PREFACE

The following "White Paper" will describe the dynamic use of a high precision Flow Management Valve, such as the one being produced by its designers and inventors, Juan Carlos Bocos and Juan Carlos Bocos Vilar, at his "high-tech" machine company. This company is located in an Industrial Park Area of Miami, Florida and quite appropriately is named Water and Volume Efficiency (W.A.V.E.) or The Watergater ™. These Flow Management Valves, produced by Mr. Bocos, will provide a multi-faceted function of not only reducing the total volume usage of water and its respective cost but will also provide a means for regulating the volumetric flow of actual water by restricting the volume of excess air. Furthermore, through the installation of such a valve, down line enhancements of the water flow and controls can be subsequently made, while also measuring the actual use at different node points. These detailed functions with a focus on back-flow prevention, referred to in the industry as "check valve" functions can be read in the U.S. Patent #8,944,098 B1issued to Mr. Bocos and Mr. Bocos Vilar on Feb. 3, 2015.

White Paper

By Dr. Héctor M. Guevara

Controlling water flow speed and volume by using a Flow Management Valve control node at meter egress connection point.

This paper is intended to support the use of placing a " flow management valve" at water meter discharge connection points. The following supporting fluid flow calculations and simulation testing will show how there is an observable reduction in the volume of water being used and respectively being metered, as a direct result of the placement of a noted "flow management valve", such as a W.A.V.E. or Watergater ™ Valve. As noted further below, this valve also prevents the abuse of over registering water volume usage due to registering of <u>air flows</u>.

The Flow Management Valve control nodes used in the initial prototype testing Watergater ™ Valves were set to execute flow control at 45 PSI. In other words, each node computes a balanced flow for the piping zone and therefore is able to identify a rupture when mass is not conserved within that piping section (i.e. when imbalance flow condition exists).

Once the simple proof of concept model was successfully demonstrated (i.e. The W.A.V.E. and Watergater Valves showed the simulation could run in real-time), they proceeded to validate the use of the flow management valve fluid network simulation. This is an ongoing effort which involves modeling existing fluid system test facilities using the different sizes of W.A.V.E. and Watergater ™ Valves and comparing simulation results to data obtained during the operation of the physical fluid systems being tested.

<u>Water Meters</u>

A **water meter** is a device used to measure the volume of water usage. This paper does not intend to provide an overview of technical aspects of all water meters. There are many as noted below. Moreover, the worldwide prevalence of metering, as well as its economic benefits and costs, can be found in many technical journals and numerous internet sources. The purpose of this paper is to support the argument for the use of a flow management valve, such as the ones being manufactured and placed in service by W.A.V.E. and Watergater™

Selection of meter type is based on different flow measurement methods, the type of end user, the required flow rates, and accuracy requirements. In North America, standards for manufacturing of water meters are made by the American Water Works Association.

Problems associated with metering arise particularly in the case of intermittent supply, which is common in many developing countries. Sudden changes in pressure can damage meters, so many meters in cities in developing countries are not functional. Also, some types of meters become less accurate as they age and under register consumption thus leading to lower revenues, unless they are being replaced regularly. Many types of meters also register air flows, which can lead to over registration of consumption, especially in systems with intermittent supply, when water supply is re-established and the incoming water pushes air through the meters

We have found the latter to be one of the most frequent and prevalent problems with the type of meters being used in local city residences and small commercial establishments whereby the end users are being over billed for water volume not actually having been used. The "flow management valve" control system, such as The W.A.V.E. and Watergater™ Valves, are designed to prevent this abuse.

There are two major methods of flow measurement in use, displacement and velocity, with sub-technologies within each of them:

- Displacement
- Oscillating Piston
- Nutating Disk

This type of water meter is most often used in residential and small commercial applications. Displacement meters are commonly referred to as Positive Displacement, or "PD" meters. Two common methods of positive displacement measuring are Oscillating Piston meters and Nutating (to rock or sway involuntarily) Disk meters. Either method relies on the water to physically displace. The moving measuring element is in direct relation to the amount of water that passes through the meter. The piston or disk moves a magnet that drives the register.

PD meters are generally very accurate at low to moderate flow rates typical of residential and small commercial users, and are common in sizes from 5/8" to 2". Because displacement meters rely on all water flowing through the meter to "push" the measuring element, they generally are not practical in large commercial applications requiring high flow rates or low pressure loss. PD meters normally have a built-in strainer to protect the measuring element from rocks or other debris that could stop or break the measuring element. PD meters normally have bronze, brass or plastic bodies with internal measuring chambers made from molded plastics and stainless steel.

a typical residential water meter

Most Common Water Meters
- Velocity
- Single jet (Paddle wheel)
- Multi jet (Horizontal impeller)
- Turbine
- Pro peller
- Electronic
- Electromagnetic
- Ultrasonic

Other Common Types of Water Meters

- Multi-jet Meter
- Single-jet Meter
- Compound Meter
- Fire Meter
- Fire Hydrant Meter

Water meters can also be used at the water source, well, or throughout a water system to determine flow through that portion of the system. Water meters typically measure and display total usage in cubic feet (ft^3), cubic meters (m^3) or US gallons on a mechanical or electronic register. Some electronic meter registers can display rate-of-flow as well as totalizing.

There are several types of water meter in common use. Selection is based on different flow measurement methods, the type of end user, the required flow rates, and accuracy requirements.

Fluid mechanics is the study of how fluids move and the forces on them. (Fluids include liquids, gases, and plasmas.) This paper is meant to deal only with the most common liquid known as water. Fluid mechanics can be divided into fluid statics, the study of fluids at rest, and fluid dynamics, the study of fluids in motion. It is a branch of continuum mechanics, a subject which models matter without using the information that it is made out of atoms. Fluid mechanics, especially fluid dynamics, is an active field of research with many unsolved or partly solved problems. Fluid mechanics can be mathematically complex. Sometimes it can best be solved by numerical methods, typically using computers. A modern discipline, called computational fluid dynamics (CFD), is devoted to this approach to solving fluid mechanics problems. Also taking advantage of the highly visual nature of fluid flow is particle image velocimetry, an experimental method for visualizing and analyzing fluid flow.

I am using the continuum mechanics numerical valuations here to show how the noted "flow management valve" affects the restriction of the fluid flow and thereby the velocity and volume of water being metered. This, in turn, provides for an overall savings to the end user having installed such a flow management valve.

Like any mathematical model of the real world, fluid mechanics makes some basic assumptions about the materials being studied. These assumptions are turned into equations that must be satisfied if the assumptions are to be held true. For example, consider an incompressible fluid in three dimensions. The assumption that mass is conserved means that for any fixed closed surface (such as a sphere) the rate of mass passing from *outside* to *inside* the surface must be the same as rate of mass passing the other way. (Alternatively, the mass *inside* remains constant, as does the mass *outside*). This can be turned into an integral equation over the surface. I will be using an integral equation like the type below for the noted reconciliation of our water flow with the use of the flow management valve.

The most basic type of integral equation is a Fredholm equation *of the first type*:

$$f(x) = \int_a^b K(x,t)\,\varphi(t)\,dt.$$

The notation follows Arfken. Here φ is an unknown function, f is a known function, and K is another known function of two variables, often called the kernel function. Note that the limits of integration are constant. This is what characterizes a Fredholm equation.

Fluid mechanics assumes that every fluid obeys the following:
- Conservation of mass
- Conservation of momentum
- The *continuum hypothesis*, detailed below.

Further, it is often useful (and realistic) to assume a fluid is incompressible – that is, the density of the fluid does not change. Liquids can often be modeled as incompressible fluids, whereas gases cannot.

Similarly, it can sometimes be assumed that the viscosity of the fluid is zero (the fluid is *in viscid*). Gases can often be assumed to be in viscid. If a fluid is viscous, and its flow contained in some way (e.g. in a pipe), then the flow at the boundary must have zero velocity. For a viscous fluid, if the boundary is not porous, the shear forces between the fluid and the boundary results also in a zero velocity for the fluid at the boundary. This is called the no-slip condition.

The Continuum Hypothesis

Fluids are composed of molecules that collide with one another and solid objects. The continuum assumption, however, considers fluids to be continuous. That is, properties such as density, pressure, temperature, and velocity are taken to be well-defined at "infinitely" small points, defining a REV (Reference Element of Volume), at the geometric order of the distance between two adjacent molecules of fluid. Properties are assumed to vary continuously from one point to another, and are averaged values in the REV. The fact that the fluid is made up of discrete molecules is ignored.

Those problems for which the continuum hypothesis does not allow solutions of desired accuracy are solved using statistical mechanics. We won't be going into statistical mechanics in this paper nor using the known method, Knudsen number, to determine whether or not to use conventional fluid dynamics or statistical mechanics.
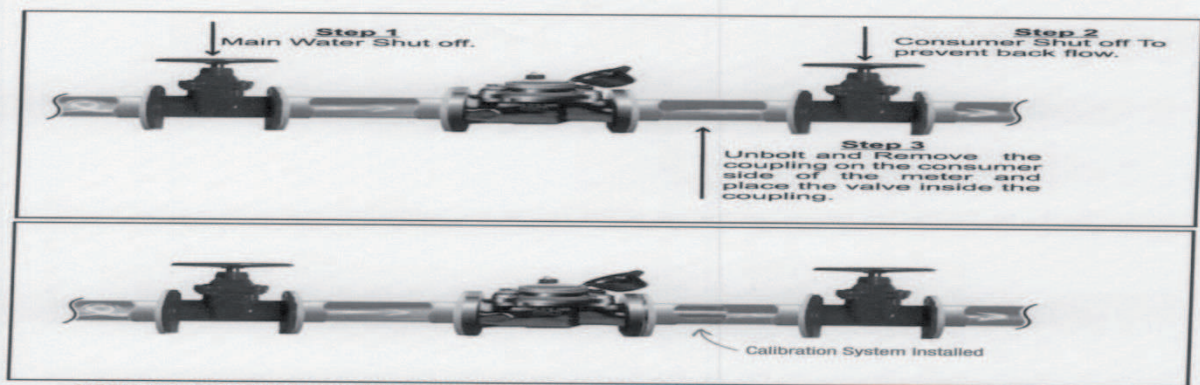
Another method for justifying the use of the "flow management valve" with the valve's being depicted here is by using the Reynolds number. This is a dimensionless number that gives a measure of the ratio of inertial forces (ρV^2) to viscous forces $\left(\dfrac{\mu V}{L}\right)$ and consequently quantifies the relative importance of these two types of forces for given flow conditions. One can use the Reynolds numbers here to perform dimensional analysis of fluid dynamics problems, and as such can be used to determine dynamic similitude between different experimental cases. They are also used to characterize different flow regimes, such as laminar or turbulent flow: laminar flow occurs at low Reynolds numbers, where viscous forces are dominant, and is characterized by smooth, constant fluid motion, while turbulent flow occurs at high Reynolds numbers and is dominated by inertial forces, which tend to produce random eddies, vortices, and other flow instabilities. Such can be seen when there is a disproportionate amount of air in the water line.

Sometimes this excessive air has been caused by a pipe rupture or break up line which induces air into the line. If this problem is not noticed immediately it will go on causing an excessive and disproportional air metering charge to the client being serviced from this faulty line. This can be remedied by using the flow management valve control, which will restrict the flow to only water. In this way a comparison can be made between the volume of water "used" and charged by the utility company against the flow of a secondary metered node, which will not reconcile the amount being charged.

As previously noted, installed "Flow Management Valves" such as WAVE or Watergater™ Valves cannot remove the air which registered as water on the City Feed Line. However, the "Flow Management Valves" will create a regulated restriction on the flow to Air Less 45 PSI, this will vary depending on site installation parameters, while at the same time providing a monitoring and control tool.

The following is a depiction of such testing:

Step 1
Main Water Shut off.

Step 2
Consumer Shut off To prevent back flow.

Step 3
Unbolt and Remove the coupling on the consumer side of the meter and place the valve inside the coupling.

Calibration System Installed

NOTE: DO NOT CONNECT THIS DEVICE ON UTILITY COMPANY SIDE OF FLOW METER BOX.

THIS IS A TEXT TEST FOR THIS HIGH PRECISION VALVE DESIGNED BY JUAN CARLOS BOCOS

Please follow STEPS below:

Product Description:
The Precision Flow Calibration System allows liquid to flow through it in only one direction.

STEP 1:
After identifying your water meter box/access, open your water meter box and make sure the working area is nice and clean before you do anything else, then shut the main water supply off to make sure there is no water running through the pipes anymore. VERY IMPORTANT TO HAVE THE PROPER SIZE CALIBRATION SYSTEM.

STEP 2:
If you have a shut off valve on the consumer side of the meter, turn it off to prevent back flow.

STEP 3:
After step 1 & 2 is completed, remove the coupling off the consumer side of the meter by using proper plumbing tools. Make sure all gaskets are usable and if not replace it with new ones when installing the Precision Flow Calibration System.

STEP 4:
After step 3 is completed, make sure area is clean and there is no dirt in pipes then install the Precision Flow Calibration System the same way that old coupling was installed. Make sure everything is well connected then open the main water by releasing the shut off valve slowly on the city side of the meter and check to see if any leak occurs.

CAUTION:
1) Please make certain the spring on the valve is suited to the PSI - Hydraulic pressure is variable.
2) Proceed with caution when you find a 90° bend within a short distance of the meter and the Calibration System.

The following are are reference test data equations:

TECHNICAL DATA

Valve Sizing – PRECISION FLOW - Calibration System furnishes two methods to aid the customer in the selection of the correct valve size to meet their flow requirements; **Flow Curves and C_V Factor.**

Flow Curves show the relationship between the rate of flow (water, gpm) and the pressure drop across the valve produced by that flow.

C_V Factor is a valve flow coefficient which mathematically gives the relationship between the rate of flow and the pressure drop.

> **Definition: C_V** is defined as the quantity of water, in gallons per minute, which will pass through a specific valve at maximum lift, at one (1) psi pressure drop.

It is experimentally determined by dividing the water flow through the valve by the square root of the pressure drop produced by that flow. Conversely, given the C_V, the water flow through the valve at any given pressure drop may be calculated by multiplying the C_V by the square root of the pressure drop. Therefore, for a given pressure drop, the higher the C_V, the higher the rate of flow.

For liquids other than water, for gases and for saturated steam, the formulae given below will show the relationship between the C_V (as obtained from water flow tests) and the flow of these fluids.

FLOW FORMULAE
(Non-Choked Turbulent Flow Only)

I. LIQUIDS

$$V = C_V \sqrt{\frac{dP}{G}} \qquad\qquad dP = \left(\frac{V}{C_V}\right)^2 G \qquad\qquad C_V = \frac{V}{\sqrt{\frac{dP}{G}}}$$

Where
V = Liquid flow (gpm)
dP = Pressure drop (psi)
G = Sp. Gravity of liquid (water = 1.0)
C_V = Valve coefficient

II. GASSES

$$Q = 1360\ C_V \sqrt{\frac{dP}{GT}} \sqrt{\frac{P_1 + P_2}{2}} \qquad dP = P_1 - \sqrt{P_1^2 - 2GT\left(\frac{Q}{1360\ C_V}\right)^2} \qquad C_V = \frac{Q}{1360\sqrt{\frac{dP}{GT}}\sqrt{\frac{P_1 + P_2}{2}}}$$

Where
Q = Gas flow (scfh)
dP = Pressure drop (psi)[1]
T = Absolute temp of flowing medium (degrees Rankin)
P_1 = Inlet pressure (psia)
P_2 = Outlet pressure (psia)
C_V = Valve coefficient
G = Sp. Gravity of gas (air = 1.0)

III. SATURATED STEAM

$$W = 3\ C_V \sqrt{dP} \sqrt{\frac{P_1 + P_2}{2}} \qquad dP = P_1 - \sqrt{P_1^2 - 2\left(\frac{W}{3\ C_V}\right)^2} \qquad C_V = \frac{W}{3\sqrt{dP}\sqrt{\frac{P_1 + P_2}{2}}}$$

Where
W = Saturated steam flow (lbs. per hour)
dP = Press drop (psi)[1]
P_1 = Inlet pressure (psia)
P_2 = Outlet pressure (psia)
C_V = Valve coefficient

1 – For calculation purposes, dP should never exceed 1/2 the inlet pressure, P_1.

The following is a pictorial sampling of W.A.V.E. and Watergater ™ Flow Management Valves: