St 4. ②
JUN 03 1997

ENGINEERING DATA TRANSMITTAL

Page 1 of 1
1. EDT 617382

2. To: (Receiving Organization) TWRS Safety Programs		3. From: (Originating Organization) Equipment Engineering, 08E00		4. Related EDT No.: n/a	
5. Proj./Prog./Dept./Div.: 241-AN Vent Upgrades/TWRS		6. Design Authority/ Design Agent/Cog. Engr.: Jack F. Thompson		7. Purchase Order No.: n/a	
8. Originator Remarks: #ETN-95-0031				9. Equip./Component No.: n/a	
For release of a supporting document.				10. System/Bldg./Facility: Tank Farms	
				12. Major Assm. Dwg. No.: n/a	
				13. Permit/Permit Application No.: n/a	
11. Receiver Remarks: 11A. Design Baseline Document? [] Yes [X] No				14. Required Response Date:	

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	HNF-SD-WM-TRP-285	--	0	Test Report, Air Flow Control Device for 241-SY Waste Tank Ventilation	NA	2	1	--

16. KEY					
Approval Designator (F)		Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)		1. Approval	4. Review	1. Approved	4. Reviewed no/comment
		2. Release	5. Post-Review	2. Approved w/comment	5. Reviewed w/comment
		3. Information	6. Dist. (Receipt Acknow. Required)	3. Disapproved w/comment	6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)											
(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
		Design Authority				2	1	JT		27 May 97	S2-03
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1	/	Cog. Mgr. DW Crass		H6-11							
		QA									
		Safety									
		Env.									

18. Signature of EDT Originator, JA Tuck		19. Authorized Representative Date for Receiving Organization		20. Design Authority/ Cognizant Manager		21. DOE APPROVAL (if required) Ctrl. No. [] Approved [] Approved w/comments [] Disapproved w/comments	
Date: 27 May 97		Date: 5-27-97		Date: 5-27-97			

Test Report, Air Flow Control Device for 241-SY Waste Tank Ventilation

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U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: 617376-⁶¹⁷³⁸² ₄₈₄₇ ^{Kind}

UC: 506

Org Code: 08E00

Charge Code: C 20887/POHLOO

B&R Code: EW3120071

Total Pages: 15

Key Words: ventilation, confinement, vent balance, air flow control, tank pressure

Abstract: This documents the testing of a passively operated, constant air flow control device for in-duct applications on waste tank ventilation systems in the 50-1000 SCFM range.

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Release Approval

Date

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TEST REPORT, AIR FLOW CONTROL DEVICE FOR 241-SY WASTE TANK VENTILATION

1.0 SUMMARY

This report documents the development and testing of a passively operated, constant air flow control device. Included in this report are a test procedure and test results. Testing determined that the device meets the stated design requirements, specifically with reference to its range of useful operating flow rate, pressure drop across the device, and ability to accurately regulate air flow.

2.0 BACKGROUND AND SCOPE

The testing reported herein is part of an ongoing effort to develop flow control technology suitable for use on waste tank ventilation systems (Minteer 1995; Tuck 1995 & 1997). Testing was conducted 10-17 April 1996, in Room 216 of building 2101M, 200 East area (see Figure 1). Test support was provided by the Vent and Balance organization, John Comer, manager.

Testing was performed to determine whether the subject device (ref. LMHC 1997) can meet or exceed the functional requirements set forth in the engineering work plan (Andersen 1997) and similar to those that governed previous designs (VanderZanden 1995; Minteer 1996; WHC 1995 & 1996) with the exception of flow rate; an increase in size of the device was expected to double the useful flow range over the previous design. Specifically, testing was based on the following design goals:

- Ability of the device to maintain air flow rate within $\pm 10\%$ of a set value, over a range of device differential pressure (δP) from 0.75 to 4.00 inches w.g. (0.19-1.0 kPa).
- Ability to control air flow over a range from approximately 50 to 1000 ft³/min (24-470 l/s).
- Extended device performance below the specified device δP range, i.e. less than 0.75 inches w.g.

3.0 DESCRIPTION

The air flow controller is a passively operated, self-regulating device designed to be installed at a system inlet or in line with a filter housing, ventilation duct header, or other equipment. A single moving part, the port controller, adjusts the internal flow resistance of the device in response to changes in pressure. Increasing pressure across the device causes the port controller to lift, gradually closing the outlet and restricting flow. By this means, an equilibrium is approached with which the device maintains a constant rate of air flow through a ventilation system as the δP across the device (or the system) varies. By means of a view port on the device, this action may be observed in operation as a slight oscillation or levitation of the port controller.

FIGURE 1. Diagram of Flow Control Device Test Setup

(Testing conducted in 2101M, Room 216, 10-17 April 1997,
with assistance of Vent and Balance organization)

The nominal flow rate for the device is set by means of a field-changeable orifice plate. The theory, operation, and attributes of the device are discussed in greater detail elsewhere (Minteer 1995; Tuck 1995).

The device was designed and fabricated per H-2-828962 (LMHC 1997). The referenced drawing is essentially a final, field-useable design, and this supporting document represents the extent of developmental testing performed on the device. The device was scaled up 50% in its critical dimensions from earlier, tested designs (e.g., shell or housing diameter was increased from 12 to 18 inches [31-46 cm]). The intent of this change was to approximately double the flow capacity of the device without affecting other performance parameters.

4.0 METHODS AND MATERIALS

Testing was conducted indoors, in a climate-controlled environment free from drafts or significant variations in air temperature and pressure during the course of testing.

Test equipment included:

- Flow control device, consisting of a shell assembly with port controller installed inside (ref. H-2-828962), orifice plates of assorted sizes, and two pressure taps (1/4-inch [6 mm] hose barbs, located to measure "device δP " and "plate δP ") arranged in a test setup as shown in Figure 1.
- Fan with capacity in excess of 1000 ft³/min at 4.0 in. w.g. static pressure (470 l/s @ 1 kPa), as measured across device being tested, in addition to losses through connecting ductwork between fan and device.
- A "flow measuring duct" consisting of a seven-foot (2.1 m) straight length of 8-inch (20 cm) diameter plain sheet metal duct, with two velocity measurement ports @ 90° apart located 60 inches (1.52 m) from one end (inlet from device), providing the required minimum of 7.5 diameters downstream length per ASHRAE *Fundamentals* (ASHRAE 1993).
- Plenum, same diameter as device shell, with a flanged bottom that mates with the top flange of the flow control device, providing a transition to the measuring duct.
- Transition fittings and flexible duct sections as required to connect the measuring duct to the device being tested, at one end, and the fan at the other end.
- In-line "fan damper" downstream of flow measuring duct to vary the external pressure across the device; in some cases this consists of two dampers in series. The "bypass damper" shown in Fig. 1 was part of the existing test facility and was left closed.
- Duct tape.
- Neoprene gaskets.

- Hardware (bolts and nuts) for joining flanged components.
- Flexible plastic or elastomer tubing, 1/4-in. (6 mm) I.D., for connecting instrumentation to test ports.
- Small Pitot tube with insertion positions marked for an 8-point velocity traverse per ASHRAE *Fundamentals*, Chapter 13, for use on the 8-inch diameter measuring duct.
- Calibrated micromanometers (3) accurate to ± 0.001 inches w.g. (0.25 Pa) over a range of 0.1 to 10.0 inches w.g. (0.025–2.5 kPa); property numbers and calibration dates are recorded on test data sheets.
- Thermometer for measuring room air temperature.

The following tests were performed, including a brief description:

4.1 Nominal Flow Rate and % Error for Various Orifices

The purpose of this test was to demonstrate that the flow controller can meet the requirements of flow and pressure range and maintain constant flow within the same $\pm 10\%$ tolerance as previous designs featuring a removable orifice plate. Also, testing was conducted to document performance data for use in definitive design. Data of interest included flow rates for a range of orifice sizes, to be included on drawings or other documentation.

The flow controller (ref. H-2-828962, or LMHC 1997) was connected to the test setup shown in Figure 1. The flow rate setting of the device was varied using various orifice plates, to obtain orifice diameters ranging from 1/2 to 9 inches (1.3–22.9 cm).

For each orifice plate installed (i.e., each flow setting), the δP across the device (as measured from the δP_1 tap in Figure 1) was varied using the downstream fan damper, from approximately 0.3 to 4.0 in. w.g. (0.07–1.0 kPa). Except in the cases of the smallest orifices (i.e., 1/2 and 1-inch diameter), this range included the minimum δP required to levitate the port controller. At each device δP , measurements were made of measuring duct air velocity and the δP across the bottom plate of the port controller. Velocity readings were taken per standard methods (ASHRAE 1993) and used to derive volume flow rate. Data were analysed statistically and used to generate performance curves for the air flow controller.

In detail, the following test steps were followed (order of damper settings was varied in some cases at the discretion of test engineer):

- 4.1.1 Configure test setup and instruments (as described above).
- 4.1.2 Select and install desired orifice plate and record size at top of data sheet.
- 4.1.3 Close fan damper (downstream, between flow control device and fan).
- 4.1.4 Start fan.

- 4.1.5 Slowly open fan damper until the Port Controller has risen as far as physically possible or the device δP reaches 4.2 ± 0.1 in. w.g. (1.05 ± 0.025 kPa). Note approximate location of Port Controller.
- 4.1.6 Determine the flow rate of air through the device, recording average velocity and flow rate on the data sheet.
- 4.1.7 Record the device and Port Controller plate δP readings on the data sheet.
- 4.1.8 Slowly close the fan damper such that the δP across the device decreases by approximately 0.5 in. w.g. (0.12 kPa) from the previous setting. Smaller or larger increments may be used depending on how many data points are desired. Measure the duct air velocity, the device and plate δP , estimate the location of the Port Controller, and record information on the data sheet.
- 4.1.9 Repeat step 4.1.8 until device δP below 0.5 in. w.g. (0.12 kPa) is reached or the lowest possible device δP occurs without the control port assembly resting on its bottom stop (i.e., not levitating).
- 4.1.10 Close fan damper and shut off fan.
- 4.1.11 Replace orifice plate and record size on a new data sheet.
- 4.1.12 Repeat steps 4.1.4 through 4.1.11 until all of the available orifice sizes have been used, including a 9-inch (22.9 cm) diameter orifice (i.e., no orifice plate installed).
- 4.1.13 Disassemble test equipment.
- 4.1.14 Perform calculations as follows:
- 4.1.14.1 For each data set (i.e. orifice size, or flow setting), calculate the mean flow rate, the sample (unbiased) standard deviation of the measured flow rates, and the estimated error or constant flow uncertainty using the formula below. Record on data sheet.

Estimated Constant Flow Uncertainty (Error), U_{FLOW} :

$$U_{\text{FLOW}}, (\pm \% \text{ flow}), = 100(2\sigma_f/F_m)$$

where: σ_f = the sample standard deviation of measured flow rates
 F_m = the mean flow rate

- 4.1.14.2 If U_{FLOW} is greater than $\pm 10\%$ at any flow setting, discard any obviously out-of-range (i.e., low flow) measurements corresponding to a low device δP while maintaining a lowest measured device δP of no more than 0.75 in. w.g. (0.19 kPa) in the remaining data set. Recalculate U_{FLOW} , if needed for the reduced data set; if U_{FLOW} is decreased from previous calculation, record this second result on the data sheet. If U_{FLOW} is not decreased from previous calculation, record the original result on the data sheet. Also, record the range of measured plate δP for the data set used to calculate the recorded value for U_{FLOW} .

- 4.1.14.3 For each data set, calculate the mean Port Controller plate δP , the sample standard deviation of the measured plate δP , and the estimated error or constant plate δP uncertainty (U_{PL-DP}) using formula below. Record U_{PL-DP} on the data sheet.

Estimated Constant Plate δP Uncertainty (Error), U_{PL-DP} :

$$U_{PL-DP}, (\pm \% \text{ flow}), = 100[\text{sqrt}(1+(2\sigma_{DP}/P_m)) - 1]$$

where: σ_{DP} = the sample or unbiased standard deviation of measured plate δP
 P_m = the mean plate δP

[BASIS: The basis for this formula (Minteer 1995) is that changes in flow through an orifice or other restriction are directly proportional to the square root of the change in δP . The measured "change" in the Port Controller plate δP is taken as $\pm$ two standard deviations. Therefore, U_{PL-DP} and U_{FLOW} are roughly equivalent measures of error but relate to different parameters. Note that changes in plate δP are influenced by experimental uncertainties such as instrument accuracy, test setup, etc. as well as by the device's accuracy; however, the error inherent in measuring flow that contributes to U_{FLOW} , especially at lower flow rates, is eliminated.]

- 4.1.14.4 Record minimum device δP vs. Mean Flow Rate, using the lowest device δP in the data set for each orifice plate; this defines the lower bounds of the operating envelope for the air flow controller, in terms of device δP and flow rate.
- 4.1.14.5 Plot mean flow rate against orifice size and determine the "best match" of the data to a linear or other algebraic function, from which a nominal mean flow rate can be predicted with reasonable accuracy for any orifice size within the range tested; this information will used to specify orifice sizes on the design media, or for planning purposes.

4.2 Relationship of Flow Rate to Port Controller Weight

The purpose of this test was to test the effect of port controller weight on device performance. This test also provides a means of extending the flow range of the device.

A test setup was constructed similar to Figure 1, with no orifice plate in the port controller (9-inch diameter, "set" orifice). A set of steel weight rings, 11-1/4-inch O.D. x 9-1/4-inch I.D. x 0.06 inch thick (28.6 x 23.5 x 0.15 cm), with an approximate weight of 0.56 lb (0.25 kg) each, was fabricated for use in this test. The weight rings fit over the cylindrical portion of the port controller to rest on top of the bottom plate. The weight rings may be stacked in this fashion, providing a means of varying the weight of the port controller without creating a weight imbalance or otherwise adversely affecting its performance.

The same test procedure was followed as in Section 4.1, with the exception that the data sets correspond to various quantities of weight rings, or port controller weights, as opposed to orifice sizes. The flow rate was expected to increase with increasing port controller weight.

5.0 RESULTS AND DISCUSSION

Test #1 (Nominal Flow Rates): Data from the first test are presented in Table 1, below. A population of flow measurements was obtained over a range of device δP for each orifice plate, or flow setting. Both port controller bottom plate δP and flow readings were analysed for a statistical mean and sample standard deviation, corresponding to each orifice plate used. From the mean and standard deviation, derived quantities U_{FLOW} and $U_{\text{PL-}\delta P}$ were computed as described in procedure steps 4.1.14.1 and 4.1.14.3.

Flows down to approximately 50 ft³/min (24 l/s) were tested. That the device is apparently not capable of regulating to lower flows is suggested by the fact that similar flows were measured for both the 1/2-inch and 1-inch orifices; no smaller orifice size was tested.

Flow measurements from orifices less than 3 inches in diameter, corresponding to flows less than 100 ft³/min (47 l/s), exceed the criterion of $U_{\text{FLOW}} \leq 10\%$. With one exception (namely the 8-inch orifice), measured flow rates above 100 ft³/min fall within $U_{\text{FLOW}} \leq 10\%$ and indicate that the device maintains constant air flow in this range, as required. The range extends only to about 700 ft³/min (330 l/s); to obtain higher flow rates the range of the device must be extended using weight rings (this is discussed later, in the results for Test #2).

These results are partly explained by limitations inherent in the use of U_{FLOW} as an indication of error. The measurements provide a reasonably accurate indication of nominal flow rate for a given orifice plate. However, U_{FLOW} relies on the ability to accurately measure the velocity of air flow in the measuring duct and includes some measurement error introduced by use of the Pitot tube to measure flow. The magnitude of this error increases toward the bottom of the useful range for this method (ASHRAE 1993), which in this case corresponds to about 60 ft³/min (28 l/s), or 180 ft/min (0.9 m/s) average velocity in the 8-inch diameter measuring duct. This increase in error at lower flows is readily apparent on inspection of the data in Table 1.

This fact is made more obvious by comparing plate δP data, where generally lower values are seen for " $U_{\text{PL-}\delta P}$ " over the range of flows. Also, the plate δP data show a more consistent performance of the device over the entire range tested. This is explained by the fact that the velocity measurement portion of the total error is eliminated. Based on $U_{\text{PL-}\delta P}$, the results show that the device operates within the required margin of error, with the exception of the 1/2-inch and 8-inch diameter orifices. As suggested above, the case of the 1/2-inch diameter orifice is probably below the useful operating range of the device and the corresponding data not relevant.

In the case of the 8-inch diameter orifice, calculated error was high in the case of both flow and plate δP measurements, which is inconsistent with the overall results and would indicate a possible problem with the data. On examination of the data, it was apparent that the relatively high error could be attributed to a single data point. Specifically, the data in question corresponded to a device δP of 0.52 in. w.g. (0.13 kPa), a plate δP of 0.227 in. w.g. (0.0565 kPa), and a flow rate of 447.2 ft³/min (211 l/s); each of these quantities represents an extreme minimum in the range of measurements

TABLE 1. Test Results for 18-inch Diameter Flow Controller

ORIFICE DIAMETER, IN.	ORIFICE AREA, IN ²	NUMBER OF δP SETTINGS, OR MEASUREMENTS	MEAN FLOW*, CFM	STD. DEV. (σ), CFM	U(FLOW), OR (2 σ /MEAN) x100%	DEVICE δP RANGE, IN. WG	RANGE OF PLATE δP OVER DEVICE USEFUL RANGE, IN. WG	MEAN PLATE δP , IN. WG	U(PL-DP)* (PLATE) [SEE TEXT]
1/2	0.1963	12	51.3	7.72	30.2	0.42-4.15	0.262-0.435	0.303	16.8
1	0.7854	10	55.1	7.75	28.2	0.50-4.10	0.262-0.328	0.274	7.2
1-1/2	1.7671	12	61.8	7.29	23.6	0.33-4.08	0.260-0.281	0.265	2.1
2	3.1416	10	81.4	5.43	13.4	0.43-4.13	0.258-0.280	0.270	2.5
2-3/8	4.4301	11	81.9	5.78	14.2	0.34-4.13	0.260-0.271	0.267	1.3
2-1/2	4.9087	11	92.1	5.52	12.0	0.50-4.09	0.250-0.286	0.269	4.3
3	7.0686	14	106.4	3.65	6.8	0.35-4.08	0.253-0.277	0.268	2.3
3-1/2	9.6211	10	127.5	3.27	5.2	0.44-4.16	0.262-0.290	0.279	3.2
4	12.5664	10	150.3	2.91	3.8	0.36-4.10	0.261-0.291	0.277	3.6
5	19.6350	12	220.2	3.42	3.2	0.31-4.12	0.263-0.294	0.280	3.9
6	28.2743	9	307.8	6.32	4.2	0.40-4.10	0.281-0.320	0.295	4.7
7	38.4845	12	426.0	7.75	3.6	0.42-4.06	0.285-0.324	0.306	4.0
8**	50.2655	9	562.9	44.67	15.8	0.52-4.09	0.227-0.368	0.327	12.1
9	63.6173	8	722.8	34.01	9.4	0.40-4.20	0.309-0.368	0.346	5.7

* Standard deviation not listed for plate δP measurements. U_{PL-DP} , a quantity derived from the mean and standard deviation, is presented alone. See Sec. 4.1 for a definition and further explanation of U_{PL-DP} .

** The values of U_{FLOW} and U_{PL-DP} are reduced to 4.0% and 5.9%, respectively, by eliminating a single data point; see text for discussion.

recorded for the corresponding parameter. It was also noted during testing that, when the data in question were recorded, the port controller was resting at the bottom of its travel and not levitating (which would have indicated proper functioning of the device).

At the next lowest device δP of 0.88 in. w.g., it was noted that the port controller was floating well above its bottom stop, as could be expected, and the recorded plate δP and flow data were within the range of other recorded values. If the apparently out-of-range data point is deleted, the values of U_{FLOW} and $U_{\text{PL-PP}}$ are reduced to 4.0% and 5.9%, respectively.

Therefore, disregarding the data points discussed above for the 1/2-inch and 8-inch orifice plates, and taking into consideration the above discussion of measurement error inherent in U_{FLOW} , the results demonstrate that the device meets the design requirements stated in Section 2.0 of this report for flow rates ranging from approximately 55 ft³/min (26 l/s) to greater than 700 ft³/min (330 l/s). The best performance appears to be above 100 ft³/min (47 l/s), where calculated error in the form of both U_{FLOW} and $U_{\text{PL-PP}}$ is below 10%. The results for the second test conducted will demonstrate how the device range can be extended beyond 1000 ft³/min (470 l/s) by the addition of weights to the port controller.

The range of measurements taken on most of the orifice plates extended below 0.5 in. w.g. (0.12 kPa), less than the 0.75 in. w.g. design criterion in Section 2.0. The minimum device δP required to levitate the port controller, an indication the device is functioning, averaged less than 0.3 in. w.g. (0.07 kPa). Therefore, the useful δP range of the device apparently extends to considerably below the required 0.75 in. w.g. for flows up to 700 ft³/min. In addition, the minimum operating device δP is apparently constant over the full range of orifice plates tested. This is consistent with results reported for previous orifice-based designs (Tuck 1995), and confirms previous conclusions that the minimum operating device δP is more a function of port controller weight and area than of orifice diameter, or flow setting.

The results of previous testing on an adjustable flow control device suggested ways to improve the design to minimize pressure losses and increase the flow range (Tuck 1997). These included reducing outlet losses by increasing the diameter of the cylindrical part of the port controller, with a corresponding increase in shell diameter to accommodate it. Both these dimensions were increased by 50% over the previous 12-inch diameter shell design, with a corresponding doubling of cross section area. The result, as shown by these results, is that the flow range of the device is approximately doubled without any loss of performance, as a result of this simple design change.

In accordance with procedure step #4.1.14.5, flow data were analysed by standard linear regression to determine a "best-fit" curve out of four possible models: linear, exponential, logarithmic, and power curve. Flow rates correlate well with orifice size (area) in a linear relationship, consistent with theory. This is readily apparent from a graphical representation of the data (Figure 2, next page), especially over 125 ft³/min (59 l/s). Below this flow rate, the curve can be seen to diverge somewhat from the straight line, its slope decreases and the vertical axis is intersected closer to 50 ft³/min than the origin; this probably indicates that the relative contribution of leakage around the port controller plate becomes

FIGURE 2. Flow vs. Orifice Size Data, Test #1
(Lines indicate "best fit" linear equations; see text)

TABLE 2. Test Results using Weighted Port Controller, Test #2

NUMBER OF WEIGHT RINGS*	WEIGHT OF PORT CONTROLLER, LB	NUMBER OF δP SETTINGS, OR MEASUREMENTS	MEAN FLOW*, CFM	STD. DEV. (σ)*, CFM	U(FLOW)*, OR (2 σ /MEAN) x100	DEVICE δP RANGE*, IN. WG	RANGE OF PLATE δP OVER DEVICE USEFUL RANGE, IN. WG	MEAN PLATE δP , IN. WG	U(PL- δP) (PLATE) [SEE TEXT]
0	2.03	8	722.8	34.01	9.4	0.40-4.20	0.309-0.368	0.346	5.7
1	2.59	10	801.8	10.22	2.6	0.50-4.30	0.407-0.462	0.444	4.0
2	3.15	6	898.9	8.50	1.8	0.71-3.90	0.530-0.570	0.553	2.7
3	3.71	9	990.7	19.99	4.0	0.73-4.20	0.588-0.640	0.619	2.6
4	4.27	11	1040.8	33.15	6.4	0.74-4.10	0.672-0.769	0.749	3.7
5	4.83	10	1105.3	63.56	11.6	0.68-4.00	0.620-0.872	0.834	8.7
6	5.39	10	1175.7	22.28	3.8	0.99-4.08	0.930-0.974	0.957	1.6

* All measurements made on port controller with 9-inch diameter, or 63.6173 in², orifice opening (i.e., no orifice plate installed). Data for zero weight rings repeated from Table 1.

significant at lower flows. It was also observed, at these lower flows, that the port controller operated at the top of its travel, i.e. practically closed, over all or most of the range of device δP tested.

Therefore, if the data for flow rates over 125 ft³/min are segregated from the rest, the following equation defines the relationship between flow rate and orifice size for these higher flow rates:

$$CFM = [11.076 \times (ORIFICE\ AREA, SQ.IN.)] + 7.654$$

The remaining data (flow rates less than 125 ft³/min) fits well with the following equation:

$$CFM = [8.1812 \times (ORIFICE\ AREA, SQ.IN.)] + 49.654$$

Either of the above equations give a better fit to the applicable data than a single linear equation based on the entire data set.

Test #2 (Weighted Port Controller/Extended Flow Range): Test data for the Test #2 are tabulated above. The "flow settings" in this case are quantities of weight rings, from 1 to 6, which varied the port controller weight from 2 to over 5 lb (0.9-2.3+ kg). The weight rings extended the total tested range to over 1100 ft³/min (520 l/s).

As in Test #1, port controller plate δP and flow readings were analysed statistically for each quantity of weight rings (i.e., flow setting) over a range of δP . From the mean and standard deviation, derived quantities U_{FLOW} and U_{PL-PP} were computed as described in procedure steps 4.1.14.1 and 4.1.14.3. Again, the results show that the device meets the design criteria stated in Section 2.0. From the data presented, the set flow rate appears to increase linearly with port controller weight.

6.0 CONCLUSIONS

Testing verified that the air flow control device will perform over the design range of flow and δP , meeting the functional requirements as stated in the Section 2.0, and will accurately regulate flow from approximately 50 to 1000 ft³/min.

The device was designed in response to recommendations in a previous test report (Tuck 1997). These recommendations included:

- Increase diameters of port controller cylinder and outer shell by approximately 50% (e.g., from 6 to 9 in. [15 to 23 cm] and from 12 to 18 in. [31 to 46 cm], respectively), for an approximate doubling of cross section area and flow range.
- Retain the original orifice-based design, with its more efficient upward-flow pattern, devising a means of changing the orifice plate with a minimum of disassembly so that adjustability is not sacrificed.

Testing showed that the resulting design changes produced the expected results.

7.0 RECOMMENDATIONS

Based on the data and observed performance of the device, it is recommended that the 18-inch diameter flow controller design (LMHC 1997) be used primarily for flows in excess of 125 ft³/min (59 l/s). For lower flows, the previous 12-inch diameter design (WHC 1995 or 1996) is more ideally suited for controlling air flow and may be somewhat more accurate. The design for the 18-inch diameter device does, however, include orifice plates for nominal flows down to 50 ft³/min.

8.0 REFERENCES

- Andersen, J. A., 1997, *Engineering Work Plan and Design Basis for 241-SY Ventilation Improvements*, HNF-SD-WM-WP-343, Rev. 0, Lockheed Martin Hanford Company, Richland, Washington.
- ASHRAE, 1993, *Fundamentals Handbook*, American Society of Heating, Refrigerating, and Air Conditioning Engineers, Atlanta.
- LMHC, 1997, *Airflow Controller* [for 241-SY Tank Farm], H-2-828962, Rev. 0, Lockheed Martin Hanford Company, Richland, Washington.
- Minteer, D. J., 1995, *Development and Testing of a Passively-Operated Air Flow Control Device*, WHC-SD-WM-TRP-234, Rev. 1, Westinghouse Hanford Company, Richland, Washington.
- Minteer, D. J., 1996, *Design Basis for Tank Inlet Air Control Stations in the 241-AN Tank Farm*, WHC-SD-WM-DB-032, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Tuck, J. A., 1995, *Test Report, Constant Air Flow Control Device for 241-AW Tank Farm*, WHC-SD-WM-TRP-247, Rev. 0 & 0-A, Westinghouse Hanford Company, Richland, Washington.
- Tuck, J. A., 1997, *Test Report, Adjustable Air Flow Control Device for Waste Tank Ventilation Systems*, WHC-SD-WM-TRP-247, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Tuck, J. A., 1997, *Test Report, Adjustable Air Flow Control Device for Waste Tank Ventilation Systems*, WHC-SD-WM-TRP-247, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- VanderZanden, M. D., 1995, *Design Basis for Inlet Filters and Constant Flow Devices in 241-AW Tank Farm*, WHC-SD-WM-DB-030, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- WHC, 1995, *Airflow Controller* [for 241-AW Tank Farm], H-2-85608, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- WHC, 1996, *Airflow Controller* [for 241-AN Tank Farm], H-2-85647, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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