

1. PROBLEM STATEMENT

1.1 Historical Introduction

In many industries, accurately measuring the flow of liquids is very important. The ability to conduct accurate flow measurements requires the use of a special liquid flow measurement instrument. One such instrument is known as the electromagnetic flow meter. This flow meter became an attractive instrument in a variety of industries because of its ability to record an instantaneous volume flow of fluid. This idea was first proposed and implemented in the 1930s by the physiologist E. J. Williams. The idea was later implemented by another physiologist named P. Fabre. After World War II, the electromagnetic flow meter was developed to nurture the power-producing nuclear reactor [1]. Electromagnetic flow meters have existed for decades in industries, such as chemical and pharmaceutical, food and beverage, water and wastewater, science and biology, and many more.

Electromagnetic flow meters are based on Faraday's Law of Magnetic Induction. In an electromagnetic flow meter, the liquid acts as a conductor. This induces a voltage directly related to the average flow velocity, as stated by the principle of "the faster the flow rate, the higher the voltage" [2]. The voltage is measured by sensing electrodes mounted in the meter tube. This voltage is then sent to the transmitter, which calculates the flow rate based on the cross-sectional area of the meter tube [2]. Electromagnetic flow meters provide the volumetric flow rate of electrically conducting liquids in pipes [3].

The life expectancy of flow meters varies but can be extended based on many factors. During the initial stages of implementing a flow meter, calibration is a major issue. Initial calibration involves checking and adjusting the flow meter so the measurements are accurate. According to *Omega Engineering*, flow meter accuracy should be recalibrated frequently based on the application [4]. "In other cases, recalibration may not be necessary for years because the application is non-critical, or nothing will change the meter's performance" [4]. Other factors that influence the life expectancy of such instruments involve cleaning impulse lines that consist of tubes and pipes, inspecting the internal components, and periodically cleaning the coatings surrounding the electrodes. Impulse lines of the flow meter may often become plugged or corroded, which leads to cleaning and/or replacement [4]. If the electrode coating is too insulated from the fluid by foreign impurities, the operation of the electromagnetic flow meter becomes impaired. All flow meters eventually require some maintenance, but those with moving parts will require more attention, especially if the fluid being measured is dirty or viscous [4]. Therefore, electromagnetic flow meters that lack moving parts and never come into contact with the fluid have an advantage over other types of flow meters.

Since the first electromagnetic flow meter, applications for such instruments have grown tremendously. Industries can measure any sonically conductive liquid without damaging the pipe. In the water and wastewater industry, such applications include well and production tests, water oil concentration measurements, leakage control, inspection of water meters, and crude oil flow measurements in oil rigs. The food and beverage market uses flow meters for hygienic measurements of clear liquids, juices, and syrups [5].

Today, the volumetric measuring of blood flow rate in animals and humans is done without the need of puncturing the vessel wall. This is done by exposing the blood vessel of anesthetized human or animal subjects and placing the probe around an intact blood vessel. Since blood is adequately conductive for induced voltages to be measured, an alternating magnetic field is used to eliminate polarization at the electrodes, and an electric field is created. William and Fabre's respective electromagnetic flow meters provided an attractive solution to recording instantaneous blood flow in arteries because it had a response rapid enough to indicate blood flow pulsations [1]. In 1941, the scientist B. Thürlemann gave the first proof of the results of an early flow meter [1]. Even though history has led to the development of a wide

assortment of commercially available electromagnetic flow meters, the specific nature of blood flow meters means that there are still areas for which a suitable meter has yet to be developed. This project focuses on the development of an electromagnetic blood flow meter to be used in the biomedical field.

1.2 Market and Competitive Product Analysis

The University of Mississippi Medical Center originally had electromagnetic flow meters which were used in research involving the measure of blood flow through a cow's aorta. However, due to undisclosed circumstances, the original source of the flow meters became unavailable. The staff at the Medical Center tried other commercially available flow meters but discovered those meters did not meet their requirements. As a result, they requested the technology behind the original flow meters be researched and a design for a new probe and calibration unit be produced with the capability of delivering precise results. This project proposes a design for a working electromagnetic flow meter that can accurately reproduce the measurements provided by the original meters. The working prototype and design documentation are to be given to the customer. The customer will then hire an outside source to produce the number of required units using the information provided by this project. Since this flow meter was designed to meet a specific customer's demands, whether or not this flow meter is commercially marketed remains outside the scope of this document.

1.3 Concise Problem Statement

The electromagnetic flow meters originally used by the University of Mississippi Medical Center provided the consistent, accurate results required by the research being conducted by the staff. However, obtaining replacements for these flow meters is no longer possible. Other commercially available flow meters were investigated to determine a suitable replacement unit, but none of them achieved satisfactory performance. This research project develops a flow meter which will allow the customer to continue their research without modifying their original procedures and data to accommodate new equipment.

Starting with the electromagnetic flow meter previously used in the customer's research as a reference point, a new probe and accommodating equipment is developed. The new flow meter is capable of reproducing similar results to the original meter. Methods to improve on the flow meter probe, as well as the accompanying electronics, were investigated. The original equipment is calibrated for use in measuring the blood flow through a cow's aorta, but the newly designed flow meter was initially calibrated to measure the volumetric flow rate of water through a pipe. However, a saline solution is later used to simulate the electrical conductivity of blood, and a testing apparatus was assembled to mimic the behavior of a cow's aorta to verify the flow meter will produce similar results in the environment for which the flow meter was originally designed.

1.4 Implications of Success

The most obvious benefit from successfully redesigning the original flow meter is the satisfaction of the research staff at the University of Mississippi Medical Center. Upon completion of this project, the original flow meter's quality will be mirrored in the performance of the new meter. This will allow the staff to resume their research with increased proficiency and at a decreased cost in comparison to purchasing new equipment from retailers. This also permits them to control a surplus stock without a significant financial investment and with little to no threat of shortages. The design and fabrication documentation for this flow meter may be commercialized by the customer, but if the market proves inadequate, it also has the potential to function as a reference to help provide a solution for institutions with similar circumstances.

Another benefit may include the possibility of modifications to the components. Given the design and fabrication documentation, the flow meter may be modified and calibrated so it gains the capability to be used with other animals. The probe could be redesigned so that the diameter would be scalable for compatibility with larger mammals such as elephants or smaller ones like canines. The resizing of the flow meter probe would also allow the unit to be used on other arteries throughout the animals' bodies given enough room for the sensor.

References

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