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RESEARCH ARTICLE OPEN ACCESS

HYDRAULIC CHARACTERIZATION OF DOMESTIC TAPS

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ABSTRACT

This work was conductedwith the objective of determining the discharge coefficient values and the characteristic curves (flow-pressure ratio) of two models of metallic silver and bronze domestic taps, with commercial diameters of ¾ and ½ inch. Each tap was subjected to 5 pre-established hydraulic loads (ranging from 2 to 30 m). Flow and discharge coefficient values differ between faucet models. The average flow rate of silver and bronze taps is 37.08 and 18.91 L min-1, respectively. The silver tap has a higher flow rate diameter inches (39.10 L min-1). In the bronze tap the flow rates do not differ according to the diameters. The highest flow values were obtained at 30 m hydraulic load, equal to 32.06 and 66.42 L min-1, in bronze and silver models, respectively, in ¾ inch diameter.

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INTRODUCTION

A hydraulic orifice consists of a closed perimeter opening, with a defined geometric shape, made in the wall or bottom of a reservoir or in the wall of a channel or forced conduit, through which the liquid at rest or in movement flows due to the energy it has (PORTO, 2006).The discharge coefficients in an orifice tell us what is the flow to be discharged, that is, the actual flow of water during diffusion through the nozzle. The correct calculation of this coefficient is important to determine the hydraulic power necessary to overcome the pressure drop at the nozzle in interface with the environment (AZEVEDO NETTO, 2015).The replacement of conventional water-sanitary equipment with water-saving models is a measure that provides significant water savings in buildings (KELLY, 2015). Marinoski and Andrade (2010) state that for the residential sector, the installation of aerators at the outlet of the taps is due. Such devices inject air into the water flow and this changes the flow from the tap to the same opening of the valve, reducing water consumption in the equipment.The average flow of the equipment has a reference value presented by NBR 5626 (ABNT 1998) for washbasin taps of 9L min-1. In the case of pressure taps with manual override, the flow has a minimum value, established by NBR 13713 (ABNT, 2009), without an aerator of 6L min-1 and with an aerator of 3L min-1 acting with a minimum pressure of 1.53 mca.The Brazilian Association of Sanitary Material Manufacturers maintains a Sectorial Program for the Quality of Sanitary Materials, managed by TESIS – "Tecnologia e Qualidade de SistemasemEngenhariaLtda" - which controls the quality of the sanitary metals produced by 22 companies participating in the program and 24 brands of companies not participating in the Quality Program. According to industry data, the brands verified by this Program represent approximately 92% of the Brazilian market for metal fittings (TECNOLOGIA, 2018).The work aimed to evaluate the discharge coefficient and the flow-pressure ratio of two models of commercial taps, with different diameters, subjected to pre-established hydraulic loads (service pressures) to ascertain their performance in hydraulic projects.

MATERIALS AND METHODS

The study was carried out in the experimental area of the Federal University of Grande Dourados, Faculty of Agricultural Sciences - FCA, located in the city of Dourados / MS. The research was conducted with the aid of a 3 hp centrifugal motor pump. Coupled to the inlet of the motor pump (suction), a pipe with a nominal diameter of 50 mm was installed, which collected water from a water reservoir. At the end of the motor pump (discharge) a 25 mm tube was fitted, a drawer register (through which the hydraulic load was controlled) and, just ahead, a "T" connection where, at one of its ends, the digital pressure gauge was attached (for checking the hydraulic load) and in the other the tap to be tested.Two different models of metallic domestic taps were tested, with aerator external diameters equal to 9 mm for the Silver ¾ and Silver ½ models; and 11 mm for Bronze ¾ and Bronze ½ models. Each tap was tested with 5 different hydraulic loads (averages of 2, 4, 8, 16 and 30 m) in 3 repetitions.The tested water collection was carried out in a 500 liter water tank, which had its base leveled and, at the bottom of it, a hose was connected that connected it to a transparent tube disposed vertically leveled, with a measuring tape attached to the side, through which, readings of the available water level inside the water tank were made. The metric graduation was performed with a volumetric pipette.

The height readings were converted to volume of water after testing each treatment.The test of each treatment was done with the taps always fully open, then the pump set was turned on and the hydraulic load was adjusted through the drawer register. After adjusting the hydraulic load, the time started to be timed and the water that passed through the tap was captured in the graduated water tank. After the standardized time for treatments, 120 seconds, the water collection in the water tank ceased and the pump set was turned off.Like AZEVEDO NETTO (1998) and ÁVILA (2002), for the calculation of the nominal flow, Torricelli's theorem (equation 1) was used, which is the direct application of the Bernoulli equation, dealing with the flow of a liquid contained in any container with constant feeding and liquid exit through a small hole (Figure 1).

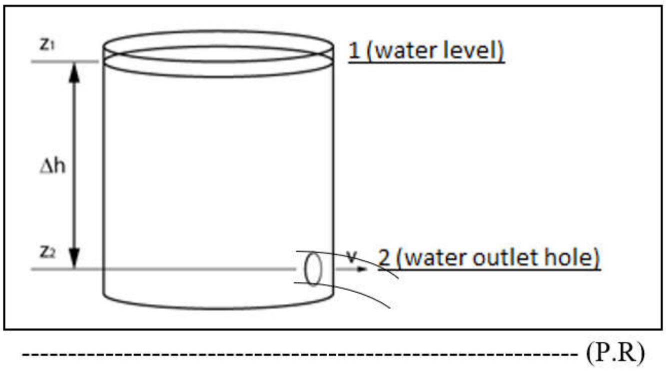

Figure 1. Scheme of a container of liquid flow contained

Applying the Bernoulli equation at points (1) and (2), we can obtain the speed of liquid exit through the orifice (point 2):

$$\frac{V_1^2}{2g} + Y_1 + Z_1 = \frac{V_2^2}{2g} + Y_2 + Z_2 \qquad \text{Equation 1}$$

Where,

V_1 e V_2 = flow speed at points 1 and 2 (m s^{-1});
g = gravity acceleration (m s^{-2});
Y_1 e Y_2 = piezometric energy at the points 1 e 2 (m);
Z_1 e Z_2 = vertical distance between the analyzed points of the flow and the horizontal reference plane (m).

Knowing that the speed in the fluid at point 1 is zero, because the fluid is at rest at the top of the container. Considering the container opened, we will have the atmospheric pressure acting on points 1 and 2, so Y1 and Y2 are also equal to zero, so we have:

$$\frac{V_2^2}{2g} = Z1 - Z_2 \qquad \text{Equation 2}$$

Knowing that Z1 - Z2 is the hydraulic load itself (CH), we have:

$$V_2 = \sqrt{2.g.CH} \qquad \text{Equation 3}$$

Substituting equation 3 in the equation of continuity (equation 4), we have:

$$Q_n = A\,.\sqrt{2.g.CH} \qquad \text{Equation 4}$$

Where,
Q_n = nominal flow (m^3 s^{-1});
A = tap outlet nozzle area (m^2);
g = gravity acceleration (m s^{-2});
CH = hydraulic load (m).

The mathematical model of the nominal flow (Qn) does not fit in reality, which is why it must be corrected by the discharge coefficient (Cd) to estimate the actual flow (Qr), described in equation 5:

$$Q_r = Q_n.C_d \qquad \text{Equation 5}$$

Where,
Q_r = actual flow (m^3 s^{-1});
Q_n = nominal flow (m^3 s^{-1});
C_d = discharge coefficient.

Based on this equation, it is possible to experimentally obtain the discharge coefficient (Cd):

$$C_d = \frac{Q_r}{Q_n} \quad \text{Equation 6}$$

The actual flow was achieved through equation 7, measuring the volume of water in the fixed time interval of 120 seconds.

$$Q_r = \frac{V}{t} \quad \text{Equation 7}$$

Where,

Q_r = actual flow ($m^3 s^{-1}$);
V = volume (m^3);
t = test duration time (s).

The Sisvar® software was used to analyze ANOVA variance at 5% probability, considering as input data: model, diameter and hydraulic load; and as output data: flow and discharge coefficient. To obtain the relationship between the flow and the hydraulic load, the data were adjusted to the regression curve to determine the equation and the determination coefficient (R^2) of each tap and diameter.

RESULTS AND DISCUSSION

The silver tap has a higher flow rate than the bronze tap, practically twice as much, 37.08 and 18.91 L min^{-1}, respectively (Table 1). The diameter does not interfere with the flow of the bronze tap. In the case of the silver tap, the largest flow occurs in the diameter ¾". According to ROMEIRO (2019) the pressure drop along with other physical factors, such as the internal construction of the valves, can differentiate the flow of identical taps even from the same manufacturing line.

Table 1. Actual flow (L min^{-1}) as a function of the evaluated diameters and models

Tap	½"	¾"	Média
Silver	35.06 b	39.10 a	37.08 A
Bronze	18.74 a	19.07 a	18.91 B

Values followed by the same lower case letters in the lines and upper case in the column do not differ significantly at the 5% probability level.The silver tap has a higher discharge coefficient (Cd) than the bronze tap, 0.705 and 0.305 L, respectively (Table 2). This means that the actual flow is closer to the nominal flow. Regarding the diameter, the silver and bronze models have opposite results. In the silver tap, the diameter ¾ inch has the largest Cd (0.741), in the bronze tap, the opposite, the largest Cd occurs in the diameter ½ inch (0.368).

Table 2. Discharge coefficient (Cd) as a function of diameters, models and hydraulic loads (CH)

Tap	½"	¾"	Média
Silver	0.668 b	0.741 a	0.705 A
Bronze	0.368 a	0.243 b	0.305 B

Values followed by the same lower case letters in the lines and upper case in the column do not differ significantly at the 5% probability level. SANTOS (2018) demonstrates that the value of Cd tends to be lower in larger diameters, different from what happened in the case of the silver tap. SILVA et al. (2015), evaluating discharge coefficients in irrigation emitters, also found that the Cd varies according to diameters, finding values between 0.88 and 0.98.

In this research, the potential adjustments (Figure 2) explain different flow amplitudes (adjustment slope) for the evaluated models.

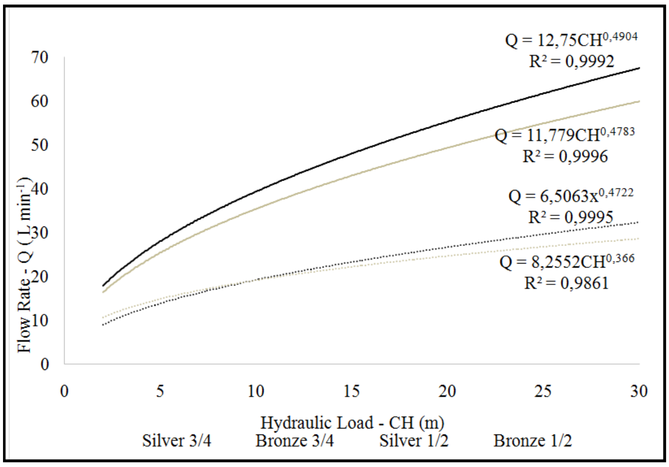

Figure 2. Characteristic curve of silver and bronze taps with diameters of ½ " and ¾ "

The NBR 13713 (ABNT, 2009) defines that in order not to compromise the performance, taps should not have low pressure (1.53 mca), flow rate below 3 L min^{-1}, in this research this condition was met in the entire series of measurements performed, when subjected to a pressure of 2 mca, the flow variation of the taps was from 8.95 to 17.69 L min^{-1}, different from that observed by DEMANBORO et al. (2015) in mechanical taps, where in most of the evaluated months they did not reach the minimum flow established by the norm.

Conclusions

- The evaluated taps have different discharge coefficients.
- There is a greater range of flow due to hydraulic loads in the silver model.
- There is no direct relationship between commercial diameter and discharge or flow coefficient. These relationships are distinct between the taps.

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