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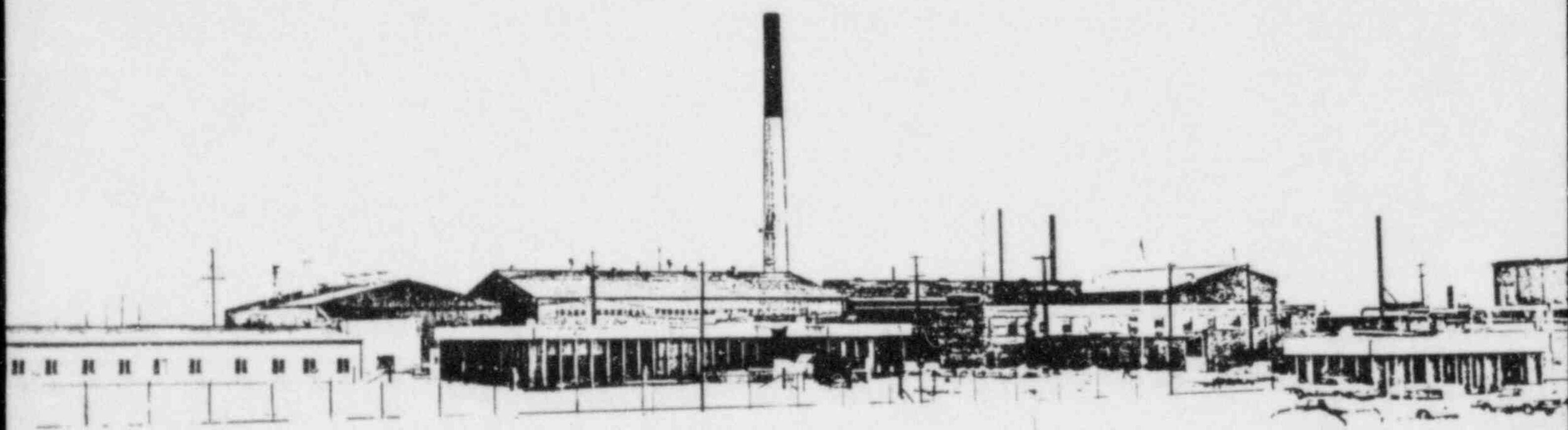
MECHANICAL RELIABILITY EVALUATION OF ALTERNATE MOTORS FOR USE IN A RADIOIODINE AIR SAMPLER



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MECHANICAL RELIABILITY EVALUATION OF ALTERNATE MOTORS FOR USE IN A RADIOIODINE AIR SAMPLER

by

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March 1984

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ABSTRACT

Detailed mechanical reliability studies of two alternate motors identified for use in the BNL Air Sampler were conducted. The two motor types were obtained from Minnesota Electric Technology, Incorporated (MET) and TCS Industries (TCSI). Planned testing included evaluation of motor lifetimes and motor operability under different conditions of temperature, relative humidity, simulated rainfall, and dusty air.

The TCSI motors were not lifetime tested due to their poor performance during the temperature/relative humidity tests. While operation on alternating current was satisfactory, on direct current only one of five TCSI motors completed all environmental testing.

The MET motors had average lifetimes of 47 hours, 97 hours, and 188 hours, respectively, and exhibited satisfactory operation under all environmental test conditions. Therefore, the MET motor appears to be the better candidate motor for use in the BNL Air Sampler. However, because of the relatively high cost of purchasing and incorporating the MET motor into the BNL Air Sampler System, it is recommended that commercial air sampler systems be evaluated for use instead of the BNL system.

ACKNOWLEDGEMENT

The authors thank Dr. P. Reed of the Siting and Environmental Branch, Mr. E. Williams of the Preparedness Development and Incident Response Branch, Dr. S. Block of the Radiological Assessment Branch, and Dr. S. McGuire of the Human Factors and Safeguards Branch, for their assistance in providing background material, technical consultation, and program guidance and draft report review. Appreciation is also extended to Mr. G. Vivian of the Reactor Operations and Programs Division, Department of Energy--Idaho Operations Office, for his assistance in program coordination. Lastly, the authors express appreciation to Dr. D. L. Plung for technical editing of the report.

SUMMARY

A prototype system is being developed for collecting and measuring airborne radioiodine in the environs of a nuclear reactor following an accident. This BNL Air Sampling System will allow government agencies to determine the magnitude of the releases and, thereby, to evaluate radiological consequences and recommend suitable protective actions.

As part of the development work for this system, previous mechanical reliability studies identified a deficiency with the motor originally used. Accordingly, two alternate motors, which had performed satisfactorily during limited evaluations, were recommended for further testing. The purpose of this study, therefore, was to evaluate these two alternate motors using lifetime testing and testing under various extreme operating conditions of temperature, relative humidity, rainfall, and dusty air.

Twenty motors were obtained, ten each from Minnesota Electric Technology (MET) and TCS Industries (TCSI). When operated on alternating current, the TCSI motors operated satisfactorily for all test conditions; yet, when on direct current, all but one of five motors failed. Therefore, these motors were not considered adequate for the air sampler system and the lifetime testing was not conducted.

In comparison, the MET motors (which are DC only) operated satisfactorily for all test conditions. Subsequent testing of these motors indicated lifetimes from 47-188 hours. As a result of these operating and lifetime tests, it was determined that the MET motors are a better potential replacement for use in the BNL Air Sampling System. However, because of the relatively high cost to manufacture, purchase, and incorporate the MET motors into the BNL system, it may be more cost effective to procure commercial air sampling equipment.

CONTENTS

Page

I. INTRODUCTION

Airborne radionuclide releases from damaged nuclear power facilities must be quantified by emergency response personnel to allow accurate evaluation of the radiological consequences and thereby allow recommendation of commensurate protective actions. To fulfill the demand for these environmental monitoring capabilities, a prototype air sampling system for collecting and measuring the concentration of airborne radioiodines was developed by the Safety and Environmental Protection Division at Brookhaven National Laboratory (BNL).

Exxon Nuclear Idaho Company, Inc. (ENICO)[a] at the Idaho National Engineering Laboratory (INEL) performed an independent assessment[1] of the BNL Air Sampling System to determine the mechanical performance of the air samplers and to identify any operational deficiencies of the system components. Reliability tests were conducted under varying environmental conditions of temperature, relative humidity, rainfall, dust-laden air, and vibrational and mechanical stress. The operational lifetimes of the air mover motors were also evaluated. Based on these studies, the original BNL motors were determined to be unsatifactory, based on two functional inadequacies: 1) they would not operate at ambient temperatures of $0^{o}F$ or less; and 2) the lifetimes of the motors were unsatisfactorily short.

Consequently, limited testing was conducted on three additional types of motors. Two of the three motors acceptably completed these tests, and recommendations were then made to perform detailed environmental and lifetime testing to determine which motor was the more appropriate replacement for use in the BNL Air Sampling System.

This report describes the detailed testing of these two alternate motors. Ten of each motor were procured from TCS Industries (TCSI) and Minnesota Electric Technology, Inc. (MET) for evaluation. Five of each motor were to be subjected to varying conditions of temperature, relative humidity, rainfall, and dust-laden air. The remaining five motors were to undergo lifetime testing.

A description of the BNL Air Sampler, the MET and TCSI motors, and the experimental testing procedures and results are given in Section II of this report. Section III details the results and recommendations of the study.

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a In March 1984, Westinghouse Idaho Nuclear Company took over administration of this contract.

II. DESCRIPTION OF BNL AIR SAMPLERS, EXPERIMENTAL PROCEDURES, AND TEST RESULTS

The prototype air sampler designed by BNL[2] to collect radioiodine is shown schematically in Figure 1. The air sampler consists of: 1) a removeable HEPA filtered radioiodine collection canister containing silver impregnated silica gel adsorption medium; 2) a dual voltage motor with an impeller to move the air; 3) a bellows/bleed port combination to adjust the air flow; 4) a 600-watt dimmer switch to adjust the motor speed on alternating current; and 5) the motor housing.

The samplers are to be used to collect samples of five minutes duration at a flowrate of 5.0 ± 0.5 SCFM with either a 110 VAC or a 12 VDC power source. Following collection of the samples, the adsorption medium canisters are removed from the air samplers and analyzed for radioioidine content with a portable radiological survey meter equipped with a specially-shielded Geiger-Mueller detector.[2]

The original motors evaluated in the BNL Air Sampler studies[1] failed at low temperatures and had relatively short motor lifetimes. Accordingly, the objective of the ENICO testing program was to determine, under various simulated environmental conditions, the mechanical performance characteristics of alternate air samplers and air sampler components. Of three alternate motors selected for limited evaluation, two motors were subsequently identified as possible candidates for use in BNL Air Sampler.

The first motor selected was a dual voltage (12 VDC/110 VAC) motor supplied by TCS Industries (TCSI) (Figure 2). This motor was an unencased, dual coil, series wound, nonpermanent magnetic field. Motor dimensions were 11.0-cm diameter by 20-cm long. Each motor weighed approximately 0.76 kilograms and cost $34. Although design specifications could not be obtained, measurements indicated nominal operational parameters of 13.8 VDC, 14 amperes, and 20,000 revolutions per minute (rpm's). Each motor employed two pairs of armature brushes, one for AC and one for DC operation. The motors had sleeve bearings.

The second motor selected was a single voltage motor (12 VDC) supplied by Minnesota Electric Technology, Inc. (MET) (Figure 3). These motors were 0.25 horsepower-rated, series wound, permanent magnetic field motors encased in 8.25-cm diameter by 17.8-cm long housings. Each motor with housing weighed approximately 3.6 kilograms and used a single pair of armature brushes. Design specifications were intermittant duty, 12 VDC only, 27.4 amperes, and 10,000 rpm's. Ball bearings are used in the MET motors.

The actual tests performed are described in Subsections 1-4 below. Included within each subsection are the descriptions of the experimental procedures, the equipment used, and the measurement results. Section 5 summerizes the modes of air sampler failures observed during the tests.

Due to the failure of the TCSI motors during the temperature/relative humidity testing, no lifetime, dust loading, or rainfall testing was conducted with them.

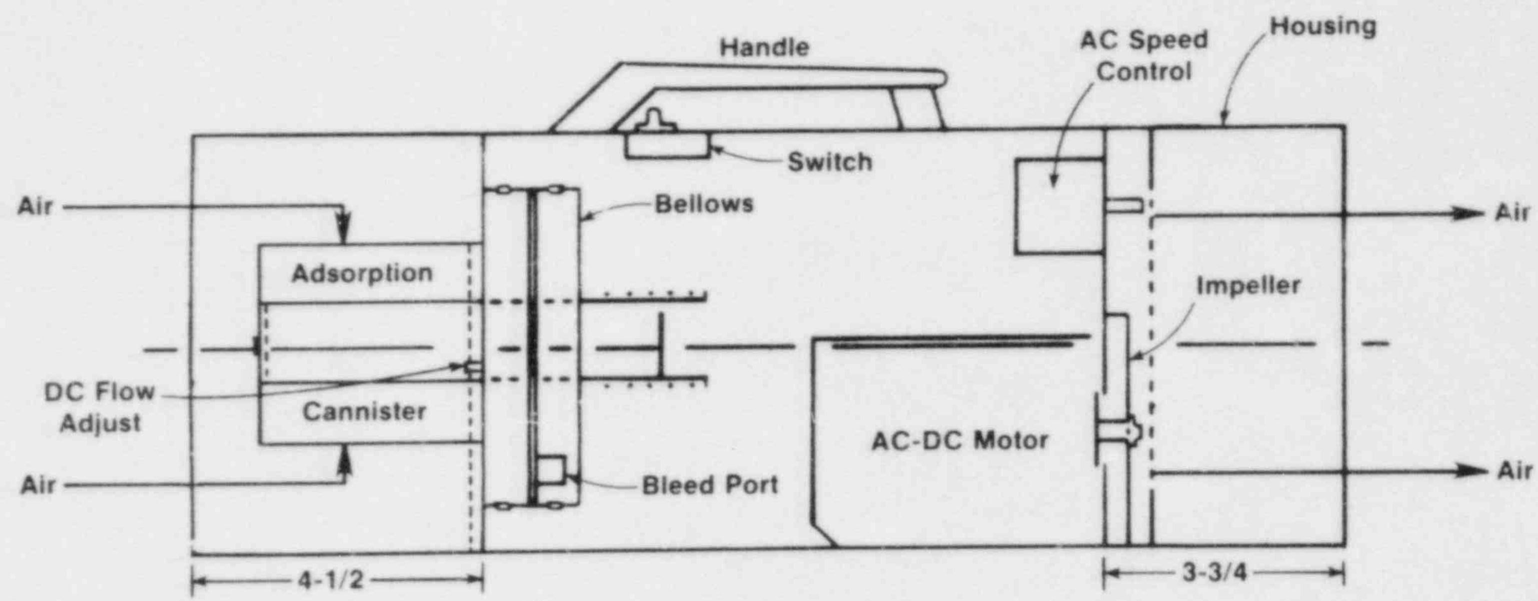

Figure 1. BNL Air Sampler (Schematic)

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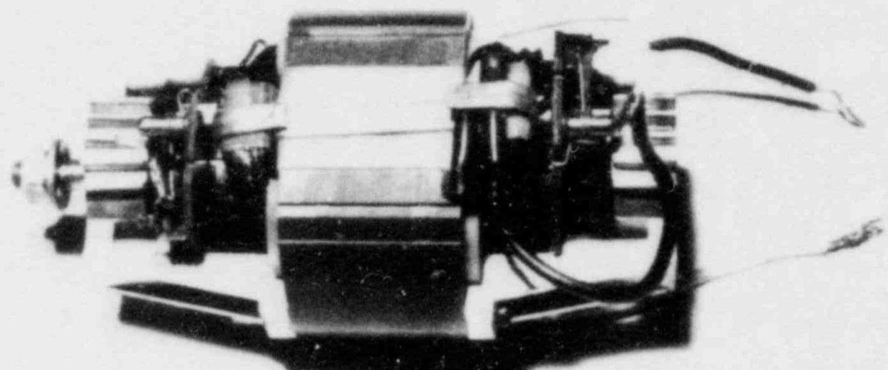

Figure 2. TCSI Industries Motor

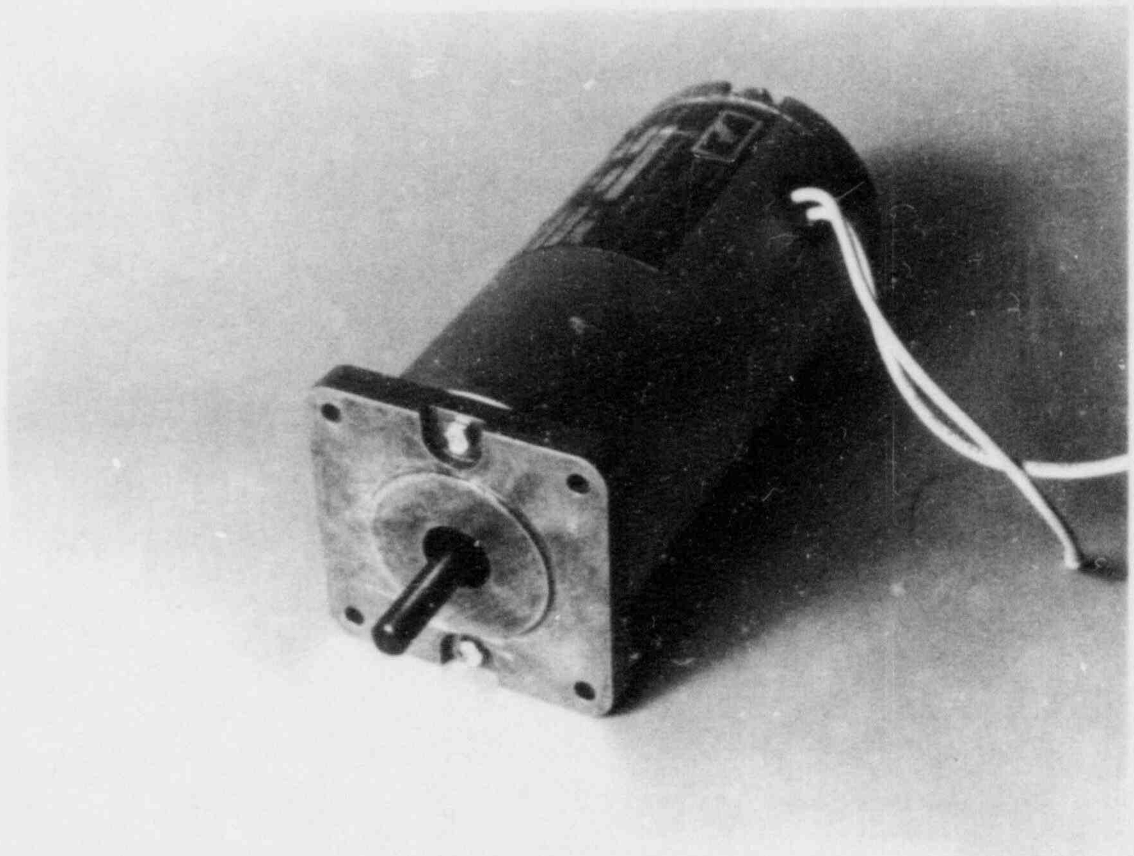

Figure 3. Minnesota Electric Technology Motor

1. Temperature and Humidity Testing

To establish the uniformity and repeatability of the BNL air samplers, the flowrates of the samplers under different temperatures, relative humidities, and operational voltages were measured. The six sets of temperature and relative humidity conditions tested were: 1)110^{o}F at 100% RH[a], 2)110^{o}F at 36% RH, 3)90^{o}F at 100% RH, 4)90^{o}F at 38% RH, 5)0^{o}F at 100% RH, and 6)0^{o}F at 100% RH. For each of these sets of conditions, ten tests each of fifteen minutes duration were performed. Five TCSI motors were tested on both on AC and DC voltage; five MET motors were tested on DC voltage.

The Environmental Test Chamber (ETC) used to simulate the desired temperatures and relative humidities was a BMA, Inc., Model TH-8C (Figure 4)[b]. It has an eight cubic feet internal working volume and uses wet and dry bulb thermocouples to control the temperatures from -85 to + -350^{o}F and humidities from 10 to 100%. The wet bulb and dry bulb temperatures are continuously recorded with a 24-hour Honeywell recorder, Model AR11AMS1057. The ETC temperature and relative humidity sensors were calibrated prior to testing.

To monitor the air sampler flowrates, Matheson Model 8115-3215 linear mass flowmeters, with Model H-3MS/L-5 transducers, were employed. The mass flowmeters and transducers were designed to operate over all humidities and temperatures in the test program. The mass flowmeter outputs were coupled to a Leeds and Northrup Speedomax® multipoint recorder. The mass flowmeters/transducers and recorders were calibrated prior to testing and at six month intervals.

Appropriate power sources were used for operation of the air samplers. Power for ACV operation was from a 110 VAC, 20-ampere laboratory service; power for DCV operation was a 0-18 VDC, 22-ampere regulated power supply.

The testing under each of the six temperature/relative humidity conditions was done in four steps: 1) The conditions to be tested were determined. 2) The equipment was assembled. The assembling step included coupling the mass flowmeter/transducers with Tygon® tubing to the air samplers (Figure 5) and placing the transducer/air sampler assemblies in the ETC. The mass flowmeters, the power sources, and the recording devices were connected via cabling through a small opening in the wall of the ETC. 3) The air sampler flowrates were set by adjusting the air sampler bellows /bleed port or the 600-watt rheostat. Although the samplers' flowrates could have been adjusted to 5.0 SCFM, the flowrate of each sampler was set at slightly different values to facilitate interpretation of the recorder charts. 4) The experiment was run. The ETC,

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a Relative humidities of 100% were estimated based on observed condensation in the test chamber.

b The mention of any specific equipment or apparatus in this report should not be construed as an endorsement or recommendation of the equipment or apparatus.

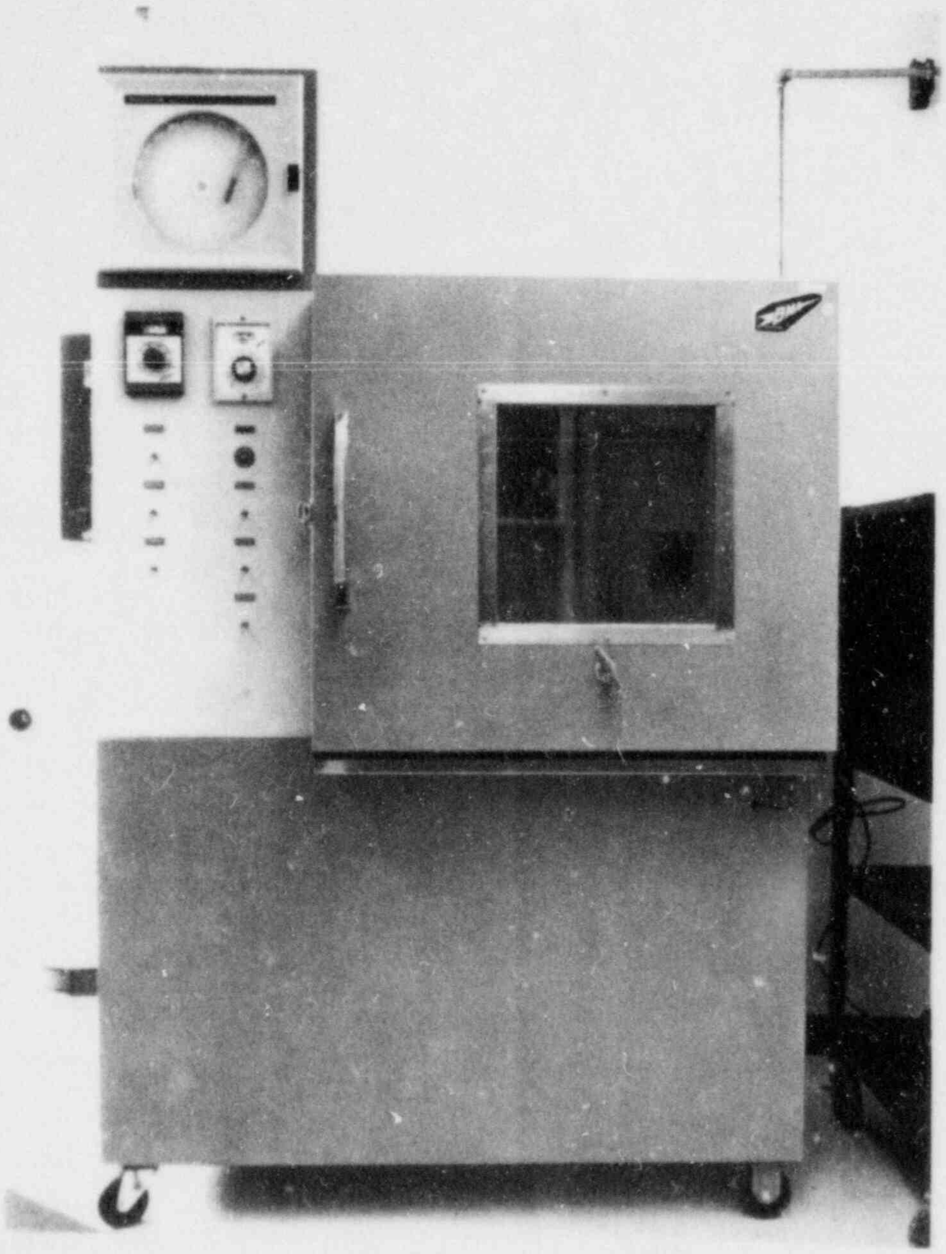

Figure 4. Environmental Test Chamber

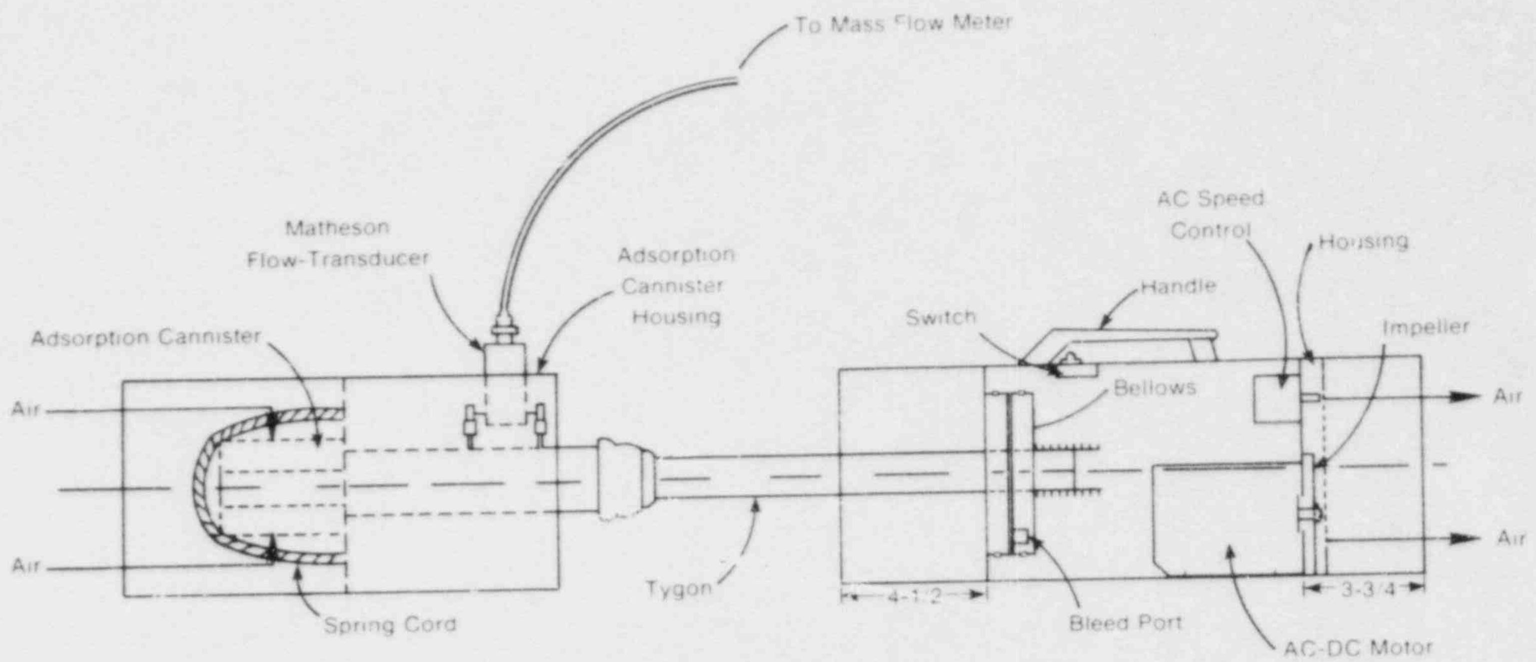

Figure 5. BNL Air Sampler/Mass Flowmeter Transducer Test Assembly (Schematic)

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the two air samplers, and the transducers were allowed to stabilize at the given test condition (normally one hour) and then experiments were performed: The air samplers were started, the voltages and sampler flowrates noted, the samplers run for fifteen minutes, and then the air samplers were turned off. Ten such tests were run for each set of test conditions, with approximately 10 minutes between each test.

The TCSI motors performed well and completed all tests on AC power, with run times of 960, 945, 945, 935, and 930 minutes. However, as shown on Table I, only one of the five motors completed the testing when run on direct current. The short lives of these motors is most likely due to a functional deficit rather than an effect of temperature or relative humidity. This conclusion is supported by the fact that motor failure did not occur as a consequence of the testing sequence (Table I). Additionally, the four failed motors exhibited a residue buildup on the brushes, apparently composed of brush carbon and excess bearing lubricant from the sleeve bearing on the DC side of the motors.

In contrast to the TCSI motors' performance, the five MET motors operated reliably throughout all of the temperature and relative humidity testing on DC power. Total operating times of the motors were 980, 960, 945, 945, and 930 minutes. The difference among the total operating times for the motors completing six series of tests is attributed to the amount of time required for the motors to stabilize during the break-in period at room temperature.

In addition, the uniformity and repeatibility of flowrates was also evaluated to determine each motor's reliability. Uniformity is the accuracy of flowrate between a number of identical motors; repeatability is the precision of one motor for reproducing the same flowrate after repeated trials.

The TCSI motors produced flowrates that were uniform and reproducible to better than 10% when operated on AC power. This variance increased when the motors were tested on DC power but generally tended to be better than 20% at temperatures above $0^{o}F$. Below $0^{o}F$, the repeatability of the motors remained at less than 10% but the uniformity variance increased to 16 to 17%. A greater variation in the flowrate ranges was also noted at the lower temperatures.

The MET motors provided better than 10% repeatability for flows at all temperatures tested. Uniformity was better than 10% at temperatures above $0^{o}F$, better than 20% at temperatures below zero.

Additionally, a comparison of the actual volumetric flowrates with the different temperature/relative humidity conditions was conducted to evaluate the reproducibility of air sampler flowrates. This data also indicated that the uniformity and repeatability are less than 10% at the higher temperatures and decrease in uniformity with temperatures below $0^{o}F$. (The data regarding repeatability and uniformity of flowrates, along with calculational methods used to reduce the data, are provided in Appendix A.)

TABLE I

TCSI MOTORS TESTED ON DIRECT CURRENT

Environmental Conditions	Motor Tested 1	2	3	4	5
110°F at 90% RH	NT[a]	97-1[b,c]	128-1	150-5	NT
110°F at 30% RH	NT	NT	66-2[c]	150-4	NT
90%F at 90% RH	NT	NT	NT	150-6	NT
90°F at 30% RH	NT	NT	NT	150-3	101-1[c]
0°F	135-2[c]	NT	NT	150-1	NT
-20°F	150-1	NT	NT	150-2	NT
Room Temperature	60	30	120	140	30
Total Operating Time (min)	345	127	314	1040	131

a NT - Not tested, motor failed during a previous test series.

b The number to the left of the dash indicates the total opera- ting time (min) completed. The number to the right of the dash indicates the sequence of testing; for example, for motor 1, the first set of tests was carried out at -20°F, the second series at 0°F.

c Motor failed during this series of tests.

2. Rainfall Testing

To study the possible effect of rainfall on the air sampler's performance, a limited number of tests were performed with two MET motors. The tests involved placement of the air samplers in a 0.5 inches/hour simulated rainfall for one hour, removing the samplers, and subsequently measuring the sampler flowrates. The air samplers were not operating while exposed to the rainfall. Due to their failure in the temperature/relative humidity tests, no rainfall tests were performed with the TSCI motors.

Flowrates were determined using the mass flowmeter/transducer instruments described in Section 1. Tests were performed outdoors, with a water nozzle used to produce the 0.5 inches/hour rainfall. The nozzle was placed approximately 10 feet from the air sampler and the three-inch-diameter (21 square inches) rain gauge. The nozzle was directed upward at approximately a 65^{o} angle and the water adjusted to give the desired rate of precipitation. Also, as with the temperature/relative humidity tests, the rainfall tests were conducted in series of ten tests at fifteen minutes duration each and the data were reduced using the calculational methods detailed in Appendix A.

The results of the simulated rainfall studies indicate that exposure to rain does not affect the air sampler's performance. As shown in Tables II and III, the sampler volumetric flowrates are uniform and reproducible to better than 10 percent.

3. Dust Loading Tests

To study the possible effects of dust-ladden air on the air sampler's performance, the air sampler flowrates of three MET motors were measured immediately before, during, and after the samplers were exposed to the dusty air. Each measurement lasted for fifteen minutes. As noted, due to the failure of the TCSI motors in the temperature/relative humidity tests, no dust loading tests were performed with these motors.

HEPA filters were tared prior to attachment to the outside of the sample canisters. The air samplers were placed in an eight-foot laboratory hood with an inverse cyclone-type particle generator[3] and a 300 CFM squirrel cage blower. Clay sieved to less than 100 microns was used in the cyclone as the source of dust particles. The cyclone was driven with compressed air and its output fed directly into the discharge of the squirrel cage blower, which, in turn, flowed over the adsorption canisters and samplers.

Afterward, the tared HEPA filters were weighed to determine the dust concentration and the dust loading of the HEPA filters. The dust concentrations ranged from 248 to 334 mg/m^3; the dust loadings varied from 3.1 to 4.4 mg/cm^2. These dust concentrations are many times the limits of the Environmental Protection Agency air quality standards[4] and are considered a stringent test on motor operation. Table IV indicates the reduction in sampler flowrates that occurred due to dust loading of the HEPA filter.

TABLE II

REPEATABILITY OF ACTUAL VOLUMETRIC SAMPLER FLOWRATES AFTER
0.5 INCHES OF RAIN FOR ONE HOUR (MET MOTORS)
INCHES OF RAIN PER ONE HOUR

Test Condition	Sampler	Ave Median Flow (A_m, ACFM)	Standard Deviation (S)	Number of Tests (n)
First Test	1	6.28	5.2%	10
First Test	4	6.51	10.1%	10
Second Test	1	6.39	3.8%	10
Second Test	4	6.43	2.3%	10
Overall Averages	1	6.34	4.5%	10
Overall Averages	4	6.47	7.3%	10

TABLE III

UNIFORMITY OF ACTUAL VOLUMETIC SAMPLER FLOWRATES AFTER
0.5 INCHES OF RAIN FOR ONE HOUR (MET MOTORS)

Test Condition	Sampler	Ave Median Flow Variation (A_r)	Max. Range Variation (V_m)	Number of Test (n)
First Test	1	6.74%	17.99%	10
First Test	4	14.37	65.24%	10
Second Test	1	5.12%	13.68%	10
Second Test	4	6.24%	27.63%	10
Overall Averages	1	5.93%	15.84%	10
Overall Averages	4	10.31%	46.44%	10

TABLE IV

ACTUAL VOLUMETRIC SAMPLER FLOWRATES BEFORE AND AFTER DUST LOAD TESTING (MET Motors)

Test Condition (mg/m_3)	Sampler	Filter Dust Load (mg/cm^2)	Flow (ACFM) Before	Flow (ACFM) After	Range Variation	Number of Tests (n)
334.0	1	4.36	4.55	4.08	10.9%	1
248.5	4	3.10	4.26	4.00	6.3%	1
311.4	8	4.37	5.17	4.09	23.3%	1

4. Lifetime Testing

To determine the lifetime of the motors, tests were performed at 110°F/100% relative humidity on three of the MET motors. To perform these tests, the motors were individually placed in the environmental test chamber and allowed to equilibrate to 110°F and 100% relative humidity. The air samplers were then started, the voltages and sampler flowrates initially noted, and additional voltages and flowrates recorded every 10 hours until failure. (Flowrate less than 4 SCFM was considered indicative of failure).

Table V presents the observed flowrates as a function of the number of hours of operation for each of the motors tested. The motors exhibited uniform flowrates (to better than 10%) throughout their lifetime tests. The operating lifetimes of the motors were 43, better than 65 hours, and 170 hours. Failure of all three motors was apparently due to factory misalignment of the brushes with the commutator, as shown in Figure 5. All failures occurred in less than five hours after flowrates began dropping and amperage draw increased.

5. Failure Modes

The mode of failure of each of the TCSI motors tested on DC voltage, based on inspection, was excessive bearing lubricant flowing onto the commutator and/or brushes. The buildup of residue (consisting of bearing lubricant and brush carbon) between the brushes and the commutator appeared to preceed motor failure. The sequence of the tests performed, in relation to temperature and humidity, had little or no affect on the failure of the motors; motors failed even when the testing sequence was varied from one condition to another.

The MET motor failures were apparently due to factory misalignment of the brushes with the commutator. The commutator would wear a 2 mm lip on the brushes (the brushes were actually overhanging the commutator), which would then fracture as the testing progressed (Figure 5). It is anticipated that the lifetime of the motors would have been greater if the brushes and commutator were properly aligned.

Table VI summarizes the total operating times for the TCSI and MET motors. The elapsed hours of operation listed are those accrued during all phases of testing, until either the tests were completed or the motors failed.

TABLE V

LIFETIME TESTS - MET MOTORS
(100°F AND 100% Relative Humidity)

Hours of Operation	Flowrate (SCFM) 1	4	5
1	5.56	5.16[a]	5.82
10	5.68	6.54	5.98
20	5.69	6.60	5.96
30	5.13	5.90	5.09
40	5.15	6.16	4.59[a]
50	5.14	6.18	
60	4.80[a]	6.48	
70		6.48	
80		6.45	
90		6.43	
100		6.28	
110		6.27	
120		6.34	
130		6.40	
140		6.42	
150		6.35	
160		4.38[a]	
170			
180			
190			
Total Hours Operation	65	170	46
Ave Median Flow (A_m, SCFM)	5.39	6.35	5.71
Standard Deviation (S, %)	5.2%	2.8%	7.4%

[a] Not used in overall average calculations

TABLE VI

ACTUAL RUN TIME FOR SAMPLERS AT THE CONCLUSION
OF THE TESTS AT THE INEL
(MET and TCSI Motors)

Sampler	Power Supply	Total Hours
TCSI #5	AC	16.00
TCSI #5	DC	2.12
TCSI #6	AC	15.50
TCSI #6	DC	2.12
TCSI #7	AC	15.58
TCSI #7	DC	5.23
TCSI #8	AC	15.75
TCSI #8	DC	17.33
TCSI #10	AC	5.75
TCSI #10	DC	2.18
MET #1	DC	
MET #2	DC	
MET #3	DC	15.75
MET #4	DC	15.75
MET #5	DC	
MET #7	DC	15.50
MET #10	DC	16.33
TSCI #5	AC & DC	18.12
TSCI #6	AC & DC	17.62
TSCI #7	AC & DC	20.81
TSCI #8	AC & DC	33.08
TSCI #10	AC & DC	17.93
	AVERAGE	21.51
MET #1	DC	97.25
MET #2	DC	15.75
MET #3	DC	15.75
MET #4	DC	188.17
MET #5	DC	47.25
MET #7	DC	15.50
MET #10	DC	16.33
	AVERAGE	56.57

III. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

The conclusions of the TCSI motor evaluation for alternate use in the BNL air sampler system are:

1. The motors provided uniform and reproducible flow to better than 10 percent on AC voltage at all test temperatures;

2. The uniformity and repeatability on DC voltage was better than 20 percent, excluding low temperature tests. However, only one out of the five motors tested operated satisfactorily at all test temperatures;

3. The failure of the motors on DC voltage was due to excessive flowing of bearing lubricant onto the commutator and/or brushes and the buildup of residue on the brushes.

The conclusions of the MET motor evaluations for potential use in the BNL Air Sampler System are:

1. The motors provided repeatability of flowrates to better than 10 percent at all test temperatures;

2. Uniformity was better than 20 percent, excluding one motor tested at -20°F;

3. The uniformity and repeatability was better than 15 percent after 0.5 inches rain/hour and in dust-ladden air containing up to 334 mg/m^3 of <100 micron size dust;

4. The lifetimes of the three motors tested were approximately 188, 97, and 47 hours; these motors failed apparently due to misalignment of the brushes with the commutator, causing uneven brush wear.

2. Recommendations

The MET motor manufactured by Minnesota Electric Technology Inc. (MET) is the more appropriate motor to replace the original BNL Air Sampler motor. However, because of the relatively high cost to purchase the MET motors, incorporate them into the BNL Air Sampler design, and have the samplers manufactured, it may be more cost effective to identify and procure commercial air sampling equipment that will fulfill NRC needs.

Commercial air sampling equipment would also have several advantages: 1) they are readily available, off-the-shelf items, 2) samplers can be purchased that utilize more standard geometry cartridges; 3) the sampling media cartridges would be less expensive due to physical size and quantity of media used; with greater selection and availability from a number of commercial vendors; and, 4) greater flexibility exists in identifying an analysis system for quantifying the adsorbed radioiodines or other radionuclides of interest contained on the sampling cartridges.

It is therefore recommended that candidate air sampling systems from several commercial vendors be identified and tested to verify sampler lifetimes and performance characteristics at environmental conditions likely to be encountered during accident monitoring at a nuclear power facility.

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APPENDIX A
EXPERIMENTAL DATA AND CALCULATIONAL METHODS

1. Experimental Data

Tables A-1 to A-6 are summary tables of the air sampler flowrates measured for the TCSI and MET motors. In the tables for each motor and each test condition are: 1) the averages of the medians of the range of flowrates (A_m); 2)the averages of the percent variation of the flowrate ranges (A_r); 3)the percent standard deviations of the average median flowrates (S); and 4)the maximum percent variations in the flowrate ranges (V_m). The definition of the terms and equations used are as follows. (The calculational method is detailed in Section 2 of this appendix).

$$M = (H+L)/2 \tag{1}$$

$$V = ((H-L)/M)\ 100\% \tag{2}$$

$$A_m = \sum_1^n M/n; \tag{3}$$

$$A_r = \sum_1^n V/n; \text{ and} \tag{4}$$

$$S = ((\sum_1^n ((M-A_m)^2)/(n-1))^{1/2}/A_m)\ 100\% \tag{5}$$

where,

- H is the maximum observed flowrate for an individual test.
- L is the minimum observed flowrate for an individual test.
- M is the median of the maximum (H) and minimum (A) observed flowrates for an individual test.
- V is the percent variation of the flowrate range for an individual test. V_m is the largest of the observed percent variations of the flowrate ranges.

- A_m is the average of the individual median flowrates (M).
- A_r is the average of the individual percent variations (V).
- n is the number of individual tests at a given test condition.
- S is the percent standard deviation of the average median flow rates (A_m).

In the tables, the standard deviation at a given test condition indicates the repeatability of sampler flows under the conditions. The standard deviation of the overall averages gives the variation of median flowrates over the entire range of conditions tested. The average range variation is a measure of the uniformity of flowrates during a given test or group of tests. The maximum range variation is the largest range of flow observed during a series of tests.

Equation 6 was used to correct the standard condition flowrates to the actual volumetric flowrates under the specific conditions:

$$F_v = F_m T_t P_s / T_s P_t \quad (6)$$

where,

- F_v is the actual volumetric sampler flowrate (CFM)[2];
- F_m is the measured standard flowrate (SCFM);
- T_t is the test temperature (^oR);
- T_s is the temperature at standard conditions;
- P_s is the pressure at standard conditions (atm.); and
- P_t is the test pressure.

The results of this comparison are shown in Tables A-7 to A-10 for the TCSI motors on AC and DC power and in Table A-11 and A-12 for the MET motors on DC power. These data coincide to that presented earlier and show the same trends. The uniformity and repeatability are less than 10% at the higher temperatures and decrease in uniformity with temperatures below 0^oF.

2. Calculational Methods

The method used for reduction of the experimental data is detailed below. Presented are example calculations of the median flowrates (M), the percent variation of the range of flowrates (V), the average of the individual median flowrates (A_m), the average of the individual percent variations (A_r), and the percent standard deviations (S) of the average media flowrates. Selection of the maximum flowrate range variation (V_m) is also shown. The method presented, unless noted in the text of the report, was used to obtain the results in all tables of the report.

Example Calculation

At a given test condition, typically 5-10 individual tests were performed. Assume for a series of five individual tests of an air sampler the following maximum (H) and minimum (L) flowrates were observed.

	(SCFM) Minimum and Maximum Flowrates	
Test #	L	M
1	4.57	4.63
2	4.51	4.94
3	4.46	4.52
4	4.49	4.55
5	4.40	4.51
6	4.49	4.55

From these data the median flowrates (M) and the percent variation of the flowrate ranges (V) are calculated for each of the 5 individual tests using the equations $M = (H+L)/2$ and $V = ((H-L)/M)100\%$. The results of the calculations yield the following values of M and V for the individual tests.

Test #	(SCFM) M	(%) V
1	4.60	1.3
2	4.73	9.1
3	4.49	1.3
4	4.46	2.5
5	4.52	1.3

Using the values of M and V from the 5 individual tests, the averages of the individual median flowrates, (A_m), and percent variations of the flowrate ranges, (A), are then calculated, using equations 3 and 4. Accordingly, the calculated values of A_m and A_r for these series of five tests are 4.56 SCFM and 3.1%, respectively.

Based on the average median flowrates (A_m) and the media flowrates (M) for the 5 individual tests, the percent standard deviations of the median flowrate are calculated. The equation used is of the standard form:

$$S = \quad \Sigma(M-A_m)^2/(n-1)\ ^{1/2}/A_m 100\%$$

The value of S for the example data set is therefore 2.37%. Lastly, to obtain the maximum percent variation of the flowrate ranges, V_m, the largest calculated value of V (shown above) is selected. In this case the value of V_m is the value of the second test, or 9.1%.

TABLE A-1

REPEATABILITY OF STANDARD CONDITION[a] SAMPLER FLOWRATES FOR TEMPERATURE/RELATIVE HUMIDITY TESTING
(TCSI Motors - AC Voltage)

Test Condition					
Temp (F°)	RH(%)[b]	Sampler	Ave Median Flow (A_m, SCFM)	Standard Deviation(S)	Number of Tests (n)
110	100	5	4.49	0.8%	10
110	100	6	4.83	0.3%	10
110	100	7	5.06	0.9%	10
110	100	8	5.09	0.9%	10
110	100	10	4.83	0.3%	10
110	36	5	4.54	1.9%	10
110	36	6	5.11	0.7%	10
110	36	7	5.03	0.7%	10
110	36	8	5.01	0.9%	10
110	36	10	5.03	1.1%	10
90	100	5	5.03	0.4%	10
90	100	6	5.17	0.9%	10
90	100	7	5.48	0.8%	10
90	100	8	5.28	2.3%	10
90	100	10	5.21	0.7%	10
90	38	5	5.32	2.0%	10
90	38	6	5.47	1.4%	10
90	38	7	5.10	0.9%	10
90	38	8	5.56	2.7%	10
90	38	10	5.39	1.5%	10
0	100	5	6.58	0.4%	10
0	100	6	6.74	1.1%	10
0	100	7	7.63	1.2%	10
0	100	8	7.00	0.5%	10
0	100	10	6.88	0.9%	10
-20	100	5	7.05	1.0%	10
-20	100	6	7.04	1.5%	10
-20	100	7	8.07	0.6%	10
-20	100	8	7.15	1.9%	10
-20	100	10	7.22	0.7%	10
Overall Averages		5	5.50	18.0%	60
Overall Averages		6	5.73	14.9%	60
Overall Averages		7	6.06	21.3%	60
Overall Averages		8	5.85	15.3%	60
Overall Averages		10	5.76	16.4%	60

(a) Based on 20°C and 760 mm Hg pressure.
(b) For tests performed at high relative humidities (100%), it should be noted that a relative humidity of 100% was only estimated.

TABLE A-2

UNIFORMITY OF STANDARD CONDITION[a] SAMPLER FLOWRATES FOR TEMPERATURE/RELATIVE HUMIDITY TESTING
(TCSI Motors - AC Voltage)

Test Condition					
Temp (F^o)	RH(%)[b]	Sampler	Ave. Range Variation(A_r)	Max. Range Variation (V_m)	Number of Tests (n)
110	100	5	2.4%	3.3%	10
110	100	6	1.5%	2.3%	10
110	100	7	1.8%	3.3%	10
110	100	8	2.8%	4.5%	10
110	100	10	1.5%	2.5%	10
110	36	5	2.8%	4.2%	10
110	36	6	1.5%	2.2%	10
110	36	7	2.6%	5.9%	10
110	36	8	3.6%	4.8%	10
110	36	10	2.0%	3.9%	10
90	100	5	3.0%	5.6%	10
90	100	6	2.3%	4.7%	10
90	100	7	1.8%	3.5%	10
90	100	8	2.9%	7.4%	10
90	100	10	1.3%	2.7%	10
90	38	5	2.4%	4.8%	10
90	38	6	2.0%	6.0%	10
90	38	7	1.7%	4.2%	10
90	38	8	1.8%	4.0%	10
90	38	10	2.0%	3.9%	10
0	100	5	1.3%	2.1%	10
0	100	6	1.7%	2.1%	10
0	100	7	3.7%	6.4%	10
0	100	8	2.2%	3.5%	10
0	100	10	1.5%	2.2%	10
-20	100	5	1.6%	2.3%	10
-20	100	6	1.9%	3.6%	10
-20	100	7	2.8%	6.5%	10
-20	100	8	3.4%	9.1%	10
-20	100	10	1.2%	2.5%	10
Overall Averages		5	2.3%	3.7%	60
Overall Averages		6	1.8%	3.5%	60
Overall Averages		7	2.5%	5.0%	60
Overall Averages		8	2.8%	5.6%	60
Overall Averages		10	1.6%	3.0%	60

(a) Based on 20°C and 760 mm Hg pressure.
(b) For tests performed at high relative humidities (100%), it should be noted that a relative humidity of 100% was only estimated.

TABLE A-3

REPEATABILITY OF STANDARD CONDITION[(a)] SAMPLER FLOWRATES FOR TEMPERATURE/RELATIVE HUMIDITY TESTING
(TCSI Motors - DC Voltage)

Test Condition Temp (F^o)	RH%[(b)]	Sampler	Ave Median Flow (A_m, SCFM)	Standard Deviation(S)	Number of Tests (n)
110	100	5	(d)	(d)	0
110	100	6	(c)	(c)	5
110	100	7	(c)	(c)	3
110	100	8	4.65	5.1%	10
110	100	10	(d)	(d)	0
110	36	5	(d)	(d)	0
110	36	6	(d)	(d)	0
110	36	7	5.11	7.1%	8
110	36	8	4.76	6.2%	10
110	36	10	(d)	(d)	0
90	100	5	(d)	(d)	0
90	100	6	(d)	(d)	0
90	100	7	(d)	(d)	0
90	100	8	5.36	4.6%	10
90	100	10	(d)	(d)	0
90	38	5	(d)	(d)	0
90	38	6	(d)	(d)	0
90	38	7	(d)	(d)	0
90	38	8	5.74	3.6%	10
90	38	10	(c)	(c)	6
0	100	5	4.97	17.0%	10
0	100	6	(d)	(d)	0
0	100	7	(d)	(d)	0
0	100	8	6.98	11.0%	10
0	100	10	(d)	(d)	0
-20	100	5	4.88	15.7%	10
-20	100	6	(d)	(d)	0
-20	100	7	(d)	(d)	0
-20	100	8	8.05	12.1%	10
-20	100	10	(d)	(d)	0
Overall Averages		5	4.92	16.0%	20
Overall Averages		6	4.91	9.8%	5
Overall Averages		7	4.85	11.5%	11
Overall Averages		8	5.92	22.6%	60
Overall Averages		10	4.74	11.3%	6

(a) Based on 20°C and 760 mm Hg pressure.
(b) For tests performed at high relative humidities (100%), it should be noted that a relative humidity of 100% was only estimated.
(c) The tests were not included in the overall average calculations.
(d) Sampler was nonoperational due to prior motor failure.

TABLE A-4

UNIFORMITY OF STANDARD CONDITION[a] SAMPLER FLOWRATES FOR TEMPERATURE/RELATIVE HUMIDITY TESTING
(TCSI Motors - DC Voltage)

Test Condition					
Temp (F°)	RH%[b]	Sampler	Ave Range Variation (A_r)	Max. Range Variation (V_m)	Number of Tests (n)
110	100	5	(d)	( )	0
110	100	6	(c)	(c)	5
110	100	7	(c)	(c)	3
110	100	8	5.6%	11.1%	10
110	100	10	(d)	(d)	0
110	36	5	(d)	(d)	0
110	36	6	(d)	(d)	0
110	36	7	14.8%	30.1%	8
110	36	8	6.1%	15.5%	10
110	36	10	(d)	(d)	0
90	100	5	(d)	(d)	0
90	100	6	(d)	(d)	0
90	100	7	(d)	(d)	0
90	100	8	6.4%	12.6%	10
90	100	10	(d)	(d)	0
90	38	5	(d)	(d)	0
90	38	6	(d)	(d)	0
90	38	7	(d)	(d)	0
90	38	8	4.4%	14.0%	10
90	38	10	(c)	(c)	6
0	100	5	15.5%	80.0%	10
0	100	6	(d)	(d)	0
0	100	7	(d)	(d)	0
0	100	8	5.6%	29.8%	10
0	100	10	(d)	(d)	0
-20	100	5	17.2%	35.4%	10
-20	100	6	(d)	(d)	0
-20	100	7	(d)	(d)	0
-20	100	8	7.6%	45.0%	10
-20	100	10	(d)	(d)	0
Overall Averages		5	--	--	--
Overall Averages		6	--	--	--
Overall Averages		7	--	--	--
Overall Averages		8	6.0%	21.3%	60
Overall Averages		10	--	--	--

(a) Based on 20°C and 760 mm Hg pressure.
(b) For tests performed at high relative humidities (100%), it should be noted that a relative humidity of 100% was only estimated.
(c) The tests were not included in the overall average calculations.
(d) Sampler was nonoperational due to prior motor failure.

TABLE A-5

REPEATABILITY OF STANDARD CONDITION[a] SAMPLER FLOWRATES FOR TEMPERATURE/RELATIVE HUMIDITY TESTING (MET Motors)

Test Condition					
Temp (F°)	RH(%)[b]	Sampler	Ave Median Flow (A_m, SCFM)	Standard Deviation(S)	Number of Tests (n)
110	100	1	5.58	1.9%	10
110	100	2	4.91	1.7%	10
110	100	3	5.48	4.7%	10
110	100	7	5.18	0.7%	10
110	100	10	5.14	4.6%	10
110	36	1	5.71	2.3%	10
110	36	2	4.67	4.3%	10
110	36	3	5.41	3.0%	10
110	36	7	5.16	0.8%	10
110	36	10	5.40	0.6%	10
90	100	1	5.79	3.6%	10
90	100	2	5.06	4.7%	10
90	100	3	5.65	3.9%	10
90	100	7	5.58	0.7%	10
90	100	10	5.98	1.7%	10
90	38	1	5.99	3.2%	10
90	38	2	4.93	4.8%	10
90	38	3	5.45	1.8%	10
90	38	7	5.52	1.1%	10
90	38	10	5.90	3.6%	10
0	100	1	6.85	6.0%	10
0	100	2	5.58	5.9%	10
0	100	3	5.95	5.5%	10
0	100	7	7.36	1.3%	10
0	100	10	6.48	5.4%	10
-20	100	1	7.04	5.4%	10
-20	100	2	5.44	9.6%	10
-20	100	3	5.85	4.5%	10
-20	100	7	7.85	0.5%	10
-20	100	10	6.32	4.2%	10
Overall Averages		1	6.16	10.3%	60
Overall Averages		2	5.10	8.4%	60
Overall Averages		3	5.63	5.4%	60
Overall Averages		7	6.11	17.9%	60
Overall Averages		10	5.87	9.0%	60

(a) Based on 20°C and 760 mm Hg pressure.

(b) For tests performed at high relative humidities (100%), it should be noted that a relative humidity of 100% was only estimated.

TABLE A-6

UNIFORMITY OF STANDARD CONDITION[a] SAMPLER FLOWRATES FOR TEMPERATURE/RELATIVE HUMIDITY TESTING (MET Motors)

Test Condition					
Temp (F°)	RH(%)[b]	Sampler	Ave Range Variation(A_r)	Max. Range Variation(V_m)	Number of Tests (n)
110	100	1	4.7%	9.0%	10
110	100	2	3.2%	11.0%	10
110	100	3	9.0%	33.5%	10
110	100	7	1.8%	4.1%	10
110	100	10	6.7%	14.8%	10
110	36	1	6.4%	19.4%	10
110	36	2	6.2%	24.5%	10
110	36	3	7.5%	22.9%	10
110	36	7	2.4%	4.5%	10
110	36	10	4.5%	10.1%	10
90	100	1	5.6%	11.6%	10
90	100	2	7.5%	29.6%	10
90	100	3	8.2%	23.5%	10
90	100	7	1.3%	2.7%	10
90	100	10	3.6%	12.0%	10
90	38	1	6.1%	16.0%	10
90	38	2	6.0%	32.2%	10
90	38	3	3.7%	6.5%	10
90	38	7	3.2%	6.7%	10
90	38	10	5.9%	24.0%	10
0	100	1	15.4%	38.5%	10
0	100	2	16.9%	42.1%	10
0	100	3	10.1%	28.8%	10
0	100	7	1.6%	3.1%	10
0	100	10	6.0%	20.0%	10
-20	100	1	12.7%	22.2%	10
-20	100	2	22.7%	63.9%	10
-20	100	3	8.2%	23.2%	10
-20	100	7	0.9%	2.1%	10
-20	100	10	4.8%	20.7%	10
Overall Averages		1	8.5%	19.5%	60
Overall Averages		2	10.4%	33.9%	60
Overall Averages		3	7.8%	23.1%	60
Overall Averages		7	1.9%	3.9%	60
Overall Averages		10	5.3%	16.9%	60

(a) Based on 20°C and 760 mm Hg pressure.
(b) For tests performed at high relative humidities (100%), it should be noted that a relative humidity of 100% was only estimated.

TABLE A-7

REPEATABILITY OF ACTUAL VOLUMETRIC SAMPLER FLOWRATES FOR TEMPERATURE/RELATIVE HUMIDITY TESTING (TCSI Motors - AC)

Test Condition		Sampler	Ave Median Flow	Standard	Number of
Temp (F°)	RH%[(a)]		(A_m, ACFM)	Deviation(S)	Tests (n)
110	100	5	5.74	0.8%	10
110	100	6	6.18	0.3%	10
110	100	7	6.48	0.9%	10
110	100	8	6.51	1.0%	10
110	100	10	6.18	0.3%	10
110	36	5	5.81	1.9%	10
110	36	6	6.54	0.7%	10
110	36	7	6.42	0.7%	10
110	36	8	6.40	0.9%	10
110	36	10	6.44	1.1%	10
90	100	5	6.24	0.4%	10
90	100	6	6.41	0.8%	10
90	100	7	6.79	0.8%	10
90	100	8	6.55	2.3%	10
90	100	10	6.46	0.7%	10
90	38	5	6.59	2.0%	10
90	38	6	6.78	1.4%	10
90	38	7	6.32	0.9%	10
90	38	8	6.89	2.7%	10
90	38	10	6.68	1.5%	10
0	100	5	6.77	0.4%	10
0	100	6	6.93	1.1%	10
0	100	7	7.86	1.2%	10
0	100	8	7.21	0.5%	10
0	100	10	7.09	0.9%	10
-20	100	5	6.97	1.0%	10
-20	100	6	6.96	1.5%	0
-20	100	7	7.98	0.6%	0
-20	100	8	7.07	1.9%	10
-20	100	10	7.14	0.7%	0
Overall Averages		5	6.35	7.5%	60
Overall Averages		6	6.63	4.5%	60
Overall Averages		7	6.98	9.9%	60
Overall Averages		8	6.77	4.8%	60
Overall Averages		10	6.67	5.4%	60

(a) For tests performed at high relative humidities (100%), it should be noted that a relative humidity of 100% was only estimated.

TABLE A-8

UNIFORMITY OF ACTUAL VOLUMETRIC SAMPLER FLOWRATES FOR TEMPERATURE/RELATIVE HUMIDITY TESTING (TCSI Motors - AC)

Test Condition					
Temp (F°)	RH%(a)	Sampler	Ave Range Variation (A_r)	Max. Range Variation (V_m)	Number of Tests (n)
110	100	5	2.4%	3.3%	10
110	100	6	1.5%	2.3%	10
110	100	7	1.9%	3.4%	10
110	100	8	2.8%	4.6%	10
110	100	10	1.5%	2.6%	10
110	36	5	2.8%	4.2%	10
110	36	6	1.5%	2.2%	10
110	36	7	2.6%	5.9%	10
110	36	8	3.5%	4.8%	10
110	36	10	2.0%	3.8%	10
90	100	5	3.0%	5.5%	10
90	100	6	2.3%	4.6%	10
90	100	7	1.8%	3.5%	10
90	100	8	3.0%	7.6%	10
90	100	10	1.3%	2.6%	10
90	38	5	2.5%	4.8%	10
90	38	6	2.0%	6.1%	10
90	38	7	1.7%	4.2%	10
90	38	8	1.8%	3.2%	10
90	38	10	2.0%	4.0%	10
0	100	5	1.2%	2.1%	10
0	100	6	1.7%	2.2%	10
0	100	7	3.7%	6.4%	10
0	100	8	2.3%	3.6%	10
0	100	10	1.4%	2.2%	10
-20	100	5	1.5%	2.2%	10
-20	100	6	1.8%	3.6%	10
-20	100	7	2.8%	5.4%	10
-20	100	8	3.4%	9.0%	10
-20	100	10	1.2%	2.5%	10
Overall Averages		5	2.3%	3.7%	60
Overall Averages		6	1.8%	3.5%	60
Overall Averages		7	2.5%	5.0%	60
Overall Averages		8	2.8%	5.6%	60
Overall Averages		10	1.6%	3.0%	60

(a) For tests performed at high relative humidities (100%), it should be noted that a relative humidity of 100% was only estimated.

TABLE A-9

REPEATABILITY OF ACTUAL VOLUMETRIC SAMPLER FLOWRATES FOR TEMPERATURE/RELATIVE HUMIDITY TESTING
(TCSI Motors - DC)

Test Condition					
Temp (F°)	RH%[(a)]	Sampler	Ave Median Flow (A_m, ACFM)	Standard Deviation(S)	Number of Tests (n)
110	100	5	(c)	(c)	0
110	100	6	(c)	(b)	5
110	100	7	(c)	(c)	3
110	100	8	5.95	5.1%	10
110	100	10	(c)	(c)	0
110	36	5	(c)	(c)	0
110	36	6	(c)	(c)	0
110	36	7	6.54	7.1%	8
110	36	8	6.09	6.1%	10
110	36	10	(c)	(c)	0
90	100	5	(c)	(c)	0
90	100	6	(c)	(c)	0
90	100	7	(c)	(c)	10
90	100	8	6.64	4.6%	0
90	100	10	(c)	(c)	0
90	38	5	(c)	(c)	0
90	38	6	(c)	(c)	0
90	38	7	(c)	(c)	0
90	38	8	7.11	3.6%	10
90	38	10	(b)	(b)	6
0	100	5	5.09	17.0%	10
0	100	6	(c)	(c)	0
0	100	7	(c)	(c)	0
0	100	8	7.19	11.0%	10
0	100	10	(c)	(c)	0
-20	100	5	4.83	15.7%	10
-20	100	6	(c)	(c)	0
-20	100	7	(c)	(c)	0
-20	100	8	7.97	12.1%	10
-20	100	10	(c)	(c)	0
Overall Averages		5	--	--	--
Overall Averages		6	--	--	--
Overall Averages		7	--	--	--
Overall Averages		8	6.83	12.9%	60
Overall Averages		10	--	--	--

(a) For tests performed at high relative humidities (100%), it should be noted that a relative humidity of 100% was only estimated.
(b) The tests were not included in the overall average calculations.
(c) Sampler was nonoperational due to prior motor failure.

TABLE A-10

UNIFORMITY OF ACTUAL VOLUMETRIC SAMPLER FLOWRATES FOR TEMPERATURE/RELATIVE HUMIDITY TESTING (TCSI Motors - DC Voltage)

Test Condition					
Temp (F^o)	RH% (a)	Sampler	Ave Range Variation (A_r)	Max. Range Variation (V_m)	Number of Tests (n)
110	100	5	(c)	(c)	0
110	100	6	(b)	(b)	5
110	100	7	(b)	(c)	3
110	100	8	5.6%	11.1%	10
110	100	10	(c)	(c)	0
110	36	5	(c)	(c)	0
110	36	6	(c)	(c)	0
110	36	7	14.8%	30.1%	8
110	36	8	6.1%	15.5%	10
110	36	10	(c)	(c)	0
90	100	5	(c)	(c)	0
90	100	6	(c)	(c)	0
90	100	7	(c)	(c)	10
90	100	8	6.4%	12.6%	0
90	100	10	(c)	(c)	0
90	38	5	(c)	(c)	0
90	38	6	(c)	(c)	0
90	38	7	(c)	(c)	0
90	38	8	4.4%	14.0%	10
90	38	10	(b)	(b)	6
0	100	5	15.5%	80.0%	10
0	100	6	(c)	(c)	0
0	100	7	(c)	(c)	0
0	100	8	5.6%	29.8%	10
0	100	10	(c)	(c)	0
-20	100	5	17.2%	38.7%	10
-20	100	6	(c)	(c)	0
-20	100	7	(c)	(c)	0
-20	100	8	7.6%	45.0%	10
-20	100	10	(c)	(c)	0
Overall Averages		5	--	--	--
Overall Averages		6	--	--	--
Overall Averages		7	--	--	--
Overall Averages		8	6.0%	21.3%	60
Overall Averages		10	--	--	--

(a) For tests performed at high relative humidities (100%), it should be noted that a relative humidity of 100% was only estimated.

(b) The tests were not included in the overall average calculations.

(c) Sampler was nonoperational due to prior motor failure.

TABLE A-11

REPEATABILITY OF ACTUAL VOLUMETRIC SAMPLER FLOWRATES FOR TEMPERATURE/RELATIVE HUMIDITY TESTING (MET Motors)

Test Condition					
Temp (F°)	RH(%)[a]	Sampler	Ave Median Flow (A_m, ACFM)	Standard Deviation(S)	Number of Tests (n)
110	100	1	7.15	1.9%	10
110	100	2	6.29	1.7%	10
110	100	3	7.00	4.8%	10
110	100	7	6.62	0.7%	10
110	100	10	6.57	4.6%	10
110	36	1	7.27	2.7%	10
110	36	2	5.97	4.4%	10
110	36	3	6.92	3.0%	10
110	36	7	6.60	0.7%	10
110	36	10	6.90	0.7%	10
90	100	1	7.17	3.6%	10
90	100	2	6.27	4.7%	10
90	100	3	7.00	4.0%	10
90	100	7	6.91	0.7%	10
90	100	10	7.41	1.7%	10
90	38	1	7.42	3.1%	10
90	38	2	6.11	4.8%	10
90	38	3	6.76	1.8%	10
90	38	7	6.84	1.1%	10
90	38	10	7.31	3.6%	10
0	100	1	7.05	6.0%	10
0	100	2	5.74	5.9%	10
0	100	3	6.12	5.5%	10
0	100	7	7.48	4.0%	10
0	100	10	6.67	5.4%	10
-20	100	1	6.97	5.4%	10
-20	100	2	5.38	9.6%	10
-20	100	3	5.79	4.4%	10
-20	100	7	7.77	0.5%	10
-20	100	10	6.25	4.2%	10
Overall Averages		1	7.17	4.4%	60
Overall Averages		2	5.96	7.5%	60
Overall Averages		3	6.60	8.2%	60
Overall Averages		7	7.04	6.6%	60
Overall Averages		10	6.85	7.0%	60

(a) For tests performed at high relative humidities (100%), it should be noted that a relative humidity of 100% was only estimated.

TABLE A-12

UNIFORMITY OF ACTUAL VOLUMETRIC SAMPLER FLOWRATES FOR TEMPERATURE/RELATIVE HUMIDITY TESTING (MET Motors)

Test Condition					
Temp (F°)	RH(%)[a]	Sampler	Ave Range Variation (A_r)	Max. Range Variation (V_m)	Number of Tests (n)
110	100	1	4.8%	9.7%	10
110	100	2	3.2%	10.9%	10
110	100	3	9.1%	33.6%	10
110	100	7	1.8%	4.1%	10
110	100	10	6.7%	14.9%	10
110	36	1	6.4%	19.4%	10
110	36	2	6.1%	24.5%	10
110	36	3	7.5%	22.9%	10
110	36	7	2.4%	4.6%	10
110	36	10	4.5%	10.0	10
90	100	1	5.6%	11.6%	10
90	100	2	7.5%	29.6%	10
90	100	3	8.2%	23.4%	10
90	100	7	1.4%	2.7%	10
90	100	10	3.6%	12.1%	10
90	38	1	6.1%	16.1%	10
90	38	2	6.0%	32.1%	10
90	38	3	3.7%	6.6%	10
90	38	7	3.2%	6.7%	10
90	38	10	5.9%	24.1%	10
0	100	1	15.4%	38.4%	10
0	100	2	16.9%	42.2%	10
0	100	3	10.1%	28.7%	10
0	100	7	1.6%	3.0%	10
0	100	10	6.1%	20.1%	10
-20	100	1	12.7%	22.2%	10
-20	100	2	22.7%	63.8%	10
-20	100	3	8.5%	23.2%	10
-20	100	7	0.9%	2.2%	10
-20	100	10	4.8%	20.8%	10
Overall Averages		1	8.5%	19.5%	60
Overall Averages		2	10.4%	33.9%	60
Overall Averages		3	7.8%	23.1%	60
Overall Averages		7	1.9%	3.9%	60
Overall Averages		10	5.3%	16.9%	60

(a) For tests performed at high relative humidities (100%), it should be noted that a relative humidity of 100% was only estimated.

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The purpose of the study was to evaluate the mechanical reliability of motors for use in a prototype system designed for post accident collection and measurement of radioiodine in the environs of a nuclear reactor. The two types of motors were tested for lifetimes and operational performance characteristics under extremes of temperature, relative humidity and/or in dusty air and rainfall. The 12 volt direct current motors exhibited satisfactory performance under all environmental conditions and demonstrated lifetimes of 47 hours, 97 hours and 188 hours. The 12 volt direct current/110 volt alternating current motors exhibited unsatisfactory operation on direct current voltage and satisfactory operation on alternating current voltage; at failure the AC/DC voltage motors demonstrated lifetimes of nominally 6 hours, 3 hours and 2 hours. The direct current voltage only motors are the better candidates for incorporation into the air sampler.

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