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# *FLOW CHARATACERISTICS OF SURGE* AND DESIGN CHARTS FOR ITS COMPUTATIONS

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**خصائص السريان للمد الموجي والمنحنيات التصميمية لحسابه**

***خلاصة البحث***

**يهدف هذا البحث لدراسة المد الموجي المتكون أمام البوابات عند خفضها أو الحمل المفاجيء لمحطات القوي . تعيين ارتفاع وسرعة الموجه أساس لتصميم محطات القوي . وقد تم رسم المنحنيات بين المتغيرات المختلفة وهي رقم فرويد ، العمق ، السرعة ، التصرف . وبمساعدة هذه المنحنيات يمكن الحصول علي العمق والسرعة للمد الموجي أمام البوابات وذلك بمعرفة متغيرات السريان .**

## ABSTRACT

**Sudden load rejection at a hydropower plant causes the development of a posituve surge or a hydraulic bore in the power canal . Determination of the bore height and velocity is necessary for the design of the power canal. Determination of these parameters involves the solution of higher simultaneous equations through trial and error procedure which is a laborious and time consuming process . In the present work, a computerized solution of the problem was developed and then a vast data pertaining to the practical range of hydraulic bores was analyzed . As a result, two very useful sets , of three parameter curves were prepared . One of these relates the depth ratios to the Froude number for different discharge ratios . With the help of these charts the depth and velocity of any hydraulic bore can be determined immediately if the initial flow conditions and the dicharge ratio are known..**

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## INTRODUCTION

Often in the hydroelectric power development schemes , sudden charges in the load result in corresponding abrupt charges of flow in the conveyance system. In a closed conduit (penstock) this sudden charge of discharge gives rise to the water hammer phenomenon, while in the open cha nnels (power canals) it produces surges of considerable consequences. The surges in power canals , like their counterpart ( water hammer ) in penstocks are hyraulic transients , demanding careful attention of the designers .

Surges in power canals are classified as positive or negative depending on , whether caused by sudden rejection or acceptance of load at the plant . Load acceptance is generally a controlled affair , affected by gradually opening the turbine gate and thus eliminating the possible occurrence of any serious negative surge . However the rejection of load often occurs suddenly due to sudden trouble in the hydroelectric equipment or the transmission to sudden trouble in the hydroelectric equipment or the transmission lines etc . This necessitates a sudden closure of the gates causing , a positive surge of considerable magnitude and velocity , to move upstream . Such a rejection surge is also popularly known as " Hydraulic bore " , which in practical cases may attain heights of up to 2 meter or more with the velocities reaching 8 m/s and above. The exact determination of the depth and velocities of such positive surges attain much practical importance in the design of power canals , for establishing the height of walls necessary to prevent overflow during rejections . \

## KEY WORDS

Hydraulic bore - Celerity - Froude number -Discharge ratio Velocity ratio - Depth ratio

## NOTATIONS USED

C= Celerity of the surge
d = Depth of flow
F= Froude number
g= Acceleration due to gravity
Q= Discharge
V= Velocity of flow
w = Specific weight of water

## COMPUTATION OF HYDRAULIC BORE

Fig. 1 Shows schematically a power canal with a gate at its downstream end . A sudden closure of the gate produces a hydraulic bore (a positive surge ) travelling upstream in the canal. In the present analysis the canal bed has been assumed to be horizontal and the frictional force has been neglected .

Since the surge is a transient phenomenon between two steady flow states corresponding to the initial and final load conditions it gives corresponds to an unsteady flow condition . Hence for analysis the flow is converted to an equivalent steady state by superimposing a celerity "c" in the downstream direction (1). Now considering a rectangular canal of unit width and applying the Bernoulli's principle we get.

$$( V_1+C )\, d_1 = ( V_2+C )\, d_2 \qquad (1)$$

In which, $V_1$ = Velocity at section 1

$V_2$ = Velocity at section 2

where subscripts 1 and 2 refer to the conditions preceding and following the surge. Similarly on the applying the Momentum principle we get :

$$W(d_2^2 /2 - d_1^2 /2) = W/g\ (V_1+ C)\, d_1\, (V_1 + C) - (V_2 + C) \qquad (2)$$

Taking the value of $V_2$ from equation (1) and substituting in equation (2), we obtain the following relation on simplification:

$$C = \{( g\, d_2 / 2d_1^2 )\, (d^2_1 + d_2) - v_1 \}^{\frac{1}{2}} \quad (3)$$

The steady state discharge before and after the load charge can be readily obtained from the turbine characteristic curves. Also the initial depth and velocity of flow in the canal are know from the steady flow conditions perior to load change.

The velocity and height of the surge corresponding to the new discharge can thus be obtained using the above equations. However the solution of these equations involves an iterative trail and error procedure, which is quit laborious and time consuming. In order to overcome this difficult computerization of the procedure was done. The flow chart of the developed computer program is given in Appendix 1. with the help of this program a vast data was analyzed to obtain the depth and velocities of hydraulic bores. The data was selected to cover a wide, practical range of initial and final condition with various combinations of $d_1$ , $v_1$ and $Q_2/Q_1$

## SELECTION OF DIMENSIONLESS PARAMETERS:-

The new depth of flow in the canal corresponding to the new load was assumed to be a function of the initial velocity, the acceleration due to gravity and the reduced new discharge:

$$d_2 = f\,(d_1 , V_1 , g., Q_2)$$

Dimensional analysis then readily leads to the non dimensional parameters of Froude number $F = V_1 / (gd_1)^{1/2}$ , the depth ratio $d_1/d_2$ and the discharge ratio $Q_2/Q_1$ .

Likewise, if the bore velocity is assumed to be a function of the same variables, i.e.

$$C= F\,(d_1 , V_1 , g, Q_2) ,$$

Then the non dimensional parameters of Froude number, velocity ratio $V_1/C$, and the discharge ratio $Q_2/Q_1$ are obtained.

## PERSENTATION OF RESULTS

Analyzing the computed data in the light of the above derived dimensionless parameters, two very useful sets of curves were prepared. One of which relates the depth ratios to the Froude number for different discharge ratios, while the other relates the velocity ratios to the Froude number for various discharge ratios. The two curves have been given in Figs. 2 and 3.

It is seen that the dimensionless depth $d_1/d_2$ and the dimensionless velocity $V_1/C$ of the surge are uniquely related to the Froude number for any given discharge ratio $Q_2/Q_1$ . The two Figures cover Froude numbers ranging from about 0.01 to 3.2 and the discharge ratios ranging from 0.00 to 0.95 . With the help of these charts the depth and velocity of any hydraulic bore can be determined immediately if, the initial flow conditions and the new discharge is known. These charts will be very useful of design engineers.

## *CONCLUSIONS*

1. The surge depth and velocity are function of Froude number for a given discharge ratio.
2. For a given Froude number, $d_2$ as well as C increase with the increasing values of $Q_2/Q_1$ . The maximum values of $d_2$ and C are obtained when $Q_2/Q_1 = 0$
3. For a given $Q_2/Q_1$ ratio, $d_2$ increases with the Froude number, while C decreases.
4. The rate of increase in $d_2$ with Froude number is different for different ratios of $Q_2/Q_1$ up to $F_r$ =3, byond which it tends to be the same for different values of $Q_2/Q_1$
5. The rate of decrease in C with the Froude number is different for different ratios of $Q_2/Q_1$ beyond $F_r$ = 0.2 but tends to be the same for Froude number lower than that.

## REFERENCES

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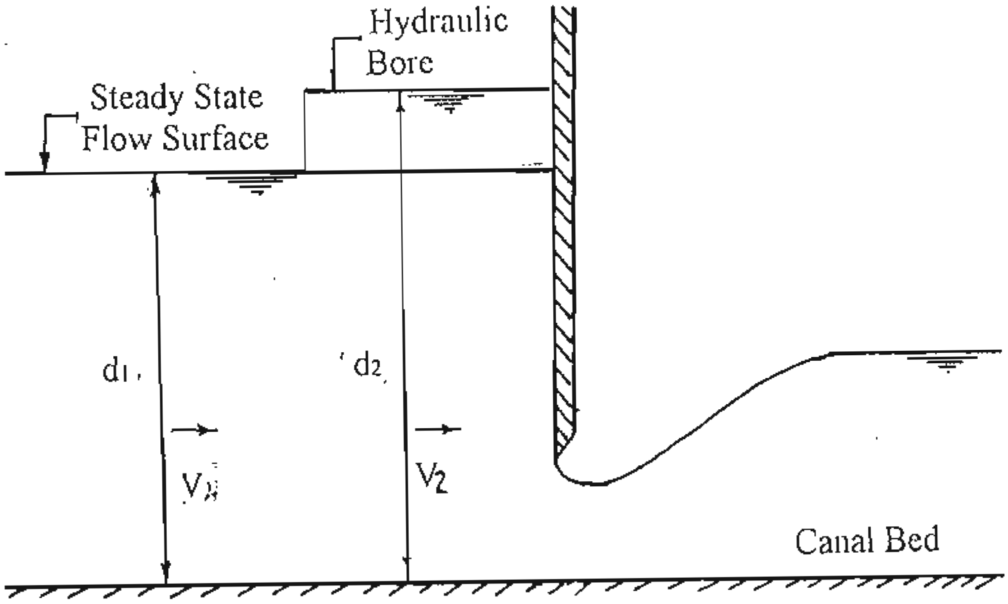



Fig.1 Schematic a power canal with a gate

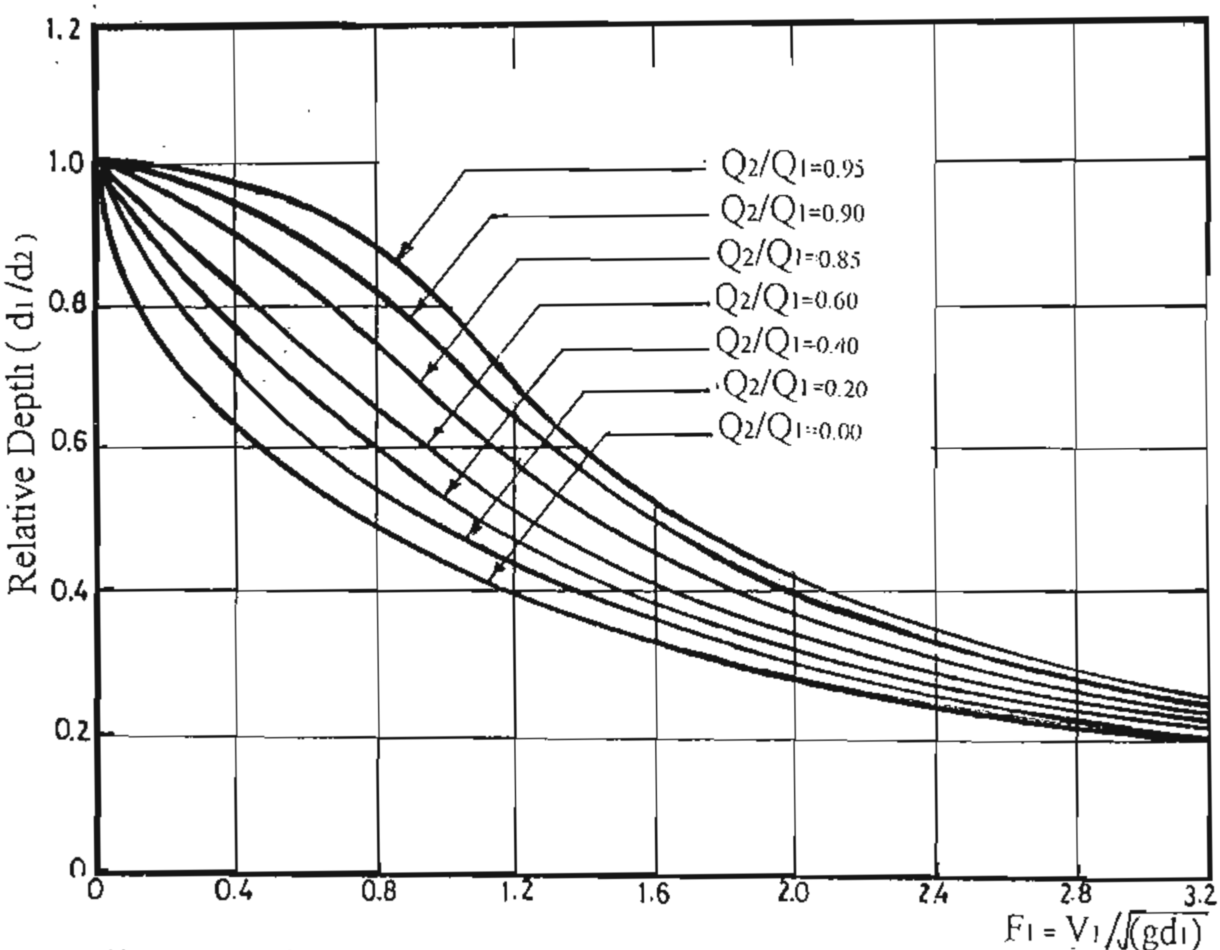



Fig.2 Variation of Froude number ($F_1$) with relative water depth ($d_1$ / $d_2$) at different discharge ratios ($Q_2/Q_1$).

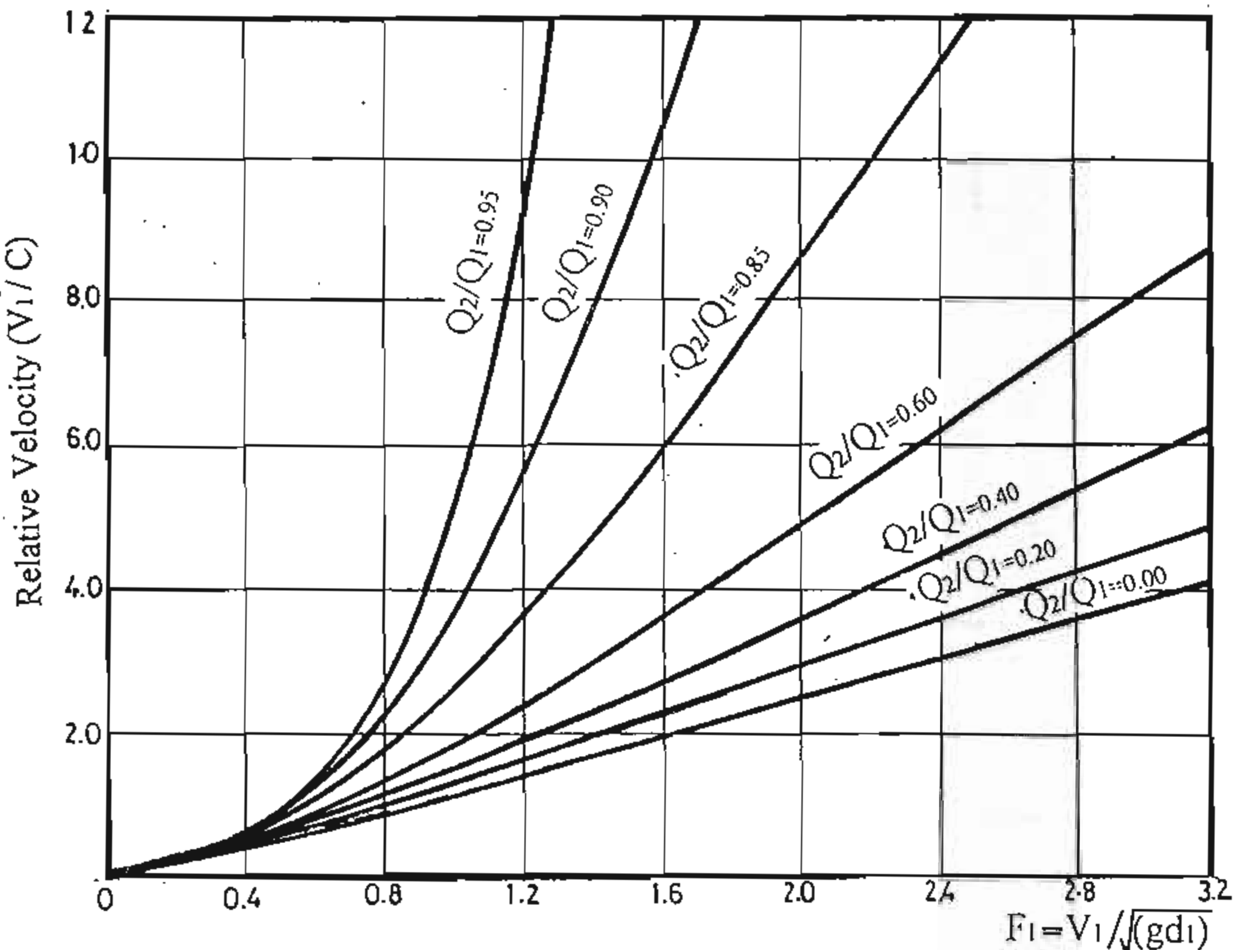
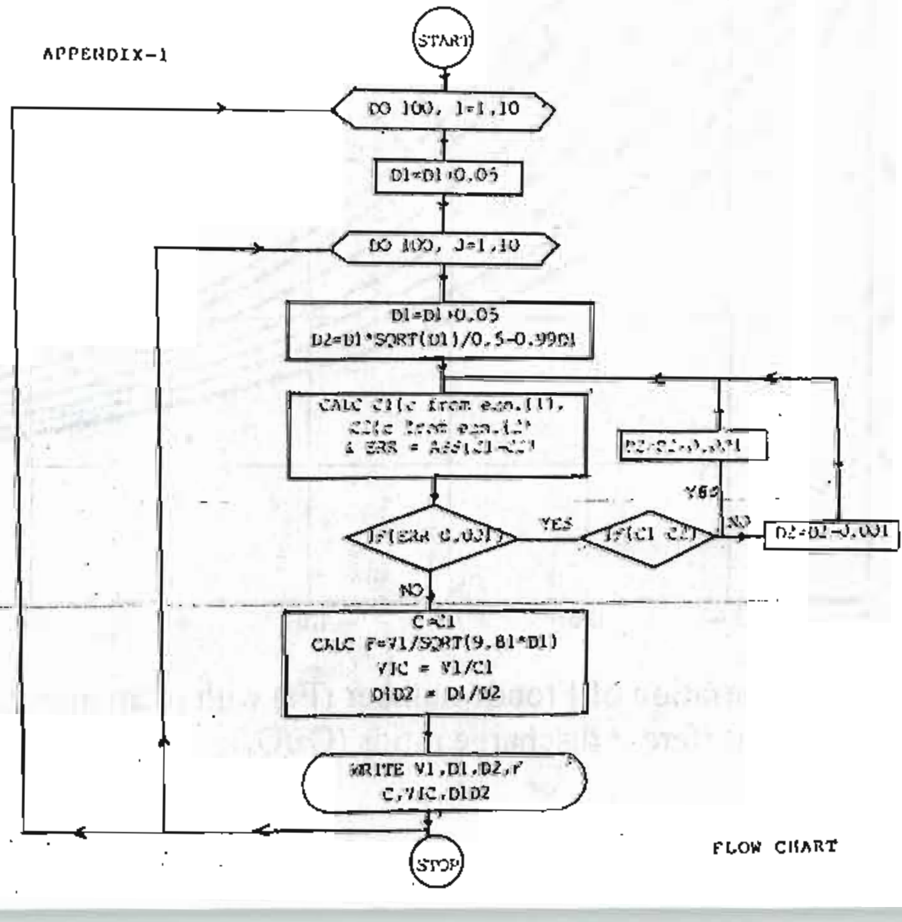



Fig.3 Variation of Froude number ($F_1$) with relative velocity ($V_1/C$) at different discharge ratios ($Q_2/Q_1$).

APPENDIX-1




FLOW CHART