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Evaluation of the Primary Bypass Flowmeters at the Tracy Fish Collection Facilities

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INTRODUCTION

The installation of an upgraded instrumentation system for the improved monitoring of critical hydraulic operating parameters at the Tracy Fish Collection Facilities (TFCF) was completed in 1995. The system is intended to provide improved salvage efficiencies through improved operation of the facilities, to support ongoing biological studies, and to provide automation capabilities for future use. The system consists of ten level sensors for monitoring water surface elevations at critical locations throughout the facilities; an acoustic, open-channel flowmeter for monitoring primary louver channel velocity and discharge; four external mount, ultrasonic flowmeters for monitoring each of the four primary bypass discharges; four dissolved oxygen/temperature/salinity sensors for monitoring water quality in each of the four holding tanks; and a data acquisition system (DAS) for providing real-time monitoring via graphical display and data logging of all system parameters. Figure 1 represents a plan view schematic of the TFCF.

An evaluation of the primary bypass flowmeters was conducted to ensure that the instruments are operating correctly. The performance of the primary bypass flowmeters directly influences two critical hydraulic operating parameters, which are determined indirectly using the primary bypass discharge measurements. These parameters consist of the primary bypass velocity ratios for each of the four primary bypass entrances and secondary channel louver approach velocities. The primary bypass velocity ratios for each of the four primary bypasses are determined indirectly as:

$$Primary\ bypass\ ratio,\ (\frac{V_{BE}}{V_A}) = (\frac{Q_B}{A_{BE}})(\frac{1}{V_A}) \qquad (1)$$

Where,

V_{BE} = Primary bypass entrance velocity [ft/s],

V_A = Measured primary louver forebay approach velocity [ft/s],

Q_B = Measured primary bypass discharge [ft^3/s], and

A_{BE} = Primary bypass entrance area [ft^2].

The secondary channel louver approach velocity is determined indirectly as:

$$Secondary\ channel\ velocity = \frac{(Q_{B1}+Q_{B2}+Q_{B3}+Q_{B4})}{d_s w_s} \qquad (2)$$

Where,

Q_{B1}, Q_{B2}, Q_{B3}, Q_{B4} = Measured primary bypass discharges for each primary bypass, respectively [ft^3/s],

d_s = Measured flow depth in the secondary channel [ft], and

w_s = Secondary louver channel width [ft].

The TFCF operating criteria as established in the Agreement for Reducing and Offsetting Direct Fish Losses - TFCF (memorandum dated July 27,1992) require that the above parameters be maintained in accordance with procedures outlined by Mecum, 1977. Therefore, since these critical parameters are determined indirectly using the direct primary bypass discharge measurements, it is important that these instruments operate correctly.

CONCLUSIONS

- The existing Polysonics flowmeters appear to be operating correctly and on average, measured +2.2 percent greater than the discharge measured by a Controlotron flowmeter of similar type.

- The current condition of the steel pipe sections on which the Polysonics flowmeters are installed is less than ideal and likely contributes to errors associated with the Polysonics instrument.

- Improvements in the accuracy of the Polysonics flowmeters will likely be realized through the replacement of each steel pipe section.

- Based on the results of this evaluation, the Polysonics flowmeters are likely operating within the ±5 percent accuracy specified by the manufacturer.

- The results of this comparative evaluation represent the relative performance of the Polysonics flowmeter as compared with the Controlotron flowmeter. There is no means available based on this evaluation, for determining, exactly, the accuracy of the Polysonics flowmeter under the unique conditions of the TFCF primary bypass applications.

TEST SETUP

The existing Polysonics flowmeters are external mount, ultrasonic, transit-time instruments which are configured for a single path, direct mode of operation. The ultrasonic transducers are installed such that the acoustic path is oriented in the horizontal plane. These instruments are located on each of the four

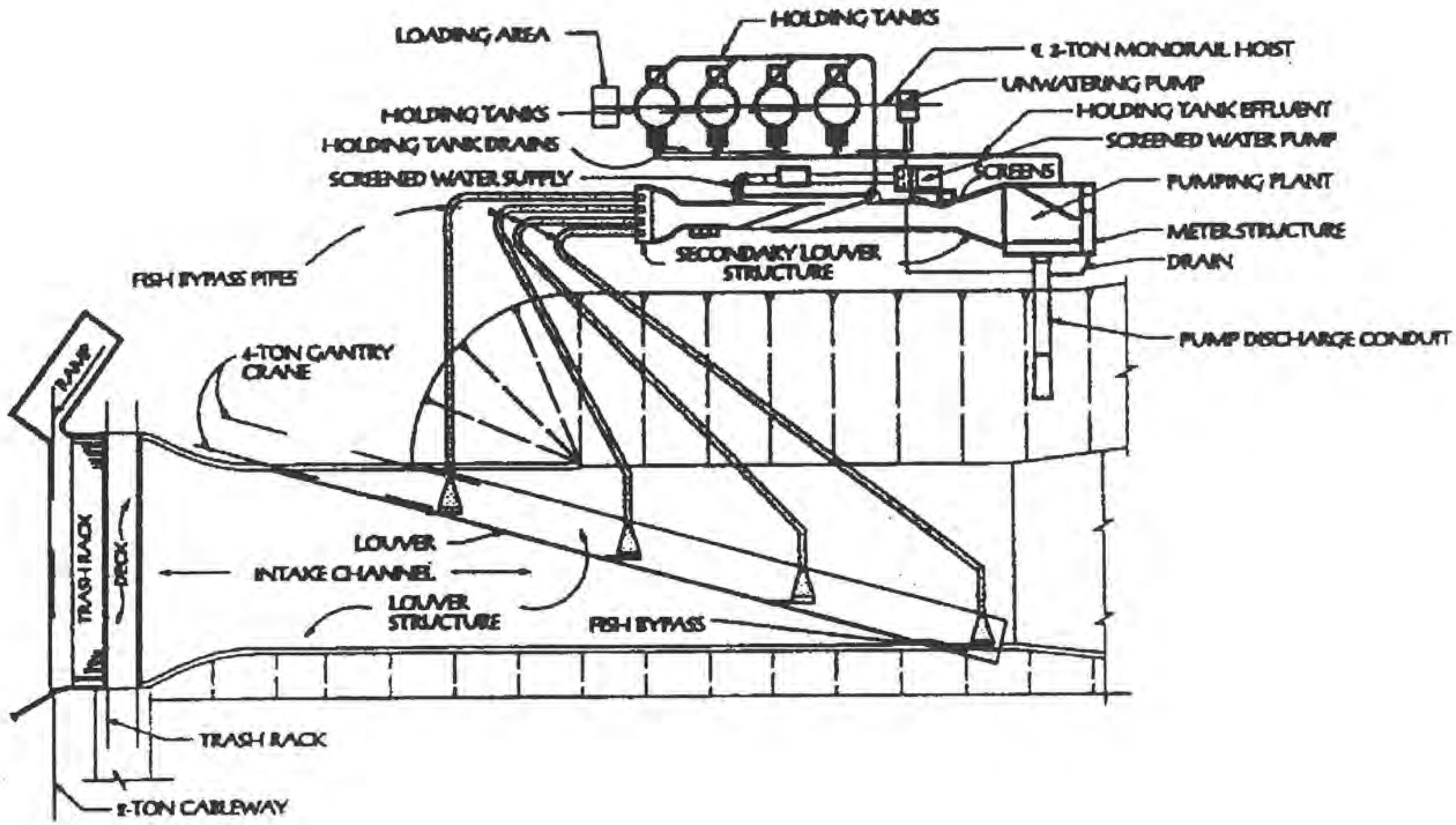

Figure 1. - Plan view schematic of the Tracy Fish Collection Facilities.

primary bypass lines. The primary bypass lines consist of 36-in, unlined steel pipe with a 3/16-in wall thickness. The steel pipe sections on which the Polysonics flowmetes are installed, for each bypass, are approximately 8-ft in length and are located between two 36-in gate valves.

The principle of operation for these instruments is based on measuring the transit-time of an acoustic signal transmitted through the pipe section to the receiving transducer. Using the measured transit-time and the known sonic velocity of the acoustic signal in water, the flow velocity is calculated. The discharge is then computed using this measured flow velocity and the known cross sectional area of the pipe.

A portable Controlotron, external mount, ultrasonic, transit-time flowmeter was installed at the same location as the Polysonics flowmeter on primary bypass No.1, for comparison. The flowmeter consists of size 5 mounting tracks for transducer alignment, size 5 ultrasonic transducers, transducer cables, and a portable flow computer. This instrument was configured for a single path, direct mode of operation. The ultrasonic transducers were mounted such that the acoustic path was oriented at 45° to the horizontal plane.

PROCEDURE

Initial attempts at installation of the Controlotron flowmeter were configured in a dual path, reflect mode which represents the most accurate configuration. A single path in reflect mode was first installed to determine the feasibility of this approach. However, upon initialization of the flow computer, detection fault errors were obtained indicating that the acoustic signal transmission was not successful. Repeated attempts at repositioning the transducers also failed. It was reasoned that the physical condition of the pipe (ie. degree of scaling on the interior walls) created significant acoustic signal attenuation. Realizing this condition, the instrument was set up in direct mode which proved to be immediately successful. This result confirmed that the previous unsuccessful attempts were likely due to the physical condition of the pipe as opposed to problems with the equipment. Due to time constraints, an additional acoustic path was not installed.

Upon successful installation of the Controlotron flowmeter in single path, direct mode, the sonic velocity, as determined by the Controlotron flow computer, was checked. The flow computer indicated a measured value of 1378 m/s. However, for this installation, given an approximate water temperature of 10 °C (50 °F) the measured sonic velocity should be closer to 1447 m/s. This value was selected and input into the flow computer. The contributing factor to this discrepancy is again likely due to the physical condition of the pipe. Scaling on the interior wall of the pipe can significantly influence the determination of this parameter. With this correction employed, primary bypass valve No. 1 was closed to allow for zeroing of the instrument. The Controlotron flow computer was then configured to provide analog output of the measured discharge for data logging purposes. A DATAQ DAS was used for A/D (analog to digital) conversion of the output and interfacing with a laptop computer. This DAS was initially programmed to log discharge data for an 8-hour test period. The intent was to compare this data with 8 hours of corresponding Polysonics data being logged by the instrumentation system (CIMPAC) DAS. However, closer inspection of the CIMPAC

DAS revealed that no data were being logged by the system. The CIMPAC system was then configured to log data for a minimum 1-minute interval. The resulting test duration was reduced to 45 minutes. The test was initiated by closing bypass valve no. 1 for a period of 2 minutes. This initiation procedure allowed for the establishment of a time datum from which corresponding data acquired by each flowmeter could be compared at the same instant in time.

RESULTS

A total of 45 minutes of comparison discharge data was acquired under the preceding test procedure. Although this was considerably less than initially desired, it has proven to be sufficient for the purposes of this evaluation. Table 1 presents the data acquired for this test and the resulting percent discrepancy between the Polysonics and Controlotron flowmeters for each measurement at the same instant in time. The percent discrepancy is determined as:

$$Percent\ discrepancy = \frac{(Q_{Polysonics} - Q_{Controlotron})}{Q_{Controlotron}}\ X\ 100 \qquad (3)$$

Where,

$Q_{Polysonics}$ = Polysonics instantaneous discharge measurement [ft^3/s], and

$Q_{Controlotron}$ = Controlotron instantaneous discharge measurement [ft^3/s].

The average percent discrepancy for all measurements is included in Table 1 and was found to be +2.2 percent. This result indicates that the Polysonics flowmeter discharge measurement was, on average, 2.2 percent greater than the discharge measured by the Controlotron flowmeter. The primary factor contributing to this discrepancy is most likely due to the respective installation locations of the two flowmeters. Recall that the Controlotron flowmeter was installed such that the acoustic path was oriented at 45° to the horizontal plane. And, the Polysonics flowmeter is installed such that the acoustic path is along the horizontal plane. Under this arrangement, any skewness of the velocity profile in the pipe would create a discrepancy between measured velocities along the two different acoustic paths. Therefore, since some skewness of the velocity profile likely exists, a discrepancy on the order of that which is indicated by these results is not suprising. Figure 2 represents the discharge verses time plot for the data acquired from both flowmeters. The Controlotron flowmeter readings appear to be somewhat more stable than the corresponding Polysonics readings. Although, this plot indicates that good agreement exists between the Polysonics and Controlotron flowmeters, the best indicator of the relative performance between these instruments is illustrated as figure 3. This figure represents the percent discrepancy verses time for each instantaneous discharge measurement.

These results indicate that the Polysonics flowmeter is operating correctly. However, no specific determination of the accuracy associated with this

Table 1. - Primary bypass No. 1 discharge measurement comparison data.

Time (minutes)	Q (Polysonics) (cfs)	Q (Controlotron) (cfs)	% Discrepancy
0	39	37.451	4.1
1	38.8	37.671	3.0
2	36.6	36.011	1.6
3	17.1	17.48	-2.2
4	0	0	0.0
5	0	0	0.0
6	17.3	17.188	0.7
7	40.7	38.794	4.9
8	43.7	42.236	3.5
9	42.1	41.846	0.6
10	44.2	42.969	2.9
11	45.6	44.702	2.0
12	44.5	43.457	2.4
13	42.9	43.262	-0.8
14	43.7	43.091	1.4
15	44.2	42.651	3.6
16	44.8	42.944	4.3
17	44.5	43.359	2.6
18	44.3	42.7	3.7
19	44	43.164	1.9
20	42.9	43.14	-0.6
21	44.5	42.798	4.0
22	45.1	42.896	5.1
23	43.4	43.042	0.8
24	43.7	43.872	-0.4
25	43.3	43.457	-0.4
26	43.2	43.481	-0.6
27	44.8	42.993	4.2
28	43.6	43.408	0.4
29	41.8	42.48	-1.6
30	46.4	42.725	8.6
31	43.4	42.651	1.8
32	39.3	42.993	-8.6
33	45.6	42.407	7.5
34	43.2	41.602	3.8
35	44.5	43.506	2.3
36	45.3	42.554	6.5
37	43.7	42.261	3.4
38	44	41.504	6.0
39	44	41.992	4.8
40	44.2	42.554	3.9
41	43.1	42.627	1.1
42	43.4	42.09	3.1
43	44	42.822	2.8
		average =	2.2

instrument can be made. This is due to the fact that this evaluation approach merely provides an indication of the relative performance of the Polysonics flowmeter as compared with the Controlotron flowmeter. However, based on the results of this comparison, previous experience with the Controlotron flowmeter, the hydraulic and physical considerations associated with this application, and engineering judgement, it can be reasoned that the Polysonics flowmeter accuracy is certainly within 10 percent of actual discharge and likely within 5 percent.

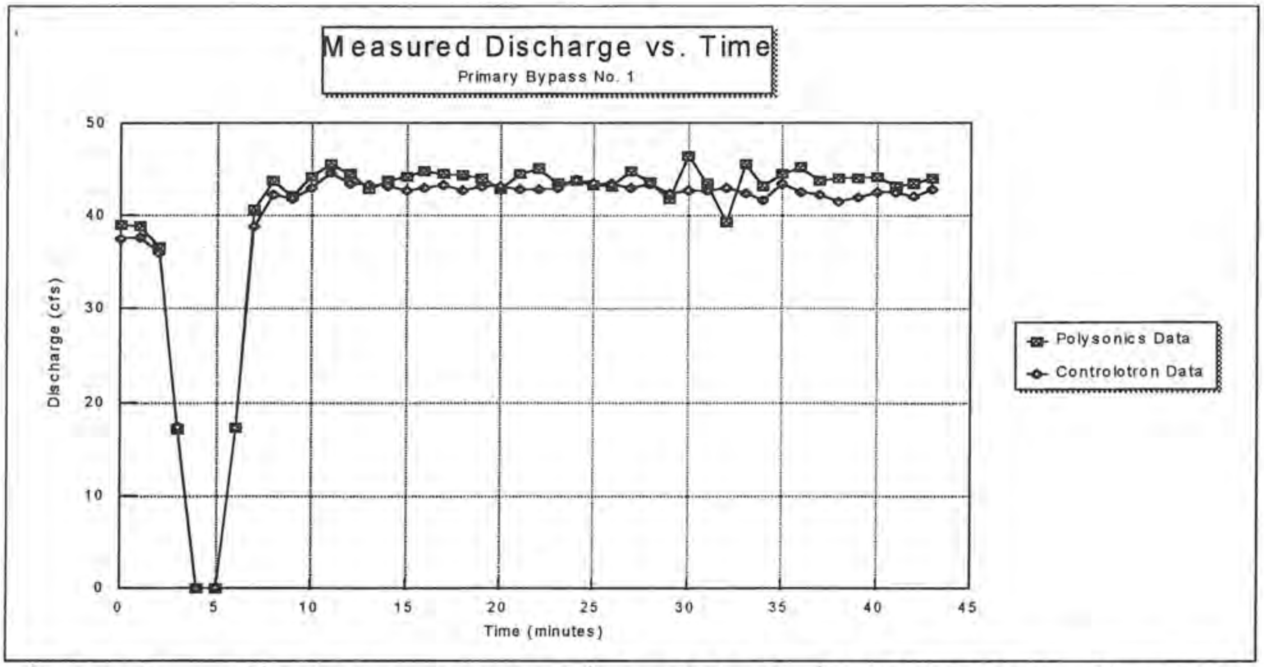

Figure 2. - Discharge verses time plot of instantaneous discharge measurement data.

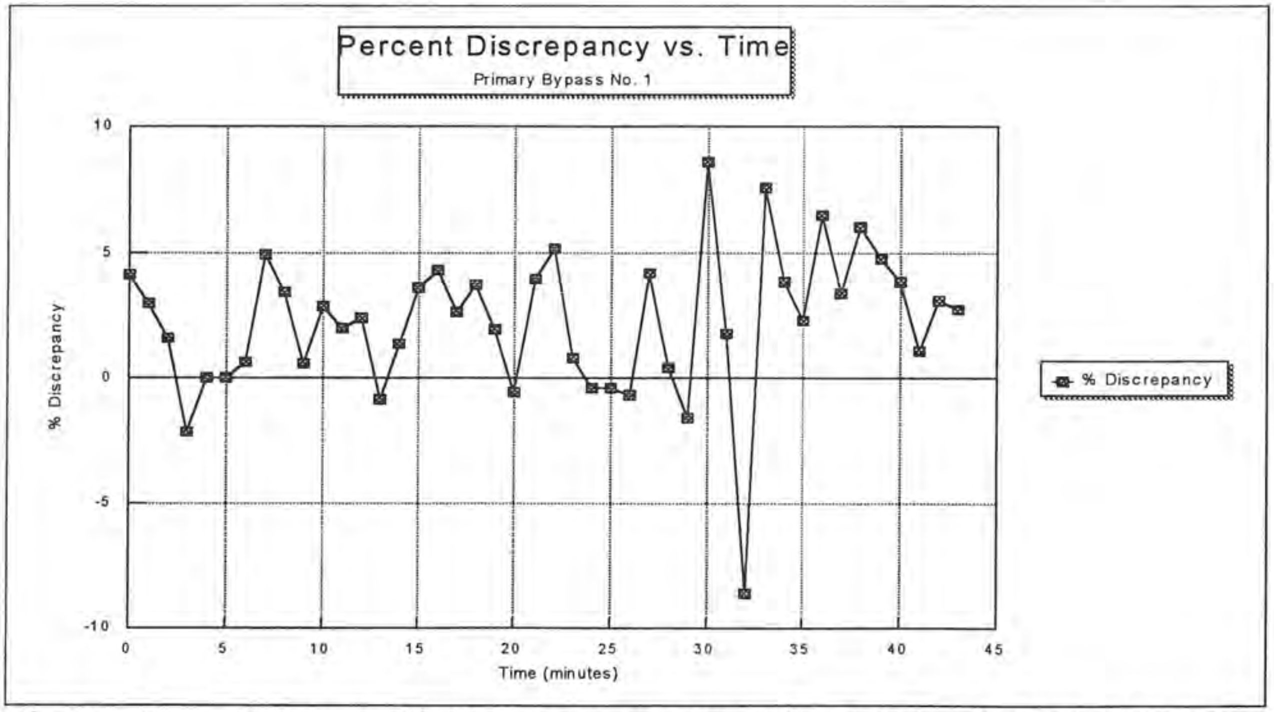

Figure 3. - Percent discrepancy verses time plot of instantaneous discharge measurement data.

DISCUSSION

A discharge measurement accuracy within 1 percent can be obtained using the Controlotron flowmeter under ideal conditions and in a dual path, reflect mode of operation. However, under less than ideal conditions and in single path, direct modes of operation this accuracy is compromised. In this case, an accuracy within 3 percent may be obtained, again if conditions are ideal. Many factors contribute to the accuracy limitations of this instrument and other instruments of this type. These factors include the installation set up (i.e, number of acoustic paths and mode of operation); the proximity of the instrument to upstream, flow disturbance generating features (i.e, valves, pipe bends, transitions, etc.); the physical condition of the pipe; the degree of debris load or air entrainment within the flow being measured; and the flow conditions within the pipe (i.e, the degree of secondary or cross flow conditions). For the TFCF application, conditions are less than ideal. The known poor physical condition of the bypass pipes on which the Polysonics flowmeters are installed, contributes to uncertainties regarding the accuracy of the Polysonics instrument. In addition, no details concerning secondary or cross flow conditions are available, which further contributes to the uncertainty associated with the accuracy of the Polysonics flowmeter. However, realizing that the secondary or cross flow conditions are likely minimal due to the size of the primary bypass pipes, the location of the flowmeters with respect to flow disturbance generating features (i.e, the minimum 20 diameters downstream of the bypass entrance transition exists), and the relatively small flow velocities (i.e, on the order of 3.0 - 8.0 ft/s), the contributing error associated with these considerations is likely small.

Assuming a 5 percent accuracy in the primary bypass discharge is attainable, an uncertainty associated with the indirectly computed parameters (i.e, primary bypass velocity ratios and secondary channel velocity) may be determined by error analysis. From equation (1), the primary bypass velocities ratios are computed using the directly measured primary bypass discharge and the primary louver channel velocity parameters. Again, assuming both of these instruments measure their respective parameters to within 5 percent, the resulting error associated with the primary bypass velocity ratios is determined as:

$$\text{Percent uncertainty} = \sqrt{\left(\frac{\delta Q_{PB}}{Q_{PB}}\right)^2 + \left(\frac{\delta V_{PA}}{V_{PA}}\right)^2}\ X\,100 \qquad (4)$$

Where,

$(\delta Q_{PB}/Q_{PB})$ = Fractional uncertainty associated with the primary bypass discharge measurement, and

$(\delta V_{PA}/V_{PA})$ = Fractional uncertainty associated with the primary louver approach velocity measurement.

The fractional uncertainty is defined as the uncertainty associated with a measured value divided by that value or in this case $(\delta Q_{PB}/Q_{PB})$ for the primary bypass entrance velocity and ($\delta V_{PA}/V_{PA}$) for the primary louver approach velocity. Where, in generalized terms δx is the uncertainty associated with the measuremed parameter, and x is the actual measured parameter. Furthermore, the fractional uncertainty multiplied by 100 gives the percent uncertainty or error. Thus, the error associated with the primary bypass velocity ratios is simply the quadratic sum of the errors associated with the directly measured parameters. For the primary bypass velocity ratio the resulting error would be on the order of 7 percent, based on this analysis.

The same analytical approach can be applied to the indirect computation of the secondary channel velocity based on the directly measured primary bypass discharges. From equation (2), the secondary channel velocity is determined using the sum of the four primary bypass discharge measurements. Again, assuming that each of the four measurements are accurate within 5 percent, the error associated with the calculated secondary channel velocity is comprised of the quadratic sum of the fractional uncertainties for each of the four measurements. This is given as:

$$\text{Percent Uncertainty} = \sqrt{\left(\frac{\delta Q_{B1}}{Q_{B1}}\right)^2 + \left(\frac{\delta Q_{B2}}{Q_{B2}}\right)^2 + \left(\frac{\delta Q_{B3}}{Q_{B3}}\right)^2 + \left(\frac{\delta Q_{B4}}{Q_{B4}}\right)^2}\ X\ 100 \quad (5)$$

Where,

($\delta Q_{B1}/Q_{B1}$), ($\delta Q_{B2}/Q_{B2}$), ($\delta Q_{B3}/Q_{B3}$), ($\delta Q_{B4}/Q_{B4}$) = Fractional uncertainties associated with each of the primary bypass discharge measurements.

Thus, the error associated with the secondary louver approach velocity will be on the order of 10 percent based on this analysis.

The results of this analysis indicate that the errors, associated with the direct measurement of the primary bypass discharge and primary louver approach velocity parameters, will influence the indirectly determined parameter calculations. The propagation of errors was determined by the quadratic sum of the independent parameter errors. This approach is valid, since it can be reasoned that these errors associated with each measurement are independent of each other and are random.

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