Predicting Noise Exposure for Flight Crew Members

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Abstract

This paper discusses a tool that predicts and analyzes noise exposure for flight crew members, including both flight attendants and pilots, during their duty.

1 Introduction

The EU (European Union) Parliament and the Council passed Directive 2003/10/EC in February 2003 to pose restrictions and regulations on workplace daily noise exposure, including flight crew members (both pilots and cabin attendants). Previous regulations exempted flight crews. The EU Directive specifies how to quantify daily noise exposure levels, what noise exposure limits are mandated, and what actions are required if these limits are exceeded. If a standard mission daily noise exposure value for a flight crew member is below the lower action level (<80 dBA LEX,8h), no further action is required by the airline. If the daily noise exposure value falls between the lower and upper (80 < LEX,8h< 85) action values, the airline is required to notify its employees and union of this finding, initiate a hearing conservation program and provide but not require hearing protection. Noise exposure levels above the upper action value (>85 LEX,8h) require the airline to mandate the use of hearing protection and to clearly mark work areas "with appropriate signs." In addition, the exposed employee has "the right to have his/her hearing checked by a doctor." If noise exposure levels exceed the exposure limit value (≥87 dBA LEX,8h), the workplace is considered an illegal work environment, requiring the airline to modify the non-compliant work environment. Changes to the employees work schedule and/or the noise levels of their work environment may be pursued.

Today, all EU countries have implemented the law. The directive allows individual countries to adopt a more stringent noise levels as specified but not lower. Some countries have elected to adopt a more stringent noise exposure level criterion. The Nordic[1] countries use the maximum level of 85 dB(A) Lex_8 in lieu of 87 dB(A) Lex_8. This is due to prior legislation precedence the workweek noise exposure option is not allowed by these countries. Germany has followed the Nordic countries implementation plan. As to dated all other EU countries have implemented the standard action levels as outlined in the directive. Other countries like Brazil, Canada are also reviewing their current laws. In the United States, the FAA has re-established the MOU from 2000 to apply OSHA rules to flight and cabin crew. The OSHA rules for the Pilots and Cabin Attendants are not as restrictive as in the EU Directive.

In order to assess whether the current in-service fleet meet the regulations, answer airline

[1] Denmark, Norway, Sweden

customers' inquiries, and improve products, we have developed a tool that predicts the noise exposure of flight crew members for a given flight mission on a Boeing airplane model.

In this paper, we are going to discuss this tool and some considerations when we calculate such exposures.

2 Data in the Analysis Tool

2.1 Flight mission

Consider a typical mission of a flight crew:

Figure 1 Example of a Flight Mission

A mission for a crew member has typically several segments: start of duty, ground operation, boarding, taxi out, take off, initial climb, climb, cruise, decent, approach, landing, taxi in, deplane, ground operation, and end of duty. Each segment has a duration or start time/end time associated with it.

Start of duty and end of duty segments are for crew members to debrief for their work day and make necessary preparations for the work day in these segments. Ground operation is a segment that crew members are on airplane and make preparations before passengers board the airplane. Boarding and deplane are the segments that passengers are boarding or leaving the airplane and the crew member may greet passengers and/or help passengers with their carry-on bags. Taxi out and taxi in are the segments that the airplane departs from a gate before taking off or approach to a gate after landing at an airport. Take off and landing are the segments that the airplane takes off from the ground or touch down on the ground. Initial climb and approach are the segments that the airplane is anywhere between above the ground level and below 5000 ft. Climb and decent are the segments that the airplane is above 5000 ft. Cruise is the segment that has the majority of time of a mission, and the segment contributes a big share of overall noise exposure in the time-weight calculation. A mission may have step climb or step decent, and therefore there are several climb and cruise or decent and cruise segments.

In addition, a mission could consist of multiple legs, and each leg would have a similar set of segments. Figure 2 shows a mission with two legs, and each leg has a step climb.

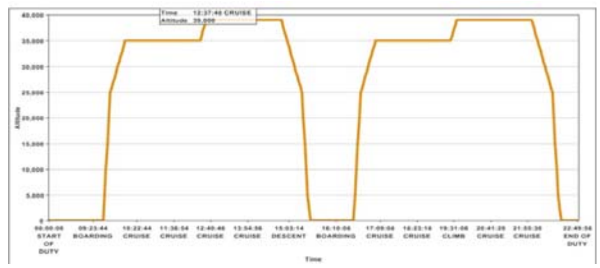

Figure 2 A Mission with Two Legs and Step Climb

2.2 Location

In order to assess the noise exposure for crew members, we have to specify where they would be located during a flight, and then we will use the noise data around that location to predict the exposure. Generally speaking, there are two types of locations for crew members: fixed location and roving location.

1. Attendant Seat
   This is a fixed location where a flight attendant would sit while the airplane is taking off or is approaching. Normally this type of seat is close to an airplane door.

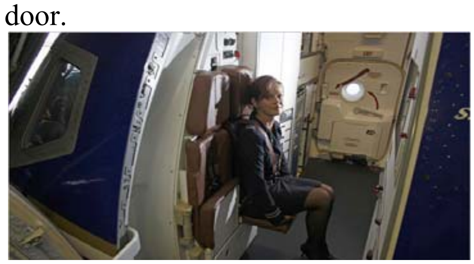

Figure 3 Attendant Seat

2. Attendant Roving
   When an airplane is taking off or approaching, this location is the same as attendant seat fixed. However, once the crew member starts to work around the airplane, this location describes work places, such as galley and cabin, where the member would stay.

Figure 4 Attendants

3. Galley
   This is a fixed location in the galley area where a crew member may prepare food or drink for passengers.

Figure 5 Galley

4. Pilot Ear
   This is a roving location. Pilots normally put a headset on their ear to listen air traffic communication and communicate with air traffic controllers. Pilot may also walk around on the airplane or may go to a rest area to take a break if this is a long flight.

Figure 6 Flight Deck

5. Co-Pilot Ear
   This is similar to pilot ear.
6. Passenger Seat
   This is a fixed location in the main cabin where a passenger would sit on.

Figure 7 Cabin and Passenger Seats

7. Cabin
   This is where a flight attendant would deliver food or drink to passengers or clean the cabin area.
8. Crew Rest Attendant
   This is a fixed location for a flight attendant to take a rest for a long haul flight.

Figure 8 Crew Rest Area

9. Crew Rest Pilot
   This is a fixed location for a pilot to take a break for a long haul flight.

Each location has a station number associated with it to indicate the relative position to the airplane body.

Each location would have a position indicator to indicate that it is either on the left or right side of the row.

AIRPLANE_MODEL	LOCATION_DESCRIPTION	STATION_NUM	FIXED	POSITION	SUB_POSITION
737-600	ATTENDANT ROVING	320	0	L	O
737-600	ATTENDANT SEAT FIXED	320	1	L	O
737-600	ATTENDANT SEAT FIXED	450	1	R	I
737-600	CABIN STOWBIN FIXED	600	1	L	I
737-800	PILOT LEFT EAR	210	0		
737-800	CO-PILOT LEFT EAR	210	0		
737-800	GALLEY FIXED	730	1	R	O
737-800	PASSENGER SEAT	500F	1	L	I

Figure 9 Location Description

Figure 9 shows the location description stored in the tool. It has airplane model, location description, station number, indicator of either fixed or roving, position, and sub-position.

2.3 Noise Measurements

A typical noise experience on a flight on various segments would look like in Figure 10.

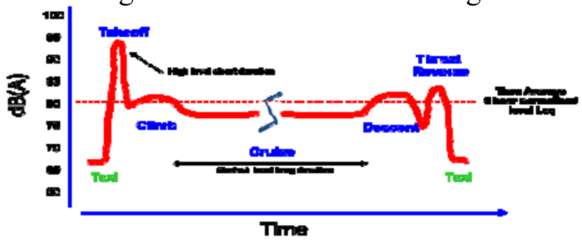

Figure 10 Example of Noise Exposure

We have two types of noise measurements saved in the tool.

1. In-service dosimeter measurements
   This data was collected on airline in-service flights, and this gives us how a crew member would experience on the flights. However it may have operational noise such as baby crying, people talking, etc. depending on an individual flight, and when we use this data for prediction, we may need to adjust the data according to passenger characters on a particular route, flight conditions, day/night flight, and etc.

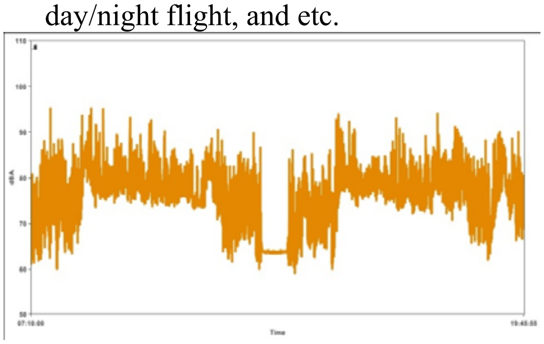

Figure 11 Example of Dosimeter Measurements with Two Legs

   Figure 11 shows dosimeter recordings on an in-service flight from a two-legs mission.
2. Flight test measurements
   An OEM may conduct various flight tests on airplane programs, and we can utilize this flight test data to predict noise exposure for airplane models that are in consideration. This may be alternative noise measurements to the in-service flight tests. Typically, these flight tests have microphones around airplanes, and locations associated with the microphones are typically fixed.

2.4 Flight Data Recorder (FDR)

Flight data recorder can help to explain the flight condition at a particular time, and it would help to build a mission profile and explain noise measurements.

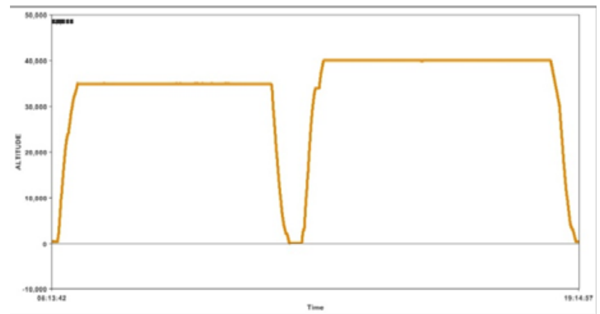

Figure 12 Example of Altitude from FDR

Figure 12 shows the altitudes from a FDR data on a two-leg mission.

3 Predicting Noise Exposure

In order to predict the noise exposure of a crew member for a given mission, we need to calculate the noise exposure for the ith segment of the mission from K samples from previous flight tests according to ISO-9612 and ISO-1999

$$L_{eq-T_i^c} = 10*\log\{\frac{1}{K}*\sum_{J=1}^{K} 10^{0.1*L_{eq-T_j}}\} \qquad 3.1$$

Then the noise exposure for the ith segment is

$$L_{Aeq-T_i} = 10*\log\{\frac{T_i}{T}*10^{0.1*L_{eq-T_i^C}}\} \qquad 3.2$$

Where T_i is the duration for the ith segment of the given mission and T_c is the total duration for the mission.

The noise exposure for the given mission is

$$L_{Aeq-T} = 10*\log\{\frac{1}{T} * \sum_{i=1}^{M} T_i *10^{0.1*L_{Aeq-T_i}}\} \qquad 3.3$$

Where M is the number of segments for the mission.

According to ISO-9612 and ISO-1999, a daily noise exposure is calculated by (3.3) and then normalized to 8 hours work day or 5 day work week.

$$L_{Aeq,8} = L_{Aeq-T} + 10\log\left(\frac{T}{T_0}\right) \quad T_0 = 8\,hr \qquad 3.4$$

$$\bar{L}_{EX,8h} = 10\,Log\left(\frac{1}{k}\sum_{i=1}^{n} 10^{.1(L_{EX,8h})^i}\right) k = 5 \text{ days} \qquad 3.5$$

Where n is the number of working days for the crew member for a week.

(3.4) shows that when $T \geq T_0$, $\log\left(\frac{T}{T_0}\right) \geq 0$.

Therefore the second term in (3.4) will be added to the first term L_{Aeq-T} and have a positive impact to the daily noise exposure $L_{Aeq,8}$.

Likewise, in (3.5), if n > k, then the total weekly noise exposure $\bar{L}_{EX,8h}$ will be positively impacted by the number of working days.

The following charts, Figure 13 and Figure 14, will illustrate the relations.

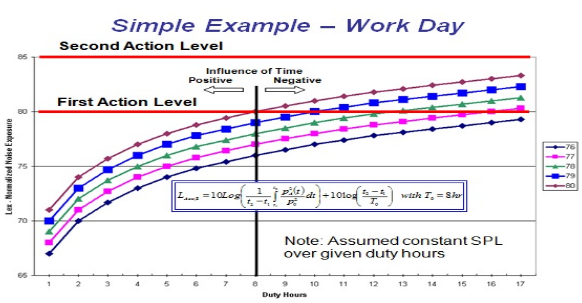

Figure 13 Relation between Daily Noise Exposure and Daily Work Hours

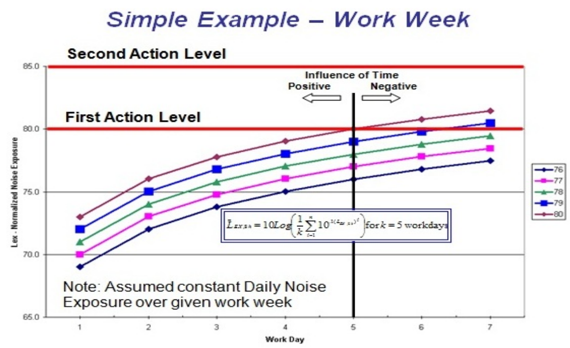

Figure 14 Relation between Weekly Noise Exposure and Number of Work Days

3.1 Fixed locations

This can be any fixed locations on an airplane, such as attendant seat, passenger seat, crew rest area, or any other nature fixed locations. Particularly, if this is a passenger seat, the results could serve as a passenger comfortable experience, and this could help passengers to select their preferred airplane models or preferred locations on a flight. Once the noise exposure is calculated, one may wish to make some adjustments for their particular routes based on the airplane interior configuration, flight condition, airplane weight, day/night flight, or other factors. If the results serve for comfortable experience, they don't need to be normalized to 8 hours working day or 5 days working week.

3.2 Flight Attendants

1. OEM flight test data used

   Since we need to predict a flight attendant's noise exposure during a flight while the attendant has to work around on an airplane and noise levels are different at different locations on the airplane, we may need to create a grid around the airplane and obtain a noise measurement for each cell in the grid. In addition, we use a probability model to describe the time that the attendant could work at a particular location. The locations at which an attendant could be are an attendant seat during the taking off and landing, galley when the attendant is preparing food or drink for passengers, cabin when the attendant is delivering food or drink, or attendant rest area (the noise level at a rest area is typically lower than that in the cabin) if the flight is a long haul flight and the attendant has to take some time off according to regulation requirements. Once the noise exposure is calculated, one may want to make some adjustments due to some considerations for the particular route/mission. Some factors may be considered, in addition to those discussed in 3.1, are the airplane equipments, attendants' talking to passengers or other attendants, etc.

2. In-Service flight test data used

   When we calculate noise exposure for attendants, we could use in-service flight test roving data to mirror the situations, segments, and flight conditions that were in the in-service flight. The in-service flight roving data may contain the noise exposure when the attendant was in the rest area, and when we use this roving data, we may have to take off this part of data from the roving data. Once the exposure is calculated, one may want to adjust it due to the difference between the in-service flight and the mission in consideration.

3.3 Pilots

For a pilot, the noise sources are not only from normal airplane noise like what an attendant is experiencing, but also from air traffic communication since the pilot needs to constantly communicate with air traffic towers. In addition, the pilot may take off the air traffic commutation device from time to time, especially for a long haul flight. Therefore, we need to add the impact of noise from air traffic communication to the regular noise level when the device is on. Moreover, some pilots/airlines may use active headsets to reduce noise exposure, and we need to deduct this factor in the calculation.

In addition, a pilot may take rest at a pilot rest area for a long haul flight due to regulation requirements, and we need to use pilot rest area noise level (this is normally lower than the noise when the pilot is at the flight deck) in the noise exposure calculation for this part of the flight.

For predicting pilot noise exposure, we have two types of data, which is similar to the situations for flight attendants.

4 Conclusion

This paper has discussed a tool to predict the noise exposure for flight attendants, pilots, and passenger seats on a given flight mission on an airplane in order to address EU's restrictions and regulations on workplace noise exposure. We also present some considerations when we calculate the exposure.

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