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ASSESSMENT AND UTILIZATION OF RECOVERABLE ENERGY OF TUBEWELL DISCHARGE

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The study reports a survey of the operational characteristics of a number of tubewells selected in Faisalabad tehsil focussed at estimating the recoverable hydraulic energy of the free fall of tubewell discharge below the delivery point of the tubewells. The discharge of the surveyed tubewells ranged from 18.4 to 48.1 lps and the height of free fall below the delivery pipe ranged from 1.1 to 2.0 m. The hydraulic energy of the jet averaged to 0.45 kW that could yield a break power of 0.2 kW through a water wheel designed for the purpose. Such a recoverable hydraulic energy of free fall can be utilized to run small farm machines such as tool grinder battery charger and mixer etc. instead of traditionally dissipating and losing the energy trough masonry tanks.

INTRODUCTION

The use of tubewells for irrigation and drainage purposes is becoming increasingly popular both under private and public sectors of the country. During 1987-88, about 250,000 tubewells have been reported to be operating in the country in the private sector (Anonymous, 1988).

The energy imparted by a pump on the fluid has to overcome the total dynamic head which includes suction head, static delivery head, well drawdown, friction losses in the system and an operating head at the discharge point. Under gravity flow irrigation systems, however, the tubewells are designed to discharge freely into a ditch or a reservoir and, therefore, no pressure/working head is needed (Jensen, 1980).

When the energy imparted by a prime mover equals the minimum system head required to lifet water to the elevation of water channel, the pump would hardly deliver water. Hence, certain additional head is indispensable for a pump installation to deliver the required flow of water. In case of tubewells discharging freely into the irrigation channels, such additional head is usually dissipated through masonry tanks to avoid the problem of erosion in the irrigation channels. This energy if recovered, may however, provide an additional source of power for running small machines such as tool grinder, blower, storage battery charger, a feed mixer or a small generator at the farm by converting the hydraulic energy to mechanical energy through a water wheel. Therefore, this study was designed to evaluate this recoverable energy and develop suitable mechanism for its utilization.

METHODOLOGY

Seventeen tubewells were selected in Faisalabad tehsil. The data were collected regarding the type and power of prime mover, pump discharger, depth of bore, effective hydraulic head, diameter of delivery pipe and the height of delivery pipe above the full supply level of water in the channel. The discharge of each well was measured with a cut throat flume. The velocity of jet at the down stream end of free fall was determined by applying the Bernoulli's theorem between the discharge point and the point of impingement at the vanes assuming that:

i. the jet diameter remains constant from the pipe exit to the point of impingement at the vanes, and
ii. the frictional losses due to air are negligible.

The velocity of water at the pipe exit was calculated from the observed discharge and diameter of delivery pipe using continuity equation. The kinetic energy of the jet was determined by the energy equation (Jain, 1988) that determined the available power at the vanes. The revolutions of the water wheel per minute (N) were determined using the equation:

$$N = \frac{61181 \times kW}{2\pi T} \quad (1)$$

The Torque (T) in equation (1) equals Q.r.g^{-1}.v.r.

where

Q = Discharge of tubewell in l sec^{-1}.
r = Unit weight of water in kg l^{-1}.
g = Acceleration due to gravity, 9.8 m sec^{-1}.
v = Velocity of jet at the vanes, m sec^{-1}.
r = Distance from the wheel axis to the centre of vanes in m.

The velocity of vanes of the wheel (V_w) was calculated as:

$$Vw = \frac{2\pi rN}{60} \quad (2)$$

The force exerted by the jet on vanes (F) was estimated using the equation by Jain (1988):

$$F = AV_j (V_j - V_w) \quad (3)$$

where A.V_j represents the mass of water striking the vanes of wheel, V_j and V_w represent the velocities of the jet and the vanes, respectively. The weight of vanes was determined using 2711.6 kg m^{-3} as the specific weight of aluminium metal to be used in the vanes. The mechanical power developed by the wheel and that transmitted to the farm machines through a pulley and belt mechanism was obtained through the equation of Baven (1962):

$$kW = \frac{(T_1 - T_2) \times V_p}{756} \quad (4)$$

where V_p is the velocity of the pulley in m sec^{-1} and T_1, T_2 are the belt tensions in m.

The number of blades for the water wheel (n) was determined by the equation:

$$n = \frac{D}{2\,d} + 15 \quad (5)$$

where

D = Diameter of wheel.
d = Diameter of jet.

RESULTS AND DISCUSSION

The data collected from selected tubewells (Table 1) showed that the motor power varied from 11.2 to 22.4 kW for lifting the water to a total head ranging from 12.81 to 32.32 m. The discharge varied from 18.4 to 48.1 lps with an average of 30.8 lps. Considering the average flow rate and a dynamic head of 20 m, using 60% efficiency of pump and 85% efficiency of motor, the power requirement of prime mover was estimated to be 11.9 kW whereas the average power of the installed motors was found to be 16.4 kW. Thus, the motor power used by the farmers was over estimated by about 37%. The elevation of delivery pipe above the full supply level of water in the channel ranged from 1.07 to 1.98 m.

well. The hydraulic power available at the water course level varied from 0.23 to 0.66 kW that could be converted to mechanical power through a water wheel. The weighted average power of the falling water at sampled tubewells was found to be 0.46 kW.

Considering the water wheel efficiency of 60%, a net available head of 0.74 m and wheel radius of 0.38 m, the energy of the free fall of water provided an average output

Table 1. Hydraulic data from selected tubewells of the Faisalabad tehsil

Tubewell No.	Motor/ engine power (kW)	Depth of bore (m)	Suction head (m)	Delivery head (m)	Diameter of delivering pipe (cm)	Height of free fall (m)
1	14.9	36.6	18.3	4.6	11.4	1.07
2	14.9	27.4	9.2	3.7	12.5	1.63
3	18.7	36.6	18.3	4.6	15.2	1.83
4	11.2	42.1	14.6	3.7	10.2	1.32
5	11.2	42.1	14.6	3.7	10.2	1.42
6	14.9	41.2	13.7	4.6	12.7	1.71
7	14.9	39.6	12.2	5.5	15.2	1.63
8	14.9	39.6	12.2	6.1	12.7	1.37
9	22.4	40.2	12.8	5.5	15.2	1.12
10	18.7	35.1	16.8	4.6	20.3	0.97
11	22.4	35.1	16.8	10.7	20.3	1.07
12	22.4	35.1	16.8	10.7	20.3	1.52
13	14.9	30.5	12.2	4.6	14.0	1.22
14	14.9	30.5	12.2	3.4	15.2	1.22
15	14.9	30.5	12.2	3.1	12.7	1.12
16	14.9	54.9	27.4	4.9	15.2	1.96
17	14.9	41.2	13.7	6.1	15.2	1.81

Table 2 summarizes the estimated velocity of jet, available energy and the power developed by the jet for each tubewell.

of 0.2 kW at the wheel shaft for an average tubewell discharge of 30.8 lps.

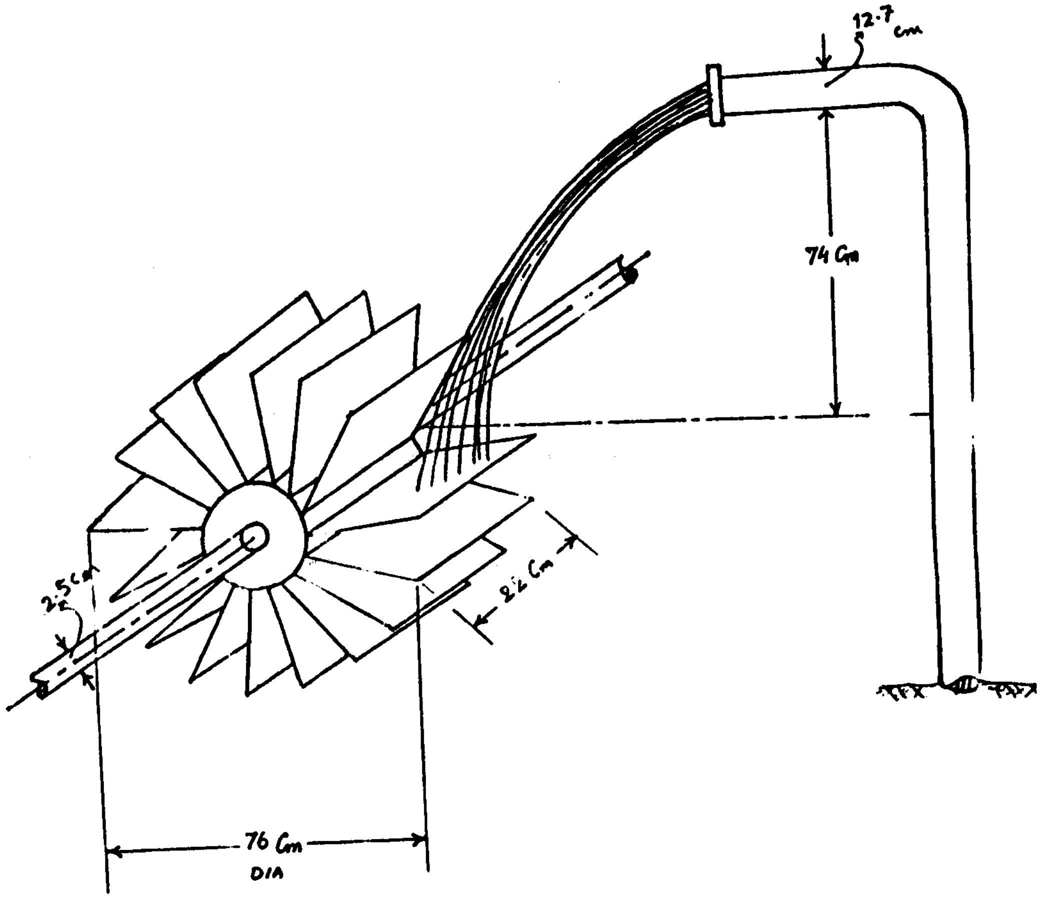

Fig. 1. Schematic diagram of the designed water wheel.

Based on the estimated recoverable energy if all the tubewells in the country are equipped with water wheels, there would be a saving of about 50355 kW power in the country which is presently going unutilized. This may bring a tangible contribution to the energy resources required at the farms. It may, however, be mentioned that each installation requires specific design considerations of water wheel depending on the specific data regarding discharge, size of delivery pipe and height of fall.

Using the design methodology (equation 1 through 5) and design data from one of the sample tubewells with a discharge of 40.7 lps, delivery pipe diameter of 12.7 cm and a net available head of 74 cm, the operational and design specifications of the water wheel were determined (Table 3) to utilize the energy of free fall from the tubewell. The methodology and results presented in this paper can be used as a tool to develop a suitable water wheel for converting the free fall energy of a given tubewell for useful purposes. Figure 1 gives a schematic diagram of the designed water wheel.

Table 2. Available power from selected tubewells of Faisalabad tehsil

Tubewell No.	Discharge	Potential head of of water	Velocity of water		Available energy	Available power
			Below jet	At pipe exit		
	($l\ sec^{-1}$)	(m)	($m\ sec^{-1}$)	($m\ sec^{-1}$)	($Joule\ sec^{-1}$)	(kW)
1	28.3	1.07	5.36	2.77	403.85	0.411
2	31.7	1.65	6.22	2.61	610.11	0.61
3	33.4	1.83	6.26	1.83	653.88	0.65
4	19.5	1.32	5.63	2.41	310.10	0.31
5	19.2	1.42	5.76	2.37	266.80	0.27
6	21.5	1.68	4.65	1.69	229.54	0.23
7	20.7	1.63	5.77	1.45	344.30	0.48
8	18.1	1.37	5.37	1.44	263.82	0.26
9	35.7	1.12	5.07	1.96	457.58	0.46
10	29.9	0.97	4.57	1.42	313.00	0.31
11	48.1	1.07	4.81	1.48	542.27	0.56
12	40.8	0.92	4.51	1.26	396.47	0.40
13	39.1	1.22	5.18	2.55	591.73	0.59
14	33.9	1.22	5.24	1.87	463.54	0.46
15	40.8	1.12	5.68	3.21	655.82	0.66
16	31.1	1.96	6.40	1.71	635.70	0.64
17	31.7	1.80	6.20	1.75	608.87	0.61

Table 3. Design specifications of water wheel

Description	Specification
Net head above vanes	0.74 m
Jet velocity at vanes	4.97 $m\ sec^{-1}$
Jet energy at vanes	545 $Joules\ sec^{-1}$
Power developed at vanes	0.67 Hp
Power developed at wheel shaft	0.40 Hp
Revolutions of wheel	88 rpm
Shaft diameter of water wheel	2.5 cm
Radius of wheel (assumed)	38 cm
Number of aluminium blades	16
Weight of blades	2.5 kg
Weight of solid wheel	1.8 kg

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