UTILITY MANAGEMENT

Determining the Economical Optimum Life of Residential Water Meters

Detection

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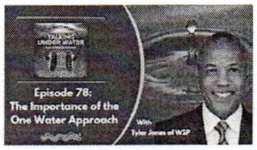
This question has become an evasive one for many Utilities that have to make this decision. On the basis of these meter readings, Utilities assess their water and wastewater customers with the corresponding consumption fees. Therefore, these fees, dictated by the meter's recordings, become the main source of income for the majority of Utilities.

The assumption that aging makes residential water meters become less accurate, leads to the hypothesis that revenues are lost because the consumption of water is not completely recorded. However, replacing residential water meters that are still providing accurate recordings is a waste of resources and an additional economic burden for the Utilities. Between these two economically opposing tendencies, there is a point that economically justifies the cost of meter replacement. The central objective of this article is to provide a methodology for the calculation of the economic optimum age for meter replacement.

This study concentrates in finding the economic optimum replacement time of non-commercial water meters. Data in this study applies to Anne Arundel County (Maryland) and is presented as an example. However, the methodology used can be adapted to any other Agency. In addition, as a secondary objective and in order to find the optimum, this study proves the assumption that water meters actually decay with age, losing their recording capabilities.

After reviewing the latest literature on water meter replacement, it was concluded that no current study recommends the proper age for water meter replacement. Water meter life expectancy, as given by manufacturers, only offers the estimated time the residential water meter can function (mostly for guarantee purposes). However, it does not offer any analysis of the progressive decay of the meter's recording capabilities. Other studies point out the tremendous variations of conditions that water meters are exposed to in different parts of the country. These multiple conditions, ranging from chemical composition of the water, to variation of temperature and humidity, prevent any universal study on the decay of residential water meter recording capability to be successful. Therefore, the analysis has to focus on zones or districts with identical conditions.



Sample

The first step in the process aimed at producing a sample, for statistical analysis, of the local water meters. The analysis will yield a correlation of the misreading factor with age. Given the number of meters in the zone under analysis and to minimize sampling size while obtaining representative groups, the following experiment was designed. Eight (8) water meters per age group and four (4) age groups were tested by qualified technicians in the Norman Test Bench at the Meter Shop. The four age groups specified were 15, 20, 25 and 30 years-old. With the total sample size being 32 meters (eight water meters in four age groups), each water meter was tested at three levels of flow intensity: low flow (1/4 gallon per minute); intermediate flow (2 gallons per minute); and fast flow (10 gallons per minute). The results assess the fraction (%) recorded by the water meter when compared to the real amount of flow forced through it. For example, a reading of 60 percent means that the water meter did not register 40 percent of the water going through; it is only 60 percent accurate. The results from this experiment are assembled in Table 1.

The test results consistently prove that the water meter's recording capability diminishes over time. This finding is accentuated when the meter operates at a low intensity flow. The results of the test show that not only the age of water meters diminishes their recording capability, but also the way customers use water affects the readings (i.e., less accuracy at low flow v. better accuracy at high flow). This additional finding complicated the study and compelled an investigation into the way customers use water.

According to the agency's statistics, a typical household is composed of four persons and consumes about 108,000 gallons of water per year. To determine the pattern of water consumption in the area under investigation, three average four-person households were sampled. In this test, we wanted to estimate the portion of water that is consumed at low flow, intermediate flow, and high flow. At the selected households, measures of flow were taken at different outlets including instances of double or multiple simultaneous use. Table 2 shows the results of the sampling.

The different water flow for the outlets in the sample is normally distributed around a mean value. Calculation of the mean and standard deviation produced the values:

μ = 0.89 GPM and s = 0.58 GPM

The results of the sample indicate that the average water flow consumption is 0.89 GPM with a standard deviation of 0.58 GPM. With these two parameters known, the normal distribution curve for flow intensity can be easily constructed. The graph on page 20 shows the pattern of this water consumption.

In order to cover the complete range of flow intensities, the ranges will be defined as follows:

Low Flow 0 to 0.25 GPM

Intermediate Flow 0.25 to 2 GPM

High Flow Above 2 GPM

With these parameters, the corresponding areas under the Normal curve can be calculated using the Normal Distribution Tables. These values represent the proportions of water flowing through the meters at low flow, intermediate flow, and high flow, which provides an interpretation of how the water is consumed in terms of flow intensity.

They are:

Low Flow 0 .12

Intermediate Flow 0.86

High Flow 0.02

This means that 12 percent of the water that flows through the meter flows at low speed, 86 percent at intermediate speed, and 2 percent at high speed. Combining in a single formula the pattern of water use, and the pattern of residential water meter reading capabilities produced by aging, it is now possible to calculate the real accuracy of the meters.

The formula is:

Real Meter Accuracy (RMA) =

MRL(pul) + MRI(pui) + MRH(puh)

Where:

MRL - Meter Reading at Low Flow as Affected by Age

MRI - Meter Reading at Intermediate Flow as Affected by Age

MRH - Meter Reading at High Flow as Affected by Age

pul - Pattern of Use at Low Flow

pui - Pattern of Use at Inter. Flow

puh - Pattern of Use at High Flow

Armed with this formula, The Real Meter Accuracy for each age group is calculated at:

Meters 15 Years Old

RAM = [(0.95)(0.12) + (1.00)(0.86) + (1.00)(0.02)] = 0.994

Meters 20 Years Old

RAM = [(0.93)(0.12) + (1.00)(0.86) + (1.00)(0.02)] = 0.990

Meters 25 Years Old

RAM = [(0.87)(0.12) + (0.97)(0.86) + (0.98)(0.02)] = 0.958

Meters 30 Years Old

RAM = [(0.35)(0.12) + (0.90)(0.86) + (0.96)(0.02)] = 0.816

A typical household uses on the average about 9,000 gallons of water per month, this according to historical data and considering the summer peak consumption. Knowing the accuracy of meters calculated previously, the gallons of water going through the meters without being recorded can be calculated by subtracting from the average consumption the result of the multiplication of the RAM (the Real Accuracy of Meters) and the average consumption.

The quantity of gallons of water that water meters do not record per month, per age group will be:

Meters 15 Years Old

9,000 Gallons - (9,000)(0.994) =

54 Gallons per month

Meters 20 Years Old

9,000 Gallons - (9,000)(0.990) =

90 Gallons per month

Meters 25 Years Old

9,000 Gallons - (9,000)(0.958) =

378 Gallons per month

Meters 30 Years Old

9,000 Gallons - (9,000)(0.816) =

1,656 Gallons per month

We can now find out the cost of these misreadings. The vast majority of customers in Anne Arundel County use both, water and wastewater services. The payment schedule in Anne Arundel County is:

First 5,000 gallons $8.82 (water) $11.58 (wastewater)

Every 1,000 gallons $1.38 (water) $2.57 (wastewater)

The combined rate for residential users is $3.95, which is the rate for water/wastewater consumption above the 5,000 gallons. Since the average household consumes well above the initial 5,000 gallons, the calculation will deal only with the rate ($3.95) that applies to every 1,000 Gallons after the initial 5,000 gallons are consumed.

The annual losses in revenue due to maintaining aging residential water meters are calculated for each age group at:

Meters 15 Years Old

12 x 54/1000 x $3.95 = $2.56

Meters 20 Years Old

12 x 90/1000 x $3.95 = $4.26

Meters 25 Years Old

12 x 398/1000 x $3.95 = $17.92

Meters 30 Years Old

12 x 1656/1000 x $3.95 = $78.64

These values (when assembled as a graphic of time vs. cost) produce a curve that resembles an exponential distribution but of unknown parameters. The cumulative cost of not replacing water meters can be obtained empirically from the curve for different years. For purpose of simplification, it is assumed that the misreading factor for the first 10 years of the meter's life is negligible, and from there the cost increases linearly between the values of 10 to 15 years, 15 to 20, 20 to 25, and 25 to 30 years.It is known that the cost of replacing a residential water meter in Anne Arundel County is $39.00. This cost is broken down into $34.00 for the new meter, and $5.00 for the installation cost.

Given these facts, Table 3 shows the annual cost of water meters. Under the column "Cost of Use" the annual cost due to meter inaccuracy is shown. Observe that this cost is zero the first 10 years. The column headed "Accumulated Cost" adds the "Meter Cost" ($39) and the "Cost of Use" up to that year. The last column presents the "Average Cost Per Year" and results from the quotient of the accumulated cost and the years in service.

Optimum

Finding the economically optimum year for replacement can be identified as a typical "replacement due to decreasing efficiency" problem. This methodology's objective locates the minimum average annual cost. It is based on the annual distribution of both costs (meter replacement and decreasing efficiency). In the table, developed for a span of 30 years, under the column "Average Cost Per Year" you will be able to pick the minimum annual cost and with it the year at which the meter should be replaced. Replacement at the end of year 16 will guarantee a minimum annual cost under the conditions specified in the presentation.

Despite the fact that the accuracy of a 16 year-old residential water meter is estimated at 0.992, replacement at this age is economically justifiable. The justification for replacement lingers on the prevention of further losses and to meter the water flow the Agency incurs in the cost of buying and installing water meters. This cost, as shown in Table 3, reaches the minimum balance with the misreading cost at the end of the 16th year. Management should decide to replace these meters at the end of year 16 (under these conditions). A significant variation in the meter installation cost or price of water, will render the numerical answer (16th year) obsolete and will demand a recalculation of the optimum life.

The value of this study rests in its methodology and not in the actual results. Even working with approximations, management can benefit from a similar study in their utility, For example, if calculations show the optimum replacement to be at the 16th year, they can decide to only replace meters older than 20 years. In the case of Anne Arundel County, it was found that by just replacing meters older than 30 years, additional revenue lost was calculated at over $201,800 per year. When comparing the potential increase in revenues and the cost of doing a similar water meter cost analysis, the keen manager will discover that the exercise presented in this paper is worth pursuing.

About the Author:

Dr. Hans D. Allender is president of "The ProducBoxTM Institute," a firm that furnishes training and management consulting services to diverse clients. As a management consultant, Dr. Allender specializes in reengineering, productivity and quality improvements under the TQM umbrella.

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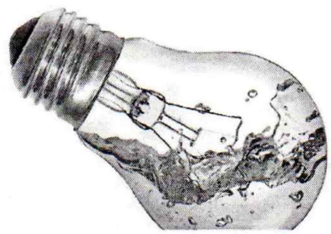

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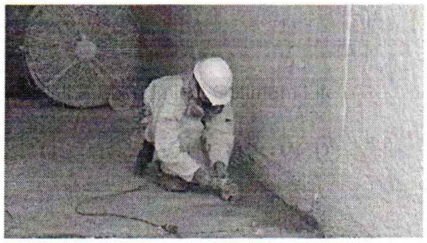

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