Noise Characteristics and Simulation of Several Full Scale Turbojet Engines at Hush-House

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A hush house is arranged not only to maintain sufficient air flow through the wind tunnel but also to minimize the noise level with acoustical baffles inside the tunnels. An experimental investigation was conducted to determine the acoustic characteristics of several full scale turbojet engines of military fights inside the hush house. Acoustic measurements were taken outside the hush house at a distance of 75 m (far field) and inside or around (near field) the hush house from the fights. The military thrust data were obtained in and out of the hush house over a range of nozzle velocity up to 1247 (m/s). These military fights include TYPE-A and TYPE-B on active duty. For aircraft TYPE-A, maximum sound pressure levels in the far field were measured at the right front of inlet and the hush house exhaust wind tunnel. Noise levels at 75 m in far field decay by 8 dB as length of the wind tunnel was increased from 2.5m to 3.3m simulated using the ray acoustic method and confirmed by measured data diagnosed at Texas, USA.
Keywords: acoustical baffles, micro perforated sheet, engine noise, sound propagation

1. INTRODUCTION

A primary function of the hush house is to provide acoustic isolation of a jet aircraft engine from the surrounding environment. In the case of bare engine test stands the prolonged engine operation associated with normal maintenance procedures produce noise of sufficient magnitude and duration to give rise to health concerns, particularly hearing loss (Baughn, 1973, Burns and Robinson, 1970). And complaints come from residents of the town approximately 4.8 km away based on military reservation routines. The structure of the current hush house consists of a sound absorbent hanger with a dimension of 25.6 by 19.8 m (**Fig.1**). The surfaces of the hanger were covered with approximately 975.5 m^2 of absorbing panels, 10.2 cm thick with a 0.093 cm perforated face sheet, 16% open area, and filled with 76.9 kg/m3 thermal, fiberglass fill. The hanger fully encloses both uninstalled engines and the entire aircraft TYPE-A or -B during ground run-up. The hush house mainly needs to be air-cooled through the inlet area allowing large air flows and low air velocity past the aircraft under test. The intake systems are sound absorbent baffles arranged as a labyrinth. The muffler inner shell is made of perforated and corrugated stainless steel with a 72.1 kg/m^3 of 10.2 cm thick fiberglass fill, behind the shell. A deflector directs the exhaust gases leaving the muffler vertically.

The mechanism by which noise is produced in a hush house is quite complex and impossible to quantify with the data available. Though, numerical analysis using finite element model (FEM) is available for the hush house structure analysis in a lower frequency range but audible sound. The ultimate power of all acoustic emissions is the operation engine in afterburner mode; they might increase the fatigue of the engines, but peak levels generated from 500 Hz ~ 4000 Hz don't decrease. However, the effect of the operation is manifested as a superposition of many virtual acoustic sources in addition to the direct engine noise. For example, the hush house intake and exhaust air flow will produce noise possessing different power spectra and source along the hush house side walls while the exhaust noise may appear to be distributing along the muffler and as a near point source at the open end. Additionally, low frequency components of the noise may drive resonant modes of the hush house, augmenter tube, or other small structural features of the building (Miller et al., 1981). The sound pressure levels (SPL) emitted from a hush house exhibit a strong angular dependent relative to the axis of the structure. For low frequencies, Miller et al. found the SPL increase in excess of 20 dB for a bare engine in afterburner mode with an angle from the front to the rear in a free field. In general, the increase in peak SPL corresponds to the increase at the respective azimuths presented in the polar sound patterns (Ciepluch, et al., 1985). The most marked changes in SPL occurred at 120° axis for frequencies from 100 to 1,000 Hz for all engines. Above around 1,000 Hz, all engine configurations produced an angular independent for all nozzles. This reflects both the spectrum of engine noise and the fact that the acoustic panel performance improves with increasing frequency. Thus, the primary objective of this study was to ensure that, a remodeled hush house must undergo acceptance tests to establish the facility to meet the criteria of: in afterburner mode, A-weighted noise level may not exceed 75 dB (A) at any specified measurement points on the circular , 75 m radius from the center of the hush house.

2. METHODOLOGY

To perform on a military fight run-up the facility has to satisfy the acceptance noise tests, so before construction, the data from full-scale checkout in the current hush house are quite necessary. T-10 hush houses, developed by the American Air Force and, currently in operation, do not meet the criteria when the aircraft TYPE-A engines were tested. Microphones were located at near field and far field in front of the main inlet area and the front door of the hush house (**Fig. 1, 2**). All of the diagnosed points are placed at a height of 1.2 m except B2, placed at 8.5 m, in vicinity of the augmenter tube. Noise data were integrated every 15 seconds (LAeq), in afterburner mode, for aircrafts installed in the hush house ground run-up. A detailed solution in the remodeled hush house design recommends the increase of the depth of the inlet area resembling the length of the muffler expansion chamber proportional to the transmission loss (TL) of the duct acoustic system (Bilawchuk et al., 2003). The spectrum of TL data in the current T-10 and the remodeled design are listed in **Table 1**, and the planning for noise attenuation at hush house is illustrated in **Fig. 3**. To enforce the insertion loss of the front door leaf, we arranged an acoustical penal with a TL of NIC45 gauge by means of avoiding air leakage. The simulation processes can be subdivided as: (1). diagnostic tests using full scale aircraft TYPE-A in an current T-10 hush house, the sound power of engines can be calculated from sound pressure levels described in ISO3746. The sound absorption area (A) of the test room was obtained using measured reverberation time in the hush house instead.

The ray acoustics simulation software EASE (Renkus - Heinz, Inc.) was applied to generate the polar pattern to evaluate the boundary noise levels at the inner side of inlet area at every 0.6 m heights of the side wall (**Fig. 4**). (2). the SPL drops in of the remodeled wind tunnels (3.3 m) obtained by ASTM E477 - 06a (**Table 1**), are assumed to be the noise attenuation at the inlet area to generate a square noise source outside. Thus, the noise energy simulated at the far field was emitted mainly from these four square inlet areas and the top of the exhaust tunnel, because the TL of the T-10 hanger was approximately 10 dB greater than the measured inlet area.

3. RESULTS AND DISCUSSIONS

The maximum noise level of interior and the far field noise survey in afterburner mode at a full scale test facilities are compiled in **Table 2** and **Fig. 5**. The differences of the spectrum between engine noise propagated on concrete and grass of each diagnosed location in afterburner mode are expressed in **Fig 6**. The objectives and key results of the simulation model are presented in **Table 2** and **Fig. 7** for that resulted at near field, and **Fig. 8** at far field. The confirmation for the reliability of these results was give by a comparison with the measured values from Texas, USA (Miller et al., 1981). In addition, the calculated horizontal and vertical inlet flow models, TYPE-B, in the current T-10 are shown in **Fig. 9**. **Fig. 5** shows that noise abatement at B4 is frequency independent, the noise drops are 44 dB for full range because of the sub- inlet area, arranged as a labyrinth. The primary air intake area shows poor noise attenuation in the low frequency range at B1, and 20 dB rising in the range of 63 to 200 Hz relative to B4. The noise attenuation in B5 is mainly caused by wind noise through air leakage of the front door leaf. Thus, noise radiated mainly at location B1, and noise abatement in the lower frequency range is difficult only if the thickness of absorbent baffles is proportional to the wavelength of the sound. Generally, the wavelength of sound at 1000 Hz needs approximately 1 inch and 50 Hz needs approximately 20 ft (Miller et al., 1981). Therefore, to increase the length of the wind tunnel at primary air intake area is the most effective approach at present.

4. CONCLUSIONS

The model of calculated noise levels at the 75 m radius contour (far field), aircraft TYPE-A engines is effective for evaluating a remodeled hush house construction. A full- scale aircraft TYPE-A testing can help us realize the noise suppression performance of the acoustical panel in the hush house. Thus, the data obtained can enhance the hush house to offer more noise attenuation.

5. REFERENCES

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Table 1. The data of transmission loss (TL) of the duct were measured in respective to ASTM E477 - 06a standard.

Hz	*63*	*125*	*250*	*500*	*1000*	*2000*	*4000*	*8000*
current (dB)	27	29	34	44	40	36	36	25
remodeled (dB)	24	48	50	50	50	50	45	41

Table 2. Noise levels (dBA) were diagnosed at the near and far field for aircraft TYPE-A engine ground run-up, in afterburner mode. Measured levels denote the noise levels recorded at the current T-10, simulated levels denote the levels of remodeled T-10.

				Near Field			
Location	P1	B1	B2	B3	B4	B5	B7
measured	89.3	98.5	69.1	87.9	95.4	98.1	142.9
simulated	86.5	86.5	-	75.6	83.4	79.5	143.1
				Far Field			
Location	M1	M2	M3	M4	M5		
measured	76.1	73.5	75.8	74.0	74.2		
simulated	71.8	71.9	71.9	71.5	71.0		

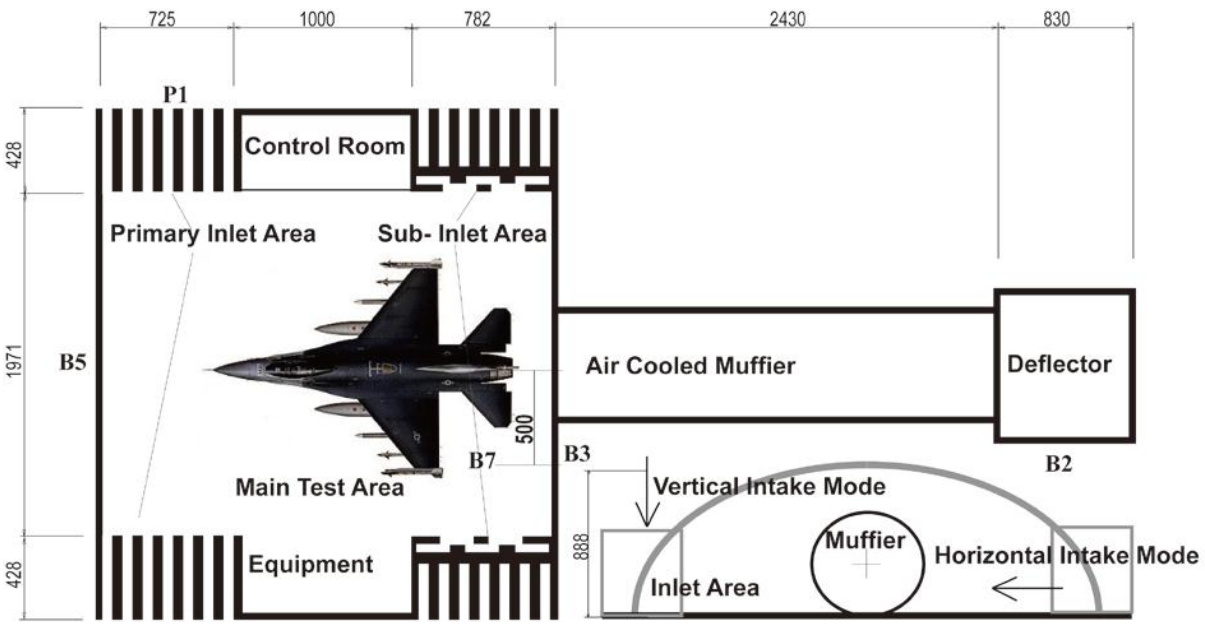

Figure1. Locations of noise survey stations and the current T-10 hush house arrangement at near-field

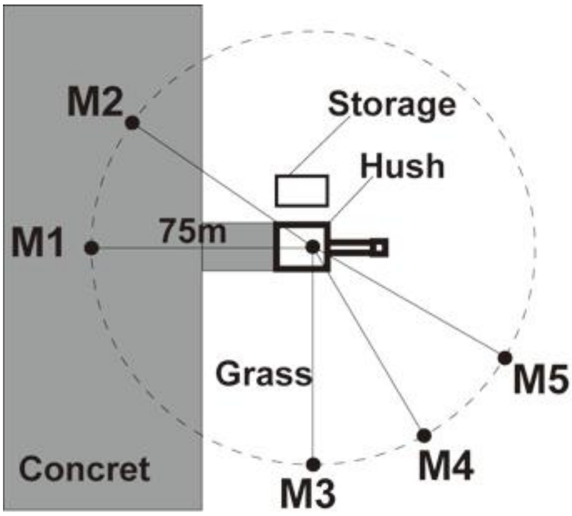

Figure2. Locations of noise survey stations (M1 ~ M5) and the current T-10 hush house at far-field

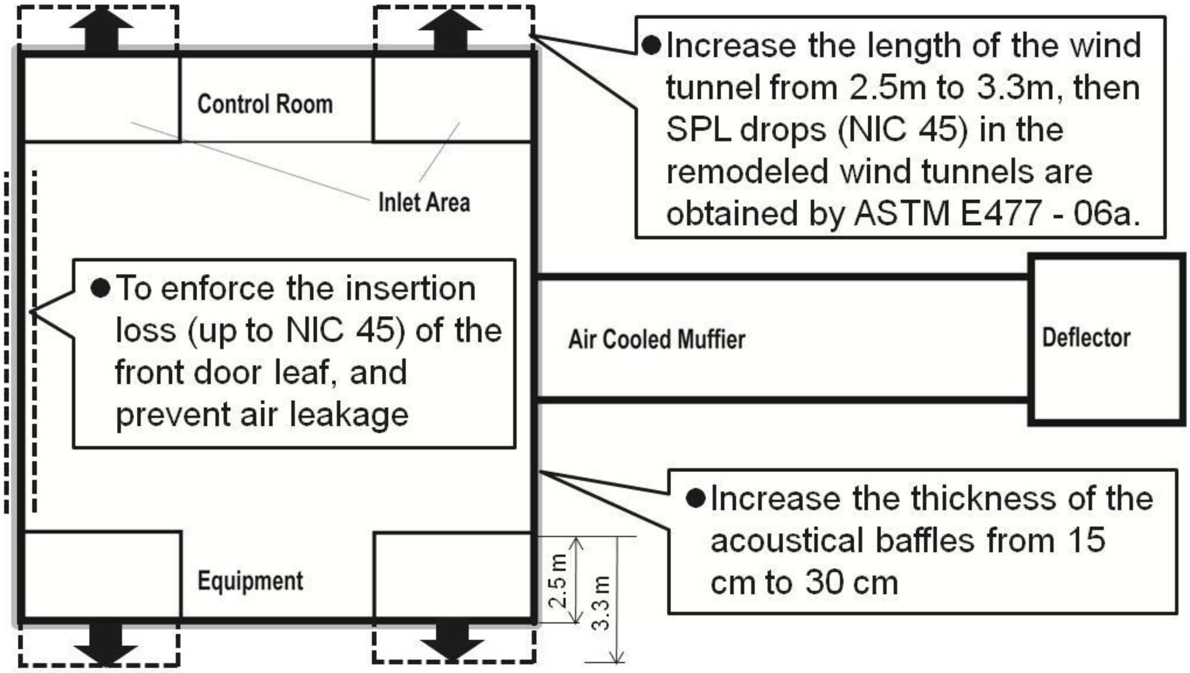

Figure3. The strategies of noise attenuation were proposed for the current hush house.

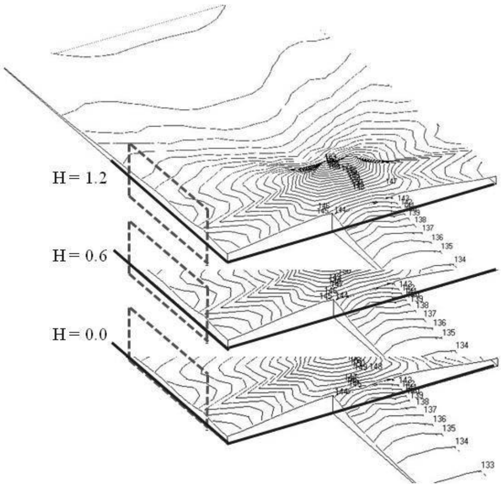

Figure4. The boundary noise levels at the inner side of the inlet area simulate a side wall at every 0.6 m height.

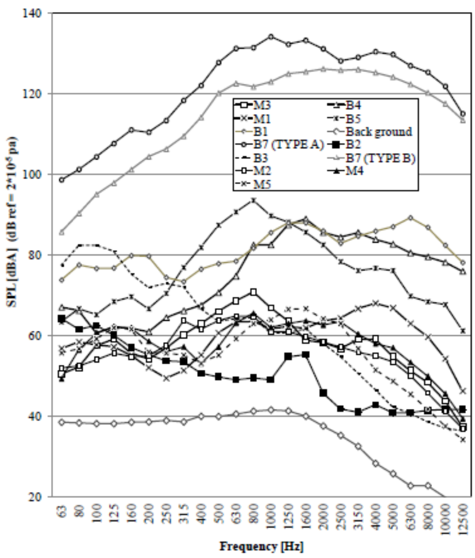

Figure5. The spectrum of each diagnosed location, in afterburner mode.

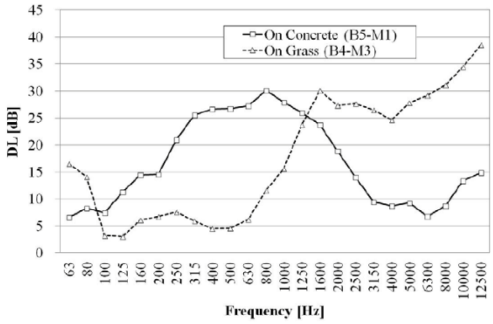

Figure6. The differences between on concrete and grass of each diagnosed location, in afterburner mode.

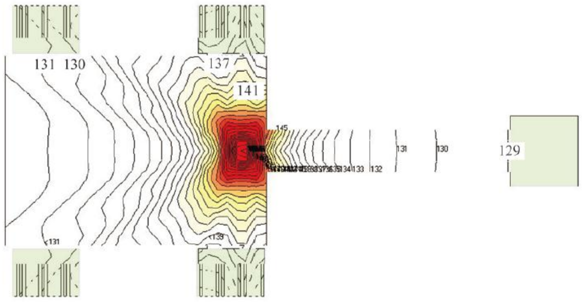

Figure7. The noise distribution at the near field is simulated using the remodeled T-10 for aircraft TYPE-A, in afterburner mode.

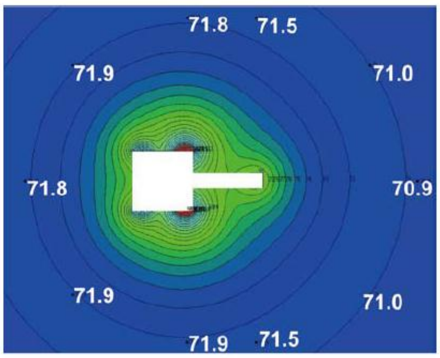

Figure8. The noise distribution at the far-field is simulated using the remodeled T-10 for aircraft TYPE-A, in afterburner mode.

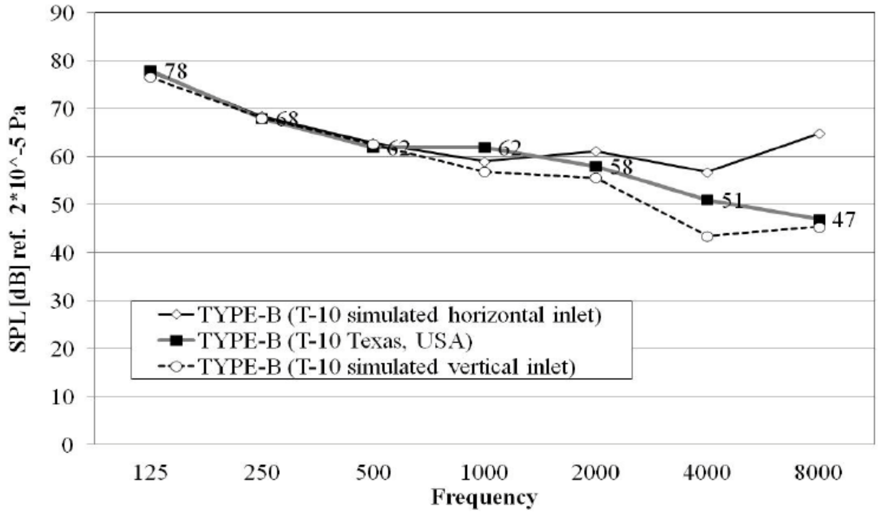

Figure9. Comparison between the measured and calculated SPL values for aircraft TYPE-B installed in the current T-10.