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DESIGN AND DEVELOPMENT OF IRRI POWER TILLER-DRIVEN DRILLING RIG FOR SHALLOW TUBEWELLS*

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ABSTRACT

IRRI Engineering Division has developed a well drilling rig attachment that matched power tiller or hand tractor. It was designed in response to the growing demand for groundwater utilization for small-scale irrigation, especially in drought-stricken and rainfed farms in Asian countries.

The power tiller-driven rig can drill 30 meters of 100 mm well in an unconsolidated formation in one day and can be rapidly converted from rotary to jetting or to the percussion method of drilling to suit different soil and rock formations. In addition, the power tiller can be quickly installed or removed from the rig frame and can be used for transporting the rig to other sites. The rig can be dismantled into smaller sub-assemblies for carrying by hand into less accessible areas.

One manufacturer in Central Luzon Philippines has started to produce the rig for well drillers in Central Luzon. The Department of Agriculture in the Philippines have procured thirty three (33) units of these machines for their Shallow Tubewell Program.

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INTRODUCTION

During the last fifty years, several types of drilling rigs have been developed to work in different formations. The mode of operation of these rigs are classified as follows:

1. Percussion Method

   a. Cable tool
   b. Hydraulic percussion

2. Hydraulic Rotary Method

   a. Direct rotary, with either stationary or traveling rotary table
   b. Reverse rotary
   c. Turbo drill

3. Water Jet Drilling Method

4. Air Rotary Method

The cable tool percussion method consists of a cutting tool which dislodge the formation, both consolidated and unconsolidated and with addition of water makes a slurry of the cutting; a casing pipe which is lowered or hammered into the formation excavated by the drill bit, and a sand pump. A cable is passed over a pulley hung on a mast of suitable height.

The hydraulic percussion method consists of a cutting tool with a ball valve and a length of drill pipe with discharge opening at the top end, suspended by a rope or cable. Unlike the cable tool, there is no need for a bailer since the slurry is discharged at the top end during lifting and dropping operations. This method is commonly use for shallow tubewell drilling.

The hydraulic rotary method consists of a rotary bit which cuts into the formation, the cuttings are removed by the continuous circulation of fluid.

Direct hydraulic rotary drilling uses a derrick or mast and hoist. A power-operated rotary table rotates the drill stem and drill bit; a pump forces fluid through a hose and a swivel through the drill stem and drill bit. This method is faster than the percussion type in unconsolidated formation. The rotary table can be either stationary or travelling.

The reverse rotary method is the reverse of direct rotary system of drilling. With this technique, large volume of water is sucked through the drilling pipe instead of water being forced out. This method requires large volumes of water to be constantly available equal to the loss by seepage through the borehole into the formation. This method is ideal for an unconsolidated formation.

Water jet drilling is used for installing small diameter tubewells. The main principle is that water under pressure is allowed to flow through the pipe to a chisel-shaped bit which has holes on either side of the bit. These holes serve as nozzles for the water jet which loosens the material and at the same time keeps the nozzle free of sand. The top of the pipe is connected to a pump delivering water through the pressure hose. The pipe is moved up and down over a short distance.

Drilling by compressed air is a modern development in well drilling. Compressed air under high pressure is circulated through a drill pipe and the drill bit. The high velocity air jet dislodges the formation into small fragments which are blown out through the annular space of the pipe and formation. Sometimes a pneumatic hammer operated by the compressed air is also used. The "down the hole hammer" requires compressed air at very high pressure.

Drilling Rig for Shallow Tubewells

The most popular and the least expensive rig for shallow tubewells is the water jet drilling rig. It consists of a tripod of bamboo or pipe, with a wooden or steel pulley hanging at the top. A pump supplies water under pressure to flow through the pipe and the drill bit while it is being moved up and down.

In the late 60's a semi-mechanized percussion drilling rig was developed by Eduardo Alcanzare, a Filipino inventor, and was introduced in the local market.

In about the same time, a simple rotary drilling rig designed by local craftsmen was popularized in Batangas Province. The travelling rotary mechanism was made out of automotive differential and belt-driven by a high speed gasoline engine.

In the early 70's an imported drilling manufactured by DeepRock Manufacturing in Alabama, USA was introduced in the Philippines. It uses a travelling rotary mechanism direct coupled to a high speed gasoline engine. This model is capable of drilling a 50 mm well down to 60 meters. This drilling rig was utilized in 1976-1977 by IRRI Engineering Department in its Savonuis Windmill Program.

In the early 80's, a small rotary drilling rig using hydraulic pump and motor was introduced in the Philippines by a mining firm. Although it was designed primarily for mining purposes, it can also be used for shallow tubewell drilling.

In 1989, IRRI's Engineering Department fabricated a rotary drilling rig which incorporated the best features of the Deeprock and the Batangas model. This rig was sent to Iloilo upon the request of the Provincial Governor. More than 80 wells where drilled by this rig.

In 1990, Deeprock Manufacturing in USA introduced a bigger model of Rotary drilling rig which could drill 100 mm well to a depth of 60 meters.

In 1991, the Agricultural Mechanization Development Program (AMDP) in UPLB developed two rotary drilling rigs for shallow tubewells which are now being used in the training program of the Bureau of Soil and Water Management (BSWM) in their Shallow Tubewell Development Program.

Tramat Mercantile Inc., a private firm in Manila, came out with a modified version of the AMDP drilling rig in 1992.

In early 1992, IRRI Engineering Division started to develop a drilling rig as an attachment of the popular power tiller as a way to cut the costs of a self-contained drilling rig.

DESIGN CONSIDERATIONS

Drilling methods are usually matched to soil certain formations. Percussion is efficient on hard rock formation, while the rotary and the water jetting drills are faster in unconsolidated formations. However, for shallow tubewell drilling rigs time to set-up and to transport to another place are critical. In addition, tightening and loosening of drill stem are still done manually. A need for a design which would address these problems to further improve the capacity of existing drilling rigs for shallow tubewell operation was perceived, as well as providing another use for the versatile power tiller.

Local well drillers had been interviewed to obtain design specifications.

1. The idea of keeping costs down by making power tiller-based was attractive. Initial investment would be lower since the engine and the hoist mechanism, the main cost components of a drilling rig are eliminated and the power tiller can transport the rig.

2. The rig should be multi-mode , that is, readily switched from rotary, to water jetting, or to percussion mode to suit different soil or rock formations.

3. The rig should be able to drill:

   60 meters of 100 mm well or

   50 meters of 150 mm well or

   40 meters of 250 mm well or

   30 meters of 300 mm well

To improve the yield of the well, a minimum of 3" thick gravel packing maybe used and the rig should be capable of drilling larger hole as shown above.

4. Tightening and loosening of drill pipes should be power-operated.

5. The existing engine of the power tiller (for example 10 Hp) should be used to simultaneously drive the rotary table, a 50 mm centrifugal pump, and the cathead pulley drive.

6. The rig must be capable of fabrication by small workshops using locally available gears, sprockets, and other materials.

7. The rig could be operated by no more than two persons with minimum training and tools.

8. The mast with pulley should be raised by the power tiller into its operating position, using the cathead pulley.

9. The rig should be profitable to operate to be attractive to contractors

Design and Development

A drilling rig was designed based on the above design criteria (Fig. 1). It consists of a rig frame made of 100 mm channel iron, 0.9 meter wide and 1.5 meters long, with mounting bars for the power tiller and pump, together with two 100 mm x 2 meters. long channel iron stabilizes hinged to one end of the frame; a 5.0 meter high tripod-type mast made of 50 mm sch.40 BI pipe with a steel pulley mounted on the top; a stationary rotary table made out of grease lubricated automotive spiral bevel gears and a drive shaft assembly with 50 mm square opening; a water swivel assembly with 38 mm dia. x 6 meters long flexible hose with connections and pull-down bracket; a 50 mm square x 3 meters long hollow drive kelly; and a 50 mm self-priming centrifugal pump (Fig. 2). An IRRI PT7 power tiller with 10 Hp overhead valve (OHV) high speed gasoline engine with 2:1 reduction, was used as the power unit.

A 100 mm OD, 4-groove engine master pulley drives the power tiller input shaft pulley; the rotary table input pulley for clockwise rotation; the pump pulley; and the vee pulley attached to one end of the lever, the other end of which is freely pivoted inside the engine pulley through ball bearings. The rotation of the vertical shaft is reversed when the reverse lever is moved toward the rotary table until the back of the moving vee belt is pressed against a 350 mm OD flat pulley (Fig. 3).

To eliminate the use of pipe wrenches in the tightening or loosening of drill stem, the drill rod is provided with 50 mm square coupling welded to one end, and a 50 mm long square bar bored to fit the outside diameter of a 32 mm drill pipe welded 0.5 m feet from the other end (Fig. 4). The square coupling of the uppermost drill pipe is held in place by a counter lever located under the rotary table while the drill pipe which is to be added or removed is being rotated through its square portion located in the center of the square opening of the rotary table.

The drill stem is lifted by a rope wound several times around the cathead pulley (Fig. 5) until rope tension is relaxed. To add additional pressure on the drill bit, a pull-down mechanism also actuated by the cathead pulley incorporated in the design.

To transport the rig, a rubber tyred axle is hitched to one end of the frame by two pins (Fig. 6). The two 100 mm x 2 meters long channel iron stabilizers are folded in to provide the hitch for towing behind the power tiller.

To raise the mast, a lifting aid tool is first fitted to the 50 mm square opening of the rotary table, With one end of the rope tied to the mast pulley assembly, and the other end to the rotating cathead pulley, the mast is slowly raised to its operating position after which the third leg of the tripod is hitched to the main frame (Fig. 7). To prevent the mast from accidentally falling down, a band brake mechanism in the rubber wheel can be actuated by the operator.

FIELD PERFORMANCE

A pròtotype drilling rig has been tested in four (4) different sites in Mexico, Pampanga. To date, it has completed 5 wells with depth ranging from 15 to 30 metrs.

The 10 Hp gasoline engine with 2:1 reduction was found to be sufficient for the clay and sand formation encountered in these tests.

The following problems were encountered during the construction of these wells:

1. Occasional clogging of the pump impeller with gravel, and other impurities, which delayed the drilling operation.

2. Leakage in the packing gland which requires frequent tightening of the adjusting nuts.

3. With only one mast pulley, addition of a drill pipe and subsequent lowering of the whole drill stem necessitates the transfer of the hook holding the swivel and drive kelly assembly to the drill stem, causing operational delays.

4. Standard pipe thread did not last long because of frequent loosening and tightening.

5. Flexible hose occasionally came out of the hose adaptor especially when the drill bit was clogged with clay, splashing muddy water over the operator.

6. Occasional rope overlapping on the cathead pulley delayed operation.

7. The pull-down rope touched the rotary table assembly near the end of the downward travel of the square drive kelly.

DESIGN MODIFICATIONS

1. A search for a suitable locally-produced pump identified a commercial model suitable for well drilling. The manufacturer was advised to change from the original semi-open 5-bladed impeller to a 3-bladed design. The stuffing box of the new pump was modified to accommodate more packing than the first, thus minimizing leakage.

2. An additional pulley was installed in the mast.

3. The thread of the drill stem was changed to 4 threads per inch Acme Standard.

4. Grooved hose adaptors together with heavy duty hose clamp replaced the old design.

5. A divider was incorporated to prevent rope overlapping in the cathead pulley.

6. The position of the pull-down bracket in the swivel assembly was changed to eliminate the problem of the rope touching the rotary table casing.

7. A band brake mechanism was incorporated in the power tiller input shaft for more compact and safer design.

After these changes the rig was again tested in Mexico, Pampanga and it was able to complete a 100 mm x 30 meters well in just 4 hours.

ECONOMIC ANALYSIS

A cost analysis of the IRRI Powertiller-driven drilling rig was undertaken and the profitability was determined, based on the following assumptions: 60 wells drilled per year; average depth of well, 20 meters three days per well on average, 3; estimated charge rate including well development, US$25.00/m; three operators (one skilled with 2 helpers) with wage rate for skilled operator US$6.00/day and US$5.00/day for helpers.

Power tiller fuel consumption, 12 liters/8 hours; allowance for workers, US$1.00/day; initial investment about US$4,600.

Five year machine life, after which net zero salvage value.

Repair and maintenance at 5%, with 20% interest on invetment and 2% taxes and insurance.

A. Annual Fixed Cost

1.	Depreciation $= \frac{4,600}{5}$	US$920	
2.	Average Interest on the Investment $= \frac{4,600}{2}$	460	
3.	Repair and Maintenance (.05 x 4,600)	230	
4.	Tax and Insurance (.02 x 4,600)	92	
			US$1,702

B. Variable Cost

1.	Labor Cost (16 x 3 x 60)	2,880
2.	Meal Allowance (1 x 3 x 3 x 60)	540
3.	Fuel Expense (.4 x 12 x 3 x 60)	864

		4,284
C.	Total Annual Cost	5,986
D.	Total Gross Income (16 x 20 x 60)	19,200
E.	Net Income before Tax	13,214
F.	Return on the Investment (ROI) $\left(\frac{13,214}{4,600} \times 100\%\right)$	287%
G.	Break-even point $= \frac{\text{Fixed Cost}}{\text{Drilling charge/well} - \text{Variable cost/well}} = \frac{1,702}{320-71.4}$	6.85 or 7

From the above computation, it can be seen that shallow tubewell drilling using the IRRI powertiller-driven drilling is profitable with an ROI of 287%. The break-even point is approximately 7 wells per year.

CONCLUSION

From the experience gained so far in operation of the IRRI powertiller-driven drilling rig, the following conclusions can be made:

1. It has been demonstrated to be fast to set up, and suitable for shallow tubewells for clay and sandy formations.

2. It can drill 300 mm diameter and 30 meters depth wells using a 10 Hp gasoline engine

3. It is portable and very convenient to operate.

4. Unskilled operators can be quickly trained to operate the machine in 3-5 days. Only two persons are needed to operate the rig.

5. The rig promise to be profitable for shallow tubewell drilling.

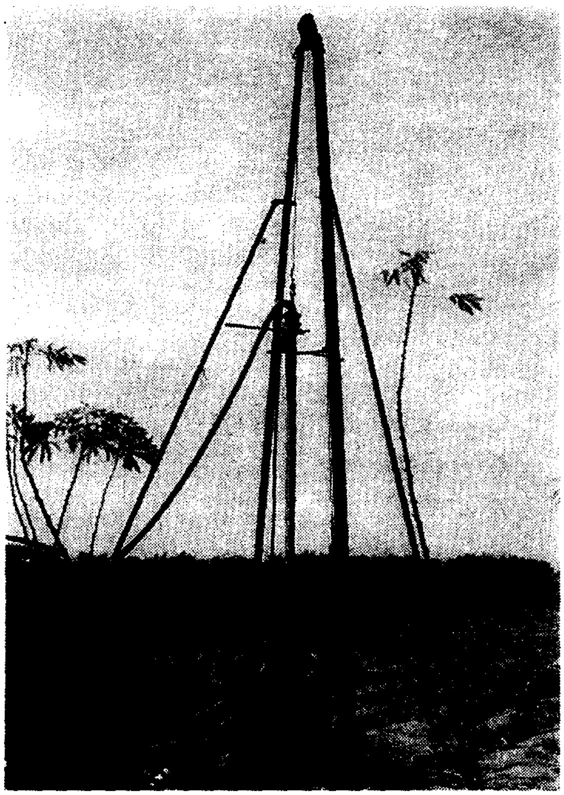

Fig. 1 IRRI Power tiller driven drilling rig.

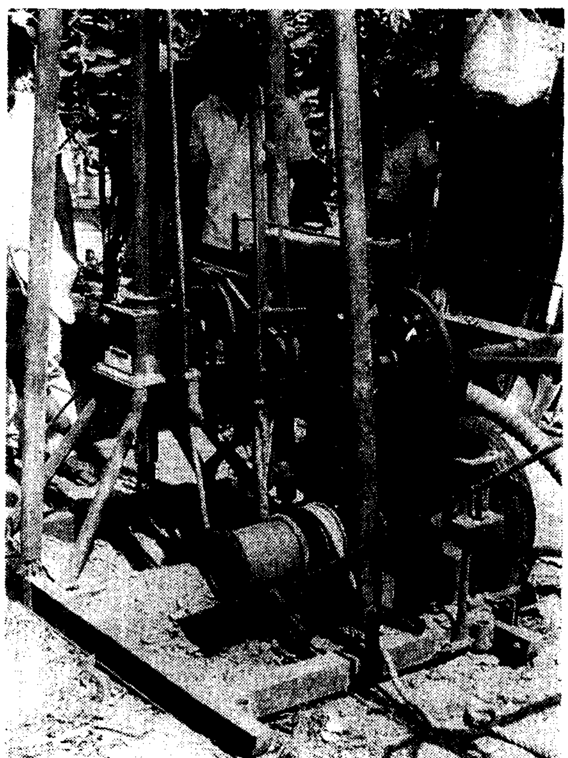

Fig. 2 Close-up showing various parts.

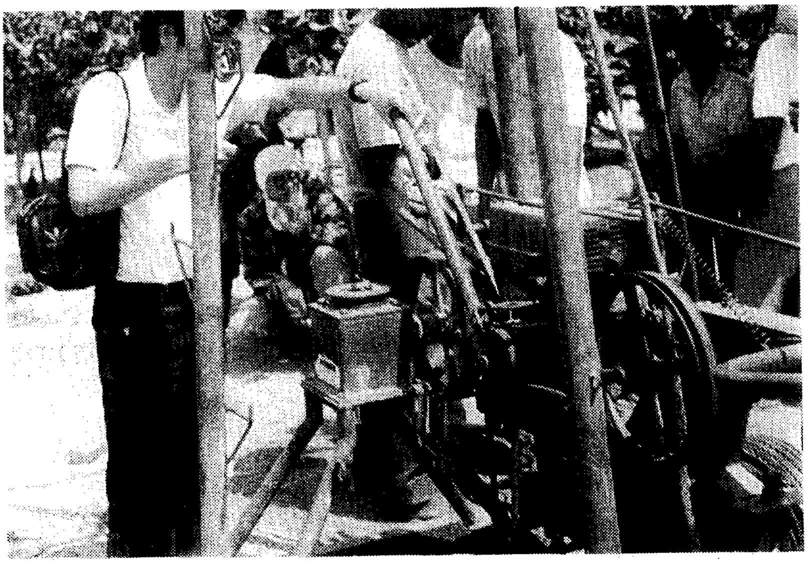

Fig. 3 Reverse drive arrangement.

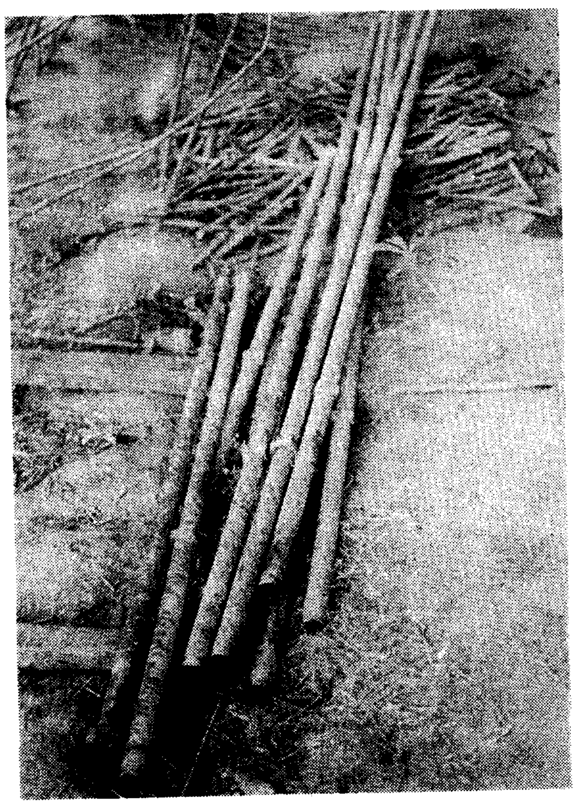

Fig. 4 Drill pipe showing location of welded hollow square bar.

Fig. 5 Lifting mechanism

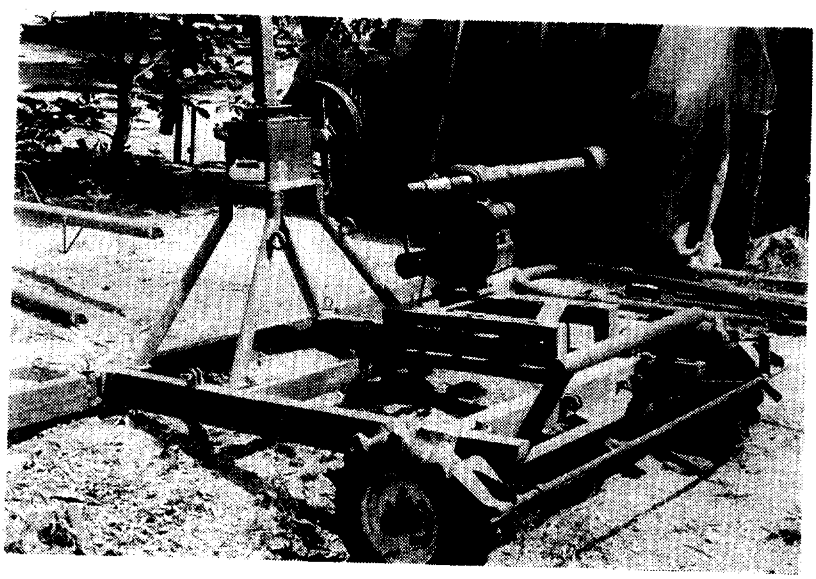

Fig. 6 Transport wheel Arrangement

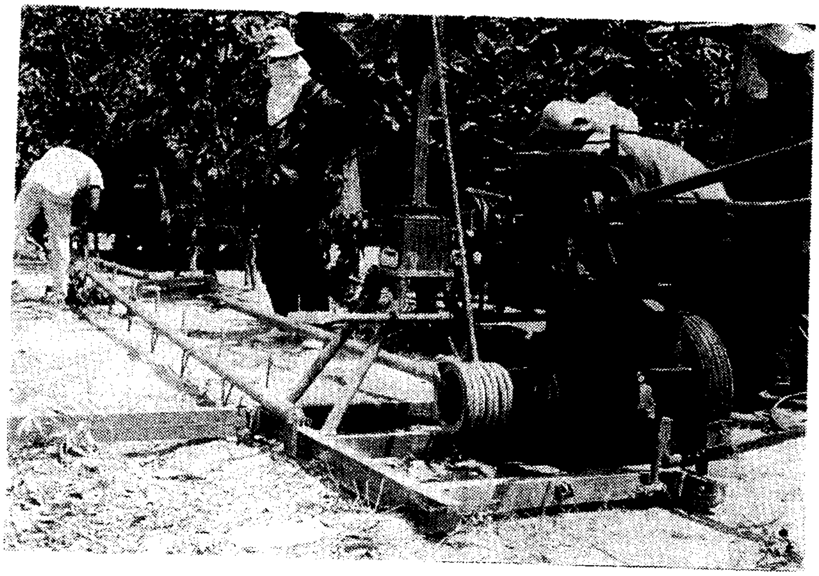

Fig. 7 Raising the mast