

# CLOSED DOOR FLIGHT TEST INVESTIGATION OF CABIN NOISE EXPOSURE IN THE NRC BELL 412 HELICOPTER

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## 1 Introduction

Aircraft interior noise impairs crew communication and degrades comfort. The helicopter cabin acoustic environment consists of multi-tonal rotor noise, broadband noise, and high frequency transmission/hydraulic systems noise. Continuous exposure may lead to hearing loss if personnel hearing protection is insufficient or improperly worn. 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 health issues. Aircrew cabin noise exposure was investigated by the National Research Council of Canada (NRC) on its Bell 412 research helicopter. Results were compiled to determine the acoustic performance of hearing protection devices. Sound Pressure Levels (SPL) were measured in the aircraft cockpit and aft cabin at three aircrew stations during a selection of standard flight maneuvers.

## 2 Flight test procedures and equipment

The objective of the flight test was to characterize the cabin noise exposure of aircrew during typical helicopter maneuvers. The NRC Bell 412, a civilian variant of the Royal Canadian Air Force's CH-146 Griffon tactical/utility helicopter, was instrumented for the investigation. The aircraft cabin retained its standard manufacturer acoustic treatments with testing performed with aft cabin doors closed. Noise measurements were recorded at three cockpit and aft cabin stations.

Standard procedures including ISO 5129 [1], ISO 9612 [2] and CSA Z107.56-06 [3] as well as MIL-STD-1294A [4] were applied in this investigation. These standards defined requirements for instrumentation, as well as test procedures for the measurement and reporting of sound pressure levels at crew and passenger locations under steady flight conditions. The flight test procedure adopted for this investigation was similar to that for the flight test performed with aft cabin doors opened. Details of this flight test plan and aircraft configuration (including microphone fixtures and instrumentation system) were presented in Ref [7].

### 2.1 Microphone mounting

In accordance to ISO 5129, the microphones were placed at fixed locations with custom designed mounts and a tripod 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 prepare them for the open doors flight test described in Ref [7]. Note that the insertion loss of all windscreens was measured in advance in the absence of wind using a reverberant chamber.

### 2.2 Airworthiness considerations

During the flight test, aircrew wore the SPH 5CF flight helmet. For safety reasons, no sensors were attached directly to the aircrew. With respect to aircraft airworthiness requirements, the TTC MSSR-100C series miniature Data Acquisition (DAQ) System installed on the NRC Bell 412 helicopter 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. Each functional module of the DAQ system was certified by TTC according to applicable MIL and non-government standards for aircraft flight test purposes. As integrated, the system was not part of the NRC Bell 412 critical flight instrumentation and did not interfere with aircraft operations.

## 3 Results

### 3.1 Flight data parameters

Flight testing was performed in Ottawa (Canada) over NRC test ranges and routes. Both acoustic and flight data were recorded for analysis. Flight test maneuvers consisted of ground interfacing, hovering, and steady forward flight conditions. Flight parameters including air data, inertial data, rotor speeds and torque data were recorded on the NRC Bell 412 research data acquisition system as follows:

- Barometric Altitude (**ALT**), feet;
- Airspeeds (Indicated, **IAS**; True, **TAS**), knots;
- Attitudes (**Pitch**, **Roll**, **Heading**), degrees;
- Rotor speeds (Main, **MRRPM**; Tail, **TRRPM**), RPM;
- Main Rotor Mast Torque (**TQMast**), %

As presented in **Table 1**, the maximum altitude and true airspeed for the flight test occurred at 1800 feet and 135 knots, respectively. Pitch and roll attitudes did not exceed 6 degrees and 3 degrees, respectively. The baseline rotor-speed (324 RPM) varied approximately 1 %. Of significance in high frequency engine noise generation, the highest mast torque (83%) was recorded during high speed descent.

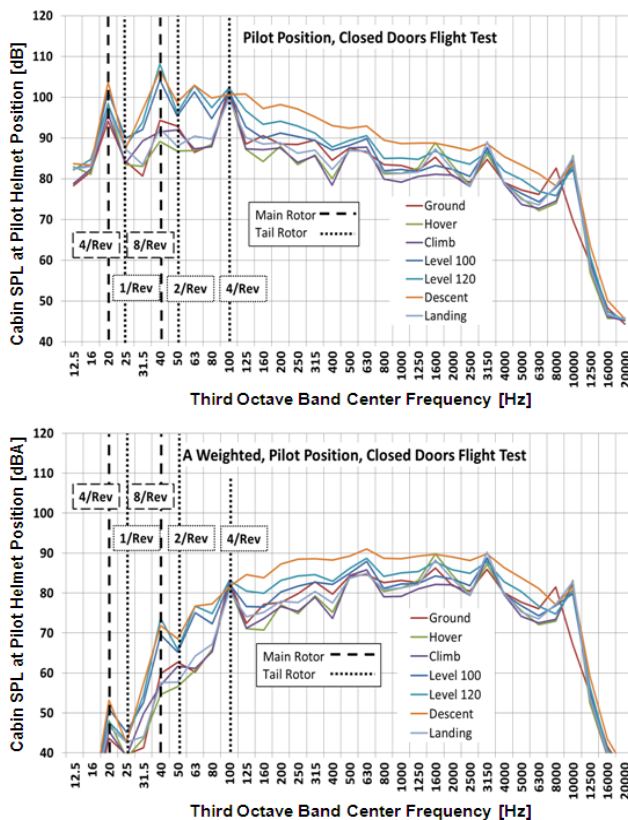
**Table 1. Recorded Flight Data Parameters**

Event	Alt (ft)	IAS (kts)	TAS (kts)	Pitch (Deg)	Roll (Deg)	Heading (Deg)	MRRPM (RPM)	TRRPM (RPM)	TQMast (%)
GROUND RUN	380.05	8.14	14.52	3.61	-0.21	278.40	323.71	1658.51	23.81
HOVER (H = 60)	434.09	10.05	15.72	6.15	-0.84	279.71	324.15	1660.78	72.60
CLIMB (V = 60)	1043.56	54.86	58.10	4.10	-2.38	37.60	325.04	1665.35	67.01
SLF (V = 100)	1390.68	91.96	96.67	0.04	-1.44	57.43	326.35	1672.06	59.70
SLF (V = 120)	1337.93	109.69	115.23	-0.80	-2.21	58.97	323.32	1656.52	78.22
DESCENT (V = 140)	1126.97	129.19	135.31	-3.10	-1.94	78.57	323.00	1654.90	80.64
CLIMB (V = 50)	1285.55	53.22	56.74	3.83	-2.18	241.35	324.95	1664.85	61.66
SLF (V = 90)	1782.17	92.21	97.65	0.29	-0.65	288.28	325.11	1665.69	63.16
SLF (V = 110)	1825.13	110.45	116.89	-0.81	-1.77	251.70	323.48	1657.31	78.23
DESCENT (V = 140)	1320.59	128.57	134.87	-3.43	-2.39	239.64	323.08	1655.28	83.29
HOVER (H = 35)	429.96	8.31	14.61	5.42	-2.20	281.87	324.04	1660.21	73.02
GROUND RUN	378.69	7.82	14.34	3.41	0.05	286.59	322.79	1653.83	24.40

### 3.2 Cabin noise exposure

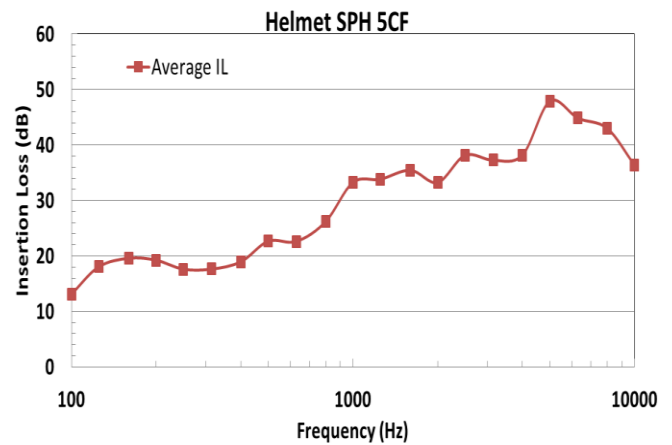
The Sound Pressure Levels at three cabin crew stations were measured during flight testing. Pilot noise exposure was evaluated using Insertion Loss data, which was measured in the SPH 5CF flight helmet in accordance to procedures specified in ANSI/ASA S12.42-2010 [5] using the GRAS Acoustic Fixture 45CB.

The un-weighted and A-weighted Sound Pressure Level spectra at the pilot's helmet position for each flight condition are presented in **Figure 1**. The highest measured noise levels were due to the main rotor 8/rev tone. The maximum measured level of this main rotor harmonic (i.e. SPL of 108 dB) occurred in the 40 Hz 1/3-octave band and was recorded during a 120 knots level flight condition. Analysis of the A-weighted SPL of the acoustic data revealed a maximum level of 91 dBA in the 630 Hz 1/3-octave band during a descending flight condition.



**Figure 1. Cockpit Noise Spectra Near the Pilot's Helmet: (Top) Un-weighted SPL; (Bottom) A-weighted SPL**

As depicted in **Figure 2** and determined previously in Ref [7], it was found that the SPH 5CF flight helmet provides acceptable noise attenuation of helicopter interior noise with the aircraft configured with its cabin doors closed. The maximum estimated sound pressure level exposure for a pilot wearing this helmet was found to be 71 dBA in the 100 Hz 1/3-octave band. This demonstrated that the flight helmet complied with Canada Labour Code, Part II. This standard dictated that the sound pressure level exposure in an aircraft for a period of 8 hours should be less than 87 dBA.



**Figure 2. Insertion Loss of the SPH 5CF Flight Helmet.**

### 4 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 NRC Bell 412 helicopter configured with aft cabin doors closed were measured at three cockpit and aft cabin stations. Cabin noise was generated during flight maneuvers consisting of ground interfacing, hovering, and steady forward flight conditions. At low frequencies, main and tail rotor tones were prevalent in many flight conditions. The 8/rev main rotor tone was prevalent with a maximum SPL of 108 dB in the 40 Hz band recorded during high speed level flight. The maximum A-weighted SPL (91 dBA in the 630 Hz band) was recorded during descending flight. Pilot noise exposure was evaluated using Insertion Loss data measured in the SPH 5CF flight helmet using the GRAS Acoustic Fixture 45CB according to ANSI/ASA S12.42-2010 [5]. It was been determined that the SPH 5CF helmet provided acceptable attenuation for the measured cabin noise in compliance with the Canada Labour Code, Part II.

### Acknowledgments

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### 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
- [7] S. Ghinet, A. Price, M. Alexander, A. Grewal, V. Wickramasinghe, Y. Chen, "Open door flight test investigation of cabin noise exposure in the NRC Bell 412 helicopter", Canadian Acoustics Week, 2014.