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Development of Fluid Transfer System (FTS)

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Abstract **- In this study, a fluid transfer system was developed using standard design procedure outlined in literatures. The effect of viscosity on the flow rate of a fluid (water) from different sources was also investigated. The development of the system involved design calculations, fabrication of metal base as well as tank guides. Similarly, plumbing of the system was done using polyvinyl chloride (PVC) pipes, gates valves, other pipe fittings and a centrifugal pump. The Reynolds number and the fluid pressure drop was also determined to investigate the nature of fluid flow through the system and the pressure drop in the motion of the transferred fluid respectively. The results showed that the flow through the system is turbulent since the Reynolds number (Re)   4000 (Re = 9160) while fluid pressure drop results indicate that there was more drop in fluid pressure at the longer lengths of pipe compared to the shorter ones. Testing of the system was also conducted sing three sources of water (rain, tap and stream) and the experimental result revealed that rain water has a higher volume flow rate compared to other sources of water with stream water having the least rate of flow.**

Keywords **- Fluid, flow rate, fluid transfer system, Reynolds number, viscosity.**

I. INTRODUCTION

Over the years, several experimental studies have been conducted using pipes and valves to analyze the dynamics of flow but just a few of these have studied the flow rate of fluid using a constructed fluid transfer system with the aim of investigating the effects of viscosity on flow rate. Fluid transfer systems are systems for transferring fluid from a filling reservoir to a receiving tank. These systems consist of a fluid transfer line which conveys fluid from the filling reservoir outlet to the receiving tank inlet and are not only applicable to domestic utilization alone, but widely used in petroleum, oil producing, foam manufacturing plants [1].

Nowadays, the use of pipes for transferring fluid is generally the most economical way to transport large quantities of oil, water, refined oil products or natural gas over land compared to shipping by railroad [1]. Also, Katrin et al. [2] reported that when a fluid flows through a pipe, the internal roughness of the pipe wall can create local eddy currents within the fluid, thereby adding a resistance to flow of the fluid. Pipes with smooth walls such as glass, copper, brass and polyethylene have only a small effect on the frictional resistance. Pipes with less smooth walls such as concrete, cast iron and steel will create larger eddy currents which will sometimes have a significant effect on the frictional resistance. All fluid flow is classified into one of two broad categories or regimes. These two flow regimes are laminar and turbulent flow and are important in the design and operation of any fluid system.

Colebrook and White [3] reported that Turbulent flow is characterized by the irregular movement of particles of the fluid while laminar flow is referred to as streamline or viscous flow. In this study, a fluid transfer system was developed using standard design procedure outlined in literatures with the aim of evaluating the effects of fluid viscosity on flow rate and thereafter, utilizing different sources of similar fluid to study how its viscosity affect the flow rate as it is been transferred through the system at specified period of time.

II. MATERIALS AND METHODS

1. Materials

As recommended by American Water Works Association [4], the developed system consists of six main parts. This parts include metal base on which the whole components

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of the system is mounted, flow meter for determining the volume as well as flow rate, gate valves for regulating the fluid flow, a strainer for filtering the transferred fluid, P.V.C pipe fittings (pipes, elbow, back nut, nipples, union) and a centrifugal pump which induces the movement of the fluid. These materials used during this research were sourced locally. The quantity and size of the materials used are shown in Table I.

Table 1 The quantity and size of the materials used

S/N	Material	Qty	Size
1	PVC pipe (tiger)	10ft	1”
2	PVC Elbow (tiger)	10	1”
3	PVC Union(tiger)	4	1”
4	PVC Tee (tiger)	3	1”
5	PVC Tank	2	50 liters
6	Tank Bank Nut	5	1”
7	PVC Plug	1	1”
8	PVC Nipple	13	1”and ¾’’
9	Plastic Tap	2	¾”
10	Measuring Container	1	10 litres
11	Gate valve ballpoint	4	1”
12	Thread Tape	10	3.5mm (big)
13	Centrifugal pump	1	0.5 hp
14	Fitter (Strainer)	1	1”
15	Water Flow meter	1	10 bar
16	Angle Iron	20ft	2”x2’’
17	Electrode	100	Gauge 10
18	Drill bit	1	M8
19	Bolt and Nut	4	M10
20	Electric Wire	3yards	2.5 mm
21	Electric Socket	1	13 Amp
22	Electric Fuse Plug	1	13 Amp
23	Flat bar	7ft	½”
24	Grinding Stone	1	

2. Methods

2.1 Design and Fabrication of System

The purpose of an engineering design is to create a system which will not only function efficiently, but will also be an economical success. In the conceptualization and design of the systems several factors were taken into consideration in order to ensure that the final product conforms strictly to the ideal. Some of the factors include available human resources, productivity, and maintainability, reduce weight and cost effectiveness.

2.2 Design of Metal Base and Tank Guides

The design of the metal base Includes; calculation of the weight and the areas of the metal frame and the two circular tank guides to ensure that it conforms to standard practice. The area of metal frame and circular tank guides were calculated using Eq. 1 and 2 while the weight was determined using Eq. 3.

Area of the frame = length (L) x width (W) (1)

$$\text{Area of tank guide} = \frac{\pi d^2}{4} \qquad (2)$$

$$\text{Weight of frame} = m \times g \qquad (3)$$

Where, d = diameter of the tank guide in meters, m= mass of frame, g= acceleration due to gravity.

2.3 Fabrication Process

The fabrication of the metal base (length, 1150mm and width, 765mm) and the circular tank guides (360 mm diameter) involved cutting of the components to their specified dimension as recommended by American Water Works Association [4]. This operation was performed manually using hacksaw and chisel. This procedure was followed by welding of the component parts using an electric arc welding machine (ESAB ORIGO, 400A, Circuit Voltage: 28 to 30 Volts) and a 10 mm cast iron electrodes.

The final stage of the fabrication process involved grinding of the welded joints using an electric grinding machine in order to get rid of rough edges and have smooth welded sections. Finally, the fabricated tank guides attached to the metal base was painted with the aim of having an aesthetic product.

2.4 Plumbing Process and Installation of Flow Meter

The plumbing of the system involve the installation of pipes, valves, plumbing fixtures, strainer and tanks that will convey fluids for use. During the plumbing process, the entire plumbing materials (pipe, elbows, tank, the flow meter, connector, valves and the centrifugal pump) were brought together and assembled.

A flow meter (BASE 165, Max. Pressure: 16 MPa, 45 oC Temperature) was also installed close to the outlet tank to measure the volume of fluid entering the outlet tank. During the installation of the flow meter, it was ensured that it remains full of liquid, because vapour in the flow meter can alter its geometry and adversely affect accuracy [5]. The tightening of the pipes and other system components was done using a pipe wrench and to prevent leakage in the piping system, a thread tape was wrapped round all the threaded pipes before tightening was carried out. Finally the entire system components were tightly placed on the fabricated metal base while the two polyvinyl chloride (PVC) tanks were been supported by the tank guides.

2.5 Calculation of Fluid Flow Parameters

The following fluid parameters were considered during the design of the system Reynolds Number

2.6 Reynolds Number

The Reynolds number (Re) of the flowing fluid was obtained by dividing the kinematic viscosity (viscous force per unit length) by the inertia force of the fluid (velocity x diameter) as shown in Eq. 4 [10]

$$\text{Re} = \frac{Fluid velocity(\varpi) x \text{int} ernal pipediameter(d)}{Kinematic Vis\cos ity(v)}$$

(4)

Where the fluid velocity and Kinematic viscosity were calculated using Eq 5 and 6 respectively.

Fluid velocity (ϖ) = $\dfrac{Maximumflowrate(Q)}{\pi\, x\, squareof\ Piperadius(R^2)}$

(5)

Kinematic viscosity = $\dfrac{Dynamic viscosity(\mu)}{Fluiddensity(\rho)}$

When the Reynolds number is less than 2300, laminar flow will occur and the resistance to flow will be independent of the pipe wall roughness. But if the Reynolds number exceeds 4000, turbulent flow occurs as a result, the pressure drop caused by friction of turbulent flow depends on the roughness of the pipe [6].

2.7 Fluid Pressure drop in the circular pipes

The pressure drop in the circular pipe can be determined using Eq. 7 [7].

$$\Delta P = \lambda\, x \frac{L}{D}\, x \frac{\rho}{2}\, x\, \varpi^2 \qquad (7)$$

Where, ΔP = Pressure drop (N/m3), λ = Pipe friction coefficient, L = length of pipe (m), D = pipe diameter (m), ρ = Density of the fluid (kg/m3) and ϖ = flow velocity (m/s).

Colebrook and White [3] reported that if the flow is laminar, the Pipe friction coefficient (λ) is calculated using Eq. 8 but if the flow is turbulent, the Pipe friction coefficient (λ) is calculated using Eq. 9.

Pipe friction coefficient for laminar flow $(\lambda) = \dfrac{64}{R_e}$ (8)

Pipe friction coefficient for turbulent flow $(\lambda) = \dfrac{16}{R_e}$ (9)

Colebrook and White [3] also reported that if there are valves, elbow and other elements along the pipe, then, pressure drop is calculated with resistance coefficients specifically for the element. The resistance coefficient is mostly found through vendor practical tests or through vendor specification documents. If the resistance coefficient is known, then, the pressure drop can be calculated for the element using Eq. 10.

Pressure drop (ΔP) = $\xi\ x\ \frac{\rho}{2}\ x\ \varpi^2$. (10)

Where, ξ = Resistance coefficient (determined using vendor specification), ρ = Density of the fluid (kg/m3) and ϖ = flow velocity (m/s).

As reported by Idel'chik [8], the resistance coefficient (ξ) of gate valves and elbow at 90o are 0.2 and 1.10 respectively. These values were used to determine the pressure drop in the system due to the presence of gate valves and elbow at 90o

3. Effects of Viscosity on Flow Rate

The effect of viscosity on the flow rate of fluid transferred through the system was examined by using three different sources of water (Rain water, Tap water and Stream water). The tap and stream water used in this work were sourced from Minna Water Board and Gurara Dam-Niger State respectively. This experiment was conducted to determine the volume flow rate of different sources of water transferred through the developed system. This experiment was carried out by filling the inlet tank of the system with the different sources of water to a specified volume (20 liters) and studying the rate at which fluid is being transferred at different time internal (5, 10, 15 and 20 minutes).

III. RESULT AND DISCUSSIONS

1. Metal Base and Tank Guides

Area of metal frame =
Length (1150mm) x Width (765mm) = 8.7975 x 105mm2
Weight of frame =
Mass (28.9 kg) x g (9.81) = 283.504N
Cross sectional area of each tank guide =

$\dfrac{\frac{22}{7} x 360^2}{4}$ = 1.018 x 105mm2

The tank guides consist of both inlet and outlet tank section. The weight of each guide was calculated to be 67.689N and 47.5785N respectively while the total weight and area covered by the metal base were found to be 446.35N and 19.5335 x 105mm2 respectively.

2. Constructed Fluid Transfer System

The developed fluid transfer system is shown in Fig.1.

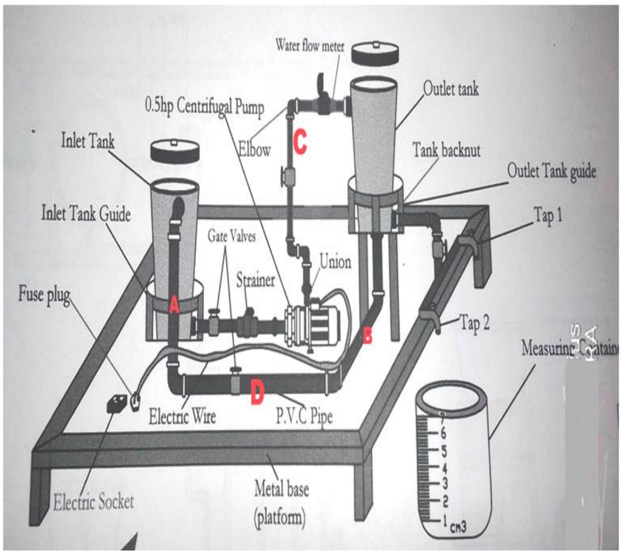

Fig.1. Fluid Transfer System.

The isometric view of the developed fluid transfer system is shown in Fig.2.

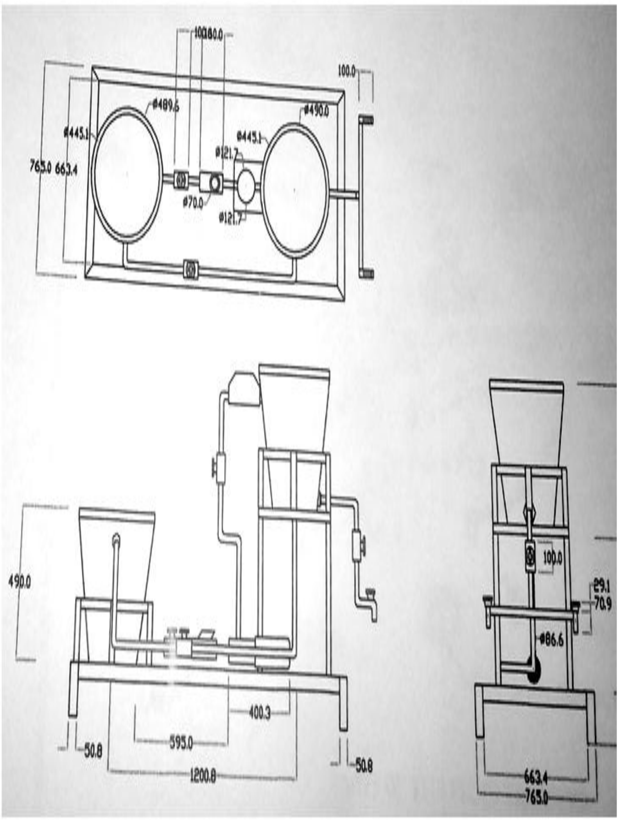

Fig.2. Isometric view of the system.

3. Reynolds Number

The Reynolds number along each pipeline was calculated using Equ. 4. The following data were used during the calculation.

Table 2 Calculation of Reynolds Number

Parameter	**Value**
Pipe diameter (D)	0.0254 m (radius = 0.0127m)
Maximum flow rate (Q_{max}) of pump	35litre/min ≈ 5.83 x 10^{-4} m^3/sec (From the pump manufacturer manual)
Density of fluid (water)	1000 Kg/m^3
Dynamic viscosity of water with 1000 Kg/m^3 density	1.519 x 10^{-3} ($kgm^{-1}s^{-1}$)
Length of pipeline A	50cm (0.5m)
Total length of pipeline B	96.5 cm (0.965m)
Total length of pipeline C	34cm (0.34m)
Total length of pipeline D	2320cm (23.20 m)

The results of Reynolds number along each pipeline (A, B, C and D) gave a value of 9160. This indicates that the flow along the pipelines is Turbulent since Re 4000. Therefore, the flow along the pipes is characterized by the irregular movement of particles of the fluid and the particles travel in irregular paths with no observable pattern and no definite layers.

4. Fluid Pressure drop in the system

The pressure drop (ΔP) along each pipeline is shown in Table 3.

Table 3 Pressure drop along each pipeline

Pipe line	**Coefficient**	**Length of pipe (m)**	**Fluid velocity (m/s)**	**Pressure drop (*N/m*^{3})**
A	λ=0.00175	0.5m	0.01461	0.00368
B	λ=0.00175	0.965m	0.01461	0.003677
C	λ=0.00175	0.34m	0.01461	0.0025
D	λ=0.00175	23.20 m	0.01461	0.171
Gate valves	ξ =0.2		0.01461	0.0214
90^o elbow	ξ = 1.10		0.01461	0.1174

From the data in Table 3, Pipeline D has the highest pressure drop with the value of 0.171 N/m3 compared to line A, B and C. Also, the results showed that motion of the fluid is greatly affected by the presence of the 90o elbows in the system as it recorded a pressure drop of 0.1174 N/m3 due the presence of the elbow. Similarly, the installation of gate valves in the system offered little drop in pressure of the transferred fluid. These findings also indicate that there is little or no drop in fluid pressure along shorter length of pipes compared to longer length of pipes and presence of an elbow.

5. Flow Rates of Fluid

The results of flow rate of the three sources of water at different time interval are shown in Table 4. These results are represented in Fig. 3.

Table 4 Flow rate of different sources of water

Time of flow (min)	**Volume flow rate (litre/min)**		
	Rain water	Tap water	Stream water
5	12.16	10.34	9.12
10	24.33	20.68	18.25
15	36.49	31.02	27.37
20	48.65	41.36	36.49

The experimental results shown in Table 4 and represented in Fig. 3 indicate that water of different sources low at varying rate This finding is in agreement with the earlier work of Douglas et al [9] who reported that the flow rate of a liquid passing through a pipe is dependent on the viscosity of the liquid as high viscous fluid flow more slowly than fluids with low viscosity.

Also, the experimental results showed that the flow rate of rain water is higher than other sources of water with stream water having the least flow rate. This implies that, a less viscous fluid is preferred in the system as it flows faster.

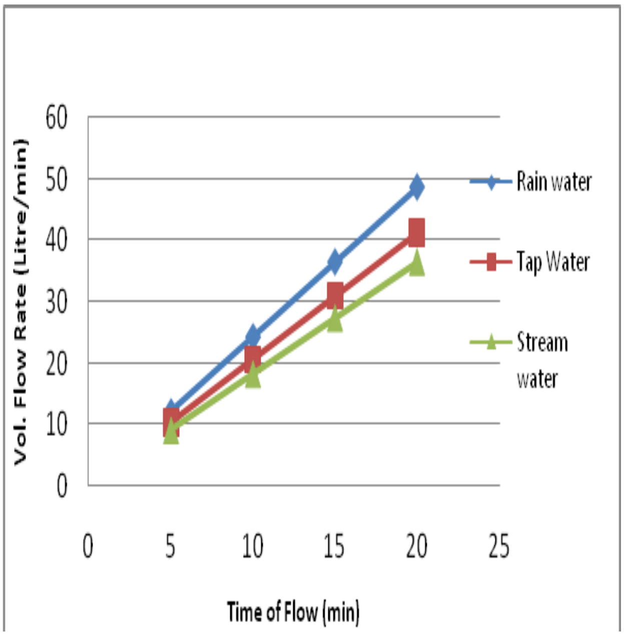

Fig.3. Variation in Flow rate of different sources of water.

IV. CONCLUSION

In this work, a fluid transfer system was developed using standard procedures with the aim of examining the volume flow rate of the fluid being transferred through the system. From the result obtained, the following conclusion can be drawn;

- The flow through the system is turbulent (Re = 9160) since the calculated Re 4000 and there is more pressure drop at longer length of the pipe compared to the shorter ones.
- Also, the presence of elbows in the system affects the speed of fluid transferred as more drop in fluid pressure was recorded as a results of the presence of 90^{o} elbows compared to that recorded due to the presence of valves and other fittings in the system.
- Stream water possesses more viscosity compared to the other sources of water (rain water and tap water) and a result, produces the least volume flow rate. Therefore, it can be concluded that, as viscosity increases, flow rate through the 25.4 mm diameter decreases and vice versa.
- Finally, based on these findings, it can be concluded that the developed system can efficiently and effectively be utilized in the transfer of light fluids such as water as it produces minima drop in pressure during operation and the flow regime is characterized by the irregular movement of particles of the fluid which is dependent on the roughness of pipes (turbulent flow).

REFERENCES

[1]. Vreeburg, J.H.G. and Boxall, J.B. "Discolouration in potable water distribution systems:" A review. Water Res. 2007, 41, 519–529.

[2]. Katrin, K., Ivar, A., Anatoli, V. and Nils, K. "Determination of Pressure Drop and Flow Velocity in Old Rough Pipes", Proceedings, 2, 590, (2018. Retrieved from doi:10.3390/proceedings2110590/.

[3]. Colebrook, C.F. and White, C.M. "Turbulent flow in pipes with particular reference to the transition region between the smooth and rough pipe laws". Proc. Inst. Civ. Eng. (U.K.) Vol II, 133, 1939.

[4]. American Water Works Association Manual of Water Supply Practices Manual M6, Franklin Publication, 7th edition, 2009, pp 40-61.

[5]. Thomas, K. "Coriolis Mass Flow Meters for Gas and Liquid Measurement, Cameron Measurement ", /Division of Schlumberger 3600 Briarpark. Houston, Texas 77042, 2018, pp 1-6.

[6]. Bruce S, Larock E. Jeppson R.W. and Watters, G.Z. "Hydraulics of Pipeline Systems", CRC Press, London, 2000.

[7]. Chung, F. "An Introduction to Fluid Mechanics, Springer International Publishing", 1st Edition, 2019, pp 31-57.

[8]. Idel'chik, I. E. "Handbook of hydraulic resistance, Federal Scientific and technical Information, Springfield", Va, 22151, 1960, pp 51-100.

[9]. Douglas J. F, Gasiorek J. M and Swaffield J. A. " Fluid Mechanics", Dorling Kinderslry Pvt. Ltd, India, 4th edition, 2000, pp 504-534.

[10]. Rainer, E. and Hans J.B. "Determination of Liquid Flow meter characteristics for precision measurement purposes by utilizing special capacities of PTV's hydrodynamic test field", 6th International Symposium of fluid flow measurement. Presented at Queretaro, Mexico, 2006.