DETERMINATION OF PRESSURE LOSSES AND FLOW DISTRIBUTION AT PIPE TRIFURCATION USING EXPERIMENTAL TECHNIQUE

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College : East Point College of Engineering and Technology
Branch : Department of Civil Engineering
Guide : Dr. Nagaraj Sitaram
Students : Ms. Varshini K R
Ms. Chaithanya S
Ms. Harshitha G S
Ms. Mamatha Shree T

Keywords:

Pipe, Trifurcation, Bifurcation, Pressure losses, Flow distribution, Coefficient of Pressure, Reynold's number.

Introduction:

- Trifurcations are the deflector devices that are often used in hydro-power plants and domestic pipelines for fluid distribution/flow collection respectively.
- They are designed to allow water to flow while also minimizing hydraulic loss and assuring uniformly distributing of flow distribution.
- Pipe Trifurcation is also used to receive the flow from three wastewater pipes in domestic pipelines.

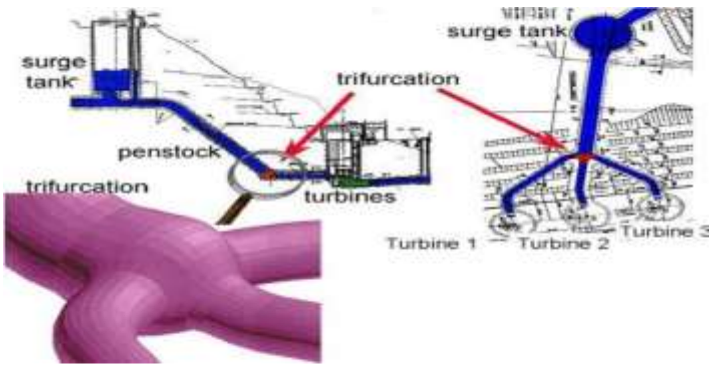


Figure 1: Schematic representation of trifurcated pipe used in hudro-power plant

Objectives:

- To determine the pressure loss and flow distribution in pipe trifurcation (Symmetrical and Unsymmetrical type) using experimental technique.
- To obtain the Coefficient of Pressure (Cp) and Reynold’s number (Re) for Pipe Bifurcation and Pipe Trifurcation arrangements.
- To investigate the pressure losses occurring at the pipe trifurcation and develop general guidelines for determination of split flow ratios.
- To draw nomograms to best operation of the penstock system.
- Design of good trifurcation with desired flow distribution with minimum hydraulic loss need to be developed.
- Determine the profile which gives maximum discharge and minimum head loss.

Methodology: Experimental approach is adopted.

- Set up of a Recirculating Flume.
- Trifurcated Pipe Models, Manifold, Bourdon Pressure gauges (Least count 0.1 kg/cm^2), 7.5 HP Centrifugal Pump.

Experimental work plan:

STAGE-1	UNSYMMETRICAL TRIFURCATION	• θ2 =12.5°, θ3 =25° • θ2 =7.5°, θ3 =15°	COMPLETED
STAGE-2	SYMMETRICAL TRIFURCATION	• θ2 =20°, θ3 =20° • θ2 =25°, θ3 =25°	COMPLETED

- The diameter of main pipeline = 25.4mm
- The diameter of Trifurcated pipeline = 19.05mm

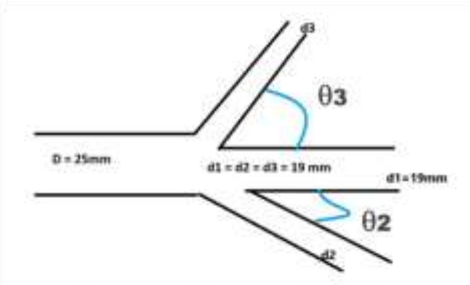
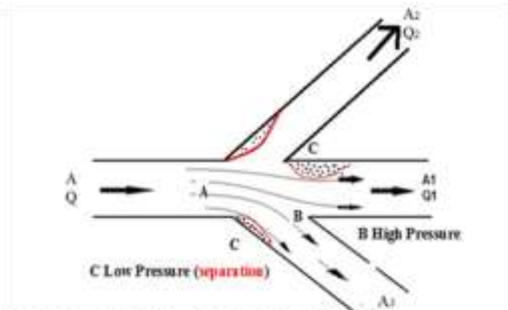


Fig. Schematic of Unsymmetrical Pipe Trifurcation



PIPE TRIFURCATION – SEPARATION LOSS

Experimental Set-up:

		
Experiment set-up	**Trifurcated Pipe Models**	**Conduction**

Results:

Data Collection

Pipe Trifurcation

Sl. No	THETA 2	THETA 3	Total discharge	Velocity in Main pipe	Main Pipe	Pressure in branch No 1 (Kg/cm^2)	Pressure in branch No 2 (Kg/cm^2)	Pressure in branch No 3 (Kg/cm^2)	Ratio	Ratio	Ratio
	DEGREE	DEGREE	Q	U	PO	P_1	P_2	P_3	P/P_1	P/P_2	P/P_3
			Cm^3/sec.	Cm/sec	Kg/cm^2	Kg/cm^2	Kg/cm^2	Kg/cm^2			
1	7.5	15	2363	466.07	1.2	0.25	0.25	0.25	4.80	4.80	4.80
2	7.5	15	3109	613.21	1.6	0.5	0.25	0.5	3.20	6.40	3.20
3	7.5	15	4616	910.45	2.5	1	1	1	2.50	2.50	2.50

Total	BRANCH '1'	BRANCH '2'	BRANCH '3'	Coefficient of pressure	Reynold's Number	Coefficient of Pressure in P1	Coefficient of Pressure in P2	Coefficient of Pressure in P3
K	K1	K2	K3	Cp	Re	Cp1	Cp2	Cp3
--								
0.88	0.84	0.85	0.94	0.87468868	13765.46947	0.87466566	0.87466566	0.87466566
0.87	0.85	0.85	0.90	0.62940018	18111.23343	0.58505562	0.718022806	0.58505562
0.87	0.83	0.89	0.90	0.36193829	26890.14265	0.361914158	0.361914158	0.361914158

Pipe Bifurcation

Flow in pipe 1 and pipe 2

Sl. No	THETA	Total discharge	Velocity in Main pipe	Main Pipe	Pressure in branch No 1 (Kg/cm^2)	Pressure in branch No 2 (Kg/cm^2)	Ratio	Ratio
	DEGREE	Q	U	PO	P_1	P_2	P/P_1	P/P_2
		Cm^3/sec.	Cm/sec	Kg/cm^2	Kg/cm^2	Kg/cm^2		--
1	7.5	1669	585.61	1.2	0.5	0.5	2.40	2.40
2	7.5	2400	842.11	2.1	1.3	1.3	1.62	1.62
3	7.5	3995	1401.75	2.7	1.3	1.2	2.08	2.25

Total	BRANCH '1'	BRANCH '2'	coefficient of pressure 'Cp'	Reynold's Number 'Re'	coefficient of pressure in P1	coefficient of pressure in P2
K	K1	K2	Cp	Re	Cp1	Cp2
--						
1.16	0.99	1.28	0.40823016	12937.9845	0.40823016	0.408230155
1.21	0.92	1.37	0.225625	18604.65116	0.225625	0.225625
1.12	1.06	1.17	0.14758905	30968.99225	0.14249978	0.152678332

Flow in pipe 1 and pipe 3

Sl No	THETA	Total discharge	Velocity in Main pipe	Main Pipe	Pressure in branch No 1 (Kg/cm^2)	Pressure in branch No 3 (Kg/cm^2)	Ratio	Ratio
	DEGREE	Q	U	PO	P1	P3	P/P1	P/P3
		Cm^3/sec.	Cm/sec	Kg/cm^2	Kg/cm^2	Kg/cm^2		--
1	15	2122	744.56	1.1	0.25	0.4	4.40	2.75
2	15	2389	838.25	1.8	1	1	1.80	1.80
3	15	3567	1251.58	2.6	1.2	1.2	2.17	2.17

Total	BRANCH '1'	BRANCH '2'	coefficient of pressure 'Cp'	Reynold's Number 'Re'	coefficient of pressure in P1	coefficient of pressure in P3
K	K1	K3	Cp	Re	Cp1	Cp3
--						
1.20	0.94	1.37	0.27959581	16449.6124	0.30665347	0.252538151
1.20	0.93	1.37	0.22770754	18519.37984	0.22770754	0.227707536
1.12	1.16	1.07	0.17874814	27651.16279	0.17874814	0.178748141

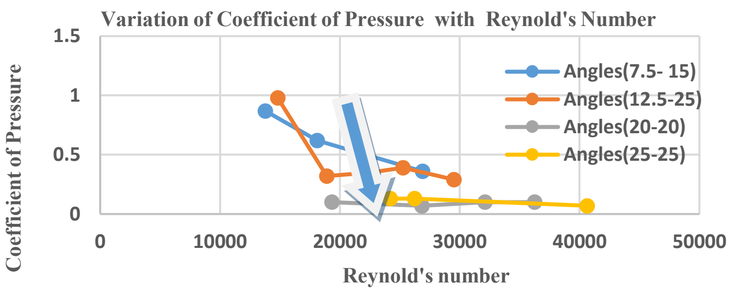
Flow in pipe 2 and pipe 3

Sl No	THETA	Total discharge	Velocity in Main pipe	Main Pipe	Pressure in branch No 2 (Kg/cm^2)	Pressure in branch No 3 (Kg/cm^2)	Ratio	Ratio
	DEGREE	Q	U	PO	P2	P3	P/P2	P/P3
		Cm^3/sec.	Cm/sec	Kg/cm^2	Kg/cm^2	Kg/cm^2		--
1	22.5	1850	649.12	1.1	0.5	0.5	2.20	2.20
2	22.5	3000	1052.63	2.0	1.2	1.0	1.67	2.00
3	22.5	3812	1337.54	2.6	1.2	1.2	2.17	2.17

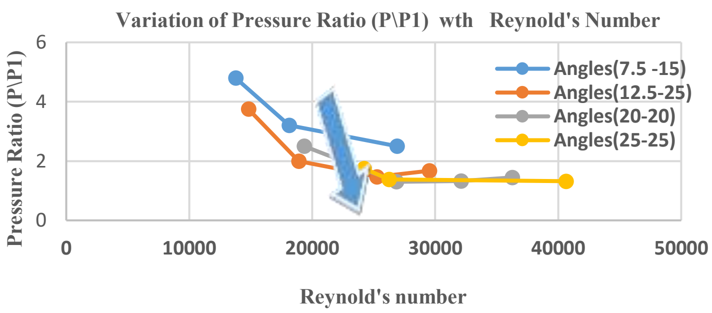
Total	BRANCH '1'	BRANCH '2'	coefficient of pressure 'Cp'	Reynold's Number 'Re'	coefficient of pressure in P2	coefficient of pressure in P3
K	K2	K3	Cp	Re	Cp2	Cp3
--						
1.13	1.05	1.2	0.28479182	14341.08527	0.28479182	0.284791819
1.12	1.12	1.11	0.16245	23255.81395	0.1444	0.1805
1.13	1.22	1.02	0.15650996	29550.3876	0.15650996	0.156509955

Graphs obtained

Trifurcation Graphs:

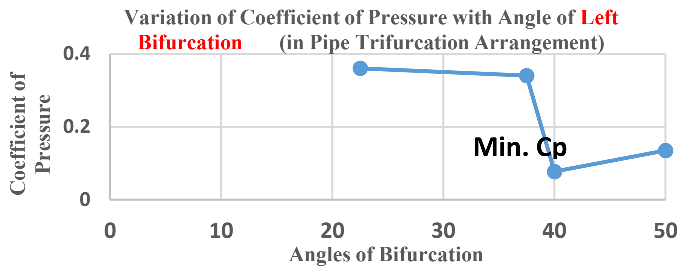


This graph shows a decreasing trend in the coefficient of pressure with increasing Reynolds number for all angle configurations. The 7.5–15° angle shows the sharpest decline, indicating higher pressure losses at lower Reynolds numbers, while the 25–25° angle remains relatively stable.



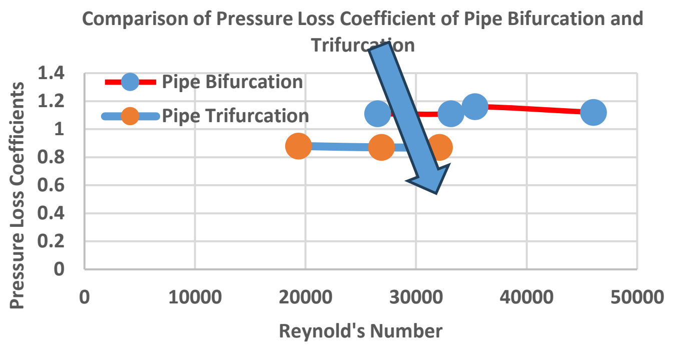
The pressure ratio decreases with increasing Reynolds number, reflecting improved flow efficiency. The 7.5–15° angle starts with the highest pressure ratio, which drops significantly with flow increase, whereas wider angles like 25–25° show less variation.

Bifurcation Graph:



The graph illustrates the variation of the coefficient of pressure with respect to the angle of left bifurcation in a pipe trifurcation arrangement. It shows that the coefficient decreases significantly as the bifurcation angle approaches 40°, where the minimum coefficient of pressure is observed, indicating an optimal flow condition.

Comparison graph:



The graph provides a comparative analysis of pressure loss coefficients between pipe bifurcation and trifurcation across varying Reynolds numbers. It highlights that the trifurcation setup consistently experiences lower pressure losses compared to the bifurcation configuration, suggesting better efficiency under dynamic flow conditions.

Conclusions:

1. The flow is fully in the Turbulent Region as the Reynolds Number is more than 10000 and the Coefficient of pressure decreases as the Reynolds Number increases
2. The collected data for Equal and Unequal Trifurcation shows more flow in Pipe bifurcation as compared to Pipe Trifurcation for the same initial pressure of pipe line
3. The pressure losses are more in Pipe Bifurcation compared to Pipe Trifurcation
4. The pressure loss coefficient is minimum for pipe bifurcation when the equal flow is flowing in both the pipes (50% in each pipe)
5. The pressure loss coefficient is minimum for pipe Trifurcation when the equal flow is flowing in both the pipes (33.33% in each pipe)
6. The overall loss coefficient 'k' remains in the range of 0.84 - 0.88 (Pipe Trifurcation)
7. The overall loss coefficient 'k' remains in the range of 1.02 – 1.3 (Pipe Bifurcation)
8. The Minimum “Cp” is observed for 20 degree in Right pipe and 40 degree for left bifurcation in pipe trifurcation arrangement.

Future Scope:

The future scope of this project includes:

- In power generation works the study and implementation of trifurcation may not only reduce cost but it is useful in many aspects. Industries using hot and cold-water supply network may also take the advantages of the trifurcation. Plumbing works in residential water supply, sanitary works may also use trifurcation.
- Energy is also computed in future days. The pipe material offering large friction to flow of fluid which may reduce the out let energy.
- Junction geometry for trifurcation for better performance yet not decided in future works has to be carried out to adopt shapes of geometry in dome, egg, wye etc. The main pipe to branch pipe ratio, manifold diameter, length etc is of future importance studies.
- Stresses occurring on the main pipe and branch pipe are of also future studies. The pipe thickness weld thicknesses in junctions' stability in extreme condition of working are in still research level.