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# Analysis of the Performance of Hydraulic Structures

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**Abstract:** The aim of this research is the study of hydraulic structures. Hydraulic structures in irrigation networks are divided into two parts, Flow control structures and water level control structures. The irrigation and drainage network of Moghan covers a net area of 72,000 hectares. Neyrpic modules are some of the most important flow measurement tools that are used in Moghan irrigation network. These modules are built in the form of duckbill weirs as discharge regulator structures and water level regulator structures. In order to study these structures, we had to simultaneously study water level control structures in Moghan network. Therefore, we selected and evaluated a number of duckbill weirs together with Neyrpic valves in Parsabad irrigation area which is one of the 4 areas of the great irrigation network of Moghan. Additionally, we studied the mechanism of action of these structures in measurement. Discharge rate was measured using a WSC flume in two cases of variable and constant upstream level. Error magnitude of Neyrpic gates, operating in free and submerged downstream level conditions, were determined and calibration and discharge coefficient curves were produced.

**Key words:** Hydraulic Structures · Canal · C coefficient · Calibration

## INTRODUCTION

A correct utilization plan not only saves water, but also leads to decreased personnel costs and other expenses. In modern irrigation networks, we expect a high level of performance and inaccuracy in regulation and delivery of water can lead to decreased performance. In designing control structures for irrigation networks, in addition to technical and hydraulic issues, the general culture of the region should be taken into account.

In improvement of Moghan irrigation and drainage network, elimination of cross regulator checks and building duckbill weirs seems to be useful for exploitation and leads to a decrease in social problems and manipulation of the gates. On the other hand, installation of Neyrpic valves, even though favorable from the hydraulic point of view, brings about social problems related to manipulation of these structures.

In improvement of irrigation networks, modification of intake system and control of water level should be kept in mind in regard to loss of energy, so that any energy loss due to modification is somehow compensated. For example, in Moghan irrigation network, the energy loss due to changing sliding gate valves to Neyrpic valves was compensated by elevation of secondary canals. As it was mentioned before, the proper performance of an irrigation network is based on the correct selection of the control structures. Also in Moghan irrigation and drainage network, accurate delivery and fair distribution of water is one of the most important duties of the network utilization management. In order to accomplish this important task, we need to have flow measurement structures with an acceptable accuracy. Moreover, utilization and proper maintenance of these structures, application of their interrelationships for proper volumetric delivery of water to users and subscribers of the network according to public policies of the government in accordance with the optimal water consumption regulations are some of the most important objectives of the network.

United Nation Office of Technical Cooperation has done researches in the field of intakes procedure, on the basis of the results, it was specified that suspended material in water and their combination, changing and vacillating the water level in water supply reservoir and expected accuracy degree of sensitivity of intakes are effective for choosing intake types [1]. Ghamarnia [2] after research on several irrigation network of Iran concerning the selection method of intake structures suggested that "due to the lack of reliable power resources and also the

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changeable scales for operating of equipment, it is recommended to use a durable system with least need for recording, maintaining and operating skill instead of an automatic system.By surveying Qazvin irrigation network, Bouchali Safiee [3] found that because of full automatic and semi automatic performance of water distribution at network with amil gates, it will be probable with putting additional weight and other obstacles these gates will exit in initial adjusting situation and is changed in crossing discharge. Montazer and Kouchakzadeh [4] had worked on different relations of hydraulic sensitivity of Neyrpic-Modules and prepared characteristics of rating curves in basis of the field data, for sensitivity study during the operating periods. They expressed that hydraulic sensitivity in Neyrpic-Modules at local situations is more than present in the typical curves.

Monem [5] studied various types of Neyrpic gates in conditions of stable and unstable flow and produced their mathematical model and discharge-level curves. Mina Behzadinasab *et al.* [6] studied Neyrpic measurement modules and their calibration in irrigation and drainage networks of Evan Plain and North East Ahvaz and investigated current problems. They calibrated the gates in this study using the current meter. Azim Shirdeli and Mahmud Shafai Bajestan studied the discharge coefficient in rectangular orifices under submerged and free conditions. In this study, they built a laboratory model and found a relationship for discharge coefficient as a function of the difference of between upstream and downstream water levels and the gate width [7].

Mahmud Bina and Tarokh Ahmadi [8] studied the *Cd* coefficient in rubber dams using a physical model and extracted linear and non-linear equations for estimation of discharge coefficient.

## MATERIALS AND METHODS

**Description of Neyrpic Module:** The Neyrpic module was designed to allow the passage of an almost constant flow from an irrigation canal in which the variation of the water level is restricted. The structure consists of a fixed weir sill with a 60-degree sloping upstream face and a 12-degree sloping downstream face. The weir crest is rounded, its radius equal to $0.2h_d$ where $h_d$ is the design head. Above the weir either one or two steel plates are fixed in a well defined position. These sloping (35-degree) sharp-edged plates cause an increase of contraction of the outflowing jet when the upstream head increases. The "near constant" orifice discharge per unit width is a function of the height of the inclined blade above the weir. Since this height cannot be altered the only way to regulate flow is to combine several orifices of different widths into one structure. The minimum width of an orifice is 0.05 m which coincides with 0.005 $m^3/s$ for the X1-type module.

Flow through the structure is regulated by opening or closing sliding gates. These gates are locked in place either fully opened or fully closed since partially opened gates would disturb the contraction of the jet. The gates slide in narrow grooves in the 0.01 m thick vertical steel divide plates. The position of the gates should be such that in an opened position the orifice flow pattern is not disturbed. Possible gate positions are shown in Figures 1.

**Essentially Two Types of Modules Are Available:**

**Type X1:** This single baffle module and has a unit discharge of 0.1 *m* 2/*s*

**Type XX2:** This double baffle moudule has two inclined orifice blades, the upstream one having the dual function of contracting the jet at low heads and of acting as a "weir" at high heads. Water passing over the upstream blade is deflected in an upstream direction and causes additional contraction of the jet through the downstream orifice. As a result the discharge through the structure remains within narrow limits over a considerable range of upstream head. The type XX2 has a unit discharge of 0.200 *m* 2.*s*. Details of the module are shown in Figure 1.

At low heads the upper surface is not in contact with the inclined baffle plate and the structure acts as a short-crested weir with rectangular control section. According section 1.10, the head-discharge equation for such a weir reads:

$$Q = C_d C_v \frac{2}{3}\sqrt{\frac{2}{3}g}\, b_c h_l^{1.5} \qquad (1)$$

The discharge coefficient $C_d$ is shown in Figure 2 as a function of the dimensionless ratio $H_l/r$. Since for practical reasons $h_l$ is used instead of $H_l$, the approach velocity coefficient $C_v$ was introduced. The value of $C_v = (H_l/h_l)^{3/2}$ is related to the ratio $C_d h_l b_c/(h_l + P_l) B_l$.

If the weir discharge approximates the design discharge plus 5%, the upper nappe surface touches the inclined baffle plate and orifice flow commences.

With rising head, flow passes through a transitional zone to stable orifice flow.

The modular discharge through an orifice equals

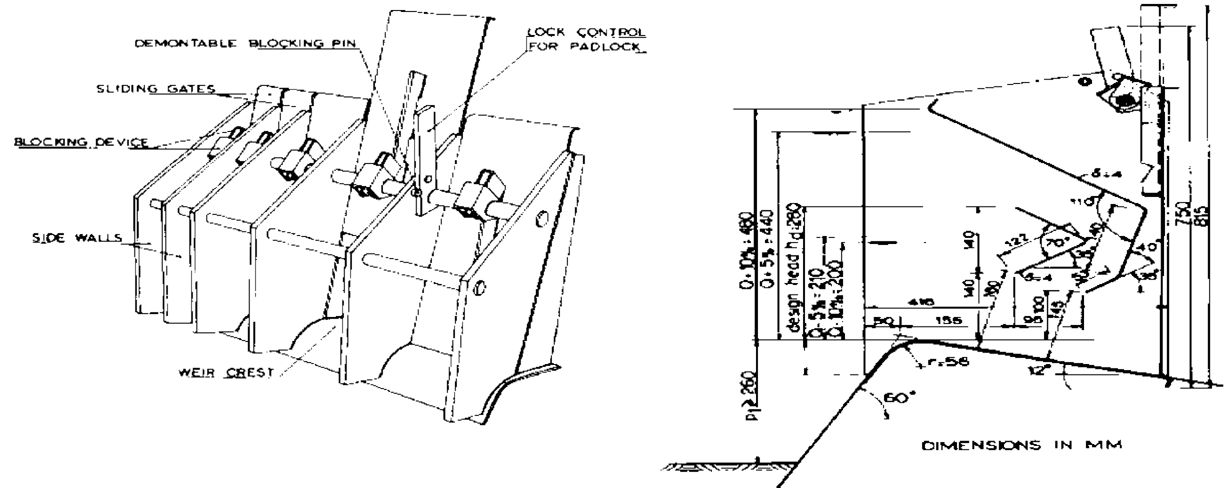


Fig. 1: The Neyrpic module and its operation

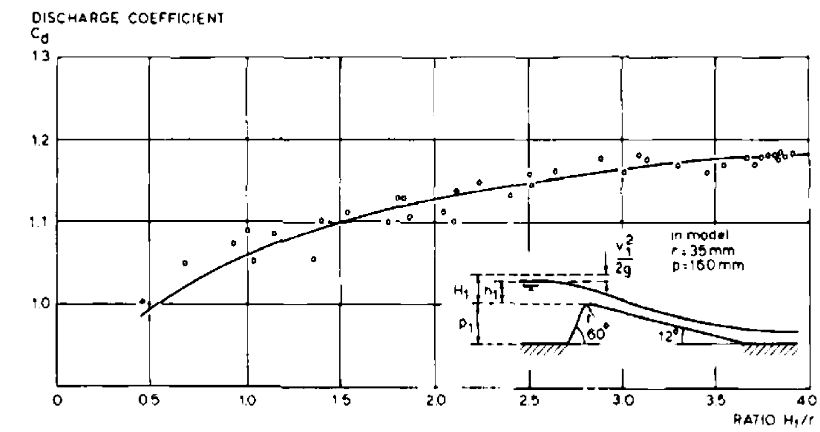


Fig. 2: $C_d$- values as a function of the ratio $H_l/r$

$$Q = C_e A\sqrt{2g\Delta h} \quad (2)$$

Where $C_e$= the effective discharge coefficient which decreases with increasing head due to contraction, A is the area of the orifice and $\Delta\ h$ equals the head over the centre of the orifice.

**Research Method:** In this study, 500 Neyrpic modules in Parsabad irrigation area of Moghan irrigation and drainage network were used for the investigation. First the active Neyrpic gates of this area were inspected physically for proper operation. Then a sample of these measurement structures was selected. The implemented codes were inspected using a total station instrument and were compared with initial design maps. Then they were examined in various flow conditions, including variable and constant upstream. As it was mentioned before, these gates are either completely open or completely closed. Therefore, in order to measure the actual discharge of each gate, its frame was removed and a WSC flume was installed in proper distance for measurement of discharge, so that there was no turbulence in the flow and there was little leak of water. The flume was installed in perfectly horizontal condition using a hand level and its intake and outflow conversion was performed using mud and earth of tertiary canals, so that it did not cause turbulence. Then the level was read and using the appropriate formula, the actual discharge was determined. These procedures were also performed for various capacities. The hydraulic conditions considered in this study were as follows:

- Water level in upstream of Neyrpic module was constant;
- Water level in upstream of Neyrpic module was not constant (variable);
- Cases 1 and 2, where opening was constant and at maximum;
- Cases 1 and 2, where opening was variable.

**Study Area:** Moghan Plain, with an area of 350,000 hectares, is situated in northwestern Iran and west of the Caspian Sea. The presence of Aras River and favorable climatic conditions have made this region into an agricultural hub. Implementation of nomads' settlement policy started in 1931 and construction of the irrigation and drainage networks of Moghan started in 1951. With the gradual completion of the network in three consecutive phases and with completion of the diversion dam of Mil and Moghan, about 72,000 hectares of the intact lands of the plain were exploited for cultivation of agricultural products. The irrigation and drainage network of Moghan includes four irrigation areas, called Aslanduz, Shahrak, Parsabad and Bileh-Savar.

## RESULTS

According to the investigations, there are two types of XX2 Neyrpic gates in Moghan irrigation network. The first type includes gates in which downstream water level is free. The second type includes gates in which downstream water level is submerged.

**Type 1 Gates with Free Downstream:** In gates with free downstream, various hydraulic conditions were examined. First with constant upstream at 10, 20, 30, 40, 50 and 60 L/s.

In the next stage, noting that water level is always fluctuating in the secondary channel during utilization, discharge was increased to elevate water level in the secondary channel and then the actual discharge was measured.

**Type 2 Gates with Submerged Downstream:** Similar to case 1, these gates were examined in constant and variable upstream conditions. First, discharges of 10, 20, 30, 40, 50 and 60 L/s were studied under constant upstream level.

Also in gates with submerged downstream, upstream water level was changed under constant discharge and the effect was investigated.

Table 1 shows the actual discharge model for type 1 and type 2 cases with free and submerged downstream level.

*Cd* coefficient is different for various flow types and conditions. Therefore, *Cd* equations were obtained for various models as shown in Table 1.

## CONCLUSION

In this network, due to the low slope of some tertiary channels and elevation of farming lands, some of the gates operate in submerged state and therefore, they have considerable errors and their accuracy is not acceptable. The accuracy of XX2 Neyrpic modules is better in normal depth and their average error is +7%. When water level is increased due to higher discharge, the accuracy decreases and the error reaches +13%.

In submerged gates, these errors are -43.7% and -52.9%, respectively. This means that the actual discharge of these gates is almost half of their nominal discharge. The actual discharge equations for gates with free and submerged downstream levels in various hydraulic conditions were presented in Table 1. The results show that *Cd* is a function of upstream and downstream water

Table 1: Actual Discharge and $C_d$ Coefficient for free and submerged downstream levels

| Flow type | Upstream level changes (cm) | Discharge model (l/s( and $C_d$) Coefficient | $R^2$ |
|---|---|---|---|
| Type 1 free | 28=h | $Q_r = 1.7218Q_n - 0.8587$ | 0.997 |
| | | $C_d = 0.5865(\frac{b}{h})^{-0.1413}$ | 0.9 |
| Type 1 free | 28≤ $h$ ≤ 36.3 | $Q_r = 0.3323h^2 + 22.55h - 311.01$ | 0.99 |
| | | $C_d = 0.3987(\frac{b}{h}) + 0.1742$ | 0.99 |
| Type 2 submer ged | 22=h | $Q_r = -0.0053Q_n^2 + 0.6844Q_n 1.575$ | 0.957 |
| | | $C_d = -.0004(\frac{b}{\Delta h})^2 + 0.0188(\frac{b}{\Delta h}) + 0.5524$ | 0.98 |
| Type 2 submer ged | 21 ≤ $h$ ≤ 44.6 | $Q_r = 42.75Ln(h) - 105.89$ | 0.98 |
| | | $C_d = -0.0002(\frac{b}{\Delta h})^2 + 0.0206(\frac{b}{\Delta h}) + 0.3667$ | |

$b$ = gate width

$\Delta h$ = difference between upstream and downstream levels

$Q_r$= Actual Discharge

$Q_n$= Nominal discharge

levels and gate width. Consequently, equations for computation of this coefficient were presented as functions of $\frac{b}{h}$ and $\frac{b}{\Delta h}$ in free and submerged conditions, where $h$ is the height of upstream water level and $\Delta h$ is the difference between upstream and downstream levels. $Cd$ varies from 0.5 to 0.77 in free flows and from 0.43 to 0.8 in submerged flows (Table 1).

The Limits of Application of the Neyrpic Module Are:

- To obtain modular flow, the ratio $h_2/h_d$ should not exceed 0.60.
- To prevent the tail water channel bottom from influencing the flow pattern through the orifice, the ratio $p_2/h_d$ should not be less than 0.35.
- Gates should operate with free downstream level. Gates with submerged downstream flow have significant errors and their efficacy is not acceptable.
- The value of $Cd$ = 0.61 for the coefficient is applicable only to water levels of 21–28 cm (upstream elevation relative to the crest). Outside this range, the value of coefficient $C$ is a function of $b$ and $h$.
- In most Neyrpic modules with submerged downstream, the problem of submersion can be solved by elevation of level control structures and Neyrpic modules. In cases where submersion is inevitable, calibration curves should be produced using the presented models and submitted to water distribution agents.

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