इंटरनेट मानक

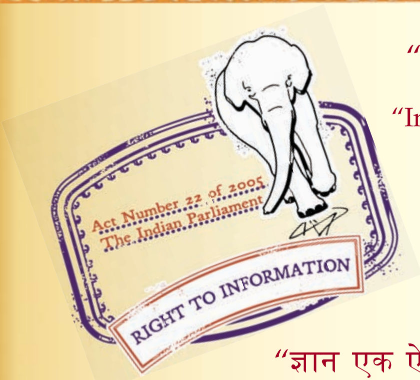
Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

"जानने का अधिकार, जीने का अधिकार"
Mazdoor Kisan Shakti Sangathan
"The Right to Information, The Right to Live"

"पुराने को छोड नये के तरफ"
Jawaharlal Nehru
"Step Out From the Old to the New"

IS 6063 (1971): Method of measuarement of flow of water in open channels using standing wave flume [WRD 1: Hydrometry]



"ज्ञान से एक नये भारत का निर्माण"
Satyanarayan Gangaram Pitroda
"Invent a New India Using Knowledge"

"ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है"
Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

BLANK PAGE

IS : 6063 - 1971
(Reaffirmed 2004)

Indian Standard

METHOD OF MEASUREMENT OF FLOW OF WATER IN OPEN CHANNELS USING STANDING WAVE FLUME

(Second Reprint JUNE 1989)

UDC 532.573.8:532.543

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 7 *November* 1971

Indian Standard

METHOD OF MEASUREMENT OF FLOW OF WATER IN OPEN CHANNELS USING STANDING WAVE FLUME

Fluid Flow Measurement Sectional Committee, BDC 17

Chairman

DR A. N. KHOSLA
15 Jangpura 'B', New Delhi 14

Vice-Chairman

SHRI N. D. GULHATI
N-111 Pancha Shila Park, New Delhi 17

Members	*Representing*
DR BHARAT SINGH	University of Roorkee
CHIEF ENGINEER (FI & T)	Central Water & Power Commission, New Delhi
DIRECTOR (CSMRS) (*Alternate*)	
CHIEF ENGINEER, PWD (SOUTH)	Public Works Department, Government of Mysore
SHRI D. DODDIAH (*Alternate*)	
DIRECTOR	Andhra Pradesh Engineering Research Laboratory, Hyderabad
DIRECTOR	Central Water & Power Research Station, Poona
DIRECTOR	Irrigation Department, Government of Uttar Pradesh
DIRECTOR	Land Reclamation, Irrigation & Power Research Institute, Government of Punjab
SHRI K. K. FRAMJI	In personal capacity [*Consulting Engineering Services (India) Pvt Ltd, M/124, Greater Kailash, New Delhi 48*]
SHRI O. P. GARG	Ganga Basin Water Resources Circle (Ministry of Irrigation & Power)
SHRI N. K. GHOSH	National Instrument (Private) Ltd, Calcutta
PROF N. S. GOVINDA RAO	In personal capacity (*89 Diagonal Road, Visvesvarapuram, Bangalore 4*)
HYDRAULIC ENGINEER	Bombay Municipal Corporation
SHRI V. D. DESAI (*Alternate*)	
JOINT DIRECTOR (BRIDGES & FLOODS)	Research, Designs & Standards Organization, Lucknow
DEPUTY DIRECTOR (*Alternate*)	
SHRI KANWAR SAIN	In personal capacity [*C/o Economic Commission for Asia and the Far East, Sala Santitham, Bangkok (Thailand)*]

(*Continued on page* 2)

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

(*Continued from page* 1)

Members	*Representing*
DR R. C. MALHOTRA	Indian Institute of Technology, New Delhi
METEOROLOGIST	India Meteorological Department, New Delhi
SHRI H. R. PRAMANIK	River Research Institute, Government of West Bengal
SHRI P. B. ROY (*Alternate*)	
SHRI B. B. RAO	Roads Wing (Ministry of Transport & Shipping)
SHRI N. C. SAKSENA	Ministry of Irrigation & Power
SHRI V. N. NAGARAJA (*Alternate*)	
SECRETARY	Central Board of Irrigation & Power, New Delhi
PROF K. SEETHARAMIAH	Indian Institute of Science, Bangalore
PROF N. S. LAKSHMANA RAO (*Alternate*)	
SUPERINTENDING ENGINEER (DESIGNS & MARINE WORKS CIRCLE)	Irrigation Department, Government of Tamil Nadu
DEPUTY CHIEF ENGINEER (I & D) (*Alternate*)	
SHRI D. AJITHA SIMHA, Director (Civ Engg)	Director General, ISI (*Ex-officio Member*)

Secretary

SHRI K. RAGHAVENDRAN
Deputy Director (Civ Engg), ISI

Notches, Weirs and Flumes Subcommittee, BDC 17 : 2

Convener	
SHRI C. V. GOLE	Central Water & Power Research Station, Poona
Members	
SHRI S. V. CHITALE (*Alternate* to Shri C. V. Gole)	
DR B. K. AGARWALA	National Physical Laboratory (CSIR), New Delhi
DR BHARAT SINGH	University of Roorkee
DIRECTOR	Andhra Pradesh Engineering Research Laboratory, Hyderabad
DIRECTOR (HYDROLOGY)	Central Water & Power Commission, New Delhi
DIRECTOR, IRIUP	Irrigation Department, Government of Uttar Pradesh, Roorkee
DIRECTOR	River Research Institute, Government of West Bengal
SHRI P. B. ROY (*Alternate*)	
SHRI K. K. FRAMJI	In personal capacity [*Consulting Engineering Services (India) Pvt Ltd, M/124 Greater Kailash, New Delhi 48*]
PROF N. S. GOVINDA RAO	In personal capacity (*89 Diagonal Road, Visvesvarapuram, Bangalore 4*)
SHRI N. C. SAKSENA	Ministry of Irrigation & Power
DIRECTOR (STATISTICS) (*Alternate*)	
PROF K. SEETHARAMIAH	Indian Institute of Science, Bangalore
PROF N. S. LAKSHMANA RAO (*Alternate*)	
SUPERINTENDING ENGINEER (DESIGNS & MARINE WORKS CIRCLE)	Irrigation Department, Government of Tamil Nadu
DEPUTY CHIEF ENGINEER (I&D) (*Alternate*)	

Indian Standard

METHOD OF MEASUREMENT OF FLOW OF WATER IN OPEN CHANNELS USING STANDING WAVE FLUME

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 16 March 1971, after the draft finalized by the Fluid Flow Measurement Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Standing wave flumes have their application in the measurement of discharge in artificial channels, such as irrigation canals. The standing wave flume may be depended upon to perform satisfactorily as a useful flow measuring device. Its chief merit lies in having only one gauge observation on the upstream as compared to venturi flumes which require two gauge observations, and also in their constancy of modularity relationship even with the sediment deposition in the upstream side.

0.3 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard covers the use of standing wave flumes, as described subsequently, for the measurement of flow of water in open channels. Flow conditions considered are limited to steady flows which are uniquely dependent on the upstream head. The submerged flows beyond modular limits which depend on downstream as well as upstream water levels are not considered herein.

*Rules for rounding off numerical values (*revised*).

1.2 An example is given in Appendix A to provide guidelines for the designer.

2. TERMINOLOGY

2.0 For the purpose of this standard, the definitions given in IS : 1191-1959* and the following shall apply.

2.1 Cistern — A pool of water maintained to take the impact of water flowing down a flume.

2.2 Deflector — A wall of suitable height built across the pavement at the end of the cistern to ensure the formation of a positive bed roller (a bed roller which will not cause retrogression of levels towards toe) immediately downstream.

2.3 Fluming Ratio — It is the ratio of bed width of the flume at contracted section (including piers) to the bed width of the channel upstream.

2.4 Glacis — The sloping floor below and in continuation of the raised crest of a flume.

3. INSTALLATION

3.1 Selection of Site — A preliminary survey should be made of physical and hydraulic features of the proposed site to check that it conforms (or may be made to conform) to the requirements necessary for measurements by standing wave flumes. Particular attention should be paid to the following features in the selection of site:

a) Availability of adequate length of straight channels;

b) Reasonably symmetrical and regular velocity distribution;

c) Avoidance of super critical flow immediately upstream;

d) Rise in upstream water levels due to the measuring structure; and

e) Absence of conditions downstream of standing wave flumes which may affect the working by drowning, such as by a controlling structure.

If the site does not possess the characteristics (a), (b) and (c) which are necessary for satisfactory measuring, it should be rejected unless suitable improvements are practicable. If an inspection of the channel shows that existing velocity distribution is regular then it may be assumed that the velocity distribution will remain satisfactory after the construction of the standing wave flume.

---

*Glossary of terms used in measurement of flow of water in open channels (*under revision*).

If the existing velocity distribution is irregular and no other site is feasible, due consideration should be given to the checking of distribution after the installation of standing wave flume, and to improve it, if necessary. A complete and quantitative assessment of velocity distribution may be made by means of a current meter. Complete information about the use of current meter is given in IS : 3918-1966*.

3.2 Installation Conditions

3.2.1 *General* — The complete measuring installation consists of an approach channel, a measuring structure (standing wave flume) and a downstream channel. The condition of each of these three components affects the overall accuracy of the measurement (*see also* **3.2.2, 3.2.3** *and* **3.2.4**).

Installation requirements include such features as precise dimensions of structure, its finish, regular cross-sectional shape of approach and exit channels, influence of control devices upstream and downstream of structures, etc.

Once an installation has been designed, any change which would affect the basis of design should be prevented.

3.2.2 *Approach Channel* — On all installations the flow in the approach channel shall be smooth, free from disturbance and have velocity distribution as normal as possible over the cross-sectional area. This may be usually verified by measurements. Unless otherwise specified in the appropriate sections, the following general requirements shall be complied with:

a) The altered flow conditions due to the construction of standing wave flume might have the effect of deposition of sediment upstream of the structure. The likely consequential changes in the water level should be taken into account in the design.

b) The natural stream or river cross-section should be reasonably uniform and the channel should be straight for such a length as to ensure uniform velocity distribution. If the entry to the approach channel is through a bend or if the flow is discharged into the channel from head regulator through a conduit of smaller cross-sectional area or at an angle, then a longer length of straight approach channel may be required to achieve an even velocity distribution.

c) The channel should be in overall regime, that is, over the year there are inappreciable changes.

3.2.3 *Measuring Structure (Standing Wave Flume)* — The standing wave flume consists of an approach transition, a throat with or without hump and an exit transition (*see* Fig. 1). The entire measuring structure shall

*Code of practice for use of current meter (cup type) for water flow measurements.

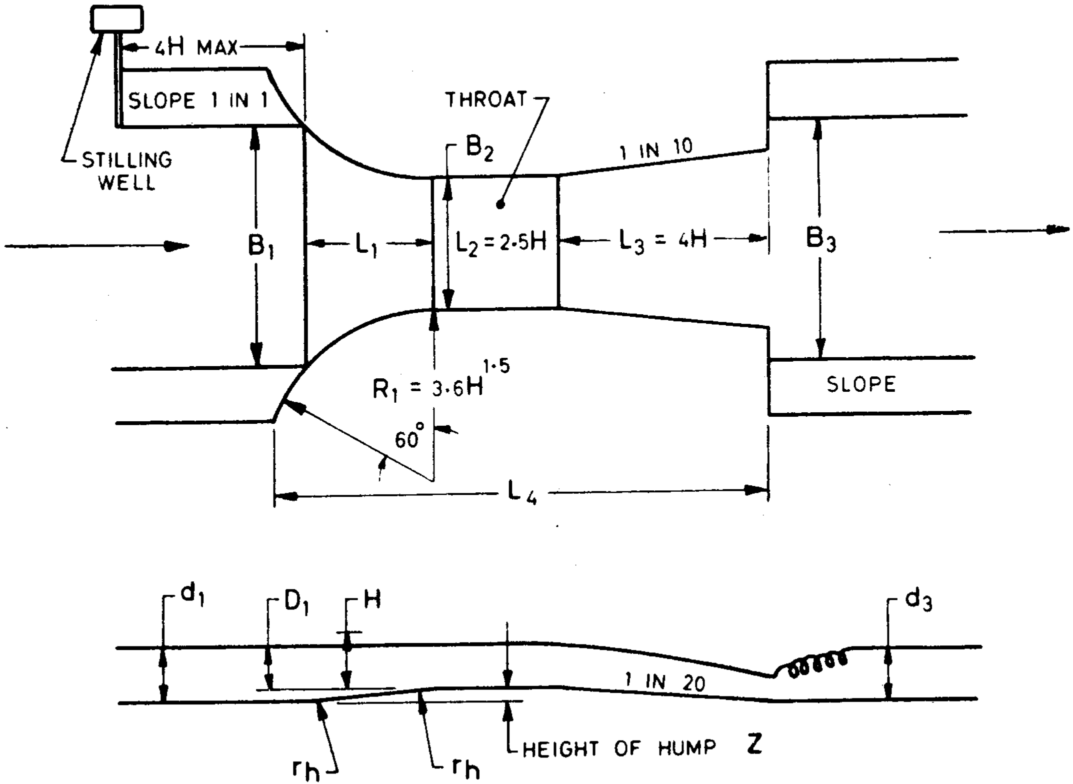


FIG. 1 DETAILS OF STANDING WAVE FLUME FOR SMALL HEAD LOSS

be rigid and water-tight, at least for a length L_4 as shown in Fig. 1. It should be at right angles to the general direction of flow and conform to the dimensions given in relevant clauses.

3.2.4 *Downstream Channel* — The channel downstream of the measuring structure (standing wave flume) is usually of little importance as such provided that the standing wave flume has been so designed that it cannot become drowned under operating conditions due to silting, back-water effects, etc.

3.2.4.1 The altered flow conditions due to construction of the measuring structure (standing wave flume) might have an effect of building shoals of sediment downstream of the structure, which in course of time might raise the water level sufficiently to cause submergence of flow. An accumulation of sediment downstream of the measuring structure should, therefore, be removed from time to time.

4. MAINTENANCE

4.1 Maintenance of the measuring structure (standing wave flume) and approach channel is important to secure accurate continuous measurements. It is essential that approach channel be kept clean and free from vegetation and sediment as far as practicable for at least the distance specified in **3.2.2** (b). The float or gauge (stilling) well and the connection to it from the approach channel shall also be kept clean and free from deposits. The measuring structure shall be kept clean and free from clinging sediment and care shall be taken in the process of cleaning to avoid damage to the measuring structure. To ensure proper maintenance, periodic inspection at suitable intervals should be made.

5. MEASUREMENT OF HEAD

5.1 General — The water level upstream of the standing wave flume may be measured by any suitable type of a gauge where only spot measurements are required, and with an automatic recording type of gauge where a continuous record is required. Gauge observation should, however, invariably be made so that fluctuations are damped down, such as in a stilling well to reduce surface irregularities.

5.2 Gauge (Stilling) Well — The stilling well should be so located as to measure the water level upstream of the sill where there is no curvature of flow. This could be ensured by locating the stilling well intake pipe at a distance of 4 H_{max} upstream of the bell mouth entrance where H_{max} is the maximum value of upstream head over sill corrected for velocity of approach.

5.2.1 The stilling well should be normally vertical and have a minimum margin of at least 15 cm over the maximum water level estimated to be recorded in the well. The stilling well should either be carried on a solid foundation slab below the bottom of the well, or when pipe construction is adopted the well pipe may be hung from an under-floor located below the point where the pipe emerges from the bank. The under-floor should extend well beyond the limit of the intake pipe trench on both sides and should be solidly bedded on undisturbed ground. The well dimensions should be large enough (say, 60 × 90 cm) to permit the bottom of the well to be cleaned. The smallest dimension of the well should be, however, not less than twice the diameter of the float of the recorder as given in the draft 'Indian Standard specification for water stage recorder (float type)' (*under preparation**). It is an advantage to fit more than one intake pipe to the well, the lowest being situated below the lowest anticipated stage of flow and the others at suitable levels below normal water level. In this way, if during the season of high water the lower pipe(s) becomes obstructed and it is not possible to clean it (them) owing to the depth of water, the recorder will continue to operate on the upper intake(s) until the water level falls sufficiently to allow access to the lower pipe(s). The upper pipes will be usually accessible for cleaning. It is convenient to provide valves in the intake pipes and install flushing systems to clear sediment from the pipes and if this arrangement is impracticable, means for cleaning with flexible sewer rods should be provided. Further, silt trap may be provided near the end of the intake pipe where it takes off from the channel in order to retard silting.

5.2.1.1 The diameter of the intake pipe should generally be 10 cm. If larger pipes or an open intake is used, a valve or penstock should be fitted to control surge in the well. Intake pipes should be laid level throughout their length; if they exceed 20 m in length an intermediate inspection manhole should be constructed. The bottom of the well should be carried at least about 30 cm below the level of the lowest intake pipe so that there may be no danger of the float grounding when the stream falls to its minimum level.

5.3 Zero Setting — A means of checking the zero setting of head measuring device should be provided, consisting of a pointer with its point set exactly level with the sill of flume and fixed permanently in the approach channel or alternatively in the stilling or gauge well, wherever provided. The zero setting should be periodically checked.

5.3.1 A checking for zero setting based on the level of water when the flow ceases is liable to serious errors from the surface tension effects and

*Until the standard under preparation is published the matter shall be subject to agreement between the concerned parties.

should not be used. As the size of standing wave flume and head on it reduces, small errors in construction, in zero setting and reading of head measuring device become more and more important.

5.4 Head Loss — This consists of the following losses:

a) Approach transition,
b) Exit transition,
c) Friction in the structure, and
d) Hydraulic jump.

Loss in approach and exit transitions depend on the amount of fluming and its gradualness. These are expressed as a fraction C of the difference in velocity head of flow in the channel and the standing wave flume. These are usually taken as 0·15 for the approach transition of cylinder quadrant type and 0·3 for exit transition with splay of 1 in 10 and 0·2 with hyperbolic type.

Loss in friction is usually small. It may be of the order of 0·015 to 0·03 m depending upon the size and the critical velocity.

Loss in a hydraulic jump H_L is given by:

$$H_L = \frac{(d'' - d')^3}{4\,d'\,d''} \qquad \ldots \ldots \ldots \ldots \quad (1)$$

where

d' = depth before jump, and
d'' = depth after jump.

6. SPECIFICATION FOR STANDING WAVE FLUMES

6.0 All the components shall be finished with smooth and true surfaces (in this specification a smooth surface shall correspond to a neat cement finish). The intersection of upstream curve and hump as well as the downstream slope shall form two parallel straight lines at right angles to the direction of flow.

6.1 Approach Transition (Bell Mouth Entrance)

6.1.1 *Side Contractions* — The radius of side walls of the bell mouth entrance should be 3·6 $H^{1\cdot5}$ m where H is the upstream head above the sill level corrected for approach velocity. But when H is less than 0·3 m, the radius may be 2 H from the throat. The curvature should continue till it subtends an angle of 60° from where it should be continued tangentially to meet the side of the channel upstream. For smaller head loss the radius of curvature should be increased to 4·5 $H^{1 \cdot 5}$ m. This curvature should be continued till it subtends an angle of 37°30′ beyond which the wall should be continued straight to meet the sides of the approach channel. The bed convergence should begin on the same cross-section as the side convergence. The radius of curvature of the hump in the bed should be:

$$r_h = \frac{L_1^2 + Z^2}{2Z} \qquad \dots \quad \dots \quad \dots \quad \dots \quad (2)$$

where

r_h = radius of curvature of the hump,

L_1 = length between the junction of the side wall with the bed of upstream channel and upstream end of the throat measured along the axis, and

Z = height of hump above upstream bed of the channel.

When the total head above the standing wave flume sill becomes considerable, say, 1·2 m, the height of hump Z becomes insignificant as compared to L_1 so that the radius becomes large and the upstream end of the throat may be joined by a straight line to the channel bed upstream.

6.2 Throat — Sides of throat should be vertical and length should be 2·5 H, where H is the upstream head above the sill level corrected for approach velocity. Width of the throat may be calculated by the formula given in **7.1**.

6.2.1 Too great a constriction, however, causes more head loss. Width should not, therefore, be kept less than 1·5 H. Where head loss provided in the design is not adequate, fluming should normally be restricted to 50 to 60 percent.

6.3 Hump — The stage discharge relation of a canal or distributory is given by:

$$Q = C_1 d_1^x \qquad \dots \quad \dots \quad \dots \quad \dots \quad (3)$$

where

Q = discharge,

C_1 = a coefficient,

d_1 = depth of water in the channel, and

x = index which varies from 1·5 to 2.

6.3.1 Values of x are summarized in Table 1.

TABLE 1 VALUES OF x

SL NO.	SHAPE OF CHANNEL	x
i)	Rectangular	1·5
ii)	Trapezoidal	Variable and increases with the flatness of the side slope
iii)	Unlined canals with design side slopes ½ to 1	1·6 to 1·7
iv)	Lined canals with slopes 1½ to 1	1·9 to 2

As compared to the equation in **6.3**, in the case of a broad crested weir Q is proportional to $H^{1\cdot5}$ where H is head upstream over sill corrected for velocity of approach. As the exponent of d_1 is greater than the exponent of H, there will be drawdown at low supplies and ponding near full supply levels provided the sill of the throat is at the same level of the channel bed. This can be avoided by providing a hump in the flume throat. The height of hump Z required to give proportionality, that is, rate of change in d_1 equal to the rate of change in D_1 at a particular discharge is given by:

$$Z = d_1 - D_1 = d_1 \left\{ m^{1/x} - \frac{3m^{2/3}}{2x} \right\} \quad \ldots \quad \ldots \quad (4)$$

where

D_1 = depth upstream over the sill of throat, and

m = any particular fraction of discharge.

The height of hump required to give proportionality for a small variation in discharge will thus vary according to the magnitude of the discharge. Figure 2 gives the height of hump required for various values of m and x.

6.3.2 Where channels are run with fluctuating discharge, the proportionality is not obtainable for the whole range and it is then desirable to design the hump such that the error over the range of discharges chosen will be minimum. This is called the bulk proportionality and in this case the height of hump is given by:

$$Z = d_1 - D_1 = d_1 m^{1/x} \left\{ 1 - \left(\frac{\frac{1}{m^{1/x}} - 1}{\frac{1}{m^{2/3}} - 1} \right) \right\} \quad \ldots \quad \ldots \quad (5)$$

Figure 3 gives the height of hump required for various values of x and fluctuations. When the head available is little less than that required to give a standing wave with this design, a higher hump and a wider flume may be adopted (*see* Note).

NOTE — In case of canals run either full or closed, it is desirable to have a flume which gives proportionality at full supply discharge. In case of channels in which discharge varies considerably, bulk proportionality is preferable.

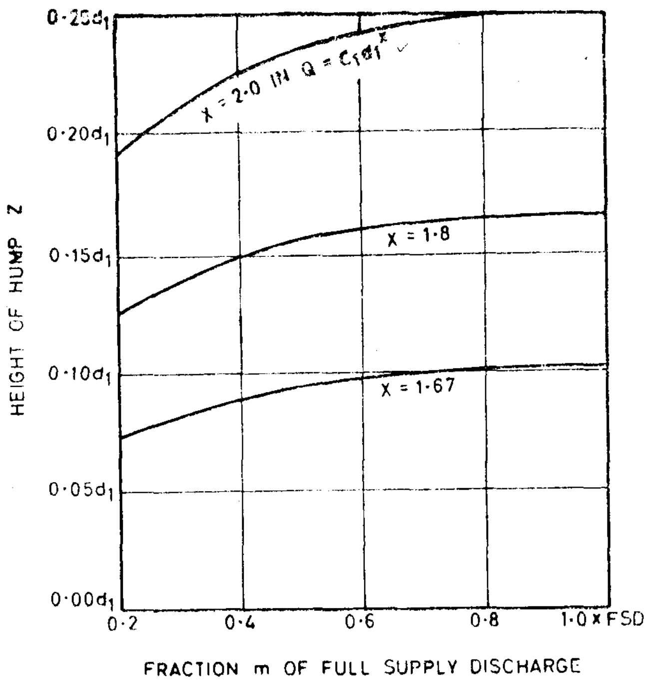


FIG. 2 HEIGHT OF HUMP REQUIRED TO GIVE PROPORTIONALITY FOR A SMALL VARIATION IN DISCHARGE

6.4 Downstream Portion

6.4.1 *For Small Head Loss* — The length of downstream glacis L_3 should be equal to 4 H, which is also the length of side walls. When recovery of head required is more than 80 percent, the slope of glacis downstream of throat should be fixed as given below:

When $4\,H<20$ times the height of hump above the toe of glacis, the slope of glacis should be 1 in 20 for a length of $2\,H$. Beyond this point, it may be made more so as to make total horizontal length of glacis equal to $4\,H$ from throat till it joins the bed of channel downstream.

When $4\,H>20$ times the height of hump above the toe of glacis, the slope of glacis may be made flatter than 20 from throat till it joins the bed of channel downstream, so as to make the horizontal length of glacis equal to $4\,H$.

The length of side walls should be $4\,H$ and their divergence should be 1 in 10 or flatter so as to make the width at the toe of glacis less than or equal to bed width B_3 (*see* Fig. 1). For still more recovery of heads, the sides may be given hyperbolic expansion in length $4\,H$ to join the downstream channel. The equation of hyperbola is:

$$B_y = \frac{B_0 B_3 L_3}{L_3 B_3 - (B_3 - B_0) y} \qquad \ldots \quad \ldots \quad \ldots \quad (6)$$

where

B_y = width at any distance y from beginning of expansion of hyperbola;

y = distance from beginning of expansion of hyperbola;

B_0 = overall throat width including piers, if provided, if not B_0 becomes B_2 the width of flume at the contracted section (excluding piers);

B_3 = bed width of downstream channel; and

L_3 = length of downstream glacis either with divergence of 1 in 10 or hyperbolic expansion = $4\,H$.

NOTE — The modularity limit is more reliable and precise in lined canals where downstream water level does not change for the same discharge. For flumes with small head loss the cistern, control blocks, deflector, etc, need not be provided.

6.4.2 *For Big Head Loss*

6.4.2.0 If bed and banks of downstream channel are erodible and it is impossible to prevent periodical scour and accretion, then the downstream portion shall be designed to work satisfactorily with variation of downstream water level. In such cases the recovery of head would be less than 80 percent.

Glacis in this case should have a slope of 2 : 1 connected with the throat upstream by a curve of radius $R = 2\,H$ and with cistern downstream by a curve of radius $R = H$. Side walls should be straight over glacis portion. With steeper glacis slope of 2 : 1 and greater loss of head

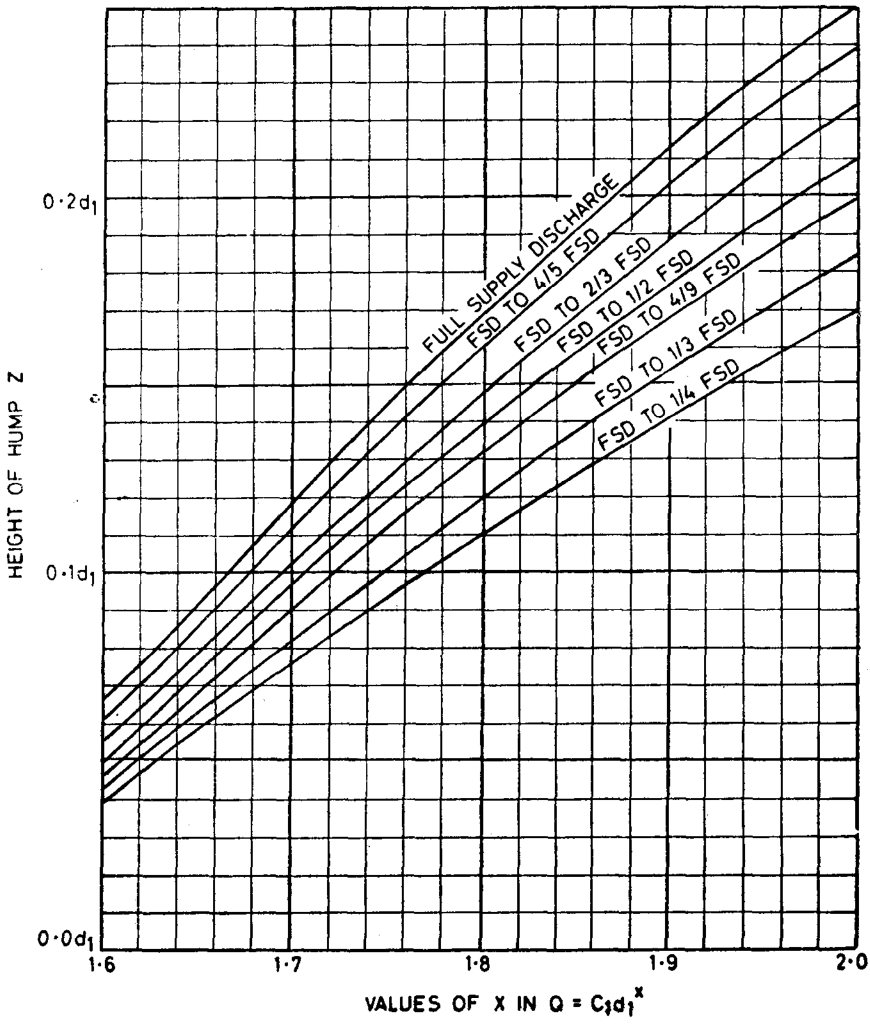


FIG. 3 HEIGHT OF HUMP TO ATTAIN BULK PROPORTIONALITY

proper expansion should be provided. For controlling the issuing flow, parallel sides should be extended down to the toe of glacis followed by hyperbolic expansion in the cistern using equation:

$$B_y = \frac{B_0\, B_3 L}{L B_3 - (B_3 - B_0)y} \qquad \dots \quad \dots \quad \dots \quad (7)$$

where

L = length of cistern (other quantities have been defined in equation 6).

No protection is necessary in the downstream of the expansion.

6.4.2.1 *Cistern* — Cistern is provided with a view to effectively dissipating the energy and therefore it is not obligatory in all cases. With gradual slope of bed at 1 in 20 and side divergence of 1 in 10, provision of cistern is not necessary. With greater loss of head cistern needs to be added below the glacis. Cistern may be at the downstream bed level of canal and hence the depth of water in downstream channel, d_3, fixes the level of toe of glacis at the sites. In order to stabilize the flow, bed of the cistern should be made deeper in the centre by providing more depth in the middle, equal to d_3 + 25 percent. To determine the cistern length, the following rules may be used:

$$L = \begin{cases} 4\, d_3 \text{ for shingle bed,} \\ 5\, d_3 \text{ for good earthern bed, and} \\ 6\, d_3 \text{ for sandy bed.} \end{cases}$$

Floor of cistern should be horizontal. This will be an advantage when there is the possibility of retrogression (*see* Fig. 4).

6.4.2.2 *Control blocks* — Two rows of staggered control blocks should be provided downstream of the toe of the glacis in the cistern for dissipation of surplus energy. These act like a baffle. If retrogression is expected to occur, it may result in the formation of a secondary wave. Under such conditions the height of the block should be equal to 1/9 the depth of water in the cistern in the mid stream. If no retrogression is anticipated the height of control blocks may be increased to 1/6 the depth of water. The first row of blocks should be at 3 to 5 times the height of blocks from the toe of glacis. Length of blocks should be 1·5 to 3 times the height of blocks and the thickness in the line of flow should be 2/3 the height of blocks. Clear distance between each block should be equal to the length of blocks and clear distance between rows may be equal to thickness of blocks (*see* Fig. 5).

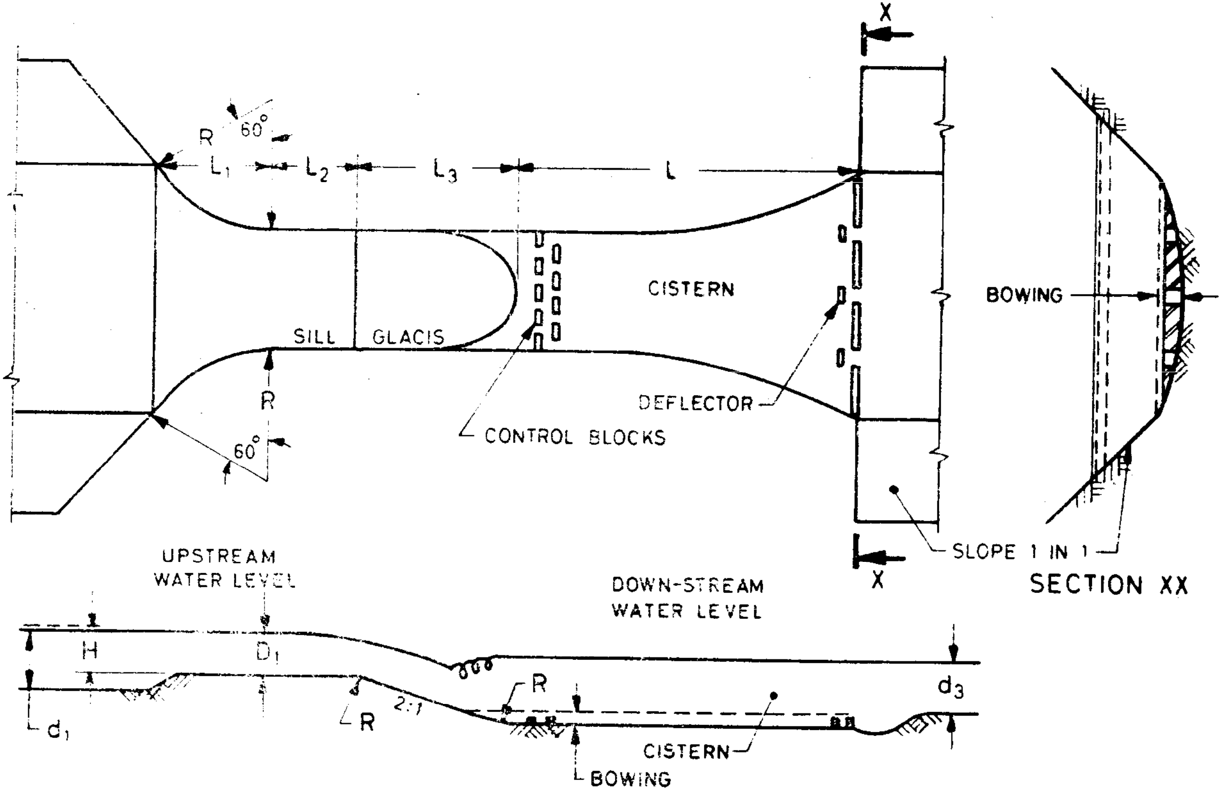
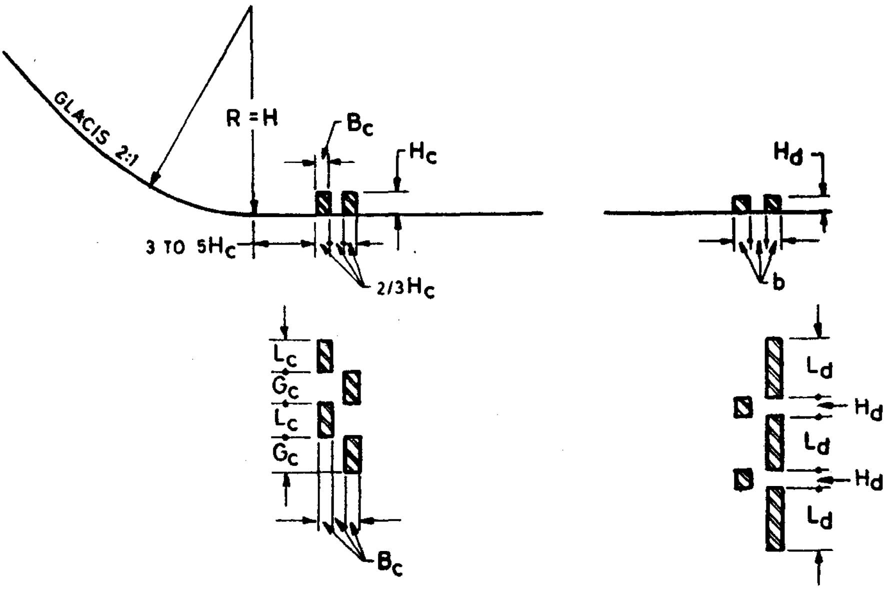


FIG. 4 DETAILS OF STANDING WAVE FLUME FOR BIG HEAD LOSS



Details of Control Blocks		*Details of Deflector*	
Height of control blocks	$= H_c = 1/9$ depth of water in mid cistern	Height	$= H_d = 1/12$ depth of water in mid cistern
Length	$= L_c = 1{\cdot}5$ to $3H_c$	Length	$= L_d = 4\ H_d$
Breadth	$= B_c = 2/3\ H_c$	Breadth	$= b\ = H_d$
Gap between two blocks	$= G_c = L_c$	Gap between two blocks	$= H_d$
Distance between two rows	$= B_c = 2/3\ H_c$	Distance between two rows	$= H_d = b$

FIG. 5 DETAILS OF CONTROL BLOCKS AND THE DEFLECTOR

6.4.2.3 *Deflector* — At the downstream end of cistern a deflector of the following dimensions should be constructed to ensure the formation of a positive bed roller:

Height of deflector should be equal to 1/12 the depth of water in mid stream. Gaps in the deflector should be equal to height of deflector and at intervals of 4 times the height with short walls placed close to the upstream of gaps to prevent jetting of water (*see* Fig. 5).

7. COMPUTATION OF DISCHARGE

7.1 The discharge equation for standing wave flumes is given below:

$$Q = \frac{2}{3} \sqrt{\frac{2}{3} . g}\ C_f\ (B_0 - mb - 2\ C_c\ mH)\ H^{1.5} \qquad \ldots \quad \ldots \quad (8)$$

where

Q = discharge,

g = gravitational acceleration,

C_f = coefficient for friction having the following values:

0·97 for Q = 0·05 to 0·3 m³/s

0·98 for Q = 0·3 to 1·5 m³/s

0·99 for Q = 1·5 to 15 m³/s

1·00 for Q = 15 m³/s and above,

B_0 = overall throat width including piers,

m = number of piers,

b = thickness of each pier,

C_c = coefficient of contraction, having a value 0·045 for piers with round nose and 0·040 for piers with pointed nose, and

H = $D_1 + h_v$ = upstream head over sill corrected for velocity of approach:

$$= D_1 + \frac{\bar{v}^2{}_a}{15{\cdot}2}$$

where

D_1 = the depth upstream over sill of throat, and

$\bar{v}_a$ = the mean velocity of approach.

Effect of velocity of approach is greater than $\frac{\bar{v}^2{}_a}{2g}$ because the velocity in the central portion is higher than $\bar{v}_a$. Therefore, the head due to velocity of approach should be taken as:

$$h_v = \frac{\bar{v}^2{}_a}{15{\cdot}2} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

8. ACCURACY OF MEASUREMENTS

8.1 The overall accuracy of measurements will depend on:

a) the proper selection of site, in particular the characteristics (a), (b) and (c) given in **3.1** are satisfied;

b) the correct observance of the installation conditions; and

c) the accuracy of zero setting and head measurements.

8.2 With skill and care in the construction of the measuring structure (standing wave flume), the basic equations and the coefficients are expected to give accurate results. Studies to determine errors are being made.

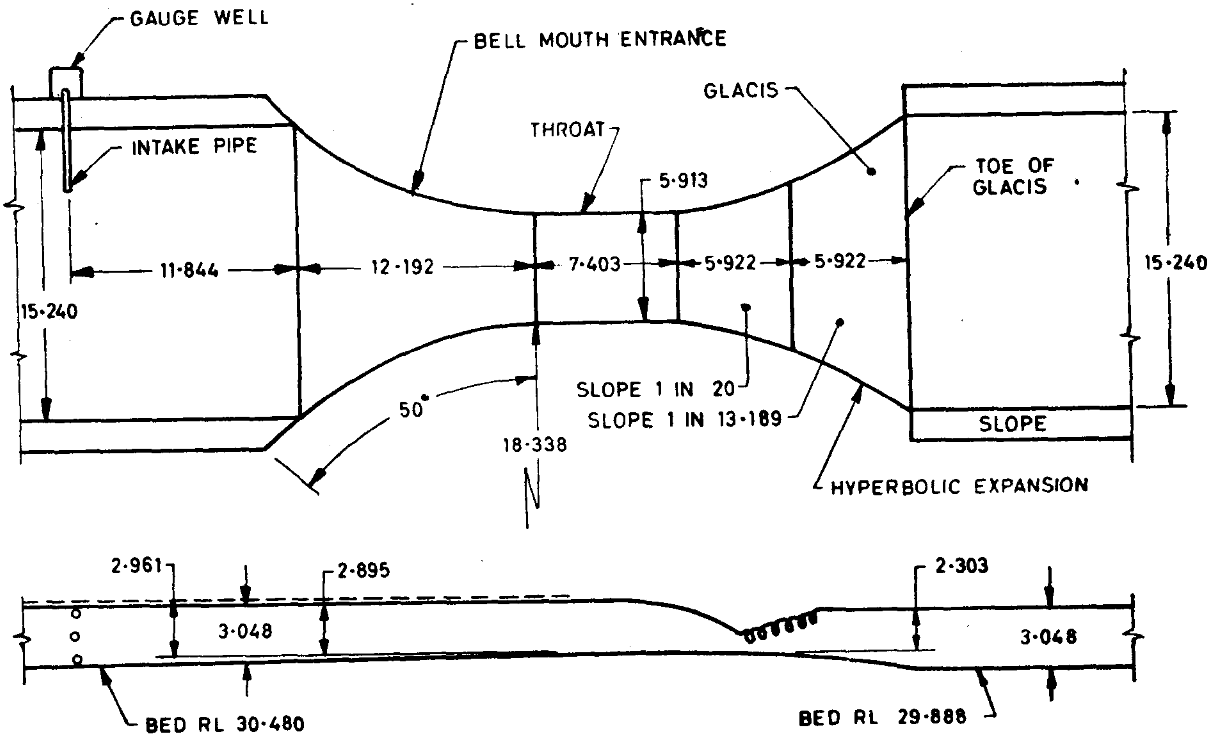
9. LIMITATIONS

9.1 For satisfactory functioning of the standing wave flume, the ratio $\frac{D_2}{D_1}$ should not be less than 0·5 (*see* Fig. 6),

where

D_1 = the depth upstream over sill of throat, and
D_2 = the depth downstream above sill of throat.

For $\frac{D_2}{D_1}$ less than 0·5, standing wave flume fall may be used for efficient dissipation of energy downstream.



All dimensions in metres.

FIG. 6 TYPICAL DESIGN OF A STANDING WAVE FLUME

APPENDIX A

(*Clause* 1.2)

A TYPICAL DESIGN OF STANDING WAVE FLUME

A-1. CRITERIA OF DESIGN

A-1.1 The following conditions shall be satisfied while designing a standing wave flume:

a) The standing wave flume should be designed for bulk proportionality between full supply discharge (FSD) and 1/3 full supply discharge (1/3 FSD), and

b) The standing wave flume should be designed for recovery of head more than 80 percent.

A-2. DATA GIVEN

A-2.1 Details are as given below:

Bed width of canal (B_1 and B_3)	15·240 m
Side slope of canal	$\frac{1}{2}$: 1
Bed slope of canal	1 : 6 000
Manning n for canal	0·022 5
Full supply depth in canal (d_1 and d_3)	3·048 m
Full supply discharge	51·352 m³/s
Bed level of canal on the upstream	30·480 m

A-3. DESIGN

A-3.1 Details of design are as given below:

a) *Height of Hump* — Hump height is designed in accordance with **6.3.** In order to estimate the height of hump for bulk proportionality, it is necessary to establish stage discharge relationship of canal which is given by $Q = c_1\, d_1^{x} = c_1\, d_3^{x}$.

Hence the discharges of the canal for various depths are first estimated.

$\therefore$ For $d_1 = 3{\cdot}048$ m

$$\text{Area} = A = (b_1 + 0{\cdot}5 \times d_1)\, d_1 = (15{\cdot}240 + 0{\cdot}5 \times 3{\cdot}048)\, 3{\cdot}048 = 51{\cdot}097 \text{ m}^2$$

$$\text{Perimeter} = P = b_1 + 2 \times d_1 \times \sqrt{1^2 + 0{\cdot}5^2} = b_1 + 2{\cdot}236\, d_1 = 15{\cdot}240 + 2{\cdot}236 \times 3{\cdot}048 = 22{\cdot}055 \text{ m}$$

$$R_h = A/P = \frac{51 \cdot 097}{22 \cdot 055} = 2 \cdot 317 \text{ m}$$

$$\text{Velocity} = V = \frac{1}{0 \cdot 0225} \times \frac{2 \cdot 317^{\frac{2}{3}}}{(6000)^{\frac{1}{2}}} = 1 \cdot 005 \text{ m/s}$$

$$\text{Discharge} = Q = A \times V = 51 \cdot 097 \times 1 \cdot 005 = 51 \cdot 352 \text{ m}^3/\text{s}$$

Adopting smaller depths than d_1 as d'_1, d''_1, d'''_1, etc,

For $d'_1 = 2 \cdot 438$ m

$$A' = (b_1 + 0 \cdot 5\, d'_1) \times d'_1 = (15 \cdot 240 + 0 \cdot 5 \times 2 \cdot 438) \times 2 \cdot 438$$
$$= 40 \cdot 127 \text{ m}^2$$

$$P' = b_1 + 2 \cdot 236\, d'_1 = 15 \cdot 240 + 2 \cdot 236 \times 2 \cdot 438 = 20 \cdot 691 \text{ m}$$

$$R'_h = A'/P' = \frac{40 \cdot 127}{20 \cdot 691} = 1 \cdot 939\ m$$

$$V' = \frac{1}{0 \cdot 0225} \times \frac{1 \cdot 939^{\frac{2}{3}}}{(6000)^{\frac{1}{2}}} = 0 \cdot 892 \text{ m/s}$$

$$Q' = A' \times V' = 40 \cdot 127 \times 0 \cdot 892 = 35 \cdot 793 \text{ m}^3/\text{s}$$

For $d''_1 = 1 \cdot 829$ m

$$\text{Area} = A'' = (b_1 + 0 \cdot 5\, d''_1) \times d''_1$$
$$= (15 \cdot 240 + 0 \cdot 5 \times 1 \cdot 829)\ 1 \cdot 829 = 29 \cdot 546 \text{ m}^2$$

$$P'' = b_1 + 2 \cdot 236\, d''_1 = 15 \cdot 240 + 2 \cdot 236 \times 1 \cdot 829$$
$$= 19 \cdot 330 \text{ m}$$

$$R''_h = A''/P'' = \frac{29 \cdot 546}{19 \cdot 330} = 1 \cdot 529 \text{ m}$$

$$V'' = \frac{1}{0 \cdot 0225} \times \frac{1 \cdot 529^{\frac{2}{3}}}{(6000)^{\frac{1}{2}}} = 0 \cdot 761 \text{ m/s}$$

$$Q'' = A'' \times V'' = 29 \cdot 546 \times 0 \cdot 761 = 22 \cdot 485 \text{ m}^3/\text{s}$$

For $d'''_1 = 1 \cdot 524$ m

$$\text{Area} = A''' = (b_1 + 0 \cdot 5\, d'''_1) \times d'''_1 = (15 \cdot 240 +$$
$$0 \cdot 5 \times 1 \cdot 524) \times 1 \cdot 524 = 24 \cdot 387 \text{ m}^2$$

$$P''' = b_1 + 2 \cdot 236\, d'''_1 = 15 \cdot 240 + 2 \cdot 236 \times 1 \cdot 524$$
$$= 18 \cdot 648 \text{ m}$$

$$R'''_h = A'''/P''' = \frac{24 \cdot 387}{18 \cdot 648} = 1 \cdot 308 \text{ m}$$

$$V''' = \frac{1}{0{\cdot}0225} \times \frac{1{\cdot}308^{\frac{2}{3}}}{(6000)^{\frac{1}{2}}} = 0{\cdot}686 \text{ m/s}$$

$$Q''' = A''' \times V''' = 24{\cdot}387 \times 0{\cdot}686 = 16{\cdot}729 \text{ m}^3/\text{s}$$

From the above sets of discharges Q, Q', Q'', Q''', etc, for the flow of depths of d_1, d'_1, d''_1, d'''_1, etc, respectively, the x in the equation $Q = c_1\, d_1{}^x$ is estimated by least square method as given below:

$$x = \frac{\Sigma \log Q \,.\, \log d_1 - \dfrac{(\Sigma \log Q)(\Sigma \log d_1)}{M}}{\Sigma (\log d_1)^2 - \dfrac{(\Sigma \log d_1)^2}{M}}$$

where

M = the number of sets, which is 4 in present case.

$\therefore\ x = 1{\cdot}615$, say, $1{\cdot}62$.

The height of hump would be estimated for bulk proportionality from Q to Q''', that is, from FSD to about 1/3 FSD.

Hence from the graph in Fig. 3, or from equation (5), height of hump Z is $0{\cdot}05\, d_1 = 0{\cdot}05 \times 3{\cdot}048 = 0{\cdot}1524$ m, say, $0{\cdot}153$ m.

b) *Width of Throat* — Throat width is designed in accordance with **6.2**. Specific energy over the sill $= H = D_1 + h_v = d_1 - Z + h_v$

$$= 3{\cdot}048 - 0{\cdot}153 + \frac{(1{\cdot}005)^2}{15{\cdot}2} = 2{\cdot}961 \text{ m}$$

The discharge formula applicable is:

$$Q = \tfrac{2}{3}\sqrt{\tfrac{2}{3} g}\,.\, C_f\,(B_o - mb - 2\, C_c\, mH)\, H^{1{\cdot}5}$$

Since there are no piers in the flumed throat, above equation is simplified to $Q = \frac{2}{3}\sqrt{2g}\,.\,C_f.B_2 \times H^{1{\cdot}5}$ giving $B_2 = \dfrac{Q}{\frac{2}{3}\sqrt{\frac{2}{3}g}\,.\,C_f.H^{1{\cdot}5}}$

wherein

$C_f = 1{\cdot}00$ given in **7.1**.

$$\text{Hence, } B_2 = \frac{51{\cdot}352}{1{\cdot}705 \times 1 \times 2{\cdot}961^{1{\cdot}5}} = 5{\cdot}913 \text{ m}$$

1) *Verification of adequacy of width of throat* — According to **6.2**, the width of throat should not be less than $1{\cdot}5\, H$.

$\therefore$ Minimum width required $= 1{\cdot}5 \times 2{\cdot}961 = 4{\cdot}442$ m

Width provided $= 5{\cdot}913$ m

$\therefore$ Width of throat provided is adequate.

2) *Verification of drawdown and ponding for smaller discharge*

For $Q' = \frac{2}{3} (\sqrt{\frac{2}{3} g}) C_f . B_2 . H'^{1.5} = 35.793 \text{ m}^3/\text{s}$

$\therefore H'^{1.5} = \dfrac{35.793}{1.705 \times 5.913} = 3.550$

$\therefore H'$, that is, the required head $= 2.327$ m

Corresponding actual head on sill $= d'_1 - Z + h'_v$

$= 2.438 - 0.153 + \dfrac{(0.892)^2}{15.2} = 2.337$ m

Comparing actual head with the required head, drawdown for Q is obtained as $2.337 - 2.327 = 0.010$ m.

Similarly for $Q'' = \frac{2}{3} (\sqrt{\frac{2}{3} g}) C_f . B_2 . H''^{1.5} = 22.485 \text{ m}^3/\text{s}$

$\therefore H''^{1.5} = \dfrac{22.485}{1.705 \times 5.913} = 2.230$

$\therefore H''$, that is, head required $= 1.707$ m

Actual head on sill $= d''_1 - Z + h''_v = 1.829 - 0.153 + \dfrac{(0.761)^2}{15.2}$

$= 1.714$ m

Comparing actual head with the required head, drawdown for Q'' is obtained as $1.714 - 1.707 = 0.007$ m.

For $Q''' = \frac{2}{3} (\sqrt{\frac{2}{3} g}) C_f . B_2 . H'''^{1.5} = 16.729 \text{ m}^3/\text{s}$

$\therefore H'''^{1.5} = \dfrac{16.729}{1.705 \times 5.913} = 1.659$

$\therefore H'''$, that is, head required $= 1.402$ m

Actual head on sill $= d'''_1 - Z + h'''_v = 1.524 - 0.153 + \dfrac{(0.686)^2}{15.2}$

$= 1.402$ m

Comparing actual head with the required head afflux for Q''' is obtained as $1.402 - 1.402 = 0.000$ m. Since the drawdown and afflux are negligible, the height of hump and width of throat as estimated above are considered satisfactory.

c) *Length of Throat*

Referring to **6.2**,

$L_2 = 2.5\ H = 2.5 \times 2.961 \text{ m} = 7.403 \text{ m}$

d) *Inlet Transition*

Referring to **6.1.1**,

Radius of side walls $= 3{\cdot}6\,H^{1{\cdot}5} = 3{\cdot}6 \times 2{\cdot}961^{1{\cdot}5} = 18{\cdot}338$ m

This curvature is to be continued till it subtends an angle of 60°. Further, onwards, it should be continued tangentially to meet the sides of the channel upstream. In the present case, however, the curved walls meet the sides of channel when it subtends an angle of 50°. It is, therefore, not necessary to continue the walls further (*see* Fig. 6).

The length of inlet transition may now be found out knowing B_1, B_2 and the radius of bell mouth entrance R using the relation

$$L_1 = \sqrt{\left(2R - \frac{B_1 - B_2}{2}\right)\left(\frac{B_1 - B_2}{2}\right)} = 12{\cdot}192 \text{ m}$$

$$\therefore \text{ Radius of curvature of hump } r_h = \frac{L_1^2 + Z^2}{2Z}$$

$$= \frac{(12{\cdot}192)^2 + (0{\cdot}153)^2}{2 \times 0{\cdot}153} = 485{\cdot}844 \text{ m}$$

The total head is much more as compared to the hump height and hence the curvature is too flat according to **6.1**. The hump should, therefore, be joined by a straight line to the channel bed on the upstream as specified in **6.1**.

e) *Glacis* — The slope of glacis downstream of throat is fixed referring to **6.4.1**.

Horizontal projected length of glacis $= 4\,H = 4 \times 2{\cdot}961 = 11{\cdot}844$ m

Since 80 percent recovery of head is required and channel section on the upstream is equal to channel section on the downstream, the fall in head and also in bed level is estimated as below:

Loss of head $= 0{\cdot}2\,H =$ fall in water level $=$ fall in bed level.

$\therefore$ Bed level on the downstream $=$ bed level on the upstream $- 0{\cdot}2\,H$

$= 30{\cdot}480 - 0{\cdot}2 \times 2{\cdot}962 = 29{\cdot}888$ m

Since the toe of glacis is at bed level of canal on the downstream, the height of hump above toe of glacis

$=$ bed level of upstream channel $+ Z -$ bed level of downstream channel

$= 30{\cdot}480 + 0{\cdot}153 - 29{\cdot}888 = 0{\cdot}745$ m

$20 \times$ height of hump above downstream glacis $= 20 \times 0{\cdot}745$
$= 14{\cdot}900$ m

$4\,H = 11{\cdot}844$ m

Since $4\,H < 20$ times height of hump above glacis, the slope of glacis is kept at 1 in 20 for length of $2\,H$

Slope 1 in 20 for $2 \times 2{\cdot}961 = 5{\cdot}922$ m

Hence fall in length of $2\,H = 5{\cdot}922/20 = 0{\cdot}296$ m

Difference between the height of hump above toe of glacis and the fall in length of $2\,H = 0{\cdot}745 - 0{\cdot}296 = 0{\cdot}449$ m

The difference is to be negotiated in the remaining length of $2\,H$.

Hence slope of glacis in the remaining length $\dfrac{0{\cdot}449}{2\,H} = \dfrac{0{\cdot}449}{5{\cdot}922}$, that is, 1 in 13·189.

f) *Expansion* — The sides would be given hyperbolic expansion in a length of $4\,H$, following equation given in **6.4.1**.

Width at throat $= B_0 = 5{\cdot}913$ m

Hence B_{y_1} at $y_1 = H$ is $\dfrac{5{\cdot}913 \times 15{\cdot}240 \times 11{\cdot}844}{11{\cdot}844 \times 15{\cdot}240 - (15{\cdot}240 - 5{\cdot}913) \times 2{\cdot}961}$

$= 6{\cdot}981$ m

B_{y_2} at $y_2 = 2\,H$ is $\dfrac{5{\cdot}913 \times 15{\cdot}240 \times 11{\cdot}844}{11{\cdot}844 \times 15{\cdot}240 - (15{\cdot}240 - 5{\cdot}913) \times 2 \times 2{\cdot}961}$

$= 8{\cdot}520$ m

B_{y_3} at $y_3 = 3\,H$ is $\dfrac{5{\cdot}913 \times 15{\cdot}240 \times 11{\cdot}844}{11{\cdot}844 \times 15{\cdot}240 - (15{\cdot}240 - 5{\cdot}913) \times 3 \times 2{\cdot}961}$

$= 10{\cdot}930$ m

B_{y_4} at $y_4 = 4\,H$ is $\dfrac{5{\cdot}913 \times 15{\cdot}240 \times 11{\cdot}844}{11{\cdot}844 \times 15{\cdot}240 - (15{\cdot}240 - 5{\cdot}913) \times 4 \times 2{\cdot}961}$

$= 15{\cdot}240$ m

g) Cistern, control blocks and deflector are not provided (*see* **6.4.1**).

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002

Telephones: 331 01 31, 331 13 75 — Telegrams: Manaksanstha (Common to all Offices)

Regional Offices:		*Telephone*
Central	Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002	331 01 31 331 13 75
*Eastern	1/14 C. I. T. Scheme VII M, V. I. P. Road, Maniktola, CALCUTTA 700054	36 24 99
Northern	SCO 445-446, Sector 35-C, CHANDIGARH 160036	2 18 43 3 16 41
Southern	C. I. T. Campus, MADRAS 600113	41 24 42 41 25 19 41 29 16
†Western	Manakalaya, E9 MIDC, Marol, Andheri (East), BOMBAY 400093	6 32 92 95

Branch Offices:	
'Pushpak', Nurmohamed Shaikh Marg, Khanpur, AHMADABAD 380001	2 63 48 2 63 49
‡Peenya Industrial Area 1st Stage, Bangalore Tumkur Road BANGALORE 560058	38 49 55 38 49 56
Gangotri Complex, 5th Floor, Bhadbhada Road, T. T. Nagar, BHOPAL 462003	6 67 16
Plot No. 82/83, Lewis Road, BHUBANESHWAR 751002	5 36 27
53/5, Ward No. 29, R.G. Barua Road, 5th Byelane, GUWAHATI 781003	3 31 77
5-8-56C L. N. Gupta Marg (Nampally Station Road), HYDERABAD 500001	23 10 83
R14 Yudhister Marg, C Scheme, JAIPUR 302005	6 34 71 6 98 32
117/418 B Sarvodaya Nagar, KANPUR 208005	21 68 76 21 82 92
Patliputra Industrial Estate, PATNA 800013	6 23 05
T.C. No. 14/1421, University P.O., Palayam TRIVANDRUM 695035	6 21 04 6 21 17

Inspection Offices (With Sale Point):	
Pushpanjali, First Floor, 205-A West High Court Road, Shankar Nagar Square, NAGPUR 440010	2 51 71
Institution of Engineers (India) Building, 1332 Shivaji Nagar, PUNE 411005	5 24 35

*Sales Office in Calcutta is at 5 Chowringhee Approach, P. O. Princep Street, Calcutta 700072 — 27 68 00

†Sales Office in Bombay is at Novelty Chambers, Grant Road, Bombay 400007 — 89 65 28

‡Sales Office in Bangalore is at Unity Building, Narasimharaja Square, Bangalore 560002 — 22 36 71

Reprography Unit, BIS, New Delhi, India