UTILIZING ORIFICES FOR FLOW CONTROL IN WATER DISTRIBUTION SYSTEMS OF CITIES OF DEVELOPING COUNTRIES

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Abstract:
Water distribution components are sized for peak demand, which is normally maximum daily demand. Although it is necessary to design a system to meet peak demand, it must not be forgotten that most of the time the system is operating under average conditions. Therefore, an acceptable design would be a marriage between economics and system performance and reliability In this work, experiments were carried out on the use of orifice plate as a means of flow control. It showed a decrease in flow and pressure when the plate was installed. The use of Fordilla pod is recommended for low income group areas or slums of our cities. The Fordilla valve is capable of discouraging waste of water and as well as ensuring that almost every person uses about the same amount of water.

Introduction:

The objectives of a municipal water system are to provide safe, potable water for domestic use, adequate quantity at sufficient pressure for fire protection, and industrial water for manufacturing. The amount of water required by a municipality depends on industrial use, climate, and economic considerations. Of these amounts, the residential water use varies seasonally, daily and hourly. Water flows used in waterworks designs depend on the magnitude and variations in municipal water consumption and the reserve needed for fire fighting. The design of a water supply system requires an estimate of future demands for water (design capacity) and determining the best combination of structural facilities and operating procedures to meet these demands. A choice of the capacity of the system is usually made after considering the following factors: growth in demand, cost of borrowing money from various sources, restrictions imposed by the character of the borrowing, the pay-back period, the character of the water supply, the quality of the raw water, scale of economics in construction and others.

It is common practice to provide water supply system capacity larger than required as it is possible to achieve economics of scale by building in anticipation of future increasing demands.

Problem Definition

The excessive growth in the population of most Nigerian cities has contributed immensely to the severe water shortage they often experience. The simple questions which people often ask are: "when will water be enough in this country"?, "who is the cause-government or the engineer"?. The people forget that the cause lies in the generality of the citizens of this nation due partly to lack of control in population growth. Water will only be enough if the growth in population becomes less excessive or normal. When the demand for water is greater than the available supply, most distribution system are forced to ration available supplies by operation on an intermittent basis. The rate at which water is supplied to the users is the principal determinant of the cost of the system and the least costly systems are those which have the lowest flow rates. Various measures, such as the use of line storage, household storage tanks, pressure reduction methods are means of flow control.

For water supply including treatment, distribution and storage, the distribution facilities range in cost from about 50% to sometimes 85% of the total cost of the project. The distribution facilities (that is pipes, pumps, valves and others) are based on peak flow which is about 2.5 to 3 times or the average flow. If the peak flow values can be reduced or the distribution facilities are not made to carry peak flows, then their sizes can be considerably reduced giving a corresponding reduction of the overall cost of water supply project. Intermittent flow results when the time of allocation is over a period less than 24 hours in a day. Although such a system is not advisable as intermittent delivery generally results in unsafe water, since periodic drops in water pressure permit entrance of subsoil water through leaking pipes, but this system of water supply is characteristic of most Nigerian cities. Flow restrictors insertion is a method by which physical controls are installed in the system to limit the capacity of the system to deliver water. An example is an orifice plate inserted in the distribution pipes. It had been shown that by using the Orifice plate, not only can peak flows operating flow range (Hughes,1974). A special self - closing tap called the "fordilla" valve has been manufactured with the purpose of discouraging the wastage of water. Another positive effect of self closing tap is that almost every person uses about the same amount of water. These have been in practice in some African countries like Ghana and Somalia.

Objective of Study

This work is aimed at examining the ways of reducing the sizes of components for water supply distribution systems and the various alternatives involved in this. Water intakes, well, treatment plant, pumping and transmission lines are sized for peak demand, normally maximum daily use where hourly variations are handled by storage. If the peak flow values can be reduced or the distribution facilities are not made to carry peak flows, then their sizes can be considerably reduced and thus their costs can also be reduced. This implies the reduction of the overall cost of the water supply project. It is also aimed at reducing cost of construction of new projects since there will be reduction in sizes of water supply and distribution components when the peak load is attenuated (Anyata, 1980).

Since the distribution facilities (i.e., pipes, pump, valves, etc) are sized based on peak flows, this project is concerned with examining ways of reducing the sizes of components for water distribution systems and the various alternative involved. Nnewi in Anambra State of Nigeria is used for case study.

Literature Review

Water Transmission and Distribution

Water use varies from city to city, depending on the population, climatic conditions, industrialization, and other factors (Linsley and Franzini, 1975; Fair et al., 1978). In a given city, water use varies from season to season and from hour to hour. The planning of a water supply system requires that the probable water use and it variations be estimated as accurately as possible. The problem of water shortage in most Nigerian cities is attributed to rapidly growing populations, wastages due to leakages and breakage as well as non-payment of water rates (Osanebi,1985). Extensive distribution systems are needed to deliver water to the individual consumer in the required quantity and under a satisfactory pressure. This distribution system is often the major investment of a municipal waterworks and is about 70% of the total cost. The difference in pressure heads takes into consideration the various losses encountered in water distribution using pipes such as leakage losses, friction losses and others. Hydraulic pressures in the system will result in reduction in flow. Thus, any reductions in flow will be less than the amount of water that the system can deliver. Reduced pressures reduce wear and tear of the faucets, and since the amount of leakage is proportional to the pressure, this is a reliable method for reducing the amount of leakage and thus providing some water saving. In a branched distribution system, consumers at the outer boundary of the system may receive very little, if any water, especially during peak periods. Hence, it may be impossible to serve these areas when or if pressures are too low (De Kruijff, 1979).

Reduced Flows

(1) Use of Flow Control Devices

Limiting the volume delivered to certain groups of customers at a time is a method to reduce demand. This may take several forms in the developing countries such as:

(a) Turning on the water to particular sectors at prescribed times sufficient to provide allocation of water to the sectors.

Varying the amount of water supplied to customers in different sectors of the network and treating different kinds of customers with different priority. This may be feasible in certain regions where there is a separation of categories or groups of customers (Anyata, 1980). These can be achieved by the use of some flow control devices such as the orifice plate. In its simplest form an orifice plate consists of a thin sheet of metal with a hole, which is generally central. This plate is inserted into the pipe main between adjacent flanges, the outside diameter of the plate being turned to fit within the flange bolts. The diameter of the hole through the plate is of the size required to produce the appropriate differential pressures at the maximum rate of flow.

Figs. 1 and 2 illustrate the orifice plate

v = the velocity of flow

z = the elevation relative to a datum

w = the specific weight of the fluid

g = acceleration due to gravity

$P_{Tot.}$ = Total head at the station.

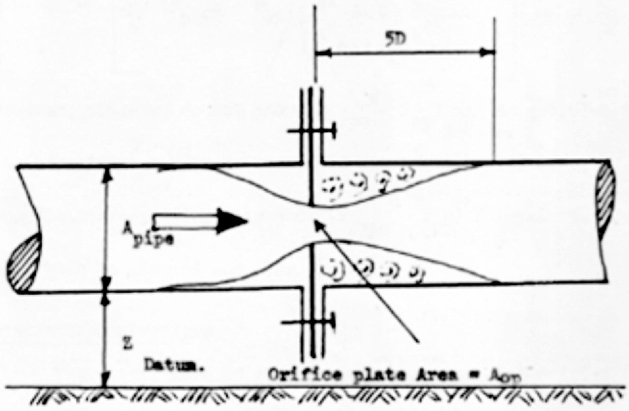
From the mass continuity equation we have that Q = VA

where

Q = flow rate

V = velocity

A = cross-sectional area of section.



Then we have $Q = V_{pipe} A_{pipe} = V_{op} A_{op}$

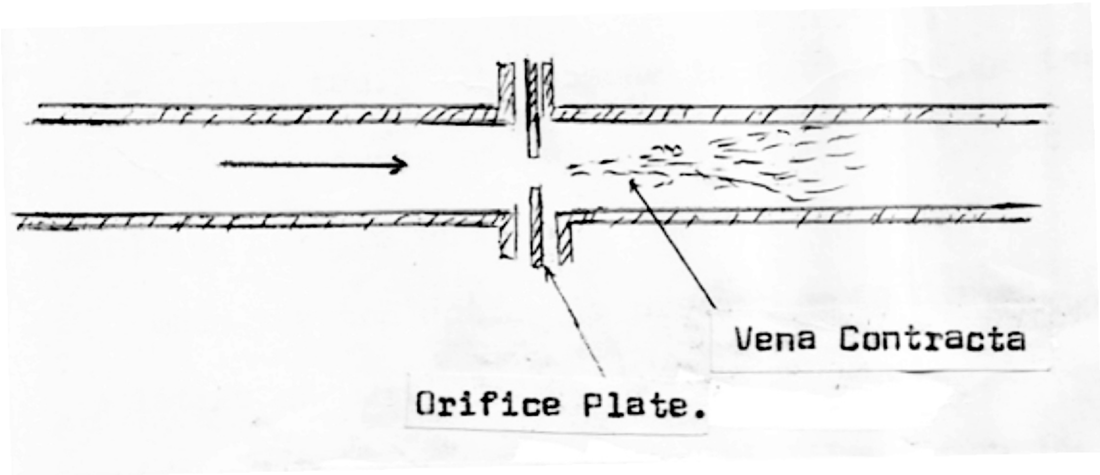
where

V_{op} = velocity of the orifice plate

A_{op} = area of the orifice plate

Then the Bernoulli's equation at the two points, one in the pipe and the

Fig. 2: Plain Type Orifice Plate



Hughes (1974) suggested that the orifices can be used very selectively to constrain peak demand only in those sections of a system that would otherwise be in danger of experiencing negative pressures during peak demand periods. The advantages of the system are (Osanebi, 1985)

(i) Easy to install and does not require any complicated maintenance.

(ii) The size can easily be changed to give more or less volume of water.

(iii) Allows the customer the freedom to choose the orifice size that he wants and to change the size should he so desire.

The disadvantages of the orifice system of control include:

(i) The system is only a very approximated flow measuring device since the flow rate changes with time of the day (i.e., pressure in the supply distribution system).

(ii) Build up of material at the orifice will greatly affect the quantity of flow.

This concept should be used as a temporary measure while additional line capacity is being developed.

Methodology

Intermittent Flow

This is one of the operational methods of rationing. This can be achieved by either:

(a) Turning on the water to a particular sectors at prescribed times sufficient to provide allocation of water to the sectors or

(b) Varying the amount of water

supplied to customers in different sectors of all the network and treating different kinds of customers with different priority.

Since larger flow rate are associated with intermittent flows, systems designed on an intermittent flow basis generally will have larger pipe size than if they were design and operated on a continuous flow basis. Thus, a major design problem in intermittent flow distribution is to devise strategies so that the flow rates are reduced. If this is achieved, smaller pipe size can be used in the network resulting in lower pipe costs as well as operating costs.

Flow Restrictors

Flow restrictors are made to limit the capacity of the portion of the system to deliver water. Such controls reduce the pressure in the system and thus limit the amount of water that can be delivered beyond the point where the regulator is installed. It also allow all consumers in a defined service area and service category to have the same flow capacity. The experiment carried out using orifice plate as the restriction device clearly showed a decrease in the quantity of flow as the diameter of the hole through the plate decreases, there was a corresponding increase in pressure drop as well. From the values obtained, a chart was prepared showing the values (p_{pipe}- p_{op}) versus Q (pressure drop versus flow rate) for some pipe areas, A_p and area of plate, A_{op}. The pipes used are 25mm, 38mm and 50mm diameter steel pipes. From the chart prepared, one can easily refer to the chart to find Q for various value of A_{op}.

The orifice plate was found to be a good flow regulator which is capable of reducing the pressure in the system and thus limiting the amount of water that can be delivered beyond the point where the regulator is installed (Figs. 2 and 3). From the experiments carried out, a chart was prepared which is capable of giving the quantity of flow that a particular orifice plate diameter can allow under a given pressure in the supply line. A Fordilla pod may also be used and is recommended for dwelling units in one level apartment house in a heavily built up areas or city slums. The Fordilla valve is also capable of discouraging the waste of water by delivering a specific amount of water at a time. The valve is in addition very sturdy and not easily broken. For effective utilization of the various alternatives in achieving the desire aim the following steps should be considered:

(i) The orifice plate should be installed at points where manhole exist to facilitate cleaning since there will be accumulation of debris at the point of installation (fig 2).

(ii) Public enlightenment campaigns should be carried out, so that consumers will know the effect of breakages on the water that is supplied to them as well as that on the Water Board. They can then, promptly report the breakages to the Water Board.

(iii) The Water Boards should ensure that the consumers know the exact time they are to be allocated with water when operating on an intermittent basis.

Nomenclature

Ap = area of pipe,
Agb = area of orifice plate
PP = static pressure of the fluid pipe before orifice
POP = Pressure in pipe at the orifice plate
Pth = theoretical pressure
dop = The diameter of the orifice plate
D = the diameter of the pipe
g = acceleration due to gravity
w = the specific weight of the fluid = (pg)
where p = density of the fluid
Qm = flow rate of the fluid at a given section
AOP = cross- sectional area of orifice plate
V = Velocity of flow
Vop = velocity of flow at the orifice plate
Z = the elevation head relative to a datum
Vtot = the total head at the section
Vop = velocity of flow at the orifice plate
Zp = the elevation head in the pipe
Zop = the elevation head at the orifice plate

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