Global Journal of Mechanical Engineering, Volume 5, Number 1, 2004.
ISSN 1595 – 7578

DEVELOPMENT AND EVALUATION OF FLUID MECHANICS LABORATORY CURRICULUM: A CASE STUDY OF THE UNIVERSITY OF IBADAN, NIGERIA

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ABSTRACT
This paper reports the effort of the authors in restructuring the teaching of Fluid Mechanics in the University of Ibadan, Nigeria. The University has been equipped with standard laboratory for the teaching of Fluid mechanics, but over the years some equipment have broken down and affected the teaching of Fluid Mechanics. All over the years the needs of the students have changed. This paper starts by reporting the rehabilitation and commissioning of one of the equipment. And then goes ahead to formulate the laboratory exercises required to be performed by the students in Fluid Mechanics before graduation in B.Sc degree programme bearing in mind the functionality of existing equipment and the environment awaiting the students on graduation. Several improvements have been made and documentation done. The paper concludes that in most first generation Universities in Nigeria Fluid Mechanics laboratories are well equipped, but most of the equipment are not functioning because of minor elements that could have been improved and installed. It recommends that with little funding and commitment of staff and students this laboratory would be kept running to meet the need of Nigerian Engineering students.

***Keywords:* Engineering, Education, Fluid Mechanics, Rehabilitation and Commissioning.**

INTRODUCTION
Commissioning provides documented confirmation that the equipment or systems function in compliance with criteria set forth in the Manufacturers' own manual. That is, the owner's operational needs are satisfied. Commissioning of existing equipment may require the development of new functional criteria in order to address the owner's current systems performance requirements. This definition is based on the critical understanding that the owner must have some means of verifying that their functional needs are rigorously addressed during design, construction and acceptance. A fluid can flow along a pipe either in **Laminar** (when Reynolds number is below 2000) or **Turbulent** (when the Reynolds number is above 2000) flow conditions. Instances of these fluid flows are seen in domestic, medical, industrial applications etc. In this paper the efforts of the authors in making the teaching of Fluid mechanics more realistic through appropriate use of laboratory equipment are well documented. In almost all the first generation Universities in Nigeria, Fluid mechanics laboratories are well equipped but the major problem is that they are not properly maintained to effectively meet the need of the students.

METHODOLOGY
The fluid (i.e. shell Tellus II oil), having the required dynamic viscosity (u) of 0.0085kg/ms, density ρ = 814kg/m^3 and can give Reynolds number well down into the Laminar region, is circulated continuously in the apparatus by the **Gear pump.** The oil is drawn from the **Reservoir** and delivered by the way of the **Delivery pipe** into the **Perspex settling chamber.** The oil passes from this chamber through the **Bell mouth** into the **Test pipe** (with a nominal diameter (d) of 19mm and a length of 6m) in which the observations are made. Downstream the Bell mouth is the **Adjustable flow disturber** for inducing turbulence. The **Pressure tapings** along the test pipe permits the determination of pressure gradient and the **vertical** and **horizontal traverses** at right angle to each other near the downstream end of the test pipe give the velocity profile. The oil discharge on leaving the pipe for the **Weighing tank** is observed through the **Perspex Deflector.** After being weighted at the weighing tank, the oil flows back into the reservoir. The flow quantity is varied using the **Adjustable By-pass valve.** The **Multi-tube manometer** measures the Head-loss along the test pipe.

ISSN 1595 – 7578

EXPERIMENTATION AND RESULT

Experiment one: Static pressure gradient determination

- Measure the distance in (mm) from the test pipe inlet to each tapping using a tape rule.
- Determine the corresponding Head-loss in (mm Hg)
- Plot graphs of Head-loss against Distance from pipe inlet.

Table 1: The static pressure gradients for the apparatus under laminar flow

PIPE PRESSURE		HEAD LOSS (Cm of Hg)			HEAD LOSS (mm of Hg)
TAPPING NUMBER	DISTANCE 'X' (mm)	INITIAL	FINAL	ACTUAL	ACTUAL
1	160	5.4	20.9	15.5	155
2	300	5.4	20.2	14.8	148
3	450	5.4	19.9	14.5	145
4	600	5.4	19.4	14.0	140
5	750	5.4	18.9	13.5	135
6	900	5.4	18.4	13.0	130
7	1050	5.4	17.9	12.5	125
8	1200	5.4	17.6	12.2	122
9	1350	5.4	17.4	12.0	120
10	1500	5.4	17.0	11.6	116
11	1800	5.4	16.4	11.0	110
12	2100	5.4	15.4	10.0	100
13	2400	5.4	14.8	9.4	94
14	2750	5.4	13.9	8.5	85
15	3550	5.4	11.9	6.5	65
16	4300	5.4	10.0	4.6	46
17	5050	5.4	7.9	2.5	25
18	5500	5.4	6.8	1.4	14
19	5750	5.4	6.4	1.0	10

Table 2: The static pressure gradients for the apparatus under turbulent flow.

PIPE PRESSURE		HEAD LOSS (Cm of Hg)			HEAD LOSS (mm of Hg)
TAPPING NUMBER	DISTANCE 'X' (mm)	INITIAL	FINAL	ACTUAL	ACTUAL
1	160	5.8	76.3	70.5	705
2	300	5.8	73.8	68.0	680
3	450	5.8	71.6	65.8	658
4	600	5.8	69.3	63.5	635
5	750	5.8	67.2	61.4	614
6	900	5.8	65.3	59.5	595
7	1050	5.8	63.4	57.6	576
8	1200	5.8	61.3	55.5	555
9	1350	5.8	59.6	53.8	538
10	1500	5.8	57.8	52.0	520
11	1800	5.8	54.3	48.5	485
12	2100	5.8	50.5	44.7	441
13	2400	5.8	46.9	41.1	411
14	2750	5.8	43.3	37.5	375
15	3550	5.8	33.4	27.6	276
16	4300	5.8	24.3	18.5	185
17	5050	5.8	15.7	9.9	99
18	5500	5.8	10.3	4.5	45
19	5750	5.8	7.3	1.5	15

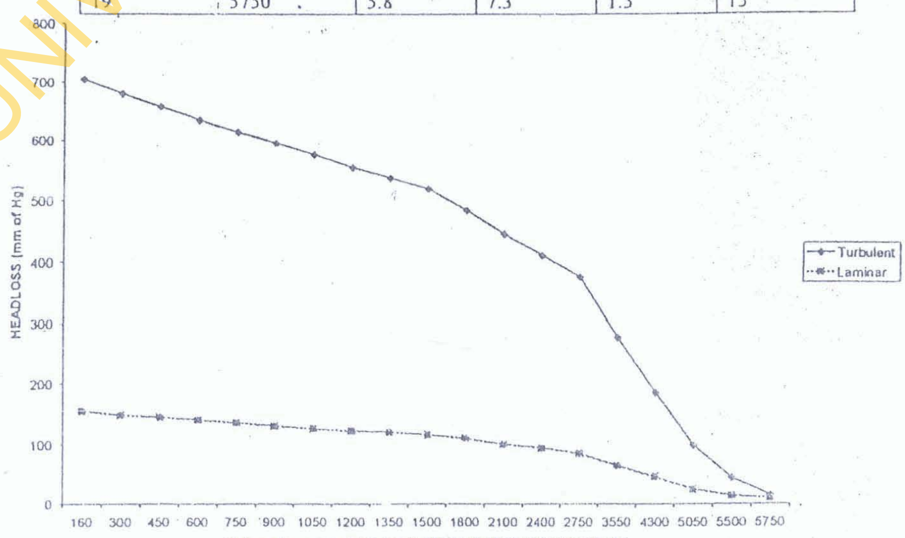

Fig.1: Graph of head loss against distance from pipe inlet (EXPERIMENT 1)

Experiment two: The relationship between the friction factor (f) and Reynolds number (Re)

- Determine the time (t) (in seconds) for measured masses (m) of oil (at 10kg interval) to pass using the weighing tank and a stop clock.
- Calculate the mean velocity of flow using $U = 4x10^6 xm/\pi d^2 et$ and Re using $\rho \bar{u} d/\mu$
- Determine the friction factor (f) for Turbulent flow using $f = 0.079(Re)^{-1/4}$ (Blasius) and f for Laminar flow using f = 16/Re (Poiseuille)
- Plot graph of $\log_{10}$ f against $\log_{10}$ Re for both flow.

Table 3: The relationship between the friction factor (f) and Reynolds number (Re) for laminar flow

MASS (M) OF OIL (Kg)	10	20	30	40	50
TIME (t) FOR OIL PASSAGE (Sec)	76.7	158.5	219	300	362
MEAN VELOCITY, U (m/s) $\bar{U} = \frac{4 \times 10^6 M}{\pi d^2 \rho t}$	0.56	0.55	0.59	0.58	0.60
$Re = \frac{\rho \bar{u} d}{\mu}$	1019	1001	1074	1055	1092
F = (16/Re)	0.0157	0.0160	0.0149	0.0152	0.0147
Log_{10} Re	3.01	3.00	3.03	3.02	3.04
Log_{10} f	-1.80	-1.80	-1.83	-1.82	-1.83

Table 4: The relationship between the friction factor (f) and Reynolds number (Re) for turbulent flow

MASS (M) OF OIL (Kg)	10	20	30	40	50
TIME (t) FOR OIL PASSAGE (Sec)	17.6	36.1	51.9	66.65	80.3
MEAN VELOCITY, U (m/s) (m/s) $\bar{U} = \frac{4 \times 10^6 M}{\pi d^2 \rho t}$	2.46	2.40	2.50	2.60	2.70
$Re = \frac{\rho \bar{u} d}{\mu}$	4476	4367	4549	4731	4913
$f = 0.079(Re)^{-1/4}$	0.0097	0.0097	0.0096	0.0095	0.00944
Log_{10} Re	3.65	3.64	3.66	3.68	3.69
Log_{10} f	-2.01	-2.01	-2.02	-2.02	-2.025

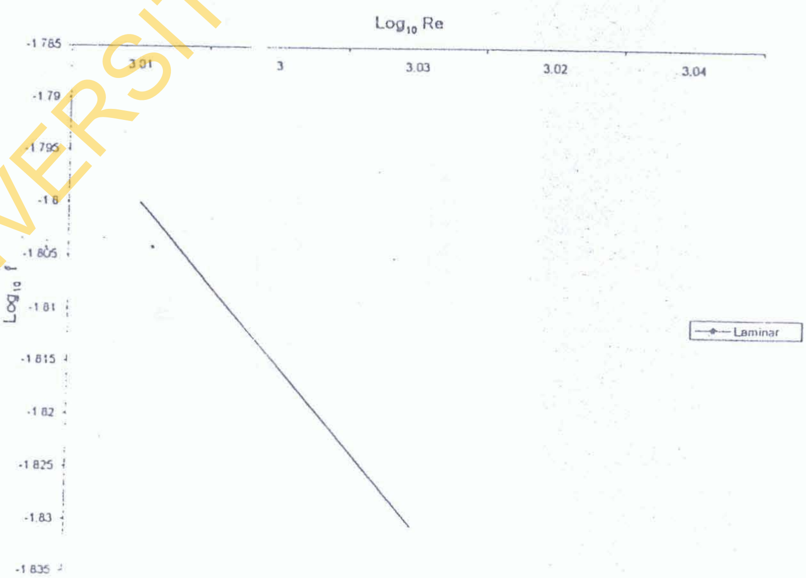

Fig.2: Log-Log graph of the friction factor against the Reynolds (Laminar)

ISSN 1595 – 7578

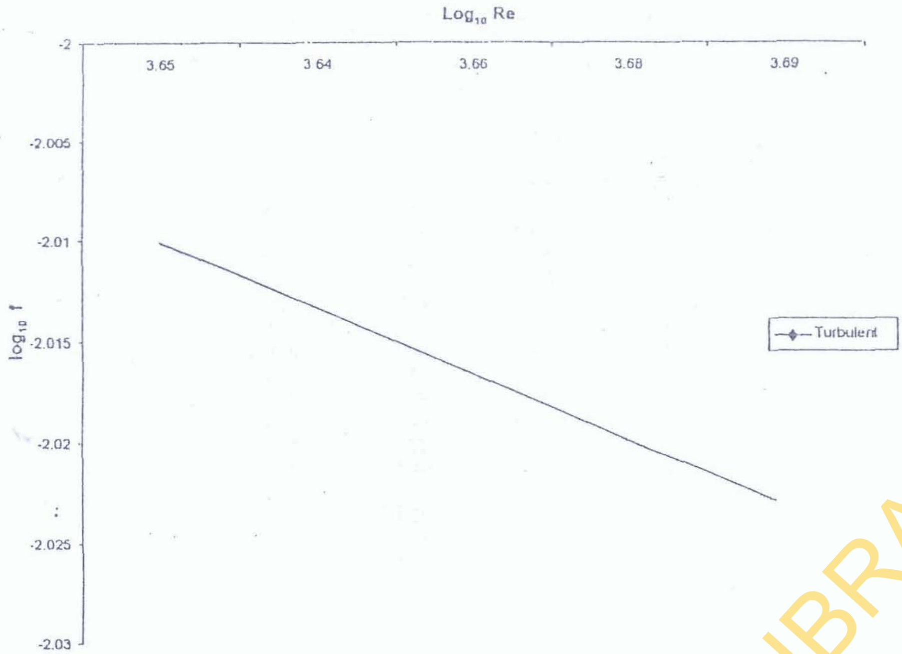

Fig.3: Log-Log graph of the friction factor against the Reynolds number (Turbulent)

EXPERIMENT THREE: DETERMINATION OF THE VELOCITY PROFILES

- Using the by-pass valve maintain laminar flow at 0.2bar and turbulent flow at 0.8 bar gauge pressures.
- Fix the micrometer head to the horizontal and vertical traverses in turn taking the micrometer readings (the distance move by the pitot head into the fluid flowing in the test pipe).
- Read the head-loss (H) at each micrometer reading and obtain the velocities in (m/s) from the H using $u = 0.5542\sqrt{H}$
- Plot graphs of velocities against micrometer readings.

Table 5: The laminar flow velocity distribution.

Micrometer Reading (Radius) mm	Vertical traverse Head, H (mmHg)	Velocity, U (m/s) $U = 0.5542\sqrt{H}$	Horizontal traverse Head, H (mmHg)	Velocity, U (m/s) $U = 0.5542\sqrt{H}$
1.5	11	1.84	11	1.84
2.0	13	2.00	12	1.92
3.0	23	2.66	21	2.54
4.0	37	3.37	32	3.14
5.0	51	3.96	45	3.72
6.0	63	4.40	58	4.22
7.5	83	5.05	75	4.80
8.0	87	5.17	80	4.96
9.0	92	5.32	90	5.26
10.0	94	5.37	92	5.32
11.0	90	5.25	83	5.05
12.0	80	4.95	72	4.70
13.0	73	4.74	61	4.33
14.5	51	3.95	45	3.72
15.0	46	3.75	39	3.46
16.5	30	3.03	24	2.72
17.5	21	2.53	16	2.22
18.0	18	2.35	12	1.92

Table 6: The turbulent flow velocity distribution

Micrometer Reading (Radius) mm	Vertical traverse Head, H (mmHg)	Velocity, U (m/s) $U = 0.5542\sqrt{H}$	Horizontal traverse Head, H (mmHg)	Velocity, U (m/s) $U = 0.5542\sqrt{H}$
1.5	44	3.68	44	3.68
2.0	48	3.84	52	4.00
3.0	56	4.15	60	4.29
4.0	61	4.33	65	4.47
5.0	66	4.50	70	4.64
6.0	70	4.65	74	4.77
7.5	75	4.80	79	4.93
8.0	77	4.86	80	4.96
9.0	79	4.93	81	4.99
10.0	80	4.96	82	5.02
11.0	80	4.96	82	5.02
12.0	79	4.93	81	4.99
13.0	77	4.86	79	4.93
14.5	72	4.70	73	4.75
15.0	70	4.64	70	4.64
16.5	63	4.40	67	4.54
17.5	58	4.22	62	4.36
18.0	55	4.11	60	4.29

Fig.5: The turbulent flow velocity profile

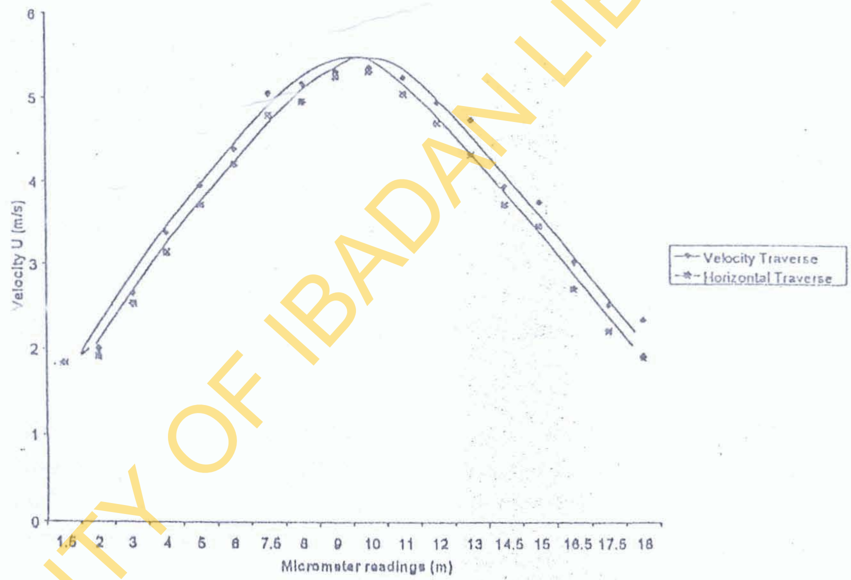

Fig.4: The laminar flow velocity profile

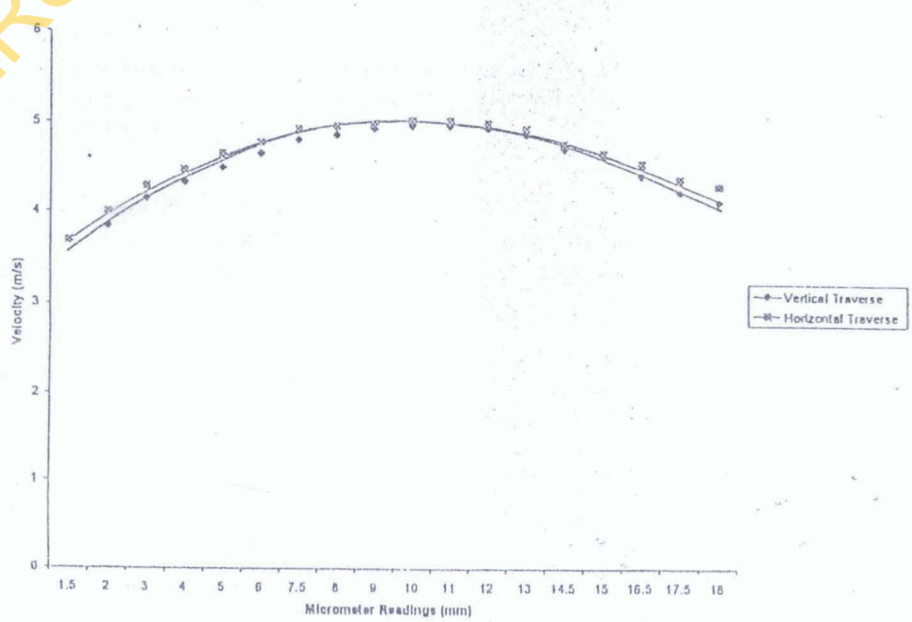

Fig.5: The turbulent flow velocity profile

ISSN 1595 – 7578

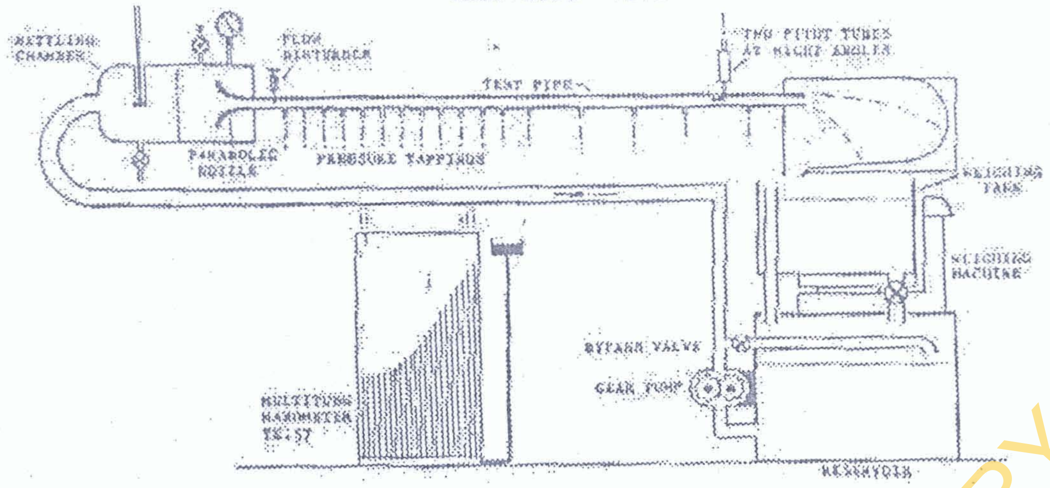

Fig.6: The apparatus showing the gear pump, the multi-tube manometer and the Laminar and turbulent jets.

RESULTS AND DISCUSSION

Experiment one

From the graph on figure 1, the pressure gradient with turbulent flow is very much greater than with Laminar flow over the length of the pipe. The fluid boundary layers also reduced in thickness downstream the pipe for both flows but with Turbulent flow reducing at a greater rate.

Experiment two

In figures 2 and 3, negative slopes were obtained. A straight line graph with negative one (-1) slope was obtained as expected for Laminar flow.

Experiment three

Velocity profiles (parabolic) closely similar on both diameters were obtained for the two flow conditions.

CONCLUSION

The Laminar/Turbulent Pipe flow Equipment, one of the Fluid Mechanics equipment in the University of Ibadan Mechanical Engineering Department was rehabilitated and then commissioned. The equipment through the efforts of the authors has been made readily available for students to perform various experiments on it and for the teachers to use it for teaching.

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