ACOUSTIC NOISE IN COLPRO

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ABSTRACT

Acoustic noise is a key factor in the usability and comfort of COLPRO shelter. The Chemically and Biologically Protected Shelter System (CBPSS) meets all acoustic requirements, below 85 dBA in the hard shelter, and below 75 dB(A) in the air beam shelter. A reduction of 10 dBA in the hard shelter or air beam shelter would have a significant impact on the shelter occupants. This 10 dBA reduction is the goal of ongoing research.

The results of this research will are presented. Key sources of noise, such as the A/C compressor, makeup fan, condenser fans, and recirculation fans, are analyzed based on collected CBPSS test data. The analysis illustrates how noise enters the shelter and is transmitted, as either airborne or structure borne. Using collected test data, the paths of noise from the environmental pod are annalized and hypothesized. The proposed acoustic noise reduction path is presented.

INTRODUCTION

A CBPSS is shown in Figure 1. Major subsystems include a dedicated M1113 HMMWV vehicle, a Lightweight Multipurpose Shelter (LMS) that is mounted on the back of the HMMWV, a 300 ft^2 air beam-supported soft shelter, a High Mobility Trailer with a 10 kW Tactical Quiet Generator (TQG). The HMMWV engine via a hydraulic pump subsystem, and the 10 kW TQG provides all needed power. The LMS contains a hydraulically powered environmental system to provide HVAC, air beam inflation, and chemical/biological filtration.

Figure 1. Chemical and Biologically Protected Shelter System (CBPSS).

There are several descriptors used to measure noise levels in an environment. The A-weighted sound pressure level is expressed in dB(A). This rating is most commonly used for outdoor applications to specify and test for community noise standards. The A-weighted sound level is a weighted sum of the energy contained in each octave band. The energy contained in each octave band is first adjusted by an adjustment factor tied to the sensitivity of the human ear at the octave band's center frequency.

The CBPSS is required to have noise levels in the rigid wall shelter below 85 dB(A) at locations RWS1, RWS2 and CP when in mobile mode. The noise levels in the Air Beam Shelter are required to be below 75 db(A) in static mode at locations ABS1 to ABS5[i]. This criteria was later modified to be consistent with contractual requirements to use the average dB(A) readings[ii]. Measurement locations are illustrated in Figure 1.

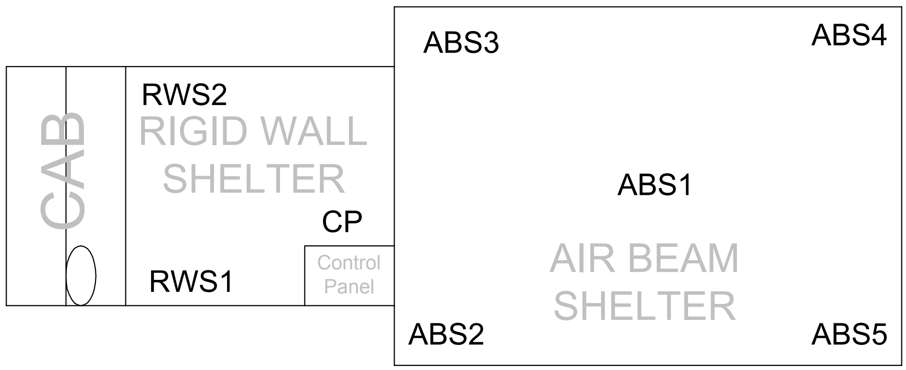

Figure 2. Noise Measurement Locations in CBPSS (RWS1, RWS2, ABS1, ABS2, ABS3, ABS4, ABS5).

During May of 2000 sound testing was conducted on CBPSS production units. The results with regards to the dB(A) criteria are shown in Table 1. The table indicates the CBPSS passes the 75 dB(A) and 85 dB(A) requirements when averaged in both the Air Beam Shelter and Rigid Wall Shelter.

TABLE 1. Sound testing Production Configuration May, 2000

SN	MODE	CP	RWS1	RWS2	ABS1	ABS2	ABS3	ABS4	ABS5	ABS AVG	RWS AVG
010	A/C Moble	80.1	84.0	80.4	NA	NA	NA	NA	NA	NA	81.5
011	A/C NBC Static	80.3	85.4	83.5	74.0	74.9	71.6	72.1	72.3	74.0	83.1
010	A/C NBC Static	83.4	87.9	83.6	76.5	75.4	72.3	72.2	74.5	74.2	84.9

APPROACH

The A-weighted sound level is considered a level sensitive measurement. There is no differentiation between acceptable and unacceptable noise environments, perceived by a human occupant. When subjectively compared, environments with the same A-weighted noise level can be judged significantly different in acceptability. An A-weighted noise spectrum may have the same value but be either hissy or rumbly, or neutral. Table 2 illustrates typical sound criteria for A-weighted measurements.

It is clear that the noise levels in the Air Beam Shelter are only slightly less that that of a Speedboat, and well above the level of being able to hold a normal conversation.

TABLE 2. Typical Sound Criteria (DBA)[iii]

Train Whistle	> 96 dB(A) at 100 ft
Factory work area	< 85 dB(A) (8 hours)
Semi-truck (35 mph)	< 83 dB(A) at 50 ft
Speed boat	< 80 dB(A) at 50 ft
Normal voice	~ 60 dB(A) at 3 ft
Open Office	45 to 50 dB(A)
Quiet Office	< 40 dB(A)
Recording Studio	< 20 dB(A)
Audiometic room	< 10 dB(A)

The purpose of the Air-Beam shelter is to serve as a chem/bio hardened hospital. Doctors will need to listen to stethoscopes, and confer with other medical professionals. A reduction of 10 dB(A) will have a significant effect on the efficiency and comfort of the occupants of the CBPSS. Looking toward this goal of 10 dB(A), testing has been performed on the CBPSS to identify key candidate improvements for noise reduction.

Four key components of the CBPSS were identified as possible key contributors to noise. The first two the HVAC compressor and condenser fan. Two other fans are of importance as well, the makeup air fan which brings in fresh air through the filtration system, and the recirculation fan that returns filtered and cooled and positively pressured air back into the shelter. These components are part of the environmental pod attached to the front of the rigid wall shelter above the HMMWV cab.

Tests were performed toggling on and off the different components to measure the effect on sound. A synopsis of the test results is shown in Table 3. Key conclusions from this analysis are:

- The Condenser Fan & Recirculation Fan appear to be the primary driver of the ABS noise. The contribution from just the Condenser Fan and Recirculation Fan is approximately 81 dB(A).
- The Secondary Driver is the Makeup Fan contributing 75.9 dB(A).
- The makeup fan at half speed contribution must be less then 70 dB(A) = 10 x log($10^{81.3/10}$-$10^{81.0/10}$).
- Assuming the increase from 80.1 to 81.3 dB(A) for turning off the A/C Comp was due to measurement error, the A/C Comp contribution alone must be less then 71 dB(A).

TABLE 3. Component Noise Effects Comparison

ABS AVG (DBA)	COND FAN	RECIRC FAN	A/C COMP.	MAKEUP FAN
80.1	On	On	On	Full
81.3	On	On	Off	Full
81.0	On	On	Off	Half
75.9	Off	Off	Off	Full
71.2	Off	Off	Off	Half

This data included none of the passive sound attenuation methods used for final qualification of the CBPSS, such as sound curtains between the Air Beam and Rigid Wall Shelters. A clear path is suggested for quieting of components. The condenser and recirculation fan must quieted first before there will be any effect from quieting any other components in the environmental pod. Due to the design the recirculation fan could not be run without the condenser fan running.

The recirculation fan is a double inlet centrifugal fan. There are two main approaches to reducing the noise levels of this centrifugal fan. The first has to do with the fact the fan always runs at worst case speed. The speed is based on moving enough air to keep the shelter cooled/heated and inflated in the hottest and coldest conditions. Table 5 indicates the range of reduction in noise that can be accomplished by adjusting the fan speed to the actual conditions encountered. In mild weather if the fan speed is reduced by only 20% a 5 dB(A) reduction is accomplished.

The second approach is to choose a more efficient fan blade design. Airfoil-blade fans tend to have the highest aerodynamic efficiency and lowest operating noise when compared to other fan types. Figure 3 illustrates a comparison between an Airfoil and Backward Curved fan. The figure illustrates it is possible to save 10 dB per octave band with the optimal fan choice.

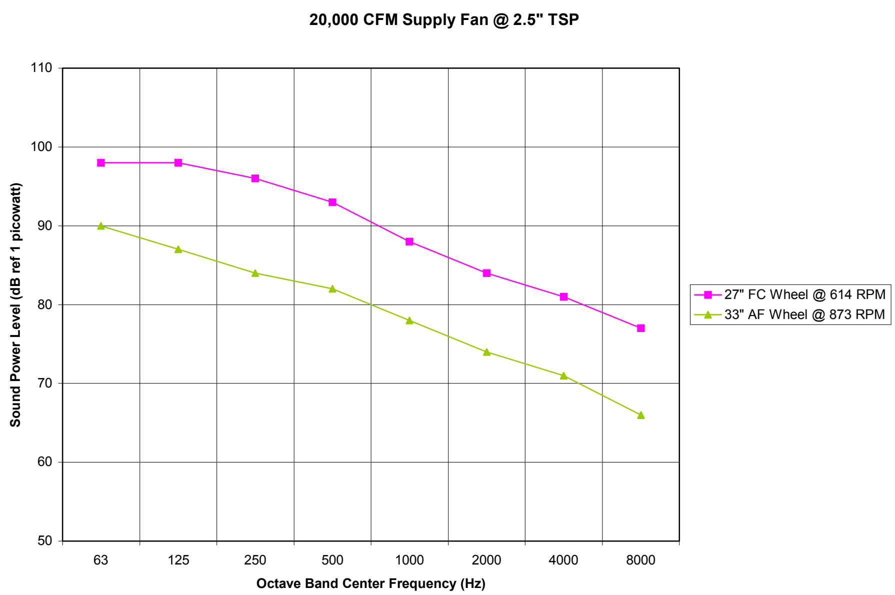

Figure 3. Comparison between Airfoil (AF) and Forward Curve Fan Blades[iv].

One question still remaining is how sound enters the Air Beam Shelter from the Rigid Wall Shelter. Sound must enter via the Rigid Wall Shelter because all mechanical equipment is structurally attached to the rigid wall shelter. Sound transmission may be airborne or structure borne. A particle board wall was placed in front of the opening of the rigid wall shelter into the air beam shelter. An attenuation effect of 4 dB(A) was found as the noise level was reduced from 79.6 dB(A) to 75.2 dB(A). This gives a starting point for attenuation regardless of how well we quiet components that generate noise. It also indicates that the primary means of sound entry into the Air Beam Shelter is through the Rigid Wall Shelter, not air ducting.

The last question remaining is how noise from components in the pod is transmitted into the Rigid Wall Shelter. Test results are shown in Table 4. The fact that the detaching of the pod from the shelter reduced noise from 80.4 dB(A) to 75.3 dB(A) clearly indicates the noise entry from the pod to the shelter is structure born. Additionally since slaving the engine/pump with the detached pod only reduced the noise less than a dB(A), somehow the transmission path of engine and pump noise is also structure born through the pod.

TABLE 4. Noise Entry from Environmental Pod to Rigid Wall Shelter

CONDITION	AVERAGE ABS (DBA)
Baseline A/C NBS on	80.4
Engine/pump slave	77.3
Pod loose	75.3
Pod loose/engine slaved	74.7

TABLE 5. Noise Reduction by Reducing Fan Speed[v]

FAN SPEED RATIO	NOISE REDUCTION, DB
1.0	0
0.8	5
0.6	11
0.4	20
0.2	35

Isolating the pod from the rigid wall shelter serves to further educe further the noise. A gasket physically separates the hard wall of the environmental pod from the wall of the rigid wall shelter to which the pod is attached. The pod is directly bolted to the wall of the shelter. Improvements in is isolating the pod would have a direct effect on reducing noise. A reduction of 5 dB(A) is entirely feasible.

CONCLUSION

The CBPSS passes all noise requirements. With crew comfort and usability in mind, analysis has been undertaken to find ways for reducing noise levels still further. The analysis presented indicates that a further reduction of 10 dB(A) is likely. Critical findings on noise sources, isolation, should be useful in future Collective Protection design criteria and decisions.

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3 – Beranek, L.L. 1971 *Noise and vibration control*. New York: McGraw Hill.

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[i] MIL-STD-1474, Section 5.1, Category E.
[ii] ECP 3009=E0604R1, SCN 010R1
[iii] from Designing HVAC Systems to Control Noise and Vibration
[iv] from Designing HVAC Systems to Control Noise and Vibration
[v] Applications of Manufacturers Sound Data pp. 44