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Extended Abstract

NASA ISS Portable Fan Assembly Acoustics

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Summary

The Portable Fan Assembly (PFA) is a variable speed fan that can be used to provide additional ventilation inside International Space Station (ISS) modules as needed for crew comfort or for enhanced mixing of the ISS atmosphere. This fan can also be configured with a Shuttle era lithium hydroxide (LiOH) canister for CO_2 removal in confined areas partially of fully isolated from the primary Environmental Control and Life Support System (ECLSS) on ISS which is responsible for CO2 removal. This report documents noise emission levels of the PFA at various speed settings and configurations. It also documents the acoustic attenuation effects realized when circulating air through the PFA inlet and outlet mufflers and when operating in its CO_2 removal configuration (CRK) with a LiOH canister (sorbent bed) installed over the fan outlet.

Contributions provided by this paper:

1. "Real world" noise levels for an ISS circulation fan operating at various speeds
2. PFA acoustic attenuation values using inlet and outlet mufflers
3. Acoustic attenuation values for a Shuttle LiOH canister

Introduction

The PFA was built by the NASA Marshall Space Flight Center (MSFC) ECLSS Branch as a portable blower for ISS crew use in areas where additional air circulation was needed/desired. The PFA uses a commercially available EG&G Rotron MIL-901 Tubeaxial Fan, and custom inlet and outlet mufflers designed and built by AcousticFab. The PFA assembly was designed and built by ION Corporation under a NASA MSFC contract. Fan performance, system curves, and other detailed information specific to the PFA can be found in Reference 1. Fan specifications and general performance curves for the integrated tubeaxial fan can be found on the Rotron website.

Testing

Acoustic testing of the PFA was conducted on August 5 and 8, 2014 in the anechoic chamber of the Acoustics and Noise Control Laboratory at the NASA Johnson Space Center. While acoustic testing had been conducted in the past for the PFA fan and custom mufflers, no acoustic data had been gathered for the fan operating in CRK and additional information was desired for the PFA operating at various speeds. Gathering this additional acoustic information at this time was driven by future planned ISS activities within the US Airlock module.

For these acoustic tests sound pressure levels (SPL) and A-weighted sound levels of the backup PFA flight unit (S/N 002) were measured at 2' from the PFA inlet, outlet and fan casing. To minimize the effects of airflow noise, windscreens were used at each microphone test location. Given the steady state nature of the noise, each set of measurements was taken over a 20-second period and averaged over the measurement. Background noise levels were found to not significantly contribute to the measured levels.

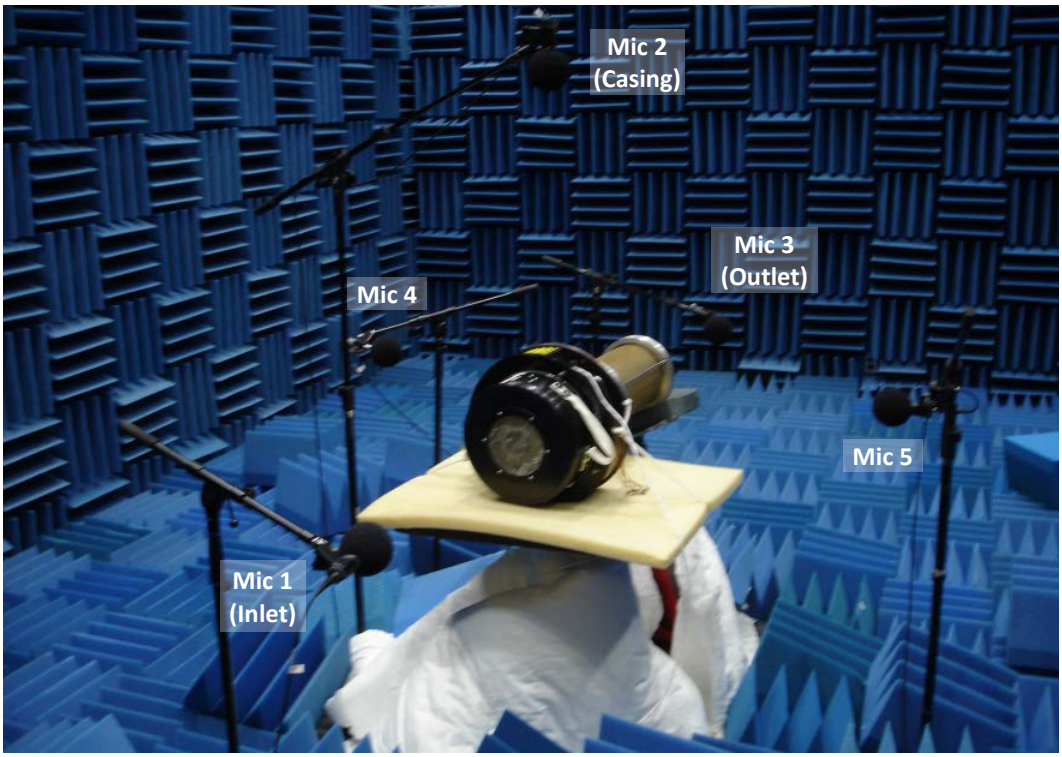


Figure 1 - PFA Measurement Setup (Shown with Inlet Muffler and LiOH Canister in Place).

Acoustic test configurations included PFA operating both with and without mufflers at fan speeds ranging from minimum (18V) and at varying increments up to maximum (30V). Measurements were also performed with the PFA in CRK both with and without inlet muffler.

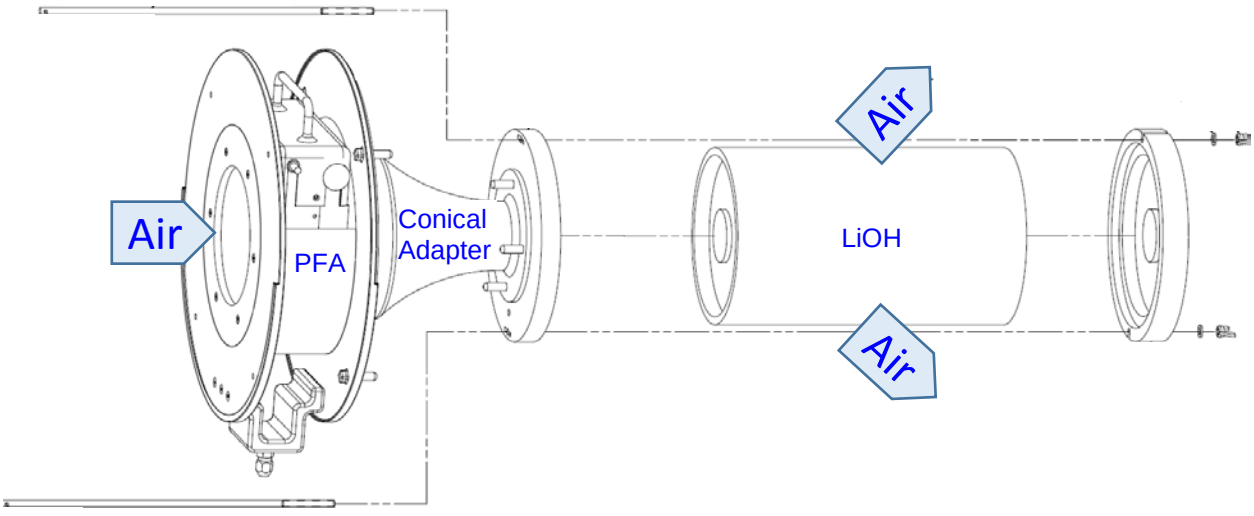
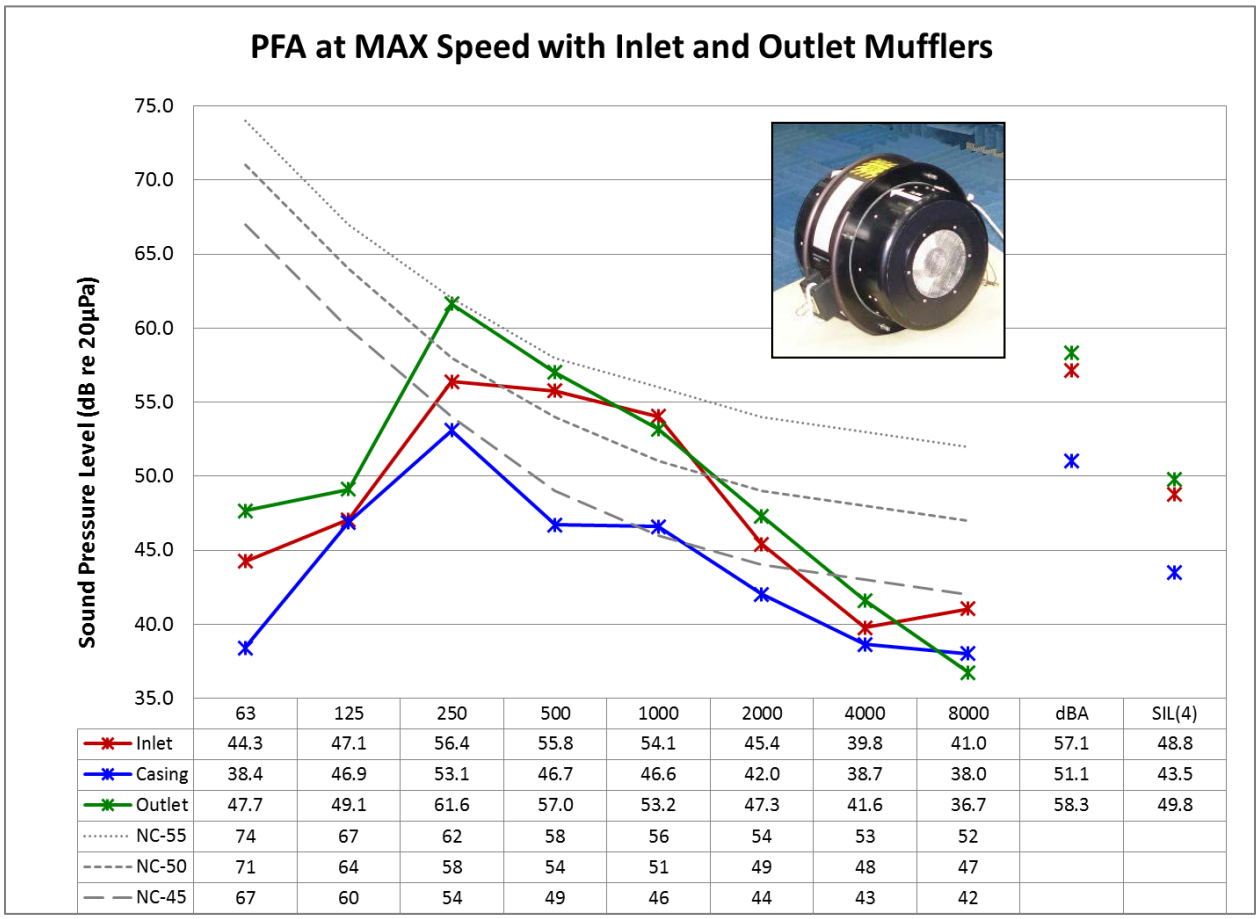


Figure 2 - Portable Fan Assembly in CRK (shown without Inlet Muffler)

Results

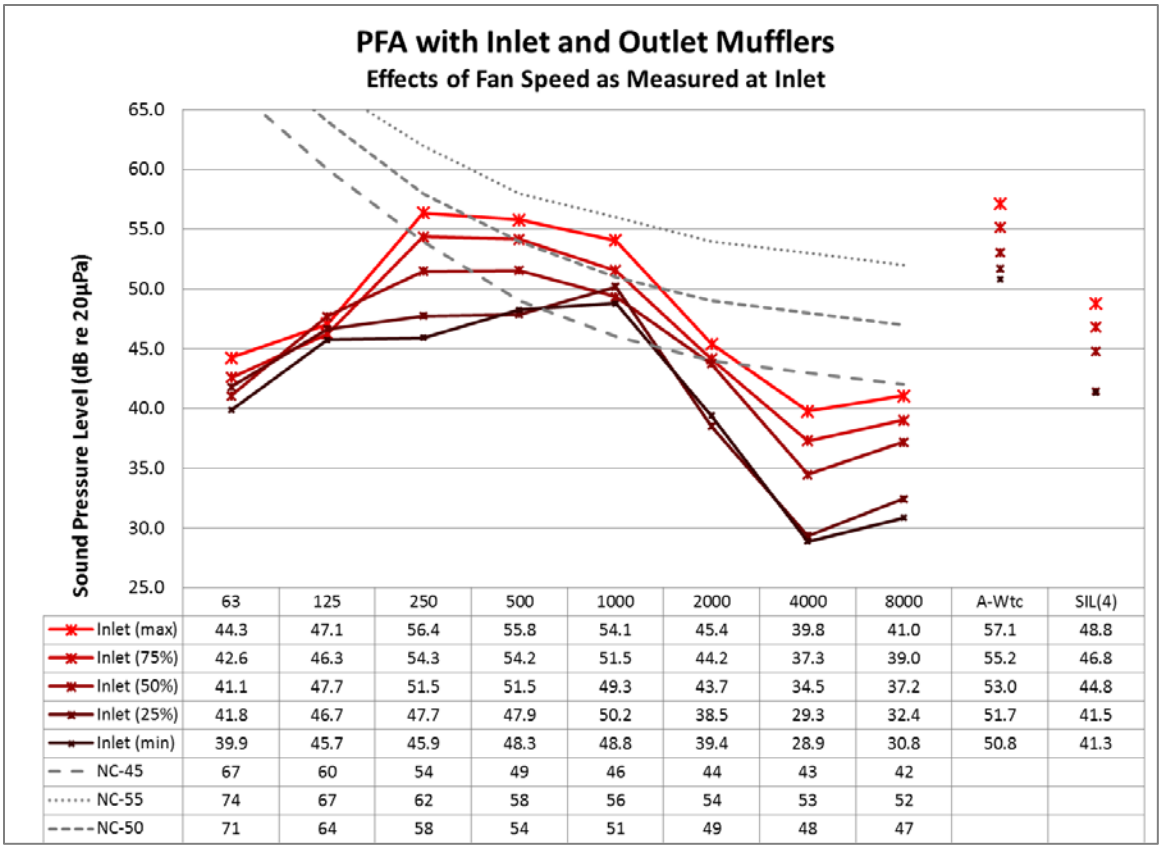
Figure 3 below presents A-weighted sound levels, Speech Interference Levels (SIL), and 1/1 Octave Band (OB) sound pressure level results for the PFA at maximum speed with the inlet and outlet mufflers in place.



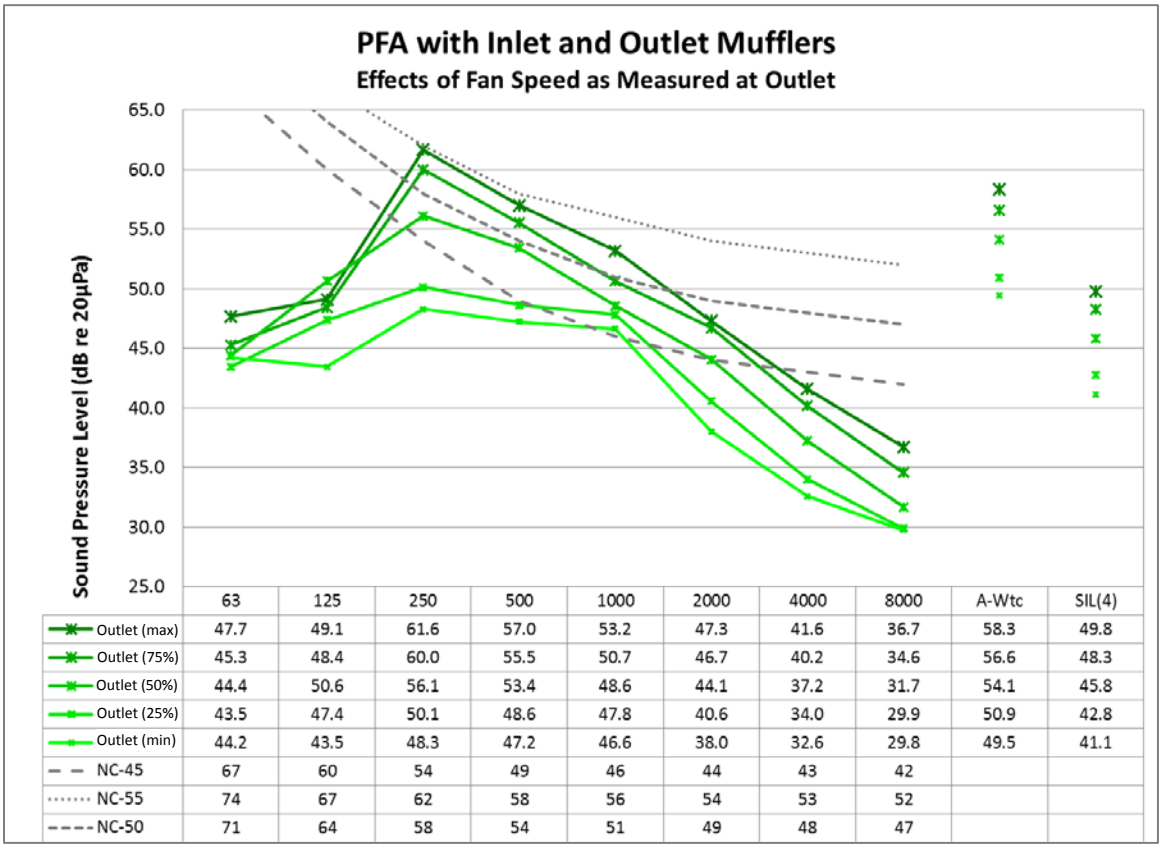
	63	125	250	500	1000	2000	4000	8000	dBA	SIL(4)
Inlet	44.3	47.1	56.4	55.8	54.1	45.4	39.8	41.0	57.1	48.8
Casing	38.4	46.9	53.1	46.7	46.6	42.0	38.7	38.0	51.1	43.5
Outlet	47.7	49.1	61.6	57.0	53.2	47.3	41.6	36.7	58.3	49.8
NC-55	74	67	62	58	56	54	53	52		
NC-50	71	64	58	54	51	49	48	47		
NC-45	67	60	54	49	46	44	43	42		

Figure 3 – PFA at Maximum Speed with Inlet and Outlet Mufflers in Place.

Figure 4 on the following page presents sound pressure levels for the PFA in this same configuration, while varying the fan speed settings. Levels are presented for both the inlet and outlet. Outlet A-weighted sound levels were the loudest location at max, 75% and 50% speed settings, while inlet A-weighted sound levels were the loudest location at 25% and min speeds.



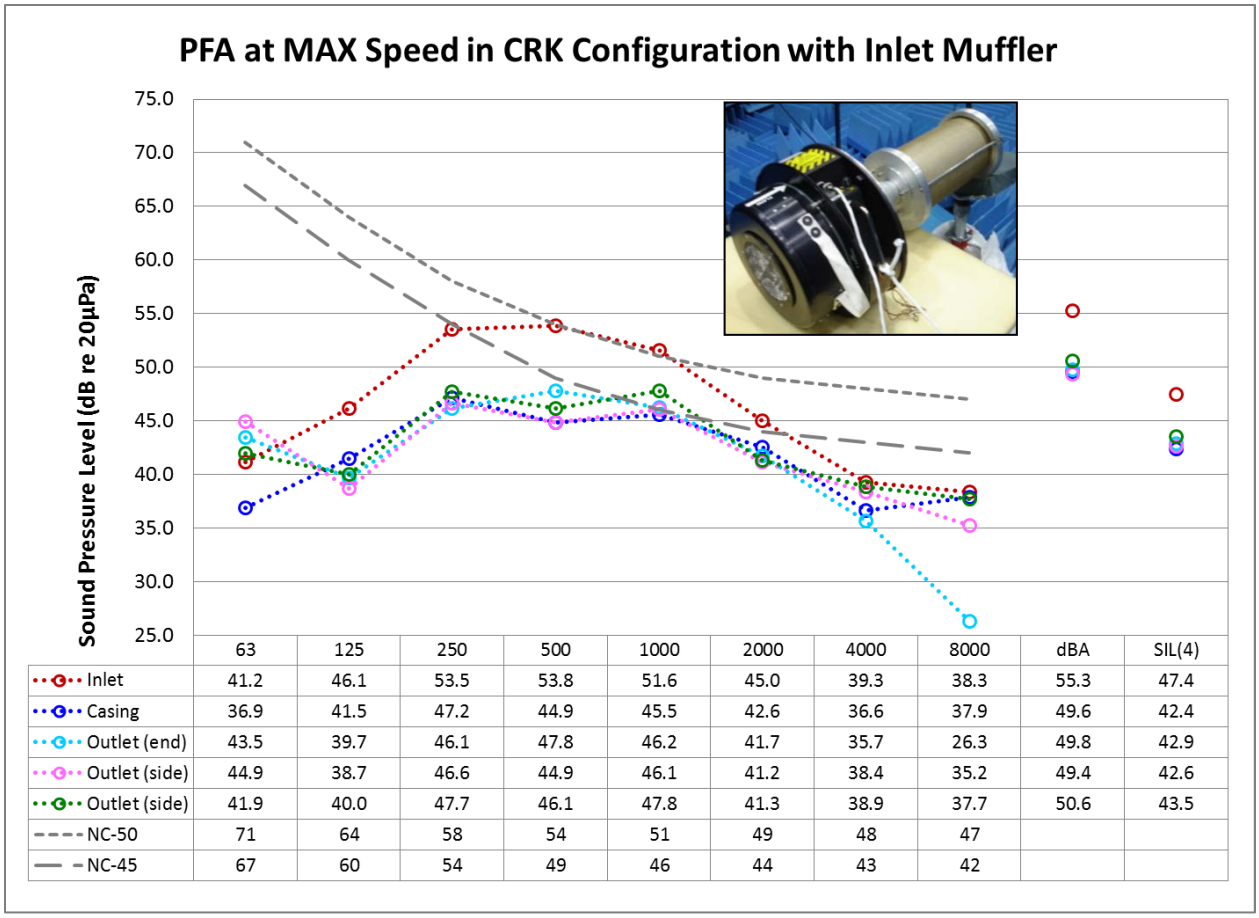
	63	125	250	500	1000	2000	4000	8000	A-Wtc	SIL(4)
Inlet (max)	44.3	47.1	56.4	55.8	54.1	45.4	39.8	41.0	57.1	48.8
Inlet (75%)	42.6	46.3	54.3	54.2	51.5	44.2	37.3	39.0	55.2	46.8
Inlet (50%)	41.1	47.7	51.5	51.5	49.3	43.7	34.5	37.2	53.0	44.8
Inlet (25%)	41.8	46.7	47.7	47.9	50.2	38.5	29.3	32.4	51.7	41.5
Inlet (min)	39.9	45.7	45.9	48.3	48.8	39.4	28.9	30.8	50.8	41.3
NC-45	67	60	54	49	46	44	43	42		
NC-55	74	67	62	58	56	54	53	52		
NC-50	71	64	58	54	51	49	48	47		



	63	125	250	500	1000	2000	4000	8000	A-Wtc	SIL(4)
Outlet (max)	47.7	49.1	61.6	57.0	53.2	47.3	41.6	36.7	58.3	49.8
Outlet (75%)	45.3	48.4	60.0	55.5	50.7	46.7	40.2	34.6	56.6	48.3
Outlet (50%)	44.4	50.6	56.1	53.4	48.6	44.1	37.2	31.7	54.1	45.8
Outlet (25%)	43.5	47.4	50.1	48.6	47.8	40.6	34.0	29.9	50.9	42.8
Outlet (min)	44.2	43.5	48.3	47.2	46.6	38.0	32.6	29.8	49.5	41.1
NC-45	67	60	54	49	46	44	43	42		
NC-55	74	67	62	58	56	54	53	52		
NC-50	71	64	58	54	51	49	48	47		

Figure 4 - PFA with Inlet and Outlet Mufflers- Effects of Fan Speed at Both Inlet (Upper) & Outlet (Lower)

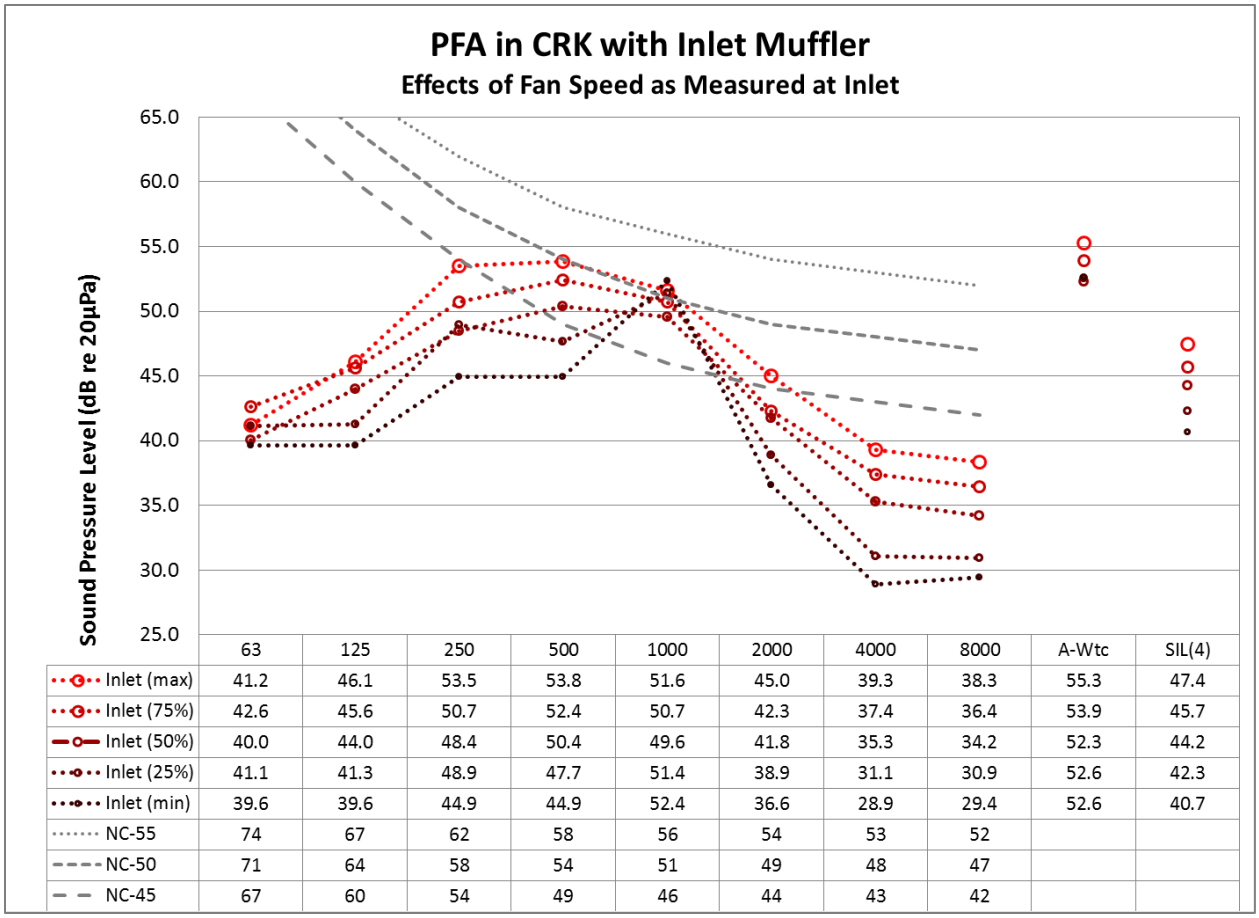
Figure 5 below presents 1/1 OB sound pressure level results for the PFA in CRK at max speed with the inlet mufflers. Data is shown at each of the five measurement locations: inlet, casing, and outlet (end), outlet (side), outlet (other side).



	63	125	250	500	1000	2000	4000	8000	dBA	SIL(4)
Inlet	41.2	46.1	53.5	53.8	51.6	45.0	39.3	38.3	55.3	47.4
Casing	36.9	41.5	47.2	44.9	45.5	42.6	36.6	37.9	49.6	42.4
Outlet (end)	43.5	39.7	46.1	47.8	46.2	41.7	35.7	26.3	49.8	42.9
Outlet (side)	44.9	38.7	46.6	44.9	46.1	41.2	38.4	35.2	49.4	42.6
Outlet (side)	41.9	40.0	47.7	46.1	47.8	41.3	38.9	37.7	50.6	43.5
NC-50	71	64	58	54	51	49	48	47		
NC-45	67	60	54	49	46	44	43	42		

Figure 5 - PFA in CRK with Inlet Muffler.

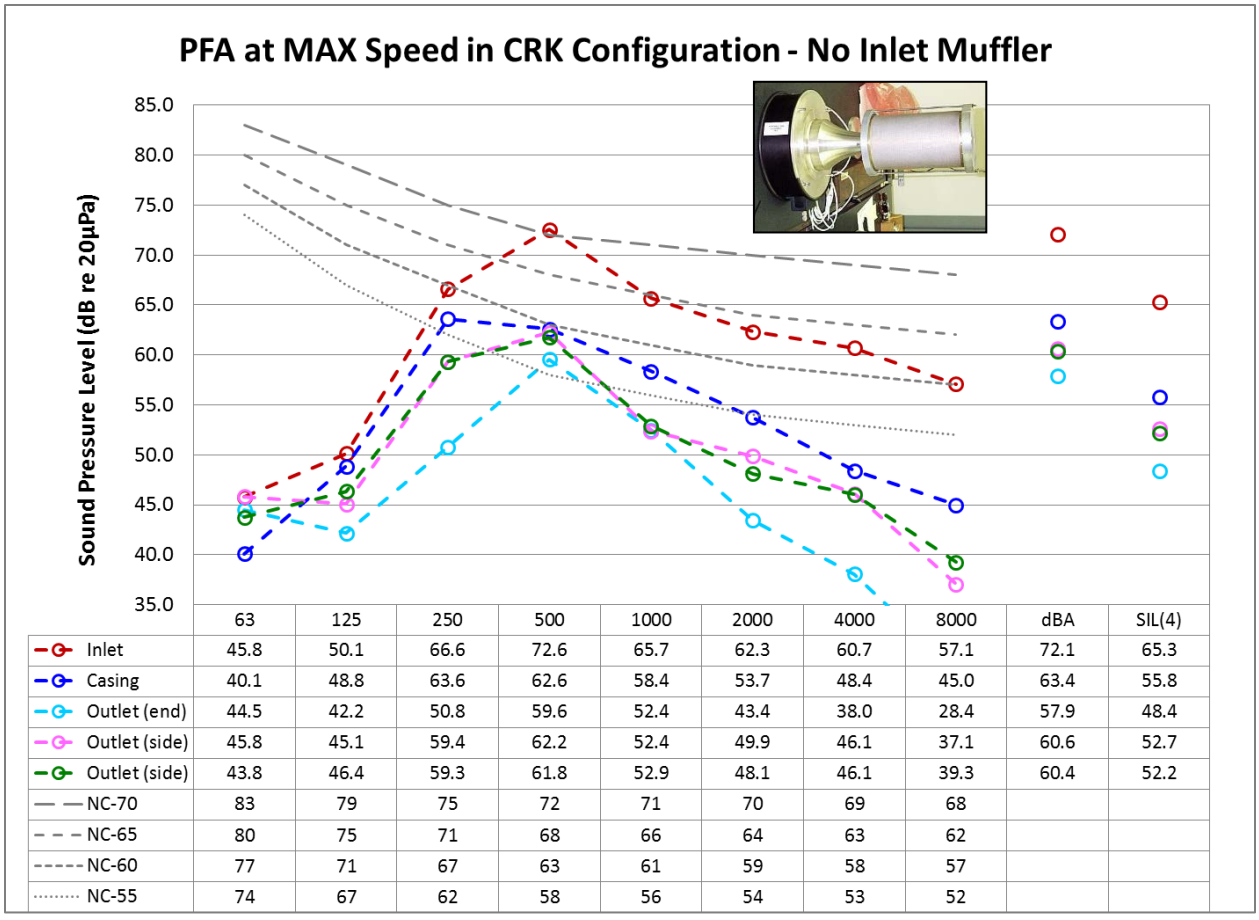
The inlet levels were loudest of the locations at all speeds for both CRK configurations. Figure 6 presents sound pressure levels as measured on the inlet side for the PFA in CRK with inlet muffler at varying speeds.



	63	125	250	500	1000	2000	4000	8000	A-Wtc	SIL(4)
Inlet (max)	41.2	46.1	53.5	53.8	51.6	45.0	39.3	38.3	55.3	47.4
Inlet (75%)	42.6	45.6	50.7	52.4	50.7	42.3	37.4	36.4	53.9	45.7
Inlet (50%)	40.0	44.0	48.4	50.4	49.6	41.8	35.3	34.2	52.3	44.2
Inlet (25%)	41.1	41.3	48.9	47.7	51.4	38.9	31.1	30.9	52.6	42.3
Inlet (min)	39.6	39.6	44.9	44.9	52.4	36.6	28.9	29.4	52.6	40.7
NC-55	74	67	62	58	56	54	53	52		
NC-50	71	64	58	54	51	49	48	47		
NC-45	67	60	54	49	46	44	43	42		

Figure 6- PFA in CRK With Inlet Muffler - Effects of Fan Speed as Measured at the Inlet.

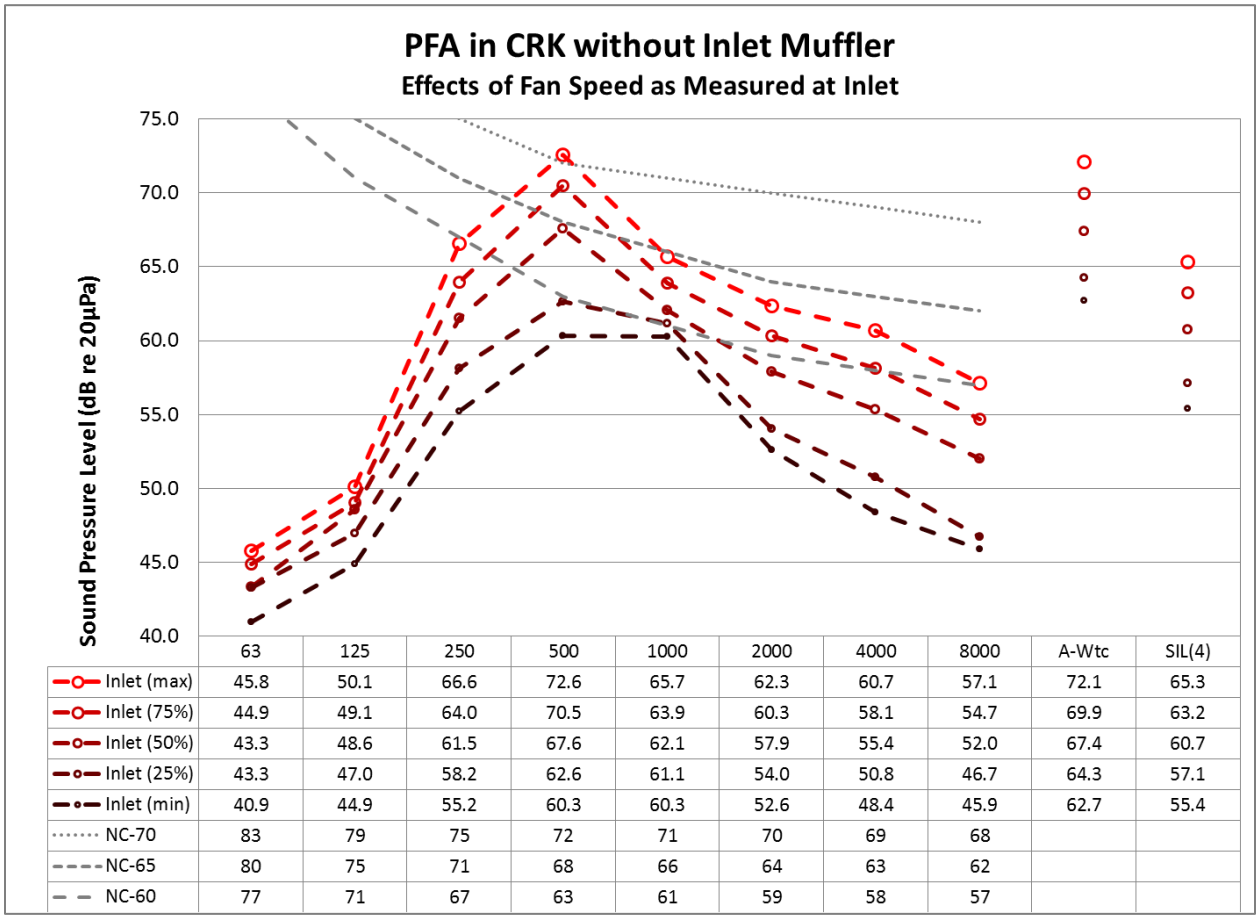
Figure 7 below presents 1/1 OB sound pressure level results for the PFA in CRK at max speed without the inlet mufflers. Data is shown at each of the five measurement locations: inlet, casing, outlet (end), outlet (side), and outlet (other side).



	63	125	250	500	1000	2000	4000	8000	dBA	SIL(4)
Inlet	45.8	50.1	66.6	72.6	65.7	62.3	60.7	57.1	72.1	65.3
Casing	40.1	48.8	63.6	62.6	58.4	53.7	48.4	45.0	63.4	55.8
Outlet (end)	44.5	42.2	50.8	59.6	52.4	43.4	38.0	28.4	57.9	48.4
Outlet (side)	45.8	45.1	59.4	62.2	52.4	49.9	46.1	37.1	60.6	52.7
Outlet (side)	43.8	46.4	59.3	61.8	52.9	48.1	46.1	39.3	60.4	52.2
NC-70	83	79	75	72	71	70	69	68		
NC-65	80	75	71	68	66	64	63	62		
NC-60	77	71	67	63	61	59	58	57		
NC-55	74	67	62	58	56	54	53	52		

Figure 7 - PFA in CRK without inlet muffler.

Figure 8 below presents sound pressure levels at the inlet for the PFA in this same configuration, while varying the fan speed.



	63	125	250	500	1000	2000	4000	8000	A-Wtc	SIL(4)
Inlet (max)	45.8	50.1	66.6	72.6	65.7	62.3	60.7	57.1	72.1	65.3
Inlet (75%)	44.9	49.1	64.0	70.5	63.9	60.3	58.1	54.7	69.9	63.2
Inlet (50%)	43.3	48.6	61.5	67.6	62.1	57.9	55.4	52.0	67.4	60.7
Inlet (25%)	43.3	47.0	58.2	62.6	61.1	54.0	50.8	46.7	64.3	57.1
Inlet (min)	40.9	44.9	55.2	60.3	60.3	52.6	48.4	45.9	62.7	55.4
NC-70	83	79	75	72	71	70	69	68		
NC-65	80	75	71	68	66	64	63	62		
NC-60	77	71	67	63	61	59	58	57		

Figure 8- PFA in CRK without inlet muffler- effects of fan speed as measured at the inlet.

References:

1. Jenkins, Arthur A. (ION Corporation), Ray, Charles D. (NASA MSFC), Roman, Monsi C. (NASA MSFC); “Portable Fan Assembly for the International Space Station”, SAE Technical Paper 1999-01-2110, 1999
2. Chan, Kevin D. (Hernandez Engineering, Inc.); “ International Space Station Portable Fan Assembly Failure Modes and Effects Analysis/ Critical Items List (FMEA/CIL)”, NASA MSFC-PLAN-3100, 22 June 2000
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4. Fluid Physics & Dynamics Group MSFC; “International Space Station Portable Fan Assembly Acoustic Noise Test Procedure”, NASA MSFC-PROC-TD63-001, 7 January 2000
5. Boone, Andrew J., Allen, Christopher S.; “Engineering Evaluation of the Portable Fan Assembly Noise Emissions when Using the LiOH Canister for CO2 Removal”, NASA JSC SF-15-007, 26 February 2015
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7. http://rotron.com/fans/tubeaxial/mil901.aspx