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High efficiency pool filtering systems utilising variable frequency drives

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ABSTRACT

Over 1 year, private swimming pools in Australia will typically consume 1680 GWh of electricity, producing 2130 kt of CO_2. Redesigning a pool's filtration system and using it more efficiently can reduce the energy use, and hence the CO_2 production, by a significant amount. This paper describes experimental measurements carried out on a new design of pool pump system. Initial experiments using a variable frequency drive (VFD) with a standard, single phase pump/motor system have achieved energy savings of 40%. Utilising a VFD and a three phase pump/motor energy savings of 61% have been achieved, without degrading the system performance.

1. Introduction

More than 10% of Australian households own a swimming pool [1]. The average swimming pool uses 1980 kWh of electricity each year and it is second only to electrical water heaters in terms of household electricity consumption [1]. Over 1 year these pools will consume 1680 GWh, 77% of which is used by the pump, and will produce 2130 kt of CO_2. Reducing the energy demand of swimming pools will not only reduce the emission of greenhouse gases, but also reduce electricity demand during peak hours [2]. Meeting peak hour demand is one of the main problems facing electricity providers; improving the performance of swimming pool pumps has been recognized by some electricity providers as one way of helping to deal with this problem [3].

Pool pump systems normally use single phase AC motors, which are typically rated at 0.75–1.5 kW. Typically they power pumps that operate at full flow rate for quite a short period of time (4–8 h per day, depending on the pool size, pool model and the season). The energy usage of the filtration system is strongly dependent on the pressure drops encountered when pumping the water. The new design, which has been described previously [4], is based on operating the pump at different flow rates (full and quarter) for longer periods of time. Lower flow rates dramatically lower the pressure drops within the system, which leads to large energy savings.

The electrical energy required per day, E_e (J), is determined by the following equation:

$$E_e = \left(\Delta P \times V_{day}\right) / \eta \qquad (1)$$

where ΔP is the pressure difference between the inlet and the outlet of the pump (Pa), V_{day} is the volume of water pumped per day (m^3) and η is the combined efficiency of the pump and the electric motor powering the pump. Usually V_{day} is chosen to be about 10% greater than the volume of the pool (the Australian standard requires "…A single turnover of the full volume of the pool water within the period that the pump would normally be operating…" [5]).

The relationship between the pressure and flow rate is typically assumed to be

$$\Delta P = K\dot{V}^2 \qquad (2)$$

where $\dot{V}$ is the volumetric flow rate [m^3/s] and K is a constant [Pa m^{-3} s]. This equation is true for turbulent flow only. It was shown [6] that for all pipe diameters and all flow rates used in the pool filtration system, the flow is turbulent (but not in the filter). From Eqs. (1) and (2) it is clear that reducing the flow rate will cause a reduction of the energy required to filter the pool water.

The lower flow rate can be used only for the filtration process. The vacuum cleaning devices (that are used at a different frequency, depending on the pool surroundings) still require the high flow rate.

2. Experimental system

2.1. Mechanical components

The pool that is used for this research is a 105,000 L, in-ground pool (Fig. 1). The pool has two suction points (skimmer boxes) and four inlet points (two close to the surface and two at half the pool depth).

The initial system was composed of a pump (Hayward, super pump 1HP), a sand filter (Davey filter, model Crystal Clear 250) and

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Fig. 1. The pool.

a chlorinator (Clearwater/Zodiac, model C140) connected with 40 mm diameter pipes. For the later experiments the single phase pump was replaced with a three phase pump (Grundfos, NB 32-200/200).

A measurement system was added to this system. A schematic diagram of the measurement system's set-up can be seen in Fig. 2. This measurement system is composed of:

(A) A differential pressure gauge (Dwyer, 629-04-CH-P2-E5-S1) which was located between the inlet to the pump (D1) and the outlet of the pump (D2).
(B) Two pressure gauges which were installed at the inlet of the filter (P3) and at the outlet of the filter (P4).
(C) A flow meter (ManuFlo, model MRPU5-F, 18–250 L/min) which was installed between the pump and filter.
(D) A valve (V), which is located between the differential pressure gauge (D2) and the flow meter.

2.2. System curve and pump working curve

To determine the pump curve (the relationship between the pressure developed by the pump and the flow rate through it) the following method was used: flow rates were varied using the valve, and measurements of the pressure and flow rate were made; changing the valve's position causes the working point of the system to change. This fact enables the determination of the relationship between the pressure developed by the pump (that given by the differential pressure gauge, see Fig. 2(a)) and the flow rate, i.e. the pump's working curve. Fig. 3 shows the working curve as measured experimentally as well as the manufacturer's curve for the pump used in this study, Grundfos NB 32-200/200 [7]. For a given flow rate the pressure measured experimentally is clearly lower than the manufacturer's data. This indicates that the pump is somewhat less efficient than would be predicted from the manufacturer's curve.

To determine the system curve (the relationship between the pressure drop and the flow rate in the system) a different method was used: the pump's motor speeds were varied using the variable frequency drive and measurements of the pressure and flow rate were made. Changing the motor speed changes the pump's working curve and causes change at the working point of the system. Changing the pump's curve does not change the system curve, so by getting a number of different working points it is possible to draw the system curve. At each working point the pressure drop of the system is equal to the pressure that is developed by the pump, so measuring the pressure that is developed by the pump (the reading of the differential pressure gauge) gives the pressure drop of the system. By this method the relationship between the pressure drop in the system and the flow rate (i.e. the system curve) was found. Fig. 4 shows the system curve as well as a polynomial fit to the data.

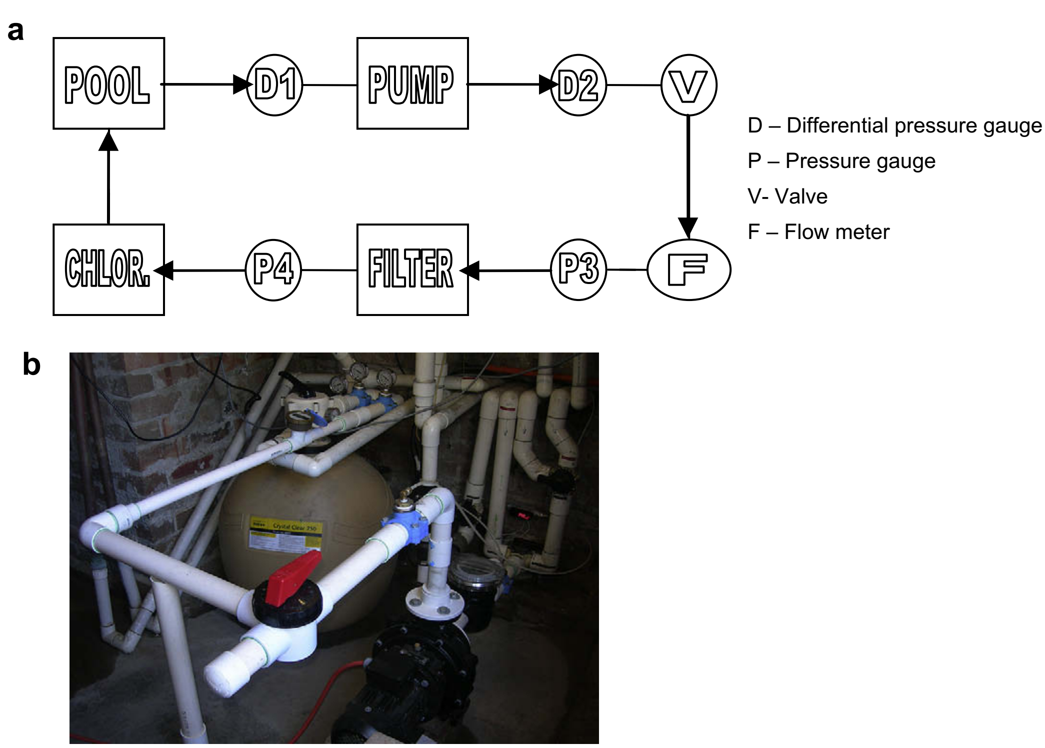

Fig. 2. Mechanical system schematic (a) and system photo (b).