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PILOTS' ENDEAVOR FOR AIRCRAFT NOISE ABATEMENT

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ABSTRACT
This paper concentrates on pilots' efforts towards achieving aircraft noise abatement during flight operation, i.e. flight procedure control as a measure to decrease noise impact around airports. It first reviews the circumstances in which a general noise abatement operation procedure was specified in Japan. Next, it speaks of pilot's struggling efforts to meet local flight rules, which happen to be incompatible with the security of safe flight.

1 - INTRODUCTION
Aircraft jet engine is one of the most powerful sound sources that humankind has ever produced. In the 1960s, severe aircraft noise pollution prevailed in the vicinity of many of the world's airports due to the general introduction of jet aircraft into commercial airways. At the end of 1969, after discussion among governments, ICAO declared the following three noise policies: (1) establishment of aircraft noise certification system, (2) enforcement of land use control, relocation of runways or airport and environmental countermeasures, which include sound insulation for schools, hospitals and residential houses, and (3) establishment of aircraft noise abatement operation procedures. Since then, aircraft manufacturers, airline industries, governments and airport authorities have made all their efforts to realize the policies. The first, i.e., noise certification has made clear the target for noise reduction, resulting in a remarkable progress by about 20 dB (see Fig. 1) owing to the efforts by manufacturers toward production of quieter aircraft and by airline industries toward introduction of such aircraft into commercial airways. The second, which should have been fulfilled by national or local governments and airport authorities, has also been valid in lessening effects of noise exposure in the surroundings of airports. In Japan, a stupendous amount of money has been spent for subsidization to soundproofing of houses, etc. The third measure, i.e. controlling flight procedures has been counted as a quick recipe for settlement of noise problems since early days. IATA (International Air Transport Association) worked out various noise abatement procedures by considering individual airport circumstances. There are, however, local rules incompatible with the security of safety flight. Sometimes, pilots may be apprehensive for safe operation of their aircraft if they stick to follow such rules for attaining noise abatement.

2 - GENERAL NOISE ABATEMENT PROCEDURES IN JAPAN

2.1 - Flight operation without restriction
Flight operation without restriction can be divided into seven segments. a) Take-off roll, b) climb after lift-off to 1000 ft above ground (priority to climb gradient), c) climb to a cruising altitude $30000 - 40000$ ft (priority to climb rate), d) cruise, e) descent to 3000 ft, f) approach to 0 ft, and g) landing and ground roll (thrust-reverse). Noise problems are in general raised when aircraft flies below 3000 ft. It suggests that the five segments except d) and e) are important to invent a means for noise abatement. On the other, noise observed on the ground is mainly determined by jet engine noise due to jet engine exhaust and fan and turbine rotation. Airframe noise is relatively small as compared to jet engine noise, even when aircraft reduces its engine thrust power for descent and approach. Therefore, the most effective means of decreasing noise observed on the ground is to control engine thrust power and flight altitude.

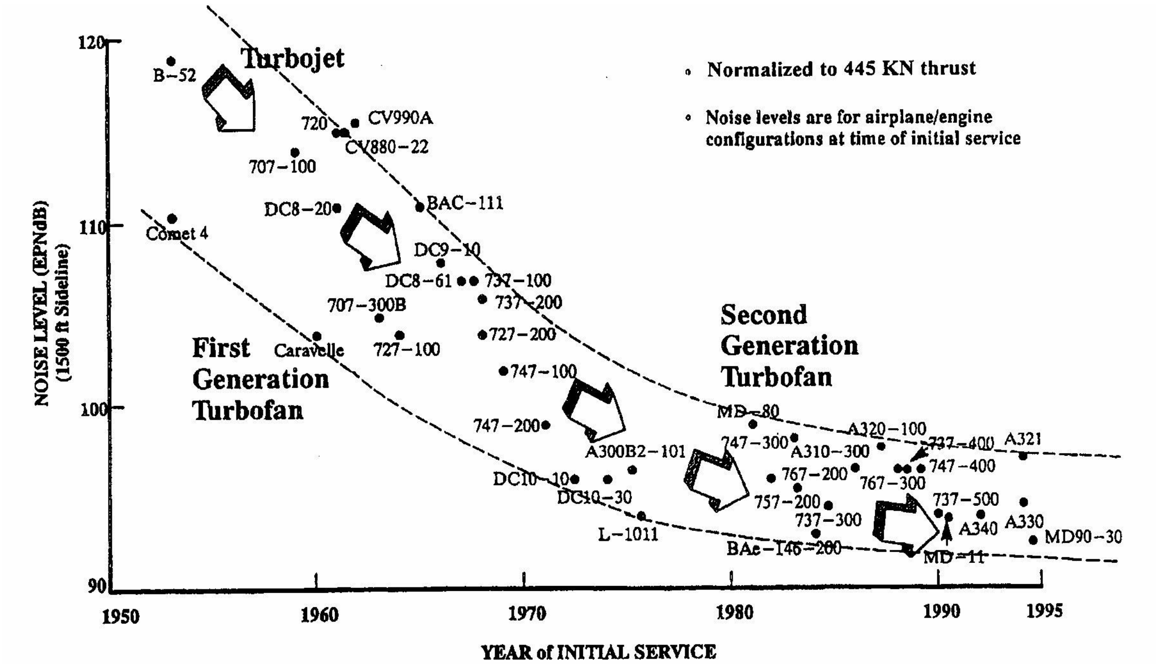

Figure 1: Progress in noise reduction of jet aircraft [1].

2.2 - General rule for noise abatement procedures in Japan

Japan Airlines has its own general flight operation procedures as standards for safety and noise abatement. It conforms to a general rule, which specifies noise abatement procedures, formed under the agreement among the government and airline industry in Japan. a) Take-off roll using the maximum take-off power, b) lift-off at a speed of V_2+10 kt, where V $_2$ means a take-off safety speed, and climb to 1500 ft using the maximum take-off power (so called, the steepest climb), and c) climb to 3000 ft at the same speed using the maximum climb power. d) The rule requires that, after the climb, pilots shall accelerate aircraft to flap up speed with the maximum climb power above 3000 ft. The rule also requires that f) approach using delayed flap and gear down with a reduced final flap angle and g) landing and ground roll with minimum use of thrust reverse. Note, however, pilots must sometimes practice further control of flight operation during flight as high as 6000 ft or more, to meet local regulations specified by individual airport authorities as is discussed later.

2.3 - Review of a comparative study discussed for determination of general rule for take-off

The government and airline industry worked out the general rule to establish an optimal noise abatement procedure, in response to a strong request by airport authorities having noise problems in the vicinity of airports. Flight technical groups in airline industry carried out comparison of various operation procedures and discussed which procedure was superior to others, from the point of view of safety flight and acoustical environment protection in the vicinity of airports in Japan, by obtaining the cooperation of IATA. Figure 2 shows a comparison of relationships between flight altitude and noise level under the flight path for three take-off profiles of a long-range aircraft equipped with four engines. (A) Normal Take-off, (B) Steepest Climb Take-off, which corresponds to the take-off procedure in the general rule, and (C) Power-Cutback Take-off, which means a climb applying engine thrust power reduction at an altitude of 1500 ft. Note that similar results were obtained for aircraft equipped with two or three engines. Note also that the flight altitude and noise levels were all obtained by calculation. The altitude was in a good agreement with measurement, irrespective of aircraft type, as far as aircraft weight and engine power rating were kept the same, while noise level was different by 3-4 dB in maximum from measurement, as is shown in Figure 3.

By comparing noise reduction effects after lift-off in Fig. 2, we see that a difference among the three profiles A-C appears within a range of distance between 20000 and 60000 ft from the start of take-off roll. At a distance of 20000 ft, noise level curve C (Power-Cutback) is 10 dB less than A (Normal) and 4 dB less than B (Steepest Climb). At 40000 ft, C becomes 4 dB higher than A and 10 dB higher than B. The difference is ascribed to how to use excess engine thrust power except indispensable lift force to float the

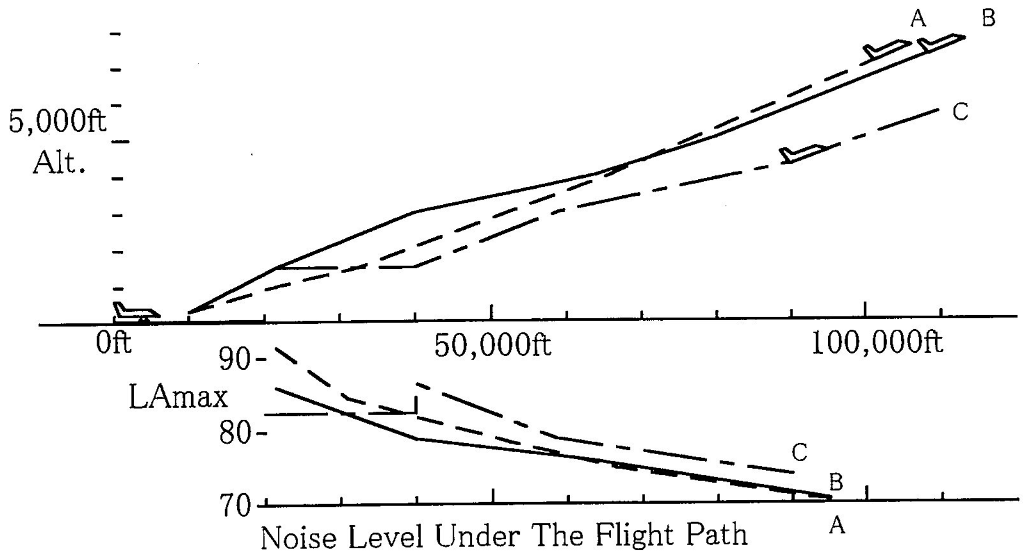

Figure 2: Calculated relationship between flight altitude and noise level under the flight path for a long-range aircraft equipped with 4 engines: A) normal take-off, (B) steepest climb take-off, and (C) power-cutback take-off.

aircraft body in the air. In case of Normal, the excess power is used both for climb and for acceleration to retract flaps with a decreased climb gradient, and finally for climb in clean configuration with the optimal climb rate. In case of Steepest Climb, the excess power is first used for a gain in altitude to decrease noise on the ground until reaching an altitude of 1500 ft, provided that aircraft speed is kept the same for the safety. Afterwards, the power is reduced to the maximum climb power at the same speed. In case of Power-Cutback, engine thrust power is reduced down to the minimum so that the aircraft flies on a level with the ground at an altitude of 1500 ft within the range of 20000 − 40000 ft from the start of take-off roll. Note that this is an unusual case, which is not practicable for large aircraft. Pilots usually keep a safety margin of at least 3 − 4 % of climb even in a reduced power segment.
In Japan many airports such as Osaka, Nagoya and Fukuoka are surrounded by densely populated residential areas. The Ministry of Transport, airport authorities and airline industry finally agreed, after discussion, to a conclusion that the Steepest Climb is the most favorable procedure as noise abatement operation procedure for take-off in Japan.

2.4 - Comparison of approach profiles

In descent phase e), when aircraft descends from cruise to about 6000 ft, it seems that noise observed on the ground is rather low because of high altitude and low engine thrust power. When once aircraft descends lower than 6000 ft, ATC controller ordinarily requires aircraft to control air speed at 250kt in order to keep aircraft separation. Then, each pilot controls his speed by adjusting flap angle and engine thrust power according to aircraft weight. Sometimes, ATC requires level flight with flap down configuration, which means a considerable "power up" maneuver, and resulting in noise increase on the ground. When, at an altitude of about 3000 ft, the pilot catches the ILS beam, aircraft commences a steady descent to the ground with final flap (deep angle of flap), landing-gear down and moderate power configuration.
In the early 1970s discussion, the following three operation procedures for final approach were studied to establish noise abatement procedures. D) ILS Approach with a descent angle 3°, E) Two-Segment Approach, in which the descent angle is set to 6° above an altitude of 1500 ft and 3° below 1500 ft, and F) Delayed Flap and Gear Down with a Reduced Final Flap Angle. Figure 4 shows relationships between flight altitude and noise level under the flight path for the two approach profiles. It can be seen that the increase of descent angle, which makes both flight altitude higher and engine power necessary for flight lower, brings a certain amount of reduction in noise levels observed on the ground. As is well known, the 3° ILS Approach has been widely accepted at the world's airports equipped with ILS. But, the Two-Segment Approach was abandoned, although it would have produced a remarkable noise reduction on the ground under the approach paths at distances 20000 ft or more distant from the runway. Approaching on the 6° glide path does require no engine power even in case of gear and flap down configuration. It

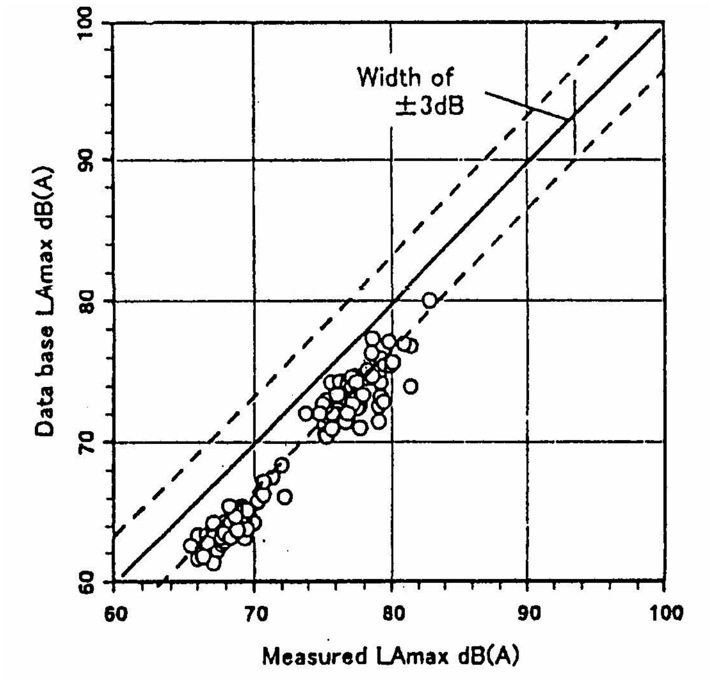

Figure 3: Relationship between calculated and measured noise levels under the flight path for a medium-range aircraft equipped with 2 engines [2].

means that pilots may get into danger that they are unable to control their aircraft speed in the final approach. Furthermore, a serious and fatal accident "crash onto the ground" might occur if a pilot failed to catch the final 3° ILS beam at 1500 ft. Finally, the procedure E (Delayed Flap and Gear Down with a Reduced Final Flap Angle) has been accepted among all Japanese airlines.

3 - LOCAL NOISE RESTRICTIONS PERPLEXING PILOTS

There is a full of variety in the geographical and social conditions of airport location, resulting in different situations in the problems of aircraft noise pollution according to the distribution of noise-sensitive facilities such as hospitals, schools and residential area. Therefore, it is understandable that local noise restrictions become "made-to-order" to suit individual local situation, but there are restrictions on flight procedures, which sometimes may puzzle pilots.

Airport A: The airport authority requires pilots to fly their aircraft according to the following restriction: "Take-off and climb to an altitude of 1500 ft above ground level with take-off power and take-off flaps at a speed of V_2+10 kt. Then, at 1500 ft, reduce power to a level not less than climb power at a normal speed with flap retraction schedules to enroute climb." From a pilot's standpoint, it is difficult and not recommendable to require two simultaneous operations (power reduction and nose-down of aircraft for acceleration) for the sake of assurance of safe operation. Pilot shall concentrate all his attention to the indicating instruments and must try to get aircraft altitude as high as possible after lift-off. Operations such as power change, nose up/down and flap operation shall be securely applied one by one.

Airports B and C: The airport authority's requirements are (1) "Take-off aircraft from runway X shall not produce noise higher than Y dB at a monitoring point Z ft distant from the runway." and (2) "Take-off aircraft from runway X shall not produce noise higher than Y1 dB at a point Z1 and noise higher than Y2 dB at another point Z2 located at the opposite side of flight track." It seems to be impracticable for extra-heavy aircraft for long range flight to satisfy the requirements, because of low flying altitude and high engine power output.

Airport D: The authority's requirement is "Take-off aircraft from runway X shall make turn as is instructed in the flight manual." The manual, however, indicates a flight course including a very sharp turn with a small turning radius. If a pilot would keep the course strictly, he has to maneuver his aircraft with a deep bank of 35° or more. It means that very narrow margin to stall are left for heavy aircraft flying at a rather low speed, e.g. V_2+10 to V_2+20.

Several Airports: The authority's requirement is "Prohibit use of engine thrust reverse except in case of emergency." The expression should be modified to be more acceptable such as "Minimum use of thrust

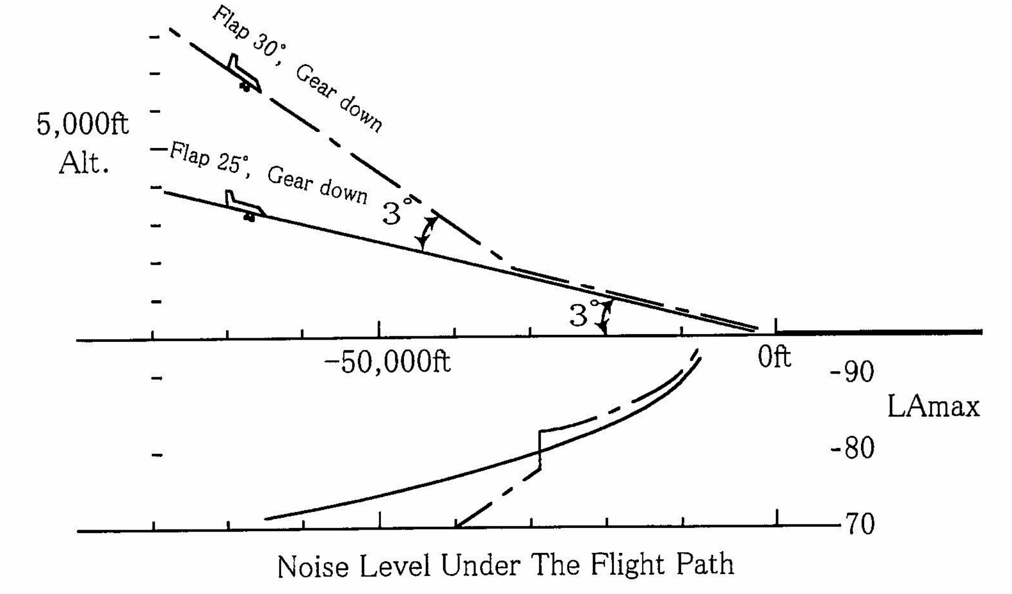

Figure 4: Calculated relationship between flight altitude and noise level under the flight path for a long-range aircraft equipped with 4 engines: D) "3°" ILS approach and (E) "6° − 3°" two-segment approach.

reverse." The control of thrust reverse shall be left to pilot's decision.
Technical discussion is necessary to be held between airport authorities and pilot groups at the airports mentioned above in order to make the noise abatement procedures so that pilots can fly their aircraft with the security of safe flight.

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