Proceedings of ASME FEDSM'02
2002 ASME Fluids Engineering Division Summer Meeting
Montreal, Quebec, Canada, July 14-18, 2002

FEDSM2002-31085

ERROR FREE LIQUID FLOW DIVERTERS FOR CALIBRATION FACILITIES

T. T. Yeh,† N. P. Yende,‡ A. N. Johnson,† and P. I. Espina†

†National Institute of Standards and Technology
100 Bureau Drive, Stop 8361
Gaithersburg, Maryland 20899-8361, USA

‡CSIR-National Metrology Laboratory
P O Box 395
Pretoria, 0001, South Africa

ABSTRACT

A design for diverter valves in gravimetric liquid flow calibration facilities is examined. The concept makes use of repeated unidirectional motions of the diverter valve to reduce errors associated with asymmetry in the diverter valve motion and in the liquid jet velocity profile. Various implementation examples are provided and their benefits are discussed.

INTRODUCTION

Flow diverter valves are important components in most gravimetric liquid flow calibration systems, functioning to direct the calibration flow to either a bypass loop or a collection tank. During a typical calibration cycle, the flow diverter valve makes two sweeps through the trajectory of the calibration flow. During the first sweep, the calibration flow is diverted from the bypass loop into the collection tank. The collection tank then accumulates liquid, followed by a second diverter valve sweep, which redirects the flow to the bypass loop. During the diverter valve sweeps, the flow into the collection tank changes from zero to the full calibration flow and from the full calibration flow to zero. Since only a fraction of the full calibration flow enters the collection tank during a diverter valve sweep, diverter valve errors are manifested as an uncertainty in the liquid collection time. It has been shown that these errors can contribute significantly to the flow measurement uncertainty whenever static weighing techniques are used to determine liquid flow rates [1,2].

Traditionally, designing fast actuation flow diverter valves and using symmetric time actuation has reduced uncertainty associated with liquid collection time. In practice, symmetric time actuation is realized by locating the time triggering signal at the diverter valve mid-trajectory point. However, the desired error reduction is only assured when both the liquid jet velocity profile and the diverter velocity are symmetric. In practice, these conditions are difficult to obtain across the entire calibration facility flow range, resulting in diverter valve errors over most of the flow range.

Various techniques have been suggested to reduce diverter valve errors [1-5]. In one technique, the diverter valve error is amplified by making repetitive liquid collections which, when totaled and compared to a single diversion, permit evaluation of the error [1,2]. Another method for determining the diverter valve error uses successive measurements of flow rate at different collection times. The results of these collections are fitted to estimate the timing error [1]. CFD designs of the feeding pipe and nozzle geometry have been used to try to achieve symmetric jet velocity profiles, thereby reducing diverter valve error [3]. Another proposed method uses symmetric triggering locations for time measurement [4]. More recently, a two-wing diverter valve was designed to reduce the diverter valve error [5].

In the present paper, a diverter valve design is introduced that helps eliminate error even when symmetrical conditions are not satisfied. This new concept makes use of a flow diversion process whereby the components of the diverter valve error are self-canceling. This self-cancellation effect occurs when the flow accumulation for the first and second diverter valve sweeps are functional inversions, summing to the full calibration flow at corresponding times in their diversion period. The proposed diverter valve design achieves the self-cancellation effect by implementing a unidirectional diverter motion, which has an identical time actuation during both sweeps. The unidirectional motion of this design contrasts with conventional designs where the diverter moves in opposite directions during the two sweeps. The advantage of the proposed design is that theoretically, it eliminates the diverter valve error for any liquid jet velocity profile. Several operational examples with different liquid jet velocity profiles and diverter speeds are examined to show the diverter characteristics for each. Several design options and their operational procedures are also considered.

NOMENCLATURE

A	extra volume collected before the trigger time, t_1, in the opening transition
B	deficit volume missed after the trigger time, t_1, in the opening transition
C	deficit volume missed before the trigger time, t_4, in the closing transition
D	extra volume collected after the trigger time, t_4, in the closing transition
E	$=T_{eff}/T_M-1$, diverter error
M_M	total mass collected
Q_C	collecting flow
Q_B	bypass flow
Q_L	flow in the left side of the diverter
Q_R	flow in the right side of the diverter
Q_T	total flow = $Q_C+Q_B=Q_L+Q_R$
T_C	$=t_3-t_2$, constant collecting flow interval
T_{eff}	$=V_M/Q_T$, effective collecting interval
T_{err}	$=T_{eff}-T_M$, diverter time error
T_M	$=t_4-t_1$, measured time interval
T_T	$=t_5-t_o$, total collecting time interval
V_d	diverter velocity
V_{do}	$=h/t_d$, average diverter velocity
V_j	jet velocity
V_{jo}	$=Q_T/w\,h$, average jet velocity
h	narrow nozzle dimension, in x direction
w	wider nozzle dimension, in y direction
x	diverter moving direction
y	direction normal to x and z
z	downward, the jet flow direction
t_i	$i=0,1,2,\ldots,5$. Time stamps
t_d	$=t_2-t_0$, or $=t_5-t_3$, diverter transit time
t_g	$=t_1-t_0$, or $=t_4-t_3$, trigger time
α	$=t/t_d$, normalized time
β	$=x/h$, normalized distance
γ	$=t_g/t_d$, normalized trigger time
ρ	fluid density

FLOW DIVERTER OPERATING PRINCIPLE

Figure 1 shows a sketch of a typical time history of a flow diverted into a collecting tank during a calibration cycle. The abscissa is the time elapsed and the ordinate is the instantaneous flow diverted to the collecting tank, Q_C. The bypassed flow rate, Q_B, is also shown. At any moment during the diversion, the total calibration flow is the summation of the collecting flow and the bypassed flow, $Q_T=Q_C+Q_B$.

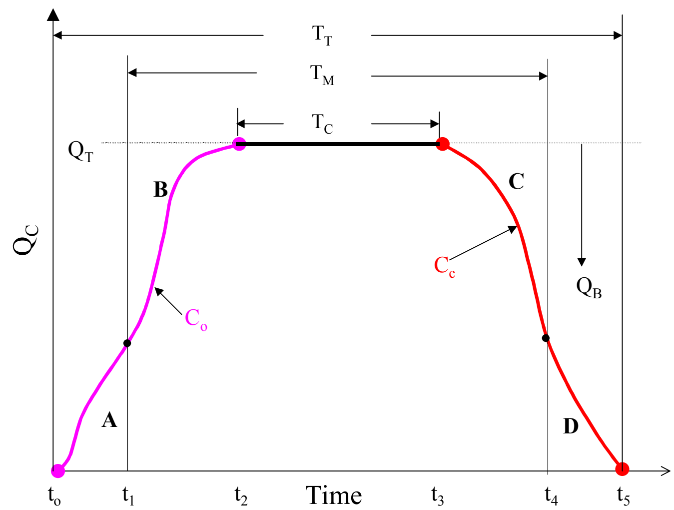

Figure 1. Liquid flow collected as function of time. For clarity, the constant collecting flow interval, T_C, has been compressed.

A calibration cycle can be broken into three distinct time periods: the *opening period* $(t_0\le t\le t_2)$, the *constant flow period* $(t_2<t<t_3)$, and the *closing period* $(t_3\le t\le t_5)$. Time t_o is the start of the opening period and denotes the instant at which the diverter valve mechanism is first activated. During the opening period, the diverter valve redirects the liquid jet from the bypass loop to the collection tank. As a result, the collecting flow changes from zero to the total calibration flow, Q_T. A signal indicating the start of the collection interval is triggered at time, t_1. By time, t_2 (the end of the opening period), all the calibration flow has been redirected to the collection tank; this is the first time when $Q_C=Q_T$. The collected flow, Q_C, during the open period is shown by the curve C_0.

During the closing period, the diverter valve redirects the liquid jet from the collection tank back into the bypass loop; thus leading to a collecting flow that changes from Q_T to zero. Curve C_C shows the transition of the collecting flow during the closing period. A signal indicating the stop of the collection interval is triggered at time, t_4.

Liquid accumulates in the collection tank during all flow periods in the calibration cycle. The total mass of liquid accumulation in the collection tank, M_M, is given by the time integration of the collection flow, Q_C, from t_0 to t_5 (see Figure 1)

$$\frac{M_M}{\rho} = \int_{t_0}^{t_5} Q_C \, dt = A + Q_T (t_4 - t_1) - B - C + D \tag{1}$$

where, ρ is the fluid density, A is the extra liquid volume collected before the starting trigger time, t_1, during the open period and is given by

$$A = \int_{t_0}^{t_1} Q_C \, dt \tag{2}$$

Thus, volume A represents the total amount of liquid diverted from the bypass into the collection tank before the activation of the starting trigger. In a similar manner, B is the liquid volume absent from the collection after the trigger time, t_1, and it is given by

$$B = \int_{t_1}^{t_2} (Q_T - Q_C)\, dt = \int_{t_1}^{t_2} Q_B \, dt \tag{3}$$

The volumes A and B are non-zero for transit periods of finite duration, and their magnitude mainly depends on the jet velocity profile, diverter speed, the duration of the open period, and the trigger time, t_1.

During the closing period, the liquid volume diverted from the collection tank before the closing trigger, t_4, is given by

$$C = \int_{t_3}^{t_4} (Q_T - Q_C)\, dt = \int_{t_3}^{t_4} Q_B \, dt \tag{4}$$

and the extra flow volume collected after trigger, t_4 is

$$D = \int_{t_4}^{t_5} Q_C \, dt \tag{5}$$

As was the case for A and B, C and D are non-zero and are determined by the jet velocity profile, diverter speed, the duration of the closing period, and the trigger time, t_4.

The measured collection time, $T_M = t_4 - t_1$, is the time from the opening trigger to the closing trigger. Because the traverse of the diverter valve during the opening and closing periods requires a finite amount of time (*i.e.,* $t_2 - t_0 > 0$ and $t_5 - t_3 > 0$), a full collected calibration flow cannot be achieved during the entire collecting period. That is, the condition of constant flow collection cannot be achieved during the entire flow collection, even under steady state calibration flow.

To estimate the flow, an effective collection time can be defined as

$$T_{eff} = V_M / Q_T = T_M + (A + D - B - C)/Q_T \tag{6}$$

The effective duration of the collection period should lie between the duration of the constant flow period, $T_C = t_3 - t_2$, and the duration of the total interval during which the collection tank receives fluid, $T_T = t_5 - t_0$. As shown in Figure 1, the fluid volumes A and D are the surplus liquid collected before and after the measured time interval, T_M, and the fluid volumes B and C are the deficit in liquid collected during the measured time. In general, these two groups of volumes are not equal (*i.e.,* not self-canceling) and thus a diverter valve error exists. The diverter valve error, T_{err}, can be defined as the difference between the effective collection time and the measured collection time, given by

$$T_{err} = T_{eff} - T_M = (A + D - B - C)/Q_T \tag{7}$$

or in dimensionless form

$$E = T_{err} / T_M = (A + D - B - C)/Q_T / T_M \tag{8}$$

Both (7) and (8) show that the condition for a zero diverter error is $A + D = B + C$. Referring to Figure 1, this can be accomplished, in principle, by adjusting the trigger positions, t_1 and t_4; that is, by adjusting the location of the timing actuation with respect to the flow emerging from the nozzle slot [3,4]. However, to precisely adjust the timing trigger is practically impossible given that the correct flow curves C_0 and C_C are functions of jet velocity distribution and the diverter velocity, both of which are typically not known.

Traditionally, reduction of the diverter valve error has relied on the assumption of symmetry in the collecting flow, Q_C, during the diverter valve transitions. In such cases, when the trigger is set at a symmetry point of the opening period, the surplus liquid volume A will be equal to the deficit liquid volume B, resulting in a null diverter error. Under the assumption of symmetry, the opening period symmetry point is at the midpoint of the diverter traverse. Similarly, when the trigger is set at a symmetry point of the closing period, the deficit liquid volume C will be equal to the surplus liquid volume D. Consequently, the net diverter error for the closing period will be zero.

Unfortunately, obtaining a symmetric flow collection for the entire flow range of the calibration facility is difficult. For curves C_0 and C_C to be symmetric, the following four conditions are typically required: (a) the jet profile must be two-dimensional (constant velocity along the width of the nozzle), (b) the jet profile must be symmetric, (c) the diverter velocity must be symmetric, and (d) there must be no misalignment between the diverter and the jet stream. Rarely are all of these conditions satisfied [actually condition (a) is physically unattainable], resulting in diverter errors over most of the calibration flow range. Another approach for reducing diverter error is to increase the measured time interval, T_M, [see eqn 8]. However, long collection times are impractical for most calibrations due to the limited capacity of the collection tanks and their scales.

In general, diverter errors are not completely eliminated using either symmetric timing actuation or increasing the measured time interval. However, (8) suggests that for the appropriate design condition, $A + D = B + C$, the diverter error can be forced to zero. Before attempting to identify diverter designs that satisfy the *zero error condition*, we shall first quantify how fundamental diverter valve parameters (*i.e.,* jet velocity profile, diverter speed, diverter misalignment, etc.) affect timing errors.

FLOW DIVERSION

As alluded to before, a flow diverter system accomplishes two main functions: (a) it divides the calibration flow into two streams, and (b) it directs the desired stream to the collection tank. In this section we explore the first function by discussing how the flow is divided and by quantifying the relationship between the liquid jet velocity profile and the divided flow. The second function of the diverter system will be discussed in the following section.

Figure 2 shows a schematic diagram of a basic flow diverter, together with a liquid jet emanating from a nozzle. Typically, the nozzle exit is rectangular, having a large aspect ratio, $w / h >> 1$. The larger dimension, w, is parallel to the y-axis (*i.e.,* perpendicular to the direction of the diverter movement) and the narrower dimension, h, is parallel to the x-direction (*i.e.,* the diverter movement direction). Typically the flow diverter is a thin plate having a sharp edge parallel to the y-axis. During operation, the diverter moves from the left to the right in the positive x-direction. The edge of the flow diverter splits the liquid jet, Q_T into two streams: Q_L on the left and Q_R on the right. At any given time, the magnitudes of the divided streams are functions of the diverter tip position. (Note that the following analysis is general, and applies even in the case of misalignment between the nozzle and diverter.)

The flow stream on the left side of the diverter can be expressed as,

$$Q_L(x) = \int_{x_o}^{x}\left[\int_y V_j(x,y,z)dy\right]dx \tag{9}$$

In (9), the integration in the y-direction is taken to be along width of the diverter edge. Although not necessary in this analysis, we shall drop the z-direction dependence from $Q_L(x)$, and assume that the diverter edge is aligned with the y-direction. Figure 3a shows a typical plot of $Q_L(x)$ versus diverter location, x. In the figure, x_o and x_d are defined as the starting and the ending points of the diverter trajectory, and x_g is the triggering location. Thus, $Q_L(x) = 0$ for $x < x_o$ and $Q_L(x) = Q_T$ for $x > x_d$, and, invoking conservation of mass, $Q_R(x) = Q_T$ for $x < x_o$ and $Q_R(x) = 0$ for $x > x_d$.

Because the flow calibration requires time information rather than position information, the diverter traversing time is more useful to know than the diverter position. The relationship between the diverter position and the diverter traversing time is given by

$$x = x_o + \int_{t_o}^{t} V_d(t)dt \tag{10}$$

where, V_d is the speed of the diverter. Equation (10) provides the necessary x-t transformation to express $Q_L(x)$ in (9) as a function time, $Q_L(t)$, as shown in Figure 3b. Note that t_o and t_d are the starting and the stopping times, corresponding to the starting and ending points x_o and x_d. Also, t_g is the trigger time corresponding to the trigger location x_g.

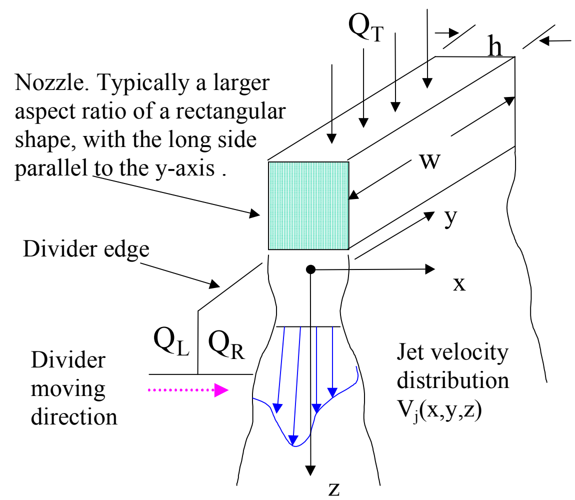

Figure 2. Liquid jet and diverter.

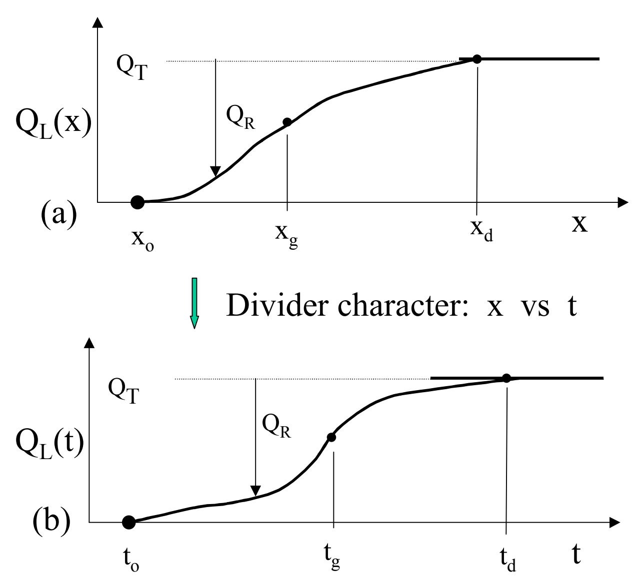

Figure 3. Divided flows as function of flow diverter position or time.

Having quantified the relationship between jet velocity profile, diverter velocity and position, total flow, and the leftward and rightward-diverted streams, the design conditions that will eliminate the diverter valve error must be ascertained. The basis for this error-free condition will rely on both diverter functions: how the flow is divided, and where each stream (Q_L and Q_R) is directed. In the remainder of this paper, we will introduce a diverter concept that helps to eliminate the diverter error for any liquid jet profile.

ERROR FREE DIVERTER

As previously discussed, obtaining the correct time symmetry for the diversion process is not a practical solution for compensating the flow measurement error. Here, we look at a different concept to compensate for the measurement error.

The error free condition, $A + D = B + C$, can be satisfied if $A = B$ and $C = D$ (*i.e.,* the symmetry assumption discussed earlier), or if $A = C$ and $B = D$. The proposed concept is to make the functional form of the closing curve, C_C, the inverse of the opening curve, C_0, rendering their sum equals the total flow at corresponding times in their period. It is worth noting that in this approach, symmetry in the C_0 and C_C functions is not required.

Traditional diverter valve mechanisms move in the opposite directions during the opening and closing periods. However, the proposed diverter valve concept uses a unidirectional mechanism that starts from the same location and moves at identical velocities during the opening and closing transitions. Since the mechanism follows an identical trajectory at the same velocity for both the opening and closing periods, the resulting flow function will be same (*i.e.,* Q_L will be identical for opening and closing periods). By appropriately directing, Q_L and Q_R to either the measurement tank or to the bypass loop, the collection flow curve in the opening period, C_0, can be made an inverse of that in the closing period, C_c.

During the opening period, Q_L is channeled to the collection tank and Q_R to the bypass loop. During the closing period, Q_L is channeled to the bypass loop and Q_R to the collection tank. By using (9) and (10) in conjunction with Figure 3, the volumes A and B, given in (2) and (3), become,

$$A = \int_{t_0}^{t_1} Q_C \, dt = \int_{t_0}^{t_g} Q_L \, dt \qquad (11)$$

and

$$B = \int_{t_1}^{t_2} Q_B \, dt = \int_{t_g}^{t_d} Q_R \, dt \qquad (12)$$

during the opening period. Similarly, the volumes C and D, given in (4) and (5), become,

$$C = \int_{t_3}^{t_4} Q_B \, dt = \int_{t_0}^{t_g} Q_L dt \qquad (13)$$

and

$$D = \int_{t_4}^{t_5} Q_C \, dt = \int_{t_g}^{t_d} Q_R \, dt \qquad (14)$$

during the closing period. In this approach the values of t_g and t_d are assumed to be identical for both the opening and closing periods. However, these are valid assumptions since the same diverter valve mechanism and time trigger are used for the opening and closing periods.

Comparing (11) with (13) yields the condition $A = C$, and a comparison of (12) and (14) yields $B = D$ for all flow conditions. By combining (1), (6), (7), and (8), the total collected flow, $M_M / \rho = Q_T(t_4 - t_1) = Q_T T_M$, is the product of the total flow and the measured time interval. The diverter timing error, T_{err} and E, are identically zero, and therefore, the effective collection time equals the measured collection time for all flow and diverter valve conditions (*i.e.,* $T_{eff} = T_M$).

EXAMPLES AND DESIGN OPTIONS

For any given jet velocity profile and diverter valve speed, the flow volumes for different periods can be calculated. The following six simple examples demonstrate how the proposed concept works:

case a the diverter valve moves at a constant velocity, $V_d = V_{do}$, and the jet flow profile is uniformly distributed, $V_j = V_{jo}$,

case b the diverter valve moves at a constant velocity, $V_d = V_{do}$, and the jet flow velocity increases linearly with distance x, $V_j = 2V_{jo}\beta$,

case c the diverter valve moves at a constant velocity, $V_d = V_{do}$, and the jet flow velocity decreases linearly with distance x, $V_j = 2V_{jo}(1-\beta)$,

case d the diverter valve speed increases linearly with time (constant acceleration) $V_d = 2V_{do}\alpha$, and the jet flow profile is uniformly distributed, $V_j = V_{jo}$,

case e the diverter valve speed increases linearly with time, $V_d = 2V_{do}\alpha$, and the jet flow velocity increases linearly with distance x, $V_j = 2V_{jo}\beta$, and,

case f the diverter valve speed increases linearly with time, $V_d = 2V_{do}\alpha$, and the jet flow velocity decreases linearly with distance x, $V_j = 2V_{jo}(1-\beta)$.

Figure 4 shows the six jet velocity distributions as a function of the diverter movement time; Figure 5 shows time traces of the collection flow for these six examples and the diverter flow characteristics for all cases are given in Table 1. In these examples, $t_0 = 0$. The filling time, $T_C = t_d$, has been compressed so the transition regions can be seen more clearly. Although the values of A, B, C, and D are all functions of the trigger time, t_1 (or $\gamma = t_1 / t_d$, as shown in Table 1), values of A always equal the values of C and values of B always equal the values of D. This happens regardless of the values of the trigger time, the conditions of jet velocity distribution, or the diverter valve speed. For these examples, the trigger time, t_1, can be set to any time between t_0 and t_2, and yet $C = A$, $D = B$, $T_{eff} = T_M$, yielding a null timing diverter error (*i.e.,* $T_{err} = 0$, and $E = 0$).

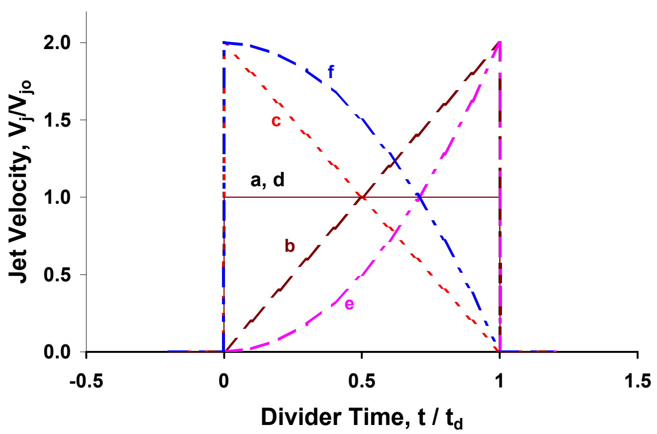

Figure 4. Jet velocity distribution as function of the diverter valve movement time. [Case (a) = Case (d)].

While the location of the time trigger is not important for the error-free diverter system, the trigger location is critical for error reduction of a traditional diverter system. Based on Table 1, the symmetry condition of $A = B$ (used for traditional diverters) gives trigger times at $\alpha = 1/2$, 2/3, 1/3, 2/3, 4/5, and 8/15; or trigger space positions at $\beta = 1/2$, 2/3, 1/3, $\sqrt{2/3}$, $\sqrt{4/5}$, and $\sqrt{8/15}$, for Cases (a), (b), (c), (d), (e), and (f) respectively. The correct trigger locations for the closing transitions satisfying $C = D$ could also be determined if the return speed of the diverter is known. However, in most applications the correct trigger positions for the opening and closing periods are different.

Plausible error-free diverter designs are now discussed. Figures 6 through 9 show four design options and their operation procedures for implementing the error-free diverter concept.

All design options consist of two basic devices: a *diverter valve* and a *flow-directing device*. To operate the diverter valve correctly, the relative position between the two devices needs to be synchronized. But basically, both the diverter valve and the flow-directing device are moving alternately between two fixed positions.

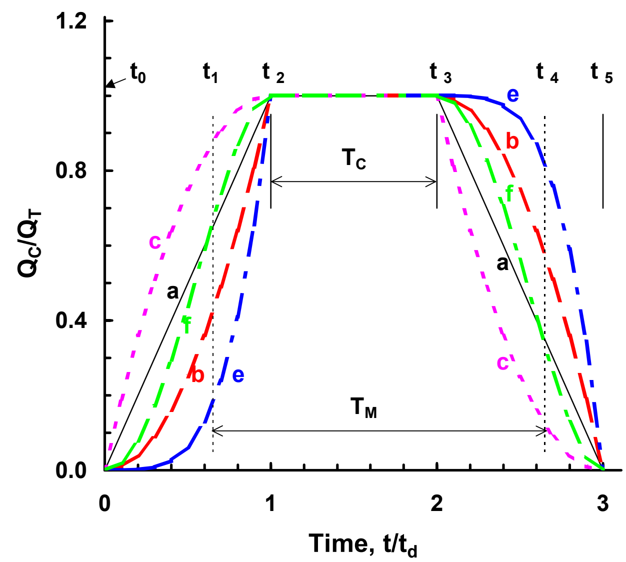

Figure 5. The collection flow as function of time for the six examples [Case (d) = Case (b)], $T_M = t_d + T_C$.

To show how the proposed diverter valve systems function, the operation procedure for each design option is broken down into six steps: (a), (b), (c), (d), (e) and (f). Step (a) shows the original positions of the diverter valve and the flow-directing device just before the start of the open period. At this time the diverter is ready to make a first sweep. Step (b) is just after the end of the first sweep of the diverter valve. At this time, the flow-directing device is ready to move to a neutral position so that the diverter valve can be moved back to the original position without affecting the total flow collection in the step (c). In step (d) the flow-directing device is reset to a new position to allow the leftward divided flow to be channeled to the bypass loop when a second sweep, in the closing period, starts. Step (e) is just before the start of the closing period and the flow diverter valve is ready to make the second sweep. Step (f) is the end of the second sweep, and also the end of a calibration cycle. After this step, both the flow diverter and the flow directing-device will return to their original positions as shown in the step (a).

Table 1. Diverter flow characteristics for six example operation cases. (a) $V_d = V_{do}$ and V_j / V_{jo}, (b) $V_d = V_{do}$ and $V_j = 2V_{jo}\beta$, (c) $V_d = V_{do}$ and $V_j = 2V_{jo}(1-\beta)$, (d) $V_d = 2V_{do}\alpha$ and $V_j = V_{jo}$, (e) $V_d = 2V_{do}\alpha$ and $V_j = 2V_{jo}\beta$, (f) $V_d = 2V_{do}\alpha$ and $V_j = 2V_{jo}(1-\beta)$.[1]

	V_j / V_{jo}	Q_L / Q_T	$A / Q_T t_d$	$B / Q_T t_d$
a	1	α	$\gamma^2/2$	$(1-\gamma)^2/2$
b	2α	α^2	$\gamma^3/3$	$(2-3\gamma+\gamma^3)/3$
c	$2(1-\alpha)$	$\alpha(2-\alpha)$	$\gamma^2-\gamma^3/3$	$(1-3\gamma+3\gamma^2 -\gamma^3)/3$
d	1	α^2	$\gamma^3/3$	$(2-3\gamma+\gamma^3)/3$
e	$2\alpha^2$	α^4	$\gamma^5/5$	$(4-5\gamma+\gamma^5)/5$
f	$2(1-\alpha^2)$	$\alpha^2(2-\alpha^2)$	$\gamma^3(10 -3\gamma^2)/15$	$(8-15\gamma+10\gamma^3 -3\gamma^5)/15$

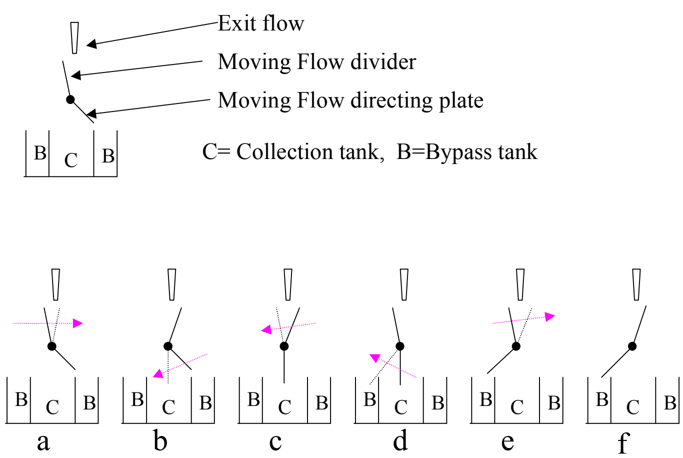

Figure 6. *Option I* – A rotating diverter valve with a rotating flow-directing device. Tanks are stationary.

[1] Note that α is normalized time, γ is normalized trigger time, t_d is the total diverter transit time, Q_L is divided flow at left side of the diverter, and Q_T is the total flow. For all these examples, $C = A$, $D = B$, $T_{eff} = T_M$, $T_{err} = 0$, and $E = 0$.

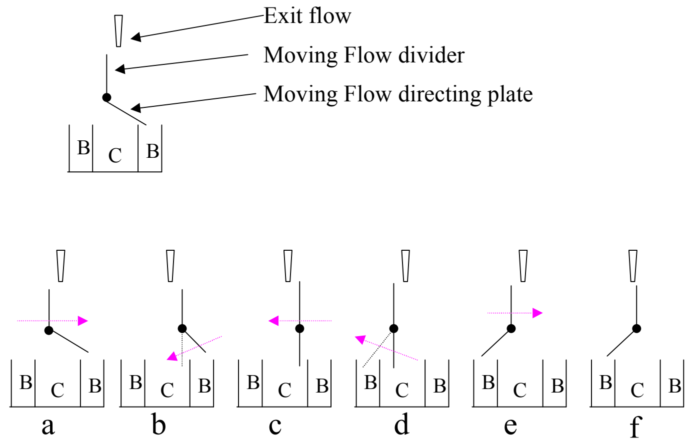

Figure 7. *Option II* – A translating diverter valve with a rotating flow-directing device. Tanks are stationary.

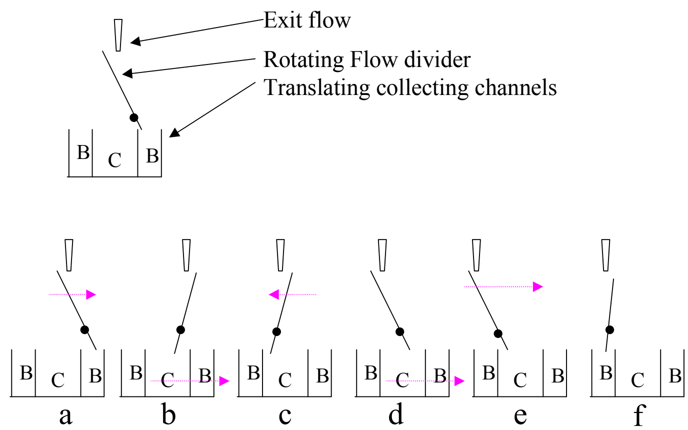

Figure 8. *Option III* – A rotating diverter valve with translating flow-directing channels.

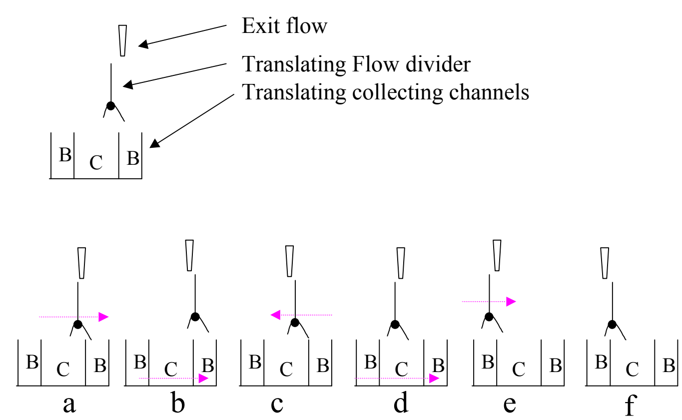

Figure 9 *Option IV* – A translating diverter valve with translating flow-directing channels**.**

The period between steps (a) and (e) is referred as a *constant flow period* or *filling period*. During this period, all flow is going to the collection tank regardless of the position of the diverter valve. The operation for the steps (c) and (d) are done in this constant flow period and before the start of the closing period. The corresponding times, as related to those shown in Figures 1 or 5, for each step are: step (a) at t_0, step (b) at t_2, step (e) at t_3, step (f) at t_5, and step (c) and (d) are completed between t_2 and t_3.

CONCLUSIONS AND DISCUSSION

A liquid flow diverter valve, using unidirectional diverter motion and a single time trigger offers several advantages:

1. It works for any trigger location. There is no need to trigger at the midpoint or adjust the triggering position as with bi-directional diverter valve designs.
2. It is insensitive to the shape and alignment of the diverter valve as well as the liquid splashing due to the diverter sweeps. The effects of the divided flow in the opening transition will be compensated by that effects in the closing transition.
3. It works for any flow and jet velocity profiles because it is insensitive to the flow jet distribution.
4. It is insensitive to the movement and the speed of the flow diverter valve. There is no need to keep the diverter speed constant or symmetrical.
5. The collection time and collection tank size, depends on error budget for weighing, can be reduced. This is especially important for large flow calibration facilities.
6. Although it has one more moving part, it will require less maintenance. The unidirectional diverter system requires only short time stability of the diverter valve during the calibration cycle and is insensitive to any long time drift of the diverter performance.
7. The design and operation of the unidirectional diverter system is relatively simple. This design adds only a flow-directing device to the traditional diverter valve. Absolute precision of the motion of the flow-directing device is not important. Both the diverter valve and the flow-directing device are simply moving alternately between two fixed positions.
8. Only a single trigger is required for the timer.

An experimental test of the performance of the unidirectional diverter is currently being built. This prototype of the concept will be assessed in a water flow system. The effects of various jet velocity profiles, flow rates, filling times, and diverter speeds on diverter performance will be quantified.

ACKNOWLEDGMENTS

The technical help from J. D. Wright and J. F. Houser and the editorial assistance of N. R. Briggs are gratefully acknowledged.

REFERENCES

[1] “Measurement of Liquid Flow in Close Conduits by Weighing Method”, ASME/ANSI MFC-9M-1988 ASME Hdqtrs., 345 East 47th Street, New York, NY, or "Measurement of liquid flow in closed conduits - Weighing methods", International Standard, IS0 4 185, 1st edition, (1980).

[2] Mattingly, G. E., "Volume Flow Measurement," in Fluid Mechanics Measurement, edited by R. J. Goldstein, Hemisphere Publishing Corporation, Washington, New York, London,(1983), pp. 245-306.

[3] Poschel, W. et al., A unique fluid diverter design for water flow calibration facilities, Proc. 10th Int. Conf. (FLOMEKO 2000 Conf. In Salvador, Brazil) on Flow Measurement, (2000), A9

[4] Engel, R., Klages, U., A novel approach to improve diverter performance in liquid flow calibration facilities, Proc. 10th Int. Conf. (FLOMEKO 2000 Conf. In Salvador, Brazil) on Flow Measurement, (2000), A10

[5] Shimada, T., Oda, S., Takamoto, M., and Nagai, S., "A Novel Diverter for Liquid Flow Calibration Facilities," 2001 NCSL International Workshop & Symposium, Wash. DC.

