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Design and Development of Check Valve for Irrigation Pump

M Maniruzzaman[1*], A K M S Islam[2] and M M Alam[3]

ABSTRACT

Shallow tube wells (STW) are widely operated in Bangladesh to draw groundwater for irrigating the crop field. About 65% of irrigated area is covered by more than 1.3 million STW. However, farmers are facing difficulties in starting STW due to priming problem. Therefore, this study was undertaken to design and develop a *check valve* (CqV)/non-return valve to overcome the priming problem as well as reduce the drudgery of farmers while starting STW. The *check valve* was designed based on the working principles of hand tubewell operating system. Considering the tubewell size of 100 mm, check valve having three diameters of 125 mm, 150 mm, and 175 mm for two-valve fitting lengths of 150 mm and 225 mm based on the flange or thread joint were fabricated using locally available material at Bangladesh Rice Research Institute (BRRI) research workshop. *Check valves* were tested at the field level in different locations of Bangladesh. The results revealed that the field performance of *check valve* overcame the priming problem, made easy starting and reduced the drudgery of farmers. The best performance was found when the diameter of the *cheque valve* was at least 50 mm over the size of tube well and the minimum length was 150 mm. The installation of *check valve* could not create any adverse effects on tube well discharge and engine revolution per minute (RPM). It could successfully reduce the starting time and facilitate the easy use of plastic pipe/ polythene pipe, which reduces the water conveyance loss and pumping hours.

Key words: Priming, groundwater, irrigation, shallow tubewell, priming, drudgery, discharge, impeller revolution

INTRODUCTION

Bangladesh agriculture and its national economy are depending upon groundwater irrigation. The net cultivated area was 8.25 million hectares (ha) in 1971, of which only 3% area was irrigated by groundwater (BBS, 2000). In 2018-19, about 5.59 million ha of land is irrigated, of which about 73 percent are served by groundwater (BADC, 2020). At present, Bangladesh has about 8.55 million ha of net cultivable land of which about 65% is irrigated by 13,57,532 shallow tube wells (STWs), 37,634 deep tube wells (DTWs), 1,87,188 low lift pumps (LLPs) and other traditional methods (BADC, 2020). Within the total irrigated area, surface water covers only about 26.9%, though it is a riverine country and groundwater covers about 73.1% (BADC, 2020) and thus groundwater irrigation plays a crucial role in Bangladesh and the national economy. In groundwater irrigation, STW contributes about 73.3%. In the farmers field, STW is more popular than DTW, because of its low installation and maintenance costs as well as ease of operation. Both, DTWs and STWs, generally pump from the same aquifer, but because of larger investment cost and complex operation and management, the number of active DTWs has steadily declined after privatisation (Mondal and Saleh, 2003). Besides, farmers are facing difficulties in STW operation due to its *priming* problem. Priming is an activity by which STW's suction pipe and pump filled with water. It is a challenging task for the farmers. At each starting time of STW, minimum two-person are needed. One person removes the air by pumping hand tubewell attached to the delivery pipe of the pump and another person closes the outlet pipe with a piece of wood and mud. In the peak irrigation period, it needs to be started STW 2-3 times a

[1]Principal Scientific Officer, Irrigation and Water Management Division; [2]Principal Scientific Officer, Farm Machinery and Post Harvest Technology Division; [3]Senior Scientific Officer, Irrigation and Water Management Division, Bangladesh Rice Research Institute, Gazipur 1701, Bangladesh
*Corresponding author's Email: mzamaniwm@yahoo.com (M Maniruzzaman)

day. This may be frequent in electrically operated pumps for uncertain power dropping.

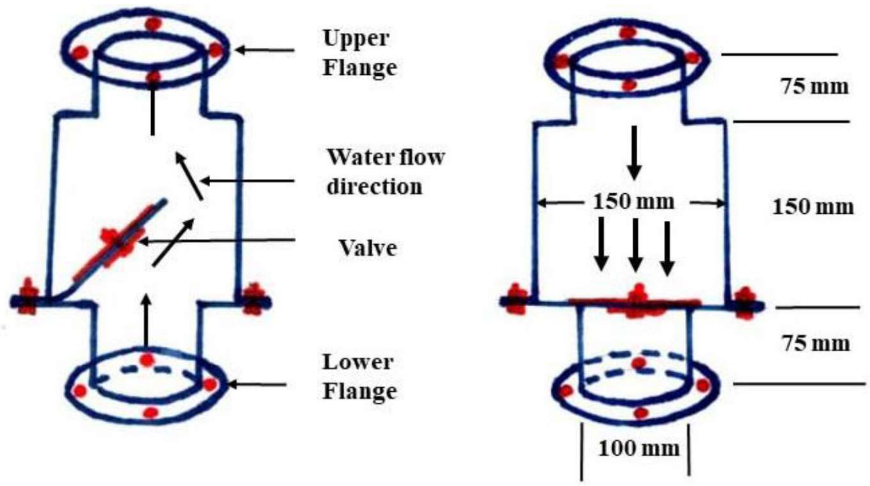
Earthen open channels are common in minor irrigation distribution systems. These channel distribution systems suffer from low conveyance and, application efficiencies, less area coverage and high maintenance cost. The open channel distribution system occupies 2 to 4% of the cultivable land (Michael, 1987) and confronts some physical obstructions such as natural drainage channels or *khals*, embankment or road, high land, irregular or fragmented topography and, permeable soils. These obstructions cause high seepage and percolation losses, leakage, and evaporation losses and right of way problem to the canals. High water loss depends upon the soil texture is a common phenomenon in the earthen channel irrigation schemes of Bangladesh. To improve scheme efficiency, this loss must be minimized. So, the farmers are thinking how to minimize the loss of costly but limited irrigation water and trying to increase the duty of water.

The performance of the existing irrigation systems was extremely poor and most of the planners, administrators and donor agencies trying to improve the performance of those systems from which the farmers achieve the benefits of costly irrigation water use. Construction of improved (compacted) earthen channels, lined channel and, buried pipe system may be the solution to improve the tubewell performance. But all are highly expensive. Buried pipe distribution systems are installed in DTW by institutions like Barind Multipurpose Development Authority (BMDA) and Bangladesh Agricultural Development Corporation (BADC). Now-a-days plastic/polythene pipe water distribution systems become popularized in STW. But farmers facing difficulties in fitting of plastic/polythene pipe on the outlets of STW due to the priming problem. Therefore, this study was undertaken for designing, development and performance testing of a *check valve* (CqV) i) to overcome the priming problem in STW; ii) to reduce the manpower in STW starting; iii) to reduce the drudgery of STW starting and iv) to ease the plastic/polythene pipe fittings on the outlet of STWs.

METHODOLOGY

Principles and Design of a *Check Valve*

Check valve/non-return valve was designed based on the working principles of the hand tubewell operating system. In hand tubewell, when pressing the handle downward then its bucket (piston) moves upward and creates upward pressure on the valve and it opens the suction pipe passage and the water flows into the tubewell chamber from the suction pipe and consequently, some water flows out through the outlet. Again, when pulling the handle upward then the bucket (piston) moves downward and creates downward pressure on the valve and it closes the opening of the suction pipe and the water could not back into the suction pipe from the tubewell chamber. Similarly, when starting the STW pump, it creates a suction pressure on the valve then the valve opens and the water flows into the pump and, it delivers water through outlet of STW. Again, when the pump stops then the weight of the water column in the suction and delivery pipe closes the valve by placing it on the suction pipe (Fig. 1). For these reasons, *check valve* was placed in the joint of tubewell and pump. By this process, the *Check Valve* retains water in whole suction pipe up to the delivery outlet of STW, by which it overcome the STW priming problem. When we start the STW again, no need to go for the priming activities. *Check* valve does not have spring, it relies on gravity to close. For the construction of a *check valve*, a rubber valve was set on a galvanized iron (GI) pipe of the same diameter as the suction pipe of STW (Fig. 1).



a) When the pump is in operation b) When the pump is stopped

Fig. 1. Working principles of *check valve* with different parts and dimensions.

Manufacturing method of *check valve*

The size of the *check valve* depends on the size of the tubewell and the jointing method in the tubewell. In field level, most of the STW size varied from 100 mm (4 inches) to 125 mm (5 inches) and the jointing method of tubewell and pump set by flange joint or thread joint. Considering the STW size of 100 mm, three diameters of the *Check Valve* were designed: i) 125 (CqV diameter) x 100 mm (tubewell suction pipe diameter), ii) 150 x 100 mm, iii) 175 x 100 mm. Also, selected two lengths of valve portion: i) 150 mm (6 inches) and ii) 225 mm (9 inches). In both the sides, 75 mm (3 inches) length of same diameter pipe of the tubewell was welded with the same diameter of flange or thread of the tubewell for easy fitting with the tubewell (Fig. 2). At the bottom of the oversized pipe i.e., *check valve*, a rubber sheet of about 3 mm thick was placed and tightened with the flange and nut-bolt that no leakage was found there. After that, the rubber sheet was cut in such a way that it was about 10 mm oversized diameter of the tubewell suction pipe and about 30-40 mm hinge (i.e., uncut part) with the flange or rubber sheet for free movement of the valve. Then a thin steel sheet of the same size of cut rubber sheet was coupled by a nut-bolt to protect the deformation of the valve from the water pressure of the tubewell suction and delivery pipe (Fig. 1). Figure 2 shows a complete *check valve* with different parts.

Fig. 2. Different components of the *check valve* with threaded fittings

Check valve fitting procedure with STW

Two types of *check valve* were designed based on the coupling system of tubewell and pump set. Normally, the northern part of Bangladesh use thread joint and, rest of the Bangladesh use flange joint system in STW. A suitable *check valve* was fitted in the joint of the tubewell, and pump set in such a way that no leakage was found (Fig. 3). For flange-type joint, a rubber gasket was placed and well tightened. For thread type joint, thread tape was used to protect leakage.

a) Check valve with flange joint. b) Check valve with thread joint.

Fig. 3. Check valve fitted with shallow tubewell.

Testing locations of *check valve* and data analysis

Different sizes of *check valve* were tested in different locations of Bangladesh with the different time span. Table 1 shows the details of locations with installation time of CqV with groundwater level. For testing the performance of the *check valve*, some necessary data like discharge, revolution of the pump impeller and time required to start the pump were recorded before and after the installation of the *check valve*. Also, the performance of plastic pipe fittings to the outlet of STW was tested and estimated the manufacturing cost. Farmers or users' opinion was collected to find out the suitability of the *check valve*. Data were analysed by using statistical tools.

RESULT AND DISCUSSION

Technical performance of *Check Valve*

Table 2 presents information about The technical performance of the different sizes of check valve with manufacturing cost. The results indicated that when the diameter of CqV portion was less than 150 mm (Treatments T1 and T4 in Table 2) for 100 mm diameter tubewell, it could not be able to hold water in the CqV due to very small part of the valve overlaped inside the diameter of valve portion. However, when the diameter of CqV increased then the manufacturing cost was also increased. Moreover, no advantage was found in case of increasing length, but it increased the cost only. Therefore, for 100 mm diameter tubewell, the size of 150 x 100 mm CqV with 150 mm valve length was found suitable in all respects. Only the differences were found in CqVs for jointing system of tubewell, i.e., flange joint or threaded joint.

Table 1. Study locations of CqV with installation year and groundwater level.

Location	CqV installation year	Groundwater level before irrigation start	Groundwater level at peak irrigation time
Vawal Mirzapur, Gazipur	2004	4.0	8.0
Kurigram Sadar, Kurigram	2004	2.0	7.0
Pirganj, Thakurgaon	2005	2.5	7.0
Ishurdi-1, Pabna	2012	2.0	8.0
Ishurdi-2, Pabna	2012	2.5	8.5
Ishurdi-3, Pabna	2015	2.4	8.3
Ishurdi-4, Pabna	2016	2.6	8.8
Mithapukur-1, Rangpur	2015	2.0	7.0
Mithapukur-2, Rangpur	2015	2.2	7.5
Mithapukur-3, Rangpur	2016	2.5	7.8

Table 2. The technical performance of different types of check valves.

Type of check valve (CqV diameter x tubewell diameter)	Length of check valve (mm)	Performance of check valve portion	Cost of check valve (Tk)
T1 = 125 x 100 mm	150	It could not be able to leak proof and hold the water above the valve.	2500-3000
T2 = 150 x 100 mm	150	Could be leak proof and hold the water above the valve.	3000-4000
T3 = 175 x 100 mm	150	Could be leak proof and hold the water above the valve.	4000-5000
T4 = 125 x 100 mm	225	It could not be able to leak proof and hold the water above the valve.	3500-4500
T5 = 150 x 100 mm	225	Could be leak proof and hold the water above the valve.	4500-5500
T6 = 175 x 100 mm	225	Could be leak proof and hold the water above the valve.	5500-6500

Note: CqV = Check valve

Different types and sizes of *check valves* were tested in different locations of Bangladesh depending upon the size of STW, coupling type of tubewell and pump set, starting from 2004 to 2020. Before installation of CqV, the discharge, rpm (revolution per minute) and fitting performance of plastic pipe use for water distribution of each STW were measured. The same data were measured after the CqV installation. There was no significant difference was found in discharge and rpm of the STW before and after installation of the CqV (Table 3). After CqV installation, use of plastic pipe becomes easier and able to reduce the conveyance loss. CqV can be able to control the water level up to the outlet of STW, which completely removed the priming problem of the STW. For that reason, one can start the STW easily. This became prominent when the electricity interruption was more in the peak irrigation season. On the other hand, farmers can easily use the plastic pipe water distribution system for easy conveyance and reduce the conveyance loss of the earthen canal.

Table 3. Effect of *check valve* on discharge, rpm and plastic pipe used.

Location	Size of check valve with joint type & power source	Discharge (l/s)		rpm		Plastic pipe use		Comment
		Before	After	Before	After	Before	After	
Vawal Mirzapur, Gazipur	150 x 100 mm, flange joint, diesel engine	6.80	6.78	2200	2200	Difficult	Easy	• No significant difference found in discharge and rpm. • After check valve installation, plastic pipe use become easier.
Kurigram Sadar, Kurigram	150 x 100mm, threaded joint, diesel engine	8.75	8.74	1500	1500	Difficult	Easy	
Pirganj, Thakurgaon	150 x 100mm, threaded joint, diesel engine	13.25	13.23	1500	1500	Difficult	Easy	
Ishwardi -1, Pabna	125 x 75mm, flange joint, diesel engine	6.75	6.74	1500	1500	Difficult	Easy	
Ishwardi -2, Pabna	150 x 100mm, flange joint, diesel engine	9.25	9.24	1500	1500	Difficult	Easy	
Ishwardi -3, Pabna	150 x 100 mm, flange joint, electric motor	14.80	14.78	2200	2200	Difficult	Easy	
Ishwardi-4, Pabna	150 x 100 mm, flange joint, diesel engine	12.65	12.65	1500	1500	Difficult	Easy	
Mithapukur-1, Rangpur	150 x 100 mm, threaded joint, electric motor	17.75	17.73	2200	2200	Difficult	Easy	
Mithapukur-2, Rangpur	125 x 75 mm, threaded joint, diesel engine	9.55	9.53	1500	1500	Difficult	Easy	
Mithapukur-3, Rangpur	150 x 100 mm, threaded joint, diesel engine	8.45	8.42	1500	1500	Difficult	Easy	

Operating time and cost savings by *check valve*

Table 4 shows a comparison between the difficulty level for starting pump before and after installation of the CqV. It shows that normally at least two persons were needed to start the STW in every starting without CqV. Time required to start the pump was 5-15 minutes. However, after installation of the CqV, it requires only one person to start the pump in each starting time. The time required to start the pump was 1-3 minutes or less than that. Therefore, it is clear that CqV has reduced human drudgery in operation of STWs. It became easier for electrically operated pump, i.e., the pump could be started by pushing the switch button only.

Table 4. Persons and time required to start the STW in every starting time.

Unit	Persons required to start pump		Time required to start the pump (min)	
	Before use of CqV	After use of CqV	Before use of CqV	After use of CqV
1	2	1	5 - 10	1
2	2	1	5 - 10	1-2
3	2	1	10 - 15	1-2
4	2	1	10 - 15	2
5	2	1	10 - 15	1
6	2	1	10 - 15	3

Note: CqV = Check valve, Unit 1= Ishurdi-1, Pabna, Unit 2 = Ishurdi-2, Pabna, Unit 3 = Ishurdi-3, Pabna, Unit 4 = Mithapukur-1, Rangpur, Unit 5 = Mithapukur-2, Rangpur, Unit 6 = Mithapukur-3, Rangpur

Table 5 shows a hypothetical analysis of labour requirement for starting STW without and with a CqV based on the labour and operating time requirement. If a pump operates for 100 days in an irrigation season and on average, it required to start the pump three times a day, then the total number of times it has to start is 300. If the mean starting time is 10 minutes, then it was taken 3,000 minutes i.e., 50 hours for two persons to start the pump in a season. But if CqV is installed in the system and the average starting time was 2 minutes then the total starting time become 10 hours only. It indicates that time requirement for pump start reduces by 90 percent, whereas labour requirement reduces by 50 percent.

Farmers/users' opinion about the use of CqV

The farmers were asked about the requirement of priming activity for pumping operation. Everyone said that it requires to prime the pump at each starting time before the use of CqV and only once in the season, i.e., at the beginning of the pumping after installation of CqV. After initial priming, water always remains above the pump as well as water remains in the pump suction pipe. Several studies (Dey *et al.*, 2017; Aziz *et al.*, 2015; Mustafa *et al.*, 2017; Pena-Arancibia *et al.*, 2020) show that groundwater levels are falling in many parts of the country especially in NW region. The groundwater levels at many areas in the region fall below the suction limit of STWs (8 m) during March to May in peak irrigation period. Therefore, in some cases STW operation became difficult in many areas. So, deep set STW with CqV may be the solution and ease of STW operation.

Other concerns for the farmers were the problems in using of low-cost polythene pipe for irrigation water distribution in a STW. Due to minimum loss in water distribution system, no requirement for canal construction and easier placement, now-a-days, the farmers

Table 5. Cost saved by installation of CqV in the STW.

Condition	Times of start daily	Person needed to start	Time taken to start (min)	Duration of operation (day)	Total time needed (min)	Total labour (man-hr)	Total wage (Tk)*	Savings (%)
Before installation of CqV	3	2	10	100	3000	100	4000	
After installation of CqV	3	1	2	100	600	10	400	90

* Contractual wage for irrigation season

preferred polythene pipe water distribution system. But due to interruption in pump operation and frequent starting farmers were reluctant to use this technology. All the farmers said that it was awfully hard to use polythene pipe for distribution as they have to start the pump many times and for leakage, damage and change in alignment of the pipe. It was very hard to start the pump before installation of the CqV as it requires at least two persons and 10-15 minutes of time. Installation of CqV in STW provides an opportunity for using polythene pipe in water distribution systems. All the pump owners informed that it becomes very convenient to use polythene pipe in distribution system as starting pump was easier after installation of CqV. By observing the field performance farmers are highly interested to installed CqV in their STWs.

Overall impact on introducing *check valve*

Pump owner's reaction

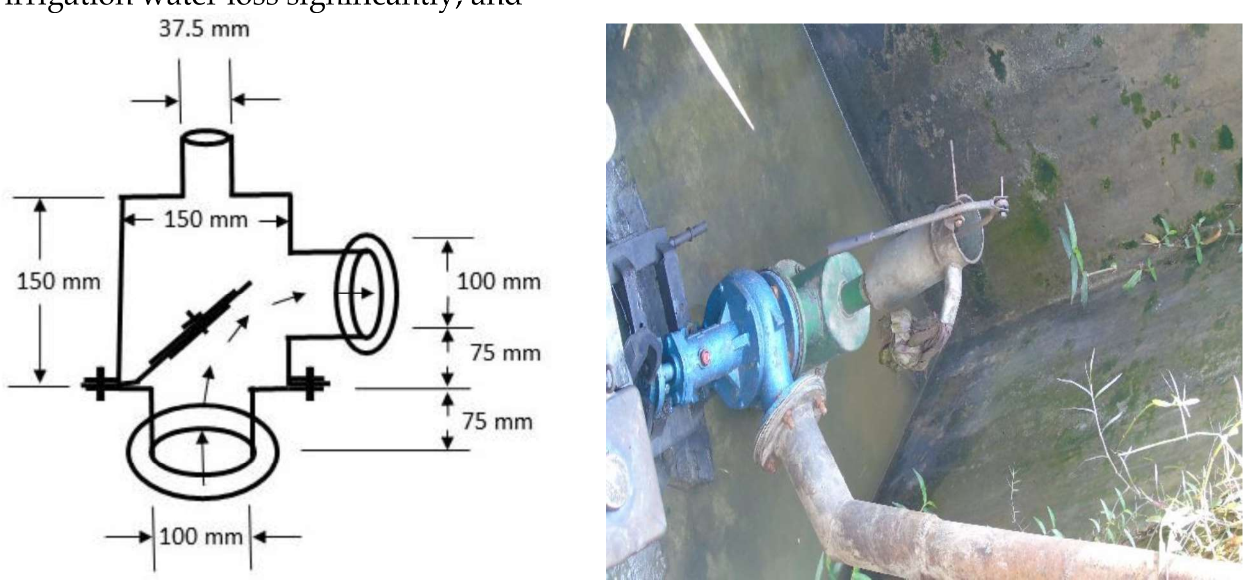
- The check valve reduced drudgery of the farmers.
- They were convinced that CqV did not reduce the discharge of the pump.
- It also provided the opportunity to use polythene pipe very easily that reduced irrigation water loss significantly; and
- Some other pump owners requested to install the CqV in their pumps.

Advantages

- Easy to install.
- Saves labour and reduced human drudgery.
- Offered uninterrupted operation while using plastic/polythene pipe for water distribution. and
- Wide-scale adoption of polythene pipe distribution system was possible by installing CqV.

Alternative design for reducing the cost of *check valve*

The cost of a CqV depends on the size and construction materials of the valve. For connecting of a pump and a tubewell, normally we use a 90^{o} band of 0.60 m to1.0 m in length, that costs about BDT 800 to 1000 at present (Fig. 3). To reduce the cost of a pump by removing this band, an alternative design of a CqV was used (Fig. 4). The field performance of the newly designed was also tested. The performance was very good in all respect of solving priming problem and ease of operation. It also reduces cost of STW pump set by removing the band of the pipe.



a) Alternative design of a CqV b) Field performance test of alternative CqV

Fig. 4. Alternative design of a check valve and its field performance test.

CONCLUSION

The field performance of CqV for overcoming the priming problem of STW for easy starting and reducing the drudgery of farmers for STW operation found successful. The most effective CqV diameter should be greater than 50 mm over the diameter of tubewell and the CqV length became 150 mm (i.e., 100 x 150 x 150 mm). The installation of a CqV have no adverse effects on tubewell discharge and impeller revolution. It could successfully reduce the starting time and reduce the labour wage to start the pump. It also facilitates the easy use of plastic pipe/ polythene pipe, which also reduced the water conveyance loss and pumping hours. It ultimately reduced the groundwater abstraction and irrigation cost for crop production.

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