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CHARACTERISTICS, SAMPLING EFFICIENCY, AND BATTERY LIFE OF SMART AIR SAMPLER SYSTEM (SASS) 3000 AND SASS 3100

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This test was conducted to support Joint Project Manager Guardian Product Manager Consequence Management decision making for modernizing National Guard Civil Support Team equipment sets. The sampling efficiency of the newer Smart Air Sampler System (SASS) 3100 filter based aerosol sampler was compared to the earlier SASS 3000 filter based aerosol sampler. Both SASS units were manufactured by Research International (Monroe, Washington). The SASS 3100 was modified from the SASS 3000 to incorporate operational suitability lessons learned from the Expeditionary Biological Detection Advanced Technology Demonstration. The battery life of the units was also determined in this study. The sampling efficiency was determined using inert and bio-particles. Solid Polystyrene Latex microspheres of 3.1 μm and fluorescent oleic acid particles of 3.7 μm were used as the inert particle challenge aerosol, and 3.5 μm of Bacillus atrophaeus (formally known as Bacillu globigii [Bg]) was used as the bio-particle. The sampling efficiency test results show no statistically significant difference in sampling efficiency between the units. The battery life test results showed that the non-rechargeable lithium MnO_2 BA 5390/U battery that was used with the SASS 3100 provided a longer run time of more than 28 hr compared to the SASS 3000 run time of 9.5 hr with the commercial off-the-shelf internal rechargeable 5 A.hr lithium-ion battery.

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PREFACE

The work described in this report was performed under Contract No. HSHQPA-05-X-00891. This work was started in March 2010 and completed in April 2010.

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CHARACTERISTICS, SAMPLING EFFICIENCY, AND BATTERY LIFE OF SMART AIR SAMPLER SYSTEM (SASS) 3000 AND SASS 3100

1. INTRODUCTION

This test was conducted to support Joint Project Manager (JPM) Guardian Product Manager (PM) Consequence Management decision making for modernizing National Guard Civil Support Team equipment sets. The sampling efficiency of the newer Smart Air Sampler System (SASS) 3100 filter based aerosol sampler was compared to the earlier SASS 3000 filter based aerosol sampler. Both SASS units were manufactured by Research International (RI [Monroe, Washington]). The SASS 3100 was modified from the SASS 3000 to incorporate operational suitability lessons learned from the Expeditionary Biological Detection Advanced Technology Demonstration (ATD). The battery life of the units was also determined in this study. The sampling efficiency was determined using inert and bio-particles. Solid Polystyrene Latex (PSL) microspheres of 3.1 µm and fluorescent oleic acid particles of 3.7 µm were used as the inert particle challenge aerosol, and 3.5 µm of Bacillus atrophaeus (formally known as Bacillus globigii [Bg]) was used as the bio-particle aerosol challenge.

The sampling efficiency of a filter based sampler depends on the collection efficiency and the elution efficiency off the filters. The fluorescein from the fluorescent oleic acid particles dissolves in the recovery solution; therefore, the elution efficiency is 100% and the sampling efficiency is equal to the collection efficiency. However, some of the PSL and bio-particles may get imbedded in the SASS filters and may not get released from the filters; hence, the sampling efficiency depends on the collection and elution efficiencies.

2. METHOD

The sampling efficiency tests with fluorescent oleic acid particles and fluorescent PSL microsphere were conducted in the laboratory 203 environmental chamber. The sampling efficiency tests with bio-particles were conducted in a smaller flow through chamber. Descriptions of the aerosol samplers and chambers are given below.

The air flow rate of both SASSs with AC and DC power were measured using a custom fabricated flow measuring device that would not significantly load the sampler during measurement. This device consisted of a vane-anemometer (LCA 6000VA, SN:A17546) that was emplaced in a large tube. This combination was calibrated against a National Institute of Standards and Technology (NIST) traceable mass flow meter. This device was sealed over the intake of the SASS instruments with a sampling filter installed for the measurement of the system flow rate as it was in operation.

Two extractors (marked A and B) were used for the elution of the particles from the SASS filters, and the extractors were alternated for the elution of the particles from the filters for each unit.

2.1 SASS 3000 Aerosol Sampler

SASS 3000 is a filter based aerosol sampler and the unit used in these tests had a serial number of EBDS3-A-01. The disposable filter is a 43.6 mm diameter micro-fibrous capture disc that is mounted in an injection-molded frame, and the designed air flow rate through the filter is 300 lpm. The manufacturer states that the power consumption is nominally 8 Watts and noise level is 56-58 dB(A) at 1 m. The manufacturer also states that the rechargeable 5 A.hr lithium-ion battery pack provides 6-8 hr of collection time or 60 hr of standby operations. SASS 3000 and SASS 3100 filters can be used in this unit; however, the SASS 3100 filter was used in this test to reduce the variability.

2.2 SASS 3100 Aerosol Sampler

SASS 3100 is a ruggedized version of the SASS 3000 and the unit used in these tests had a serial number of S10024. The filter is a 45 mm active diameter, micro-fiber electret capture filter mounted in a plastic frame. The filter media is a fibrous polymer material. Each fiber has an electric field frozen into its structure. Electric fields induce a charge in aerosols passing through the filter and provide a capture mechanism much more effective than impaction.

The centrifugal fan pulls about 300 lpm of air through the filter cartridge. The manufacturer states that the power consumption is 8.4 W and the noise level is 45-61 dB(A) at 1 m. The manufacturer suggests that the field operation may be powered by either a BA5590B/U or BA5390/U primary battery, or by the UBI 2590 / BB2590 rechargeable battery.

2.3 SASS 3010 Extractor

SASS 3010 extractor was used to recover particles from the SASS 3000 and SASS 3100 filters. A filter was placed with the sampling side face down in the extractor and the extracting fluid was poured into a small reservoir attached to the upper extractor section. The extracting fluid flows into the filter. The start button was pushed for a moment and the agitator ran for 15 s. At the end of the agitation, the plunger was pushed down three times manually to force the liquid through the filter into a collection vial.

Two to three washes of the extractor were conducted using the wash fluid provided by the RI to clean the extractor before processing subsequent filters. A wash was similar to a filter extraction without the filter.

2.4 Laboratory 203 Environmental Chamber

The Laboratory 203 Environmental Chamber, as shown in Figure 1, is 4.6 m wide × 4.6 m long × 3 m high (15 × 15 × 10 ft). Temperature and humidity of the chamber were under computer control, and power receptacles inside the chamber were controlled by a computer to allow devices to be turned on and off remotely.

High Efficiency Particulate Air (HEPA) filters are installed at the air inlet to achieve very low background particle concentrations and at the exhaust port for safety reasons. The chamber aerosol is cleaned by exhausting the air through the HEPA filters and simultaneously pumping HEPA-filtered air into the chamber. The maximum airflow that can be exhausted from the chamber is approximately 20 m^3/min.

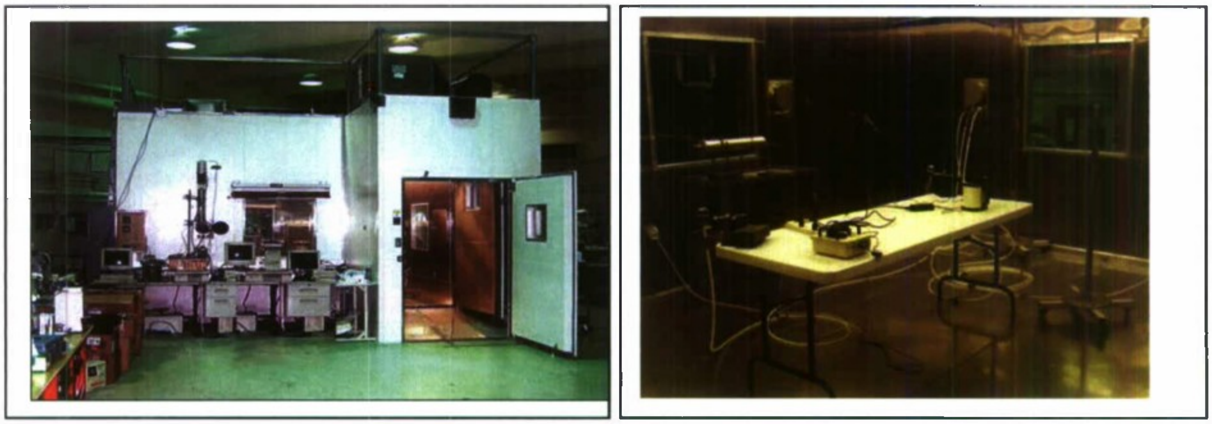


Figure 1. Outside and Inside Views of Laboratory 203 Chamber.

2.5 Flow Through Chamber

This chamber, as shown in Figure 2, is a 2 x 2 x 2.8 ft^3 plexiglass chamber with a mixing portion. An aerosol generator called Calliope is used to generate the aerosol for this flow through chamber. The Calliope is comprised of five Sono-Tek generators that are independently controlled. The Sono-Tek is a 120 kilohertz (kHz) piezoelectric-driven atomizer fed by a syringe pump that produces particles by generating ~25 µm, 8 pL* droplets. The five generators feed into a common column of rising air, which is heated to dry the droplets. The sizes of the residual particles are directly related to the concentration of material in solution or suspension. The dried particles are transported by the air column at a rate of 4 lpm. The air column is introduced into the flow-thru chamber and mixed with HEPA filtered air at 1700 lpm. Aerosols travel through the mixing portion of the chamber to achieve uniformity, and then into the larger portion of the chamber from which samples are drawn. The concentration of aerosol inside the flow-thru chamber is controlled by the liquid feed rate of the syringe pump and the air flow rate into the chamber. The Sono-Tek atomizers and syringe pumps can be controlled manually or automatically with a pre-programmed cycle. For this test, the particles generated were Bg suspended in water tagged with sodium fluorescein to produce dry particles approximately 3.5 µm in aerodynamic diameter.

* pL stands for picoliter.

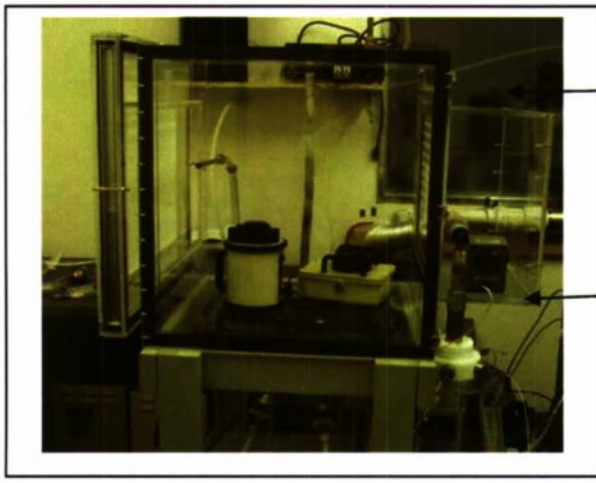


Figure 2. Flow Through Chamber with Five-Jet Sono-Tek Generator (Calliope)

2.6 Fluorescent Oleic Acid Tests

These tests were conducted in the laboratory 203 chamber. A total of six runs were conducted with the 3.7 µm fluorescent oleic acid particles generated by the vibrating orifice aerosol generator (VOAG). Following the aerosol generation for 8 to 10 min, the chamber air was mixed for 1 min. The samplers and the two reference filters simultaneously sampled the aerosol for 8 to 10 min, during which the chamber air was mixed for 5 s every 2 min to maintain uniform aerosol concentration in the chamber.

Reference filters were 47 mm open face glass fiber filters and the air flow rate through them was 40 lpm. After sampling, the reference filters were placed in 50 ml centrifuge tubes and 20 ml of recovery solution was added to them. These filters were shaken for 15 min on a Model 22407A table shaker (Daigger Lab Equipment and Supplies, Vernon Hills, IL) and the solution was analyzed by a fluorometer (model 450, Sequoia-Turner, Mountain View, CA). SASS 3100 filters were used in both test units and the samples from the filters were extracted using the model 3010 extractor as described by the company. The liquid samples were analyzed by fluorometry.

All the filters (reference and SASS) from the first three runs were extracted using ECBC's recovery solution which contains de-ionized water (50%), isopropanol (50%), 0.01% Triton X 100, and NH_4OH. The NH_4OH was added to the recovery solution to bring the pH to ≥8. All filters from the last three runs were extracted using the RI's recovery solution that contained sodium carbonate with 0.05% Triton X 100. First three washes each from Runs 1 and 4 were analyzed for carryover.

2.7 Fluorescent Polystyrene Latex (PSL) Microspheres Test

These tests were conducted in the laboratory 203 chamber. Green fluorescent polystyrene latex (PSL) microspheres of 3.1 µm were used in this test. PSL microspheres were aerosolized using two collision nebulizers and the generated particles were charge neutralized using a Kr 85 neutralizer. The aerosol was generated for 15 min and the chamber air was mixed for 1 min to achieve uniform aerosol concentration in the chamber. In addition, the chamber air was mixed for 5 s every 2 min to maintain uniform aerosol concentration in the chamber during sampling. The two SASS samplers and the reference filters simultaneously sampled the air for 15 to 20 min to collect adequate particles for fluorometry.

The reference filters were 1.0 μm pore size membrane filters and the recovery solution for these filters was de-ionized water with 0.01% Triton X 100. The recovery solution for the SASS filters was the solution that was provided by the company. The filters were put into 20 ml of recovery solution and vortexed for 5 min. The SASS filters were processed per manufacturer's instructions using the extractor 3010. The fluorescence of the samples was measured using the fluorometer and the sampling efficiency was determined. Two washes of the extractor were conducted after processing each sample to determine the amount of PSL microsphres remaining in the extractor.

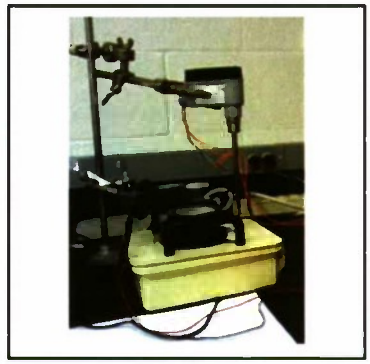
2.8 Biological Sampling Efficiency Tests

These tests were conducted in the flow through chamber. Bg particles (3.5 μm) tagged with fluorescein were generated by the Calliope aerosol generator, and four test runs were conducted. Both SASS units were put in the chamber and the units and the reference filters were turned on. The aerosol was generated for 4 min for sampling by the units. An Aerodynamic Particle Sizer (APS) measured the aerosol concentration in the chamber and the units and reference filters were turned off when the APS showed the test particles to have been flushed out of the chamber. Glass fiber filters were used as reference filters to collect the fluorescent bio particles. Glass fiber filters were put into a 50 ml centrifuge tube and 20 ml of phosphate buffered saline with 0.01% triton X 100 was added for processing. The centrifuge tube was vortexed using a multi-tube vortexer (VX-2500, VWR Scientific, West Chester, PA) for approximately 10 min to recover the particles from the filters into the liquid. Particles collected on SASS filters were recovered using the SASS 3010 extractor and SASS extraction fluid. Each sample was analyzed by fluorometry and culturing. The NH4OH solution was added to one half of the sample to increase the pH before fluorometry and the other half was used for plating. One hundred microliter samples were plated in duplicate to determine colony forming unit counts.

2.9 Battery Life Tests

This test was conducted to determine the run time of SASS units on Battery. A new non-rechargeable lithium MnO2 BA 5390/U battery (Ultra life batteries Inc., Newark, NY) was installed into the SASS 3100 for this test. SASS 3100 was connected to a computer through the RS232 cable to read the fan revolution per minute. In addition, a Kestrel 4000 pocket weather tracker flow meter (QuantumGear, Fishers, IN) was positioned above the SASS 3100, as shown in Figure 3, to determine the operation of the SASS by the air flow measurements. The unit was turned on to run on March 17, 2010 at 4:50 pm.

SASS 3000 has a built in internal rechargeable 4 lithium-ion battery and the battery life was determined using three methods. A 4000 pocket weather tracker flow meter was positioned above the inlet and a Dwyer hotwire anemometer (Dwyer Instruments, Inc. Michigan City, IN) was placed a few inches away at the exhaust. The battery voltage was also measured during the test. The test was started on March 22, 2010 at 4:20 pm.



Figurc 3. Battery Life Test Setup for SASS 3100 and SASS 3000

3. RESULTS

Thc characteristics of both SASS samplers are given in Table 1, and the sampling efficiency results are given in Table 2 and Figure 4. The carryover of particles in the wash solution is shown in Table 3. The sample time on battery for both SASS units are given in Table 4 and Figures 5 and 6.

The results show that there is very little difference in sampling cfficiency betwcen the units, which is not statistically significant in most cases. The sampling efficiency results of bio-particles had a larger standard deviation compared to the inert particle results. The sampling efficiency of PSL microspheres were significantly lower than the fluorescent oleic acid rcsults because of the lower recovery efficiency of the microspheres from the filters for both units ($p < 0.001$). The wash results showed that a small amount of sample was remaining in the extractor after the sample was removed. The first wash had lcss than 2% and the second wash had lcss than 0.1% of the sample in them. These wash results are similar to the numbers reported by thc manufacturer of this equipment The battery life test results showed that SASS 3100 sampled for a longer time (~28 hr) compared to SASS 3000 (~9.5 hr) on battery power. The SASS 3100 had a stable RPM during the 28 hr of sample time; however, the battery voltage reduced for SASS 3000 during the 9.5 hr of sample time, as shown in Figures 5 and 6. The flow measuring instruments were used as indicators to determinc the function of the SASS units and they were not used to measure the air flow rate of the SASS units.

Table 1. Characteristics of SASS 3000 and SASS 3100

	Sampler Characteristics	
	SASS 3000	SASS 3100
Designed air flow rate, lpm	300	300
Measured air flow rate with AC Power, lpm	299	317
Measured air flow rate with Battery Power, lpm	297	324
Dimensions	H = 5"; L = 8.6"; W = 7"	Diameter = 7"; H = 7.8"
Weight, lb	5.1 (with internal battery)	7.1 - with battery 4.1 - without battery
Power, W*	8	8.4
Noise levels at 1 m *	56–58 dB(A)	45–61 dB(A)

*Obtained from the manual

Table 2. Sampling Efficiency Results of SASS 3000 and SASS 3100 Using Various Test Methods

	Sampling Efficiency	
	SASS 3000	SASS 3100
3.7 µm Fluorescent oleic acid tests with ECBC recovery solution(n = 3)	65.0 + 3.0	62.1 + 5.5
3.7 µm Fluorescent oleic acid tests with RI recovery solution(n = 3)	55.6 + 6.5	59.2 + 7.8
3.1 µm Fluorescent PSL microspheres	42.2 + 1.5	39.5 + 1.3
3.5 µm Bio-particle tests with fluorescein analysis	79.2 + 0.7	71.9 + 0.3
3.5 µm Bio-particle tests with culture analysis	64.1 + 17.5	81.5 + 26.1

Table 3. Percent Carryover of Samples in the Wash Solution

	Percentage of Sample in Wash	
	SASS 3000	SASS 3100
Fluorescent Oleic Acid Wash 1	0.81	0.84
Fluorescent Oleic Acid Wash 2	0.08	0.08
Fluorescent Oleic Acid Wash 3	0.02	0.02
PSL Wash 1	1.73	1.00
PSL Wash 2	0.08	0.13

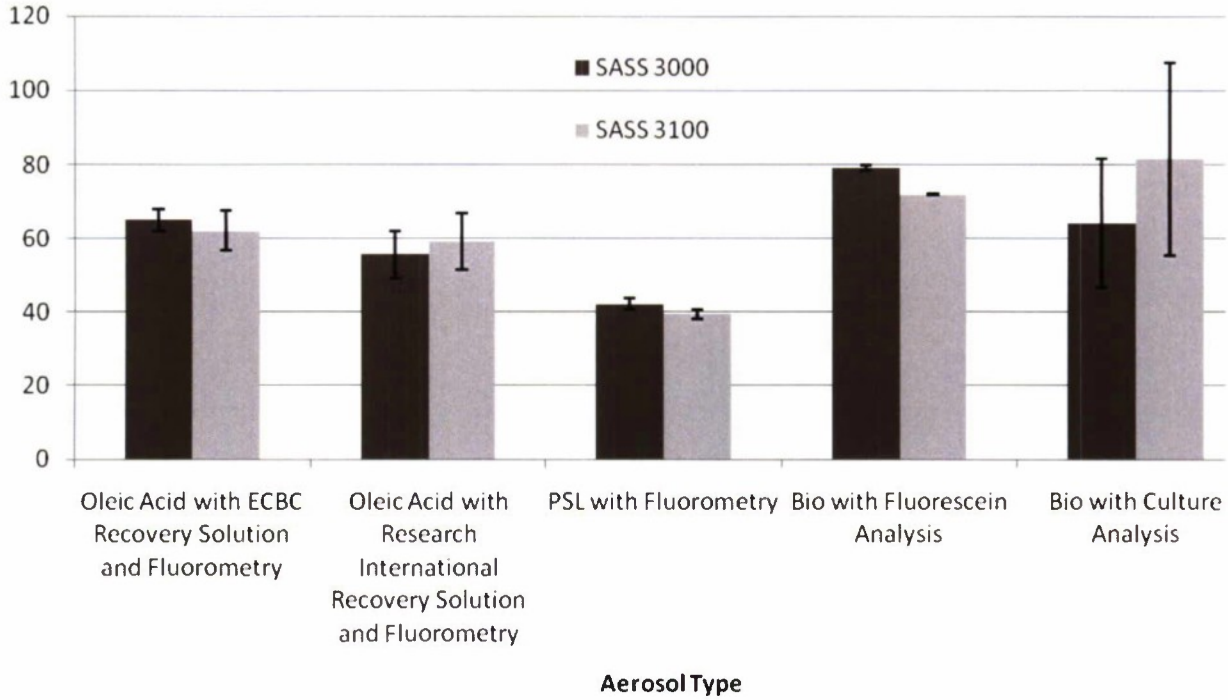


Figure 4. Sampling Efficiency of SASS 3000 and SASS 3100 Using Different Aerosol Types (3.1 to 3.7 μm Diameter Particles)

Table 4. Sampling Time of SASS 3000 and SASS 3100 on Battery Power

Unit	Run Time
SASS 3000 (Internal rechargeable 5 A.hr lithium-ion battery)	~9.5 hr
SASS 3100 (non-rechargeable lithium MnO2 BA 5390/U battery)	~28 hr

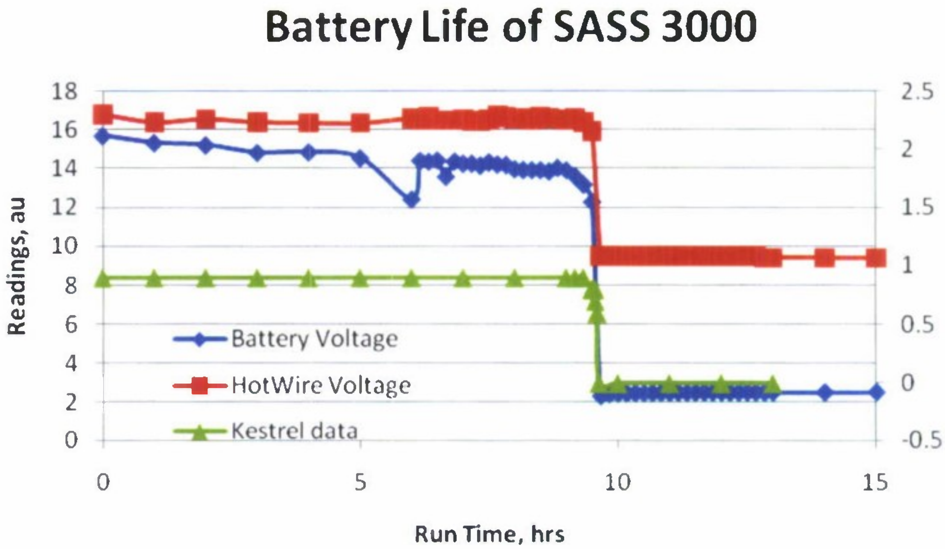


Figure 5. Sample Time of SASS 3000 on Battery

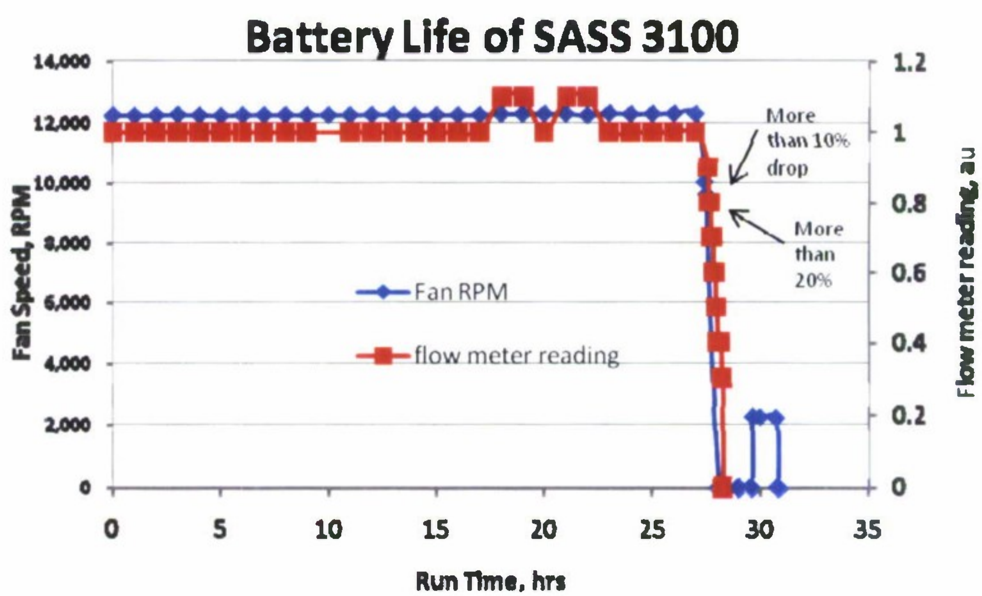


Figure 6. Sample Time of SASS 3100 on Battery

4. CONCLUSIONS

This test was conducted to compare the sampling efficiency and the battery life of SASS 3000 and SASS 3100 units to support JPM Guardian PM Consequence Management decision making for modernizing National Guard Civil Support Team equipment sets. Both SASS units are filter based aerosol samplers with the SASS 3100 made for field use with a conveniently placed handle and sturdy base. The sampling efficiency test results show very little difference in sampling efficiency between the units, which is not statistically significant in most cases. The battery life test results showed that the non-rechargeable lithium MnO_2 UBI 2590/ BB2590 battery that was used with the SASS 3100 provided a longer run time of more than 28 hr compared to the SASS 3000 run time of 9.5 hr with the Internal rechargeable 5 A.hr lithium-ion battery.