Axial-flow propeller pump for small rice farms and fishponds

by R.E. Stickney and G.C. Salazar

Work on propeller pump which combines indigenous innovations and modern technology has reduced its price by more than 50 per cent. It also maintains high pumping efficiency, and is easy to make and repair. Consequently, acceptance by rice farmers and prawn producers in the Philippines has increased markedly.

IN THE LOWLAND FARMING areas of Vietnam and Thailand, axial-flow propeller (AFP) pumps have proven to be a highly appropriate technology for low-lift irrigation and drainage. There have been reports that 50,000 of them are being used in the upper Mekong delta of Vietnam in the late 1960s. In Thailand it is estimated that 600,000 pumps were in use in 1983, principally in the central plain. In both countries the AFP pump technology is an indigenous development which, in some cases, has benefited from adaptations of the available technology of outboard engines for small boats. The pump may be fabricated in small shops using easily available tools and materials. Competition between numerous manufacturers has ensured low prices while also stimulating innovations in response to customers' preferences.

High efficiency

The main advantage of the AFP pump is that its efficiency is substantially higher than that of the centrifugal pump for low-lift applications (when water is lifted no more than three metres). For example, the results of our previous study illustrated that the efficiency of the AFP pump is approximately two to three times that of the centrifugal pump for lifts (static heads) of one to three metres; consequently, the AFP pump is far more economical than the centrifugal pump for low-lift applications.

Based on the AFP pumps of Thailand and Vietnam, the International Rice Research Institute (IRRI) has developed a modified version shown in Figure 1a. The impeller and diffuser were designed to improve the pumping efficiency, but the price of the pump was relatively high (approximately US$200 for the 15cm-diameter pump, without an engine. We found that small farmers in the Philippines did not accept this pump, primarily because of its relatively high price plus the widespread availability and use of centrifugal pumps.

Since low-cost irrigation pumps are a high priority for small rice farmers, we have searched for ways to reduce the cost of the AFP pump. Our main approach was to study indigenous AFP-like pumps which have been popular for over 20 years in two small areas of the Philippines, Camarines Sur and Candaba. The Camarines design (Figure 1b) showed us that the price of the axial-flow pump may be reduced dramatically by using plastic or canvas tubes to reduce the length of the costly metal tube (compare Figures 1a and 1b). Some farmers make these tubes by sewing together empty fertilizer bags; others have upholstery shops make tubes from available plastic cloth or canvas.

The Camarines design uses a wooden frame made from rough wood. A boat propeller is used as the pump impeller, which is a low-cost innovation but has two serious disadvantages. Firstly, the pumping efficiency is low because the rounded tips of the propeller blade are not the best shape for pumping water; and secondly, since the angle of a propeller blade is the reverse of the desired blade angle for a pump impeller, water is pumped in the opposite direction (that is, away from the engine rather than towards it, as seen in Figure 1b). This is a major inconvenience for pump operators, who generally prefer to have the engine on solid ground (as in Figure 1a). The impeller of the IRRI pump overcomes both of these disadvantages at modest cost. By

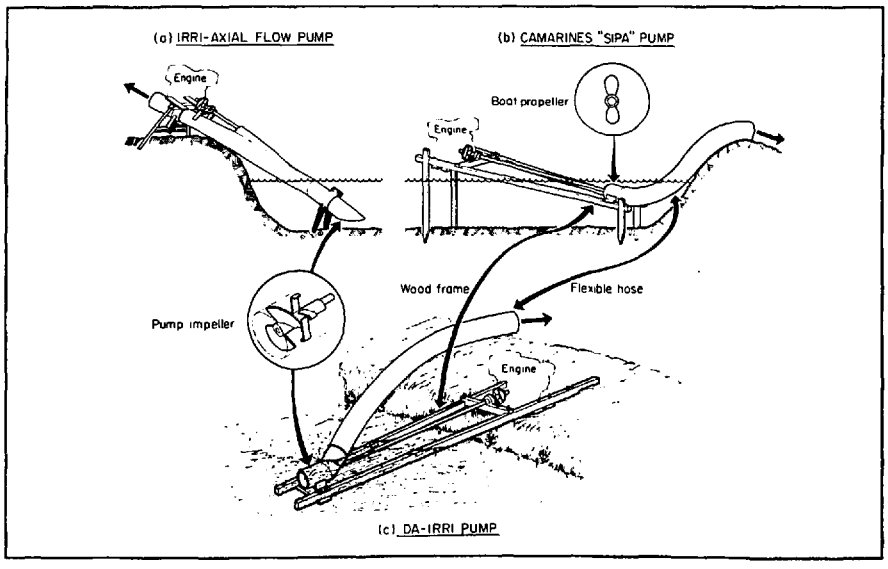

Figure 1. Evolution of the DA – IRRI pump.

G.C.Salazar works on the DA-IRRI Program for Small Farm Equipment at the International Rice Research Institute.
R.E. Stickney's present address is: IINGR Program, Wheaton College, Wheaton, Illinois 60187, USA. Detailed drawings of the AFP pump may be obtained from IRRI Agricultural Engineering, PO Box 933, Manila, Philippines.

combining the best features of the Camarines and IRRI pumps, we have arrived at the design illustrated in Figure 1c.

Design

The major components of the AFP pump are shown in Figure 2. The impeller is fabricated from commonly available metal plate and round bar. Proper blade curvature is obtained by hammering the pre-cut metal pieces into a simple fixture which also serves to align the blades and hub for welding. Some manufacturers have sufficient sales to justify metal casting of the impeller.

A major innovation is the use of pipe thread as a simple way to fasten the impeller to the pump shaft. For example, a 3/8-inch nominal pipe-thread die can conveniently cut thread on a 5/8-inch shaft without needing any machining. Pipe thread is also used at the other end of the shaft to join it to the flexible coupling. Since available engines generally produce anticlockwise rotation of the crankshaft, this ensures that both the impeller and flexible coupling will tend to be tightened on the shaft during operation, rather than becoming unscrewed. Fabrication is greatly simplified by the pipe-thread innovation because it eliminates the need for a lathe, broach, or milling machine for cutting tapers and keyways in the shaft and impeller hub. Several small-scale shops are making the entire pump without lathes or milling machines. They find that careful drilling with the aid of simple jigs provides adequate precision.

The shaft has two water-lubricated bushings (Figure 2) which are either wood (bamboo or oil-soaked hardwood) or hard rubber bearings forced into a metal pipe. A pillow-block bearing is mounted near the flexible coupling which joins the shaft to the engine. The shaft diameter and pillow-block bearing are selected from standard sizes so the shaft fits snugly into the bearing without needing machining. The engine is mounted on to wooden cross-members which help both alignment and adapting the pump to different sizes and makes of petrol and diesel engines or electric motors.

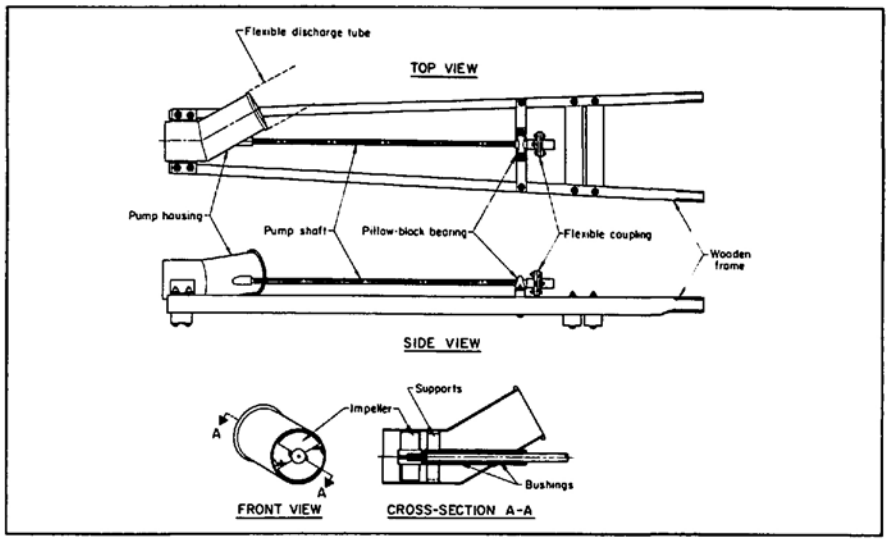

Figure 2. Principal components and assembly of DA – IRRI pump.

Fabrication

The pump housing is fabricated from 1.6mm sheet metal. Our blueprints provide full-size patterns which simplify cutting the housing pieces so that, after rolling, the two cylinders fit together without endless trimming to form the elbow with proper positioning of the oblong hole for the bushing holder. Small shops which do not have sheet-metal rollers are able to hand form the housing pieces around an available cylinder of suitable diameter. With the help of a welding fixture, four metal strips are used to centre the impeller bushing holder inside the housing to attain the desired clearance (approximately 2mm) between the blade tips and the housing wall. One authority's results indicate that smaller clearances are impractical

Table 1. Approximate performance and specifications of 15, 20, and 25cm – diameter AFP pumps with 20 ° pitch impeller*

Performance and specifications	*Diameter of pump* 15cm	20cm	25cm
Pumping capacity			
At 1.5m lift Litres/sec.	44	75	100
At 3m lift Litres/sec.	32	57	70
Shaft Speed (typical value) Revolutions/min.	2,400	1,800	1,200
Power (for 0 to 3m lift)			
Petrol engine: hp (kW)	6.0 (3.7)	10.0 (5.6)	15.0 (7.5)
Diesel engine: hp (kW)	4.5 (3.0)	7.5 (4.5)	11.0 (6.0)
Electric motor: hp (kW)	3.0 (2.2)	5.0 (2.6)	7.5 (3.7)

*See text for explanation. These values are highly approximate, but are useful guides for pump selection.

because shaft or frame deflections cause the impeller tips to rub against the housing. It was found that larger clearances result in decreased capacity due to the reverse flow of water through the clearance space from the downstream (higher pressure) side of the impeller. Since proper alignment of the housing, impeller, bushings, pillow-block bearing, shaft, and engine appears to be the most critical factor influencing pump performance and durability, it has been a top priority of our technical assistance and extension efforts. Alignment is greatly simplified by the AFP pump's pattern and welding fixture which provide adequate centring of the impeller in the pump housing.

The discharge tube may be made from a variety of available low-cost materials, such as second-hand urea fertilizer bags (woven plastic with a coating impermeable to water), woven plastic cloth used for awnings and seat covers, canvas used for tarps and tents, and polyethylene pipe for irrigation and drainage. Some pump owners use PVC pipe or sheet-metal tubes, but these are more expensive and more fragile than other materials. In Camarines Sur, pump owners generally prefer to use the cheapest materials — urea bags and plastic cloth — which are slipped over the pump housing and held by a rubber strip. In Iloilo, polyethylene pipe is preferred because it is readily available at reasonable cost: about $4.50 per metre for 15cm diameter, and $3 per metre for 10cm diameter. Some manufacturers have slightly tapered the end of the pump housing so that polyethylene pipe may be attached simply by forcing it over the housing. In prawn-production areas, (for example, Pangasinan and Negros), stainless-steel sheet-metal tubes are most popular for large diameter (two to 5cm) pumps.

Commercial production

The 6A-IRRI Programme for Small Farm Equipment has assisted more than 25 manufacturers to begin commercial production of the AFP pump in the Philippines. In 1988, we estimate that over 500 pumps were sold to rice farmers and prawn producers. Based on these preliminary experiences, we believe that acceptance by small farmers in developing countries should be substantially greater than for most existing AFP pumps, because the present design is generally easier to fabricate and repair in small rural shops and its price is substantially lower (for example, $50 for a 15cm pump). Because of the higher efficiency of the AFP pump at low lifts, it is far more economical than the centrifugal pump under these operating conditions. Another advantage of the pump is that it may be easily adapted to particular operating conditions and farmers' preferences, which can vary substantially from one area to another.

The principal limitations of the AFP pump must be kept in mind when considering potential applications. The first is that it is limited to low lifts where the centrifugal pump has poor efficiency. At higher lifts (above three to five metres, depending upon impeller design), the centrifugal pump is more appropriate than the AFP pump. Basic staples such as rice, however, require low-lift pumps for irrigation. For this reason, we expect that the pump will have greatest acceptability in the flood plains of south and south-east Asia and in swampy areas of Africa. A second limitation of the AFP pump, as well as any pump powered by an engine or motor, is that the poorest areas of developing countries often do not have either the capital or infrastructure necessary to purchase and maintain any type of engine. In such areas the most appropriate pump would be one that is powered either by human or animal. The RDRS twin-treadle pump is an example of a human-powered pump which the DA-IRRI Programme is promoting in the Philippines.