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Flight test investigation of cabin noise exposure in the Royal Canadian Air Force CH-147F helicopter

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High levels of helicopter cabin noise affects communication, but more importantly, prolonged exposure may lead to hearing loss and disability or eventual loss of flight status if aircrew hearing protection is insufficient or improperly worn. The helicopter cabin acoustic environment consists of multi-tonal rotor noise, broadband noise, and high frequency transmission/hydraulic systems noise. In addition, military helicopter missions may involve a large diversity of maneuvers requiring flight with cabin doors open or closed. For such missions, the noise components in helicopter cabin also vary significantly depending on mechanical and aerodynamic conditions. Aircrew cabin noise exposure was investigated in a Royal Canadian Air Force CH-147F helicopter during a number of representative flight maneuvers with the cabin doors open and closed. The results were analyzed and evaluated to determine the acoustic performance of aircrew hearing protection equipment.

1 INTRODUCTION

The evaluation of noise levels experienced by helicopter aircrew is essential for the selection of optimum hearing protection for enhancing aircrew safety and mitigating long term

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health issues. Military helicopter missions such as rappelling, search and rescue, as well as the delivery of payloads and weapons require flight with helicopter cabin doors open. In this configuration the helicopter cabin noise levels may exceed the limits of aircrew hearing protection equipment. This paper presents a flight test performed on a Royal Canadian Air Force (RCAF) CH-147F Chinook helicopter. Sound Pressure Levels (SPL) were measured in the aircraft cockpit and aft cabin at nine aircrew stations during a selection of standard and combat flight maneuvers to characterize the cabin noise environment in representative flight conditions and configurations. The results were compiled to determine the acoustic performance of aircrew hearing protection equipment.

2 FLIGHT TEST PROCEDURE

The objective of the flight test was to characterize the cabin noise exposure of aircrew during typical helicopter maneuvers with cabin doors closed and open. A Royal Canadian Air Force's (RCAF) CH-147F Chinook Medium-to-Heavy-Lift helicopter was instrumented for the investigation.

Requirements for test instrumentation, as well as procedures for the measurement and reporting of cabin interior sound pressure levels under steady flight conditions were obtained from ISO 5129, ISO 9612, and CSA Z107.56-06 standards[1,2,3]. In accordance to ISO 5129, the interior of the aircraft was unaltered with reference to the normal mission configuration. Seat backrests were set to their most upright position, while the number of occupants in the test aircraft was kept to the minimum (5) required for conducting the tests. To eliminate interference of sound propagation, care was taken to ensure that no obstructions were placed between the microphone locations and the aircrew positions. The positions of crew members included the pilot-in-command (right seat, cockpit), copilot (left seat, cockpit), load master flight engineer at STA120 and two NRC research officers performing the data acquisition at STA250 and STA320 respectively as shown in Fig. 1.

The flight test sorties encompassing standard helicopter maneuvers can be categorized into three groups. Flight sequence measurement runs for both open and closed doors configurations are shown in Table 1. Ground interface maneuvers included ground running, take-off, and landing on a paved tarmac. Stationary flight involved hovering in helicopter ground effect at two altitudes of 10 feet and 40 feet, respectively, as well as a sling configuration at two altitudes of 40 feet and 80 feet respectively. Steady airspeed maneuvers included climbing, level, and descending flight. The maximum flight speed attained during testing was 150 knots. Flight conditions for each maneuver were maintained for a minimum of 60 seconds to provide steady acoustic environments suitable for recording. The test aircraft layout and instrumentation suite are shown in Fig. 1.

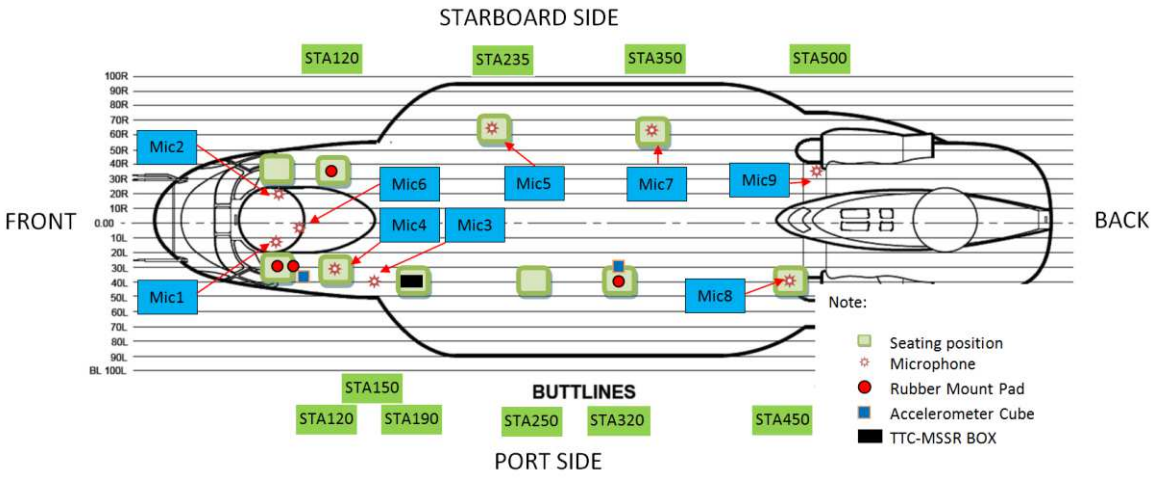

Fig. 1 – Sensor and aircrew locations in the CH-147F helicopter cabin.

Table 1 – Flight sequence measurement runs with doors open (a) and closed (b)

a)

Run ID	Flight Condition	Description	Duration
1	Ground	EPUSHA ON	60s
2		Ground Power, Avionics ON	60s
4		APU ON, Avionics Running	60s
6		APU ON, Engine Levers Idle	60s
8b		APU ON, Engine Levers Flight	60s
10		APU OFF, Engine Levers Flight	60s
11	Hover	Hover 10 feet, doors open, hatch open	60s
12		Hover 40 feet, doors open, hatch open	60s
13	Sling	Sling 40 feet door open, hatch open	60s
14		Sling 80 feet door open, hatch open	60s
35	Level	30 kts	60s
36		80 kts	60s
37		120 kts	60s
38		140 kts	60s
39		150 kts	60s
40	Manoeuvre	80 kts, 30Deg Bank	60s
41		80 kts, 45 Deg Bank	60s
42		100kts, 30 Deg bank	60s
43		100kts, 45 Deg bank	60s
44		120 kts, Rate 1 Turn	60s
45		140 kts, Rate 1 Turn	60s
46		70kts, Descend Turn, 60Deg	60s
47		70kts, Descend Turn, 60Deg, reverse	60s

b)

Run ID	Flight Condition	Description	Duration
15	Hover	Hoover 10ft door closed	60s
16		Hover 40ft door closed	60s
17	Sling	Sling 40ft door closed, hatch closed	60s
18		Sling 80ft door closed, hatch closed	60s
19	Level	30 kts	60s
20		80 kts	60s
21		120 kts	60s
22		140 kts	60s
23		150 kts (optional)	60s
24	Manoeuvre	80 kts, 30Deg Bank	60s
25		80 kts, 45 Deg Bank	60s
26		100kts, 30 Deg bank	60s
27		100kts, 45 Deg bank	60s
28		120 kts, Rate 1 Turn	60s
29		140 kts, Rate 1 Turn	60s
30		70kts, Descend Turn, 60Deg	60s
31		70kts, Descend Turn, 60Deg, reverse	60s
32	Approach	Normal Approach to Hover	60s
33		Normal Approach to No Hover Ldg	60s
34		Roll on landing	60s

2.1 Microphone mounting

In accordance to ISO 5129, the microphones were placed at fixed locations with custom designed mounts and tripods to minimize measurement interference. The hands-free design eliminated the need for operators to grasp microphone extension rods during measurements. Windscreens were fitted over all microphones in order to accommodate the open doors flight test. Note that the insertion loss of all windscreens was measured in advance in the absence of wind within a reverberant chamber to determine the correction factors.

Nine PCB Piezotronics microphones (ICP type PCB 378B02 with preamplifier type 426E01) were used for acoustic measurement. These microphones were calibrated according to standard test procedures using a GRAS Type 42AC sound calibrator.

Each of the seven seated position microphones were located on the seat centerline. In accordance with standard procedure[4] MIL-STD-1294A, they were oriented with the vertical axis pointed upwards, located at a distance of 0.15 meters from the headrest, and 0.8 meters above the unoccupied seat cushion. Pictures of microphone and fixture configuration on flight engineer seat and at a cabin passenger seat station are shown in Fig. 2. The pilot microphone position was located at the seated pilot head height with the pilot present and seated. It was located within 0.1 meters of the helmet position. The two standing crew microphone positions were located at 1.65 meters above the floor. The microphone locations in the helicopter cabin are shown in Fig. 1.

a) b)

Fig. 2 – Microphone and fixture configuration on: a) flight engineer seat and b) at a cabin passenger seat station

2.2 Airworthiness considerations

During the flight test, the HGU-56P-CF flight helmet was worn by all aircrew members. For safety reasons, no sensors were attached directly to the aircrew. With respect to aircraft airworthiness requirements, a TTC MSSR-100C series miniature Data Acquisition (DAQ) System was installed on the RCAF CH-147F Chinook helicopter, and this instrument was considered a non-essential item for normal flight operations. This DAQ system was configured as a self-powered, standalone unit operating on batteries. The unit was installed in the aircraft by strapping it to a passenger seat (see Fig. 3) at location STA190 as shown in Fig. 1. Each functional module of the DAQ system was certified by TTC according to applicable MIL and other non-government standards for aircraft flight test purposes. As integrated, the system was not part of the RCAF CH-147F Chinook helicopter critical flight instrumentation and did not interfere with aircraft operations.

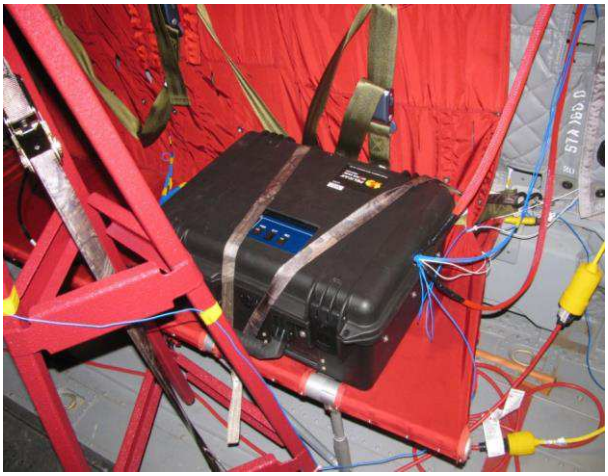

Fig. 3 – Portable data recording instrumentation box (TTC-MSSR).

3 CABIN NOISE EXPOSURE

The Sound Pressure Levels at nine cabin crew stations were measured during the flight test. Aircrew noise exposure was evaluated using Insertion Loss data, which was measured for the HGU-56P-CF flight helmet in accordance to procedures[5] specified in ANSI/ASA S12.42-2010 using the GRAS Acoustic Fixture 45CB. The averaged Insertion Loss data is shown in Fig. 4.

The Power Spectral Density at all nine aircrew stations for the Closed Doors configuration at 150 knots level flight condition (Run 23) is shown in Fig. 5. The Power Spectral Density at all nine aircrew stations for the Open Doors configuration at 150 knots level flight condition (Run 39) is shown in Fig. 6. It can be observed that the low frequency noise spectrum is mainly influenced by N/rev harmonics of the helicopter rotors while the high frequency behavior is mainly influenced by rotor transmission gear meshing tonal noise despite the door configurations.

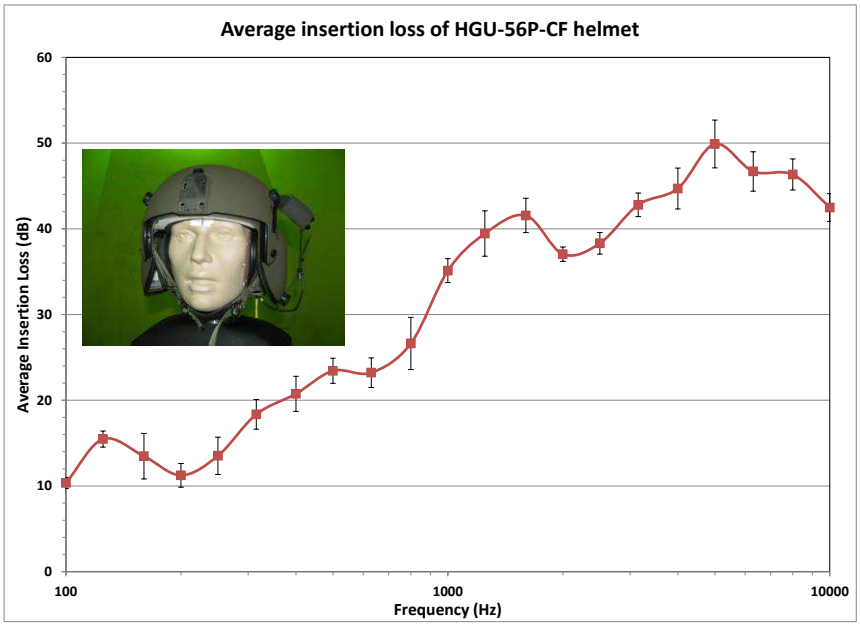

Fig. 4 – Average Insertion Loss of HGU-56P-CF helmet

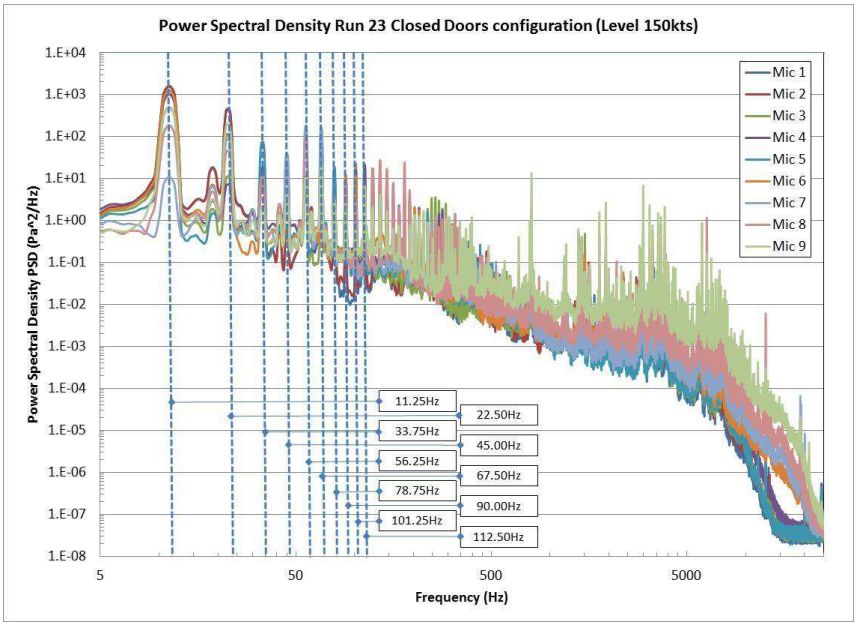

Fig. 5 – Power Spectral Density for Closed Doors configuration Level 150 knots flight segment

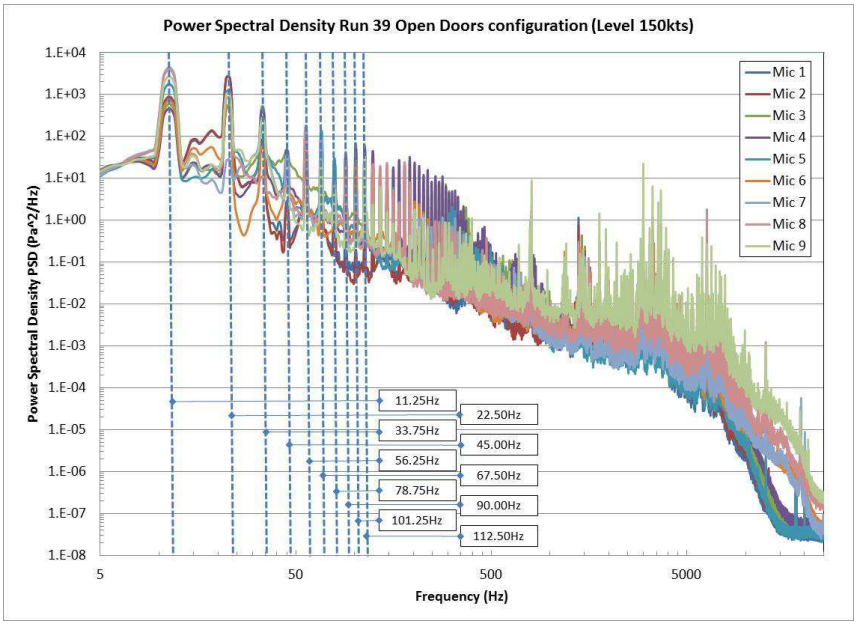

Fig. 6 – Power Spectral Density for Open Doors configuration Level 150 knots flight segment

The A-weighted Sound Pressure Level spectra for all nine aircrew stations at 150 knots level flight conditions are presented in Fig. 7 (doors closed, Run 23) and Fig. 8 (doors open, Run 39) respectively. According to Fig. 7 and Fig. 8, during flight segments Run 23 and Run 39, a maximum overall A-Weighted SPL of 119 dB(A) was measured by Mic 9 at the aircrew station located at STA500 starboard side. The Mic9 location is shown in Fig. 1.

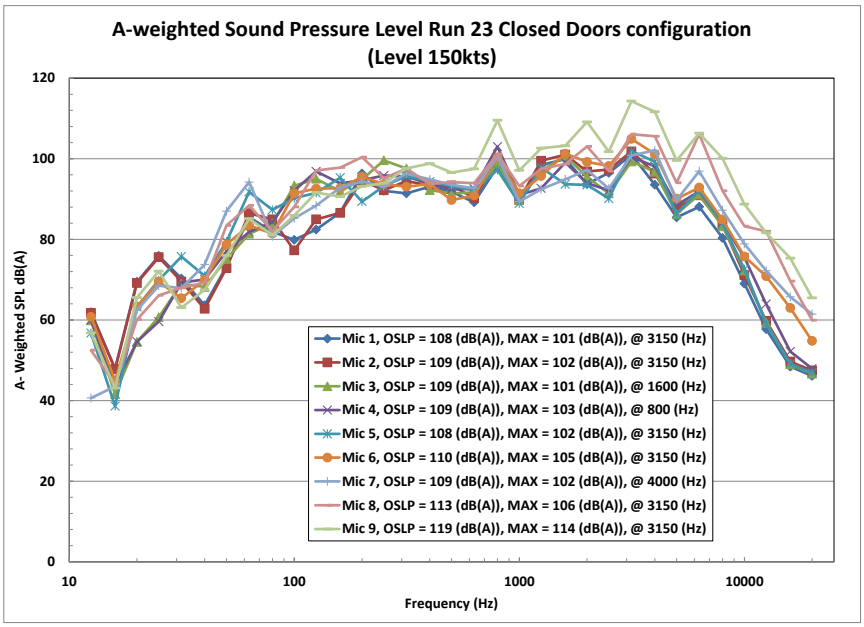

Fig. 7 – Sound Pressure Level for Closed Doors configuration Level 150 knots flight segment

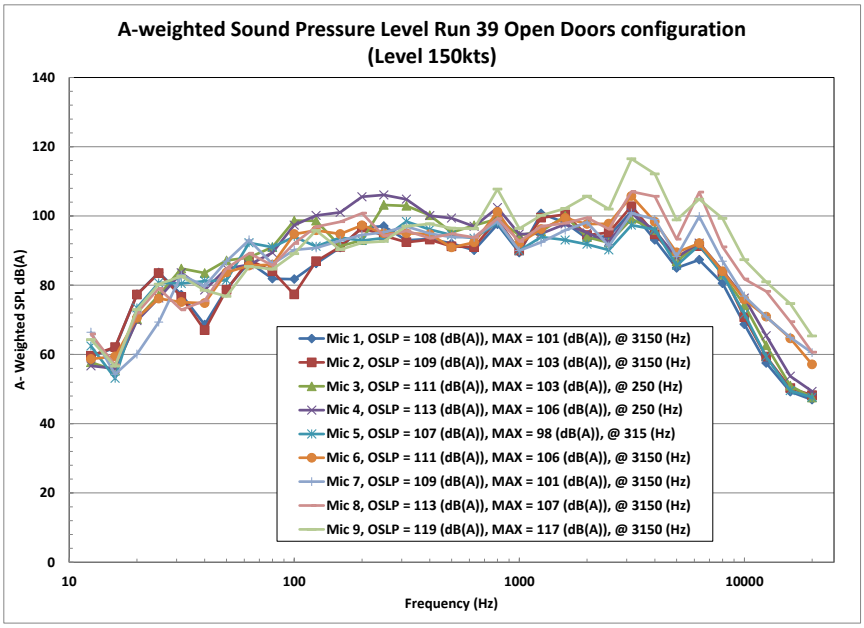

Fig. 8 – Sound Pressure Level for Open Doors configuration Level 150 knots flight segment

The average measured Insertion Loss of HGU-56P-CF helmet was used to determine the sound pressure levels to which aircrew members are exposed at different stations in the cabin.

The A-Weighted overall SPL measured at different stations in the cabin, for each flight segment, for aircrew protected with a HGU-56P-CF helmet is shown in Fig. 9. It has to be mentioned that the flight test included most of the critical flight segment maneuvers in real flight missions. Using the measured sound pressure levels and the real accumulated time for each flight segment during a mission, the aircrew noise exposure can be determined for each station. As an indication, the maximum noise exposure limits from 8 hours to 0.5 hours, according to CSA Z107.56-06 standard[3] and the Canada Labour Code, Part II[6], are also shown in Fig. 9.

It can be observed from Fig. 9 that the HGU-56P-CF provides acceptable noise attenuation to the CH-147F helicopter interior noise for most aircrew stations over most flight segments for durations higher than 8 hours. However, high noise levels were measured at some stations during specific flight segments. As an example, at the Mic 4 aircrew location, an overall level of 98 dB(A) was measured for aircrew protected with a HGU-56P-CF helmet during Run 39 Open Doors configuration in Level 150 knots flight condition,. According to CSA Z107.56-06 standard and the Canada Labour Code, Part II, the maximum allowed exposure to the SPL measured during Run 39 is approximately 38 minutes. Considering the mission-type profile of this helicopter it is expected that long durations and often Open Doors configuration of Level 150 knots flight segments would be part of daily missions. Following this reasoning, a close surveillance of the noise exposure for Mic 4 crew station is recommended.

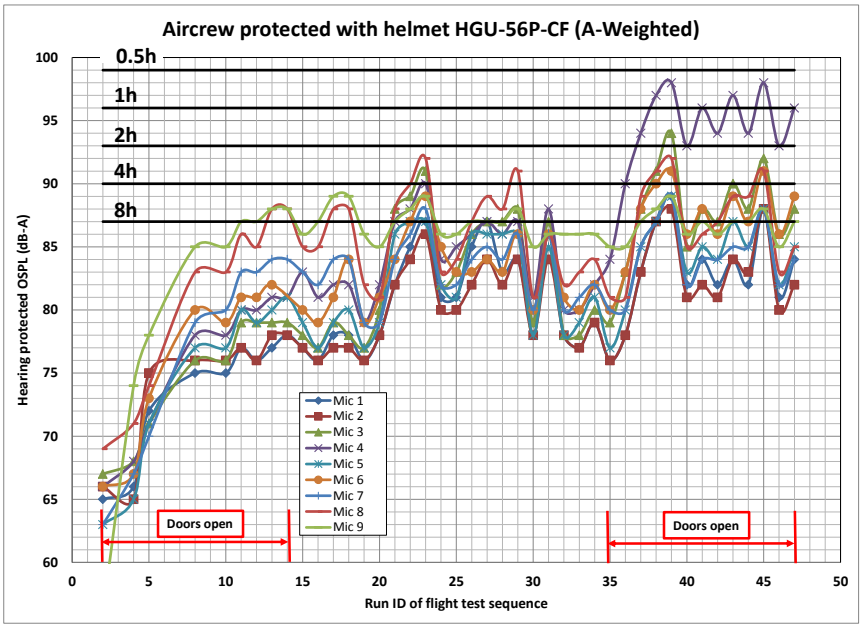

Fig. 9 – Overall Sound Pressure Levels for all flight segments at all stations for aircrew wearing a HGU-56P-CF helmet.

4 DISCUSSION AND CONCLUSIONS

The main objective of the work was to characterize the cabin noise exposure of aircrew during a range of flight maneuvers. Noise levels in the Royal Canadian Air Force's CH-147F Chinook Medium-to-Heavy-Lift helicopter configured with aft cabin doors closed or opened were measured at nine cockpit and aft cabin stations. Cabin noise was measured during flight maneuvers consisting of ground interfacing, sling, hovering, and steady forward flight conditions.

At low frequencies, tonal harmonics of the rotor rotating speed were prevalent in all flight conditions while the high frequencies SPL was mainly dictated by the rotor transmission gear meshing tonal noise. Aircrew overall noise levels exposure was evaluated using Insertion Loss data measured in the HGU-56P-CF flight helmet using the GRAS Acoustic Fixture 45CB according to ANSI/ASA S12.42-2010. It has been determined that the HGU-56P-CF helmet provided acceptable attenuation for the measured cabin noise in compliance with the Canada Labour Code, Part II. However a close surveillance of the noise exposure is required for some aircrew stations.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

1. ISO 5129:2001, “Acoustics - Measurement of sound pressure levels in the interior of aircraft during flight”.
2. ISO 9612:2009, “Acoustics - Determination of occupational noise exposure - Engineering method”.
3. CSA Z107.56-06, “Procedures for the measurement of occupational noise exposure”.
4. MIL-STD-1294A, “Acoustical noise limits in helicopters”.
5. ANSI/ASA S12.42-2010, “Methods for the Measurement of Insertion Loss of Hearing Protection Devices in Continuous or Impulsive Noise Using Microphone-in-Real-Ear or Acoustic Test Fixture Procedures”.
6. Canada Labour Code, Department of Justice Canada.