

## Measuring local losses in pipe flows utilising data acquisition cards and a computer

Riza Gürbüz

Ankara University  
Ankara, Turkey

**ABSTRACT:** The purpose of this article is to measure velocity of fluid, pressure difference, flow rate, Reynolds number, friction factor, local losses and K factor of some valves and fittings such as tee, elbow, Y Junction, gate and globe valves by using data acquisition cards and a computer. This study utilised a computer, venturi and orifice meter to measure flow rates, pressure differential transmitters to measure pressure drops on flow rate measurement devices and pressure drops of some valves and fittings with measured K factors. The temperature of fluid in the tank was also determined. A computer program was written in order to calculate the Reynolds number of fluid, friction factor of the pipe, velocity, local losses of fluid, flow rate and the K factor of valves and fittings. Required data was received from the measured quantities. The conclusion of the experiment is graphically shown in the article. The volumetric flow rate limitation was determined to be 0-60 (Lpm), while the pressure drop was 0-100 kPa in this experiment.

### INTRODUCTION

When fluid flows through a pipe or conduit, it counters resistance to its flow. In straight piping, this resistance is caused by the roughness of the pipe surface. In addition to friction losses, there are also losses due to turning gate valves, globe valves, flow control valves, sudden enlargements, 45° or 90° junctions, etc. Finally, if the pressure drops in these sections of fluid systems also take place. Local losses must be taken into account in fluid power systems.

All losses can be determined for each of the various elements in a system and then added together in order to ascertain the total system loss. The K factor of some elements can be determined using empirical formulae that have been developed via experimentation. This permits the calculation of energy losses for any system components. Bernoulli's equation and the continuity equation can be utilised in order to perform a complete analysis of a fluid power system. This includes calculating the pressure drops, flow rates and horsepower losses for all of the components of a fluid power system.

There are two basic types of flow in pipes, depending on the nature of the different factors mentioned above that affect the flow. The first type is laminar flow, which is characterised by the fluid flowing in smooth layers of laminae. This type of fluid motion is called *streamline flow* because all of the particles of fluid are moving in parallel paths.

If the velocity of flow reaches a high enough value, the flow ceases to be laminar and becomes turbulent. The movement of a particle becomes random and fluctuates up and down in a perpendicular direction, as well as parallel to the mean flow direction, in a turbulent flow. Reynolds numbers (Re) are very important in identifying whether or not the flow pattern inside a pipe is laminar or turbulent [1].

If the Re value is less than 2,000 the flow is laminar, but if the Re value is greater than 4,000, the flow is turbulent. Reynolds numbers between 2,000 and 4,000 cover a critical zone between laminar and turbulent flow [2].

There are well-established methods to determine friction losses, which can be found in numerous textbooks and engineering handbooks [3]. Two frequently cited references are *Cameron Hydraulic Data*, and the *Flow of Fluids through Valves, Fittings and Pipe* [4][5].

Additionally, manufacturer-produced data sheets and engineering handbooks frequently contain relevant design information that aid in determining line losses.

Friction losses are a function of velocity (flow rate); there is a unique pressure value for every flow rate value. Therefore, friction and local losses should be calculated experimentally to determine the minimum and maximum flow rates.

Manufacturers of pipes, valves, fittings, elbows, XYT junctions, etc, are identify values using computerised friction or local losses apparatuses and prepare information in their catalogue or on their Internet site, as well as in some books on fluids.

### Fluid Friction Apparatus and Specifications

Fluid friction apparatus are designed to allow a detailed study of fluid friction and local losses that occur when an incompressible fluid flows through pipe bends, valves and pipe flow metering devices. Pressure differential transmitters and data acquisition cards are added later to help in the computerised experimental analysis of the local losses of valves, fittings and bends. An example of a fluid friction apparatus is shown in Figures 1 and 2.



Figure 1: Picture of a fluid friction apparatus and a data acquisition system.

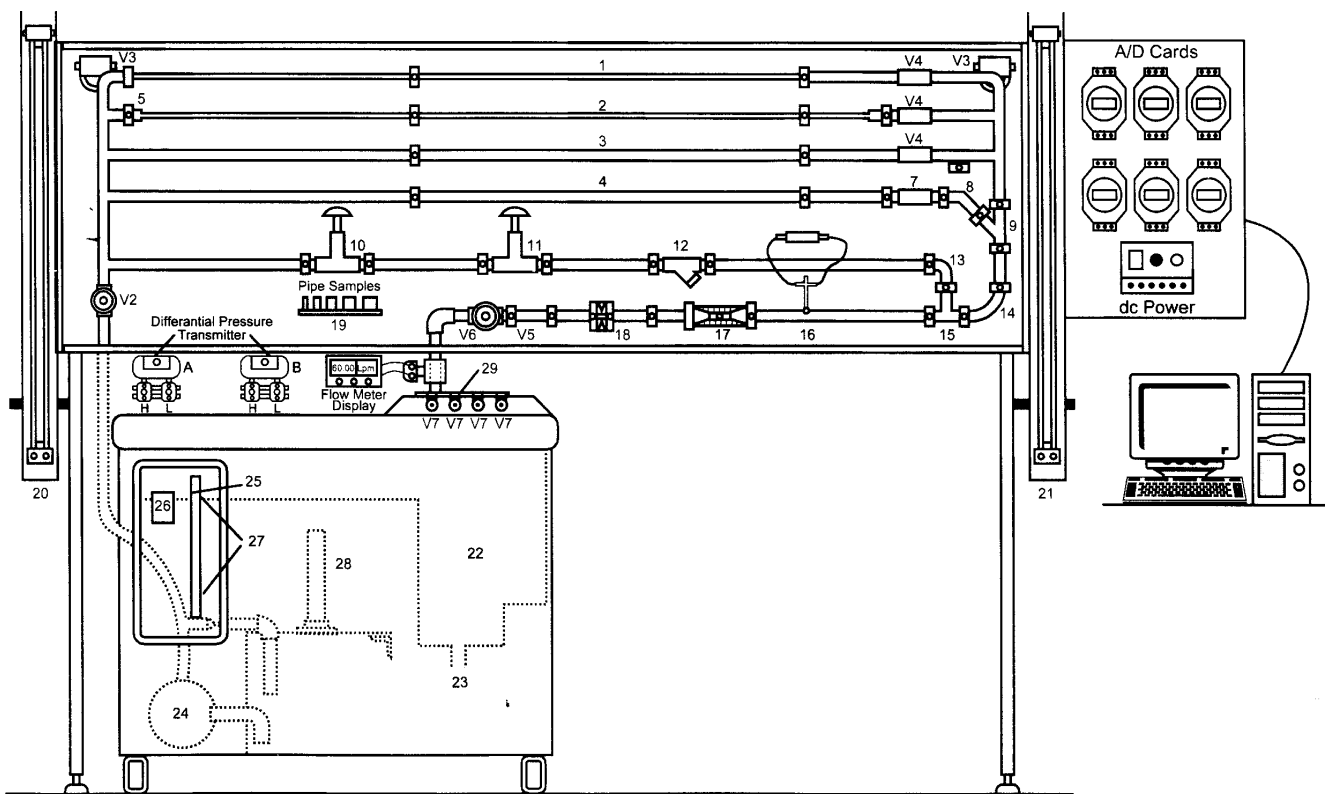


Figure 2: Schematic diagram of a fluid friction apparatus and data acquisition cards.

### SYSTEM DESIGN FOR LOCAL LOSS MEASUREMENT IN PIPES

The calculation of frictional and local losses in pipes by a computer needs pressure transmitters, analogue-digital cards, fluid flow rate or velocity of flow devices, such as a venture meter or orifice plate, a computer and a program to evaluate the data. To calculate some of the data, like Reynolds numbers, friction factor, velocity, flow rate and local losses, K factor specific values should be given for parameters, including pipe

diameters, pipe lengths, fluid specific gravity and the K constant of flow rate measurement devices. Analogue-digital cards should be suitable to measure the physical quantity and maximum-minimum values of a system [6][7].

It becomes necessary to utilise computers in order to perform the enormous number of calculations required to optimise complete fluid friction measurement systems in a reasonable time period. The value of any number's parameters can be changed and the impact on the overall system performance

determined. Thus, the use of computers permits the analysis of some parameters very quickly and sensitively. Furthermore, all data can be stored on analogue-digital cards, which are used in order to convert the analogue signals into digital signals for computerised systems and utilised for measurement. The requested data can be obtained as an *Excel* sheet or graphic [8].

### PROCEDURE OF EXPERIMENTAL ANALYSIS

To begin the experiment, the first valve is opened a quarter, half, three quarters or full. The corresponding data is measured, such as friction factors, flow rate, velocity of fluid in pipe, Reynolds number, local losses and the K factor of some valves, bends and fittings by using data acquisition cards and a computer. Data can also be received at pre-determined intervals [9].

As 10-20 data sets are acquired, the friction factor  $f$  is displayed as a function of the flow rate expressed in terms of a Reynolds number (Re). Data is recorded, with the results presented graphically [10].

A  $\Delta p$  signal is received from pressure differential transmitter between 4-20 mA and changed as pressure (Pa). The flow rate is calculated with the computer program as  $m^3/s$  and converted L/s by multiplying 1/1,000. A graphic of the experiment to measure a 90° elbow (Figure 3) is shown in Figure 4.

In these experiments, the Reynolds number observed is above 4,000; therefore, the fluid flow type is turbulent.

The electrical outputs of a pair of Foxboro pressure transducers are connected via an Advantech data acquisition board to a computer. The pressure measurement outputs of the Foxboro pressure differential transducers are connected to a venture meter or orifice plate, while a second pressure differential transducer is connected to the inlets and outlets of fittings, bends or valves. Pressure differential transducers convert pressure (0-150 kPa) to electrical signals (4-20 mA); the analogue-digital cards convert analogue signals (4-20 mA) to digital signals (I/O). The received digital signals are evaluated in the computer by the developed program; some values are measured and some values are calculated in this experiment. Some values are inputted, measured and calculated using equations (see Table 1). The result of a selected sample experiment is shown in Figure 4.

Computer and data acquisition cards are needed in order to perform a complete analysis of the controlled system. A computer becomes necessary in order to calculate or measure



Figure 3: Illustration of the 90° elbow.

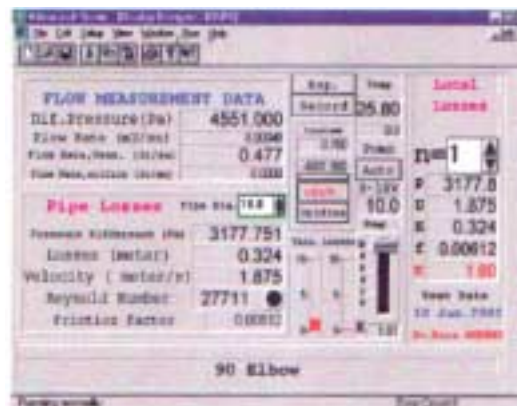


Figure 4: K value of the 90° elbow.

some parameters, like velocity, pressure, flow rate, Reynolds number, friction factor, K factors and pump power [11]. Figure 5 gives a flow chart of a computerised fluid friction apparatus.

In this study, a Windows-based program (*Genie 4.0*) is used to measure and calculate the local losses of some of the fittings, bends and valves. The program is menu driven, allowing users to easily understand and recognise the various options. These advantages, together with the program's ability to generate different types of plots, comprise the menu driver's interface.

### Result of the Experimental Analysis

The results of the experimental analysis are given in Table 2. The K factors of some fittings, bends and valves are very close to the tabulated values in some fluid power books and company catalogues.

Table 1: Input and calculated data and used equations.

Input Data		Measured and Calculated Data		Equations Utilised
Fluid Type	Water	Velocity (U)	m/s	$U = 4 \dot{v} / \pi d^2$
Density ( $\rho$ )	999 kg/m <sup>3</sup>	Pressure Difference ( $\Delta p$ )	Pa	
Specific gravity (g)	9.81 m/s <sup>2</sup>	Flow Rate ( $\dot{v}$ )	m <sup>3</sup> /s, L/s	$\dot{v} = K \sqrt{p/\rho g}$
Viscosity ( $\mu$ )	0.001 Pa.s	Reynold Number (Re)		$Re = dU\rho/\mu$
Pipe Diameter (d)	7, 5, 16, 18 mm	Friction Factor (f)		$f = 0.079/Re^{0.25}$
Temperature ( $\theta$ )	(25°C)	Local Losses (H)	m	$H = p_1 - p_2$
K factor of Venturimeter	0.0007	K Factor ( $K_L$ )	m	$H = K (U^2/2g)$
K factor of Orifice Plate	0.00112	Turning Number (n)	1.2	

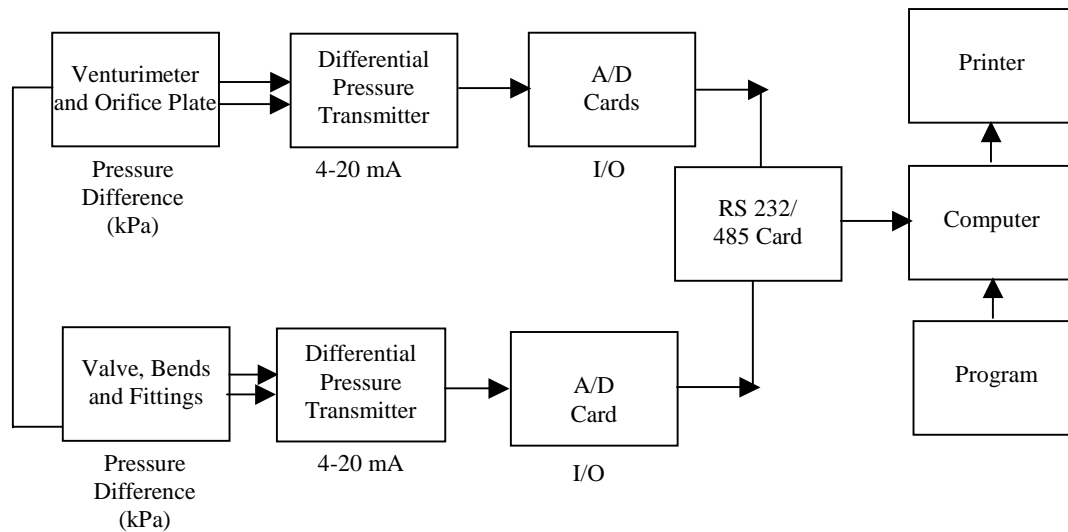


Figure 5: Block diagram of a computerised fluid friction apparatus.

Table 2: Measured and calculated K factor values.

Valve and Bends	K Factor (Measured)
Globe valve: full open	10.2
¾ open	32.2
½ open	13.1
¼ open	52.0
Gate valve: full open	0.35
¾ open	4.3
½ open	5.4
¼ open	26.0
45° elbow	0.28
90° elbow	0.81
Standard elbow (Figure 4b)	1.8

## SUMMARY AND CONCLUSION

Energy losses occur in pipeline restrictions called fittings, valve sudden enlargement, bends, tees, elbows and orifices. It is very important to keep all of the energy losses in a fluid system to a minimum, acceptable level. This requires the proper selection of pipe sizes and fittings that make up a system. The resistance of fittings can be determined using empirical formulae that have been developed via experimentation. This permits the calculation of energy losses for any system component [12].

Computer, data acquisition cards and transmitters allow researchers to make a sensitive, yet quick, experimental analysis of fluid systems. This study provides a simple application of the mentioned experiments. The results of experiments are positively measured, with the target being that the calculated values fall within acceptable limits.

Determining the K factor of some valves and fittings are useful experimental techniques for students. Experimental tests have shown that local losses are proportional to the square of the velocity of the fluid and inside diameter of pipe and viscosity of fluid. Analogue or digital devices were used to measure pressure differences and the flow rate of the fluid. Analogue devices do not provide sufficiently sensitive measurements. Therefore, it is advisable to use digital pressure differential measurements. A computer program helps to calculate quickly and correctly the K factor, as well as other values. This

experimental study has a universal structure and can be applied to all kind of valves and fittings.

Pressure differences and other transmitters must be changed according to the range of pressure, temperature, flow rate, etc. Proportional valves or frequency motor converters can be used to control flow rate, instead of manual valve control. This will give more sensitive graphics than the applied method.

## REFERENCES

- Hardy, J.E. and Hylton, J.O., *Flow Measurement Methods and Applications*. Hoboken: John Wiley & Sons (1999).
- Bentley, J., *Principles of Measurement Systems*. New York: Longman Scientific and Technical (1988).
- Ostand, R.P. and Richards, P.G. Minimizing Piping Friction Losses in Low-Pressure Regulating Valves. Control Engineering, [www.controleng.com/archives/](http://www.controleng.com/archives/)
- Ingersoll-Rand, *Cameron Hydraulic Data*. New York: Ingersoll-Rand (1970).
- Crane Co., Flow of Fluids through Valves, Fittings and Pipe. Technical paper, No. 410, New York: Crane Co. (1981).
- Spitzer, D., *Industrial Flow Measurement*. New York: ISA Press (1990).
- Omega Co., *Trans. in Measurement and Control*. Vol. 4, Flow and Level Measurement (2002), Omega Engineering, Inc., [www.omega.com](http://www.omega.com)
- Morison, K.R. and Jordan, P.J., Spreadsheet documentation for students and engineers. *Inter. J. of Engng. Educ.*, 16, 6, 509-515 (2000).
- Gürbüz, R., The measurement of pipe and local friction losses by interactive computer program. *Proc. Inter. Conf. on Engng. Educ. (ICEE)*, Manchester, England, UK, PO9, (2002), <http://itservices.umist.ac.uk/icee2002>
- Gürbüz, R., The measurement of local and continuous losses against the increasing flow the by computer. *Proc. UMTİK 2000*, Ankara, Turkey, 433-451 (2001).
- Armfield Ltd, Armfield Fluid Friction Apparatus. Issue 7a (1987), <http://www.armfield.co.uk>
- Espisito, A., *Fluid Power with Applications*. Upper Saddle River: Prentice Hall International (2000).