KPU International Journal of Engineering & Technology
Volume 6, Issue 2, Sep. 2026
e-ISSN:2790-0819, p-ISSN:2790-0800
Date Received: 2025-11-23
Date Accepted: 2026-04-19
Date Published: 2026-09-30

Empirical Analysis of Pressure Drop in Different Types of Fittings: A Case Study with AFT/FME00

ZABDAMIR MIRZADA[1*] & ASRARUDDIN GULZAD[2]

[1]Student of the master's program in oil and gas refining Engineering, Kabul Polytechnic University, District 5, Kabul, Afghanistan. E-mail: zabdamirmirzada.1234@gmail.com.

[2] Professor of the Department of Petroleum and Gas Industrial Engineering, Kabul Polytechnic University, District 5, Kabul, Afghanistan. E-mail: a.gulzad@kpu.edu.af.

Abstract

Local resistance in hydraulic systems is one of the important design and application parameters that has a direct effect on the operation and energy consumption of pumps. In this study, pressure drop in six types of local resistance, including filter, T-connection, 90-degree knee bend, two consecutive 90-degree knee bends, 45-degree knee bend, and parallel pipe system, were experimentally investigated using the AFT/FME00 laboratory device manufactured by Edibon Company in the Laboratory of Chemical Engineering, Kabul Polytechnic University. The research was carried out using water as a fluid in the work area and at a flow of about 600 to 2400 liters per hour. For each flow size, pressure drop, flow velocity, Reynolds number, and local pressure drop coefficient (ζ) were calculated. The Reynolds number in this study was between 11,253 and 45,015, which indicates turbulent flow in the experiments, and the results showed that the ratio filter produces the greatest pressure drop. At 2400 liters per hour, its pressure drop reached 19999.94 Pascals, and its average pressure drop coefficient was about ζ = 9.50. In contrast, the kneecap of 45 degrees showed the lowest pressure drop, varying from 49.05 to 568.98 Pascals, and its average pressure drop coefficient was about ζ = 0.267. The results also showed that with increasing the size of the flow, the pressure drop increases significantly, and in irregular flow conditions, the pressure drop coefficient tends to decrease with increasing the Reynolds number. These results show the necessity and importance of proper selection of fittings in the design of hydraulic systems to reduce energy loss and improve system performance.

Keywords: Filter and Positional Resistance, Fitting, Knee, Pressure Drop.

* Corresponding Author

https://doi.org/10.68924/b6c0v440

1. Introduction

Pressure drop in hydraulic systems is one of the key design and operation parameters that has a direct impact on the performance and energy consumption of the system[1]. In various industries, including petrochemicals, refineries, and chemical industries, high pressure drops increase the power consumption of pumps and ultimately running costs. Fittings, as local resistance, are more likely to cause pressure height loss in hydraulic systems than direct pipes. Choosing the type of fitting and the shape of the local resistance can have a great impact on the better performance of the system [2].

Each local resistor has a specific geometric shape that affects the behavior of the fluid flow as it passes through it. For example, 90-degree knees compared to 45-degree knees cause fluid behavior to be disturbed, resulting in more pressure drops. Also, the placement of filters and T-shaped joints in the flow path of fluids in hydraulic systems changes the flow path and changes the flow path and behavior of the flow, and as a result, increases the hydraulic resistance of the system [2].

The pressure drop of all the components of the system can be calculated by the $\Delta P = \zeta(w^2/2g)$ relationship. In this regard, ζ is the geometric resistance factor, w the flow velocity, and g the gravity of the Earth. The ζ value for different local resistances is based on the trade-off, the figures obtained from the experiments, and the Reynolds number. The Reynolds criterion shows the fluid flow behavior, which can be laminar (slow), transition, and turbulent (turbulent), which is seen in most industrial systems[3].

An increase in the flow velocity causes a nonlinear increase in pressure drops. Since the local resistance with a lower pressure drop, especially in systems with a large current amount, will result in huge energy savings. Also, in comparative cases, the excess pressure drop caused by the blocking or blockage of local resistors such as filters should be considered, and it needs to be checked periodically so that the flow path is not blocked [4].

The main purpose of this study was to compare the pressure drop and pressure drop coefficient in six types of local resistors and to investigate their behavior in a wide flow rate (between 600 and 2400 liters per hour). From an operational point of view, this research can play a key role in better selection of equipment, reduction of energy consumption, and power estimation of pumps.

In this paper, first, the experimental conditions are explained, then the results of each type of local resistance are analyzed and compared with graphs and tables, and the fluid behavior is investigated in terms of the pressure loss coefficient relative to the Reynolds number. Finally, it is recommended that this article can be used as a reference by analyzing the pressure height loss in industrial cases.

The theoretical foundations of pressure drop are based on the basic equations of hydrodynamics and the laws of energy conservation and the law of conservation of momentum. Pressure drops in fluid flow systems are divided into two categories: first, pressure drop due to internal ducts (viscosity) that occurs in straight pipes and is caused by fluid friction with the walls of the pipes, and second, pressure drop due to local resistance that occurs in fittings and valves. The pressure drop due to local resistance is caused by a sudden change in flow velocity, a change in flow direction, and the creation of local complexities [5].

Studies in this field date back to the 1950s and 1970s. At that time, American researchers conducted extensive research to determine pressure height loss coefficients for different types of industrial fittings. The results of these studies were displayed in well-known tables based on ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) and ASME (American Society of Mechanical Engineers) systems. These tables have been used for many years as the primary reference for engineers [6].

In the following years, with the advancement of computers and numerical technology, researchers turned to the use of numerical simulations. CFD (Computational Fluid Dynamics) and AFD (Analytical Fluid Dynamics) methods were developed and allowed for more accurate flow analysis in complex fittings. These numerical methods can visualize the exact behavior of fluid flow with its bends and twists and provide a better view of the fluid behavior inside the barrel or local resistors [7,8].

Despite this, empirical figures have remained a reliable and valuable reference to this day. Many universities and research centers conduct experimental research to gain a better understanding of fluid behavior and pressure drop under different conditions.

The gaps in existing knowledge are mainly in two areas. Firstly, the pressure height loss coefficients in the guide tables are determined for specific conditions and may not be generalizable for all fluid flows and conditions. Secondly, the effect of the Reynolds number on the coefficient of pressure height loss for more complex fittings, such as instantaneous shrinkage of the flow path or specially structured filters, has not been fully clarified. These research gaps require further empirical research [9].

Conducting this scientific research is important in several ways. Firstly, the results of this research provide the most practical and direct solution for engineers designing and using fluid transmission systems. Secondly, it provides empirical data on the behavior of fluids in different fittings in a wider flow range (between 600 and 2400 liters per hour). Third, this research can be the basis for the development of better and more accurate mathematical and numerical models. Fourthly, receiving computational figures more often (up to 10 times) can provide calculation errors and better experimental results for the researcher in this regard. This can save time and research costs for researchers and engineers.

This research was an experimental analysis of local pressure drop in a variety of fittings using AFT/FME00 software and equipment provided by Edibon in a laboratory system that includes precise high-precision flow control machines that have the ability to simulate real conditions in industrial piping networks. The collected data included the parameters of pressure, discharge, and energy loss coefficient in different operating ranges (0.52 to 0.76), which made it possible to compare the experimental results with the theoretical predictions. This experimental method not only increased the accuracy of pressure analysis, but also paved the way for improving the design of fittings and improving the performance of hydraulic systems at the industrial level. The importance of using standard equipment and valid software in obtaining empirical (reliable) and reliable results has been clearly demonstrated in international articles, especially in the field of fluid engineering.

The main purpose of this study is to describe the empirical analysis of local pressure drop in various types of fittings and piping using AFT/FME00 software and basic equipment of the Edibon company. This research seeks to provide practical and reliable information in different operational experiments (0.52 to 0.76) to allow for accurate comparisons between experimental results and theoretical predictions. Therefore, the research has been conducted with the aim of identifying the effects of flow and pressure parameters on the energy loss coefficient and providing recommendations for improving the design of joints and improving the performance of industrial hydraulic systems. The emphasis on the use of precision laboratory equipment and validated software has enabled this research to produce credible and documented results that will be valuable both for industrial applications and for the development of future research in fluid engineering.

2. Research Methodology

2.1. Overall research approach

This study was conducted with an experimental-analytical approach and with the aim of investigating the local pressure drop in various types of fittings in fluid flow networks. The main focus of the research is to directly measure the primary hydraulic parameters, including volumetric flow intensity and pressure difference, and then, using the main fluid mechanics equations, the secondary parameters such as energy loss coefficient (ζ) have been calculated.

Unlike other studies that use prepared or simulated data, in this study, all the data were collected experimentally in the laboratory in a real way, and the analyses were performed based on this information.

2.2. Laboratory Equipment and Test Conditions

The data collection operation was carried out using the AFT/FME00 device manufactured by Edibon Company in the Chemical Engineering Laboratory of Kabul Polytechnic University.

This device is a semi-automatic (manual/semi-manual) educational-laboratory system, and its main function is to create regular flow conditions and measure parameters, not direct data analysis.

The main components of the system include:

- Flow meter for measuring volumetric flow intensity
- Differential manometer to measure pressure difference
- Calibrated pressure sensors
- Fittings set with fixed inner diameter (20 mm)

It does not perform numerical or computational analysis and only provides raw experimental information; all calculations are performed later by the researcher.

2.3. Fluid Specifications and Operating Conditions

The fluid used in the water laboratory is considered as a fluid with a constant viscosity and the following characteristics:

$$\rho = 1000\ kg/m^3$$

$$\mu = 9.433 \times 10^{-4}\, Pa.s$$

Experiments in the flow range:

$$Q = 600\ to\ 2400\ L/h$$

It has been done in accordance with:

$$Re = 11253\ to\ 45015$$

Because it indicates the intensity of a fully turbulent flow.

2.4. Data Collection Method

In this study, empirical information has been collected in a step-by-step and systematic manner:

1. Adjust the flow intensity to a certain amount
2. Wait until it reaches a stable state
3. Measurement of the difference between the input and output pressure of the fitting
4. Record the height of the fluid column in the manometer
5. Repeat each test at least three times

Recorded information includes:

- Volumetric flow intensity (Q)
- Fall Pressure Drop (ΔP)
- This is considered to be primary data.

2.5. Calculations and parameter extraction

After collecting the primary information, the secondary parameters are calculated through the following relationships:

Flow Rate:

$$w = \frac{4Q}{\pi d^2}$$

Reynolds Number:

$$Re = \frac{\rho w d}{\mu}$$

Pressure Drop:

$$\Delta P = \rho g \Delta h$$

Drop coefficient of local pressure:

$$\zeta = \frac{2\Delta P}{\rho w^2}$$

The ζ coefficient is not measured as the primary data, but as the final result of the calculations extracted from the laboratory data.

Therefore, the ζ is not placed next to the flow intensity but is considered the output of the analysis.

2.6. Data Analysis

After performing the calculations, the behavior of the parameters has been checked:

1. Changes in pressure drop relative to flow intensity
2. ζ changes relative to the Reynolds number
3. Comparison of the performance of different types of fittings

These analyses are performed in the form of graphs and figures.

3. Theoretical Foundations of Local Resistance and Loss Coefficient

3.1. Definition of Loss Coefficient of Local Pressure Height

The Local Pressure Height Loss Coefficient (ζ) (Zeta) is a dimensionless parameter used to measure energy fall in plumbing system components such as knees, walls, filters, and tees. This coefficient is related to pressure drop based on the following relationship:

$$\Delta P = \zeta \cdot \frac{w^2}{2g}$$

where ΔP is the drop pressure (Pascal), ρ is the fluid density (kg/m3), w is the flow rate (m/s), and ζ is the loss coefficient of the height of the local pressure. This relationship shows that the pressure drop is directly proportional to the square of the flow velocity, so as the velocity increases, the pressure drop increases significantly.

3.2. The Effect of Reynolds Number on Wasting Coefficient

The Reynolds number (Re) is a parameter that shows the ratio of the anarchy forces to the forces caused by viscosity in a fluid flow and is used to determine the flow regime (calm or turbulent). In calm flows, the coefficient of loss of local pressure height is usually strongly dependent on the Reynolds number and decreases as the Re increases. In turbulent flows, the dependence of ζ on the Reynolds number is less, and the coefficient of loss of pressure height reaches a value close to a constant. In the experiments, the Reynolds number is in the interval of 11,254 to 45,015, indicating a restless flow [3].

3.3. The Importance of Localized Resistors in System Design

Positional resistors, contrary to the name "small" or "minor," can have a significant impact on the overall performance of pumping and plumbing systems, especially in complex hydraulic systems. Ignoring these losses can lead to incorrect design, excessive energy consumption, and reduced system efficiency. Therefore, accurate calculation of pressure loss coefficients for all components of the hydraulic system is necessary [10].

3.4. Introduction and experimental conditions

The collected figures included fluid physical information (water with a density of $1000\ kg/m^3$ kilogram and viscosity $\mu = 9.433 \times 10^{-4}\ Pa \cdot s$), the type of local resistance (with an internal diameter of 20 mm), and the flow rate of 600 to 2400 L/h. For each state, pressure drop (ΔP), fluid flow velocity (w), Reynolds number (Re), and pressure height loss coefficient (ζ) are measured or calculated.

The types of resistance studied in this study include:

1. Filter: With Inner Diameter 20mm
2. T-Connector (Tri-Way): Includes oblique and similar T-knees
3. Two 90-degree knee flexions: two consecutive directional shifts
4. A 90-degree knee bend: a one-time change of direction
5. 45° knee bend: gentle change of direction
6. Parallel system of pipes: instantaneous fracking of fluid flow cross-section

4. Analysis of laboratory results for any type of local resistance

The analysis of the figures shows that the pressure drop in all fittings is almost proportional to the square of the flow velocity. This process is explained by the localized pressure collapse equation:

$$\Delta P = \zeta \cdot \frac{w^2}{2g}$$

The velocity of fluid flow inside the fittings is calculated by the following equation:

$$Q = F \cdot W$$

$$Q = \frac{\pi d^2}{4} \cdot W$$

$$W = \frac{4Q}{\pi d^2}$$

Reynolds is a dimensionless quantitative flow that is obtained by the following equation to obtain the type of flow (laminar, transition, and turbulent):

$$Re = \frac{w \cdot d \cdot \rho}{\mu}$$

In this research, a liquid manometer is used, and the pressure received in the meter of the water column is converted to Pascal by the following equation:

$$\Delta P = \rho \cdot g \cdot \Delta h_{avg}$$

4.1. Filter with 20mm inner diameter

The filter used in this study has the highest coefficient of local height loss among all the fittings studied in this paper. Laboratory figures show that the ζ coefficient in the interval ranges from 7.46 to 11.49, with an average pressure of 9.50. This value represents the significant resistance of the filter to fluid flow, which is caused by the complex internal structure and the presence of filtration gills. With the increase in the flow value from 600 to 1400 liters per hour, the zeta coefficient shows a gradual decrease from 11.49 to 9.91, but at 1600 liters per hour, a sudden decrease to 7.46 is observed. This nonlinear behavior may be caused by sudden changes in the flow regime.

Table 1. Experimental figures received by the pressure drop device in the filter with an internal diameter of 20 mm (Author)

Positional Resistance Type*:*				
Properties of Spot Resistance: Filter with Inner Diameter 20mm				
$t_1(℃): 19$		$t_2(℃): 26$		$t_1(℃): 22.5$
$\rho\left(\frac{kg}{m^3}\right): 1000$		$\mu(Pa \cdot s): 9.433 \cdot 10^{-4}$		
No	$Q\left(\frac{lit}{hr}\right)$	$\Delta h_1(mm - H_2O)$ $\Delta P_1(bar)$	$\Delta h_2(mm - H_2O)$ $\Delta P_2(bar)$	$\Delta h_{avg}(mm - H_2O)$ $\Delta P_{avg}(bar)$
1	600	160	170	165
2	800	280	280	280
3	1000	435	420	427.5
4	1200	590	602	596
5	1400	775	775	775
6	1600	810	713.55	761.775

7	1800	1019.36	1019.36	1019.36
8	2000	1427.11	1325.17	1376.14
9	2200	1732.92	1630.988	1681.954
10	2400	2038.73	2038.73	2038.73

Table 2. Calculations of the experimental figures received by the pressure drop device in the filter with an internal diameter of 20 mm (Author)

No	$Q\left(\frac{lit}{hr}\right)$	$Q\left(\frac{m^3}{s}\right)$	$\Delta h_{avg}(mr - H_2O)$	$\Delta P_{avg}(Pa)$	$W\left(\frac{m}{s}\right)$	Re	ζ
1	600	0.000166667	165	1618.65	0.531	11253.802	11.491
2	800	0.000222222	280	2746.8	0.708	15005.069	10.968
3	1000	0.000277778	427.5	4193.775	0.885	18756.336	10.718
4	1200	0.000333333	596	5846.76	1.062	22507.604	10.376
5	1400	0.000388889	775	7602.75	1.238	26258.871	9.913
6	1600	0.000444444	761.775	7473.013	1.415	30010.138	7.46
7	1800	0.0005	1019.36	9999.922	1.592	33761.405	7.888
8	2000	0.000555556	1376.14	13499.933	1.769	37512.673	8.625
9	2200	0.000611111	1681.954	16499.969	1.946	41263.94	8.712
10	2400	0.000666667	2038.73	19999.941	2.123	45015.207	8.874

The pressure drop in the filter increases dramatically as the flow rate increases, so that at the highest flow value (2400 l/h), the pressure drop reaches 19,999.94 Pa, which is almost 12 times the pressure drop at the lowest value (600 l/h). This suggests that filters can be the main source of pressure drop in hydraulic systems and should be considered more carefully in the design of pumping systems.

The filter shows the highest resistance with a pressure drop of 1618.65 Pa at low current (600 L/h) and 19999.94 Pa at the highest flow value (2400 L/h). This 12.36-fold increase reflects a strong dependence on speed. In contrast, a 45° knee bend produces the lowest pressure drop (49.05 to 568.98 Pascal), which is approximately 1/35th of the filter pressure drop.

The T-like joint and the knee bend represent a 90-degree average pressure drop. Two 90° knees have a compressive fall almost twice as much as a 90° knee (2815.47 Pa vs. 1177.2 Pa), which indicates the incremental effect of local resistance geometry.

4.2. 45° T-mile tee with 20mm inner diameter

The 45° T-mile triangle has a relatively low localized loss coefficient that ranges from 0.400 to 0.522, with an average of 0.438. This low value indicates that this type of fastener

provides less resistance to current compared to other resistors. By increasing the flow value from 600 to 2400 L/h, the ζ coefficient decreases from 0.522 to 0.400, indicating the fluid behavior in turbulent flows.

Table 3. Experimental figures received by the pressure drop device at three T miles 45 degrees with an inner diameter of 20 mm (Author)

Positional Resistance Type:				
Positional Strength Characteristics: T-like 45 tee with inner diameter 20mm T-like with inner diameter 20mm				
$t_1(℃): 19$		$t_2(℃): 26$		$t_1(℃): 22.5$
$\rho\left(\frac{kg}{m^3}\right): 1000$		$\mu(Pa \cdot s): 9.433 \cdot 10^{-4}$		
No	$Q\left(\frac{lit}{hr}\right)$	$\Delta h_1(mm - H_2O)$ $\Delta P_1(bar)$	$\Delta h_2(mm - H_2O)$ $\Delta P_2(bar)$	$\Delta h_{avg}(mm - H_2O)$ $\Delta P_{avg}(bar)$
1	600	7	8	7.5
2	800	11	13	12
3	1000	19	16	17.5
4	1200	25	27	26
5	1400	35	34	34.5
6	1600	43	43	43
7	1800	54	53	53.6
8	2000	65	65	65
9	2200	80	77	78.5
10	2400	92	92	92

Table 4. Experimental figures received by the pressure drop device at three T miles 45 degrees with an inner diameter of 20 mm (Author)

No	$Q\left(\frac{lit}{hr}\right)$	$Q\left(\frac{m^3}{s}\right)$	$\Delta h_{avg}(mm - H_2O)$	$\Delta P_{avg}(Pa)$	$w\left(\frac{m}{s}\right)$	Re	Z
1	600	0.000167	7.5	73.575	0.530786	11253.8	0.522302
2	800	0.000222	12	117.72	0.707714	15005.07	0.470072
3	1000	0.000278	17.5	171.675	0.884643	18756.34	0.438734
4	1200	0.000333	26	255.06	1.061571	22507.6	0.452662
5	1400	0.000389	34.5	338.445	1.2385	26258.87	0.441292
6	1600	0.000444	43	421.83	1.415428	30010.14	0.421106
7	1800	0.0005	53.6	525.816	1.592357	33761.41	0.414747
8	2000	0.000556	65	637.65	1.769285	37512.67	0.407396
9	2200	0.000611	78.5	770.085	1.946214	41263.94	0.406619
10	2400	0.000667	92	902.52	2.123142	45015.21	0.400432

The pressure drop in this resistance increases from 73.58 Pa at 600 liters per hour to 902.52 Pascals at the highest flow value of 2400 liters per hour. This increase, although significant, is much smaller compared to the filter, which indicates the relatively better efficiency of this type of connection in hydraulic systems.

4.3. Two 90° knees with an inner diameter of 20mm

The use of two knees of 90° in the flow path results in a local elevation loss coefficient in the range of 1.215 to 1.393, with an average of 1.276. This value is almost twice the

coefficient of a single 90° knee bend, suggesting that the cumulative effects of knees are almost retractable. The pressure height loss coefficient shows a relatively stable decreasing trend with increasing flow value, which is consistent with the turbulent flow theory.

Table 5. Experimental figures received by the pressure drop device in two 90° knee bends with an inner diameter of 20 mm (Author)

Positional Resistance Type:				
Positional Strength Characteristics: Double 90 knees with an inner diameter of 20mm				
$t_1(℃): 20$		$t_2(℃): 27$		$t_1(℃): 23.5$
$\rho\left(\frac{kg}{m^3}\right): 1000$		$\mu(Pa \cdot s): 9.433 \cdot 10^{-4}$		
No	flow $Q\left(\frac{lit}{hr}\right)$	$\Delta h_1(mm - H_2O)$ $\Delta P_1(bar)$	$\Delta h_2(mm - H_2O)$ $\Delta P_2(bar)$	$\Delta h_{avg}(mm - H_2O)$ $\Delta P_{avg}(bar)$
1	600	20	20	20
2	800	32	35	33.5
3	1000	50	50	50
4	1200	74	75	74.5
5	1400	95	95	95
6	1600	130	128	129
7	1800	162	163	162.5
8	2000	200	197	198.5
9	2200	247	245	246
10	2400	287	287	287

Table 6. Experimental figures received by the pressure drop device in two 90° knee bends with an inner diameter of 20 mm (Author)

No	$Q\left(\frac{lit}{hr}\right)$	$Q\left(\frac{m^3}{s}\right)$	$\Delta h_{avg}(mm - H_2O)$	$\Delta P_{avg}(Pa)$	$w\left(\frac{m}{s}\right)$	Re	Z
1	600	0.000167	20	196.2	0.530786	11253.8	1.392807
2	800	0.000222	33.5	328.635	0.707714	15005.07	1.312285
3	1000	0.000278	50	490.5	0.884643	18756.34	1.253526
4	1200	0.000333	74.5	730.845	1.061571	22507.6	1.297051
5	1400	0.000389	95	931.95	1.2385	26258.87	1.215153
6	1600	0.000444	129	1265.49	1.415428	30010.14	1.263319
7	1800	0.0005	162.5	1594.125	1.592357	33761.41	1.257395
8	2000	0.000556	198.5	1947.285	1.769285	37512.67	1.244124
9	2200	0.000611	246	2413.26	1.946214	41263.94	1.274245
10	2400	0.000667	287	2815.47	2.123142	45015.21	1.249173

The pressure drop in this resistance increases from 196.2 Pa at the lowest flow value to 2815.47 Pa at the highest flow value to 2815.47. This amount of pressure drop is significant and suggests that the use of multiple knees in the flow path can result in a significant energy drop. Therefore, in the design of hydraulic systems, efforts should be made to minimize the number of knees.

4.4. A 90° knee bend with an inner diameter of 20 mm

A 90° knee bend has a local pressure elevation coefficient at the interval of 0.522 to 0.766 with an average of 0.595. This value compares to the standard values reported in engineering resources for normal 90-degree knees (0.3 for 90-degree flange knees and 1.5 for ribs). The loss coefficient decreases with increasing flow value, which indicates the complete deployment of the turbulent flow regime.

Table 7. Experimental figures received by the pressure drop device in a 90° knee bend with an inner diameter of 20 mm (Author)

Positional Resistance Type:				
Positional Strength Characteristics: A 90 knee bend with an inner diameter of 20mm				
$t_1(℃): 20$		$t_2(℃): 27$		$t_1(℃): 23.5$
$\rho\left(\frac{kg}{m^3}\right): 1000$		$\mu(Pa \cdot s): 9.433 \cdot 10^{-4}$		
No	$Q\left(\frac{lit}{hr}\right)$	$\Delta h_1(mm - H_2O)$ $\Delta P_1(bar)$	$\Delta h_2(mm - H_2O)$ $\Delta P_2(bar)$	$\Delta h_{avg}(mm - H_2O)$ $\Delta P_{avg}(bar)$
1	600	11	11	11
2	800	17	15	16
3	1000	24	25	24.5
4	1200	33	30	31.5
5	1400	50	50	50
6	1600	60	60	60
7	1800	72	70	71
8	2000	85	90	87.5
9	2200	105	105	105
10	2400	120	120	120

Table 8. Experimental figures received by the pressure drop device in a 90° knee bend with an inner diameter of 20 mm (Author)

No	$Q\left(\frac{lit}{hr}\right)$	$Q\left(\frac{m^3}{s}\right)$	$\Delta h_{avg}(mm - H_2O)$	$\Delta P_{avg}(Pa)$	$w\left(\frac{m}{s}\right)$	Re	Z
1	600	0.000167	11	107.91	0.530786	11253.8	0.766044
2	800	0.000222	16	156.96	0.707714	15005.07	0.626763
3	1000	0.000278	24.5	240.345	0.884643	18756.34	0.614228
4	1200	0.000333	31.5	309.015	1.061571	22507.6	0.548418
5	1400	0.000389	50	490.5	1.2385	26258.87	0.639554
6	1600	0.000444	60	588.6	1.415428	30010.14	0.58759
7	1800	0.0005	71	696.51	1.592357	33761.41	0.549385
8	2000	0.000556	87.5	858.375	1.769285	37512.67	0.548418
9	2200	0.000611	105	1030.05	1.946214	41263.94	0.543885
10	2400	0.000667	120	1177.2	2.123142	45015.21	0.522302

The pressure drop in this resistance increases from 107.91 Pa at a flow rate of 600 liters per hour to 1177.2 Pa at a flow rate of 2400 liters per hour. This value is almost half of the 90-degree pressure drop in the knees, which confirms that the effects of the knees can be retracted. The 90° knee bend is one of the most common components of hydraulic systems, and a detailed understanding of its pressure height loss coefficient is essential for effective design.

4.5. 45° knee bend with an inner diameter of 20mm

The 45° knee has the lowest local loss coefficient of all knees, with an interval of 0.240 to 0.348, with an average of 0.267. That's almost half the 90-degree knee coefficient, suggesting that a gentler change of direction leads to less energy falls. As the flow rate increases, the loss coefficient shows a relatively constant decreasing trend.

Table 9. Experimental figures received by the pressure drop device at the 45-degree knee with an internal diameter of 20 mm (Author)

Positional Resistance Type:				
Positional Strength Characteristics: 45 knee bends with an inner diameter of 20mm				
$t_1(℃): 20$		$t_2(℃): 27$		$t_1(℃): 23.5$
$\rho\left(\frac{kg}{m^3}\right): 1000$		$\mu(Pa \cdot s): 9.433 \cdot 10^{-4}$		
No	$Q\left(\frac{lit}{hr}\right)$	$\Delta h_1(mm - H_2O)$ $\Delta P_1(bar)$	$\Delta h_2(mm - H_2O)$ $\Delta P_2(bar)$	$\Delta h_{avg}(mm - H_2O)$ $\Delta P_{avg}(bar)$
1	600	5	8	5
2	800	8	7	7.5
3	1000	10	12	11
4	1200	15	14	14.5
5	1400	20	20	20
6	1600	25	27	26
7	1800	32	30	31
8	2000	40	40	40
9	2200	48	48	48
10	2400	58	58	58

Table 10. Experimental figures received by the pressure drop device at the knee 45 degrees with an internal diameter of 20 mm (Author)

No	$Q\left(\frac{lit}{hr}\right)$	$Q\left(\frac{m^3}{s}\right)$	$\Delta h_{avg}(mm - H_2O)$	$\Delta P_{avg}(Pa)$	$W\left(\frac{m}{s}\right)$	Re	ζ
1	*600*	0.000167	5	49.05	0.530786	11253.8	0.348202
2	*800*	0.000222	7.5	73.575	0.707714	15005.07	0.293795
3	*1000*	0.000278	11	107.91	0.884643	18756.34	0.275776
4	*1200*	0.000333	14.5	142.245	1.061571	22507.6	0.252446
5	*1400*	0.000389	20	196.2	1.2385	26258.87	0.255822
6	*1600*	0.000444	26	255.06	1.415428	30010.14	0.254622
7	*1800*	0.0005	31	304.11	1.592357	33761.41	0.239872
8	*2000*	0.000556	40	392.4	1.769285	37512.67	0.250705
9	*2200*	0.000611	48	470.88	1.946214	41263.94	0.248633
10	*2400*	0.000667	58	568.98	2.123142	45015.21	0.252446

The pressure drop in the knee increases 45 degrees from 49.05 Pa at the lowest value to 568.98 Pa at the highest. These values are significantly lower than the 90-degree knee, suggesting that using 45-degree knees where possible can help reduce the overall system pressure drop. This is very important for the design of hydraulic systems.

4.6. Parallel system of hoses, 90° double knee bend with 20mm inner diameter

The parallel system of pipes with a 90-degree double knee suggests more complex behavior. The local loss coefficient in this system ranges from 0.122 to 2.368, with an average of 0.886 (eliminating the data point with an error at a flow rate of 2000 liters per hour). This wide variability suggests that the hydraulic behavior of parallel systems is more complex than series systems and depends on factors such as flow distribution between parallel branches and the interference of currents at junction points.

Table 11. Experimental figures received by the pressure drop device in a parallel system with a 90° double knee bend with an internal diameter of 20 mm (Author)

Positional Resistance Type:				
Positional Strength Characteristics: Parallel System of 90 Double Knee Hoses with Inner Diameter 20mm				
$t_1(℃): 20$		$t_2(℃): 27$		$t_1(℃): 23.5$
$\rho\left(\frac{kg}{m^3}\right): 1000$		$\mu(Pa \cdot s): 9.433 \cdot 10^{-4}$		
No	$Q\left(\frac{lit}{hr}\right)$	$\Delta h_1(mm - H_2O)$ $\Delta P_1(bar)$	$\Delta h_2(mm - H_2O)$ $\Delta P_2(bar)$	$\Delta h_{avg}(mm - H_2O)$ $\Delta P_{avg}(bar)$
1	600	43	25	34
2	800	37	35	36
3	1000	25	53	39
4	1200	14	45	29.5
5	1400	27	30	28.5
6	1600	10	15	12.5
7	1800	50	50	50
8	2000	105	98	101,5
9	2200	160	160	160
10	2400	230	230	230

Table 12. Experimental figures received by the pressure drop device in a parallel system with a 90° double knee bend with an internal diameter of 20 mm (Author)

No	$Q\left(\frac{lit}{hr}\right)$	$Q\left(\frac{m^3}{s}\right)$	$\Delta h_{avg}(mm - H_2O)$	$\Delta P_{avg}(Pa)$	$w\left(\frac{m}{s}\right)$	Re	Z
1	600	0.000167	34	333.54	0.530786	11253.8	2.367771
2	800	0.000222	36	353.16	0.707714	15005.07	1.410217
3	1000	0.000278	39	382.59	0.884643	18756.34	0.97775
4	1200	0.000333	29.5	289.395	1.061571	22507.6	0.513597
5	1400	0.000389	28.5	279.585	1.2385	26258.87	0.364546
6	1600	0.000444	12.5	122.625	1.415428	30010.14	0.122415
7	1800	0.0005	50	490.5	1.592357	33761.41	0.386891
8	2000	0.000556	101,5	#VALUE!	1.769285	37512.67	#VALUE!
9	2200	0.000611	160	1569.6	1.946214	41263.94	0.828777
10	2400	0.000667	230	2256.3	2.123142	45015.21	1.00108

At low flow values between (600 to 1000 L/h), the pressure drop coefficient is higher (2.368 to 0.978), which may be due to an uneven flow distribution between parallel branches. By increasing the value to 1600 liters per hour, the coefficient reaches a minimum of 0.122, which indicates a better flow distribution. Then, as the amount of flow

increases further, the coefficient rises again, which can be caused by an increase in the interference of currents and turbulent currents.

5. Pressure Loss Coefficient Analysis

The pressure loss coefficient (ζ) or local resistance coefficient is very important for understanding the behavior of local resistors under different flow conditions. This coefficient of dependence shows a Reynolds number that can be seen in the range of Re = 11253.8 to Re = 45015.2.

The loss coefficient of pressure height (ζ) in different local resistors such as filter, tee, double knee 90 degrees, one knee 90 degrees, 45 degrees knee bend, and shrinkage of the flow duct has been investigated, and the relationship between Reynolds flow and pressure height coefficient has been investigated. Figure (1).

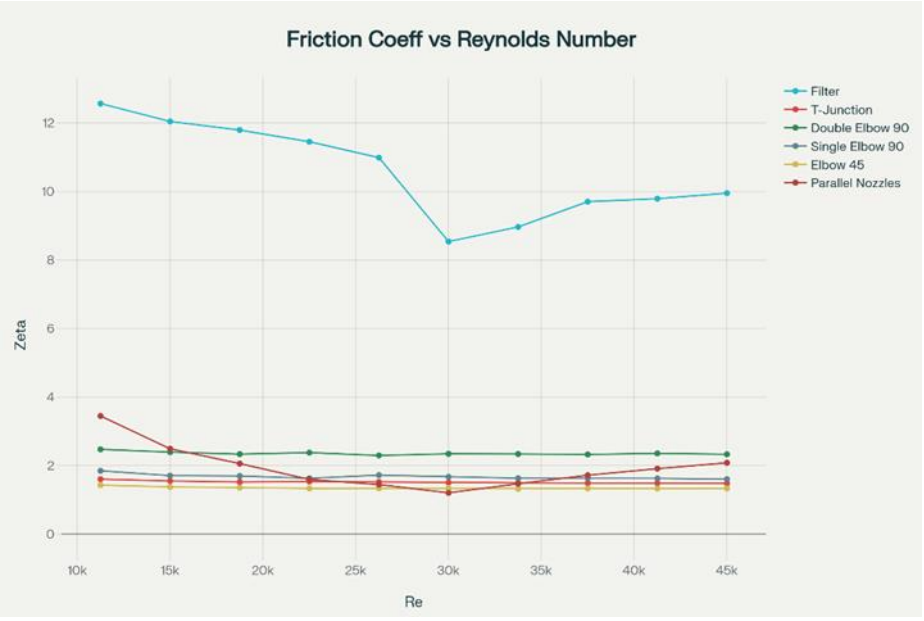


Fig. 1. Relationship between pressure height loss coefficient and Reynolds flow at different local resistors (Author)

For the filter: The ζ coefficient is reduced from 11.49 in Re = 11253 to 8.87 in Re = 45015. This 23% decrease indicates that as the Reynolds number increases, the local resistance factor decreases.

For the T-coupling: the coefficient of ζ is almost more constant (0.40-0.52), which indicates that this type of local resistance has a more consistent behavior under variable flow conditions.

For two knees 90 degrees: the ζ coefficient is around 1.25-1.29 in the change, which is almost constant.

For a 90-degree knee bend: The ζ factor decreases from 0.77 to 0.52 (28%).

For knee flexion 45 degrees: The ζ coefficient is very low (0.24-0.35), and shows consistent behavior.

For parallel systems, more complex behavior is observed. The ζ coefficient drops from 2.37 in the low flow to 0.12 in the 1600 l/h flow, then increases again. This behavior indicates a change in the flow pattern in this system.

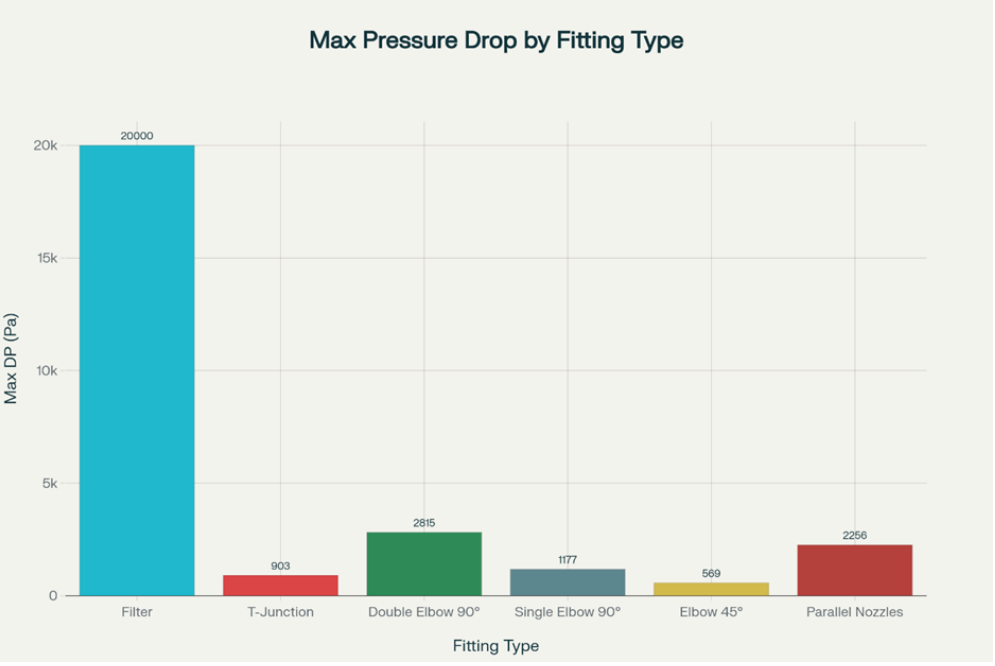


Fig. 2. Graph of the changes in the pressure drop coefficient ζ vs. Reynolds number for the sequential system of pipes (Author)

5.1. Functional Comparison

By examining the pressure drop among all local resistors at 2400 L/h (maximum flow value), the following results were obtained.

Table 13. Pressure drop coefficient (ζ) for parallel systems with two knees of 90 degrees and inner diameter of 20 mm (Author)

Fitting	Pressure Drop (Pa)	Percentage of Filters	Coefficient of ζ
Filter	19999.94	100%	8.87
Double knees 90°	2815.47	14.1%	1.25
Hose System	2256.30	11.3%	1.00
A 90° knee	1177.20	5.9%	0.52
T connection	902.52	4.5%	0.40
Knee 45°	568.98	2.8%	0.25

This table clearly shows that the filter produces 36 times more pressure than a 45-degree knee drop, but because of its protective role, it is necessary to use it to keep destructive solids away from hydraulic systems.

6. Discussion and Comparison with Literature

The results of this research have been compared with the information provided by reliable sources in the specialized engineering sector, including ASHRAE and ASME standards, as well as previous empirical research studies. For the 90-degree knee, the pressure drop coefficient for the 90-degree knee in this study ranged from 0.52 to 0.76. It shows an acceptable conformity in the range up to the reported range in the sources (approximately from 0.3 to 1.5 depending on the type of connection, in the curvature radius, and fluid flow conditions). This consistency indicates the validity of the laboratory method and the accuracy of the obtained information.

In the case of the 45° knee, the values of the local pressure drop coefficient (0.24 to 0.35) are significantly lower than the 90° knee. This result is consistent with the theoretical principles of fluid mechanics and the results of previous research, in which it is confirmed that reducing the angle of change of flow leads to a reduction in the instabilities of local pressure drop, energy loss, and consequently a decrease in pressure drop.

Regarding the expression of these T-shaped joints, the relatively stable value of the pressure drop coefficient between (0.40 and 0.52) indicates a more uniform hydraulic flow in this type of irregular flow connection. This study is consistent with the results reported in previous experimental studies that show that in the case of irregular flow, the sensitivity of the pressure drop coefficient to the Reynolds number is reduced.

At the same time, in the case of the filter, the value of the local pressure drop coefficient obtained (average about 9.50) is significantly higher than some of the values reported in theoretical sources, which can be caused by factors such as the complex internal structure of the filter, the local pressure drop caused by extreme turbulence, surface roughness, or actual laboratory conditions that are simplified in ideal structures and theoretical relationships. Therefore, the results of this section highlight the importance of using empirical information in the actual design of systems.

Also, the general trend of decreasing the pressure drop coefficient (ζ) with the increase of the Reynolds number in all the studied joints is very similar to the theory of irregular current and previous experimental studies. This function indicates a decrease in the effect of viscosity forces and the predominance of inertial forces in the range of irregular flow. However, in parallel systems, nonlinear performance has been observed to represent a greater complexity of the flow mode and the interaction between segments, which is not fully considered in many classical designs.

7. Novelty and Future Research Directions

The main focus of this research is to provide a rigorous empirical analysis of local pressure falls in different fittings and to critically review the reliability of information and reference relationships. The key innovation in this research is in the production and analysis of a coherent empirical data set under appropriate and fully controlled laboratory conditions that allows for direct and valid comparisons between the actual behavior of the fitting and the values provided in past sources.

The results of this study clearly show that the pressure drop coefficients obtained in real conditions (laboratory), especially in a field with great geometric complexity such as filters and parallel flow systems, have a significant deviation from the standard values.

These differences clearly indicate that many of the existing empirical equations and tables, which are mainly developed on the basis of ideal or simplified conditions, are not sufficiently accurate in practical and industrial applications.
From the point of view of the scientific community, this research, with an emphasis on the actual behavior of irregular flow, shows that local pressure fall is a sensitive function of the interaction between the geometric structure of the fitting and the dynamic characteristics of the flow. The simultaneous analysis of several types of fittings in the same framework and structure allows for a deeper understanding of the contribution of each parameter to the energy loss of the system and shows that the inappropriate selection of fittings can directly lead to a significant increase in energy consumption in hydraulic systems.
In the scope of this research, in the future, it is necessary to emphasize the development of forecast structures based on factual information and operational conditions. The use of advanced tools and devices such as computational fluid dynamics (CFD) along with information-driven methods such as machine learning can lead to a redefinition of traditional relationships and provide a more accurate structure for predicting pressure drops. Also, the study of the effect of advanced geometric parameters, surface roughness, and more complex flow conditions can provide a more comprehensive understanding of the hydraulic behavior of systems.
In this study, by highlighting the limitations of reference information and providing reliable empirical evidence, it is considered a more effective step towards better design accuracy, reducing energy losses, and improving the performance of fluid transfer systems on an industrial scale.

8. Analytical analysis and conclusions

In this experimental study, the local pressure drop coefficient (ζ) for different types of joints in fluid flows has been investigated. The main results are as follows:

1. The effect of the type of connection on pressure drops: Joints with gradual directional changes of currents, such as a 45-degree knee, have produced the lowest pressure drops, while filters have had the highest pressure drops. These results show the importance of choosing the right connector more accurately in reducing energy consumption in industrial piping systems.
2. The effect of the number of joints: An increase in the number of joints, such as two 90-degree knees versus one knee, has an almost cumulative effect, and the pressure drop coefficient as a whole is equal to the sum of the ζ of both knees. This research emphasizes the importance of better design of the flow path.
3. The effect of fluid flow and Reynolds number: In the range of irregular fluid flows, it was studied, and it was observed that as the Reynolds number increases, the ζ coefficient decreases. This flow shows that viscous changes play less role in pressure fall than inertial changes, and turbulent flow characteristics are dominant.
4. Practical application in chemical and petrochemical industries: Correct selection of fluid flow system fittings and components can significantly reduce energy loss at altitudes. Connectors and filters that cause high-pressure drops require monitoring and specific intervals to maintain better system performance.

5. Comparison of experimental results with theoretical sources: The results obtained from the laboratory had differences with the available book data, articles, and standards due to the actual laboratory conditions, geometric complexity in the connections, and practical differences in fluid flow. These differences indicate that empirical studies are necessary for better design of fluid flow systems.

9. Acknowledgements

I would like to express my gratitude and appreciation to the professors who played a role in this research, especially the Department of Chemical Engineering, Faculty of Chemical Industries Engineering, Kabul Polytechnic University, who did not spare any help in conducting this research and provided a suitable environment for this research by providing the necessary laboratories and facilities. I also express my gratitude and gratitude to the head of the Department of Chemical Engineering, the Assistant prof. Engineer Ainullah Yasini, for his cooperation in conducting the laboratory business and his constructive advice in conducting this research. I pray to Almighty Allah for his long life with happiness and success in serving the country.

10. Abbreviations

Re: Reynold's number, indicating fluid flow
L/h: Quantity, volume of currents per hour
ASHRAE: American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASME: American Society of Mechanical Engineers
AFD: Analytical Fluid Dynamics
CFD: Computational Fluid Dynamics
Pa: Pascal
W: fluid flow velocity
ΔP: pressure drop
ζ: pressure height loss coefficient

References

[1] H. Wagener and K. Pahl, "Energy flow, energy losses and efficiency of the hydraulic press system," *Journal of Mechanical Working Technology,* vol. 17, pp. 93-102, 1988.
[2] R. Darby, "Correlate pressure drops through fittings," *Chemical Engineering,* vol. 108, no. 4, pp. 127-127, 2001.
[3] H. Wadell, "The coefficient of resistance as a function of Reynolds number for solids of various shapes," *Journal of the Franklin Institute,* vol. 217, no. 4, pp. 459-490, 1934.
[4] T. Xia, Y. Bian, L. Zhang, and C. Chen, "Relationship between pressure drop and face velocity for electrospun nanofiber filters," *Energy and Buildings,* vol. 158, pp. 987-999, 2018.
[5] B. Dietrich, W. Schabel, M. Kind, and H. Martin, "Pressure drop measurements of ceramic sponges—determining the hydraulic diameter," *Chemical Engineering Science,* vol. 64, no. 16, pp. 3633-3640, 2009.
[6] D. F. Geary, "American Society of Heating, Refrigerating and Air-conditioning Engineers Guideline 12-2000: Minimizing the Risk of Legionellosis Associated with Building Water Systems," *Legionella,* pp. 376-384, 2001.
[7] S. R. Zanje, I. Jain, and S. Dhar, "Design and Analysis of Novel Antifouling Device (AFD) by FEM," in *International Conference on Advances in Thermal Systems, Materials and Design Engineering (ATSMDE2017)*, 2017.

[8] M. H. Zawawi *et al.*, "A review: Fundamentals of computational fluid dynamics (CFD)," in *AIP conference proceedings*, 2018, vol. 2030, no. 1: AIP Publishing LLC, p. 020252.
[9] M. Lupion, B. Alonso-Fariñas, M. Rodriguez-Galan, and B. Navarrete, "Modelling pressure drop evolution on high temperature filters," *Chemical Engineering and Processing-Process Intensification*, vol. 66, pp. 12-19, 2013.
[10] P. DRUMEA, "Energy losses in hydraulic systems," *Articol Hidrolica digitala-iasi, FLUIDAS*, pp. 1-10, 2001.