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NOISE CONTROL FOR A BETTER ENVIRONMENT

# A Study of the Noise Sensitivity Around of Military Airport

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## ABSTRACT

**Recently, there are many problems caused by aircraft noise. Most of the problems lead to disputes, and lawsuits are increasing. The aircraft noise is measured in three steps to resolve the increasing aircraft noise dispute. Firstly, based on the noise and vibration process test method notified by the Ministry of Environment, noise in the damaged area is measured and the WECPNL value is calculated by using the measured data. Secondly modeling by using INM software is made to predict aircraft noise in the damaged area and obtain the WECPNL value. Finally, if the error between the measured value and the value obtained through modeling does not exceed 3 WECPNL, the modeled value is used to resolve the dispute. However, there are many trials and error in modeling. In order to solve this problem, the sensitivity of aircraft noise was analyzed. Knowing what factors affect aircraft noise can reduce many trials and errors.**

**In this study, for sensitivity analysis, the effects of aircraft noise were largely divided into three factors: number of flights, airplane engine power, and altitude. First, when increasing the number of flights by five, approximately 0.26 WECPNL was increased. Next, at a 2% increase in engine power, 2.6 WECPNL was increased and 0.35 WECPNL was decreased at a 100 ft increase in flight altitude. From the quantitative viewpoint, it can be seen that the engine power affects the noise of the aircraft the most among the three factors. Therefore, countermeasures against engine power are most effective.**

**Keywords:** Aircraft noise, Sensitivity analysis, WECPNL, The number of flights, Flight altitude, Engine power, INM
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## 1. INTRODUCTION

For aircraft, the extent of the damage is extensive because of the large sound power level. And the number of people suffering from noise damage is larger than other means of transportation. Aircraft noise is difficult to handle in one way due to its characteristics. It can be expected effectively when a comprehensive set of measures includes sound source, propagation path, and noise reduction are implemented.

Aircraft are divided into civil and military aircraft. In the case of civil aircraft, it acts an important role in connecting each country or cities, and its size is growing. According to the Korea Airport Corporation, the number of passengers using Incheon International Airport in 2017 was 61,568,936 and 57,765,397 in 2016. As a result, the number of flights has increased. And demand for private aircraft will increase exponentially in the future. In the case of military aircraft, unlike civil aircraft, generate very high noise levels by the engine operates, flight altitude, and flight type. Furthermore, the number of military aircraft and training flights continues to increase around the world. As a result, disputes and lawsuits between the air force and residents in the vicinity of airports continue to grow with regard to military aircraft noise. Therefore, it is necessary to deal effectively with arising disputes from the noise of military aircraft.

## 2. THEORY

### 2.1 $WECPNL_k$ (Korean aircraft noise evaluation unit) [1]

In Korea, the briefly modified $WECPNL_k$ of WECPNL made by ICAO is used, and the calculation process is as follows.

(1) The maximum noise recorded on the noise meter is also obtained for each day of the flight

$$L_{max} = 10\log\left(\frac{1}{n}\sum_{i=1}^{n} 10^{\frac{L_i}{10}}\right) \text{ [dB(A)]} \tag{1}$$

Where n is the number of times the noise of the airplane is measured in one day, and $L_i$ is the high noise level when passing through the i-th aircraft.

(2) Daily $WECPNL_k$ has followed such as the following equation.

$$WECPNL_k = L_{max} + 10\log N - 27 \tag{2}$$

$N = N_2 + 3N_3 + 10(N_1 + N_4)$

$N_1$ : The number of flights between 00 and 07 o' time

$N_2$ : The number of flights between 07 and 19 o' time

$N_3$ : The number of flights between 19 and 22 o' time

$N_4$ : The number of flights between 22 and 24 o' time

(3) The average WECPNL between m days is obtained by the following formula.

$$\mathrm{WECPNL} = 10\log\left(\frac{1}{m}\sum_{i=1}^{m}10^{\frac{\mathrm{WECPNL}_i}{10}}\right)\ [\mathrm{dB(A)}] \tag{3}$$

Where m is the number of days of aircraft noise measurements and it is usually used for seven days. $\mathrm{WECPNL}_i$ is the WECPNL value of day i.

(4) In addition, if the average duration of aircraft noise higher than 10 dB about the background noise, and it is longer than 30 seconds, the WECPNL value shall be corrected of $+\mathbf{10\log\left(\frac{D}{20}\right)}$.

### 2.2 INM (Integrated noise model) [2]

INM is an aircraft noise prediction program that has been supplemented and modified so far. Since it was published by the Federal Aviation Administration (FAA) in 1978. The advantage of INM is that it is easy to review of flight routes and change of routes. Also, it is currently being used by the Ministry of Environment and the Airport Management Corporation in Korea. In addition, accuracy was verified with the U.S. and Europe. And the average error between the actual and the forecast was found to be within 2 dB (A).

## 3. MEASUREMENT

### 3.1 Measuring locations characteristics

A military airfield was selected for the aircraft noise measurement area. It was used as a civil and military airfield in the past. But, it has been turned into a military airfield due to a decrease in the number of the runway. It is 9000 ft long, and the width is 150 ft, and the main aircraft is T-50. For flights, training such as take-off and landing, flying, and touch-and-go. And, it has 13.2 degrees of annual temperature and 1,076 mm of precipitation.

### 3.2 Region selection [3]

The noise measurement points are less affected by road traffic, trains and other noise sources. And the six points were selected where damage is expected by the flight training of military aircraft (forwarding, low-altitude, rapid rise, and rapid descent).

The sound meter was selected as shown in the following figures and measured at the measurement points.

*Figure 1: Measuring points*

### 3.3 Experimental equipment

The equipment used for noise measurements were NL-42, NL-20, and TES-53H.

## 4. RESULTS

For two weeks, the daily take-off and landing of military aircraft during the measurement period were 35 to 48 during the day, and 6 to 12 in the evening. Except for the weekend, and bad weather conditions.

In order to analyze the sensitivity of aircraft noise. The basic result values were analyzed based on actual measurements and data received at the airport. The analysis was divided into three conditions. The first was increasing the number of flights. The second was the change in the output of the aircraft, and finally, by changing the flight altitude.

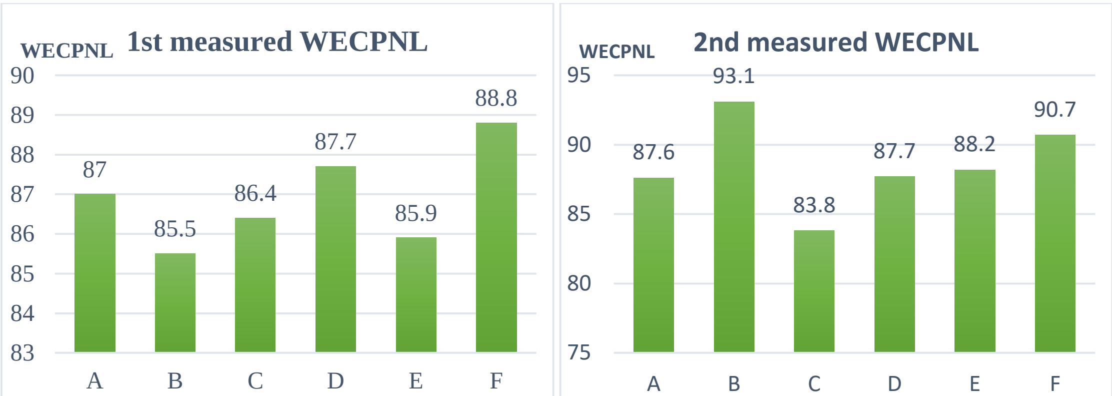


*Figure 2: 1st, 2nd aircraft noise level graphs*

### 4.1 INM modeling results

The values modeled based on the sensitivity analysis of aircraft noise are shown in Table 1 and 2. Both primary and secondary are under the error range of 3 WECPNL, where the average difference between the actual value and the simulated value is the error range. Therefore, the values obtained from the simulations are reliable.

*Table 1 - 1st Comparison of measured and predicted value (unit: WECPNL)*

| | Actual value | INM value | Error |
|---|---|---|---|
| **A** | 87.0 | 86.2 | -0.8 |
| **B** | 85.5 | 88.2 | 2.7 |
| **C** | 86.4 | 85.5 | -0.9 |
| **D** | 87.7 | 88.6 | 0.9 |
| **E** | 85.9 | 85.2 | -0.7 |
| **F** | 88.8 | 84.9 | -3.9 |
| **Average error** | | | 1.7 |

*Table 2 - 2nd Comparison of measured and predicted value (unit: WECPNL)*

| | Actual value | INM value | Error |
|---|---|---|---|
| **A** | 87.6 | 89.6 | 2.0 |
| **B** | 93.1 | 91.1 | -2.0 |
| **C** | 83.8 | 86.0 | 2.2 |
| **D** | 87.7 | 88.7 | 1.0 |
| **E** | 88.2 | 85.8 | -2.4 |
| **F** | 90.7 | 88.9 | -1.8 |
| **Average error** | | | 1.9 |

**4.2 Noise variation due to the change in the number of flights**

For the number of flights, the aircraft noise process test method was divided by three time periods: day, evening and night. The basic number of flights per day at the airport was 46. So, the basic analysis was made of 46 aircraft. Assuming a total of 30 aircraft increases, the daytime per 5 units increased by 0.26 WECPNL, 0.6 WECPNL at evening and 1.18 WEPCNL at night. And the noise growth rate is reduced as a total number of flights increase. Late at night, the WECPNL value increased by about twice. The plane noise graphs are shown in Figure 3,4,5.

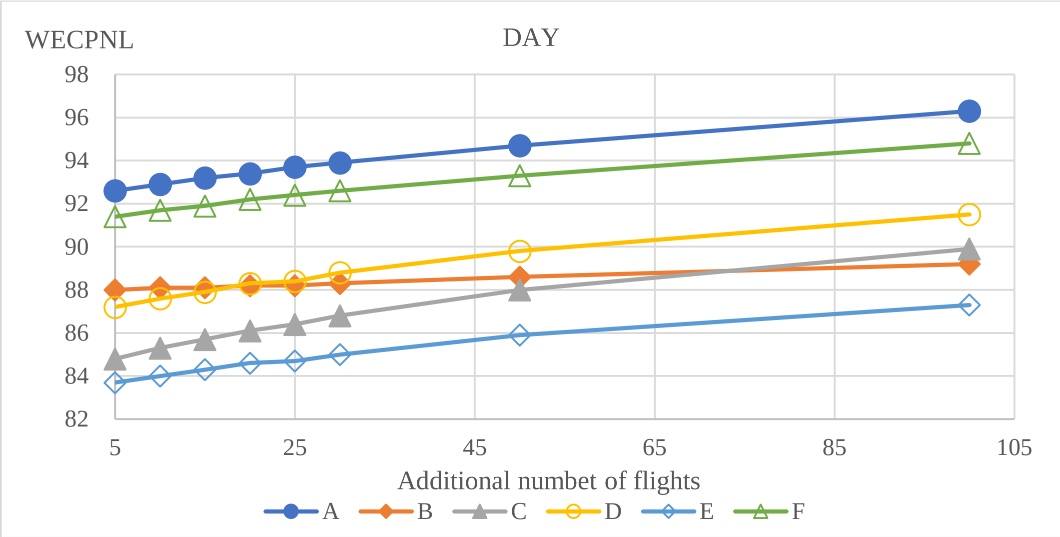


*Figure 3: Graph of noise variation with the number of flights in the daytime*

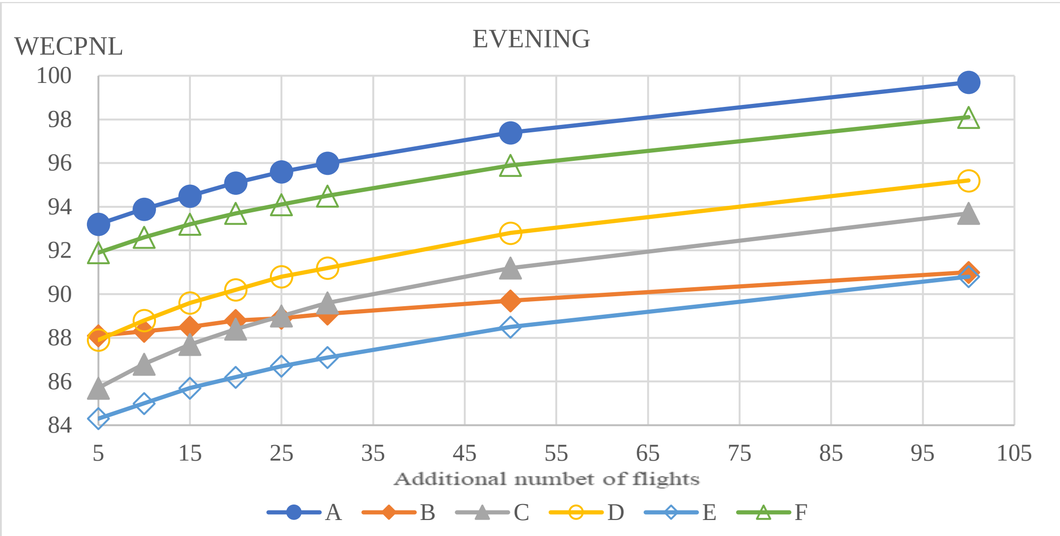


*Figure 4: Graph of noise variation with the number of flights in the evening*

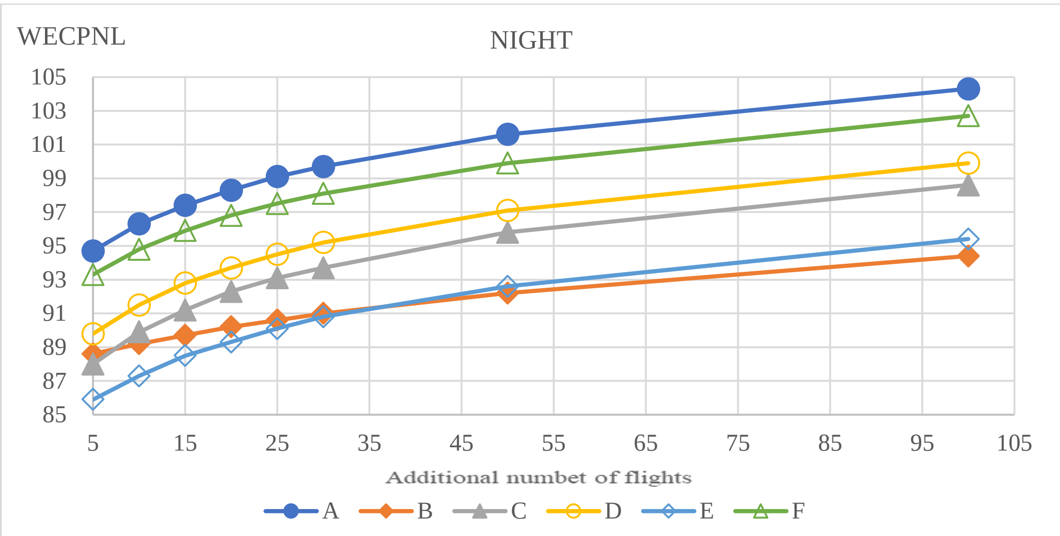


*Figure 5: Graph of noise variation with the number of flights in the night*

### 4.3 Noise due to engine power change

Different flight positions have different engine power when it flies. Assumed the engine power was the same around all sections. To make comparison easier.

The analysis showed there is no change in noise at the flight engine power of 10% to 85%. It is estimated that the minimum engine power when the aircraft takes off or flies should be at least 85%. Therefore, in this analysis, the section of engine power was divided as one section between 10% and 85%, and engine power increased by 2%, from 90% to 100%. The graph showed an average of 2.6 WECPNL increases at each point, with similar increases in all area, as with the number of flights. The graph is shown in Figure 6.

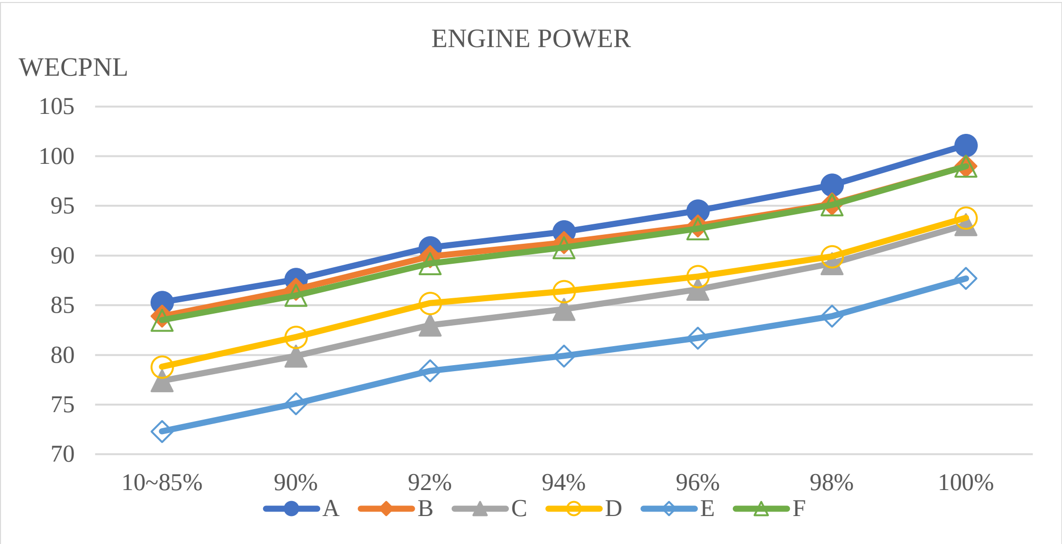


*Figure 6: Graph of noise variation with engine power*

### 4.4 Noise due to flight altitude

The altitude of the aircraft is also different from one section to the other, as is the engine power. All sections except the take-off and landing sections were set at the same altitude for easy comparison. The starting point for take-off and landing was set at the airport runway altitude. The altitude of the airport runway is 354 ft and analyzed under two conditions: 100 ft and 500 ft.

The analysis showed an average decrease of 0.35 WECPNL per 100 ft increase. In the case of altitude changes, the noise variance in each position was different from the engine power. And the deviation was greater than in other conditions. Each measurement graph is shown in  Figure 7 and 8.

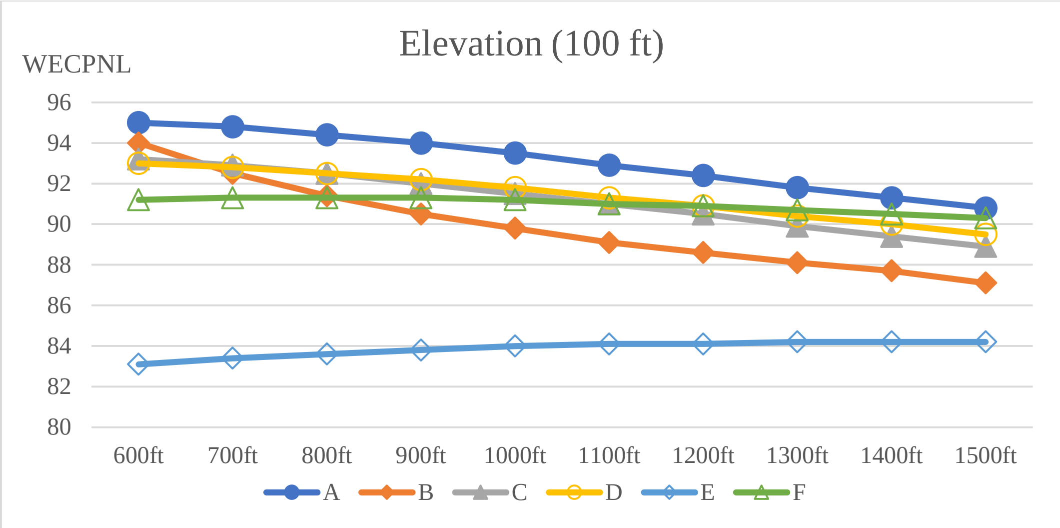


*Figure 7: Graph of noise variation according to elevation of flights (100 ft)*

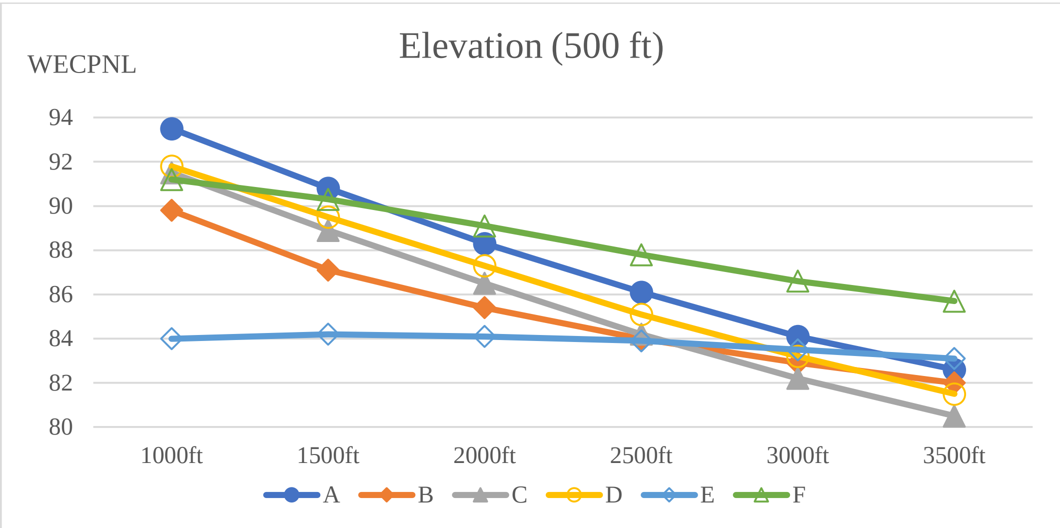


*Figure 8: Graph of noise variation according to elevation of flights (500 ft)*

## 5. CONCLUSIONS

Noise sensitivity analysis was conducted based on simulation using the INM program to produce a noise map around an airport. And the aircraft noise impact factors were divided into three types: the number of flights, flight altitude, and engine power. The increase in the number of flights represented an increase in WECPNL. The increase widened as time went by night.

For engine power, there was no change in the WECPNL value until 85% and the value increased after 85%. The increase was similar at each point. The damage area also varied from the section.

For flight altitudes, the WECPNL values were expected to decrease as the altitude increases. However, despite the elevated flight altitudes at the two measured points, WECPNL values were shown to increase. This is expected to occur as the engine is directed downwards when the aircraft takes off.

The comparison of the noise impact of the number of flights with the engine power resulted in an average increase of 0.26 WECPNL as engine power was fixed and the number of flights increased. The average increase in WECPNL was 2.6 WECPNL when the number of flights was fixed and the engine power increased. In other words, changing engine power has resulted in an effect of about 10 times noise than changing the number of flights. Quantitatively it was shown that airplane engine power had a much greater effect on noise. The altitude of the flight is less likely to affect the noise than engine power.

Thus, aircraft noise in the around airports depends mostly on engine power. To decrease aircraft noise, it is most effective to reduce engine noise when operating in the affected areas. Rather than flying at high altitudes or reducing the number of flights. And further study of noise effects according to the flight path and aircraft type is required.

## 6. ACKNOWLEDGMENTS

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