ERJ
Engineering Research Journal
Faculty of Engineering
Minoufiya University

EFFECT OF MOUTHPIECE LENGTH AND POSITION ON THE DISCHARGE COEFFICIENT

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ABSTRACT

This research investigates experimentally the different lengths, positions and direction of mouthpieces to determine the value of the corresponding discharge coefficient (C_d) in order to specify the orifice characteristics that can be properly implemented in the field of irrigation. The experiments were carried out in the Hydraulic Research Institute in a two sided glass flume (40 m long, 0.4 m wide and 0.6 m deep). 126 runs were executed during which the length and position of the mouthpiece were varied. The tested lengths, with respect to the orifice diameter, were 0.5d, 1d, 1.5d, 2d, 3d, 4d and 5d, while the tested positions of mouthpieces were fitted either internally (opposite to the flow direction) or externally (along the flow direction). Supplementary tests (36 tests) were carried out for determining the discharge coefficient of the orifice (without mouthpieces) to act as a reference to the results using mouthpieces. The discharge was varied from 5 to 13 l/s with increment of 1 l/s. Measurements were carried out using point gauges, ultrasonic flow-meter, current meters and a digital camera to monitor the flow inside and outside the tested mouthpieces.

The results were analyzed and represented. The results revealed that increasing the throat length results in decreasing the loss coefficient to a certain limit after which "C_d" becomes constant. Also, the results proved that the discharge coefficient in the case of an internal mouthpiece is less than that of the case of an external mouthpiece as the separation increases. It was also found that lowering the mouthpiece under the free surface causes the increase in the head (H) which produces more losses.

يعرض البحث نتائج دراسة عملية عن تأثير الأطوال والمواضع المختلفة للبزباز (mouthpiece) علي قيمة معامل التصرف "C_d" وذلك للحصول على أعلى تصرفات. يتناول البحث أيضا نتائج دراسة تأثير مكان الفتحه الرأسي بالنسبه لسطح المياه ومنسوب القاع، إ تجاه الفتحه سواء كانت فى نفس إتجاه السريان أو عكسه وتأثير نسبة الضاغط الأمامي إلى الضاغط الخلفى على قيمة معامل التصرف"C_d" . تم هذا البحث بمعمل معهد بحوث الهيدروليكا بمجرى إختبار زجاجى بطول ٤٠م وعرض ٠,٤ م وعمق ٠,٦م . تم إجراء ١٢٦ تجربه تم خلالها تغيير أطوال وإتجاه ومنسوب البزباز لحساب مقدار الفاقد بطريقة دقيقة . تم تغيير أطوال البزباز بالنسبه لقطره والتي تراوحت من نصف القطر إلى خمسة أمثال القطر. تم إجراء ٣٦ تجربه إضافيه على فتحه بدون بزباز لمقارنة قيمة معامل التصرف مع مثيلاتها عند الأطوال المختلفه للبزباز. تم تغيير وضع البزباز ليكون مرة خارجية (فى نفس إتجاه السريان) ومرة داخلية (عكس إتجاه السريان) عند تصرفات مختلفة تبدأ من ٥ لتر/ث إلى ١٣ لتر/ث بزيادة ١ لتر/ث خلال كل تجربه . تم استخدام أحدث الأجهزة لقياس السرعات والتصرفات والأعماق مثل مقياس الأعماق ، جهاز قياس التصرفات ، عداد السرعه وكاميرا رقمية وأيضا كاميرا فيديوا لمتابعة شكل الإنسياب داخل وخارج الفتحة .

تم تحليل وتمثيل نتائج القراءات والتى أوضحت أن زيادة طول البزباز يؤدى إلى تقليل معامل التصرف حتى قيمة معينة لتصبح بعد ذلك ثابته بينما إستخدام البزباز الداخلي يؤدى إلى زيادة الفواقد نظرا لزيادة انفصال الإنسياب كما أثبتت أن وضع البزباز أسفل سطح المياه يؤدى إلى زيادة الفاقد وأن النسبة بين الضاغط الأمامي إلى الضاغط الخلفى تتأثر بمقدار التصرفات وأطوال وأرتفاع وأوضاع البزباز .

Keywords: Mouthpiece, Discharge Coefficient, Physical Model, Calibration, Separation, Losses.

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1. INTROUDUCTION

Mouthpieces have many applications in irrigation and drainage systems in Egypt. Among these applications are irrigation sprinklers and pressurized irrigation and some drainage systems. In most of the cases the system faces one main problem which is the deficiency of supplying the required designed discharge. This is due to the fact that the coefficient of discharge "C_d" is somehow small. This coefficient is defined as the ratio between the actual discharge and the theoretical discharge which is expressed as follows:

$$\boxed{C_d = \frac{Q_{act}}{Q_{th}} = \frac{Q_{act}}{A_o \sqrt{2gH}}}$$

Where:

C_d	discharge coefficient	(–)
Q_{act}	actual discharge	(m^3/s)
Q_{th}	theoretical discharge	(m^3/s)
A_o	area of mouthpiece ($\pi d^2/4$)	(m^2)
G	acceleration due to gravity	(m/s^2)
H	distance from mouthpiece center to water surface	(m)
D	mouthpiece diameter	(m)

In order to enhance the efficiency of any hydraulic system, this coefficient is desired to be close to one "1". That means it is required to make the actual discharge "Q_{act}" very close to the value of the theoretical discharge "Q_{th}".

Many researches were carried out worldwide to investigate the discharge coefficient of the orifice and mouthpiece. These researches focused on evaluating the discharge coefficient of the mouthpiece shapes and cross sections. Most of these researches just conducted experiments on mouthpiece lengths from 2 to 3 the mouthpiece diameter. Moreover, they did not take into consideration two important factors; **the first** is the effect of position level with respect to the water free surface and **the second** is the mouthpiece direction whether it was along the flow direction or opposite to it. This current research involved also the effect of the mouthpiece lengths on the ratio of upstream head to the downstream head ($H_{U/S}/H_{D/S}$). The length was taken as a ratio with the diameter and also most output results were taken as a ratio (dimensionless) to facilitate applying these results for any different diameter or length.

This research was thus initiated to investigate the effect of various factors affecting the discharged quantities from mouthpieces in order to specify the orifice characteristics that can be properly implemented in the field of irrigation. Different mouthpieces were tested varying their lengths, directions, and position from the water surface. 126 runs were executed during which the length and position of the mouthpiece were varied. The tested lengths, with respect to the orifice diameter, were 0.5d, 1d, 1.5d, 2d, 3d, 4d and 5d, while the tested positions of the mouthpieces were fitting them either internally (opposite to the flow direction) or externally (along the flow direction). The discharge was varied from 5 to 13 l/s with an increment of 1 l/s.

The investigation phases are presented in this paper under the following topics:

- Experimental work
- Executed measurements
- Analyses and results
- Conclusion

2. EXPERIMENTAL WORK

As a preparation to the experimental work, a testing flume in the Hydraulic Research Institute (HRI) was prepared to calibrate the measuring devices (flow-meters, current-meters, point gauges and the water pump). The preparation was also to adjust the flume slope, water depth, and flow velocity at the downstream.

2-a. Description of the Flume

The flume, used for the present investigation, has a rectangular cross section with total length 40.0 m, 0.6 m height, and 0.4 m width. It has glass sheets of 1.10 m×0.6 m, and 6 mm thickness, photos (1) to (7). The flume is placed over a concrete base 0.8 m high. A rectangular sluice gate is fixed at 13.5 m apart of the end of the entrance channel. This sluice gate can be manually operated up and down to pass different discharges at different gate openings. A movable tail gate is located at the end of the flume so as to control the tail water depth of the flume.

A plate of wood is placed at a distance of 7.0 m away from the inlet of the flume with the following dimensions (0.6mx 0.4m x 0.01m). An orifice of 10 cm diameter in the plate was made at a height of 20 cm above the bed.

An exact description to the flume parts, Fig. (1) and photo (1), is given as follows:

- **The Flume Inlet** consists of masonry to receive the delivered water from the centrifugal pump through a pipe line that dissipates the energy of the flow to enter the model to avoid any disturbance of flow in the flume, Photo (2).
- **Deceleration plate:** the water passes through a deceleration movable plate (1.0m x 0.33m) that makes the flow to be steady without any disturbances.
- **Rectangular Sluice Gate:** It is used for controlling the water, Photo (3).
- **Tailgate** (0.4 x0.4): it was installed at the downstream end of the flume to control the

downstream tail water depth and to control water.

- **The Flume Outlet:** The flume outlet consists of a basin that starts directly at its end followed by a tail control gate to adjust the water levels in the model, Photo (4).

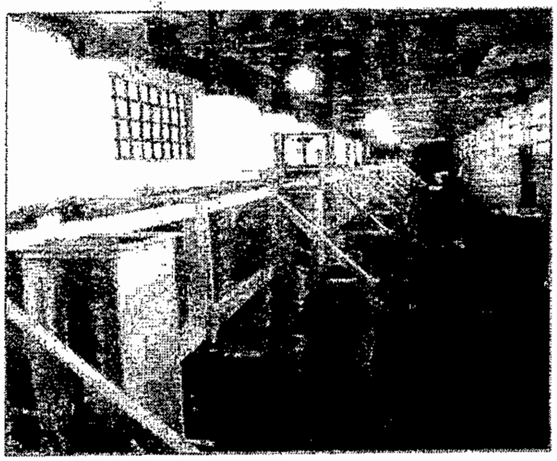

Photo (1). General Photo of the Flume

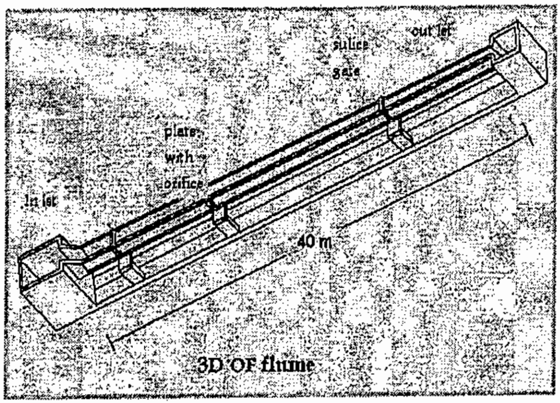

Figure 1. Cross-Section of the Flume

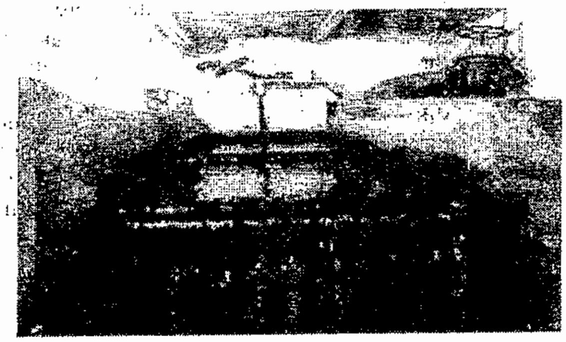

Photo (2) Flume Inlet

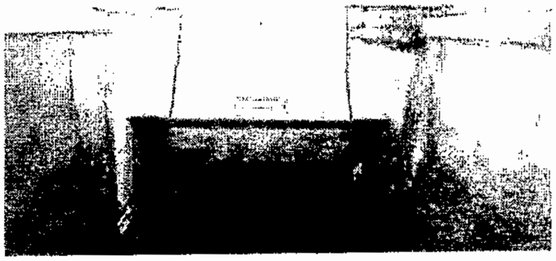

Photo (3) Control Gate

Photo (4) Flume Outlet

Photo (5) Feeding Water Pump

2-C. Experiment Procedure

During each run, the discharge was adjusted and determined using an ultrasonic flow meter. The upstream head H_t is firstly adjusted, then the downstream head H is adjusted. The length of mouthpiece is changed as a function of the diameter L = f (d), Figs. (2) and (3). The water velocity is measured using a current meter and is compared to the calculated values. The Froude number F_r and C_d are calculated. This was achieved 126 times to every mouthpiece length, discharge, water level and mouthpiece direction, Photos (6) and (7).

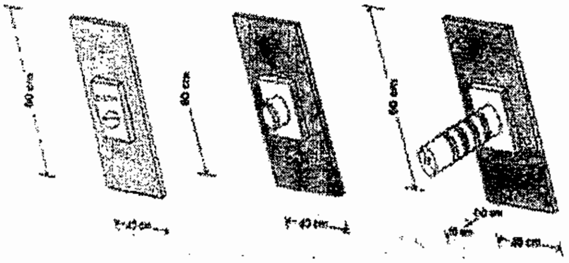

Figure 2. Cross-Sections of Different Mouthpiece Lengths

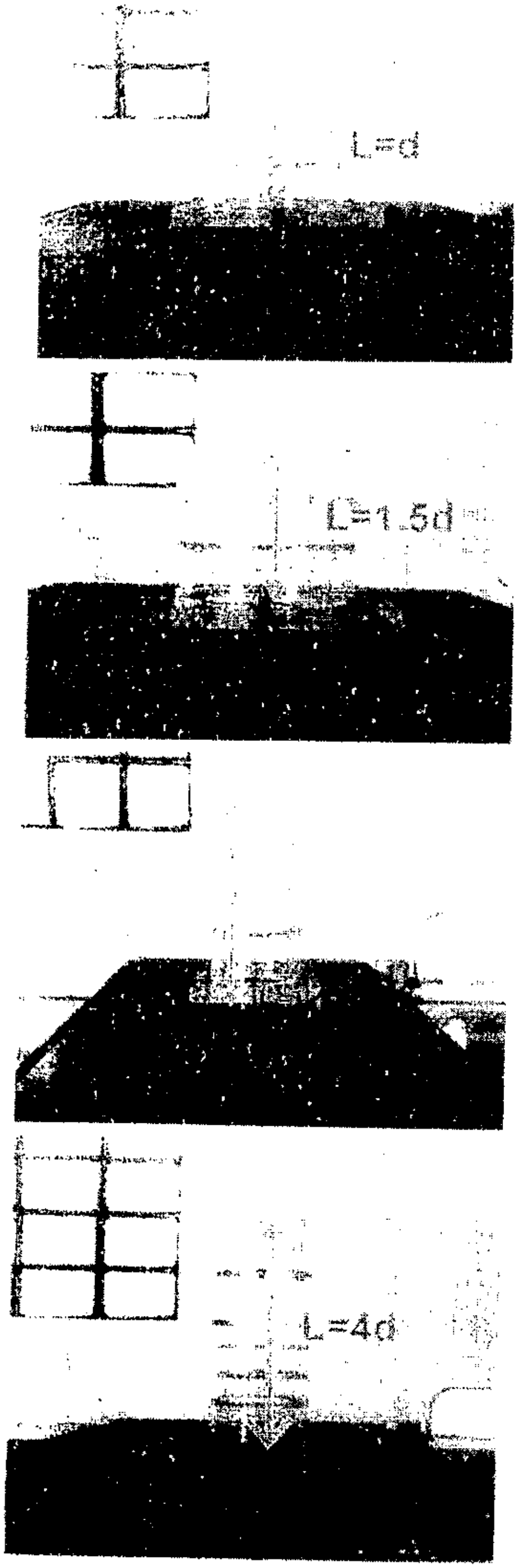

Photo (6) Different lengths of Transparent Mouthpieces

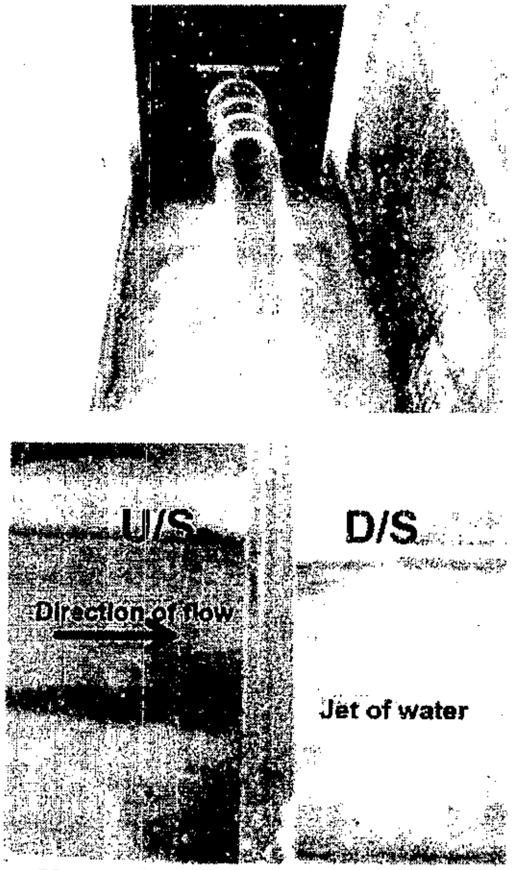

Photo (7) Monitoring the Flow at External Mouthpieces

3. TEST PROGRAM AND EXECUTED MEASUREMENTS

The test program was planned to check the different values of discharge coefficient at different operation conditions. Therefore, 126 runs were executed during which the length and position of the mouthpiece were varied. The tested lengths, with respect to the orifice diameter, were 0.5d, 1d, 1.5d, 2d, 3d, 4d and 5d, while the tested positions of mouthpieces were fitting them either internally (opposite to the flow direction) or externally (along the flow direction). The discharge was varied from 5 to 13 l/s with an increment of 1 l/s.

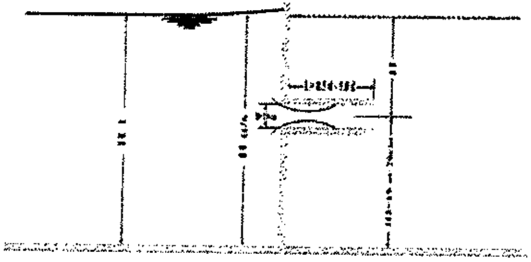

Figure 3. Mouthpiece with sharp entrance

4. TEST RESULTS

The measurements were analyzed and graphically represented. A sample of the measurements is given in figures 4 to 11.

These measurements were conducted at discharges that ranged between 5 l/s and 13 l/s with an increment of 1 l/s at a head of (H) = Hu/s – 20 cm, external pipe orifice at a head of (H) = Hu/s –15 cm, internal pipe orifice at a head of (H) = Hu/s – 20 cm, and internal pipe orifice at a head of (H) = Hu/s – 15 cm. The presented sample figures are at flowing discharges of 7 l/s and 13 l/s at different mouthpiece directions and positions of the mouthpiece.

As for the produced graphs, a sample is given on Figs. (4) to (11). They show the results of one test series that was investigated for the external pipe direction and internal pipe direction at a head of (H) = Hu/s – 20 cm and (H) = Hu/s – 15 cm at flowing discharges 7 l/s and 13 l/s.

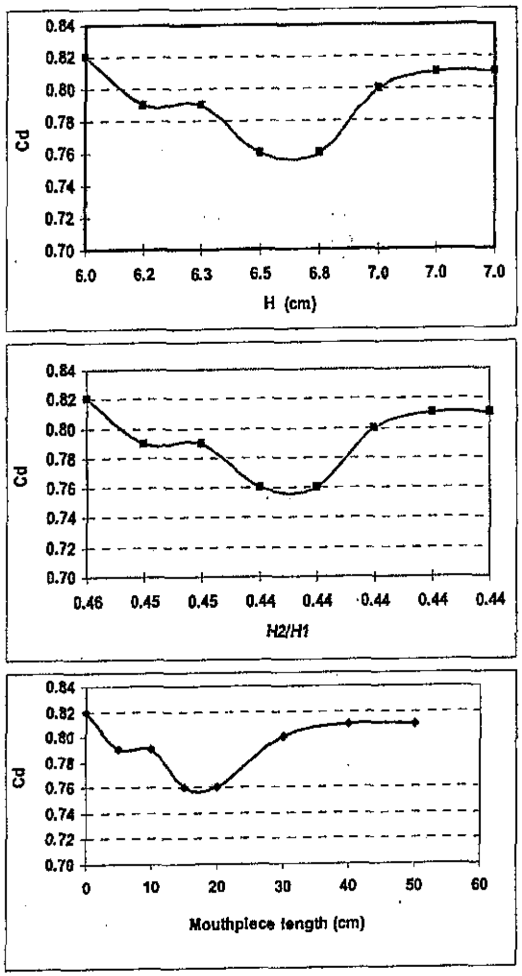

Figure 4. Effect of H, L & H_2/H_1 on C_d (External Mouthpiece -Q= 7 L/S-{H = HU/S – 20 }

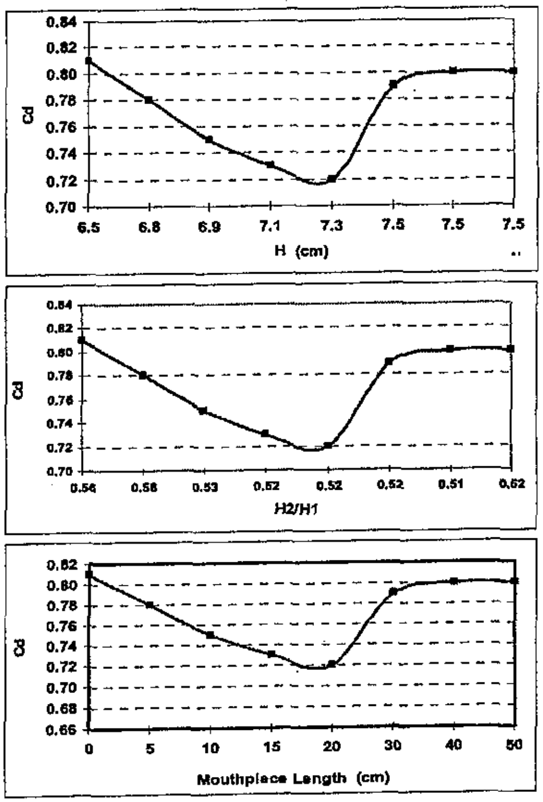

Figure 5. Effect of H, L & H_2/H_1 on C_d (External Mouthpiece - Q= 7 L/S-{H = HU/S– 15 }

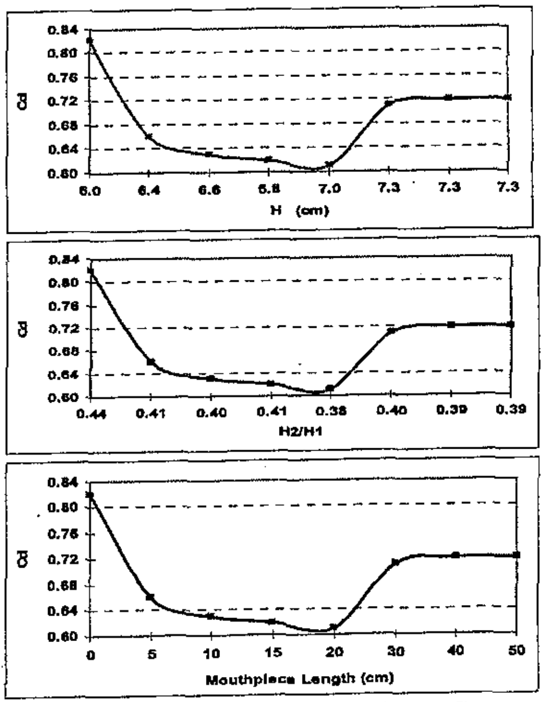

Figure 6. Effect of H, L & H_2/H_1 on C_d (Internal Mouthpiece -Q= 7 L/S -{H = HU/S– 20 }

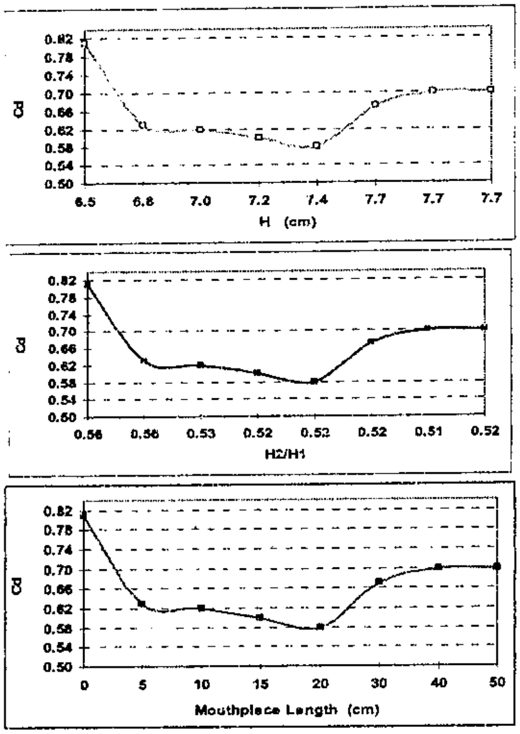

Figure 7. Effect of H, L & H_2/H_1 on C_d
(Internal Mouthpiece -Q= 7L/S - {H = HU/S – 15 }

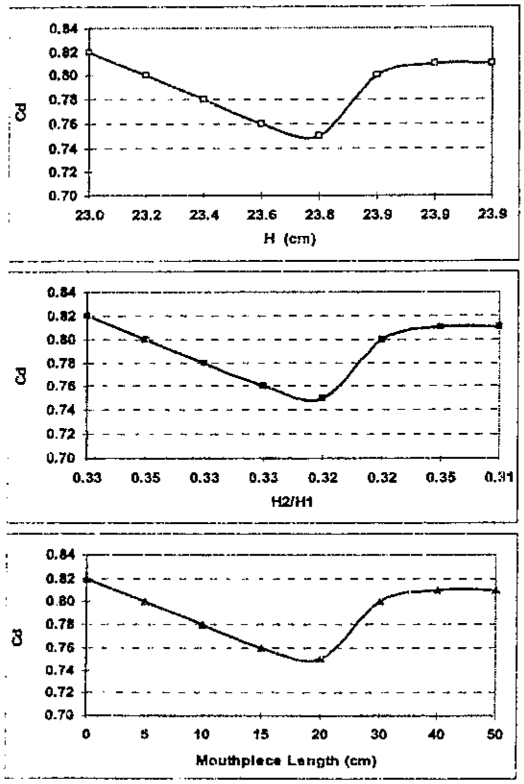

Figure 8. Effect of H, L & H_2/H_1 on C_d
(External Mouthpiece -Q= 13L/S-{H= HU/S –20}

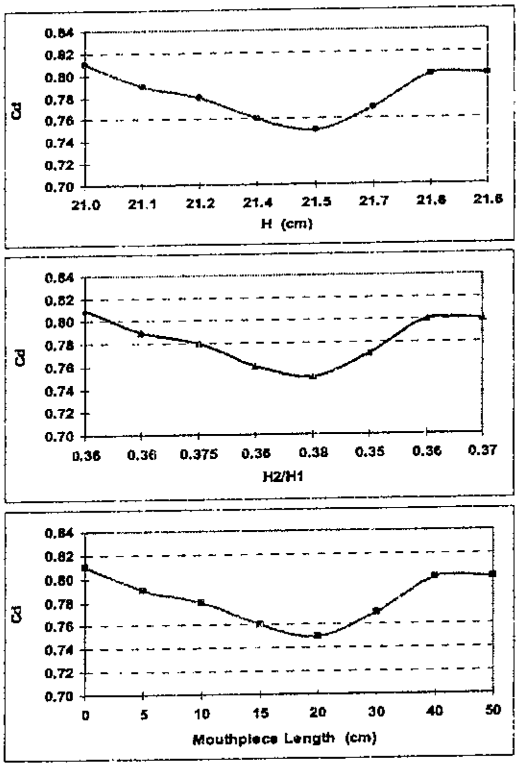

Figure 9. Effect of H, L & H_2/H_1 on C_d
(External Mouthpiece -Q= 3L/S-{H= HU/S–15}

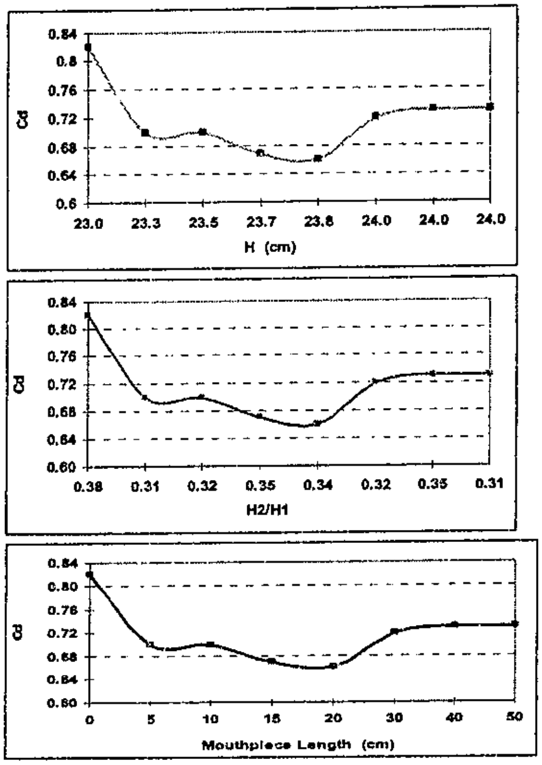

Figure 10. Effect of H, L & H_2/H_1 on C_d
(Internal Mouthpiece-Q=13L/S-{H = HU/S–20}

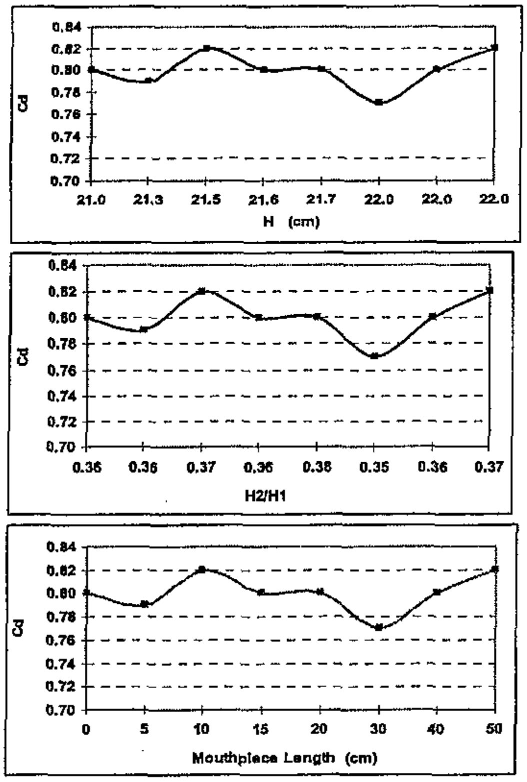

Figure 11. Effect of H, L & H_2/H_1 on C_d (Internal Mouthpiece- Q=13L/S-{H =HU/S–15}

5. CONCLUSIONS

From the experimental work, the following was concluded:

- As the length of the mouthpiece increases, the discharge coefficient (C_d) decreases till a limit after which it becomes constant.
- Using internal mouthpieces increases the losses in case of using external mouthpieces due to the fact that the separation increases.
- Using internal mouthpieces, the discharge coefficient (C_d) is less with about 20%.
- Increasing discharge leads to decreasing H_2/H_1.
- Lowering the orifices under free surface induces higher losses.
- Lowering the orifices under free surface results in decreasing HU/S and increasing H_2/H_1.
- HU/S /HD/S are affected by the discharge, the length, the height and direction of the mouthpiece.

6. BIBLIOGRAPHY

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