An automation system based on LabVIEW to control the test of mechanical flow meters

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Abstract

We present a computational system, based on a PC and LabVIEW, to test and characterize the response of conical cup type mechanical flow meters with vertical axes. A mechanical flow meter is a device used mainly to measure and calculate the velocity of water flow in rivers and open channels.

These devices suffer mechanical imperfections over time, which is why it is important to calibrate them, normally twice a year, depending on the length of time the device has been used for. At the Mexican Institute of Water Technology (IMTA in Spanish) a circular water tank was designed and developed for the purpose of testing these meters.

This paper shows the automation systems designed to control the tests to calibrate these mechanical meters. The system is based on LabVIEW. LabVIEW is a general purpose programming tool with extensive libraries for data acquisition instrument control, data analysis, and data presentation. With this tool and a special hardware interface, it was possible to automate the process to test these mechanical meters.

The system is called SCM (System for characterization of mechanical meters). SCM controls the testing of two mechanical meters simultaneously, and has some user control features that provide the Operator with an easy to use human machine interface.

Keywords: mechanical flow meters, testing laboratory, LabVIEW based automation system.

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1 Introduction

In 1996, the Mexican Institute of Water Technology built a water channel laboratory to test and calibrate the mechanical meters that are used all around Mexico [1]. These mechanical meters are very robust and priceless, which is the reason why they are very common in many countries. Figure 1 shows a typical mechanical flow meter.

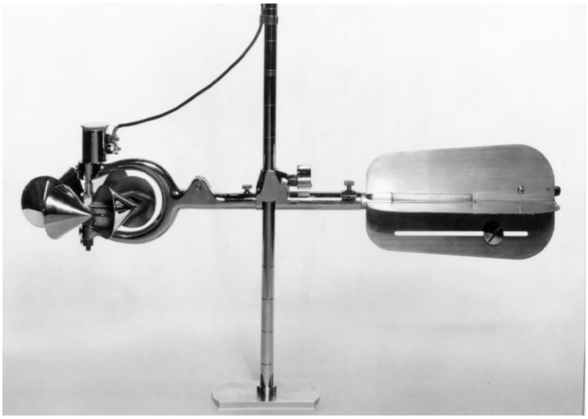

Figure 1: A typical conical cup type mechanical meter.

Figure 2: A picture of the circular channel.

The conical cup type flow mechanical meters with vertical axes are devices that convert the velocity of flow water into revolutions per minute. This effect is produced because the force produced by the flow water into the conical cup converts velocity into counts of rotations. At each rotation a mechanical contact, inside a contact chamber, closes momentarily. This relationship between velocity and revolution per minute [RPM] is a characteristic obtained by experiments [2]. The purpose of the water tank laboratory is to obtain the characteristics of each mechanical meter. To test, two mechanical meters are placed at the end of the rotary metallic arm. This arm moves around the channel producing the same effect of water stream flow.

The circular water channel laboratory has 12 meters of diameter, 80 centimeters of cross section and 1.40 meters depth. The channel is associated to a mechanical arm moved by a 15 HP motor. At the end of the arms, there are two vertical axes to carry up one mechanical meter on each [1]. A picture of this channel is shown in figure 2. This circular channel is the first of its type, as shown by the different water channels, normally linear and 100 or 200 meters long [3]. This circular channel represents a real challenge in this kind of laboratory.

2 Methodology

The objective of the system was to create an automation system that is easy to use, and flexible, in such a way that all the different versions of mechanical meters could be characterized. At the same time, the resulting system must be capable of performing as good a calibration as would be made by a linear channel. We used a top-down methodology to arrive at the design and development of the SCM system:

ii) First of all, we analyzed the different requirements
iii) We decomposed our problem into two subsystems: hardware and software
iv) We selected the architecture for each subsystem
v) We designed and developed each subsystem
vi) We integrated and tested the two subsystems
vii) We had a stage of testing by the end user: the Operator

The following sections show the design of the two main subsystems: software and hardware.

3 The System for Characterization of Mechanical Meters (SCM)

This system's mission is to control all the processes to characterize the mechanical meters. In figure 3 we show the architecture of the SCM.

3.1 The computational subsystem (software)

The functions of the subsystem are:
i) To control the characterization process of two simultaneous mechanical meters with the help of a man-machine interface.

ii) To manage the data base with the history of the mechanical meters tested
iii) To control the different velocities of testing based on the control of a motor drive, from 0.14 to 3 meter per second with 12 different velocities.
iv) To calculate the characteristic equation velocity vs. RPM for each mechanical meter under test.
v) To generate the graphs, the reports and the tables for every mechanical meter tested.
vi) To eliminate the electrical spurious bounces.

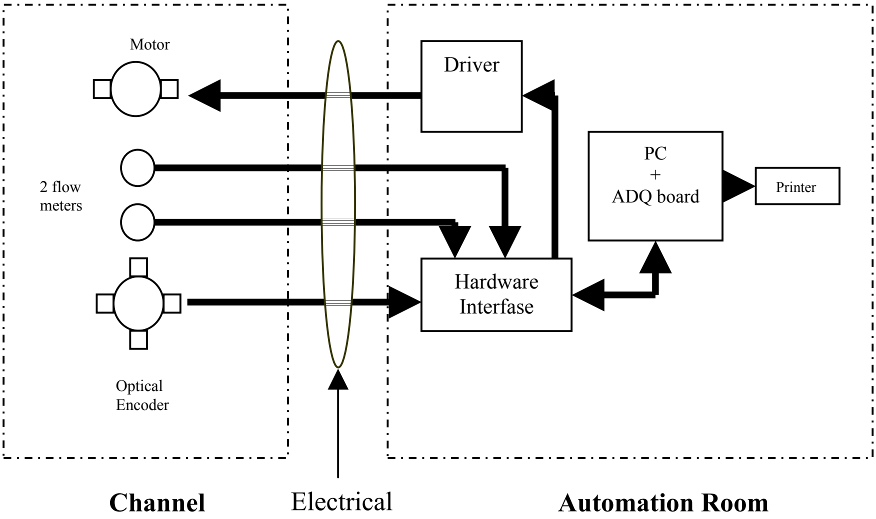

Figure 3: Architecture of the SCM.

3.1.1 Controlling the characterizing process

LabVIEW is a very easy to use language for creating man machine interfaces in automation systems. The system consists of different dialog menus to help the human Operator control the test of two different mechanical meters. The principal program follows the next sequence:

```
Initialize all different parameters
    REPEAT
        Select option
        IF option is characterize the meters:
            Ask for the different parameters: time and velocity of test
            Manage the test at different velocities
            Make the final graphs and update the Data Base
        ENDIF
          ELSE
          IF option is consulting Data Base:
            Select Data Base.
            Show it
        ENDIF
```

```
        ELSE
        IF option configuration of the system:
            Show parameters
                Select parameters.
            Change them
    ENDIF
UNTIL Operator exit the system
```

The full system based LabVIEW has approximately 64 different routines.

3.1.2 Managing the data base

The Data Base is an array of registers, one for each mechanical meter. The SCM can make updates to each register, based on the parameters read during the test. Also, it is possible for the Operator to review and update some of the fields on the register, for example:

ii) Details of the maintenance made,
iii) Date of entrance to the laboratory
iv) Owner
v) Special features

3.1.3 Controlling the different velocities

This characteristic permits the selection of 12 different velocities in a wide range, from 0.14 to 3 meters per second. It also performs global or individual tests. The global test means that the system automatically begins at the lower velocity and step by step reaches the highest velocity. In each step, the system makes the arrangement to control the velocity of the test, and it also reads the train of pulses of the two mechanical meters.

It is also possible to perform individual tests. In this mode, the Operator selects one special velocity and the system executes the entire process automatically, including the steps to move the arm to reach the velocity. It is important to note that the final velocity is reached following the dynamic conditions of the motor and its load.

3.1.4 Calculating the characteristic equation velocity vs. RPM

When the process of testing is finished, the arm's movement stops, then the system calculates, based on the data read, the equation of the line. Two parameters are calculated, the slop "m" and the intersection "b". We use the function that LabVIEW has for this purpose, and the system graphs this result.

3.1.5 Generating the graphs, reports and tables

Finally, the SCM system generates a table, based on the equation of the line calculated. This table is practically the tabular representation of the graph. It is important because this table is the tool people will use when they use this mechanical meter in the field. In figure 4 we show one typical graph.

At the end of this process, the system prints out this information.

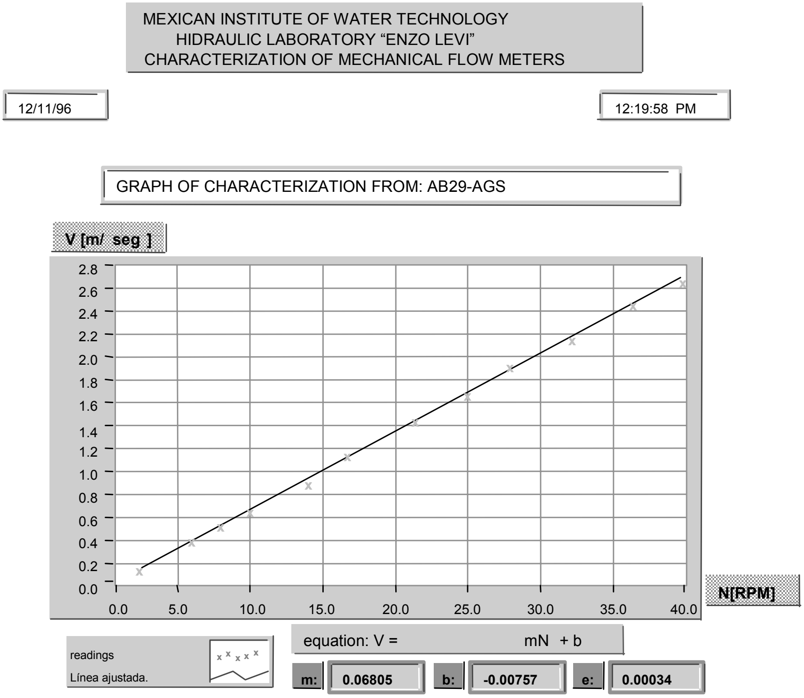

Figure 4: Typical graph based on the incoming data.

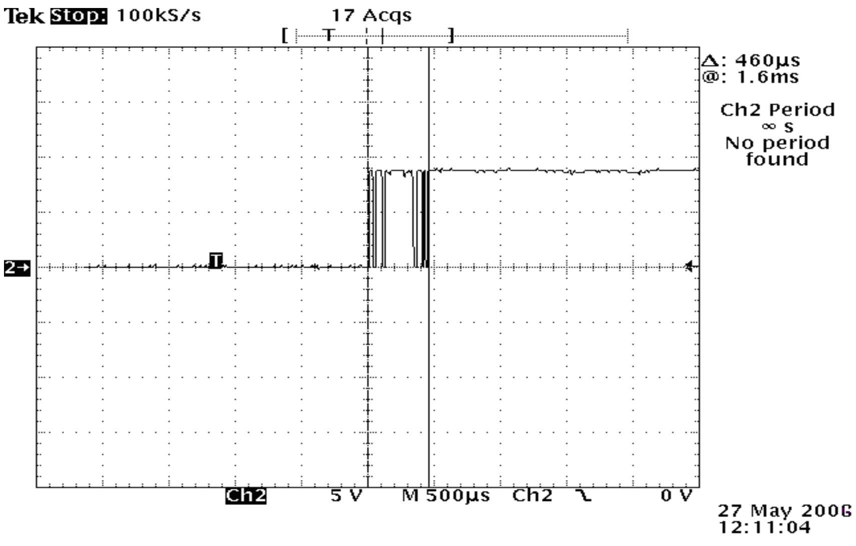

Figure 5: Noisy electrical signal produced by the mechanical flow meter when the contact is close.

3.1.6 Elimination of the electrical bounces

The process to convert the revolutions per minute produced by the stream flow into the electrical train of pulses consists of injecting an electrical current through the mechanical movement of the meter to transform the revolutions per minute into a train of electrical pulses. In this process, electrical bounces appear because of the mechanical nature of the contacts. A typical pulse is shown in figure 5. The problem arrives because the range of velocities that the mechanical meters measure is wide, from 0.14 to 3 mps (meters per second). With this range of velocity, the frequency of the electrical pulse varies from 0.2Hz to 5Hz.

As seen in figure 5, the train of pulses is associated with a train of electrical bounces from the mechanical nature of the meter. These bounces have a random behavior, however based on experiments, we found that it has some characteristics that we can use to eliminate this electrical noise:

i) The maximal frequency of rotation is 300 RPM, at a period of 200 msec.
ii) The minimal frequency is 12 RPM, at a period of 5 sec.
iii) The duty cycle between the time the contacts are closed and opened is less than 30%.
iv) The maximum time the electrical bounces appear at the maximal frequency is less than 10 msec.
v) The maximal time the electrical bounces appear at the minimal frequency is less than 300 msec.

The analysis of this data shows that, for low frequency, the electrical spurious bounces are equivalent to a train of pulses generated by the mechanical meter at high frequency. If we decided to eliminate that noise with a low-pass filter, this filter could also eliminate valid pulses. This problem is amplified because every mechanical meter has its own response. To solve this problem, we need an adaptable filter, based on an estimated frequency of rotation, that is able to eliminate the spurious noise. We can then calculate the right rotary frequency of the mechanical meter. To implement this dynamic filter, we use two different approaches depending on the system, as we will see in the next section.

To build the debouncing filter, we use the knowledge related to the behavior of this quasi-random noise. Furthermore, we know the velocity of testing because we control the rotary electrical motor. Our algorithm takes into account these two factors and adapts the parameter of the filter to eliminate these electrical spurious pulses. The algorithm, for a specific velocity of test, is shown in figure 6.

3.2 The electronic subsystem (hardware)

The hardware consists of a PC Pentium II 400 MHz computer associated to a dispositive date acquisition (DAQ) board. We use the PCI-6071-E from National Instruments, and it is charged to communicate with our homemade interface board. Finally, we have a drive to control the motor. We use the ACS 501, adjustable frequency (ABB mark) driver.

Control the electrical motor to put the testing velocity
Put the filter parameters based on the velocity
REPEAT
Monitoring the pulse arrival
Monitoring the actual velocity with the optical encoder and modify if necessary
IF pulse arrives:
Check if the period of arrives was larger than the filter parameter.
IF yes, pulse is ok, count it
ELSE ignore pulse
ENDIF
UNTIL time of test ends **or** Operator stops the test

Figure 6: Algorithm to denounce electrical noisy signals.

We designed an electronic board to interface the different devices to the dispositive date acquisition (DAQ) board. The elements and function of the interface are:

i) Injection of electrical current at each mechanical meter in test.
ii) Reading of two asynchronous trains of electrical pulses, each one may have different behavior
iii) Generation of different electrical control signals to the motor drive
iv) Reading the different electrical status signals from the motor drive
v) Reading the train of pulses generated by the optical encoder to measure the actual velocity of movement.

4 Results and conclusions

We presented an automation system completely operative at this time. This system represents a technological innovation, in size, form, time on test, and ease of use, because we can obtain characteristic results similar to others that are bigger and based on a different technology. When our results are compared with Internationally certified Laboratory of Canada Center for Inland Waters [3], there was less than 5% difference. The big difference is that they have different technologies. We can conclude that with smart automation, we can achieve equal or better results than other laboratories based on older and more expensive technology.

The characteristics of the system are:

i) Ease of use
ii) One hour per test,
iii) Easy management of the Data Base
iv) Statistical analysis

Right now we are preparing the testing laboratory to achieve an international certification.

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