seal designs is described in subsequent paragraphs.

CORRECTION ALGORITHMS ANALYTICAL DEVELOPMENT

General

The gate lip seal design is one of the critical variables that affects the coefficient of discharge characteristics of a canal radial gate. Discharge algorithms developed so far in this investigation are based on the Bureau's standard hard-rubber-bar gate lip seal design, figure 10a. Two other gate lip seal designs—the music note, figure 10b, and (2) the sharp edge, figure 9b—were also included in the laboratory test program.

The music note is an older design that exists in numerous canal radial gate check structures. However, at many locations, the music note seals are being replaced by the hard-rubber-bar design. The hard-rubber-bar has a longer life, thereby reducing replacement costs. There are indications that it also reduces vibration characteristics, particularly at the smaller gate openings. The sharp edge design is seldom used on the Bureau's canal radial gates; however, it was included in the laboratory test program to help demonstrate the effects of gate lip configuration on the coefficient of discharge.

The same test program conducted for models No. 1, 2, and 3 would be required to develop accurate algorithms for the music note and sharp edge gate lip configurations. It was not reasonable to repeat 1,825 test runs twice because the music note is no longer being installed and the sharp edge is seldom used. However, an initial analysis indicated that "correction algorithms" could be developed. For each of the two different gate lip seal configurations, only about 400 test runs would be required.

The correction algorithms adjust the coefficient of discharge calculated by the discharge algorithms developed for the hard-rubber-bar design.

The discharge algorithms consider the nonlinear effects of the HU, HD, GO, and RAD/PH critical variables to some degree; whereas the correction algorithms consider the nonlinear variation of the different gate lip seal designs compared to the hard-rubber-bar design as a function of the gate opening. Varying the pinion height did not cause large variation of the coefficient of discharge, at least in a systematic manner, for the two different gate lip seal designs. However, the coefficient of discharge for the different gate lip designs did vary significantly as a function of the gate opening.

The correction algorithm technique developed from minimal laboratory test data to accommodate different gate lip configurations is not precise. However, the technique produced satisfactory results.

Music Note Gate Lip Design, Models No. 4, 5, and 6

The correction algorithms for the submerged and free flow conditions are based on the music note seal design shown in figure 10b. The collected laboratory test data for the music note study are included in appendix II as models No. 4, 5, and 6. Physical properties for each of the models are listed in table 1.

Submerged flow.—For each of the submerged flow test runs, a correction factor was calculated:

$$CSCDA = \frac{CDM}{CDA} \qquad (9)$$

where:

CSCDA = correction factor for submerged flow conditions

CDM = coefficient of discharge calculated by equation (1) using the upstream depth, HU, as the head term, H

CDA = coefficient of discharge calculated by the algorithms developed for the hard-rubber-bar gate lip seal design based on equation (4)

Results for the submerged flow conditions are shown on figure 29. The correction factor, CSCDA, calculated for each test run using equation (9) is plotted at the "+" points as a function of the gate opening, GO/PH. The solid line represents the final best fit straight line that produced the smallest average percent error when the correction algorithm technique was applied to the laboratory test data. The algorithm of the straight solid line is:

$$CSCDA1 = 0.125*GO/PH + 0.88 \qquad (10)$$

and represents the "correction algorithm" for the music note seal for submerged flow conditions based on laboratory data. The correction factor, CSCDA1, calculated by algorithm (10), is applied to the submerged flow discharge coefficient, SCDA, calculated by the algorithms developed for the hard-rubber-bar, algorithms (4), as follows:

$$SCDA = \left(\sqrt{E^2 * (D+VX)^2 - VX^2} + FY \right) * CSCDA1 \tag{11}$$

The spread of the correction factor, CSCDA, compared to the solid straight line in figure 29 appears to be significant. The spread is an indication of the music note seal design effect on the coefficient of discharge compared to the hard-rubber bar. However, a statistical analysis of the deviation between the use of algorithms (10) and (11) and the laboratory data for models No. 4, 5, and 6 produced an average error of +0.41 percent and a standard deviation of ±3.0 percent. Without the use of correction algorithm (10), i.e., setting CSCDA1 = 1.0 in algorithm (11), the average error would have been +7.77 percent, with a standard deviation of ±9.6 percent. Therefore, satisfactory results were achieved through the application of correction algorithm technique to the laboratory data.

The dashed line in figure 29, having the following algorithm:

$$CSCDA1 = 0.39 * GO/PH + 0.85 \tag{12}$$

represents the music note seal correction developed from field data (West Canal before 1974 test data, app. III). Considerable difference exists between the two correction algorithms (10) and (12). The following significant factors could have contributed to this difference:

1. The laboratory and the field correction algorithms were based on the minimal amount of test data.

2. Laboratory test data were collected for discharges at or near the maximum discharge for each gate opening, GO/PH, included in the study; whereas the field data were limited to the smaller gate openings range.

3. It is not known if the design of the gate lip seal of the prototype canal radial gate used to develop the field correction algorithm was exactly like that shown in figure 10b.

4. The lower horizontal I-beam of the prototype radial gate that uses the music note seal design (fig. 9a) does not have holes through the web. The laboratory model, however, had three holes drilled through the web (fig. 9b) which were not plugged during the music note test runs. These holes may have influenced the development of the vena contracta of the flow jet downstream, resulting in a different coefficient of discharge.

5. It is possible that the slight variation between the model construction and the prototype caused part of the difference observed between the laboratory and the field developed correction algorithms.

6. The music note gate lip seal for the laboratory canal radial model, item M in figure 10b, was fabricated from 5/16-in (7.9-mm) diameter steel rod. It therefore:

a. Was slightly larger in diameter (when scaled up to prototype)—1.875 in (48 mm)—than the 1-3/4-in (44-mm) prototype seal, and

b. Did not represent the deformation of the prototype rubber material that would occur at the different gate openings at high and low discharges.

Correction algorithm (12) developed from field data provides good results for field data from the five Friant-Kern Canal check gate structures (which also have the music note gate lip design) included in appendix III. The results were significantly better compared to the use of the correction algorithm (10) developed in the laboratory. Therefore, correction algorithm (12) was adopted in lieu of laboratory algorithm (10) for the general algorithm to correct for the music note gate lip seal for submerged flow conditions and was included in the general use computer program, appendix V.

Free Flow.—The same technique described above was used to develop a correction algorithm for the music note seal for the free flow conditions. Algorithm (9) was used to calculate the correction factor, designated CFCDA. Results are shown on figure 30. the solid line is the best fit straight line that produced the smallest average error of +0.06 percent at a standard deviation of ±2.1 percent. The algorithm of the solid straight line is:

$$CFCDA1 = 0.125 * GO/PH + 0.91 \tag{13}$$

and represents the correction of the music note gate lip seal for free flow conditions based on laboratory data. Without correction algorithm (13), i.e., CFCDA1 = 1.0, the average error would have been +6.5 percent with a standard deviation of ±7.4 percent.

Correction factor CFCDA1 calculated by algorithm (13), is applied to free discharge coefficient

LABORATORY TEST PROGRAM
MODELS NO. 4, 5, & 6
SUBMERGED FLOW
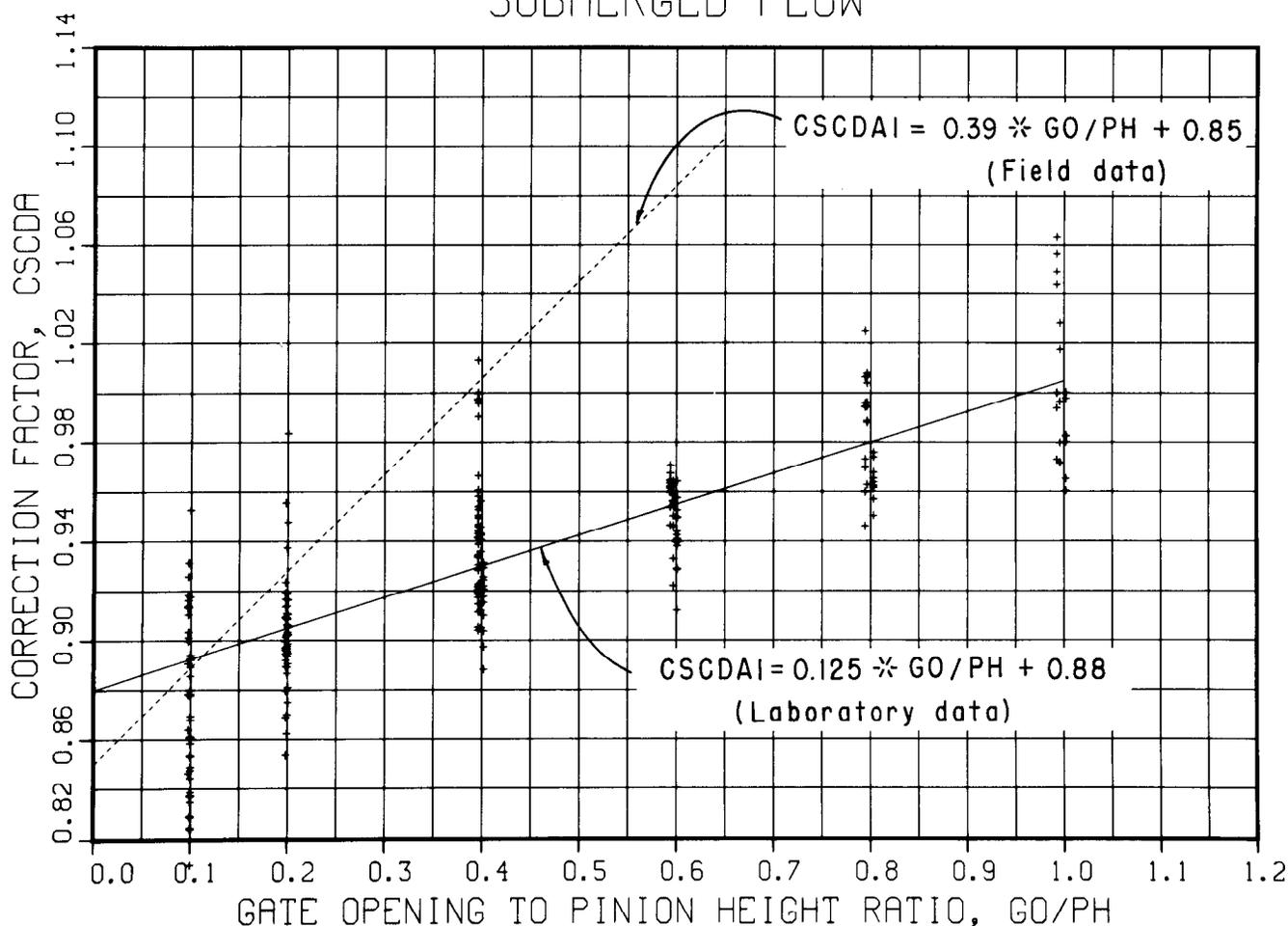
Figure 29.—Music note gate lip seal correction factor, CSCDA, versus the submerged flow GO/PH, including the best fit lines and correction algorithms.

FCDA calculated by the algorithms developed for the hard-rubber-bar equation (7) as follows:

$$FCDA = \left(\sqrt{FE^2*(FD+FXV)^2 - FXV^2} + FY1 \right) * CFCDA1 \quad (14)$$

The dashed line in figure 30, having the following algorithm:

CFCDA1 = 1.15

$$- \sqrt{\left[1.0 + \frac{(GO/PH-0.4)^2}{0.024} \right]*0.014} \quad (15)$$

represents the music note correction algorithm for free flow developed from field data (East Low Canal test data, app. III). The difference between laboratory correction algorigthm (13) and field algorithm (15) is not significantly different on an overall basis. Correction algorithm (15) appears to be a truer representation of the music note variation as a function of the gate opening. The field verification test program indicates algorithm (15) provides slightly better results than laboratory algorithm (13). However, field data for only one prototype canal radial check gate with a music note design and operating at free flow conditions were available for verification studies. The correction algorithms could not be applied to other field installations. Therefore, it was decided to adopt laboratory correction algorithm (13) for the music note gate seal correction for free flow conditions and it was included in the general use computer program, appendix V.

Sharp Edge Gate Lip Models No. 7, 8, and 9

The sharp edge gate lip configuration was obtained by removing the music note gate lip seal

43

LABORATORY TEST PROGRAM
MODELS NO. 4, 5, & 6
FREE FLOW

$$CFCDAI = 1.15 - \sqrt{\left[1.0 + \frac{(GO/PH - 0.4)^2}{0.024}\right] * 0.014}$$

(Field data)

$$CFCDAI = 0.125 * GO/PH + 0.91$$

(Laboratory data)

CORRECTION FACTOR, CFCDA

GATE OPENING TO PINION HEIGHT RATIO, GO/PH
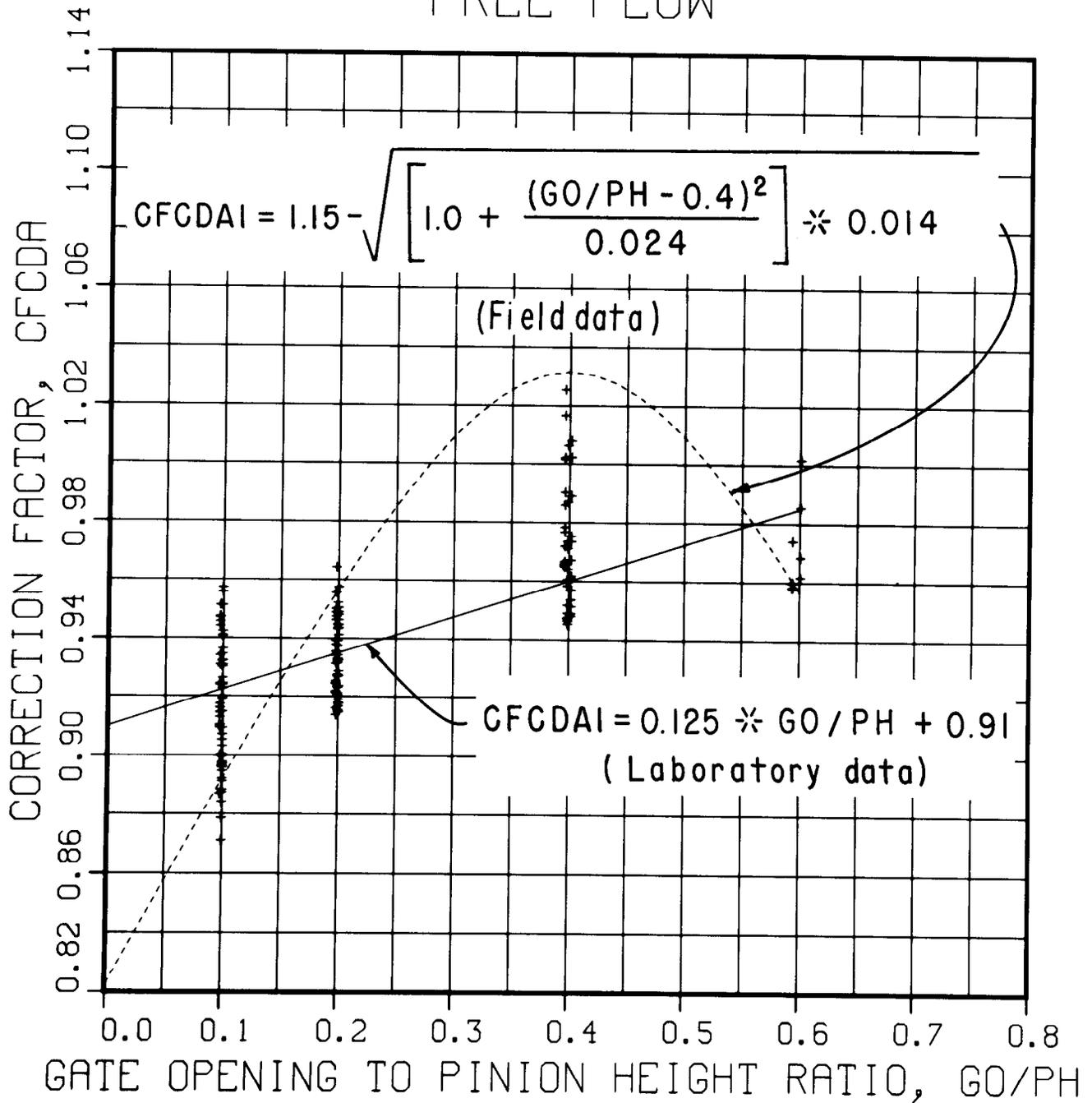
Figure 30.—Music note gate lip seal correction factor, CFCDA, versus the free flow GO/PH, including the best fit lines and correction algorithms.
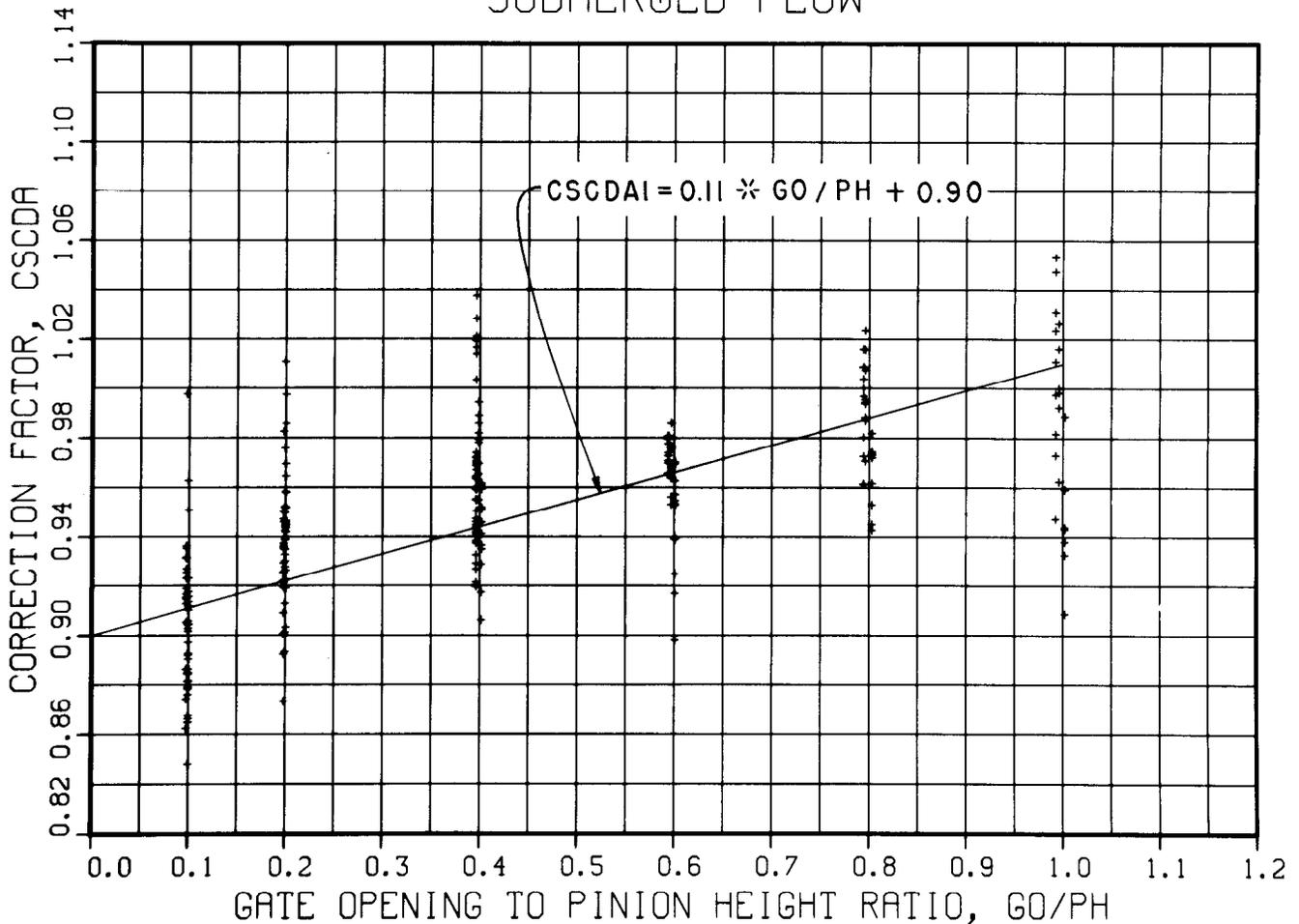
Figure 31.—Sharp-edge gate lip seal conection factor CSCDA versus the submerged flow GO/PH, including the best fit straight line and correction algorithm.

and filling the mounting screw holes with solder. The gate lip piezometer taps (fig. 10b) were filed flush to the face plate including the solder fill to achieve the sharp edge shown on figure 9b. The laboratory data for the sharp edge gate lip are included in appendix II, designated models No. 7, 8, and 9. The physical properties for each of the models are listed in table 1.

The same correction algorithm development technique used for the music note design above was applied to sharp edge gate lip configuration for the submerged and free flow conditions. Field data for the sharp edge gate lip were not available for verification studies.

Submerged flow.—The results for the sharp edge correction factor for the submerged flow conditions are shown on figure 31. The correc-

tion algorithm for the best fit solid straight line of the laboratory data is:

$$CSCDA1 = 0.11*GO/PH + 0.90 \qquad (16)$$

This produces the smallest average error of -0.26 percent and a standard deviation of ±3.2 percent. Without correction algorithm (16), i.e., setting CSDCA1 = 1.0 in equation (11), the average error would have been +5.44 percent and a standard deviation of ±7.0 percent. Correction algorithm (16), therefore, provides a satisfactory technique to obtain acceptable accuracy levels for the sharp-edge gate lip, submerged flow conditions.

Free Flow.—The results for the sharp edge correction factor for the free flow conditions are shown in figure 32. The correction algorithm for the best fit solid straight line of the laboratory data is:
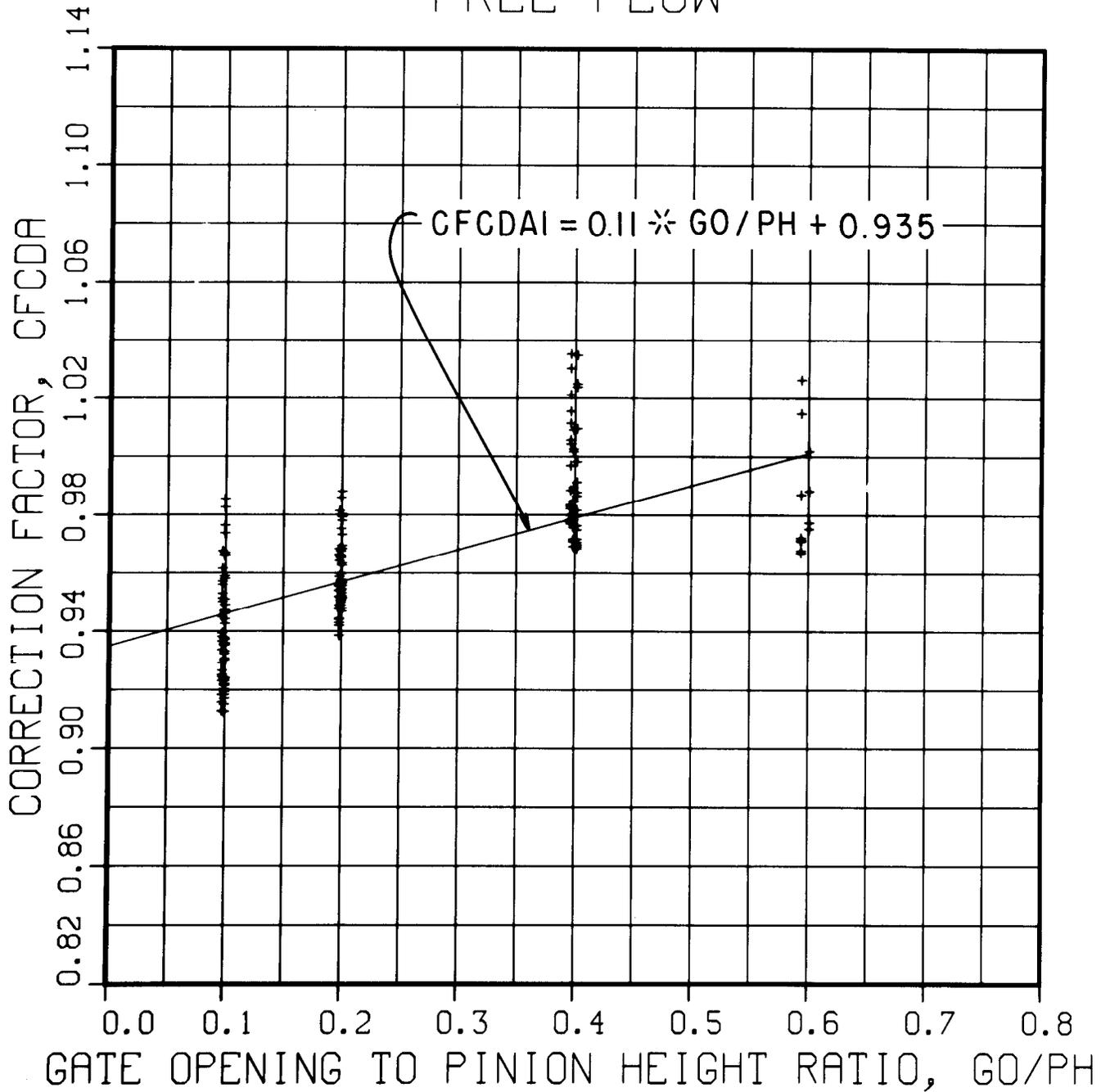
Figure 32.—Sharp-edge gate lip seal correction factor, CFCDA1, versus the free flow GO/PH, including the best fit straight line and correction algorithm.
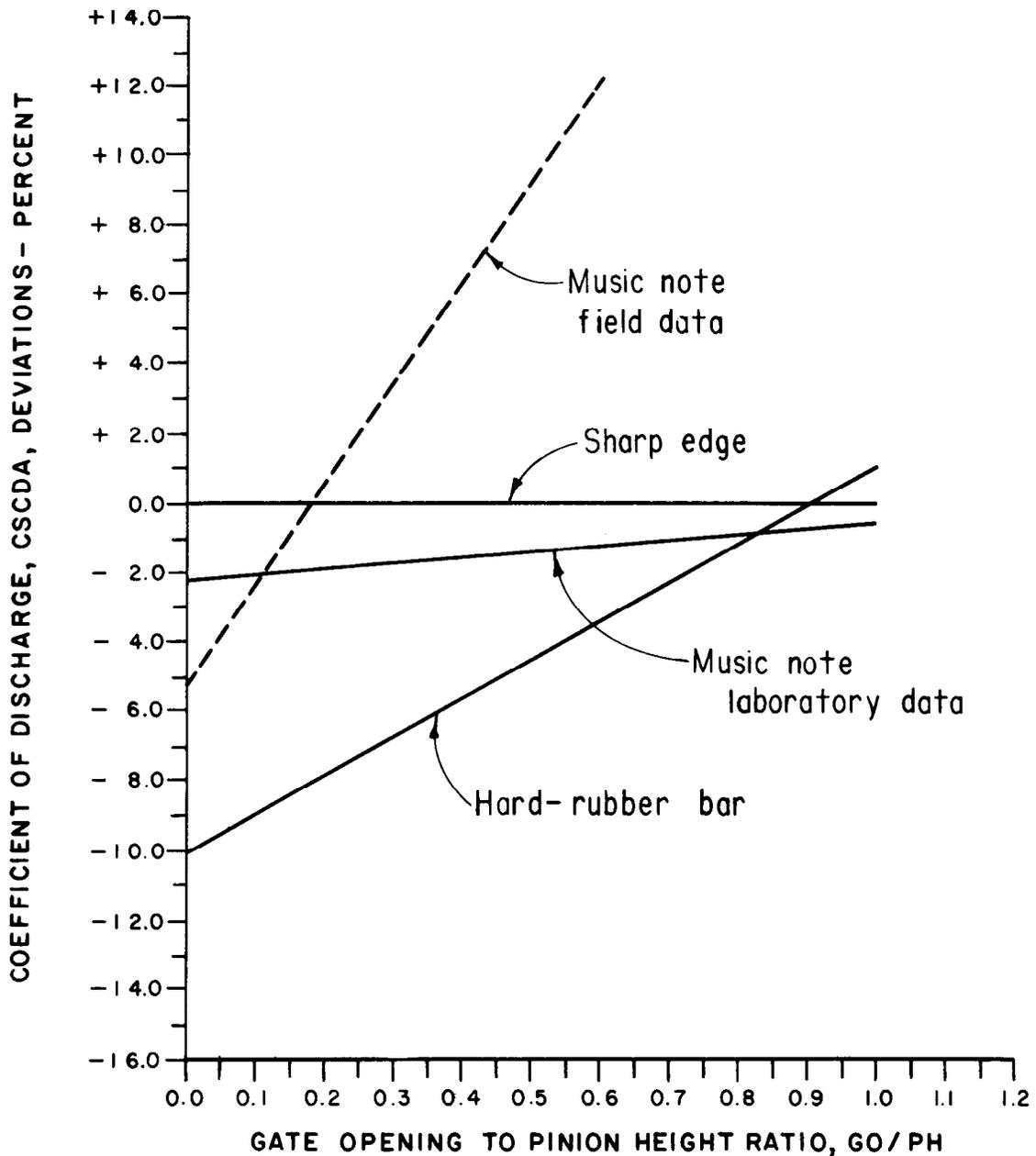
Figure 33.—Summary comparison of the submerged flow correction algorithm's coefficient of discharge, CSCDA1, deviation between the different gate lip seal designs investigated, using the sharp edge as a base.

$$CFCDA1 = 0.11*GO/PH + 0.935 \qquad (17)$$

This produces the smallest average error of -0.00 percent and a standard deviation of ±1.9 percent. Without correction algorithm (17), i.e., setting CFCDA1=1.0 in equation (14), the average error would have been +4.01 percent and a standard deviation of ±5.0 percent. Therefore, correction algorithm (17) also provides satisfactory results for the sharp edge gate lip for the free flow conditions.

Summary

A comparison of the different gate lip seal configurations for the submerged flow conditions is shown on figure 33. The sharp edge gate lip design is used as the base to compare the percent deviation of the music note and hard-rubber bar configurations. Correction algorithms developed for the music note and sharp edge were used to represent the average correction factor of the laboratory data. The correction algorithm deviation for the music note based on field data is

47

shown as the dashed line. The field data emphasize the magnitude of deviation that could occur as a result of some minor variation in the gate lip configuration.

The music note (laboratory data) deviation compared to the sharp edge is not significant. It is believed that the faceplate downstream angle leg of the music note design (item L on fig. 10b) causes the contraction of the downstream jet, GAXCO, (fig. 1) to develop in a manner similar to that of the sharp edge design. However, there is a large difference when the sharp edge is compared to the field music note data. The field music note data more accurately reflect the true relationship of the deviation (particularly the steep slope of the straight line) for the smaller gate openings. There is a substantial difference between the music note and the hard-rubber-bar gate lip designs.

A negative deviation in figure 33 indicates that the coefficient of discharge is smaller compared to the sharp edge design. Positive deviations indicate the coefficient of discharge is larger. Therefore, a gate lip design that is unlike the sharp edge will tend to have much smaller coefficients of discharge at the small gate openings and slightly larger or equal values for the larger gate openings. The range could vary from about -10 percent to +1 percent based on laboratory data, or up to +12 percent based on field data.

The comparison of the free flow data (not included) is very similar to the submerged flow summary shown on figure 33.

Results from the laboratory and field data analyses have demonstrated three main factors:

1. Significant variations in the coefficient of discharge do occur for different gate lip configurations. Even minor changes in the gate lip seal design can have the same effect (refer to field verification tests, West Canal headworks before and after 1974 data, fig. III-48).

2. The deviation can range from -10 percent to +12 percent from the small to the large gate openings compared to the sharp edge gate lip configuration.

3. The correction algorithm provides an adequate technique to adjust the coefficient of discharge of the hard-rubber-bar algorithms for different gate lip configurations on an overall basis. However, on a point-by-point basis, the error could be substantial.

It is extremely important, therefore, to identify the exact gate lip configuration before the results

of this investigation can have practical application. Gate lip configuration has the greatest effect on the coefficient of discharge characteristics compared to all the other critical variables that are involved in the design and operation of the prototype canal radial gate check structure.

COMPARISON OF ALGORITHM-PREDICTED TO ACTUAL DISCHARGE

Laboratory Model Data

A total of 2647 test runs were made on the nine canal radial gate laboratory models. The difference between the algorithm-predicted and the laboratory-measured coefficients of discharge produced the following statistics:

NUMBER OF DATA POINTS = 2647
AVERAGE DIFFERENCE (ACTUAL) = +0.00098
AVERAGE DIFFERENCE (PERCENT) = +0.36
STANDARD DEVIATION (ACTUAL) = 0.01249
STANDARD DEVIATION (PERCENT) = 4.9

A summary of the laboratory statistical analyses for the three groups of model data by gate lip seal design for the submerged and free flow conditions are listed in table 4. The differences of the algorithm-predicted and the laboratory-measured coefficients of discharge used in the statistical analysis are tabulated in appendix II.

The average differences indicate the algorithm-predicted discharge coefficient is slightly biased in the positive direction. The standard deviation is considered to be small except for the submerged flow data of models No. 1, 2, and 3. The standard deviation of ±5.9 percent for models No. 1, 2, and 3 is considered to be high. The actual standard deviation of 0.01233 is considered normal. There is a reason for the higher percent standard deviation.

Considerable data (about 144 test runs) were collected at very small head differentials, where the ratio of the downstream depth to the upstream depth, HD/HU, was greater than 0.99. In the laboratory model, at small gate openings and low flow conditions, the head differential would be on the order of 0.3 mm (0.001 ft). The resolution or capability of the water level measurement transducer was about ±0.3 mm (±0.001 ft). Therefore, large percent errors, particularly at very low flow conditions, occurred in the test data results using the following expression:

48

Difference (percent) = $\dfrac{(\text{CDA}-\text{CDM})}{\text{CDM}} * 100.0$ (18)

where:

CDA = the algorithm-predicted coefficient of discharge

CDM = the laboratory measurement of the coefficient of discharge based on Metzler's concept using equation (1), with the upstream depth, HU, for the head term, H.

As the measured coefficient of discharge, CDM, approaches zero and with a small error of the water level measurement caused by the transducer error, the difference in percent would quickly become very large (40 to 50 percent). The same phenomenon will occur in the prototype application, which is discussed in appendix IV. Therefore, these laboratory data points were included in the statistical analysis, except test runs were omitted when the measured head differential was zero or negative. The test runs that were omitted are included in the appendix II tabulation of the laboratory data.

Figure 34 illustrates the wide spread of the percent deviation, equation (18), as the ratio of the downstream to the upstream depth, HD/HU, approaches 1.00.

The maximum deviation for HD/HU values greater than 0.99 is about ±40 percent. Figure 35

is a plot of the average error and standard deviation as a function of the HD/HU ratio. The standard deviation decreases rapidly from 5.9 to 3.8 percent when test points greater than HD/HU = 0.99 are not included. However, the average error remains about the same, increasing slightly from +0.54 to +0.66 percent. The actual standard deviation and average error also remained nearly constant, increasing slightly as test data points were excluded above the high values of HD/HU. Therefore, the detailed statistical analysis will be based on the actual difference:

Difference (actual) = CDA−CDM (19)

rather than the percent difference, equation (18). The actual difference of all the laboratory test data points are also tabulated in appendix II.

A detailed statistical analysis was made on the 1646 submerged flow test data points of models No. 1, 2, and 3 to demonstrate the normal distribution and the linear characteristics of the actual difference between the algorithm-predicted, algorithm (4), and the laboratory-measured, equation (1), coefficients of discharge, CDA and CDM, respectively. The detailed statistical analysis followed the same procedure used in the field verification tests, which is discussed in greater detail in the next section of this report and in appendix III. Therefore, the discussion of the laboratory model data statistical analysis will be brief.

Table 4. — *Summary of the laboratory test program statistical analysis of the difference between the algorithm-predicted and laboratory-measured coefficients of discharge, CDA and CDM*

Statistical description	Model No.	Hard rubber bar 1, 2, and 3	Music note 4, 5, and 6	Sharp edge 7, 8, and 9
Submerged flow:				
Number of data points		1646	237	242
Maximum positive difference (actual)		0.054	0.042	0.030
Maximum negative difference (actual)		− 0.056	− 0.043	− 0.055
Maximum positive difference (percent)		40.7	10.2	11.2
Maximum negative difference (percent)		−38.5	− 8.2	− 9.1
Average difference (actual)		0.00160	0.00097	− 0.00225
Average difference (percent)		0.54	0.41	− 0.26
Standard deviation (actual)		0.01233	0.01291	0.01344
Standard deviation (percent)		5.9	3.0	3.2
Free flow:				
Number of data points		179	166	177
Maximum positive difference (actual)		0.059	0.040	0.026
Maximum negative difference (actual)		− 0.031	− 0.033	− 0.033
Maximum positive difference (percent)		12.4	5.9	3.7
Maximum negative difference (percent)		− 5.9	− 6.4	− 5.5
Average difference (actual)		0.00044	0.00078	0.00033
Average difference (percent)		0.08	0.06	− 0.00
Standard deviation (actual)		0.01274	0.01291	0.01185
Standard deviation (percent)		2.1	2.1	1.9

The histogram shown in the frequency distribution graphs (fig. 36) is symmetrical about the center of gravity at the actual difference of +0.0016. It also has the bell shape, indicating the distribution of the actual difference is normal. The cumulative probability distribution curve on figure 36 shows that about 75.5 percent of the data points fall within one standard deviation, ±0.0123, which is another indication that normal distribution has occurred. At two standard deviations, ±0.0246, 92.7 percent of the data points are included and at three standard deviations, ±0.0369, 99.0 percent of the data points are included.

Two hypothesis tests for goodness-of-fit were performed to determine how close the data are to the normal distribution. The first test is demonstrated graphically on normal probability paper on figure 37. The dashed line is the laboratory test data and the straight solid line is the hypothesis model drawn through the average difference of +0.0016 and one standard deviation of +0.0123 at the 50 and 84.1 percent cumulative probability distribution, respectively (marked at the "+" points). The test data points fall within a reasonable variation of the hypothesized straight line. The Kologorov-Smirnov critical statistic at the 1 percent significant level is

$$c = \sqrt{\frac{1.63}{n}} * 100.0 = \pm 4.0 \text{ percent}$$

where:

n = the sample size of 1,646 test data points
c = critical statistic reference [16] table A.7

The Kologorov-Smirnov test curves are plotted above and below the hypothesized straight line by an amount equal to the above critical statistic, ±4.0 percent. The fact that some of the laboratory test data fall outside the upper and lower curves may indicate the data are not normally distributed at the 1 percent significance level. However, since the test data points do not lie outside the curves by
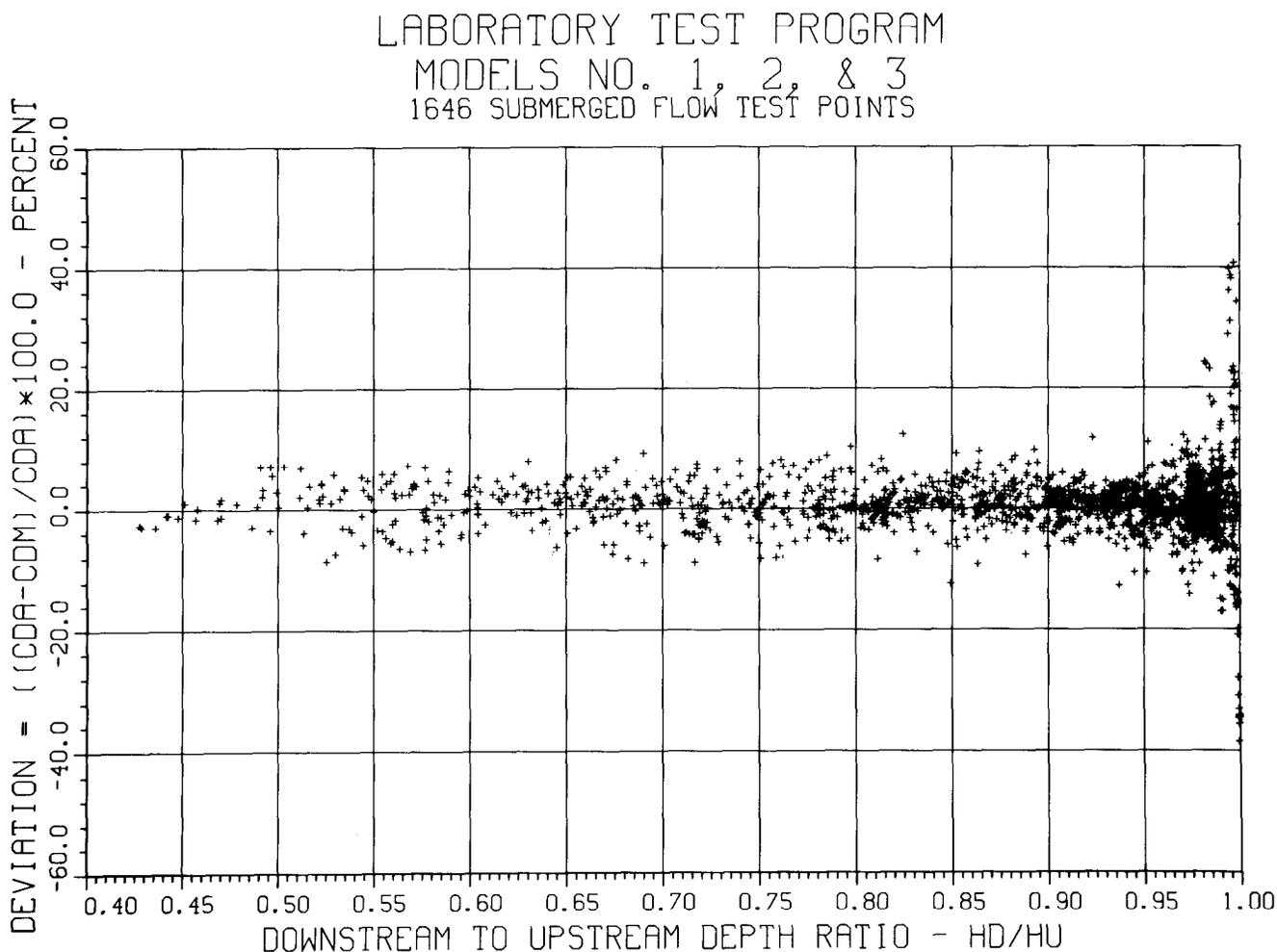
Figure 34.—Illustration of the wide spread of the deviation of the algorithm-predicted and the measured coefficients of discharge, CDA and CDM, when the downstream-to-upstream-depth ratio, HD/HU, is greater than 0.99 for submerged flow conditions.

50

LABORATORY TEST PROGRAM
MODELS NO. 1,2 AND 3
1646 Submerged flow test points
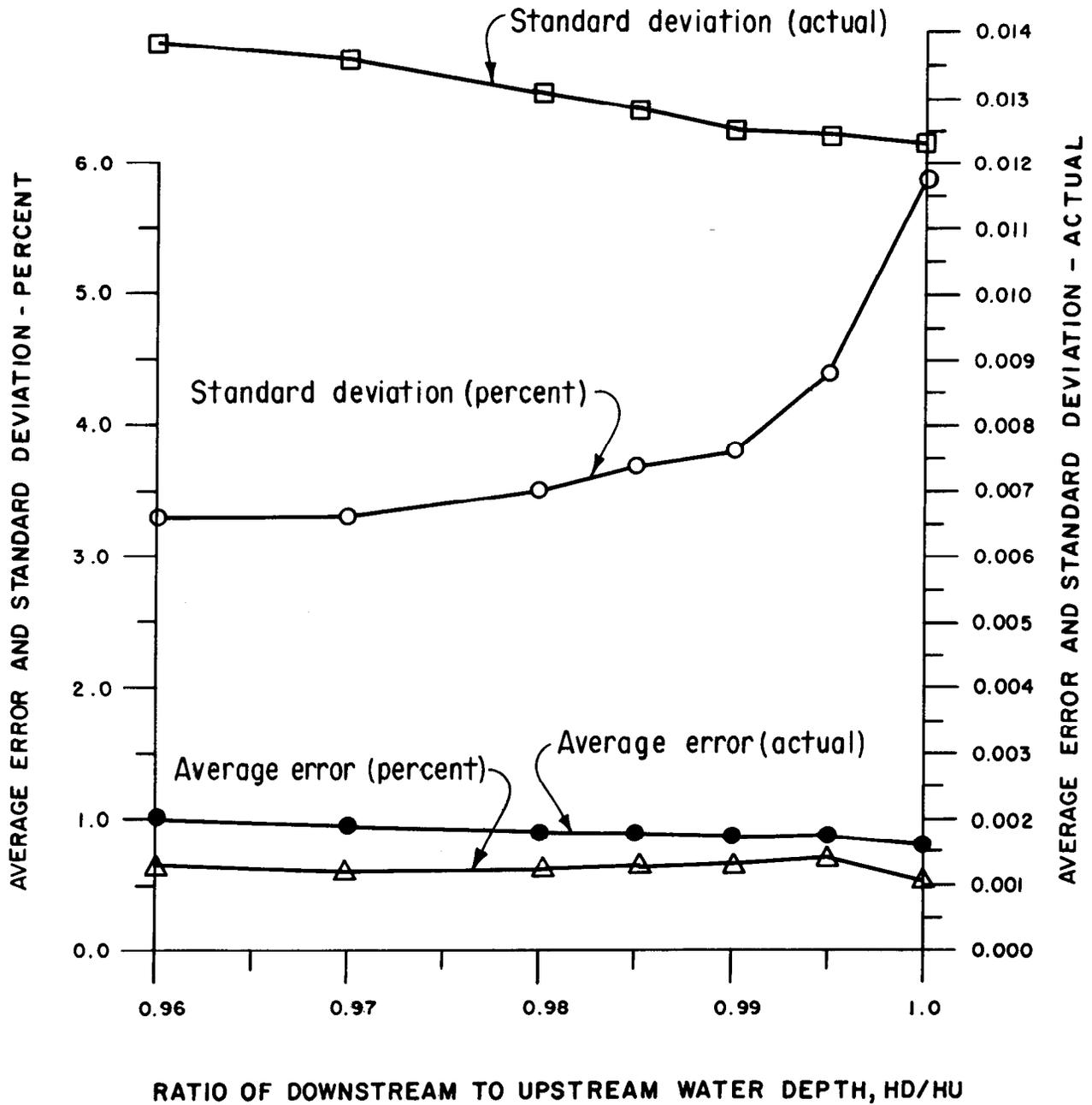
Figure 35.—The results of the average error and standard deviation (percent and actual) of CDA when laboratory test data
points above the indicated HD/HU ratio are not included.

Observed probability distribution histogram

Observed cumulative probability distribution

DIFFERENCE (ACTUAL) = CDA-CDM
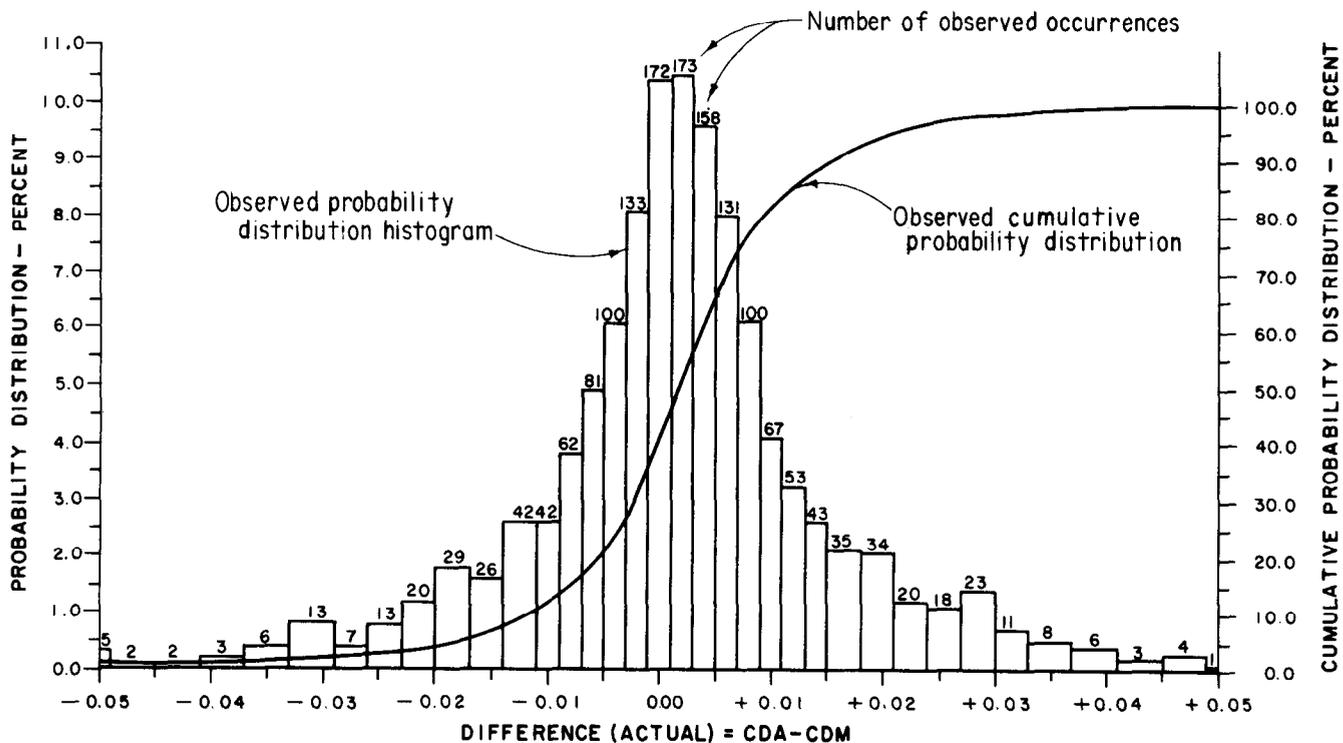
Figure 36.—Laboratory test program statistical analysis frequency distribution graph of the difference (actual) between the algorithm-predicted and the measured coefficients of discharge, CDA and CDM for the 1,646 submerged flow test data of models No. 1, 2, and 3.

a significant amount, the hypothesis that the data are normally distributed is not rejected.

The second goodness-of-fit performed is the χ^2 test. The observed χ_o^2 statistic, normalized squared deviations, was calculated to be:

$$\chi_o^2 = \frac{\Sigma(\text{observed}-\text{expected})^2}{\text{expected}} = 1000.2$$

The critical statistic for the χ^2 test at the 1 percent significance level is:

$$\chi^2_{0.01,2} = 1/2 \, (Zp + \sqrt{2*v-1})^2 = 1511.7$$

where:

Zp = -2.33 (table A-2, reference [12]
v = degrees of freedom = K-r-1 = 1646-2-1 = 1643
K = number of test points = 1646
r = number of parameters estimated from the data = 2

The observed χ_o^2 = 1000.2 being less than the critical value $\chi^2_{0.01,2}$= 1511.7, suggests that the assumption that the data distribution is normal would be correct at the 1 percent significance level.

The plot of the algorithm-predicted, CDA, versus the laboratory-measured, CDM, coefficient of discharge is shown on figure 38, which illustrates the linearity of the algorithm-predicted

coefficient. The best fit straight line for the 1646 data points using the method of least squares is:

CDA = 1.0002*CDM + 0.0016

where:

1.0002 = the slope of the line
+0.0016 = the offset at the zero intercept of CDM

and is shown as the solid line of figure 38. There is very close agreement to the 45° line shown as the dashed line.

The linearity and unbiased characteristics of the best fit line is confirmed by hypothesis tests at the slope and offset parameters [15]. The test for unity of the slope as compared to the observed value of 1.0002 using the t statistic has an acceptance interval at the 1 percent significance level of:

$$1.0 \pm t_{\alpha/2, n-2}*SA = 1.0000 \pm 0.0048$$

where:

$t_{\alpha/2, n-2}$ = t statistic = 2.576 (table A-4 of [12]) at significance level, = 1 percent and 2 degrees of freedom

$$SA = \sqrt{\frac{S^2}{n*SY^2}} = 0.00187$$

= the estimated variance of the slope parameter
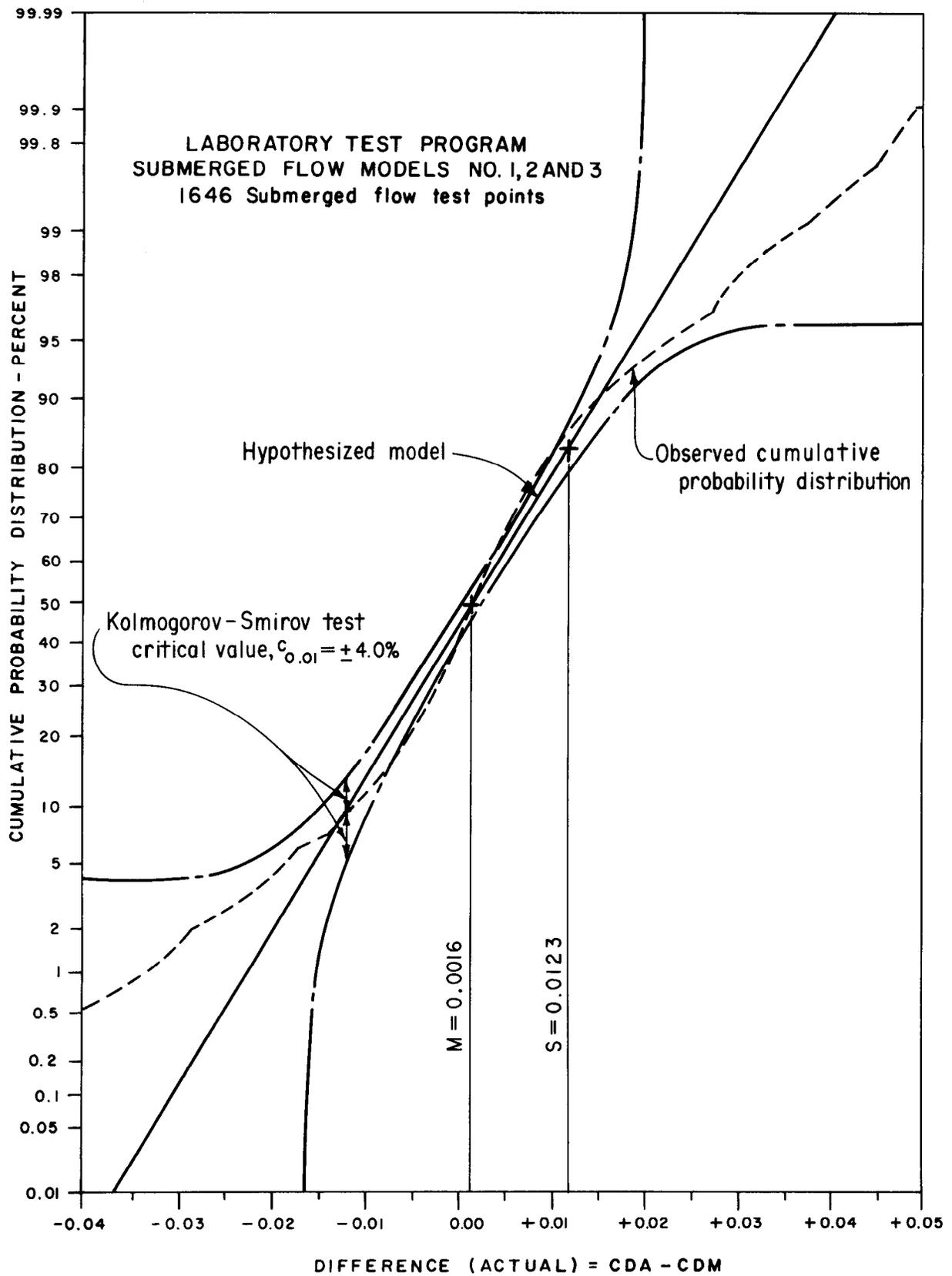
Figure 37.—Laboratory submerged flow test data hypothesis model and Kolmogorov-Smirov test shown graphically on probability paper.
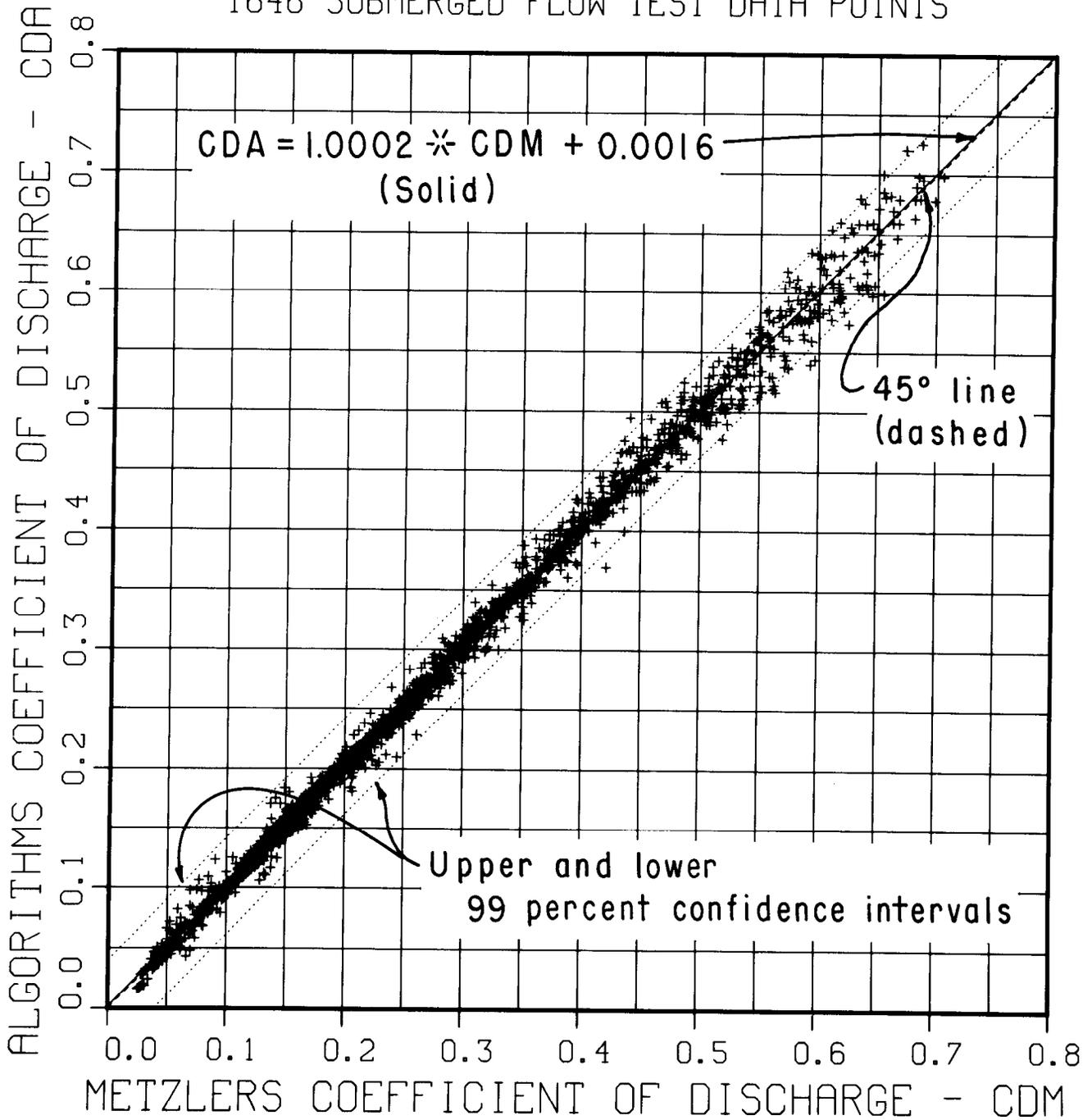
Figure 38.—Comparison of the algorithm-predicted and the laboratory-measured coefficients of discharge, CDA and CDM, for submerged flow conditions.

S = the standard deviation (actual)
= 0.0123

$$SY^2 = \frac{1}{n}\left[\ \Sigma Y_i^2 - n\ (\bar{Y})^2\right]\ = 0.02627$$

ΣY_i = summation of algorithm-predicted coefficient of discharge = 190.4

$\bar{Y}$ = the average of the algorithm-predicted coefficient of discharge = 0.299

n = 1646 test data points.

The observed slope = 1.0002 is not significantly different from unity since it is considerably less than the critical value of +1.0048.

The critical value for the intercept parameter at zero CDM using the same t statistic is:

$$C = \pm\ t_{\alpha/2,\,n-2}\ *SB = 0.00164$$

where:

SB = the estimated variance of the intercept parameter

$$= \sqrt{\frac{S^2}{n}\left[\ 1 + \frac{(\bar{Y})^2}{SY^2}\right]}\ = 0.000636$$

The observed intercept of 0.0016 is just within the critical value of 0.00164. Therefore, the offset at zero CDM is not significantly different from zero.

The upper and lower 99 percent confidence intervals for a single future value of the algorithm coefficient, CDA, corresponding to a selected value of the measured coefficient of discharge, CDM, are shown on figure 38 as the dotted lines. The confidence interval implies that the predicted coefficient of discharge by algorithms will be within the upper and lower curves 99 percent of the time.

The same detailed statistical analysis was also performed on the differences of the 179 free flow test data points of the models No. 1, 2, and 3. The two hypothesis tests, Kolmogorov-Smirnov and X^2, for goodness-of-fit were successful. Therefore, the free flow data are normally distributed, indicating the errors are of a random nature and not systematic. However, significant tests on the slope and intercept of the best fit straight line of the data figure 39 (solid line) were not successful. The straight line equation for the free flow data, using the method of least squares, is:

$$CDA = 0.9753*CDM + 0.01535$$

The slope and the intercept are significantly different from unity and zero, respectively. Therefore, the free flow, algorithm-predicted

coefficient of discharge relationship to the measured value is not considered to be linear. The closeness of the best fit line (solid) to the 45° line (dashed) in figure 39 through the data points, however, indicates that the nonlinear relationship is not of a magnitude to warrant further analysis of a nonlinear regression line.

The basic algorithms that predict the coefficient of discharge for the submerged and free flow conditions are based on the canal radial gate with the hard-rubber-bar design, models No. 1, 2, and 3. Statistical analysis of the difference between the algorithm-predicted and the laboratory-measured coefficients of discharge indicates that a high degree of accuracy can be achieved. The validity of the algorithms' capability to represent the true coefficient of discharge (based on Metzler's concept) for the laboratory canal radial gate 1:6 scale model is based on the following:

1. The average error for submerged and free flow conditions is slightly biased in the positive direction. The error, however, is not significant and therefore considered unbiased.

2. The standard deviation of the actual difference is considered to be at an acceptable level. The percent standard deviation of all the submerged flow data (including data points above the ratio of HD/HU = 0.99) is considered to be high. However, the high spread in percent is caused primarily by errors of the water level measurements when a better resolution of the laboratory transducer of ±0.3 mm (±0.001 ft) was required.

3. The distribution of the free and submerged flow data is normal, indicating the errors are random and not of a systematic nature.

4. The functional relationship of the submerged flow, algorithm-predicted to the laboratory-measured coefficient of discharge is linear. The functional relationship of the free flow algorithms is not linear; however, the nonlinearity is small in magnitude and is considered to be inconsequential.

Field Verification Tests Summary

An analysis·of all the field test data included in the field verification test program, tables III-6 through III-18, produced the following statistics:

NUMBER OF DATA POINTS = 468
AVERAGE DIFFERENCE (Actual) = 18.4 ft³/s
AVERAGE DIFFERENCE (Percent) = 0.7
STANDARD DEVIATION (Actual) = 140.9 ft³/s
STANDARD DEVIATION (Percent) = 4.9
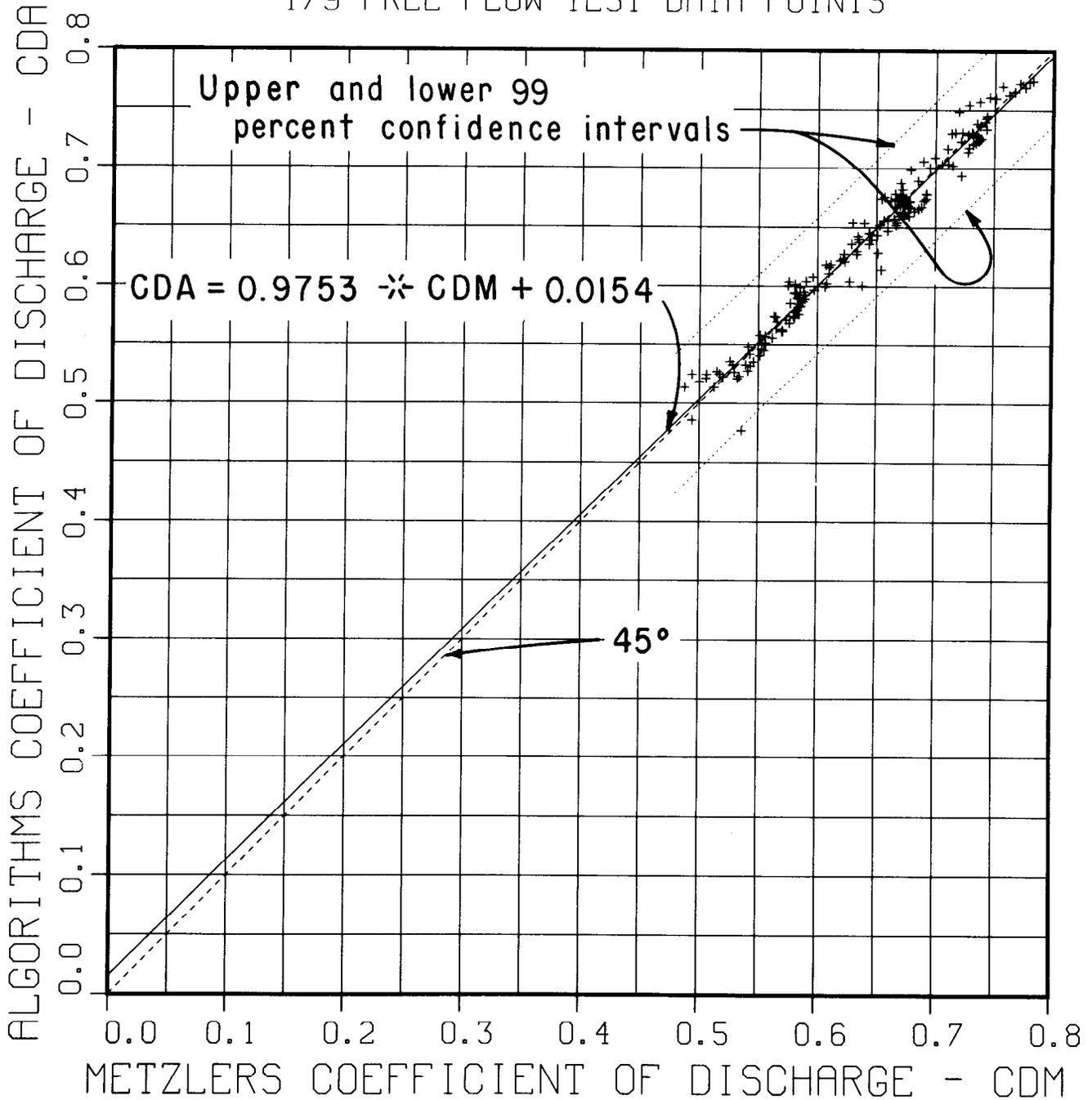
Figure 39.—Comparison of the algorithm-predicted and the laboratory-measured coefficients of discharge, CDA and CDM, for free flow conditions.
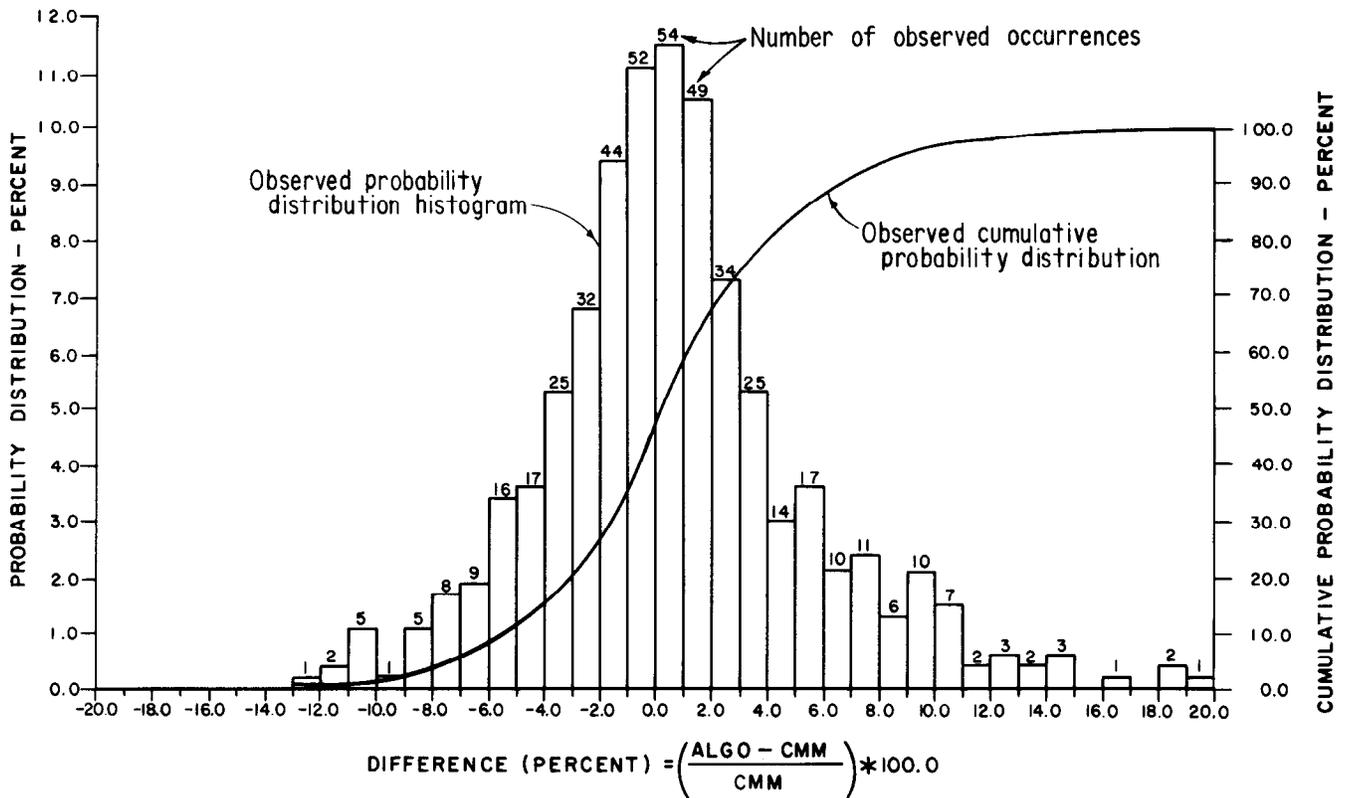
Figure 40.—Field verification test program statistical analysis frequency distribution graph of the difference (percent) between all the algorithm-predicted and the measured discharges, ALGO and CMM, for all of the 468 field test data points.

Appendix III discusses the field verification test program in detail for each of the 13 prototype canal check gate structures investigated.

The average difference indicates that the algorithm-predicted discharge is slightly biased in the positive direction, by +0.7 percent, compared to the field measurement of discharge. The standard deviation of ±4.9 percent indicates that a high spread in the comparison has occurred.

The overall results can best be illustrated by observing the shape of the histogram shown in the frequency distribution graph (fig. 40) for the percent difference. The histogram is symmetrical about the center of gravity (+0.7 percent) and has a bell shape. The bell shape indicates that the difference between the algorithm-predicted discharge and the field-measured discharge is normally distributed. Note that between one standard deviation of ±4.9 percent, the observed cumulative probability distribution, figure 40, shows that about 73 percent of the test data points are included within this interval, which is another indication that normal distribution of the test data has occurred.

At two standard deviations of ±9.8 percent, 92 percent of the test points occur, and at three

standard deviations of ±14.7 percent, 99 percent of test data points are included in the interval.

If the difference between the algorithm-predicted and the field-measured discharge has normal distribution, the difference or errors are of a random nature and not of the systematic type. Significant errors of the systematic type would degrade the ability of the algorithms to predict the true discharge with accuracy; whereas, close agreement to normal distribution characteristics would lend credence that the discharge algorithms accurately represent the true flow characteristics of canal radial gates. Therefore, it is important to know if the observed distribution of the test comparisons deviates, statistically, a significant amount from a hypothesized normal distribution. To ascertain the validity of the assumption that normal distribution has occurred, and if the deviation of critical statistics is within acceptable limits, two hypothesis tests for "goodness-of-fit" are performed.

The first quantitative goodness-of-fit evaluation can be demonstrated graphically through the use of normal probability paper as illustrated in figure 41, and executing the Kolmogorov-Smirnov test [15].

57
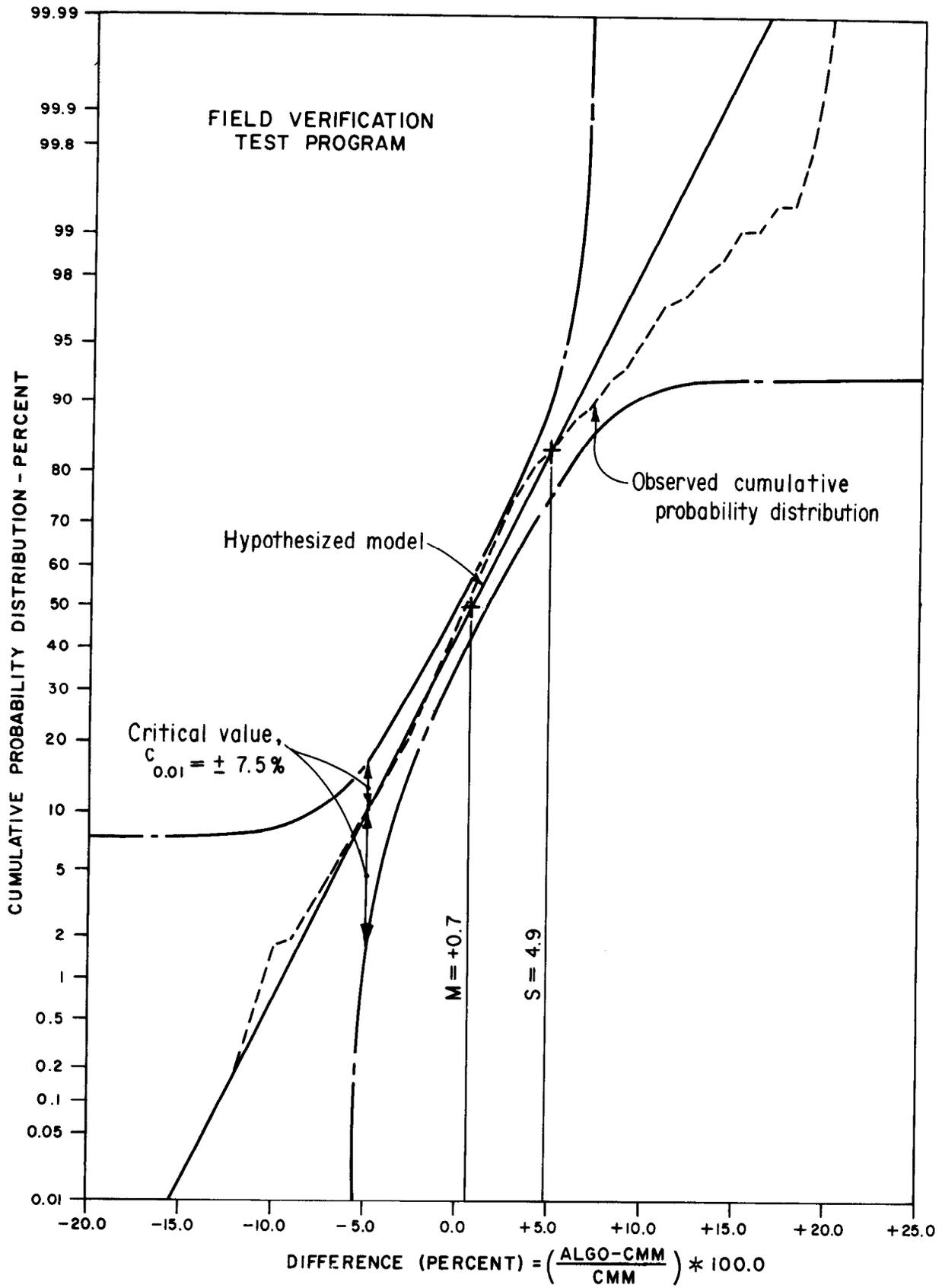
Figure 41.—Field verification test data, hypothesized model, and Kolmogorov-Smirnov test shown graphically on probability paper.

Normal probability paper graphical construction is based on a normal distribution. If the distribution is normal, the cumulative probability distribution plotted on normal probability paper would be a straight line. The hypothesized normal straight line (solid line on fig. 41) is drawn through two points shown at the "+" marks. These two points are determined from the data statistics and are:

1. The average difference, m, at +0.7 percent (abscissa) and the cumulative probability at 50 percent (ordinate)

2. One standard deviation, s, of +4.9 percent (abscissa) and the cumulative probability at 84.1 percent (ordinate)

The observed cumulative probability distribution, figure 40, is plotted on the normal probability paper, figure 41, as the dashed line.

The Kolmogorov-Smirnov goodness-of-fit test determines if the observed data points fall within a reasonable sampling variation upon the straight line [15]. It concentrates on the deviation between the observed and the hypothesized model cumulative probability distribution and can be shown in a graphical manner directly on the normal probability paper, figure 41. The critical statistic for the Kolmogorov-Smirnov test at the 1 percent significance level is (table A.7 of reference [16]):

$$c = \pm \frac{1.63}{\sqrt{n}} * 100.0 = \pm 7.5 \text{ percent}$$

where:

n = the sample size of 468 test data points.

The Kolmogorov-Smirnov test is executed by plotting curved lines above and below the hypothesized model offset by an amount equal to the critical value, c, of ±7.5 percent. The fact that none of the observed plotted points (dashed line) fall significantly outside the curved lines implies that the assumption that the distribution of the test data points is normal is correct at the 1 percent significance level.

The second goodness-of-fit is the χ^2 test. It concentrates on the deviation between the observed and hypothesized model probability distribution histograms. The hypothesized probability distribution histogram is derived from the hypothesized model which is shown as the straight solid line on figure 41. From the hypothesized model histogram, the "expected" number of occurrences for normal distribution can be determined at the same intervals of the difference (percent) used for the "observed" histogram (fig. 40).

The χ_0^2 statistic is calculated by normalized squared deviations and is found to be:

$$\chi_0^2 = \frac{\Sigma(\text{observed}-\text{expected})^2}{\text{expected}} = 200.4$$

The critical statistic for the χ^2 goodness-of-fit at the 1 percent significance level is:

$$\chi_{0.01,2}^2 = 1/2 \ (Z_p + \sqrt{2*v-1})^2 = 396.2$$

where:

Z_p = -2.33 (table A-2, reference [12])
v = degrees of freedom = k–r–l = 468–2–1 = 465
k = number of test points = 468
r = number of parameters estimated from the data = 2

Since the observed χ_0^2 = 200.4 is less than the critical value of $\chi_{0.01,2}^2$ = 396.2, suggests the assumption, that the observed probability distribution is normal, is correct at the 1 percent significance level.

An analysis of the linearity of the algorithms' predicted discharge offers further verification of the algorithms' accuracy. Figure 42 is a plot of the algorithm-predicted versus the field measured discharge 468 field test data points (tables III-6 through III-18). A perfect agreement would equal the 45° dashed line. However, the algorithm-predicted and field-measured discharge both have errors of measurement; therefore, a scatter in the data points about the 45° line has occurred.

Very close agreement of a best fit straight line of the 468 test data points with the 45° line would indicate the algorithm-predicted discharge is linear and unbiased. The fundamental assumption of linearity is:

$$\text{ALGO} = A*\text{CMM}+B$$

where:

ALGO = the predicted discharge by algorithms
CMM = the true discharge by field measurement
A = the slope of the straight line
B = the offset of the straight line at zero discharge

For the 45° line, A equals 1.0 and B equals 0.0.

Using the method of least squares fit, the straight line equation for the 468 field test points is (solid line, fig. 42):

$$\text{ALGO} = 1.005*\text{CMM}+5.2$$

To demonstrate the linearity and unbiased characteristics, hypothesis tests are performed on the

59
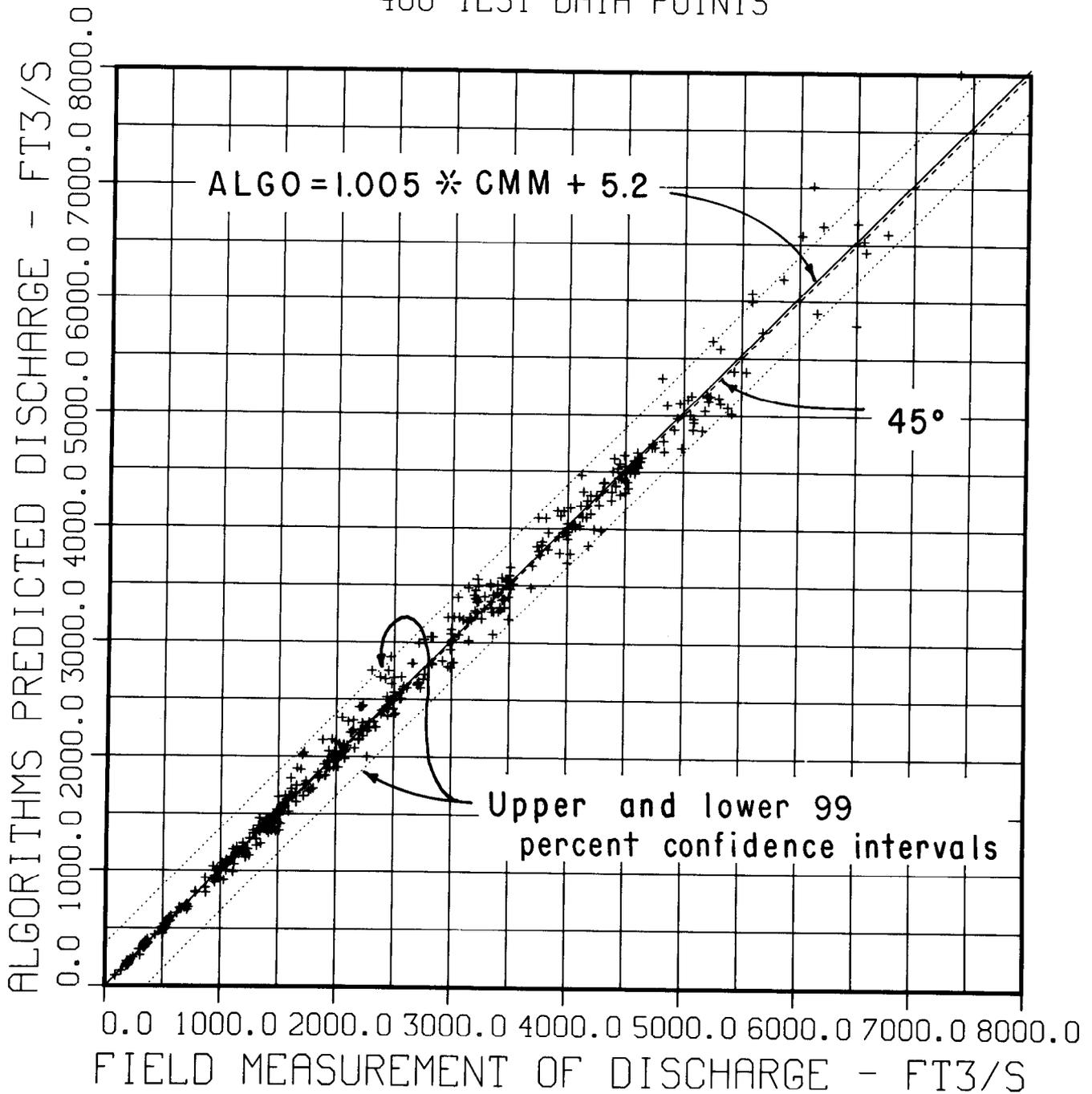
Figure 42.—Comparison of the algorithm-predicted and the field-measured discharges, ALGO and CMM.

A and B parameters of the above linear equation. The test for unity of the slope parameter A as compared to the observed value of 1.005 using the t statistic has an acceptance interval at the 1 percent significance level of:

$$1.0 \pm t_{\alpha/2, n-2} * SA = 1.0 \pm 0.011$$

where:

$t_{\alpha/2, n-2}$ = t statistic = 2.576 (table A-4 in [12]) at significance level, α = 1 percent and two degrees of freedom

$$SA = \sqrt{\frac{S^2}{n \, SY^2}} = 0.0042$$

= the estimated variance of the parameter A

S = the standard deviation (actual)
= 140.9 ft³/s

$$SY^2 = \frac{1}{n} \left[\Sigma Y_i^2 - n \, (\bar{Y})^2 \right] = 2409535.1$$

ΣY_i = algorithm-predicted discharge
= 4234411280.5

$\bar{Y}$ = average algorithm-predicted discharge = 2576.5

n = 468 test data points

The hypothesis test suggests the slope, A, of the line is not significantly different from unity at the 1 percent significance level since the observed value of A = +1.005 is less than the critical value of +1.011.

The critical value for the intercept parameter, B, at zero discharge using the same t statistic at the 1 percent significance level, is:

$$C = \pm t_{\alpha/2, n-2} * SB = \pm 32.6$$

where:

SB = the estimated variance of the parameter B

$$= \sqrt{\frac{S^2}{n} \left[1 + \frac{(\bar{Y})^2}{SY^2} \right]} = 12.63$$

The observed value of B equals +5.2 and is well within the critical value of +32.6. Therefore, the offset at zero discharge is not significantly different than zero at the 1 percent significance level.

The results of the hypothesis tests on the two parameters A and B of the linear equation for the best fit of the test data confirm that the functional relationship of the algorithm-predicted and the field-measured discharge is linear and unbiased.

The upper and lower confidence bands at the 1 percent significance level for the single future value of the algorithm-perdicted discharge are shown as dotted lines in figure 42. It is expected that algorithm-predicted discharge will be within the upper and lower confidence intervals 99 percent of the time.

The results of the field verification program have confirmed that the discharge algorithms applied to radial gate check structures of an actual operating canal system are capable of predicting the true discharge as accurately as any measuring device or procedure presently available for measuring flows in canal systems. The field data consisted of 468 test data points from 13 canal radial gate check structures (including the Coalinga Canal check No. 1 special field test), 12 of which have significant variations in geometry. Therefore, an adequate base was provided to determine the validity of the discharge algorithms' accuracy, which is summarized as follows (also refer to detailed discussions in app. III):

1. Overall average error is +0.7 percent and may be slightly biased in the positive direction. However, statistical analysis indicates the error is within critical limits and therefore can be considered as being unbiased.

2. Overall standard deviation is ±4.9 percent, indicating a high spread in the difference between the algorithm-predicted discharge and the field-measured discharge. The high spread in the results is believed to be caused primarily by the coarse resolution of the field data measurements.

3. The range of the overall average differences between algorithm-predicted and field-measured discharges for the 13 canal radial gate structures investigated was from -1.4 to +2.6 percent, and the standard deviation ranged from ±2.2 to ±6.1 percent.

4. The range of the error can approach ±20 percent if the critical field measurements are not made carefully or the discharge algorithms are improperly applied.

5. Minor changes in the hard-rubber-bar gate lip seal design can cause errors in the range of about -8 to +13 percent if a correction algorithm to adjust the coefficient of discharge is not applied.

6. Statistical analysis has demonstrated (a) distribution of the errors is normal, (b) the functional relationship is linear and unbiased, and (c) the algorithms predict the discharge very near to the true value.

7. Errors are of a random nature and are not of the systematic type.

8. Statistical analysis of the field data is very similar to the statistical analysis of the laboratory data.

Discharge algorithms were developed from hydraulic laboratory studies on a 1:6 scale model of a single radial gate. Field test results verified that the laboratory hydraulic model is an accurate representation of the prototype canal radial gate check structure. The number of radial gates at the canal check structure does not affect the accuracy of the discharge algorithms. The gate lip seal design configuration is an important variable that has the most effect on the coefficient of discharge characteristics. The coefficient of dis-

charge changes significantly even with minor changes in the standard hard-rubber-bar gate lip seal design.

Some check structures have significant energy losses between the water level measurement location and radial gate. In these cases additional field measurements are required to adequately define the loss coefficient as a function of the discharge algorithms to produce accurate results.

Proper application of the discharge algorithms, including the proper resolution [± 2 mm (± 0.005 ft)] of measurement of the upstream and downstream water levels and the vertical distance of gate openings, is essential to achieve and maintain a high degree of accuracy.

BIBLIOGRAPHY

[1] Metzler, D.E., "A Model Study of Tainter-Gate Operation," M.S. Thesis, State University of Iowa, Iowa City, Iowa, August 1948.

[2] Ippen, A. T., *Engineering Hydraulics,* Chapter VIII, "Channel Transitions and Controls," edited by Rouse, H., John Wiley and Sons, Inc., New York, N.Y., March 1958.

[3] Harder, J.A., "Feedback Control of Irrigation Canal Systems Using the Harder-Smith Control Algorithm," Final Report UCB/HEL-79-01, University of California, Berkeley, Calif., November 1979.

[4] Falvey, H.T., and P.C. Luning, *Gate Stroking,* Report No. REC-ERC-79-7, Engineering and Research Center, Bureau of Reclamation, Denver, Colo., July 1979.

[5] U.S. Army Engineers Waterways Experiment Station, "Hydraulic Design Criteria," Charts 320-3 to 320-8, 1959.

[6] Babb, A., Moayeri, M., and J. Amorocho, "Discharge Coefficients of Radial Gates," Water Science and Engineering Paper No. 1013, Department of Water Science and Engineering, University of California, Davis, Calif., July 1966.

[7] Toch, A., "Discharge Characteristics of Tainter Gates," American Society of Civil Engineers *Transactions,* vol. 120, pp. 290-300, 1955.

[8] Shand, M.J., "The Hydraulic Filter Level Offset Method for the Feedback Control of Canal Checks," Final Report HEL-8-3, Univeristy of California, Berkeley, Calif., June 1968.

[9] Shand, M.J., "Automatic Downstream Control Systems for Irrigation Canals,"

Final Report HEL-8-4, University of California, Berkeley, Calif., August 1971.

[10] Sokolnikoff, I.S., and R.M. Redheffer, *Mathematics of Physics and Modern Engineering,* McGraw Hill Book Company, Inc., New York, N.Y., 1958.

[11] *Water Measurement Manual,* second edition reprint, Bureau of Reclamation, Denver, Colo., 1981.

[12] *Experimental Statistics Handbook 91,* National Bureau of Standards, August 1963.

[13] Chatfield, Christopher, *Statistics for Technology, A Course in Applied Statistics,* second edition, Halsted Press Book, John Wiley and Sons, New York, N.Y., 1978.

[14] "Control Facilities — State of California Water Project," Bulletin No. 200, Vol. V, Department of Water Resources, State of California, November 1974.

[15] Benjamin, Jack R., and C. Allin Cornell, *Probability, Statistics, and Decision for Civil Engineers,* McGraw Hill Book Company, New York, N.Y., 1970.

[16] "Water Operation and Maintenance," Bulletin No. 117, Bureau of Reclamation, Denver, Colo., September 1981.

[17] Buyalski, C.P., "Report on a New Version of a Water Surface Level Gage Used in Canal Performance Test in Region 2," Bureau of Reclamation, Denver, Colo., November 1966.

[18] Burington, R.S., *Handbook of Mathematical Tables and Formulas,* Handbook Publishers, Inc., Sandusky, Ohio, 1953.

APPENDIX I

**Graphical Display of the Hydraulic Laboratory
Canal Radial Gate Model Data Collection and
Algorithm-Predicted Results**

CANAL RADIAL GATE MODEL NO. 1
Coefficient of Discharge
RAD/PH= 1.521   GO/PH= 0.100
———— Metzlers,CDM   ·········· Algorithms,CDA

o - FREE DISCHARGE
+ - SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH
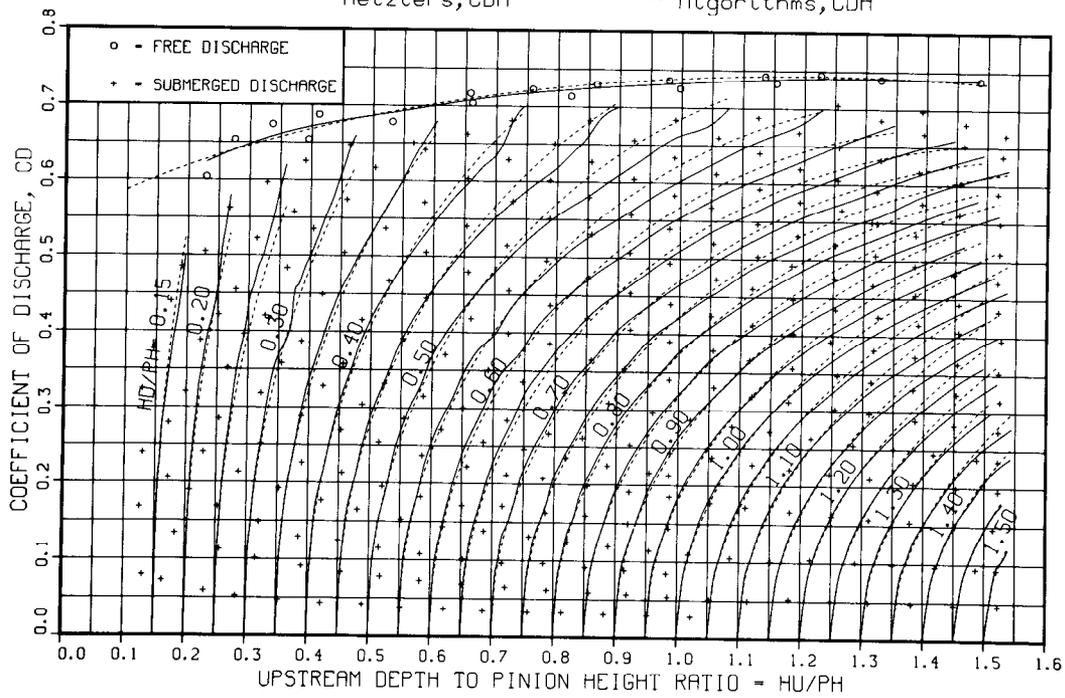
CANAL RADIAL GATE MODEL NO. 1
Coefficient of Discharge
RAD/PH= 1.521   GO/PH= 0.200
———— Metzlers,CDM   ·········· Algorithms,CDA

o - FREE DISCHARGE
+ - SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH
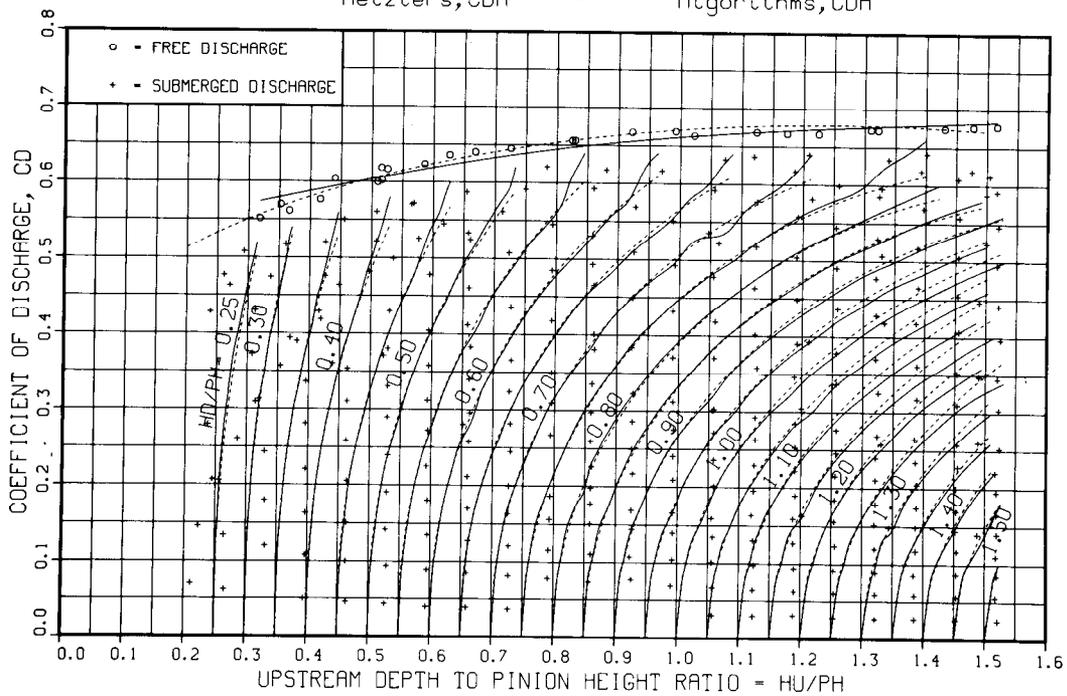
CANAL RADIAL GATE MODEL NO. 1
Coefficient of Discharge
RAD/PH= 1.521   GO/PH= 0.402
——— Metzlers,CDM   ··········· Algorithms,CDA

o - FREE DISCHARGE
+ - SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH
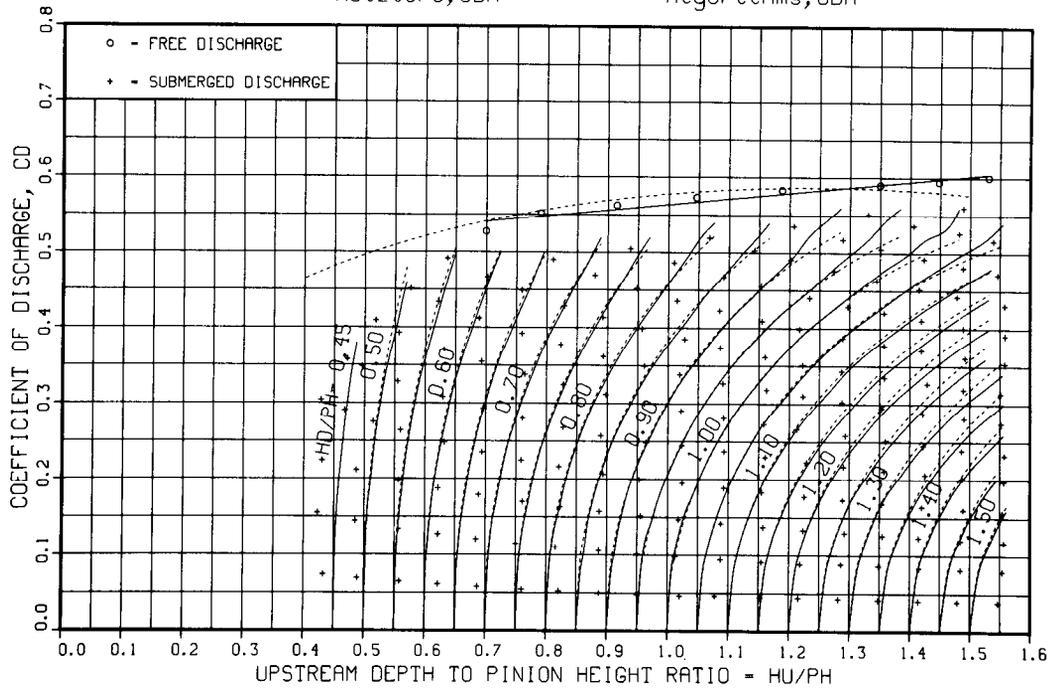
CANAL RADIAL GATE MODEL NO. 1
Coefficient of Discharge
RAD/PH= 1.521   GO/PH= 0.601
——— Metzlers,CDM   ··········· Algorithms,CDA

o - FREE DISCHARGE
+ - SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH

67
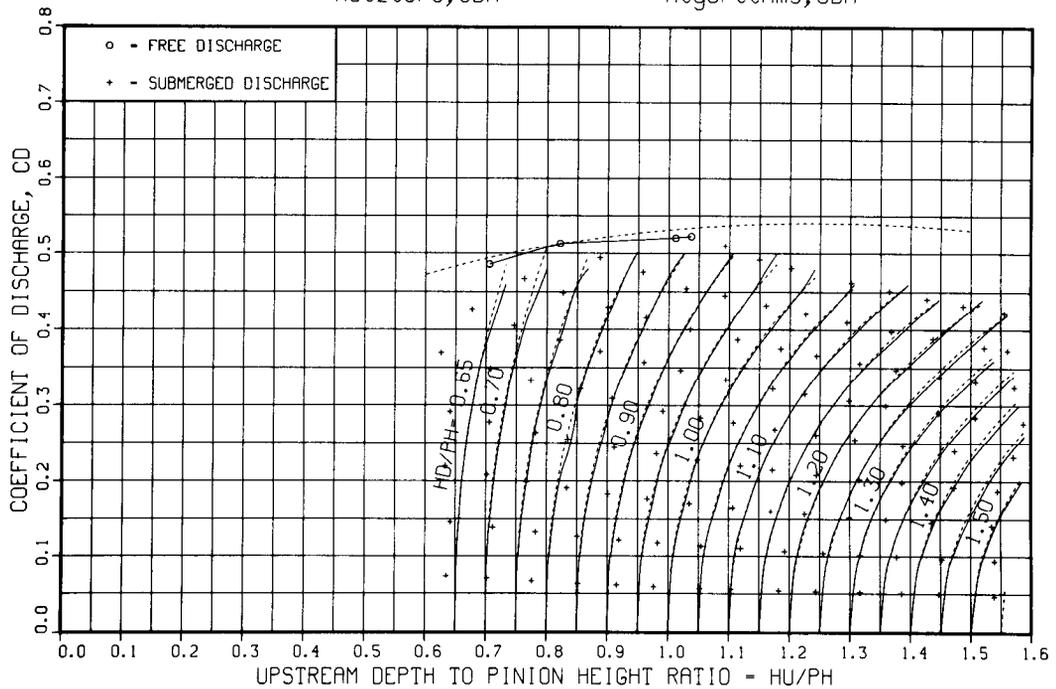
CANAL RADIAL GATE MODEL NO. 1
Coefficient of Discharge
RAD/PH= 1.521   GO/PH= 0.803
———— Metzlers,CDM   ············· Algorithms,CDA

o - FREE DISCHARGE

+ - SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH

HD/PH= 0.85 0.90 1.00 1.10 1.20 1.30 1.40 1.50
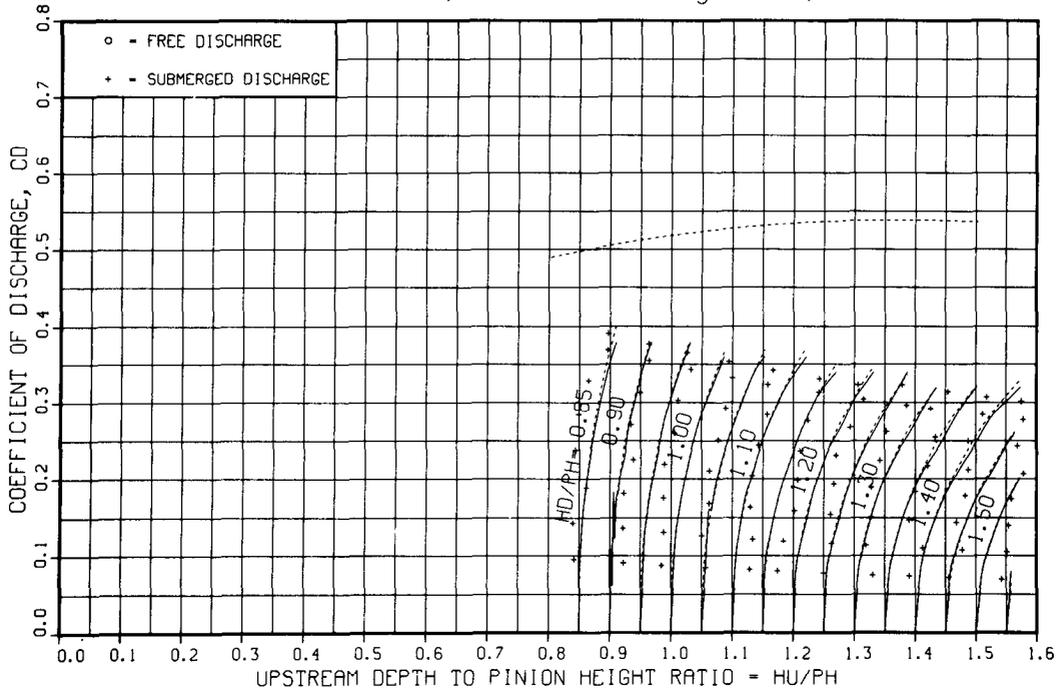
CANAL RADIAL GATE MODEL NO. 1
Coefficient of Discharge
RAD/PH= 1.521   GO/PH= 1.002
———— Metzlers,CDM   ············· Algorithms,CDA

o - FREE DISCHARGE

+ - SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH

HD/PH= 1.05 1.10 1.20 1.30 1.40 1.50
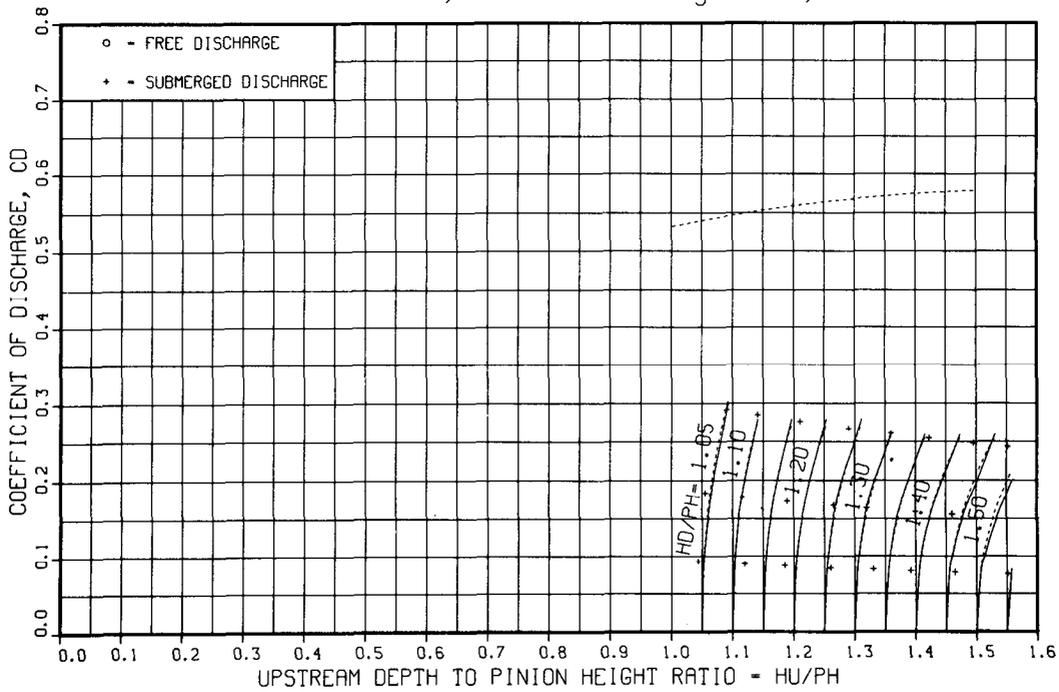
CANAL RADIAL GATE MODEL NO. 1
Coefficient of Discharge
RAD/PH= 1.521   GO/PH= 1.202
————— Metzlers,CDM   ------------ Algorithms,CDA

o = FREE DISCHARGE

+ = SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH

HD/PH= 1.25   1.30   1.40   1.50
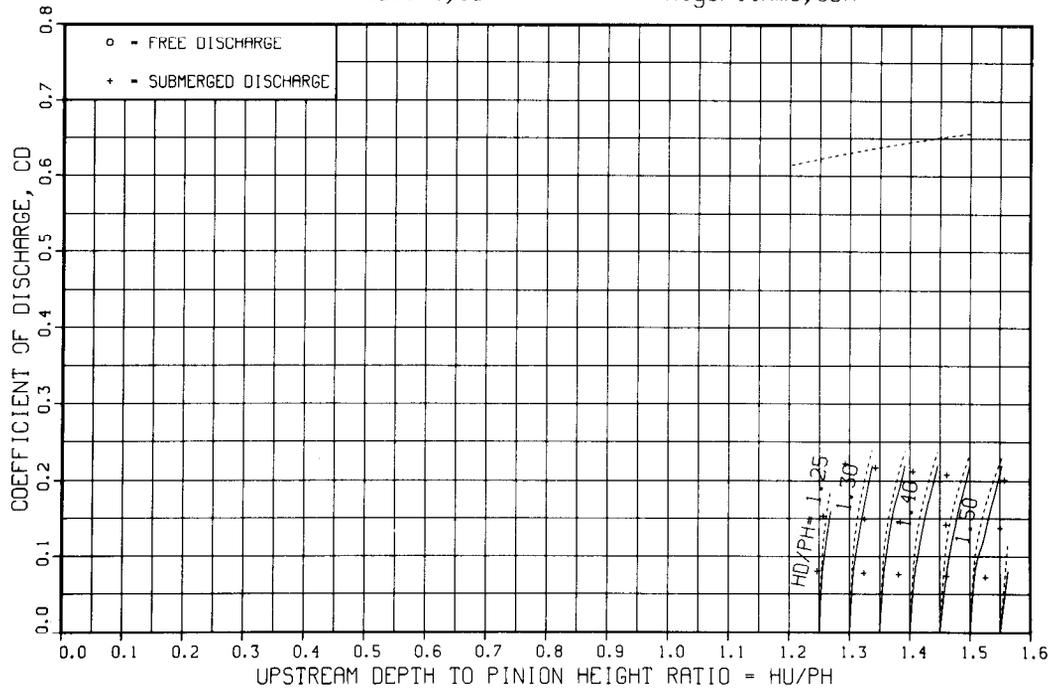
CANAL RADIAL GATE MODEL NO. 2

Coefficient of Discharge

RAD/PH= 1.373   GO/PH= 0.100

———— Metzlers,CDM   ········· Algorithms,CDA

o - FREE DISCHARGE

+ = SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

HD/PH= 0.15   0.20   0.30   0.40   0.50   0.60   0.70   0.80   0.90   1.00   1.10   1.20   1.30   1.40

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH
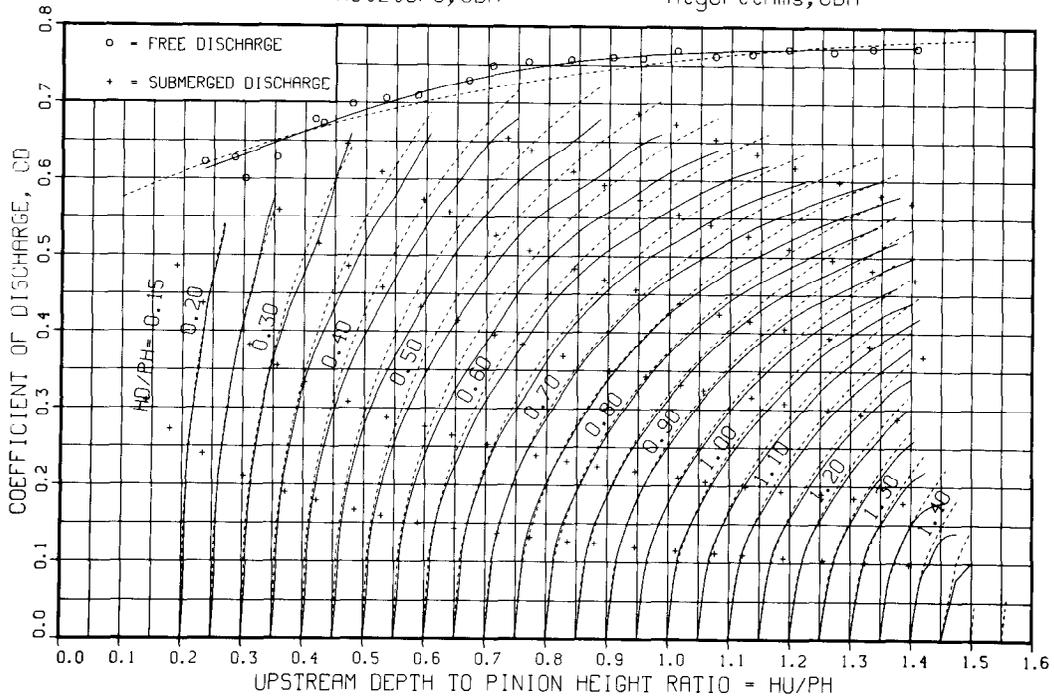
CANAL RADIAL GATE MODEL NO. 2

Coefficient of Discharge

RAD/PH= 1.373   GO/PH= 0.200

———— Metzlers,CDM   ············ Algorithms,CDA

o - FREE DISCHARGE

+ = SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

HD/PH= 0.25   0.30   0.40   0.50   0.60   0.70   0.80   0.90   1.00   1.10   1.20   1.30   1.40

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH

70
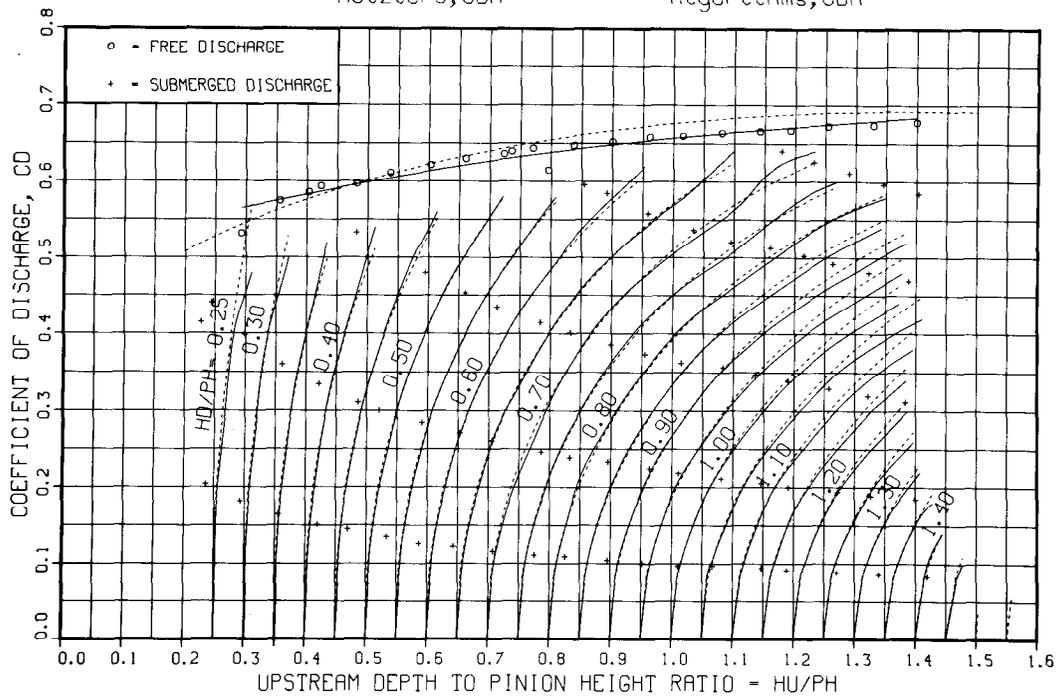
CANAL RADIAL GATE MODEL NO. 2

Coefficient of Discharge

RAD/PH= 1.373   GO/PH= 0.399

———— Metzlers,CDM   ············· Algorithms,CDA

o – FREE DISCHARGE

+ – SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

UPSTREAM DEPTH TO PINION HEIGHT RATIO – HU/PH
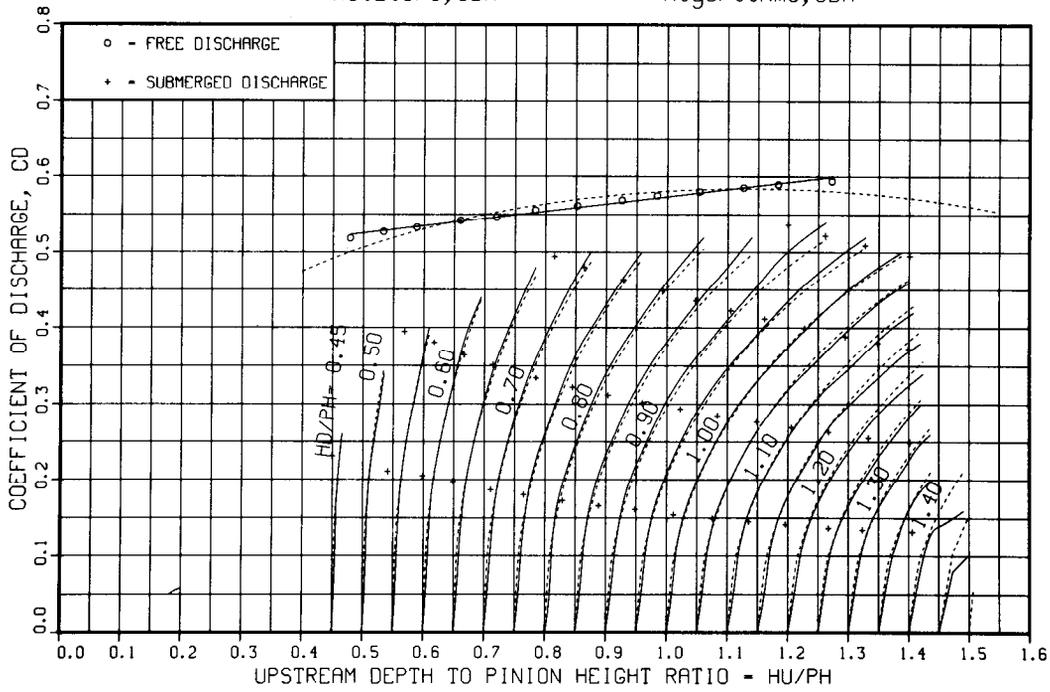
CANAL RADIAL GATE MODEL NO. 2

Coefficient of Discharge

RAD/PH= 1.373   GO/PH= 0.597

———— Metzlers,CDM   ············· Algorithms,CDA

o – FREE DISCHARGE

+ – SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

UPSTREAM DEPTH TO PINION HEIGHT RATIO – HU/PH
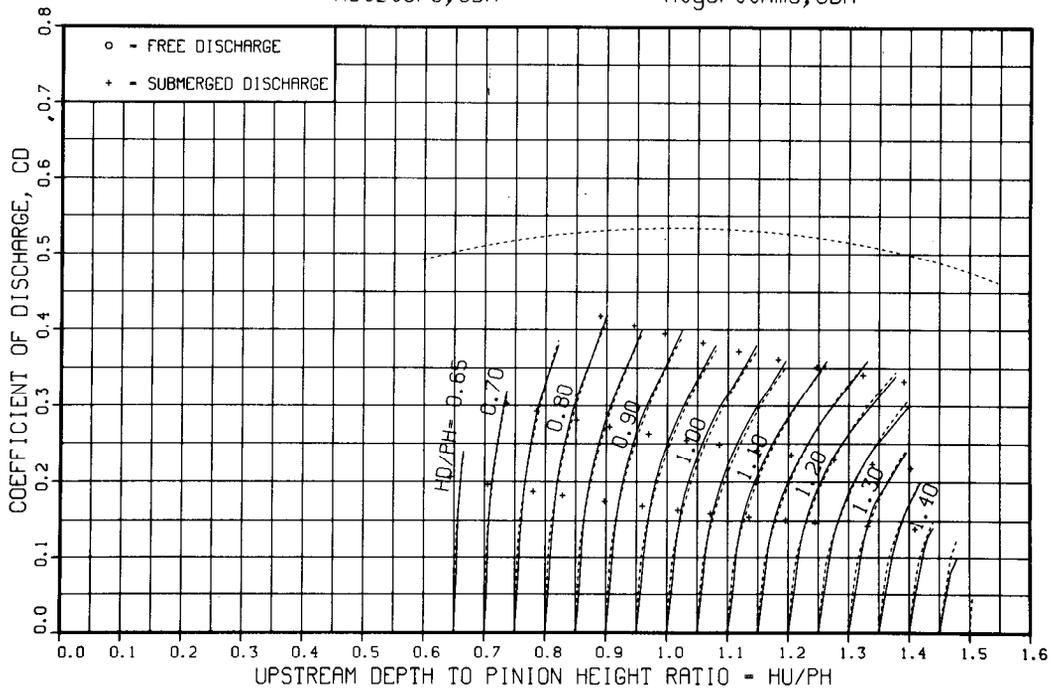
CANAL RADIAL GATE MODEL NO. 2

Coefficient of Discharge
RAD/PH= 1.373   GO/PH= 0.796
———— Metzlers,CDM   ············ Algorithms,CDA

○ = FREE DISCHARGE
+ = SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD (vertical axis)

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH

HD/PH= 0.85   0.90   1.00   1.10   1.20   1.30   1.40
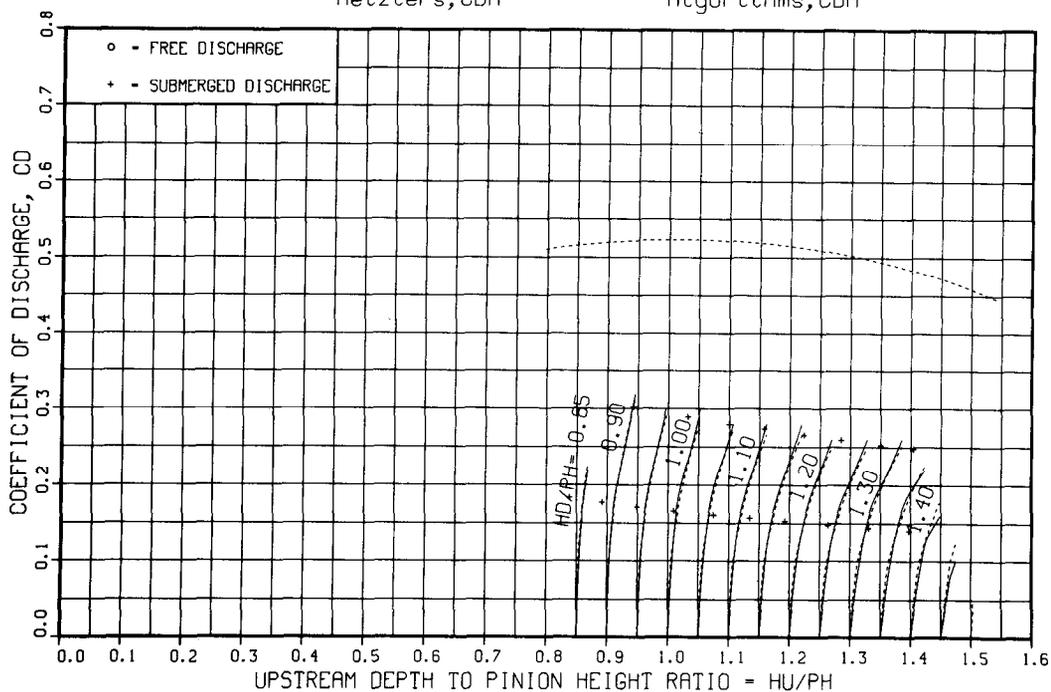
CANAL RADIAL GATE MODEL NO. 2

Coefficient of Discharge
RAD/PH= 1.373   GO/PH= 0.996
———— Metzlers,CDM   ············ Algorithms,CDA

○ = FREE DISCHARGE
+ = SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD (vertical axis)

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH

HD/PH= 1.10   1.20   1.30   1.40

72
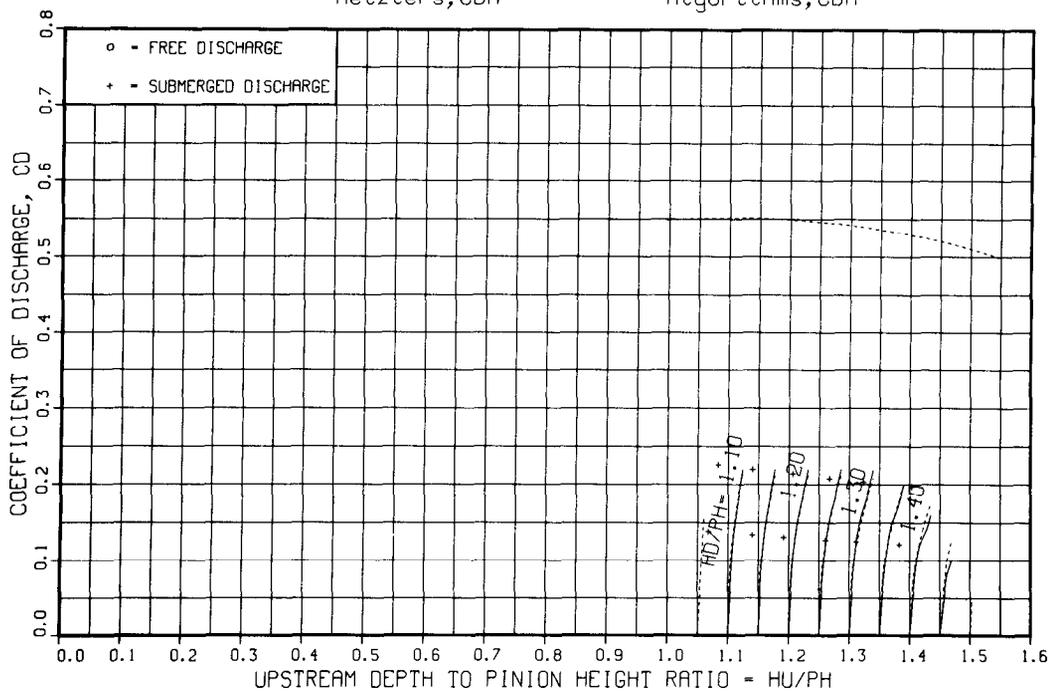
CANAL RADIAL GATE MODEL NO. 2

Coefficient of Discharge

RAD/PH= 1.373   GO/PH= 1.196

———— Metzlers,CDM   ············ Algorithms,CDA

Chart with y-axis "COEFFICIENT OF DISCHARGE, CD" ranging from 0.0 to 0.8, and x-axis "UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH" ranging from 0.0 to 1.6. Legend: o = FREE DISCHARGE, + = SUBMERGED DISCHARGE. Curves labeled HD/PH = 1.25, 1.30, 1.40.
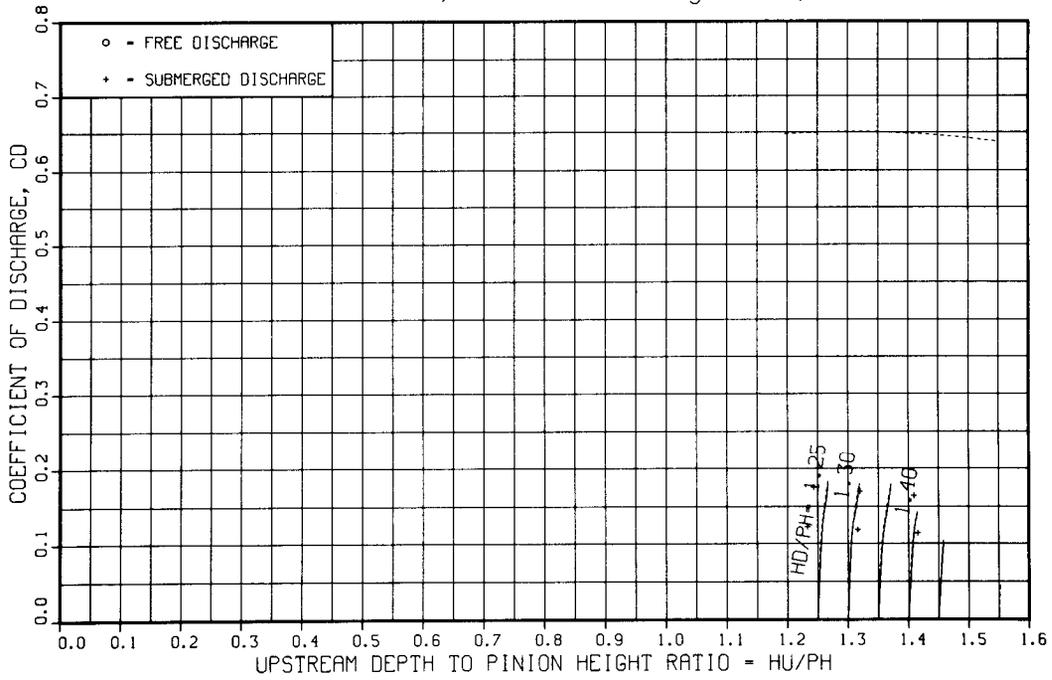
CANAL RADIAL GATE MODEL NO. 3

Coefficient of Discharge

RAD/PH= 1.715   GO/PH= 0.098

————— Metzlers,CDM   ··········· Algorithms,CDA

o - FREE DISCHARGE

+ - SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH
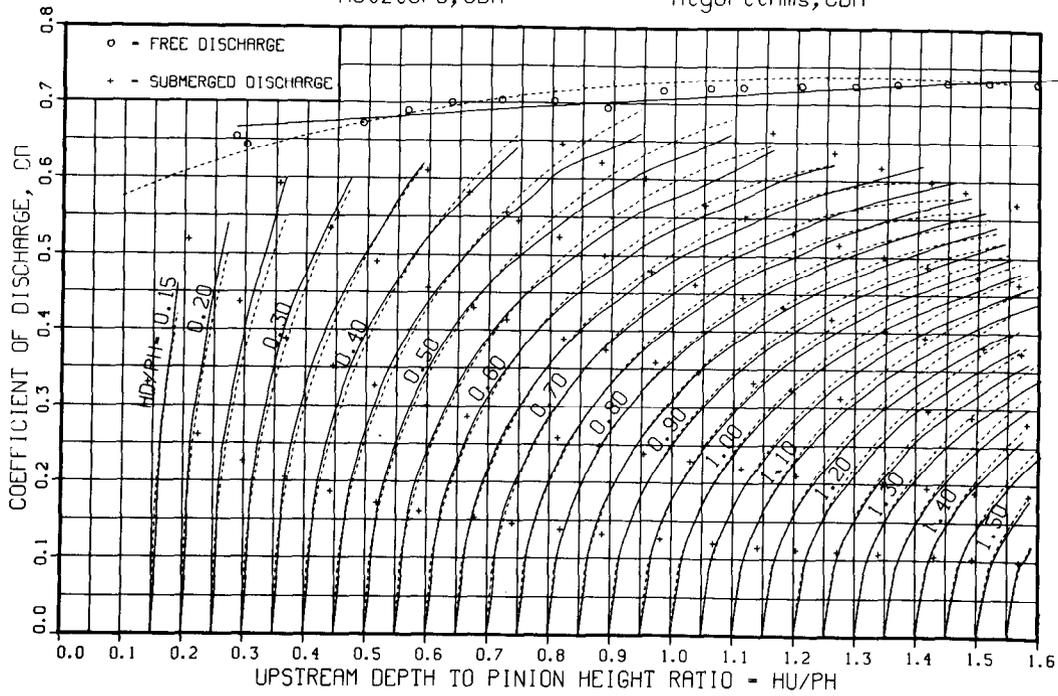
CANAL RADIAL GATE MODEL NO. 3

Coefficient of Discharge

RAD/PH= 1.715   GO/PH= 0.198

————— Metzlers,CDM   ··········· Algorithms,CDA

o - FREE DISCHARGE

+ - SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

UPSTREAM DEPTH TO PINION HEIGHT RATIO - HU/PH
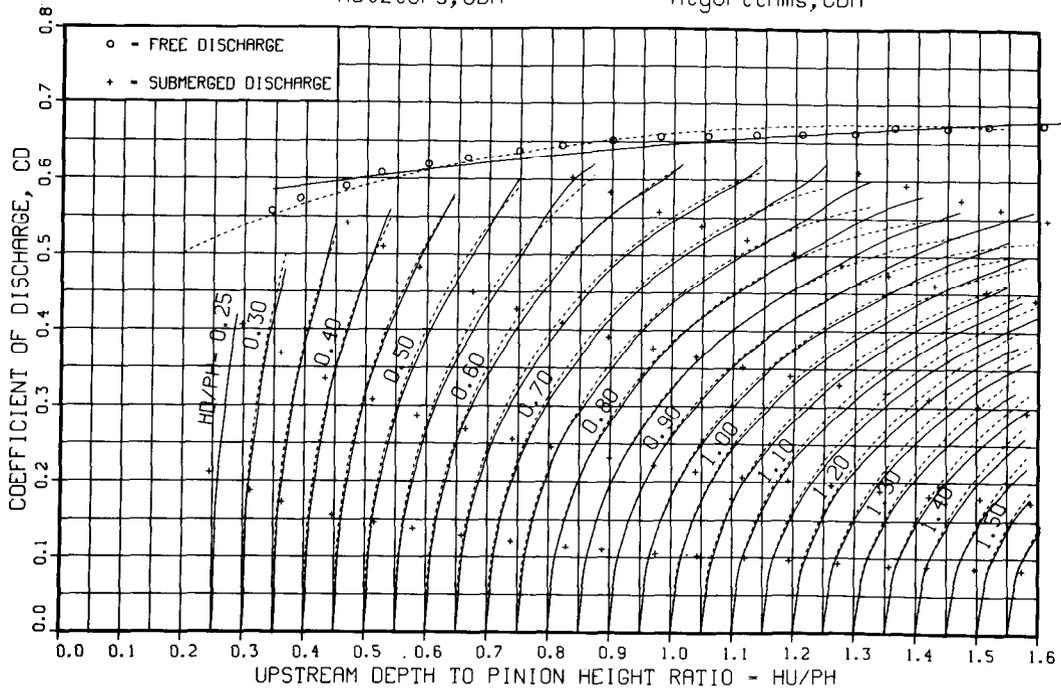
CANAL RADIAL GATE MODEL NO. 3
Coefficient of Discharge
RAD/PH= 1.715   GO/PH= 0.396
————— Metzlers,CDM   ·········· Algorithms,CDA

o - FREE DISCHARGE
+ - SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH
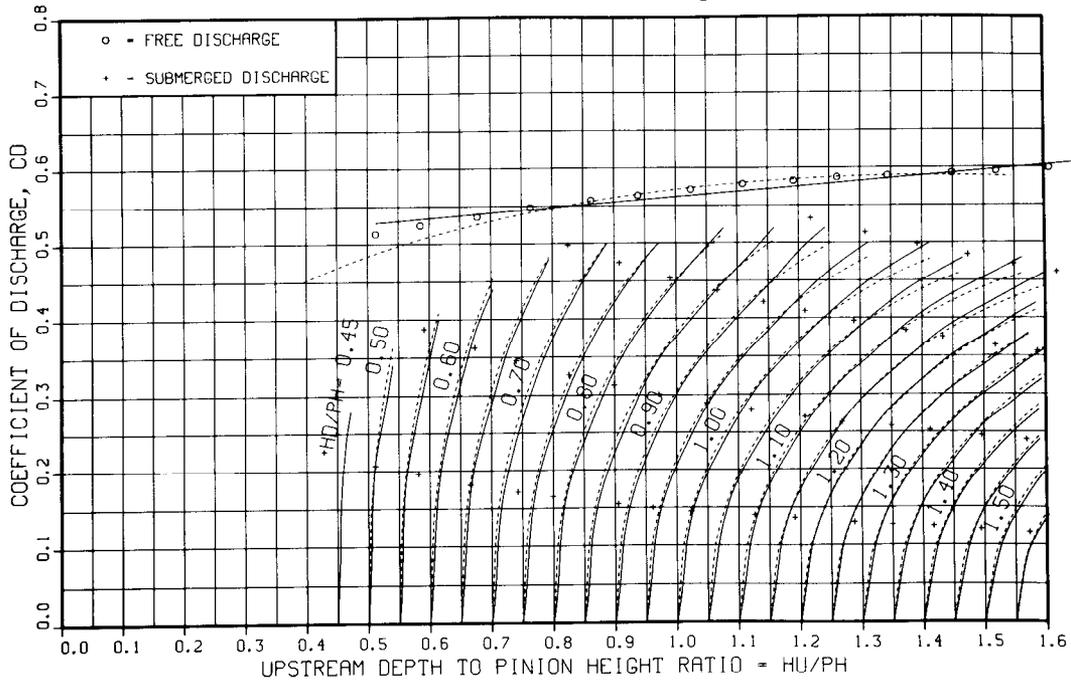
CANAL RADIAL GATE MODEL NO. 3
Coefficient of Discharge
RAD/PH= 1.715   GO/PH= 0.594
————— Metzlers,CDM   ·········· Algorithms,CDA

o - FREE DISCHARGE
+ - SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH

75
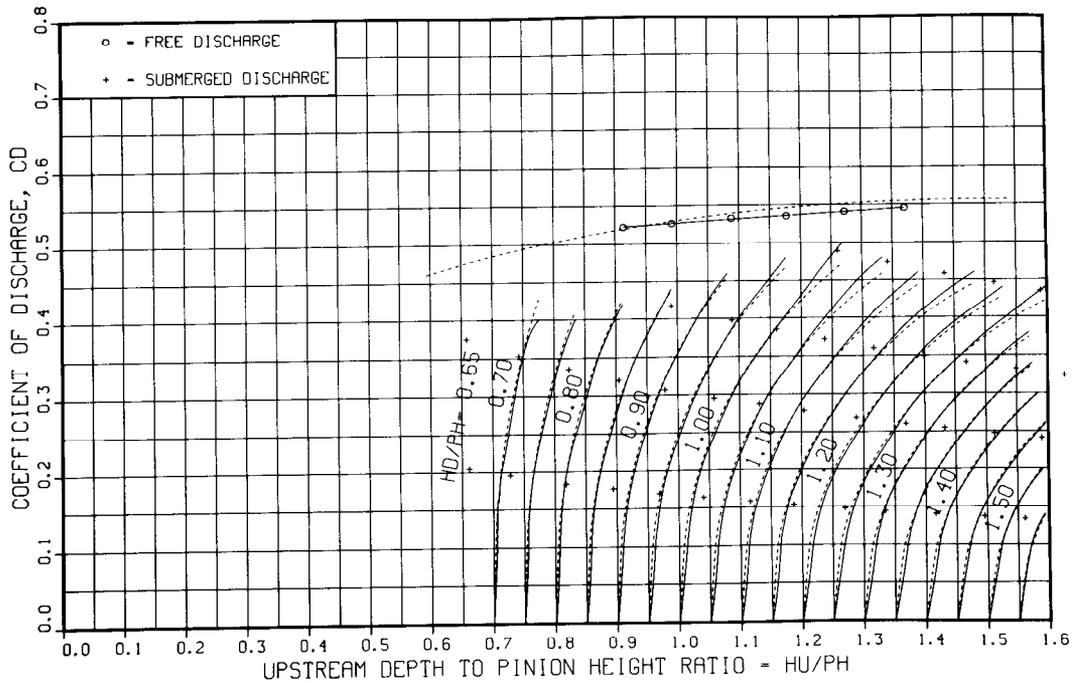
CANAL RADIAL GATE MODEL NO. 3

Coefficient of Discharge

RAD/PH= 1.715   GO/PH= 0.794

———— Metzlers,CDM   ·········· Algorithms,CDA

o - FREE DISCHARGE

+ - SUBMERGED DISCHARGE

HD/PH= 0.85   0.90   1.00   1.10   1.20   1.30   1.40   1.50

COEFFICIENT OF DISCHARGE, CD

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH
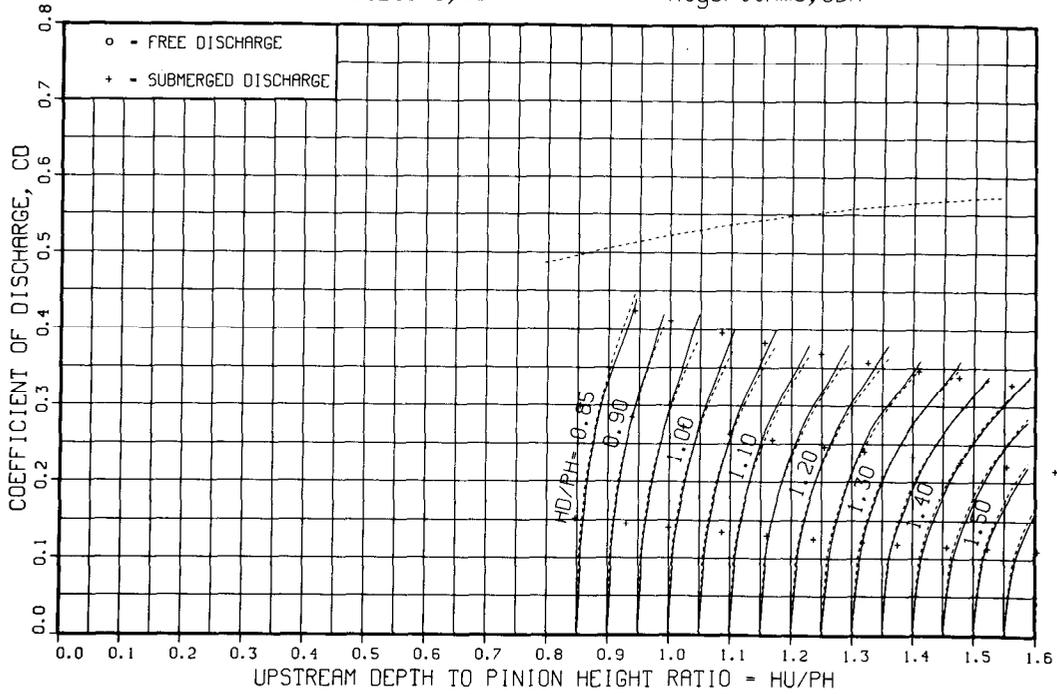
CANAL RADIAL GATE MODEL NO. 3

Coefficient of Discharge

RAD/PH= 1.715   GO/PH= 0.993

———— Metzlers,CDM   ·········· Algorithms,CDA

o - FREE DISCHARGE

+ - SUBMERGED DISCHARGE

HD/PH= 1.05   1.10   1.20   1.30   1.40   1.50

COEFFICIENT OF DISCHARGE, CD

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH
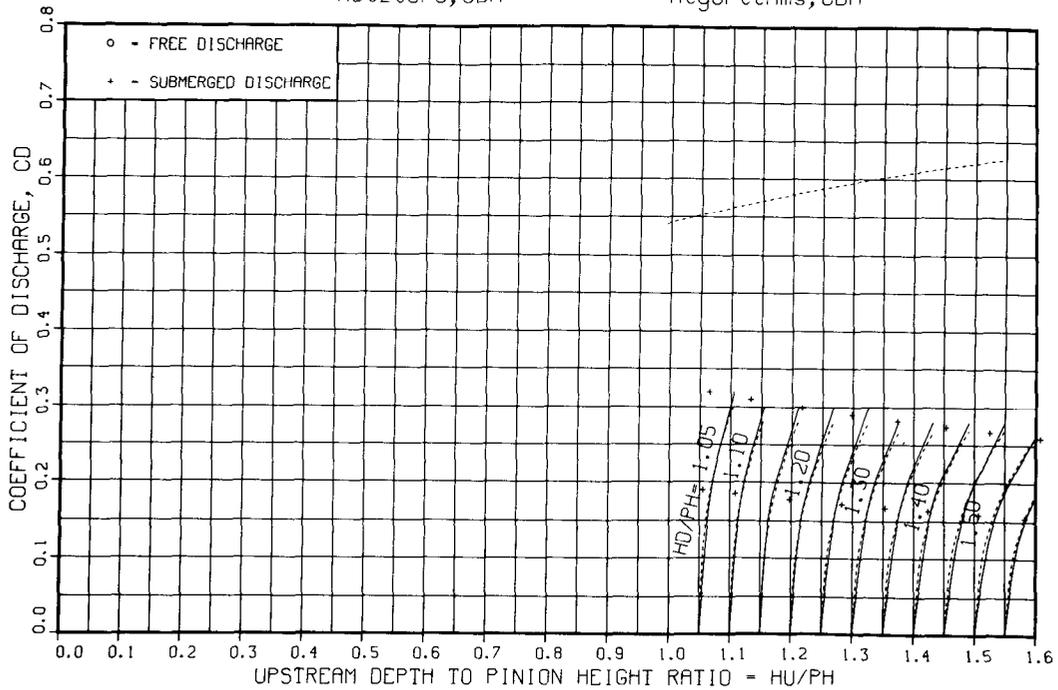
CANAL RADIAL GATE MODEL NO. 3
Coefficient of Discharge
RAD/PH= 1.715   GO/PH= 1.191
———— Metzlers,CDM   ············ Algorithms,CDA

o - FREE DISCHARGE

+ - SUBMERGED DISCHARGE

COEFFICIENT OF DISCHARGE, CD

HD/PH= 1.25   1.30   1.40   1.50

UPSTREAM DEPTH TO PINION HEIGHT RATIO = HU/PH
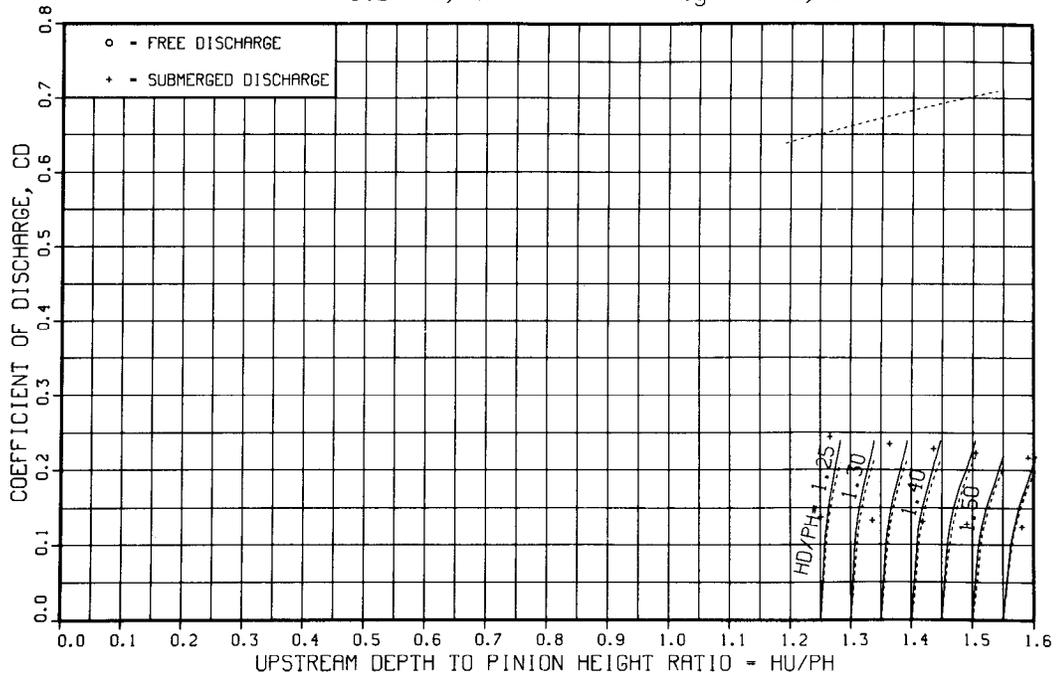
APPENDIX II

Tabulation of the Hydraulic Laboratory
Canal Radial Gate Model Studies and
Algorithm-Predicted Results

Note:
All of the laboratory data were measured in inch-pound units. Therefore, only the inch-pound units will be presented. It will be the responsibility of the reader to convert to metric units for his or her own purposes.

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI-ATION (CDA-CDM)	DEVI-ATION (PERCENT)
47	1.430	FREE	.151	.100	.598	.191	.395	.126	.654	.667	.013	2.0
48	1.720	FREE	.151	.100	.804	.172	.531	.113	.679	.692	.014	2.0
49	1.990	FREE	.151	.100	1.000	.152	.661	.100	.704	.711	.007	1.0
50	2.250	FREE	.151	.100	1.242	.151	.821	.100	.714	.727	.013	1.9
51	2.520	FREE	.151	.100	1.509	.161	.997	.106	.726	.739	.013	1.8
52	2.740	FREE	.151	.100	1.746	.169	1.154	.111	.733	.743	.010	1.3
53	2.960	FREE	.151	.100	2.004	.174	1.325	.115	.740	.742	.002	.3
54	3.130	FREE	.151	.100	2.250	.179	1.487	.118	.738	.735	-.003	-.4
482	.102	OMIT	.151	.100	.247	.245**						
483	.099	SUBM	.151	.100	.351	.349	.232	.231	.059	.083	.024	39.8
484	.097	SUBM	.151	.100	.429	.427	.284	.282	.052	.072	.020	39.2
485	.098	OMIT	.151	.100	.534	.531**						
486	.098	SUBM	.151	.100	.639	.638	.422	.422	.043	.040	-.004	-8.6
487	.102	SUBM	.151	.100	.741	.739	.490	.488	.042	.051	.009	21.3
488	.099	SUBM	.151	.100	.835	.834	.552	.551	.038	.032	-.006	-15.5
489	.100	SUBM	.151	.100	.942	.940	.623	.621	.036	.036	-.000	-.1
490	.098	SUBM	.151	.100	1.038	1.037	.686	.685	.034	.025	-.010	-28.0
491	.098	SUBM	.151	.100	1.148	1.146	.759	.757	.032	.033	.001	1.8
492	.101	SUBM	.151	.100	1.231	1.229	.814	.812	.032	.032	-.000	-1.3
493	.100	SUBM	.151	.100	1.335	1.333	.882	.881	.031	.030	-.000	-.5
494	.100	SUBM	.151	.100	1.440	1.438	.952	.950	.029	.029	-.000	-.6
495	.099	SUBM	.151	.100	1.547	1.545	1.022	1.021	.028	.028	.000	.3
496	.200	SUBM	.151	.100	.278	.273	.184	.180	.134	.149	.015	11.4
497	.199	SUBM	.151	.100	.380	.303	.256	.253	.113	.120	.007	6.4
498	.198	SUBM	.151	.100	.477	.473	.315	.313	.101	.095	-.006	-6.0
499	.199	SUBM	.151	.100	.591	.585	.391	.387	.092	.099	.007	8.1
500	.197	SUBM	.151	.100	.688	.682	.455	.451	.084	.088	.004	5.0
501	.196	SUBM	.151	.100	.785	.779	.519	.515	.078	.078	.000	.0
502	.194	SUBM	.151	.100	.882	.876	.583	.579	.073	.068	-.005	-6.5
503	.193	SUBM	.151	.100	.986	.980	.652	.648	.069	.062	-.007	-10.2
504	.193	SUBM	.151	.100	1.092	1.086	.722	.718	.065	.059	-.007	-10.3
505	.191	SUBM	.151	.100	1.194	1.188	.789	.785	.062	.056	-.006	-9.5
506	.190	SUBM	.151	.100	1.297	1.290	.857	.853	.059	.058	-.001	-1.8
507	.190	SUBM	.151	.100	1.390	1.383	.919	.914	.057	.056	-.001	-1.9
508	.189	SUBM	.151	.100	1.490	1.483	.985	.980	.055	.054	-.001	-1.5
509	.184	SUBM	.151	.100	1.592	1.586	1.052	1.048	.052	.048	-.003	-6.5
510	.183	SUBM	.151	.100	1.686	1.681	1.114	1.111	.050	.043	-.007	-14.3
511	.199	SUBM	.151	.100	1.788	1.779	1.182	1.176	.053	.056	.003	5.6
512	.198	SUBM	.151	.100	1.890	1.881	1.249	1.243	.051	.054	.003	6.0
513	.197	SUBM	.151	.100	1.983	1.977	1.311	1.307	.049	.043	-.007	-13.2
514	.196	SUBM	.151	.100	2.089	2.081	1.381	1.375	.048	.048	.000	.6
515	.196	SUBM	.151	.100	2.194	2.185	1.450	1.444	.047	.050	.003	6.6
516	.195	SUBM	.151	.100	2.303	2.295	1.522	1.517	.045	.046	.000	.8
517	.300	SUBM	.151	.100	.313	.303	.207	.200	.190	.188	-.002	-1.1
518	.295	SUBM	.151	.100	.303	.372	.253	.246	.169	.172	.003	1.9
519	.293	SUBM	.151	.100	.485	.473	.321	.313	.149	.154	.005	3.2
520	.280	SUBM	.151	.100	.583	.571	.385	.377	.130	.136	.006	4.9
521	.292	SUBM	.151	.100	.681	.669	.450	.442	.125	.122	-.004	-2.9
522	.289	SUBM	.151	.100	.781	.768	.516	.508	.116	.113	-.003	-2.6
523	.287	SUBM	.151	.100	.883	.871	.584	.576	.108	.096	-.012	-11.2
524	.285	SUBM	.151	.100	.988	.974	.653	.644	.101	.094	-.007	-6.9
525	.284	SUBM	.151	.100	1.084	1.070	.716	.707	.096	.090	-.006	-6.7
526	.297	SUBM	.151	.100	1.185	1.169	.783	.773	.097	.092	-.005	-4.7
527	.295	SUBM	.151	.100	1.288	1.271	.851	.840	.092	.091	-.001	-1.2
528	.294	SUBM	.151	.100	1.384	1.369	.915	.905	.088	.082	-.006	-7.0
529	.292	SUBM	.151	.100	1.487	1.472	.983	.973	.085	.079	-.006	-6.5
530	.400	SUBM	.151	.100	.346	.328	.229	.217	.241	.229	-.011	-4.6
531	.399	SUBM	.151	.100	.434	.415	.287	.274	.214	.203	-.011	-5.2
532	.397	SUBM	.151	.100	.534	.512	.353	.338	.192	.190	-.002	-1.0
533	.400	SUBM	.151	.100	.639	.617	.422	.408	.177	.169	-.008	-4.7
534	.398	SUBM	.151	.100	.728	.705	.481	.466	.165	.157	-.008	-5.1
535	.395	SUBM	.151	.100	.836	.810	.553	.535	.153	.148	-.004	-2.8
536	.394	SUBM	.151	.100	.938	.910	.620	.601	.144	.139	-.005	-3.7
537	.399	SUBM	.151	.100	1.039	1.013	.687	.670	.138	.126	-.013	-9.1
538	.398	SUBM	.151	.100	1.150	1.122	.760	.742	.131	.124	-.007	-5.6
539	.393	SUBM	.151	.100	1.244	1.216	.822	.804	.125	.119	-.006	-4.5
540	.392	SUBM	.151	.100	1.344	1.316	.888	.870	.120	.114	-.005	-4.4
541	.389	SUBM	.151	.100	1.444	1.415	.954	.935	.115	.112	-.002	-2.1
542	.386	SUBM	.151	.100	1.540	1.511	1.018	.999	.110	.108	-.002	-1.4
543	.382	SUBM	.151	.100	1.643	1.615	1.086	1.067	.105	.103	-.002	-2.3
544	.378	SUBM	.151	.100	1.742	1.714	1.151	1.133	.101	.100	-.001	-1.4
545	.400	SUBM	.151	.100	1.840	1.809	1.216	1.196	.104	.102	-.002	-2.0
546	.399	SUBM	.151	.100	1.951	1.920	1.289	1.269	.101	.099	-.002	-1.9
547	.399	SUBM	.151	.100	2.043	2.013	1.350	1.330	.099	.095	-.004	-3.6
548	.398	SUBM	.151	.100	2.148	2.116	1.420	1.399	.096	.096	-.000	-.2
549	.397	SUBM	.151	.100	2.249	2.218	1.486	1.466	.094	.092	-.002	-1.6
550	.397	SUBM	.151	.100	2.300	2.269	1.520	1.500	.093	.091	-.002	-1.7
551	.499	SUBM	.151	.100	.384	.354	.254	.234	.285	.273	-.012	-4.0
552	.497	SUBM	.151	.100	.489	.456	.323	.301	.251	.244	-.007	-2.8
553	.492	SUBM	.151	.100	.590	.553	.390	.365	.227	.228	.002	.8

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 1
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
554	.501	SUBM	.151	.100	.689	.649	.455	.429	.213	.213	-.000	-.0
555	.490	SUBM	.151	.100	.788	.746	.521	.493	.195	.198	.003	1.5
556	.484	SUBM	.151	.100	.883	.841	.584	.556	.182	.181	-.001	-.8
557	.480	SUBM	.151	.100	.985	.944	.651	.624	.171	.163	-.008	-4.5
558	.502	SUBM	.151	.100	1.084	1.034	.716	.683	.171	.172	.001	.8
559	.501	SUBM	.151	.100	1.190	1.140	.787	.753	.162	.164	.001	.8
560	.510	SUBM	.151	.100	1.288	1.236	.851	.817	.159	.160	.001	.8
561	.499	SUBM	.151	.100	1.392	1.344	.920	.888	.150	.148	-.002	-1.3
562	.497	SUBM	.151	.100	1.491	1.443	.985	.954	.144	.142	-.002	-1.0
563	.632	SUBM	.151	.100	.404	.359	.267	.237	.352	.325	-.027	-7.6
564	.629	SUBM	.151	.100	.487	.438	.322	.289	.319	.298	-.020	-6.4
565	.624	SUBM	.151	.100	.587	.532	.388	.352	.288	.280	-.009	-3.0
566	.632	SUBM	.151	.100	.685	.624	.453	.412	.270	.265	-.005	-1.8
567	.634	SUBM	.151	.100	.779	.717	.515	.474	.254	.244	-.010	-4.0
568	.630	SUBM	.151	.100	.885	.820	.585	.542	.237	.227	-.010	-4.2
569	.628	SUBM	.151	.100	.996	.928	.658	.613	.223	.211	-.012	-5.2
570	.626	SUBM	.151	.100	1.093	1.024	.722	.677	.212	.202	-.010	-4.5
571	.638	SUBM	.151	.100	1.183	1.112	.782	.735	.207	.197	-.011	-5.2
572	.637	SUBM	.151	.100	1.292	1.219	.854	.806	.198	.190	-.008	-3.9
573	.638	SUBM	.151	.100	1.394	1.319	.921	.872	.191	.186	-.006	-2.9
574	.639	SUBM	.151	.100	1.493	1.417	.987	.937	.185	.180	-.005	-2.6
575	.634	SUBM	.151	.100	1.593	1.519	1.053	1.004	.178	.172	-.006	-3.3
576	.631	SUBM	.151	.100	1.680	1.606	1.110	1.061	.172	.167	-.005	-2.9
577	.630	SUBM	.151	.100	1.789	1.715	1.182	1.134	.167	.162	-.005	-2.8
578	.627	SUBM	.151	.100	1.892	1.816	1.250	1.200	.161	.160	-.002	-1.0
579	.627	SUBM	.151	.100	1.984	1.909	1.311	1.262	.157	.155	-.003	-1.7
580	.630	SUBM	.151	.100	2.085	2.009	1.378	1.328	.154	.152	-.002	-1.5
581	.630	SUBM	.151	.100	2.197	2.120	1.452	1.401	.150	.149	-.001	-.8
582	.627	SUBM	.151	.100	2.291	2.215	1.514	1.464	.147	.145	-.001	-.9
583	.747	SUBM	.151	.100	.444	.378	.293	.250	.397	.371	-.025	-6.4
584	.742	SUBM	.151	.100	.537	.466	.355	.308	.358	.340	-.019	-5.2
585	.743	SUBM	.151	.100	.640	.562	.423	.371	.329	.317	-.012	-3.6
586	.739	SUBM	.151	.100	.737	.655	.487	.433	.304	.294	-.010	-3.3
587	.740	SUBM	.151	.100	.840	.754	.555	.498	.286	.274	-.011	-3.9
588	.740	SUBM	.151	.100	.932	.842	.616	.557	.271	.260	-.012	-4.3
589	.734	SUBM	.151	.100	1.036	.944	.685	.624	.255	.242	-.013	-5.0
590	.742	SUBM	.151	.100	1.136	1.040	.751	.687	.246	.236	-.011	-4.4
591	.740	SUBM	.151	.100	1.239	1.141	.819	.754	.235	.227	-.008	-3.4
592	.738	SUBM	.151	.100	1.340	1.242	.886	.821	.226	.218	-.008	-3.5
593	.735	SUBM	.151	.100	1.443	1.345	.954	.889	.216	.209	-.007	-3.3
594	.736	SUBM	.151	.100	1.491	1.391	.985	.919	.213	.208	-.005	-2.5
595	.837	SUBM	.151	.100	.495	.420	.327	.278	.421	.369	-.052	-12.3
596	.837	SUBM	.151	.100	.586	.491	.387	.324	.387	.376	-.011	-2.9
597	.839	SUBM	.151	.100	.689	.586	.455	.387	.358	.350	-.008	-2.1
598	.836	SUBM	.151	.100	.791	.682	.523	.451	.332	.327	-.006	-1.7
599	.841	SUBM	.151	.100	.887	.771	.586	.510	.316	.311	-.005	-1.7
600	.844	SUBM	.151	.100	.985	.863	.651	.570	.301	.294	-.006	-2.2
601	.841	SUBM	.151	.100	1.093	.971	.722	.642	.285	.273	-.011	-3.9
602	.825	SUBM	.151	.100	1.196	1.074	.790	.710	.267	.260	-.007	-2.6
603	.836	SUBM	.151	.100	1.279	1.152	.845	.761	.261	.256	-.006	-2.1
604	.845	SUBM	.151	.100	1.395	1.266	.922	.837	.253	.246	-.007	-2.7
605	.840	SUBM	.151	.100	1.494	1.366	.987	.903	.243	.236	-.007	-2.8
606	.848	SUBM	.151	.100	1.597	1.463	1.056	.967	.237	.234	-.004	-1.5
607	.840	SUBM	.151	.100	1.696	1.563	1.121	1.033	.228	.226	-.002	-1.0
608	.841	SUBM	.151	.100	1.787	1.654	1.181	1.093	.223	.220	-.003	-1.2
609	.841	SUBM	.151	.100	1.886	1.752	1.247	1.158	.217	.215	-.002	-.7
610	.839	SUBM	.151	.100	1.986	1.851	1.313	1.223	.211	.211	-.000	-.0
611	.835	SUBM	.151	.100	2.093	1.958	1.383	1.294	.204	.205	.001	.6
612	.835	SUBM	.151	.100	2.199	2.062	1.453	1.363	.199	.202	.003	1.6
613	.839	SUBM	.151	.100	2.303	2.166	1.522	1.432	.195	.198	.003	1.5
614	1.013	SUBM	.151	.100	.548	.425	.362	.281	.484	.460	-.024	-4.9
615	1.012	SUBM	.151	.100	.636	.501	.420	.331	.449	.434	-.015	-3.4
616	1.007	SUBM	.151	.100	.734	.590	.485	.390	.416	.406	-.010	-2.4
617	1.011	SUBM	.151	.100	.836	.682	.553	.451	.391	.383	-.009	-2.2
618	1.015	SUBM	.151	.100	.940	.780	.621	.516	.370	.357	-.013	-3.5
619	1.014	SUBM	.151	.100	1.046	.879	.691	.581	.351	.336	-.014	-4.1
620	1.010	SUBM	.151	.100	1.131	.964	.748	.637	.336	.318	-.018	-5.3
621	1.012	SUBM	.151	.100	1.234	1.058	.816	.699	.322	.311	-.011	-3.4
622	1.012	SUBM	.151	.100	1.342	1.163	.887	.769	.309	.300	-.009	-3.1
623	1.010	SUBM	.151	.100	1.450	1.266	.958	.837	.297	.291	-.005	-1.8
624	1.008	SUBM	.151	.100	1.543	1.358	1.020	.898	.287	.283	-.005	-1.6
624	1.011	SUBM	.151	.100	1.645	1.456	1.087	.962	.279	.276	-.003	-.9
625	1.016	SUBM	.151	.100	1.738	1.545	1.149	1.021	.273	.272	-.001	-.3
626	1.012	SUBM	.151	.100	1.840	1.647	1.216	1.089	.264	.264	.000	.1
627	1.006	SUBM	.151	.100	1.944	1.750	1.285	1.157	.255	.258	.003	1.1
628	1.013	SUBM	.151	.100	2.044	1.846	1.351	1.220	.251	.255	.004	1.7
629	1.012	SUBM	.151	.100	2.143	1.947	1.416	1.287	.245	.248	.004	1.6
630	1.010	SUBM	.151	.100	2.250	2.053	1.487	1.357	.238	.244	.006	2.4
631	1.010	SUBM	.151	.100	2.302	2.107	1.521	1.393	.235	.240	.005	2.1
632	1.184	SUBM	.151	.100	.612	.442	.404	.292	.535	.519	-.016	-3.1

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
633	1.183	SUBM	.151	.100	.689	.506	.455	.334	.504	.495	-.009	-1.8
634	1.182	SUBM	.151	.100	.799	.599	.528	.396	.468	.466	-.002	-.3
635	1.188	SUBM	.151	.100	.891	.679	.589	.449	.445	.443	-.002	-.5
641	1.175	SUBM	.151	.100	1.490	1.240	.985	.820	.340	.339	-.002	-.4
642	1.183	SUBM	.151	.100	1.600	1.343	1.058	.888	.331	.331	.000	.0
643	1.176	SUBM	.151	.100	1.693	1.435	1.119	.948	.320	.322	.002	.7
644	1.180	SUBM	.151	.100	1.784	1.525	1.179	1.008	.312	.314	.002	.5
645	1.182	SUBM	.151	.100	1.898	1.633	1.254	1.079	.303	.309	.005	1.7
636	1.184	SUBM	.151	.100	1.002	.781	.662	.516	.418	.413	-.005	-1.3
637	1.180	SUBM	.151	.100	1.094	.854	.723	.564	.399	.404	.005	1.4
638	1.194	SUBM	.151	.100	1.196	.960	.790	.635	.386	.374	-.012	-3.2
639	1.177	SUBM	.151	.100	1.298	1.057	.858	.699	.365	.360	-.006	-1.5
640	1.177	SUBM	.151	.100	1.380	1.136	.912	.751	.354	.349	-.005	-1.4
646	1.185	SUBM	.151	.100	1.983	1.717	1.311	1.135	.298	.303	.006	1.9
647	1.182	SUBM	.151	.100	2.097	1.827	1.386	1.208	.289	.298	.010	3.4
648	1.183	SUBM	.151	.100	2.193	1.924	1.449	1.272	.283	.293	.010	3.5
649	1.180	SUBM	.151	.100	2.303	2.032	1.522	1.343	.275	.288	.013	4.8
650	1.353	SUBM	.151	.100	.694	.473	.459	.312	.574	.561	-.014	-2.4
651	1.348	SUBM	.151	.100	.790	.545	.522	.360	.536	.539	.003	.5
652	1.353	OMIT	.151	.100	1.096	.713**						
653	1.353	SUBM	.151	.100	.994	.716	.657	.473	.480	.483	.003	.6
654	1.347	SUBM	.151	.100	1.094	.805	.723	.532	.456	.456	.000	.1
655	1.350	SUBM	.151	.100	1.196	.896	.790	.592	.437	.432	-.004	-1.0
656	1.348	SUBM	.151	.100	1.287	.984	.851	.650	.420	.413	-.008	-1.8
657	1.354	SUBM	.151	.100	1.393	1.080	.921	.714	.406	.400	-.006	-1.4
658	1.347	SUBM	.151	.100	1.490	1.175	.985	.777	.390	.385	-.005	-1.2
659	1.354	SUBM	.151	.100	1.597	1.270	1.056	.839	.379	.378	-.001	-.2
660	1.347	SUBM	.151	.100	1.687	1.358	1.115	.898	.367	.368	.001	.4
661	1.350	SUBM	.151	.100	1.792	1.456	1.184	.962	.357	.361	.004	1.3
662	1.356	SUBM	.151	.100	1.903	1.559	1.258	1.030	.348	.355	.008	2.2
663	1.354	SUBM	.151	.100	1.987	1.642	1.313	1.085	.340	.349	.009	2.8
664	1.352	SUBM	.151	.100	2.091	1.744	1.382	1.153	.331	.343	.012	3.7
665	1.360	SUBM	.151	.100	2.198	1.843	1.453	1.218	.324	.341	.016	5.0
666	1.354	SUBM	.151	.100	2.306	1.954	1.524	1.291	.315	.333	.018	5.7
667	1.523	SUBM	.151	.100	.763	.488	.504	.323	.617	.605	-.011	-1.8
668	1.520	SUBM	.151	.100	.885	.572	.585	.378	.572	.582	.010	1.7
669	1.519	SUBM	.151	.100	.989	.654	.654	.432	.540	.552	.012	2.2
670	1.519	SUBM	.151	.100	1.088	.736	.719	.487	.515	.524	.009	1.7
671	1.525	SUBM	.151	.100	1.186	.816	.784	.539	.495	.502	.007	1.4
672	1.519	SUBM	.151	.100	1.288	.905	.851	.598	.473	.477	.003	.7
673	1.515	SUBM	.151	.100	1.392	1.000	.920	.661	.454	.457	.003	.6
674	1.518	SUBM	.151	.100	1.491	1.090	.985	.720	.440	.443	.003	.7
675	1.515	SUBM	.151	.100	1.591	1.185	1.052	.783	.425	.428	.003	.8
676	1.521	SUBM	.151	.100	1.693	1.275	1.119	.843	.413	.420	.006	1.6
677	1.524	SUBM	.151	.100	1.794	1.370	1.186	.905	.402	.410	.008	1.9
678	1.521	SUBM	.151	.100	1.886	1.459	1.247	.964	.392	.402	.010	2.5
679	1.523	SUBM	.151	.100	1.993	1.558	1.317	1.030	.382	.396	.014	3.7
680	1.526	SUBM	.151	.100	2.095	1.651	1.385	1.091	.373	.392	.019	5.1
681	1.527	SUBM	.151	.100	2.201	1.756	1.455	1.161	.364	.386	.021	5.9
682	1.514	SUBM	.151	.100	2.303	1.862	1.522	1.231	.353	.378	.025	7.1
683	1.701	SUBM	.151	.100	.856	.521	.566	.344	.650	.634	-.016	-2.5
684	1.704	SUBM	.151	.100	.885	.535	.585	.354	.641	.635	-.005	-.8
685	1.698	SUBM	.151	.100	.991	.600	.655	.396	.603	.621	.017	2.9
686	1.702	SUBM	.151	.100	1.102	.680	.728	.449	.574	.593	.020	3.5
687	1.702	SUBM	.151	.100	1.193	.752	.788	.497	.551	.567	.016	2.9
688	1.709	SUBM	.151	.100	1.296	.830	.857	.549	.531	.545	.014	2.6
689	1.690	SUBM	.151	.100	1.390	.912	.919	.603	.507	.519	.012	2.4
690	1.703	SUBM	.151	.100	1.488	.997	.983	.659	.494	.501	.007	1.5
691	1.694	SUBM	.151	.100	1.602	1.101	1.059	.728	.473	.482	.009	1.8
692	1.696	SUBM	.151	.100	1.692	1.186	1.118	.784	.461	.468	.007	1.6
693	1.694	SUBM	.151	.100	1.792	1.274	1.184	.842	.448	.459	.011	2.5
694	1.693	SUBM	.151	.100	1.897	1.371	1.254	.906	.435	.449	.014	3.3
695	1.693	OMIT	.151	.100	1.994	1.936**						
696	1.705	SUBM	.151	.100	2.103	1.557	1.390	1.029	.416	.438	.022	5.3
697	1.704	SUBM	.151	.100	2.203	1.654	1.456	1.093	.406	.432	.026	6.4
698	1.697	SUBM	.151	.100	2.309	1.758	1.526	1.162	.395	.427	.032	8.0
699	1.862	SUBM	.151	.100	.988	.569	.653	.376	.663	.660	-.003	-.4
700	1.855	SUBM	.151	.100	1.090	.622	.720	.411	.628	.652	.024	3.8
701	1.858	SUBM	.151	.100	1.193	.690	.788	.456	.602	.629	.028	4.6
702	1.860	SUBM	.151	.100	1.288	.759	.851	.501	.580	.605	.026	4.4
703	1.859	SUBM	.151	.100	1.392	.839	.920	.555	.557	.578	.020	3.7
704	1.858	SUBM	.151	.100	1.487	.919	.983	.608	.539	.551	.012	2.2
705	1.857	SUBM	.151	.100	1.595	1.014	1.054	.670	.520	.530	.010	1.9
706	1.859	SUBM	.151	.100	1.704	1.108	1.126	.732	.504	.513	.010	1.9
707	1.861	SUBM	.151	.100	1.788	1.182	1.182	.781	.492	.503	.010	2.1
708	1.852	SUBM	.151	.100	1.893	1.278	1.251	.845	.476	.490	.014	3.0
709	1.863	SUBM	.151	.100	1.989	1.356	1.315	.896	.467	.486	.018	3.9
710	1.860	SUBM	.151	.100	2.095	1.456	1.385	.962	.455	.477	.022	4.9
711	1.858	SUBM	.151	.100	2.203	1.557	1.456	1.029	.443	.471	.028	6.3
712	1.860	SUBM	.151	.100	2.301	1.652	1.521	1.092	.434	.466	.032	7.4

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 1
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI- ATION (CDA-CDM)	DEVI- ATION (PERCENT)
713	2.022	JUMP	.151	.100	.995	.113	.658	.074	.717	.710	-.007	-.9
714	2.016	SUBM	.151	.100	1.097	.603	.725	.399	.681	.679	-.002	-.3
715	2.017	SUBM	.151	.100	1.203	.655	.795	.433	.650	.671	.021	3.2
716	2.015	SUBM	.151	.100	1.294	.708	.855	.468	.627	.656	.030	4.7
717	2.021	SUBM	.151	.100	1.398	.778	.924	.514	.605	.631	.026	4.3
718	2.018	SUBM	.151	.100	1.498	.854	.990	.564	.583	.603	.020	3.4
719	2.023	SUBM	.151	.100	1.589	.923	1.050	.610	.568	.582	.014	2.4
720	2.016	SUBM	.151	.100	1.703	1.018	1.126	.673	.546	.560	.014	2.5
721	2.016	SUBM	.151	.100	1.802	1.103	1.191	.729	.531	.544	.013	2.4
722	2.022	SUBM	.151	.100	1.895	1.183	1.252	.782	.520	.532	.013	2.4
723	2.022	SUBM	.151	.100	1.995	1.268	1.319	.838	.506	.523	.016	3.2
724	2.019	SUBM	.151	.100	2.093	1.358	1.383	.898	.494	.513	.020	4.0
725	2.022	SUBM	.151	.100	2.190	1.445	1.447	.955	.483	.508	.024	5.0
726	2.022	SUBM	.151	.100	2.298	1.541	1.519	1.019	.472	.504	.032	6.8
727	2.190	JUMP	.151	.100	1.148	.122	.759	.081	.723	.722	-.001	-.2
728	2.189	SUBM	.151	.100	1.289	.673	.852	.445	.682	.690	.008	1.1
729	2.192	SUBM	.151	.100	1.398	.722	.924	.477	.656	.681	.025	3.8
730	2.190	SUBM	.151	.100	1.497	.783	.989	.517	.633	.659	.026	4.0
731	2.189	SUBM	.151	.100	1.600	.855	1.058	.565	.612	.631	.019	3.2
732	2.190	SUBM	.151	.100	1.707	.934	1.128	.617	.593	.606	.013	2.2
733	2.189	SUBM	.151	.100	1.807	1.014	1.194	.670	.576	.587	.011	1.9
734	2.186	OMIT	.151	.100	1.859	1.102**						
735	2.194	SUBM	.151	.100	1.998	1.168	1.321	.772	.549	.562	.013	2.3
736	2.182	SUBM	.151	.100	2.094	1.255	1.384	.829	.533	.550	.017	3.1
737	2.188	SUBM	.151	.100	1.985	1.134	1.312	.749	.549	.572	.023	4.1
738	2.189	SUBM	.151	.100	2.303	1.434	1.522	.948	.510	.538	.028	5.5
739	2.359	JUMP	.151	.100	1.305	.152	.863	.101	.730	.731	.000	.0
740	2.366	SUBM	.151	.100	1.498	.737	.990	.487	.684	.698	.014	2.1
741	2.364	SUBM	.151	.100	1.604	.790	1.060	.522	.660	.682	.022	3.3
742	2.363	SUBM	.151	.100	1.706	.852	1.128	.563	.640	.658	.019	2.9
743	2.354	SUBM	.151	.100	1.806	.924	1.194	.610	.620	.632	.013	2.1
744	2.360	SUBM	.151	.100	1.900	.991	1.256	.655	.606	.616	.010	1.7
745	2.360	SUBM	.151	.100	1.997	1.063	1.320	.703	.591	.601	.011	1.8
746	2.362	SUBM	.151	.100	2.109	1.157	1.394	.765	.575	.585	.010	1.7
747	2.353	SUBM	.151	.100	2.202	1.235	1.455	.816	.561	.576	.015	2.7
748	2.355	SUBM	.151	.100	2.303	1.318	1.522	.871	.549	.570	.021	3.8
749	2.534	JUMP	.151	.100	1.482	.429	.980	.283	.736	.738	.002	.2
750	2.536	SUBM	.151	.100	1.702	.799	1.125	.528	.688	.696	.008	1.2
751	2.534	SUBM	.151	.100	1.802	.848	1.191	.560	.668	.679	.011	1.7
752	2.530	SUBM	.151	.100	1.902	.910	1.257	.601	.649	.655	.006	1.0
753	2.531	SUBM	.151	.100	2.006	.981	1.326	.649	.632	.635	.003	.5
754	2.528	SUBM	.151	.100	2.100	1.051	1.388	.695	.617	.620	.003	.4
755	2.528	SUBM	.151	.100	2.204	1.136	1.457	.751	.602	.604	.002	.4
756	2.523	SUBM	.151	.100	2.297	1.212	1.518	.801	.589	.595	.006	1.1
757	2.752	JUMP	.151	.100	1.718	.454	1.135	.300	.743	.743	.000	.0
758	2.745	SUBM	.151	.100	1.897	.838	1.254	.554	.705	.698	-.007	-.9
759	2.744	SUBM	.151	.100	2.005	.887	1.325	.586	.685	.679	-.006	-.9
760	2.743	SUBM	.151	.100	2.112	.946	1.396	.625	.668	.659	-.008	-1.2
761	2.742	SUBM	.151	.100	2.212	1.011	1.462	.668	.652	.642	-.010	-1.5
762	2.739	SUBM	.151	.100	2.308	1.082	1.525	.715	.638	.628	-.010	-1.6
763	2.867	JUMP	.151	.100	1.855	.465	1.226	.307	.745	.743	-.001	-.1
764	2.864	SUBM	.151	.100	2.107	.903	1.393	.597	.698	.678	-.020	-2.8
765	2.865	SUBM	.151	.100	2.215	.947	1.464	.626	.681	.664	-.017	-2.5
766	2.864	SUBM	.151	.100	2.314	1.009	1.529	.667	.666	.647	-.019	-2.9
767	.100	SUBM	.151	.100	.198	.197	.131	.130	.079	.070	-.010	-12.5
768	.207	SUBM	.151	.100	.190	.186	.126	.123	.168	.153	-.015	-9.1
769	.300	SUBM	.151	.100	.196	.181	.130	.120	.240	.268	.028	11.7
770	.298	SUBM	.151	.100	.260	.253	.172	.167	.207	.181	-.026	-12.6
771	.404	SUBM	.151	.100	.194	.165	.128	.109	.324	.359	.030	9.1
772	.402	SUBM	.151	.100	.260	.243	.172	.161	.279	.270	-.008	-3.0
773	.500	SUBM	.151	.100	.221	.184	.146	.121	.376	.397	.021	5.5
774	.498	SUBM	.151	.100	.301	.275	.199	.182	.321	.303	-.019	-5.8
775	.636	SUBM	.151	.100	.262	.208	.173	.137	.440	.468	.028	6.4
776	.636	SUBM	.151	.100	.336	.290	.222	.192	.388	.374	-.014	-3.6
777	.738	SUBM	.151	.100	.289	.223	.191	.147	.486	.510	.024	5.0
778	.735	SUBM	.151	.100	.380	.315	.251	.208	.422	.415	-.007	-1.6
779	.839	SUBM	.151	.100	.345	.270	.228	.178	.505	.489	-.016	-3.1
780	.836	SUBM	.151	.100	.422	.340	.279	.224	.455	.440	-.015	-3.3
781	.837	SUBM	.151	.100	.504	.411	.333	.272	.417	.412	-.005	-1.1
782	1.006	JUMP	.151	.100	.347	.110	.229	.073	.604	.627	.023	3.8
783	1.013	SUBM	.151	.100	.405	.304	.268	.201	.563	.517	-.046	-8.1
784	1.016	SUBM	.151	.100	.473	.360	.313	.238	.523	.490	-.032	-6.2
785	1.192	FREE	.151	.100	.416	.247	.275	.163	.654	.639	-.014	-2.2
786	1.189	SUBM	.151	.100	.497	.356	.328	.235	.597	.544	-.053	-8.8
787	1.185	SUBM	.151	.100	.564	.405	.373	.268	.558	.530	-.028	-5.0
788	1.360	FREE	.151	.100	.509	.177	.336	.117	.674	.654	-.020	-3.0
789	1.359	SUBM	.151	.100	.591	.403	.391	.266	.625	.574	-.051	-8.2
790	1.348	SUBM	.151	.100	.890	.626	.588	.414	.505	.512	.006	1.3
791	1.534	FREE	.151	.100	.623	.187	.412	.124	.687	.671	-.017	-2.5
792	1.532	SUBM	.151	.100	.701	.452	.463	.299	.647	.607	-.041	-6.3

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
793	1.702	SUBM	.151	.100	2.003	1.469	1.324	.971	.425	.442	.016	3.8
794	2.211	SUBM	.151	.100	1.910	1.078	1.262	.713	.566	.580	.014	2.4
1	1.700	JUMP	.303	.200	.395	.180	.261	.119	.477	.536	.059	12.4
2	2.360	JUMP	.303	.200	.533	.249	.352	.164	.570	.566	-.004	-.7
3	3.100	FREE	.303	.200	.780	.290	.516	.192	.619	.607	-.012	-1.9
4	3.650	FREE	.303	.200	1.010	.301	.668	.199	.640	.635	-.005	-.8
5	4.170	FREE	.303	.200	1.255	.276	.829	.182	.656	.656	.000	.0
6	4.650	FREE	.303	.200	1.501	.262	.992	.173	.669	.670	.001	.2
7	5.040	FREE	.303	.200	1.775	.254	1.173	.168	.667	.678	.011	1.6
8	5.370	FREE	.303	.200	1.982	.255	1.310	.168	.672	.678	.005	.8
9	5.740	FREE	.303	.200	2.235	.261	1.477	.173	.677	.672	-.005	-.7
10	5.250	OMIT	.303	.200	1.976	1.111**						
11	4.790	SUBM	.303	.200	2.010	1.158	1.328	.766	.596	.586	-.010	-1.7
12	4.080	SUBM	.303	.200	2.011	1.325	1.329	.876	.507	.513	.005	1.1
13	3.370	SUBM	.303	.200	2.019	1.523	1.334	1.007	.418	.428	.010	2.3
14	2.080	SUBM	.303	.200	2.013	1.800	1.330	1.190	.258	.271	.013	5.0
15	1.200	SUBM	.303	.200	2.033	1.955	1.344	1.292	.148	.159	.011	7.3
16	1.190	SUBM	.303	.200	2.251	2.173	1.488	1.436	.140	.151	.011	7.8
17	2.220	SUBM	.303	.200	2.252	2.013	1.488	1.330	.261	.273	.013	4.8
18	2.960	SUBM	.303	.200	2.253	1.839	1.489	1.215	.348	.369	.021	6.0
19	3.800	SUBM	.303	.200	2.253	1.608	1.489	1.063	.446	.466	.020	4.5
20	4.480	SUBM	.303	.200	2.270	1.428	1.500	.944	.524	.531	.007	1.3
21	5.770	OMIT	.303	.200	2.281	1.211**						
22	5.020	SUBM	.303	.200	2.269	1.274	1.500	.842	.587	.577	-.010	-1.7
23	1.250	SUBM	.303	.200	1.819	1.736	1.202	1.147	.163	.175	.011	7.0
24	2.330	SUBM	.303	.200	1.816	1.559	1.200	1.030	.305	.317	.013	4.2
25	3.020	SUBM	.303	.200	1.833	1.435	1.212	.949	.393	.401	.008	1.9
26	3.370	OMIT	.303	.200	1.837	1.318**						
27	4.470	SUBM	.303	.200	1.838	1.111	1.215	.734	.581	.577	-.004	-.7
28	5.070	OMIT	.303	.200	1.831	1.052**						
29	1.200	OMIT	.303	.200	1.600	1.515**						
30	2.160	SUBM	.303	.200	1.597	1.375	1.056	.909	.301	.317	.015	5.1
31	2.750	OMIT	.303	.200	1.603	1.260**						
32	3.760	SUBM	.303	.200	1.609	1.066	1.063	.705	.523	.539	.017	3.2
33	4.570	SUBM	.303	.200	1.623	.981	1.073	.648	.632	.607	-.026	-4.0
35	1.280	SUBM	.303	.200	1.300	1.223	.859	.808	.198	.205	.007	3.5
36	2.470	SUBM	.303	.200	1.307	1.068	.864	.706	.381	.386	.005	1.4
37	3.190	SUBM	.303	.200	1.300	.939	.859	.621	.493	.505	.012	2.5
38	3.560	OMIT	.303	.200	1.304	.870**						
39	1.580	SUBM	.303	.200	.986	.890	.652	.588	.280	.295	.015	5.3
40	2.330	SUBM	.303	.200	.995	.811	.658	.536	.412	.423	.012	2.8
41	3.020	SUBM	.303	.200	.995	.741	.658	.490	.534	.520	-.013	-2.5
42	1.870	SUBM	.303	.200	.789	.686	.521	.453	.371	.371	-.000	-.1
43	2.550	SUBM	.303	.200	.811	.635	.536	.420	.499	.499	-.001	-.1
44	2.240	OMIT	.303	.200	.503	.410**						
186	5.807	FREE	.302	.200	2.294	.236	1.516	.156	.678	.670	-.008	-1.2
187	5.612	FREE	.302	.200	2.164	.235	1.430	.155	.675	.675	.000	.0
188	5.374	FREE	.302	.200	2.000	.235	1.322	.155	.672	.678	.006	.9
189	5.134	FREE	.302	.200	1.853	.235	1.225	.155	.667	.679	.012	1.7
190	4.930	FREE	.302	.200	1.700	.242	1.124	.160	.669	.677	.008	1.2
191	4.666	FREE	.302	.200	1.547	.246	1.022	.163	.663	.672	.009	1.3
192	4.459	FREE	.302	.200	1.395	.257	.922	.170	.668	.665	-.002	-.3
193	4.144	FREE	.302	.200	1.248	.265	.825	.175	.656	.656	.000	.0
194	3.820	JUMP	.302	.200	1.097	.290	.725	.192	.645	.644	-.001	-.2
195	3.500	JUMP	.302	.200	.947	.226	.626	.149	.636	.629	-.007	-1.2
196	3.110	JUMP	.302	.200	.795	.202	.525	.133	.617	.610	-.007	-1.2
197	2.978	JUMP	.302	.200	.771	.194	.510	.128	.600	.606	.007	1.1
198	.222	SUBM	.302	.200	.319	.318	.211	.210	.070	.098	.028	40.7
199	.221	SUBM	.302	.200	.402	.401	.266	.265	.062	.075	.014	22.4
200	.221	OMIT	.302	.200	.500	.500**						
201	.218	SUBM	.302	.200	.597	.596	.395	.394	.050	.067	.017	34.2
202	.218	SUBM	.302	.200	.702	.701	.464	.463	.046	.054	.008	16.4
203	.219	SUBM	.302	.200	.797	.796	.527	.526	.043	.037	-.007	-15.2
204	.213	SUBM	.302	.200	.898	.897	.594	.593	.040	.034	-.006	-13.9
205	.221	SUBM	.302	.200	.997	.995	.659	.658	.039	.047	.008	20.6
206	.219	SUBM	.302	.200	1.100	1.098	.727	.726	.037	.041	.004	11.2
202	.226	OMIT	.302	.200	1.199	1.199**						
208	.221	OMIT	.302	.200	1.299	1.299**						
209	.220	OMIT	.302	.200	1.398	1.398**						
210	.217	OMIT	.302	.200	1.496	1.496**						
211	.217	SUBM	.302	.200	1.599	1.598	1.057	1.056	.030	.020	-.010	-33.1
212	.219	SUBM	.302	.200	1.699	1.698	1.123	1.122	.030	.020	-.010	-34.0
213	.234	SUBM	.302	.200	1.798	1.797	1.188	1.188	.031	.019	-.012	-38.5
214	.219	SUBM	.302	.200	1.897	1.896	1.254	1.253	.028	.018	-.010	-34.6
215	.217	SUBM	.302	.200	1.999	1.998	1.321	1.321	.027	.018	-.009	-34.2
216	.221	SUBM	.302	.200	2.096	2.095	1.385	1.385	.027	.017	-.010	-35.7
217	.220	SUBM	.302	.200	2.198	2.197	1.453	1.452	.026	.017	-.009	-35.6
218	.215	SUBM	.302	.200	2.301	2.300	1.521	1.520	.025	.016	-.009	-34.3
219	.476	SUBM	.302	.200	2.296	2.285	1.518	1.510	.056	.055	-.001	-1.3
220	.472	SUBM	.302	.200	2.199	2.189	1.453	1.447	.056	.054	-.003	-4.8

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 1
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI-ATION (CDA-CDM)	DEVI-ATION (PERCENT)
221	.477	SUBM	.302	.200	2.096	2.084	1.385	1.377	.058	.060	.002	3.6
222	.474	SUBM	.302	.200	2.000	1.989	1.322	1.315	.059	.059	.000	.1
223	.473	SUBM	.302	.200	1.898	1.886	1.254	1.247	.061	.064	.003	5.2
224	.475	SUBM	.302	.200	1.800	1.788	1.190	1.182	.063	.066	.003	5.2
225	.477	SUBM	.302	.200	1.699	1.687	1.123	1.115	.065	.068	.003	5.2
226	.479	SUBM	.302	.200	1.600	1.588	1.058	1.050	.067	.070	.003	5.2
227	.479	SUBM	.302	.200	1.498	1.487	.990	.983	.069	.070	.001	1.2
228	.516	SUBM	.302	.200	1.401	1.390	.926	.919	.077	.073	-.004	-5.5
229	.474	SUBM	.302	.200	1.297	1.288	.857	.851	.074	.069	-.005	-6.4
230	.481	SUBM	.302	.200	1.197	1.187	.791	.785	.078	.076	-.001	-1.7
231	.481	SUBM	.302	.200	1.100	1.090	.727	.720	.081	.086	.005	6.5
232	.481	SUBM	.302	.200	.998	.988	.660	.653	.085	.097	.012	13.7
233	.480	SUBM	.302	.200	.900	.892	.595	.590	.089	.097	.008	8.5
234	.476	SUBM	.302	.200	.801	.794	.529	.525	.094	.101	.007	7.8
235	.474	SUBM	.302	.200	.700	.693	.463	.458	.100	.113	.013	13.1
236	.475	SUBM	.302	.200	.601	.595	.397	.393	.108	.120	.011	10.5
237	.482	SUBM	.302	.200	.502	.498	.332	.329	.120	.116	-.004	-3.4
238	.479	SUBM	.302	.200	.400	.396	.264	.262	.134	.139	.005	4.1
239	.479	SUBM	.302	.200	.337	.332	.223	.219	.146	.142	-.004	-2.8
240	.723	SUBM	.302	.200	.387	.378	.256	.250	.206	.184	-.021	-10.4
241	.719	SUBM	.302	.200	.500	.489	.330	.323	.180	.184	.004	2.1
242	.716	SUBM	.302	.200	.600	.587	.397	.388	.163	.169	.006	3.5
243	.713	SUBM	.302	.200	.701	.685	.463	.453	.151	.164	.013	8.6
244	.716	SUBM	.302	.200	.798	.781	.527	.516	.142	.151	.009	6.7
245	.724	SUBM	.302	.200	.901	.883	.596	.584	.135	.140	.005	3.7
246	.722	SUBM	.302	.200	1.001	.982	.662	.649	.128	.130	.002	1.8
247	.718	SUBM	.302	.200	1.100	1.080	.727	.714	.121	.121	-.000	-.3
248	.718	SUBM	.302	.200	1.198	1.177	.792	.778	.116	.112	-.004	-3.8
249	.716	SUBM	.302	.200	1.301	1.279	.860	.845	.111	.108	-.003	-2.9
250	.722	SUBM	.302	.200	1.397	1.374	.923	.908	.108	.106	-.002	-2.1
251	.725	SUBM	.302	.200	1.501	1.477	.992	.976	.105	.104	-.001	-1.0
252	.727	SUBM	.302	.200	1.598	1.573	1.056	1.040	.102	.102	.000	.3
253	.722	SUBM	.302	.200	1.701	1.674	1.124	1.106	.098	.102	.004	4.6
254	.714	SUBM	.302	.200	1.800	1.773	1.190	1.172	.094	.099	.005	5.3
255	.712	SUBM	.302	.200	1.897	1.869	1.254	1.235	.091	.098	.007	7.2
256	.707	SUBM	.302	.200	2.000	1.971	1.322	1.303	.088	.097	.008	9.5
257	.695	SUBM	.302	.200	2.094	2.073	1.384	1.370	.085	.080	-.005	-5.7
258	.723	SUBM	.302	.200	2.199	2.175	1.453	1.438	.086	.083	-.003	-3.3
259	.722	SUBM	.302	.200	2.299	2.275	1.519	1.504	.084	.081	-.003	-3.5
260	.948	SUBM	.302	.200	2.297	2.253	1.518	1.489	.111	.111	.000	.2
261	.987	SUBM	.302	.200	2.200	2.152	1.454	1.422	.118	.119	.001	.8
262	.966	SUBM	.302	.200	2.099	2.055	1.387	1.358	.118	.116	-.001	-1.2
263	.963	SUBM	.302	.200	1.998	1.955	1.321	1.292	.120	.118	-.002	-1.8
264	.965	SUBM	.302	.200	1.900	1.857	1.256	1.227	.124	.122	-.002	-1.7
265	.965	SUBM	.302	.200	1.798	1.755	1.188	1.160	.127	.126	-.002	-1.3
266	.963	SUBM	.302	.200	1.699	1.657	1.123	1.095	.131	.128	-.002	-1.9
267	.965	SUBM	.302	.200	1.600	1.559	1.058	1.030	.135	.131	-.004	-2.9
268	.968	SUBM	.302	.200	1.502	1.462	.993	.966	.140	.134	-.005	-3.9
269	.967	SUBM	.302	.200	1.402	1.362	.927	.900	.144	.140	-.005	-3.2
270	.971	SUBM	.302	.200	1.299	1.261	.859	.833	.151	.142	-.008	-5.5
271	.969	SUBM	.302	.200	1.200	1.164	.793	.769	.156	.147	-.009	-5.9
272	.968	SUBM	.302	.200	1.098	1.063	.726	.703	.163	.159	-.004	-2.4
273	.962	SUBM	.302	.200	.999	.966	.660	.638	.170	.170	-.001	-.4
274	.966	SUBM	.302	.200	.900	.869	.595	.574	.180	.181	.000	.2
275	.965	SUBM	.302	.200	.800	.771	.529	.510	.191	.193	.002	1.2
276	.973	SUBM	.302	.200	.702	.676	.464	.447	.205	.204	-.001	-.7
277	.967	SUBM	.302	.200	.600	.577	.397	.381	.221	.220	-.001	-.6
278	.973	SUBM	.302	.200	.499	.479	.330	.317	.244	.239	-.005	-2.0
279	.969	SUBM	.302	.200	.432	.415	.286	.274	.261	.254	-.007	-2.6
280	1.232	SUBM	.302	.200	.484	.452	.320	.299	.313	.311	-.003	-.9
281	1.231	SUBM	.302	.200	.599	.561	.396	.371	.281	.278	-.003	-1.0
282	1.225	SUBM	.302	.200	.699	.657	.462	.434	.259	.258	-.001	-.3
283	1.213	SUBM	.302	.200	.802	.756	.530	.500	.240	.240	.001	.4
284	1.206	SUBM	.302	.200	.897	.848	.593	.560	.225	.226	.001	.4
285	1.195	SUBM	.302	.200	.998	.946	.660	.625	.212	.213	.001	.5
286	1.183	SUBM	.302	.200	1.099	1.044	.726	.690	.200	.200	.001	.4
287	1.159	SUBM	.302	.200	1.201	1.145	.794	.757	.187	.185	-.002	-.9
288	1.144	SUBM	.302	.200	1.300	1.242	.859	.821	.177	.177	-.001	-.3
289	1.133	SUBM	.302	.200	1.400	1.342	.925	.887	.169	.169	-.000	-.1
290	1.152	SUBM	.302	.200	1.501	1.438	.992	.950	.166	.169	.003	1.9
291	1.139	SUBM	.302	.200	1.597	1.533	1.056	1.013	.159	.165	.005	3.3
292	1.205	SUBM	.302	.200	1.695	1.631	1.120	1.078	.164	.159	-.005	-2.8
293	1.210	SUBM	.302	.200	1.797	1.731	1.188	1.144	.160	.156	-.003	-2.0
294	1.217	SUBM	.302	.200	1.898	1.829	1.254	1.209	.156	.155	-.001	-.7
295	1.216	SUBM	.302	.200	1.997	1.927	1.320	1.274	.152	.152	-.000	-.1
296	1.219	SUBM	.302	.200	2.099	2.025	1.387	1.338	.149	.152	.003	2.3
297	1.209	SUBM	.302	.200	2.197	2.121	1.452	1.402	.144	.151	.006	4.4
298	1.200	SUBM	.302	.200	2.299	2.223	1.519	1.469	.140	.147	.007	5.0
299	1.420	SUBM	.302	.200	2.298	2.199	1.519	1.453	.166	.169	.003	1.9
300	1.426	SUBM	.302	.200	2.199	2.098	1.453	1.387	.170	.175	.005	2.7

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 1
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
301	1.433	SUBM	.302	.200	2.101	2.000	1.389	1.322	.175	.179	.004	2.3
302	1.433	SUBM	.302	.200	2.000	1.901	1.322	1.256	.179	.182	.003	1.4
303	1.437	SUBM	.302	.200	1.899	1.801	1.255	1.190	.184	.186	.002	.8
304	1.440	SUBM	.302	.200	1.802	1.704	1.191	1.126	.190	.191	.002	.9
305	1.443	SUBM	.302	.200	1.700	1.603	1.124	1.059	.196	.197	.001	.6
306	1.444	SUBM	.302	.200	1.602	1.506	1.059	.995	.202	.203	.001	.5
307	1.451	SUBM	.302	.200	1.502	1.408	.993	.931	.209	.208	-.001	-.5
308	1.453	SUBM	.302	.200	1.403	1.311	.927	.866	.217	.215	-.002	-1.1
309	1.457	SUBM	.302	.200	1.302	1.212	.861	.801	.226	.222	-.004	-1.7
310	1.454	SUBM	.302	.200	1.103	1.019	.729	.673	.245	.249	.004	1.7
311	1.459	SUBM	.302	.200	1.001	.925	.662	.611	.258	.257	-.001	-.2
312	1.463	SUBM	.302	.200	.900	.827	.595	.546	.273	.276	.003	1.2
313	1.465	SUBM	.302	.200	.800	.731	.529	.483	.290	.294	.005	1.6
314	1.471	SUBM	.302	.200	.701	.639	.463	.422	.311	.312	.002	.5
315	1.471	SUBM	.302	.200	.599	.543	.396	.359	.336	.339	.003	.9
316	1.479	SUBM	.302	.200	.536	.484	.354	.320	.357	.361	.004	1.2
317	1.673	SUBM	.302	.200	.576	.509	.381	.336	.390	.390	-.000	-.1
318	1.675	SUBM	.302	.200	.701	.622	.463	.411	.354	.355	.001	.2
319	1.672	SUBM	.302	.200	.800	.714	.529	.472	.331	.332	.001	.4
320	1.672	SUBM	.302	.200	.898	.805	.594	.532	.312	.313	.001	.4
321	1.673	SUBM	.302	.200	1.002	.901	.662	.595	.296	.299	.004	1.3
322	1.673	SUBM	.302	.200	1.102	.995	.728	.658	.282	.284	.002	.7
323	1.656	SUBM	.302	.200	1.201	1.090	.794	.720	.267	.268	.001	.3
324	1.672	SUBM	.302	.200	1.299	1.184	.859	.783	.259	.254	-.006	-2.2
325	1.669	SUBM	.302	.200	1.400	1.282	.925	.847	.249	.245	-.005	-1.9
326	1.666	SUBM	.302	.200	1.501	1.379	.992	.911	.241	.239	-.002	-.7
327	1.689	SUBM	.302	.200	1.601	1.474	1.058	.974	.236	.235	-.001	-.6
328	1.691	SUBM	.302	.200	1.701	1.567	1.124	1.036	.229	.233	.004	1.6
329	1.686	SUBM	.302	.200	1.801	1.667	1.190	1.102	.222	.226	.003	1.5
330	1.682	SUBM	.302	.200	1.900	1.766	1.256	1.167	.216	.219	.003	1.4
331	1.686	SUBM	.302	.200	1.999	1.862	1.321	1.231	.211	.215	.005	2.2
332	1.679	SUBM	.302	.200	2.101	1.964	1.389	1.298	.205	.210	.005	2.5
333	1.680	SUBM	.302	.200	2.198	2.059	1.453	1.361	.200	.207	.006	3.1
334	1.675	SUBM	.302	.200	2.298	2.161	1.519	1.428	.195	.201	.005	2.7
335	1.894	SUBM	.302	.200	2.295	2.120	1.517	1.401	.221	.229	.008	3.5
336	1.915	SUBM	.302	.200	2.202	2.024	1.455	1.338	.228	.236	.007	3.3
337	1.918	SUBM	.302	.200	2.098	1.921	1.387	1.270	.234	.241	.006	2.8
338	1.918	SUBM	.302	.200	1.999	1.824	1.321	1.206	.240	.245	.005	2.2
339	1.918	SUBM	.302	.200	1.902	1.728	1.257	1.142	.246	.251	.005	2.1
340	1.923	SUBM	.302	.200	1.801	1.628	1.190	1.076	.253	.258	.005	1.8
341	1.943	SUBM	.302	.200	1.703	1.531	1.126	1.012	.263	.266	.002	.9
342	1.948	SUBM	.302	.200	1.601	1.433	1.058	.947	.272	.272	-.000	-.1
343	1.910	SUBM	.302	.200	1.502	1.343	.993	.888	.276	.275	-.001	-.3
344	1.915	SUBM	.302	.200	1.401	1.248	.926	.825	.286	.281	-.005	-1.8
345	1.918	SUBM	.302	.200	1.300	1.151	.859	.761	.298	.294	-.004	-1.3
346	1.920	SUBM	.302	.200	1.203	1.060	.795	.700	.310	.308	-.001	-.4
347	1.922	SUBM	.302	.200	1.099	.964	.726	.637	.324	.324	-.000	-.0
348	1.922	SUBM	.302	.200	1.000	.872	.661	.576	.340	.341	.001	.2
349	1.923	SUBM	.302	.200	.901	.782	.596	.517	.358	.359	.000	.1
350	1.925	SUBM	.302	.200	.800	.690	.529	.456	.381	.380	-.001	-.2
351	1.926	SUBM	.302	.200	.630	.539	.416	.356	.429	.425	-.004	-1.0
352	2.162	SUBM	.302	.200	.679	.561	.449	.371	.464	.461	-.003	-.6
353	2.176	SUBM	.302	.200	.803	.667	.531	.441	.429	.429	-.001	-.2
354	2.169	SUBM	.302	.200	.900	.752	.595	.497	.404	.407	.002	.6
355	2.170	SUBM	.302	.200	1.003	.842	.663	.557	.383	.387	.004	1.0
356	2.173	SUBM	.302	.200	1.103	.933	.729	.617	.366	.368	.002	.5
357	2.168	SUBM	.302	.200	1.202	1.022	.794	.676	.350	.352	.002	.5
358	2.164	SUBM	.302	.200	1.302	1.115	.861	.737	.335	.335	-.001	-.2
359	2.165	SUBM	.302	.200	1.402	1.209	.927	.799	.323	.319	-.004	-1.3
360	2.163	SUBM	.302	.200	1.500	1.301	.991	.860	.312	.310	-.002	-.6
361	2.169	SUBM	.302	.200	1.601	1.396	1.058	.923	.303	.303	-.000	-.1
362	2.158	SUBM	.302	.200	1.702	1.491	1.125	.985	.293	.296	.004	1.3
363	2.163	SUBM	.302	.200	1.801	1.585	1.190	1.048	.285	.290	.005	1.9
364	2.158	SUBM	.302	.200	1.902	1.684	1.257	1.113	.277	.283	.006	2.3
365	2.154	SUBM	.302	.200	2.003	1.782	1.324	1.178	.269	.278	.008	3.1
366	2.172	SUBM	.302	.200	2.095	1.868	1.385	1.235	.265	.275	.010	3.7
367	2.166	SUBM	.302	.200	2.200	1.972	1.454	1.303	.258	.269	.011	4.3
368	2.169	SUBM	.302	.200	2.305	2.075	1.523	1.371	.253	.265	.012	4.9
369	2.605	SUBM	.302	.200	2.303	1.976	1.522	1.306	.304	.321	.018	5.8
370	2.603	SUBM	.302	.200	2.200	1.876	1.454	1.240	.310	.326	.016	5.0
371	2.603	SUBM	.302	.200	2.100	1.779	1.388	1.176	.318	.331	.014	4.3
372	2.607	SUBM	.302	.200	2.005	1.684	1.325	1.113	.326	.339	.013	4.1
373	2.630	SUBM	.302	.200	1.901	1.586	1.256	1.048	.337	.345	.008	2.4
374	2.628	SUBM	.302	.200	1.798	1.490	1.188	.985	.347	.352	.006	1.6
375	2.644	SUBM	.302	.200	1.706	1.403	1.128	.927	.358	.361	.003	.7
376	2.653	SUBM	.302	.200	1.600	1.304	1.058	.862	.371	.370	-.001	-.2
377	2.577	SUBM	.303	.200	1.499	1.228	.991	.812	.371	.368	-.003	-.7
378	2.567	SUBM	.302	.200	1.398	1.138	.924	.752	.384	.381	-.003	-.7
379	2.589	SUBM	.302	.200	1.305	1.051	.863	.694	.401	.401	.001	.1
380	2.592	SUBM	.302	.200	1.201	.959	.794	.634	.418	.420	.002	.5

85

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 1
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
381	2.583	SUBM	.302	.200	1.101	.875	.728	.578	.435	.438	.002	.5
382	2.603	SUBM	.302	.200	.998	.787	.660	.520	.461	.459	-.001	-.3
383	2.566	SUBM	.302	.200	.901	.709	.596	.468	.478	.477	-.001	-.3
384	2.588	SUBM	.302	.200	.769	.604	.508	.399	.522	.504	-.018	-3.5
385	2.984	SUBM	.302	.200	.855	.642	.565	.424	.571	.538	-.032	-5.7
386	2.967	SUBM	.302	.200	1.000	.742	.661	.491	.525	.522	-.002	-.4
387	3.004	SUBM	.302	.200	1.095	.811	.724	.536	.508	.509	.002	.3
388	3.004	SUBM	.302	.200	1.201	.896	.794	.592	.485	.489	.004	.8
389	3.004	SUBM	.302	.200	1.304	.980	.862	.648	.465	.468	.003	.6
390	3.004	SUBM	.302	.200	1.399	1.060	.925	.701	.449	.451	.001	.3
391	2.989	SUBM	.302	.200	1.498	1.146	.990	.758	.432	.432	-.000	-.1
392	2.995	SUBM	.302	.200	1.602	1.238	1.059	.818	.419	.417	-.002	-.4
393	2.966	SUBM	.302	.200	1.700	1.328	1.124	.878	.402	.405	.003	.6
394	2.966	SUBM	.302	.200	1.804	1.421	1.192	.939	.391	.396	.006	1.4
395	2.952	SUBM	.302	.200	1.901	1.510	1.256	.998	.379	.389	.010	2.7
396	2.964	SUBM	.302	.200	1.998	1.599	1.321	1.057	.371	.382	.012	3.1
397	2.964	SUBM	.302	.200	2.100	1.690	1.388	1.117	.362	.378	.017	4.6
398	2.948	SUBM	.302	.200	2.199	1.785	1.453	1.180	.352	.372	.021	5.9
399	2.955	SUBM	.302	.200	2.299	1.870	1.519	1.236	.345	.373	.028	8.1
400	3.406	SUBM	.302	.200	2.306	1.759	1.524	1.162	.397	.424	.027	6.9
401	3.417	SUBM	.302	.200	2.203	1.664	1.456	1.100	.407	.428	.021	5.2
402	3.422	SUBM	.302	.200	2.097	1.571	1.386	1.038	.418	.433	.015	3.6
403	3.423	SUBM	.302	.200	1.998	1.483	1.321	.980	.428	.439	.011	2.6
404	3.404	SUBM	.302	.200	1.903	1.407	1.258	.930	.436	.443	.007	1.5
405	3.403	SUBM	.302	.200	1.803	1.318	1.192	.871	.448	.453	.004	1.0
406	3.414	SUBM	.302	.200	1.698	1.228	1.122	.812	.463	.464	.001	.1
407	3.414	SUBM	.302	.200	1.597	1.143	1.056	.755	.478	.480	.002	.4
408	3.414	SUBM	.302	.200	1.502	1.065	.993	.704	.493	.497	.005	1.0
409	3.414	SUBM	.302	.200	1.401	.985	.926	.651	.510	.516	.006	1.2
410	3.423	SUBM	.302	.200	1.300	.907	.859	.600	.531	.536	.005	1.0
411	3.378	SUBM	.302	.200	1.201	.839	.794	.555	.545	.550	.004	.8
412	3.781	SUBM	.302	.200	2.301	1.649	1.521	1.090	.441	.465	.024	5.4
413	3.812	SUBM	.302	.200	2.200	1.557	1.454	1.029	.455	.470	.016	3.5
414	3.814	SUBM	.302	.200	2.102	1.471	1.389	.973	.465	.476	.011	2.4
415	3.814	SUBM	.302	.200	1.997	1.388	1.320	.917	.477	.482	.004	.9
416	3.823	SUBM	.302	.200	1.900	1.302	1.256	.860	.491	.493	.003	.5
417	3.828	SUBM	.302	.200	1.801	1.221	1.190	.807	.504	.503	-.001	-.2
418	3.823	SUBM	.302	.200	1.701	1.142	1.124	.755	.518	.519	.001	.1
419	3.814	SUBM	.302	.200	1.584	1.066	1.047	.705	.536	.530	-.006	-1.1
420	3.812	SUBM	.302	.200	1.497	.988	.989	.653	.551	.557	.005	1.0
421	3.812	SUBM	.302	.200	1.404	.924	.928	.611	.569	.572	.003	.5
422	3.824	SUBM	.302	.200	1.302	.865	.861	.572	.593	.580	-.013	-2.2
423	3.824	SUBM	.302	.200	1.186	.800	.784	.529	.621	.585	-.037	-5.9
424	4.224	SUBM	.302	.200	1.468	.928	.970	.614	.617	.595	-.022	-3.5
425	4.229	SUBM	.302	.200	1.598	.998	1.056	.659	.592	.586	-.006	-1.0
426	4.260	SUBM	.302	.200	1.703	1.059	1.126	.700	.577	.575	-.003	-.5
427	4.238	SUBM	.302	.200	1.804	1.134	1.192	.749	.558	.555	-.003	-.6
428	4.239	SUBM	.302	.200	1.898	1.199	1.254	.793	.544	.541	-.003	-.5
429	4.239	SUBM	.302	.200	2.000	1.275	1.322	.843	.530	.531	.001	.2
430	4.239	SUBM	.302	.200	2.099	1.355	1.387	.896	.517	.521	.004	.7
431	4.244	SUBM	.302	.200	2.201	1.437	1.455	.950	.506	.514	.008	1.6
432	4.239	SUBM	.302	.200	2.297	1.516	1.518	1.002	.495	.509	.014	2.9
433	4.683	SUBM	.302	.200	2.300	1.390	1.520	.918	.546	.548	.002	.3
434	4.683	SUBM	.302	.200	2.203	1.315	1.456	.869	.558	.555	-.003	-.5
435	4.680	SUBM	.302	.200	2.114	1.249	1.397	.825	.569	.564	-.005	-.9
436	4.683	SUBM	.302	.200	2.004	1.173	1.325	.775	.585	.577	-.008	-1.4
437	4.670	SUBM	.302	.200	1.904	1.111	1.258	.734	.599	.591	-.007	-1.2
438	4.678	SUBM	.302	.200	1.795	1.053	1.186	.696	.618	.602	-.015	-2.4
439	5.099	SUBM	.302	.200	2.026	1.128	1.339	.745	.634	.604	-.030	-4.7
440	5.078	SUBM	.302	.200	2.107	1.163	1.393	.769	.619	.598	-.021	-3.4
441	5.100	SUBM	.302	.200	2.199	1.220	1.453	.806	.608	.586	-.022	-3.6
442	5.064	SUBM	.302	.200	2.295	1.285	1.517	.849	.591	.577	-.014	-2.4
443	5.519	SUBM	.302	.200	2.288	1.213	1.512	.802	.645	.598	-.048	-7.4
444	.712	SUBM	.302	.200	.370	.359	.245	.238	.207	.194	-.014	-6.5
445	.946	SUBM	.302	.200	.358	.337	.237	.223	.280	.261	-.019	-6.7
446	1.209	OMIT	.302	.200	.365	.339**						
447	1.206	SUBM	.302	.200	.475	.446	.314	.295	.309	.301	-.009	-2.8
448	1.456	SUBM	.302	.200	.362	.301	.239	.199	.428	***		
449	1.439	SUBM	.302	.200	.466	.421	.308	.278	.373	.382	.009	2.4
450	1.675	SUBM	.302	.200	.409	.335	.270	.222	.463	.445	-.019	-4.0
451	1.672	SUBM	.302	.200	.473	.408	.313	.270	.430	.457	.027	6.3
452	1.666	SUBM	.302	.200	.559	.495	.369	.327	.394	.388	-.006	-1.5
453	1.662	SUBM	.302	.200	.664	.591	.439	.391	.361	.357	-.004	-1.0
454	1.914	SUBM	.302	.200	.444	.352	.293	.233	.508	.489	-.019	-3.7
455	1.916	SUBM	.302	.200	.510	.429	.337	.283	.475	.491	.016	3.4
456	1.884	SUBM	.302	.200	.634	.542	.419	.358	.418	.424	.005	1.3
457	2.163	JUMP	.302	.200	.482	.214	.319	.141	.551	.556	.005	.9
458	2.163	SUBM	.302	.200	.546	.449	.361	.297	.518	.511	-.007	-1.3
459	2.160	SUBM	.302	.200	.644	.534	.426	.353	.476	.465	-.011	-2.3
460	2.362	JUMP	.302	.200	.554	.198	.366	.131	.561	.571	.009	1.7

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
461	2.362	SUBM	.302	.200	.644	.520	.426	.343	.521	.502	-.018	-3.5
462	2.362	SUBM	.302	.200	.752	.609	.497	.402	.482	.470	-.011	-2.3
463	2.587	JUMP	.302	.200	.630	.193	.416	.128	.576	.584	.008	1.4
464	2.586	SUBM	.302	.200	.690	.543	.456	.359	.551	.523	-.028	-5.1
465	2.788	JUMP	.302	.200	.666	.208	.440	.137	.604	.590	-.014	-2.3
466	2.779	SUBM	.302	.200	.769	.591	.508	.391	.560	.530	-.031	-5.5
467	2.778	SUBM	.302	.200	.873	.669	.577	.442	.526	.511	-.014	-2.8
468	3.010	JUMP	.302	.200	.781	.195	.516	.129	.602	.608	.005	.9
469	3.000	SUBM	.302	.200	.860	.641	.568	.424	.572	.544	-.028	-4.9
470	2.979	SUBM	.302	.200	.934	.695	.617	.460	.545	.531	-.014	-2.5
471	3.320	JUMP	.302	.200	.886	.199	.586	.131	.624	.622	-.002	-.4
472	3.303	SUBM	.302	.200	.990	.709	.654	.468	.587	.562	-.025	-4.3
473	3.297	SUBM	.302	.200	1.078	.766	.712	.506	.562	.553	-.008	-1.5
474	3.560	SUBM	.302	.200	1.134	.780	.750	.516	.591	.575	-.016	-2.7
475	4.030	SUBM	.302	.200	1.332	.867	.880	.573	.618	.593	-.025	-4.1
476	4.684	SUBM	.302	.200	1.694	1.009	1.120	.667	.636	.606	-.030	-4.7
477	4.893	SUBM	.302	.200	1.830	1.057	1.210	.699	.640	.608	-.032	-5.0
478	5.280	SUBM	.302	.200	2.120	1.155	1.401	.763	.641	.603	-.038	-5.9
479	5.229	SUBM	.302	.200	2.232	1.202	1.475	.795	.619	.596	-.023	-3.7
480	5.225	SUBM	.302	.200	2.277	1.224	1.505	.809	.612	.593	-.019	-3.1
481	5.631	SUBM	.302	.200	2.311	1.214	1.527	.803	.655	.599	-.056	-8.6
795	.682	SUBM	.608	.402	.655	.654	.433	.432	.074	***		
796	.681	SUBM	.608	.402	.740	.738	.489	.488	.070	.085	.016	22.4
797	.681	SUBM	.608	.402	.845	.843	.558	.557	.065	.071	.006	9.6
798	.678	SUBM	.608	.402	.941	.940	.622	.621	.061	.049	-.013	-20.9
799	.676	SUBM	.608	.402	1.039	1.036	.687	.685	.058	.070	.012	20.2
800	.670	SUBM	.608	.402	1.150	1.147	.760	.758	.055	.063	.008	14.4
801	.668	SUBM	.608	.402	1.242	1.238	.821	.818	.053	.065	.012	23.4
802	.663	SUBM	.608	.402	1.342	1.338	.887	.884	.050	.058	.008	15.4
803	.661	SUBM	.608	.402	1.437	1.433	.950	.947	.048	.051	.003	5.4
804	.658	SUBM	.608	.402	1.543	1.540	1.020	1.018	.047	.039	-.007	-15.7
805	.678	SUBM	.608	.402	1.631	1.627	1.078	1.075	.047	.044	-.003	-6.7
806	.672	SUBM	.608	.402	1.744	1.740	1.153	1.150	.045	.042	-.003	-7.1
807	.684	SUBM	.608	.402	1.839	1.835	1.215	1.213	.044	.040	-.004	-9.7
808	.683	SUBM	.608	.402	1.939	1.934	1.282	1.278	.043	.043	-.000	.2
809	.682	SUBM	.608	.402	2.039	2.034	1.348	1.344	.042	.042	-.000	-.6
810	.680	SUBM	.608	.402	2.140	2.134	1.414	1.410	.041	.044	.003	8.4
811	.678	SUBM	.608	.402	2.238	2.231	1.479	1.475	.040	.046	.007	16.6
812	.677	SUBM	.608	.402	2.340	2.335	1.547	1.543	.039	.038	-.001	-2.1
813	1.413	SUBM	.608	.402	.640	.634	.423	.419	.155	***		
814	1.410	SUBM	.608	.402	.734	.729	.485	.482	.145	.136	-.008	-5.7
815	1.405	SUBM	.608	.402	.843	.834	.557	.551	.134	.147	.013	9.5
816	1.402	SUBM	.608	.402	.941	.931	.622	.615	.127	.135	.008	6.3
817	1.397	SUBM	.608	.402	1.036	1.025	.685	.677	.121	.126	.006	4.6
818	1.393	SUBM	.608	.402	1.135	1.123	.750	.742	.115	.118	.003	3.0
819	1.393	SUBM	.608	.402	1.234	1.220	.816	.806	.110	.115	.005	4.3
820	1.394	SUBM	.608	.402	1.342	1.321	.887	.873	.106	.125	.020	18.5
821	1.388	SUBM	.608	.402	1.437	1.422	.950	.940	.102	.097	-.005	-4.8
822	1.384	SUBM	.608	.402	1.532	1.516	1.013	1.002	.098	.091	-.007	-7.0
823	1.380	SUBM	.608	.402	1.645	1.626	1.087	1.075	.095	.095	.000	.1
824	1.374	SUBM	.608	.402	1.747	1.727	1.155	1.141	.091	.093	.002	1.9
825	1.368	SUBM	.608	.402	1.844	1.824	1.219	1.206	.089	.090	.001	1.3
826	1.404	SUBM	.608	.402	1.946	1.923	1.286	1.271	.088	.093	.004	4.9
827	1.401	SUBM	.608	.402	2.040	2.017	1.348	1.333	.086	.090	.004	4.2
828	1.398	SUBM	.608	.402	2.142	2.119	1.416	1.401	.084	.087	.003	3.6
829	1.392	SUBM	.608	.402	2.246	2.223	1.484	1.469	.082	.084	.003	3.3
830	1.388	SUBM	.608	.402	2.351	2.328	1.554	1.539	.080	.082	.002	2.8
831	2.059	SUBM	.608	.402	.651	.636	.430	.420	.224	***		
832	2.067	SUBM	.608	.402	.737	.721	.487	.476	.212	.216	.005	2.3
833	2.068	SUBM	.608	.402	.842	.822	.557	.543	.198	.212	.014	7.2
834	2.068	SUBM	.608	.402	.941	.919	.622	.607	.187	.192	.005	2.5
835	2.078	SUBM	.608	.402	1.042	1.015	.689	.671	.179	.187	.008	4.7
836	2.077	SUBM	.608	.402	1.151	1.121	.761	.741	.170	.178	.008	4.9
837	2.075	SUBM	.608	.402	1.246	1.212	.824	.801	.163	.173	.010	5.8
838	2.077	SUBM	.608	.402	1.343	1.308	.888	.865	.157	.161	.003	2.0
839	2.074	SUBM	.608	.402	1.446	1.407	.956	.930	.152	.155	.003	2.2
840	2.075	SUBM	.608	.402	1.540	1.502	1.018	.993	.147	.141	-.006	-3.9
841	2.072	SUBM	.608	.402	1.646	1.603	1.088	1.059	.142	.143	.001	.9
842	2.069	SUBM	.608	.402	1.751	1.708	1.157	1.129	.137	.137	-.000	-.3
843	2.066	SUBM	.608	.402	1.851	1.806	1.223	1.194	.133	.135	.001	1.1
844	2.066	SUBM	.608	.402	1.955	1.908	1.292	1.261	.130	.133	.003	2.3
845	2.062	SUBM	.608	.402	2.050	2.002	1.355	1.323	.127	.130	.003	2.8
846	2.061	SUBM	.608	.402	2.141	2.092	1.415	1.383	.124	.128	.004	3.2
847	2.052	SUBM	.608	.402	2.246	2.196	1.484	1.451	.120	.125	.005	4.0
848	2.051	SUBM	.608	.402	2.355	2.304	1.557	1.523	.117	.123	.005	4.4
849	2.787	SUBM	.608	.402	.648	.619	.428	.409	.304	***		
850	2.783	SUBM	.608	.402	.707	.677	.467	.447	.291	***		
851	2.769	SUBM	.608	.402	.779	.747	.515	.494	.276	.285	.009	3.2
852	2.768	SUBM	.608	.402	.847	.811	.560	.536	.264	.274	.010	3.8
853	2.763	SUBM	.608	.402	.956	.914	.632	.604	.248	.256	.007	2.9

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
854	2.747	SUBM	.608	.402	1.050	1.004	.694	.664	.236	.241	.006	2.4
855	2.739	SUBM	.608	.402	1.148	1.099	.759	.726	.225	.227	.002	.9
856	2.741	SUBM	.608	.402	1.242	1.187	.821	.785	.216	.220	.004	1.6
857	2.733	SUBM	.608	.402	1.352	1.291	.894	.853	.206	.210	.004	1.8
858	2.723	SUBM	.608	.402	1.442	1.379	.953	.911	.199	.200	.001	.3
859	2.760	SUBM	.608	.402	1.549	1.478	1.024	.977	.195	.195	.000	.2
860	2.758	SUBM	.608	.402	1.653	1.579	1.093	1.044	.188	.189	.000	.2
861	2.754	SUBM	.608	.402	1.747	1.670	1.155	1.104	.183	.185	.002	1.0
862	2.750	SUBM	.608	.402	1.854	1.774	1.225	1.173	.177	.181	.003	1.9
863	2.750	SUBM	.608	.402	1.950	1.870	1.289	1.236	.173	.175	.002	1.0
864	2.743	SUBM	.608	.402	2.048	1.966	1.354	1.299	.168	.171	.003	1.7
865	2.743	SUBM	.608	.402	2.149	2.063	1.420	1.364	.164	.170	.006	3.4
866	2.740	SUBM	.608	.402	2.253	2.167	1.489	1.432	.160	.165	.005	2.9
867	2.734	SUBM	.608	.402	2.351	2.263	1.554	1.496	.157	.163	.006	3.8
868	3.438	SUBM	.608	.402	.713	.667	.471	.441	.358	***		
869	3.436	SUBM	.608	.402	.751	.702	.496	.464	.348	.328	-.021	-5.9
870	3.424	SUBM	.608	.402	.839	.786	.555	.520	.328	.339	.011	3.2
871	3.424	SUBM	.608	.402	.952	.890	.629	.588	.308	.314	.006	2.0
872	3.426	SUBM	.608	.402	1.053	.982	.696	.649	.293	.299	.006	2.1
873	3.422	SUBM	.608	.402	1.151	1.073	.761	.709	.280	.285	.005	1.8
874	3.418	SUBM	.608	.402	1.252	1.167	.827	.771	.268	.273	.004	1.6
875	3.401	SUBM	.608	.402	1.346	1.256	.890	.830	.258	.259	.001	.6
876	3.414	SUBM	.608	.402	1.459	1.359	.964	.898	.248	.252	.003	1.3
877	3.466	SUBM	.608	.402	1.548	1.439	1.023	.951	.245	.246	.002	.6
878	3.466	SUBM	.608	.402	1.653	1.539	1.093	1.017	.237	.236	-.001	-.2
879	3.462	SUBM	.608	.402	1.756	1.636	1.161	1.082	.230	.232	.002	1.0
880	3.460	SUBM	.608	.402	1.860	1.735	1.229	1.146	.223	.228	.005	2.3
881	3.454	SUBM	.608	.402	1.952	1.824	1.290	1.205	.217	.223	.006	2.8
882	3.455	SUBM	.608	.402	2.054	1.922	1.358	1.270	.212	.219	.007	3.4
883	3.451	SUBM	.608	.402	2.157	2.022	1.426	1.336	.206	.215	.008	4.0
884	3.450	SUBM	.608	.402	2.250	2.115	1.487	1.398	.202	.209	.007	3.4
885	3.451	SUBM	.608	.402	2.355	2.216	1.557	1.465	.198	.206	.009	4.5
886	4.126	SUBM	.608	.402	.784	.712	.518	.471	.409	.408	-.001	-.3
887	4.102	SUBM	.608	.402	.842	.764	.557	.505	.393	.416	.023	5.8
888	4.126	SUBM	.608	.402	.955	.865	.631	.572	.371	.383	.012	3.2
889	4.138	SUBM	.608	.402	1.048	.950	.693	.628	.355	.358	.003	.9
890	4.138	SUBM	.608	.402	1.156	1.044	.764	.690	.338	.345	.007	2.2
891	4.138	SUBM	.608	.402	1.252	1.131	.827	.747	.325	.330	.005	1.5
892	4.138	SUBM	.608	.402	1.358	1.226	.898	.810	.312	.317	.005	1.5
893	4.122	SUBM	.608	.402	1.454	1.313	.961	.868	.300	.304	.004	1.2
894	4.115	SUBM	.608	.402	1.546	1.399	1.022	.924	.291	.291	.001	.2
895	4.115	SUBM	.608	.402	1.652	1.496	1.092	.989	.281	.280	-.002	-.6
896	4.115	SUBM	.608	.402	1.752	1.589	1.158	1.051	.273	.273	.000	.0
897	4.115	SUBM	.608	.402	1.835	1.664	1.213	1.100	.267	.272	.005	1.7
898	4.115	SUBM	.608	.402	1.956	1.777	1.293	1.174	.258	.266	.007	2.8
899	4.106	SUBM	.608	.402	2.057	1.873	1.360	1.238	.252	.260	.009	3.5
900	4.094	SUBM	.608	.402	2.152	1.965	1.422	1.299	.245	.255	.010	4.0
901	4.076	SUBM	.608	.402	2.249	2.061	1.486	1.362	.239	.249	.011	4.4
902	4.062	SUBM	.608	.402	2.356	2.165	1.557	1.431	.232	.245	.012	5.2
903	4.793	SUBM	.608	.402	.871	.767	.576	.507	.451	.471	.019	4.3
904	4.784	SUBM	.608	.402	.940	.827	.621	.546	.433	.448	.015	3.4
905	4.790	SUBM	.608	.402	1.042	.914	.689	.604	.412	.421	.009	2.2
906	4.785	SUBM	.608	.402	1.149	1.006	.759	.665	.392	.400	.008	2.1
907	4.793	SUBM	.608	.402	1.245	1.089	.823	.720	.377	.383	.005	1.4
908	4.790	SUBM	.608	.402	1.351	1.180	.893	.780	.362	.368	.006	1.6
909	4.795	SUBM	.608	.402	1.454	1.270	.961	.840	.349	.354	.004	1.3
910	4.781	SUBM	.608	.402	1.542	1.350	1.019	.892	.338	.340	.002	.5
911	4.777	SUBM	.608	.402	1.650	1.446	1.091	.956	.327	.327	.000	.1
912	4.805	SUBM	.608	.402	1.759	1.540	1.163	1.018	.318	.320	.002	.5
913	4.804	SUBM	.608	.402	1.850	1.622	1.223	1.072	.310	.315	.005	1.6
914	4.806	SUBM	.608	.402	1.948	1.709	1.288	1.130	.303	.311	.008	2.8
915	4.800	SUBM	.608	.402	2.047	1.804	1.353	1.193	.295	.303	.008	2.8
916	4.798	SUBM	.608	.402	2.151	1.900	1.422	1.256	.287	.299	.011	4.0
917	4.810	SUBM	.608	.402	2.255	1.999	1.490	1.321	.281	.293	.012	4.2
918	4.794	SUBM	.608	.402	2.348	2.087	1.552	1.379	.275	.289	.015	5.3
919	5.486	SUBM	.608	.402	.962	.820	.636	.542	.491	.501	.010	2.0
920	5.476	SUBM	.608	.402	1.062	.902	.702	.596	.467	.472	.005	1.2
921	5.471	SUBM	.608	.402	1.148	.971	.759	.642	.449	.456	.007	1.6
922	5.463	SUBM	.608	.402	1.254	1.059	.829	.700	.429	.435	.006	1.4
923	5.471	SUBM	.608	.402	1.350	1.139	.892	.753	.414	.419	.005	1.2
924	5.465	SUBM	.608	.402	1.448	1.220	.957	.806	.399	.404	.005	1.4
925	5.463	SUBM	.608	.402	1.554	1.308	1.027	.865	.385	.391	.006	1.5
926	5.459	SUBM	.608	.402	1.643	1.388	1.086	.917	.374	.375	.001	.3
927	5.453	SUBM	.608	.402	1.755	1.484	1.160	.981	.362	.362	.000	.1
928	5.436	SUBM	.608	.402	1.849	1.568	1.222	1.037	.351	.353	.002	.5
929	5.453	SUBM	.608	.402	1.947	1.654	1.287	1.093	.343	.348	.004	1.3
930	5.468	SUBM	.608	.402	2.054	1.746	1.358	1.154	.335	.344	.008	2.5
931	5.477	SUBM	.608	.402	2.162	1.841	1.429	1.217	.327	.340	.013	3.9
932	5.456	SUBM	.608	.402	2.253	1.928	1.489	1.274	.319	.333	.014	4.4
933	5.476	SUBM	.608	.402	2.347	2.011	1.551	1.329	.314	.331	.017	5.6

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 1
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI-ATION (CDA-CDM)	DEVI-ATION (PERCENT)
934	6.178	JUMP	.608	.402	1.058	.358	.699	.236	.528	.541	.013	2.5
935	6.175	SUBM	.608	.402	1.226	1.004	.810	.664	.490	.486	-.004	-.9
936	6.164	SUBM	.608	.402	1.330	1.082	.879	.715	.470	.472	.002	.5
937	6.162	SUBM	.608	.402	1.434	1.165	.948	.770	.452	.453	.001	.3
938	6.145	SUBM	.608	.402	1.535	1.244	1.015	.822	.436	.440	.005	1.0
939	6.168	SUBM	.608	.402	1.641	1.331	1.085	.880	.423	.424	.001	.2
940	6.159	SUBM	.608	.402	1.747	1.418	1.155	.937	.409	.410	.001	.2
941	6.159	SUBM	.608	.402	1.841	1.497	1.217	.990	.399	.397	-.001	-.3
942	6.154	SUBM	.608	.402	1.949	1.589	1.288	1.050	.387	.389	.002	.5
943	6.159	SUBM	.608	.402	2.053	1.677	1.357	1.108	.378	.384	.006	1.6
944	6.192	SUBM	.608	.402	2.147	1.751	1.419	1.157	.371	.382	.011	3.0
945	6.181	SUBM	.608	.402	2.257	1.850	1.492	1.223	.361	.376	.015	4.0
946	6.181	SUBM	.608	.402	2.357	1.942	1.558	1.284	.354	.370	.017	4.7
947	6.863	JUMP	.608	.402	1.195	.400	.790	.264	.552	.555	.004	.7
948	6.845	SUBM	.608	.402	1.418	1.117	.937	.738	.505	.496	-.009	-1.7
949	6.842	SUBM	.608	.402	1.527	1.196	1.009	.791	.486	.482	-.004	-.9
950	6.839	SUBM	.608	.402	1.651	1.288	1.091	.852	.468	.466	-.001	-.3
951	6.846	SUBM	.608	.402	1.745	1.359	1.153	.898	.455	.455	-.000	-.0
952	6.843	SUBM	.608	.402	1.866	1.451	1.233	.959	.440	.441	.001	.2
953	6.836	SUBM	.608	.402	1.962	1.531	1.297	1.012	.429	.429	.000	.1
954	6.860	SUBM	.608	.402	2.053	1.604	1.357	1.060	.421	.424	.003	.7
955	6.854	SUBM	.608	.402	2.147	1.684	1.419	1.113	.411	.417	.006	1.5
956	6.850	SUBM	.608	.402	2.253	1.773	1.489	1.172	.401	.411	.010	2.6
957	6.834	SUBM	.608	.402	2.358	1.859	1.558	1.229	.391	.409	.018	4.5
958	7.536	JUMP	.608	.402	1.384	.376	.915	.249	.563	.570	.008	1.4
959	7.518	SUBM	.608	.402	1.615	1.224	1.067	.809	.520	.504	-.015	-2.9
960	7.533	SUBM	.608	.402	1.728	1.299	1.142	.858	.503	.494	-.009	-1.8
961	7.535	SUBM	.608	.402	1.819	1.362	1.202	.900	.491	.484	-.006	-1.3
962	7.527	SUBM	.608	.402	1.927	1.442	1.274	.953	.476	.471	-.005	-1.1
963	7.524	SUBM	.608	.402	2.034	1.521	1.344	1.005	.463	.461	-.003	-.6
964	7.529	SUBM	.608	.402	2.141	1.606	1.415	1.062	.452	.452	.000	.1
965	7.527	SUBM	.608	.402	2.237	1.683	1.479	1.112	.442	.447	.004	1.0
966	7.522	SUBM	.608	.402	2.357	1.785	1.558	1.180	.430	.439	.009	2.1
967	8.210	FREE	.608	.402	1.582	.444	1.046	.294	.573	.581	.007	1.2
968	8.236	SUBM	.608	.402	1.826	1.330	1.207	.879	.535	.511	-.025	-4.6
969	8.231	SUBM	.608	.402	1.949	1.403	1.288	.927	.518	.504	-.014	-2.8
970	8.227	SUBM	.608	.402	2.044	1.469	1.351	.971	.506	.492	-.013	-2.6
971	8.223	SUBM	.608	.402	2.153	1.546	1.423	1.022	.492	.484	-.008	-1.6
972	8.218	SUBM	.608	.402	2.252	1.620	1.488	1.071	.481	.478	-.003	-.7
973	8.213	SUBM	.608	.402	2.339	1.689	1.546	1.116	.472	.472	.001	.1
974	8.896	FREE	.608	.402	1.796	.415	1.187	.275	.583	.586	.003	.5
975	8.904	SUBM	.608	.402	2.012	1.410	1.330	.932	.551	.518	-.033	-6.1
976	8.905	SUBM	.608	.402	2.127	1.476	1.406	.975	.536	.511	-.025	-4.7
977	8.975	SUBM	.608	.402	2.242	1.543	1.482	1.020	.527	.507	-.019	-3.7
978	8.972	SUBM	.608	.402	2.328	1.602	1.539	1.059	.517	.502	-.014	-2.7
979	9.600	FREE	.608	.402	2.042	.388	1.350	.256	.590	.585	-.005	-.9
980	9.584	SUBM	.608	.402	2.252	1.518	1.488	1.003	.561	.520	-.041	-7.4
981	9.585	SUBM	.608	.402	2.345	1.571	1.550	1.038	.550	.517	-.032	-5.9
982	10.017	FREE	.608	.402	2.190	.375	1.447	.248	.595	.581	-.014	-2.3
983	10.405	FREE	.608	.402	2.316	.367	1.531	.243	.601	.575	-.026	-4.3
984	1.229	SUBM	.909	.601	.961	.960	.635	.635	.074	.059	-.015	-19.8
985	1.226	SUBM	.909	.601	1.063	1.062	.703	.702	.070	.048	-.022	-30.9
986	1.223	SUBM	.909	.601	1.174	1.173	.776	.775	.066	.043	-.023	-34.5
987	1.214	SUBM	.909	.601	1.289	1.287	.852	.851	.063	.056	-.007	-10.9
988	1.226	SUBM	.909	.601	1.385	1.383	.915	.914	.061	.051	-.010	-15.9
989	1.217	SUBM	.909	.601	1.477	1.473	.976	.974	.059	.065	.006	10.9
990	1.217	SUBM	.909	.601	1.592	1.588	1.052	1.050	.057	.058	.001	2.4
991	1.226	SUBM	.909	.601	1.670	1.665	1.104	1.100	.056	.059	.003	5.6
992	1.226	SUBM	.909	.601	1.789	1.785	1.182	1.180	.054	.045	-.009	-16.0
993	1.232	SUBM	.909	.601	1.881	1.876	1.243	1.240	.053	.048	-.005	-9.6
994	1.243	SUBM	.909	.601	1.992	1.986	1.317	1.313	.052	.050	-.002	-3.7
995	1.243	SUBM	.909	.601	2.096	2.091	1.385	1.382	.050	.044	-.007	-13.4
996	1.246	SUBM	.909	.601	2.189	2.182	1.447	1.442	.049	.050	.000	1.0
997	1.212	SUBM	.909	.601	2.328	2.320	1.539	1.533	.047	.051	.004	9.1
998	2.447	SUBM	.909	.601	.971	.964	.642	.637	.146	.144	-.002	-1.5
999	2.447	SUBM	.909	.601	1.077	1.068	.712	.706	.139	.146	.007	5.2
1000	2.447	SUBM	.909	.601	1.183	1.171	.782	.774	.132	.142	.010	7.7
1001	2.440	SUBM	.909	.601	1.287	1.274	.851	.842	.126	.135	.008	6.7
1002	2.440	SUBM	.909	.601	1.391	1.376	.919	.909	.122	.129	.007	5.7
1003	2.440	SUBM	.909	.601	1.487	1.470	.983	.972	.118	.124	.006	5.3
1004	2.440	SUBM	.909	.601	1.595	1.578	1.054	1.043	.114	.112	-.001	-1.2
1005	2.447	SUBM	.909	.601	1.694	1.676	1.120	1.108	.110	.105	-.005	-4.7
1006	2.440	SUBM	.909	.601	1.804	1.783	1.192	1.178	.107	.103	-.004	-3.9
1007	2.440	SUBM	.909	.601	1.900	1.878	1.256	1.241	.104	.100	-.004	-4.2
1008	2.440	SUBM	.909	.601	1.992	1.967	1.317	1.300	.102	.102	.001	.7
1009	2.440	SUBM	.909	.601	2.084	2.059	1.377	1.361	.099	.099	-.001	-.7
1010	2.433	SUBM	.909	.601	2.197	2.170	1.452	1.434	.096	.098	.002	2.0
1011	2.433	SUBM	.909	.601	2.329	2.300	1.539	1.520	.094	.098	.004	4.1
1012	3.654	SUBM	.909	.601	.958	.940	.633	.621	.219	.209	-.010	-4.5
1013	3.654	SUBM	.909	.601	1.062	1.041	.702	.688	.208	.216	.008	3.8

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 1
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI-ATION (CDA-CDM)	DEVI-ATION (PERCENT)
1014	3.649	SUBM	.909	.601	1.160	1.134	.767	.750	.199	.211	.012	6.1
1015	3.654	SUBM	.909	.601	1.261	1.231	.833	.813	.191	.202	.011	5.7
1016	3.644	SUBM	.909	.601	1.363	1.330	.901	.879	.183	.189	.006	3.1
1017	3.644	SUBM	.909	.601	1.461	1.423	.966	.940	.177	.186	.009	5.2
1018	3.644	SUBM	.909	.601	1.566	1.524	1.035	1.007	.171	.178	.007	4.1
1019	3.649	SUBM	.909	.601	1.674	1.629	1.106	1.077	.166	.168	.003	1.6
1020	3.644	SUBM	.909	.601	1.769	1.721	1.169	1.138	.161	.161	-.000	-.0
1021	3.639	SUBM	.909	.601	1.854	1.804	1.225	1.193	.157	.154	-.003	-2.1
1022	3.639	SUBM	.909	.601	1.966	1.913	1.299	1.264	.152	.152	-.000	-.3
1023	3.639	SUBM	.909	.601	2.057	2.003	1.360	1.324	.149	.148	-.001	-.9
1024	3.644	SUBM	.909	.601	2.171	2.111	1.435	1.395	.145	.149	.004	2.7
1025	3.649	SUBM	.909	.601	2.322	2.259	1.535	1.493	.141	.145	.005	3.2
1026	4.884	SUBM	.909	.601	.970	.936	.641	.619	.291	.274	-.018	-6.0
1027	4.881	SUBM	.909	.601	1.068	1.029	.706	.680	.278	.289	.012	4.3
1028	4.881	SUBM	.909	.601	1.183	1.138	.782	.752	.264	.269	.005	1.9
1029	4.877	SUBM	.909	.601	1.263	1.203	.835	.795	.255	.283	.028	11.0
1030	4.874	SUBM	.909	.601	1.379	1.320	.911	.872	.244	.249	.005	1.9
1031	4.884	SUBM	.909	.601	1.484	1.418	.981	.938	.236	.238	.002	1.0
1032	4.874	SUBM	.909	.601	1.586	1.514	1.048	1.001	.227	.229	.002	.9
1033	4.874	SUBM	.909	.601	1.693	1.615	1.119	1.067	.220	.221	.001	.4
1034	4.867	SUBM	.909	.601	1.773	1.691	1.172	1.118	.215	.213	-.001	-.7
1035	4.860	SUBM	.909	.601	1.883	1.793	1.245	1.185	.208	.207	-.001	-.6
1036	4.860	SUBM	.909	.601	1.990	1.896	1.315	1.253	.202	.202	-.000	-.1
1037	4.881	SUBM	.909	.601	2.097	1.996	1.386	1.319	.198	.201	.003	1.4
1038	4.884	SUBM	.909	.601	2.228	2.119	1.473	1.401	.192	.199	.007	3.6
1039	4.881	SUBM	.909	.601	2.337	2.225	1.545	1.471	.188	.195	.007	3.8
1040	6.121	SUBM	.909	.601	.947	.879	.626	.581	.370	***		
1041	6.137	SUBM	.909	.601	1.071	1.011	.708	.668	.348	.356	.007	2.1
1042	6.137	SUBM	.909	.601	1.171	1.103	.774	.729	.333	.337	.003	1.0
1043	6.235	SUBM	.909	.601	1.294	1.209	.855	.799	.322	.327	.005	1.5
1044	6.170	SUBM	.909	.601	1.373	1.283	.907	.848	.309	.311	.002	.6
1045	6.088	SUBM	.909	.601	1.499	1.395	.991	.922	.292	.298	.006	2.1
1046	6.088	SUBM	.909	.601	1.593	1.483	1.053	.980	.283	.285	.001	.4
1047	6.104	SUBM	.909	.601	1.675	1.557	1.107	1.029	.277	.278	.001	.4
1048	6.088	SUBM	.909	.601	1.779	1.652	1.176	1.092	.268	.269	.001	.3
1049	6.088	SUBM	.909	.601	1.881	1.745	1.243	1.154	.261	.260	-.001	-.3
1050	6.088	SUBM	.909	.601	1.979	1.836	1.308	1.213	.254	.253	-.001	-.5
1051	6.071	SUBM	.909	.601	2.099	1.946	1.387	1.286	.246	.249	.003	1.3
1052	6.088	SUBM	.909	.601	2.229	2.068	1.473	1.367	.240	.245	.005	2.2
1053	6.088	SUBM	.909	.601	2.377	2.209	1.571	1.460	.232	.238	.006	2.8
1054	7.353	SUBM	.909	.601	1.024	.922	.677	.610	.427	.446	.019	4.6
1055	7.326	SUBM	.909	.601	1.129	1.035	.746	.684	.405	.423	.018	4.5
1056	7.326	SUBM	.909	.601	1.243	1.135	.822	.750	.386	.396	.010	2.6
1057	7.326	SUBM	.909	.601	1.343	1.223	.888	.808	.371	.376	.005	1.3
1058	7.326	SUBM	.909	.601	1.452	1.317	.960	.871	.357	.360	.003	.8
1059	7.326	SUBM	.909	.601	1.543	1.397	1.020	.923	.347	.348	.001	.3
1060	7.326	SUBM	.909	.601	1.656	1.493	1.095	.987	.335	.337	.003	.8
1061	7.312	SUBM	.909	.601	1.773	1.597	1.172	1.055	.323	.324	.001	.4
1062	7.312	SUBM	.909	.601	1.853	1.667	1.225	1.102	.316	.316	.000	.1
1063	7.312	SUBM	.909	.601	1.964	1.764	1.298	1.166	.307	.307	.000	.1
1064	7.312	SUBM	.909	.601	2.056	1.847	1.359	1.221	.300	.300	.001	.3
1065	7.298	SUBM	.909	.601	2.188	1.966	1.446	1.299	.290	.295	.005	1.8
1066	7.298	SUBM	.909	.601	2.281	2.049	1.508	1.354	.284	.292	.008	2.9
1067	7.284	SUBM	.909	.601	2.402	2.166	1.588	1.431	.276	.284	.008	3.0
1068	8.538	JUMP	.909	.601	1.067	.542	.705	.358	.486	.494	.008	1.7
1069	8.538	SUBM	.909	.601	1.154	1.019	.763	.673	.467	.508	.041	8.7
1070	8.538	SUBM	.909	.601	1.250	1.113	.826	.736	.449	.453	.004	1.0
1071	8.538	SUBM	.909	.601	1.362	1.203	.900	.795	.430	.435	.006	1.3
1072	8.538	SUBM	.909	.601	1.457	1.282	.963	.848	.416	.417	.002	.4
1073	8.526	SUBM	.909	.601	1.567	1.373	1.036	.907	.400	.403	.002	.6
1074	8.550	SUBM	.909	.601	1.685	1.469	1.114	.971	.387	.389	.002	.6
1075	8.550	SUBM	.909	.601	1.793	1.557	1.185	1.029	.375	.379	.004	1.1
1076	8.550	SUBM	.909	.601	1.882	1.634	1.244	1.080	.366	.367	.001	.3
1077	8.550	SUBM	.909	.601	1.990	1.723	1.315	1.139	.356	.358	.002	.6
1078	8.526	SUBM	.909	.601	2.081	1.800	1.375	1.190	.347	.350	.003	.8
1079	8.526	SUBM	.909	.601	2.190	1.893	1.447	1.251	.339	.345	.007	2.0
1080	8.526	SUBM	.909	.601	2.281	1.977	1.508	1.307	.332	.339	.007	2.1
1081	8.514	SUBM	.909	.601	2.379	2.068	1.572	1.367	.324	.332	.008	2.4
1082	9.745	FREE	.909	.601	1.243	.696	.822	.460	.514	.513	-.001	-.2
1083	9.745	SUBM	.909	.601	1.342	1.146	.887	.757	.494	.511	.016	3.3
1084	9.745	SUBM	.909	.601	1.449	1.241	.958	.820	.476	.471	-.005	-1.0
1085	9.651	SUBM	.909	.601	1.557	1.326	1.029	.876	.454	.452	-.002	-.5
1086	9.735	SUBM	.909	.601	1.653	1.397	1.093	.923	.445	.444	-.001	-.1
1087	9.745	SUBM	.909	.601	1.756	1.474	1.161	.974	.432	.434	.002	.5
1088	9.756	SUBM	.909	.601	1.855	1.550	1.226	1.025	.421	.424	.003	.8
1089	9.756	SUBM	.909	.601	1.958	1.632	1.294	1.079	.410	.413	.003	.8
1090	9.735	SUBM	.909	.601	2.069	1.720	1.367	1.137	.398	.402	.005	1.2
1091	9.745	SUBM	.909	.601	2.174	1.806	1.437	1.194	.388	.392	.004	.9
1092	9.735	SUBM	.909	.601	2.303	1.919	1.522	1.268	.377	.383	.006	1.5
1093	9.756	SUBM	.909	.601	2.362	1.972	1.561	1.304	.373	.378	.005	1.4

90

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
1094	10.968	FREE	.909	.601	1.530	.653	1.011	.431	.521	.532	.011	2.2
1095	11.151	FREE	.909	.601	1.569	.647	1.037	.428	.523	.534	.011	2.1
1096	11.160	SUBM	.909	.601	1.653	1.339	1.093	.885	.510	.508	-.002	-.4
1097	11.041	SUBM	.909	.601	1.739	1.415	1.149	.935	.492	.482	-.010	-1.9
1098	10.041	SUBM	.909	.601	1.819	1.481	1.202	.979	.437	.466	.028	6.5
1099	11.032	SUBM	.909	.601	1.969	1.582	1.301	1.046	.462	.458	-.004	-1.0
1100	11.032	SUBM	.909	.601	2.065	1.648	1.365	1.089	.451	.452	.000	.1
1101	11.023	SUBM	.909	.601	2.159	1.719	1.427	1.136	.441	.442	.001	.3
1102	11.023	SUBM	.909	.601	2.250	1.795	1.487	1.186	.432	.430	-.002	-.4
1103	11.023	SUBM	.909	.601	2.354	1.882	1.556	1.244	.422	.422	-.000	-.1
1104	1.226	OMIT	1.215	.601	1.292	1.250**						
1105	1.220	OMIT	1.215	.601	1.405	1.362**						
1106	1.223	OMIT	1.215	.601	1.515	1.473**						
1107	1.220	OMIT	1.215	.601	1.590	1.578**						
1108	1.217	OMIT	1.215	.601	1.695	1.674**						
1109	1.217	OMIT	1.215	.601	1.789	1.767**						
1110	1.229	OMIT	1.215	.601	1.901	1.880**						
1111	1.223	OMIT	1.215	.601	1.993	1.975**						
1112	1.220	OMIT	1.215	.601	2.101	2.081**						
1113	1.217	OMIT	1.215	.601	2.224	2.206**						
1114	1.214	OMIT	1.215	.601	2.347	2.332**						
1115	2.447	SUBM	1.215	.803	1.274	1.272	.842	.840	.095	.080	-.016	-16.4
1116	2.440	SUBM	1.215	.803	1.396	1.388	.923	.917	.091	.124	.033	36.1
1117	2.426	SUBM	1.215	.803	1.490	1.483	.985	.980	.087	.104	.017	19.0
1118	2.446	SUBM	1.215	.803	1.599	1.589	1.057	1.050	.085	.110	.025	28.9
1119	2.440	SUBM	1.215	.803	1.708	1.701	1.129	1.124	.082	.085	.003	3.5
1120	2.440	SUBM	1.215	.803	1.777	1.772	1.174	1.171	.080	.069	-.012	-14.3
1121	2.426	SUBM	1.215	.803	1.891	1.884	1.250	1.245	.078	.073	-.005	-6.0
1122	2.419	SUBM	1.215	.803	2.013	2.004	1.330	1.325	.075	.074	-.001	-1.8
1123	2.433	SUBM	1.215	.803	2.104	2.092	1.391	1.383	.074	.078	.004	5.5
1124	2.426	SUBM	1.215	.803	2.202	2.192	1.455	1.449	.072	.065	-.007	-9.9
1125	2.412	SUBM	1.215	.803	2.334	2.323	1.543	1.535	.069	.064	-.006	-8.5
1126	3.672	SUBM	1.215	.803	1.271	1.265	.840	.836	.143	.125	-.018	-12.8
1127	3.668	SUBM	1.215	.803	1.394	1.383	.921	.914	.137	.139	.003	2.1
1128	3.658	SUBM	1.215	.803	1.495	1.483	.988	.980	.132	.133	.001	1.1
1129	3.644	SUBM	1.215	.803	1.589	1.577	1.050	1.042	.127	.120	-.007	-5.6
1130	3.654	SUBM	1.215	.803	1.715	1.699	1.134	1.123	.123	.121	-.001	-1.1
1131	3.658	SUBM	1.215	.803	1.791	1.773	1.184	1.172	.120	.120	-.000	-.1
1132	3.649	SUBM	1.215	.803	1.910	1.889	1.262	1.248	.116	.120	.004	3.1
1133	3.658	SUBM	1.215	.803	1.996	1.972	1.319	1.303	.114	.119	.005	4.6
1134	3.658	SUBM	1.215	.803	2.137	2.112	1.412	1.396	.110	.109	-.001	-1.3
1135	3.658	SUBM	1.215	.803	2.236	2.209	1.478	1.460	.108	.104	-.003	-3.1
1136	3.654	SUBM	1.215	.803	2.347	2.317	1.551	1.531	.105	.105	.000	.1
1137	4.891	SUBM	1.215	.803	1.303	1.286	.861	.850	.188	.190	.001	.7
1138	4.884	SUBM	1.215	.803	1.396	1.376	.923	.910	.182	.184	.002	1.2
1139	4.884	SUBM	1.215	.803	1.494	1.471	.987	.972	.176	.177	.002	1.0
1140	4.867	SUBM	1.215	.803	1.607	1.581	1.062	1.045	.169	.166	-.002	-1.4
1141	4.867	SUBM	1.215	.803	1.709	1.681	1.130	1.111	.164	.159	-.004	-2.6
1142	4.881	SUBM	1.215	.803	1.818	1.782	1.202	1.178	.159	.164	.005	3.0
1143	4.860	SUBM	1.215	.803	1.908	1.868	1.261	1.235	.155	.161	.006	3.9
1144	4.877	SUBM	1.215	.803	2.009	1.967	1.328	1.300	.151	.154	.003	2.1
1145	4.856	SUBM	1.215	.803	2.103	2.059	1.390	1.361	.147	.148	.000	.3
1146	4.888	SUBM	1.215	.803	2.221	2.171	1.468	1.435	.144	.145	.001	.5
1147	4.884	SUBM	1.215	.803	2.351	2.298	1.554	1.519	.140	.140	-.000	-.1
1148	6.121	SUBM	1.215	.803	1.277	1.251	.844	.827	.238	.230	-.008	-3.4
1149	6.121	SUBM	1.215	.803	1.419	1.383	.938	.914	.226	.236	.010	4.4
1150	6.121	SUBM	1.215	.803	1.496	1.457	.989	.963	.220	.226	.006	2.5
1151	6.104	SUBM	1.215	.803	1.607	1.566	1.062	1.035	.212	.208	-.004	-2.0
1152	6.104	SUBM	1.215	.803	1.713	1.664	1.132	1.100	.205	.207	.002	1.1
1153	6.104	SUBM	1.215	.803	1.826	1.772	1.207	1.172	.199	.198	-.001	-.4
1154	6.104	SUBM	1.215	.803	1.916	1.856	1.266	1.227	.194	.196	.002	1.3
1155	6.104	SUBM	1.215	.803	2.009	1.945	1.328	1.286	.189	.190	.000	.1
1156	6.088	SUBM	1.215	.803	2.118	2.047	1.400	1.353	.184	.187	.003	1.6
1157	6.088	SUBM	1.215	.803	2.243	2.165	1.482	1.431	.179	.181	.002	1.2
1158	6.088	SUBM	1.215	.803	2.358	2.276	1.558	1.505	.174	.175	.001	.5
1159	7.312	SUBM	1.215	.803	1.285	1.244	.849	.822	.284	.281	-.003	-.9
1160	7.326	SUBM	1.215	.803	1.414	1.365	.935	.902	.271	.276	.005	2.0
1161	7.298	SUBM	1.215	.803	1.522	1.467	1.006	.970	.260	.260	.000	.0
1162	7.298	SUBM	1.215	.803	1.630	1.567	1.077	1.036	.251	.250	-.001	-.3
1163	7.312	SUBM	1.215	.803	1.730	1.659	1.143	1.097	.244	.245	.000	.1
1164	7.298	SUBM	1.215	.803	1.832	1.753	1.211	1.159	.237	.239	.002	.8
1165	7.298	SUBM	1.215	.803	1.921	1.837	1.270	1.214	.231	.232	.000	.2
1166	7.284	SUBM	1.215	.803	2.030	1.938	1.342	1.281	.225	.226	.002	.7
1167	7.270	SUBM	1.215	.803	2.149	2.045	1.420	1.352	.218	.223	.005	2.4
1168	7.270	SUBM	1.215	.803	2.250	2.138	1.487	1.413	.213	.219	.006	2.9
1169	7.312	SUBM	1.215	.803	2.388	2.270	1.578	1.500	.208	.210	.002	1.0
1170	8.550	SUBM	1.215	.803	1.309	1.250	.865	.826	.329	.331	.002	.7
1171	8.538	SUBM	1.215	.803	1.436	1.368	.949	.904	.313	.318	.005	1.5
1172	8.526	SUBM	1.215	.803	1.530	1.454	1.011	.961	.303	.305	.002	.7
1173	8.538	SUBM	1.215	.803	1.648	1.559	1.089	1.030	.292	.296	.003	1.1

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
1174	8.538	SUBM	1.215	.803	1.751	1.652	1.157	1.092	.284	.286	.002	.8
1175	8.538	SUBM	1.215	.803	1.852	1.745	1.224	1.153	.276	.277	.001	.3
1176	8.514	SUBM	1.215	.803	1.957	1.836	1.293	1.213	.268	.274	.007	2.5
1177	8.526	SUBM	1.215	.803	2.047	1.917	1.353	1.267	.262	.268	.006	2.3
1178	8.538	SUBM	1.215	.803	2.169	2.024	1.434	1.338	.255	.264	.009	3.6
1179	8.534	SUBM	1.215	.803	2.251	2.099	1.488	1.387	.250	.259	.009	3.6
1180	8.538	SUBM	1.215	.803	2.374	2.220	1.569	1.468	.244	.243	-.000	-.1
1181	9.756	SUBM	1.215	.803	1.356	1.274	.896	.842	.368	.383	.015	4.1
1182	9.745	SUBM	1.215	.803	1.458	1.370	.964	.906	.355	.356	.001	.3
1183	9.756	SUBM	1.215	.803	1.561	1.458	1.032	.963	.343	.348	.005	1.3
1184	9.745	SUBM	1.215	.803	1.664	1.546	1.100	1.022	.332	.338	.006	1.8
1185	9.735	SUBM	1.215	.803	1.752	1.628	1.158	1.076	.323	.322	-.001	-.3
1186	9.776	SUBM	1.215	.803	1.879	1.738	1.242	1.149	.314	.314	.000	.1
1187	9.766	SUBM	1.215	.803	1.990	1.835	1.315	1.213	.304	.307	.002	.7
1188	9.756	SUBM	1.215	.803	2.097	1.928	1.386	1.274	.296	.300	.004	1.4
1189	9.756	SUBM	1.215	.803	2.157	1.983	1.426	1.310	.292	.295	.003	.9
1190	9.766	SUBM	1.215	.803	2.287	2.098	1.512	1.386	.284	.287	.003	1.0
1191	9.745	SUBM	1.215	.803	2.388	2.185	1.578	1.444	.277	.283	.006	2.0
1192	10.360	SUBM	1.215	.803	1.357	1.262	.897	.834	.391	.408	.017	4.4
1193	10.360	SUBM	1.215	.803	1.457	1.357	.963	.897	.377	.383	.006	1.6
1194	10.350	SUBM	1.215	.803	1.552	1.439	1.026	.951	.365	.369	.004	1.0
1195	10.340	SUBM	1.215	.803	1.655	1.526	1.094	1.009	.353	.358	.005	1.5
1196	10.340	SUBM	1.215	.803	1.765	1.620	1.167	1.071	.342	.348	.006	1.8
1197	10.330	SUBM	1.215	.803	1.880	1.718	1.243	1.136	.331	.339	.007	2.2
1198	10.330	SUBM	1.215	.803	1.976	1.800	1.306	1.189	.323	.332	.009	2.8
1199	10.611	SUBM	1.215	.803	2.086	1.895	1.379	1.253	.323	.323	.000	.0
1200	10.601	SUBM	1.215	.803	2.200	1.996	1.454	1.319	.314	.314	-.000	-.1
1201	10.592	SUBM	1.215	.803	2.297	2.078	1.518	1.373	.307	.310	.003	.9
1202	10.601	SUBM	1.215	.803	2.383	2.145	1.575	1.418	.302	.311	.009	2.9
1203	3.299	SUBM	1.516	1.002	1.579	1.575	1.044	1.041	.092	.082	-.010	-10.8
1204	3.294	SUBM	1.516	1.002	1.694	1.689	1.120	1.116	.089	.091	.002	2.3
1205	3.309	SUBM	1.516	1.002	1.793	1.788	1.185	1.182	.087	.082	-.005	-6.2
1206	3.283	SUBM	1.516	1.002	1.907	1.900	1.260	1.256	.084	.087	.003	3.4
1207	3.309	SUBM	1.516	1.002	2.013	2.006	1.330	1.326	.082	.080	-.002	-3.0
1208	3.294	SUBM	1.516	1.002	2.106	2.097	1.392	1.386	.080	.084	.004	5.5
1209	3.299	SUBM	1.516	1.002	2.216	2.208	1.465	1.459	.078	.075	-.004	-4.5
1210	3.299	SUBM	1.516	1.002	2.347	2.336	1.551	1.544	.076	.080	.004	4.8
1211	6.598	SUBM	1.516	1.002	1.597	1.574	1.056	1.040	.184	.194	.010	5.2
1212	6.583	SUBM	1.516	1.002	1.689	1.666	1.116	1.101	.178	.179	.001	.6
1213	6.583	SUBM	1.516	1.002	1.800	1.774	1.190	1.172	.173	.172	-.001	-.3
1214	6.598	SUBM	1.516	1.002	1.915	1.886	1.266	1.247	.168	.164	-.004	-2.6
1215	6.583	SUBM	1.516	1.002	1.997	1.967	1.320	1.300	.164	.158	-.006	-3.7
1216	6.583	SUBM	1.516	1.002	2.119	2.083	1.401	1.377	.159	.158	-.002	-1.1
1217	6.583	SUBM	1.516	1.002	2.210	2.169	1.461	1.433	.156	.160	.003	2.2
1218	6.568	SUBM	1.516	1.002	2.210	2.169	1.461	1.433	.156	.159	.004	2.5
1219	10.630	SUBM	1.516	1.002	1.649	1.588	1.090	1.050	.292	.297	.005	1.7
1220	10.630	SUBM	1.516	1.002	1.726	1.662	1.141	1.098	.285	.282	-.004	-1.2
1221	10.620	SUBM	1.516	1.002	1.831	1.760	1.210	1.163	.277	.269	-.007	-2.7
1222	10.611	SUBM	1.516	1.002	1.952	1.869	1.290	1.235	.268	.265	-.003	-1.1
1223	10.611	SUBM	1.516	1.002	2.057	1.966	1.360	1.300	.261	.257	-.004	-1.5
1224	10.611	SUBM	1.516	1.002	2.152	2.055	1.422	1.358	.255	.251	-.004	-1.6
1225	10.601	SUBM	1.516	1.002	2.263	2.155	1.496	1.424	.248	.248	-.000	-.1
1226	10.592	SUBM	1.516	1.002	2.348	2.231	1.552	1.475	.244	.246	.002	.9
1227	3.714	SUBM	1.818	1.202	1.886	1.879	1.247	1.242	.079	.098	.018	22.8
1228	3.709	SUBM	1.818	1.202	2.003	1.993	1.324	1.317	.077	.107	.030	38.7
1229	3.700	SUBM	1.818	1.202	2.090	2.080	1.381	1.375	.075	.099	.023	31.1
1230	3.700	OMIT	1.818	1.202	2.211	2.196**						
1231	3.705	SUBM	1.818	1.202	2.308	2.298	1.525	1.519	.072	.084	.012	16.7
1232	7.186	SUBM	1.818	1.202	1.901	1.875	1.256	1.240	.153	.180	.027	17.7
1233	7.186	SUBM	1.818	1.202	2.004	1.973	1.325	1.304	.149	.184	.034	23.1
1234	7.172	SUBM	1.818	1.202	2.094	2.063	1.384	1.364	.146	.171	.025	17.1
1235	7.158	SUBM	1.818	1.202	2.209	2.171	1.460	1.435	.141	.175	.034	23.8
1236	7.158	SUBM	1.818	1.202	2.345	2.302	1.550	1.522	.137	.171	.033	24.2
1237	10.553	SUBM	1.818	1.202	1.956	1.903	1.293	1.258	.222	.246	.024	11.0
1238	10.515	SUBM	1.818	1.202	2.032	1.976	1.343	1.306	.217	.238	.021	9.6
1239	10.515	SUBM	1.818	1.202	2.126	2.065	1.405	1.365	.212	.231	.019	9.2
1240	10.515	SUBM	1.818	1.202	2.211	2.145	1.461	1.417	.208	.228	.020	9.5
1241	10.525	SUBM	1.818	1.202	2.356	2.284	1.557	1.509	.201	.218	.016	8.1

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
1	.469	SUBM	.167	.100	.234	.209	.140	.125	.310	.340	.030	9.6
2	.467	SUBM	.167	.100	.301	.284	.179	.169	.272	.265	-.008	-2.8
3	.471	SUBM	.167	.100	.393	.373	.234	.222	.240	.239	-.002	-.6
4	.471	SUBM	.167	.100	.506	.483	.302	.288	.212	.217	.006	2.7
5	.468	SUBM	.167	.100	.621	.596	.370	.355	.190	.199	.009	4.8
6	.472	SUBM	.167	.100	.708	.680	.422	.405	.179	.193	.013	7.5
7	.471	SUBM	.167	.100	.813	.784	.485	.468	.167	.179	.012	6.9
8	.470	SUBM	.167	.100	.887	.857	.529	.511	.160	.170	.011	6.7
9	.469	SUBM	.167	.100	.988	.958	.589	.571	.151	.157	.006	3.7
10	.467	SUBM	.167	.100	1.089	1.059	.649	.631	.143	.143	.000	.2
11	.470	SUBM	.167	.100	1.207	1.174	.720	.700	.137	.135	-.002	-1.2
12	.470	SUBM	.167	.100	1.297	1.266	.773	.755	.132	.122	-.010	-7.3
13	.469	SUBM	.167	.100	1.401	1.369	.835	.816	.127	.119	-.007	-5.8
14	.472	SUBM	.167	.100	1.475	1.440	.880	.859	.124	.122	-.003	-2.1
15	.470	SUBM	.167	.100	1.586	1.551	.946	.925	.119	.117	-.002	-1.9
16	.469	SUBM	.167	.100	1.698	1.665	1.013	.993	.115	.110	-.005	-4.7
17	.470	SUBM	.167	.100	1.806	1.771	1.077	1.056	.112	.109	-.002	-2.2
18	.470	SUBM	.167	.100	1.883	1.847	1.123	1.101	.110	.109	-.001	-.9
19	.468	SUBM	.167	.100	1.995	1.960	1.190	1.169	.106	.104	-.002	-2.0
20	.467	SUBM	.167	.100	2.104	2.067	1.255	1.233	.103	.104	.001	.9
21	.470	SUBM	.167	.100	2.220	2.183	1.324	1.302	.101	.101	.000	.1
22	.468	SUBM	.167	.100	2.342	2.306	1.397	1.375	.098	.097	-.001	-1.0
23	.857	SUBM	.167	.100	.318	.248	.190	.148	.486	.525	.039	8.0
24	.855	SUBM	.167	.100	.392	.325	.234	.194	.437	.436	-.001	-.2
25	.863	SUBM	.167	.100	.521	.445	.311	.265	.382	.383	.000	.1
26	.858	SUBM	.167	.100	.598	.516	.357	.308	.355	.362	.007	2.1
27	.856	SUBM	.167	.100	.674	.588	.402	.351	.333	.343	.009	2.8
28	.858	SUBM	.167	.100	.793	.696	.473	.415	.308	.327	.019	6.1
29	.853	SUBM	.167	.100	.900	.800	.537	.477	.288	.304	.016	5.7
30	.865	SUBM	.167	.100	1.006	.895	.600	.534	.276	.296	.020	7.3
31	.860	SUBM	.167	.100	1.080	.966	.644	.576	.265	.284	.020	7.4
32	.860	SUBM	.167	.100	1.179	1.069	.703	.637	.253	.260	.006	2.5
33	.856	SUBM	.167	.100	1.313	1.201	.783	.716	.239	.238	-.001	-.3
34	.857	SUBM	.167	.100	1.398	1.280	.834	.763	.232	.235	.003	1.3
35	.856	SUBM	.167	.100	1.482	1.362	.884	.812	.225	.229	.005	2.0
36	.864	SUBM	.167	.100	1.586	1.468	.946	.875	.219	.219	-.000	-.0
37	.862	SUBM	.167	.100	1.704	1.583	1.016	.944	.211	.214	.003	1.3
38	.857	SUBM	.167	.100	1.778	1.657	1.060	.988	.206	.209	.004	1.9
39	.853	SUBM	.167	.100	1.888	1.765	1.126	1.052	.199	.205	.006	3.2
40	.850	SUBM	.167	.100	1.987	1.863	1.185	1.111	.193	.200	.008	3.9
41	.858	SUBM	.167	.100	2.099	1.974	1.252	1.177	.189	.196	.007	3.5
42	.853	SUBM	.167	.100	2.190	2.067	1.306	1.233	.184	.190	.006	3.2
43	.849	SUBM	.167	.100	2.326	2.204	1.387	1.314	.178	.184	.006	3.4
44	1.354	FREE	.167	.100	.476	.297	.284	.177	.628	.633	.006	.9
45	1.354	SUBM	.167	.100	.600	.433	.358	.258	.559	.547	-.012	-2.1
46	1.357	SUBM	.167	.100	.710	.507	.423	.302	.515	.543	.028	5.4
47	1.352	SUBM	.167	.100	.792	.577	.472	.344	.486	.517	.031	6.4
48	1.349	SUBM	.167	.100	.887	.656	.529	.391	.458	.494	.036	7.9
49	1.347	SUBM	.167	.100	.993	.752	.592	.448	.432	.465	.033	7.5
50	1.357	SUBM	.167	.100	1.094	.840	.652	.501	.415	.444	.030	7.1
51	1.354	SUBM	.167	.100	1.196	.929	.713	.554	.396	.426	.031	7.7
52	1.354	SUBM	.167	.100	1.273	1.004	.759	.599	.384	.407	.023	6.0
53	1.357	SUBM	.167	.100	1.385	1.120	.826	.668	.369	.376	.007	1.9
54	1.344	SUBM	.167	.100	1.514	1.246	.903	.743	.349	.351	.002	.5
55	1.362	SUBM	.167	.100	1.614	1.335	.962	.796	.343	.346	.003	1.0
56	1.357	SUBM	.167	.100	1.710	1.428	1.020	.852	.332	.338	.006	1.7
57	1.354	SUBM	.167	.100	1.773	1.494	1.057	.891	.325	.329	.004	1.2
58	1.362	SUBM	.167	.100	1.904	1.615	1.135	.963	.316	.324	.008	2.5
59	1.360	SUBM	.167	.100	1.995	1.703	1.190	1.016	.308	.318	.010	3.3
60	1.362	SUBM	.167	.100	2.117	1.825	1.262	1.088	.299	.310	.010	3.4
61	1.362	SUBM	.167	.100	2.208	1.913	1.317	1.141	.293	.306	.013	4.3
62	1.365	SUBM	.167	.100	2.309	2.015	1.377	1.202	.287	.300	.012	4.3
63	1.790	FREE	.167	.100	.722	.222	.431	.132	.674	.669	-.005	-.7
64	1.794	SUBM	.167	.100	.788	.503	.470	.300	.646	.633	-.014	-2.1
65	1.790	SUBM	.167	.100	.882	.555	.526	.331	.610	.633	.023	3.8
66	1.790	SUBM	.167	.100	.999	.630	.596	.376	.573	.618	.045	7.9
67	1.790	OMIT	.167	.100	1.083	.693**						
68	1.784	OMIT	.167	.100	1.191	.779**						
69	1.784	OMIT	.167	.100	1.279	.848**						
70	1.784	OMIT	.167	.100	1.389	.943**						
71	1.792	OMIT	.167	.100	1.480	1.006**						
72	1.786	OMIT	.167	.100	1.605	1.120**						
73	1.788	OMIT	.167	.100	1.709	1.211**						
74	1.782	OMIT	.167	.100	1.810	1.301**						
75	1.782	OMIT	.167	.100	1.907	1.386**						
76	1.786	OMIT	.167	.100	1.989	1.479**						
77	1.788	OMIT	.167	.100	2.144	1.610**						
78	1.782	OMIT	.167	.100	2.252	1.718**						
79	1.790	OMIT	.167	.100	2.362	1.801**						
80	2.270	OMIT	.167	.100	1.102	.185**						

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI-ATION (CDA-CDM)	DEVI-ATION (PERCENT)
81	2.268	OMIT	.167	.100	1.191	.662**						
82	2.273	OMIT	.167	.100	1.287	.705**						
83	2.273	OMIT	.167	.100	1.416	.784**						
84	2.273	OMIT	.167	.100	1.510	.850**						
85	2.270	OMIT	.167	.100	1.608	.924**						
86	2.266	OMIT	.167	.100	1.694	.995**						
87	2.270	OMIT	.167	.100	1.809	1.083**						
88	2.271	OMIT	.167	.100	1.914	1.172**						
89	2.268	OMIT	.167	.100	1.999	1.245**						
90	2.266	OMIT	.167	.100	2.115	1.344**						
91	2.268	OMIT	.167	.100	2.216	1.435**						
92	2.262	OMIT	.167	.100	2.341	1.549**						
93	2.763	OMIT	.167	.100	1.507	.190**						
94	2.763	OMIT	.167	.100	1.636	.797**						
95	2.775	OMIT	.167	.100	1.706	.822**						
96	2.756	OMIT	.167	.100	1.820	.877**						
97	2.738	OMIT	.167	.100	1.913	.928**						
98	2.744	OMIT	.167	.100	2.006	.987**						
99	2.756	OMIT	.167	.100	2.127	1.059**						
100	2.738	OMIT	.167	.100	2.234	1.156**						
101	2.738	OMIT	.167	.100	2.348	1.230**						
102	.467	OMIT	.167	.100	.251	.223**						
103	.794	OMIT	.167	.100	.326	.273**						
104	1.220	JUMP	.167	.100	.393	.128	.234	.076	.622	.619	-.003	-.5
105	1.336	JUMP	.167	.100	.506	.134	.302	.080	.601	.638	.037	6.2
106	1.514	FREE	.167	.100	.593	.217	.354	.129	.629	.651	.022	3.5
107	1.774	FREE	.167	.100	.699	.217	.417	.130	.679	.666	-.013	-1.9
108	1.955	FREE	.167	.100	.801	.197	.478	.117	.699	.679	-.020	-2.8
109	2.086	FREE	.167	.100	.893	.187	.532	.112	.706	.690	-.016	-2.3
110	2.197	FREE	.167	.100	.981	.176	.585	.105	.709	.699	-.010	-1.4
111	2.416	FREE	.167	.100	1.121	.175	.668	.104	.730	.714	-.016	-2.2
112	2.550	FREE	.167	.100	1.187	.171	.708	.102	.749	.720	-.029	-3.9
113	2.674	FREE	.167	.100	1.286	.170	.767	.101	.754	.728	-.026	-3.5
114	2.803	FREE	.167	.100	1.403	.167	.837	.100	.757	.737	-.020	-2.6
115	2.931	FREE	.167	.100	1.519	.217	.906	.129	.761	.746	-.015	-2.0
116	3.006	FREE	.167	.100	1.601	.175	.955	.104	.760	.751	-.009	-1.2
117	3.134	FREE	.167	.100	1.696	.168	1.011	.100	.770	.757	-.013	-1.7
118	3.200	FREE	.167	.100	1.801	.175	1.074	.104	.763	.762	-.000	-.1
119	3.299	FREE	.167	.100	1.902	.177	1.134	.105	.765	.767	.002	.3
120	3.416	FREE	.167	.100	2.003	.172	1.194	.103	.772	.771	-.001	-.1
121	3.506	FREE	.167	.100	2.128	.181	1.269	.108	.769	.776	.007	.9
122	3.616	FREE	.167	.100	2.236	.174	1.333	.104	.773	.779	.006	.8
123	3.718	FREE	.167	.100	2.360	.192	1.407	.114	.774	.782	.008	1.1
348	1.802	SUBM	.167	.100	1.070	.696	.638	.415	.557	.585	.028	5.1
349	1.800	SUBM	.167	.100	1.197	.799	.714	.476	.526	.554	.028	5.2
350	1.800	SUBM	.167	.100	1.290	.879	.769	.524	.507	.529	.022	4.4
351	1.798	SUBM	.167	.100	1.414	.986	.843	.588	.484	.502	.018	3.8
352	1.796	SUBM	.167	.100	1.497	1.062	.893	.633	.469	.482	.013	2.8
353	1.796	SUBM	.167	.100	1.584	1.142	.945	.681	.456	.464	.007	1.6
354	1.792	SUBM	.167	.100	1.706	1.253	1.017	.747	.439	.443	.004	1.0
355	1.788	SUBM	.167	.100	1.813	1.353	1.081	.807	.425	.432	.007	1.6
356	1.788	SUBM	.167	.100	1.898	1.434	1.132	.855	.415	.423	.008	1.9
357	1.791	SUBM	.167	.100	1.994	1.524	1.189	.909	.406	.416	.010	2.5
358	1.789	SUBM	.167	.100	2.118	1.642	1.263	.979	.393	.407	.014	3.6
359	1.785	SUBM	.167	.100	2.231	1.750	1.330	1.044	.382	.401	.019	4.9
360	1.778	SUBM	.167	.100	2.380	1.897	1.419	1.131	.369	.393	.024	6.5
361	2.269	SUBM	.167	.100	1.230	.688	.733	.410	.654	.685	.031	4.7
362	2.269	SUBM	.167	.100	1.293	.725	.771	.432	.638	.676	.037	5.9
363	2.265	SUBM	.167	.100	1.409	.800	.840	.477	.610	.654	.044	7.2
364	2.267	SUBM	.167	.100	1.495	.862	.891	.514	.593	.634	.041	6.9
365	2.266	SUBM	.167	.100	1.593	.939	.950	.560	.574	.610	.036	6.2
366	2.264	SUBM	.167	.100	1.701	1.028	1.014	.613	.555	.584	.029	5.2
367	2.264	SUBM	.167	.100	1.789	1.099	1.067	.656	.541	.566	.025	4.6
368	2.264	SUBM	.167	.100	1.892	1.188	1.128	.708	.526	.546	.020	3.7
369	2.260	SUBM	.167	.100	2.005	1.284	1.196	.766	.510	.531	.021	4.1
370	2.262	SUBM	.167	.100	2.126	1.387	1.268	.827	.496	.522	.026	5.2
371	2.260	SUBM	.167	.100	2.237	1.489	1.334	.888	.483	.513	.030	6.2
372	2.258	SUBM	.167	.100	2.356	1.593	1.405	.950	.471	.509	.038	8.2
373	2.706	SUBM	.167	.100	1.588	.789	.947	.471	.687	.725	.038	5.6
374	2.738	SUBM	.167	.100	1.692	.831	1.009	.495	.673	.720	.047	7.0
375	2.745	SUBM	.167	.100	1.802	.894	1.075	.533	.654	.700	.046	7.1
376	2.744	SUBM	.167	.100	1.915	.964	1.142	.575	.634	.680	.045	7.2
377	2.744	SUBM	.167	.100	2.020	1.034	1.205	.617	.617	.660	.042	6.9
378	2.738	SUBM	.167	.100	2.144	1.135	1.278	.677	.598	.632	.034	5.7
379	2.732	SUBM	.167	.100	2.260	1.229	1.348	.733	.581	.612	.030	5.2
380	2.732	SUBM	.167	.100	2.345	1.300	1.398	.775	.571	.604	.033	5.8
124	1.611	SUBM	.336	.200	.381	.322	.227	.192	.415	***		
125	2.344	JUMP	.336	.200	.491	.228	.293	.136	.532	.543	.011	2.1
126	2.790	JUMP	.336	.200	.596	.283	.355	.169	.574	.563	-.011	-1.9
127	3.145	FREE	.336	.200	.709	.310	.423	.185	.594	.582	-.011	-1.9

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI-ATION (CDA-CDM)	DEVI-ATION (PERCENT)
128	3.376	FREE	.336	.200	.808	.313	.482	.187	.597	.597	.000	.0
129	3.649	FREE	.336	.200	.900	.328	.537	.196	.611	.610	-.002	-.3
130	3.934	FREE	.336	.200	1.012	.331	.603	.198	.622	.623	.002	.2
131	4.173	FREE	.336	.200	1.108	.314	.661	.187	.630	.634	.003	.5
132	4.408	FREE	.336	.200	1.213	.305	.723	.182	.636	.644	.007	1.2
133	4.602	FREF	.336	.200	1.292	.290	.770	.173	.644	.651	.007	1.1
134	4.825	FREE	.336	.200	1.404	.287	.837	.171	.647	.659	.012	1.9
135	5.041	FREE	.336	.200	1.510	.282	.900	.168	.652	.667	.015	2.2
136	5.258	FREE	.336	.200	1.612	.271	.961	.162	.658	.673	.014	2.2
137	5.417	FREE	.336	.200	1.703	.266	1.016	.158	.660	.677	.017	2.7
138	5.620	FREE	.336	.200	1.810	.268	1.079	.160	.664	.682	.018	2.7
139	5.798	FREE	.336	.200	1.915	.268	1.142	.160	.666	.686	.020	3.0
140	5.936	FREE	.336	.200	1.999	.537	1.192	.320	.667	.688	.021	3.1
141	6.137	FREE	.336	.200	2.103	.273	1.254	.163	.673	.690	.018	2.6
142	6.332	FREE	.336	.200	2.228	.277	1.329	.165	.674	.692	.018	2.6
143	6.536	FREE	.336	.200	2.347	.273	1.400	.163	.678	.692	.014	2.1
144	.809	SUBM	.336	.200	.397	.388	.237	.232	.204	.199	-.005	-2.3
145	.800	SUBM	.336	.200	.491	.481	.293	.287	.181	.190	.008	4.5
146	.796	SUBM	.336	.200	.596	.584	.355	.348	.164	.172	.008	5.1
147	.796	SUBM	.336	.200	.704	.689	.420	.411	.151	.166	.015	9.8
148	.809	SUBM	.336	.200	.788	.774	.470	.462	.145	.146	.001	1.0
149	.806	SUBM	.336	.200	.895	.878	.534	.524	.135	.144	.008	6.0
150	.790	SUBM	.336	.200	.984	.967	.587	.577	.127	.132	.005	4.2
151	.802	SUBM	.336	.200	1.078	1.059	.643	.631	.123	.127	.004	3.5
152	.797	SUBM	.336	.200	1.187	1.165	.708	.695	.116	.123	.006	5.6
153	.797	SUBM	.336	.200	1.301	1.278	.776	.762	.111	.112	.001	.5
154	.810	SUBM	.336	.200	1.385	1.360	.826	.811	.109	.112	.002	2.0
155	.805	SUBM	.336	.200	1.502	1.480	.896	.883	.104	.100	-.005	-4.5
156	.799	SUBM	.336	.200	1.597	1.572	.952	.937	.101	.103	.002	2.1
157	.796	SUBM	.336	.200	1.695	1.671	1.011	.996	.097	.097	-.000	-.2
158	.820	SUBM	.336	.200	1.789	1.765	1.067	1.052	.097	.094	-.003	-3.5
159	.821	SUBM	.336	.200	1.924	1.896	1.147	1.131	.094	.097	.003	3.6
160	.813	SUBM	.336	.200	1.994	1.968	1.189	1.174	.092	.092	.000	.5
161	.811	SUBM	.336	.200	2.132	2.107	1.271	1.256	.088	.087	-.002	-1.7
162	.810	SUBM	.336	.200	2.248	2.222	1.340	1.325	.086	.086	-.000	-.0
163	.808	SUBM	.336	.200	2.381	2.355	1.420	1.404	.083	.083	-.000	-.2
164	1.772	SUBM	.336	.200	.409	.337	.244	.201	.440	.495	.054	12.3
165	1.772	SUBM	.336	.200	.501	.448	.299	.267	.398	.412	.014	3.4
166	1.762	SUBM	.336	.200	.605	.549	.361	.327	.360	.353	-.007	-2.0
167	1.768	SUBM	.336	.200	.707	.643	.422	.383	.334	.328	-.006	-1.9
168	1.764	SUBM	.336	.200	.815	.742	.486	.442	.311	.311	.001	.2
169	1.766	SUBM	.336	.200	.874	.797	.521	.475	.300	.301	.001	.3
170	1.782	SUBM	.336	.200	.990	.906	.590	.540	.285	.285	-.000	-.0
171	1.782	SUBM	.336	.200	1.094	1.004	.652	.599	.271	.270	-.001	-.3
172	1.784	SUBM	.336	.200	1.183	1.089	.705	.649	.261	.257	-.003	-1.3
173	1.777	SUBM	.336	.200	1.318	1.204	.786	.718	.246	.258	.012	4.9
174	1.776	SUBM	.336	.200	1.397	1.295	.833	.772	.239	.229	-.010	-4.0
175	1.798	SUBM	.336	.200	1.502	1.391	.896	.829	.233	.229	-.004	-1.7
176	1.796	SUBM	.336	.200	1.616	1.503	.964	.896	.225	.221	-.003	-1.5
177	1.790	SUBM	.336	.200	1.695	1.582	1.011	.943	.219	.215	-.004	-1.6
178	1.790	SUBM	.336	.200	1.813	1.693	1.081	1.010	.211	.213	.002	.9
179	1.790	SUBM	.336	.200	1.923	1.802	1.147	1.075	.205	.207	.002	.9
180	1.778	SUBM	.336	.200	1.998	1.880	1.191	1.121	.200	.200	.000	.1
181	1.782	SUBM	.336	.200	2.134	2.011	1.273	1.199	.194	.197	.003	1.7
182	1.772	SUBM	.336	.200	2.226	2.104	1.327	1.255	.189	.192	.003	1.7
183	1.778	SUBM	.336	.200	2.347	2.222	1.400	1.325	.184	.189	.005	2.5
184	3.029	FREE	.336	.200	.676	.360	.403	.215	.586	.577	-.009	-1.5
185	3.014	SUBM	.336	.200	.808	.640	.482	.382	.533	.504	-.029	-5.4
186	3.012	OMIT	.336	.200	.902	1.718**						
187	3.012	SUBM	.336	.200	.997	.788	.595	.470	.480	.473	-.007	-1.4
188	3.000	SUBM	.336	.200	1.108	.880	.661	.525	.453	.452	-.001	-.3
189	2.989	SUBM	.336	.200	1.195	.956	.713	.570	.435	.434	-.001	-.2
190	2.989	SUBM	.336	.200	1.315	1.060	.784	.632	.414	.413	-.001	-.3
191	2.983	SUBM	.336	.200	1.397	1.132	.833	.675	.401	.399	-.002	-.5
192	2.977	SUBM	.336	.200	1.507	1.231	.899	.734	.386	.381	-.004	-1.1
193	2.972	SUBM	.336	.200	1.601	1.315	.955	.784	.373	.369	-.004	-1.1
194	2.972	SUBM	.336	.200	1.701	1.407	1.014	.839	.362	.360	-.002	-.6
195	3.026	SUBM	.336	.200	1.816	1.503	1.083	.897	.357	.358	.001	.3
196	3.012	SUBM	.336	.200	1.905	1.585	1.136	.945	.347	.353	.006	1.6
197	3.006	SUBM	.336	.200	1.996	1.672	1.190	.997	.338	.345	.007	2.1
198	3.006	SUBM	.336	.200	2.109	1.780	1.258	1.061	.329	.338	.009	2.7
199	2.994	SUBM	.336	.200	2.217	1.885	1.322	1.124	.320	.331	.012	3.6
200	2.989	SUBM	.336	.200	2.320	1.984	1.383	1.183	.312	.326	.014	4.6
201	4.471	FREE	.336	.200	1.234	.314	.736	.187	.640	.646	.006	.9
202	4.467	JUMP	.336	.200	1.334	.200	.795	.120	.615	.654	.039	6.4
203	4.482	SUBM	.336	.200	1.432	.952	.854	.568	.595	.584	-.011	-1.9
204	4.494	SUBM	.336	.200	1.495	.993	.891	.592	.584	.576	-.008	-1.3
205	4.452	SUBM	.336	.200	1.608	1.070	.959	.638	.558	.560	.002	.4
206	4.444	SUBM	.336	.200	1.733	1.156	1.033	.689	.537	.544	.008	1.4
207	4.436	SUBM	.336	.200	1.837	1.233	1.095	.735	.520	.529	.009	1.7

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 2
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
208	4.505	SUBM	.336	.200	1.946	1.312	1.160	.783	.513	.518	.004	.9
209	4.516	SUBM	.336	.200	2.037	1.384	1.215	.825	.503	.510	.007	1.5
210	4.505	SUBM	.336	.200	2.117	1.452	1.262	.866	.492	.503	.010	2.1
211	4.500	SUBM	.336	.200	2.217	1.533	1.322	.914	.480	.497	.017	3.5
212	4.505	SUBM	.336	.200	2.327	1.628	1.388	.971	.469	.490	.021	4.5
213	5.664	SUBM	.336	.200	1.976	1.154	1.178	.688	.641	.617	-.023	-3.6
214	5.658	SUBM	.336	.200	2.065	1.195	1.231	.713	.626	.614	-.012	-1.9
215	5.656	SUBM	.336	.200	2.161	1.248	1.289	.744	.612	.605	-.006	-1.0
216	5.638	SUBM	.336	.200	2.256	1.303	1.345	.777	.597	.598	.001	.2
217	5.638	SUBM	.336	.200	2.353	1.368	1.403	.816	.584	.591	.007	1.2
218	5.817	JUMP	.669	.399	.802	.528	.478	.315	.519	.500	-.018	-3.6
219	6.244	JUMP	.669	.399	.894	.514	.533	.306	.527	.515	-.012	-2.3
220	6.629	FREE	.669	.399	.986	.559	.588	.333	.533	.528	-.005	-.9
221	7.144	FREE	.669	.399	1.107	.551	.660	.329	.542	.543	.001	.1
222	7.516	FREE	.669	.399	1.206	.569	.719	.340	.546	.553	.006	1.2
223	7.974	FREE	.669	.399	1.313	.562	.783	.335	.556	.562	.006	1.1
224	8.407	FREE	.669	.399	1.429	.563	.852	.336	.561	.570	.008	1.5
225	8.875	FREE	.669	.399	1.552	.549	.925	.327	.569	.576	.007	1.3
226	9.244	FREE	.669	.399	1.649	.541	.983	.322	.575	.580	.005	.9
227	9.651	FREE	.669	.399	1.766	.536	1.053	.320	.580	.583	.003	.5
228	10.072	FREE	.669	.399	1.888	1.877	1.126	1.119	.585	.584	-.001	-.2
229	10.399	FREE	.669	.399	1.984	.510	1.183	.304	.589	.584	-.006	-1.0
230	10.865	FREE	.669	.399	2.133	.502	1.272	.300	.594	.581	-.013	-2.2
231	2.516	SUBM	.669	.399	.754	.736	.450	.439	.231	.220	-.011	-4.8
232	2.516	SUBM	.669	.399	.908	.886	.541	.528	.211	.211	-.000	-.0
233	2.574	SUBM	.669	.399	1.004	.978	.599	.583	.205	.199	-.006	-2.8
234	2.582	SUBM	.669	.399	1.088	1.057	.649	.630	.198	.199	.001	.7
235	2.554	SUBM	.669	.399	1.192	1.158	.711	.691	.187	.186	-.001	-.5
236	2.558	SUBM	.669	.399	1.283	1.246	.765	.743	.180	.177	-.003	-1.8
237	2.550	SUBM	.669	.399	1.390	1.353	.829	.807	.173	.162	-.011	-6.1
238	2.537	SUBM	.669	.399	1.490	1.448	.888	.863	.166	.158	-.008	-5.0
239	2.546	SUBM	.669	.399	1.590	1.544	.948	.921	.161	.156	-.006	-3.5
240	2.519	SUBM	.669	.399	1.696	1.649	1.011	.983	.154	.150	-.005	-3.0
241	2.512	SUBM	.669	.399	1.804	1.755	1.076	1.047	.149	.146	-.003	-2.1
242	2.512	SUBM	.669	.399	1.904	1.852	1.135	1.104	.145	.145	-.000	-.2
243	2.511	SUBM	.669	.399	2.006	1.952	1.196	1.164	.142	.143	.001	.7
244	2.496	SUBM	.669	.399	2.125	2.070	1.267	1.234	.137	.138	.002	1.1
245	2.510	SUBM	.669	.399	2.219	2.163	1.323	1.290	.135	.136	.001	.8
246	2.540	SUBM	.669	.399	2.358	2.298	1.406	1.370	.132	.135	.003	2.2
247	4.828	SUBM	.669	.399	.953	.867	.568	.517	.395	.395	.000	.0
248	4.850	SUBM	.669	.399	1.035	.941	.617	.561	.381	.374	-.007	-1.8
249	4.822	SUBM	.669	.399	1.118	1.015	.667	.605	.364	.357	-.007	-2.0
250	4.818	SUBM	.669	.399	1.198	1.086	.714	.648	.351	.344	-.008	-2.2
251	4.804	SUBM	.669	.399	1.316	1.192	.785	.711	.334	.327	-.008	-2.3
252	4.806	SUBM	.669	.399	1.417	1.283	.845	.765	.322	.314	-.009	-2.7
253	4.805	SUBM	.669	.399	1.515	1.370	.903	.817	.312	.303	-.009	-2.8
254	4.800	SUBM	.669	.399	1.610	1.456	.960	.868	.302	.293	-.009	-3.1
255	4.816	SUBM	.669	.399	1.714	1.552	1.022	.926	.294	.285	-.009	-3.1
256	4.812	SUBM	.669	.399	1.817	1.646	1.083	.981	.285	.281	-.004	-1.6
257	4.807	SUBM	.669	.399	1.926	1.746	1.148	1.041	.277	.276	-.001	-.3
258	4.791	SUBM	.669	.399	2.022	1.836	1.206	1.095	.269	.271	.002	.6
259	4.798	SUBM	.669	.399	2.125	1.936	1.267	1.154	.263	.264	.001	.5
260	4.782	SUBM	.669	.399	2.236	2.037	1.333	1.215	.255	.262	.007	2.7
261	4.787	SUBM	.669	.399	2.351	2.150	1.402	1.282	.249	.255	.006	2.4
262	7.232	SUBM	.669	.399	1.366	1.115	.815	.665	.494	.480	-.014	-2.9
263	7.228	SUBM	.669	.399	1.448	1.179	.863	.703	.480	.467	-.012	-2.5
264	7.241	SUBM	.669	.399	1.556	1.259	.928	.751	.463	.456	-.007	-1.5
265	7.256	SUBM	.669	.399	1.664	1.345	.992	.802	.449	.441	-.008	-1.8
266	7.228	SUBM	.669	.399	1.756	1.420	1.047	.846	.435	.428	-.007	-1.7
267	7.206	SUBM	.669	.399	1.853	1.500	1.105	.894	.423	.417	-.006	-1.4
268	7.199	SUBM	.669	.399	1.947	1.580	1.161	.942	.412	.408	-.004	-.9
269	7.173	SUBM	.669	.399	2.058	1.673	1.227	.998	.399	.401	.002	.5
270	7.168	SUBM	.669	.399	2.171	1.769	1.295	1.055	.388	.395	.006	1.6
271	7.160	SUBM	.669	.399	2.261	1.849	1.348	1.103	.380	.389	.008	2.2
272	7.146	SUBM	.669	.399	2.346	1.925	1.399	1.148	.372	.384	.012	3.1
273	9.527	SUBM	.669	.399	2.012	1.467	1.200	.875	.536	.507	-.030	-5.5
274	9.508	SUBM	.669	.399	2.115	1.533	1.261	.914	.522	.503	-.018	-3.5
275	9.513	SUBM	.669	.399	2.226	1.610	1.327	.960	.509	.498	-.011	-2.2
276	9.506	SUBM	.669	.399	2.350	1.697	1.401	1.012	.495	.493	-.002	-.4
277	11.010	FREE	1.001	.597	1.252	.893	.747	.532	.525	.517	-.008	-1.5
278	9.581	SUBM	1.001	.597	1.492	1.329	.890	.792	.419	.413	-.006	-1.4
279	9.572	SUBM	1.001	.597	1.585	1.405	.945	.838	.406	.401	-.005	-1.3
280	9.560	SUBM	1.001	.597	1.670	1.475	.996	.880	.395	.390	-.005	-1.2
281	9.556	SUBM	1.001	.597	1.775	1.567	1.058	.934	.383	.373	-.009	-2.4
282	9.537	SUBM	1.001	.597	1.874	1.645	1.117	.981	.372	.367	-.005	-1.2
283	9.530	SUBM	1.001	.597	1.984	1.743	1.183	1.039	.361	.353	-.008	-2.3
284	9.525	SUBM	1.001	.597	2.091	1.832	1.247	1.093	.351	.349	-.003	-.8
285	9.524	SUBM	1.001	.597	2.219	1.942	1.323	1.158	.341	.343	.002	.6
286	9.523	SUBM	1.001	.597	2.333	2.040	1.391	1.216	.333	.339	.006	1.9
287	6.300	SUBM	1.001	.597	1.234	1.179	.736	.703	.303	.298	-.004	-1.4

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 2
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI-ATION (CDA-CDM)	DEVI-ATION (PERCENT)
288	6.297	SUBM	1.001	.597	1.317	1.256	.785	.749	.293	.285	-.007	-2.5
289	6.292	SUBM	1.001	.597	1.427	1.356	.851	.809	.281	.273	-.008	-2.8
290	6.286	SUBM	1.001	.597	1.518	1.439	.905	.858	.272	.265	-.007	-2.7
291	6.277	SUBM	1.001	.597	1.626	1.541	.970	.919	.263	.252	-.010	-3.9
292	6.274	SUBM	1.001	.597	1.730	1.635	1.032	.975	.255	.245	-.009	-3.7
293	6.286	SUBM	1.001	.597	1.821	1.720	1.086	1.026	.249	.237	-.011	-4.6
294	6.281	SUBM	1.001	.597	1.926	1.816	1.148	1.083	.241	.234	-.007	-2.9
295	6.268	SUBM	1.001	.597	2.020	1.903	1.205	1.135	.235	.233	-.003	-1.2
296	6.269	SUBM	1.001	.597	2.139	2.017	1.275	1.203	.229	.226	-.003	-1.3
297	6.260	SUBM	1.001	.597	2.246	2.118	1.339	1.263	.223	.223	-.000	-.0
298	6.258	SUBM	1.001	.597	2.351	2.217	1.402	1.322	.218	.220	.002	.9
299	4.015	SUBM	1.001	.597	1.079	1.063	.643	.634	.206	.192	-.015	-7.0
300	4.005	SUBM	1.001	.597	1.182	1.163	.705	.694	.197	.188	-.009	-4.5
301	4.018	SUBM	1.001	.597	1.308	1.281	.780	.764	.187	.191	.003	1.7
302	4.030	SUBM	1.001	.597	1.389	1.360	.828	.811	.182	.182	-.000	-.1
303	4.024	SUBM	1.001	.597	1.505	1.473	.897	.878	.175	.169	-.006	-3.4
304	4.017	SUBM	1.001	.597	1.609	1.572	.959	.937	.169	.167	-.002	-1.4
305	4.006	SUBM	1.001	.597	1.707	1.668	1.018	.995	.164	.156	-.007	-4.5
306	4.002	SUBM	1.001	.597	1.797	1.755	1.072	1.047	.159	.151	-.008	-5.0
307	4.002	SUBM	1.001	.597	1.904	1.860	1.135	1.109	.155	.147	-.008	-5.3
308	4.002	SUBM	1.001	.597	2.005	1.957	1.196	1.167	.151	.146	-.005	-3.0
309	3.994	SUBM	1.001	.597	2.087	2.038	1.244	1.215	.148	.144	-.003	-2.3
310	3.996	SUBM	1.001	.597	2.233	2.181	1.332	1.300	.143	.140	-.002	-1.7
311	3.990	SUBM	1.001	.597	2.364	2.307	1.410	1.376	.138	.140	.002	1.3
312	5.434	SUBM	1.335	.796	1.406	1.389	.838	.828	.183	.179	-.004	-2.2
313	5.417	SUBM	1.335	.796	1.496	1.477	.892	.881	.177	.175	-.002	-1.0
314	5.406	SUBM	1.335	.796	1.592	1.571	.949	.937	.171	.162	-.009	-5.2
315	5.400	SUBM	1.335	.796	1.693	1.670	1.010	.996	.166	.155	-.011	-6.8
316	5.396	SUBM	1.335	.796	1.802	1.773	1.075	1.058	.161	.155	-.005	-3.4
317	5.400	SUBM	1.335	.796	1.902	1.871	1.134	1.116	.157	.149	-.008	-4.9
318	5.400	SUBM	1.335	.796	1.999	1.963	1.192	1.171	.153	.148	-.005	-3.4
319	5.381	SUBM	1.335	.796	2.119	2.078	1.264	1.239	.148	.143	-.005	-3.3
320	5.381	SUBM	1.335	.796	2.231	2.187	1.330	1.304	.144	.141	-.003	-2.0
321	5.381	SUBM	1.335	.796	2.343	2.297	1.397	1.370	.141	.137	-.003	-2.3
322	9.503	SUBM	1.335	.796	1.581	1.511	.943	.901	.302	.301	-.002	-.5
323	9.503	SUBM	1.335	.796	1.730	1.650	1.032	.984	.289	.278	-.011	-4.0
324	9.493	SUBM	1.335	.796	1.844	1.751	1.100	1.044	.280	.273	-.007	-2.4
325	9.527	SUBM	1.335	.796	1.941	1.842	1.157	1.099	.274	.261	-.012	-4.5
326	9.511	SUBM	1.335	.796	2.051	1.943	1.223	1.158	.266	.254	-.012	-4.5
327	9.511	SUBM	1.335	.796	2.154	2.035	1.284	1.213	.259	.249	-.010	-3.8
328	9.501	SUBM	1.335	.796	2.264	2.134	1.350	1.273	.253	.245	-.008	-3.1
329	9.494	SUBM	1.335	.796	2.355	2.218	1.404	1.323	.248	.242	-.005	-2.1
330	9.516	SUBM	1.670	.996	1.817	1.777	1.083	1.059	.226	.230	.004	1.9
331	9.500	SUBM	1.670	.996	1.912	1.871	1.140	1.116	.220	.212	-.008	-3.5
332	9.514	SUBM	1.670	.996	2.024	1.976	1.207	1.178	.214	.208	-.006	-2.7
333	9.482	SUBM	1.670	.996	2.125	2.071	1.267	1.235	.208	.204	-.004	-1.8
334	9.471	SUBM	1.670	.996	2.220	2.163	1.324	1.290	.203	.197	-.007	-3.3
335	9.471	SUBM	1.670	.996	2.354	2.284	1.404	1.362	.197	.199	.001	.6
336	5.780	SUBM	1.670	.996	1.790	1.773	1.067	1.057	.138	.158	.020	14.2
337	5.780	SUBM	1.670	.996	1.911	1.895	1.140	1.130	.134	.135	.001	.8
338	5.780	SUBM	1.670	.996	1.998	1.982	1.191	1.182	.131	.128	-.003	-2.4
339	5.780	SUBM	1.670	.996	2.114	2.094	1.261	1.249	.127	.128	.001	.6
340	5.798	SUBM	1.670	.996	2.199	2.179	1.311	1.300	.125	.120	-.005	-4.4
341	5.780	SUBM	1.670	.996	2.319	2.296	1.383	1.369	.121	.119	-.002	-1.8
342	9.496	SUBM	2.005	1.196	2.085	2.059	1.243	1.228	.175	.178	.002	1.4
343	9.490	SUBM	2.005	1.196	2.213	2.184	1.320	1.302	.170	.173	.003	1.6
344	9.469	SUBM	2.005	1.196	2.363	2.329	1.409	1.389	.164	.168	.004	2.2
345	6.610	SUBM	2.005	1.196	2.068	2.056	1.233	1.226	.122	.125	.002	2.0
346	6.595	SUBM	2.005	1.196	2.207	2.195	1.316	1.309	.118	.117	-.002	-1.4
347	6.583	SUBM	2.005	1.196	2.374	2.358	1.416	1.406	.114	.117	.003	2.6

97

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI- ATION (CDA-CDM)	DEVI- ATION (PERCENT)
1	1.349	FREE	.131	.098	.650	.192	.484	.143	.682	.672	-.010	-1.5
2	.990	JUMP	.131	.098	.381	.109	.284	.081	.654	.630	-.024	-3.7
3	1.471	FREE	.131	.098	.757	.183	.564	.136	.689	.685	-.004	-.6
4	1.587	FREE	.131	.098	.853	.159	.636	.119	.701	.695	-.005	-.7
5	1.693	FREE	.131	.098	.963	.150	.718	.112	.703	.706	.002	.3
6	1.788	FREE	.131	.098	1.077	.149	.803	.111	.702	.715	.012	1.7
7	1.859	FREE	.131	.098	1.194	.156	.890	.116	.694	.722	.028	4.1
8	2.019	FREE	.131	.098	1.316	.157	.981	.117	.718	.728	.011	1.5
9	2.106	FREE	.131	.098	1.420	.163	1.058	.121	.721	.732	.012	1.6
10	2.163	FREE	.131	.098	1.492	.160	1.112	.120	.722	.734	.012	1.7
11	2.260	FREE	.131	.098	1.620	.161	1.207	.120	.724	.736	.012	1.7
12	2.340	FREE	.131	.098	1.737	.170	1.294	.127	.724	.737	.013	1.8
13	2.412	FREE	.131	.098	1.830	.174	1.364	.129	.727	.736	.009	1.3
14	2.489	FREE	.131	.098	1.940	.171	1.446	.128	.729	.734	.006	.8
15	2.550	FREE	.131	.098	2.033	.180	1.515	.134	.729	.732	.003	.3
16	2.616	FREE	.131	.098	2.142	.178	1.596	.132	.729	.727	-.001	-.2
17	2.681	FREE	.131	.098	2.239	.178	1.668	.132	.731	.723	-.008	-1.1
18	2.738	FREE	.131	.098	2.336	.182	1.741	.136	.730	.717	-.014	-1.9
19	.353	SUBM	.131	.098	.190	.164	.142	.122	.330	.300	-.030	-9.1
20	.352	SUBM	.131	.098	.302	.283	.225	.211	.261	.228	-.033	-12.6
21	.352	SUBM	.131	.098	.400	.378	.298	.282	.227	.203	-.024	-10.5
22	.354	SUBM	.131	.098	.494	.470	.368	.350	.205	.184	-.022	-10.5
23	.353	SUBM	.131	.098	.594	.566	.443	.422	.187	.174	-.013	-6.8
24	.352	SUBM	.131	.098	.696	.666	.519	.496	.172	.165	-.008	-4.4
25	.351	SUBM	.131	.098	.790	.762	.589	.568	.161	.149	-.012	-7.7
26	.358	SUBM	.131	.098	.910	.877	.678	.654	.153	.150	-.003	-1.8
27	.356	SUBM	.131	.098	.993	.963	.740	.718	.146	.137	-.009	-6.1
28	.355	SUBM	.131	.098	1.098	1.065	.818	.794	.138	.136	-.002	-1.2
29	.353	SUBM	.131	.098	1.190	1.159	.887	.864	.132	.127	-.005	-3.9
30	.353	SUBM	.131	.098	1.318	1.285	.982	.958	.125	.124	-.001	-.9
31	.352	SUBM	.131	.098	1.433	1.401	1.068	1.044	.120	.117	-.003	-2.3
32	.350	SUBM	.131	.098	1.531	1.499	1.141	1.117	.115	.113	-.002	-1.8
33	.350	SUBM	.131	.098	1.615	1.582	1.203	1.179	.112	.112	-.000	-.3
34	.352	SUBM	.131	.098	1.706	1.673	1.271	1.247	.110	.109	-.001	-.9
35	.352	SUBM	.131	.098	1.798	1.766	1.340	1.316	.107	.104	-.003	-2.5
36	.356	SUBM	.131	.098	1.921	1.887	1.431	1.406	.105	.104	-.001	-.6
37	.355	SUBM	.131	.098	2.004	1.969	1.493	1.467	.102	.103	.001	1.1
38	.351	SUBM	.131	.098	2.106	2.072	1.569	1.544	.099	.099	.001	.7
39	.350	SUBM	.131	.098	2.214	2.180	1.650	1.624	.096	.097	.001	1.0
40	.349	SUBM	.131	.098	2.360	2.328	1.759	1.735	.093	.091	-.002	-1.8
41	.670	SUBM	.131	.098	.277	.210	.206	.157	.519	.477	-.042	-8.1
42	.669	SUBM	.131	.098	.391	.317	.291	.236	.436	.400	-.037	-8.4
43	.669	SUBM	.131	.098	.493	.410	.367	.306	.388	.361	-.028	-7.1
44	.667	SUBM	.131	.098	.598	.507	.446	.378	.352	.331	-.021	-6.0
45	.666	SUBM	.131	.098	.690	.592	.514	.441	.327	.311	-.016	-4.9
46	.663	SUBM	.131	.098	.804	.700	.599	.522	.301	.294	-.008	-2.6
47	.662	SUBM	.131	.098	.893	.788	.665	.587	.286	.278	-.008	-2.8
48	.663	SUBM	.131	.098	.984	.875	.733	.652	.273	.268	-.004	-1.6
49	.663	SUBM	.131	.098	1.092	.982	.814	.732	.259	.254	-.004	-1.7
50	.663	SUBM	.131	.098	1.184	1.071	.882	.798	.248	.247	-.002	-.6
51	.661	SUBM	.131	.098	1.280	1.166	.954	.869	.238	.238	-.000	-.2
52	.661	SUBM	.131	.098	1.381	1.264	1.029	.942	.229	.232	.002	1.0
53	.659	SUBM	.131	.098	1.494	1.379	1.113	1.028	.220	.220	.001	.3
54	.656	SUBM	.131	.098	1.615	1.499	1.203	1.117	.210	.213	.002	1.1
55	.660	SUBM	.131	.098	2.241	2.122	1.670	1.581	.180	.185	.005	3.0
56	.658	SUBM	.131	.098	1.807	1.688	1.346	1.258	.200	.204	.005	2.3
57	.660	SUBM	.131	.098	1.904	1.784	1.419	1.329	.195	.200	.005	2.6
58	.657	SUBM	.131	.098	2.009	1.890	1.497	1.408	.189	.194	.005	2.8
59	.662	SUBM	.131	.098	2.126	2.003	1.584	1.493	.185	.193	.008	4.2
60	.660	SUBM	.131	.098	2.227	2.106	1.659	1.569	.180	.187	.007	3.9
61	.661	SUBM	.131	.098	2.343	2.220	1.746	1.654	.176	.185	.009	5.1
62	1.003	JUMP	.131	.098	.405	.110	.302	.082	.643	.634	-.008	-1.3
63	1.005	SUBM	.131	.098	.478	.330	.356	.246	.593	.540	-.052	-8.9
64	1.005	SUBM	.131	.098	.589	.408	.439	.304	.534	.521	-.013	-2.4
65	1.002	SUBM	.131	.098	.692	.491	.516	.366	.491	.487	-.004	-.8
66	1.003	SUBM	.131	.098	.804	.589	.599	.439	.456	.450	-.006	-1.4
67	1.002	SUBM	.131	.098	.905	.679	.674	.506	.429	.426	-.003	-.7
68	1.004	SUBM	.131	.098	.978	.746	.729	.556	.414	.411	-.003	-.8
69	1.001	SUBM	.131	.098	1.102	.859	.821	.640	.389	.390	.001	.3
70	1.004	SUBM	.131	.098	1.195	.946	.890	.705	.374	.376	.001	.3
71	1.004	SUBM	.131	.098	1.304	1.049	.972	.782	.358	.361	.002	.7
72	1.005	SUBM	.131	.098	1.399	1.141	1.042	.850	.346	.349	.002	.7
73	1.006	SUBM	.131	.098	1.520	1.256	1.133	.936	.333	.337	.005	1.4
74	1.004	SUBM	.131	.098	1.604	1.338	1.195	.997	.323	.329	.006	1.9
75	1.004	SUBM	.131	.098	1.712	1.442	1.276	1.075	.313	.321	.009	2.7
76	1.000	SUBM	.131	.098	1.812	1.540	1.350	1.148	.303	.314	.011	3.8
77	1.006	SUBM	.131	.098	1.905	1.630	1.420	1.215	.297	.309	.012	4.1
78	1.002	SUBM	.131	.098	2.001	1.727	1.491	1.287	.289	.303	.014	4.8
79	1.002	SUBM	.131	.098	2.122	1.849	1.581	1.378	.280	.296	.015	5.4
80	1.002	SUBM	.131	.098	2.219	1.942	1.654	1.447	.274	.294	.019	7.1

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 3
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
81	1.000	SUBM	.131	.098	2.323	2.047	1.731	1.525	.268	.289	.021	8.0
82	1.339	JUMP	.131	.098	.659	.087	.491	.065	.673	.673	.001	.1
83	1.339	SUBM	.131	.098	.800	.479	.596	.357	.610	.609	-.001	-.2
84	1.336	OMIT	.131	.098	.909	.551**						
85	1.336	SUBM	.131	.098	1.001	.620	.746	.462	.544	.558	.014	2.6
86	1.341	SUBM	.131	.098	1.091	.690	.813	.514	.523	.538	.014	2.8
87	1.338	SUBM	.131	.098	1.191	.774	.887	.577	.500	.513	.013	2.6
88	1.337	SUBM	.131	.098	1.293	.865	.963	.645	.479	.489	.009	2.0
89	1.335	SUBM	.131	.098	1.389	.951	1.035	.709	.462	.470	.008	1.8
90	1.334	SUBM	.131	.098	1.495	1.050	1.114	.782	.445	.451	.007	1.5
91	1.333	SUBM	.131	.098	1.585	1.133	1.181	.844	.432	.439	.007	1.7
92	1.330	SUBM	.131	.098	1.692	1.234	1.261	.920	.417	.426	.009	2.2
93	1.328	SUBM	.131	.098	1.808	1.345	1.347	1.002	.403	.415	.012	3.0
94	1.329	SUBM	.131	.098	1.896	1.426	1.413	1.063	.394	.409	.016	4.0
95	1.328	SUBM	.131	.098	2.025	1.550	1.509	1.155	.381	.401	.021	5.5
96	1.328	SUBM	.131	.098	2.108	1.632	1.571	1.216	.373	.397	.024	6.4
97	1.326	SUBM	.131	.098	2.238	1.757	1.668	1.309	.361	.393	.032	8.8
98	1.323	SUBM	.131	.098	2.354	1.877	1.754	1.399	.352	.388	.036	10.3
99	1.659	OMIT	.131	.098	1.006	.538**						
100	1.657	SUBM	.131	.098	1.096	.574	.817	.427	.645	.660	.014	2.2
101	1.655	SUBM	.131	.098	1.182	.618	.881	.461	.621	.647	.027	4.3
102	1.667	SUBM	.131	.098	1.279	.684	.953	.509	.601	.621	.020	3.4
103	1.652	SUBM	.131	.098	1.412	.782	1.052	.583	.567	.586	.019	3.3
104	1.652	SUBM	.131	.098	1.498	.852	1.116	.635	.550	.564	.013	2.4
105	1.648	SUBM	.131	.098	1.605	.943	1.196	.703	.530	.539	.009	1.6
106	1.652	SUBM	.131	.098	1.706	1.030	1.271	.768	.516	.520	.005	.9
107	1.651	SUBM	.131	.098	1.805	1.113	1.345	.829	.501	.507	.006	1.3
108	1.651	SUBM	.131	.098	1.900	1.197	1.416	.892	.488	.497	.008	1.7
109	1.648	SUBM	.131	.098	2.009	1.297	1.497	.966	.474	.487	.013	2.7
110	1.650	SUBM	.131	.098	2.101	1.383	1.566	1.031	.464	.481	.017	3.7
111	1.647	SUBM	.131	.098	2.218	1.488	1.653	1.109	.451	.479	.028	6.1
112	1.643	SUBM	.131	.098	2.363	1.631	1.761	1.215	.436	.476	.040	9.2
113	2.028	SUBM	.131	.098	1.558	.703	1.161	.524	.662	.670	.007	1.1
114	2.028	SUBM	.131	.098	1.693	.775	1.262	.578	.635	.637	.002	.3
115	2.026	SUBM	.131	.098	1.796	.845	1.338	.630	.616	.609	-.008	-1.3
116	2.026	SUBM	.131	.098	1.907	.928	1.421	.692	.598	.581	-.018	-2.9
117	2.025	SUBM	.131	.098	1.982	.983	1.477	.733	.586	.566	-.020	-3.5
118	2.025	SUBM	.131	.098	2.096	1.077	1.562	.802	.570	.548	-.023	-3.9
119	2.021	SUBM	.131	.098	2.232	1.192	1.663	.888	.552	.535	-.017	-3.0
120	2.028	SUBM	.131	.098	2.359	1.283	1.758	.956	.539	.532	-.006	-1.1
419	1.348	SUBM	.131	.098	.893	.536	.665	.399	.582	.594	.013	2.2
420	1.346	SUBM	.131	.098	.974	.599	.726	.446	.556	.566	.010	1.8
121	1.888	JUMP	.266	.198	.462	.189	.344	.141	.558	.552	-.006	-1.1
122	2.069	JUMP	.266	.198	.524	.210	.390	.156	.574	.565	-.009	-1.6
123	2.324	FREE	.266	.198	.625	.281	.466	.210	.590	.584	-.007	-1.1
124	2.537	FREE	.266	.198	.702	.257	.523	.192	.608	.596	-.012	-1.9
125	2.766	FREE	.266	.198	.805	.279	.600	.208	.619	.611	-.008	-1.3
126	2.953	FREE	.266	.198	.892	.281	.665	.210	.628	.622	-.005	-.9
127	3.183	FREE	.266	.198	1.004	.275	.748	.205	.638	.635	-.003	-.5
128	3.366	FREE	.266	.198	1.098	.260	.818	.194	.645	.644	-.001	-.2
129	3.568	FREE	.266	.198	1.208	.245	.900	.183	.652	.653	.001	.1
130	3.746	FREE	.266	.198	1.313	.239	.978	.178	.656	.659	.003	.5
131	3.898	FREE	.266	.198	1.417	.234	1.056	.174	.658	.665	.007	1.1
132	4.057	FREE	.266	.198	1.523	.227	1.135	.169	.660	.669	.009	1.4
133	4.198	FREE	.266	.198	1.625	.229	1.211	.171	.661	.672	.011	1.6
134	4.354	FREE	.266	.198	1.742	.233	1.298	.174	.662	.674	.011	1.7
135	4.513	FREE	.266	.198	1.829	.234	1.363	.175	.670	.674	.004	.6
136	4.644	FREE	.266	.198	1.944	.234	1.449	.175	.669	.673	.004	.6
137	4.774	FREE	.266	.198	2.034	.236	1.516	.176	.672	.671	-.001	-.1
138	4.936	FREE	.266	.198	2.159	.241	1.609	.179	.675	.667	-.007	-1.1
139	5.047	FREE	.266	.198	2.268	.240	1.690	.178	.673	.662	-.011	-1.6
140	5.169	FREE	.266	.198	2.359	.248	1.758	.185	.676	.657	-.019	-2.8
141	.603	SUBM	.266	.198	.328	.318	.244	.237	.211	***		
142	.601	SUBM	.266	.198	.418	.407	.311	.303	.187	.197	.011	5.7
143	.600	SUBM	.266	.198	.488	.475	.364	.354	.172	.187	.015	8.6
144	.601	SUBM	.266	.198	.599	.584	.446	.435	.156	.170	.014	8.7
145	.605	SUBM	.266	.198	.692	.676	.516	.504	.146	.156	.010	6.8
146	.607	SUBM	.266	.198	.776	.759	.578	.566	.138	.147	.008	5.9
147	.605	SUBM	.266	.198	.883	.864	.658	.644	.129	.139	.009	7.2
148	.604	SUBM	.266	.198	.991	.971	.738	.724	.122	.128	.006	4.9
149	.600	SUBM	.266	.198	1.112	1.092	.829	.814	.114	.113	-.001	-.7
150	.600	SUBM	.266	.198	1.191	1.170	.887	.872	.110	.108	-.002	-1.9
151	.600	SUBM	.266	.198	1.308	1.286	.975	.958	.105	.105	-.000	-.3
152	.600	SUBM	.266	.198	1.400	1.376	1.043	1.025	.102	.106	.004	3.7
153	.606	SUBM	.266	.198	1.504	1.481	1.121	1.104	.099	.099	-.000	-.0
154	.605	SUBM	.266	.198	1.602	1.578	1.194	1.176	.096	.098	.002	1.9
155	.601	SUBM	.266	.198	1.709	1.684	1.273	1.255	.092	.096	.004	4.3
156	.599	SUBM	.266	.198	1.820	1.796	1.356	1.338	.089	.091	.002	2.2
157	.609	SUBM	.266	.198	1.903	1.880	1.418	1.401	.089	.087	-.002	-1.9
158	.608	SUBM	.266	.198	2.008	1.984	1.496	1.478	.086	.086	.000	.1

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 3
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI-ATION (CDA-CDM)	DEVI-ATION (PERCENT)
159	.606	SUBM	.266	.198	2.112	2.089	1.574	1.557	.084	.082	-.002	-2.0
160	.606	SUBM	.266	.198	2.239	2.215	1.668	1.651	.081	.081	-.000	-.1
161	.603	SUBM	.266	.198	2.359	2.334	1.758	1.739	.079	.081	.002	2.3
162	1.277	OMIT	.266	.198	.399	.354**						
163	1.277	SUBM	.266	.198	.484	.430	.361	.321	.369	.375	.007	1.9
164	1.274	SUBM	.266	.198	.582	.523	.434	.389	.335	.336	.001	.3
165	1.271	SUBM	.266	.198	.687	.619	.512	.462	.308	.314	.006	1.9
166	1.268	SUBM	.266	.198	.784	.711	.584	.530	.288	.294	.006	2.2
167	1.266	SUBM	.266	.198	.891	.813	.664	.606	.269	.274	.005	1.8
168	1.271	SUBM	.266	.198	.994	.909	.741	.677	.256	.262	.006	2.4
169	1.271	SUBM	.266	.198	1.079	.992	.804	.739	.246	.247	.002	.7
170	1.266	SUBM	.266	.198	1.207	1.114	.899	.830	.231	.232	.001	.3
171	1.260	SUBM	.266	.198	1.304	1.209	.972	.901	.222	.222	.000	.1
172	1.255	SUBM	.266	.198	1.395	1.298	1.039	.967	.213	.215	.002	.9
173	1.257	SUBM	.266	.198	1.498	1.400	1.116	1.043	.206	.208	.001	.7
174	1.273	SUBM	.266	.198	1.599	1.495	1.192	1.114	.202	.206	.004	2.0
175	1.269	SUBM	.266	.198	1.693	1.588	1.262	1.183	.196	.201	.005	2.5
176	1.264	SUBM	.266	.198	1.799	1.693	1.341	1.262	.189	.195	.006	3.2
177	1.256	SUBM	.266	.198	1.908	1.801	1.422	1.342	.183	.190	.008	4.2
178	1.273	SUBM	.266	.198	2.021	1.912	1.506	1.425	.180	.186	.007	3.7
179	1.270	SUBM	.266	.198	2.132	2.021	1.589	1.506	.175	.183	.009	4.9
180	1.264	SUBM	.266	.198	2.246	2.135	1.674	1.591	.169	.179	.009	5.5
181	1.266	SUBM	.266	.198	2.354	2.241	1.754	1.670	.166	.177	.011	6.5
182	2.138	SUBM	.266	.198	.628	.487	.468	.363	.542	.522	-.020	-3.6
183	2.136	SUBM	.266	.198	.707	.547	.527	.407	.510	.505	-.005	-.9
184	2.133	SUBM	.266	.198	.788	.609	.587	.454	.482	.488	.006	1.2
185	2.130	SUBM	.266	.198	.905	.703	.674	.524	.450	.462	.013	2.8
186	2.129	SUBM	.266	.198	1.001	.785	.746	.585	.427	.440	.012	2.9
187	2.139	SUBM	.266	.198	1.101	.869	.820	.647	.409	.422	.012	3.0
188	2.134	SUBM	.266	.198	1.203	.961	.896	.716	.391	.399	.008	2.0
189	2.134	SUBM	.266	.198	1.300	1.050	.969	.783	.376	.379	.003	.7
190	2.149	SUBM	.266	.198	1.395	1.133	1.039	.844	.365	.366	.000	.1
191	2.146	SUBM	.266	.198	1.497	1.224	1.115	.912	.352	.355	.003	.9
192	2.148	SUBM	.266	.198	1.601	1.321	1.193	.984	.341	.345	.004	1.3
193	2.143	SUBM	.266	.198	1.709	1.420	1.273	1.058	.329	.338	.009	2.6
194	2.142	SUBM	.266	.198	1.812	1.516	1.350	1.130	.320	.331	.012	3.7
195	2.140	SUBM	.266	.198	1.908	1.609	1.422	1.199	.311	.324	.013	4.2
196	2.136	SUBM	.266	.198	2.015	1.715	1.501	1.278	.302	.317	.015	4.8
197	2.132	SUBM	.266	.198	2.122	1.819	1.581	1.355	.294	.311	.018	6.0
198	2.115	SUBM	.266	.698	2.226	1.923	1.659	1.433	.285	.306	.021	7.4
199	2.163	SUBM	.266	.198	2.362	2.041	1.760	1.521	.283	.309	.027	9.4
200	3.178	SUBM	.266	.198	1.120	.734	.835	.547	.603	.584	-.019	-3.2
201	3.188	SUBM	.266	.198	1.204	.779	.897	.581	.583	.579	-.005	-.8
202	3.179	SUBM	.266	.198	1.311	.844	.977	.629	.558	.564	.006	1.1
203	3.175	SUBM	.266	.198	1.403	.908	1.045	.677	.538	.545	.006	1.2
204	3.178	SUBM	.266	.198	1.503	.982	1.120	.732	.521	.523	.003	.6
205	3.173	SUBM	.266	.198	1.606	1.064	1.197	.793	.503	.501	-.002	-.4
206	3.180	SUBM	.266	.198	1.712	1.146	1.276	.854	.488	.482	-.006	-1.2
207	3.182	SUBM	.266	.198	1.817	1.229	1.354	.916	.474	.470	-.004	-.8
208	3.181	SUBM	.266	.198	1.918	1.316	1.429	.980	.461	.460	-.001	-.3
209	3.213	SUBM	.266	.198	2.031	1.398	1.513	1.042	.453	.456	.003	.8
210	3.214	SUBM	.266	.198	2.139	1.491	1.594	1.111	.441	.451	.009	2.1
211	3.208	SUBM	.266	.198	2.260	1.591	1.684	1.186	.428	.449	.020	4.7
212	3.206	SUBM	.266	.198	2.377	1.707	1.771	1.272	.418	.445	.027	6.6
213	4.020	SUBM	.266	.198	1.749	.979	1.303	.730	.610	.578	-.032	-5.3
214	4.024	SUBM	.266	.198	1.854	1.036	1.382	.772	.593	.560	-.033	-5.6
215	4.018	SUBM	.266	.198	1.975	1.113	1.472	.829	.574	.537	-.037	-6.4
216	4.019	SUBM	.266	.198	2.062	1.173	1.537	.874	.562	.523	-.039	-7.0
217	4.017	SUBM	.266	.198	2.166	1.249	1.614	.931	.548	.511	-.037	-6.7
218	4.011	SUBM	.266	.198	2.279	1.334	1.698	.994	.534	.503	-.030	-5.7
219	4.002	SUBM	.266	.198	2.378	1.417	1.772	1.056	.521	.499	-.022	-4.2
220	4.245	JUMP	.532	.396	.689	.400	.513	.298	.513	.488	-.026	-5.0
221	4.633	JUMP	.532	.396	.786	.453	.586	.338	.525	.506	-.018	-3.5
222	5.091	FREE	.532	.396	.910	.455	.678	.339	.536	.526	-.010	-1.8
223	5.530	FREE	.532	.396	1.026	.449	.765	.334	.548	.541	-.007	-1.2
224	5.970	FREE	.532	.396	1.158	.464	.863	.345	.557	.556	-.001	-.2
225	6.300	FREE	.532	.396	1.260	.468	.939	.349	.563	.565	.002	.3
226	6.675	FREE	.532	.396	1.375	.448	1.025	.334	.572	.574	.002	.4
227	7.031	FREE	.532	.396	1.489	.443	1.110	.330	.578	.580	.002	.3
228	7.342	FREE	.532	.396	1.600	.434	1.192	.323	.583	.585	.002	.4
229	7.614	FREE	.532	.396	1.695	.421	1.263	.314	.587	.588	.000	.1
230	7.883	FREE	.532	.396	1.804	.413	1.344	.307	.589	.589	.000	.0
231	8.230	FREE	.532	.396	1.944	.402	1.449	.299	.593	.590	-.003	-.5
232	8.469	FREE	.532	.396	2.041	.393	1.521	.293	.595	.588	-.007	-1.1
233	8.769	FREE	.532	.396	2.159	.390	1.609	.290	.599	.585	-.014	-2.3
234	9.021	FREE	.532	.396	2.265	.387	1.688	.289	.602	.581	-.021	-3.5
235	9.235	FREE	.532	.396	2.359	.391	1.758	.292	.604	.576	-.028	-4.6
236	1.709	SUBM	.532	.396	.575	.562	.428	.419	.226	***		
237	1.708	SUBM	.532	.396	.687	.671	.512	.500	.207	.212	.005	2.6
238	1.724	SUBM	.532	.396	.781	.761	.582	.567	.196	.208	.012	6.3

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 3
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI- ATION (CDA-CDM)	DEVI- ATION (PERCENT)
239	1.707	SUBM	.532	.396	.894	.871	.666	.649	.181	.194	.013	7.1
240	1.707	SUBM	.532	.396	.997	.968	.743	.721	.172	.192	.021	12.1
241	1.705	SUBM	.532	.396	1.073	1.047	.800	.780	.165	.170	.005	2.9
242	1.701	SUBM	.532	.396	1.215	1.182	.905	.881	.155	.168	.013	8.5
243	1.699	SUBM	.532	.396	1.290	1.257	.961	.937	.150	.158	.008	5.4
244	1.693	SUBM	.532	.396	1.373	1.338	1.023	.997	.145	.152	.007	5.1
245	1.717	SUBM	.532	.396	1.511	1.471	1.126	1.096	.140	.146	.006	4.3
246	1.717	SUBM	.532	.396	1.598	1.558	1.191	1.161	.136	.137	.000	.2
247	1.710	SUBM	.532	.396	1.728	1.686	1.288	1.256	.131	.130	-.001	-.6
248	1.706	SUBM	.532	.396	1.812	1.768	1.350	1.317	.127	.129	.002	1.3
249	1.720	SUBM	.532	.396	1.902	1.857	1.417	1.384	.125	.126	.001	.9
250	1.712	SUBM	.532	.396	2.005	1.959	1.494	1.460	.121	.123	.002	1.7
251	1.694	SUBM	.532	.396	2.110	2.063	1.572	1.537	.117	.121	.004	3.3
252	1.697	SUBM	.532	.396	2.228	2.179	1.660	1.624	.114	.119	.005	4.7
253	1.703	SUBM	.532	.396	2.364	2.314	1.762	1.724	.111	.116	.005	4.8
254	3.438	SUBM	.532	.396	.794	.717	.592	.534*	.387	.398	.010	2.7
255	3.433	SUBM	.532	.396	.904	.813	.674	.606	.363	.375	.013	3.5
256	3.431	SUBM	.532	.396	.994	.893	.741	.665	.346	.356	.011	3.1
257	3.428	SUBM	.532	.396	1.109	.996	.826	.742	.327	.337	.010	3.1
258	3.426	SUBM	.532	.396	1.207	1.085	.899	.809	.313	.322	.009	3.0
259	3.426	SUBM	.532	.396	1.304	1.177	.972	.877	.301	.305	.004	1.4
260	3.422	SUBM	.532	.396	1.408	1.271	1.049	.947	.290	.294	.005	1.6
261	3.423	SUBM	.532	.396	1.505	1.359	1.121	1.012	.280	.285	.005	1.9
262	3.429	SUBM	.532	.396	1.622	1.465	1.209	1.092	.270	.275	.005	1.7
263	3.420	SUBM	.532	.396	1.703	1.542	1.269	1.149	.263	.265	.002	.7
264	3.458	SUBM	.532	.396	1.811	1.642	1.349	1.224	.258	.256	-.001	-.6
265	3.462	SUBM	.532	.396	1.896	1.719	1.413	1.281	.252	.255	.002	1.0
266	3.463	SUBM	.532	.396	2.008	1.829	1.496	1.363	.245	.248	.003	1.1
267	3.459	SUBM	.532	.396	2.105	1.921	1.569	1.431	.239	.245	.005	2.2
268	3.445	SUBM	.532	.396	2.238	2.047	1.668	1.525	.231	.241	.010	4.3
269	3.436	SUBM	.532	.396	2.374	2.179	1.769	1.624	.224	.237	.013	5.7
270	5.220	SUBM	.532	.396	1.108	.891	.826	.664	.498	.496	-.002	-.4
271	5.218	SUBM	.532	.396	1.219	.975	.908	.726	.474	.476	.002	.4
272	5.212	SUBM	.532	.396	1.329	1.061	.990	.791	.454	.457	.003	.7
273	5.211	SUBM	.532	.396	1.432	1.143	1.067	.851	.437	.440	.003	.7
274	5.202	SUBM	.532	.396	1.533	1.225	1.142	.913	.422	.424	.003	.6
275	5.198	SUBM	.532	.396	1.624	1.303	1.210	.971	.410	.409	-.000	-.1
276	5.192	SUBM	.532	.396	1.731	1.391	1.290	1.036	.396	.396	-.000	-.1
277	5.188	SUBM	.532	.396	1.844	1.487	1.374	1.108	.384	.381	-.002	-.5
278	5.184	SUBM	.532	.396	1.924	1.559	1.434	1.162	.375	.371	-.004	-1.1
279	5.178	SUBM	.532	.396	2.038	1.650	1.519	1.230	.364	.365	.001	.3
280	5.175	SUBM	.532	.396	2.129	1.738	1.586	1.295	.356	.358	.002	.5
281	5.166	SUBM	.532	.396	2.256	1.850	1.681	1.379	.345	.354	.009	2.5
282	5.161	SUBM	.532	.396	2.365	1.947	1.762	1.451	.337	.352	.015	4.5
283	6.787	SUBM	.532	.396	1.637	1.177	1.220	.877	.533	.506	-.026	-5.0
284	6.779	SUBM	.532	.396	1.756	1.254	1.308	.934	.514	.492	-.022	-4.2
285	6.782	SUBM	.532	.396	1.869	1.330	1.393	.991	.498	.478	-.020	-4.0
286	6.782	SUBM	.532	.396	1.978	1.408	1.474	1.049	.484	.465	-.020	-4.0
287	6.773	SUBM	.532	.396	2.077	1.480	1.548	1.103	.472	.454	-.018	-3.9
288	6.773	SUBM	.532	.396	2.173	1.558	1.619	1.161	.461	.442	-.019	-4.2
289	6.778	SUBM	.532	.396	2.261	1.629	1.685	1.214	.453	.434	-.018	-4.1
290	6.788	SUBM	.532	.396	2.373	1.710	1.768	1.274	.442	.434	-.009	-2.0
291	7.843	JUMP	.797	.594	1.003	.560	.747	.417	.525	.494	-.031	-5.9
292	8.140	FREE	.797	.594	1.095	.766	.816	.571	.521	.506	-.016	-3.0
293	8.635	FREE	.797	.594	1.226	.643	.914	.479	.523	.520	-.003	-.5
294	9.067	FREE	.797	.594	1.331	.632	.992	.471	.527	.530	.003	.6
295	9.609	FREE	.797	.594	1.460	.625	1.088	.465	.533	.539	.006	1.2
296	10.042	FREE	.797	.594	1.580	.626	1.177	.466	.535	.546	.011	2.0
297	10.544	FREE	.797	.594	1.707	.610	1.272	.455	.541	.551	.011	1.9
298	11.032	FREE	.797	.594	1.839	.598	1.370	.445	.545	.555	.010	1.8
299	2.878	SUBM	.797	.594	.898	.872	.662	.650	.205	.208	.004	1.7
300	2.884	SUBM	.797	.594	.977	.960	.728	.715	.196	.195	-.000	-.1
301	2.872	SUBM	.797	.594	1.098	1.076	.818	.802	.184	.185	.002	1.0
302	2.889	SUBM	.797	.594	1.200	1.174	.894	.875	.177	.182	.005	3.1
303	2.887	SUBM	.797	.594	1.300	1.269	.969	.946	.170	.179	.010	5.7
304	2.892	SUBM	.797	.594	1.396	1.362	1.040	1.015	.164	.173	.009	5.2
305	2.883	SUBM	.797	.594	1.498	1.462	1.116	1.089	.158	.166	.008	5.0
306	2.885	SUBM	.797	.594	1.593	1.555	1.187	1.159	.153	.158	.005	3.4
307	2.883	SUBM	.797	.594	1.704	1.660	1.270	1.237	.148	.157	.009	6.1
308	2.881	SUBM	.797	.594	1.791	1.747	1.335	1.302	.144	.148	.004	2.5
309	2.889	SUBM	.797	.594	1.900	1.855	1.416	1.382	.140	.139	-.001	-1.0
310	2.894	SUBM	.797	.594	2.007	1.957	1.496	1.458	.137	.136	-.001	-.4
311	2.888	SUBM	.797	.594	2.095	2.044	1.561	1.523	.134	.131	-.003	-2.1
312	2.884	SUBM	.797	.594	2.229	2.173	1.661	1.619	.129	.132	.002	1.6
313	2.878	SUBM	.797	.594	2.345	2.292	1.747	1.708	.126	.123	-.002	-2.0
314	5.267	SUBM	.797	.594	.884	.816	.659	.608	.375	.383	.007	2.0
315	5.267	SUBM	.797	.594	.997	.931	.743	.694	.354	.359	.006	1.6
316	5.267	SUBM	.797	.594	1.106	1.027	.824	.765	.336	.342	.007	2.0
317	5.267	SUBM	.797	.594	1.214	1.126	.905	.839	.320	.321	.001	.2
318	5.248	SUBM	.797	.594	1.314	1.216	.979	.906	.307	.310	.003	.9

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
319	5.248	SUBM	.797	.594	1.421	1.312	1.059	.977	.295	.299	.004	1.3
320	5.287	SUBM	.797	.594	1.519	1.401	1.132	1.044	.287	.288	.001	.2
321	5.281	SUBM	.797	.594	1.616	1.491	1.204	1.111	.278	.278	-.001	-.2
322	5.277	SUBM	.797	.594	1.729	1.591	1.288	1.185	.269	.272	.003	1.3
323	5.274	SUBM	.797	.594	1.837	1.690	1.369	1.260	.261	.363	.003	1.0
324	5.267	SUBM	.797	.594	1.922	1.771	1.432	1.319	.255	.255	.001	.3
325	5.258	SUBM	.797	.594	2.031	1.870	1.513	1.393	.247	.249	.002	.6
326	5.256	SUBM	.797	.594	2.133	1.962	1.589	1.462	.241	.244	.003	1.1
327	5.252	SUBM	.797	.594	2.242	2.066	1.671	1.539	.235	.238	.003	1.2
328	5.246	SUBM	.797	.594	2.368	2.184	1.765	1.627	.228	.235	.007	3.1
329	7.180	SUBM	.797	.594	1.329	1.155	.990	.861	.417	.417	-.000	-.1
330	7.169	SUBM	.797	.594	1.461	1.267	1.089	.944	.397	.395	-.003	-.6
331	7.172	SUBM	.797	.594	1.557	1.344	1.160	1.002	.385	.385	-.000	-.0
332	7.158	SUBM	.797	.594	1.661	1.437	1.238	1.071	.372	.368	-.004	-1.1
333	7.144	SUBM	.797	.594	1.768	1.527	1.317	1.138	.360	.357	-.003	-.7
334	7.144	SUBM	.797	.594	1.879	1.622	1.400	1.209	.349	.347	-.002	-.7
335	7.144	SUBM	.797	.594	1.971	1.698	1.469	1.265	.341	.341	.000	.1
336	7.144	SUBM	.797	.594	2.079	1.798	1.549	1.340	.332	.329	-.003	-.9
337	7.129	SUBM	.797	.594	2.183	1.887	1.627	1.406	.323	.323	.000	.0
338	7.115	SUBM	.797	.594	2.277	1.968	1.697	1.466	.316	.318	.002	.8
339	7.115	SUBM	.797	.594	2.414	2.090	1.799	1.557	.307	.315	.008	2.5
340	9.476	SUBM	.797	.594	1.691	1.346	1.260	1.003	.488	.464	-.024	-5.0
341	9.483	SUBM	.797	.594	1.801	1.422	1.342	1.059	.474	.454	-.019	-4.0
342	9.485	SUBM	.797	.594	1.925	1.510	1.434	1.125	.458	.443	-.015	-3.4
343	9.491	SUBM	.797	.594	2.032	1.588	1.514	1.183	.446	.434	-.013	-2.8
344	9.486	SUBM	.797	.594	2.133	1.677	1.589	1.250	.435	.419	-.016	-3.8
345	9.484	SUBM	.797	.594	2.223	1.741	1.656	1.297	.426	.415	-.011	-2.6
346	9.483	SUBM	.797	.594	2.359	1.844	1.758	1.374	.414	.409	-.004	-1.1
347	3.231	SUBM	1.066	.794	1.136	1.124	.846	.837	.152	.166	.015	9.6
348	3.226	SUBM	1.066	.794	1.248	1.234	.930	.920	.145	.153	.009	6.0
349	3.220	SUBM	1.066	.794	1.341	1.326	.999	.988	.139	.146	.007	5.1
350	3.215	SUBM	1.066	.794	1.458	1.440	1.086	1.073	.133	.142	.008	6.2
351	3.226	SUBM	1.066	.794	1.557	1.539	1.160	1.147	.130	.130	.001	.6
352	3.215	SUBM	1.066	.794	1.660	1.639	1.237	1.221	.125	.132	.007	5.9
353	3.204	SUBM	1.066	.794	1.768	1.744	1.317	1.299	.121	.131	.010	8.1
354	3.210	SUBM	1.066	.794	1.846	1.823	1.376	1.358	.118	.122	.003	2.8
355	3.215	SUBM	1.066	.794	1.955	1.927	1.457	1.436	.115	.124	.009	8.0
356	3.229	SUBM	1.066	.794	2.044	2.016	1.523	1.502	.113	.118	.005	4.3
357	3.226	SUBM	1.066	.794	2.152	2.121	1.604	1.580	.110	.116	.006	5.4
358	3.220	SUBM	1.066	.794	2.253	2.222	1.679	1.656	.107	.109	.002	1.9
359	3.218	SUBM	1.066	.794	2.357	2.324	1.756	1.732	.105	.106	.001	1.0
360	6.390	SUBM	1.066	.794	1.146	1.100	.854	.820	.299	.293	-.006	-2.0
361	6.380	SUBM	1.066	.794	1.260	1.207	.939	.900	.285	.283	-.001	-.5
362	6.380	SUBM	1.066	.794	1.373	1.312	1.023	.978	.273	.269	-.004	-1.3
363	6.373	SUBM	1.066	.794	1.474	1.406	1.098	1.048	.263	.260	-.003	-1.0
364	6.377	SUBM	1.066	.794	1.568	1.497	1.168	1.115	.255	.247	-.009	-3.4
365	6.371	SUBM	1.066	.794	1.683	1.602	1.254	1.194	.246	.242	-.004	-1.6
366	6.380	SUBM	1.066	.794	1.772	1.685	1.320	1.256	.240	.236	-.004	-1.8
367	6.364	SUBM	1.066	.794	1.879	1.782	1.400	1.328	.233	.234	.001	.5
368	6.364	SUBM	1.066	.794	1.984	1.879	1.478	1.400	.226	.230	.003	1.5
369	6.364	SUBM	1.066	.794	2.085	1.973	1.554	1.470	.221	.225	.004	1.7
370	6.364	SUBM	1.066	.794	2.190	2.069	1.632	1.542	.215	.222	.006	2.8
371	6.348	SUBM	1.066	.794	2.299	2.170	1.713	1.617	.210	.218	.009	4.1
372	6.348	SUBM	1.066	.794	2.399	2.267	1.788	1.689	.205	.211	.006	2.9
373	9.529	SUBM	1.066	.794	1.264	1.144	.942	.852	.425	.438	.013	3.1
374	9.525	SUBM	1.066	.794	1.343	1.226	1.001	.914	.412	.390	-.022	-5.2
375	9.517	SUBM	1.066	.794	1.456	1.323	1.085	.986	.395	.373	-.022	-5.5
376	9.508	SUBM	1.066	.794	1.551	1.400	1.156	1.043	.383	.367	-.016	-4.1
377	9.518	SUBM	1.066	.794	1.676	1.504	1.249	1.121	.368	.357	-.012	-3.2
378	9.512	SUBM	1.066	.794	1.780	1.594	1.326	1.188	.357	.346	-.011	-3.2
379	9.502	SUBM	1.066	.794	1.891	1.686	1.409	1.256	.346	.340	-.006	-1.7
380	9.510	SUBM	1.066	.794	1.980	1.761	1.475	1.312	.339	.335	-.004	-1.0
381	9.504	SUBM	1.066	.794	2.095	1.861	1.561	1.386	.329	.328	-.001	-.3
382	9.525	SUBM	1.066	.794	2.204	1.949	1.642	1.452	.321	.327	.006	1.7
383	9.525	SUBM	1.066	.794	2.315	2.044	1.725	1.523	.314	.323	.010	3.1
384	9.525	SUBM	1.066	.794	2.382	2.102	1.775	1.566	.309	.321	.012	3.8
385	5.638	SUBM	1.332	.993	1.417	1.392	1.056	1.037	.190	.194	.005	2.4
386	5.638	SUBM	1.332	.993	1.488	1.462	1.109	1.090	.185	.183	-.002	-1.0
387	5.638	SUBM	1.332	.993	1.607	1.580	1.197	1.177	.178	.169	-.010	-5.5
388	5.638	SUBM	1.332	.993	1.721	1.688	1.282	1.258	.172	.171	-.001	-.8
389	5.620	SUBM	1.332	.993	1.816	1.780	1.353	1.327	.167	.166	-.001	-.7
390	5.635	SUBM	1.332	.993	1.911	1.873	1.424	1.395	.163	.162	-.001	-.9
391	5.627	SUBM	1.332	.993	2.023	1.978	1.507	1.474	.159	.164	.005	3.4
392	5.612	SUBM	1.332	.993	2.124	2.077	1.583	1.548	.154	.158	.004	2.6
393	5.621	SUBM	1.332	.993	2.243	2.192	1.671	1.633	.151	.157	.006	4.1
394	5.615	SUBM	1.332	.993	2.368	2.312	1.765	1.723	.146	.154	.008	5.6
395	9.538	SUBM	1.332	.993	1.430	1.360	1.066	1.014	.320	.301	-.019	-5.9
396	9.538	SUBM	1.332	.993	1.519	1.445	1.132	1.077	.310	.294	-.017	-5.4
397	9.531	SUBM	1.332	.993	1.632	1.550	1.216	1.155	.299	.280	-.019	-6.4
398	9.518	SUBM	1.332	.993	1.742	1.651	1.298	1.231	.289	.271	-.018	-6.2

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 3
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
399	9.517	SUBM	1.332	.993	1.843	1.742	1.373	1.298	.281	.268	-.014	-4.8
400	9.525	SUBM	1.332	.993	1.951	1.841	1.454	1.372	.273	.261	-.012	-4.5
401	9.514	SUBM	1.332	.993	2.047	1.926	1.525	1.435	.267	.260	-.007	-2.4
402	9.503	SUBM	1.332	.993	2.157	2.023	1.607	1.508	.259	.260	.000	.1
403	9.503	SUBM	1.332	.993	2.270	2.125	1.692	1.584	.253	.257	.004	1.7
404	9.493	SUBM	1.332	.993	2.376	2.220	1.770	1.654	.247	.257	.010	3.9
405	5.344	SUBM	1.598	1.191	1.679	1.664	1.251	1.240	.138	.117	-.021	-15.1
406	5.344	SUBM	1.598	1.191	1.793	1.777	1.336	1.324	.133	.111	-.023	-17.0
407	5.450	SUBM	1.598	1.191	1.904	1.885	1.419	1.405	.132	.112	-.020	-15.0
408	5.438	SUBM	1.598	1.191	2.001	1.981	1.491	1.476	.128	.107	-.022	-17.1
409	5.421	SUBM	1.598	1.191	2.122	2.096	1.581	1.562	.124	.117	-.007	-5.7
410	5.418	SUBM	1.598	1.191	2.226	2.199	1.659	1.638	.121	.116	-.006	-4.8
411	5.401	SUBM	1.598	1.191	2.368	2.339	1.765	1.743	.117	.112	-.005	-4.4
412	9.533	SUBM	1.598	1.191	1.699	1.654	1.266	1.233	.244	.210	-.034	-14.1
413	9.526	SUBM	1.598	1.191	1.831	1.777	1.364	1.324	.235	.212	-.024	-10.0
414	9.525	SUBM	1.598	1.191	1.927	1.869	1.436	1.392	.229	.206	-.024	-10.4
415	9.514	SUBM	1.598	1.191	2.020	1.954	1.505	1.456	.224	.207	-.016	-7.3
416	9.514	SUBM	1.598	1.191	2.135	2.065	1.591	1.539	.218	.201	-.017	-7.7
417	9.503	SUBM	1.598	1.191	2.242	2.162	1.671	1.611	.212	.204	-.008	-3.6
418	9.503	SUBM	1.598	1.191	2.363	2.274	1.761	1.695	.207	.204	-.003	-1.3

*ADJUSTED DEPTH FOR PIER WIDTH CORRECTION
**ERROR IN DATA COLLECTION OR ITERATION LIMIT EXCEEDED FOR PEIR CORRECTION
***DATA NOT COMPATABLE FOR THE COEFFICIENT OF DISCHARGE ALGORYTHMS
END OF DATA

NUMBER OF DATA POINTS= 1646
MAXIMUM POSITIVE DEVIATION =   .054
MAXIMUN NEGATIVE DEVIATION =   -.056
MAXIMUM POSITIVE PERCENT DEVIATION=   40.7
MAXIMUM NEGATIVE PERCENT DEVIATION=   -38.5
AVERAGE DEVIATION =   .00160
AVERAGE PERCENT DEVIATION =   .541
STANDARD DEVIATION (ACTUAL)=   .01233
STANDARD DEVIATION (PERCENT)=   5.9

STATISTICAL ANALYSIS
FOR SUBMERGED FLOW CONDITIONS
HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NOS. 1, 2 AND 3
****

FOR ALGORYTHMS COEFFICIENT OF DISCHARGE - CDA
VERSUS METZLERS COEFFICIENT OF DISCHARGE - CDM

DEVIATION INTERVAL (ACTUAL)	ACCUMULATED DEVIATION (ACTUAL)	NUMBER OF DATA POINTS PER INTERVAL	PROBABILITY DISTRIBUTION (PERCENT)	CUMULATIVE PROBABILITY DISTRIBUTION (PERCENT)
	-.057			
.004	-.053	1	.1	.1
.004	-.049	4	.2	.3
.004	-.045	2	.1	.4
.004	-.041	2	.1	.5
.004	-.037	3	.2	.7
.004	-.033	6	.4	1.1
.004	-.029	13	.8	1.9
.003	-.026	7	.4	2.3
.003	-.023	13	.8	3.1
.003	-.020	20	1.2	4.3
.003	-.017	29	1.8	6.1
.003	-.014	26	1.6	7.7
.003	-.011	42	2.6	10.2
.002	-.009	42	2.6	12.8
.002	-.007	62	3.8	16.5
.002	-.005	81	4.9	21.4
.002	-.003	100	6.1	27.5
.002	-.001	133	8.1	35.6
.002	.001	172	10.4	46.1
.002	.003	173	10.5	56.6
.002	.005	158	9.6	66.2
.002	.007	131	8.0	74.1
.002	.009	100	6.1	80.2
.002	.011	67	4.1	84.3
.002	.013	53	3.2	87.5
.002	.015	43	2.6	90.1
.003	.018	35	2.1	92.2
.003	.021	34	2.1	94.3
.003	.024	20	1.2	95.5
.003	.027	18	1.1	96.6
.003	.030	23	1.4	98.0
.003	.033	11	.7	98.7
.004	.037	8	.5	99.1
.004	.041	6	.4	99.5
.004	.045	3	.2	99.7
.004	.049	4	.2	99.9
.004	.053	0	0.0	99.9
.004	.057	1	.1	100.0
		TOTAL=1646	TOTAL= 100.0	

STATISTICS FOR FREE FLOW CONDITIONS
HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NOS. 1, 2 AND 3
****

```
             NUMBER OF DATA POINTS=  179
             MAXIMUM POSITIVE DEVIATION =       .059
             MAXIMUN NEGATIVE DEVIATION =      -.031
             MAXIMUM POSITIVE PERCENT DEVIATION=      12.4
             MAXIMUM NEGATIVE PERCENT DEVIATION=      -5.9
             AVERAGE DEVIATION =    .00044
             AVERAGE PERCENT DEVIATION =     .078
             STANDARD DEVIATION (ACTUAL)=    .01274
             STANDARD DEVIATION (PERCENT)=      2.1
```

STATISTICAL ANALYSIS
FOR FREE FLOW CONDITIONS
HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NOS. 1, 2 AND 3
****

FOR ALGORYTHMS COEFFICIENT OF DISCHARGE - CDA
VERSUS METZLERS COEFFICIENT OF DISCHARGE - CDM

DEVIATION INTERVAL (ACTUAL)	ACCUMULATED DEVIATION (ACTUAL)	NUMBER OF DATA POINTS PER INTERVAL	PROBABILITY DISTRIBUTION (PERCENT)	CUMULATIVE PROBABILITY DISTRIBUTION (PERCENT)
	-.032			
.004	-.028	2	1.1	1.1
.003	-.025	4	2.2	3.4
.003	-.022	1	.6	3.9
.003	-.019	5	2.8	6.7
.003	-.016	5	2.8	9.5
.003	-.013	9	5.0	14.5
.002	-.011	6	3.4	17.9
.002	-.009	5	2.8	20.7
.002	-.007	10	5.6	26.3
.002	-.005	10	5.6	31.8
.002	-.003	9	5.0	36.9
.002	-.001	11	6.1	43.0
.002	.001	16	8.9	52.0
.002	.003	14	7.8	59.8
.002	.005	4	2.2	62.0
.002	.007	15	8.4	70.4
.002	.009	12	6.7	77.1
.002	.011	11	6.1	83.2
.002	.013	10	5.6	88.8
.002	.015	8	4.5	93.3
.003	.018	4	2.2	95.5
.003	.021	2	1.1	96.6
.003	.024	2	1.1	97.8
.003	.027	0	0.0	97.8
.003	.030	1	.6	98.3
.004	.034	0	0.0	98.3
.004	.038	1	.6	98.9
.004	.042	1	.6	99.4
.004	.046	0	0.0	99.4
.004	.050	0	0.0	99.4
.004	.054	0	0.0	99.4
.004	.058	0	0.0	99.4
.004	.062	1	.6	100.0
		TOTAL= 179	TOTAL= 100.0	

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 4
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI-ATION (CDA-CDM)	DEVI-ATION (PERCENT)
54	.877	JUMP	.131	.098	.363	.093	.270	.069	.593	.578	-.016	-2.7
55	1.072	FREE	.131	.098	.503	.226	.375	.168	.616	.600	-.016	-2.6
56	1.206	FREE	.131	.098	.603	.195	.449	.146	.633	.614	-.019	-3.1
57	1.312	FREE	.131	.098	.698	.184	.520	.137	.640	.625	-.015	-2.3
58	1.428	FREE	.131	.098	.797	.162	.594	.121	.652	.636	-.016	-2.5
59	1.514	FREE	.131	.098	.893	.157	.665	.117	.653	.645	-.008	-1.3
60	1.629	FREE	.131	.098	1.011	.148	.753	.110	.661	.654	-.006	-.9
61	1.701	FREE	.131	.098	1.098	.146	.818	.109	.662	.660	-.002	-.2
62	1.765	FREE	.131	.098	1.185	.146	.883	.108	.661	.665	.004	.7
63	1.856	FREE	.131	.098	1.307	.148	.974	.110	.662	.671	.009	1.4
64	1.916	FREE	.131	.098	1.407	.149	1.048	.111	.659	.675	.016	2.5
65	1.958	FREE	.131	.098	1.502	.147	1.119	.110	.651	.677	.026	4.0
66	2.083	FREE	.131	.098	1.606	.153	1.197	.114	.670	.679	.009	1.3
67	2.146	FREE	.131	.098	1.701	.154	1.268	.115	.671	.680	.009	1.3
68	2.218	FREE	.131	.098	1.809	.161	1.348	.120	.672	.679	.007	1.0
69	2.276	FREE	.131	.098	1.905	.165	1.420	.123	.672	.678	.006	.8
70	2.344	FREE	.131	.098	2.025	.169	1.509	.126	.672	.675	.003	.5
71	2.411	FREE	.131	.098	2.137	.170	1.592	.127	.672	.671	-.001	-.2
72	1.339	SUBM	.131	.098	.834	.475	.621	.354	.598	.573	-.025	-4.2
73	1.334	SUBM	.131	.098	.946	.542	.705	.404	.559	.554	-.006	-1.0
74	1.328	SUBM	.131	.098	1.053	.623	.785	.464	.528	.521	-.007	-1.3
75	1.320	SUBM	.131	.098	1.173	.727	.874	.542	.497	.485	-.011	-2.3
76	1.315	SUBM	.131	.098	1.279	.819	.953	.610	.474	.461	-.014	-2.9
77	1.328	SUBM	.131	.098	1.399	.910	1.035	.678	.459	.443	-.017	-3.6
78	1.338	SUBM	.131	.098	1.488	.978	1.109	.729	.447	.437	-.010	-2.3
79	1.340	SUBM	.131	.098	1.590	1.070	1.185	.797	.433	.422	-.011	-2.6
80	1.337	SUBM	.131	.098	1.687	1.160	1.257	.864	.420	.410	-.010	-2.4
81	1.334	SUBM	.131	.098	1.792	1.261	1.335	.940	.406	.398	-.008	-2.0
82	1.334	SUBM	.131	.098	1.903	1.362	1.418	1.015	.394	.391	-.003	-.9
83	1.337	SUBM	.131	.098	2.008	1.460	1.496	1.088	.385	.385	.001	.2
84	1.336	SUBM	.131	.098	2.096	1.542	1.562	1.149	.376	.382	.006	1.6
85	1.335	SUBM	.131	.098	2.200	1.642	1.639	1.224	.367	.379	.012	3.3
86	1.344	SUBM	.131	.098	2.339	1.773	1.743	1.321	.358	.378	.019	5.4
87	1.816	JUMP	.266	.198	.474	.180	.353	.134	.530	.518	-.012	-2.2
88	2.173	FREE	.266	.198	.622	.279	.463	.208	.553	.545	-.008	-1.5
89	2.355	FREE	.266	.198	.692	.248	.516	.185	.568	.556	-.013	-2.2
90	2.590	FREE	.266	.198	.806	.267	.601	.199	.579	.572	-.008	-1.3
91	2.781	FREE	.266	.198	.909	.277	.677	.207	.586	.584	-.002	-.3
92	2.960	FREE	.266	.198	.996	.267	.742	.199	.596	.593	-.003	-.5
93	3.156	FREE	.266	.198	1.105	.256	.823	.191	.603	.602	-.001	-.1
94	3.278	FREE	.266	.198	1.211	.239	.902	.178	.598	.610	.012	2.0
95	3.436	FREE	.266	.198	1.311	.230	.977	.172	.603	.616	.014	2.3
96	3.676	FREE	.266	.198	1.435	.222	1.069	.165	.616	.622	.006	1.0
97	3.780	FREE	.266	.198	1.515	.219	1.129	.163	.617	.625	.009	1.4
98	3.921	FREE	.266	.198	1.608	.217	1.198	.162	.621	.628	.007	1.1
99	4.089	FREE	.266	.198	1.749	.224	1.303	.167	.621	.630	.009	1.4
100	4.174	FREE	.266	.198	1.808	.225	1.347	.167	.623	.630	.007	1.1
101	4.331	FREE	.266	.198	1.923	.227	1.433	.169	.627	.629	.002	.4
102	4.467	FREE	.266	.198	2.047	.236	1.525	.176	.627	.627	.000	.0
103	4.625	FREE	.266	.198	2.165	.241	1.613	.180	.631	.623	-.008	-1.2
104	4.698	FREE	.266	.198	2.238	.240	1.668	.179	.631	.620	-.010	-1.6
105	4.852	FREE	.266	.198	2.374	.242	1.769	.180	.632	.613	-.019	-3.1
106	2.149	SUBM	.266	.198	.692	.520	.516	.387	.519	.491	-.028	-5.3
107	2.146	SUBM	.266	.198	.804	.597	.599	.445	.481	.478	-.002	-.5
108	2.143	SUBM	.266	.198	.899	.669	.670	.498	.454	.459	.005	1.1
109	2.140	SUBM	.266	.198	1.002	.753	.747	.561	.429	.435	.006	1.4
110	2.142	SUBM	.266	.198	1.100	.835	.820	.623	.410	.414	.004	1.0
111	2.141	SUBM	.266	.198	1.205	.925	.898	.689	.392	.394	.002	.6
112	2.141	SUBM	.266	.198	1.302	1.011	.970	.754	.377	.375	-.002	-.5
113	2.136	SUBM	.266	.198	1.405	1.104	1.047	.822	.362	.357	-.005	-1.3
114	2.152	SUBM	.266	.198	1.508	1.195	1.124	.890	.352	.345	-.007	-2.0
115	2.149	SUBM	.266	.198	1.611	1.290	1.200	.961	.340	.335	-.005	-1.6
116	2.144	SUBM	.266	.198	1.701	1.374	1.268	1.024	.330	.327	-.003	-1.0
117	2.141	SUBM	.266	.198	1.804	1.467	1.344	1.093	.320	.321	.001	.4
118	2.148	SUBM	.266	.198	1.905	1.562	1.420	1.164	.312	.315	.003	.9
119	2.146	SUBM	.266	.198	2.005	1.658	1.494	1.235	.304	.310	.005	1.7
120	2.143	SUBM	.266	.198	2.099	1.748	1.564	1.303	.297	.305	.008	2.8
121	2.140	SUBM	.266	.198	2.207	1.853	1.645	1.381	.289	.301	.012	4.1
122	2.138	SUBM	.266	.198	2.358	2.001	1.757	1.491	.280	.296	.017	6.0
1	4.221	FREE	.532	.396	.707	.574	.527	.428	.504	.472	-.032	-6.4
2	4.589	FREE	.532	.396	.811	.468	.604	.349	.512	.490	-.022	-4.3
3	5.001	FREE	.532	.396	.928	.447	.692	.333	.521	.507	-.014	-2.7
4	5.324	FREE	.532	.396	1.023	.413	.762	.308	.528	.519	-.009	-1.8
5	5.745	FREE	.532	.396	1.154	.446	.860	.332	.537	.533	-.004	-.7
6	6.088	FREE	.532	.396	1.256	.450	.936	.335	.545	.542	-.004	-.6
7	6.427	FREE	.532	.396	1.362	.436	1.015	.325	.553	.550	-.003	-.6
8	6.735	FREE	.532	.396	1.465	.451	1.092	.336	.559	.555	-.003	-.6
9	7.044	FREE	.532	.396	1.574	.439	1.173	.327	.564	.560	-.003	-.6
10	7.367	FREE	.532	.396	1.699	.427	1.266	.318	.567	.564	-.004	-.6
11	7.624	FREE	.532	.396	1.805	.408	1.345	.304	.570	.566	-.004	-.7

106

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
12	7.910	FREE	.532	.396	1.919	.398	1.430	.296	.573	.566	-.007	-1.3
13	8.150	FREE	.532	.396	2.017	.396	1.503	.295	.576	.565	-.011	-1.9
14	8.479	FREE	.532	.396	2.156	.392	1.607	.292	.580	.562	-.018	-3.1
15	8.714	FREE	.532	.396	2.258	.392	1.683	.292	.582	.558	-.024	-4.2
16	8.978	FREE	.532	.396	2.381	.400	1.774	.298	.584	.551	-.033	-5.6
17	5.190	SUBM	.532	.396	1.136	.901	.846	.672	.489	.470	-.019	-3.8
18	5.190	SUBM	.532	.396	1.240	.975	.924	.726	.468	.458	-.010	-2.2
19	5.199	SUBM	.532	.396	1.336	1.043	.996	.777	.452	.447	-.004	-1.0
20	5.199	SUBM	.532	.396	1.444	1.127	1.076	.840	.434	.429	-.006	-1.3
21	5.190	SUBM	.532	.396	1.536	1.200	1.145	.894	.420	.415	-.005	-1.2
22	5.190	SUBM	.532	.396	1.656	1.295	1.234	.965	.405	.399	-.006	-1.4
23	5.190	SUBM	.532	.396	1.751	1.374	1.305	1.024	.394	.385	-.008	-2.1
24	5.170	SUBM	.532	.396	1.834	1.447	1.367	1.078	.383	.373	-.010	-2.6
25	5.170	SUBM	.532	.396	1.942	1.541	1.447	1.148	.372	.360	-.012	-3.2
26	5.160	SUBM	.532	.396	2.050	1.628	1.528	1.213	.362	.353	-.009	-2.4
27	5.150	SUBM	.532	.396	2.154	1.723	1.605	1.284	.352	.347	-.005	-1.5
28	5.150	SUBM	.532	.396	2.248	1.807	1.675	1.346	.345	.343	-.002	-.4
29	5.150	SUBM	.532	.396	2.387	1.929	1.779	1.438	.335	.341	.007	2.0
30	3.447	SUBM	.532	.396	.732	.655	.545	.488	.404	.397	-.007	-1.8
31	3.433	SUBM	.532	.396	.821	.732	.612	.545	.380	.387	.006	1.6
32	3.438	SUBM	.532	.396	.911	.811	.679	.604	.362	.364	.003	.7
33	3.439	SUBM	.532	.396	1.001	.889	.746	.662	.345	.348	.003	.9
34	3.431	SUBM	.532	.396	1.123	.996	.837	.742	.325	.329	.004	1.3
35	3.433	SUBM	.532	.396	1.201	1.066	.895	.794	.315	.318	.004	1.2
36	3.433	SUBM	.532	.396	1.311	1.165	.977	.868	.301	.304	.003	1.1
37	3.431	SUBM	.532	.396	1.408	1.252	1.049	.933	.290	.293	.003	1.0
38	3.426	SUBM	.532	.396	1.512	1.349	1.127	1.005	.280	.280	.000	.1
39	3.431	SUBM	.532	.396	1.612	1.440	1.201	1.073	.271	.270	-.001	-.4
40	3.406	SUBM	.532	.396	1.707	1.528	1.272	1.139	.262	.260	-.001	-.5
41	3.421	SUBM	.532	.396	1.819	1.637	1.355	1.220	.255	.247	-.008	-3.0
42	3.416	SUBM	.532	.396	1.913	1.725	1.425	1.285	.248	.244	-.004	-1.7
43	3.411	SUBM	.532	.396	2.017	1.821	1.503	1.357	.241	.241	-.000	-.1
44	3.444	SUBM	.532	.396	2.127	1.922	1.585	1.432	.237	.239	.002	.8
45	3.435	SUBM	.532	.396	2.246	2.034	1.674	1.516	.230	.236	.006	2.7
46	3.432	SUBM	.532	.396	2.361	2.149	1.759	1.601	.224	.231	.006	2.8
47	6.808	SUBM	.532	.396	1.685	1.180	1.256	.879	.527	.483	-.043	-8.2
48	6.799	SUBM	.532	.396	1.809	1.252	1.348	.933	.508	.472	-.036	-7.1
49	6.793	SUBM	.532	.396	1.918	1.321	1.429	.985	.492	.459	-.033	-6.8
50	6.784	SUBM	.532	.396	2.009	1.383	1.497	1.031	.481	.448	-.033	-6.8
51	6.776	SUBM	.532	.396	2.120	1.461	1.580	1.089	.467	.436	-.032	-6.8
52	6.765	SUBM	.532	.396	2.240	1.552	1.669	1.156	.454	.424	-.030	-6.7
53	6.761	SUBM	.532	.396	2.360	1.649	1.759	1.229	.442	.415	-.027	-6.2
123	8.656	FREE	.797	.594	1.284	.622	.957	.464	.512	.517	.005	1.0
124	9.130	FREE	.797	.594	1.414	.629	1.054	.469	.515	.528	.013	2.5
125	9.535	FREE	.797	.594	1.512	.617	1.127	.460	.520	.534	.014	2.7
126	10.094	FREE	.797	.594	1.647	.604	1.227	.450	.527	.540	.013	2.5
127	10.598	FREE	.797	.594	1.791	.597	1.335	.445	.531	.545	.014	2.7
128	7.202	SUBM	.797	.594	1.331	1.147	.992	.854	.418	.411	-.007	-1.7
129	7.198	SUBM	.797	.594	1.448	1.240	1.079	.924	.401	.397	-.004	-1.1
130	7.190	SUBM	.797	.594	1.548	1.321	1.154	.984	.387	.384	-.003	-.8
131	7.179	SUBM	.797	.594	1.665	1.421	1.241	1.059	.373	.368	-.005	-1.4
132	7.172	SUBM	.797	.594	1.764	1.502	1.314	1.119	.362	.358	-.003	-1.0
133	7.172	SUBM	.797	.594	1.881	1.601	1.402	1.193	.350	.347	-.004	-1.0
134	7.172	SUBM	.797	.594	1.982	1.686	1.477	1.256	.341	.339	-.003	-.8
135	7.172	SUBM	.797	.594	2.076	1.768	1.547	1.317	.334	.331	-.003	-.8
136	7.158	SUBM	.797	.594	2.184	1.862	1.627	1.388	.325	.323	-.002	-.6
137	7.158	SUBM	.797	.594	2.286	1.950	1.703	1.453	.317	.317	.000	.0
138	7.144	SUBM	.797	.594	2.387	2.040	1.779	1.520	.310	.312	.003	.8
139	9.516	SUBM	1.066	.794	1.494	1.347	1.113	1.004	.390	.373	-.017	-4.5
140	9.513	SUBM	1.066	.794	1.607	1.437	1.197	1.071	.376	.366	-.010	-2.7
141	9.510	SUBM	1.066	.794	1.715	1.526	1.278	1.137	.364	.358	-.006	-1.7
142	9.514	SUBM	1.066	.794	1.797	1.595	1.339	1.189	.356	.350	-.005	-1.5
143	9.521	SUBM	1.066	.794	1.894	1.679	1.411	1.251	.347	.341	-.005	-1.5
144	9.516	SUBM	1.066	.794	2.010	1.771	1.498	1.320	.336	.338	.002	.6
145	9.519	SUBM	1.066	.794	2.098	1.847	1.563	1.377	.329	.333	.003	1.0
146	9.506	SUBM	1.066	.794	2.219	1.952	1.654	1.454	.320	.326	.006	2.0
147	9.523	SUBM	1.066	.794	2.321	2.036	1.730	1.518	.313	.324	.011	3.5
148	9.556	SUBM	1.332	.993	1.621	1.538	1.208	1.146	.301	.286	-.015	-5.0
149	9.556	SUBM	1.332	.993	1.740	1.648	1.297	1.228	.290	.274	-.016	-5.6
150	9.535	SUBM	1.332	.993	1.847	1.745	1.376	1.300	.281	.269	-.012	-4.3
151	9.546	SUBM	1.332	.993	1.938	1.828	1.444	1.362	.275	.265	-.010	-3.8
152	9.535	SUBM	1.332	.993	2.059	1.929	1.534	1.438	.266	.269	.003	1.0
153	9.535	SUBM	1.332	.993	2.162	2.027	1.611	1.511	.260	.261	.001	.4
154	9.525	SUBM	1.332	.993	2.258	2.118	1.683	1.578	.254	.255	.001	.4
155	9.525	SUBM	1.332	.993	2.364	2.211	1.762	1.647	.248	.256	.008	3.2

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
1	1.020	JUMP	.151	.100	.381	.108	.252	.071	.585	.584	-.000	-.0
2	1.269	FREE	.151	.100	.535	.205	.354	.136	.614	.607	-.006	-1.0
3	1.361	FREE	.151	.100	.590	.176	.390	.116	.627	.614	-.012	-2.0
4	1.495	FREE	.151	.100	.691	.190	.457	.126	.636	.627	-.010	-1.5
5	1.626	FREE	.151	.100	.807	.178	.533	.117	.640	.639	-.001	-.2
6	1.732	FREE	.151	.100	.900	.164	.595	.109	.646	.647	.002	.3
7	1.826	FREE	.151	.100	.999	.157	.660	.104	.646	.656	.009	1.4
8	1.917	FREE	.151	.100	1.099	.151	.726	.100	.647	.663	.016	2.4
9	2.020	FREE	.151	.100	1.208	.157	.798	.104	.650	.669	.019	2.9
10	2.128	FREE	.151	.100	1.309	.158	.865	.105	.658	.674	.016	2.5
11	2.203	FREE	.151	.100	1.395	.159	.922	.105	.660	.678	.018	2.7
12	2.302	FREE	.151	.100	1.501	.161	.992	.107	.665	.681	.017	2.5
13	2.379	FREE	.151	.100	1.601	.165	1.058	.109	.665	.684	.019	2.8
14	2.435	FREE	.151	.100	1.704	.168	1.126	.111	.660	.685	.025	3.9
15	2.532	FREE	.151	.100	1.807	.171	1.194	.113	.666	.686	.020	2.9
16	2.590	FREE	.151	.100	1.913	.175	1.264	.116	.662	.686	.023	3.5
17	2.662	FREE	.151	.100	2.012	.176	1.330	.117	.664	.684	.021	3.1
18	2.740	FREE	.151	.100	2.121	.181	1.402	.120	.665	.682	.017	2.5
19	2.866	FREE	.151	.100	2.206	.178	1.458	.118	.683	.680	-.003	-.4
20	2.947	FREE	.151	.100	2.349	.184	1.553	.122	.680	.674	-.006	-.9
21	1.525	SUBM	.151	.100	.767	.467	.507	.308	.616	.577	-.039	-6.3
22	1.522	SUBM	.151	.100	.887	.526	.586	.347	.572	.581	.009	1.6
23	1.528	SUBM	.151	.100	.979	.583	.647	.386	.546	.566	.020	3.6
24	1.522	SUBM	.151	.100	1.079	.660	.713	.436	.518	.538	.019	3.7
25	1.524	SUBM	.151	.100	1.181	.742	.781	.491	.496	.509	.013	2.6
26	1.519	SUBM	.151	.100	1.291	.835	.853	.552	.473	.481	.008	1.7
27	1.503	SUBM	.151	.100	1.374	.918	.908	.607	.454	.453	-.001	-.2
28	1.514	SUBM	.151	.100	1.490	1.013	.985	.670	.439	.439	.000	.0
29	1.512	SUBM	.151	.100	1.580	1.096	1.044	.724	.425	.425	-.000	-.0
30	1.507	SUBM	.151	.100	1.694	1.202	1.120	.794	.410	.411	.001	.4
31	1.503	SUBM	.151	.100	1.795	1.298	1.186	.858	.397	.400	.003	.8
32	1.500	SUBM	.151	.100	1.883	1.381	1.245	.913	.387	.392	.006	1.4
33	1.523	SUBM	.151	.100	2.015	1.488	1.332	.983	.380	.390	.011	2.8
34	1.525	SUBM	.151	.100	2.107	1.575	1.393	1.041	.372	.385	.014	3.6
35	1.521	SUBM	.151	.100	2.222	1.686	1.469	1.114	.361	.380	.019	5.2
36	1.516	SUBM	.151	.100	2.340	1.806	1.547	1.194	.351	.373	.023	6.4
37	2.228	JUMP	.302	.200	.536	.230	.354	.152	.538	.530	-.008	-1.5
38	2.451	FREE	.302	.200	.620	.309	.410	.204	.551	.545	-.006	-1.1
39	2.683	FREE	.302	.200	.709	.276	.469	.183	.564	.558	-.005	-.9
40	2.922	FREE	.302	.200	.809	.289	.535	.191	.575	.572	-.003	-.5
41	3.140	FREE	.302	.200	.907	.304	.599	.201	.583	.584	.000	.1
42	3.390	FREE	.302	.200	1.019	.295	.673	.195	.594	.595	.001	.2
43	3.583	FREE	.302	.200	1.111	.282	.734	.186	.601	.603	.002	.3
44	3.764	FREE	.302	.200	1.208	.269	.798	.178	.606	.611	.005	.8
45	3.946	FREE	.302	.200	1.309	.259	.865	.171	.610	.617	.007	1.2
46	4.145	FREE	.302	.200	1.425	.252	.942	.166	.614	.624	.009	1.5
47	4.311	FREE	.302	.200	1.520	.245	1.005	.162	.618	.628	.009	1.5
48	4.478	FREE	.302	.200	1.641	.244	1.085	.162	.618	.631	.013	2.1
49	4.654	FREE	.302	.200	1.733	.245	1.145	.162	.625	.633	.008	1.3
50	4.826	FREE	.302	.200	1.840	.240	1.216	.158	.629	.634	.005	.8
51	4.950	FREE	.302	.200	1.935	.248	1.279	.164	.629	.634	.005	.8
52	5.096	FREE	.302	.200	2.035	.248	1.345	.164	.632	.634	.002	.3
53	5.267	FREE	.302	.200	2.169	.258	1.434	.171	.633	.631	-.002	-.3
54	5.382	FREE	.302	.200	2.256	.259	1.491	.171	.634	.628	-.006	-.9
55	5.519	FREE	.302	.200	2.360	.262	1.560	.173	.635	.624	-.012	-1.8
56	2.616	SUBM	.302	.200	.818	.614	.541	.406	.512	.494	-.018	-3.5
57	2.606	SUBM	.302	.200	.910	.680	.601	.449	.483	.481	-.002	-.4
58	2.612	SUBM	.302	.200	1.008	.754	.666	.498	.460	.464	.004	.9
59	2.606	SUBM	.302	.200	1.097	.827	.725	.547	.440	.445	.005	1.1
60	2.600	SUBM	.302	.200	1.193	.907	.788	.599	.421	.426	.005	1.3
61	2.606	SUBM	.302	.200	1.307	1.002	.864	.663	.403	.406	.003	.8
62	2.600	SUBM	.302	.200	1.406	1.091	.929	.721	.388	.387	-.001	-.2
63	2.601	SUBM	.302	.200	1.503	1.176	.993	.777	.375	.372	-.004	-1.0
64	2.603	SUBM	.302	.200	1.607	1.268	1.062	.838	.363	.361	-.002	-.7
65	2.603	SUBM	.302	.200	1.700	1.355	1.124	.895	.353	.351	-.002	-.5
66	2.597	SUBM	.302	.200	1.803	1.450	1.192	.958	.342	.343	.001	.3
67	2.590	SUBM	.302	.200	1.896	1.537	1.253	1.016	.333	.336	.003	1.0
68	2.577	SUBM	.302	.200	1.998	1.636	1.321	1.081	.322	.328	.006	1.8
69	2.577	SUBM	.302	.200	2.096	1.732	1.385	1.145	.315	.321	.006	2.1
70	2.583	SUBM	.302	.200	2.209	1.832	1.460	1.211	.307	.320	.012	4.0
71	2.577	SUBM	.302	.200	2.309	1.930	1.526	1.276	.300	.315	.015	4.9
72	5.922	FREE	.608	.402	1.001	.479	.662	.316	.520	.513	-.007	-1.4
73	6.453	FREE	.608	.402	1.147	.495	.758	.327	.529	.529	-.000	-.1
74	6.822	FREE	.608	.402	1.249	.496	.826	.328	.536	.538	.002	.3
75	7.215	FREE	.608	.402	1.369	.501	.905	.331	.542	.547	.005	.9
76	7.566	FREE	.608	.402	1.481	.492	.979	.325	.546	.553	.007	1.3
77	7.925	FREE	.608	.402	1.594	.488	1.054	.322	.551	.558	.007	1.2
78	8.278	FREE	.608	.402	1.703	.476	1.126	.315	.557	.561	.004	.7
79	8.632	FREE	.608	.402	1.810	.460	1.196	.304	.564	.563	-.001	-.2
80	8.955	FREE	.608	.402	1.924	.452	1.272	.299	.567	.563	-.004	-.7

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 5
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI-ATION (CDA-CDM)	DEVI-ATION (PERCENT)
81	9.288	FREE	.608	.402	2.045	.447	1.352	.295	.571	.562	-.009	-1.6
82	9.630	FREE	.608	.402	2.160	.437	1.428	.289	.576	.559	-.017	-2.9
83	9.920	FREE	.608	.402	2.266	.434	1.498	.287	.579	.555	-.024	-4.2
84	10.082	FREE	.608	.402	2.352	.440	1.555	.291	.578	.550	-.027	-4.7
85	5.455	SUBM	.608	.402	1.134	.943	.750	.623	.450	.452	.002	.5
86	5.456	SUBM	.608	.402	1.241	1.023	.820	.676	.430	.440	.009	2.2
87	5.458	SUBM	.608	.402	1.341	1.107	.886	.732	.414	.418	.004	1.0
88	5.463	SUBM	.608	.402	1.431	1.178	.946	.779	.401	.407	.005	1.4
89	5.465	SUBM	.608	.402	1.527	1.257	1.009	.831	.389	.393	.004	1.0
90	5.469	SUBM	.608	.402	1.638	1.349	1.083	.891	.375	.379	.003	.9
91	5.459	SUBM	.608	.402	1.743	1.439	1.152	.951	.363	.364	.000	.1
92	5.458	SUBM	.608	.402	1.841	1.524	1.217	1.007	.353	.353	-.000	-.1
93	5.470	SUBM	.608	.402	1.940	1.609	1.282	1.063	.345	.347	.002	.6
94	5.465	SUBM	.608	.402	2.034	1.690	1.344	1.117	.337	.342	.005	1.6
95	5.465	SUBM	.608	.402	2.142	1.783	1.416	1.179	.328	.338	.010	2.9
96	5.462	SUBM	.608	.402	2.242	1.875	1.482	1.239	.320	.332	.012	3.7
97	5.470	SUBM	.608	.402	2.356	1.978	1.557	1.307	.313	.328	.015	4.7
98	9.535	FREE	.909	.601	1.206	.774	.512	.797	.510	.502	-.009	-1.7
99	9.818	FREE	.909	.601	1.285	.718	.849	.474	.509	.509	-.000	-.0
100	10.242	FREE	.909	.601	1.401	.709	.926	.469	.508	.517	.009	1.7
101	10.553	FREE	.909	.601	1.481	.699	.979	.462	.510	.522	.012	2.4
102	7.375	SUBM	.909	.601	1.176	1.071	.777	.708	.400	.407	.007	1.8
103	7.367	SUBM	.909	.601	1.093	1.002	.722	.662	.414	.410	-.004	-.9
104	7.369	SUBM	.909	.601	1.254	1.134	.829	.750	.387	.398	.011	2.9
105	7.360	SUBM	.909	.601	1.355	1.223	.896	.809	.372	.374	.002	.6
106	7.353	SUBM	.909	.601	1.460	1.307	.965	.864	.358	.368	.010	2.8
107	7.346	SUBM	.909	.601	1.549	1.386	1.024	.916	.347	.352	.006	1.6
108	7.358	SUBM	.909	.601	1.652	1.473	1.092	.974	.336	.341	.005	1.5
109	7.352	SUBM	.909	.601	1.756	1.563	1.161	1.033	.326	.330	.004	1.2
110	7.352	SUBM	.909	.601	1.858	1.650	1.228	1.091	.317	.321	.004	1.3
111	7.328	SUBM	.909	.601	1.946	1.731	1.286	1.144	.309	.309	.001	.3
112	7.344	SUBM	.909	.601	2.060	1.833	1.362	1.211	.301	.300	-.001	-.3
113	7.371	SUBM	.909	.601	2.152	1.913	1.422	1.265	.295	.297	.002	.5
114	7.362	SUBM	.909	.601	2.269	2.019	1.500	1.334	.287	.292	.005	1.7
115	7.365	SUBM	.909	.601	2.359	2.090	1.559	1.382	.282	.295	.013	4.7
116	9.535	SUBM	1.215	.803	1.524	1.428	1.007	.944	.340	.341	.002	.5
117	9.535	SUBM	1.215	.803	1.639	1.526	1.083	1.008	.327	.332	.005	1.5
118	9.535	SUBM	1.215	.803	1.752	1.624	1.158	1.073	.317	.322	.005	1.7
119	9.525	SUBM	1.215	.803	1.844	1.707	1.219	1.129	.308	.310	.002	.7
120	9.525	SUBM	1.215	.803	1.963	1.809	1.297	1.196	.299	.305	.006	1.9
121	9.514	SUBM	1.215	.803	2.080	1.911	1.375	1.263	.290	.297	.007	2.4
122	9.514	SUBM	1.215	.803	2.176	1.998	1.438	1.321	.284	.289	.005	1.9
123	9.514	SUBM	1.215	.803	2.285	2.097	1.510	1.386	.277	.280	.004	1.3
124	9.503	SUBM	1.215	.803	2.366	2.164	1.564	1.430	.272	.280	.009	3.2
125	9.534	SUBM	1.516	1.002	1.695	1.640	1.120	1.084	.258	.270	.012	4.7
126	9.525	SUBM	1.516	1.002	1.822	1.762	1.204	1.165	.249	.250	.002	.7
127	9.523	SUBM	1.516	1.002	1.928	1.859	1.274	1.228	.242	.248	.006	2.5
128	9.525	SUBM	1.516	1.002	2.034	1.958	1.344	1.294	.235	.241	.005	2.3
129	9.514	SUBM	1.516	1.002	2.129	2.047	1.407	1.353	.230	.235	.005	2.3
130	9.514	SUBM	1.516	1.002	2.242	2.155	1.482	1.425	.224	.225	.001	.5
131	9.503	SUBM	1.516	1.002	2.353	2.253	1.555	1.489	.218	.227	.009	4.1

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 6
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
1	1.188	JUMP	.167	.100	.419	.126	.250	.075	.587	.575	-.012	-2.0
2	1.383	FREE	.167	.100	.522	.295	.311	.176	.612	.591	-.021	-3.5
3	1.528	FREE	.167	.100	.610	.197	.364	.117	.626	.603	-.023	-3.6
4	1.662	FREE	.167	.100	.703	.219	.419	.131	.634	.615	-.019	-3.0
5	1.805	FREE	.167	.100	.811	.196	.484	.117	.641	.627	-.014	-2.1
6	1.929	FREE	.167	.100	.914	.182	.545	.109	.645	.638	-.007	-1.1
7	2.058	FREE	.167	.100	1.006	.169	.600	.101	.656	.648	-.009	-1.3
8	2.168	FREE	.167	.100	1.098	.167	.655	.100	.662	.656	-.006	-.8
9	2.275	FREE	.167	.100	1.195	.168	.713	.100	.666	.664	-.001	-.2
10	2.391	FREE	.167	.100	1.301	.167	.776	.099	.670	.673	.002	.3
11	2.496	FREE	.167	.100	1.401	.169	.835	.101	.674	.680	.006	.8
12	2.590	FREE	.167	.100	1.504	.173	.897	.103	.675	.687	.011	1.7
13	2.694	FREE	.167	.100	1.605	.175	.957	.105	.680	.693	.013	1.9
14	2.800	FREE	.167	.100	1.713	.182	1.021	.108	.684	.699	.015	2.1
15	2.878	FREE	.167	.100	1.826	.185	1.089	.110	.681	.704	.023	3.4
16	2.966	FREE	.167	.100	1.902	.186	1.134	.111	.688	.708	.020	2.9
17	3.029	FREE	.167	.100	2.003	.190	1.194	.114	.685	.712	.027	4.0
18	3.112	FREE	.167	.100	2.108	.193	1.257	.115	.686	.715	.030	4.3
19	3.194	FREE	.167	.100	2.227	.191	1.328	.114	.685	.719	.034	5.0
20	3.278	FREE	.167	.100	2.365	.196	1.410	.117	.682	.722	.040	5.9
21	1.791	SUBM	.167	.100	.888	.538	.530	.321	.608	.591	-.017	-2.8
22	1.781	SUBM	.167	.100	.992	.589	.592	.351	.572	.595	.023	4.0
23	1.791	SUBM	.167	.100	1.102	.656	.657	.391	.546	.582	.036	6.6
24	1.791	SUBM	.167	.100	1.191	.718	.710	.428	.525	.565	.040	7.7
25	1.783	SUBM	.167	.100	1.297	.797	.773	.475	.501	.542	.042	8.3
26	1.793	SUBM	.167	.100	1.396	.873	.832	.521	.485	.522	.037	7.6
27	1.795	SUBM	.167	.100	1.500	.953	.894	.568	.469	.505	.036	7.7
28	1.797	SUBM	.167	.100	1.597	1.033	.952	.616	.455	.486	.031	6.9
29	1.798	SUBM	.167	.100	1.687	1.116	1.006	.665	.443	.466	.023	5.3
30	1.792	SUBM	.167	.100	1.786	1.204	1.065	.718	.429	.449	.020	4.6
31	1.788	SUBM	.167	.100	1.891	1.302	1.128	.776	.416	.435	.019	4.6
32	1.778	SUBM	.167	.100	1.993	1.396	1.188	.832	.403	.426	.023	5.7
33	1.782	SUBM	.167	.100	2.089	1.481	1.246	.883	.394	.420	.026	6.6
34	1.770	SUBM	.167	.100	2.204	1.590	1.314	.948	.381	.413	.031	8.2
35	1.768	SUBM	.167	.100	2.329	1.704	1.389	1.016	.371	.408	.038	10.2
36	2.491	JUMP	.336	.200	.554	.250	.330	.149	.532	.519	-.013	-2.4
37	2.814	FREE	.336	.200	.668	.334	.398	.199	.547	.538	-.009	-1.6
38	3.013	FREE	.336	.200	.739	.308	.441	.184	.557	.549	-.008	-1.5
39	3.215	FREE	.336	.200	.815	.310	.486	.185	.566	.559	-.007	-1.2
40	3.476	FREE	.336	.200	.910	.324	.543	.193	.579	.571	-.008	-1.4
41	3.732	FREE	.336	.200	1.020	.323	.608	.193	.587	.584	-.004	-.7
42	4.007	FREE	.336	.200	1.128	.316	.673	.189	.600	.594	-.005	-.9
43	4.178	FREE	.336	.200	1.198	.298	.714	.178	.607	.601	-.006	-1.0
44	4.358	FREE	.336	.200	1.312	.295	.782	.176	.605	.610	.005	.8
45	4.573	FREE	.336	.200	1.399	.283	.834	.169	.615	.616	.002	.3
46	4.789	FREE	.336	.200	1.511	.272	.901	.162	.619	.623	.004	.7
47	4.947	FREE	.336	.200	1.604	.269	.956	.160	.621	.629	.008	1.2
48	5.150	FREE	.336	.200	1.721	.266	1.026	.159	.624	.634	.010	1.6
49	5.334	FREE	.336	.200	1.830	.269	1.091	.160	.627	.638	.012	1.9
50	5.530	FREE	.336	.200	1.946	.269	1.160	.160	.630	.642	.012	1.9
51	5.675	FREE	.336	.200	2.046	.272	1.220	.162	.631	.644	.014	2.2
52	5.836	FREE	.336	.200	2.153	.275	1.284	.164	.632	.646	.014	2.2
53	6.007	FREE	.336	.200	2.264	.280	1.350	.167	.635	.647	.013	2.0
54	6.138	FREE	.336	.200	2.350	.278	1.401	.166	.636	.648	.011	1.7
55	3.028	SUBM	.336	.200	.819	.629	.488	.375	.532	.489	-.042	-8.0
56	3.017	SUBM	.336	.200	.886	.673	.528	.402	.510	.487	-.023	-4.5
57	3.033	SUBM	.336	.200	1.005	.757	.599	.452	.481	.475	-.006	-1.2
58	3.003	SUBM	.336	.200	1.110	.840	.662	.501	.453	.456	.003	.7
59	3.021	SUBM	.336	.200	1.207	.921	.720	.549	.437	.437	-.000	-.0
60	3.014	SUBM	.336	.200	1.310	1.007	.781	.600	.419	.419	.001	.2
61	3.003	SUBM	.336	.200	1.398	1.081	.834	.645	.404	.405	.001	.3
62	3.011	SUBM	.336	.200	1.490	1.161	.888	.693	.392	.390	-.002	-.6
63	3.020	SUBM	.336	.200	1.601	1.258	.955	.750	.379	.374	-.006	-1.5
64	3.023	SUBM	.336	.200	1.707	1.351	1.018	.806	.368	.363	-.005	-1.3
65	3.017	SUBM	.336	.200	1.806	1.438	1.077	.858	.357	.356	-.000	-.1
66	3.012	SUBM	.336	.200	1.904	1.531	1.135	.913	.347	.348	.001	.3
67	3.000	SUBM	.336	.200	1.994	1.615	1.189	.963	.338	.342	.004	1.1
68	2.977	SUBM	.336	.200	2.095	1.716	1.249	1.023	.327	.332	.005	1.6
69	2.972	SUBM	.336	.200	2.214	1.828	1.320	1.090	.318	.326	.009	2.7
70	3.012	SUBM	.336	.200	2.334	1.935	1.392	1.154	.313	.324	.011	3.4
71	5.895	JUMP	.669	.399	.848	.444	.506	.265	.511	.488	-.024	-4.6
72	6.170	FREE	.669	.399	.943	.552	.562	.329	.507	.501	-.006	-1.2
73	6.584	FREE	.669	.399	1.044	.534	.623	.318	.514	.514	-.000	-.1
74	6.981	FREE	.669	.399	1.146	.527	.683	.314	.521	.525	.004	.8
75	7.396	FREE	.669	.399	1.254	.542	.748	.323	.527	.535	.007	1.4
76	7.838	FREE	.669	.399	1.368	.542	.816	.323	.535	.543	.008	1.5
77	8.270	FREE	.669	.399	1.481	.538	.883	.321	.543	.550	.007	1.3
78	8.627	FREE	.669	.399	1.580	.521	.942	.311	.548	.554	.006	1.1
79	8.946	FREE	.669	.399	1.684	.521	1.004	.311	.550	.558	.007	1.3
80	9.451	FREE	.669	.399	1.821	.508	1.086	.303	.559	.560	.001	.2

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 6
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI-ATION (CDA-CDM)	DEVI-ATION (PERCENT)
81	9.793	FREE	.669	.399	1.929	.501	1.150	.299	.563	.560	-.003	-.4
82	10.155	FREE	.669	.399	2.042	.491	1.218	.293	.567	.559	-.008	-1.4
83	10.556	FREE	.669	.399	2.169	.482	1.293	.288	.572	.556	-.016	-2.8
84	7.256	SUBM	.669	.399	1.461	1.158	.871	.690	.479	.466	-.013	-2.8
85	7.228	SUBM	.669	.399	1.548	1.221	.923	.728	.464	.456	-.008	-1.7
86	7.214	SUBM	.669	.399	1.661	1.307	.990	.780	.447	.441	-.006	-1.4
87	7.200	SUBM	.669	.399	1.754	1.380	1.046	.823	.434	.428	-.006	-1.3
88	7.200	OMIT	.669	.399	1.840	1.460**						
89	7.200	OMIT	.669	.399	1.934	1.536**						
90	7.255	SUBM	.669	.399	1.875	1.468	1.118	.875	.423	.418	-.005	-1.1
91	7.247	SUBM	.669	.399	1.971	1.547	1.175	.923	.412	.409	-.003	-.6
92	7.240	SUBM	.669	.399	2.086	1.638	1.244	.977	.400	.403	.003	.7
93	7.227	SUBM	.669	.399	2.192	1.727	1.307	1.030	.390	.396	.006	1.6
94	7.237	SUBM	.669	.399	2.271	1.796	1.354	1.071	.383	.391	.007	1.9
95	7.246	SUBM	.669	.399	2.356	1.867	1.405	1.113	.377	.387	.010	2.7
96	9.558	SUBM	1.001	.597	1.483	1.307	.884	.779	.419	.417	-.002	-.4
97	9.547	SUBM	1.001	.597	1.581	1.383	.943	.825	.405	.407	.002	.5
98	9.546	SUBM	1.001	.597	1.683	1.467	1.004	.875	.393	.393	-.000	-.0
99	9.535	SUBM	1.001	.597	1.778	1.545	1.060	.921	.382	.381	-.001	-.2
100	9.525	SUBM	1.001	.597	1.891	1.639	1.128	.977	.370	.368	-.002	-.5
101	9.525	SUBM	1.001	.597	1.989	1.722	1.186	1.027	.360	.357	-.004	-1.0
102	9.514	SUBM	1.001	.597	2.084	1.802	1.243	1.074	.352	.351	-.001	-.2
103	9.514	SUBM	1.001	.597	2.199	1.899	1.311	1.132	.342	.345	.003	.9
104	9.503	SUBM	1.001	.597	2.304	1.987	1.374	1.185	.334	.342	.008	2.3
105	9.503	SUBM	1.001	.597	2.384	2.054	1.422	1.225	.328	.340	.012	3.5
106	9.448	SUBM	1.335	.796	1.632	1.558	.973	.929	.296	.289	-.007	-2.5
107	9.525	SUBM	1.335	.796	1.752	1.662	1.045	.991	.288	.285	-.002	-.9
108	9.527	SUBM	1.335	.796	1.839	1.743	1.097	1.039	.281	.273	-.008	-2.7
109	9.533	SUBM	1.335	.796	1.948	1.841	1.162	1.098	.273	.266	-.008	-2.8
110	9.538	SUBM	1.335	.796	2.050	1.930	1.222	1.151	.267	.262	-.004	-1.5
111	9.520	SUBM	1.335	.796	2.158	2.028	1.287	1.210	.259	.255	-.004	-1.7
112	9.537	SUBM	1.335	.796	2.257	2.116	1.346	1.262	.254	.252	-.002	-.9
113	9.530	SUBM	1.335	.796	2.362	2.208	1.408	1.317	.248	.252	.004	1.7
114	9.515	SUBM	1.670	.996	1.816	1.776	1.083	1.059	.226	.231	.006	2.5
115	9.525	SUBM	1.670	.996	1.916	1.873	1.143	1.117	.220	.217	-.003	-1.3
116	9.525	SUBM	1.670	.996	2.023	1.975	1.206	1.178	.214	.209	-.005	-2.3
117	9.514	SUBM	1.670	.996	2.129	2.072	1.270	1.235	.209	.210	.002	.8
118	9.514	SUBM	1.670	.996	2.250	2.183	1.342	1.302	.203	.210	.007	3.4
119	9.514	SUBM	1.670	.996	2.342	2.269	1.397	1.353	.199	.206	.007	3.4

*ADJUSTED DEPTH FOR PIER WIDTH CORRECTION
**ERROR IN DATA COLLECTION OR ITERATION LIMIT EXCEEDED FOR PEIR CORRECTION
END OF DATA

```
                STATISTICS FOR SUBMERGED FLOW CONDITIONS
      HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NOS.  4,  5 AND  6
      ********************************************************************


                NUMBER OF DATA POINTS=  237
                MAXIMUM POSITIVE DEVIATION =      .042
                MAXIMUN NEGATIVE DEVIATION =     -.043
                MAXIMUM POSITIVE PERCENT DEVIATION=      10.2
                MAXIMUM NEGATIVE PERCENT DEVIATION=      -8.2
                AVERAGE DEVIATION =    .00097
                AVERAGE PERCENT DEVIATION =      .410
                STANDARD DEVIATION (ACTUAL)=    .01291
                STANDARD DEVIATION (PERCENT)=     3.0



                          STATISTICAL ANALYSIS
                     FOR SUBMERGED FLOW CONDITIONS
      HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NOS.  4,  5 AND  6
      ********************************************************************

            FOR ALGORYTHMS COEFFICIENT OF DISCHARGE - CDA
            VERSUS METZLERS COEFFICIENT OF DISCHARGE - CDM

                                NUMBER OF              CUMULATIVE
       DEVIATION   ACCUMULATED  DATA POINTS  PROBABILITY   PROBABILITY
       INTERVAL    DEVIATION    PER INTERVAL DISTRIBUTION  DISTRIBUTION
       (ACTUAL)    (ACTUAL)                  (PERCENT)     (PERCENT)
       ********************************************************************
                    -.044
         .004       -.040          2            .8            .8
         .004       -.036          1            .4           1.3
         .004       -.032          3           1.3           2.5
         .004       -.028          2            .8           3.4
         .003       -.025          2            .8           4.2
         .003       -.022          2            .8           5.1
         .003       -.019          0           0.0           5.1
         .003       -.016          5           2.1           7.2
         .003       -.013          3           1.3           8.4
         .002       -.011          4           1.7          10.1
         .002       -.009          7           3.0          13.1
         .002       -.007          7           3.0          16.0
         .002       -.005         14           5.9          21.9
         .002       -.003         19           8.0          30.0
         .002       -.001         19           8.0          38.0
         .002        .001         17           7.2          45.1
         .002        .003         24          10.1          55.3
         .002        .005         25          10.5          65.8
         .002        .007         28          11.8          77.6
         .002        .009         11           4.6          82.3
         .002        .011          7           3.0          85.2
         .002        .013         10           4.2          89.5
         .002        .015          3           1.3          90.7
         .003        .018          3           1.3          92.0
         .003        .021          6           2.5          94.5
         .003        .024          4           1.7          96.2
         .003        .027          1            .4          96.6
         .003        .030          0           0.0          96.6
         .003        .033          2            .8          97.5
         .004        .037          2            .8          98.3
         .004        .041          3           1.3          99.6
         .004        .045          1            .4         100.0
                            TOTAL= 237   TOTAL= 100.0
```

112

STATISTICS FOR FREE FLOW CONDITIONS
HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NOS. 4, 5 AND 6
****

```
NUMBER OF DATA POINTS=  166
MAXIMUM POSITIVE DEVIATION =        .040
MAXIMUN NEGATIVE DEVIATION =       -.033
MAXIMUM POSITIVE PERCENT DEVIATION=        5.9
MAXIMUM NEGATIVE PERCENT DEVIATION=       -6.4
AVERAGE DEVIATION =     .00078
AVERAGE PERCENT DEVIATION =      .061
STANDARD DEVIATION (ACTUAL)=      .01291
STANDARD DEVIATION (PERCENT)=       2.1
```

STATISTICAL ANALYSIS
FOR FREE FLOW CONDITIONS
HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NOS. 4, 5 AND 6
****

FOR ALGORYTHMS COEFFICIENT OF DISCHARGE - CDA
VERSUS METZLERS COEFFICIENT OF DISCHARGE - CDM

DEVIATION INTERVAL (ACTUAL)	ACCUMULATED DEVIATION (ACTUAL)	NUMBER OF DATA POINTS PER INTERVAL	PROBABILITY DISTRIBUTION (PERCENT)	CUMULATIVE PROBABILITY DISTRIBUTION (PERCENT)
	-.034			
.004	-.030	2	1.2	1.2
.003	-.027	1	.6	1.8
.003	-.024	2	1.2	3.0
.003	-.021	4	2.4	5.4
.003	-.018	4	2.4	7.8
.003	-.015	6	3.6	11.4
.003	-.012	5	3.0	14.5
.002	-.010	5	3.0	17.5
.002	-.008	12	7.2	24.7
.002	-.006	11	6.6	31.3
.002	-.004	9	5.4	36.7
.002	-.002	10	6.0	42.8
.002	.000	11	6.6	49.4
.002	.002	9	5.4	54.8
.002	.004	5	3.0	57.8
.002	.006	11	6.6	64.5
.002	.008	13	7.8	72.3
.002	.010	10	6.0	78.3
.002	.012	5	3.0	81.3
.002	.014	10	6.0	87.3
.003	.017	7	4.2	91.6
.003	.020	5	3.0	94.6
.003	.023	2	1.2	95.8
.003	.026	3	1.8	97.6
.003	.029	1	.6	98.2
.003	.032	1	.6	98.8
.004	.036	1	.6	99.4
.004	.040	1	.6	100.0
		TOTAL= 166	TOTAL= 100.0	

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 7
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI-ATION (CDA-CDM)	DEVI-ATION (PERCENT)
1	.877	JUMP	.131	.098	.357	.104	.266	.078	.598	.591	-.007	-1.2
2	1.040	JUMP	.131	.098	.472	.113	.352	.084	.617	.611	-.007	-1.1
3	1.196	FREE	.131	.098	.585	.169	.436	.126	.638	.627	-.011	-1.7
4	1.318	FREE	.131	.098	.693	.172	.516	.128	.646	.641	-.005	-.8
5	1.439	FREE	.131	.098	.801	.146	.597	.109	.656	.653	-.003	-.5
6	1.531	FREE	.131	.098	.901	.145	.671	.108	.658	.662	.004	.7
7	1.626	FREE	.131	.098	.998	.136	.744	.101	.664	.670	.006	1.0
8	1.724	FREE	.131	.098	1.121	.143	.835	.107	.664	.679	.015	2.2
9	1.793	FREE	.131	.098	1.212	.144	.903	.108	.664	.684	.020	3.0
10	1.871	FREE	.131	.098	1.317	.141	.981	.105	.665	.689	.024	3.6
11	1.951	FREE	.131	.098	1.409	.145	1.050	.108	.670	.692	.022	3.3
12	2.035	FREE	.131	.098	1.494	.141	1.113	.105	.679	.694	.016	2.3
13	2.102	FREE	.131	.098	1.591	.137	1.186	.102	.679	.696	.017	2.4
14	2.202	FREE	.131	.098	1.703	.146	1.269	.109	.688	.697	.009	1.3
15	2.265	FREE	.131	.098	1.832	.152	1.365	.114	.682	.696	.014	2.1
16	2.326	FREE	.131	.098	1.930	.157	1.438	.117	.683	.695	.012	1.8
17	2.384	FREE	.131	.098	1.999	.156	1.490	.116	.687	.693	.006	.8
18	2.454	FREE	.131	.098	2.111	.156	1.573	.116	.689	.689	.001	.1
19	2.510	FREE	.131	.098	2.206	.160	1.644	.119	.689	.685	-.004	-.6
20	2.613	FREE	.131	.098	2.383	.161	1.776	.120	.690	.675	-.016	-2.3
21	1.336	SUBM	.131	.098	.745	.437	.555	.326	.631	.576	-.055	-8.7
22	1.331	SUBM	.131	.098	.850	.486	.633	.362	.589	.579	-.009	-1.6
23	1.331	SUBM	.131	.098	.932	.539	.694	.401	.562	.561	-.001	-.2
24	1.338	SUBM	.131	.098	1.049	.623	.782	.464	.533	.530	-.003	-.5
25	1.330	SUBM	.131	.098	1.138	.697	.848	.519	.508	.505	-.003	-.6
26	1.333	SUBM	.131	.098	1.246	.783	.928	.583	.487	.483	-.004	-.9
27	1.334	SUBM	.131	.098	1.337	.867	.996	.646	.470	.460	-.010	-2.2
28	1.325	SUBM	.131	.098	1.439	.960	1.072	.715	.450	.440	-.010	-2.3
29	1.353	SUBM	.131	.098	1.537	1.033	1.145	.770	.445	.433	-.012	-2.7
30	1.349	SUBM	.131	.098	1.632	1.122	1.216	.836	.431	.419	-.011	-2.6
31	1.344	SUBM	.131	.098	1.755	1.235	1.308	.920	.414	.406	-.007	-1.7
32	1.344	SUBM	.131	.098	1.836	1.312	1.368	.978	.404	.399	-.005	-1.3
33	1.339	SUBM	.131	.098	1.961	1.437	1.461	1.071	.390	.388	-.002	-.4
34	1.336	SUBM	.131	.098	2.042	1.516	1.522	1.130	.381	.383	.002	.6
35	1.331	SUBM	.131	.098	2.181	1.652	1.625	1.231	.367	.378	.010	2.8
36	1.331	SUBM	.131	.098	2.264	1.732	1.687	1.291	.361	.376	.015	4.2
37	1.331	SUBM	.131	.098	2.373	1.844	1.768	1.374	.352	.372	.020	5.6
38	1.810	JUMP	.266	.198	.473	.179	.352	.133	.528	.530	.002	.3
39	1.907	JUMP	.266	.198	.512	.191	.382	.142	.535	.538	.003	.5
40	2.173	FREE	.266	.198	.606	.283	.452	.211	.561	.555	-.005	-1.0
41	2.381	FREE	.266	.198	.700	.256	.522	.191	.571	.570	-.001	-.2
42	2.599	FREE	.266	.198	.800	.272	.596	.203	.583	.584	.001	.1
43	2.842	FREE	.266	.198	.901	.268	.671	.200	.601	.597	-.005	-.8
44	3.024	FREE	.266	.198	1.023	.262	.762	.195	.600	.609	.009	1.5
45	3.200	FREE	.266	.198	1.117	.236	.832	.176	.608	.618	.010	1.6
46	3.425	FREE	.266	.198	1.228	.229	.915	.171	.621	.626	.005	.8
47	3.569	FREE	.266	.198	1.314	.205	.979	.153	.625	.631	.006	.9
48	3.723	FREE	.266	.198	1.418	.220	1.057	.164	.628	.636	.008	1.3
49	3.872	FREE	.266	.198	1.515	.218	1.129	.163	.632	.640	.008	1.3
50	4.015	FREE	.266	.198	1.633	.220	1.217	.164	.631	.643	.012	1.9
51	4.158	FREE	.266	.198	1.712	.215	1.276	.160	.638	.644	.006	1.0
52	4.322	FREE	.266	.198	1.830	.217	1.364	.162	.642	.645	.003	.5
53	4.445	FREE	.266	.198	1.932	.226	1.440	.168	.642	.644	.002	.3
54	4.553	FREE	.266	.198	2.031	.224	1.513	.167	.642	.642	.001	.1
55	4.718	FREE	.266	.198	2.159	.230	1.609	.171	.645	.638	-.006	-1.0
56	4.791	FREE	.266	.198	2.242	.231	1.671	.172	.642	.635	-.008	-1.2
57	4.938	FREE	.266	.198	2.374	.237	1.769	.177	.644	.627	-.016	-2.5
58	2.146	SUBM	.266	.198	.682	.519	.508	.386	.522	.489	-.032	-6.2
59	2.141	SUBM	.266	.198	.789	.594	.588	.442	.484	.477	-.007	-1.5
60	2.138	SUBM	.266	.198	.898	.679	.669	.506	.453	.453	-.000	-.0
61	2.138	SUBM	.266	.198	1.000	.763	.745	.569	.429	.430	.001	.2
62	2.142	SUBM	.266	.198	1.094	.844	.815	.629	.411	.410	-.002	-.4
63	2.143	SUBM	.266	.198	1.204	.938	.897	.699	.392	.389	-.003	-.8
64	2.142	SUBM	.266	.198	1.302	1.024	.970	.763	.377	.371	-.005	-1.5
65	2.137	SUBM	.266	.198	1.389	1.106	1.035	.824	.364	.354	-.010	-2.7
66	2.137	SUBM	.266	.198	1.506	1.213	1.122	.904	.350	.339	-.011	-3.0
67	2.132	SUBM	.266	.198	1.597	1.298	1.190	.967	.339	.330	-.009	-2.6
68	2.128	SUBM	.266	.198	1.702	1.395	1.268	1.039	.328	.322	-.005	-1.7
69	2.130	SUBM	.266	.198	1.794	1.477	1.337	1.101	.319	.318	-.001	-.4
70	2.132	SUBM	.266	.198	1.909	1.588	1.423	1.183	.310	.310	.000	.1
71	2.151	SUBM	.266	.198	2.005	1.671	1.494	1.245	.305	.309	.004	1.4
72	2.148	SUBM	.266	.198	2.124	1.788	1.583	1.332	.296	.303	.007	2.3
73	2.145	SUBM	.266	.198	2.229	1.892	1.661	1.410	.288	.298	.010	3.3
74	2.143	SUBM	.266	.198	2.353	2.009	1.753	1.497	.281	.296	.016	5.6
75	4.112	JUMP	.532	.396	.680	.384	.507	.286	.501	.476	-.025	-5.0
76	4.290	JUMP	.532	.396	.731	.368	.545	.275	.504	.485	-.018	-3.6
77	4.679	FREE	.532	.396	.822	.449	.613	.334	.518	.501	-.017	-3.2
78	5.118	FREE	.532	.396	.934	.434	.696	.323	.532	.518	-.014	-2.6
79	5.437	FREE	.532	.396	1.044	.441	.778	.329	.534	.532	-.002	-.4
80	5.841	FREE	.532	.396	1.155	.448	.861	.334	.546	.544	-.002	-.4

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 7
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI-ATION (CDA-CDM)	DEVI-ATION (PERCENT)
81	6.170	FREE	.532	.396	1.258	.456	.937	.339	.552	.553	.001	.1
82	6.506	FREE	.532	.396	1.361	.450	1.014	.335	.560	.560	.000	.1
83	6.839	FREE	.532	.396	1.465	.445	1.092	.332	.567	.566	-.001	-.1
84	7.172	FREE	.532	.396	1.590	.439	1.185	.327	.571	.572	.001	.2
85	7.490	FREE	.532	.396	1.709	.422	1.273	.314	.575	.575	.000	.0
86	7.785	FREE	.532	.396	1.817	.402	1.354	.300	.580	.577	-.003	-.5
87	8.051	FREE	.532	.396	1.923	.400	1.433	.298	.583	.577	-.006	-1.0
88	8.357	FREE	.532	.396	2.047	.390	1.525	.291	.586	.576	-.011	-1.8
89	8.606	FREE	.532	.396	2.154	.391	1.605	.291	.589	.573	-.016	-2.7
90	8.893	FREE	.532	.396	2.265	.387	1.688	.289	.593	.569	-.025	-4.2
91	9.138	FREE	.532	.396	2.377	.389	1.771	.290	.595	.563	-.033	-5.5
92	3.457	SUBM	.532	.396	.747	.666	.557	.496	.402	.411	.010	2.4
93	3.466	SUBM	.532	.396	.825	.734	.615	.547	.383	.393	.010	2.5
94	3.458	SUBM	.532	.396	.904	.806	.674	.601	.365	.367	.002	.6
95	3.460	SUBM	.532	.396	.995	.885	.741	.659	.348	.352	.004	1.2
96	3.474	SUBM	.532	.396	1.104	.983	.823	.733	.332	.332	-.000	-.0
97	3.466	SUBM	.532	.396	1.198	1.067	.893	.795	.318	.319	.001	.3
98	3.460	SUBM	.532	.396	1.312	1.169	.978	.871	.303	.305	.002	.6
99	3.479	SUBM	.532	.396	1.398	1.251	1.042	.932	.295	.290	-.005	-1.7
100	3.463	SUBM	.532	.396	1.523	1.361	1.135	1.014	.282	.281	-.000	-.1
101	3.462	SUBM	.532	.396	1.616	1.448	1.204	1.079	.273	.270	-.003	-1.2
102	3.471	SUBM	.532	.396	1.729	1.552	1.288	1.157	.265	.259	-.006	-2.2
103	3.460	SUBM	.532	.396	1.824	1.642	1.359	1.224	.257	.250	-.007	-2.7
104	3.458	SUBM	.532	.396	1.922	1.736	1.432	1.293	.250	.245	-.005	-2.1
105	3.456	SUBM	.532	.396	2.024	1.831	1.508	1.364	.244	.242	-.002	-.7
106	3.455	SUBM	.532	.396	2.141	1.943	1.595	1.448	.237	.237	.000	.2
107	3.455	SUBM	.532	.396	2.254	2.050	1.680	1.528	.231	.235	.004	1.6
108	3.448	SUBM	.532	.396	2.378	2.171	1.772	1.618	.224	.230	.006	2.6
109	5.223	SUBM	.532	.396	1.112	.882	.829	.657	.497	.483	-.014	-2.8
110	5.219	SUBM	.532	.396	1.231	.973	.917	.725	.472	.461	-.011	-2.4
111	5.212	SUBM	.532	.396	1.352	1.058	1.007	.788	.450	.448	-.002	-.4
112	5.207	SUBM	.532	.396	1.454	1.142	1.083	.851	.434	.428	-.005	-1.2
113	5.204	SUBM	.532	.396	1.544	1.215	1.151	.905	.420	.414	-.007	-1.6
114	5.197	SUBM	.532	.396	1.657	1.308	1.235	.975	.405	.397	-.009	-2.1
115	5.189	SUBM	.532	.396	1.745	1.383	1.300	1.030	.394	.384	-.010	-2.6
116	5.190	SUBM	.532	.396	1.857	1.477	1.384	1.101	.382	.370	-.012	-3.1
117	5.175	SUBM	.532	.396	1.945	1.551	1.449	1.156	.373	.362	-.011	-2.9
118	5.188	SUBM	.532	.396	2.054	1.644	1.531	1.225	.363	.353	-.011	-2.9
119	5.209	SUBM	.532	.396	2.166	1.739	1.614	1.296	.355	.350	-.006	-1.6
120	5.200	SUBM	.532	.396	2.282	1.845	1.700	1.375	.346	.345	-.001	-.3
121	5.194	SUBM	.532	.396	2.393	1.943	1.783	1.448	.337	.343	.006	1.8
122	6.816	SUBM	.532	.396	1.608	1.145	1.198	.853	.540	.491	-.049	-9.1
123	6.810	SUBM	.532	.396	1.727	1.219	1.287	.908	.520	.477	-.043	-8.2
124	6.803	SUBM	.532	.396	1.830	1.281	1.364	.955	.505	.467	-.037	-7.4
125	6.772	SUBM	.532	.396	1.926	1.346	1.435	1.003	.490	.456	-.034	-6.9
126	6.774	SUBM	.532	.396	2.031	1.421	1.513	1.059	.477	.443	-.034	-7.2
127	6.786	SUBM	.532	.396	2.162	1.520	1.611	1.133	.463	.428	-.035	-7.6
128	6.785	SUBM	.532	.396	2.256	1.593	1.681	1.187	.454	.420	-.034	-7.5
129	6.786	SUBM	.532	.396	2.367	1.675	1.764	1.248	.443	.416	-.028	-6.0
130	7.768	JUMP	.797	.594	1.036	.559	.772	.417	.511	.498	-.013	-2.5
131	7.857	FREE	.797	.594	1.067	.662	.795	.493	.510	.502	-.007	-1.4
132	8.209	FREE	.797	.594	1.173	.620	.874	.462	.508	.515	.007	1.4
133	8.668	FREE	.797	.594	1.292	.625	.963	.466	.511	.526	.015	3.0
134	9.090	FREE	.797	.594	1.381	.619	1.029	.461	.518	.534	.015	3.0
135	9.683	FREE	.797	.594	1.526	.619	1.137	.462	.525	.543	.018	3.4
136	10.092	FREE	.797	.594	1.625	.611	1.211	.455	.531	.548	.018	3.3
137	10.725	FREE	.797	.594	1.783	.593	1.329	.442	.538	.554	.016	2.9
138	7.179	SUBM	.797	.594	1.367	1.178	1.019	.878	.411	.408	-.004	-.9
139	7.172	SUBM	.797	.594	1.467	1.262	1.093	.941	.397	.391	-.006	-1.6
140	7.174	SUBM	.797	.594	1.576	1.346	1.174	1.003	.383	.383	-.000	-.0
141	7.167	SUBM	.797	.594	1.665	1.424	1.241	1.061	.372	.369	-.003	-.8
142	7.158	SUBM	.797	.594	1.764	1.511	1.314	1.126	.361	.355	-.006	-1.6
143	7.157	SUBM	.797	.594	1.867	1.597	1.391	1.190	.351	.347	-.004	-1.3
144	7.146	SUBM	.797	.594	1.967	1.685	1.466	1.256	.341	.336	-.005	-1.5
145	7.142	SUBM	.797	.594	2.077	1.781	1.548	1.327	.332	.327	-.005	-1.5
146	7.135	SUBM	.797	.594	2.199	1.884	1.639	1.404	.322	.321	-.001	-.5
147	7.129	SUBM	.797	.594	2.273	1.951	1.694	1.454	.317	.315	-.002	-.6
148	7.123	SUBM	.797	.594	2.379	2.047	1.773	1.526	.309	.309	-.000	-.0
149	9.538	SUBM	1.066	.794	1.460	1.315	1.088	.980	.396	.384	-.011	-2.8
150	9.525	SUBM	1.066	.794	1.563	1.399	1.165	1.042	.382	.376	-.006	-1.6
151	9.514	SUBM	1.066	.794	1.668	1.490	1.243	1.110	.369	.361	-.008	-2.1
152	9.514	SUBM	1.066	.794	1.778	1.584	1.325	1.180	.358	.350	-.008	-2.1
153	9.503	SUBM	1.066	.794	1.886	1.675	1.405	1.248	.347	.342	-.004	-1.3
154	9.503	SUBM	1.066	.794	1.993	1.767	1.485	1.317	.337	.334	-.003	-.9
155	9.493	SUBM	1.066	.794	2.091	1.848	1.558	1.377	.329	.331	.002	.7
156	9.482	SUBM	1.066	.794	2.205	1.947	1.643	1.451	.320	.325	.005	1.5
157	9.489	SUBM	1.066	.794	2.296	2.023	1.711	1.508	.314	.322	.009	2.7
158	9.496	SUBM	1.066	.794	2.362	2.084	1.760	1.553	.310	.318	.008	2.7
159	9.643	SUBM	1.332	.993	1.558	1.472	1.161	1.097	.310	.309	-.001	-.2
160	9.520	SUBM	1.332	.993	1.634	1.546	1.218	1.152	.299	.292	-.006	-2.1
161	9.525	SUBM	1.332	.993	1.748	1.654	1.303	1.233	.289	.277	-.012	-4.2
162	9.510	SUBM	1.332	.993	1.860	1.757	1.386	1.309	.280	.269	-.010	-3.7
163	9.503	SUBM	1.332	.993	1.957	1.842	1.458	1.373	.272	.269	-.004	-1.4
164	9.527	SUBM	1.332	.993	2.060	1.931	1.535	1.439	.266	.269	.003	1.2
165	9.521	SUBM	1.332	.993	2.182	2.042	1.626	1.521	.258	.266	.007	2.8
166	9.535	SUBM	1.332	.993	2.274	2.125	1.694	1.584	.254	.263	.009	3.7
167	9.525	SUBM	1.332	.993	2.382	2.220	1.775	1.654	.247	.264	.016	6.5

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
1	.990	JUMP	.151	.100	.356	.108	.235	.071	.587	.595	.008	1.4
2	1.165	JUMP	.151	.100	.451	.128	.298	.085	.614	.610	-.003	-.5
3	1.317	FREE	.151	.100	.558	.182	.369	.120	.624	.626	.002	.4
4	1.462	FREE	.151	.100	.655	.196	.433	.130	.639	.638	-.001	-.1
5	1.544	FREE	.151	.100	.716	.190	.473	.126	.645	.645	-.000	-.0
6	1.642	FREE	.151	.100	.802	.174	.530	.115	.649	.655	.006	.9
7	1.757	FREE	.151	.100	.896	.165	.592	.109	.657	.664	.007	1.1
8	1.866	FREE	.151	.100	.988	.148	.653	.098	.664	.671	.007	1.1
9	1.977	FREE	.151	.100	1.095	.147	.724	.097	.668	.679	.011	1.6
10	2.090	FREE	.151	.100	1.217	.157	.804	.104	.670	.687	.017	2.5
11	2.162	FREE	.151	.100	1.292	.157	.854	.104	.673	.691	.018	2.7
12	2.268	FREE	.151	.100	1.408	.157	.931	.104	.676	.696	.020	2.9
13	2.355	FREE	.151	.100	1.511	.162	.999	.107	.678	.699	.021	3.1
14	2.461	FREE	.151	.100	1.614	.161	1.067	.106	.685	.701	.016	2.4
15	2.537	FREE	.151	.100	1.710	.165	1.130	.109	.686	.703	.017	2.4
16	2.616	FREE	.151	.100	1.814	.173	1.199	.114	.687	.703	.016	2.4
17	2.671	FREE	.151	.100	1.901	.178	1.256	.117	.685	.703	.018	2.6
18	2.781	FREE	.151	.100	2.009	.175	1.328	.116	.694	.702	.008	1.1
19	2.838	FREE	.151	.100	2.103	.170	1.390	.112	.692	.700	.008	1.1
20	2.933	FREE	.151	.100	2.229	.176	1.473	.116	.695	.696	.001	.2
21	3.023	FREE	.151	.100	2.393	.179	1.582	.119	.691	.689	-.002	-.3
22	1.526	SUBM	.151	.100	.783	.478	.518	.316	.610	.584	-.026	-4.2
23	1.521	SUBM	.151	.100	.907	.548	.599	.362	.565	.577	.012	2.1
24	1.531	SUBM	.151	.100	.992	.603	.656	.399	.544	.562	.018	3.3
25	1.527	SUBM	.151	.100	1.103	.691	.729	.457	.514	.530	.015	3.0
26	1.526	SUBM	.151	.100	1.212	.784	.801	.518	.490	.498	.008	1.6
27	1.531	SUBM	.151	.100	1.312	.865	.867	.572	.473	.476	.003	.7
28	1.531	SUBM	.151	.100	1.402	.946	.927	.625	.457	.455	-.002	-.5
29	1.523	SUBM	.151	.100	1.495	1.031	.988	.681	.441	.439	-.001	-.3
30	1.524	SUBM	.151	.100	1.604	1.129	1.060	.746	.426	.425	-.000	-.1
31	1.519	SUBM	.151	.100	1.694	1.215	1.120	.803	.413	.413	.000	.1
32	1.512	SUBM	.151	.100	1.808	1.324	1.195	.875	.398	.401	.003	.7
33	1.512	SUBM	.151	.100	1.895	1.408	1.252	.931	.389	.392	.004	1.0
34	1.524	SUBM	.151	.100	1.998	1.494	1.321	.987	.381	.390	.009	2.3
35	1.524	SUBM	.151	.100	2.104	1.598	1.391	1.056	.372	.383	.011	3.0
36	1.517	SUBM	.151	.100	2.212	1.699	1.462	1.123	.361	.379	.018	5.0
37	1.517	SUBM	.151	.100	2.303	1.796	1.522	1.187	.354	.372	.018	5.2
38	2.137	JUMP	.302	.200	.496	.212	.328	.140	.537	.535	-.002	-.3
39	2.384	JUMP	.302	.200	.577	.232	.381	.154	.555	.550	-.005	-.9
40	2.707	FREE	.302	.200	.694	.276	.459	.182	.575	.569	-.005	-.9
41	2.975	FREE	.302	.200	.795	.291	.525	.192	.590	.584	-.007	-1.1
42	3.226	FREE	.302	.200	.895	.301	.592	.199	.603	.596	-.007	-1.2
43	3.447	FREE	.302	.200	1.008	.308	.666	.203	.607	.608	.001	.1
44	3.677	FREE	.302	.200	1.108	.286	.732	.189	.618	.617	-.001	-.1
45	3.888	FREE	.302	.200	1.220	.270	.806	.178	.623	.626	.003	.6
46	4.096	FREE	.302	.200	1.327	.262	.877	.173	.629	.633	.004	.7
47	4.259	FREE	.302	.200	1.418	.263	.937	.174	.633	.638	.005	.8
48	4.450	FREE	.302	.200	1.521	.255	1.005	.168	.638	.642	.004	.7
49	4.649	FREE	.302	.200	1.643	.252	1.086	.167	.641	.646	.005	.7
50	4.803	FREE	.302	.200	1.729	.247	1.143	.164	.646	.648	.002	.3
51	4.936	FREE	.302	.200	1.814	.244	1.199	.161	.648	.649	.001	.1
52	5.127	FREE	.302	.200	1.950	.256	1.289	.169	.649	.649	-.000	-.0
53	5.228	FREE	.302	.200	2.032	.261	1.343	.173	.649	.648	-.000	-.0
54	5.400	FREE	.302	.200	2.145	.257	1.418	.170	.652	.646	-.006	-.9
55	5.584	FREE	.302	.200	2.278	.263	1.506	.174	.654	.642	-.012	-1.9
56	5.728	FREE	.302	.200	2.379	.269	1.572	.178	.657	.638	-.019	-2.9
57	2.629	SUBM	.302	.200	.716	.551	.473	.364	.550	.501	-.049	-8.8
58	2.624	SUBM	.302	.200	.796	.607	.526	.401	.520	.491	-.029	-5.5
59	2.618	SUBM	.302	.200	.892	.679	.590	.449	.490	.475	-.015	-3.1
60	2.616	SUBM	.302	.200	1.001	.762	.662	.504	.462	.457	-.005	-1.2
61	2.605	SUBM	.302	.200	1.111	.854	.734	.565	.437	.433	-.004	-.9
62	2.613	SUBM	.302	.200	1.218	.945	.805	.625	.419	.413	-.006	-1.4
63	2.606	SUBM	.302	.200	1.317	1.032	.870	.682	.402	.394	-.007	-1.8
64	2.604	SUBM	.302	.200	1.406	1.109	.929	.733	.388	.380	-.008	-2.2
65	2.601	SUBM	.302	.200	1.502	1.196	.993	.791	.375	.363	-.012	-3.2
66	2.603	SUBM	.302	.200	1.603	1.285	1.059	.850	.364	.355	-.009	-2.4
67	2.619	SUBM	.302	.200	1.691	1.369	1.118	.905	.356	.346	-.010	-2.9
68	2.616	SUBM	.302	.200	1.806	1.473	1.194	.973	.344	.338	-.006	-1.8
69	2.583	SUBM	.302	.200	1.895	1.560	1.252	1.031	.332	.330	-.002	-.6
70	2.583	SUBM	.302	.200	2.002	1.660	1.323	1.097	.323	.324	.001	.3
71	2.570	SUBM	.302	.200	2.128	1.785	1.406	1.180	.312	.315	.003	1.0
72	2.570	SUBM	.302	.200	2.209	1.859	1.460	1.229	.306	.313	.007	2.3
73	2.563	SUBM	.302	.200	2.334	1.983	1.543	1.311	.297	.306	.010	3.2
74	4.948	JUMP	.608	.402	.741	.447	.490	.295	.505	.483	-.022	-4.4
75	5.199	JUMP	.608	.402	.823	.404	.544	.267	.503	.497	-.006	-1.2
76	5.638	FREE	.608	.402	.921	.499	.609	.330	.516	.512	-.004	-.7
77	6.082	FREE	.608	.402	1.036	.491	.685	.325	.525	.527	.002	.4
78	6.557	FREE	.608	.402	1.155	.505	.763	.334	.536	.540	.004	.8
79	6.942	FREE	.608	.402	1.258	.514	.831	.339	.544	.549	.006	1.0
80	7.391	FREE	.608	.402	1.382	.512	.913	.339	.552	.558	.006	1.1

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVI-ATION (CDA-CDM)	DEVI-ATION (PERCENT)
81	7.739	FREE	.608	.402	1.479	.503	.978	.332	.559	.564	.005	.9
82	8.080	FREE	.608	.402	1.588	.498	1.050	.329	.563	.569	.005	1.0
83	8.483	FREE	.608	.402	1.706	.484	1.128	.320	.571	.572	.002	.3
84	8.869	FREE	.608	.402	1.833	.470	1.212	.310	.575	.574	-.001	-.2
85	9.174	FREE	.608	.402	1.937	.466	1.280	.308	.579	.574	-.005	-.9
86	9.513	FREE	.608	.402	2.049	.454	1.354	.300	.584	.573	-.011	-1.9
87	9.849	FREE	.608	.402	2.173	.448	1.436	.296	.587	.569	-.018	-3.0
88	10.162	FREE	.608	.402	2.279	.438	1.506	.289	.591	.565	-.026	-4.5
89	10.360	FREE	.608	.402	2.360	.446	1.560	.295	.592	.561	-.032	-5.4
90	5.456	SUBM	.608	.402	1.100	.926	.727	.612	.457	.449	-.008	-1.8
91	5.456	SUBM	.608	.402	1.214	1.011	.802	.668	.435	.439	.004	.8
92	5.456	SUBM	.608	.402	1.326	1.103	.876	.729	.416	.418	.001	.3
93	5.456	SUBM	.608	.402	1.443	1.203	.954	.795	.399	.396	-.003	-.8
94	5.456	SUBM	.608	.402	1.540	1.283	1.018	.848	.386	.383	-.003	-.8
95	5.494	SUBM	.608	.402	1.641	1.361	1.085	.899	.377	.376	-.001	-.2
96	5.497	SUBM	.608	.402	1.749	1.456	1.156	.963	.365	.359	-.006	-1.6
97	5.488	SUBM	.608	.402	1.826	1.525	1.207	1.008	.357	.350	-.007	-1.8
98	5.486	SUBM	.608	.402	1.931	1.616	1.276	1.068	.347	.344	-.003	-.8
99	5.469	SUBM	.608	.402	2.057	1.724	1.360	1.140	.335	.338	.003	1.0
100	5.467	SUBM	.608	.402	2.168	1.826	1.433	1.207	.326	.332	.005	1.7
101	5.466	SUBM	.608	.402	2.281	1.927	1.508	1.274	.318	.327	.009	2.9
102	5.455	SUBM	.608	.402	2.410	2.047	1.593	1.353	.309	.322	.013	4.2
103	9.461	FREE	.909	.601	1.193	.772	.788	.510	.509	.509	-.000	-.1
104	9.828	FREE	.909	.601	1.282	.705	.847	.466	.510	.517	.007	1.3
105	10.232	FREE	.909	.601	1.380	.710	.912	.469	.512	.524	.012	2.4
106	10.696	FREE	.909	.601	1.480	.693	.978	.458	.517	.530	.014	2.6
107	7.326	SUBM	.909	.601	1.325	1.192	.876	.788	.374	.394	.020	5.4
108	7.326	SUBM	.909	.601	1.435	1.289	.948	.852	.359	.370	.010	2.8
109	7.356	SUBM	.909	.601	1.557	1.392	1.029	.920	.346	.356	.010	2.9
110	7.342	SUBM	.909	.601	1.636	1.464	1.081	.968	.337	.342	.005	1.4
111	7.340	SUBM	.909	.601	1.764	1.574	1.166	1.041	.325	.329	.004	1.2
112	7.365	SUBM	.909	.601	1.847	1.650	1.221	1.091	.318	.317	-.001	-.4
113	7.357	SUBM	.909	.601	1.963	1.748	1.297	1.155	.309	.310	.001	.4
114	7.354	SUBM	.909	.601	2.066	1.843	1.365	1.218	.301	.300	-.001	-.4
115	7.361	SUBM	.909	.601	2.165	1.929	1.431	1.275	.294	.297	.003	.9
116	7.353	SUBM	.909	.601	2.255	2.013	1.490	1.330	.288	.292	.004	1.3
117	7.342	SUBM	.909	.601	2.383	2.121	1.575	1.402	.279	.292	.012	4.5
118	7.357	SUBM	.909	.601	1.225	1.104	.810	.730	.391	.420	.030	7.6
119	9.514	SUBM	1.215	.803	1.485	1.388	.981	.918	.343	.360	.017	4.8
120	9.503	SUBM	1.215	.803	1.634	1.518	1.080	1.003	.327	.342	.015	4.6
121	9.503	SUBM	1.215	.803	1.753	1.628	1.159	1.076	.316	.320	.004	1.4
122	9.503	SUBM	1.215	.803	1.863	1.727	1.231	1.141	.306	.308	.002	.6
123	9.493	SUBM	1.215	.803	1.969	1.818	1.301	1.202	.297	.302	.005	1.7
124	9.514	SUBM	1.215	.803	2.072	1.909	1.369	1.262	.291	.295	.004	1.5
125	9.503	SUBM	1.215	.803	2.174	2.000	1.437	1.322	.283	.288	.004	1.6
126	9.503	SUBM	1.215	.803	2.279	2.090	1.506	1.381	.277	.284	.008	2.8
127	9.547	SUBM	1.215	.803	2.379	2.175	1.572	1.437	.272	.282	.010	3.7
128	9.526	SUBM	1.516	1.002	1.721	1.658	1.137	1.096	.256	.284	.029	11.2
129	9.526	SUBM	1.516	1.002	1.834	1.768	1.212	1.169	.248	.261	.013	5.3
130	9.525	SUBM	1.516	1.002	1.935	1.859	1.279	1.228	.241	.260	.019	7.7
131	9.529	SUBM	1.516	1.002	2.032	1.957	1.343	1.293	.236	.241	.005	2.2
132	9.527	SUBM	1.516	1.002	2.154	2.063	1.424	1.363	.229	.245	.016	7.0
133	9.528	SUBM	1.516	1.002	2.270	2.171	1.500	1.435	.223	.239	.016	7.1
134	9.526	SUBM	1.516	1.002	2.362	2.254	1.561	1.490	.218	.237	.018	8.3

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 9
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
1	1.181	JUMP	.167	.100	.403	.125	.240	.074	.595	.587	-.008	-1.3
2	1.368	JUMP	.167	.100	.498	.143	.297	.085	.620	.602	-.018	-2.9
3	1.540	FREE	.167	.100	.590	.196	.352	.117	.641	.616	-.026	-4.0
4	1.709	FREE	.167	.100	.698	.215	.416	.128	.654	.630	-.024	-3.7
5	1.792	FREE	.167	.100	.759	.211	.453	.126	.658	.637	-.021	-3.1
6	1.961	FREE	.167	.100	.887	.187	.529	.111	.666	.652	-.014	-2.1
7	2.101	FREE	.167	.100	.987	.177	.589	.105	.676	.662	-.014	-2.1
8	2.243	FREE	.167	.100	1.090	.163	.650	.097	.687	.672	-.015	-2.2
9	2.352	FREE	.167	.100	1.188	.161	.708	.096	.690	.681	-.009	-1.4
10	2.450	FREE	.167	.100	1.290	.168	.769	.100	.690	.689	-.001	-.1
11	2.577	FREE	.167	.100	1.396	.173	.832	.103	.698	.697	-.001	-.1
12	2.682	FREE	.167	.100	1.508	.172	.899	.103	.699	.705	.006	.9
13	2.771	FREE	.167	.100	1.602	.175	.955	.104	.700	.710	.010	1.5
14	2.892	FREE	.167	.100	1.721	.185	1.026	.110	.705	.717	.012	1.7
15	2.961	FREE	.167	.100	1.813	.182	1.081	.108	.703	.722	.018	2.6
16	3.052	FREE	.167	.100	1.910	.187	1.139	.112	.706	.726	.020	2.8
17	3.132	FREE	.167	.100	2.021	.185	1.205	.110	.705	.730	.026	3.7
18	3.216	FREE	.167	.100	2.103	.185	1.254	.110	.709	.733	.024	3.4
19	3.328	FREE	.167	.100	2.215	.185	1.321	.110	.715	.737	.021	3.0
20	3.439	FREE	.167	.100	2.372	.189	1.414	.113	.714	.740	.026	3.7
21	1.790	SUBM	.167	.100	.846	.526	.504	.314	.622	.589	-.033	-5.4
22	1.786	SUBM	.167	.100	.978	.604	.583	.360	.578	.581	.003	.6
23	1.770	SUBM	.167	.100	1.104	.695	.658	.415	.539	.554	.015	2.8
24	1.782	SUBM	.167	.100	1.191	.757	.710	.451	.522	.540	.018	3.4
25	1.772	SUBM	.167	.100	1.298	.847	.774	.505	.497	.512	.015	3.0
26	1.782	SUBM	.167	.100	1.398	.919	.834	.548	.482	.500	.018	3.7
27	1.780	SUBM	.167	.100	1.486	.988	.886	.589	.467	.486	.019	4.0
28	1.774	SUBM	.167	.100	1.607	1.095	.958	.653	.448	.461	.013	3.0
29	1.795	SUBM	.167	.100	1.695	1.190	1.011	.710	.441	.435	-.006	-1.3
30	1.785	SUBM	.167	.100	1.796	1.280	1.071	.763	.426	.423	-.003	-.7
31	1.783	SUBM	.167	.100	1.903	1.370	1.135	.817	.413	.417	.004	.9
32	1.778	SUBM	.167	.100	2.008	1.465	1.197	.874	.401	.410	.009	2.1
33	1.793	SUBM	.167	.100	2.105	1.541	1.255	.919	.395	.410	.014	3.6
34	1.797	SUBM	.167	.100	2.235	1.657	1.333	.988	.384	.405	.021	5.3
35	1.782	SUBM	.167	.100	2.376	1.796	1.417	1.071	.370	.397	.027	7.4
36	2.407	JUMP	.336	.200	.523	.235	.312	.140	.529	.526	-.003	-.6
37	2.698	JUMP	.336	.200	.602	.273	.359	.163	.553	.540	-.013	-2.3
38	3.030	FREE	.336	.200	.703	.307	.419	.183	.574	.556	-.018	-3.1
39	3.300	FREE	.336	.200	.807	.313	.481	.186	.584	.571	-.013	-2.2
40	3.568	FREE	.336	.200	.910	.342	.543	.204	.595	.585	-.010	-1.7
41	3.827	FREE	.336	.200	1.015	.346	.605	.206	.604	.597	-.007	-1.2
42	4.074	FREE	.336	.200	1.093	.326	.652	.194	.619	.605	-.015	-2.4
43	4.307	FREE	.336	.200	1.206	.319	.719	.190	.623	.615	-.008	-1.3
44	4.535	FREE	.336	.200	1.331	.307	.794	.183	.625	.626	.001	.1
45	4.749	FREE	.336	.200	1.410	.293	.841	.175	.636	.631	-.004	-.7
46	4.957	FREE	.336	.200	1.522	.287	.908	.171	.639	.639	-.000	-.0
47	5.153	FREE	.336	.200	1.619	.268	.965	.160	.644	.644	.000	.1
48	5.344	FREE	.336	.200	1.729	.269	1.031	.161	.646	.649	.003	.5
49	5.542	FREE	.336	.200	1.838	.268	1.096	.160	.650	.654	.004	.6
50	5.711	FREE	.336	.200	1.946	.279	1.160	.166	.651	.657	.006	1.0
51	5.896	FREE	.336	.200	2.061	.282	1.229	.168	.653	.660	.007	1.1
52	6.064	FREE	.336	.200	2.149	.277	1.281	.165	.658	.661	.004	.6
53	6.236	FREE	.336	.200	2.258	.280	1.346	.167	.660	.662	.003	.4
54	6.408	FREE	.336	.200	2.375	.290	1.416	.173	.661	.663	.002	.3
55	3.026	SUBM	.336	.200	.823	.636	.491	.379	.530	.490	-.040	-7.6
56	3.027	SUBM	.336	.200	.895	.692	.534	.413	.509	.476	-.033	-6.5
57	3.006	SUBM	.336	.200	1.012	.780	.603	.465	.475	.460	-.015	-3.1
58	3.030	SUBM	.336	.200	1.113	.859	.664	.512	.457	.445	-.011	-2.5
59	3.023	SUBM	.336	.200	1.203	.936	.717	.558	.438	.427	-.011	-2.6
60	3.017	SUBM	.336	.200	1.311	1.027	.782	.612	.419	.409	-.010	-2.3
61	3.012	SUBM	.336	.200	1.398	1.108	.834	.661	.405	.390	-.015	-3.8
62	3.000	SUBM	.336	.200	1.500	1.197	.894	.714	.389	.375	-.015	-3.8
63	2.994	SUBM	.336	.200	1.615	1.300	.963	.775	.375	.358	-.017	-4.4
64	3.006	SUBM	.336	.200	1.706	1.386	1.017	.827	.366	.348	-.018	-4.9
65	3.006	SUBM	.336	.200	1.809	1.469	1.079	.876	.355	.347	-.009	-2.4
66	3.016	SUBM	.336	.200	1.912	1.565	1.140	.933	.347	.339	-.007	-2.1
67	3.005	SUBM	.336	.200	2.017	1.659	1.203	.989	.336	.335	-.002	-.5
68	3.012	SUBM	.336	.200	2.111	1.745	1.259	1.040	.330	.331	.001	.3
69	3.076	SUBM	.336	.200	2.225	1.847	1.327	1.101	.328	.328	-.000	-.0
70	3.029	SUBM	.336	.200	2.375	1.995	1.416	1.190	.312	.319	.006	2.1
71	5.819	JUMP	.669	.399	.838	.487	.500	.291	.508	.496	-.012	-2.4
72	6.206	FREE	.669	.399	.933	.731	.556	.436	.513	.510	-.003	-.6
73	6.673	FREE	.669	.399	1.037	.542	.618	.323	.523	.523	.000	.0
74	7.147	FREE	.669	.399	1.151	.539	.686	.322	.532	.536	.004	.8
75	7.578	FREE	.669	.399	1.252	.550	.747	.328	.541	.545	.004	.8
76	8.055	FREE	.669	.399	1.368	.556	.816	.332	.550	.554	.004	.7
77	8.428	FREE	.669	.399	1.472	.567	.878	.338	.555	.560	.006	1.0
78	8.887	FREE	.669	.399	1.585	.543	.945	.324	.564	.565	.002	.3
79	9.320	FREE	.669	.399	1.706	.539	1.017	.321	.570	.569	-.001	-.1
80	9.672	FREE	.669	.399	1.808	.526	1.078	.314	.574	.571	-.003	-.6

HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NO. 9
STANDARD DEVIATION ANALYSIS
(INCH-POUND UNITS)

TEST RUN NUMBER	CANAL FLOW (FT3/S)	FLOW COND.	GATE OPENING (FT)	RATIO GO/PH (FT/FT)	UPSTREAM DEPTH (FT)	DOWNSTREAM DEPTH* (FT)	RATIO HU/PH (FT/FT)	RATIO HD/PH (FT/FT)	METZLER COEFF. CDM	ALGORITHM COEFF. CDA	DEVIATION (CDA-CDM)	DEVIATION (PERCENT)
81	10.062	FREE	.669	.399	1.934	.516	1.153	.308	.578	.572	-.006	-1.1
82	10.428	FREE	.669	.399	2.033	.503	1.212	.300	.584	.571	-.013	-2.3
83	10.725	FREE	.669	.399	2.135	.502	1.273	.299	.586	.568	-.018	-3.0
84	7.214	SUBM	.669	.399	1.386	1.118	.826	.667	.489	.464	-.025	-5.1
85	7.258	SUBM	.669	.399	1.464	1.174	.873	.700	.479	.457	-.022	-4.6
86	7.254	SUBM	.669	.399	1.549	1.236	.924	.737	.465	.448	-.017	-3.6
87	7.241	SUBM	.669	.399	1.662	1.327	.991	.791	.448	.431	-.017	-3.9
88	7.236	SUBM	.669	.399	1.759	1.401	1.049	.836	.436	.420	-.015	-3.5
89	7.239	SUBM	.669	.399	1.859	1.486	1.109	.886	.424	.406	-.018	-4.3
90	7.228	SUBM	.669	.399	1.975	1.577	1.178	.940	.411	.400	-.011	-2.7
91	7.236	SUBM	.669	.399	2.074	1.661	1.237	.990	.401	.392	-.009	-2.2
92	7.241	SUBM	.669	.399	2.188	1.755	1.305	1.047	.391	.386	-.005	-1.2
93	7.238	SUBM	.669	.399	2.275	1.829	1.357	1.091	.383	.382	-.001	-.3
94	7.234	SUBM	.669	.399	2.369	1.911	1.413	1.139	.375	.378	.003	.7
95	9.541	SUBM	1.001	.597	1.466	1.292	.874	.770	.420	.426	.005	1.3
96	9.534	SUBM	1.001	.597	1.570	1.379	.936	.822	.406	.407	.001	.2
97	9.514	SUBM	1.001	.597	1.684	1.472	1.004	.878	.391	.392	.001	.2
98	9.525	SUBM	1.001	.597	1.772	1.548	1.057	.923	.382	.378	-.004	-1.1
99	9.525	SUBM	1.001	.597	1.883	1.643	1.123	.980	.370	.363	-.008	-2.1
100	9.535	SUBM	1.001	.597	1.988	1.726	1.185	1.029	.361	.357	-.004	-1.1
101	9.525	SUBM	1.001	.597	2.093	1.819	1.248	1.085	.351	.348	-.004	-1.1
102	9.514	SUBM	1.001	.597	2.194	1.906	1.308	1.137	.343	.342	-.001	-.2
103	9.514	SUBM	1.001	.597	2.301	1.997	1.372	1.191	.335	.338	.003	1.0
104	9.529	SUBM	1.335	.796	1.562	1.493	.931	.890	.305	.303	-.002	-.8
105	9.533	SUBM	1.335	.796	1.645	1.567	.981	.934	.297	.296	-.002	-.6
106	9.526	SUBM	1.335	.796	1.744	1.654	1.040	.987	.289	.288	-.000	-.1
107	9.522	SUBM	1.335	.796	1.844	1.744	1.100	1.040	.281	.281	.000	.0
108	9.520	SUBM	1.335	.796	1.953	1.843	1.165	1.099	.273	.271	-.002	-.7
109	9.518	SUBM	1.335	.796	2.067	1.951	1.233	1.163	.265	.258	-.007	-2.8
110	9.528	SUBM	1.335	.796	2.171	2.043	1.295	1.218	.259	.254	-.005	-2.0
111	9.533	SUBM	1.335	.796	2.268	2.135	1.352	1.273	.253	.244	-.009	-3.5
112	9.528	SUBM	1.335	.796	2.383	2.230	1.421	1.330	.247	.251	.004	1.7
113	9.484	SUBM	1.670	.996	1.825	1.783	1.088	1.063	.225	.236	.011	4.9
114	9.546	SUBM	1.670	.996	1.918	1.873	1.144	1.117	.220	.223	.002	1.1
115	9.525	SUBM	1.670	.996	2.020	1.971	1.205	1.175	.214	.213	-.001	-.6
116	9.514	SUBM	1.670	.996	2.135	2.078	1.273	1.239	.208	.210	.002	1.0
117	9.514	SUBM	1.670	.996	2.230	2.167	1.330	1.292	.204	.207	.004	1.7
118	9.493	SUBM	1.670	.996	2.353	2.287	1.403	1.364	.198	.195	-.003	-1.7

*ADJUSTED DEPTH FOR PIER WIDTH CORRECTION
**ERROR IN DATA COLLECTION OR ITERATION LIMIT EXCEEDED FOR PEIR CORRECTION
END OF DATA

119

```
                    STATISTICS FOR SUBMERGED FLOW CONDITIONS
         HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NOS.  7,  8 AND  9
         ****************************************************************


                   NUMBER OF DATA POINTS=  242
                   MAXIMUM POSITIVE DEVIATION =        .030
                   MAXIMUN NEGATIVE DEVIATION =       -.055
                   MAXIMUM POSITIVE PERCENT DEVIATION=       11.2
                   MAXIMUM NEGATIVE PERCENT DEVIATION=       -9.1
                   AVERAGE DEVIATION =    -.00225
                   AVERAGE PERCENT DEVIATION =      -.263
                   STANDARD DEVIATION (ACTUAL)=     .01344
                   STANDARD DEVIATION (PERCENT)=        3.2




                             STATISTICAL ANALYSIS
                         FOR SUBMERGED FLOW CONDITIONS
         HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NOS.  7,  8 AND  9
         ****************************************************************


                  FOR ALGORYTHMS COEFFICIENT OF DISCHARGE - CDA
                  VERSUS METZLERS COEFFICIENT OF DISCHARGE - CDM

                                    NUMBER OF              CUMULATIVE
         DEVIATION   ACCUMULATED   DATA POINTS    PROBABILITY   PROBABILITY
         INTERVAL    DEVIATION     PER INTERVAL   DISTRIBUTION  DISTRIBUTION
         (ACTUAL)    (ACTUAL)                     (PERCENT)     (PERCENT)
         ****************************************************************
                     -.056
          .004       -.052             1             .4            .4
          .004       -.048             2             .8           1.2
          .004       -.044             0            0.0           1.2
          .004       -.040             2             .8           2.1
          .004       -.036             1             .4           2.5
          .004       -.032             7            2.9           5.4
          .004       -.028             1             .4           5.8
          .003       -.025             2             .8           6.6
          .003       -.022             1             .4           7.0
          .003       -.019             1             .4           7.4
          .003       -.016             5            2.1           9.5
          .003       -.013             6            2.5          12.0
          .002       -.011             9            3.7          15.7
          .002       -.009            12            5.0          20.7
          .002       -.007            16            6.6          27.3
          .002       -.005            22            9.1          36.4
          .002       -.003            19            7.9          44.2
          .002       -.001            22            9.1          53.3
          .002        .001            20            8.3          61.6
          .002        .003            14            5.8          67.4
          .002        .005            22            9.1          76.4
          .002        .007             8            3.3          79.8
          .002        .009             7            2.9          82.6
          .002        .011            11            4.5          87.2
          .002        .013             4            1.7          88.8
          .002        .015             6            2.5          91.3
          .003        .018             9            3.7          95.0
          .003        .021             9            3.7          98.8
          .003        .024             0            0.0          98.8
          .003        .027             0            0.0          98.8
          .003        .030             3            1.2         100.0
                            TOTAL= 242     TOTAL= 100.0
```

STATISTICS FOR FREE FLOW CONDITIONS
HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NOS. 7, 8 AND 9
****

```
NUMBER OF DATA POINTS=  177
MAXIMUM POSITIVE DEVIATION =        .026
MAXIMUN NEGATIVE DEVIATION =       -.033
MAXIMUM POSITIVE PERCENT DEVIATION=       3.7
MAXIMUM NEGATIVE PERCENT DEVIATION=      -5.5
AVERAGE DEVIATION =    .00033
AVERAGE PERCENT DEVIATION =      -.000
STANDARD DEVIATION (ACTUAL)=    .01185
STANDARD DEVIATION (PERCENT)=       1.9
```

STATISTICAL ANALYSIS
FOR FREE FLOW CONDITIONS
HYDRAULICS LABORATORY CANAL RADIAL GATE MODEL NOS. 7, 8 AND 9
****

FOR ALGORYTHMS COEFFICIENT OF DISCHARGE - CDA
VERSUS METZLERS COEFFICIENT OF DISCHARGE - CDM

DEVIATION INTERVAL (ACTUAL)	ACCUMULATED DEVIATION (ACTUAL)	NUMBER OF DATA POINTS PER INTERVAL	PROBABILITY DISTRIBUTION (PERCENT)	CUMULATIVE PROBABILITY DISTRIBUTION (PERCENT)
	-.034			
.004	-.030	2	1.1	1.1
.003	-.027	0	0.0	1.1
.003	-.024	5	2.8	4.0
.003	-.021	2	1.1	5.1
.003	-.018	5	2.8	7.9
.003	-.015	7	4.0	11.9
.003	-.012	9	5.1	16.9
.002	-.010	4	2.3	19.2
.002	-.008	3	1.7	20.9
.002	-.006	12	6.8	27.7
.002	-.004	9	5.1	32.8
.002	-.002	10	5.6	38.4
.002	.000	16	9.0	47.5
.002	.002	18	10.2	57.6
.002	.004	13	7.3	65.0
.002	.006	15	8.5	73.4
.002	.008	10	5.6	79.1
.002	.010	5	2.8	81.9
.002	.012	5	2.8	84.7
.002	.014	2	1.1	85.9
.003	.017	10	5.6	91.5
.003	.020	8	4.5	96.0
.003	.023	3	1.7	97.7
.003	.026	4	2.3	100.0
		TOTAL= 177	TOTAL= 100.0	

121

APPENDIX III

Field Verification Tests

FIELD VERIFICATION TESTS

General

The objective of the field verification test program was to establish the degree of accuracy that can be anticipated when the discharge algorithms are applied to the radial gate check structures of an actual operating canal system. Thirteen canal check structures were investigated. Twelve have significant variations in geometry. The number of radial gates per check structure ranged from one to five. The radial gates investigated have gate lip seals of the hard-rubber-bar or the music-note design, except for one, which has a combination of both. Flow conditions were submerged at all check structures but one. The check structures included in the program, therefore, provide a realistic test of the discharge algorithms' accuracy for variations in geometry, the number of gates per check structure, gate lip seal design, and free and submerged flow conditions. The physical properties of the check structures investigated are listed in table III-5.

The algorithm-predicted discharge was compared to field data obtained primarily from historical records. A total of 468 field data points were obtained from the 13 check structures. The measured discharge was determined from permanent gaging stations located near each of the check structures. Most of the discharge measurements were determined by cableway or bridge current meter measurements, employing the two-point method to obtain mean velocity of flow using the Price meter (cup type with vertical axis). The canal discharge accuracy obtainable by this procedure is high [11].

At one check structure—the Putah South Canal headworks—the flow is measured by a Parshall flume. At California Aqueduct check No. 21, an open channel acoustic velocity meter obtains the mean velocity. During each discharge measurement, the concurrent upstream and downstream water depths or elevations and each gate opening for the check structure were recorded. At the five check structures on the Friant-Kern Canal, the downstream water level staff gage is located on the check structure pier immediately downstream of the radial gate. The downstream water level staff gage is located in the recovery area of the submerged hydraulic jump. It was necessary to correct the recorded downstream water depth to an equivalent depth downsteam of the submerged hydraulic jump to correspond to the location used by the discharge algorithms. The correction was made by balancing the momentum and hydrostatic forces. In many cases, water depths were recorded to the nearest 30-mm

(0.1-ft) instead of the 3-mm (0.01-ft) resolution required to maintain accuracy of the algorithm-predicted discharge. The geometry and the invert elevations of the radial gate structures were obtained primarily from design drawings, using "as-built" drawings when available.

At three of the check structures—Tehama-Colusa Canal velocity barrier check No. 1, Coalinga Canal check No. 1, and Putah South Canal headworks—special field tests were conducted. The data collected provided information to evaluate the ability of the discharge algorithms (developed from a single-gate hydraulic model) to predict discharge for multigated check structures with accuracy. Also, data were obtained for determining the head loss in the downstream check structure transition at the Putah South Canal headworks, which has an invert drop of 0.8 m (2.55 ft) in a distance of 9.8 m (32 ft).

The field data for the 13 check structures used in the field verification test program are shown in tables III-6 through III-18. Each table has computed data showing a comparison of the algorithm-predicted discharge to the field-measured discharge. The algorithms use the field mesurement of the upstream and downstream water surface elevations or depth and the vertical distance of each gate opening to compute the predicted total discharge. The field-measured discharge is subtracted from the algorithm-predicted discharge to obtain the actual difference. The percent difference is obtained by dividing the actual difference by the field measured discharge, which is considered to be the true value, and multiplied by 100.0 as follows:

$$\text{Difference (actual)} = \text{ALGO--CMM}$$

$$\text{Difference (percent)} = \left(\frac{(\text{ALGO--CMM})}{\text{CDM}} \right) * 100.0$$

where:

ALGO = the computed algorithm-predicted total discharge (ft^3/s) for the canal radial gate check structure, using the field measurements of upstream and downstream water depths (ft) and vertical gate openings (ft).

CMM = field current meter measurement of the total discharge (ft^3/s)

Positive values of the above differences indicate that the algorithms predict a higher discharge than the field current meter measurement. Negative values indicate a lower predicted discharge.

The statistical analysis to obtain the average difference and standard deviation (actual and percent) of the field data is similar to the statistical

analysis of the laboratory data, except that comparisons are made of discharge (ft³/s) instead of the coefficient of discharge. The following general equations derive the two most important simple statistics—average difference (actual and percent) and standard deviation (actual and percent) — which are shown at the bottom of each table:

$$\text{Average difference (actual)} = \frac{\sum\limits_{i=1}^{n}(\text{ALGO–CMM})}{n}$$

$$\text{Average difference (percent)} = \frac{\sum\limits_{i=1}^{n}(\text{difference (percent)})}{n}$$

$$\text{Standard deviation (actual)} = \frac{\sum\limits_{i=1}^{n}(\text{ALGO–CMM})^2}{n-1}$$

$$\text{Standard deviation (percent)} = \frac{\sum\limits_{i=1}^{n}(\text{difference (percent)})^2}{n-1}$$

where: n = the number of test points

The average difference (actual or percent) is a measure of the location or error of the algorithm-predicted discharge with respect to the true value, which in the field verification test program is the field measurement of the discharge. The standard deviation is a measure of the deviation or "spread" of the algorithm-predicted discharge from the accepted standard for measuring discharge in the canal such as the current meter, Parshall flume, and acoustic velocity meter. The standard deviation also signifies that two out of three observations should be within this interval if the distribution of errors is normal.

All the field data were measured in inch-pound units. Therefore, only the inch-pound units will be presented.

The details of each check structure in the field verification test program, including the results of the comparison between the predicted and the measured discharges, are discussed in greater detail in the subsequent paragraphs. The results and conclusions are then summarized.

Velocity Barrier

The velocity barrier, check No. 1 on the Tehama-Colusa Canal, located near Red Bluff, California, is an important check structure in the field verification program. The velocity barrier check was used to design the hydraulic laboratory 1:6 scale radial gate model. It has the standard hard-rubber-bar gate lip seal design and a radius-to-pinion-height ratio of 1.530, which is near the average ratio of 1.514 of the radial gates constructed by the Bureau of Reclamation.

The velocity barrier check structure is at the beginning of the first reach of the Tehama-Colusa Canal. This reach is a 4.8-km (3-mi) long, dual-purpose irrigation/fish spawning channel with a bottom width of 30.5 m (100 ft) and side slopes of 2:1. The channel invert has a 1-m (3-ft) layer of gravel formed into redds, providing ideal spawning grounds for salmon. The check structure is designed with a higher than normal head differential to prevent the small salmon from migrating upstream, hence the name "velocity barrier."

Immediately upstream is a settling basin having a depth of 7.01 m (23 ft) and a bottom width of 75.57 m (248 ft) to allow sediment deposition before entering the fish spawning channel gravels. The invert of the settling basin slopes up 3.68 m (12.08 ft) to the invert of the check structure. The entrance to the check structure is a 13.7-m (45-ft) wide rectangular section with rounded corners of 1.5-m (5-ft) radius to a headwall that is perpendicular to the flow direction. An entrance loss coefficient, UPK, of 0.5 in terms of the change in velocity head was used because of the abrupt transition from the settling basin to the rectangular entrance of the check structure. The energy loss coefficient of 0.5 was confirmed from field data collected on February 12, 1980.

The invert of the velocity barrier check from the entrance to the beginning of the downstream transition to the fish spawning channel is horizontal. The check has three gates—each 4.27 m (14 ft) wide—and, therefore, two piers—each 0.46 m (1.5 ft) wide. The maximum design discharge is 71.6 m³/s (2530 ft³/s). Other physical properties are listed in table III-5.

Data for the Tehama-Colusa Canal velocity barrier field verification tests are listed in table III-6 and consist of 38 data points. Each data point involved the measurement of the upstream and downstream water surface elevations, the vertical distance of each gate opening, and the total discharge. Upstream and downstream water surface elevations were obtained from continuous water stage recorders housed in stilling wells. The upstream stilling well is a corrugated metal pipe 0.76-m (2.5-ft) in diameter attached to the upstream face of the check structure headwall. The water level inside the stilling well is the water surface elevation of the settling basin. The

Table III-5. — *Physical properties of the canal radial gate check structures included in the field verification test program.*

Physical properties[1]	Tehama-Colusa Canal — Velocity barrier No. 1	Tehama-Colusa Canal — Fish screen No. 2	Tehama-Colusa Canal — Coyote Creek No. 3	Coalinga Canal No. 1	California Aqueduct No. 21	Putah South Canal Headworks	West Canal Headworks	East Canal Headworks	Friant-Kern Canal — Sand Creek No. 3	Friant-Kern Canal — Dodge Avenue No. 4	Friant-Kern Canal — Kaweah River No. 5	Friant-Kern Canal — Fifth Avenue No. 7	Friant-Kern Canal — Tule River No. 8
Gate geometry:													
Number of gates, GN	3	3	2	1	3	2	3	2	3	3	5	3	4
Gate width (each), GW, m (ft)	4.27 (14.0)	4.27 (14.0)	5.49 (18.0)	5.18 (17.0)	7.62 (25.0)	3.05 (10.0)	4.65 (15.25)	4.88 (16.0)	6.10 (20.0)	6.10 (20.0)	3.35 (11.0)	5.49 (18.0)	3.66 (12.0)
Pier width (each), PW, m (ft)	0.46 (1.5)	0.38 (1.25)	0.38 (1.25)	0.00 (0.0)	0.91 (3.0)	0.41 (1.33)	0.53 (1.75)	0.61 (2.0)	0.61 (2.0)	0.61 (2.0)	0.30 (1.0)	0.51 (1.67)	0.30 (1.0)
Gate radius, RAD, m (ft)	4.20 (13.77)	4.96 (16.27)	6.48 (21.27)	4.20 (13.77)	11.44 (37.52)	3.44 (11.27)	6.10 (20.02)	8.01 (26.27)	6.48 (21.27)	6.48 (21.27)	7.93 (26.02)	6.48 (21.27)	7.93 (26.02)
Pinion height, PH, m (ft)	2.74 (9.0)	3.20 (10.5)	4.11 (13.5)	2.74 (9.0)	7.62 (25.0)	2.13 (7.0)	3.66 (12.0)	4.57 (15.0)	4.11 (13.5)	4.11 (13.5)	5.12 (16.8)	4.11 (13.5)	5.12 (16.8)
Ratio, RAD/PH	1.530	1.550	1.576	1.530	1.501	1.610	1.668	1.751	1.576	1.576	1.549	1.576	1.549
Gate lip seal design[2]	H-R-B	H-R-B	H-R-B	H-R-B	H-R-B	M-N	[11]M-N, H-R-B	M-N	M-N	M-N	M-N	M-N	M-N
Flow properties:													
Max. designed discharge, Q, m³/s (ft³/s)	71.6 (2530)	65.1 (2300)	65.1 (2300)	28.3 (1000)	236.4 (8350)	27.1 (956)	144.4 (5100)	127.4 (4500)	141.6 (5000)	141.6 (5000)	127.4 (4500)	127.4 (4500)	113.3 (4000)
Max. upstream depth,[4] HU, m (ft)	3.29 (10.80)	4.26 (13.99)	4.26 (13.99)	3.45 (11.33)	7.28 (23.9)	4.04 (13.25)	6.32 (20.73)	6.32 (20.73)	5.28 (17.32)	5.28 (17.32)	5.56 (18.25)	5.19 (17.04)	5.19 (17.04)
Max. downstream depth,[5] HD, m (ft)	2.51 (8.25)	4.26 (13.99)	4.26 (13.99)	3.30 (10.83)	8.11 (26.6)	3.13 (10.28)	5.00 (16.4)	5.86 (19.22)	5.28 (17.32)	5.28 (17.32)	5.19 (17.04)	5.19 (17.04)	5.25 (17.21)
Flow condition[3]	SUBM	SUBM	SUBM	SUBM	SUBM	SUBM	SUBM	FREE	SUBM	SUBM	SUBM	SUBM	SUBM
Check structure transition properties:													
Upstream invert el. UPINV, m (ft)	69.35 (227.54)	70.94 (232.74)	69.35 (227.54)	148.73 (487.97)	88.31 (289.74)	35.97 (118.0)	399.07 (1309.28)	[6]2.83 (9.28)	128.07 (420.18)	126.25 (414.20)	123.85 (406.32)	121.00 (396.98)	119.66 (392.58)
Gate sill invert el. GOINV, m (ft)	[8]73.04 (239.62)	70.94 (232.74)	68.73 (225.48)	148.86 (488.37)	88.28 (289.64)	37.49 (123.00)	400.31 (1313.35)	399.07 (1309.29)	128.07 (420.17)	126.25 (414.19)	123.85 (406.32)	121.00 (396.97)	119.66 (392.58)
Downstream invert el. DNINV, m (ft)	[8]73.04 (239.62)	69.55 (228.19)	69.24 (227.18)	148.77 (488.09)	87.36 (286.63)	36.71 (120.45)	400.31 (1313.34)	396.25 (1300.03)	128.07 (420.17)	126.25 (414.19)	123.83 (406.28)	121.00 (396.97)	119.46 (391.92)
Upstream invert change,[7] YINVERT, m (ft)	-3.68 (-12.08)	0.00 (0.0)	0.63 (2.06)	-0.12 (-0.4)	0.03 (0.10)	-1.52 (-5.00)	-1.24 (-4.07)	-0.00 (-0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.0)	0.00 (0.01)	0.00 (0.0)
Downstream invert change,[7] YSYFON, m (ft)	0.00 (0.0)	1.39 (4.55)	-0.52 (-1.70)	0.09 (0.28)	0.92 (3.01)	0.78 (2.55)	0.00 (0.01)	2.80 (9.26)	0.00 (0.0)	0.00 (0.0)	0.01 (0.04)	0.00 (0.0)	0.20 (0.66)
Downstream siphon loss coeff., SYFON	0.0		[9] 0.000000038	0.000000172	0.0	0.000001010	0.0	0.000000406	0.0	0.0	0.000000018	0.0	0.000000024
Upstream transition loss coeff., UPK	0.5	0.2	0.2	0.2	0.5	0.5	[8,12]0.23	0.2	0.5	0.2	0.2	0.2	0.2
Downstream transition loss coeff., DNK	0.1	0.1	0.1	0.1	[10]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Upstream bottom width, BWUP, m (ft)	75.59 (248.0)	30.48 (100.0)	7.32 (24.0)	3.66 (12.0)	15.24 (50.0)	22.86 (75.0)	15.24 (50.0)	13.11 (43.0)	19.51 (64.0)	19.51 (64.0)	10.97 (36.0)	10.97 (36.0)	10.97 (36.0)
Downstream bottom width, BWDN, m (ft)	13.72 (45.0)	7.32 (24.0)	7.32 (24.0)	3.66 (12.0)	9.75 (32.0)	3.66 (12.0)	11.58 (38.0)	6.81 (22.33)	19.51 (64.0)	19.51 (64.0)	10.97 (36.0)	10.97 (36.0)	10.97 (36.0)
Upstream side slope, ZUP	2.0	0.0	1.5	1.5	2.0	0.0	1.5	0.0	1.5	1.5	1.25	1.25	1.25
Downstream side slope, ZDN	0.0	1.5	1.5	1.5	2.0	1.5	1.5	0.0	1.5	1.5	1.25	1.25	1.25

[1] For nomenclature of physical properties, see figure 61, appendix IV.
[2] H-R-B for hard rubber bar design and M-N for music note design.
[3] SUBM for submerged flow and FREE for free flow conditions.
[4] Depth at the beginning of the upstream transition.
[5] Depth at the end of the downstream transition.
[6] Add 396.24 (1300.0) to get the elevation.
[7] Minus value signifies invert elevation has increased.
[8] Special survey or field test measurement.
[9] IF(Q.LT. 1520.0) SYFON = (-0.001136 ∗ Q+2.505)/Q∗∗2.
  IF(Q.GE. 1520.0) SYFON = (0.00165 ∗ Q+0.528)/Q∗∗2.
[10] IF(GO.LE. 6.0) DNK = 0.5∗GO+4.0.
  IF(GO.GT. 6.0) DNK = 8.6-0.27∗GO.
[11] The music note seal was replaced by the hard rubber bar seal in 1974. However, the downstream face plate angle leg (fig. 10b, item L) was not removed. Therefore, the gate lip seal is a combination of the music note and hard rubber bar designs.
[12] An additional head loss equal to 0.000000319∗Q∗∗2 is included to correct the upstream water level measurement to a depth downstream of the fish screen.

downstream stilling well is a concrete pipe 0.91-m (3-ft) in diameter located 24.38 m (80 ft) downstream of the gate, near the end of the rectangular section and approximately 1.5 m (5 ft) from the vertical wall on the left embankment. The recorded water surface at the downstream stilling well represents the water surface elevation at the end rectangular section.

The gate opening measurement for each gate was obtained by visual readings of staff gages attached to the face of each radial gate. These gages have been calibrated to read the vertical distance directly from a pointer attached to the check structure gate hoist concrete deck (see fig. IV-57a). The index elevation for the water stage recorders and the radial gate invert at the gate sill were surveyed to obtain the required resolution of 3 mm (0.01 ft) in the measurement of water elevations and gate openings.

Total discharge was determined from a permanent gaging station located at the end of the rectangular section, 30.5 m (100 ft) downstream of the gate sills, using a cableway current meter measurement [11]. The location of the gaging station immediately downstream of the radial gates does not provide ideal streamlines of flow for current meter measurements; however, it is the best location available in the vicinity of the velocity barrier check. Upstream is the wide settling basin, which has very low flow velocity and does not provide ideal gaging station properties. Downstream is the wide fish spawning channel which has the gravel redds that produce very turbulent flow conditions, so it does not provide ideal gaging station properties either.

At the gaging station, the flow streamlines are not parallel. The jet of the underflow radial gate creates high turbulence and the turbulence is still significant at the gaging station, which is only 30.5 m (100 ft) downstream. Also, the flow streamlines have a high upward vertical vector component at the gaging station. It appears the upward velocity vector causes the current meter (cup type with vertical axis) to register a lower mean velocity. This conclusion was somewhat confirmed during the special field test of February 13, 1980, table III-6.

An additional current meter measurement was made at the next permanent gaging station 8 km (5 mi) downstream, which is located immediately upstream of the Tehama-Colusa Canal check No. 3. Total measured discharge at the check No. 3 gaging station plus the measured flow diversions at check No. 2 was 3.8 percent higher than the total measured discharge at the velocity barrier, check No. 1, for the same steady-state flow condition. Also, the two field test data points of

July 2, 1980, velocity barrier check No. 1, table III-6, when compared to the two test data points of the same date for check No. 3, table III-8, indicated 3.9 and 4.5 percent higher discharges than measured at the velocity barrier gaging station.

The conclusion made from the three comparisons is that the velocity barrier check No. 1 gaging station measures a mean velocity lower than the true value. The minimum data available do not permit the exact discharges to be established with a high degree of confidence. Therefore, no corrections are made to the field current meter measurement data shown in table III-6.

It is also interesting to note that the algorithms predict higher discharges, up to +7.8 percent, at the lower discharge range. At the higher discharges, the average difference is near zero. Apparently, the smaller gate openings have a greater effect on the accuracy of the gaging than do the larger gate openings. Therefore, the error of the velocity barrier gaging station is probably a function of the gate opening.

The overall difference of the 38 test data points is +1.7 percent, which indicates the algorithms are predicting higher discharges compared to the field current meter measurements at the velocity barrier gaging station. Because the gaging station measures discharge lower than the true value, it is concluded that the algorithms predict the discharge at the velocity barrier closer to the true value than shown in table III-6. The discharge algorithms were developed from a single-gate, 1:6 scale hydraulic laboratory model. Results of the field verification tests demonstrate that the algorithms predict the total discharge for the multiple radial gated prototype check structure with accuracy. The field data verify that the hydraulic laboratory model is an accurate representation of the prototype. The standard deviation of 3.1 percent is a moderate spread from the standard current meter measurements, considering the nature of the velocity barrier gaging station.

More information about the variable characteristics of the differences can be observed on figure III-43, which is the frequency distribution graph of the percent difference between the algorithm-predicted discharge and the field current meter measurement of discharge data from table III-6. The frequency distribution graph describes other statistics that are of interest. First, the histogram bar chart shows the probability distribution (percent) of the 38 test data points that occur at selected intervals of the difference. The sum of all the bar heights is equal to 100 percent. It is important that the histogram bar chart have a

symmetrical bell shape about the true average value, or the center of gravity, which in this analysis should be zero. The symmetrical bell shape is called the "normal" or "Gaussian" distribution [12, 13]. If the error of the difference in table III-6 is the sum of all errors of measurement, which should be positive or negative at random, the result will be a normal distribution. However, if the distribution is not normal or symmetrical about the true average value, then a systematic error has occurred and the comparison is biased. Observing the shape of the histogram bar chart, figure III-43, the distribution is moderately skewed, with the center of gravity at the average difference of +1.7 percent. The histograms confirm that a systematic error has occurred at the velocity barrier. As discussed previously, there is a strong indication the velocity barrier gaging station is registering a lower discharge than the

true value (the exact amount is unknown). The conclusion is that the gaging station characteristics cause the systematic error and not the discharge algorithms.

Secondly, the cumulative probability distribution (percent) curve is developed and is a summation of all the histogram bars in ascending order of the selected intervals. The cumulative curve is of interest because it determines the frequency of observation that will occur for any selected interval of the difference. The cumulative curve indicates that 68 percent, or two out of three test data points, will fall within the standard deviation intervals of ±3.1 percent which is expected for normal distributions. Ninety percent of the data fall within the ±5 percent difference interval, and 100 percent of the data fall within a range of –4 to +8 percent.

Table III-6.—*Field verification tests for Tehama-Colusa Canal check No. 1.*

FIELD VERIFICATION TESTS
CANAL RADIAL GATES – DISCHARGE ALGORITHMS
TEHAMA – COLUSA CANAL

	FIELD DATA FROM TEHAMA-COLUSA CANAL CHECK NO. 1						*	COMPUTED DATA		
DATE	WATER SURFACE ELEV. UPSTREAM FT.	DOWNSTREAM FT.	GATE NO.1 FT.	OPENINGS NO.2 FT.	NO.3 FT.	TOTAL DISCH. BY CMM FT3/S	*	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO. – CMM) FT3/S	DIFFERENCE PERCENT
4/10/80	248.30	245.40	.80	.80	.80	369.0	*	397.7	28.7	7.8
4/15/80	249.31	245.90	1.24	1.24	1.24	646.0	*	678.4	32.4	5.0
4/ 2/80	248.27	246.18	1.89	1.89	1.89	784.0	*	817.5	33.5	4.3
4/16/80	249.24	246.00	1.50	1.50	1.50	786.0	*	810.2	24.2	3.1
4/17/80	249.17	246.20	1.80	1.80	1.80	869.0	*	937.1	68.1	7.8
4/16/81	250.55	246.23	1.61	1.61	1.61	997.0	*	1008.7	11.7	1.2
4/25/80	249.34	246.49	2.00	2.00	2.00	973.0	*	1016.0	43.0	4.4
5/22/81	249.20	246.43	2.16	2.16	2.16	1054.0	*	1094.1	40.1	3.8
4/24/80	249.33	246.55	2.12	2.12	2.12	1019.0	*	1066.9	47.9	4.7
2/12/80*	248.28	246.52	2.67	2.67	2.67	1049.2	*	1079.4	30.2	2.9
2/13/80*	248.26	246.53	2.67	2.67	2.67	1055.6	*	1068.8	13.2	1.3
5/27/81	249.23	246.38	2.17	2.17	2.17	1127.0	*	1119.9	-7.1	-.6
4/17/81	250.74	246.56	1.95	1.95	1.95	1142.0	*	1205.9	63.9	5.6
4/21/80	249.22	246.62	2.38	2.38	2.38	1189.0	*	1167.8	-21.2	-1.8
4/22/80	249.20	246.72	2.58	2.58	2.58	1197.0	*	1240.6	43.6	3.6
4/23/80	249.25	246.75	2.52	2.52	2.52	1197.0	*	1211.5	14.5	1.2
8/ 7/80	251.80	247.48	2.21	2.21	2.21	1334.0	*	1354.3	20.3	1.5
7/ 2/80	251.40	246.92	2.15	2.15	2.15	1341.0	*	1366.8	25.8	1.9
7/ 1/80	251.44	247.02	2.15	2.15	2.15	1344.0	*	1344.6	.6	.0
8/ 4/80	251.62	246.84	2.09	2.09	2.09	1358.0	*	1372.8	14.8	1.1
7/ 2/80	251.69	246.94	2.11	2.11	2.11	1370.0	*	1376.1	6.1	.4
6/11/81	249.20	246.80	2.90	2.90	2.90	1387.0	*	1385.7	-1.3	-.1
6/ 2/81	249.36	247.06	3.10	3.10	3.10	1397.0	*	1441.9	44.9	3.2
7/ 3/80	251.55	246.88	2.15	2.15	2.15	1377.0	*	1398.0	21.0	1.5
7/29/80	251.30	246.94	2.25	2.25	2.25	1393.0	*	1417.4	24.4	1.8
7/30/80	251.56	246.97	2.18	2.18	2.18	1393.0	*	1401.2	8.2	.6
5/ 1/80	249.21	247.15	3.25	3.25	3.25	1405.0	*	1426.1	21.1	1.5
8/ 5/80	251.69	246.98	2.18	2.18	2.18	1419.0	*	1418.3	-.7	-.0
8/ 1/80	251.60	246.99	2.15	2.15	2.15	1422.0	*	1381.2	-40.8	-2.9
7/28/80	251.40	246.94	2.24	2.24	2.24	1429.0	*	1426.4	-2.6	-.2
7/17/80	251.42	246.85	2.20	2.20	2.20	1445.0	*	1421.7	-23.3	-1.6
7/ 3/80	251.55	246.91	2.19	2.19	2.19	1445.0	*	1420.4	-24.6	-1.7
7/ 1/80	251.72	247.24	2.30	2.30	2.30	1448.0	*	1450.2	2.2	.2
7/30/80	251.59	247.06	2.24	2.24	2.24	1452.0	*	1428.5	-23.5	-1.6
4/29/81	249.13	246.87	3.17	3.17	3.17	1452.0	*	1478.0	26.0	1.8
6/16/81	249.30	247.08	3.45	3.45	3.45	1549.0	*	1594.8	45.8	3.0
6/25/81	249.27	247.05	3.50	3.50	3.50	1575.0	*	1623.2	48.2	3.1
7/ 1/81	249.46	247.65	4.70	4.70	4.70	1988.0	*	1959.5	-28.5	-1.4

* Special field tests.

* NUMBER OF DATA POINTS = 38
* AVERAGE DIFFERENCE (ACTUAL) = 16.6
* AVERAGE DIFFERENCE (PERCENT) = 1.7
* STANDARD DEVIATION (ACTUAL) = 31.2
* STANDARD DEVIATION (PERCENT) = 3.1
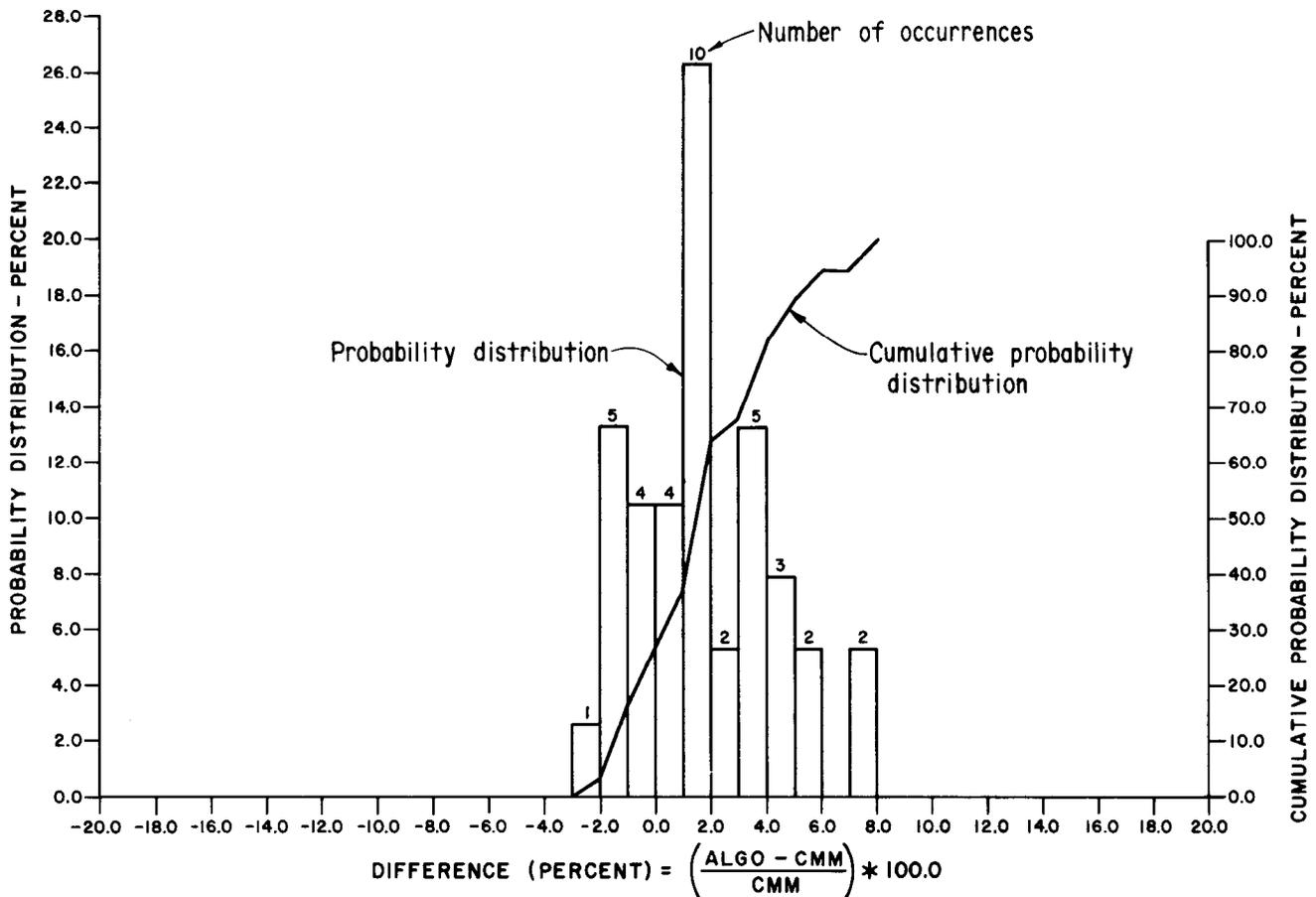
Figure III-43.—Field verification program statistical analysis frequency distribution graph of the difference (percent) between the algorithm-predicted and the measured discharges, ALGO and CMM, for 38 field data test points at Tehama-Colusa Canal check No. 1.

Another way to observe the success of the discharge algorithms is to plot the algorithm-predicted discharge versus the 38 test points measured in the field with the current meter, as shown on figure III-44. The plot indicates a linear relationship. For a normal distribution the best fit straight line should coincide with the 45° dashed line; however, using the least squares method, the best straight line fit (shown as the solid line in fig. III-44) produced the following equation:

$$ALGO = 0.961*CMM+64.8$$

The distribution is biased particularly at the lower discharges. It is the opinion of the author that the smaller gate opening causes an underflow jet which results in a high vertical velocity vector at the gaging station and thereby causes the cup-type vertical axis current meter to register low.

A detailed statistical analysis as described for the velocity barrier check in the preceding paragraphs will not be performed individually for the remaining 12 check structures. However, the same statistical analysis was applied to all 468

test data points and the results are presented in the field verification tests summary section of this report.

The remaining 12 check structures will be described briefly, including the results of the field verification test analysis performed on field data for each check structure. There are significant variations at some of the check structures and these will be discussed in greater detail in subsequent paragraphs.

Fish Screen

The fish screen, check structure No. 2 on the Tehama-Colusa Canal, is about 4.8 km (3 mi) downstream of the velocity barrier check. It is located at the end of the dual-purpose irrigation and fish spawning channel immediately downstream of the fish screen which prevents the small salmon from migrating downstream.

The approach channel is rectangular with a bottom width of 30.5 m (100 ft), and the bottom slope is horizontal. Starting 0.61 m (2.0 ft) downstream of the gate sill, the canal invert drops 1.39 m

FIELD VERIFICATION PROGRAM
VELOCITY BARRIER CHECK

ALGO = 0.961 ✳ CMM + 64.8

45°

ALGORYTHMS PREDICTED DISCHARGE – FT3/S

FIELD MEASUREMENT OF DISCHARGE – FT3/S
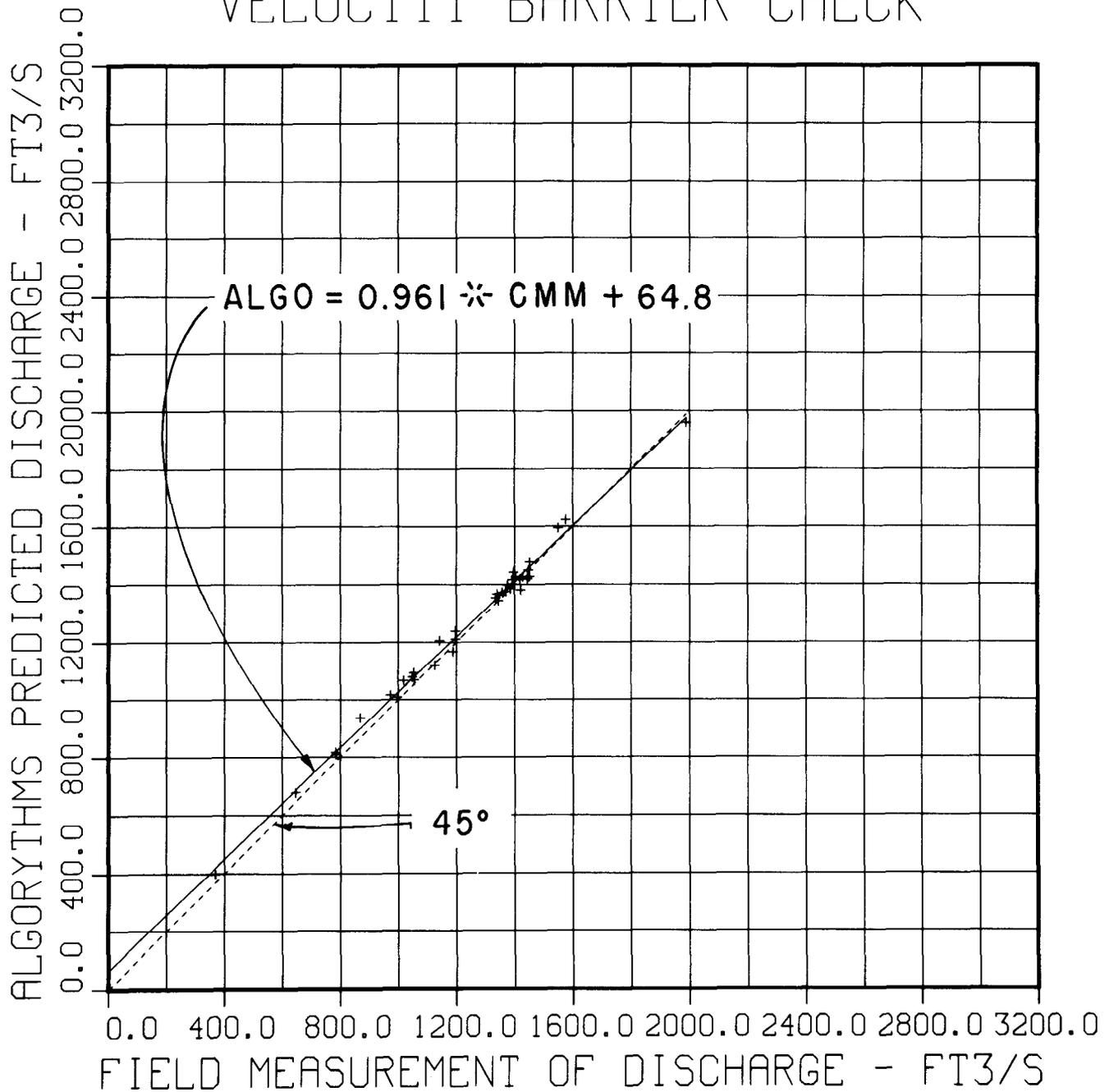
Figure III-44.—Comparison of the algorithm-predicted and the field-measured discharges, ALGO and CMM, at Tehama-Colusa Canal check No. 1.

130

(4.55 ft) in a horizontal distance of 4.60 m (15.08 ft) in the form of an ogee curve having the following equation:

$$X^2 = 50Y$$

where: X = horizontal distance
Y = vertical distance

The fish screen check is not considered a typical canal check structure because of the significant drop in the canal invert immediately downstream of the radial gate sill. However, the fish screen field data, table III-7, is included in the field verification test program to demonstrate that the algorithms can predict the discharge with accuracy if the proper energy loss is identified in the downstream energy balance equation which defines the downstream water depth used by the discharge algorithms. The field current meter measurements shown in table III-7 were obtained from the permanent check No. 3 gaging station about 3.2 km (2 mi) downstream. Using the field data from table III-7 and the discharge algorithms, the following energy loss equations were developed that provide the overall average difference of zero for the nine test data points:

If the canal discharge is less than 1520 ft³/s,

$$SYFON = (-0.00136*Q + 2.505)/Q**2$$

If the canal discharge is greater than or equal to 1520 ft³/s,

$$SYFON = (0.000165*Q + 0.528)/Q**2$$

where:

SYFON = siphon energy loss coefficient
Q = canal discharge

The energy loss coefficient is nonlinear and is expressed as a function of the canal discharge. The above equations demonstrate the nonlinear energy loss coefficient and is represented by two linear equations with the breaking point at 1520 ft³/s. The energy loss of the ogee drop is treated as though a siphon existed downstream and the head loss, HL, is:

$$HL = SYFON*Q**2$$

Developing the above energy loss based on the algorithm-predicted discharge disguises the true comparison of the algorithm-predicted discharge to the field current meter measurement of discharge. The proper procedure would have been to measure the head loss in the field using water surface level gages between the downstream side of the radial gate (at the beginning of the ogee curve) and downstream of the ogee curve, in order to have an independent measurement and provide unbiased results. However, the technique used to identify the head loss caused by the significant canal invert drop does produce very good results, with an overall average error of 0.0 percent and a standard deviation of 4.2 percent. Therefore, the algorithms adjusted by the above energy loss equation have practical application at the fish screen check and can be used with a high degree of confidence.

Coyote Creek

The Coyote Creek check is check structure No. 3 on the Tehama-Colusa Canal, about 3.2 km (2 mi) downstream of the fish screen check. The Coyote Creek check has a short upstream transition 8.1 m (26.5 ft) long and the canal invert drops 0.63 m (2.06 ft) in this distance. Immediately

Table III-7.—*Field verification tests for Tehama-Colusa Canal check No. 2.*

```
                              FIELD VERIFICATION TESTS
                     CANAL RADIAL GATES - DISCHARGE ALGORITHMS
                             TEHAMA - COLUSA CANAL


        FIELD DATA FROM TEHAMA-COLUSA CANAL CHECK NO.  2          *            COMPUTED DATA
                                                                 *
        WATER  SURFACE ELEV.    GATE  OPENINGS   TOTAL DISCH.  * TOTAL DISCH.  DIFFERENCE    DIFFERENCE
  DATE  UPSTREAM  DOWNSTREAM   NO.1  NO.2  NO.3    BY CMM      * BY ALGORITHM  (ALGO. - CMM)  PERCENT
          FT.       FT.        FT.   FT.   FT.     FT3/S       *    FT3/S         FT3/S
                                                                 *
************************************************************************************************************
                                                                 *
8/20/81   244.30    239.88    2.02  2.02  2.02    1052.0       *   1050.5         -1.5          -.1
8/ 4/81   244.05    240.75    2.85  2.85  2.85    1255.0       *   1283.2         28.2          2.2
8/ 5/81   244.28    240.95    2.85  2.85  2.85    1311.0       *   1278.2        -32.8         -2.5
8/11/80   244.38    239.90    2.45  2.45  2.45    1341.0       *   1463.9        122.9          9.2
8/ 6/81   244.35    240.84    2.80  2.80  2.80    1418.0       *   1331.9        -86.1         -6.1
8/ 4/80   244.70    240.70    2.73  2.73  2.73    1509.0       *   1490.4        -18.6         -1.2
8/ 7/80   245.66    241.95    4.00  4.00  4.00    2062.0       *   2096.7         34.7          1.7
8/ 6/80   245.12    241.85    4.18  4.18  4.18    2074.0       *   2042.2        -31.8         -1.5
8/ 5/80   244.85    241.60    4.18  4.18  4.18    2084.0       *   2059.3        -24.7         -1.2
                                                                 *
                                                                 * NUMBER OF DATA POINTS =    9
                                                                 * AVERAGE DIFFERENCE (ACTUAL)  =   -1.1
                                                                 * AVERAGE DIFFERENCE (PERCENT) =     .0
                                                                 * STANDARD DEVIATION (ACTUAL)  =   58.7
                                                                 * STANDARD DEVIATION (PERCENT) =    4.2
```

downstream of the radial gate—a distance of 11.1 m (36.5 ft)—the 73.4-m (240.8-ft) long Coyote Creek siphon begins. It conveys the canal flow underneath the Coyote Creek crossing. The canal invert slopes 0.217 m/m downward from the gate sill to the entrance of the siphon.

The field current meter measurements for the Coyote Creek check were made at the permanent check No. 3 gaging station, located about 61 m (200 ft) upstream. It is the same gaging station mentioned earlier in the discussions for the velocity barrier and the fish screen check. The field data and computed results are shown in table III-8 for the four test data points. The overall average of +2.5 percent indicates the algorithm-predicted discharge is too high compared to the field current meter measurement. An independent field measurement of the Coyote Creek siphon energy loss coefficient may result in a more realistic value than the theoretical calculated value that was used in the downstream energy balance equations. However, the results are satisfactory and probably could be improved with additional field data.

Coalinga Canal No. 1

Coalinga Canal check No. 1 is located near Coalinga, California. A special field test consisting of one data point was conducted on this check on July 15, 1981. The Coalinga single-gate check structure has geometric properties identical to the velocity barrier three-gated check structure, except the Coalinga gate is 1 m (3 ft) wider (refer to table III-5).

The purpose of the special field test of July 15, 1981, was to determine the accuracy of the algorithm-predicted discharge for the Coalinga single-gate structure compared to the velocity barrier three-gate check structure.

The Coalinga No. 1 check structure, the first check structure on the Coalinga Canal, is 2.2 km (1.4 mi) downstream from the outlet of the Pleasant Valley Pumping Plant, which lifts water from the San Luis Canal to the Coalinga Canal system. The special field test and the results are summarized as follows:

1. An absolute steady-state flow condition could not be maintained at check No. 1. During the test period, the water level in the first canal reach upstream of the check gate was decreasing at a steady rate of 0.20 ft/h. A drawdown rate of 17.8 ft³/s at check No. 1 was calculated based on the water level rate of drawdown of 0.20 ft/h.

2. the estimated discharge is as follows:

+235 ft³/s	Pleasant Valley Pumping Plant
−65 ft³/s	Turnout delivery upstream of check No. 1
+17.8 ft³/s	Calculated drawdown rate
+187.8 ft³/s	Total estimated discharge at check No. 1

3. The average upstream water surface elevation was 499.461 ft, the average downstream water surface elevation was 498.278 ft, and the gate opening was 1.56 ft during the test period. Using the average water surface elevation and gate opening, the algorithms predicted a discharge of 192.0 ft³/s.

4. The difference, or error, is:

$$\text{Error} = \frac{(192.0 - 187.8)}{187.8} \times 100.0 = 2.2 \text{ percent}$$

Comparing this error to the Tehama-Colusa velocity barrier special field tests (of February 12 and 13, 1980, table III-6) which had an average

Table III-8.—*Field verification tests for Tehama-Colusa Canal check No. 3.*

```
                          FIELD VERIFICATION TESTS
                  CANAL RADIAL GATES - DISCHARGE ALGORITHMS
                         TEHAMA - COLUSA CANAL
```

	FIELD DATA FROM TEHAMA-COLUSA CANAL CHECK NO. 3						*	COMPUTED DATA		
DATE	WATER SURFACE ELEV. UPSTREAM FT.	DOWNSTREAM FT.	GATE OPENINGS NO.1 FT.	NO.2 FT.	NO.3 FT.	TOTAL DISCH. BY CMM FT3/S	*	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO. - CMM) FT3/S	DIFFERENCE PERCENT
7/ 2/80	241.49	239.78	4.55	4.55		1404.0	*	1451.7	47.7	3.4
7/15/80	239.94	239.05	5.99	5.99		1416.0	*	1458.7	42.7	3.0
7/ 2/80	241.36	239.70	4.55	4.55		1426.0	*	1431.2	5.2	.4
7/17/80	239.95	239.03	6.17	6.17		1491.0	*	1539.1	48.1	3.2

```
                                                 * NUMBER OF DATA POINTS =    4
                                                 * AVERAGE DIFFERENCE (ACTUAL)  =   35.9
                                                 * AVERAGE DIFFERENCE (PERCENT)=    2.5
                                                 * STANDARD DEVIATION (ACTUAL)  =   46.4
                                                 * STANDARD DEVIATION (PERCENT)=    3.2
```

error of +2.1 percent, indicates very close agreement between the two structures. As mentioned previously, the velocity barrier check results are biased in the positive direction. However, it can be concluded that the discharge algorithms developed from the single-gate laboratory model predicted discharges for the prototype check structures having more than one radial gate with an accuracy of +2.2 percent, based on the results of the special tests.

The single test data point from Coalinga Canal check No. 1 is not included in the statistical analysis of all the 468 test data points discussed in the field verification tests summary section.

California Aqueduct No. 21

California Aqueduct check No. 21 is located near Kettleman City, 84 km (52 mi) southwest of Fresno, California. The California Aqueduct upstream is a joint-use facility shared by the California Department of Water Resources and the Bureau of Reclamation. Downstream of check No. 21 is the State of California-owned aqueduct, which has a maximum flow capacity of 229 m³/s (8100 ft³/s). It is important for water accounting purposes between the two agencies that the flow leaving the end of the joint-use facility be measured with accuracy. An open channel acoustic velocity meter immediately upstream of check No. 21 is currently being used by the Department of Water Resources to measure the mean velocity to determine the total discharge. The Department is also interested in developing discharge algorithms for their aqueduct radial gate check structures [6].

The necessary water levels and gate openings for determining the algorithms were collected for a wide range of discharges. Data collected and furnished by the Department are included in this report's field verification test program, table III-9, consisting of 201 test data points for a range of discharges from 1112.0 to 7386 ft³/s.

The upstream and downstream water levels are measured inside typical canalside stilling wells, using water level instrumentation which has been indexed by survey. Gate openings are obtained from the outputs of a digital encoder and an onsite computer. The angular motion of the radial gate arm is converted to the rotation of the encoder input shaft by the use of a pantograph linkage. The onsite computer converts the output of the encoder into feet of vertical gate opening, GO, at the gate lip to an accuracy of 0.1 ft [14].

The vertical gate opening, GO, can be calculated from the following equation:

$$GO = PH-RAD$$

$$*SIN\left[\Theta\left(1-\frac{\text{encoder output at GO}}{\text{encoder output at PH}}\right)\right] \text{(A)}$$

where:

GO = vertical distance of the gate opening (feet)

PH = pinion height above the gate sill invert (feet)

RAD = radial gate arm radius (feet)

Θ = arc SIN of PH/RAD (degrees)

The initial application of the discharge algorithms to the data received from the California Department of Water Resources produced poor agreement. An examination of the results indicated the gate opening was nonlinear compared to the value computed by the discharge algorithms. Also, the downstream transition invert, which drops 0.91 m (3.0 ft) in a distance of 24.4 m (80 ft), is apparently performing similarly to a plunge basin, causing additional energy losses. Since the downstream water level is measured downstream of the transition, the energy loss caused by the transition drop must be included in the downstream energy balance equations to obtain correct downstream depth for the discharge algorithms.

The apparent cause of the nonlinear gate opening is the result of the onsite computer using a different form of the equation (A) to convert the radial gate arm angular motion (the output of the digital encoder) to vertical distance as follows:

$$GO = PH-RAD*SIN(\Theta)$$

$$* \left[1-\frac{\text{encoder output at GO}}{\text{encoder output at PH}}\right] \quad \text{(B)}$$

Figure III-45 illustrates the relationship between the two forms of the above equations (A) and (B). Assuming equation B is being used by the onsite computer, the gate opening vertical distance was adjusted as follows:

$$\Theta' = [(PH-GO)/PH]*\Theta$$

$$GOA = PH-RAD*SIN(\Theta')$$

where:

GO = gate opening output of the onsite computer

GOA = adjusted gate opening as shown in table III-9

Using the field data and the adjusted gate openings, table III-9, with the discharge algorithms, the following energy loss coefficient equations for the downstream transition drop were developed that provide the best overall average difference for the 201 test data points:

Table III-9.—*Field verification tests for California Aqueduct check No. 21.*

FIELD VERIFICATION TESTS
CANAL RADIAL GATES - DISCHARGE ALGORITHMS
CALIFORNIA AQUEDUCT CHECK NO. 21

| FIELD DATA FROM CALIFORNIA AQUEDUCT CHECK NO. 21 | | | | | | | | COMPUTED DATA | | |
| FURNISHED BY STATE OF CALIF. DWR 7/16/81 (FILE FT08F001 A) | | | | | | | | | | |
HEAD DIFF. FT.	WATER SURFACE ELEV. UPSTREAM FT.	DOWNSTREAM FT.	GATE OPENINGS 1/ NO.1 FT.	NO.2 FT.	NO.3 FT.	TOTAL DISCH. BY AVM FT3/S		TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO. - AVM) FT3/S	DIFFERENCE PERCENT
1.29	313.22	311.93	2.19	2.19	2.19	1112.0	*	1187.6	75.6	6.8
1.03	313.17	312.14	2.19	2.19	2.19	1120.0	*	1057.8	-62.2	-5.6
1.21	313.23	312.02	2.19	2.19	2.19	1164.0	*	1149.1	-14.9	-1.3
1.21	312.99	311.78	2.19	2.19	2.19	1219.0	*	1149.2	-69.8	-5.7
1.22	313.03	311.81	2.19	2.19	2.19	1225.0	*	1154.1	-70.9	-5.8
1.18	313.12	311.94	2.19	2.19	2.19	1251.0	*	1134.4	-116.6	-9.3
1.17	313.09	311.92	2.37	2.37	2.37	1315.0	*	1220.9	-94.1	-7.2
1.41	313.11	311.70	2.45	2.45	2.45	1331.0	*	1394.9	63.9	4.8
1.12	312.84	311.72	2.45	2.45	2.45	1350.0	*	1239.0	-111.0	-8.2
1.16	312.84	311.68	2.63	2.63	2.63	1402.0	*	1353.5	-48.5	-3.5
1.18	312.92	311.74	2.63	2.63	2.63	1408.0	*	1365.4	-42.6	-3.0
1.20	313.26	312.06	2.63	2.63	2.63	1414.0	*	1376.8	-37.2	-2.6
1.16	313.18	312.02	2.63	2.63	2.63	1445.0	*	1353.1	-91.9	-6.4
1.16	312.90	311.74	2.63	2.63	2.63	1446.0	*	1353.5	-92.5	-6.4
1.18	312.88	311.70	2.63	2.63	2.63	1473.0	*	1365.4	-107.6	-7.3
1.15	312.94	311.79	2.63	2.63	2.63	1480.0	*	1347.4	-132.6	-9.0
1.16	313.10	311.94	2.63	2.63	2.63	1510.0	*	1353.2	-156.8	-10.4
1.27	312.90	311.63	2.63	2.63	2.63	1522.0	*	1418.1	-103.9	-6.8
.91	313.29	312.38	3.61	3.61	3.61	1504.0	*	1647.7	143.7	9.6
.92	313.30	312.38	3.61	3.61	3.61	1563.0	*	1656.9	93.9	6.0
1.09	313.44	312.35	3.61	3.61	3.61	1610.0	*	1806.6	196.6	12.2
1.04	313.04	312.00	3.88	3.88	3.88	1663.0	*	1898.8	235.8	14.2
1.03	313.05	312.02	3.88	3.88	3.88	1696.0	*	1889.4	193.4	11.4
1.13	313.15	311.02	3.88	3.88	3.88	2076.0	*	1985.2	-90.8	-4.4
1.12	313.18	312.06	3.97	3.97	3.97	1709.0	*	2018.1	309.1	18.1
1.14	313.09	311.95	3.97	3.97	3.97	1723.0	*	2036.9	313.9	18.2
1.10	312.24	311.14	3.97	3.97	3.97	2267.0	*	2003.7	-263.3	-11.6
1.01	313.12	312.11	4.06	4.06	4.06	1924.0	*	1958.4	34.4	1.8
1.16	312.67	311.51	4.06	4.06	4.06	2069.0	*	2104.5	35.5	1.7
1.15	312.61	311.46	4.06	4.06	4.06	2095.0	*	2095.5	.5	.0
1.19	312.83	311.64	4.15	4.15	4.15	2233.0	*	2179.5	-53.5	-2.4
1.22	313.05	311.83	4.33	4.33	4.33	2105.0	*	2303.7	198.7	9.4
1.13	312.22	312.09	4.33	4.33	4.33	2137.0	*	2214.0	77.0	3.6
.99	312.05	311.06	4.33	4.33	4.33	2161.0	*	2075.0	-86.0	-4.0
1.15	313.12	311.97	4.33	4.33	4.33	2228.0	*	2234.5	6.5	.3
1.16	312.52	311.36	4.33	4.33	4.33	2287.0	*	2247.8	-39.2	-1.7
1.22	313.17	311.95	4.33	4.33	4.33	2326.0	*	2303.0	-23.0	-1.0
1.17	312.58	311.41	4.33	4.33	4.33	2342.0	*	2257.4	-84.6	-3.6
1.17	312.71	311.54	4.33	4.33	4.33	2343.0	*	2256.6	-86.4	-3.7
1.02	313.20	312.18	4.42	4.42	4.42	1884.0	*	2145.3	261.3	13.9
1.16	313.25	312.09	4.42	4.42	4.42	2228.0	*	2291.1	63.1	2.8
1.17	313.27	312.10	4.42	4.42	4.42	2285.0	*	2301.1	16.1	.7
1.19	313.32	312.13	4.52	4.52	4.52	2389.0	*	2368.8	-20.2	-.8
1.19	312.93	311.74	4.61	4.61	4.61	2495.0	*	2419.2	-75.8	-3.0
1.15	312.70	311.55	4.61	4.61	4.61	2514.0	*	2378.6	-135.4	-5.4
1.13	312.43	311.30	4.70	4.70	4.70	2396.0	*	2405.9	9.9	.4
1.14	312.62	311.48	4.70	4.70	4.70	2414.0	*	2415.5	1.5	.1
1.15	312.49	311.34	4.70	4.70	4.70	2435.0	*	2427.3	-7.7	-.3
1.16	312.79	311.63	4.79	4.79	4.79	2466.0	*	2483.4	17.4	.7
.96	312.86	311.90	4.98	4.98	4.98	2052.0	*	2339.9	287.9	14.0
1.05	312.11	311.06	4.98	4.98	4.98	2461.0	*	2455.0	-6.0	-.2
1.00	312.60	311.60	5.07	5.07	5.07	2201.0	*	2434.8	233.8	10.6
1.00	312.66	311.66	5.07	5.07	5.07	2218.0	*	2434.4	216.4	9.8
1.01	312.61	311.60	5.07	5.07	5.07	2232.0	*	2447.1	215.1	9.6
1.13	312.99	311.86	5.07	5.07	5.07	2576.0	*	2588.9	12.9	.5
1.15	313.17	312.02	5.07	5.07	5.07	2585.0	*	2610.9	25.9	1.0
1.14	313.05	311.91	5.07	5.07	5.07	2613.0	*	2600.1	-12.9	-.5
1.12	312.79	311.67	5.16	5.16	5.16	2706.0	*	2625.0	-81.0	-3.0
1.14	312.87	311.73	5.16	5.16	5.16	2713.0	*	2648.3	-64.7	-2.4
1.10	312.66	311.56	5.16	5.16	5.16	2730.0	*	2601.9	-128.1	-4.7
1.09	313.33	312.24	5.63	5.63	5.63	2831.0	*	2811.5	-19.5	-.7
1.11	312.95	311.84	5.63	5.63	5.63	2920.0	*	2841.1	-78.9	-2.7
1.07	313.09	312.02	5.63	5.63	5.63	2967.0	*	2787.1	-179.9	-6.1
1.10	312.95	311.85	5.63	5.63	5.63	3018.0	*	2827.9	-190.1	-6.3
1.01	312.92	311.91	5.72	5.72	5.72	2306.0	*	2751.0	445.0	19.3
.97	312.95	311.98	5.72	5.72	5.72	2380.0	*	2694.7	314.7	13.2
.96	313.00	312.04	5.72	5.72	5.72	2424.0	*	2680.1	256.1	10.6
.93	313.14	312.21	5.72	5.72	5.72	2479.0	*	2636.0	157.0	6.3
1.07	313.07	312.00	5.82	5.82	5.82	2472.0	*	2876.5	404.5	16.4
.95	312.92	311.97	5.91	5.91	5.91	2451.0	*	2750.4	299.4	12.2
.91	313.03	312.12	5.91	5.91	5.91	2502.0	*	2689.9	187.9	7.5
.97	313.38	312.41	6.00	6.00	6.00	2654.0	*	2818.4	164.4	6.2
.97	313.36	312.39	6.00	6.00	6.00	2665.0	*	2818.6	153.6	5.8
1.07	312.55	311.48	6.10	6.10	6.10	3147.0	*	3017.3	-129.7	-4.1
.94	313.10	312.16	6.48	6.48	6.48	2714.0	*	2992.1	278.1	10.2
.96	313.07	312.11	6.48	6.48	6.48	2763.0	*	3024.6	261.6	9.5
.95	313.44	312.49	6.57	6.57	6.57	2819.0	*	3048.2	229.2	8.1
.95	313.51	312.56	6.57	6.57	6.57	2835.0	*	3047.5	212.5	7.5
1.09	312.60	311.51	6.76	6.76	6.76	3433.0	*	3372.6	-60.4	-1.8
.92	313.24	312.32	7.05	7.05	7.05	2966.0	*	3214.6	248.6	8.4
.82	313.20	312.38	7.15	7.15	7.15	2994.0	*	3073.2	79.2	2.6
.84	313.14	312.30	7.15	7.15	7.15	2997.0	*	3111.6	114.6	3.8
.97	312.78	311.81	7.24	7.24	7.24	3053.0	*	3396.1	343.1	11.2
.98	312.78	311.80	7.34	7.34	7.34	3205.0	*	3458.2	253.2	7.9
.83	313.09	312.26	7.44	7.44	7.44	3064.0	*	3215.3	151.3	4.9
.82	313.11	312.29	7.44	7.44	7.44	3099.0	*	3195.4	96.4	3.1
.81	313.15	312.34	7.44	7.44	7.44	3133.0	*	3175.1	42.1	1.3
.95	313.60	312.65	7.53	7.53	7.53	3143.0	*	3480.1	337.1	10.7
.81	313.19	312.38	7.53	7.53	7.53	3157.0	*	3214.7	57.7	1.8
.80	313.21	312.41	7.53	7.53	7.53	3169.0	*	3194.3	25.3	.8
.90	313.61	312.71	7.53	7.53	7.53	3205.0	*	3385.8	180.8	5.6
.91	313.65	312.74	7.53	7.53	7.53	3284.0	*	3404.4	120.4	3.7
.81	313.10	312.29	7.63	7.63	7.63	3207.0	*	3256.2	49.2	1.5
.96	312.79	311.83	7.63	7.63	7.63	3224.0	*	3553.5	329.5	10.2
1.09	312.87	311.78	7.63	7.63	7.63	3932.0	*	3789.3	-142.7	-3.6
.87	313.37	312.50	7.73	7.73	7.73	3194.0	*	3414.1	220.1	6.9
1.05	312.65	311.60	7.73	7.73	7.73	3763.0	*	3772.9	9.9	.3
1.04	313.26	312.22	7.83	7.83	7.83	4024.0	*	3784.8	-239.2	-5.9
.78	312.72	311.94	8.02	8.02	8.02	3338.0	*	3360.0	22.0	.7
1.00	312.35	311.35	8.02	8.02	8.02	4181.0	*	3854.8	-326.2	-7.8
1.05	312.58	311.53	8.12	8.12	8.12	4290.0	*	3985.6	-304.4	-7.1
.70	312.55	311.85	8.22	8.22	8.22	3199.0	*	3277.6	78.6	2.5
.76	313.44	312.68	8.22	8.22	8.22	3214.0	*	3381.7	167.7	5.2
.70	312.78	312.08	8.22	8.22	8.22	3222.0	*	3258.3	36.3	1.1
.75	313.17	312.42	8.22	8.22	8.22	3229.0	*	3362.7	133.7	4.1
.68	313.02	312.34	8.22	8.22	8.22	3258.0	*	3202.6	-55.4	-1.7
.72	313.06	312.34	8.22	8.22	8.22	3281.0	*	3295.8	14.8	.4
.72	312.79	312.07	8.22	8.22	8.22	3343.0	*	3305.2	-37.8	-1.1
.62	312.64	312.02	8.22	8.22	8.22	3356.0	*	3072.0	-284.0	-8.5
.67	312.31	311.64	8.31	8.31	8.31	3343.0	*	3267.2	-75.8	-2.3
.76	312.87	312.11	8.31	8.31	8.31	3393.0	*	3436.9	43.9	1.3
.68	312.61	311.93	8.31	8.31	8.31	3403.0	*	3267.1	-135.9	-4.0
.74	313.06	312.32	8.31	8.31	8.31	3446.0	*	3380.1	-65.9	-1.9
.81	313.19	312.38	8.31	8.31	8.31	3474.0	*	3536.1	62.1	1.8
.78	313.22	312.44	8.31	8.31	8.31	3507.0	*	3468.7	-38.3	-1.1
.80	312.98	312.18	8.41	8.41	8.41	3432.0	*	3566.0	134.0	3.9
.69	312.95	312.26	8.41	8.41	8.41	3454.0	*	3306.0	-148.0	-4.3

FIELD VERIFICATION TESTS
CANAL RADIAL GATES - DISCHARGE ALGORITHMS
CALIFORNIA AQUEDUCT CHECK NO. 21

FIELD DATA FROM CALIFORNIA AQUEDUCT CHECK NO. 21   COMPUTED DATA
FURNISHED BY STATE OF CALIF. DWR 7/16/81 (FILE FT08F001 A)

HEAD DIFF. FT.	WATER SURFACE ELEV. UPSTREAM FT.	DOWNSTREAM FT.	GATE OPENINGS 1/ NO.1 FT.	NO.2 FT.	NO.3 FT.	TOTAL DISCH. BY AVM FT3/S	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO. - AVM) FT3/S	DIFFERENCE PERCENT
.66	313.06	312.40	8.51	8.51	8.51	3361.0	3263.9	-97.1	-2.9
.76	313.11	312.35	8.51	8.51	8.51	3396.0	3506.4	110.4	3.2
.68	313.58	312.90	8.51	8.51	8.51	3416.0	3305.7	-110.3	-3.2
.67	313.30	312.63	8.51	8.51	8.51	3421.0	3284.7	-136.3	-4.0
.71	313.74	313.03	8.51	8.51	8.51	3456.0	3376.4	-79.6	-2.3
.83	313.27	312.44	8.51	8.51	8.51	3507.0	3660.0	153.0	4.4
.75	313.39	312.64	8.61	8.61	8.61	3332.0	3514.3	182.3	5.5
.74	313.22	312.48	8.61	8.61	8.61	3335.0	3493.2	158.2	4.7
.96	312.90	311.94	8.61	8.61	8.61	4105.0	4025.7	-79.3	-1.9
.88	313.14	312.26	8.91	8.91	8.91	4001.0	3972.0	-29.0	-.7
.90	313.18	312.28	8.91	8.91	8.91	4066.0	4014.6	-51.4	-1.3
.67	313.31	312.64	9.00	9.00	9.00	3686.0	3481.3	-204.7	-5.6
.91	313.11	312.20	9.00	9.00	9.00	3747.0	4092.4	345.4	9.2
.61	313.08	312.47	9.20	9.20	9.20	3359.0	3419.7	60.7	1.8
.79	313.25	312.46	9.30	9.30	9.30	3924.0	3931.4	7.4	.2
.84	313.29	312.45	9.40	9.40	9.40	4129.0	4100.0	-29.0	-.7
.84	313.30	312.46	9.40	9.40	9.40	4163.0	4099.2	-63.8	-1.5
.85	313.23	312.38	9.40	9.40	9.40	4201.0	4130.2	-70.8	-1.7
.80	313.34	312.54	9.40	9.40	9.40	4230.0	3994.9	-235.1	-5.6
.73	312.98	312.25	9.50	9.50	9.50	3782.0	3888.1	106.1	2.8
.84	313.71	312.87	9.50	9.50	9.50	3940.0	4109.8	169.8	4.3
.78	313.74	312.96	9.80	9.80	9.80	3811.0	4090.8	279.8	7.3
.73	313.61	312.88	9.80	9.80	9.80	3833.0	3966.5	133.5	3.5
.83	313.42	312.59	9.80	9.80	9.80	4379.0	4250.7	-128.3	-2.9
.85	313.44	312.59	9.80	9.80	9.80	4454.0	4300.8	-153.2	-3.4
.76	313.05	312.29	10.30	10.30	10.30	4137.0	4322.6	185.6	4.5
.74	313.25	312.51	10.30	10.30	10.30	4171.0	4248.4	77.4	1.9
.81	313.69	312.88	10.30	10.30	10.30	4316.0	4406.7	90.7	2.1
.78	313.68	312.90	10.30	10.30	10.30	4382.0	4324.5	-57.5	-1.3
.70	312.94	312.24	10.40	10.40	10.40	4113.0	4201.5	88.5	2.2
.71	313.29	312.58	10.40	10.40	10.40	4167.0	4201.6	34.6	.8
.74	313.22	312.48	10.40	10.40	10.40	4197.0	4295.4	98.4	2.3
.78	313.09	312.31	10.50	10.50	10.50	4117.0	4466.7	349.7	8.5
.75	313.25	312.50	10.81	10.81	10.81	4389.0	4500.9	111.9	2.5
.77	313.16	312.39	10.91	10.91	10.91	4401.0	4613.0	212.0	4.8
.73	313.25	312.52	10.91	10.91	10.91	4581.0	4485.5	-95.5	-2.1
.74	313.16	312.42	11.01	11.01	11.01	4450.0	4567.9	117.9	2.6
.66	312.94	312.28	11.11	11.11	11.11	4415.0	4377.3	-37.7	-.9
.80	313.39	312.59	11.11	11.11	11.11	4828.0	4773.8	-54.2	-1.1
.71	313.27	312.56	11.32	11.32	11.32	4577.0	4597.5	20.5	.4
.71	313.38	312.67	11.32	11.32	11.32	4630.0	4588.4	-41.6	-.9
.72	313.27	312.55	11.52	11.52	11.52	4729.0	4717.2	-11.8	-.2
.73	313.28	312.55	11.52	11.52	11.52	4733.0	4748.5	15.5	.3
.72	313.26	312.54	11.52	11.52	11.52	4753.0	4718.0	-35.0	-.7
.66	312.97	312.31	11.83	11.83	11.83	4603.0	4670.7	67.7	1.5
.77	313.34	312.57	11.83	11.83	11.83	5058.0	5005.4	-52.6	-1.0
.76	313.37	312.61	11.83	11.83	11.83	5086.0	4970.9	-115.1	-2.3
.75	313.37	312.62	11.83	11.83	11.83	5090.0	4938.8	-151.2	-3.0
.74	312.74	312.00	12.13	12.13	12.13	4858.0	5089.8	231.8	4.8
.79	313.55	312.76	12.44	12.44	12.44	4813.0	5325.9	512.9	10.7
.68	313.21	312.53	12.44	12.44	12.44	4947.0	4977.0	30.0	.6
.74	313.92	313.18	12.55	12.55	12.55	5068.0	5173.5	105.5	2.1
.70	313.58	312.88	12.65	12.65	12.65	5319.0	5105.4	-213.6	-4.0
.69	313.57	312.88	12.65	12.65	12.65	5381.0	5070.6	-310.4	-5.8
.58	312.82	312.24	13.06	13.06	13.06	5082.0	4875.5	-206.5	-4.1
.58	312.89	312.31	13.06	13.06	13.06	5163.0	4870.4	-292.6	-5.7
.64	312.98	312.34	13.17	13.17	13.17	5036.0	5141.0	105.0	2.1
.52	313.16	312.64	13.27	13.27	13.27	4834.0	4679.9	-154.1	-3.2
.53	313.30	312.77	13.27	13.27	13.27	4986.0	4713.0	-273.0	-5.5
.60	313.27	312.67	13.38	13.38	13.38	5185.0	5044.5	-140.5	-2.7
.62	313.28	312.66	13.38	13.38	13.38	5216.0	5123.4	-92.6	-1.8
.61	313.27	312.66	13.58	13.58	13.58	5212.0	5166.1	-45.9	-.9
.60	313.10	312.50	13.69	13.69	13.69	5202.0	5177.6	-24.4	-.5
.58	313.14	312.56	13.90	13.90	13.90	5230.0	5171.2	-58.8	-1.1
.58	313.38	312.80	13.90	13.90	13.90	5305.0	5154.8	-150.2	-2.8
.60	312.95	312.35	14.21	14.21	14.21	5435.0	5389.3	-45.7	-.8
.66	313.38	312.72	14.32	14.32	14.32	5248.0	5652.1	404.1	7.7
.64	313.20	312.56	14.32	14.32	14.32	5315.0	5582.1	267.1	5.0
.56	313.38	312.82	14.74	14.74	14.74	5540.0	5383.4	-156.6	-2.8
.71	313.91	313.20	14.74	14.74	14.74	5589.0	5992.0	403.0	7.2
.65	314.15	313.50	14.74	14.74	14.74	5681.0	5728.6	47.6	.8
.44	312.66	312.22	15.26	15.26	15.26	5416.0	5018.7	-397.3	-7.3
.63	313.41	312.78	15.69	15.69	15.69	5586.0	6065.4	479.4	8.6
.57	313.23	312.66	16.75	16.75	16.75	5860.0	6194.3	334.3	5.7
.60	313.51	312.91	17.39	17.39	17.39	6020.0	6580.7	560.7	9.3
.45	313.34	312.89	17.82	17.82	17.82	6156.0	5899.5	-256.5	-4.2
.38	313.24	312.86	18.90	18.90	18.90	6500.0	5794.2	-705.8	-10.9
.56	312.96	312.40	19.01	19.01	19.01	6116.0	7013.5	897.5	14.7
.51	313.45	312.94	19.01	19.01	19.01	6505.0	6690.9	185.9	2.9
.47	313.01	312.54	19.22	19.22	19.22	6561.0	6532.7	-28.3	-.4
.48	313.35	312.87	19.44	19.44	19.44	6203.0	6664.6	461.6	7.4
.43	313.56	313.13	19.76	19.76	19.76	6579.0	6434.0	-145.0	-2.2
.47	313.57	313.10	22.92	22.92	22.92	7386.0	7999.3	613.3	8.3
.28	313.34	313.06	24.12	24.12	24.12	6769.0	6599.7	-169.3	-2.5

1/ Adjusted gate openings (refer to the text).

NUMBER OF DATA POINTS = 201
AVERAGE DIFFERENCE (ACTUAL) = 38.6
AVERAGE DIFFERENCE (PERCENT)= 1.3
STANDARD DEVIATION (ACTUAL) = 201.5
STANDARD DEVIATION (PERCENT)= 6.1

If the gate opening, GOA, is less than or equal to 6.0 ft:

$$DNK = 0.5*GOA + 4.0$$

If the gate opening, GOA, is greater than 6.0 ft:

$$DNK = 8.6-0.27*GOA$$

where:

GOA = adjusted gate opening (ft), table III-9
DNK = downstream transition loss coefficient

The energy loss coefficient is nonlinear and expressed as a function of the adjusted gate opening, GOA. The nonlinear energy loss coefficient is represented by two linear equations with the breaking point at GOA = 6.0 ft. The energy loss of the downstream transition is presented in this analysis in terms of the change in the velocity head, and the head loss is:

$$HL = (VH3-VH4)*DNK$$

where:

VH3 = velocity head at the beginning of the downstream transition
VH4 = velocity head at the end of the downstream transition

The results of the comparison of the algorithm-predicted discharge to the field acoustic velocity water measurement of discharge shown in table III-9 are disguised by the techniques used to correct the nonlinear gate opening data and the downstream energy loss. The correct procedure would be to calibrate the gate opening by field measurements and to measure the transition loss in the field with water surface level gages as a function of discharge. These data, however, could not be obtained in a short period of time for inclusion in this report.

The results again indicate that adjustments based on field data available can be made to predict the discharge accurately by the algorithms. In the analysis of the California Aqueduct No. 21 check structure, the overall average for 201 test data points resulted in a +1.3 percent difference, biased in the positive direction. The standard deviation of ±6.1 percent indicates a rather large spread in the comparisons. It is believed that the large spread is caused by the coarseness of the gate opening resolution of 0.1 ft for each of the three gates, the nonlinearity of the measured gate opening, and the downstream transition energy loss.

Putah South Canal Headworks

The Putah South Canal headworks is the first check structure at the beginning of the Putah South Canal system. It is located about 72 km (45 mi) west and north of Sacramento, California. This check structure was included in the field verification test program because an excellent 6.10-m (20-ft) wide modified Parshall flume that measures the total discharge with good accuracy is located 230 m (754 ft) downstream. However, the site has many additional losses that must be included in the upstream and downstream energy balance equations to obtain the correct water depths for the discharge algorithms.

The upstream water surface elevation is measured in Solano Lake. The entrance to the Putah South Canal headworks is from Solano Lake through a 22.9-m (75-ft) wide fish screen consisting of 4.76-mm (0.0156-ft) wide metal bars spaced at 23.81 mm (0.0781 ft) center to center. Head loss through the fish screen is extremely variable depending upon weed, moss, and debris buildup and its removal. The upstream transition to the two-radial-gate check structure has vertical concrete sides and changes in bottom width from 22.9 m (75 ft) at the fish screen to 6.50 m (21.33 ft) at the rectangular gate section. The invert rises 1.52 m (5.0 ft) in a distance of 25 m (82.0 ft).

The invert is covered with a layer of 0.15-m (0.5-ft) diameter riprap; therefore, the upstream transition would appear to have a higher than normal energy loss. The downstream transition begins with a bottom width of 6.50 m (21.33 ft) at the rectangular gate section and ends with a trapezoidal section having a bottom width of 3.66 m (12.0 ft) and side slopes of 1.5 to 1.0. The downstream transition invert drops 0.78 m (2.55 ft) in a distance of 9.75 m (32.0 ft). It was anticipated that the energy loss of the downstream transition would be extraordinarily high because of the drop in the invert, based on the experiences at the Tehama-Colusa Canal check No. 2 and California Aqueduct check No. 21.

A special field test was conducted at the Putah South Canal headworks on July 17, 1981, to make field measurements of all sources of energy losses from the upstream to the downstream water surface elevation measurement locations. The fish screen energy loss coefficient expressed in terms of siphon coefficient, SYFON, was measured to be 0.000000319. The inlet transition energy loss coefficient, UPK, expressed in terms of the change in velocity head was measured to be 0.23, which is near the value of 0.2 normally used for inlet transitions. The downstream transition energy loss coefficient expressed in terms of the siphon coefficient, SYFON, was measured to be 0.000001010,
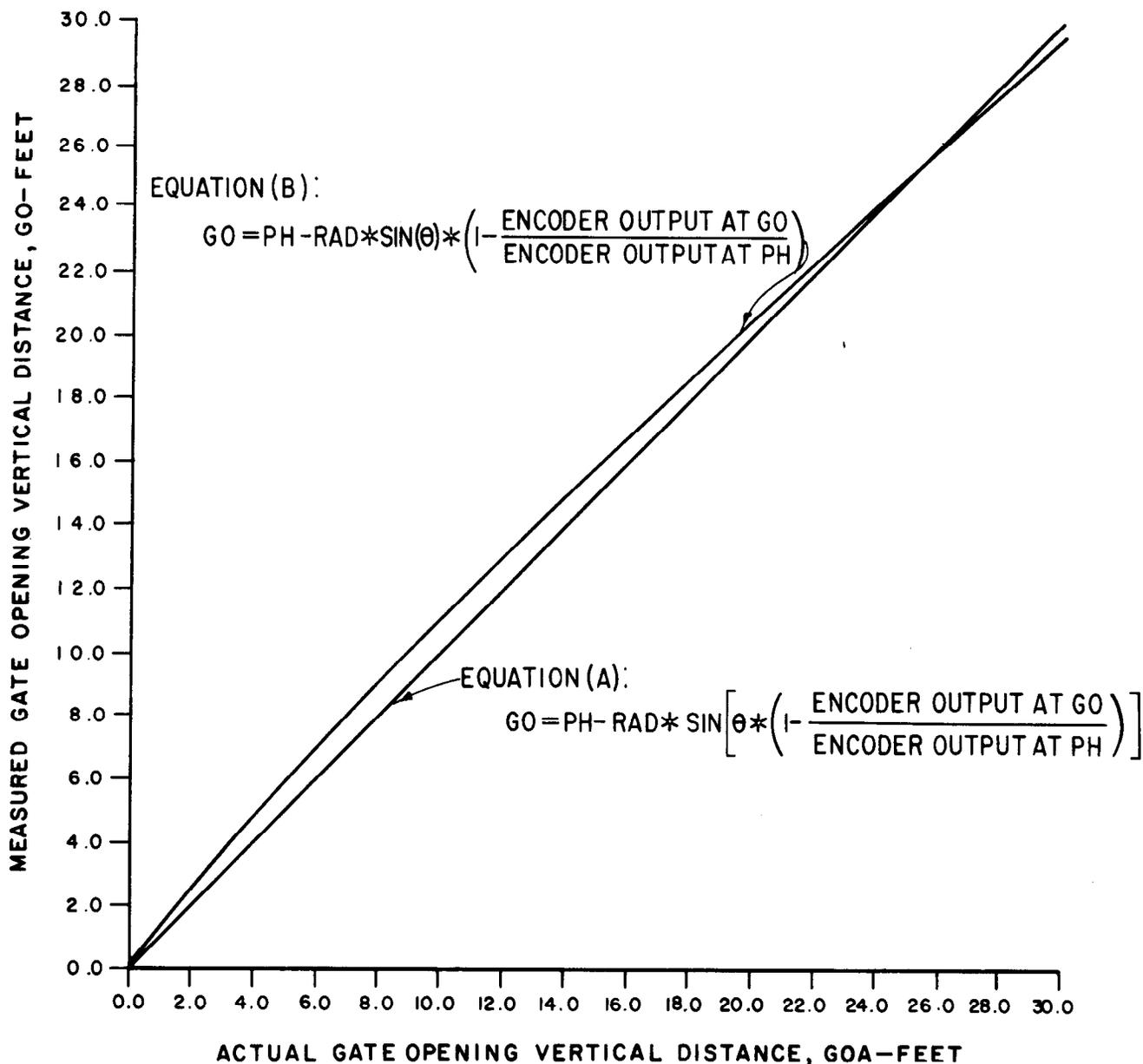
Figure III-45.—Relationship of the two equation forms used to convert the angular motion of the radial gate arm to the actual gate opening, GOA, for California Aqueduct check No. 21.

which was about 10 times higher than anticipated. The special field test measurements confirm that transitions downstream of the check gate structure having a significant drop in the invert act as miniature plunge basins. The head loss is high relative to the normal transition design [which have 30 mm (0.1 ft) or less drop in the invert] and must be included in the downstream energy balance equations in order to achieve accuracy of the algorithm-predicted discharge. When it is anticipated the energy loss is significant, the proper procedure is to obtain accurate field measurements of the head loss as a function of the discharge.

Using the field measurements of energy loss obtained during the special field test of July 17, 1981, the comparison of the algorithm-predicted to the Parshall-flume measurement of discharge for four test data points is shown in table III-10. The error of the special field test is +1.5 percent and it is in the same positive direction and magnitude as the other three special field tests; i.e., +2.2 percent at the Coalinga Canal No. 1 test of July 15, 1981, and +2.9 and +1.3 percent at the velocity barrier tests of February 12 and 13, 1980. The average of the four special field test errors is +2.0 percent. As mentioned previously, it appears the velocity barrier gaging station is

137

Table III-10.—*Field verification tests for Putah South Canal headworks.*

FIELD VERIFICATION TESTS
CANAL RADIAL GATES - DISCHARGE ALGORITHMS
PUTAH SOUTH CANAL HEADWORKS

	FIELD DATA FROM PUTAH SOUTH CANAL HEADWORKS						*	COMPUTED DATA		
DATE	WATER SURFACE ELEV.		GATE OPENINGS			TOTAL DISCH.	*	TOTAL DISCH.	DIFFERENCE	DIFFERENCE
	UPSTREAM FT.	DOWNSTREAM FT.	NO.1 FT.	NO.2 FT.	NO.3 FT.	BY CMM FT3/S	*	BY ALGORITHM FT3/S	(ALGO. - CMM) FT3/S	PERCENT
11/11/80	130.30	126.03	.33	.33		90.1	*	95.2	5.1	5.7
10/14/80	130.11	126.93	.84	.84		202.3	*	207.7	5.4	2.7
8/25/80	130.88	128.66	2.41	2.41		500.2	*	479.7	-20.5	-4.1
7/17/81*	130.91	129.27	4.17	4.23		662.4	*	672.1	9.7	1.5

* Special field test (refer to text).

NUMBER OF DATA POINTS =   4
AVERAGE DIFFERENCE (ACTUAL) =   -.1
AVERAGE DIFFERENCE (PERCENT)=   1.4
STANDARD DEVIATION (ACTUAL) =   13.8
STANDARD DEVIATION (PERCENT)=   4.4

registering a low discharge, causing the algorithms to predict discharges in the positive direction. Therefore, the average error indication of +2.0 percent or less gives a good indication of the potential accuracy of the discharge algorithms. Again, the number of radial gates involved does not affect the accuracy since check structures having one, two, and three radial gates were involved in the special field tests.

Table III-10 shows an overall average difference of +1.4 percent of the four test data points at the Putah South Canal headworks. The standard deviation is ±4.4 percent, indicating a moderate spread of the data. However, the same energy loss coefficients derived from the special field test of July 17, 1981, were used for the other three test data points which are of different discharges. A wider spread of the data was expected since the relationship of the energy loss coefficients as a function of discharge was not defined. The analysis demonstrates the importance of knowing the relationship. Also, the upstream water level should not be measured upstream of a fish screen or trashrack because of the extreme variation in the head loss characteristics caused by debris buildup and its removal.

West Canal Headworks Before 1974

The headworks of the West Canal is one of two diversion check structures at the end of the Columbia Basin Project's Main Canal. The end of the Main Canal, is usually referred to as the bifurcation structure, supplies irrigation water to the Columbia Basin Project and is located about 18 km (11 mi) northeast of Ephrata, Washington. The other diversion check structure is the East Low Canal headworks and it will be discussed in the next section. The centerline of the West Canal headworks is in line with the Main Canal; whereas the East Low Canal headworks centerline is perpendicular to the Main Canal.

The West Canal headworks is considered to be a very typical canal structure, having three radial gates with a radius-to-pinion-height ratio of 1.668 and a maximum flow capacity of 144.4 m³/s (5100 ft³/s). The only atypical feature may be the significant rise in the invert of the upstream transition of 1.24 m (4.07 ft) in a distance of 7.6 m (25 ft). However, experience gained from the Putah South Canal headworks special field test of July 17, 1981, indicates that significant variations in upstream transitions do not significantly increase the energy loss. Therefore, the normal value of 0.2 was used for the energy loss coefficient, UPK (in terms of the change in velocity head), to obtain an estimated head loss for the West Canal headworks upstream transition.

The three radial gates of the West Canal headworks were constructed with the music note gate lip seal design, figure 10b. In 1974, all of the music note seals were replaced by the hard-rubber-bar design, figure 10a. However, the gate faceplate angle leg extension dowstream, figure 10b, item L, was not removed. Therefore, the present gate lip seal configuration is a combination of the music note and hard-rubber-bar designs.

Fortunately, a considerable amount of historical data is available from before and after the gate lip design change was made in 1974. The data prior to 1974 give the opportunity to analyze the effects the critical variable gate lip seal design (hard-rubber-bar versus the music note design) has on the flow characteristics for canal radial gates. The data after 1974 allow the development of a correction algorithm for a different gate lip seal design configuration than was used in the Hydraulic Laboratory model studies. The gate lip seal modification will again demonstrate that significant changes in flow characteristics occur

138

when only what may seem to be minor changes in the gate lip seal are made.

The field data before 1974 were furnished in the form of a rating chart dated March 10, 1969. The chart tabulates the head differential versus the discharge for selected gate openings. The discharge for each tabulated head differential at the selected gate opening is calculated using the orifice equation. The coefficient of discharge, CD, is an average value for the range of head differential for the selected gate opening and was developed from many field measurements. The general equation used is:

$$Q = "C"*GO*\sqrt{\Delta H}$$

where:

Q = total discharge

"C" = CD*GW $\sqrt{2*GC}$

CD = average coefficient of discharge as a function of gate opening

GW = total width of the three radial gates

GC = gravitation constant

GO = average gate opening of the three radial gates

ΔH = head differential between the upstream and downstream water level measurements

To analyze the comparison of the algorithm-predicted discharges to March 10, 1969, rating chart discharges, 35 test data points were selected, consisting of the head differential, gate opening, and the total discharge, and tabulated in the field data section of table III-11. The table indicates that the total discharge is by current meter measurement, "BY CMM." As discussed above, the current meter measurements were used to develop the average coefficient of discharge, CD, and the discharges tabulated in the March 10, 1969, chart were calculated using the orifice equation based on the average coefficient of discharge for a range of head differentials at selected gate openings. Therefore, the total discharge tabulated in table III-11 was obtained indirectly from current water measurements.

Because the rating chart of March 10, 1969, provided only the head differential, it was first necessary to obtain the equivalent upstream and downstream water surface elevations before the discharge algorithms could be applied. The tabulation of the downstream water surface elevations in table III-11 was obtained from figure III-46, which is a rating curve of the West Canal headworks downstream water surface elevation, as a function of the field measurement of discharge. Figure III-46 was developed from the field data of September 2, 1981, table III-12. The upstream water surface elevation then was obtained by adding the head differential to the downstream water surface elevation. It was anticipated that the procedure used to obtain the upstream and downstream water surface elevations would increase the "spread" of the difference between the algorithm-predicted discharge and the March 10, 1969, rating table discharge. However, the overall average difference should not be biased and should give reasonably accurate results of the West Canal headworks field verification test for flow conditions prior to 1974.

Once the field data tabulation of table III-11 was established, three different computer data outputs predicting the discharge by algorithms using the field data before 1974 were obtained: (1) no correction is made for the music note gate lip seal design, (2) correction is made using an algorithm developed from the hydraulic laboratory model studies, and (3) correction is made using a similar algorithm that is developed from the field data before 1974 and from the output of the No. 1 computed data.

The coefficient of discharge calculated by the discharge algorithms (which are based on the hard-rubber-bar design and developed from the hydraulic laboratory single radial gate model studies) is multiplied by the correction factor, CSCDA, to obtain the adjustment for the music note gate lip seal design. The No. 1 computed data output, table III-11, assumes a hard-rubber-bar gate lip seal design; i.e., the correction factor, CSCDA, for the music note design is equal to unity. The overall average difference, or error, is +4.9 percent and is severely biased in the positive direction. Therefore, the coefficient of discharge for the music note design, on the average, should be smaller than the coefficient of discharge for the hard-rubber-bar design. However, observe that the average error for the first three small discharges is +12.7 percent and the average error for the three largest discharges is −7.8 percent. The coefficient of discharge for the music note seal is actually very much smaller at the low discharges or small gate openings and is actually larger at the larger discharges or gate openings as compared to the hard-rubber-bar seal design.

The same relationship observed from the No. 1 computed data was experienced in the hydraulic laboratory model studies, figure 29. From the laboratory studies, an algorithm was developed representing the average correction for the music note seal design for all of the laboratory data which included the model No's. 4, 5, and 6 with the music note gate lip seal at three different gate-arm-radius-to-pinion-height ratios,

139

RAD/PH, of 1.373, 1.521, and 1.715. The laboratory data music note correction algorithm for submerged flow conditions is as follows:

$$CSCDA = 0.125*GOPH+0.88$$

(laboratory data, fig. 29)

where:

CSCDA = the music note gate lip seal correction fator for submerged flow conditions, and is multiplied by the coefficient of discharge, SCDA, obtained by the discharge algorithms based on the hard-rubber-bar gate lip seal design

GOPH = ratio of the gate opening to the pinion height

The laboratory data algorithm is linear and is a function of the gate opening. It produces a smaller coefficient of discharge at the smaller gate openings. However, a correction factor larger than 1.0 does not occur until GOPH is greater than unity, or when the gate is near the maximum opening. The laboratory music note correction factor algorithm was applied to the field data of the West Canal headworks and the results are tabulated as the No. 2 computed data, table III-11.

Results of the No. 2 computed data output show that the average difference is now –4.3 percent as compared to the +4.9 percent when the correction factor was unity in the No. 1 computed data output. The average difference is severely biased in the negative direction and is a complete reversal from the No. 1 computed data results. The average error for the first three lowest discharges is now –0.5 percent and the average error for the last three largest discharges is now –11.9 percent as compared to +12.7 and –7.8 percent, respectively, from the No. 1 computed data. The laboratory data algorithm has produced close agreement for the low discharge range; however, the agreement is more biased in the negative direction for the high discharge range. The conclusion is that the laboratory data algorithm does not adequately represent the music note gate lip seal design of the prototype at the higher discharges or the larger gate openings. As discussed in the laboratory model data comparison section of this report, the data collected for the models representing the scaled 1:6 music note design were minimal and the range of flow conditions were not represented adequately.

Using the field data and the No. 1 computed data output, table III-11, the necessary correction factor was calculated and plotted versus the ratio of GO/PH in figure III-47. Comparing the laboratory data algorithm with the plotted data points indicates that reasonable agreement does occur at the lower gate openings. At the higher gate openings, there is a significant disagreement as compared to the estimated straight line fit of the data points. The algorithm based on field data before 1974 representing the estimated straight line fit of the data points is:

$$CSCDA = 0.39*GOPH+0.85$$

(field data before 1974, Fig. III-47)

The field data algorithm before 1974 produces slightly smaller correction factors at the very low gate openings, where the ratio GO/PH is less than 0.1. Larger correction factors occur at larger ratios, and are more than 1.0 when the ratio is greater than 0.4, or about 40 percent gate opening.

The results of applying the field data algorithm are shown in the No. 3 computer data output, table III-11. The overall average difference is –0.6 percent. The average difference of the first three small discharges is –2.9 percent, and for the last three large discharges the average difference is –0.8 percent. The field data algorithm produces a small bias in the negative direction; however, the overall accuracy is considered to be very good.

The standard deviation of the field data algorithm from the No. 3 computer data shows a moderate spread of ±3.5 percent. However, as discussed previously, the field data discharges are based on an average coefficient of discharge for a range of head differential. It is believed the averaging technique to obtain a field discharge rating table produces the wider deviation when compared to the algorithm-predicted discharge, which considers the variations in the upstream and downstream water surface elevations.

West Canal Headworks After 1974

The data furnished for the West Canal headworks after 1974 by a rating table dated September 2, 1981, represent the flow characteristics of the present gate lip seal configuration, which is a combination of the music note and hard-rubber-bar designs. Field data shown in table III-12 are from actual current meter measurement notes. The total discharge "BY CMM" is the field measurement of the discharge by the current meter and not an indirect calculated value as developed for the March 10, 1961, rating chart prior to 1974. Analysis of the field data after 1974 demonstrates again that significant changes in the flow characteristics occur when the gate lip seal design is modified in what may appear to be only a minor change.

Table III-11.—*Field verification tests for West Canal headworks before 1974.*

FIELD VERIFICATION TESTS
CANAL RADIAL GATES - DISCHARGE ALGORITHMS
WEST CANAL BIFURCATION
Before 1974

FIELD DATA FROM WEST CANAL HEADWORKS RATING CHART OF 3/10/69							No. 1 COMPUTED DATA[1/]			No. 2 COMPUTED DATA[2/]			No. 3 COMPUTED DATA[3/]		
CHART HD. DIFF. FT.	WATER SURFACE ELEV. UPSTREAM FT.	DOWNSTREAM FT.	GATE OPENINGS NO.1 FT.	NO.2 FT.	NO.3 FT.	TOTAL DISCH. BY CMM FT3/S	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO. - CMM) FT3/S	DIFFERENCE PERCENT	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO. - CMM) FT3/S	DIFFERENCE PERCENT	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO. - CMM) FT3/S	DIFFERENCE PERCENT
2.00	1321.24	1319.24	.37	.37	.37	141.0	156.6	15.6	11.1	138.4	-2.6	-1.8	135.0	-6.0	-4.2
2.00	1321.27	1319.27	.50	.50	.50	194.0	213.2	19.2	9.9	188.7	-5.3	-2.7	184.7	-9.3	-4.8
3.50	1322.76	1319.26	.37	.37	.37	186.0	216.5	30.5	16.4	191.4	5.4	2.9	186.7	.7	.4
5.00	1324.29	1319.29	.37	.37	.37	223.0	265.7	42.7	19.2	234.9	11.9	5.3	229.1	6.1	2.7
2.30	1321.80	1319.50	1.15	1.15	1.15	508.0	549.0	41.0	8.1	490.4	-17.6	-3.5	487.9	-20.1	-4.0
3.90	1323.39	1319.49	.89	.89	.89	501.0	568.0	67.0	13.4	505.3	4.3	.9	499.5	-1.5	-.3
5.50	1324.99	1319.49	.76	.76	.76	502.0	584.6	82.6	16.4	519.2	17.2	3.4	511.5	9.5	1.9
8.00	1327.48	1319.48	.63	.63	.63	494.0	582.5	88.5	17.9	516.4	22.4	4.5	507.1	13.1	2.6
2.10	1322.06	1319.96	2.21	2.21	2.21	1010.0	1098.2	88.2	8.7	996.2	-13.8	-1.4	1016.1	6.1	.6
4.70	1324.65	1319.95	1.54	1.54	1.54	1000.0	1131.3	131.3	13.1	1014.6	14.6	1.5	1019.1	19.1	1.9
8.00	1328.02	1320.02	1.28	1.28	1.28	1060.0	1195.0	135.0	12.7	1067.6	7.6	.7	1065.5	5.5	.5
3.10	1323.12	1320.02	1.94	1.94	1.94	1060.0	1169.3	109.3	10.3	1055.3	-4.7	-.4	1070.0	10.0	.9
3.10	1323.67	1320.57	2.63	2.63	2.63	1500.0	1634.9	134.9	9.0	1489.0	-11.0	-.7	1533.4	33.4	2.2
4.60	1325.17	1320.57	2.21	2.21	2.21	1500.0	1654.4	154.4	10.3	1495.9	-4.1	-.3	1526.7	26.7	1.8
6.20	1326.77	1320.57	1.94	1.94	1.94	1500.0	1658.7	158.7	10.6	1493.5	-6.5	-.4	1514.8	14.8	1.0
8.00	1328.47	1320.47	1.67	1.67	1.67	1440.0	1575.0	135.0	9.4	1412.9	-27.1	-1.9	1423.7	-16.3	-1.1
2.30	1323.70	1321.40	3.91	3.91	3.91	2030.0	2154.7	124.7	6.1	1998.8	-31.2	-1.5	2110.0	80.0	3.9
4.90	1326.25	1321.35	2.77	2.77	2.77	2000.0	2151.0	151.0	7.6	1956.5	-43.5	-2.2	2023.1	23.1	1.2
8.00	1329.31	1321.31	2.21	2.21	2.21	1980.0	2070.7	90.7	4.6	1868.1	-111.9	-5.6	1907.4	-72.6	-3.7
3.50	1325.75	1322.25	3.91	3.91	3.91	2500.0	2619.7	119.7	4.8	2418.9	-81.1	-3.2	2561.8	61.8	2.5
5.00	1327.22	1322.22	3.33	3.33	3.33	2490.0	2597.0	107.0	4.3	2375.9	-114.1	-4.6	2488.7	-1.3	-.1
7.70	1329.95	1322.25	2.77	2.77	2.77	2500.0	2518.6	18.6	.7	2286.0	-214.0	-8.6	2365.4	-134.6	-5.4
2.20	1325.47	1323.27	5.70	5.70	5.70	3020.0	3120.4	100.4	3.3	2952.8	-67.2	-2.2	3216.0	196.0	6.5
5.00	1328.22	1323.22	3.91	3.91	3.91	2990.0	3008.2	18.2	.6	2769.2	-220.8	-7.4	2939.0	-51.0	-1.7
7.20	1330.42	1323.22	3.33	3.33	3.33	2990.0	2901.8	-88.2	-3.0	2650.5	-339.5	-11.4	2778.5	-211.5	-7.1
3.60	1327.88	1324.28	5.25	5.25	5.25	3500.0	3517.9	17.9	.5	3293.3	-206.7	-5.9	3588.7	88.7	2.5
5.00	1329.25	1324.25	4.50	4.50	4.50	3490.0	3412.5	-77.5	-2.2	3161.6	-328.4	-9.4	3399.6	-90.4	-2.6
6.80	1331.05	1324.25	3.91	3.91	3.91	3490.0	3277.3	-212.7	-6.1	3013.5	-476.5	-13.7	3200.8	-289.2	-8.3
4.70	1330.08	1325.38	5.25	5.25	5.25	4000.0	3832.8	-167.2	-4.2	3581.6	-418.4	-10.5	3912.3	-87.7	-2.2
3.40	1328.78	1325.38	6.00	6.00	6.00	4000.0	3874.0	-126.0	-3.2	3657.2	-342.8	-8.6	4043.1	43.1	1.1
6.10	1331.48	1325.38	4.65	4.65	4.65	4000.0	3697.4	-302.6	-7.6	3429.3	-570.7	-14.3	3701.6	-298.4	-7.5
3.50	1330.25	1326.75	6.60	6.60	6.60	4540.0	4226.6	-313.4	-6.9	4014.7	-525.3	-11.6	4492.6	-47.4	-1.0
4.60	1331.25	1326.65	5.85	5.85	5.85	4500.0	4150.0	-350.0	-7.8	3904.8	-595.2	-13.2	4316.8	-183.2	-4.1
2.80	1330.74	1327.94	7.95	7.95	7.95	4970.0	4633.7	-336.3	-6.8	4469.9	-500.1	-10.1	5105.9	135.9	2.7
3.20	1331.01	1327.81	7.35	7.35	7.35	4920.0	4491.4	-428.6	-8.7	4302.4	-617.6	-12.6	4876.0	-44.0	-.9

No. 1
NUMBER OF DATA POINTS = 35
AVERAGE DIFFERENCE (ACTUAL) = -6.3
AVERAGE DIFFERENCE (PERCENT)= 4.9
STANDARD DEVIATION (ACTUAL) = 168.1
STANDARD DEVIATION (PERCENT)= 9.6

1/ Assumes the music note gate lip seal design correction factor is equal to unity, CSCDA1=1.0.

No. 2
NUMBER OF DATA POINTS = 35
AVERAGE DIFFERENCE (ACTUAL) =-166.1
AVERAGE DIFFERENCE (PERCENT)= -4.3
STANDARD DEVIATION (ACTUAL) = 271.7
STANDARD DEVIATION (PERCENT)= 7.1

2/ Applies laboratory data algorithm for the music note gate lip seal design correction factor, CSCDA1=0.125*GOPH+0.88.

No. 3
NUMBER OF DATA POINTS = 35
AVERAGE DIFFERENCE (ACTUAL) = -22.6
AVERAGE DIFFERENCE (PERCENT)= -.6
STANDARD DEVIATION (ACTUAL) = 105.4
STANDARD DEVIATION (PERCENT)= 3.5

3/ Applies field data algorithm for music note gate lip seal design correction factor, CSCDA1=0.39*GOPH+0.85.
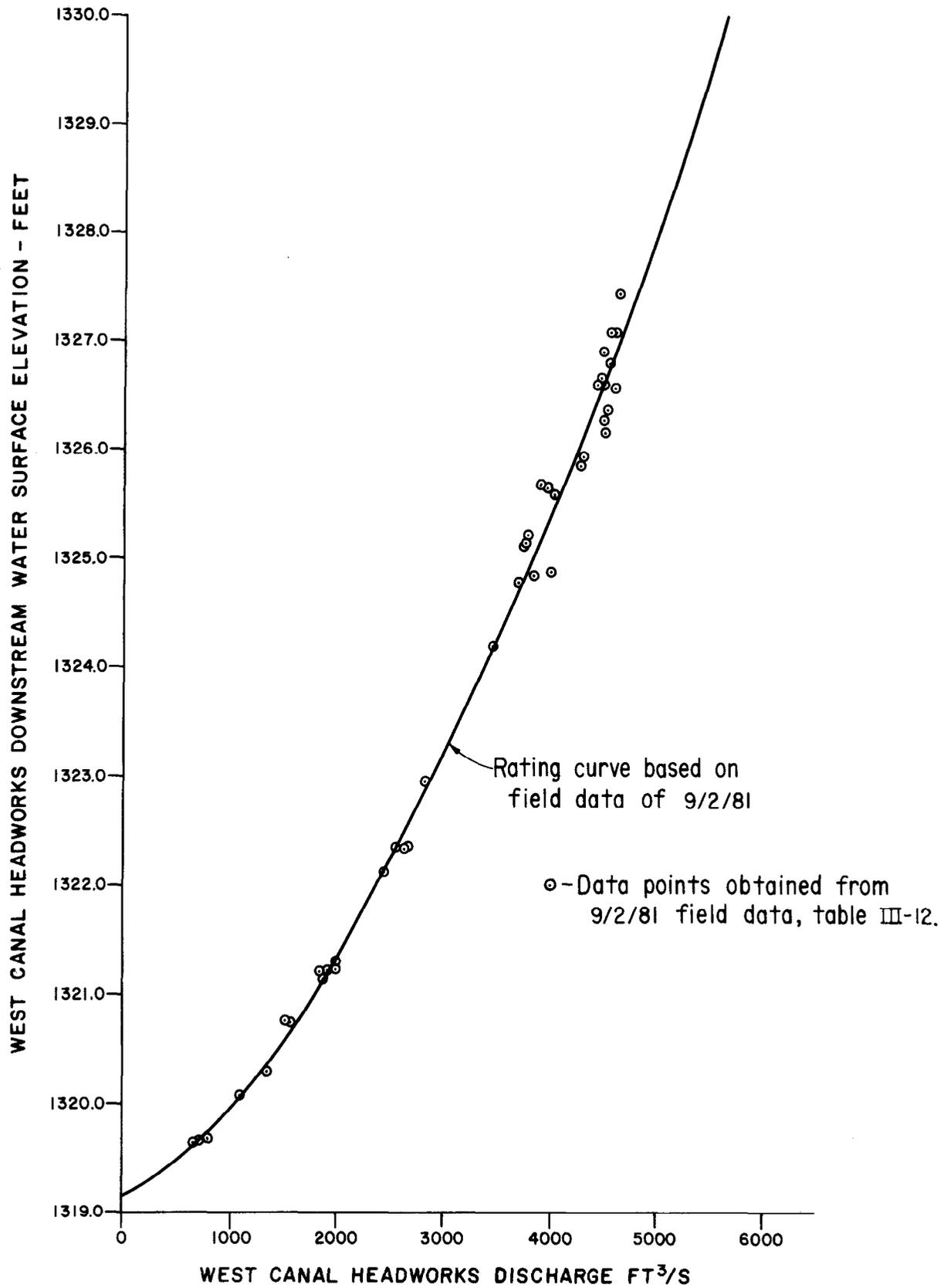
Figure III-46.—Downstream water surface elevation versus canal discharge rating curve for West Canal headworks.
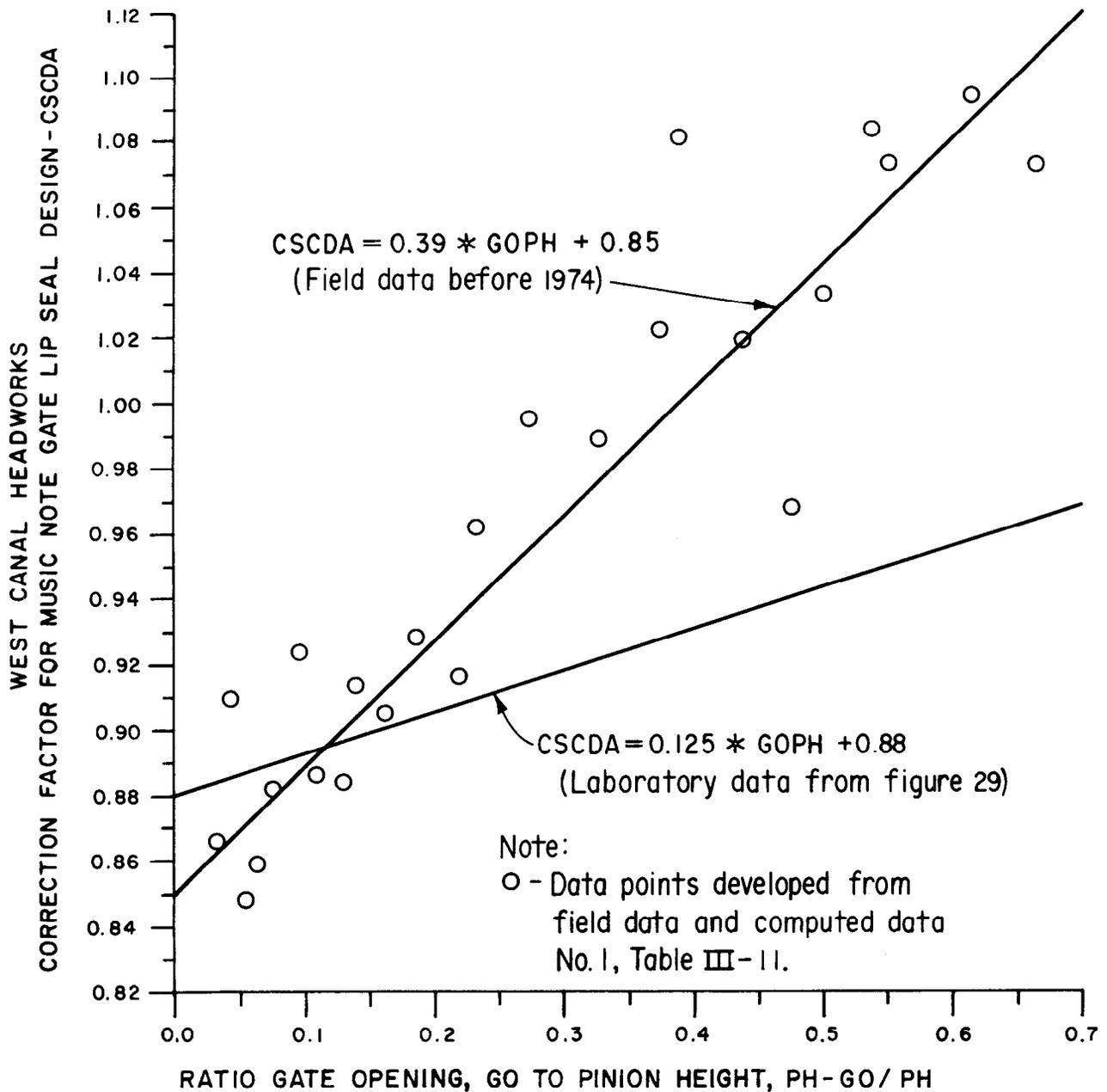
Figure III-47.—Correction factor, CSCDA, for the West Canal headworks music note gate lip seal versus the submerged flow gate opening, GO/PH, developed from field data before 1974 (table III-11).

Three different computer outputs predicting the discharge by algorithms were obtained, table III-12, using the field data after 1974: (1) no correction is made for the music note gate lip seal design, (2) correction is made using the field data before 1974 algorithm, and (3) correction is made using a hyperbolic algorithm that is developed from the field data after 1974 and from the output of the No. 4 computed data.

Observing the No. 4 computed data output, table III-12, which assumes no correction for the combined music note and hard-rubber-bar gate lip

seal, the overall average difference is +4.1 percent. The average error of the three smallest discharges is +12.4 percent and the average error of the three largest discharges is -9.5 percent. These results are similar to the results of No. 1 computed data output from the field data before 1974, table III-11, and appear to indicate that the combined music note/hard-rubber-bar gate lip seal requires the same correction factor as developed for the music note design. However, when the music note correction factor algorithm developed from the field data before 1974 is applied to

143
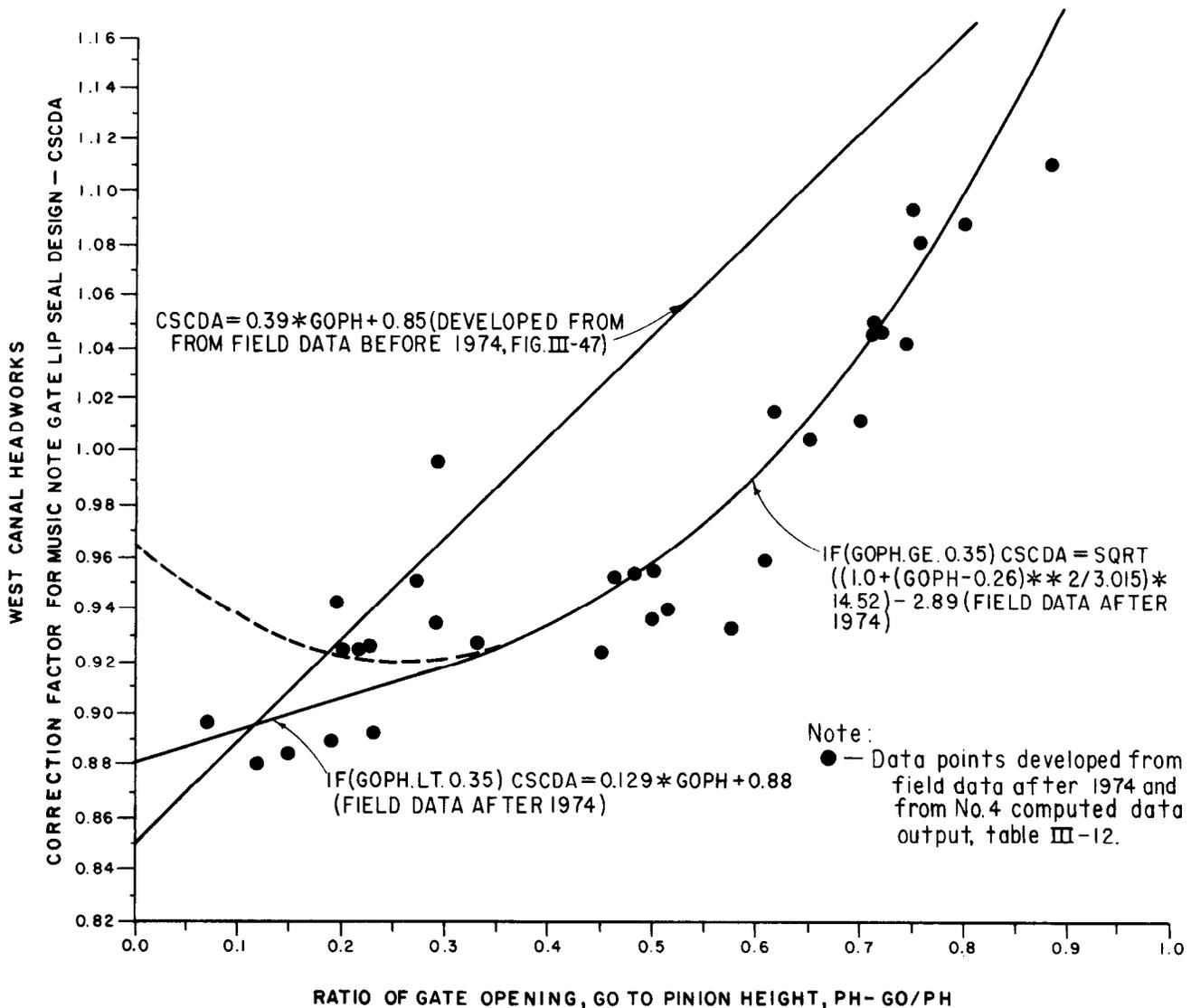
Figure III-48.—Correction factor, CSCDA, for the West Canal headworks combined music note/hard-rubber-bar gate lip seal versus the submerged flow gate opening, GO/PH, developed from field data after 1974 (table III-12).

the field data after 1974, which represents the present combined gate seal design, different results occur.

The No. 5 computed data output are the results of applying the field data before 1974 algorithm, which represents the correction required for the music note gate lip seal without modifications. The overall average difference is +4.9 percent and is still severely biased in the positive direction. The average of the three smallest discharges is –0.7 percent, and the average for the three largest discharges is +2.0 percent, which is a great improvement over the No. 4 computed data. However, the midrange of discharges is now heavily biased in the positive direction, which causes the average difference of the 48 test points to be biased in the positive direction.

An algorithm was developed to correct for the combined music note/hard-rubber-bar gate lip seal using the same procedure used to develop the algorithm for the music note without modifications. Figure III-48 is a plot of the correction factor versus the ratio of the gate-opening-to-pinion-height, GO/PH, based on the field data after 1974 and the output of the No. 4 computed data, table III-12. The combined music note/hard-rubber-bar gate lip seal shows a definite shift of the correction factor, CSCDA, in the midrange of discharges as compared to the music note design. The relationship with GO/PH is nonlinear compared to the field data before 1974 algorithm. Two algorithms were developed to best fit the correction factor for the field data after 1974. If the GO/PH ratio is less than 0.35, the

144

Table III-12.—*Field verification tests for West Canal headworks after 1974.*

FIELD VERIFICATION TESTS
CANAL RADIAL GATES - DISCHARGE ALGORITHMS
WEST CANAL BIFURCATION
After 1974

	FIELD DATA FROM WEST CANAL HEADWORKS RATING TABLE OF 9/ 2/81						No. 4 COMPUTED DATA 1/			No. 5 COMPUTED DATA 2/			No. 6 COMPUTED DATA 3/		
DATE	WATER SURFACE ELEV. UPSTREAM FT.	DOWNSTREAM FT.	GATE OPENINGS NO.1 FT.	NO.2 FT.	NO.3 FT.	TOTAL DISCH. BY CMM FT3/S	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO.-CMM) FT3/S	DIFFERENCE PERCENT	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO.-CMM) FT3/S	DIFFERENCE PERCENT	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO.-CMM) FT3/S	DIFFERENCE PERCENT
4/ 1/79	1327.53	1319.67	.85	.85	.85	702.0	782.9	80.9	11.5	687.2	-14.8	-2.1	696.2	-5.8	-.8
4/ 1/79	1327.54	1319.68	.85	.85	.85	702.0	782.5	80.5	11.5	686.8	-15.2	-2.2	695.8	-6.2	-.9
3/23/81	1327.01	1320.05	1.41	1.41	1.41	1094.0	1248.0	154.0	14.1	1118.1	24.1	2.2	1117.3	23.3	2.1
3/23/81	1327.03	1320.08	1.41	1.41	1.41	1101.0	1244.7	143.7	13.1	1115.2	14.2	1.3	1114.4	13.4	1.2
4/ 5/79	1326.60	1320.31	1.78	1.78	1.78	1359.0	1537.1	178.1	13.1	1395.9	36.9	2.7	1382.4	23.4	1.7
4/ 5/79	1326.61	1320.30	1.78	1.78	1.78	1363.0	1539.4	176.4	12.9	1398.0	35.0	2.6	1384.5	21.5	1.6
10/20/78	1326.25	1320.76	2.15	2.15	2.15	1538.0	1737.5	199.5	13.0	1598.7	60.7	3.9	1569.9	31.9	2.1
10/20/78	1326.22	1320.75	2.15	2.15	2.15	1560.0	1733.9	173.9	11.1	1595.4	35.4	2.3	1566.7	6.7	.4
10/ 3/80	1327.02	1321.21	2.41	2.41	2.41	1848.0	1996.7	148.7	8.0	1853.5	5.5	.3	1808.9	-39.1	-2.1
10/ 3/80	1327.04	1321.16	2.41	2.41	2.41	1860.0	2014.6	154.6	8.3	1870.0	10.0	.5	1825.0	-35.0	-1.9
9/14/78	1327.56	1321.22	2.35	2.35	2.35	1905.0	2025.3	120.3	6.3	1875.8	-29.2	-1.5	1833.0	-72.0	-3.8
9/14/78	1327.55	1321.22	2.35	2.35	2.35	1912.0	2024.5	112.5	5.9	1875.1	-36.9	-1.9	1832.3	-79.7	-4.2
4/ 9/81	1326.59	1321.15	2.56	2.56	2.56	1923.0	2088.3	165.3	8.6	1949.2	26.2	1.4	1895.8	-27.2	-1.4
4/ 9/81	1326.58	1321.14	2.56	2.56	2.56	1943.0	2089.5	146.5	7.5	1950.4	7.4	.4	1896.9	-46.1	-2.4
10/13/80	1326.83	1321.45	2.77	2.77	2.77	1988.0	2244.4	256.4	12.9	2110.1	122.1	6.1	2042.4	54.4	2.7
10/10/80	1326.80	1321.52	2.77	2.77	2.77	1994.0	2213.9	219.9	11.0	2081.6	87.6	4.4	2014.9	20.9	1.0
9/17/80	1327.14	1321.31	2.59	2.59	2.59	2007.0	2170.1	163.1	8.1	2027.0	20.0	1.0	1969.9	-37.1	-1.8
9/13/80	1327.27	1322.14	3.26	3.26	3.26	2447.0	2572.9	125.9	5.1	2459.6	12.6	.5	2354.6	-92.4	-3.8
9/11/80	1327.52	1322.37	3.45	3.45	3.45	2551.0	2732.3	181.3	7.1	2628.6	77.6	3.0	2505.5	-45.5	-1.8
9/11/80	1327.52	1322.36	3.45	3.45	3.45	2564.0	2736.5	172.5	6.7	2632.6	68.6	2.7	2509.3	-54.7	-2.1
9/ 2/81	1327.77	1322.97	3.98	3.98	3.98	2826.0	3051.9	225.9	8.0	2988.3	162.3	5.7	2815.9	-10.1	-.4
9/ 2/81	1327.78	1322.96	3.98	3.98	3.98	2828.0	3056.0	228.0	8.1	2992.3	164.3	5.8	2819.7	-8.3	-.3
8/26/81	1327.94	1324.21	5.43	5.43	5.43	3469.0	3760.6	291.6	8.4	3858.5	389.5	11.2	3553.1	84.1	2.4
8/26/81	1327.94	1324.21	5.43	5.43	5.43	3478.0	3760.6	282.6	8.1	3858.5	380.5	10.9	3553.1	75.1	2.2
8/ 4/80	1328.73	1324.79	5.55	5.55	5.55	3696.0	3878.2	182.2	4.9	3995.1	299.1	8.1	3672.1	-23.9	-.6
7/14/81	1328.70	1325.13	6.00	6.00	6.00	3735.0	4017.8	282.8	7.6	4194.7	459.7	12.3	3947.7	112.7	3.0
7/14/81	1328.64	1325.14	6.00	6.00	6.00	3752.0	3974.2	222.2	5.9	4148.5	396.5	10.6	3806.4	54.4	1.4
7/15/81	1328.58	1325.21	6.15	6.15	6.15	3775.0	4013.8	238.8	6.3	4207.7	432.7	11.5	3860.3	85.3	2.3
7/29/81	1328.68	1324.85	5.78	5.78	5.78	3831.0	4015.1	184.1	4.8	4164.9	333.9	8.7	3821.8	-9.2	-.2
7/ 9/81	1328.57	1325.68	6.90	6.90	6.90	3913.0	4225.4	312.4	8.0	4519.8	606.8	15.5	4156.4	243.4	6.2
7/ 9/81	1328.54	1325.66	6.90	6.90	6.90	3967.0	4220.9	253.9	6.4	4514.7	547.7	13.8	4152.0	185.0	4.7
7/21/77	1328.65	1324.88	6.00	6.00	6.00	3998.0	4186.0	188.0	4.7	4372.8	374.8	9.4	4006.8	8.8	.2
6/24/81	1328.10	1325.60	7.28	7.28	7.28	4025.0	4199.2	174.2	4.3	4525.7	500.7	12.4	4182.1	157.1	3.9
8/22/77	1328.29	1325.87	7.43	7.43	7.43	4272.0	4206.5	-65.5	-1.5	4550.8	278.8	6.5	4210.3	-61.7	-1.4
8/ 2/78	1328.15	1325.93	7.80	7.80	7.80	4301.0	4274.4	-26.6	-.6	4658.2	357.2	8.3	4332.6	31.6	.7
7/ 9/80	1328.63	1326.61	8.40	8.40	8.40	4433.0	4372.1	-60.9	-1.4	4827.8	394.8	8.9	4526.6	93.6	2.1
7/10/80	1328.56	1326.70	8.55	8.55	8.55	4464.0	4268.6	-195.4	-4.4	4722.5	258.5	5.8	4441.6	-22.4	-.5
6/30/81	1328.63	1326.90	8.92	8.92	8.92	4498.0	4312.5	-185.5	-4.1	4800.6	302.6	6.7	4545.4	47.4	1.1
7/10/80	1328.54	1326.69	8.55	8.55	8.55	4493.0	4257.6	-235.4	-5.2	4709.7	216.7	4.8	4429.9	-63.1	-1.4
8/12/77	1327.98	1326.17	8.63	8.63	8.63	4508.0	4325.0	-183.0	-4.1	4773.5	265.5	5.9	4505.8	-2.2	-.0
6/30/79	1327.81	1326.29	9.08	9.08	9.08	4517.0	4177.3	-339.7	-7.5	4628.7	111.7	2.5	4411.3	-105.7	-2.3
6/29/79	1327.90	1326.37	9.00	9.00	9.00	4524.0	4134.0	-390.0	-8.6	4580.7	56.7	1.3	4357.1	-166.9	-3.7
6/28/81	1328.75	1326.80	8.55	8.55	8.55	4549.0	4364.6	-184.4	-4.1	4834.6	285.6	6.3	4543.4	-5.6	-.1
7/ 1/81	1328.48	1327.08	9.60	9.60	9.60	4566.0	4211.6	-354.4	-7.8	4721.9	155.9	3.4	4535.6	-30.4	-.7
6/13/79	1328.46	1326.58	8.63	8.63	8.63	4597.0	4363.1	-233.9	-5.1	4831.1	234.1	5.1	4551.0	-46.0	-1.0
7/ 1/81	1328.48	1327.08	9.60	9.60	9.60	4609.0	4211.6	-397.4	-8.6	4721.9	112.9	2.5	4535.6	-73.4	-1.6
7/ 2/81	1328.50	1327.40	10.62	10.62	10.62	4622.0	4169.2	-452.8	-9.8	4711.9	89.9	1.9	4621.2	-.8	-.0
7/ 2/81	1328.50	1327.40	10.62	10.62	10.62	4639.0	4169.2	-469.8	-10.1	4711.9	72.9	1.6	4621.2	-17.8	-.4

NUMBER OF DATA POINTS = 48
AVERAGE DIFFERENCE (ACTUAL) = 51.0
AVERAGE DIFFERENCE (PERCENT)= 4.1
STANDARD DEVIATION (ACTUAL) = 231.4
STANDARD DEVIATION (PERCENT)= 8.3

NUMBER OF DATA POINTS = 48
AVERAGE DIFFERENCE (ACTUAL) = 183.1
AVERAGE DIFFERENCE (PERCENT)= 4.9
STANDARD DEVIATION (ACTUAL) = 254.8
STANDARD DEVIATION (PERCENT)= 6.7

NUMBER OF DATA POINTS = 48
AVERAGE DIFFERENCE (ACTUAL) = 3.9
AVERAGE DIFFERENCE (PERCENT)= .0
STANDARD DEVIATION (ACTUAL) = 74.6
STANDARD DEVIATION (PERCENT)= 2.2

1/ Assumes the music note gate lip seal design correction factor is equal to unity, CSCDA1=1.0.

2/ Applies the field data before 1974 algorithm for the music note gate lip seal design correction factor, CSCDA1=0.39*GOPH+0.85.

3/ Applies the field data after 1974 algorithms for the music note gate lip seal design correction factor,
IF(GOPH.LT.0.35)
CSCDA1=0.129*GOPH+0.88
IF(GOPH.GE.0.35)
CSCDA1=SQRT((1.0+(GOPH-0.26)**2/ 3.015)*14.52)-2.89

combined music note/hard-rubber-bar gate lip seal correction factor is:

IF (GOPH.LT.0.35)

CSCDA = 0.129*GOPH+0.88

(field data after 1974, Fig. III-48)

where:

GOPH = the ratio of the gate opening to the pinion height

CSCDA = the correction factor for the combined music note/hard-rubber-bar gate lip seal, and is multiplied by the coefficient of discharge SCDA obtained by the discharge algorithms based on the hard-rubber-bar gate lip seal design

If the GOPH ratio is greater than or equal to 0.35, the correction factor is:

IF (GOPH.GE.0.35)

CSCDA = SQRT ((1.0+(GOPH-0.26)**2 /3.015)*14.52)-2.89

(field data after 1974, fig. III-48)

The combined music note/hard-rubber-bar design correction factor is overall less than the correction factor for just the music note gate lip seal design, except at the very small gate openings when the ratio GO/PH is less than 0.1. The linear algorithm for ratios less than 0.35 was used in lieu of the hyperbolic algorithm (shown as the dashed line in fig. III-48) to provide a more realistic correction factor at the very small gate openings or discharges. The correction factor becomes larger than 1.0 when the ratio GO/PH is larger than 0.6, or about 60 percent gate opening.

Computed data output No. 6, in table III-12, shows the results of applying the field data after 1974 algorithms to correct for the combined gate lip seal. The overall average is 0.0 percent. The average error for the three smallest discharges is +0.1 percent and the average error for the three largest discharges is –0.7 percent. The midrange of discharges is no longer significantly biased in the positive direction as compared to the No. 5 computed data output.

The standard deviation of the No. 6 computed data output shows a very small spread of ±2.2 percent, indicating the algorithm-predicted discharge deviation is equivalent to the deviation of good current meter measurements made in the field.

Analysis of the field data after 1974 has shown that even a minor modification in the gate lip seal design results in significant variations in the flow characteristics. An error of about –8 to +12 percent would occur if a correction to the coefficient of discharge is not applied. The correction algorithms developed from the field data can predict the discharge with an overall average error near zero percent. The correction algorithm developed for the combined music note/hard-rubber-bar gate lip seal design will have application to other canal radial gates having the gate seal modified in the same manner.

East Low Canal Headworks

The headworks of the East Low Canal system is the second of the two diversions (the other being the West Canal headworks discussed previously) at the end of the Main Canal. The flow direction through the East Low headworks, however, is perpendicular to the Main Canal flow. It is the only check structure included in the field test verification program that operates under free flow conditions for the entire flow range up to 127.4 m³/s (4500 ft³/s). Free flow conditions exist because of the significant drop in the canal invert of 2.80 m (9.26 ft) through the Crab Creek siphon located immediately downstream. The check structure has two radial gates with the music note gate lip seal design.

The East Low Canal headworks is not considered a typical canal check structure because the flow condition is free and the flow is perpendicular to the flow direction of the Main Canal. However, the analysis of the field data allows an examination of the accuracy of the free flow and music note correction algorithms developed from laboratory model data. Since the flow turns 90° and the upstream transition is not streamlined, an energy loss coefficient, UPK, of 0.5 in terms of the approaching velocity head was used to estimate the head loss of the upstream transition.

Field data were furnished in the form of a rating chart dated September 17, 1974. The rating chart was developed in the same manner as the rating chart for the West Canal headworks before 1974. However, instead of tabulating the discharge as a function of the head differential, the East Low Canal headworks rating chart tabulates just the upstream water surface elevation (less 1300 ft), which is measured in the Main Canal. Discharge is calculated based on an average coefficient of discharge for a range of the upstream water surface elevation. The average coefficient of discharge was developed from field current meter measurements and concurrent measurements of the upstream water surface elevation and gate openings using the orifice equation as described for the West Canal headworks.

Table III-13 is a tabulation of 37 test data points selected from the East Low Canal rating chart of September 17, 1974, for discharges from low to the maximum flow capacity. The upstream water surface elevation is the rating chart elevation plus 1300.0 ft. The free flow discharge algorithms do not require a downstream water depth; however, the general computer program includes a test to determine if the flow condition is free or submerged. Therefore, a downstream water depth is required for the flow condition test. The downstream water surface elevation shown in table III-13 was determined from a rating curve shown on figure III-49, which was developed from a backwater surface profile computer program model of the downstream canal reach.

Using the field data three computer data outputs were obtained similar to those of the West Canal headworks; i.e., (1) no correction is made for the music note gate lip seal design, (2) correction is made using an algorithm developed from the hydraulic laboratory model free flow studies, and (3) correction is made using an algorithm that is developed from the output of the No. 1 computer data.

The No. 1 computer data output assumed a hard-rubber-bar gate lip seal design; i.e., the correction factor, CFCDA, is equal to unity. The overall average difference is +3.6 percent, indicating the music note seal requires a smaller coefficient of discharge than the hard-rubber-bar gate lip seal design.

The No. 2 computer data output applies the correction factor algorithm, CFCDA, for free flow conditions developed from laboratory data. The laboratory data algorithm for free flow conditions is:

CFCDA = 0.125*GOPH+0.91
(laboratory data from fig. 30)

where:

CFCDA = the music note gate lip seal design correction factor for free flow conditions and is multiplied by the coefficient of discharge, FCDA, obtained by the free flow discharge algorithms based on the hard-rubber-bar design
GOPH = the ratio of the gate opening to the pinion height

The laboratory algorithm above is linear and is a function of the gate-opening-to-pinion-height ratio, GO/PH. It also represents an average of all the laboratory data, which included models No. 4,

5, and 6 at three different ratios of the gate arm radius-to-pinion height, RAD/PH, of 1.373, 1.521, and 1.715. The East Low Canal headworks gate-arm-radius-to-pinion-height ratio is 1.751, which is slightly above the maximum ratio used in the laboratory model. Results of the No. 2 computer data output, table III-13, show an overall average difference of –2.2 percent, which indicates too much correction was applied as compared to the No. 1 computer data output. The correction algorithm developed from the laboratory data does not adequately represent the prototype; however, a –2.2 percent average difference is not too unreasonable.

Following the same technique used for the West Canal headworks, a plot of the corection factor as a function of the GO/PH ratio was made, figure III-50. The correction factor is the ratio of the algorithm-predicted discharge from the No. 1 computer data output, and the discharge from the rating of September 17, 1974, table III-13.

The correction factor plot of figure III-50 shows a definite nonlinear relationship, with the GO/PH ratio having conic characteristics. The data also show a significant spread at the lower gate openings or discharges that is caused by the characteristics of the rating chart. Discharge for each tabulated upstream water surface elevation (the upstream water depth is referenced to the center of the gate opening) is calculated for selected gate openings based on an average coefficient of discharge using the orifice equation. An algorithm was developed to best fit the correction factor data points as follows:

CFCDA = 1.15–SQRT((1.0+(GOPH–0.4)**2
/0.024)*0.014

The No. 3 computed data output of table III-13 shows the results of applying the algorithm developed from the field data. The overall average difference is –1.1 percent, and indicates a moderate bias in the negative direction. The large negative errors of the data at the low discharges cause the results to be biased in the negative direction. It also causes a moderate spread in the standard deviation of ±3.7 percent.

Analysis of the East Low Canal headworks field data has shown that the algorithm developed from laboratory data inadequately represent the prototype music note seal, as shown on figure III-50. The laboratory linear algorithm represents an overall average. However, at any particular discharge or gate opening, the error can be significant, ranging from about +11 percent at the GO/PH ratio of 0.0 to about –7 percent at the GO/PH ratio of 0.4. The analysis has again shown that the variation in the gate lip seal

147

Table III-13.—*Field verification tests for East Low Canal headworks.*

FIELD VERIFICATION TESTS
CANAL RADIAL GATES - DISCHARGE ALGORITHMS
EAST LOW CANAL BIFURCATION

FIELD DATA FROM EAST LOW CANAL HEADWORKS RATING CHART OF 9/17/74							No. 1 COMPUTED DATA 1/			No. 2 COMPUTED DATA 2/			No. 3 COMPUTED DATA 3/		
CHART BIF GAGE FT.	WATER SURFACE ELEV. UPSTREAM FT.	DOWNSTREAM FT.	GATE OPENINGS NO.1 FT.	NO.2 FT.	NO.3 FT.	TOTAL DISCH. BY CMM FT3/S	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO. - CMM) FT3/S	DIFFERENCE PERCENT	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO. - CMM) FT3/S	DIFFERENCE PERCENT	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO. - CMM) FT3/S	DIFFERENCE PERCENT
17.0	1317.00	1309.89	.45	.45		208.0	231.0	23.0	11.1	211.1	3.1	1.5	195.0	-13.0	-6.3
26.0	1326.00	1309.88	.29	.29		200.0	238.5	38.5	19.2	217.6	17.6	8.8	199.4	-.6	-.3
11.0	1311.00	1309.88	1.11	1.11		201.0	199.2	-1.8	-.9	187.1	-13.9	-6.9	179.6	-21.4	-10.6
28.0	1328.00	1309.89	.29	.29		211.0	253.5	42.5	20.1	231.3	20.3	9.6	211.9	.9	.4
25.0	1325.00	1310.05	.77	.77		507.0	590.2	83.2	16.4	540.9	33.9	6.7	506.9	-.1	-.0
17.0	1317.00	1310.02	1.11	1.11		500.0	537.2	37.2	7.4	494.2	-5.8	-1.2	470.3	-29.7	-5.9
13.0	1313.00	1310.03	1.79	1.79		502.0	492.9	-9.1	-1.8	459.8	-42.2	-8.4	450.9	-51.1	-10.2
28.0	1328.00	1310.09	.77	.77		553.0	649.3	96.3	17.4	595.0	42.0	7.6	557.5	4.5	.8
19.0	1319.00	1310.70	2.13	2.13		1050.0	1090.4	40.4	3.8	1013.4	-36.6	-3.5	1005.3	-44.7	-4.3
15.0	1315.00	1310.66	3.00	3.00		1030.0	951.6	-78.4	-7.6	897.2	-132.8	-12.9	915.6	-114.4	-11.1
25.0	1325.00	1310.68	1.62	1.62		1040.0	1166.4	126.4	12.2	1077.7	37.7	3.6	1047.5	7.5	.7
28.0	1328.00	1310.67	1.45	1.45		1030.0	1163.8	133.8	13.0	1073.4	43.4	4.2	1036.0	6.0	.6
19.0	1319.00	1311.46	3.18	3.18		1500.0	1478.0	-22.0	-1.5	1388.8	-111.2	-7.4	1427.5	-72.5	-4.8
28.1	1328.10	1311.46	2.13	2.13		1500.0	1635.2	135.2	9.0	1517.8	17.8	1.2	1505.4	5.4	.4
25.8	1325.80	1311.46	2.30	2.30		1500.0	1623.7	123.7	8.2	1509.7	9.7	.6	1507.1	7.1	.5
24.0	1324.00	1312.47	3.36	3.36		2000.0	2051.8	51.8	2.6	1927.6	-72.4	-3.6	1993.6	-6.4	-.3
28.0	1328.00	1312.64	3.00	3.00		2070.0	2168.8	98.8	4.8	2029.3	-40.7	-2.0	2076.1	6.1	.3
30.0	1330.00	1312.36	2.66	2.66		1940.0	2070.8	130.8	6.7	1931.2	-8.8	-.5	1953.1	13.1	.7
28.0	1328.00	1313.71	3.72	3.72		2510.0	2571.6	61.6	2.5	2422.3	-87.7	-3.5	2531.8	21.8	.9
30.0	1330.00	1313.82	3.54	3.54		2550.0	2612.1	62.1	2.4	2455.7	-94.3	-3.7	2554.5	4.5	.2
26.4	1326.40	1313.68	3.90	3.90		2500.0	2527.9	27.9	1.1	2385.7	-114.3	-4.6	2504.5	4.5	.2
30.0	1330.00	1314.88	4.26	4.26		3010.0	3019.0	9.0	.3	2856.9	-153.1	-5.1	3025.5	15.5	.5
28.0	1328.00	1315.00	4.62	4.62		3060.0	3028.6	-31.4	-1.0	2876.4	-183.6	-6.0	3065.2	5.2	.2
25.6	1325.60	1314.83	4.98	4.98		3000.0	2954.4	-45.6	-1.5	2816.5	-183.5	-6.1	3013.2	13.2	.4
28.5	1328.50	1316.17	5.34	5.34		3500.0	3445.2	-54.8	-1.6	3292.6	-207.4	-5.9	3535.4	35.4	1.0
25.0	1325.00	1316.25	6.25	6.25		3530.0	3414.4	-115.6	-3.3	3293.1	-236.9	-6.7	3512.7	-17.3	-.5
30.0	1330.00	1316.01	4.98	4.98		3440.0	3402.4	-37.6	-1.1	3240.5	-199.5	-5.8	3471.7	31.7	.9
29.0	1329.00	1317.43	6.07	6.07		3970.0	3850.8	-119.2	-3.0	3703.6	-266.4	-6.7	3968.4	-1.6	-.0
25.0	1325.00	1317.47	7.54	7.54		3990.0	3921.0	-69.0	-1.7	3824.3	-165.7	-4.2	3949.4	-40.6	-1.0
27.0	1327.00	1317.60	6.80	6.80		4040.0	3939.7	-100.3	-2.5	3815.4	-224.6	-5.6	4031.9	-8.1	-.2
26.1	1326.10	1317.60	7.16	7.16		4040.0	3957.8	-82.2	-2.0	3846.1	-193.9	-4.8	4022.8	-17.2	-.4
27.6	1327.60	1317.67	6.61	6.61		4060.0	3936.8	-123.2	-3.0	3805.6	-254.4	-6.3	4040.2	-19.8	-.5
26.3	1326.30	1318.22	7.92	7.92		4250.0	4307.2	57.2	1.3	4212.4	-37.6	-.9	4293.5	43.5	1.0
26.6	1326.60	1318.40	8.11	8.11		4310.0	4440.1	130.1	3.0	4348.9	38.9	.9	4400.3	90.3	2.1
28.0	1328.00	1318.87	7.54	7.54		4440.0	4413.7	-26.3	-.6	4300.4	-139.6	-3.1	4447.1	7.1	.2
27.7	1327.70	1318.90	8.30	8.30		4490.0	4713.0	223.0	5.0	4622.0	132.0	2.9	4641.1	151.1	3.4
27.9	1327.90	1318.93	7.73	7.73		4500.0	4485.6	-14.4	-.3	4377.7	-122.3	-2.7	4496.1	-3.9	-.1

No. 1
NUMBER OF DATA POINTS = 37
AVERAGE DIFFERENCE (ACTUAL) = 21.7
AVERAGE DIFFERENCE (PERCENT) = 3.6
STANDARD DEVIATION (ACTUAL) = 87.9
STANDARD DEVIATION (PERCENT) = 7.9

No. 2
NUMBER OF DATA POINTS = 37
AVERAGE DIFFERENCE (ACTUAL) = -79.3
AVERAGE DIFFERENCE (PERCENT) = -2.2
STANDARD DEVIATION (ACTUAL) = 130.5
STANDARD DEVIATION (PERCENT) = 5.6

No. 3
NUMBER OF DATA POINTS = 37
AVERAGE DIFFERENCE (ACTUAL) = .3
AVERAGE DIFFERENCE (PERCENT) = -1.1
STANDARD DEVIATION (ACTUAL) = 42.1
STANDARD DEVIATION (PERCENT) = 3.7

1/ Assumes the music note gate lip seal design correction factor is equal to unity, CFCDA1=1.0.

2/ Applies the laboratory data algorithm for the music note gate lip seal design correction factor, CFCDA1=0.125*GOPH+0.91.

3/ Applies the field data algorithm for the music note gate lip seal design correction factor, $CFCDA1 = 1.15 - \sqrt{(1.0 + (GOPH - 0.4)^{2}/0.024) \cdot 0.014}$.
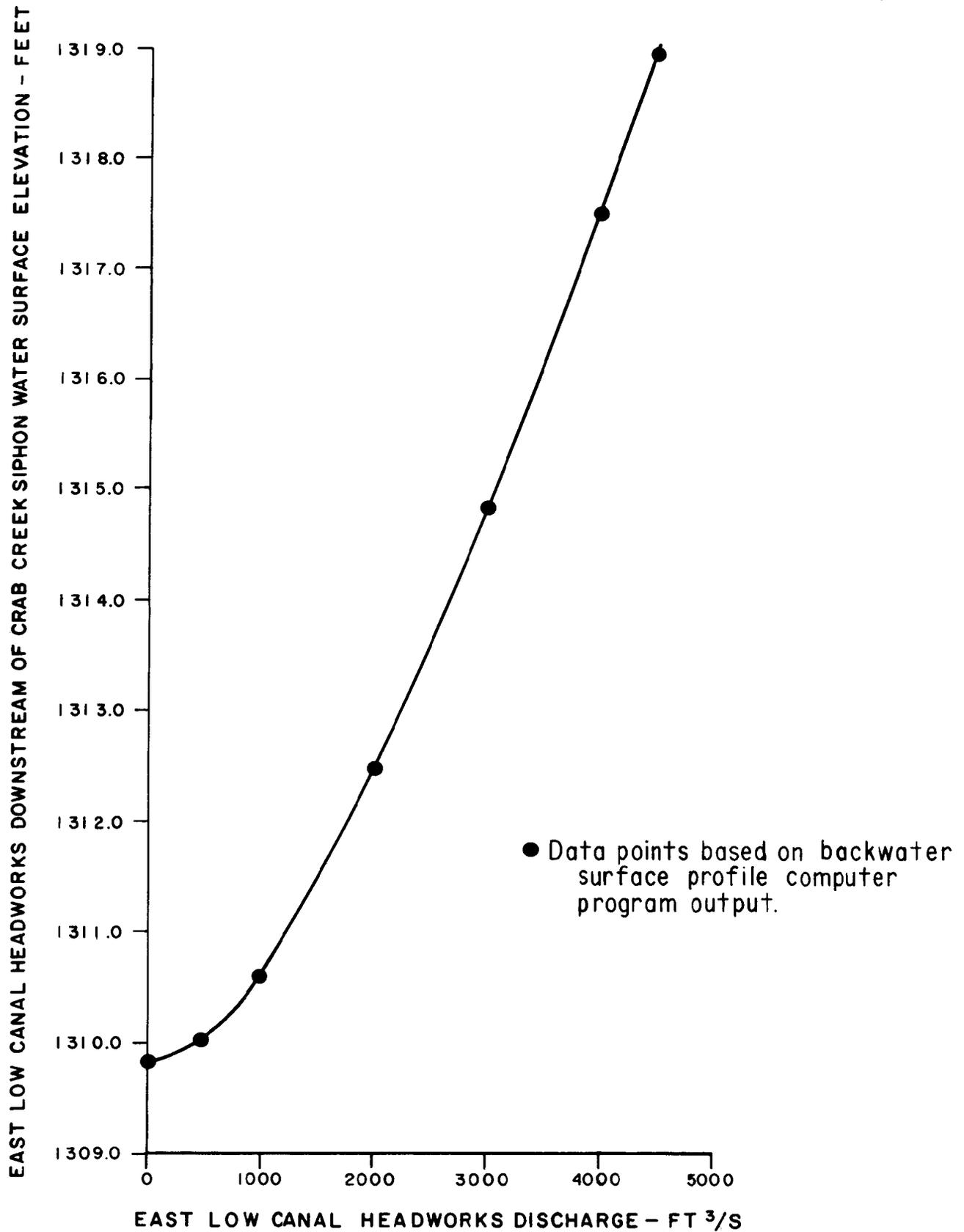
Figure III-49.—Downstream water surface elevation versus canal discharge rating curve for East Low Canal headworks.

149

CFCDA = $1.15 - SQRT((1.0 + (GOPH - 0.4)**2/0.024)*0.014)$ (FIELD DATA)

CFCDA = $0.125 * GOPH + 0.91$ (LABORATORY DATA)

NOTE:
● - Data points developed from field data and computed data output No. I, table III-13.

Y-axis: CORRECTION FACTOR FOR MUSIC NOTE SEAL DESIGN - CFCDA / EAST LOW CANAL HEADWORKS

X-axis: RATIO OF GATE OPENING, GO TO PINION HEIGHT, PH - GO/PH
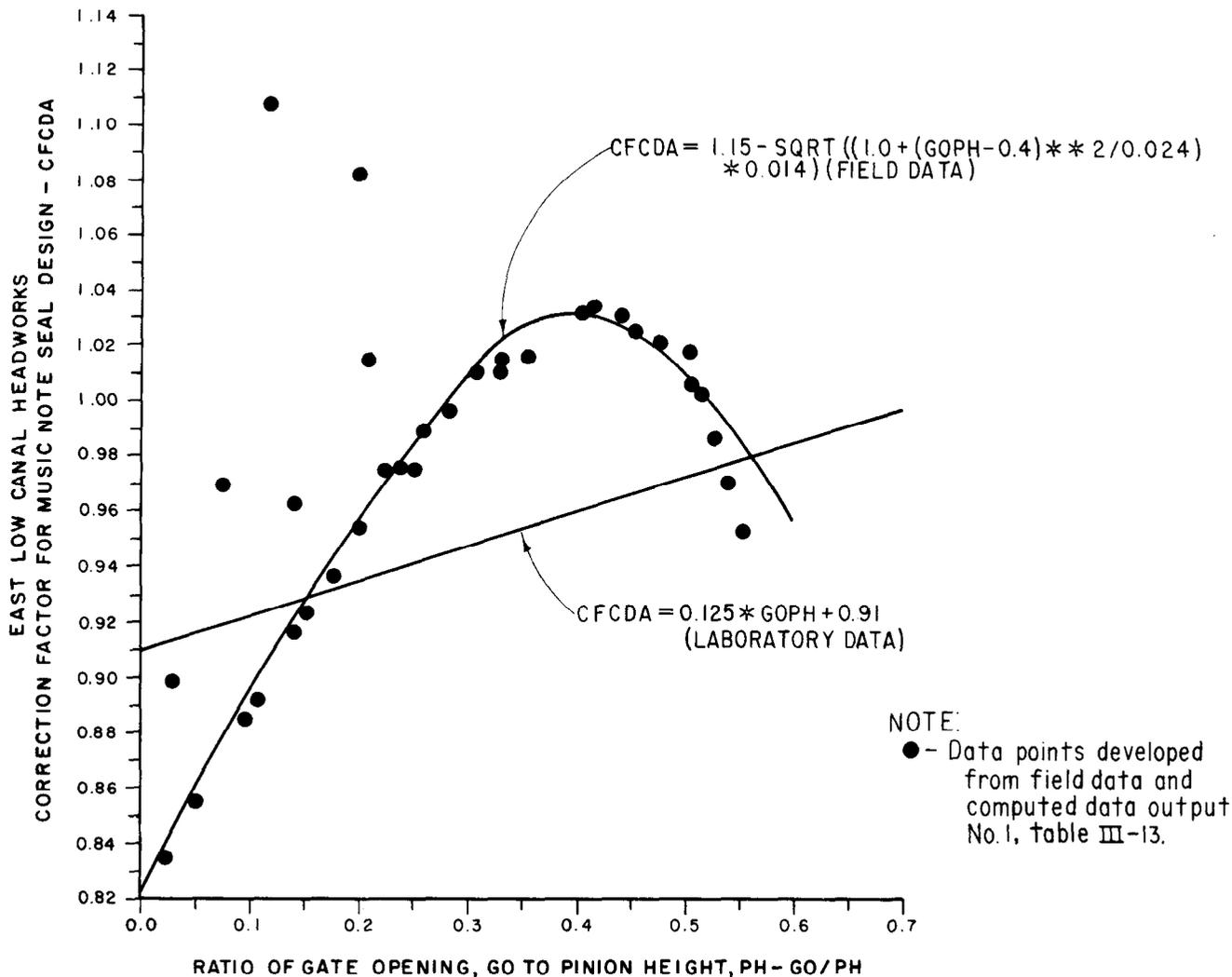
Figure III-50.—Correction factor, CDCDA, for the East Low Canal headworks music note gate lip seal versus the free flow gate opening, GO/PH, developed from the field data (table III-13).

design causes significant variations in the flow characteristics. In the case of free flow conditions, the variation in the coefficient of discharge is very nonlinear. The algorithm developed from the field data to correct for the music note gate lip seal design under free flow conditions can be applied to similar check structures achieving good accuracy with a high degree of confidence.

Friant-Kern Canal Check Structures

General. — The Friant-Kern Canal begins at Friant Dam, which is located about 32 km (20 mi) north and east of Fresno, California. The canal traverses in a southerly direction to Bakersfield for a distance of 245 km (152 mi) and has 14 check structures. The five structures included in the field verification test program are typical canal check structures, having three to five radial gates with music note gate lip seals. Table III-5

lists the main physical properties of the structures. The ratio of the radial gate arm to pinion height ranges from 1.549 to 1.576, which is close to the average ratio of 1.514 for all canal radial gates constructed by the Bureau of Reclamation.

The upstream water depth is measured in stilling wells using the float-tape-pulley-counterweight method. In some cases, the downstream water depths were obtained by visual readings of a staff gage mounted on the outside pier facing the canal bank. Downstream staff gages are located immediately downstream of the sidebay overflow for the Sand Creek, Dodge Avenue, and Fifth Avenue check structures and are not inside the gate bay. The Kaweah River and Tule River check structures do not have sidebay overflows and have siphons immediately downstream. Downstream staff gages for the latter two check structures are on the outside wall and are inside the

Table III-14.—Field verification tests for Sand Creek check No. 3, Friant-Kern Canal.

```
                          FIELD VERIFICATION TESTS
                 CANAL RADIAL GATES - DISCHARGE ALGORITHMS
                          FRIANT - KERN CANAL
```

	WATER SURFACE ELEV.		GATE OPENINGS					TOTAL DISCH.	COMPUTED DATA		
DATE	UPSTREAM FT.	DOWNSTREAM 1/ FT.	NO.1 FT.	NO.2 FT.	NO.3 FT.	NO.4 FT.	NO.5 FT.	BY CMM FT3/S	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO. - CMM) FT3/S	DIFFERENCE PERCENT.
12/ 9/71	435.23	429.24	.35	.40	.35			297.0	316.9	19.9	6.7
12/16/71	435.17	429.30	.43	.43	.43			368.0	368.5	.5	.1
12/15/71	435.17	429.40	.43	.43	.43			370.0	364.8	-5.2	-1.4
12/14/71	435.17	429.21	.43	.44	.43			374.0	374.9	.9	.2
11/ 7/64	433.87	428.29	.50	.56	.50			436.0	441.5	5.5	1.3
10/31/63	435.16	429.41	0.00	1.76	0.00			513.0	539.3	26.3	5.1
10/29/63	435.17	429.71	1.00	.80	0.00			529.0	506.5	-22.5	-4.3
10/29/63	435.17	429.45	0.00	1.95	0.00			571.0	604.6	33.6	5.9
10/23/63	435.18	430.31	1.30	.88	1.30			963.0	930.5	-32.5	-3.4
10/24/63	435.17	430.40	1.19	1.19	1.19			973.0	942.8	-30.2	-3.1
3/ 2/72	435.17	431.51	2.28	2.28	2.28			1625.0	1651.2	26.2	1.6
3/ 9/72	435.17	431.48	2.40	2.40	2.40			1742.0	1759.9	17.9	1.0
6/20/72	435.17	432.08	2.90	3.00	2.90			2024.0	2007.1	-16.9	-.8
8/ 9/72	435.18	432.17	3.10	2.92	2.96			2038.0	2025.2	-12.8	-.6
6/27/72	435.17	432.57	3.50	3.45	3.45			2270.0	2222.9	-47.1	-2.1
4/11/74	435.17	432.77	3.87	3.87	3.85			2457.0	2427.5	-29.5	-1.2
7/10/64	435.17	433.41	5.50	3.00	5.50			2564.0	2695.9	131.9	5.1
7/12/72	435.17	433.63	5.05	5.00	5.05			2756.0	2675.7	-80.3	-2.9
4/23/73	435.30	433.49	4.78	4.78	4.78			2765.0	2716.7	-48.3	-1.7
4/17/74	435.15	434.36	7.41	7.41	7.41			3217.0	3354.4	137.4	4.3

```
* NUMBER OF DATA POINTS = 20
* AVERAGE DIFFERENCE (ACTUAL) =   3.7
* AVERAGE DIFFERENCE (PERCENT)=    .5
* STANDARD DEVIATION (ACTUAL) =  53.5
* STANDARD DEVIATION (PERCENT)=   3.4
```

1/ Adjusted to represent an equivalent water surface elevation downstream of the submerged hydraulic jump.

gate bay. In all cases, the downstream water depth measured at those locations are within the recovery area of the submerged hydraulic jump. Using a depth measured at this location would cause the algorithms to predict the discharge with large errors. The downstream depth used in the algorithms are based on a downstream depth located below the submerged hydraulic jump; therefore, it was necessary to adjust the field measurement of the downstream water depth to an equivalent depth downstream of the submerged hydraulic jump. The adjustment was accomplished by balancing momentum and hydrostatic forces. The adjusted downstream water surface elevations are the values shown in the field data, tables III-14 through III-18, for the five Friant-Kern Canal check structures. Upstream and downstream water levels were furnished as a measurement of the depth from the canal invert. Elevations were determined by adding the canal invert elevation obtained from the design drawings to the field measurement of water depth.

All radial gates of these five Friant-Kern Canal structures operate under submerged flow conditions. Flow conditions at the downstream staff gage locations are very turbulent within the recovery area of the submerged hydraulic jump. The required resolution of ±3 mm (±0.01 ft) could not be obtained because of water level disturbance. It is believed the resolution of the downstream water depth measurements was somewhat greater than ±30 mm (±0.1 ft) and, therefore, a high deviation or spread in the results was anticipated.

It is believed the nearness of the downstream siphon entrances (at the end of the radial gate arms) at the Kaweah and Tule Rivers check structures may be causing a drawdown effect at the downstream staff location. The drawdown effect was not taken into consideration because of the many unknowns. Therefore, an even wider deviation in the results was expected for the Kaweah and Tule River check structures.

Field measurements of discharge were obtained from bridge current meter measurements made at the first bridge crossing downstream of each check structure.

The algorithm developed from the field data of the West Canal headworks before 1974 was used to correct for the music note gate lip seal design. The music note gate lip seal design correction factor algorithm is:

CSCDA = 0.39*GOPH+0.85
(field data from fig. III-47)

where:

CSCDA = the music note gate lip seal correction factor for submerged flow conditions, and is multiplied by the coefficent of discharge, SCDA, obtained by the discharge algorithms

Table III-15.—*Field verification tests for Dodge Ave. check No. 4, Friant-Kern Canal.*

```
                              FIELD VERIFICATION TESTS
                    CANAL RADIAL GATES - DISCHARGE ALGORITHMS
                              FRIANT - KERN CANAL
```

	WATER SURFACE ELEV.		GATE OPENINGS					TOTAL DISCH.	*	COMPUTED DATA		
DATE	UPSTREAM FT.	DOWNSTREAM1/ FT.	NO.1 FT.	NO.2 FT.	NO.3 FT.	NO.4 FT.	NO.5 FT.	BY CMM FT3/S	*	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO. - CMM) FT3/S	DIFFERENCE PERCENT,
2/21/73	429.19	421.96	0.00	.38	.38			245.0	*	246.8	1.8	.8
12/16/71	429.19	421.73	.35	.35	.35			343.0	*	347.7	4.7	1.4
12/16/71	429.19	421.73	.35	.35	.35			344.0	*	347.7	3.7	1.1
12/14/71	429.19	421.56	0.00	1.02	0.00			351.0	*	361.2	10.2	2.9
10/31/63	429.21	421.93	0.00	1.41	0.00			503.0	*	497.7	-5.3	-1.1
11/ 4/63	429.24	422.02	0.00	1.46	0.00			514.0	*	514.2	.2	.0
10/28/63	429.20	422.30	0.00	1.49	0.00			520.0	*	507.8	-12.2	-2.3
11/ 1/63	429.18	422.04	0.00	1.60	0.00			551.0	*	569.3	18.3	3.3
10/30/63	429.19	422.16	0.00	1.61	0.00			567.0	*	565.6	-1.4	-.2
4/ 3/72	429.19	422.36	.68	.73	.73			722.0	*	684.2	-37.8	-5.2
3/29/72	429.19	422.84	.99	.99	.99			938.0	*	922.2	-15.8	-1.7
10/23/63	429.21	423.22	1.00	1.00	1.00			952.0	*	897.8	-54.2	-5.7
10/24/63	429.21	423.15	1.00	1.09	1.00			985.0	*	933.2	-51.8	-5.3
3/21/72	429.19	423.64	1.31	1.31	1.31			1219.0	*	1144.0	-75.0	-6.1
2/29/72	429.29	424.64	2.05	2.05	2.05			1654.0	*	1682.4	28.4	1.7
3/ 6/72	429.19	424.84	2.05	2.00	2.05			1657.0	*	1604.7	-52.3	-3.2
3/ 7/72	429.19	424.95	2.12	2.12	2.12			1719.0	*	1656.2	-62.8	-3.7
3/14/72	429.19	425.15	2.25	2.25	2.25			1803.0	*	1721.6	-81.4	-4.5
8/ 9/72	429.19	425.56	2.60	2.60	2.60			2019.0	*	1910.1	-108.9	-5.4
6/27/72	429.19	426.00	3.05	3.05	3.07			2195.0	*	2145.4	-49.6	-2.3
7/12/72	429.19	426.94	4.18	4.22	4.30			2701.0	*	2633.6	-67.4	-2.5
4/17/74	429.14	428.21	7.15	7.23	7.23			3230.0	*	3493.8	263.8	8.2

```
* NUMBER OF DATA POINTS = 22
* AVERAGE DIFFERENCE (ACTUAL) = -15.7
* AVERAGE DIFFERENCE (PERCENT)= -1.4
* STANDARD DEVIATION (ACTUAL) = 74.4
* STANDARD DEVIATION (PERCENT)=  3.9
```

1/ Adjusted to represent an equivalent water surface elevation downstream of the submerged hydraulic jump.

based on the hard-rubber-bar gate lip seal design

GOPH = the ratio of the gate opening to the pinion height

The above algorithm provided the best overall comparison of the algorithm-predicted discharge to the field measured discharge. An attempt was made to develop an algorithm for the music note correction on the Friant-Kern Canal check structures because the ratio of the gate arm radius to the pinion height ranges from 1.549 to 1.576 as compared to the West Canal headworks ratio of 1.668. However, the results were inconclusive, mainly because of an insufficient number of data points for the entire range of discharge. Also, the resolution of the recorded downstream water depth, the staff gate location, and the adjustment required may not be representative of the true flow conditions and could produce results that could not be used with a high degree of confidence.

Sand Creek. — The Sand Creek check structure is check No. 3 on the Friant-Kern Canal, at mile 46.04, which is about 48 km (30 mi) east of Fresno, California. Field data, consisting of 20 test data points, are shown in table III-14. The computed data output of table III-14 shows an overall average difference of +0.5 percent and standard deviation of ±3.4 percent. These results are good. The comparison of the algorithm-predicted discharge to the field measurement of discharge is slightly biased in the positive direction, and the deviation, or spread, in the test data points is moderate.

Dodge Avenue. — The Dodge Avenue check structure is check No. 4 on the Friant-Kern Canal, at mile 61.03, or about 24 km (15 mi) downstream of the Sand Creek check No. 3. Geometry of the Dodge Avenue check is identical to the Sand Creek check and the field data could have been combined as one check structure. However, the current meters were at different locations and, therefore, the field data were not combined since the gaging stations may have different characteristics.

The field data, consisting of 22 test data points, are shown in table III-15; and the computed data output shows the average difference of -1.4 percent as compared to +0.5 percent for the Sand Creek check, table III-14. If the two identical checks were combined, the average difference would be biased in the negative direction by about -0.9 percent. The standard deviation of the Dodge Avenue test points is ±3.9 percent and is slightly higher than the Sand Creek standard deviation of ±3.4 percent. Results of the algorithm-predicted discharge compared to the field measured discharge is good, having a moderate standard deviation.

Kaweah River — The Kaweah River check structure is check No. 5 on the Friant-Kern Canal, at

mile 71.29, about 16.5 km (10 mi) downstream of the Dodge Avenue check No. 4. The Kaweah River check has a siphon immediately downstream and the radial gate arm trunnion blocks are mounted on the headwall of the siphon. The Kaweah River check has five radial gates, which is the maximum number of gates in a structure for the field installations investigated.

Field data, consisting of 35 test data points, are shown in table III-16. The computed data output shows an average difference of +1.4 percent, which indicates the algorithm-predicted discharge is moderately biased in the positive direction; i.e., predicting higher discharges. The standard deviation is ±5.7 percent, which indicates a high spread in the test data points. The higher deviation is probably caused by the location of the downstream staff gage, its adjusted water surface elevation, and the drawdown effects of the downstream siphon. However, overall, the results are reasonable.

Fifth Avenue — The Fifth Avenue check structure is check No. 7 on the Friant-Kern Canal, at mile 88.22, about 27.2 km (17 mi) downstream of

the Kaweah River Check No. 5. Geometry of the Fifth Avenue check structure is similar to the Sand Creek and Dodge Avenue check structures.

Field data, consisting of nine test data points, are shown in table III-17. The computed data output shows an average difference of –0.7 percent and a standard deviation of ±4.3 percent. The results are considered reasonable and are comparable to the results of the Sand Creek and Dodge Avenue check structures, tables III-14 and III-15.

Tule River. — The Tule River check structure is check No. 8 on the Friant-Kern Canal, at mile 95.67, about 12.0 km (7.5 mi) downstream of the Fifth Avenue check No. 7. The Tule River check has a siphon immediately downstream and the geometry is similar to the Kaweah River check except the Tule River check has four radial gates instead of five.

Field data, consisting of six test points, are shown in table III-18. The computed data output shows an average difference of +2.6 percent, which is higher than the Kaweah River check of +1.4 percent, table III-16. The standard deviation for the

Table III-16.—*Field verification tests for Kaweah River check No. 5, Friant-Kern Canal.*

FIELD VERIFICATION TESTS
CANAL RADIAL GATES - DISCHARGE ALGORITHMS
FRIANT - KERN CANAL

	FIELD DATA FROM FRIANT - KERN CANAL - KAWEAH CHECK								*	COMPUTED DATA		
DATE	WATER SURFACE ELEV. UPSTREAM FT.	DOWNSTREAM1/ FT.	NO.1 FT.	GATE NO.2 FT.	OPENINGS NO.3 FT.	NO.4 FT.	NO.5 FT.	TOTAL DISCH. BY CMM FT3/S	*	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO. - CMM) FT3/S	DIFFERENCE PERCENT.
2/26/62	421.82	416.65	0.00	0.00	1.40	0.00	0.00	192.0	*	215.4	23.4	12.2
11/23/71	421.42	417.64	.30	.30	.98	.30	.30	306.0	*	266.8	-39.2	-12.8
3/12/62	421.32	416.75	.50	.50	2.10	.50	.50	557.0	*	588.8	31.8	5.7
3/13/62	421.32	417.39	1.00	1.00	1.30	1.00	1.00	689.0	*	680.1	-8.9	-1.3
3/14/62	421.32	417.14	1.00	1.00	1.00	1.00	1.00	712.0	*	662.8	-49.2	-6.9
	421.32	417.11	1.00	1.00	1.30	1.00	1.00	712.0	*	707.4	-4.6	-.7
2/21/63	421.32	417.18	1.30	1.30	1.18	1.30	1.30	871.0	*	852.3	-18.7	-2.1
3/16/62	421.32	417.28	1.00	1.00	3.38	1.00	1.00	939.0	*	1039.4	100.4	10.7
2/25/63	421.22	417.20	1.40	1.40	1.60	1.40	1.40	952.0	*	954.6	2.6	.3
4/ 4/67	421.32	417.34	1.50	1.50	1.50	1.50	1.50	1110.0	*	990.7	-119.3	-10.7
2/26/63	421.32	417.28	1.80	1.80	1.40	1.80	1.80	1137.0	*	1160.5	23.5	2.1
4/ 6/67	421.32	417.01	1.50	1.50	1.75	1.78	1.50	1219.0	*	1118.6	-100.4	-8.2
4/29/63	421.32	417.62	1.80	1.80	2.05	1.80	1.80	1239.0	*	1192.3	-46.7	-3.8
5/ 1/63	421.52	417.52	1.80	1.80	2.70	1.80	1.80	1286.0	*	1353.5	67.5	5.2
4/24/63	421.32	417.77	2.30	2.30	2.27	2.30	2.30	1483.0	*	1474.8	-8.2	-.6
4/23/63	421.32	417.95	2.50	2.50	2.50	2.50	2.50	1554.0	*	1580.7	26.7	1.7
3/20/62	421.32	418.05	2.80	2.80	1.95	2.80	2.80	1596.0	*	1657.2	61.2	3.8
	421.32	417.86	2.80	2.80	1.95	2.80	2.80	1614.0	*	1716.4	102.4	6.3
3/ 1/72	421.32	418.35	2.80	2.80	2.80	2.80	2.80	1652.0	*	1677.5	25.5	1.5
3/ 8/72	421.32	418.36	2.91	2.91	2.91	2.91	2.91	1729.0	*	1750.3	21.3	1.2
4/19/63	421.32	418.10	3.00	3.00	2.08	3.00	3.00	1741.0	*	1781.7	40.7	2.3
6/18/64	421.32	418.67	2.90	2.90	3.34	2.90	2.90	1764.0	*	1695.2	-68.8	-3.9
	421.32	418.31	3.00	3.00	3.16	3.00	3.00	1844.0	*	1859.1	15.1	.8
6/19/64	421.32	419.02	3.50	3.50	3.84	3.50	3.50	1900.0	*	1935.8	35.8	1.9
5/15/63	421.32	418.39	3.25	3.25	3.64	3.25	3.25	1937.0	*	2048.6	111.6	5.8
	421.32	418.55	3.56	3.56	3.56	3.56	3.56	1967.0	*	2148.8	181.8	9.2
6/28/71	421.32	418.94	3.62	3.62	3.62	3.60	3.62	1970.0	*	2002.2	32.2	1.6
6/28/72	421.32	418.94	3.62	3.67	3.67	3.60	3.62	1970.0	*	2015.9	45.9	2.3
5/16/63	421.32	418.40	3.50	3.50	3.20	3.50	3.50	1996.0	*	2128.2	132.2	6.6
8/10/72	421.32	419.05	4.00	4.00	4.00	4.00	4.00	2125.0	*	2207.3	82.3	3.9
7/10/64	421.82	419.03	3.70	3.70	3.70	3.70	3.70	2149.0	*	2231.9	82.9	3.9
3/26/62	421.32	418.86	4.00	4.00	4.00	4.00	4.00	2150.0	*	2312.9	162.9	7.6
3/23/62	421.32	419.10	4.00	4.00	3.80	4.00	4.00	2199.0	*	2153.0	-46.0	-2.1
7/13/72	421.32	419.25	4.20	4.20	4.22	4.22	4.22	2213.0	*	2232.8	19.8	.9
3/29/62	421.32	419.36	5.00	5.00	3.70	5.00	5.00	2439.0	*	2523.0	84.0	3.4

1/ Adjusted to represent an equivalent water surface elevation downstream of the submerged hydraulic jump.

* NUMBER OF DATA POINTS = 35
* AVERAGE DIFFERENCE (ACTUAL) = 28.7
* AVERAGE DIFFERENCE (PERCENT)= 1.4
* STANDARD DEVIATION (ACTUAL) = 74.3
* STANDARD DEVIATION (PERCENT)= 5.7

153

Table III-17.—Field verification tests for Fifth Avenue check No. 7, Friant-Kern Canal.

FIELD VERIFICATION TESTS
CANAL RADIAL GATES - DISCHARGE ALGORITHMS
FRIANT - KERN CANAL

	FIELD DATA FROM FRIANT - KERN CANAL - 5TH AVE. CHECK								*	COMPUTED DATA		
DATE	WATER SURFACE ELEV. UPSTREAM FT.	DOWNSTREAM 1/ FT.	NO.1 FT.	GATE OPENINGS NO.2 FT.	NO.3 FT.	NO.4 FT.	NO.5 FT.	TOTAL DISCH. BY CMM FT3/S	*	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO. - CMM) FT3/S	DIFFERENCE PERCENT,
12/22/71	409.85	407.10	.65	.65	.65			336.0	*	332.4	-3.6	-1.1
12/22/71	409.91	407.13	.65	.65	.65			347.0	*	334.4	-12.6	-3.6
12/13/71	409.45	407.17	.80	.80	.80			353.5	*	372.7	19.2	5.4
12/21/71	410.24	407.17	.65	.65	.65			356.0	*	353.0	-3.0	-.8
4/28/72	411.62	407.42	1.40	.91	0.00			509.0	*	511.8	2.8	.6
3/28/72	409.94	407.72	1.73	1.70	1.60			875.0	*	809.2	-65.8	-7.5
8/23/72	411.99	408.74	2.52	2.52	2.52			1554.0	*	1552.0	-2.0	-.1
3/ 1/72	409.97	408.74	5.50	0.00	5.50			1658.0	*	1746.1	88.1	5.3
3/16/72	409.97	408.93	4.40	4.37	4.35			1784.0	*	1712.8	-71.2	-4.0

NUMBER OF DATA POINTS = 9
AVERAGE DIFFERENCE (ACTUAL) = -5.4
AVERAGE DIFFERENCE (PERCENT)= -.7
STANDARD DEVIATION (ACTUAL) = 47.1
STANDARD DEVIATION (PERCENT)= 4.3

1/ Adjusted to represent an equivalent water surface elevation downstream of the submerged hydraulic jump.

Table III-18.—Field verification tests for Tule River check No. 8, Friant-Kern Canal.

FIELD VERIFICATION TESTS
CANAL RADIAL GATES - DISCHARGE ALGORITHMS
FRIANT - KERN CANAL

	FIELD DATA FROM FRIANT - KERN CANAL - TULE RIVER CHECK								*	COMPUTED DATA		
DATE	WATER SURFACE ELEV. UPSTREAM FT.	DOWNSTREAM 1/ FT.	NO.1 FT.	GATE OPENINGS NO.2 FT.	NO.3 FT.	NO.4 FT.	NO.5 FT.	TOTAL DISCH. BY CMM FT3/S	*	TOTAL DISCH. BY ALGORITHM FT3/S	DIFFERENCE (ALGO. - CMM) FT3/S	DIFFERENCE PERCENT,
12/22/71	407.36	402.34	.58	.58	.58	.58		341.0	*	367.1	26.1	7.6
12/21/71	407.48	402.36	.60	.60	.60	.60		352.0	*	384.4	32.4	9.2
4/20/71	407.65	402.80	1.00	1.00	1.00	1.00		624.0	*	632.3	8.3	1.3
8/24/72	407.50	403.18	2.10	2.10	2.10	2.10		1287.0	*	1327.5	40.5	3.1
3/ 2/72	407.54	403.70	0.00	3.31	2.90	2.90		1460.0	*	1440.6	-19.4	-1.3
3/16/72	407.58	403.89	2.40	2.62	2.58	2.69		1592.0	*	1521.3	-70.7	-4.4

NUMBER OF DATA POINTS = 6
AVERAGE DIFFERENCE (ACTUAL) = 2.9
AVERAGE DIFFERENCE (PERCENT)= 2.6
STANDARD DEVIATION (ACTUAL) = 42.0
STANDARD DEVIATION (PERCENT)= 5.9

1/ Adjusted to represent an equivalent water surface elevation downstream of the submerged hydraulic jump.

Tule River check is ±5.9 percent and is about the same as the Tule River check of ±5.7 percent. The results are reasonable and are comparable to the Kaweah River check.

Summary of the Friant-Kern Canal check structures. — The results of five Friant-Kern Canal check structures included in the field verification test program are summarized as follows:

NUMBER OF TEST POINTS = 92
AVERAGE DIFFERENCE
(ACTUAL)   = +7.6 ft³/s
AVERAGE DIFFERENCE
(PERCENT)   = +0.4
STANDARD DEVIATION
(ACTUAL)   = 65.0 ft³/s
STANDARD DEVIATION
(PERCENT)   = 4.6

The above results indicate that the algorithm-predicted discharge compared to the field measured discharge is slightly biased in the positive direction. As was anticipated, the standard deviation is high but not unreasonably high considering the characteristics of the downstream staff location and resolution of the recorded depths. The method used to correct the recorded downstream depth to an equivalent water surface elevation downstream of the submerged hydraulic jump by balancing momentum and hydrostatic forces worked satisfactorily.

The plot of the algorithm-predicted discharge versus the field-measured discharge is shown in figure III-51. The best fit line (solid) using the least squares method produced the following equation as compared to the 45° line (dashed):

$$ALGO = 1.020*CMM-19.1$$

where:

ALGO = algorithm-predicted discharge
CMM = field current meter measurement of discharge

The correction algorithm developed from the West Canal headworks (before-1974 data) predicted the discharge for the Friant-Kern Canal check structures with accuracy, the average difference being +0.4 percent.
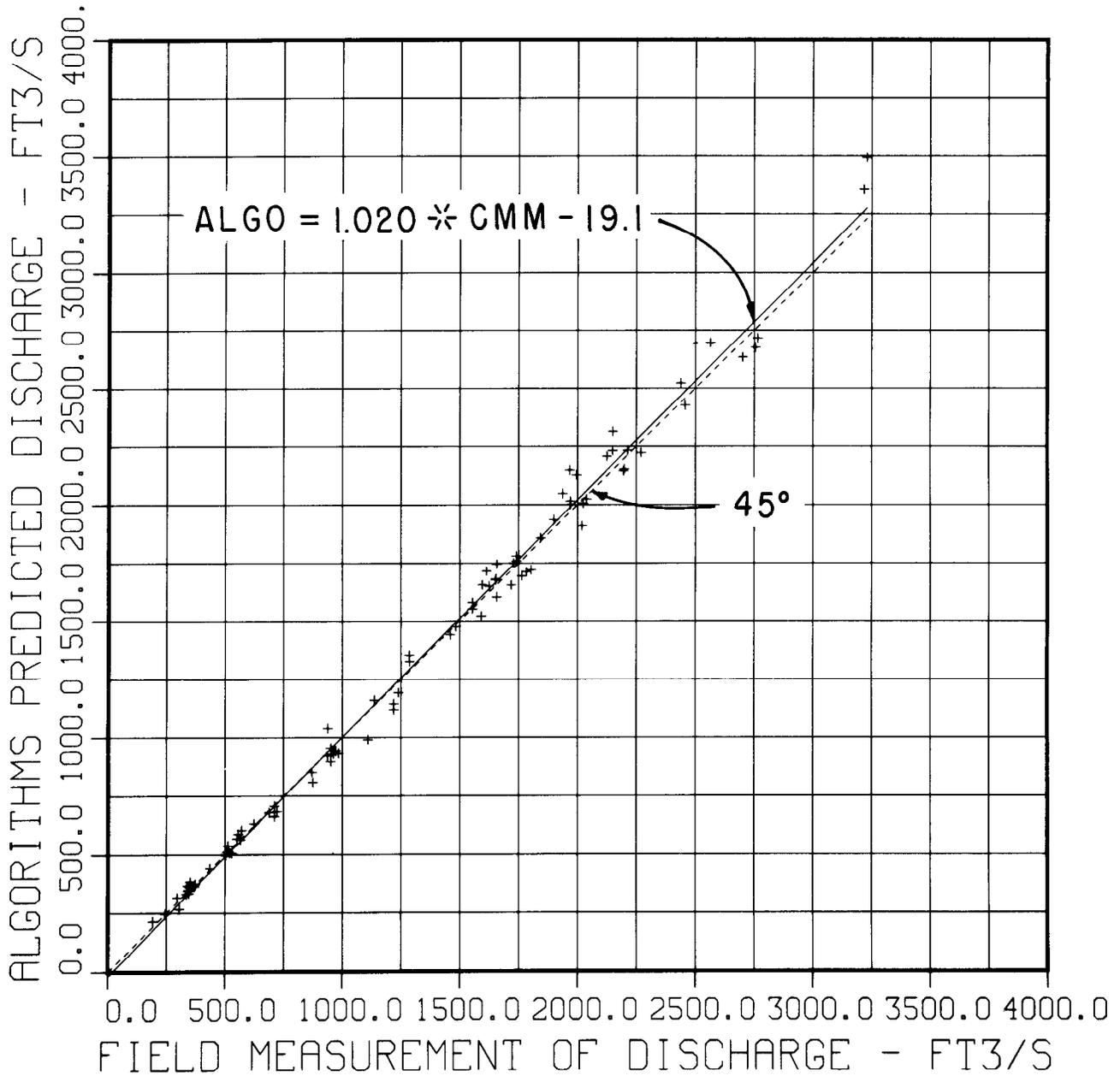
Figure III-51.—Comparison of the algorithm-predicted and the field-measured discharges, ALGO and CMM, for Friant-Kern Canal structures.

APPENDIX IV

Application Details

APPLICATION DETAILS

General

The results of the field verification test program have demonstrated that the discharge algorithms have the potential of being as accurate as any measuring device or procedure currently available for measuring the discharge in small or large canal systems. The algorithms should therefore have extensive application. However, the correct application, including the required resolution of ±2 mm (±0.005 ft) of the upstream and downstream water levels and vertical gate opening measurements is essential if the high degree of accuracy is to be achieved and maintained.

The discharge algorithms apply primarily to canal radial gate check structures that are designed and constructed by the Bureau of Reclamation, which have the following basic characteristics:

1. The canal invert through the radial gate check structure is nearly horizontal; i.e., the invert is flat through the gate bay (from the upstream pier nose to the end of the pier downstream).

2. The radius-to-pinion-height ratio ranges from about 1.2 to 1.7.

3. The maximum upstream and downstream water-depth-to-pinion-height ratio range is up to 1.6.

4. The discharge algorithms apply to the Bureau's standard hard-rubber-bar gate lip seal design, figure 10a. The correction algorithms apply only to the music note gate lip design, figure 10b, and to the hard-rubber-bar/music note design—which is a replacement of the music note (fig. 10b, item M) with the hard-rubber bar (fig. 10a, item L).

5. The radial gate face plate is flat and smooth.

Upstream and Downstream Water Depth Measurements

The upstream and downstream water depths used in the discharge algorithms are based on a depth that would occur in a rectangular channel having the same width as the radial gate and the same invert elevation as the gate sill. However, a rectangular channel of sufficient length upstream and downstream of the radial gate that would produce a normal depth measurement seldom exists in the prototype canal system. Usually the prototype canal has a trapezoidal cross section and a transition between the trapezoidal section and short rectangular section of the radial gate bay(s). Upstream and downstream water levels are therefore measured in the canal trape-zoidal section. To obtain a "normal" depth measurement for use in the discharge algorithms, energy balance equations and an iterative procedure are used to convert the actual water depth measurement made in the trapezoidal section to an equivalent depth that would have occurred in the rectangular section. The energy balance equations are discussed in greater detail in the "Head Loss Measurement" section below.

Locations of the upstream and downstream water level gages are important. Measurement of the actual water levels within the transitions or within the recovery area of the submerged hydraulic jump of the radial gate downstream should be avoided. Typically, the upstream water level gage should be located about 15 m (50 ft) upstream from the beginning of the upstream check structure transition. The downstream water level gage should be located about 30 m (100 ft) downstream from the end of the downstream check structure transition. If a canal siphon is located immediately downstream of the radial gate, the downstream water level gage should be located about 30 m (100 ft) downstream from the end of the siphon outlet transition.

The canal invert elevation at the upstream and downstream water level gage locations needs to be known in order to obtain a reference to the discharge algorithm's datum, which is the gate sill elevation. Canal invert elevation, including the gate sill, can be obtained from an "as-built" drawing. However, if the drawings are incorrect, a potential biased error can be easily introduced. Therefore, if possible, a second order survey should be conducted to obtain the invert elevations within a resolution of ±2 mm (0.005 ft) to eliminate this source of error.

To obtain the required resolution of the water level measurements of ±2 mm (±0.005 ft), a properly designed stilling well should be used. Staff gages located within the canal prism for visual observations are necessary for quick readings and checks by the ditchrider, but ordinarily do not provide the required resolution for the discharge algorithms, particularly when wind waves are present. A typical stilling well used by the Bureau of Reclamation is shown in figure IV-52 (drawing 214-D-20596) and figure IV-53. The stilling well has an inside diameter of 1.1 m (3.5 ft) and two inlet copper tubes, each with an inside diameter of 51 mm (2 in). Notice the inlet tubes each have a shutoff valve and a riser pipe. By shutting off the valve and connecting the outlet of a portable water pump to the riser pipe, any sediment deposit accumulation in the feeder pipe can be effectively flushed out to the canal. The piping and valve arrangement also prevents
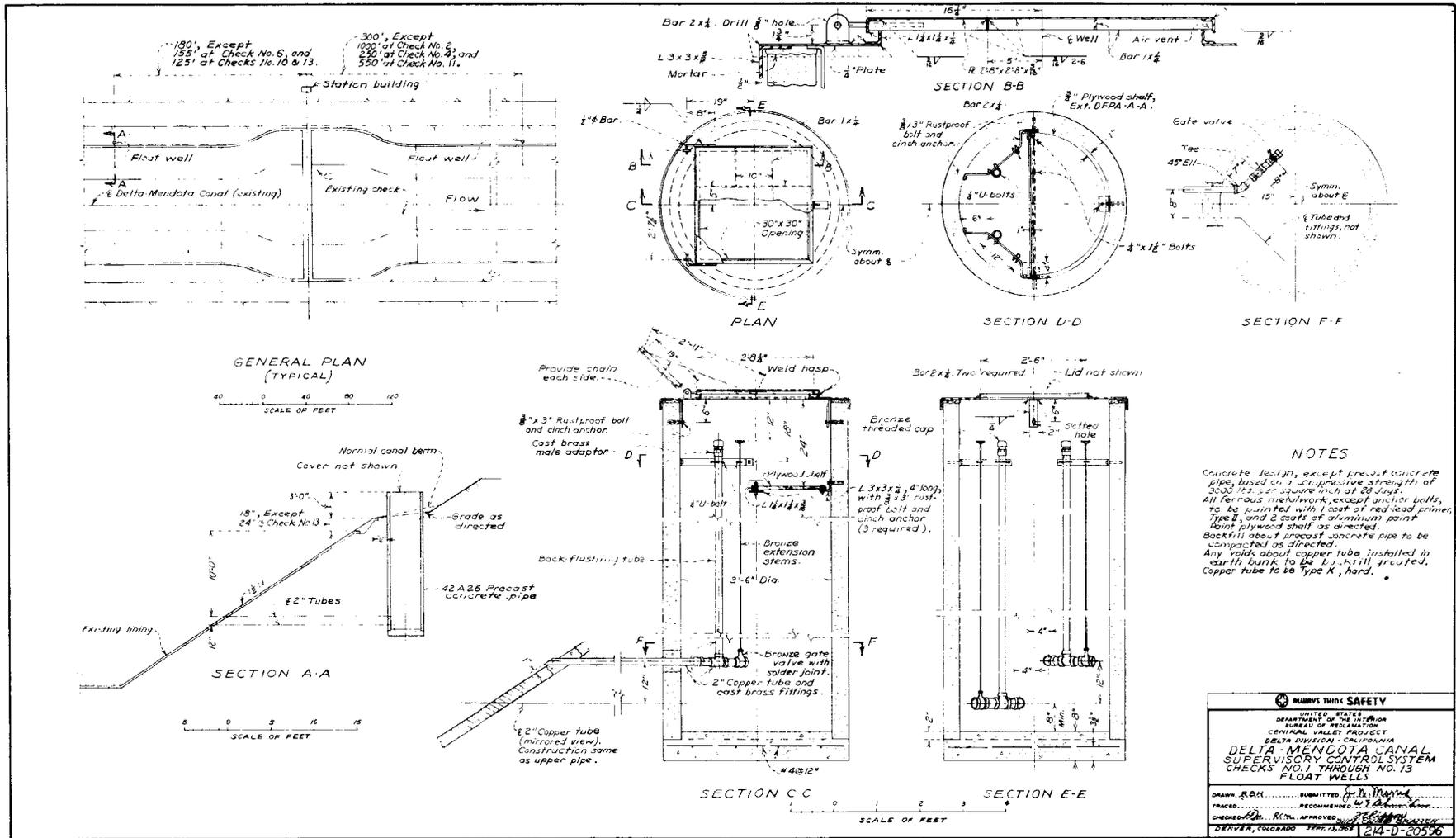
Figure IV-52.—Typical canalside stilling well design. Drawing No. 214-D-20596.

disturbance of the water level inside the stilling well during the flushing operation. This is an important feature for most canal automatic control systems which use the water level as a primary signal. Without the shutoff valve, the automatic control system would have to be deactivated to prevent unnecessary control action during the flushing operations. It is also extremely important to use noncorrosive metals for all piping, fittings, and valves, including valve handles and their extension stems, if frequent outages and high maintenance costs are to be avoided.

A plywood shelf is placed inside the well or its shelter housing for mounting the water-stage gage as shown in figure IV-54. The most common method used to measure the water stage is with the 0.3-m (12-in) diameter float, graduated steel tape, pulley, and counterweight. The rise and fall of the water stage is converted to a rotating shaft which then can be used to drive a shaft encoder (fig. IV-54a) or a water-stage recorder (fig. IV-54b). For visual observations (without continuous recording) and for calibration purposes, the water stage can be read directly from the steel tape using an indexed pointer (fig. IV-54b) when the steel tape is graduated in meters or feet at 5-mm or 0.01-ft increments. The graduated steel tape can be arranged to measure the water depth from the canal invert to the water surface or to read the last significant digits of the actual water surface elevation. In either case, the index pointer and tape graduations must be properly referenced to the canal invert elevation at the measurement location (which, as previously dis-

cussed, is referenced to the gate sill elevation) by a second-order survey. Further details regarding the proper installation of water-stage gages, recorders, and stilling wells can be found in chapter VI of reference [11].

Figure IV-53 shows the stilling well located adjacent to the top of the canal concrete lining with the instrumentation shelf inside the well, figure IV-54a, protected by a metal access lid that can be locked. An upper level shelter made of corrugated metal pipe, figure IV-54b, or a cinder-block house, figure IV-55a, provides easier access to the water-stage instrumentation shelf, but may interfere with the canal cleaning and maintenance operations. Therefore, on many canal systems, the stilling well with an upper shelter housing is located across the canal operation and maintenance roadway as shown in figure IV-55b. The cinder-block-type construction provides better temperature insulating and aesthetic characteristics than the corrugated-metal-type shelter.

Gate Opening Vertical Distance Measurement

The discharge algorithms require the vertical distance of the radial gate opening measured from the gate sill to the lowest part of gate lip seal. A direct measurement of the radial gate vertical opening is not easily obtained. There are three common methods used, each requiring an equation to convert the measured movement of the gate to the vertical distance:

1. Measure the arc distance of the gate faceplate movement.
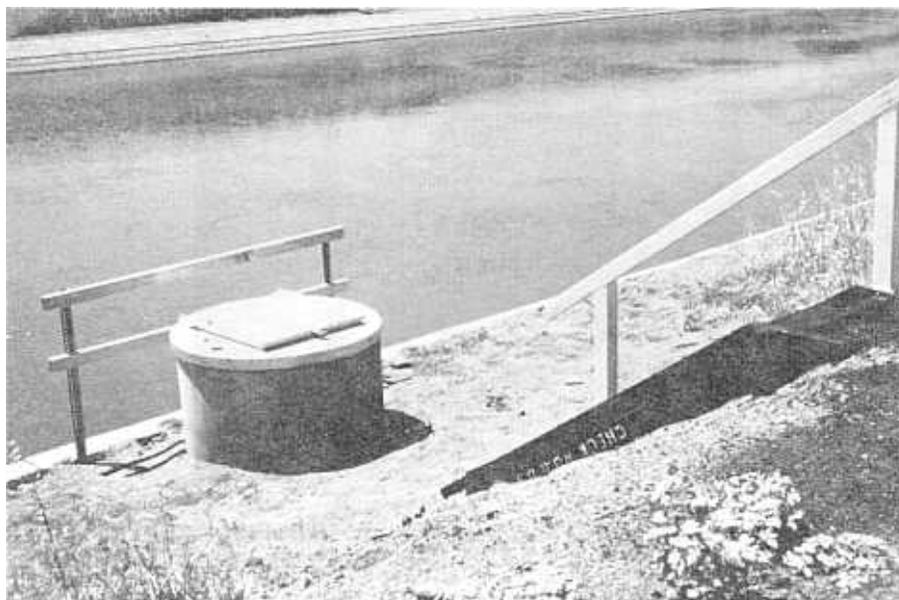
Figure IV-53.—View of a typical canalside stilling well installation. P801-D-80380

159
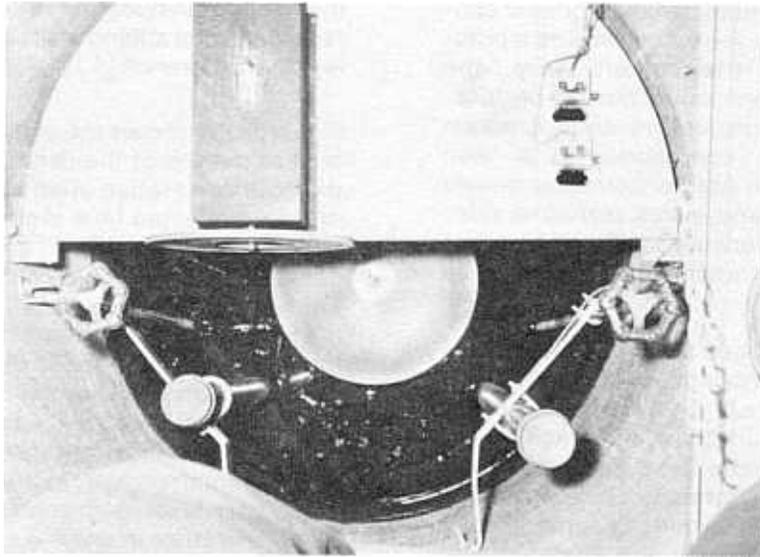
(a) Instrumentation inside concrete pipe stilling well. P801-D-80381
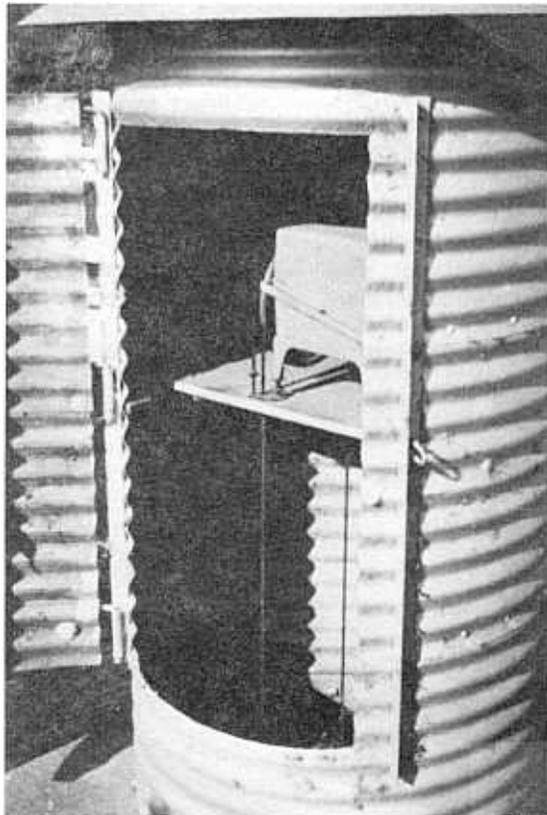
(b) Instrumentation inside corrugated metal pipe shelter. P801-D-80382

Figure IV-54.—Views of instrumentation in typical canal stilling wells.
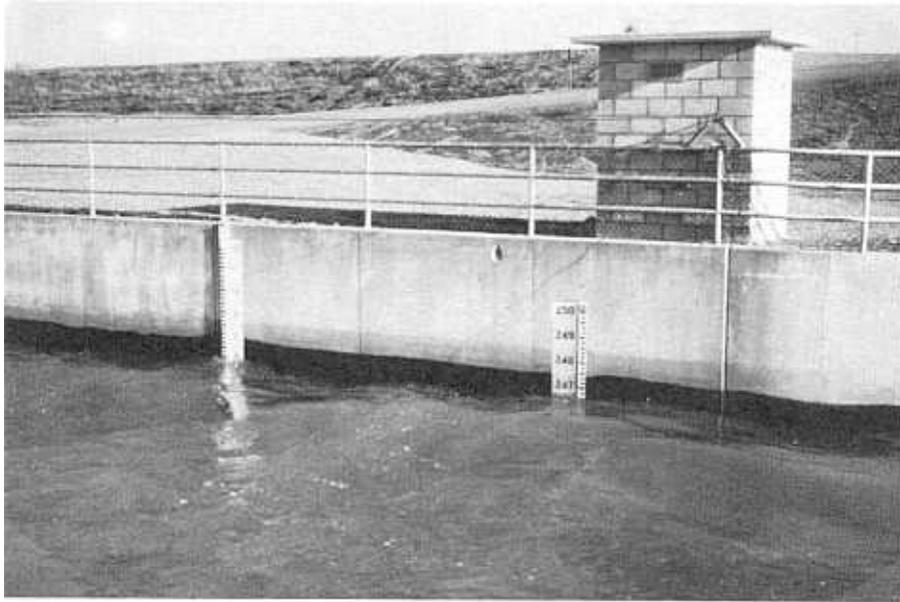
(a) Located next to canal section. P801-D-80383

(b) Located across operations and maintenance roadway. P801-D-80384

Figure IV-55.—Views of stilling wells with upper cinder block shelter housings.

161

Figure IV-56.—Typical visual staff gage for determining vertical opening of canal radial gates. This gage is known as the "rooster tail" and has an index pointer located on the concrete deck. P801-D-80385.

2. Measure the revolutions of the gate hoist shaft, which is essentially a measurement of the arc distance of the gate faceplate movement.

3. Measure the radial gate arm angular movement.

The first method provides an easy visual observation to determine the vertical distance of the gate opening. A staff gage is fastened to the radial gate faceplate as shown in figure IV-56. An index pointer is attached to the top of the check structure deck. When the gate is closed, the index pointer is at the zero position of the staff gage. An extension arm attached to the top of the radial gate (on the same radius as the faceplate) is usually required to obtain the zero position. This has become known as the "rooster tail" gage. The radial gate staff gage shown in figure IV-56 is an important basic requirement for canal operations. It is used by the ditchriders to obtain an accurate gate opening measurement. It is also used to calibrate other sensors used in remote manual/automatic supervisory control systems that measure the radial gate movement.

If the standard staff gage adopted by the Bureau of Reclamation (fig. 9, reference [11]) — graduated in feet at 0.01-ft increments — is used, the index pointer will indicate the arc distance the radial gate faceplate has traveled. To obtain the corresponding vertical distance the following equation is used:

$$GO(vertical) = PH - RAD$$
$$* COS \left[\left(\frac{GO\ (ARC) * 57.296}{RAD} \right) + \Theta \right]$$

where:

GO(vertical) = calculated value of the gate opening vertical distance from the gate sill to the bottom of the gate lip seal.

GO (ARC) = measured arc distance of the radial gate faceplate movement using a standard staff gage.

PH = pinion height measured from the gate sill to the centerline of the radial gate arm pivot pin.

RAD = radial gate arm radius measured from the upstream side of the gate faceplate to the centerline of the radial gate arm pivot pin.

COS = trigonometric cosine function.

Θ = vertical angle (degrees) of the gate lip radii when the gate is at zero position and is equal to the arc cosine function
= $cos^{-1}(PH/RAD)$.

57.296 = conversion factor for radians to degrees.

Using the standard staff gage (which is available commercially) and the above equation, the required resolution of ±2 mm (±0.005 ft) for the vertical distance of the radial gate opening can easily be achieved. Rather than solve the equation for every arc distance measurement, a computer program could be developed to generate a

162

table of the gate opening vertical distance, GO(vertical), versus the measured arc distance, GO(arc), for use by the ditchrider. However, a table would be required for each radial gate that has a different pinion height, PH, or gate arm radius, RAD.

At many field installations, the staff gage is calibrated by the field operators to read the vertical distance directly. This can be done by solving the above equation for the arc distance, GO(arc), at vertical distance intervals of 0.1 ft. The arc distances for each interval are then carefully measured, marked, and painted black, with the 0.5- and 1.0-ft increments having longer markings, on a flat piece of white material—thin gage plastic or galvanized sheet metal. The gage, now calibrated to read the gate opening vertical distance directly, is mounted to the gate faceplate with the zero at the index pointer when the gate is in the closed position. Figure IV-57a shows an example of a calibrated staff gage made by field personnel. Figure IV-57b is another example, showing a technique for marking the 0.1-, 0.5-, and 1.0-ft increments following the stadia survey rod method. The 0.1-ft interval markings allow the gate opening to be estimated only to the nearest 0.1 ft. Therefore, the resolution will be coarser ($\pm$0.05 ft) than that required to take full advantage of the discharge algorithm's potential accuracy. These gages could be re-calibrated to the 0.01-ft increments to improve the resolution of the gate opening measurement. The equation that can be used to obtain the arc distance measurements for selected calibrated vertical distances is as follows:

$$GO(ARC) = \frac{RAD}{57.296} * \left[COS^{-1}\left(\frac{PH - GO(Vertical)}{RAD} \right) - \Theta \right]$$

The rating chart of the gate opening vertical distance, GO(vertical), versus the measured arc distance, GO(arc), as mentioned previously, could also be used to obtain the calibrated staff gage increment arc distances. Also, for each radial gate that has a different pinion height, PH, or gate arm radius, RAD, a different calibration will be required.

The second method for obtaining the vertical distance of the radial gate opening involves the measurement of gate hoist shaft revolutions. Using the gate hoist shaft revolutions, the arc distance of the radial gate faceplate movement can be calculated by the following equation:

$$GO(ARC) = 3.142 * REV * DIA * GR$$

where:

GO(ARC) = the arc distance of the radial gate faceplate movement.

REV = measured number of revolutions of the gate hoist shaft.

DIA = diameter of the hoist cable drum measured center to center of the gate hoist cable as it is wrapped around the drum cable grooves.

GR = gear reduction ratio, and is used when the revolution counter is attached to the end of an intermediate gear reduction shaft. Otherwise, the gear reduction ratio is 1.0 when the revolution counter is attached directly to the end of the gate hoist cable drum shaft as shown in figure IV-58.

The above arc distance, GO(arc), can then be used in the previous equation to calculate the vertical distance of the gate opening.

The measurement of the number of revolutions, REV, to be used in the above equation requires the attachment of a revolution counter, which can be purchased commercially. However, it must be capable of dividing one revolution into about 600 increments to obtain the required resolution of $\pm$2mm ($\pm$0.005 ft) for the radial gate opening vertical distance calculation. Shaft encoders (used mainly for remote manual/automatic supervisory control systems) can also count the number of gate hoist revolutions. The shaft encoder, too, must be capable of counting 600 increments per revolution. A radial gate that opens 4.5 m (15 ft) requires about 5 revolutions of the hoist shaft; therefore, total count of about 3,000 is required to maintain the required gate opening resolution over the full range of the gate travel distance. Electronic potentiometers having a resolution of about $\pm$1 mV can also measure the number of revolutions of the hoist shaft by selecting a scale of 1 V output equals 1 revolution, for example.

The same basic technique used to calibrate the "rooster tail" staff gage can be used to calibrate a dial such as shown in figure IV-59. A pointer is attached to the gate hoist shaft and set to zero on the dial when the gate is closed. The pointer in figure IV-59 does not distinguish which revolution the gate hoist shaft is on; it is left up to the ditchrider to determine which scale on the dial should be read. The same requirements for obtaining the required resolution of $\pm$2 mm ($\pm$0.005 ft) of measurement of the vertical distance of the gate opening as discussed for the

163

(a) Line calibration technique. P801-D-80386
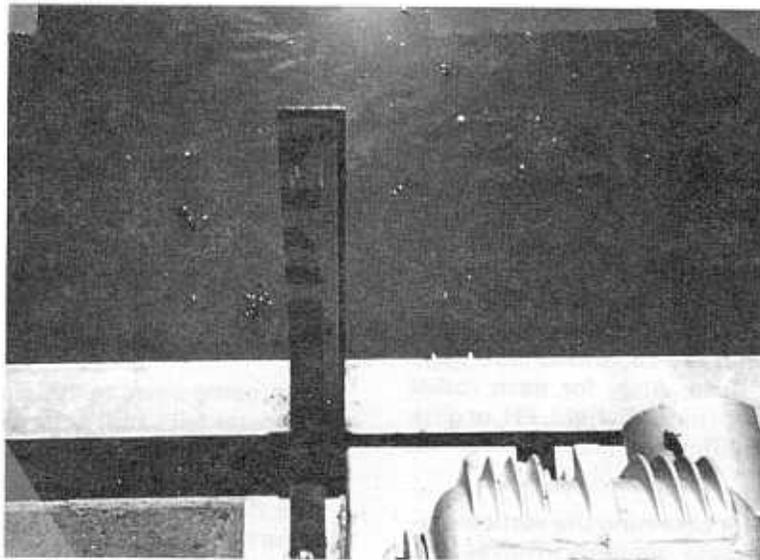
(b) Stadia survey rod markings. P801-D-80387

Figure IV-57.—Visual staff gages calibration techniques.
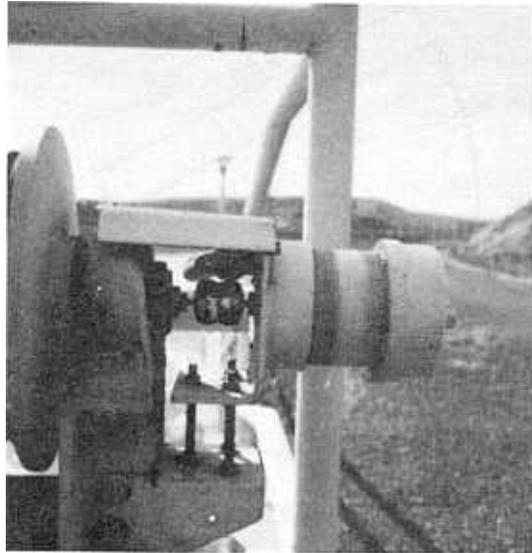
Figure IV-58.—Revolution-counter sensor on gate
hoist drum for determining gate position.
P801-D-80388
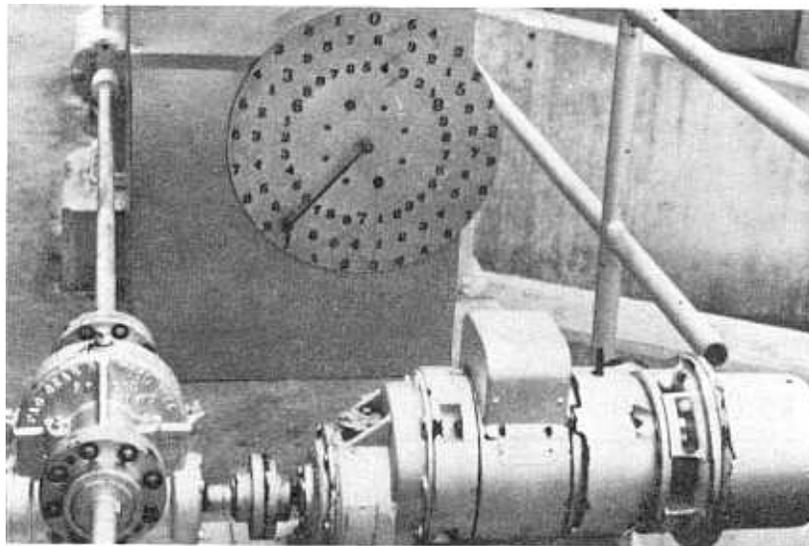
Figure IV-59.—Visual revolution counter for determining gate position.
P801-D-80389

165
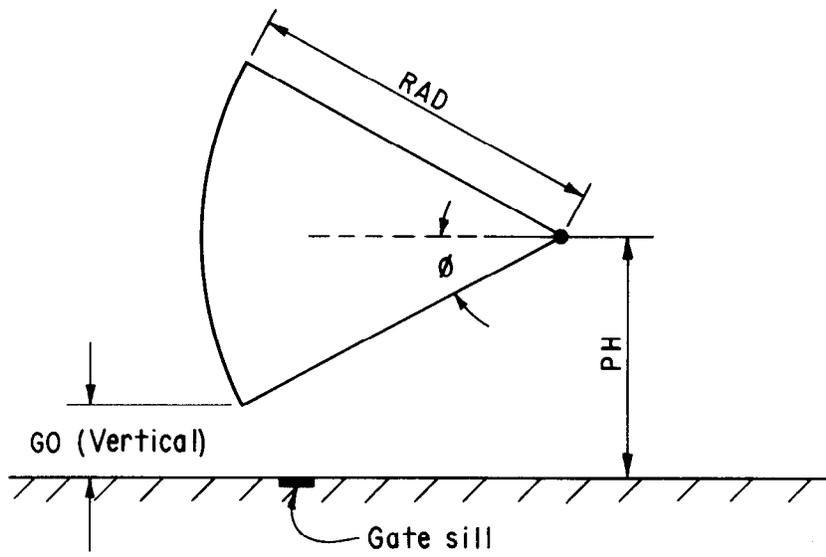
a. Measurement of horizontal angle Θ
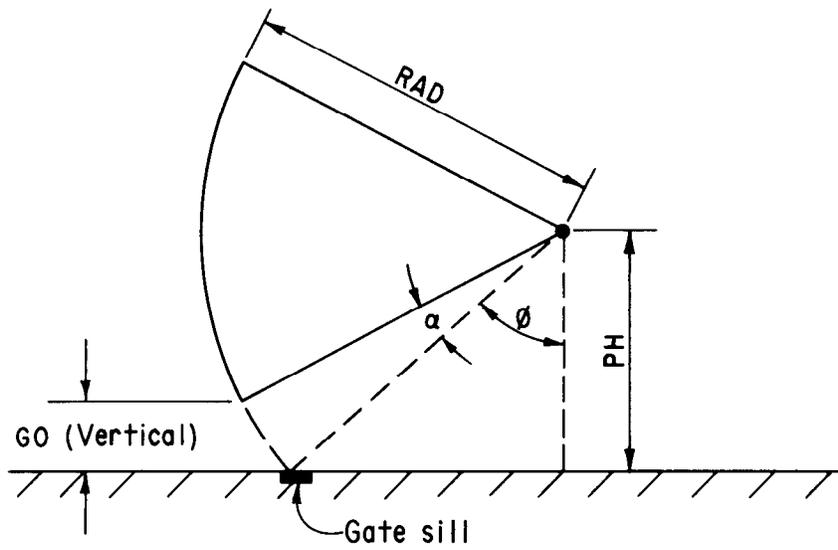
b. Measurement of vertical angle α + Θ

Figure IV-60.—Inclinometer measurement of canal radial gate arm angular movement.

166

revolution counter or shaft encoder applies to the dial calibration.

The third method used to determine the vertical distance of the gate opening is accomplished by measuring the angular movement of the radial gate arm. Using the angular movement of the gate arm, the vertical distance of the gate opening can be calculated by the following equation (refer to fig. IV-60a):

$$GO(vertical) = PH - SIN (\Theta) * RAD$$

where:

GO(vertical) = vertical distance of the gate opening measured from the gate sill to the bottom of the gate lip seal.

PH = pinion height measured from the gate sill to the centerline of the gate arm pivot pin.

SIN = trigonometric sine function

Θ = measured horizontal angle of the radial gate lip radii.

RAD = gate arm radius measured from the upstream side of the gate faceplate to the centerline of the pivot pin.

The above equation requires the angle Θ to be equal to SIN^{-1} (PH/RAD) when the gate is in the closed position. The angle Θ then decreases as the gate opens.

The following equation is another method that can be used and in some cases is preferred (refer to fig. IV-60b):

$$GO(vertical) = PH - COS (\alpha + \Theta) * RAD$$

where:
COS = the trigometric cosine function

α = measured angle movement of the radial gate arm.

Θ = vertical angle of the gate lip radii when the gate is closed and is equal to the COS^{-1} (PH/RAD)

Using the above equation, the angle α is zero when the gate is closed and increases as the gate opens.

Two devices have been used to measure the angular movement of the gate lip radii. California Aqueduct check No. 21 uses a pantograph arrangement attached to the gate arm to drive the shaft of a digital encoder. The rotation of the shaft determines the angle Θ by the number of counts the encoder outputs (refer to app. III and ref.[15]), and uses the first equation above. Inclinometers

are available commercially that can be attached to the radial gate arm near the pivot pin (if this location is not submerged at maximum flow conditions) which measure the angle α of the gate arm used in the second equation above. The inclinometer requires a balanced ±d-c voltage supply and a high resolution voltmeter (±0.1 mV) to read the output signal. Both devices should have the capability to read the angular movement with a resolution of about ±1 minute. The maximum angular movement of a typical radial gate is about 50°. Therefore, the angular movement must be divided into about 3,000 equal increments to obtain the required resolution of ±2 mm (±0.005 ft) of the gate opening vertical measurement.

Head Loss Measurements and Energy Balance Equations

The correct application of the discharge algorithms requires that any head losses that occur between the upstream and downstream water level measurement locations and the radial gate be included in the energy balance equations. In reference to figure IV-61, the upstream and downstream water levels, Y2 and Y3, are used in the discharge algorithms and are located in the rectangular sections 2 and 3. The upstream and downstream water level measurements at sections 1 and 4 are at a more convenient measuring location in the prototype canal, usually having a trapezoidal cross section. Located between sections 1 and 2, and 3 and 4, are the canal transitions from the trapezoidal to the rectangular sections. Also, the downstream canal siphon is located between section 3 and 4. The upstream and downstream energy balance equations are applied between sections 1 and 2 and between 3 and 4 and are as follows:

<u>Upstream Energy Balance Between Sections 1 and 2</u>

$$HU + VH1 = Y2 + VH2 - YINVERT + HLUP$$

where:

HU = measured upstream depth at section 1.

VH1 = velocity head at section 1 and is equal to V1**2/2*GC, where V1 is the mean velocity at section 1 and is equal to Q/AREAUP, where Q is the canal discharge, AREAUP is the canal cross-sectional area at section 1 equal to HU*(BWUP+ZUP*HU), where BWUP is the canal bottom width at section 1, ZUP is the canal sideslope horizontal-to-vertical-distance ratio (zero if vertical).

167
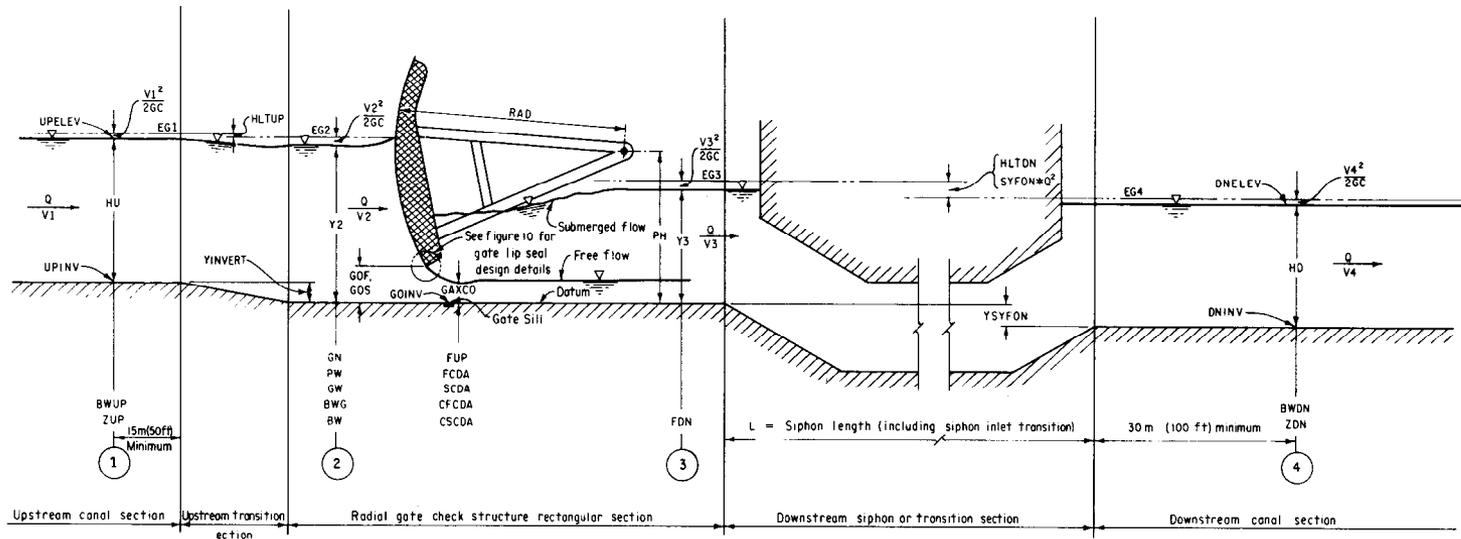
DEFINITION OF VARIABLES BY SECTION

Upstream Canal Section:

①= Location of prototype water depth measurement
EG1 = Energy gradient for upstream canal section
UPELEV = Water surface elevation
HU = Water depth
Q = Discharge rate
V1 = Velocity
UPINV = Invert elevation
BWUP = Bottom width
ZUP = Side slope

Upstream Transition Section:

HLTUP = Energy loss of transition
YINVERT = Change in invert elevation (negative
    when downstream elevation increases)

General Energy Balance Equations:

HU + V1**2/2GC + YINVERT = Y2 + V2**2/2GC + HLTUP

where: HLTUP = (ABS(V1**2/2GC - V2**2/2GC))*UPK
    UPK = Energy loss coefficient (normally 0.2)
    GC = Local acceleration due to gravity
    ABS = Absolute value

Y3 +V3**2/2GC = HD + V4**2/2GC - YSYFON + SYFON*Q**2 + HLTDN

where: HLTDN = (ABS(V3**2/2GC - V4**2/2GC))*DNK
    DNK = Energy loss coefficient (normally 0.1)
    SYFON = ((n/1.486)**2*L/(R**1.333*A**2))
    n = Roughness coefficient of Mannings formula
    1.486 = Conversion factor for English units
    L = Siphon length including upstream siphon transitions
    R = Hydraulic radius = A/P
    A = Cross section area
    P = Wetted perimeter

Radial Gate Check Structure Rectangular Section:

②= Location of upstream flow conditions used in algorithms
    and measured in Hydraulic Laboratory model
EG2 = Energy gradient upstream of radial gates
Y2 = Upstream water depth used in algorithms
Q = Discharge rate
V2 = Velocity
GN = Number of radial gates
PW = Pier width (each)
GW = Gate width (each)
BWG = Total gate width
BW = Bottom width of rectangular section
GOF = Gate opening for free flow conditions
GOS = Gate opening for submerged flow conditions
GOINV = Datum = Invert elevation of gate sill
GAXCO = Depth for contracted jet for free or submerged flow
RAD = Radial gate arm radius
PH = Radial gate pinion height
FUP = Upstream momentum plus hydrostatic force at contracted
    jet assuming free flow conditions
FCDA = Algorithm coefficient of discharge, free flow conditions
SCDA = Algorithm coefficient of discharge, submerged flow
    conditions
CFCDA = Correction to FCDA for music note gate lip seal, free
    flow conditions
CSCDA = Correction to SCDA for music note gate lip seal,
    submerged flow conditions
EG3 = Energy gradient downstream of radial gate(s)
Y3 = Downstream water depth used in algorighms
V3 = Velocity
FDN = Downstream momentum plus hydrostatic force based on
    water depth
③ = Location of downstream flow conditions used in algorithms
    and measured in Hydraulic Laboratory model

Momentum Plus Hydrostatic Force Equations:

FUP = Q**1/(GC*GW*GAXCO) + (BW/GN)*GAXCO**2/2.0

FDN = (Q**2/(GC*BW*Y3) + BW*Y3**2/2.0)/GN

where: FUP and FDN are the upstream and downstream momentum
    plus hydrostatic forces, respectively, for each
    radial gate and are used to determine if the flow
    condition for each gate is free or submerged, i.e.,

    IF(FUP.GT.FDN) Flow condition is free

    IF(FUP.LE.FDN) Flow condition is submerged

Downstream Siphon or Transition Section:

HLTDN = Energy loss of transition
SYFON*Q² = Energy loss of siphon
SYFON = Energy loss coefficient of siphon
Q = Discharge rate
YSYFON = Change in invert elevation (negative
    when downstream elevation increases)

Downstream Canal Section:

④= Location of prototype water depth measurement
EG4 = Energy gradient for downstream canal section
DNELEV = Water surface elevation
HD = Water depth
Q = Discharge rate
V4 = Velocity
DNINV = Invert elevation
BWDN = Bottom width
ZDN = Side slope

Figure IV-61.—Definitions of variables and equations for canal radial gate structures.

Y2 = upstream depth used in the discharge algorithm located in the rectangular section 2.

VH2 = velocity head at section 2 and is equal to $V2**2/2*GC$, where V2 is the mean velocity at section 2 and is equal to $Q/BWG*Y2$, where Q is the canal discharge, and $BWG*Y2$ is the cross-sectional area at the rectangular section 1, BWG is the total width of the gate(s) not including piers.

YINVERT = change in the canal invert from section 1 to section 2 (negative if the canal invert elevation increases from sections 1 to 2).

HLTUP = transition head losses between sections 1 and 2 and is equal to [ABS (VH1-VH2)] * UPK, where ABS is the absolute value function and UPK is the energy loss coefficient, normally 0.2.

GC = gravitational constant.

Downstream Energy Balance Between Sections 3 and 4

$$Y3 + VH3 = HD + VH4 - YSYFON + SYFON*Q**2 + HLTDN$$

where:

Y3 = downstream depth used in the discharge algorithm located in the rectangular section 3.

VH3 = velocity head at section 3 and is equal to $V3**2/2*GC$, where V3 is the mean velocity at section 3 and is equal to $Q/BWG*Y3$, where Q is the canal discharge and $BWG*Y3$ is the cross-sectional area at the rectangular section 3, BWG is the total width of the gate(s) not including piers.

HD = measured downstream depth at section 4.

VH4 = velocity head at section 4 and is equal to $V4**2/2*GC$, where V4 is the mean velocity at section 4 and is equal to $Q/AREADN$, where Q is the canal discharge, AREADN is the canal cross-sectional area at section 4 equal to $HD*(BWDN + ZDN*HD)$, where BWDN is the canal bottom width at section 4, ZDN is the canal sideslope horizontal to vertical ratio (zero if vertical).

YSYFON = change in the canal invert elevation from section 3 to section 4 (negative if the canal invert elevation increases from section 3 to 4).

SYFON

*Q**2 = siphon head loss, where SYFON is the energy loss coefficient (set to zero when the siphon does not exist) and is equal to $(n/1.486)**2*(1.0/R**1.333)*(1.0/A**2)*L$ (inch-pound units; for metric units the constant 1.486 is replaced by 1), where n = Mannings friction factor typically equal to 0.013, R is the hydraulic radius and is equal to the total cross-sectional area of the siphon, A, divided by the wetted perimeter of the siphon, P, L is the nominal length of the siphon including the length of the siphon's upstream transition, and Q is the canal discharge.

HLTDN = transition head losses between sections 3 and 4 and is equal to [ABS (VH3-VH4)]*DNK, where ABS is the absolute value function and DNK is the energy loss coefficient, normally 0.1.

The upstream and downstream energy balance equations described above accomplish two objectives:

1. Convert the upstream and downstream water depths, HU and HD, measured at the canal sections 1 and 4 to the depths, Y2 and Y3, at the rectangular sections 2 and 3 for use by the discharge algorithms and requires an iterative solution.

2. Adjusts the upstream and downstream depths, Y2 and Y3, at the rectangular sections 2 and 3 for head losses that occur between the measured upstream and downstream depths, HU and HD, at the canal sections 1 and 4 and the rectangular sections 2 and 3 and requires an iterative solution when solving for the canal discharge, Q.

The discharge algorithms upstream and downstream water depths, Y2 and Y3, are determined by an iterative solution of the upstream and downstream energy balance equations. First, it is necessary to make an estimate of the depths, Y2 and Y3, by equating Y2 and Y3 to the energy gradients, EG2 and EG3, at sections 2 and 3 using the measured epths HU and HD as the initial depth estimate, respectively. The procedure of the iterative solution is as follows:

Iterative Solution of the Upstream Energy Balance Equations Between Sections 1 and 2

1. Estimate the depth Y2 for the initial iteration:

Y2 = EG2 = HU + VH1 + YINVERT–HLTUP

2. Then use the convergence routine (Newton method of successive approximation [10]):

VH2 = [(Q/(BWG*Y2))**2]/(2.0*GC)
DY2 = – (EG2 – Y2 – VH2)
      /(–1.0 + 2.0*VH2/Y2)
Y2 = Y2 + DY2

If ABS (DY2) is greater than YDELTA equal to 0.002 (or greater than a desired water depth tolerance level), repeat the above latter three equations.

Iterative Solution of the Downstream Energy Balance Equations Between Sections 2 and 4

1. Estimate the depth Y3 for the initial iteration:

Y3 = EG3 = HD + VH4 – YSYFON
            + SYFON*Q**2 + HLTDN

2. Then use the convergence routine (Newton's method of successive approximation [10]):

VH3 = [(Q/(BWG*Y3))* 2]/(2.0*GC)
DY3 = –(EG3 – Y3 – VH3)
      /(–1.0 + 2.0*VH3/Y3)
Y3 = Y3 + DY3

If ABS (DY3) is greater than YDELTA equal to 0.002 (or greater than a desired water depth tolerance level) repeat the above latter three equations.

The iterative solution of the downstream energy balance equations is not necessary for the free flow discharge algorithms. It is required for the submerged discharge algorithms, and for conducting the free and submerged flow tests when the flow condition is unknown.

With the upstream and downstream depths, Y2 and Y3, known, the discharge algorithms can now be solved. However, if the discharge algorithms are being used to solve for the canal discharge, it is then necessary to estimate the initial discharge for the iterative solution of the discharge algorithms as follows:

1. Estimate the free flow discharge, QFT, to be used by the free flow discharge algorithms when solving for the canal discharge (with the gate(s) openings known):

QFT = 0.6*GW*GOT*SQRT(2.0*GC*HU2)

where:

0.6 = estimated free flow coefficient of discharge, FCDA.

GW = gate width for one gate.
GOT = sum total of all the gate openings.
SQRT = square root function.
GC = gravitation constant.
HU2 = upstream depth, HU plus the change in canal invert elevation, YINVERT between secitons 1 and 2.

2. Estimate the submerged flow discharge, QST, to be used by the submerged flow discharge algorithms when solving for the canal discharge (with the gate(s) openings known):

QST = 0.3*GW*GOT*SQRT(2.0*GC*HU2)

where:

0.3 = estimated submerged flow coefficient of the discharge, SCDA.

3. Solve the energy balance equations above using the estimated free and submerged discharges, QFT and QST, replacing Q with QFT and QST to obtain an estimate for upstream and downstream depths, Y2 and Y3.

4. Solve the free and submerged flow discharge algorithms using the estimated quantities, QFT and Y2, and QST, Y2, and Y3, respectively, to obtain a new estimate of the discharges, QFT and QST.

5. If the absolute value of the difference between the old and new discharges is greater than QDELTA equal to 1.0 (or greater than a desired discharge tolerance level), repeat the process starting at 3 above, using the new values of QFT and QST. The computer program listing and description, appendix V, shows a procedure of convergency for the discharge calculation using Newton's method of approximation [10] that can be used and results in fewer iterations required to converge onto the correct canal discharge.

If the discharge algorithms are being used to solve for the gate opening(s), the total discharge will be known. Therefore, the upstream and downstream depths, Y2 and Y3, can be determined with one iteration of the energy balance equations without estimating the inital discharge. However, the discharge algorithms are a function of the gate opening. Since the gate opening is unknown, it will be necessary to first estimate the gate opening and then solve the discharge algorithms iteratively until the new and old values agree. The procedure is as follows:

1. estimate the free flow gate opening, GOF, to be used by the free flow discharge algorithms when solving the gate openings(s) (with the total discharge known):

GOF = QF/(0.7*GW*SQRT(2.0*GO*HU2))

170

where:

QF = free discharge per gate, determined by dividing the known total discharge, QFT, by the number of gates, GN.

0.7 = estimated free flow coefficient of discharge, FCDA.

2. Estimate the submerged gate opening, GOS, to be used by the submerged flow discharge algorithms when solving for the gate opening(s) (with the total discharge known):

GOS = QS/(0.3*GW*SQRT(2.0*GC*Y2))

where:

QS = submerged discharge per gate determined by dividing the known total discharge, QST, by the number of gates, GN.

0.3 = estimated submerged flow coefficient of discharge, SCDA.

Y2 = upstream depth determined from the upstream energy balance equations.

3. Solve the free flow and submerged flow discharge algorithms using the known values of QF, QS, Y2, and Y3, respectively, to obtain a new estimate of the gate opening(s), GOF and GOS.

4. If the absolute value of the difference between the old and new gate openings is greater than GDELTA equal to 0.002 (or greater than a desired gate opening tolerance level), repeat item 3 above using the new values of GOF and GOS. A procedure of convergency using Newton's method of approximation [10] is shown in the program listing, appendix V. The program description and listing also describes the procedure to use when gates are limited to fixed positions.

The above iterative procedures sometimes will not converge onto the true values of discharge or gate openings when the initial estimate are too far away from the true value. In these cases, it may be necessary to adjust the estimated values of the coefficient of discharges for free and submerged flow conditions in the proper direction until the iterative procedure converges instead of diverging.

It was necessary to develop the discharge algorithms based on the upstream and downsteam water depths, Y2 and Y3, for the equivalent rectangular channel upstream and downstream of the radial gate without energy losses. The discharge algorithms can, therefore, be applied to any canal check structure having an infinite variety of geometric configurations upstream and downstream of the radial gate. Prototype canal

water depths, HU and HD, measured at a more convenient location are interfaced to the discharge algorithms through the use of the energy balance equations to calculate the correct upstream and downstream depths, Y2 and Y3.

Transitions—The energy losses for typical streamlined canal transitions are usually small. However, if they are not included, the error of the discharge algorithms will be biased by about +0.3 percent (based on experimental analysis of the field verification test data, app. III, with and without transition losses). The energy loss coefficients, UPK and DNK, are expressed interms of the change in the velocity head between the beginning and the end of the transition. Head losses for the upstream and downstream transitions, respectively, are:

HLTUP = [ABS (VH1 − VH2)]*UPK

and

HLDTN = [ABS (VH3 − VH4)]*DNK

where:

HLTUP = head loss of the upstream transition.

ABS = absolute value function.

VH1 and VH2 = velocity head at the beginning and end of the upstream transition.

UPK = energy loss coefficient for the upstream transition.

HLDTN = head loss of the downstream transition.

VH3 and VH4 = velocity head at the beginning and end of the downstream transition.

DNK = energy loss coefficient for the downstream transition.

For the typical streamlined canal transitions, the energy loss coefficients, UPK and DKN, normally used are 0.2 and 0.1, respectively. Transitions that are not streamlined or that have an abrupt change in the cross-sectional area from beginning to the end may require higher values. When the velocity changes significantly, such as at canalside turnouts at right angles to the approaching flow, an energy loss coefficient of 0.5 should be used, with the approach velocity set equal to zero.

From field experience (Putah South Canal special field test of July 17, 1980, app. III), downstream transitions that have significant drops in the canal invert from beginning to end (more than about 0.15 m [0.5 ft]) have considerable losses, because they begin to act like miniature plunge basins. Little experimental data are available in

literature to obtain an accurate estimate of the energy loss coefficient for these miniature plunge basins. Therefore, it will be necessary in these cases to make field measurements to obtain the true value of the energy loss coefficient. Water depths at the beginning and end of the transition will have to be measured accurately using water surface level gages [17] designed especially for this purpose. Canal discharge will also have to be measured at the same time using the best practices of current meter measurement [11]. Several test data points should be collected at various discharge stages, from small to the maximum, if possible. The head loss equations can be used to solve for the loss coefficient, DNK, because the energy gradients and velocity heads are known, as follows:

$$DNK = (EGUP - EGDN)/[ABS (VHUP - VHDN)]$$

where:

> EGUP = is the upstream energy gradient, and is equal to DUP + VHUP, where DUP is the measured depth at the beginning of the transition measured from the canal invert to the water surface.

> EGDN = is the downstream energy gradient, and is equal to DDN + VHDN + YSYFON, where DDN is the measured depth at the end of the transition measured from the canal invert to the water surface and YSYFON is the change in the canal invert elevation from the beginning to the end of the transition.

> VHUP and
> VHDN = velocity head at the beginning and end of the transition, respectively, and is equal to V**2/2*GC, where V is the mean velocity equal to the measured discharge, Q, divided by the cross-sectional area of the respective upstream and downstream ends of the transition, and GC is the gravitational constant equal to 32.2 ft/s^2.

Another method that can be used to calculate the head loss of the miniature plunge basin is to assume that a siphon exists where the head loss would be SYFON*Q**2, and the loss coefficient, SYFON, if found in this manner:

$$SYFON = (EGUP - EGDN)/Q**2$$

where: EGUP, EGDN, and Q are determined from field measurements as described above.

Either method described works satisfactorily and both require the same accurate field data, including the elevations of the canal invert at the beginning and end of the transition, which should be accurately measured by a second order survey. The energy loss coefficients, DNK and SYFON, probably vary as a function of the canal discharge or gate opening. A sufficient number of test data points would permit the development of an algorithm to vary the loss coefficients as the discharge changes, such as discussed for the Tehama-Colusa Canal check No. 3 and the California Aqueduct check No. 21 included in the field verification test program, appendix III.

A significant increase in the canal invert elevation from the beginning to the end of the canal transition appears not to have high energy-loss characteristics. The Putah South Canal headworks upstream transition has a significant rise in the canal invert (1.52 m [5.0 ft] in a distance of 25 m [82.0 ft]). Data from the special field test of July 17, 1982, appendix III, determined the energy loss coefficient to be 0.23, which is very near the nominal value of 0.2. Therefore, nominal values for the loss coefficients can be used without introducing significant errors when the canal transition invert elevation rises significantly from the beginning to the end.

Siphons.—Many typical canal check structures have a siphon located immediately downstream, as shown in figure IV-61. It is difficult to obtain a satisfactory downstream water level measurement between the radial gate and the entrance to the siphon. Therefore, the downstream water level is measured about 30 m (100 ft) downstream from the end of the siphon outlet transition in canal section at section 4. The head losses caused by the siphon must therefore be included in the downstream energy balance equations as discussed previously. Head loss for the siphon is usually expressed as SYFON*Q**2, where SYFON is the energy loss coefficient and Q is the canal discharge. The energy loss coefficient, SYFON, can be determined theoretically with a fair degree of confidence using the following equation:

$$SYFON = (n/1.486)**2*(1.0/R**1.333)$$
$$*(1.0/A**2)*L$$

where:

> n = Manning's coefficient of friction and has a design value of 0.013 for concrete siphons. However, a slightly larger value of 0.014 is often used to account for the growth of algae and other encrustations on the concrete surfaces.

1.486 = conversion factor for inch-pound units (for metric units, the factor 1.486 is replaced by 1.0).

R = hydraulic radius, and is equal to the total cross-sectional area, A, divided by the wetted perimeter, P, of the siphon.

A = cross-sectional area of the siphon.

L = total nominal length of the siphon, including the length of the siphon inlet transition.

An example for calculating the energy loss coefficient, SYFON, including the change in the siphon invert elevation, YSYFON, is shown on figure IV-62. The total length of the siphon includes the length of the siphon inlet transition in order to account for energy losses at the entrance to the siphon. Energy losses of the siphon outlet transition are the same as for the downstream canal transition discussed previously. Geometry of the siphon is usually obtained from design or "as-built" drawings. If the geometry is not available from drawings, it will be necessary to obtain field measurements to determine the length, width, and height dimensions for box siphons, or the diameter for pipe siphons, before an accurate calculation of the siphon energy loss coefficient, SYFON, can be made.

Usually the theoretical computations for the energy loss coefficient, SYFON, as shown on figure IV-62, provide satisfactory results. However, to avoid the introduction of a biased error, the theoretical value should be verified by obtaining at least one field measurement at the higher flow range. Field measurement of the siphon head loss and discharge is similar to the procedure discussed for canal transition head loss and discharge field measurements. Specially designed water surface level gages[17] are used to obtain an accurate measurement of the siphon inlet and outlet water surface elevations. The difference between the upstream and downstream measured water surface elevations would be the head loss of the siphon, and by measuring the canal discharge using the best practices of current meter measurement [11], the energy loss coefficient, SYFON, can be calculated as follows:

$$SYFON = (ELUP - ELDN)/Q**2$$

where:

SYFON = the field measurement of the siphon energy loss coefficient.

ELUP = field measurement of the water surface elevation upstream at the siphon inlet.

ELDN = field measurement of the water surface elevation downstream at the siphon outlet.

Q = field current meter measurement of the canal discharge.

Since the current meter measurements take a relatively long period to complete, the water surface level gages should be read at about 15-min intervals. All readings taken during the current-meter-measurements period would then be summated and divided by the number of readings to obtain the average water surface elevation that would correspond to the measured canal discharge.

Better results could also be obtained if the energy loss coefficient, SYFON, could be determined for several canal discharges ranging from small to the maximum. If the values of the calculated SYFON versus the measured discharges, Q, do not show a definite linear or nonlinear relationship, the average of all the calculated values of SYFON should then be used. If there is a definite trend, an algorithm should be developed to vary the siphon energy loss coefficient, SYFON, as a function of the canal discharge, Q, or the gate opening, GO, similar to the procedures used at the Tehama-Colusa Canal check No. 2 and the California Aqueduct check No. 21, described in appendix III.
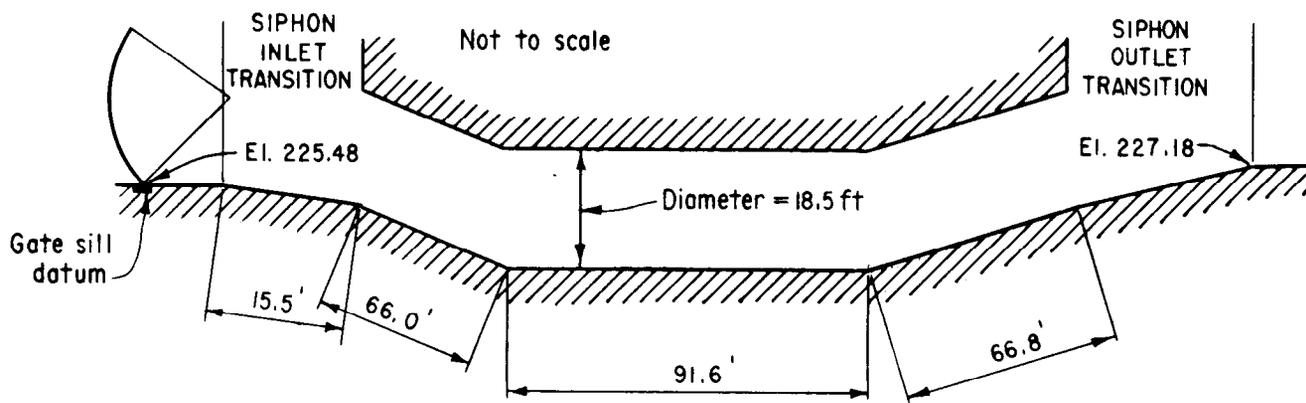
Trashracks. — Locating trashracks between the water level measurement station and the radial gate should be avoided. The head loss of a trashrack is unpredictable because of the debris buildup and its removal characteristics.

Other. — Canal transitions and downstream siphons are the main canal structures that cause significant head losses between the water level measurements and the radial gate equivalent rectangular section. There are undoubtedly other types of canal configurations that can cause significant head loss that must be included in the energy balance equations. The procedures that account for the head losses for the other types of canal structures would follow closely those for transitions and siphons, including the determination of the energy loss coefficients by field measurements.

Summary

The geometry of all the radial gate variables used in the energy balance equations and the discharge algorithms (listed in table III-5) should be verified by field measurements to ensure that the values obtained from engineering drawings are correct. If there are no drawings available, it is absolutely necessary to obtain accurate field measurements of the geometry. Also, the critical canal invert elevations at the upstream and downstream water level locations and at the gate

173

Tehama-Colusa Canal Coyote Creek Siphon, Mile 5.03
(located immediately downstream of check No. 3)

SIPHON INLET TRANSITION

Not to scale

SIPHON OUTLET TRANSITION

El. 225.48

El. 227.18

Diameter = 18.5 ft

Gate sill datum

15.5'   66.0'   91.6'   66.8'

YSYFON = gate sill datum elevation - siphon outlet elevation = 225.48 -227.18 = -1.70
SYFON = (n/1.486)**2*(1.0/R**1.333)*(1.0/A**2)*L

Where: n = 0.014
(n/1.486)**2 = 0.000088760
A = π * D**2/4.0 = 3.14 * 18.5** 2/4.0 = 268.8
P = π * D = 3.14 * 18.5 = 58.1
R = A/P = 268.8/58.1 = 4.626
R**1.333 = 4.63 **1.333 = 7.713
A**2 = 268.8 **2 = 72253.4
1.0/A**2 = 0.000013840
L = 15.5 + 66.0 + 91.6 + 66.8 = 239.9

SYFON = (0.000088760/7.713/72253.4) * 239.9 = 0.000000038

Figure IV-62.—Example calculations for the change in the siphon invert elevation, YSYFON, and the siphon energy loss coefficient, SYFON.

sill should be obtained by second order survey if at all possible, to determine accurately the change of invert elevations, YINVERT and YSYFON (refer to fig. IV-61). The index pointer elevations for the water level gages should also be obtained by the second order survey. The index pointer for the gate-opening staff gage should be at zero when the gate is closed. The gate-opening calibration from the method of measurement to the vertical distance must be accurately defined. Head loss calculations must be accurate in order to avoid the possibility of having large biased errors even before the discharge algorithms are applied.

The exact configuration of the gate lip seal must be examined closely. Results of the laboratory and field verification test programs have illustrated that what may seem to be minor deviations

from the standard hard-rubber-bar design can cause significant changes in the coefficient of discharge—as much as 20 percent for the full range of gate openings. Correction algorithms that produce satisfactory results have been developed for the music note seal, a combination of the hard-rubber-bar and music note design, and for the sharp edge (without a gate lip seal). However, if the gate lip seal design is different, even in a minor way, from the designs included in this report, the correction algorithms can be recalibrated. It will require about 30 test data points over the full range of operation to develop the correction factor relationship from which a new correction algorithm can be developed. The discussion of the West Canal and East Low Canal headworks, appendix III, provides the technique that can, with sufficient test data points, be used to develop the correction algorithms.

174

General Use Computer Program

The application of the discharge algorithms to operating canal check structures can be made through the use of the general use computer program. The program description and listing are included in appendix V.

The general use computer program solves the energy balance equations and the free- and submerged-discharge algorithms. A test is included to determine if the flow is either free, submerged, or in the transition zone where the flow is unstable and oscillates between free and submerged conditions. The transition zone discharge is simply the average of the free and submerged discharges calculated by the algorithms. The general use computer program can be used by operators in the form of interactive computer terminal response or by developing rating tables.

Interactive computer terminal response.—The watermaster can determine the discharge or the required gate opening for the canal check structures by using the interactive computer terminal response feature of the general use computer program. A typical example is shown on figure IV-63. The first line, -, RGRUN is a procedure file used to execute the general use computer program. The first data input at the first "?" is the check number entered from the computer terminal. The check number identifies the canal and radial gate geometry (which are in the program as data statements) that are to be used. The second data input are the upstream and downstream water surface elevations. The next question asks the operator if he wants to solve for the discharge, Q, or the gate opening, G. "Q" was entered becauses he wanted to calculate the discharge based on known gate openings. The program then asks for three gate openings (because there are three radial gates at this check structure).

If the operator had wanted to solve for the gate opening based on a desired discharge and had entered "G" instead of "Q", the program would have asked for the total discharge for this check structure instead of the three gate openings. It would then ask, however, if there are any gate opening limits. By entering "Y" for yes, the operator would have the opportunity to enter a value for the gate openings that are fixed in position. Keeping the gate in a fixed position could mean that it is mechanically inoperable or set at a limit, or simply that the operator only wants to move one of the gates, etc., A-1 is entered for the gates that are not limited or the ones that are to change position.

The computer program then outputs the solution of the discharge algorithms as shown next on figure IV-63. The table shows "∗∗∗∗∗" for the "INPUT DISCH" column. In this example "Q" was entered in order to calculate the discharge as shown in the "OUTPUT DISCH" column. If "G" had been enered, the "INPUT DISCH" column would have listed the total discharge entered by the operator. The "OUTPUT DISCH" column would then be the calculated discharge for the check structure, including the gate limit considerations if any were entered. Usually the discharge input by the operator and the output calculated by the algorithms agree. However, in some cases the discharge input by the operator will differ from the calculated discharge. The calculated discharge is based on the upstream and downstream water levels and the gate openings that were fixed into position. The gate opening for the movable gates is automatically limited to the maximum upstream water depth; therefore, the discharge calculated by the algorithms may be less than the given input discharge. The program output also includes the check number; check name; upstream and downstream water surface elevations (or depths); and the gate openings, discharge, and flow condition for each radial gate at the check structure. The data used in the above example are taken from the Tehama-Colusa Canal check No. 1 field verification test data, table III-6, special field test dated February 12, 1980.

The program then asks if the data just printed are "OK." At this point, the operator can review his entries and check for any mistakes. If he wants the run saved for later tabulation, he enters "Y" for yes, or if he does not want to save the data, he enters "N" for no and the run is deleted. The next question asks if he wants to enter more data; i.e., redo the run just deleted, enter an alternative flow condition, or obtain solutions for a different check structure. If he wishes to continue, he enters "Y." When he has completed all his runs, he enters "N," rolls the carriage to the top of a new page, and hits carriage return. At this point, the program tabulates all the runs that were saved. When the tabulation is completed, the program ends. More examples of the interactive terminal response feature of the general use computer program are shown in appendix V.

The use of the interactive terminal response feature can become laborious, particularly when there are many check structures involved. The program could be modified to read a file that contains the necessary data inputs that have been entered by the operator, or by a remote supervisory control system using real time data from the check structures and future flow inputs from the operator. The interactive terminal

-,RGRUN

    INPUT CHECK DATA AS FOLLOWS:
    CHECK NO. =
? 1
    UPSTREAM AND DOWNSTREAM WATER ELEVATIONS=
? 248.28,246.52
    DO YOU WANT TO CALCULATE DISCHARGE,Q OR GATE OPENINGS,G ?
    ENTER Q OR G
? Q
    GATE OPENINGS FOR 3. GATES =
? 2.67,2.67,2.67
                    CANAL RADIAL CHECK GATES
            DISCHARGE AND/OR GATE OPENINGS BY ALGORITHMS

CHECK	CHECK	H2O UP	H2O DOWN	INPUT	OUTPUT	****GATE	PROPERTIES	****	
NO.	NAME	ELEV.	ELEV.	DISCH.	DISCH.	NO. OPEN.	DISCH.	COND.	
		FT.	FT.	FT3/S	FT3/S	FT.	FT3/S		

****

1	VEL. BARR.	248.280	246.520	*****	1079.4	1	2.670	359.8	SUBM
						2	2.670	359.8	SUBM
						3	2.670	359.8	SUBM

****

    IS THIS RUN OK?
    ENTER YES OR NO
? Y
    DO YOU WANT TO ENTER MORE DATA ?
    ENTER YES OR NO
? N

                    CANAL RADIAL CHECK GATES
            DISCHARGE AND/OR GATE OPENINGS BY ALGORITHMS

CHECK	CHECK	H2O UP	H2O DOWN	INPUT	OUTPUT	****GATE	PROPERTIES	****	
NO.	NAME	ELEV.	ELEV.	DISCH.	DISCH.	NO. OPEN.	DISCH.	COND.	
		FT.	FT.	FT3/S	FT3/S	FT.	FT3/S		

****

1	VEL. BARR.	248.280	246.520	*****	1079.4	1	2.670	359.8	SUBM
						2	2.670	359.8	SUBM
						3	2.670	359.8	SUBM

****

1# END OF DATA INPUT #
READY.

Figure IV-63.—Typical interactive computer terminal response.
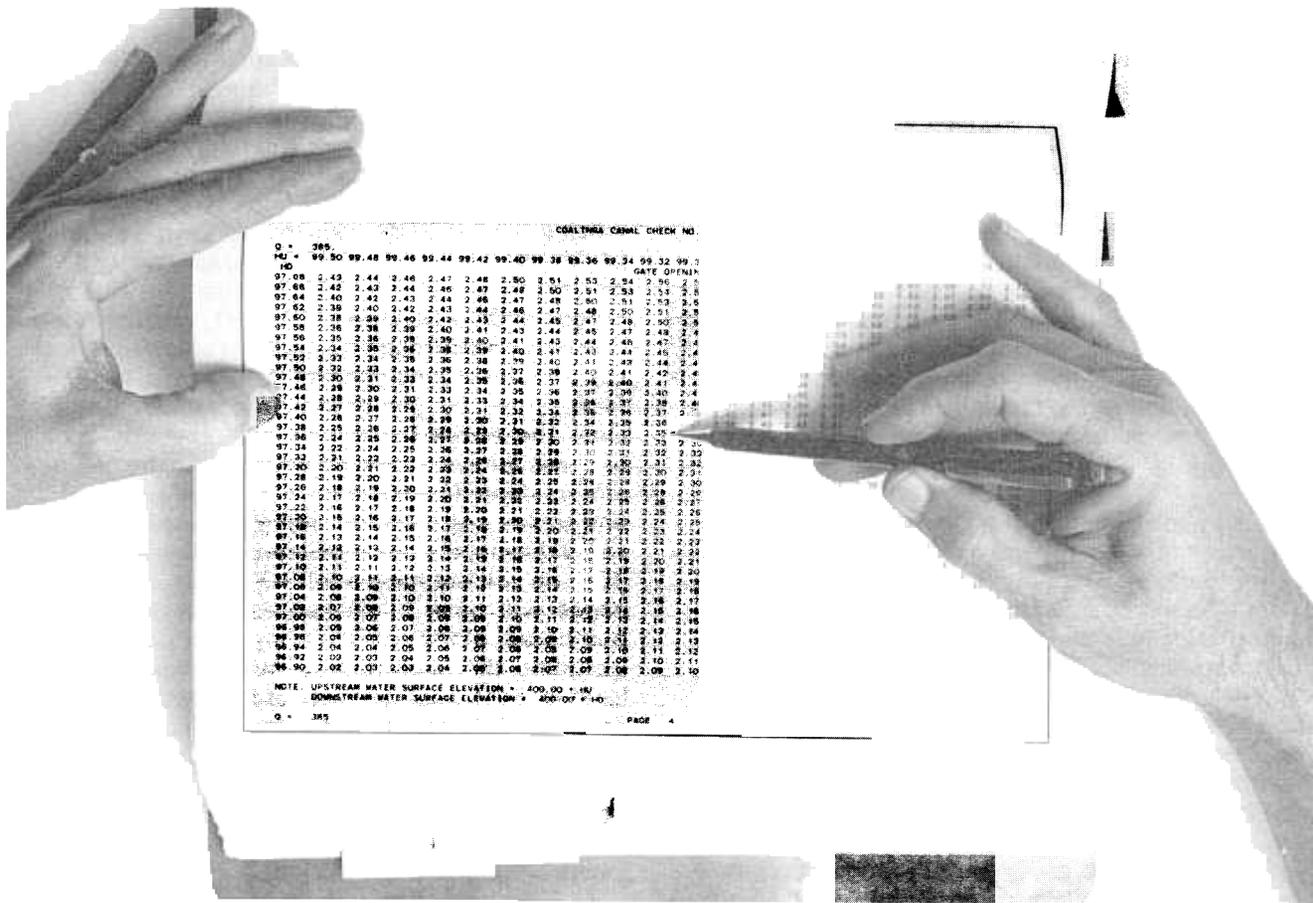

176

Figure IV-64.—Typical computer generated rating table. P801-D-80390

response feature is very useful for the daily operations of the total canal system and for making adjustments for the individual check structures when flow conditions change.

Rating tables.—The use of rating tables is essentially another form of interactive terminal response where all solutions are available in tabular format. The general use program can be flagged to generate rating tables, as shown in figure IV-64, for use by the ditchrider. Each page of the rating table represents one discharge for a selected range of upstream and downstream water levels for the check structure. Across the top of the page is the upstream depth, HU. The downstream depth, HD, is tabulated in the left column. In the center of the table are all the tabulations of the gate opening corresponding to each tabulated upstream and downstream water level that can occur for the discharge shown at the upper and lower left side of the table. For example, using figure IV-64, if the upstream water level is 99.32 and the downstream water level is 97.38, the gate opening would be 2.35 for the discharge of 385.0. If there is more than one

radial gate at the check structure, the gate opening of 2.35 would be the gate opening for each gate; i.e., the rating tables assume all the gates of the check structure will have equal openings. If the gate openings are not equal, the value obtained from the rating tables can be considered an average gate opening of all the radial gates at the check structure. However if the gate openings differ by more than about 10 percent from the average, significant errors can be introduced because the coefficient of discharge varies nonlinearly as a function of the gate opening.

The upstream and downstream water levels on figure IV-64 are tabulated in 0.02 ft increments. The 0.02 ft is probably the smallest increment necessary, as the table can be easily interpolated for the 0.01-ft resolution. The 0.01-ft resolution is required when accurate measurement of the water levels and gate openings are being made using good measurement practices discussed previously. Larger water level increments could be used to increase the range of water levels for each page of the rating table and decrease the number of pages needed to cover the desired

177

range of water operations. However, complex interpolation schemes would be required for each solution to obtain the desired accuracy of the discharge algorithms. Also, linear interpolation schemes can introduce errors when the increments are large because of the nonlinear characteristics of the coefficient of discharge. A larger increment of 0.05 ft could be used when the water levels are obtained by visual observations of staff gages located within the canal prism where the resolution of the staff gage reading is to the nearest 0.05 ft. It should be kept in mind, however, that coarser resolution of measurements and the rating tables will cause inaccuracies in the solution for the gate opening or discharge.

The number of pages in a rating table covering the entire range of operation of a check structure can become very large when the water level and discharge increments are small. Each page of the rating table has space for 20 intervals for the upstream depth, HU (across the top of the page), and 40 intervals for the downstream depth, HD (down the left side of the page). At an ideal water level increment of 0.02 ft, the range of the upstream water level, HU, per page is $20 * 0.02 = 0.4$ ft and the downstream level, HD, is $40 * 0.02 = 0.8$ ft per page. Therefore, many sets of tables will be required to cover the full range of water level operations when using small water level increments.

The following illustrates the procedure used to generate a series of rating tables and to estimate the number of pages involved:

Twenty-two thousand five hundred pages would require about 8 feet of bookshelf space for one check structure. However, the example can be used to demonstrate that the required gate opening/discharge values can be obtained in a matter of seconds regardless of the size of the rating table. Each set of tables is numbered and a simple index chart can be developed as shown on figure IV-65. The upstream and downstream water levels, HU and HD, are divided into the interval ranges of $20 * DH1$ and $40 * DH1$, respectively, that occur on the pages of each set of tables. Each set of tables consisting of 100 pages is then represented by the drawn intervals or boxes. Only the boxes below the 45° line are used because for everything above that line the downstream depth is greater than the upstream depth and tables are therefore not generated. For the same reason, the boxes or sets of tables along the 45° line will not have a full 100 pages and many pages will have blank spaces. The tables are numbered along the bottom and right side, including the book number where the table is located. Each book consists of four sets of tables or about 400 pages. Referring to figure IV-65, with an upstream depth of 11.33 and a downstream depth of 9.06, the table set number would be 227, located in book number 60. Thus, the table set to be used can be quickly identified and located, within 100 pages.

Having identified and located the set of tables to be used, the total discharge based on a known gate opening can be found as follows:

1. Find the page in the set of tables that has the estimated discharge located at upper or lower

Decision	Example data
1. Range of upstream water level	HUR1 to HUR2 = 0 to 12 ft
2. Range of downstream water level	HDR1 to HDR2 = 0 to 12 ft
3. Water level increment	DH1 = 0.02 ft
4. Range of discharge	QR1 to QR2 = 0 to 500 ft^3/s
5. Discharge increment	DQ1 = 5 ft^3/s

6. The number of sets of tables are:
   HU Range = (HUR2 − HUR1)/20 $*$ DH1 = (12.0)/20 $*$ 0.02 = 30
   HD Range* = [(HDR2 − HDR1)/40 $*$ DH1]/2 = [(12 − 0)/40 $*$ 0.02]/2 = 7.5
   The total number of table sets would be equal to:
   (HU Range) $*$ (HD Range) = 30 $*$ 7.5 = 225

7. The number of pages for each set of tables would be equal to:
   Q Range = (QR2 − QR1)/DQ1 = (500 − 0)/5 = 100

8. The total number of pages for the entire rating table to cover the range of water levels and discharge would be approximately:
   Number of table sets $*$ number of pages per set = 225 $*$ 100 = 22,500

*NOTE: Tables are not generated when the downstream depth is greater than the upstream depth for obvious reasons. Therefore, the number of table sets for the HD range are divided by a factor of 2.

CHECK NO. <u>EXAMPLE</u>, NAME: <u>BULKY</u>

UPSTREAM DEPTH, HU
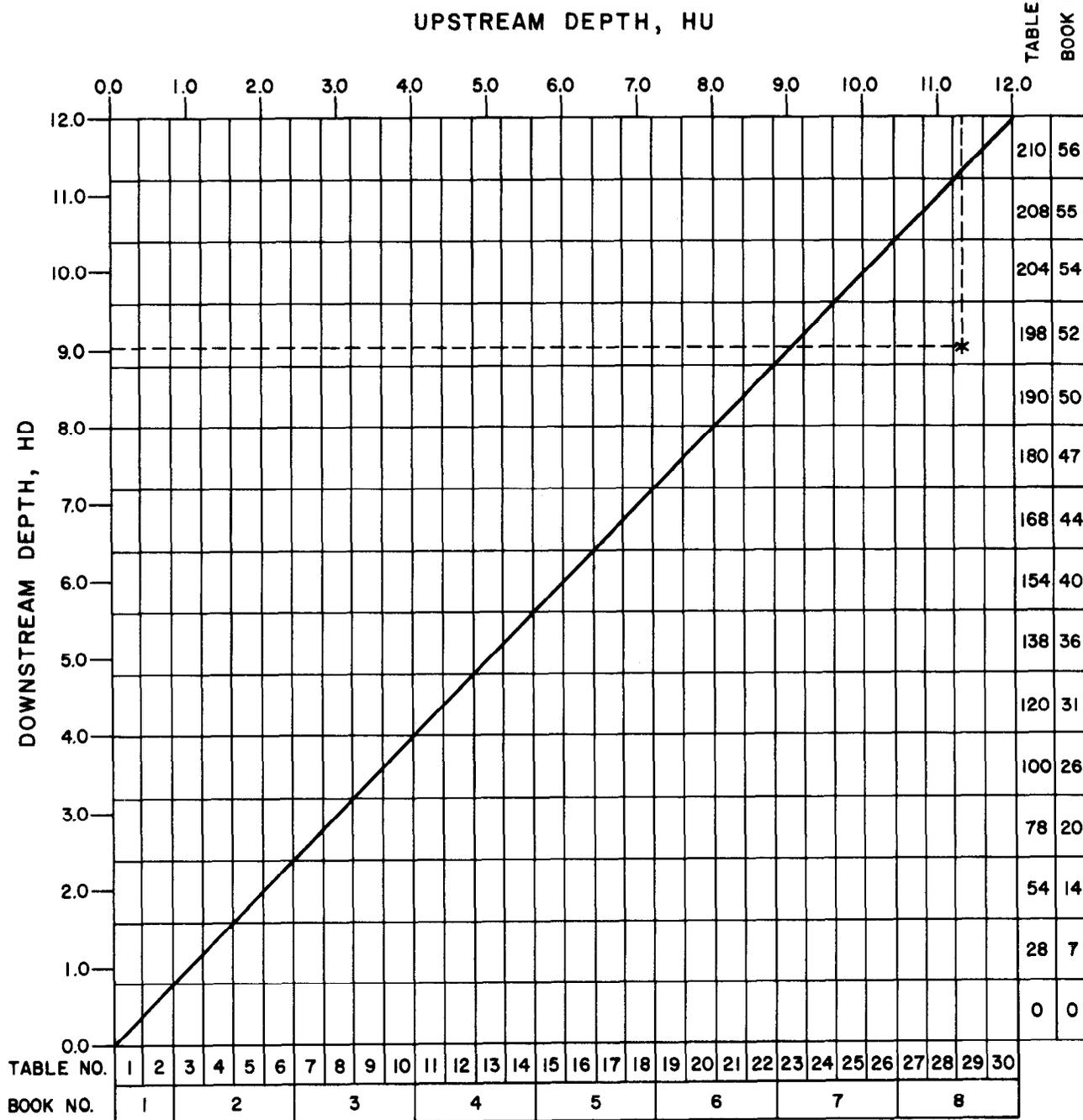
Note: To obtain Table No. and Book No. add numbers of bottom scale to the right scale

Example: If HU = 11.33 and HD = 9.06

Table No. = 29 + 198 = 227

Book No. = 8 + 52 = 60

Figure IV-65.—Example of rating table index chart for entire range of gate openings and discharges.

left side of the page. (If the estimate of discharge is unknown, start at the midrange or about page 50).

2. Enter the table with the known upstream and downstream water levels, HU and HD, and read the gate opening as shown on figure IV-64.

3. If the gate opening reading is *higher* than the known gate opening (or as measured), the estimated discharge is too *high*. Thumb several pages to a lower discharge and repeat item 2 above. If the gate reading is still too high, continue thumbing the pages in the direction of lower discharges until the gate opening is smaller than the known gate opening. Now the estimated discharge is too low. Thumb the pages back to a higher discharge and repeat No. 2 above.

4. Continue the iteration process, thumbing pages back and forth, until the gate opening reading in the table has the closest agreement to the known or measured gate opening.

The procedure just described may sound overwhelmingly complicated. However, after the first time the procedure is used, it will become evident that the rating tables are easy to use. The time involved to obtain a solution using the rating tables is about equivalent to using the interactive terminal response. The difference would be the availability of bookshelf space or access to a computer system on an hourly basis.

It is easy to obtain the required gate opening when the discharge is known. The index chart, figure IV-65, is again used to locate the correct set of tables that correspond to the known upstream and downstream water levels as before. Find the page in the set of tables that has the known discharge listed (upper or lower left

side of the page). The correct gate opening will be found at the intersection of the upstream and downstream water levels. The main use of the tables in this mode is to obtain the new gate opening for a new steady-state flow condition which is known or has been scheduled in the daily operations of the canal system. However, at the new steady-state flow conditions the water levels will probably be different, particularly the downstream water level because it usually varies as a function of the canal discharge.

The correct procedure is to estimate the new water levels for the new steady-state flow condition. The upstream water level is usually held constant and, therefore, the depth measured prior to the flow change should be used as an estimate. The downstream water level can be estimated from a rating curve (such as shown on fig. III-46), which has been developed based on the operator's experience or from a few field measurements. An estimate of the downstream depth can then be quickly obtained from the rating curve based on the new steady-state discharge. The required gate opening can then be determined from the rating table as before, using the estimated water levels. After a period of time, or when the new flow condition approaches steady state, the actual water levels can be measured. Using the updated estimate of the water levels, a more exact gate opening can be determined from the rating tables for the new steady-state discharge. Typically, the gate would require at least one more fine adjustment to obtain the final position when the canal is being operated in the conventional manner.

The operating range of the upstream and downstream water levels that occur 90 percent of the time for a typical canal check structure is relatively narrow. A more practical rating table can be developed having fewer sets of tables and thus fewer pages, based on the following criteria:

Decision	Example data

A. For operating ranges that occur 90 percent of the time:

   1. Range of upstream water level, ... HUR1 to HUR2 = 8 to 12 ft
   2. Range of downstream water level, ... HDR1 to HDR2 = 8 to 12 ft
   3. Water level increment, ... DH1 = 0.02 ft
   4. Range of discharge, ... QR1 to QR2 = 0 to 500 ft^3/s
   5. Discharge increment, ... DQ1 = 5 ft^3/s

B. For operating ranges that occur 10 percent of the time:

   1. Range of upstream water level, ... HUR3 to HUR4 = 0 to 8 ft
   2. Range of downstream water level, ... HDR3 to HDR4 = 0 to 8 ft
   3. Water level increment, ... DH2 = 0.1 ft
   4. Range of discharge, ... QR3 to QR4 = 0 to 300 ft^3/s
   5. Discharge increment, ... DQ2 = 10 ft^3/s

C. The approximate number of sets of tables and total number of pages:
1. The number of table sets are:

90 percent operating range:
$HU90 = (HUR2 - HUR1)/20 * DH1 = (12 - 8)/(20 * 0.02) = 10$
$HD90 = [(HDR2 - HDR1)/40 * DH1]/2 = [(12 - 8)/(40 * 0.02)]/2 = 2.5$

10 percent operating range:
$HU10 = (HUR4 - HUR3)/20 * DH2 = (8 - 0)/(20 * 0.1) = 4$
$HD10 = ([(HDR4 - HDR3)/40 * DH2)]/2) * HDR4/HUR4 =$
$([(8 - 0)/40 * 0.1)/2] = 1.0$

The total number of table sets would be equal to:
90 percent operating range $= (HU90 * HD90) = 10 * 2.5 = 25$
10 percent operating range $= (HU10 * HD10) = 4 * 1.0 = \underline{4}$

Total number of table sets $= 29$

2. The number of pages for each set of tables would be equal to:
90 percent operating range $= (QR2 - QR1)/DQ1 = (500 - 0)/5 = 100$
10 percent operating range $= (QR4 - QR3)/DQ2 = (300 - 0)/10 = 30$

3. The total number of pages for the entire rating table would be approximately:

90 percent operating range = 25 table sets * 100 pages per set= 2,500
10 percent operating range = 4 table sets * 30 pages per set . = $\underline{120}$

Total number of pages = 2,620

The total number of pages for the 29 sets of tables would be about 2,620, bound in about 8 books, and would require about 14 inches of bookshelf space. This would be considerably more practical and manageable than the previous example. A simple index chart, figure IV-66, can be developed to quickly locate the set of tables to be used for the known upstream and downstream depths to obtain a solution for the gate opening or the discharge. The tables with the smallest increments are located in the range of water operations that occur 90 percent of the time. The other 10 percent of the time will require interpolation of the tables to get an accurate solution. The total number of tables on the index chart, figure IV-66, is 40. The number increases when partial tables are counted.

The example above also illustrates how the tables could be reduced even further in size by selecting different ranges of water levels, discharges, and the increments of the discharge and water levels. It should be kept in mind when developing the criteria, that small rating tables for a wide range of operations will require a complex interpolation scheme to obtain an accurate solution. The interpolation will take time for the operator and could quickly become more costly than shelf space, including the cost of the computer run to generate the tables, which is estimated to be $ 0.14 per page.

Further reduction in the rating table size can be accomplished by varying the downstream depth as a function of the discharge using two linear equations developed from the rating curve as shown on figure IV-67, as an example. The two straight line equations are fitted to the rating curve with the discontinuous point located at QRC2 and RB2. When the linear equations variables are entered in the general use computer program, the downstream depth, for each page or discharge will begin (top left column) at its largest value. The value will be equal to the calculated HDRE (see fig. IV-67) plus DH1 multiplied by 20 spaces, or half of the 40 spaces available. Therefore, the estimated downstream depth, HDRE, for normal operations will be near the middle of the downstream depth range for each page of the table. The downstream depth, HD, will vary as the discharge for each table is incremented by DQ1. Using this technique assumes that the upstream water level at the next canal check structure downstream will be held nearly constant for all discharges, which is normal for a typical canal operation. The number of pages for each table will decrease as the upstream water level decreases. Tables are not generated when the downstream depth is greater than the upstream depth. The maximum discharge for each table set also decreases as the upstream depth decreases.

The following procedure establishes the criteria for the general use computer program to generate a series of rating tables using the two linear equations to obtain the downstream depth:

Decision	**Example data**

A. For normal ranges of operation:
  1. Range of upstream water level, ...HUR1 to HUR2 = 8 to 12 ft
  2. Linear equation parameters for the downstream depth, HD,
     (see fig. IV-67 for nomenclature)
                                                                RB1 = 8 ft
                                                                RB2 = 10 ft
                                                                RB3 = 12 ft
                                                                RB4 = 2 ft
                                                                QRC1 = 0 ft^3/s
                                                                QRC2 = 300 ft^3/s
                                                                QRC3 = 500 ft^3/s

$$RA1 = (RB2 - RB1)/(QRC2 - QRC1) = (10 - 8)/(300-0) = 0.0067$$
$$RA2 = (RB3 - RB4)/(QRC3 - QRC1) = (12 - 2)/(500-0) = 0.02000$$

  3. Water level increment, ... DH1 = 0.02 ft
  4. Range of discharge, ... QR1 to QR2 = 0 to 500 ft^3/s
  5. Discharge increment, ... DQ1 = 5 ft^3/s
B. For ranges of operation other than normal:
  1. Range of upstream water level, ...HUR3 to HUR4 = 0 to 12 ft
  2. Range of downstream water level, ...HDR3 to HDR4 = 0 to 12 ft
  3. Water level increment, ... DH2 = 0.1 ft
  4. Range of discharge, ... QR3 to QR4 = 0 to 500 ft^3/s
  5. Discharge increment, ... DQ2 = 10 ft^3/s
C. The approximate number of sets of tables and total number of pages:
  1. The number of table sets are:
     Normal range of operations:
     HU (Normal) = [(HUR2 - HUR1)/(20 * DH1)]/2 = [(12 - 8)/(20 * 0.02)]/2 = 5
     Other than normal operations:
     HU (Other) = (HUR4 - HUR3)/(20 * DH2) = (12 - 0)/(20 * 0.1) = 6
     HD (Other) = [(HDR4 - HDR3)/(40 * DH2)/2 = [(12 - 0)/(40 * 0.1)]/2 = 1.5
     The total number of table sets would be equal to:
     Normal range = HU (Normal)   = 5
     Other than normal = HU (Other) * HD (Other) = 6 * 1.5=   9

                         Total number of table sets = 14
  2. The number of pages for each set of tables would be equal to:
     Normal range = (QR2 - QR1)/DQ1 = (500 - 0)/5 = 100
     Other than normal = (QR4 - QR3)/DQ2 = (500 - 0)/10 = 50
  3. The total number of pages for the entire rating table would be approximately:
     Normal range = 5 table sets * 100 pages per set   = 500
     Other than normal = 9 table sets * 50 pages per set= 450

   Total number of pages = 950

The total number of pages for the entire rating table is now about 950 and can be contained in 3 books requiring about 5 inches of book shelf space. However, whenever the canal downstream depth, HD, varies more than ±20 * DH1 from the rating curve, figure IV-67, the tables with the larger increments of discharge, DQ2, and water level, DH2, will have to be used and will require interpolation to obtain the correct solution. The index chart to identify and locate the table sets for the above example is shown in figure IV-68. Note that tables 11 and 12 (larger increments) of the example overlap tables 1 through 10 (smaller increments) used for the normal operating range. The overlap of tables 11 and 12 simplifies the table generation procedure and is also necessary to cover the downstream depth,

HD, that may occur outside the range of normal operations or when the downstream depth varies more than ±20 * DH1 from the rating curve, figure IV-67.

By following the above procedures, two objectives are accomplished: (1) the necessary parameters for the general use computer program rating table feature are defined, and (2) the size of the rating table is estimated before the computer program is executed to avoid unnecessary (or unwanted) large quantities of computer printout. The general use computer program description in appendix V shows how the parameters for the rating table defined above are entered into the computer program including an example output of one page, figure IV-71.

CHECK NO. EXAMPLE, NAME : BETTER

UPSTREAM DEPTH, HU
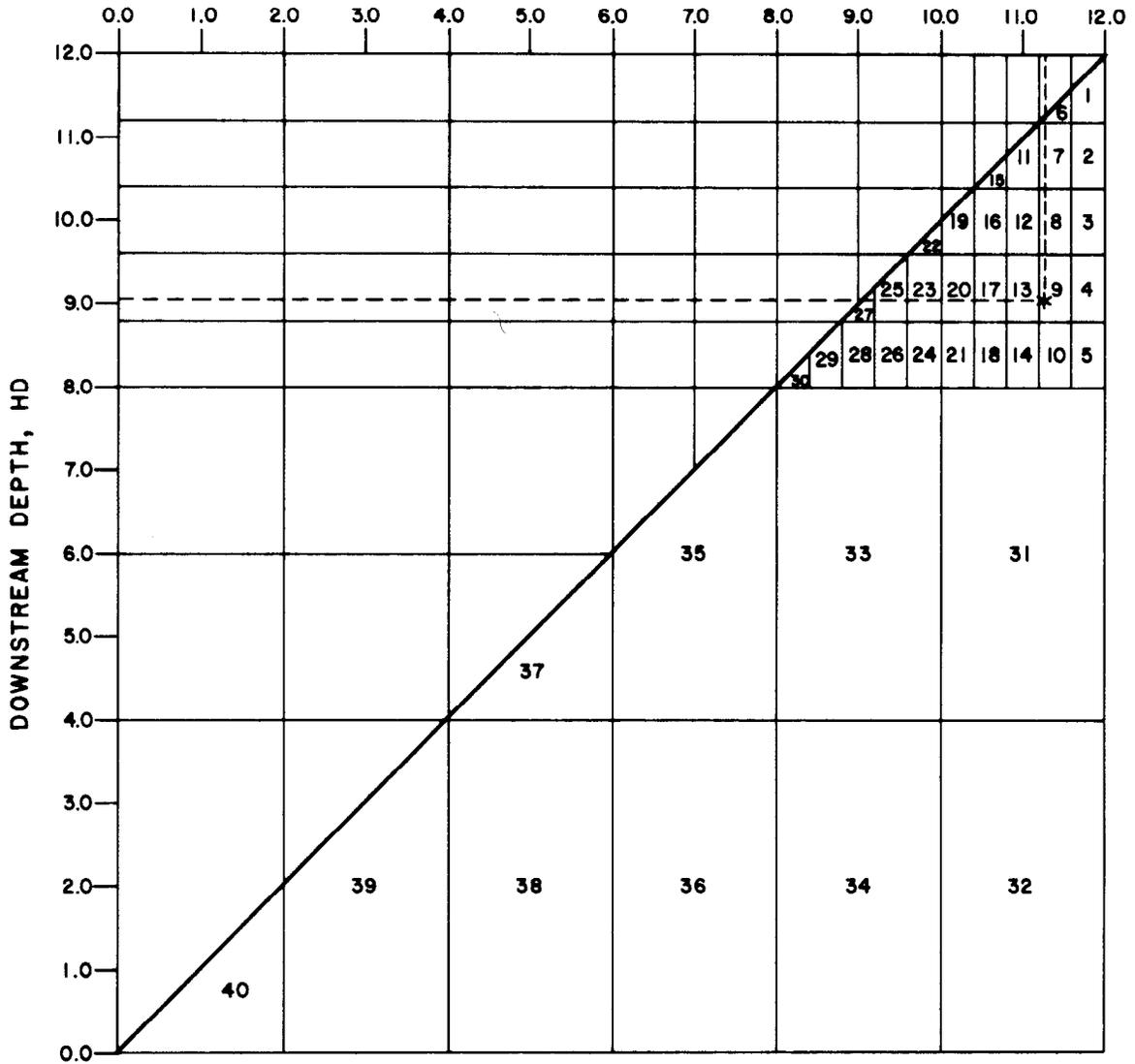
Note : To obtain the Table No. and Book No. first find the Table No. using the top index chart then find the Book No. containing that Table No. from the lower bar graph.

Example : If HU = 11.33 and HD = 9.06
From upper chart, Table No. = 9
From lower bar graph, Book No. = 3

Figure IV-66.—Example of a rating table index chart with emphasis on the normal range of operations.

Figure IV-67.—Illustration of the downstream depth rating curve versus the canal discharge, including linear rating equations.

Figure IV-68.—Example of a rating table index chart with emphasis on the normal range of operations and when the downstream depth, HD, varies as a function of the canal discharge, QT.
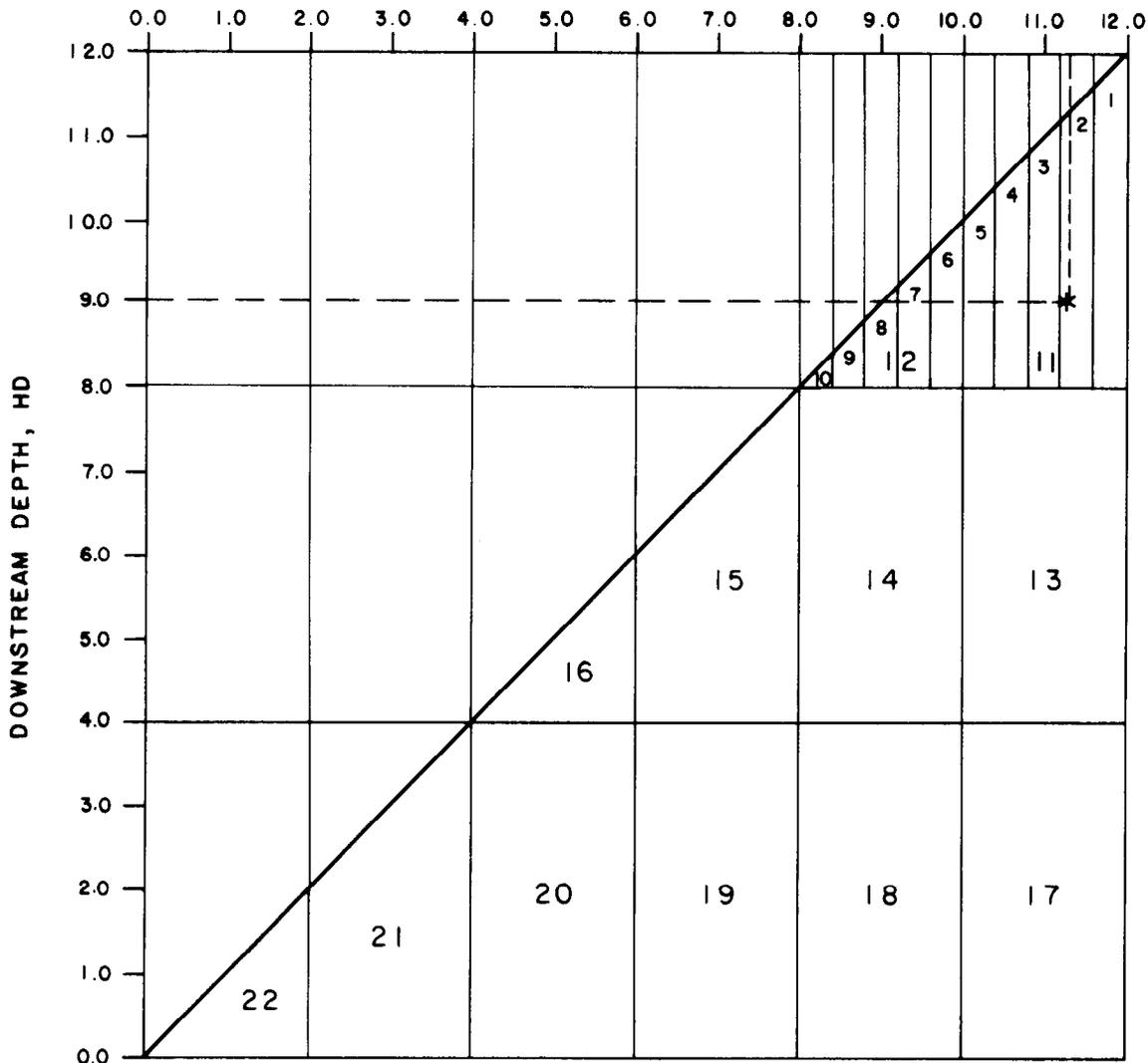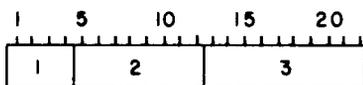
APPENDIX V

Discharge Algorithm General Use Computer Program

PROGRAM DESCRIPTION

General

The purpose of the general use computer program is to apply the discharge algorithms to the prototype canal radial gate check structures. A listing of the program is included in this appendix. The program has been written for use by the canal operators in the form of interactive computer terminal response or to generate a series of rating tables. No attempt has been made to write the program for other uses such as mathematical canal system models or the RTU's of a remote control system. The assumption is that anyone using the general use computer system for other purposes will have the expertise to modify the programs for their application.

The interactive computer terminal response feature solves for the discharge of each canal check structure when the gate openings are known, based on the known upstream and downstream water levels. Each gate opening can be solved for when the total discharge is known. The generation of rating tables solves for the gate opening, assuming all the gates at the check structure are at the same opening, based on an established incremental discharge and range of upstream and downstream water levels. Examples of how to use the interactive computer terminal response feature and how to generate a series of rating tables are included at the end of the program description.

The computer program is rather complex. However, several objectives had to be accomplished in order to have a computer program that has general application and can be implemented by canal operators. These objectives are summarized as follows:

1. The upstream and downstream energy balance equations interface the canal system to the discharge algorithms.

2. Provisions for typical upstream and downstream head losses caused by transitions and siphons are included and special head loss algorithms for other types of structures can be accommodated.

3. The discharge algorithms for both free and submerged flow conditions are included.

4. A test procedure is included to determine if the flow condition is free, submerged, or in the transition zone (between free and submerged) when the flow condition is unknown.

5. Either or both of two forms of input and output can be utilized by the canal operator:

a. Interactive computer terminal response.
b. Generation of rating tables.

The program is written in FORTRAN and implemented on the CDC (Control Data Corporation) CYBER 170/730 60 bit word computer system. The program length is 30,500 octal words, requires 45,000 octal words to load, and 60,500 octal words to run. Comment cards are inserted at appropriate locations within the computer program to explain certain computational procedures and the general flow of the program.

The program is dimensioned for 20 canal gate check structures up to 5 gates each. However, 40 output runs can be made when using the interactive computer terminal response feature. When generating rating tables, only one check structure at a time can be rated. The geometry of the check structure is included in the program as data statements. Certain parameters are required to generate a series of rating tables and are included in the program as constants equal to the appropriate variable name. It is assumed that the canal operators or someone within their organization will have the skills necessary to edit the computer source program file to insert their geometry and other variables into the program. It is not necessary to have computer program editing skills, however, to run or execute the program once the proper steps have been taken to initialize the geometry and other variables.

Examples for executing the computer program for interactive terminal response and generating rating tables are included in this appendix. The purpose of the examples is to assist in the application of the general use program.

The main computational procedure of the general use program is summarized as follows:

1. The proper geometry and rating table variables are edited into the source program before the program can be executed the first time.

2. Execution of the computer program establishes the following input data:

a. Check number to identify the geometry.
b. Upstream and downstream water levels.
c. The flag QORG equal to 1HQ to solve for discharge or equal to 1HG to solve for gate openings.
d. Each gate opening or the total discharge.
e. Gate openings that have limits when solving for the gate openings and using the interactive terminal response feature.

3. Free and submerged flow algorithms, including the energy balance equations, are solved to determine the free and submerged discharge or

gate openings, assuming the flow condition is unknown.

4. Tests are then performed to determine if the flow condition is free, submerged, or in the transition zone by balancing momentum and hydrostatic forces for each gate for the free and submerged flow results.

5. The results are then printed out in the appropriate format for the interactive computer terminal response feature or for a series of rating tables.

Subsequent paragraphs describe the program computational procedures in greater detail.

Data Statements

Before the program can be executed for the first time, the necessary geometry for the canal radial gate check structures must be edited into the data statements starting with check No. 1. The geometric data are entered between the / delimiters, separated by commas, and must be in sequential order. The program listing defines each geometric variable by comment statements. Reference to figure IV-61 will offer further assistance in defining each geometric variable. However, the last three variables — CFCDA, CSCDA, and FCOND — require further explanation.

The free and submerged discharge algorithms are based on the Bureau of Reclamation's standard hard-rubber-bar gate lip seal design. A correction is necessary when the radial gate has a different gate lip seal design and this is accomplished through the use of the CFCDA and CSCDA variables for the free and submerged flow conditions, respectively. If the check gate has the standard hard-rubber-bar design, figure 10a, the variables CFCDA and CSCDA are set to 1.0 and no corrections will be made to the coefficients of discharge, FCDA and SCDA, calculated by the free and submerged flow algorithms. If the check gate has the music note gate lip seal design, figure 10b, the general correction algorithms developed from laboratory and field data to correct for the music note design for free and submerged flow conditions can be used by setting the variables CFCDA and CSCDA to 0.0. The variables CFCDA and/or CSCDA can be set to −1.0 (or any negative number) to use specially developed algorithms to correct for other types of gate lip seal designs. Examples are the combined music note/hard-rubber-bar design (West Canal check, refer to app. III) and the algorithm that provides a more accurate correction (East Low Canal check, refer to app. III). A constant value can be entered into the variables CFCDA and/or CSCDA data statements (other than the flags 1.0,

0.0, or −1.0) if the correction factor is a constant (Putah South Canal check, refer to app. III).

The variable FCOND is used when the normal flow conditions are known to always be free or submerged, by setting FCOND to either 1HF or 1HS, respectively. By setting FCOND to 1HF or 1HS, the free or submerged flow calculations including the free or submerged flow tests are bypassed, reducing the computational time for each run. If the flow condition is unknown, or it can be either free or submerged within the normal range of operations, FCOND is set to 0.0, FCOND should be set to 0.0 when generating rating tables for other than the normal range of operations because either free or submerged conditions usually occur.

The data statements shown in the listing have included the geometry for the 13 check gate structures used in the field verification program, table III-5. It is possible, therefore, to execute the source program as shown in the listing using the interactive terminal response feature (with NRATE set to 0) to obtain the same results that have been presented in appendix III. The order of the check gate geometry as shown in the program listing data statements is as follows:

Program listing data statement check No.	Program listing check name	Canal name & check No.	
1	VEL. BARR	Tehama-Colusa	1
2	FISH SCRN.	Tehama-Colusa	2
3	COYOTE	Tehama-Colusa	3
4	WEST CANAL	West Canal	Headworks
5	EAST LOW	East Low Canal	Headworks
6	PUTAH SO.	Putah South	Headworks
7	CAL AQ #21	California Aqueduct	21
8	SAND CREEK	Friant-Kern	3
9	DODGE AVE.	Friant-Kern	4
10	KAWEAH	Friant-Kern	5
11	5TH AVE.	Friant-Kern	7
12	TULE RIVER	Friant-Kern	8
13	COALINGA	Coalinga	1

Select Program Mode, NRATE

The next variable that must be initialized before the program is executed is the integer NRATE, which immediately follows the data statements. NRATE is set to 0 when the interactive computer terminal response feature is going to be used. When generating a series of rating tables, NRATE is set to an integer equal to the check structure number (maximum number is 20) that is to be rated. Only one check structure can be rated at a time. The program listing shows that NRATE is set to 1; i.e., if the program is executed as shown, a series of rating tables will be produced for the program's check No.1.

188

Rating Table Parameters

Before a series of rating tables can be generated, the next series of parameters following the variable NRATE must be initialized for both the normal and other than normal range of operations. The first parameter is the canal name and/or check number, CANALN(1) through CANALN(4), which is in Hollerith format for 10 characters and spaces each. The program listing shows how the Tehama-Colusa Canal check No. 1 canal name has been entered by dividing the name into 10 characters and spaces. A canal name up to 40 characters and spaces can be accommodated.

The next series of 19 parameters, HUR1 through DQ2, define upstream and downstream water levels, discharge, and increments of discharge and water levels that are to be used in the generation of rating tables for the normal and other than normal range of operations. Reference should be made to appendix IV, Application Details, and to the example at the end of this section to obtain the definition of each rating table parameter and how to determine the values to be used in the program. If rating tables are not to be generated, these parameters should be set to 0.0.

When QR2 is set to 0.0, the rating tables for the normal range of operation are bypassed. When QR4 is set to 0.0, the other than normal range of operations rating tables are bypassed. If both QR2 and QR4 are set to 0.0 and NRATE is set to an integer (greater than 0) to generate rating tables, the program will end immediately without any output other than printing a message saying "END OF DATA INPUT." The bypass feature is useful when generating rating tables. By setting QR2 to its selected value and QR4 to 0.0, only the rating tables for the normal range of operations will be generated for the first execution of the program. Then taking the number of the last table generated for the normal range of operations and initializing the parameter NTABNO to that number and setting QR2 to 0.0 and QR4 to its selected value, the second execution of the program will only generate the rating tables for the other than normal range of operations, continuing the table numbers in sequential order. Executing the program twice reduces the run time and output quantity for each execution to a more manageable level. Also, by setting the incremental discharge parameters, DQ1 and DQ2, to a much higher value than desired, the output of the rating tables for each range of operations (having a lot fewer pages) can be checked before proceeding with the desired values of DQ1 and DQ4, which could produce as much as 1,000 pages of output.

The next four parameters listed as "other parameters for rating tables" are not to be changed from that shown except when the starting table number NTABNO is other than zero as discussed above. The flag QORG is set to 1HG when generating rating tables to solve for the gate openings at selected upstream and downstream water levels and discharge incremented by the rating table parameters initialized above.

Initialize Constants (Metric Conversion)

The next four constants — the gravitational constant, GC, and the iteration limit resolutions YDELTA for water levels, QDELTA for discharge, and GDELTA for gate opening as listed — are in inch-pound units. These constants require metric equivalents when using metric units. Also, the values listed for the iteration limit resolutions can be changed to any value desired by the program user. Larger values of YDELTA, QDELTA, and GDELTA will reduce the number of iterations to converge on the water levels, discharge, or gate openings and thereby reduce computational time for each run. However, values that are too large will reduce the accuracy of the calculated discharge or gate openings.

Initialize Flags and Counters

The variables NIU through NL2 are used throughout the program as flags and counters for DO loops, page numbers, etc. The two variables NIU and NID have been set to 21 and 41, respectively. These counters are used in the generation of rating tables to increment the upstream depth, HU (across the top of each page), and the downstream depth, HD (down the left side of each page). These values can be reduced, particularly NIU, if a rating table with a narrower page width is desired; however, a proportionally greater number of pages will be generated for the same data output.

Program Execution

With the above data statements and parameters initialized, the program can now be executed. Figure V-69 shows an example of the procedure

```
82/02/26.  08.22.09.
PROGRAM    RGRUN

.PROC,RGRUN.
GET,RADGAT.
FTN,PMD,I=RADGAT,L=0.
LGO,OP=T.
READY.
```

Figure V-69.—Example of procedure
file RGRUN.

189

file which will execute the program from the computer terminal on the CDC CYBER 74 computer system by entering -, RGRUN, where RADGAT is the source program as shown in the listing. Using the figure V-69 procedure file, the interactive computer terminal response feature can be used, with NRATE equal to 0. Rating tables can be generated, with NRATE equal to an integer greater than 0. However, when generating rating tables from the computer terminal, the terminal should be of high speed (1200 baud) and have the 14-7/8-inch-wide paper. It would take slower speed terminals a long time to generate rating tables having many pages. The page width would have to be reduced for the terminals having narrower width paper. When generating tables, the program should be submitted to the batch process with a low priority to reduce the cost. An example of a submit batch process program is shown on figure V-70, where the parameter T is set to 12,000 seconds, CM is set to 70000 central memory, priority is set to P5, and PL is set to 80,000 lines of output or about 1,200 pages. The ROUTE control card identifiers are set for the Xerox printer output. The user must use his or her own account and charge number including heading identifications.

Begin Interactive Terminal Response, NRATE is Set to 0

The input sequence for the interactive computer terminal response feature begins at statement 1. Examples for the interactive terminal response input mode of operation are described at the end of this section. The first input entered at the ter-

```
82/05/04.  14.46.31.
PROGRAM    RGOUT

/JOB
JOB,T12000,CM70000,P5.
ACCOUNT,
CHARGE,         .       .
XFORM,OUTPUT,1,LINE1.
HEADING.* NAME
HEADING.* EXT,
GET,RADGAT.
FTN,PMD,I=RADGAT,L=0.
LGO,PL=80000,OP=T.
ROUTE(OUTPUT,DC=HR,FC=63)
EXIT.
/EOR
/EOF
READY.
```

Figure V-70.—Example submit batch program RGOUT.

minal is the check number, NC, which identifies the geometry to be used. The second input is the upstream and downstream water levels, UPELEV and DNELEV. If FCOND is set to 1HF, only the UPELEV will be read since the free-flow-only calculations do not require the downstream water level. The next input is the flag QORG. If the discharge is to be calculated based on known gate openings, Q is entered. If the gate openings are to be calculated based on the known total discharge, G is entered. If Q is entered, the program goes to statement 3, and the gate openings for each gate of the check structure are entered. If G is entered, the total discharge is entered, and all gate openings are initialized to 0.0. If any gates have limits — such as a gate is fixed in position, is inoperable, or only one gate is to be moved — the limited gate openings are entered and gates without limits are entered with a -1.0 value. The flag GOL(NC,I) is set to 2H* for the gate(s) that are limited, the number of gates that can move, GX, are determined, and the flag GOL(NC,I) is set to 1H+ for the gates that can move. If FCOND is set to 1HS, the flag GOL(NC,I) is set to 1H- when solving for gate opening (QORG is set to 1HG). The DO 9 loop also determines the total gate opening, GOT, for all the gates that are not limited. GOT is used in estimating the initial discharge. The flag NL is set to 1, and the flag GOL(NC,I) is set to 1H, when QORG is equal to 1HQ. After statement 9, the upstream and downstream water depths, HU and HD are determined. HU1 and HU2 are variations of upstream depths used when special upstream head losses are encountered in the program.

The input from the interactive terminal response feature is now complete at this point for one run. The program continues at statement 998 to begin the free and submerged flow calculations. Up to 40 runs (data saved for later tabulation) can be made. J is a counter for the saved runs and, if it exceeds 40, the program goes to statement 73 and begins immediately to print out the saved runs. When complete, the program ends. However, the program can end any time the operator desires, as will be explained later.

Begin Generation of Rating Tables When NRATE is Greater Than 0

The generation of rating tables begins at statement 999 by initializing variables for input data. The check number NC is set to NRATE to identify the geometry of the check gate structure to be rated. The number of gates at the check gate structure, L and GX, are identified and all gate openings are initialized to 0.0. The next sequence of statements beginning at statement 989 identifies the starting upstream and downstream level

and the discharge for the first table of the normal range of operations, based on the parameters that were initialized above. The flag NTAB has been set to 1 to identify later that rating tables for the normal range of operations are being generated. If the parameter QR2 is set to 0.0, the generation of rating tables for the normal range of operations are bypassed and the program goes to statement 986. The downstream depth, HDRE, is based on an estimated rating curve consisting of two linear equations biased by the parameter QRC2. The maximum or starting downstream depth, HDN1, for the rating table is determined by adding to HDRE one-half of the tables downstream depth range, which is a function of the depth increment, DH1, and the counter NID for the downstream depth range. J is a counter for the page number and is set to 1 at the beginning of each rating table set.

The generation of rating tables for other than normal range of operation begins at statement 986. The starting upstream and downstream levels and the discharge are initialized based on the parameters that were initialized above. NTAB is set to 2 to identify later that rating tables for the other than normal range of operations are being generated. J is set to 1 to start the page numbering for a new table set. If the parameter QR4 is set to 0.0, the program goes to statement 72, bypassing the generation of rating tables for the other than normal operating range, and the program will end.

Statement 985 is common to both the normal and other than normal range of operation rating tables. The starting upstream water levels, HUS, are rounded to the nearest even increment of DH to provide easier interpolation of the water levels. The end value of the upstream water level, HUP1, on the page is then determined and is used later when incrementing the upstream water level. Only six spaces are provided for each water level tabulation. The value DUPL1 is determined and represents the water level above 99.99, and it will be printed out at the bottom of the page when its value is 100.00 or greater. Next, the upstream water levels, HU, that are to be tabulated across the top of the page at increments of DH are initialized into X2(1) through X2(NIU) by DO 991 loop.

The next sequence of statements after DO 991 loop rounds off the starting downstream depth, HDS, to the nearest even increment following the same procedure used for rounding off the starting upstream depth, HUS. The starting downstream depth, HDS, is not allowed to be greater than the starting upstream depth, HUS, for the normal range of operating rating tables when NTAB is set to 1. The value DNPL1 is found for the

same reasons explained above for DUPL1. The upstream and downstream water depths, HU and HD, above the canal invert (plus an increment of DH) are determined next. HUP is set to the upstream depth, HU, for later reference in DO 995 loop. Next, a test is made for the other than normal operating range rating tables when NTAB is set to 2, to eliminate the rating table set if the starting upstream water level, HUS, is less than the end value of the downstream water level, HDN. If the test is positive, the table number, NTABNO, is reduced by 1, and the program continues to statement 980, which increments the downstream water level.

The generation of each page of the rating table starts by initializing the counter NTP and the flag NGPP to 0. The counter NTP is used to eliminate the printing of the page when there are less than 50 values of the gate opening calculated for the page. NGPP is a flag to print a message at the bottom of the page when unreliable gate opening calculations are encountered.

An estimate of the critical flow, QC, is made based on an upstream depth at the gate in the rectangular section. If the page discharge, QT, is greater than the estimated critical discharge, QC, the program continues to statement 979 to increment the QT by DQ to the next smaller value. Therefore, the rating table discharge will only be for the subcritical flow conditions upstream of the canal check gate structure.

The DO 995 loop increments the downstream depth, HD, by the increment DH from 1 to NID and sets the starting upstream depth, HU, to the reference HUP. The inner DO 994 loop increments the upstream depth, HUS, by the increment DH from 1 through NIU. The program sequence calculates the gate openings across the page (left to right), row by row from the top to the bottom of the page for one discharge value, QT, assigned to the page; i.e., NID*NIU computer runs are made for each page.

The DO 990 loop initializes the flag GOL(NC,I) to 1H+, and if the data statement FCOND(NC) is set to 1HS, GOL(NC,I) is set to 1H−, where NC is the check number and I is the gate number. These flags are used to estimate and initialize the first gate openings for the free and submerged flow calculations, respectively, when solving for the gate opening with QORG set to 1HG. HU1 and HU2 are determined and are used later in the upstream energy balance equations.

Next, the value of HD3 that is an estimate of the downstream water depth in the rectangular section downstream of the gate is determined. If the HD3 estimate is greater than the upstream depth,

HU2, in the rectangular section upstream of the gate, the program continues to statement 981 and a blank is printed in the rating table. Also, if the downstream depth, HD, is less than or equal to 0.0 (which could happen in the incrementing of HD by DH), the program continues to statement 981 and a blank is printed in the rating table.

Free and Submerged Flow Calculations

Statement 998 is common to both the interactive terminal response and the generation of rating tables modes of program operation. Variables common to both free and submerged flow calculations are initialized where BWG is the total width of the gates, BW is the total width of the gates including the width of the piers, PW(NC), and AREAUP and AREADN are the cross-sectional areas of the canal sections at the upstream and downstream water measurement locations, respectively. NGF, NGS, and NGP are flags intitialized to 0 and are used in the generation of rating tables when iteration limits have been exceeded, to indicate the results are unreliable.

Free Flow Calculations

The free flow calculations are made first. If the data statement FCOND(NC) is set to the 1HS, the program continues to statement 19, bypassing the free flow calculations. If FCOND(NC) is set to 1HF or to 0.0, the free flow calculations begin. Comment statements are included in the program listing to identify the general computational procedures at appropriate locations. However, further discussion is required:

1. When the free flow calculations are being made, it is assumed that the flow condition is free. Therefore, only the upstream energy balance equations, including the calculations for special head losses and transition losses, are solved. The downstream depth is not required because it does not control the discharge through the gate when the flow condition is free. The free and submerged flow tests performed later in the program will determine if the flow is actually free. If FCOND(NC) is set to 1HF (free flow only), the free and submerged flow tests are bypassed and the results will be incorrect if the flow condition is actually submerged.

2. Usually, for normal conditions, only three or four iterations are required to converge onto the correct value of Y2 within the iteration limit resolution, YDELTA. If the iteration limit, MM, is exceeded, the program continues at statement 65. If the program is generating rating tables (NRATE greater than 0), the program continues to statement 981 and prints a blank

in the rating table. Also, a blank is printed when the iteration produces a Y2 value less than or equal to zero or a Y2 value greater than EG2. If the program is in the interactive terminal response mode (NRATE is set to 0), an appropriate message is printed at the terminal when the iteration limit, MM, is exceeded, to indicate results are unreliable, and the program continues using the last value calculated for Y2.

3. Usually, for normal conditions, only four or five iterations are required to converge onto the correct value of the free discharge, QFT, when solving for discharge, or onto the correct values of the free flow gate openings, GOF(I), when solving for the gate openings within the iteration limit resolutions, QDELTA and GDELTA, respectively. If the iterations exceed the limits of MQF or MGF, respectively, appropriate messages are printed at the interactive terminal. When generating rating tables and the iteration limit of MGF is exceeded, the flag NGF is set to 1 to indicate that the results are unreliable. However, the program continues with the submerged flow calculation, beginning at statement 19.

4. The convergence routine by the Newton method [10] requires two iterations for QFT or GOF(I) to establish the first old and new values before the convergence routine can be implemented, using the flag MQF1.

Submerged Flow Calculations

The submerged flow calculations are made next, and begin at statement 19. If the data statement FCOND(NC) is set to 1HF, the submerged flow calculations are bypassed. If FCOND(NC) is set to 1HS or 0.0, the submerged flow calculations begin. Comment statements have also been included in the program listing at appropriate locations to identify computational procedures. However, additional discussion is also required:

1. It is assumed that the flow condition is submerged when making the submerged flow calculations. Both the upstream and downstream energy balance equations, including the calculations for special head losses and transition losses, are solved. The free and submerged flow tests are performed later in the program to determine if the flow condition is actually submerged. If FCOND(NC) is set to 1HS (submerged flow only), the free and submerged flow tests are bypassed and the results will be incorrect if the flow condition is actually free.

2. Usually, for normal conditions, only three or four iterations are required to converge onto

the correct values of Y2 and Y3 within the iteration limit resolution, YDELTA. If the iteration limit, MM, is exceeded, the program continues at statement 44 and at 66 when solving for Y2 and Y3, respectively. If the program is generating rating tables (NRATE is greater than 0), the program continues to statement 981 and prints a blank in the rating table. A blank will also be printed when Y2 or Y3 is less than or equal to zero or greater than EG2 or EG3, respectively. If the program is in the interactive terminal mode (NRATE is set to 0), an appropriate message is printed at the terminal when the iteration limit, MM, is exceeded to indicate the results are unreliable, and the program continues using the last value calculated for Y2 or Y3. A test is also included to determine if the energy gradient EG2 or EG3 is less than the critical energy gradient, EGC. If the test is positive, the discharge, QT, cannot occur at the assigned water depth upstream or downstream and, therefore, continuity requirements cannot be achieved. The program then continues to statements 132 and 133, respectively, to print an appropriate message to the interactive terminal response and omits the computer run or continues to statement 981 to print a blank in the rating table.

3. Usually, for normal conditions, only four or five iterations are required to converge onto the correct values of QST or GOS(I) within the iteration limit resolutions, QDELTA and GDELTA, respectively. If the iterations exceed the limits of MQS or MHF, respectively, appropriate messages are printed at the interactive terminal. When generating rating tables and the iteration limit of MGS is exceeded, the flag NGS is set to 1 to indicate the results are unreliable. However, the program continues at statement 31 using the last calculated values of QST or GOS(I).

4. The convergence routine by the Newton method[10] requires two iterations for QST or GOS(I) to establish the first old and new values before the convergence routine can be implemented, using the flag MQS1.

Free and Submerged Flow Tests

After the free and submerged flow calculations are completed and when the data statement FCOND(NC) is set to 0.0, the free and submerged flow tests are conducted. The free flow test is conducted first by setting the flags NGW to 0 and NF to 2 and the discharge, Q, to the calculated total free discharge, QFT. The program goes to statement 13 to obtain the upstream energy gradient, EG2, and the downstream depth, Y3. The downstream depth, Y3, is now based on the total

width of the gates, BW, (include the width of the piers PW(NC)) because the flag NGW is not set to 0. The program returns to statement 32 after the upstream and downstream submerged flow energy balance equations which began at statement 13 are solved. After statement 32, the downstream momentum and hydrostatic forces, FDN, are calculated for each gate by DO 33 loop. The value of GAXCO is determined by an iteration and convergency routine. GAXCO is the contracted depth of the flow jet immediately downstream of the gate (refer to fig. IV-61, for identification) and it is assumed that the jet is free.

If the iteration limit, MM, for GAXCO convergence is exceeded, an appropriate message is printed at the interactive terminal. However, if rating tables are being generated (NRATE is greater than 0), the program continues at statement 262 using the last calculated value of GAXCO, and the flag NGS is set to 1 to indicate the results are unreliable. If GAXCO is greater than the critical depth, DC, the program assumes that the flow condition is submerged and continues to statement 34. If GAXCO is less than the critical depth, DC, the program calculates the upstream momentum and hydrostatic forces, FUP, using the value GAXCO as the upstream depth.

The test for free and submerged flow is made by comparing the calculated upstream forces, FUP, to the calculated downstream forces, FDN. The test is simple: If the upstream forces, FUP, are greater than the downstream forces, FDN, the flow condition is free and the program continues to statement 35. If the upstream forces, FUP, are less than the downstream forces, FDN, the flow condition is submerged and the program continues at statement 34. The tests for the free flow calculations are now complete.

However, the entire procedure is repeated beginning at statement 33 for the submerged flow calculations. The flag NBW is set to 0 and NF is set to 3, and the discharge, Q, is set to the submerged flow discharge, QST. The program goes back to statement 13 to determine the upstream energy gradient, EG2, and downstream depth, Y3, using the submerged flow discharge, QST, and returns to the statement 32 to repeat the calculations for the upstream and downstream momentum and hydrostatic forces FUP and FDN, respectively. The free and submerged flow test is again made to determine if flow is free or submerged and the variable COND(NF,I) is initialized appropriately, where NF is the discharge calculation, free or submerged, (2 or 3), and I is the gate number. The tests for the submerged flow calculations are now complete.

193

The next step is to compare the flow conditions (COND(NF,I) for NF equal to 2 and 3 for each gate by the DO 37 loop. If the data statement FCOND(NC) is set to either 1HF or 1HS, the comparison is bypassed and the program continues at statements 38 and 39, respectively. If both test conditions, COND(2,I) and COND(3,I), have passed the free flow test (at statement 35), the flow condition is free and the program goes to statement 38 and initializes the output values of discharge, QG(I), gate openings, GOP(I), and flow condition, CONDF(I) to the values determined for the free flow calculations. If both test conditions, COND(2,I) and COND(3,I), have passed the submerged flow test (at statement 34), the flow condition is submerged and the program goes to statement 39 and initializes the output values to the values determined for the submerged flow calculations. If both test conditions, COND(2,I) and COND(3,I), have passed both the submerged and free flow test (at statements 35 and 34), the flow condition is in the transition zone and is unstable, and the program continues to statement 40 where the output values are initialized to the average values of the free and submerged flow calculations. The flow condition, CONDF(I), is set to 7H TRANS.

At statements 38, 39, and 40, the flag NGP is set to 1 when the flags NGF or NGS have been initialized to 1 when iteration limits for the gate opening for free and submerged calculations, MGF and MGS, respectively, are exceeded. With NGP set to 1, a message is printed at the bottom of the rating table page to indicate that gate opening values within the table having an "*" are unreliable.

All the calculations for one run are now completed at statement 37. The remainder of the program outputs the results of the computer run. If the program operational mode is for the interactive terminal response (NRATE is set to 0), the program continues at statement 993.

Output for the Generation of Rating Tables

If the program is in the generation-of-rating-tables mode of operation (NRATE is greater than 0), the program continues. If the output value of GOP(1) is less than or equal to 0.0, or greater than the upstream depth, HU2, the program continues to statement 981 and a blank is printed in the rating table. GOP(1) is the gate opening calculated for the first gate number of the check structure. The rating tables assume all the gate openings will be of equal value. Therefore, only the first gate opening, GOP(1), is used to initialize the rating table gate opening GOTAB(NHD,NHU). If the flag NGP is set to 0, the program goes to statement 786 and writes the value of

GOTAB(NHD,NHU) to the scratch TAPE3 according to an F6.2 format, and the value of NTP is increased by a count of 1. If NGP is set to 1 (indicating the results are unreliable), the program writes the value of GOTAB(NHD,NHU) to TAPE3 according to an F5.1 format and includes an "*" with it to signify that the calculated value is unreliable. Statement 981 prints a blank to TAPE3 according to a 6H Hollerith format when certain tests have failed within the computer run to signify that a solution is not possible with the given data.

After the inner DO 994 loop which increments the upstream water depth, HU, by the value of DH from 1 to NIU is completed, the values of HDN, DNPL2, HDTAB(NHD), and HUP1 are initialized before continuing with the next decrement of the outer DO 995 loop which increments the downstream water depth, HD, by the value of DH from 1 to NID. When the outer DO 995 loop is completed, all the calculated values, including the blanks, of the gate opening for one page of the rating table for one value of the discharge, QT, have been written to TAPE3. TAPE3 is then rewound to the beginning. If there are less than 50 values of GOTAB(NHD,NHU) (not including unreliable values or blanks), the page is skipped and the program continues to statement 987, where the discharge and water levels are incremented as necessary.

If there are more than 50 values of GOTAB(NHD,NHU) written to TAPE3, all the values of GOTAB(NHD,NHU) (including the unreliable values and the blanks) are read from TAPE3 according to an A6 format. The printing of the rating table page then begins with the printing of the canal name, CANALN, and ends with the printing of the page number, J, and the table number, NTABNO. A typical page of a rating table is shown on figure V-71 and demonstrates most of the printing formats, with the exeption of the values of DUPL2 and DNPL2, which are equivalent to DUPL1 and DNPL1 as explained earlier. DUPL2 and DNPL2 will be printed out when they are less than DUPL1 and DNPL1, respectively, by format statements 791 and 789, respectively.

After the printing of the rating table page to the output file TAPE2 is completed, the program continues at statement 987. The page number, J, is increased by a count of 1. If the discharge, QT, is greater than the end discharge, QE, plus one increment of DQ, and NTAB is set to 1 for the normal range of operation rating tables, the program goes back to statement 996 and the discharge, QT, is incremented to the next smaller value by the value of DQ1 and the computational procedures for producing the next complete page of the rating table with the new page discharge,

TEHAMA-COLUSA CANAL CHECK NO. 1

Q = 1080.

HU =	48.40	48.38	48.36	48.34	48.32	48.30	48.28	48.26	48.24	48.22	48.20	48.18	48.16	48.14	48.12	48.10	48.08	48.06	48.04	48.02	48.00
HD											GATE OPENING										
46.92	2.95	2.97	2.99	3.01	3.03	3.05	3.07	3.09	3.12	3.14	3.16	3.19	3.21	3.24	3.26	3.29	3.32	3.34	3.37	3.40	3.43
46.90	2.93	2.95	2.97	2.99	3.01	3.03	3.05	3.07	3.09	3.11	3.14	3.16	3.18	3.21	3.23	3.26	3.29	3.31	3.34	3.37	3.40
46.88	2.91	2.93	2.95	2.96	2.98	3.00	3.03	3.05	3.07	3.09	3.11	3.13	3.16	3.18	3.21	3.23	3.26	3.28	3.31	3.34	3.37
46.86	2.89	2.91	2.92	2.94	2.96	2.98	3.00	3.02	3.04	3.07	3.09	3.11	3.13	3.16	3.18	3.20	3.23	3.26	3.28	3.31	3.34
46.84	2.87	2.89	2.90	2.92	2.94	2.96	2.98	3.00	3.02	3.04	3.06	3.09	3.11	3.13	3.15	3.18	3.20	3.23	3.25	3.28	3.31
46.82	2.85	2.87	2.88	2.90	2.92	2.94	2.96	2.98	3.00	3.02	3.04	3.06	3.08	3.11	3.13	3.15	3.18	3.20	3.23	3.25	3.28
46.80	2.83	2.85	2.86	2.88	2.90	2.92	2.94	2.96	2.98	3.00	3.02	3.04	3.06	3.08	3.10	3.13	3.15	3.17	3.20	3.22	3.25
46.78	2.81	2.83	2.84	2.86	2.88	2.90	2.92	2.93	2.95	2.97	2.99	3.01	3.04	3.06	3.08	3.10	3.12	3.15	3.17	3.20	3.22
46.76	2.79	2.81	2.82	2.84	2.86	2.88	2.89	2.91	2.93	2.95	2.97	2.99	3.01	3.03	3.05	3.08	3.10	3.12	3.15	3.17	3.19
46.74	2.77	2.79	2.80	2.82	2.84	2.86	2.87	2.89	2.91	2.93	2.95	2.97	2.99	3.01	3.03	3.05	3.07	3.10	3.12	3.14	3.17
46.72	2.75	2.77	2.79	2.80	2.82	2.84	2.85	2.87	2.89	2.91	2.93	2.95	2.97	2.99	3.01	3.03	3.05	3.07	3.09	3.12	3.14
46.70	2.74	2.75	2.77	2.78	2.80	2.82	2.83	2.85	2.87	2.89	2.91	2.93	2.94	2.96	2.98	3.01	3.03	3.05	3.07	3.09	3.12
46.68	2.72	2.73	2.75	2.77	2.78	2.80	2.82	2.83	2.85	2.87	2.89	2.90	2.92	2.94	2.96	2.98	3.00	3.02	3.05	3.07	3.09
46.66	2.70	2.72	2.73	2.75	2.76	2.78	2.80	2.81	2.83	2.85	2.87	2.88	2.90	2.92	2.94	2.96	2.98	3.00	3.02	3.04	3.07
46.64	2.68	2.70	2.71	2.73	2.75	2.76	2.78	2.79	2.81	2.83	2.85	2.86	2.88	2.90	2.92	2.94	2.96	2.98	3.00	3.02	3.04
46.62	2.67	2.68	2.70	2.71	2.73	2.74	2.76	2.78	2.79	2.81	2.83	2.84	2.86	2.88	2.90	2.92	2.94	2.96	2.98	3.00	3.02
46.60	2.65	2.67	2.68	2.69	2.71	2.73	2.74	2.76	2.77	2.79	2.81	2.82	2.84	2.86	2.88	2.90	2.91	2.93	2.95	2.97	2.99
46.58	2.63	2.65	2.66	2.68	2.69	2.71	2.72	2.74	2.75	2.77	2.79	2.80	2.82	2.84	2.86	2.88	2.89	2.91	2.93	2.95	2.97
46.56	2.62	2.63	2.65	2.66	2.68	2.69	2.71	2.72	2.74	2.75	2.77	2.79	2.80	2.82	2.84	2.85	2.87	2.89	2.91	2.93	2.95
46.54	2.60	2.62	2.63	2.64	2.66	2.67	2.69	2.70	2.72	2.73	2.75	2.77	2.78	2.80	2.82	2.83	2.85	2.87	2.89	2.91	2.93
46.52	2.59	2.60	2.61	2.63	2.64	2.66	2.67	2.69	2.70	2.72	2.73	2.75	2.76	2.78	2.80	2.82	2.83	2.85	2.87	2.89	2.91
46.50	2.57	2.59	2.60	2.61	2.63	2.64	2.65	2.67	2.68	2.70	2.71	2.73	2.75	2.76	2.78	2.80	2.81	2.83	2.85	2.87	2.89
46.48	2.56	2.57	2.58	2.60	2.61	2.62	2.64	2.65	2.67	2.68	2.70	2.71	2.73	2.74	2.76	2.78	2.79	2.81	2.83	2.85	2.86
46.46	2.54	2.55	2.57	2.58	2.59	2.61	2.62	2.64	2.65	2.66	2.68	2.69	2.71	2.73	2.74	2.76	2.77	2.79	2.81	2.83	2.84
46.44	2.53	2.54	2.55	2.57	2.58	2.59	2.61	2.62	2.63	2.65	2.66	2.68	2.69	2.71	2.72	2.74	2.76	2.77	2.79	2.81	2.82
46.42	2.51	2.52	2.54	2.55	2.56	2.58	2.59	2.60	2.62	2.63	2.65	2.66	2.68	2.69	2.71	2.72	2.74	2.75	2.77	2.79	2.80
46.40	2.50	2.51	2.52	2.54	2.55	2.56	2.57	2.59	2.60	2.62	2.63	2.64	2.66	2.67	2.69	2.70	2.72	2.74	2.75	2.77	2.79
46.38	2.48	2.50	2.51	2.52	2.53	2.55	2.56	2.57	2.59	2.60	2.61	2.63	2.64	2.66	2.67	2.69	2.70	2.72	2.73	2.75	2.77
46.36	2.47	2.48	2.49	2.51	2.52	2.53	2.54	2.56	2.57	2.58	2.60	2.61	2.63	2.64	2.65	2.67	2.68	2.70	2.72	2.73	2.75
46.34	2.46	2.47	2.48	2.49	2.50	2.52	2.53	2.54	2.55	2.57	2.58	2.60	2.61	2.62	2.64	2.65	2.67	2.68	2.70	2.71	2.73
46.32	2.44	2.45	2.47	2.48	2.49	2.50	2.51	2.53	2.54	2.55	2.57	2.58	2.59	2.61	2.62	2.64	2.65	2.66	2.68	2.70	2.71
46.30	2.43	2.44	2.45	2.46	2.48	2.49	2.50	2.51	2.52	2.54	2.55	2.56	2.58	2.59	2.60	2.62	2.63	2.65	2.66	2.68	2.69
46.28	2.42	2.43	2.44	2.45	2.46	2.47	2.49	2.50	2.51	2.52	2.54	2.55	2.56	2.58	2.59	2.60	2.62	2.63	2.65	2.66	2.68
46.26	2.40	2.41	2.42	2.44	2.45	2.46	2.47	2.48	2.50	2.51	2.52	2.53	2.55	2.56	2.57	2.59	2.60	2.61	2.63	2.64	2.66
46.24	2.39	2.40	2.41	2.42	2.43	2.45	2.46	2.47	2.48	2.49	2.51	2.52	2.53	2.54	2.56	2.57	2.58	2.60	2.61	2.63	2.64
46.22	2.38	2.39	2.40	2.41	2.42	2.43	2.44	2.46	2.47	2.48	2.49	2.50	2.52	2.53	2.54	2.56	2.57	2.58	2.60	2.61	2.62
46.20	2.36	2.37	2.39	2.40	2.41	2.42	2.43	2.44	2.45	2.46	2.48	2.49	2.50	2.51	2.53	2.54	2.55	2.57	2.58	2.59	2.61
46.18	2.35	2.36	2.37	2.38	2.39	2.41	2.42	2.43	2.44	2.45	2.46	2.47	2.49	2.50	2.51	2.52	2.54	2.55	2.56	2.58	2.59
46.16	2.34	2.35	2.36	2.37	2.38	2.39	2.40	2.41	2.43	2.44	2.45	2.46	2.47	2.48	2.50	2.51	2.52	2.54	2.55	2.56	2.58
46.14	2.33	2.34	2.35	2.36	2.37	2.38	2.39	2.40	2.41	2.42	2.43	2.45	2.46	2.47	2.48	2.50	2.51	2.52	2.53	2.55	2.56
46.12	2.31	2.32	2.33	2.35	2.36	2.37	2.38	2.39	2.40	2.41	2.42	2.43	2.44	2.46	2.47	2.48	2.49	2.51	2.52	2.53	2.54

NOTE: UPSTREAM WATER SURFACE ELEVATION = HU + 200.00
DOWNSTREAM WATER SURFACE ELEVATION = HD + 200.00

Q = 1080.   PAGE 22   TABLE NO. 10

Figure V-71.—Example of a typical page of a rating table generated by the general use computer program.

QT, are repeated. The program continues producing pages of the rating table until the value of the discharge, QT, is less than or equal to the end discharge, QE, plus one increment of DQ, and one set of a rating table is completed.

The next sequence compares the end value of the rating tables' upstream depth, HUP1, to the lowest value of the upstream water level of the normal range of operations, HUR1. If the HUP1 is greater than HUR1 and NTAB is set to 1, the program goes back to statement 989, where a new table set is started by initializing the page number, J, to 1, incrementing the table number, NTABNO, by a count of 1, setting the discharge, QT, to the value of the largest discharge, QR2, plus one increment of DQ1, and the starting upstream depth, HUS, is now set to HUP1, which is the end value of the upstream water level of the previous rating table set. The program continues producing pages of rating tables and rating table

sets for the normal range of operations until the end value of the upstream water level, HUP1, is less than or equal to the lowest value of the upstream water level for the normal range, HUR1, completing the generation of rating tables for the normal range of operations.

When the normal range of operation rating table is completed, the program goes back to statement 986 to start the generation of the rating tables for the other than normal range of operations. The starting upstream and downstream water levels are initialized to the maximum values of the other than normal range HUR4 and HDR4, respectively, and NTAB is now set to 2 to indicate the other than normal range of operations rating tables are being generated.

The computational procedures for the other than normal range continues at statement 984, starting with a new page number set to 1, and initializing the page discharge, QT, to QR4, and

195

incrementing the table number, NTABNO, by a count of 1. The computational sequence for the other than normal range is similar to the normal range described above with the exception that both the upstream and downstream water levels are incremented for each rating table set until they are less than or equal to the lowest values of the other than normal range of upstream and downstream water levels, HUR3 and HDR3, respectively. The generation of the other than normal range of operations rating tables is now complete and the program goes to statement 72 when NRATE is greater than 0, and ends by printing "END OF DATA INPUT."

Output of the Interactive Terminal Response

The output of the interactive terminal response features begins at statement 993 when NRATE is equal to 0. The output sequence begins by storing the results of one computer run into the X1 through X8 arrays. Each run prints out headings and then output values, as shown in the examples following this section.

After the data for one computer run are printed, a question is asked at statement 71 if the run is "OK." If a "Y" for yes is entered at this point, the run is saved for later tabulation. If "N" for no is entered, the run number J is decreased by a count of 1 and the output data will not be tabulated later. If the run number J exceeds 40, the program continues to statement 112 and the tabulation of all the saved computer runs begins.

At statement 58, the program asks if more data are to be entered. If "Y" for yes is entered at this point, the program goes back to statement 1 to begin the input for the next computer run. If "N" for no is entered, the program will begin the tabulation of all the saved runs and then end by printing the message "END OF DATA INPUT." If there are no saved runs, J is set to 0, the program ends without any tabulation by printing the same message. The remaining paragraphs describe examples for the interactive terminal response and the generation of rating tables modes of program operation.

Examples of Interactive Terminal Response

The six examples shown on figure V-72 demonstrate the use of the computer program for the interactive terminal response mode when NRATE is set to 0. Each example is summarized as follows:

1. Example No. 1, figure V-72(a) — demonstrates solving for the discharge,
   a. Use check No. 1
   b. Enter the upstream and downstream water surface elevations, 249.46 and 247.64

   c. Solve for the discharge by entering Q
   d. Enter the gate openings for each of three gates, equal to 4.7, 4.7, and 4.7
   e. Enter Y to save the data
   f. Enter Y to continue with more data

2. Example No. 2, figure V-72(b) — demonstrates solving for the gate openings.
   a. Use check No. 1
   b. Enter the upstream and downstream water surface elevations, 249.46 and 247.65
   c. Solve for each gate opening by entering G
   d. Enter the total discharge, equal to 1959.5
   e. Enter N for no gate limits
   f. Enter Y to save the data
   g. Enter Y to continue with more data

3. Example No. 3, figure V-72(c) — demonstrates solving for gate opening with two of the three gates limited.
   a. Use check No. 7
   b. Enter the upstream and downstream water surface elevations, 313.22 and 311.93
   c. Solve for the gate opening by entering G
   d. Enter the total discharge, equal to 1185.9
   e. Enter Y for gate limits
   f. Enter the limited gate openings as 1.85, -1.0, and 1.50. Note: Gate No. 2 is entered as a -1.0 to indicate this gate is not limited. However, the gates No. 1 and 3 are limited to a fixed opening of 1.85 and 1.50, respectively.
   g. Enter Y to save the data
   h. Enter Y to continue with more data

4. Example No. 4, figure V-72(d) — demonstrates solving for the discharge when the gate opening given is greater than the given upstream depth.
   a. Use check No. 7
   b. Enter the upstream and downstream water surface elevations as 313.34 and 313.06
   c. Solve for the discharge by entering Q
   d. Enter the gate openings for each of three gates as 24.12, 24.12, and 24.12
   e. Enter Y to save the data
   f. Enter Y to continue with more data

5. Example No. 5, figure V-72(e) — demonstrates solving for the gate openings when the flag FCOND(NC) is set to 1HF (free flow only).
   a. Use check No. 5 when FCOND(5) is set to 1HF in statement
   b. Enter the upstream water surface elevation only as 30.00. (Note: for check No. 5, the actual upstream water surface elevation is 1300.00 + 30.00.)
   c. Solve for the gate openings by entering G
   d. Enter total discharge, equal to 3025.5

```
-,RGRUN

    INPUT CHECK DATA AS FOLLOWS:
    CHECK NO. =
?  1
    UPSTREAM AND DOWNSTREAM WATER ELEVATIONS=
?  249.46,247.65
    DO YOU WANT TO CALCULATE DISCHARGE,Q OR GATE OPENINGS,G ?
    ENTER Q OR G
?  Q
    GATE OPENINGS FOR 3. GATES =
?  4.7,4.7,4.7
                         CANAL RADIAL CHECK GATES
                DISCHARGE AND/OR GATE OPENINGS BY ALGORITHMS

 CHECK    CHECK    H2O UP H2O DOWN  INPUT    OUTPUT ****GATE PROPERTIES****
 NO.      NAME      ELEV.   ELEV.   DISCH.   DISCH. NO. OPEN.  DISCH. COND.
           FT.       FT.    FT3/S   FT3/S          FT.    FT3/S

 ***** ********** **** ******** **** ****** ** ******** ** ************ ****** ****

  1    VEL. BARR.  249.460  247.650 *****   1959.5  1  4.700    653.2  SUBM
                                            2  4.700    653.2  SUBM
                                            3  4.700    653.2  SUBM



 ***** ****** *** **** ** **** ** **** ***** ** *********** **** ****** ** ****** **

    IS THIS RUN OK?
    ENTER YES OR NO
?  Y
    DO YOU WANT TO ENTER MORE DATA ?
    ENTER YES OR NO
?  Y
```

EXAMPLE NO. I

Figure V-72(a).—Demonstrates solving for the discharge.

```
 INPUT CHECK DATA AS FOLLOWS,
 CHECK NO. =
? 1
 UPSTREAM AND DOWNSTREAM WATER ELEVATIONS=
? 249.46,247.65
 DO YOU WANT TO CALCULATE DISCHARGE,Q OR GATE OPENINGS,G ?
 ENTER Q OR G
? G
 TOTAL DISCHARGE =
? 1959.5
 ARE THERE GATE LIMITS ?
 ENTER YES OR NO
? N
 CHECK   CHECK    H2O UP H2O DOWN  INPUT    OUTPUT ****GATE PROPERTIES****
 NO.     NAME      ELEV.  ELEV.    DISCH.   DISCH. NO. OPEN.  DISCH. COND.
                   FT.    FT.      FT3/S    FT3/S       FT.    FT3/S
 ***********************************************************************

 1  VEL. BARR.  249.460  247.650  1959.5  1959.5  1  4.700     653.2   SUBM
                                                  2  4.700     653.2   SUBM
                                                  3  4.700     653.2   SUBM


 ***********************************************************************

 IS THIS RUN OK?
 ENTER YES OR NO
? Y
 DO YOU WANT TO ENTER MORE DATA ?
 ENTER YES OR NO
? Y
```

EXAMPLE NO. 2

Figure V-72(b).—Demonstrates solving for the gate opening.

```
    INPUT CHECK DATA AS FOLLOWS:
    CHECK NO. =
?  7
    UPSTREAM AND DOWNSTREAM WATER ELEVATIONS=
?  313.22,311.93
    DO YOU WANT TO CALCULATE DISCHARGE,Q OR GATE OPENINGS,G ?
    ENTER Q OR G
?  G
    TOTAL DISCHARGE =
?  1185.9
    ARE THERE GATE LIMITS ?
    ENTER YES OR NO
?  Y
    GATE OPENING LIMITS FOR 3. GATES =
    NOTE: ENTER -1.0 FOR GATES WITHOUT LIMITS
?  1.85,-1.0,1.50
    CHECK   CHECK     H2O UP  H2O DOWN   INPUT    OUTPUT  ****GATE PROPERTIES****
    NO.     NAME      ELEV.   ELEV.      DISCH.   DISCH.  NO. OPEN.   DISCH. COND.
      .                FT.     FT.       FT3/S    FT3/S        FT.    FT3/S
    ***************************************************************************************

    7   CAL AQ #21   313.220  311.930  1185.9  1185.9   1  1.850*    332.3  SUBM
                                                        2  3.193     585.5  SUBM
                                                        3  1.500*    268.1  SUBM


    ***************************************************************************************

    *GATE OPENING LIMITED
    IS THIS RUN OK?
    ENTER YES OR NO
?  Y
    DO YOU WANT TO ENTER MORE DATA ?
    ENTER YES OR NO
?  Y
```

EXAMPLE NO. 3

Figure V-72(c).—Demonstrates solving for the gate opening with two of the three gates limits.

```
    INPUT CHECK DATA AS FOLLOWS!
    CHECK NO. =
? 7
    UPSTREAM AND DOWNSTREAM WATER ELEVATIONS=
? 313.34,313.06
    DO YOU WANT TO CALCULATE DISCHARGE,Q OR GATE OPENINGS,G ?
    ENTER Q OR G
? Q
    GATE OPENINGS FOR 3. GATES =
? 24.12,24.12,24.12
    CHECK   CHECK     H2O UP  H2O DOWN  INPUT    OUTPUT  ****GATE PROPERTIES****
    NO.     NAME      ELEV.   ELEV.     DISCH.   DISCH.  NO. OPEN.   DISCH.  COND.
                      FT.     FT.       FT3/S    FT3/S       FT.     FT3/S
    ****************************************************************************

    7   CAL AQ #21  313.340  313.060  *****   6598.5   1 23.568** 2199.5 CLEAR
                                                        2 23.568** 2199.5 CLEAR
                                                        3.23.568** 2199.5 CLEAR



    ****************************************************************************

    **GATE OPENING ABOVE WATER SURFACE        #RESULTS ARE UNRELIABLE#
    IS THIS RUN OK?
    ENTER YES OR NO
? Y
    DO YOU WANT TO ENTER MORE DATA ?
    ENTER YES OR NO
? Y
```

EXAMPLE NO. 4

Figure V-72(d).—Demonstrates solving for the discharge when the gate openings given are greater than the upstream depth.

```
     INPUT CHECK DATA AS FOLLOWS:
     CHECK NO. =
?  5
     UPSTREAM AND DOWNSTREAM WATER ELEVATIONS=
?  30.0
     DO YOU WANT TO CALCULATE DISCHARGE,Q OR GATE OPENINGS,G ?
     ENTER Q OR G
?  G
     TOTAL DISCHARGE =
?  3025.5
     ARE THERE GATE LIMITS ?
     ENTER YES OR NO
?  N
 CHECK   CHECK    H2O UP H2O DOWN  INPUT    OUTPUT  ****GATE PROPERTIES****
 NO.     NAME     ELEV.   ELEV.    DISCH.   DISCH. NO. OPEN.  DISCH. COND.
                  FT.     FT.      FT3/S    FT3/S       FT.    FT3/S
 ***************************************************************************

 5   EAST LOW    30.000 1300.030 3025.5  3025.5   1  4.260-  1512.8   FREE
     •                                            2  4.260-  1512.8   FREE


 ***************************************************************************

     IS THIS RUN OK?
     ENTER YES OR NO
?  Y
     DO YOU WANT TO ENTER MORE DATA ?
     ENTER YES OR NO
?  N
```

EXAMPLE NO. 5

Figure V-72(e).—Demonstrates solving for the gate openings when the flag FCOND(NC) is set to 1HF (free flow only).

e. Enter N for no gate limits
f. Enter Y to save the data
g. Enter N to end computer runs and to begin tabulation of all save runs as shown in example 6, figure V-72 (f).

Note in figure V-72(e) that the invert elevation, DNINV(5), equal to 1300.03, is printed as the downstream water surface elevation "H2O DOWN ELEV." when FCOND(NC) is set to 1HF. Also, when solving for the gate openings, a "−" sign is printed after each gate opening. The "−" sign is not printed when solving for the discharge and FCOND(NC) is set to 1HF.

6. Example No. 6, figure V-72(f) — demonstrates the tabulation of all saved runs after computer runs have been completed.

Example for Generating Rating Tables

The Tehama-Colusa Canal check No. 1 is used as an example to develop the necessary parameters for generating rating tables, which is also check No. 1 in the program listing geometry data statements. Therefore, NRATE is set to the integer 1 and the rating table parameters are initialized based on the following criteria:

Decision	Example data

A. For normal ranges of operation:
 1. Range of upstream water level,........................HUR1 to HUR2 = 248.0 to 252.0 ft
 2. Linear equations: (refer to fig. V-73)

$$RB1 = 244.2 \text{ ft}$$
$$RB2 = 245.7 \text{ ft}$$
$$RB3 = 248.68 \text{ ft}$$
$$RB4 = 245.00 \text{ ft}$$
$$QRC1 = 0.0 \text{ ft}^3/\text{s}$$
$$QRC2 = 500.0 \text{ ft}^3/\text{s}$$
$$QRC3 = 2600.0 \text{ ft}^3/\text{s}$$

$$RA1 = (RB2-RB1)/(QRC2-QRC1) = (245.7-244.2)/(500.0-0.0) = 0.00300$$
$$RA2 = (RB3-RB4)/(QRC3-QRC1) = (248.68-245.00)/(2600-0.0) = 0.001415$$

 3. Water level increment,...................................... DH1 = 0.02 ft
 4. Range of discharge, ... QR1 to QR2 = 0 to 2600 ft³/s
 5. Discharge increment, ... QR1 = 40.0 ft³/s

B. For ranges of operation other than normal:
 1. Range of upstream water level,........................HUR3 to HUR4 = 239.62 to 252.0 ft
 2. Range of downstream water level,....................HDR3 to HDR4 = 239.62 to 249.0 ft
 3. Water level increment,.. DH2 = 0.1 ft
 4. Range of discharge, ... QR3 to QR4 = 0 to 2600.0 ft³/s
 5. Discharge increments   = 100.0 ft³/s

C. Approximate number of sets of tables and total number of pages:
 1. Number of table sets:
    Normal range of operations:
    HU(normal) = (HUR2−HUR1)/(40*DH1) = (252.0−248.0)/(20*0.02) = 10
    Other than normal operations:
    HU(other) = (HUR4−HUR3)/(20*DH2) = (252.0−239.62)/(20*0.1) = 6
    HD(other) = [(HDR4−HDR3)/(40*DH2)]/1.4 = [(249.0−239.62)/(40*0.1)]/1.4 = 1.7

 2. Approximate total number of tables sets:
    Normal range = HU(normal)   = 10
    Other than normal = HU(other)*HD(other) = 6*1.7 = 10.2

                                    Number of table sets = 20.2

 3. Approximate number of pages for each set of tables:
    Normal range = (QR2−QR1)/DQ1 = (2600.0−0.0)/40 = 65
    Other than normal = (QR4−QR3)/DQ2 = (2600.0−0.0)/100.0 = 26

 4. Approximate total number of pages for the entire rating table could be:
    Normal range = 10 table sets * 65 pages per set   = 650
    Other than normal = 10.2 table sets * 26 pages per set = 265

                        Approximate total number of pages = 915

202

CANAL RADIAL CHECK GATES
DISCHARGE AND/OR GATE OPENINGS BY ALGORITHMS

CHECK NO.	CHECK NAME	H2O UP ELEV. FT.	H2O DOWN ELEV. FT.	INPUT DISCH. FT3/S	OUTPUT DISCH. FT3/S	****GATE PROPERTIES**** NO.	OPEN. FT.	DISCH. FT3/S	COND.
************* ** ** ** *** *** ** ** ** *** ** ** *** *** ** ** ** *** ** ** *** *** ** ** ***
1	VEL. BARR.	249.460	247.650	*****	1959.5	1	4.700	653.2	SUBM
						2	4.700	653.2	SUBM
						3	4.700	653.2	SUBM
*********** ** ** ** ** *** *** ** ** *** *** *** ** *** *** *** ** *** ** ***
1	VEL. BARR.	249.460	247.650	1959.5	1959.5	1	4.700	653.2	SUBM
						2	4.700	653.2	SUBM
						3	4.700	653.2	SUBM
*** *** ** ** ** ** *** ** ** *** *** *** ** ** *** *** *** ** *** *** ** **
7	CAL AQ #21	313.220	311.930	1185.9	1185.9	1	1.850*	332.3	SUBM
						2	3.193	585.5	SUBM
						3	1.500*	268.1	SUBM
*** ** *** *** **** *** *** ** ** *** *** ** ** *** *** *** *** ** ** ***
7	CAL AQ #21	313.340	313.060	*****	6598.5	1	23.568**	2199.5	CLEAR
						2	23.568**	2199.5	CLEAR
						3	23.568**	2199.5	CLEAR
*** ** ** ** ** *** ** ** *** *** ** ** *** *** *** ** ** *** ***
5	EAST LOW	30.000	1300.030	3025.5	3025.5	1	4.260-	1512.8	FREE
						2	4.260-	1512.8	FREE

****** ** ** ** ** *** *** *** ** *** ** ** ** *** *** *** ** *** *** *** *** ** *** ** ** *** ** ** *** *** *** *** ***

*GATE OPENING LIMITED
**GATE OPENING ABOVE WATER SURFACE   #RESULTS ARE UNRELIABLE#
1# END OF DATA INPUT #
READY.

EXAMPLE NO. 6

Figure V-72(f).—Demonstrates the tabulation of all saved runs after computer runs have been completed.

The computer program was executed as shown in the listing on the Bureau's CDC CYBER 170/730 60-bit computer system using the submit program shown on figure V-70. A P5 priority (lowest cost) was used. The computer run took 9112.3 seconds of computer time and 10506.0 SRU's to produce 892 pages of tables (4.0 inches of shelf space) for a total cost of $122.90, or about 14 cents per page using the Xerox printer. Figure V-71 shows one page (No. 22) of table III-10 as an example output format. Figure V-74 shows how the table number and book number can be located based on the range of upstream and downstream water levels.
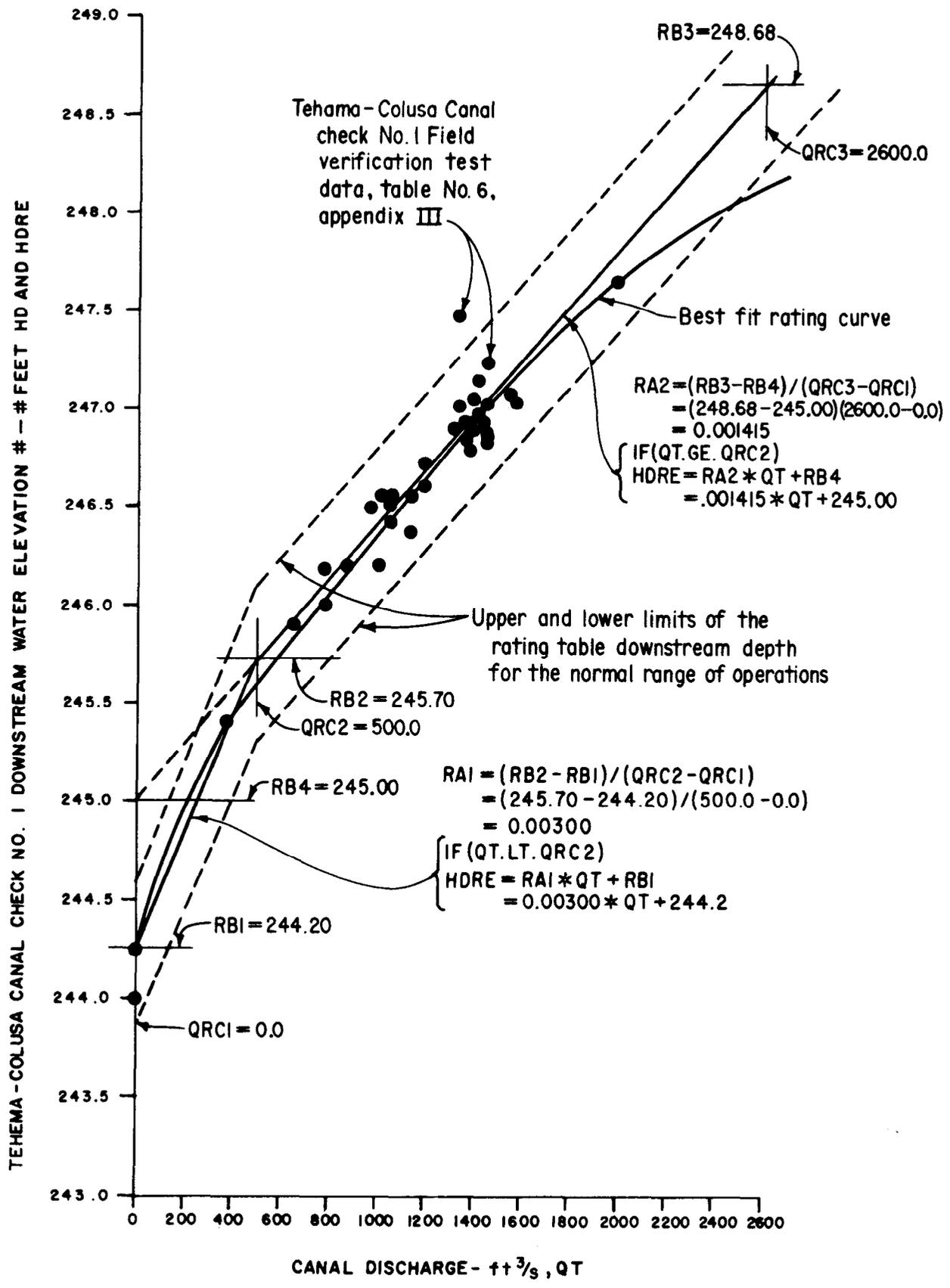
Figure V-73.—Tehama-Colusa Canal check No. 1 downstream depth, HD, and HDRE, versus canal discharge, QT, rating curve for generating rating tables for the normal range of operations.

205

TEHAMA-COLUSA CANAL CHECK NO. I
RATING TABLE INDEX CHART
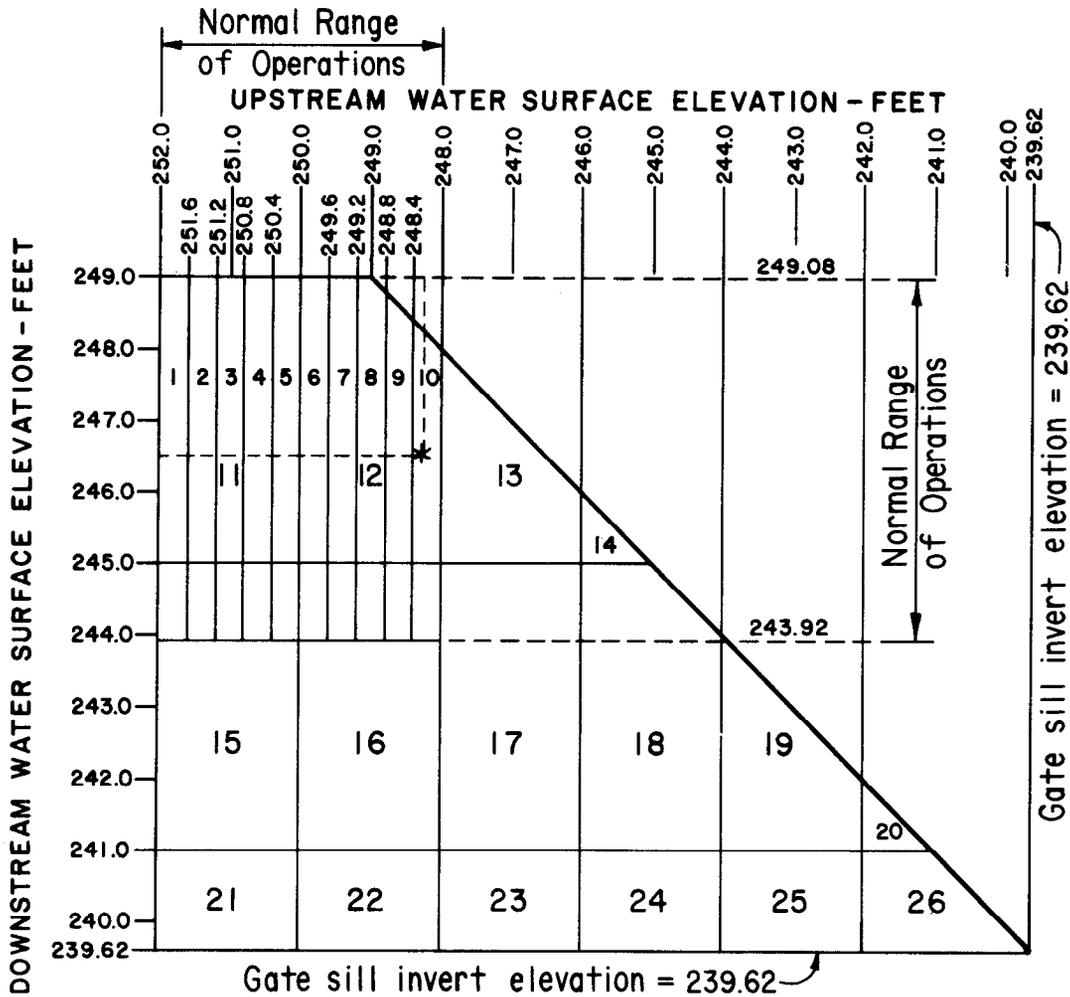
TABLE NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
BOOK NUMBER		1					2								3											

Note : To use index chart, enter upper chart with upstream and downstream water surface elevations and find table number. Then using lower chart, enter Table numbers and find Book number.

Example : Given : Upstream water surface elevation = 248.28
Downstream water surface elevation = 246.52
Find : Table number upper chart = 10 (Normal Range)
or = 12 (Other than Normal Range)
Book number lower chart = 2 (Normal Range)
or = 3 (Other than Normal Range)

Figure V-74.—Rating table index chart for Tehama-Colusa Canal check No. 1 for normal and other-than-normal range of operations.

Program Listing

```
    1                    PROGRAM RADGAT(INPUT,OUTPUT,TABLE,TAPE1=INPUT,TAPE2=OUTPUT,
                        +TAPE3=TABLE)
              C
              C  THIS IS A GENERAL PROGRAM THAT USES CANAL RADIAL GATE DISCHARGE
    5         C  ALGORITHMS TO CALCULATE EITHER THE DISCHARGE FROM A KNOWN GATE
              C  OPENING(S) OR THE GATE OPENING(S) FROM A KNOWN DISCHARGE FOR KNOWN
              C  UPSTREAM AND DOWNSTREAM WATER DEPTHS.
              C
              C  THE PROGRAM ALSO DETERMINES IF THE FLOW CONDITION IS SUBMERGED,
   10         C  FREE, IN THE TRANSITION ZONE(BETWEEN SUBMERGED AND FREE), OR CLEAR
              C  WHEN THE GATE OPENING(S) ARE AT OR ABOVE THE UPSTREAM WATER DEPTH.
              C
              C  THE PROGRAM CAN BE USED INTERACTIVELY WITH THE COMPUTER TERMINAL
              C  OR WITH CERTAIN VARIABLES INITIALIZED, A SERIES OF RATING TABLES
   15         C  CAN BE GENERATED.
              C
              C  THE PROGRAM IS IN ENGLISH UNITS. THE GRAVITATIONAL CONSTANT,GC,
              C  AND THE ITERATION LIMIT RESOLUTIONS FOR WATER DEPTHS,YDELTA, THE
              C  FOR DISCHARGE,QDELTA, AND FOR THE GATE OPENING,GDELTA, ARE THE ONLY
   20         C  CHANGES REQUIRED FOR METRIC CONVERSION OTHER THAN THE OUTPUT PRINT
              C  FORMATS.
              C
              C
              C  THE PROGRAM IS DIMENSIONED FOR 20 CHECK GATES UP TO 5 GATES EACH.
   25         C  HOWEVER, 40 OUTPUT RUNS CAN BE MADE WHEN USING THE INTERACTIVE
              C  COMPUTER TERMINAL RESPONSE FEATURE.
              C
                       DIMENSION GW(20),PW(20),RAD(20),PH(20),UPINV(20),DNINV(20),GN(20)
                       DIMENSION CHECKN(20),YINVERT(20),YSYFON(20),SYFON(20)
   30                  DIMENSION UPK(20),DNK(20),BWUP(20),BWDN(20),ZUP(20),ZDN(20)
                       DIMENSION CFCDA(20),CSCDA(20),FCOND(20)
                       DIMENSION QF(5),QS(5),QG(5),GO(20,5),GOL(20,5),GOF(5),GOS(5),
                      +OLDG(5),COND(3,5),CONDF(5),GOP(5),FOLDG(5),OLDG1(5),SCDA(5)
                       DIMENSION J1(40),X1(40),X2(40),X3(40,5),X4(40,5),X5(40,5),
   35                 +X6(40,5),X7(40),X8(40),CANALN(4),HDTAB(41),GOTAB(41,21)
              C
              C  SET UP CHECK GATE GEOMETRY STARTING WITH CHECK NO.1
              C
              C  DATA STATEMENTS ARE LIMITED TO 20 CHECK GATE STRUCTURES.
   40         C  DEFINITION OF GEOMETRY VARIABLES ARE AS FOLLOWS
              C
              C     GW=GATE WIDTH PER GATE
              C     PW=PIER WIDTH
              C     RAD=GATE RADIUS
   45         C     PH=PINION HEIGHT
              C     UPINV=UPSTREAM INVERT ELEVATION AT GAGE
              C     DNINV=DOWNSTREAM INVERT ELEVATION AT GAGE
              C     GN=NUMBER OF GATES AT THE CHECK STRUCTURE
              C     CHECKN=CHECK NAME (MAX. 10 CHARACTERS)
   50         C     YINVERT=CHANGE IN CANAL INVERT FROM UPSTREAM GAGE TO GATE SILL
              C             (MINUS FOR AN INCREASE IN ELEVATION, OR PLUS FOR DECREASE)
              C     YSYFON=CHANGE IN CANAL INVERT FROM GATE SILL TO DOWNSTREAM GAGE
              C             (MINUS FOR AN INCREASE IN ELEVATION, OR PLUS FOR DECREASE)
              C     SYFON=ENERGY LOSS COEFFICIENT FOR THE SIPHON LOCATED BETWEEN GATE
   55         C             AND THE DOWNSTREAM DEPTH GAGE EQUAL TO HEAD LOSS DIVIDED
              C             BY THE DISGHARGE SQUARED
              C     UPK=HEAD LOSS COEFICIENT FOR UPSTREAM CANAL TRANSITION
```

```
        C      DNK=HEAD LOSS COEFICIENT FOR DOWNSTREAM CANAL TRANSITION
        C      BWUP=CANAL BOTTOM WIDTH AT UPSTREAM GAGE
 60     C      BWDN=CANAL BOTTOM WIDTH AT DOWNSTREAM GAGE
        C      ZUP=CANAL SIDE SLOPE AT UPSTREAM GAGE (HORIZ. TO UNITY VERT. DISTANCE)
        C      ZDN=CANAL SIDE SLOPE AT DOWNSTREAM GAGE (HORIZ. TO UNITY VERT. DISTANCE)
        C      CFCDA=CORRECTION COEFFICIENT FOR GATE LIP SEAL DESIGN FREE FLOW
        C           CONDITIONS OR FLAGS TO USE CORRECTION ALGORITHMS.
 65     C           ENTER 1.0 FOR NO CORRECTION (HARD-RUBBER-BAR DESIGN), OR 0.0
        C           FOR THE GENERAL CORRECTION ALGORITHM, OR -1.0 FOR THE SPECIAL
        C           CORRECTION ALGORITHM, OR ANY CONSTANT VALUE(OTHER THAN 1.0,
        C           0.0,OR-1.0) WHEN THE CORRECTION IS CONSTANT.
        C      CSCDA=CORRECTION COEFFICIENT FOR GATE LIP SEAL DESIGN SUBMERGED
 70     C           FLOW CONDITIONS OR FLAGS TO USE CORRECTION ALGORITHMS.
        C           ENTER 1.0 FOR NO CORRECTION (HARD-RUBBER-BAR DESIGN), OR 0.0
        C           FOR THE GENERAL CORRECTION ALGORITHM, OR -1.0 FOR THE SPECIAL
        C           CORRECTION ALGORITHM, OR ANY CONSTANT VALUE(OTHER THAN 1.0,
        C           0.0,OR-1.0) WHEN THE CORRECTION IS CONSTANT.
 75     C      FCOND=PRESELECTED FLOW CONDITIONS (1HS=SUBMERGED ONLY OR 1HF=FREE
        C           ONLY). IF FLOW CONDITION IS UNKNOWN OR CAN BE EITHER FREE OR
        C           SUBMERGED, ENTER 0.0.
        C
        C
 80            DATA GW/14.0,14.0,18.0,15.25,16.0,10.0,25.0,2*20.0,11.0,18.0,
              +12.0,17.0,7*0.0/
               DATA PW/1.5,1.25,1.25,1.75,2.0,1.33,3.0,2*2.0,1.0,1.67,1.0,
              +0.0,7*0.0/
               DATA RAD/13.771,16.27,21.27,20.02,26.27,11.27,37.52,2*21.27,26.02,
 85           +21.27,26.02,13.77,7*0.0/
               DATA PH/9.0,10.5,13.5,12.0,15.0,7.0,25.0,2*13.5,16.80,13.5,
              +16.80,9.0,7*0.0/
               DATA UPINV/227.54,232.74,227.54,1309.28,9.28,118.0,289.74,420.18,
              +414.20,406.32,396.98,392.58,487.97,7*0.0/
 90            DATA DNINV/239.62,228.19,227.18,1313.34,1300.03,120.45,286.632,
              +420.17,414.19,406.28,396.97,391.92,488.09,7*0.0/
               DATA GN/3.,3.,2.,3.,2.,2.,3.,3.,3.,5.,3.,4.,1.,7*0.0/
               DATA CHECKN/10HVEL. BARR.,10HFISH SCRN.,10H  COYOTE  ,10HWEST CANA
              +L,10HEAST LOW  ,10HPUTAH SO. ,10HCAL AQ "21,10HSAND CREEK,10HDODGE
 95           + AVE.,10H  KAWEAH  ,10H 5TH  AVE.,10HTULE RIVER,10HCOALINGA 1,
              +7*0.0/
               DATA YINVERT/-12.08,0.0,2.06,-4.07,-0.01,-5.00,0.10,2*0.01,0.0,
              +0.01,0.0,-0.4,7*0.0/
               DATA YSYFON/0.0,4.55,-1.70,0.01,9.26,2.55,3.01,2*0.0,0.04,0.0,
 100          +0.66,0.28,7*0.0/
               DATA SYFON/0.0,0.000000000,0.000000038,0.0,0.000000406,
              +0.000001010,0.000000000,2*0.0,0.000000018,0.0,0.000000024,
              +0.000000172,7*0.0/
               DATA UPK/0.5,0.2,0.2,0.5,0.23,0.5,6*0.2,7*0.0/
 105           DATA DNK/13*0.1,7*0.0/
               DATA BWUP/248.0,100.0,24.0,50.0,43.0,75.0,50.0,2*64.0,3*36.0,
              +12.0,7*0.0/
               DATA BWDN/45.0,24.0,24.0,38.0,22.33,12.0,32.0,2*64.0,3*36.0,
              +12.0,7*0.0/
 110           DATA ZUP/2.0,0.0,1.5,1.5,0.0,0.0,2.0,2*1.5,3*1.25,1.5,7*0.0/
               DATA ZDN/0.0,3*1.5,0.0,1.5,2.0,2*1.5,3*1.25,1.5,7*0.0/
               DATA CFCDA/3*1.0,0.0,-1.0,0.938,1.0,5*0.0,1.0,7*1.0/
               DATA CSCDA/3*1.0,-1.0,0.0,0.0,0.928,1.0,5*0.0,1.0,7*1.0/
               DATA FCOND/0.0,0.0,0.0,1HS,1HF,0.0,1HS,5*0.0,1HS,7*0.0/
```

209

```
 115          C
              C  SELECT PROGRAM MODE TO EITHER INTERACTIVE TERMINAL RESPONSE WITH
              C  NRATE = 0, OR GENERATE RATING TABLES WITH NRATE = AN INTEGER EQUAL
              C  TO THE CHECK NO. TO BE RATED (RATING TABLES CAN ONLY BE GENERATED FOR
              C  ONE CHECK GATE STRUCTURE AT A TIME).
 120          C
                     NRATE=1
              C
              C  INITIALIZE PARAMETERS FOR NORMAL OPERATING RANGE FOR RATING TABLES.
              C
 125                 CANALN(1)=10HTEHAMA-COL
                     CANALN(2)=10HUSA CANAL
                     CANALN(3)=10HCHECK NO.
                     CANALN(4)=10H1
                     HUR1=248.00
 130                 HUR2=252.00
                     DH1=0.02
                     QR1=0.0
                     QR2=2600.0
                     DQ1=40.0
 135                 RA1=0.003
                     RB1=244.20
                     RA2=0.001415
                     RB4=245.00
                     QRC2=500.0
 140          C
              C  INITIALIZE PARAMETERS FOR OTHER THAN NORMAL OPERATING RANGE FOR
              C  RATING TABLES.
              C
                     HUR3=239.62
 145                 HUR4=252.00
                     HDR3=239.62
                     HDR4=249.00
                     DH2=0.1
                     QR3=0.0
 150                 QR4=2600.0
                     DQ2=100.0
              C
              C  OTHER PARAMETERS FOR THE RATING TABLES.
              C
 155                 NTABNO=0
                     QORG=1HG
                     UPELEV=0.0
                     DNELEV=0.0
              C
 160          C  INITIALIZE GC GRAVITATIONAL CONSTANT (FT/S**2), AND ITERATION LIMIT
              C  RESOLUTIONS YDELTA FOR WATER LEVELS(FT), QDELTA FOR DISCHARGE(FT**3/S),
              C  AND GDELTA FOR GATE OPENINGS(FT). NOTE THE VALUES SHOWN ARE IN
              C  ENGLISH UNITS. THEY NEED TO BE CHANGED TO METRIC EQUIVALENTS WHEN
              C  USING METRIC UNITS.
 165          C
                     GC=32.2
                     YDELTA=0.002
                     QDELTA=1.0
                     GDELTA=0.002
 170          C
              C  INITIALIZE FLAGS AND COUNTERS.
```

210

```
       C
             NIU=21
             NID=41
175          J=0
             MP=0
             JP=0
             JPP=0
             NL=0
180          NLL=0
             NL1=0
             NL2=0
       C
       C  WHEN NRATE IS GREATER THAN 0, BEGIN GENERATION OF RATING TABLES AT
185    C  STATEMENT 999.
       C
             IF(NRATE.GT.0) GO TO 999
       C
       C  BEGIN INTERACTIVE TERMINAL RESPONSE WHEN NRATE = 0
190    C  INPUT FLOW CONDITIONS CHECK NO.,NC; UPSTREAM WATER ELEV.,UPELEV;
       C  DOWNSTREAM WATER ELEV.,DNELEV; DISCHARGE,QT; OR GATE OPENING(S),GO(S)
       C
       C   OUTPUT IS MADE FOR EACH RUN AND WHEN FINISHED ALL SAVED RUNS
       C   ARE TABULATED BY CHECK NUMBER GIVING ELEVATIONS,TOTAL DISCHARGE,
195    C   GATE OPENINGS AND DISCHARGE FOR EACH GATE AND FLOW CONDITION
       C
           1 PRINT(2,*) '  INPUT CHECK DATA AS FOLLOWS '
             IF(J.GE.40) GO TO 73
             J=J+1
200          IF(J.LE.0)  J=0
             NF=0
             QT=0.0
             GOT=0.0
             YN=1HN
205        7 PRINT(2,*) ' CHECK NO. ='
             READ(1,*) NC
             IF(NC.LE.0.OR.NC.GT.20) GO TO 7
             GX=GN(NC)
             L=INT(GN(NC)+0.01)
210          PRINT(2,*) ' UPSTREAM AND DOWNSTREAM WATER ELEVATIONS='
             IF(FCOND(NC).NE.1HF) READ(1,*) UPELEV,DNELEV
             IF(FCOND(NC).EQ.1HF) READ(1,*) UPELEV
             IF(FCOND(NC).EQ.1HF) DNELEV=DNINV(NC)
             PRINT(2,*) ' DO YOU WANT TO CALCULATE DISCHARGE,Q OR GATE OPENINGS
215         +,G *'
           2 PRINT(2,*) ' ENTER Q OR G'
             QORG=1HX
             READ(1,6) QORG
           6 FORMAT(1A1)
220          IF(QORG.NE.1HQ.AND.QORG.NE.1HG) GO TO 2
             IF(QORG.EQ.1HQ) GO TO 3
         111 PRINT(2,*) ' TOTAL DISCHARGE ='
             READ(1,*) QT
             IF(QT.LE.0.0) PRINT(2,*) ' TOTAL DISCHARGE MUST BE .GT. 0.0'
225          IF(QT.LE.0.0) GO TO 111
             QIN=QT
             GO(NC,1)=0.0
             GO(NC,2)=0.0
```

211

```
                        GO(NC,3)=0.0
      230               GO(NC,4)=0.0
                        GO(NC,5)=0.0
                        PRINT(2,*) ' ARE THERE GATE LIMITS #'
                      4 PRINT(2,*) ' ENTER YES OR NO'
                        READ(1,6) YN
      235               IF(YN.NE.1HN.AND.YN.NE.1HY) GO TO 4
                        IF(YN.EQ.1HN) GO TO 10
                        PRINT(2,*) ' GATE OPENING LIMITS FOR ',GN(NC),' GATES ='
                        PRINT(2,*) ' NOTE ENTER -1.0 FOR GATES WITHOUT LIMITS'
                        GO TO 5
      240             3 PRINT(2,*) ' GATE OPENINGS FOR ',GN(NC),' GATES ='
                      5 READ(1,*) (GO(NC,K), K=1,L)
                     10 DO 9 I=1,L
                        GOT=GOT+GO(NC,I)
                        IF(YN.EQ.1HN) GO TO 8
      245               IF(GO(NC,I).LT.0.0) GO TO 8
            C
            C  IF A GATE OPENING IS LIMITED, THE FLAG GOL(NC,I) IS SET TO 2H*
            C  WHERE NC IS THE CHECK NUMBER AND I IS THE GATE NUMBER.
            C
      250               GOL(NC,I)=2H*
                        GX=GX-1.0
                        NL=1
                        GO TO 9
                      8 GOL(NC,I)=1H+
      255               IF(QORG.EQ.1HG.AND.FCOND(NC).EQ.1HS) GOL(NC,I)=1H-
                        IF(QORG.EQ.1HQ) GOL(NC,I)=1H
                      9 CONTINUE
            C
            C  SET UP CONSTANTS AND INITIALIZE VARIABLES
      260   C
                        HU=UPELEV-UPINV(NC)
                        HU1=HU
                        HD=DNELEV-DNINV(NC)
                        HU2=HU+YINVERT(NC)
      265   C
            C  WHEN USING THE INTERACTIVE TERMINAL RESPONSE, NRATE IS EQUAL TO 0,
            C  CONTINUE AT STATEMENT 998.
            C
                        IF(NRATE.EQ.0) GO TO 998
      270   C
            C  BEGIN GENERATION OF RATING TABLES WHEN NRATE IS GREATER THAN 0 BY
            C  INITIALIZING VARIABLES FOR TABLE INPUT.
            C
                    999 NC=NRATE
      275               L=INT(GN(NC)+0.01)
                        GX=GN(NC)
                        GO(NC,1)=0.0
                        GO(NC,2)=0.0
                        GO(NC,3)=0.0
      280               GO(NC,4)=0.0
                        GO(NC,5)=0.0
            C
            C  NORMAL OPERATING RANGE TABLES
            C
      285               HUP1=HUR2
```

```
            NTAB=1
        989 J=1
            IF(QR2.EQ.0.0) GO TO 986
            NTABNO=NTABNO+1
290         QT=QR2+DQ1
            HUS=HUP1
        996 QT=QT-DQ1
            IF(QT.LT.QRC2) HDRE=RA1*QT+RB1
            IF(QT.GE.QRC2) HDRE=RA2*QT+RB4
295         HDN1=HDRE+FLOAT(NID)*DH1/2.0
            DH=DH1
            DQ=DQ1
            QE=QR1
            GO TO 985
300     C
        C   OTHER THAN NORMAL OPERATING RANGE TABLES
        C
        986 HDN=HDR4
        982 HUP1=HUR4
305         HDN1=HDN
            NTAB=2
        984 J=1
            IF(QR4.EQ.0.0) GO TO 72
            NTABNO=NTABNO+1
310         QT=QR4+DQ2
            HUS=HUP1
        983 QT=QT-DQ2
            DH=DH2
            DQ=DQ2
315         QE=QR3
        C
        C   FIND STARTING UPSTREAM DEPTH,HUS, AND ROUND OFF TO EVEN NUMBER AND
        C   SET UP TABLE HEADINGS.
        C
320     985 DX1=1.0/DH
            DX2=HUS*DX1+0.01
            HUS=FLOAT(INT(DX2))/DX1
            XNIU=FLOAT(NIU)
            HUP1=HUS-(XNIU-1.0)*DH
325         DUPL1=HUS/100.0
            DUPL1=FLOAT(INT(DUPL1))*100.0
            X2(1)=HUS-DUPL1
            DO 991 NHU=2,NIU
        991 X2(NHU)=X2(NHU-1)-DH
330     C
        C   FIND STARTING DOWNSTREAM DEPTH,HDS, AND ROUND OFF TO EVEN NUMBER.
        C
            HDS=HDN1
            DX2=HDS*DX1+0.01
335         HDS=FLOAT(INT(DX2))/DX1
            IF(HDS.GT.HUS.AND.NTAB.EQ.1) HDS=HUS
            DNPL1=HDS/100.0
            DNPL1=FLOAT(INT(DNPL1))*100.0
            HU=HUS-UPINV(NC)+DH
340         HD=HDS-DNINV(NC)+DH
            HUP=HU
            XNID=FLOAT(NID)
```

213

```
                    HDN=HDS-(XNID-1.0)*DH
                    IF(HUS.LE.HDN.AND.NTAB.EQ.2) NTABNO=NTABNO-1
345                 IF(HUS.LE.HDN.AND.NTAB.EQ.2) GO TO 980
            C
            C  START RATING TABLE GENERATION FOR EACH PAGE
            C
                    NTP=0
350                 NGPP=0
            C
            C  ESTIMATE CRITICAL FLOW,QC, AND IF THE DISCHARGE,QT, FOR THE RATING
            C  TABLE IS GREATER, SKIP THE PAGE.
            C
355                 HUC=HU+YINVERT(NC)
                    IF(HUC.LT.0.0) HUC=0.0
                    QC=5.67*GW(NC)*GN(NC)*((HUC*0.8)**1.333)
                    IF(QT.GT.QC) GO TO 979
                    DO 995 NHD=1,NID
360                 HD=HD-DH
                    HU=HUP
                    DO 994 NHU=1,NIU
                    DO 990 I=1,L
                    GOL(NC,I)=1H+
365           990 IF(QORG.EQ.1HG.AND.FCOND(NC).EQ.1HS) GOL(NC,I)=1H-
                    HU=HU-DH
                    HU1=HU
                    HU2=HU+YINVERT(NC)
                    HD3=HD-YSYFON(NC)+SYFON(NC)*QT**2
370                 IF(HD3.GE.HU2) GO TO 981
                    IF(HD.LE.0.0) GO TO 981
            C
            C  STATEMENT 998 IS COMMON TO INTERACTIVE COMPUTER TERMINAL RESPONSE
            C  AND TO THE GENERATION OF RATING TABLES.
375         C
            C  INITIALIZE VARIABLES COMMON TO THE FREE AND SUBMERGED FLOW
            C  CALCULATIONS.
            C
              998 BWG=GW(NC)*GN(NC)
380                 BW=BWG+PW(NC)*(GN(NC)-1.0)
                    AREAUP=HU*(BWUP(NC)+ZUP(NC)*HU)
                    AREADN=HD*(BWDN(NC)+ZDN(NC)*HD)
                    QTOUT=0.0
                    NGF=0
385                 NGS=0
                    NGP=0
            C
            C    IF FCOND(NC)=1HS (SUBMEREGED FLOW ONLY) BY-PASS FREE FLOW CALCULATIONS
            C
390                 IF(FCOND(NC).EQ.1HS) GO TO 19
            C
            C  BEGIN FREE FLOW CALCULATIONS
            C
            C  ESTIMATE INITIAL FREE DISCHARGE WHEN SOLVING FOR DISCHARGE WHERE QFT
395         C  IS THE TOTAL FREE FLOW.
            C  NOTE THE FLAG QORG IS SET TO 1HQ WHEN SOLVING FOR DISCHARGE OR TO
            C        1HG WHEN SOLVING FOR THE GATE OPENING AT STATEMENT 2 FROM THE
            C        TERMINAL. IT IS SET TO 1HG WHEN GENERATING RATING TABLES.
            C
```

```
400          C
                    IF(HU2.LE.0.0) HU2=0.1
                    IF(QORG.EQ.1HQ) QFT=0.6*GW(NC)*GOT*SQRT(2.0*GC*HU2)
                    IF(QORG.EQ.1HG) QFT=QT
             C
405          C  BEGIN FREE FLOW UPSTREAM ENERGY BALANCE EQUATIONS
             C
             C  DETERMINE ENERGY GRADE LINE UPSTREAM OF GATE IN RECTANGULAR SECTION
             C  REFERENCED TO THE GATE SILL INVERT ELEVATION AND SET Y2=EG2 FOR
             C  INITIAL ITERATION VALUE TO SOLVE FOR Y2.
410          C
                    MQF=0
                    MGF=0
                    MQF1=0
                 22 QFOLD=QFT
415                 MQF=MQF+1
             C
             C  SPECIAL UPSTREAM HEAD LOSS EQUATIONS ARE ENTERED AT THIS POINT.
             C
                    IF(NC.EQ.6) HU1=HU-0.000000337*QFT**2
420                 VH1=(QFT/AREAUP)**2/(2.0*GC)
                    VH2=(QFT/(BWG*(HU1+YINVERT(NC))))**2/(2.0*GC)
                    HLTUP=(ABS(VH1-VH2))*UPK(NC)
             C
             C  IF THE CHECK GATE IS AT RIGHT ANGLES TO APPROACHING FLOW (TURNOUT
425          C  FOR EXAMPLE), THE UPSTREAM TRANSITION LOSS HLTUP IS BASED ON ONLY
             C  THE VELOCITY HEAD VH2 AT THE GATE.
             C
                    IF(NC.EQ.5) HLTUP=VH2*UPK(NC)
                    EG2=HU1+(QFT/AREAUP)**2/(2.0*GC)+YINVERT(NC)-HLTUP
430                 Y2=EG2
             C
             C  FIND CRITICAL DEPTH,DC, AND CRITICAL ENERGY GRADIANT,EGC.
             C
                    DC=(QFT/(5.67*BWG))**0.667
435                 EGC=DC+(QFT/(DC*BWG))**2/(2.0*GC)
             C
             C  IF CRITICAL ENERGY GRADIANT,EGC, AT Y2 IS GREATER THAN EG2, A
             C  SOLUTION IS NOT POSSIBLE AS CONTINUITY REQUIREMENTS HAVE FAILED.
             C  GO TO STATEMENT 132 TO PRINT APPROPRIATE MESSAGE AT INTERACTIVE
440          C  TERMINAL OR THEN TO 981 TO PRINT A BLANK IN THE RATING TABLE.
             C
                    IF(EGC.GT.EG2) GO TO 132
                    MM=0
                 45 MM=MM+1
445                 VH2=((QFT/(BWG*Y2))**2)/(2.0*GC)
             C
             C  CONVERGENCE ROUTINE NEWTON METHOD (UPSTREAM DEPTH,Y2)
             C
                    DY2=-(EG2-Y2-VH2)/(-1.0+2.0*VH2/Y2)
450                 Y2=Y2+DY2
                    IF(MM.GT.20) GO TO 65
                    IF(ABS(DY2).GE.YDELTA) GO TO 45
                 65 IF(MM.GT.20.AND.NRATE.GT.0) GO TO 981
                    IF(Y2.LE.0.0.AND.NRATE.GT.0) GO TO 981
455                 IF(Y2.GT.EG2.AND.NRATE.GT.0) GO TO 981
                    IF(MM.GT.20) PRINT(2,*) ' ITERATION LIMIT FOR Y2(FREE) EXCEEDED
```

```
                + " RESULTS ARE UNRELIABLE "'
                  IF(MQF.GT.10) GO TO 42
            C
460         C IF THE UPSTREAM DEPTH IS LESS THAN ZERO, TRY A SMALLER INITIAL
            C FREE DISCHARGE.
            C
                  IF(Y2.LE.0.0) QFT=QFT*0.9
                  IF(Y2.LE.0.0) GO TO 22
465               GO TO 14
            C
            C NOTE ALL ITERATIONS HAVE LIMITS TO PREVENT CONTINUOS DO LOOPS
            C      WHICH CAN HAPPEN WHEN THE INPUT DATA IS INCORRECT, ABMORNAL, OR
            C      DOES NOT SATISFY CONTINUITY REQUIREMENTS. APPROPRIATE MESSAGES
470         C      ARE PRINTED AT THE TERMINAL OR THE RATING TABLE GATE OPENING
            C      VALUES ARE PRINTED WITH AN '*' INDICATING THE RESULTS ARE
            C      UNRELIABLE.
            C
                42 IF(MQF.GT.10) PRINT(2,*)' ITERATION LIMIT FOR FREE Q EXCEEDED
475             +"RESULTS ARE UNRELIABLE"'
            C
            C BEGIN FREE DISCHARGE ALGORITHMS CALCULATIONS FOR EACH GATE
            C
                14 QFT=0.0
480               MGF=MGF+1
                  DO 11 I=1,L
                  IF(QORG.EQ.1HQ) GO TO 24
            C
            C WHEN SOLVING FOR FREE GATE OPENING(S) THAT DO NOT HAVE LIMITS,
485         C FIRST GO TO STATEMENT 11 AND THEN TO 29 TO GET AN ESTIMATE FOR
            C THE INITIAL GATE OPENING(S).
            C
                  IF(GOL(NC,I).EQ.1H+) GO TO 11
                  IF(GOL(NC,I).EQ.2H* ) GOF(I)=GO(NC,I)
490               OLDG(I)=GOF(I)
                24 IF(QORG.EQ.1HQ) GOF(I)=GO(NC,I)
                  GOPH=GOF(I)/PH(NC)
                  RADPH=RAD(NC)/PH(NC)
                  Y2PH=Y2/PH(NC)
495         C
            C START OF FREE DISCHARGE ALGORITHMS
            C
                  AFE=SQRT((1.0+(RADPH-1.60)**2*31.2)*0.00212)+0.901
                  BFE=SQRT((1.0+(RADPH-1.635)**2*187.7)*0.00212)-0.079
500               AFD=0.788-SQRT((1.0+(RADPH-1.619)**2*89.2)*0.04)
                  BFD=0.0534*RADPH+0.0457
                  FE=AFE-BFE*GOPH
                  FD1=(1.0-(GOPH-AFD)**2)*BFD
                  IF(FD1.LT.0.0) FD1=0.0
505               FD=0.472-SQRT(FD1)
                  IF(GOPH.LE.0.277) FX1=1.94*GOPH-0.377
                  IF(GOPH.GT.0.277) FX1=0.180*GOPH+0.111
                  FY1=0.309-0.192*GOPH
                  FXV=Y2PH-FX1
510               FCD=FE**2*(FD+FXV)**2-FXV**2
                  IF(FCD.LT.0.0) FCD=0.0
            C
            C FREE FLOW ALGORITHM COEFFICIENT OF DISCHARGE,FCDA
```

216

```
        C
515     C  CORRECTIONS FOR GATE LIP SEAL DESIGNS (OTHER THAN THE HARD-RUBBER
        C  -BAR) ARE MADE AT THIS POINT FOR FREE FLOW.
        C
              CFCDA1=CFCDA(NC)
              IF(CFCDA(NC).EQ.0.0) CFCDA1=0.125*GOPH+0.91
520           IF(CFCDA(NC).EQ.-1.0) CFCDA1=1.15-SQRT((1.0+(GOPH-0.4)**2/0.024)*
             +0.014)
              FCDA=(SQRT(FCD)+FY1)*CFCDA1
              IF(GOL(NC,I).NE.2H* .AND.QORG.EQ.1HG) GO TO 17
        C
525     C  FREE DISCHARGE CALCULATION,QF(I) PER GATE,GO(NC,I)
        C
              QF(I)=FCDA*GW(NC)*GOF(I)*SQRT(2.0*GC*Y2)
              QFT=QFT+QF(I)
              GO TO 11
530     C
        C  FREE GATE OPENING CALCULATION
        C
           17 IF(FCDA.LE.0.0) FCDA=0.01
              GOF(I)=QF(I)/(FCDA*GW(NC)*SQRT(2.0*GC*Y2))
535           QFT=QFT+QF(I)
           11 CONTINUE
        C
        C  THE SOLUTION FOR FREE GATE OPENING(S),GOF(I) WHEN SOLVING FOR THE
        C  FREE GATE OPENING(S) CONTINUES AT STATEMENT 29
540     C
              IF(QORG.EQ.1HG) GO TO 29
              IF(MQF.GT.10) GO TO 19
        C
        C  THE SOLUTION FOR THE FREE DISCHARGE IS COMPLETED WHEN THE OLD AND
545     C  NEW DISCHARGES ARE WITHIN QDELTA.
        C
              IF(ABS(QFOLD-QFT).LT.QDELTA) GO TO 47
              IF(MQF1.GT.0) GO TO 49
        C
550     C  WHEN SOLVING FOR THE FREE DISCHARGE, A SECOND VALUE IS NEEDED TO
        C  INITIALIZE THE CONVERGENCE ROUTINE BY THE NEWTON METHOD.
        C
              MQF1=1
              FOLDF=QFOLD-QFT
555           QFOLD1=QFOLD
              QFT=QFOLD+(QFT-QFOLD)*0.2
              GO TO 22
        C
        C  CONVERGENCE ROUTINE BY NEWTON METHOD(FREE DISCHARGE,QFT)
560     C
           49 FNEWF=QFOLD-QFT
              FONF=FOLDF-FNEWF
              IF(ABS(FONF).LT.0.001) FONF=0.001
              QFT=QFOLD-FNEWF*(QFOLD1-QFOLD)/FONF
565           FOLDF=FNEWF
              QFOLD1=QFOLD
        C
        C  REPEAT FREE FLOW CALCULATIONS INCLUDING THE ENERGY BALANCE EQUATIONS
        C  RETURNING TO STATEMENT 22 IF THE OLD AND NEW DISCHARGES ARE NOT
570     C  WITHIN QDELTA.
```

```
      C
            GO TO 22
      C
      C  THE SOLUTION FOR FREE DISCHARGE IS NOW COMPLETED WHEN SOLVING FOR
      C  THE FREE DISCHARGE,QFT. NOW SOLVE FOR THE SUBMERGED DISCHARGE,QST,
      C  BEGINNING AT STATEMENT 19
      C
         47 IF(QORG.EQ.1HQ) GO TO 19
      C
      C  BEGIN THE ITERATIONS FOR DETERMINING THE FREE GATE OPENING(S),GOF(I)
      C  WHEN SOLVING FOR THE FREE GATE OPENING(S).
      C
         29 NF=0
            DO 23 I=1,L
      C
      C  IF THE GATE OPENING IS LIMITED GO TO STATEMENT 23
      C
            IF(GOL(NC,I).EQ.2H* ) GO TO 23
      C
      C  IF THE GATE OPENING HAS BEEN INITIALIZED GO TO STATEMENT 25
      C
            IF(GOL(NC,I).EQ.1H-) GO TO 25
            Q=QT-QFT
            IF(Q.LT.0.0) Q=0.0
      C
      C  DETERMINE THE FREE DISCHARGE,QF(I), FOR EACH GATE THAT IS NOT
      C  LIMITED AND ESTIMATE THE INITIAL GATE OPENING,GOF(I), WHEN SOLVING
      C  FOR THE FREE GATE OPENING.
      C
            QF(I)=Q/GX
            IF(Y2.LE.0.0) Y2=0.1
            GOF(I)=QF(I)/(0.7*GW(NC)*SQRT(2.0*GC*Y2))
      C
      C  IF THE INITIAL FREE GATE OPENING,GOF(I), ESTIMATE IS GREATER THAN
      C  THE UPSTREAM DEPTH,Y2, SET GOF(I) TO Y2.
      C
            IF(GOF(I).GT.Y2) GOF(I)=Y2
            GOL(NC,I)=1H-
            OLDG(I)=0.0
            NF=5
            GO TO 23
      C
      C  THE SOLUTION FOR THE FREE GATE OPENING(S),GOF(I), IS COMPLETED WHEN
      C  THE OLD AND NEW FREE GATE OPENING(S) ARE WITHIN GDELTA.
      C
         25 IF(ABS(OLDG(I)-GOF(I)).GT.GDELTA) NF=5
            IF(MGF.GT.2) GO TO 53
      C
      C  WHEN SOLVING FOR THE FREE GATE OPENING, A SECOND VALUE IS  NEEDED
      C  TO INITIALIZE THE CONVERGENCE ROUTINE BY THE NEWTON METHOD.
      C
            FOLDG(I)=OLDG(I)-GOF(I)
            OLDG1(I)=OLDG(I)
            GOF(I)=OLDG(I)+(GOF(I)-OLDG(I))*0.2
            IF(GOF(I).GT.Y2) GOF(I)=Y2
            NF=5
            GO TO 23
```

575

580

585

590

595

600

605

610

615

620

625

218

```
        C
        C    CONVERGENCE ROUTINE BY NEWTON METHOD(FREE GATE OPENING,GOF(I))
630     C
           53 FNEWF=OLDG(I)-GOF(I)
              FONF=FOLDG(I)-FNEWF
              IF(ABS(FONF).LT.0.001) FONF=0.001
              GOF(I)=OLDG(I)-FNEWF*(OLDG1(I)-OLDG(I))/FONF
635           IF(GOF(I).GT.Y2) GOF(I)=Y2
              FOLDG(I)=FNEWF
              OLDG1(I)=OLDG(I)
           23 CONTINUE
        C
640     C    IF THE ITERATION LIMIT, MGF, IS EXCEEDED, THE FLAG NGF IS SET TO 1
        C    AND THE GATE OPENING PRINTED IN THE RATING TABLE WILL INCLUDE AN '*'
        C    INDICATING RESULTS ARE UNRELIABLE IF THE FLOW IS FREE.
        C
              IF(MGF.GT.20) NGF=1
645           IF(MGF.GT.20.AND.NRATE.GT.0) GO TO 19
              IF(MGF.GT.20) PRINT(2,*) 'ITERATION LIMIT FOR FREE G EXCEEDED
             +"RESULTS ARE UNRELIABLE"'
              IF(MGF.GT.20) GO TO 19
        C
650     C    THE FLAG NF IS SET TO 5 TO REPEAT THE FREE GATE OPENING CALCULATIONS
        C    RETURNING TO STATEMENT 14 WHEN THE FIRST AND SECOND GATE OPENINGS
        C    ARE SOLVED AND WHEN THE NEW AND OLD GATE OPENINGS ARE GREATER THAN
        C    GDELTA.
        C
655           IF(NF.EQ.5) GO TO 14
        C
        C    THE SOLUTION FOR THE FREE GATE OPENING(S),GOF(I) IS NOW COMPLETED
        C    WHEN SOLVING FOR THE GATE OPENING(S). NOW SOLVE THE SUBMERGED FLOW
        C    CALCULATIONS FOR THE SUBMERGED FLOW GATE OPENING(S),GOS(I).
660     C
        C
        C    IF FCOND(NC)=1HF (FREE FLOW ONLY) BY-PASS SUBMERGED FLOW CALCULATIONS
        C    AND THE FREE AND SUBMERGED FLOW TEST.
        C
665        19 IF(FCOND(NC).EQ.1HF) GO TO 36
        C
        C    BEGIN SUBMERGED FLOW CALCULATIONS
        C
        C    ESTIMATE INITIAL SUBMERGED DISCHARGE,QST WHEN SOLVING FOR THE
670     C    DISCHARGE WHERE QST IS THE TOTAL SUBMERGED FLOW.
        C
              IF(HU2.LE.0.0) HU2=0.1
              IF(QORG.EQ.1HQ) QST=0.3*GW(NC)*GOT*SQRT(2.0*GC*HU2)
              IF(QORG.EQ.1HG) QST=QT
675           MQS=0
              MGS=0
              MQS1=0
        C
        C    SUBMERGED FLOW UPSTREAM ENERGY BALANCE EQUATIONS
680     C
           18 Q=QST
              QSOLD=QST
              NBW=1
        C
```

```
685         C  SPECIAL UPSTREAM HEAD LOSS EQUATIONS ARE ENTERED AT THIS POINT.
            C
               13 IF(NC.EQ.6) HU1=HU-0.000000337*Q**2
                  Q1=Q
                  IF(Q1.EQ.0.0) Q1=0.0001
690         C
            C  SPECIAL DOWNSTREAM HEAD LOSS COEFFICIENT EQUATIONS ARE ENTERED AT
            C  THIS POINT.
            C
                  IF(NC.EQ.2.AND.Q1.LT.1520.0) SYFON(NC)=(-0.001136*Q1+2.505)/Q1**2
695               IF(NC.EQ.2.AND.Q1.GE.1520.0) SYFON(NC)=(0.000165*Q1+0.528)/Q1**2
                  MQS=MQS+1
                  VH1=(Q/AREAUP)**2/(2.0*GC)
                  VH2=(Q/(BWG*(HU1+YINVERT(NC))))**2/(2.0*GC)
            C
700         C  SPECIAL UPSTREAM TRANSITION HEAD LOSS COEFFICIENT EQUATIONS ARE
            C  ENTERED AT THIS POINT.
            C
                  HLTUP=(ABS(VH1-VH2))*UPK(NC)
                  VH4=(Q/AREADN)**2/(2.0*GC)
705               VH3=(Q/(BWG*(HD-YSYFON(NC)+SYFON(NC)*Q**2)))**2/(2.0*GC)
            C
            C  SPECIAL DOWNSTREAM TRANSITION HEAD LOSS COEFFICIENT EQUATIONS ARE
            C  ENTERED AT THIS POINT.
            C
710               IF(NC.EQ.7.AND.GO(NC,1).LE.6.0) DNK(NC)=0.5*GO(NC,1)+4.0
                  IF(NC.EQ.7.AND.GO(NC,1).GT.6.0) DNK(NC)=8.6-0.27*GO(NC,1)
                  HLTDN=(ABS(VH3-VH4))*DNK(NC)
            C
            C  DETERMINE ENERGY GRADE LINE UPSTREAM AND DOWNSTREAM OF GATE IN
715         C  RECTANGULAR SECTION REFERENCED TO THE GATE SILL INVERT ELEVATION AND
            C  SET Y2=EG3 AND SET Y3=EG3 FOR INITIAL ITERATION OF Y2 AND Y3.
            C
                  EG2=HU1+(Q/AREAUP)**2/(2.0*GC)+YINVERT(NC)-HLTUP
                  EG4=HD+(Q/AREADN)**2/(2.0*GC)-YSYFON(NC)
720               EG3=EG4+SYFON(NC)*Q**2+HLTDN
                  Y2=EG2
                  Y3=EG3
            C
            C  FIND CRITICAL DEPTH,DC, AND CRITICAL ENERGY GRADIANT,EGC.
725         C
                  DC=(QST/(5.67*BWG))**0.667
                  EGC=DC+(QST/(DC*BWG))**2/(2.0*GC)
            C
            C  FIND ESTIMATE OF DOWNSTREAM DEPTH,Y3E, AND IF LESS THAN OR EQUAL TO
730         C  THE CRITICAL DEPTH,DC, RESET Y3 EQUAL TO Y3E.
            C
                  Y3E=HD-YSYFON(NC)+SYFON(NC)*Q**2+HLTDN
                  IF(Y3E.LE.DC) Y3=Y3E
            C
735         C  IF CRITICAL ENERGY GRADIANT,EGC, AT Y2 IS GREATER THAN EG2, A
            C  SOLUTION IS NOT POSSIBLE AS CONTINUITY REQUIREMENTS HAVE FAILED.
            C  GO TO STATEMENT 132 TO PRINT APPROPRIATE MESSAGE AT INTERACTIVE
            C  TERMINAL OR THEN TO 981 TO PRINT A BLANK IN THE RATING TABLE.
            C
740               IF(EGC.GT.EG2) GO TO 132
                  MM=0
```

```
      43 MM=MM+1
         VH2=((Q/(BWG*Y2))**2)/(2.0*GC)
   C
   C  CONVERGENCE ROUTINE NEWTON METHOD(SUBMERGED UPSTREAM DEPTH,Y2)
   C
         DY2=-(EG2-Y2-VH2)/(-1.0+2.0*VH2/Y2)
         Y2=Y2+DY2
         IF(Y2.LE.0.0) Y2=0.1
         IF(MM.GT.40) GO TO 44
         IF(ABS(DY2).GE.YDELTA) GO TO 43
      44 IF(MM.GT.40.AND.NRATE.GT.0) GO TO 981
         IF(Y2.LE.0.0.AND.NRATE.GT.0) GO TO 981
         IF(Y2.GT.EG2.AND.NRATE.GT.0) GO TO 981
         IF(MM.GT.40) PRINT(2,*)' ITERATION LIMIT FOR Y2 (SUBM) EXCEEDED
        +"RESULTS ARE UNRELIABLE"'
   C
   C  THE TOTAL WIDTH,BW, OF ALL THE GATES INCLUDING THE WIDTH OF THE
   C  PIERS,PW, IS USED TO DETERMINE THE DOWNSTREAM FORCES IN THE FREE AND
   C  SUBMERGED FLOW TESTS WHEN FLAG NBW IS SET TO 0. THE TOTAL WIDTH OF ALL
   C  THE GATES,BWG, IS USED IN THE SUBMERGED FLOW CALCULATIONS WHEN
   C  THE FLAG NBW IS SET TO 1.
   C
         BOTW=BW
         IF(NBW.EQ.1) BOTW=BWG
   C
   C  IF CRITICAL ENERGY GRADIANT,EGC, AT Y3 IS GREATER THAN EG3, A
   C  SOLUTION IS NOT POSSIBLE AS CONTINUITY REQUIREMENTS HAVE FAILED.
   C  GO TO STATEMENT 133 TO PRINT APPROPRIATE MESSAGE AT INTERACTIVE
   C  TERMINAL OR THEN TO 981 TO PRINT A BLANK IN THE RATING TABLE.
   C
         IF(EGC.GT.EG3) GO TO 133
         MM=0
      50 MM=MM+1
         VH3=((Q/(BOTW*Y3))**2)/(2.0*GC)
   C
   C  CONVERGENCE ROUTINE NEWTON METHOD(SUBMERGED DOWNSTREAM DEPTH,Y3)
   C
         DY3=-(EG3-Y3-VH3)/(-1.0+2.0*VH3/Y3)
         Y3=Y3+DY3
         IF(MM.GT.20) GO TO 66
         IF(ABS(DY3).GE.YDELTA) GO TO 50
      66 IF(MM.GT.20.AND.NRATE.GT.0) GO TO 981
         IF(Y3.LE.0.0.AND.NRATE.GT.0) GO TO 981
         IF(Y3.GT.EG3.AND.NRATE.GT.0) GO TO 981
         IF(MM.GT.20) PRINT(2,*) ' ITERATION LIMIT FOR Y3(SUBM) EXCEEDED
        + " RESULTS ARE UNRELIABLE "'
   C
   C  WHEN THE FLAG NF IS SET TO 2 OR 3 , THE ENERGY BALANCE EQUATIONS
   C  ARE USED TO DETERMINE THE UPSTREAM AND DOWNSTREAM CONDITIONS FOR
   C  THE FREE AND SUBMERGED FLOW TESTS WHICH START AT STATEMENT 32.
   C
         IF(NF.EQ.2) GO TO 32
         IF(NF.EQ.3) GO TO 32
         IF(NRATE.GT.0) GO TO 80
         IF(MQS.GT.20) GO TO 60
         IF((Y2-(Y3+0.05)).GT.0.0) GO TO 60
   C
```

221

```
       C  IF THE HEAD DIFFERENTIAL ACROSS THE GATE IS LESS THAN 0.05, TRY A
800    C  SMALLER DISCHARGE.
       C
             QST=QST*0.9
             GO TO 18
          60 IF(MQS.GT.20) PRINT(2,*)' ITERATION LIMIT FOR SUBM Q EXCEEDED
805         +"RESULTS ARE UNRELIABLE"'
       C
       C  WHEN THE HEAD DIFFERENTIAL IS LESS THAN OR EQUAL TO 0.0, A SOLUTION
       C  IS NOT POSSIBLE WITH THE GIVEN INPUT DATA. STATEMENT 146 OMITS THE RUN
       C  OR PRINTS A BLANK IN THE RATING TABLE.
810    C
          80 IF((Y2-Y3).LE.0.0) GO TO 146
       C
       C  BEGIN SUBMERGED DISCHARGE ALGORITHMS CALCULATIONS FOR EACH GATE
       C
815       15 QST=0.0
             MGS=MGS+1
             DO 12 I=1,L
             IF(QORG.EQ.1HQ) GO TO 26
       C
820    C  WHEN SOLVING FOR SUBMERGED GATE OPENING(S),GOS(I) THAT DO NOT HAVE
       C  LIMITS, FIRST GO TO STATEMENT 12 AND THEN TO 21 TO FIND AN ESTIMATE
       C  FOR THE INITIAL GATE OPENING(S).
       C
             IF(GOL(NC,I).EQ.1H-) GO TO 12
825          IF(GOL(NC,I).EQ.2H* ) GOS(I)=GO(NC,I)
             OLDG(I)=GOS(I)
          26 IF(QORG.EQ.1HQ) GOS(I)=GO(NC,I)
             IF(QORG.EQ.1HQ.AND.GOS(I).GT.HU2) GOS(I)=HU2
             GOPH=GOS(I)/PH(NC)
830          RADPH=RAD(NC)/PH(NC)
             Y2PH=Y2/PH(NC)
             Y3PH=Y3/PH(NC)
       C
       C  CHECK TO BE SURE FLOW IS SUBMERGED BEFORE PROCEEDING.
835    C
       C  SET SUBMERGED,QS(I) TO FREE,QF(I) IF DOWNSTREAM DEPTH,Y3 IS LESS
       C  THAN CRITICAL DEPTH,DC OR RATIO Y3PH IS LESS THAN RATIO GOPH.
       C  IF FCOND.EQ.1HS (SUBMERGED ONLY) , THIS TEST IS BYPASSED,HOWEVER,
       C  THE RESULTS WILL BE INCORRECT IF THE FLOW IS ACTUALY FREE.
840    C
             IF(FCOND(NC).EQ.1HS) GO TO 46
             IF(Y3.LE.DC.OR.Y3PH.LT.GOPH) QS(I)=QF(I)
             IF(Y3.LE.DC.OR.Y3PH.LT.GOPH) GOS(I)=GOF(I)
             IF(Y3.LE.DC.OR.Y3PH.LT.GOPH) GO TO 20
845    C
       C  START OF SUBMERGED DISCHARGE ALGORITHMS
       C
       C  DIRECTRIX ALGORITHMS
       C
850       46 ADA=1.0/(11.98*RADPH-26.7)
             ADB=-0.276/RADPH+0.620
             AD1=ADA*GOPH+ADB
       C
       C  NOTE SEVERAL TEST ARE MADE TO PREVENT THE COMPUTER PROGRAM RUN
855    C       FROM ABORTING. THE TESTS ALSO INDICATE THE INPUT DATA OR THE
```

```
      C          ITERATION OF THE FIRST ESTIMATED VALUES OF THE DISCHARGE OR
      C          GATE OPENING(S) ARE OUT OF RANGE OF THE ALGORITHMS CAPABILITY.
      C          STATEMENT 131 WILL OMIT THE RUN OR PRINT A BLANK IN THE RATING
      C          TABLE.
860   C
             IF(AD1.LE.0.0) GO TO 131
             AD=1.0/AD1
             BDA=0.025*RADPH-2.711
             BDB=-0.033*RADPH+0.071
865          BD=BDA*GOPH+BDB
             DR=AD*Y3PH+BD
             IF(DR.LE.0.0) GO TO 131
             D=(1.0/DR)**1.429
      C
870   C ECCENTRICITY ALGORITHMS
      C
             AEA=-0.019*RADPH+0.060
             AEB=0.0052*RADPH+0.996
             AE=1.0/(AEA*GOPH+AEB)
875          BEK=-0.293*RADPH+0.320
             BE=SQRT((1.0+(GOPH-0.44)**2/0.700)*0.255)+BEK
             E1=(AE*D+BE)/D
             P=1.0
             IF(E1.LT.1.0) P=-1.0
880          E=SQRT(P*ALOG(E1))
      C
      C VECTOR V1 CALCULATION
      C
             V1=E*D/(1.0+E)
885   C
      C FOCAL ADJUSTMENT,FY FOR Y AXIS AS A FUNCTION OF Y3PH
      C
             AFA=-0.158/RADPH+0.038
             AFB=-0.115*RADPH+0.290
890          AF=AFA*GOPH+AFB
             BFA=0.0445/RADPH-0.0321
             BFB=-0.092/RADPH+0.155
             GOPH1=GOPH
             IF(GOPH.LE.0.0) GOPH1=0.001
895          BF=BFA/GOPH1+BFB
             FY=-AF*Y3PH+BF
             IF(FY.LT.0.0) FY=0.0
      C
      C FOCAL ADJUSTMENT,FX FOR X AXIS AS A FUNCTION OF Y AXIS FOCAL,FY
900   C
             FX=SQRT(V1**2+FY**2)-V1
      C
      C SUBMERGED FLOW ALGORITHM COEFFICIENT OF DISCHARGE,SCDA WHERE
      C VX=THE DISTANCE FROM ORIGIN FOR GENERAL CONIC EQUATION
905   C
             VX=Y2PH-(V1+Y3PH+FX)
             CDA1=E**2*(D+VX)**2-VX**2
             IF(CDA1.LT.0.0) CDA1=0.0
      C
910   C CORRECTIONS FOR THE GATE LIP SEAL DESIGN (OTHER THAN THE HARD-
      C RUBBER-BAR) ARE ENTERED AT THIS POINT FOR SUBMERGED FLOW.
      C
```

223

```
                   CSCDA1=CSCDA(NC)
                   IF(CSCDA(NC).EQ.0.0) CSCDA1=0.39*GOPH+0.85
915                IF(CSCDA(NC).EQ.-1.0) CSCDA1=SQRT(((1.0+(GOPH-0.26)**2/3.015)*
                  +14.52)-2.89
                   IF(CSCDA(NC).EQ.-1.0.AND.GOPH.LT.0.35) CSCDA1=0.129*GOPH+0.88
                   SCDA(I)=(SQRT(CDA1)+FY)*CSCDA1
                   IF(GOL(NC,I).EQ.1H .AND.QORG.EQ.1HG) GO TO 16
920          C
             C  SUBMERGED DISCHARGE CALCULATION PER GATE OPENING,GO(NC,I)
             C
                   QS(I)=SCDA(I)*GW(NC)*GOS(I)*SQRT(2.0*GC*Y2)
                20 QST=QST+QS(I)
925                GO TO 12
             C
             C  SUBMERGED GATE OPENING CALCULATION
             C
                16 IF(SCDA(I).LE.0.0) SCDA(I)=0.01
930                GOS(I)=QS(I)/(SCDA(I)*GW(NC)*SQRT(2.0*GC*Y2))
                   QST=QST+QS(I)
                12 CONTINUE
             C
             C  THE SOLUTION FOR THE SUBMERGED GATE OPENING(S),GOS(I), WHEN SOLVING
935          C  FOR THE SUBMERGED GATE OPENING(S) CONTINUES AT STATEMENT 21
             C
                   IF(QORG.EQ.1HG) GO TO 21
                   IF(MQS.GT.20) GO TO 31
             C
940          C  THE SOLUTION FOR SUBMERGED DISCHARGE,QST, IS COMPLETED WHEN THE OLD
             C  AND NEW DISCHARGES ARE WITHIN QDELTA.
             C
                   IF(ABS(QSOLD-QST).LT.QDELTA) GO TO 67
             C
945          C  CONVERGENCE ROUTINE BY NEWTON METHOD(SUBMERGED DISCHARGE,QST)
             C
                   IF(MQS1.GT.0) GO TO 68
             C
             C  WHEN SOLVING FOR THE SUBMERGED DISCHARGE, A SECOND VALUE IS NEEDED
950          C  TO INITIALIZE THE CONVERGENCE ROUTINE BY THE NEWTON METHOD.
             C
                   MQS1=1
                   FOLD=QSOLD-QST
                   QSOLD1=QSOLD
955                QST=QSOLD+(QST-QSOLD)*0.2
                   GO TO 18
                68 FNEW=QSOLD-QST
                   FON=FOLD-FNEW
                   IF(ABS(FON).LT.0.001) FON=0.001
960                QST=QSOLD-FNEW*(QSOLD1-QSOLD)/FON
                   FOLD=FNEW
                   QSOLD1=QSOLD
             C
             C  REPEAT SUBMERGED FLOW CALCULATIONS INCLUDING THE ENERGY BALANCE
965          C  EQUATIONS RETURNING TO STATEMENT 18, IF THE OLD AND NEW DISCHARGES
             C  ARE NOT WITHIN QDELTA.
             C
                   GO TO 18
             C
```

```
970         C   THE SOLUTION FOR SUBMERGED DISCHARGE,QST, IS NOW COMPLETED WHEN
            C   SOLVING FOR THE SUBMERGED DISCHARGE.
            C
                67 IF(QORG.EQ.1HQ) GO TO 31
            C
975         C   BEGIN ITERATIONS FOR DETERMINING THE SUBMERGED GATE OPENING(S) ,GOS(I),
            C   WHEN SOLVING FOR THE SUBMERGED GATE OPENING(S).
            C
                21 NF=0
                   DO 27 I=1,L
980         C
            C   IF THE GATE OPENING IS LIMITED GO TO STATEMENT 27
            C
                   IF(GOL(NC,I).EQ.2H* ) GO TO 27
            C
985         C   IF THE GATE OPENING HAS BEEN INITIALIZED GO TO STATEMENT 28
            C
                   IF(GOL(NC,I).EQ.1H ) GO TO 28
                   Q=QT-QST
                   IF(Q.LT.0.0) Q=0.0
990         C
            C   DETERMINE THE SUBMERGED DISCHARGE,QS(I), FOR EACH GATE THAT IS NOT
            C   LIMITED AND ESTIMATE THE INITIAL SUBMERGED GATE OPENING(S),GOS(I)
            C   WHEN SOLVING FOR THE SUBMERGED GATE OPENING(S).
            C
995                QS(I)=Q/GX
                   IF(Y2.LE.0.0) Y2=0.1
                   GOS(I)=QS(I)/(0.3*GW(NC)*SQRT(2.0*GC*Y2))
            C
            C   IF THE INITIAL SUBMERGED GATE OPENING IS GREATER THAN THE UPSTREAM
1000        C   DEPTH,Y2, SET GOS(I) TO Y2.
            C
                   IF(GOS(I).GT.Y2) GOS(I)=Y2
                   GOL(NC,I)=1H
                   OLDG(I)=0.0
1005               NF=6
                   GO TO 27
            C
            C   THE SOLUTION FOR THE SUBMERGED GATE OPENING(S),GOS(I), IS COMPLETED
            C   WHEN THE OLD AND NEW GATE OPENING(S) ARE WITHIN GDELTA.
1010        C
                28 IF(ABS(OLDG(I)-GOS(I)).GT.GDELTA) NF=6
                   IF(MGS.GT.2) GO TO 69
            C
            C   WHEN SOLVING FOR THE SUBMREGED GATE OPENING(S),GOS(I),A SECOND
1015        C   VALUE IS NEEDED TO INITIALIZE THE CONVERGENCE ROUTINE BY THE
            C   NEWTON METHOD.
            C
                   FOLDG(I)=OLDG(I)-GOS(I)
                   OLDG1(I)=OLDG(I)
1020               GOS(I)=OLDG(I)+(GOS(I)-OLDG(I))*0.2
                   IF(GOS(I).GT.Y2) GOS(I)=Y2
                   NF=6
                   GO TO 27
            C
1025        C   CONVERGENCE ROUTINE BY NEWTON METHOD(SUBMERGED GATE OPENING,GOS(I))
            C
```

225

```
              69 FNEW=OLDG(I)-GOS(I)
                 FON=FOLDG(I)-FNEW
                 IF(ABS(FON).LT.0.001) FON=0.001
1030             GOS(I)=OLDG(I)-FNEW*(OLDG1(I)-OLDG(I))/FON
                 IF(GOS(I).GT.Y2) GOS(I)=Y2
                 FOLDG(I)=FNEW
                 OLDG1(I)=OLDG(I)
              27 CONTINUE
1035          C
              C IF THE ITERATION LIMIT, MGS, IS EXCEEDED, THE FLAG NGS IS SET TO 1
              C AND THE GATE OPENING PRINTED IN THE RATING TABLE WILL INCLUDE AN
              C ' * ' INDICATING RESULTS ARE UNRELIABLE IF THE FLOW IS SUBMERGED.
              C
1040             IF(MGS.GT.20) NGS=1
                 IF(MGS.GT.20.AND.NRATE.GT.0) GO TO 31
                 IF(MGS.GT.20) PRINT(2,*) ' ITERATION LIMIT FOR SUBM G EXCEEDED
                +"RESULTS ARE UNRELIABLE"'
                 IF(MGS.GT.20) GO TO 31
1045          C
              C THE FLAG NF IS SET TO 6 TO REPEAT SUBMERGED GATE OPENING CALCULATIONS
              C RETURNING TO STATEMENT 15 WHEN THE FIRST AND SECOND GATE OPENINGS ARE
              C SOLVED AND WHEN THE OLD AND NEW SUBMERGED GATE OPENING(S) ARE GREATER
              C THAN GDELTA.
1050          C
                 IF(NF.EQ.6) GO TO 15
              C
              C THE SOLUTION FOR THE SUBMERGED GATE OPENING(S),GOS(I), IS NOW
              C COMPLETED WHEN SOLVING FOR GATE OPENING(S).
1055          C
              31 QST=0.0
              C
              C IF THE GATE OPENING IS GREATER THAN THE UPSTREAM DEPTH,Y2, SET
              C GOS(I) EQUAL TO Y2. THEN CALCULATE THE SUBMERGED DISCHARGE USING
1060          C GOS(I)=Y2 AND THE LAST CALCULATED VALUE OF THE COEFFICIENT OF
              C DISCHARGE,SCDA(I). THE RESULTING DISCHARGE IS INCORRECT, HOWEVER, THE
              C GATE(S) ARE NOT CONTROLLING THE DISCHARGE. THE RATING TABLE WILL
              C PRINT AN ' * ' WITH THE GATE OPENING TO INDICATE THE RESULTS ARE
              C UNRELIABLE BY SETTING THE FLAG NGS TO 1.
1065          C
                 DO 51 I=1,L
                 IF(GOS(I).LT.(Y2-0.1)) GO TO 52
                 GOS(I)=Y2
                 NGS=1
1070             IF(NRATE.GT.0) GO TO 52
                 QS(I)=SCDA(I)*GW(NC)*GOS(I)*SQRT(2.0*GC*Y2)
              C
              C SET FLAG GOL(NC,I) TO 2H** WHEN THE GATE OPENING(S) ARE AT OR ABOVE
              C THE UPSTREAM WATER DEPTH.
1075          C
                 GOL(NC,I)=2H**
              52 QST=QST+QS(I)
              51 CONTINUE
              C
1080          C IF FCOND(NC) DATA STATEMENT IS SET TO 1HS (SUBMERGED FLOW ONLY),
              C THE FREE AND SUBMERGED FLOW TEST IS BYPASSED.
              C
                 IF(FCOND(NC).EQ.1HS) GO TO 36
```

226

```
                    C
        1085        C   GET Y3 AND EG2 WITH NBW=0 FOR FREE FLOW DOWNSTREAM MOMENTUM AND
                    C   HYDROSTATIC FORCES CALCULATION, WITH THE FLAG NF SET TO 2 USING THE
                    C   SUBMERGED ENERGY BALANCE EQUATIONS.
                    C
                          NBW=0
        1090              NF=2
                          Q=QFT
                          GO TO 13
                    C
                    C   BEGIN FREE AND SUBMERGED FLOW TESTS
        1095        C
                    C
                    C   DETERMINE IF JET IS SUBMERGED OR FREE BY BALANCING MOMENTUM AND
                    C   HYDROSTATIC FORCES. INITIALIZE GAXCO=GOF(I) OR GOS(I) AND ASSUME JET
                    C   IS FREE. IF UPSTREAM FORCES,FUP.GE.DOWNSTREAM FORCES,FDN THE JET IS
        1100        C   FREE. IF FUP.LT.FDN THE JET IS SUBMERGED.
                    C
                    C   WHEN THE FLAG NF IS SET TO 2, THE FREE FLOW TEST IS BEING MADE, AND
                    C   WHEN THE FLAG NF IS SET TO 3, THE SUBMERGED FLOW TEST IS BEING MADE,
                    C   FOR EACH GATE.
        1105        C
                       32 IF(NF.EQ.2) Q=QFT
                          IF(NF.EQ.3) Q=QST
                    C
                    C   CALCULATE DOWNSTREAM FORCES,FDN
        1110        C
                          FDN=(Q**2/(32.2*BW*Y3)+BW*Y3**2/2.0)/GN(NC)
                          A=GW(NC)**2*64.4
                    C
                    C   DETERMINE THE DEPTH GAXCO AT THE VENA CONTRACTA IMEDIATELY DOWNSTREAM
        1115        C   OF THE GATE(S) TO BE USED IN THE CALCULATIONS OF THE UPSTREAM FORCES,
                    C   FUP.
                    C
                          MM=0
                          DO 33 I=1,L
        1120              IF(NF.EQ.2) Q=QF(I)
                          IF(NF.EQ.3) Q=QS(I)
                          IF(NF.EQ.2) GAXCO=GOF(I)*0.6
                          IF(NF.EQ.3) GAXCO=GOS(I)*0.6
                          IF(GAXCO.LE.0.0) GO TO 30
        1125        C
                    C   CONVERGENCE ROUTINE BY NEWTON METHOD(GAXCO)
                    C
                      250 MM=MM+1
                          OLDGAX=GAXCO
        1130              DY=EG2-GAXCO
                          FGAXCO=Q**2-A*GAXCO**2*DY
                          DFGAXCO=A*(3.*GAXCO**2-2.*GAXCO*EG2)
                          IF(ABS(DFGAXCO).LT.0.0001) DFGAXCO=0.0001
                          DGAXCO=-FGAXCO/DFGAXCO
        1135              GAXCO=GAXCO+DGAXCO
                          IF(MM.GT.30) NGS=1
                          IF(MM.GT.30) GO TO 260
                          IF(GAXCO.GT.0.0) GO TO 261
                          GAXCO=OLDGAX*0.9
        1140              GO TO 250
```

227

```
                       261 IF(ABS(DGAXCO).GE.GDELTA) GO TO 250
                       260 IF(MM.GT.30.AND.NRATE.GT.0) GO TO 262
                           IF(MM.GT.30) PRINT(2,*) ' ITERATION LIMIT FOR GAXCO EXCEEDED "RESU
                          +LTS ARE UNRELIABLE"'
           1145          262 IF(GAXCO.GE.DC) GO TO 34
                       C
                       C  CALCULATE UPSTREAM FORCES,FUP, ASSUMING THE JET IS FREE
                       C
                           FUP=Q**2/(32.2*GW(NC)*GAXCO)+(BW/GN(NC))*GAXCO**2/2.0
           1150          30 IF(GAXCO.LE.0.0) FUP=0.0
                           IF(FUP.GE.FDN) GO TO 35
                        34 COND(NF,I)=4HSUBM
                           GO TO 33
                        35 COND(NF,I)=4HFREE
           1155          33 CONTINUE
                       C
                       C WITH THE FLAG NF SET TO 3, THE FREE AND SUBMERGED FLOW TESTS ARE
                       C COMPLETED. NOW DECIDE IF THE FLOW IS FREE, SUBMERGED, OR IN THE
                       C TRANSITION ZONE BEGINNING AT STATEMENT 36.
           1160        C
                           IF(NF.EQ.3) GO TO 36
                       C
                       C  GET Y3 AND EG2 WITH NBW=0 FOR SUBMERGED FLOW DOWNSTREAM MOMENTUM
                       C  AND HYDROSTATIC FORCES CALCULATION WITH THE FLAG SET TO 3.
           1165        C
                           NBW=0
                           NF=3
                           Q=QST
                           GO TO 13
           1170        C
                       C  PROGRAM TEST FAILURE STATEMENTS 131 AND 146 OMIT RUNS AND GOES TO
                       C  STATEMENT 73 FOR MORE TERMINAL INPUT, OR GOES TO STATEMENT 992 TO
                       C  PRINT EITHER A BLANK OR THE UNRELIABLE RESULT MARKED BY AN ' * ' IN
                       C  THE RATING TABLE.
           1175        C
                         131 IF(NRATE.GT.0) GO TO 981
                           J=J-1
                           PRINT(2,*) ' INPUT DATA IS EITHER INCORRECT OR EXCEEDS ALGORITHMS'
                           PRINT(2,*) ' RANGE CAPABILITY  "JOB IS OMITTED"'
           1180            GO TO 73
                         132 IF(NRATE.GT.0) GO TO 981
                           J=J-1
                           PRINT(2,*) ' INPUT DATA FOR UPSTREAM CONDITIONS IS INCORRECT AND
                          +DOES NOT MEET CONTINUITY REQUIREMENTS " JOB IS OMITTED "'
           1185            GO TO 73
                         133 IF(NRATE.GT.0) GO TO 981
                           J=J-1
                           PRINT(2,*) ' INPUT DATA FOR DOWNSTREAM CONDITIONS IS INCORRECT AND
                          + DOES NOT MEET CONTINUITY REQUIREMENTS " JOB IS OMITTED "'
           1190            GO TO 73
                         146 IF(NRATE.GT.0) GO TO 981
                           J=J-1
                           PRINT(2,*) ' DY.LE.0.0  "JOB IS OMITTED"'
                           GO TO 73
           1195        C
                       C  DETERMINE IF FLOW CONDITION IS FREE, SUBM, OR TRANS
                       C
```

```
       C   IF FCOND(NC) DATA STATEMENT IS SET TO 0.0, BOTH THE FREE AND
       C   SUBMERGED FLOW TEST CONDITIONS (COND(2,I) AND COND(3,I) RESPECTIVELY)
1200   C   FOR EACH GATE (I) IS NOW DETERMINED. IF THE TWO TEST CONDITIONS ARE
       C   BOTH FREE, THE FLOW IS FREE STATEMENT 38. IF THE TWO TEST CONDITIONS
       C   ARE BOTH SUBMERGED, THE FLOW IS SUBMERGED STATEMENT 39. IF THE TWO
       C   TEST CONDITIONS ARE FREE AND SUBMERGED, THE FLOW IS IN THE TRANSITION
       C   ZONE(BETWEEN FREE AND SUBMERGED AND IS UNSTABLE) STATEMENT 40. IF THE
1205   C   FLOW CONDITION IS IN THE TRANSITION ZONE, THE CALCULATED FREE AND
       C   SUBMERGED DISCHARGES OR GATE OPENING(S) ARE AVERAGED.
       C
          36 DO 37 I=1,L
             IF(FCOND(NC).EQ.1HF) GO TO 38
1210         IF(FCOND(NC).EQ.1HS) GO TO 39
             IF(COND(2,I).EQ.4HFREE.AND.COND(3,I).EQ.4HFREE) GO TO 38
             IF(COND(2,I).EQ.4HSUBM.AND.COND(3,I).EQ.4HSUBM) GO TO 39
             IF(COND(2,I).EQ.4HFREE.AND.COND(3,I).EQ.4HSUBM) GO TO 40
             IF(COND(2,I).EQ.4HSUBM.AND.COND(3,I).EQ.4HFREE) GO TO 40
1215      38 QTOUT=QTOUT+QF(I)
             QG(I)=QF(I)
             GOP(I)=GOF(I)
             CONDF(I)=7H   FREE
             IF(NGF.EQ.1) NGP=1
1220         GO TO 37
          39 QTOUT=QTOUT+QS(I)
             QG(I)=QS(I)
             GOP(I)=GOS(I)
             IF(QORG.EQ.1HG) GO(NC,I)=GOS(I)
1225         CONDF(I)=7H   SUBM
       C
       C   IF THE GATE OPENING(S) ARE EQUAL TO OR ABOVE THE UPSTREAM WATER
       C   DEPTH (GOS(I)=Y2), THE FLOW CONDITION IS SUBMERGED BUT THE CONDITION
       C   IS PRINTED AS 'CLEAR' AT THE TERMINAL OUTPUT, I.E. THE GATE IS NOT
1230   C   CONTROLLING THE DISCHARGE.
       C
             IF(GOL(NC,I).EQ.2H**) CONDF(I)=7H CLEAR
             IF(NGS.EQ.1) NGP=1
             GO TO 37
1235      40 QAVE=(QF(I)+QS(I))/2.0
             GAVE=(GOF(I)+GOS(I))/2.0
             QTOUT=QTOUT+QAVE
             QG(I)=QAVE
             GOP(I)=GAVE
1240         CONDF(I)=7H   TRANS
             IF(NGF.EQ.1.OR.NGS.EQ.1) NGP=1
          37 CONTINUE
       C
       C   ALL CALCULATIONS FOR ONE RUN ARE NOW COMPLETED. THE REMAINDER OF THE
1245   C   PROGRAM OUTPUTS THE RESULTS FOR THE INTERACTIVE TERMINAL RESPONSE
       C   FEATURE_OR THE RATING TABLES BEGINNING AT STATMENT 993 WHEN NRATE
       C   IS SET TO 0.
       C
             IF(NRATE.EQ.0) GO TO 993
1250   C
       C   SET UP RATING TABLE OUTPUT WHEN NRATE IS GREATER THAN 0
       C
       C
             IF(GOP(1).LE.0.0.OR.GOP(1).GT.HU2) GO TO 981
```

229

```
1255                       GOTAB(NHD,NHU)=GOP(1)
                           IF(NGP.EQ.0) GO TO 786
                           WRITE(3,785) GOTAB(NHD,NHU)
                       785 FORMAT(F5.1,1H*)
                           NGPP=1
1260                       GO TO 994
                       786 WRITE(3,796) GOTAB(NHD,NHU)
                       796 FORMAT(F6.2)
                           NTP=NTP+1
                           GO TO 994
1265                   981 GOTAB(NHD,NHU)=6H
                           WRITE(3,795) GOTAB(NHD,NHU)
                       795 FORMAT(A6)
                       994 CONTINUE
                           HDN=HD+DNINV(NC)
1270                       DNPL2=HDN/100.0
                           DNPL2=FLOAT(INT(DNPL2))*100.0
                           HDTAB(NHD)=HDN-DNPL2
                           HUP1=HU+UPINV(NC)
                       995 CONTINUE
1275                       REWIND 3
                       979 IF(NTP.LT.50) J=J-1
                           IF(NTP.LT.50) GO TO 987
      C
      C   READ AND PRINT RATING TABLE OUTPUT FOR ONE PAGE AT A TIME.IF THERE
1280  C   ARE NO GATE OPENINGS CALCULATED ON A PAGE, (WHEN NTP=0), SKIP
      C   THE PAGE.
      C
                           READ(3,794) ((GOTAB(NHD,NHU),NHU=1,NIU),NHD=1,NID)
                       794 FORMAT(A6)
1285                       REWIND 3
                           PRINT(2,792) CANALN
                       792 FORMAT(1H1,9(/),56X,4A10,/)
                           PRINT(2,798) QT
                       798 FORMAT(4X,5H  Q = ,F6.0)
1290                       PRINT(2,797) (X2(NHU),NHU=1,NIU)
                       797 FORMAT(1X,6H  HU = ,21F6.2)
                           PRINT(2,793)
                       793 FORMAT(1X,6H  HD   ,58X,12HGATE OPENING)
                           PRINT(2,799) (HDTAB(NHD),(GOTAB(NHD,NHU),NHU=1,NIU),NHD=1,NID)
1295                   799 FORMAT(1X,F6.2,21A6)
                           DUPL2=HUP1/100.0
                           DUPL2=FLOAT(INT(DUPL2))*100.0
                           IF(DUPL2.LT.DUPL1) PRINT(2,791) DUPL1,DUPL2
                       791 FORMAT(/,4X,47HNOTE UPSTREAM WATER SURFACE ELEVATION   = HU +,
1300                      +F8.2,10H  OR = HU +,F8.2)
                           IF(DUPL1.GT.0.01) PRINT(2,790) DUPL1
                       790 FORMAT(/,4X,47HNOTE UPSTREAM WATER SURFACE ELEVATION   = HU +,
                          +F8.2)
                           IF(DNPL2.LT.DNPL1) PRINT(2,789) DNPL1,DNPL2
1305                   789 FORMAT(10X,41HDOWNSTREAM WATER SURFACE ELEVATION = HD +,F8.2,
                          +10H  OR = HD +,F8.2)
                           IF(DNPL1.GT.0.01) PRINT(2,788) DNPL1
                       788 FORMAT(10X,41HDOWNSTREAM WATER SURFACE ELEVATION = HD +,F8.2)
                           IF(NGPP.EQ.1) PRINT(2,*) ' * GATE OPENING VALUES WITH * INDICATE
1310                      +ITERATION LIMITS HAVE BEEN EXCEEDED. RESULTS ARE UNRELIABLE'
                           PRINT(2,787) QT,J,NTABNO
```

```
          787 FORMAT(/,4X,5H Q = ,F6.0,41X,4HPAGE,I4,3X,9HTABLE NO.,I4)
          987 J=J+1
              IF(QT.GT.(QE+DQ+1.0).AND.NTAB.EQ.1) GO TO 996
1315          IF(HUP1.GT.HUR1.AND.NTAB.EQ.1) GO TO 989
              IF(NTAB.EQ.1) GO TO 986
              IF(QT.GT.(QE+DQ+1.0).AND.NTAB.EQ.2) GO TO 983
              IF(HUP1.GT.HUR3.AND.NTAB.EQ.2) GO TO 984
          980 IF(HDN.GT.HDR3.AND.NTAB.EQ.2) GO TO 982
1320          IF(NRATE.GT.0) GO TO 72
          C
          C   SET UP OUTPUT PRINT FOR INTERACTIVE TERMINAL RESPONSE WHEN NRATE=0
          C
          993 J1(J)=NC
1325          X1(J)=UPELEV
              X2(J)=DNELEV
              DO 41 I=1,L
              X3(J,I)=GOP(I)
              X4(J,I)=QG(I)
1330          X5(J,I)=GOL(NC,I)
              IF(GOL(NC,I).EQ.2H**) NLL=1
              X6(J,I)=CONDF(I)
           41 CONTINUE
              X7(J)=QTOUT
1335          X8(J)=QIN
              IF(QORG.EQ.1HQ) X8(J)=7H *****
              YN=1HX
              KK=J
           70 IF(MP.EQ.0) PRINT(2,54)
1340          JJ=0
           54 FORMAT(  17X,38H          CANAL RADIAL CHECK GATES           /14X,44HDIS
             +CHARGE AND/OR GATE OPENINGS BY ALGORITHMS,/)
              PRINT(2,55)
           55 FORMAT(72H CHECK   CHECK       H2O UP H2O DOWN   INPUT    OUTPUT ****GAT
1345         +E PROPERTIES****/72H NO.    NAME        ELEV.   ELEV.   DISCH.  DISC
             +H. NO. OPEN.  DISCH. COND./65H                           FT.     FT.     FT
             +3/S   FT3/S       FT.    FT3/S)
              PRINT(2,59)
           59 FORMAT(1X,71(1H*),/)
1350          MP=1
              DO 56 K=KK,J
              L=INT(GN(J1(K))+0.1)
              IF(X8(K).EQ.7H *****  ) GO TO 63
              PRINT(2,57) J1(K),CHECKN(J1(K)),X1(K),X2(K),X8(K),X7(K),((I,
1355         +X3(K,I),X5(K,I),X4(K,I),X6(K,I)), I=1,L)
           57 FORMAT(I3,2X,1A10,2F9.3,2F7.1,(I3,F7.3,1A2,F7.1,1A6,4(/,47X,I3,
             +F7.3,1A2,F7.1,1A6)))
              GO TO 64
           63 PRINT(2,61) J1(K),CHECKN(J1(K)),X1(K),X2(K),X8(K),X7(K),((I,
1360         +X3(K,I),X5(K,I),X4(K,I),X6(K,I)), I=1,L)
           61 FORMAT(I3,2X,1A10,2F9.3,1A7,F7.1,(I3,F7.3,1A2,F7.1,1A6,4(/,47X,I3,
             +F7.3,1A2,F7.1,1A6)))
           64 PRINT(2,62)
           62 FORMAT(/,1X,71(1H*),/)
1365          JJ=JJ+1
              IF(JJ.LT.8) GO TO 56
              JJ=0
              JPP=JPP+1
```

231

```
              PRINT(2,76)
1370       76 FORMAT(///)
              PRINT(2,74) JPP,JP
              PRINT(2,54)
              PRINT(2,55)
              PRINT(2,59)
1375       56 CONTINUE
              IF(NL.EQ.1) PRINT(2,*) ' *GATE OPENING LIMITED'
              IF(NLL.EQ.1) PRINT(2,*)' **GATE OPENING ABOVE WATER SURFACE
             + "RESULTS ARE UNRELIABLE"'
              IF(NL.EQ.1) NL1=1
1380          IF(NLL.EQ.1) NL2=1
              NL=0
              NLL=0
              IF(YN.EQ.1HN) GO TO 77
              PRINT(2,*) ' IS THIS RUN OK*'
1385       71 PRINT(2,*) ' ENTER YES OR NO'
              READ(1,6) OK
              IF(OK.NE.1HN.AND.OK.NE.1HY) GO TO 71
              IF(OK.EQ.1HN) J=J-1
           73 IF(J.GE.40) PRINT(2,*) ' NUMBER OF RUNS EXCEEDS 40'
1390          IF(J.GE.40) GO TO 112
              PRINT(2,*) ' DO YOU WANT TO ENTER MORE DATA *'
           58 PRINT(2,*) ' ENTER YES OR NO'
              YN=1HX
              READ(1,6) YN
1395          IF(YN.NE.1HN.AND.YN.NE.1HY) GO TO 58
              IF(YN.EQ.1HY) GO TO 1
              IF(J.EQ.0) GO TO 72
          112 MP=0
              KK=1
1400          JP=J/8+1
              JPP=1
              PRINT(2,74) JPP,JP
           74 FORMAT(////,58X,5HSHEET,I3,3H OF,I3)
              GO TO 70
1405       77 IF(NL1.EQ.1) PRINT(2,*) ' *GATE OPENING LIMITED'
              IF(NL2.EQ.1) PRINT(2,*)' **GATE OPENING ABOVE WATER SURFACE
             + "RESULTS ARE UNRELIABLE"'
           72 PRINT(2,75)
           75 FORMAT(1H1,21H" END OF DATA INPUT ")
1410          CALL EXIT
              END
```