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WATER EFFICIENCY OF KITCHEN FAUCET IN MANUAL DISHWASHING

BY

YIM KA CHUN MARTIN

A Dissertation submitted to the Hong Kong Polytechnic University
in partial fulfillment of the requirements of a

MASTER OF ENGINEERING

Department of Building Services Engineering
Faculty of Construction and Environment
May 2018
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ABSTRACT

Abstract of dissertation entitled:
Water efficiency of kitchen faucet in manual dishwashing
submitted by Yim Ka Chun Martin
for the degree of MEng in Building Services Engineering
at The Hong Kong Polytechnic University in May, 2018.

The existing fresh water landscape in Hong Kong relies majority of its fresh water supply from China. Government initiatives to reduce water utilization were futile as the city’s water consumption is growing at an increment rate and over 900 million cubic meters of fresh water are consumed annually across six sectors. With residential users being the largest consumer accounting for more than half of the expenditure. Faced with the imminent threat of global water shortage, heavy reliance on water supply from China and increasing price of water, the city must do more to reduce the total water consumption and placed greater emphasis on water conversation measures and awareness. The largest contribution to the domestic water consumption are caused by water faucet, with half of the water usage coming from manual dishwashing. This research aims to construct a working experimental model to investigate the optimization of kitchen faucet in terms of water efficiency and ultimately reducing the overall water consumption.

Keywords: Hong Kong, water efficiency, faucets, water conversation, manual dishwashing, water consumption.
ACKNOWLEDGEMENTS

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Last but not least, the author offers his utmost acknowledgement to his family for their unconditional patience and kindness.
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CHAPTER 1. INTRODUCTION

This chapter gives an introduction of this dissertation by detailing the research background, objectives and scope.

1.1 Research Background

Water scarcity is an imminent problem that affects every continent in the world. In fact, “demand is projected to grow by more than 40% by 2050” (Jan, 2014). In a decade time, approximately 1.8 billion people will dwell in countries where water is limited and 66% of the people of the world’s population could be living in shortages of clean water supply for daily necessity (Kummu et al., 2016).

The global water crisis is both a natural and a man-made phenomenon. It can be physical or social, influenced by political power and socio-economic policies. Physical water scarcity can be classified into two main groups either driven by population (i.e. water shortage) or driven by demand (i.e. water stress). Water shortages exist in areas where large community are dependent on a limited resource, whilst water stress is associated with the excessive use of available water resources that may potentially lead to future difficulties in accessing the reserves (Porkka, Kummu, Siebert, & Flörke, 2012).

The rapid rise of human population contributed by urbanization from developing countries such as China, India and Nigeria will account for 37% growth by 2050 (United Nations, 2015). With continuous expanding communities, global water consumption in cities has surge up to an estimated six-times which is double the rate of population growth (Guinness and Walpole, 2012).
Stevenson et al., (2016) mentions that government, private organizations and businesses have collaborate to establish water conversation measures aimed at reducing water consumption and preventing water shortages.

Due to the geographical and natural resources constraints, Hong Kong has been heavily reliant to China for 80% of its fresh water supply since 1964 (South China Morning Post, 2017) which accounts for 951 million cubic meters in 2007 and foresee that it will surge to 1.35 billion cubic meters in 2030 (Water Supplies Department, 2008). An estimated population of 7 million people (C. a. S. Department, 2017) are being supplied with fresh water from these three main sources, Dongjiang, Guangdong Province, local freshwater sources in reservoirs and seawater for flushing toilets. The total annual consumption in 2015 exceeds the global average by 260 million cubic meters. With the fixated lump sum water contract and substantial increase of water price from our supplier which often results in surplus (Chen, 2015), the Hong Kong government are venturing different ways to reduce water consumption and external reliance through its total water management strategy. It introduces new initiatives for rainwater harvesting, greywater reuse, future desalination plants and promote water conservation (Water Supplies Department, 2018).

In view of regional domestic consumption, Hong Kong had increased consumption from 190 to 220 litres per day per capita in 2015 as compared to Singapore at 160 litres and Shanghai 106 litres (South China Morning Post, 2017). The Hong Kong government announced a voluntary water efficiency labelling scheme (WELS) which is part of a water conversation initiative to include plumbing fixtures and water-consuming appliance. A joint domestic water consumption survey conducted by the government and consultant (Water Supplies Department, 2011) shows a high readiness 86% and 98.8% of the
household awareness and in favor of supporting water conversation respectively. Figure 1 identified the different usage of domestic fresh water which are mainly water tap, shower heads, washing machine and bath tubs. Out of the various selection, water taps accounts for 46.6% which over half of the water consumption is used for dishwashing. A global manual dishwashing behavioral study shown that washing dishes under constant running tap water is the most water consuming method. Therefore, it is believed that introducing water efficient technologies on kitchen faucets as part of water conversation efforts will reduce the overall household water consumption.

1.2 Research Objective

The main objective of this research is to investigate the water efficiency associated with different types of kitchen faucets used in manual dishwashing of regular domestic household.

Therefore, the objectives of this research are outlined as follows:
1. Explore a number of influencing factors and their characteristics and inter-relationships that may potentially affect the nature and performance of the outcome.

2. Construct a working model to perform experimental tests.

3. Verify the characteristics and inter-relationships of the factors and setting within the working model based on the results.

1.3 Research Scope

This research seeks to address the central question in water conversation within the context of Hong Kong domestic household, with a specific focus on exploring the water efficiency of kitchen faucets which is associated with (L.S. YEE., L.T. WONG., K.W. MUI., & ZHOU, 2017). As the key question surrounding water efficiency is largely on consuming less water to deliver or maintain same output through water efficiency faucets, thus the research question of this study is:

Water efficiency is defined by the proportion of the minimum water consumption with existing technology and domestic water consumption with water efficient technology. In an effort to reduce the water consumption in domestic household, we need to investigate on the improvement of water efficiency of kitchen faucets under manual dishwashing conditions.

1.4 Structure of Dissertation

The arrangement of this dissertation is compiled as follows:
Chapter 1 Introduction

This chapter gives an introduction of this dissertation by detailing the research background, objectives and scope.

Chapter 2 Literature Review

This chapter addresses the overview of water utilization in Hong Kong. First, it analyzes the major users and correlated government intervention, it then examines the existing standards and past research on water efficiency that is associated to domestic household with focus in manual dishwashing. Lastly, it reviews those literature and research gaps to provide a theoretical basis for the experiment to be conducted in further chapter.

Chapter 3 Research Methodology

This chapter outlines the methodology used to test the water efficiency of kitchen faucets. It investigates the development of water efficiency and approaches for the research including a description of the process used to develop the experimental setup, research study procedures, and sample selection.

Chapter 4 Results and Analysis

This chapter evaluates the findings derived through the experimental and analytical method in the working model. First, it determines faucet water flow and water pressure as a key qualitative parameter, it then identifies the discharge characteristics of the kitchen faucets. Finally, it examines the results of the experiment to test the research hypothesis and re-evaluate the dishwashing method.
Chapter 5 Conclusion and Recommendation

This chapter outlines the summary of the research study, it then clarifies some of the limitations in this study and in conclusion, propose recommendations on future research.
CHAPTER 2. LITERATURE REVIEW

This chapter addresses the overview of water utilization in Hong Kong. First, it analyzes the major users and correlated government intervention, it then examines the existing standards and past research on water efficiency that is associated to domestic household with focus in manual dishwashing. Lastly, it reviews those literature and research gaps to provide a theoretical basis for the experiment to be conducted in further chapter.

2.1 Overview of Hong Kong’s Water Consumption Scenario

In the past decade, the total water consumption of fresh water in Hong Kong had declined 4% from 2006 to 2011 and had been gradually increased over the course of 5 years dated with cumulative 7% to 987 million cubic meters in 2016. Despite continuous efforts from the government with water conversion initiatives such as “Let’s Save 10L Water” Campaign in 2014, individual on average consumed 135 cubic meters of water in 2016, an increase of 5 cubic meters from 2013 (Legislative Council Secretariat, 2017).

The fresh water consumption in Hong Kong as shown in Figure 2 is segregated 6 sectors; Industrial (6.2%), Construction & shipping (2.4%), Government (4.4%), Service trades (25%), Flushing (7.9%) and Domestic (54.1%). Residential household users prevailed as the largest fresh water consumer in 2015 accounting for 54% of the overall consumption, followed by service sector (25%) and use of toilet flushing (8%). According to Water Supplies Department (2017), the government has been increasingly replacing the use of precious freshwater for toilet flushing with seawater and reclaimed water supply, from 80% of the population in 2015 to 90% in 2022.
The government had also taken steps to reduce the water main leakages, inaccurate metering and illegal water consumption that contributes up to 30% of the fresh water (equivalent to 296 million cubic meters of fresh water). The “Replacement and Rehabilitation Programme of Water Mains” was one of the plan to rectify the problems which resulted in a reduction in the public mains leakage rate down to 15% from 23% within a decade.

One of the city’s main source of water supply came from Dongjiang, China, in the regions of 60% to 70% while the rest are mainly from local catchments. The main water source is purchased from the Guangdong Provincial Government under a lump sum package deal of HK $4.22 billion yearly since 2006 (South China Morning Post, 2017) which saw the water unit price surged from HK$3.04 to HK$5.83, at an average yearly rate of 6.1%. Under the new agreement made in November 2017, the water utilize price will be incremented by

Figure 2 - Fresh water consumption by sectors
0.3% yearly to HK$5.88 in 2020 (Audit Commission, 2017) due to monetary changes in exchange rate between Hong Kong Dollar and Renminbi and inflation of individual cities. Desalination plant in Tseung Kwan O with annual capacity of 49 million cubic meters are being planned with completion in 2020 as an on-going effort by the Hong Kong government to improve water security and reliance. This plan sees a reduction of approximately 5% to the annual fresh water consumption in Hong Kong as seen in Figure 3 below.

![Figure 3 – Estimated sources of fresh water supply in 2020](image)

2.2 Domestic Water Consumption in Hong Kong

Annually, more than half of the fresh water in Hong Kong are consumed for domestic household (refer to Figure 2). It is estimated that the daily domestic water consumption is 0.2 cubic meter per capita and water consumption is expanding at 3% yearly (E. W. M. Lee. & K. P. W. K., 2017). As shown in Figure 1, the different usage of domestic fresh water consolidated are namely water tap, shower heads, washing machine and bath tubs.
The household average per capita daily domestic fresh water consumption was 143L with the largest portion of 61.1L used for water faucets, 55.2L for showering and the remaining for washing machine and bath tubs. A questionnaire was conducted to investigate whether family conditions were a major factor in affecting domestic water consumption. The findings suggested that domestic water consumption strongly correlates to the residential floor area and number of family members. It also points out that families with stronger financial capabilities consumes more water. This suggestion was consistent with the Domestic Water Consumption (H. K. W. S. Department, 2011) survey indicating that household with high per capita consumption uses 57.8% of water through water faucet as compared to low per capita consumption of 33% of water through water faucet.

### 2.3 Existing standards on water efficiency of faucets

In 2010, Water Supplies Department introduces a voluntary Water Efficiency Labelling Scheme (WELS) to incorporate water efficiency label which cover most of domestic water-consuming appliances such as water faucet and shower heads. This scheme encourages more public awareness on water conservation and efficiency issues, also to achieve actual water savings through more efficiency appliances. The water efficiencies of the water faucets are rated according to their types and nominal flow rates (refer to Figure 4) with Grade 1 as the most water efficient and Grade 4 as the least water efficient.
<table>
<thead>
<tr>
<th>Water Efficiency Grade</th>
<th>Symbolic Presentation on the Water Efficiency Label</th>
<th>Mixing Type* Water Taps Nominal Flow Rate: $f$ (litres/minute)</th>
<th>Non-mixing Type* Water Taps Nominal Flow Rate: $f$ (litres/minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 1</td>
<td>1 water droplet</td>
<td>$f \leq 5.0$</td>
<td>$f \leq 2.0$</td>
</tr>
<tr>
<td>Grade 2</td>
<td>2 water droplets</td>
<td>$5.0 &lt; f \leq 7.0$</td>
<td>$2.0 &lt; f \leq 4.0$</td>
</tr>
<tr>
<td>Grade 3</td>
<td>3 water droplets</td>
<td>$7.0 &lt; f \leq 9.0$</td>
<td>$4.0 &lt; f \leq 6.0$</td>
</tr>
<tr>
<td>Grade 4</td>
<td>4 water droplets</td>
<td>$f &gt; 9.0$</td>
<td>$f &gt; 6.0$</td>
</tr>
</tbody>
</table>

Figure 4 - Grading of Water Efficiency Level (Water Supplies Department, 2010)
CHAPTER 3. METHODOLOGY

This chapter outlines the methodology used to test the water efficiency of kitchen faucets. It investigates the development of water efficiency and approaches for the research including a description of the process used to develop the experimental setup, research study procedures, and sample selection.

3.1 Research Approach

The total water consumption for cleaning a plate, \( V \) (L) is defined by equation number (1) where it describes the relationship between the experimental water consumption for cleaning the plate, \( V_e \) (L), and the measured cleanliness, \( \varphi \), where \( \phi_0 \) and \( \phi_1 \) are the visual values for the soiled area of the plate before and after washing respectively.

\[
V = \frac{V_e}{\varphi}; \quad \varphi = \frac{\phi_0 - \phi_1}{\phi_0}
\]  

(1)

Equation 2 derives the experimental water consumption \( V_e \) (L) where it is determined by the tap flow rate \( v \) (L/s) and tap discharge time \( t \) (s) as shown on (2).

\[
V_e = vt
\]

(2)
3.2 Development of Experimental Setup

3.2.1 Illustration of the Preliminary Experimental Setup

This initial experimental setup demonstrated in Figure 1 mimic actual domestic household kitchen condition where water storage tank supply undisturbed flow of fresh water through a booster pump passing through a series of ball valve for maintenance purposes before entering flow meter and pressure gauge for operational purposes and eventually released from the kitchen faucet on to the soiled glass tile surrounding the sink. Further improvements were considered and implemented in the actual experimental setup shown on Figure 2.
3.2.2 Actual Experimental Setup

Figure 6 – Working Experimental Model
The working experimental model (Figure 2 and 3) provided few improvements from the preliminary design such as an interchangeable position for the various types of kitchen faucets during the testing to reduce time. Drain outlet were constructed from sink to facilitate the waste water discharge from the incoming faucet water. The addition of sump pit box was associated with the waste water outlet.

**Figure 7 – Side view of working experimental model**
3.3 Types of kitchen faucets

The following kitchen faucets are generally used by the domestic household population. The discharge characteristics of the various kitchen faucets will be discussed in future subheadings.

3.3.1 Column type faucet

![Figure 8 – Aesthetics of column type faucet](image)

3.3.2 Spray type faucet

![Figure 6 – Aesthetics of spray type faucet](image)

![Figure 5 – Column faucet outlet](image)

![Figure 7 – Spray faucet outlet](image)
3.3.3 Mixed type faucet

Figure 8 – Mixed type faucet outlet

3.4 Sample Selection

3.4.1 Ceramic Plate

Figure 9 – Sample of ceramic plate
The ceramic plate is measured 206mm in diameter with a base of 125mm and thickness of 40mm. The preliminary material selection ranged from glass, wood, plastic, stainless steel and ceramic. Despite the several choices, ceramic materials were evaluated to be most affordable and commonly used in Hong Kong household for serving foods in variety of sizes and types such as saucer, dessert, lunch, dinner plates.

3.4.2 Selection of Soil

In this experiment, ketchup was selected to resemble leftover sauces on plate based on actual household scenario. The viscosity of the sauce makes it resistance to flow and can only be moved with decent amount of shearing force as opposed to soy sauce of a lower viscosity index. The availability and affordability of the product also contributed to the selection.
3.5 Discharge characteristics of sample faucets

The experiment on the three faucets namely column, spray and mixed type were conducted to establish individual discharge characteristic. The flow rate of the faucets was measured based on the water meter and the aid of a stopwatch to calculate the time duration. Similarly, the faucet pressure was taken from the pressure gauge readings.

3.6 Dishwashing method

The dishwashing test were conducted in the following settings. Three water faucet variation for dishwashing were considered in this study. Figure 5, 7 and 8 exhibits the column, spray and mixed faucet respectively. A tablespoon of ketchup was disseminated evenly over the surface of the plate as shown in Figure 12 and was washed beneath a kitchen faucet under certain time duration. Followed by a visual assessment of cleanliness in decrement of 10 from 100 (being filled with soil) to 0 (completely clean of soil).

Figure 12 – Soiled plate before washing
CHAPTER 4. RESULTS AND ANALYSIS

This chapter evaluates the findings derived through the experimental and analytical method in the working model. First, it determines faucet water flow and water pressure as a key qualitative parameter, it then identifies the discharge characteristics of the kitchen faucets. Finally, it examines the results of the experiment to test the research hypothesis and re-evaluate the dishwashing method.

4.1 Discharge characteristics

The graph shown in Figure 13 identify the baseline for faucet water flow rates under different water pressure for the various types of kitchen faucet. The results were conducted with a time constant of 10 seconds. It interprets that the faucet flow rates correlate to the water pressure. An increase in the water pressure will increase the flow rate output. It is
noted that under the same water pressure at 50kPa, the amount of faucet output from spray type is more than twice the amount of column type. In this case, the column type faucet is said to have better water saving capacity amongst the three types.

4.2 Plate Cleanliness

The measured cleanliness ($\varphi$), is derived by the visual values for the soiled area of the plate before and after ($\varphi_0$ and $\varphi_1$) washing respectively. The level of cleanliness is determined by a visual assessment of the plate from a decrement of 5 from 100 (being filled fully with soil) to 0 (completely clean of soil). For example, illustrated in Figure 14, using column faucet at 150kPa water pressure, using 0.83 L/s faucet water in 10 secs.

$$\varphi = \frac{\varphi_0 - \varphi_1}{\varphi_0}$$

$$\varphi = \frac{100 - 15}{100} = 0.85$$

Figure 14 – Measurement of plate cleanliness
4.3 Total Volume Consumption

The total volume consumption for cleaning a plate \((V)\), is defined by equation number 1 where it describes relationship between the experimental water consumption for cleaning the plate \((V_e)\), and measured cleanliness \((\varphi)\) and equation 2 derives the experimental water consumption \((V_e)\) where it is determined by the tap flow rate \((v)\) and tap discharge time \((t)\) as shown on (2).

\[
V = \frac{V_e}{\varphi}; \quad \varphi = \frac{\phi_0 - \phi_1}{\phi_0} \tag{2}
\]

\[
V_e = vt \tag{2}
\]

Table 1 – Combination of total volume consumption

<table>
<thead>
<tr>
<th>Pressure (kPa)</th>
<th>(v) (L/s)</th>
<th>(V_e) (L)</th>
<th>(\varphi) (%)</th>
<th>(V) (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column Faucet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>0.050</td>
<td>0.50</td>
<td>0.40</td>
<td>1.25</td>
</tr>
<tr>
<td>100</td>
<td>0.064</td>
<td>0.64</td>
<td>0.55</td>
<td>1.16</td>
</tr>
<tr>
<td>150</td>
<td>0.083</td>
<td>0.83</td>
<td>0.80</td>
<td>1.03</td>
</tr>
<tr>
<td>Spray Faucet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>0.123</td>
<td>1.23</td>
<td>0.55</td>
<td>2.23</td>
</tr>
<tr>
<td>100</td>
<td>0.137</td>
<td>1.37</td>
<td>0.75</td>
<td>1.83</td>
</tr>
<tr>
<td>150</td>
<td>0.176</td>
<td>1.76</td>
<td>0.90</td>
<td>1.95</td>
</tr>
<tr>
<td>Mixed Faucet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>0.149</td>
<td>1.49</td>
<td>0.60</td>
<td>2.48</td>
</tr>
<tr>
<td>100</td>
<td>0.166</td>
<td>1.66</td>
<td>0.85</td>
<td>1.96</td>
</tr>
<tr>
<td>150</td>
<td>0.191</td>
<td>1.91</td>
<td>0.95</td>
<td>2.01</td>
</tr>
</tbody>
</table>
The consolidation of the total volume consumption \((V)\) for various type of kitchen faucets are tabulated in Table 1. All of the above collection data are executed for 5 times to ensure the accuracy. In this experimental setup, qualitative parameters such as working water pressure and average water faucet flow rate were measured in time constant of 10 seconds to derive the experimental water consumption \((V_e)\) and visual values to derive measured cleanliness \((\varphi)\).

The first sequence of the subject testing was column faucet. It was tested under three different water pressures namely 50kPa, 100kPa and 150kPa, each with an increased faucet flow rate as demonstrated in their discharge characteristics earlier on at Chapter 4.1. The derived experimental water consumption shows a steady increasing consumption of 0.05 liters, 0.064 liters and 0.083 liters associated with the associated raising water pressure. The measured cleanliness correlates with the experimental water consumption from 40%, 55% to 80%. This shows a linear correlation between the experimental water consumption and measured cleanliness. With the above two variables, the total volume consumption is then derived with a decreasing of 1.25 liters, 1.16 liters and 1.03 liters. This indicates that it takes less amount of water consumption to dishwash a plate with increasing water pressure and faucet flow rate.

The second sequence of the subject testing was spray faucet. All the parameter remains unchanged from previous experiment. The derived experimental water consumption was 0.12 liters, 0.137 liters and 0.176 liters and measured cleanliness was at 55%, 75% and 90%. The total volume consumption derived to be 2.23 liters, 1.83 liters and 1.95 liters.
The third and last sequence of the subject testing was mixed faucet. All the parameter remains unchanged from previous experiment. The derived experimental water consumption was 0.149 liters, 0.166 liters and 0.191 liters and measured cleanliness was at 60%, 85% and 95%. The total volume consumption derived to be 2.48 liters, 1.96 liters and 2.01 liters.

From the experimental data of the three types of kitchen faucet, they provide a good linear correlation between faucet flow water and water pressure, experimental water consumption and measured cleanliness. There was a strong correlation between experimental water consumption and total volume consumption for column faucet but not for spray faucet and mixed faucet as both of the latter uses more volume of water todishwash a plate at 150kPa water pressure than at 100kPa which results were opposite for column faucet. In view of the discrepancy for spray and mixed faucet, it shall be noted that the measured cleanliness at 100kPa shows partial cleanliness at 75% and 85% as compared to 90% and 95% at 150kPa. This mean that more water volume is consumed to achieve higher measured cleanliness for these two types.

Comparing among the faucets, column faucet uses the least water volume of 1.03 liters at 150kPa to achieve 80% of cleanliness while spray and mixed faucet uses 1.95 liters and 2.01 liters to achieve 90% and 95% cleanliness.
CHAPTER 5. CONCLUSION AND RECOMMENDATIONS

This chapter outlines the summary of the research study, it then clarifies some of the limitations in this study and in conclusion, propose recommendations on future research.

5.1 Conclusions

The fundamental of this research study is to investigate the water efficiency from various types of kitchen faucets in manual dishwashing for domestic household. It is achieved by the collection and analysis of experimental data conducted using the working model.

The results of this research study suggest that certain type of kitchen faucet consumes less water and achieve better cleaning results using the static placement dishwashing method. This application of using the most water-efficient kitchen faucet can potentially reduce the household total water consumption and reduce utility bills. Hypothetically, this water saving opportunity extends beyond dishwashing application any usage associated with the water-efficient kitchen faucet might potentially result in water saving. This could range from washing of hands, kitchen equipment to food preparation.

Realistically, for this water saving concept to be effectively put in place the domestic household must first be willing to invest in new technologies of water-efficient faucets. The results of the effort could be reflected immediately on the financial reduction in existing utility bills. However, this might be hard to achieve as many domestic household are unwilling to change the status quo to replace the kitchen faucet unless it reaches equipment end-life. Moreover, the associated cost of replacing the faucet with professional plumbers certainly is not favorable for most families. Therefore, the government or public...
funded bodies needs to take various approaches to encourage improved water efficiency in domestic household. It can be achieved by establishing information program as a supportive role and most effective with the technologies are promoted with good sense for the people. These are to inform people of the latest technology development which can help improve the water use efficiency in household and equipped them with better informed knowledge of water-efficient kitchen faucet in the market. It can also be achieved by providing financial inducement to support water conservation activities by giving tax relief for a sum of money to a household if proof can be provided that the money was solely used for water saving activities such as purchasing and installing water efficient kitchen faucet.

Ultimately, this longstanding strategy would raise more awareness on environmental conservation and curtail the annual increase of fresh water consumption anticipated from the largest consumers in particular, the residential users.

5.2 Limitations and Future Research Directions

Despite the fact that this study had provided insight into the water efficiency of kitchen faucet, in particularly manual dishwashing, it has some limitations.

Firstly, given the research time frame of 7 months from September 2017 to April 2018, this study is likely to be met with some degree of time constraints. As an experimental research, this study was conducted over a short period of time and does not fully explore the specification detailing the kitchen faucets.

The second limitation is the vast selection of kitchen faucets available in the market ranging from basic faucets to high-end aesthetics kitchen faucets with additional function.
In addition to the above limitation, South China Morning Post reported that more residential households are installing water filter since the 2015 lead incident where excess metal was found in drinking water at residential buildings (SCMP, 2015). If the above two limitations were implemented, there might be a distinctive difference in the results outcome as the latter is correlated with water pressure drop due to filtering mechanism.

The third limitation is in regard to the experimental subject employed in this study only covers the washing of dish and ketchup as soil. Based on a typical Asian household in Hong Kong which uses an extensive range of dish and utensils, more should be considered in future research. Future efforts should also include leftover crud that dry overnight to simulate real life conditions.

Fourth, as the results of this study was conducted in the absence of dishwashing detergent and dish sponge which are commonly employed in a domestic household to facilitate the manual dishwashing. The inclusion of detergent or sponge will exploit the overall efficiency in manual dishwashing under the same testing conditions and therefore, the emphasis on kitchen faucets might render non-substantial.

Finally, a possible shift to dishwasher as manual dishwashing even with best practices are effective for heavy loads coupled with limited kitchen space. Majority of domestic household in Hong Kong does not have the recommended two washing sinks to execute best practices tips.
REFERENCES


20th century and pathways towards sustainability. *Scientific Reports, 6*, 38495. doi:10.1038/srep38495


APPENDIX A. KIKAWA KQ400 BOOSTER PUMP

A.1 Pump Specification and Performance Curve
### PERFORMANCE CURVES

![Graphs showing performance curves for KIKAWA Multistage Booster Pump.

### SPECIFICATIONS

<table>
<thead>
<tr>
<th>MODEL</th>
<th>Rated Input</th>
<th>Pipe Dia. (mm)</th>
<th>Rated Head (M)</th>
<th>Rated Capacity (l/min)</th>
<th>Hz</th>
<th>Voltage 1th</th>
<th>Stages</th>
<th>Max. Head (M)</th>
<th>Max. Capacity (l/min)</th>
<th>A (mm)</th>
<th>B (mm)</th>
<th>C (mm)</th>
<th>D (mm)</th>
<th>E (mm)</th>
<th>Weight (Kg)</th>
<th>Packing LxWxH (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KQ200</td>
<td>200W 1/4HP</td>
<td>20</td>
<td>15</td>
<td>50</td>
<td>26</td>
<td>220/240</td>
<td>3</td>
<td>23</td>
<td>48</td>
<td>168</td>
<td>171</td>
<td>214</td>
<td>80</td>
<td>85</td>
<td>9.5</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>50</td>
<td>110/220</td>
<td>2</td>
<td>23</td>
<td>55</td>
<td>140</td>
<td>146</td>
<td>214</td>
<td>80</td>
<td>85</td>
<td>9.0</td>
<td>7.5</td>
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<td>400W 1/2HP</td>
<td>25</td>
<td>20</td>
<td>50</td>
<td>32</td>
<td>220/240</td>
<td>3</td>
<td>26</td>
<td>56</td>
<td>168</td>
<td>171</td>
<td>230</td>
<td>80</td>
<td>85</td>
<td>11.0</td>
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<td>110/220</td>
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<td>146</td>
<td>146</td>
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<td>85</td>
<td>10.5</td>
<td>9.0</td>
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<tr>
<td>KQ800</td>
<td>800W 1 HP</td>
<td>25</td>
<td>25</td>
<td>50</td>
<td>50</td>
<td>220/240</td>
<td>3</td>
<td>32</td>
<td>88</td>
<td>182</td>
<td>168</td>
<td>252</td>
<td>82</td>
<td>90</td>
<td>14.0</td>
<td>12.0</td>
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<tr>
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<td></td>
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<td>155</td>
<td>161</td>
<td>252</td>
<td>82</td>
<td>90</td>
<td>13.5</td>
<td>11.5</td>
</tr>
</tbody>
</table>

*1 Cast iron or stainless steel pump casing models

*2 Thermoplastic pump casing models

---

-3-
KIKAWA Multistage Booster Pump

KQ Series

- Cast Iron/Stainless Steel
- Normal Temperature

- RATED HEAD / HEIGHT
  - KQ200(S): 1.5 kg/cm² / 15 m
  - KQ400(S): 2.0 kg/cm² / 20 m
  - KQ800(S): 2.5 kg/cm² / 25 m

- LIQUID TEMPERATURE
  - +5 °C ~ +40 °C

- MAIN MATERIAL

<table>
<thead>
<tr>
<th>Part</th>
<th>KQ200</th>
<th>KQ400</th>
<th>KQ800</th>
<th>KQ200S</th>
<th>KQ400S</th>
<th>KQ800S</th>
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<tbody>
<tr>
<td>Motor</td>
<td>Steel Plate</td>
<td></td>
<td>Aluminum</td>
<td>Steel Plate</td>
<td>Aluminum</td>
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</tr>
<tr>
<td>Pump Casing</td>
<td>Cast Iron (FC200)</td>
<td></td>
<td>Stainless Steel (SUS304)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump Shaft</td>
<td>Stainless Steel (SUS410)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical Seal</td>
<td>Ceramic+Carbon+NBR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impeller</td>
<td>Thermoplastic (Noryl)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure Tank</td>
<td>Stainless Steel+Rubber</td>
<td></td>
<td></td>
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<td></td>
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</table>

- CONSTRUCTION

<table>
<thead>
<tr>
<th>Item</th>
<th>Part Name</th>
<th>Item</th>
<th>Part Name</th>
<th>Item</th>
<th>Part Name</th>
<th>Item</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Motor</td>
<td>11</td>
<td>Pump Cover</td>
<td>21</td>
<td>Priming Plug</td>
<td>29</td>
<td>Pressure Switch</td>
</tr>
<tr>
<td>2</td>
<td>Bolt</td>
<td>12</td>
<td>O Ring</td>
<td>22</td>
<td>Flow Switch</td>
<td>30</td>
<td>Switch Cover</td>
</tr>
<tr>
<td>3</td>
<td>Pump Casing</td>
<td>13</td>
<td>Pressure Tank</td>
<td>22-1</td>
<td>Spring</td>
<td>31</td>
<td>Pump Thermal Protector (Auto Reset)</td>
</tr>
<tr>
<td>4</td>
<td>Mechanical Seal</td>
<td>14</td>
<td>Pump Cover Bolt</td>
<td>22-2</td>
<td>Stopper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Impeller Chamber</td>
<td>15</td>
<td>Inlet Flange Gasket</td>
<td>23</td>
<td>Seal Gasket</td>
<td>32</td>
<td>Pump Base</td>
</tr>
<tr>
<td>6</td>
<td>Impeller</td>
<td>16</td>
<td>Inlet Flange</td>
<td>24</td>
<td>Wiring Box</td>
<td>33</td>
<td>Bolt</td>
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<tr>
<td>7</td>
<td>Diffuser</td>
<td>17</td>
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<td>Bolt</td>
<td>34-2</td>
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<td>8</td>
<td>Impeller</td>
<td>16</td>
<td>Outlet Flange Gasket</td>
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<td>Wiring Box Cover</td>
<td>36-2</td>
<td>Impeller</td>
</tr>
<tr>
<td>9</td>
<td>O Ring</td>
<td>19</td>
<td>Outlet Flange</td>
<td>27</td>
<td>Bolt</td>
<td>36-2</td>
<td>Pump Cover</td>
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<td>Bolt</td>
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<td>28</td>
<td>Controller</td>
<td>37</td>
<td>Motor Capater</td>
</tr>
</tbody>
</table>

*1 Part for 50Hz 2-stage models
*2 Parts for 50Hz 3-stage models
A.2 Installation Manual

KQ Series

Multistage Booster Pump System

Installation Manual

ISO 9001 Certified
§ Description

The KQ series booster pump is an all-in-one compact and reliable automatic multistage centrifugal booster pump, which integrates motor, pump, accumulator, pressure switch and flow switch in one set. The flow switch equipped with KQ pump prevents the pump from continuously starting and stopping under small discharge, and provide stable water supply. It is very suitable for domestic water supply.

§ Operating Conditions

1. Ambient Temperature: +2 °C ~ +40 °C
2. Liquid Temperature: +2°C ~ +40°C
3. Maximum Operating Pressure: 5 kg/cm²
4. Rated Discharge Head / Height
   KQ200: 1.5 kg/cm² / 15 m
   KQ400: 2.0 kg/cm² / 20 m
   KQ800: 2.5 kg/cm² / 25 m

§ Construction

<table>
<thead>
<tr>
<th>Item</th>
<th>Name</th>
<th>Description</th>
<th>Item</th>
<th>Name</th>
<th>Description</th>
<th>Item</th>
<th>Name</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Motor</td>
<td>1φ/2 Poles</td>
<td>14</td>
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<td>SUS304</td>
<td>25</td>
<td>Bolt</td>
<td>S45C</td>
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<tr>
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<td>Bolt</td>
<td>S45C</td>
<td>15</td>
<td>Flange Gasket</td>
<td>Rubber</td>
<td>26</td>
<td>Wiring Box Cover</td>
<td>NYLON</td>
</tr>
<tr>
<td>3</td>
<td>Pump Casing</td>
<td>FC200 / SUS304</td>
<td>16</td>
<td>Inlet Flange</td>
<td>SUS304</td>
<td>27</td>
<td>Screw</td>
<td>S45C</td>
</tr>
<tr>
<td>4</td>
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<td>NBR+Carbon</td>
<td>17</td>
<td>Flange Bolt</td>
<td>SUS304</td>
<td>28</td>
<td>Controller</td>
<td>Triac Bazed</td>
</tr>
<tr>
<td>5</td>
<td>Impeller Chamber</td>
<td>NORYL</td>
<td>18</td>
<td>Flange Gasket</td>
<td>Rubber</td>
<td>29</td>
<td>Pressure Switch</td>
<td>Salt Pressure Setting</td>
</tr>
<tr>
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<td>NORYL</td>
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<td>Outlet Flange</td>
<td>SUS304</td>
<td>30</td>
<td>Switch Cover</td>
<td>NYLON</td>
</tr>
<tr>
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<td>NORYL</td>
<td>20</td>
<td>Flange Bolt</td>
<td>SUS304</td>
<td>31</td>
<td>Thermal Protector</td>
<td>Auto Reset</td>
</tr>
<tr>
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<td>Impeller</td>
<td>NORYL</td>
<td>21</td>
<td>Priming Plug</td>
<td>NYLON</td>
<td>32</td>
<td>Pump Base</td>
<td>PVC</td>
</tr>
<tr>
<td>9</td>
<td>O Ring</td>
<td>NBR</td>
<td>22</td>
<td>Flow Switch</td>
<td>NYLON</td>
<td>33</td>
<td>Bolt</td>
<td>S45C</td>
</tr>
<tr>
<td>10</td>
<td>Bolt</td>
<td>SUS304</td>
<td>22-1</td>
<td>Return Spring</td>
<td>SUS304</td>
<td>34</td>
<td>Impeller Chamber</td>
<td>NORYL</td>
</tr>
<tr>
<td>11</td>
<td>Pump Cover</td>
<td>NYLON</td>
<td>22-2</td>
<td>Stopper</td>
<td>NORYL</td>
<td>35</td>
<td>Impeller</td>
<td>NORYL</td>
</tr>
<tr>
<td>12</td>
<td>Tank O Ring</td>
<td>NBR</td>
<td>23</td>
<td>Seal</td>
<td>Rubber</td>
<td>36</td>
<td>Pump Cover</td>
<td>NYLON</td>
</tr>
<tr>
<td>13</td>
<td>Pressure Tank</td>
<td>SUS304</td>
<td>24</td>
<td>Wiring Box</td>
<td>NYLON</td>
<td>37</td>
<td>Motor Capacitor</td>
<td>Plastic Film</td>
</tr>
</tbody>
</table>

*1 Item No. 11 (pump cover) for 60Hz, 2-stage models.
*2 Item No. 34, 35 and 36 for 50Hz, 3-stage models.
§ Installation and Piping

1. For stable operation, please mount and bolt the booster pump securely. The installation place must be dry with good ventilation and adequate space for future maintenance and service. A proper shelter is required for outdoor installation; exposure to rain will damage the insulation of electrical wiring.

2. The pump should be installed as close as to the reservoir or well. Piping joints should be fitted carefully to prevent leak. Leak in the suction piping will cause the pump suction capacity lost, while leak in the discharge piping will cause a high frequency ON/OFF motor operation while the faucets valves are closed.

3. Be careful not to allow the foreign objects (PVC adhesive gum, dirt, sand etc) into the pump, otherwise the pump will be damaged and shortened the life. It is recommended to use a strainer to prevent that.

4. Check the voltage and wiring of the motor power according to the connecting diagram shown below or inside the cover. Be sure to arrange earth or circuit breaker against electric leakage in accordance with local government electrical code.

5. Do not dry run, or pump hot water (more than 40 °C), and the other liquid except water. For higher temperature application, please contact with the local agency.

6. Two auto-reset thermal protectors are equipped with the motor wiring and pump casing respectively. Power will be cut off when one of the temperatures is abnormal, and will restart when the abnormal temperature back to normal.

7. The pump thermal switch is designed to protect the pump from dry run. It is also used to prevent hot water pumping which will damage the pump structure.

§ Operation and Important Notes

1. Before set the power on, the pump chamber and suction pipe must be filled with water in accordance with the following:

- For the positive suction head application (inlet water level is below the pump input), remove the priming plug, loose the flow switch, and pour water into the pump via priming hole until the water drain out from the loosing flow switch thread. Then, secure them.

- For the negative suction head application (inlet water level is higher than pump input), loose the priming plug, and then secure it after the water drain out from the priming hole.
2. Insert a crossed screwdriver into motor shaft end, and turn the shaft several turns clockwise to check whether the pump can be rotated freely. If not, disassemble and clean the pump chamber.

3. Double check the voltage and wiring of the motor power and then turn the power switch ON. Open faucet or water appliances on the discharge piping side. The water should be delivered after several seconds.

4. If the water does not be delivered after several minutes, turn off the pump immediately. Repeat step 1 to pour water into the pump and suction piping, and switch power ON and OFF continuously.

5. Once the water is pumped out, close and open the water appliances on the discharge side repeatedly to check automatic ON/OFF operation.

6. Measure the motor current and check with the data shown on the nameplate. If the current is over, check the voltage again.

7. When re-start the pump after long term shut down, please repeat step1~6 to ensure the normal operation.

§ Pressure Switch Adjustment

The pressure switch set is designed inside the control box. In general, the pressure has been set by factory properly to meet most situations. However, for some special cases, when the pump cannot operate normally, it can be adjusted easily. Please check the trouble shooting procedures, and read the following instructions carefully before to do it. For pressure adjustment, first remove the switch cover, and loose the lock nut counterclockwise by using a 12mm wrench.

1. Motor fails to stop
   It is because of the pressure setting too high. By using a flat-end screwdriver, turn the screw counterclockwise slowly, until the motor stop; then, turn an extra small rotation, about 5 degrees. Finally, check if the motor can start normally.

2. Motor fail to start
   It is because of the pressure setting too low. By using a flat-end screwdriver, turn the screw clockwise slowly, until the motor start, then an extra small rotation, about 5 degree, is added. Finally, check if the motor can stop normally.

3. After the pressure setting, screw the lock nut, and put the cover back.

Shaft Rotation Check

Pressure Setting
$§$ Troubleshooting

**CAUTION**

PLEASE DO NOT ADJUST PRESSURE SWITCH SETTING UNLESS ALL THE TROUBLESHOOTING PROCESS HAS BEEN DONE.

### PROBLEM – Pumps fail to start when the discharge devices are opened.

<table>
<thead>
<tr>
<th>Test</th>
<th>Schematic</th>
<th>Status</th>
<th>Causes / Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>Input Voltage Check</td>
<td>Voltage is normal</td>
<td>Go to test &quot;A-2&quot;.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No power</td>
<td>Check the controller power source and circuit breaker.</td>
</tr>
<tr>
<td>A-2</td>
<td>Output Voltage Check</td>
<td>Voltage is normal</td>
<td>1: Turn the power off, and check if the motor rotate manually.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2: If the motor or pump casing is overheating, the motor winding or pump casing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>thermal might be tripped due to motor overloading or pump dry running. The motor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>will start running automatically, when the motor winding or pump casing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>temperature back to normal.</td>
</tr>
<tr>
<td>A-3</td>
<td>Short &quot;P&quot; Socket</td>
<td>Motor still</td>
<td>Go to test &quot;A-3&quot;.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fails to start</td>
<td>Replace the controller.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Motor starts running</td>
<td>1: Make sure the discharge device is fully opened, or discharge piping is blocked.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2: Lower the pressure switch setting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3: Replace the pressure switch.</td>
</tr>
</tbody>
</table>

### PROBLEM – Pumps fail to stop after all the discharge appliances are closed.

<table>
<thead>
<tr>
<th>Test</th>
<th>Schematic</th>
<th>Status</th>
<th>Causes / Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>Remove &quot;P, A, Q&quot; Plug</td>
<td>Motor stops</td>
<td>Go to test &quot;B-2&quot; and &quot;B-3&quot;.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Motor still running</td>
<td>Replace the controller.</td>
</tr>
<tr>
<td>B-2</td>
<td>Remove &quot;P&quot; Plug</td>
<td>Motor stops</td>
<td>The flow switch function is normal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Motor still running</td>
<td>1: Make sure if the flow switch is activated due to the leakage of discharge</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>piping or devices.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2: Clean the inlet check valve to ensure the flow switch can back to normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>position.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3: Replace the flow switch.</td>
</tr>
<tr>
<td>B-3</td>
<td>Remove &quot;Q&quot; Plug</td>
<td>Motor stops</td>
<td>The pressure switch function is normal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Motor still running</td>
<td>1: Make sure the inlet water source is enough.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2: Check the suction piping for air-locked or leakage which result low pump</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>output pressure.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3: Lower the pressure switch setting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4: Replace the pressure switch.</td>
</tr>
</tbody>
</table>

### PROBLEM – Pumps cycle frequency or unstable under “Power ON”

<table>
<thead>
<tr>
<th>Test</th>
<th>Schematic</th>
<th>Status</th>
<th>Causes / Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-1</td>
<td>Short &quot;Q&quot; Socket</td>
<td>Motor back to normal</td>
<td>1: Avoid small discharge piping leakage or operation which will cause unstable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Motor still</td>
<td>flow switch ON/OFF switching.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>unstable</td>
<td>2: Recharge pressure tank air up to 1~1.2 kg/cm².</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3: Replace the flow switch.</td>
</tr>
</tbody>
</table>

Replace the controller.
§ Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>Rated Input (W)</th>
<th>Pipe Dia. (mm)</th>
<th>Rated Head (M)</th>
<th>Rated Capacity (l/min)</th>
<th>Hz</th>
<th>Voltage (1Phase)</th>
<th>Stage(s)</th>
<th>A (mm)</th>
<th>B (mm)</th>
<th>C (mm)</th>
<th>D (mm)</th>
<th>E (mm)</th>
<th>Weights (Kg)</th>
<th>Packing LxWxH (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KQ200</td>
<td>200W</td>
<td>20 (3/4&quot;)</td>
<td>15</td>
<td>28</td>
<td>50</td>
<td>220/230</td>
<td>3</td>
<td>165</td>
<td>171</td>
<td>214</td>
<td>80</td>
<td>85</td>
<td>11.0</td>
<td>40.0X20X27</td>
</tr>
<tr>
<td>KQ200S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td>110/220</td>
<td>2</td>
<td>140</td>
<td>146</td>
<td>214</td>
<td>80</td>
<td>85</td>
<td>10.5</td>
<td>39.0X20X27</td>
</tr>
<tr>
<td>KQ400</td>
<td>400W</td>
<td>25 (1&quot;)</td>
<td>20</td>
<td>32</td>
<td>50</td>
<td>220/230</td>
<td>3</td>
<td>165</td>
<td>171</td>
<td>230</td>
<td>80</td>
<td>85</td>
<td>11.5</td>
<td>41.5X20X27</td>
</tr>
<tr>
<td>KQ400S</td>
<td></td>
<td></td>
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<td></td>
<td>60</td>
<td>110/220</td>
<td>2</td>
<td>140</td>
<td>146</td>
<td>230</td>
<td>80</td>
<td>85</td>
<td>11.0</td>
<td>39.5X20X27</td>
</tr>
<tr>
<td>KQ800</td>
<td>800W</td>
<td>25 (1&quot;)</td>
<td>25</td>
<td>50</td>
<td>50</td>
<td>220/230</td>
<td>3</td>
<td>182</td>
<td>188</td>
<td>249</td>
<td>80</td>
<td>90</td>
<td>15.0</td>
<td>44.7X21X27</td>
</tr>
<tr>
<td>KQ800S</td>
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<td></td>
<td></td>
<td></td>
<td>60</td>
<td>110/220</td>
<td>2</td>
<td>155</td>
<td>161</td>
<td>249</td>
<td>80</td>
<td>90</td>
<td>14.5</td>
<td>41.7X21X27</td>
</tr>
</tbody>
</table>

† KQ200, KQ400 and KQ800 are with electro-coating cast iron pump casing.
‡ KQ200S, KQ400S and KQ800S are with stainless steel pump casing.
§ KQ200 and KQ400 are with steel plate motor frame; KQ800 is with aluminium motor frame.

§ Performance Curves

- Head vs. Capacity (L/min) for 50 Hz and 60 Hz.