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INTERNATIONAL COUNCIL OF THE AERONAUTICAL SCIENCES

14TH CONGRESS

TOULOUSE , FRANCE

SEPTEMBER 9-14, 1984

PROGRESS ACHIEVED IN REDUCING JET AIRCRAFT NOISE

BY ANDRÉ GAUTIER (AIR FRANCE)

AIR FRANCE
TECHNICAL DEVELOPMENT
JUNE, 1984

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1. INTRODUCTION

- AIRCRAFT NOISE WAS IDENTIFIED AS A POTENTIAL PROBLEM PRIOR TO THE INTRODUCTION OF JET AIRCRAFT INTO COMMERCIAL SERVICE. IT BECAME A SERIOUS CONCERN WHEN THOSE AIRCRAFT WERE INTRODUCED IN LARGE QUANTITIES.

- AS AVIATION WAS DEVELOPING QUICKLY, THE NEED FOR REDUCTIONS OF COMMUNITY NOISE HAS RAPIDLY BEEN RECOGNIZED BY THE AIRCRAFT INDUSTRY, THE AIRLINES, AND FIRMLY DEMANDED BY POPULATIONS WITHIN AIRPORT COMMUNITIES.

- THIS PAPER IS INTENTED TO PRESENT THE PROGRESS ACCOMPLISHED TO DATE, CURRENT ACHIEVEMENTS AND WHAT CAN BE EXPECTED IN THE FUTURE.

SLIDE 1

- IN THE MID 1950'S, THE FIRST GENERATION OF JET POWERED COMMERCIAL TRANSPORT AIRCRAFT WAS INTRODUCED INTO SERVICE.

- THESE EARLY JETS, POWERED BY PURE SINGLE-FLOW TURBOJETS WERE GENERALLY NOISIER THAN THE PROPELLER AIRCRAFT THEY REPLACED. IN FACT, THE ANNOYANCE PERCEIVED WAS DIFFERENT DUE TO A CHANGE IN THE FREQUENCY SPECTRUM.IN ADDITION, THE NUMBER OF OPERATIONS PER DAY WAS MULTIPLIED OWING TO THE INCREASED SPEED OF AIRCRAFT.

- AT THIS TIME THERE WERE NO NOISE CERTIFICATION, NO NOISE REGULATION REQUIREMENTS TO COMPLY WITH.

- INCREASING NUMBERS OF BOEING 707, DOUGLAS DC.8 AND OTHER AIRCRAFT SUCH AS CARAVELLE WERE PUT IN OPERATION, OBVIOUSLY MODIFYING THE ENVIRONMENT AT AND AROUND AIRPORTS.

- THIS SITUATION RAPIDLY WORSENED THROUGHOUT THE 1960'S, THE NUMBER OF JET AIRCRAFT IN OPERATION INCREASING AT AN ALMOST EXPONENTIAL RATE TO REACH MORE THAN 3,500 BY 1970.

- A CHANGEOVER TO LOW BY-PASS RATIO TURBOFAN ENGINES RESULTED IN AN INCREASED NOISE DUE TO THE ADDITION OF FAN STAGES. NOTWITHSTANDING THE ABSENCE OF REGULATIONS, ENGINE MANUFACTURERS MADE SERIOUS EFFORTS TO REDUCE THAT NOISE AND DEVELOPED HUSH KITS FOR RETROFIT, WHICH WERE RAPIDLY INTRODUCED IN THE PRODUCTION LINE.

- AT THIS TIME, INCREASING COMMUNITY ACTION AGAINST NOISE AND MULTIPLYING LAWSUITS PROMPTED ADMINISTRATIONS TO UNDERTAKE NOISE REDUCTION PROGRAMMES AND SEVERE OPERATIONAL RESTRICTIONS BEGAN TO BE IMPOSED.

- IN THE LATE 1960'S TWO IMPORTANT EVENTS HAPPENNED - FIRSTLY, AN IMPORTANT PROGRESS WAS ACHIEVED IN THE INDUSTRY WITH THE INTRODUCTION OF THE HIGH BY-PASS RATIO TURBOFAN ENGINE AT A SIZE TO POWER THE BOEING 747.

  SECONDLY, THE FIRST NOISE REGULATION WAS PROMULGATED.

- SUBSEQUENTLY, OTHER HIGH BY-PASS RATIO TURBOFAN ENGINES WERE PRODUCED FOR THE DOUGLAS DC.10, LOCKHEED L1011 AND AIRBUS A300.

- THE THRUST OF THESE SIGNIFICANTLY MORE FUEL EFFICIENT ENGINES, I.E. PRATT AND WHITNEY JT9, GENERAL ELECTRIC CF6 AND ROLLS ROYCE RB211 WAS TWICE THE THRUST OF THE PREVIOUS LARGEST COMMERCIAL ENGINES.

- CONCURRENTLY, THE AIRCRAFT SEATING CAPACITY WAS ALSO MULTIPLIED BY TWO.

- BUT NO HIGH BY-PASS RATIO ENGINE WAS DEVELOPED AT THIS TIME TO POWER THE OLDER BOEING 727 737 AND DOUGLAS DC9 WHICH WERE PRODUCED IN LARGE QUANTITIES.

- THESE FLEETS ARE NOW RESPONSIBLE FOR AN IMPORTANT PART OF THE NOISE PROBLEM ON THE MAJORITY OF THE WORLD'S AIRPORTS, PARTICULARLY DOMESTIC AIRPORTS IN THE U.S. BUT ALSO INTERNATIONAL AIRPORTS ABROAD.

- THE PRICE INCREASE OF FUEL LED MANUFACTURERS TO INCORPORATE HIGH BY-PASS RATIO TECHNOLOGY IN ENGINES TO POWER SHORT AND MEDIUM HAUL AIRCRAFT. THESE NEW ENGINES NOW BEGIN TO BE AVAILABLE.

TO SUMMARIZE,

SLIDE 2 RECALLS THE 3 GENERATIONS OF AFORE MENTIONNED AIRCRAFT ENGINES.

SLIDE 3 ILLUSTRATES THE STEP BY STEP PROGRESS MADE IN NOISE REDUCTION WITH THE INTRODUCTIO OF DIFFERENT TECHNOLOGY LEVELS.

3. REGULATIONS IMPOSED BY STATES AND ADMINISTRATIONS

SLIDE 4

- GOVERNMENTS WORLDWILDE WERE FORCED TO IMPOSE SEVERE CONSTRAINTS ON AIRCRAFT AND ENGINE MANUFACTURERS. AS OF 1967, AMERICAN AND EUROPEAN SPECIALISTS BEGAN ELABORATING A DRAFT OF NOISE REQUIREMENTS FOR THE CERTIFICATION OF NEW AIRCRAFT TYPES.
- IN 1969, THE UNITED STATES INTRODUCED THE FIRST NOISE REGULATION IN THE FORM OF FAR 36.
- IN 1971, THE ICAO (INTERNATIONAL CIVIL AVIATION ORGANIZATION) REACHED AGREEMENT ON SIMILAR CERTIFICATION FOR NEW AIRCRAFT IN THE FORM OF ANNEX 16 TO THE CHICAGO CONVENTION.
- AS NEW AIRCRAFT EQUIPPED WITH HIGH BY-PASS RATIO ENGINES PROVED TO BE ABLE TO MEET THE FIRST CERTIFICATION STANDARDS WITH A CONSIDERABLE MARGIN, NEW AND MORE STRINGENT STANDARDS FOR NEW AIRCRAFT WERE ADOPTED BY ICAO'S COMMITTEE ON AIRCRAFT NOISE ~~ON~~ AT THEIR FIFTH MEETING (CAN 5) IN 1976.
- FAA AND ICAO ALSO REACHED A GENERAL AGREEMENT ON THE NEW STANDARDS BUT THE US REGULATION STILL REMAINS MORE STRINGENT IN TERMS OF CERTIFICATION PROCEDURE.

SLIDE 5

- COMPLIANCE WITH THESE CERTIFICATION REGULATIONS REQUIRES AIRCRAFT TO SATISFY NOISE LIMITS FOR A GIVEN TAKE-OFF WEIGHT AT THREE REFERENCE POINTS, NAMELY : TAKE-OFF, SIDELINE, AND APPROACH.
- IN THE MEANTIME, THE FAA HAS PROMULGATED A RULE IMPOSING JANUARY 1ST 1985 AS THE CUT-OFF DATE FOR OPERATION OF NON-NOISE CERTIFICATED AIRCRAFT ON THE US TERRITORY.
- AN ICAO RECOMMENDATION REQUIRED STATES NOT TO ADOPT ANY DEADLINE PRIOR JANUARY 1ST 1988 FOR AIRCRAFT WITH FOREIGN REGISTRATION, AND THIS, ONLY ON NOISE SENSITIVE AIRPORTS.
- THE EEC, EUROPEAN ECONOMIC COMMUNITY, HAS ALSO ADOPTED A DIRECTIVE WHICH BANS OPERATION OF NON NOISE CERTIFICATED AIRCRAFT AS OF JANUARY 1ST 1988 (ONE YEAR EARLIER FOR EEC REGISTERED AIRCRAFT BUT A TWO YEAR DELAY IS GRANTED IF NEW TECHNOLOGY REPLACEMENT AIRCRAFT HAVE BEEN ORDERED).

SLIDE 6

- TO SUMMARIZE, THERE ARE PRESENTLY THREE CATEGORIES OF AIRCRAFT :
  - THE OLDER AIRCRAFT WHICH ARE NOT NOISE CERTIFICATED, AND WHICH MUST BE EITHER RETROFITTED, RE-ENGINED OR REPLACED,
  - AIRCRAFT COMPLYING WITH ICAO ANNEX 16 CHAPTER 2 (OR FAR 36 STAGE 2) STANDARDS,
  - AIRCRAFT COMPLYING WITH ICAO ANNEX 16 CHAPTER 3 (OR FAR 36 STAGE 3) STANDARDS.

SLIDE 7

- TO DAY, AN INCREASING PROPORTION OF THE 7,000 A/C WORLD FLEET IS POWERED BY THE QUIETER HIGH BY-PASS RATIO ENGINES.
- WITHIN TEN YEARS, THERE WILL BE A COMPLETE REVERSAL OF THE PRESENT SITUATION, WITH AS BIG A PROPORTION OF HIGH BY-PASS RATIO ENGINES IN THE AIRLINES FLEET AS IS NOW TAKEN UP BY OLDER LOW BY-PASS TYPES.
- THE GRADUAL REPLACEMENT OF OLD NOISY AIRCRAFT BY QUIETER MODERN TURBOFAN WILL CONTINUE TO ENSURE A DOWNWARD TREND DURING THE NEXT FIVE YEARS.
- BUT, WE SHOULD NOT CONSIDER THAT THE NOISE PROBLEM HAS BEEN SOLVED. IT IS NECESSARY TO CARRY ON FUNDAMENTAL RESEARCH TO MAINTAIN THIS DOWNWARD TREND AND AVOID AN UPTURN IN THE NINETIES AND BEYOND.

SLIDE 8

- IN TERMS OF AIRCRAFT SEATING CAPACITY, THE PERCENTAGE OF PASSENGERS TRAVELLING ABOARD NEW TECHNOLOGY AIRCRAFT IS ALREADY MORE THAN 50 PERCENT AND WILL OVERPASS 85 PERCENT WITHIN THE NEXT 10 YEARS.

5.1 Slide 9

- During the past 20 years the noise energy generated by new aircraft introduced into service has been reduced by (15 EPNdB).
- A further reduction of about 5 EPNdB is expected over the next 10 years or so with the introduction of new and quieter aircraft such as the Boeing B757, B767, A310, A320.
- The impact of the remaining older aircraft will be reduced rapidly because newer types carrying more passengers will be used more frequently.
- Noise contours for individual aircraft have been significantly reduced in area. These contours of equal noise levels such as 90 EPNdB are very useful in estimating exposure areas. However, they must be used very carefully as only comparable data can be compared. i.e. footprints of aircraft having a similar range and seating capacity.
- Furthurmore their accuracy is far from being perfect. A noise increase of only 4dB may double their size. Therefore only approximate values of areas are given here to illustrate an order of magnitude.

5.2 Slide 10

If we divide the footprint area by the aircraft seating capacity in order to obtain a noise dose per aircraft seat or passenger, we observe that the value of that index is significantly reduced with the new technology aircraft (around 10 to 20 percent of the value obtained with older aircraft).

5.3 NOWADAYS, AIRPORT AUTHORITIES ESTABLISH ANNUAL ESTIMATES OF THE CUMULATIVE NOISE EXPOSURE SITUATIONS BASED UPON NOISE LEVELS AND TRAFFIC FIGURES. THIS CONCEPT IS USED WORLDWIDE TO ASSESS THE ANNOYANCE FOR COMMUNITIES AROUND AIRPORTS.

MANY SCHEMES AND INDICES HAVE BEEN PROPOSED.

THE MOST POPULAR METHOD IS TO ADD A 10 $LOG_{10}.N$ FACTOR TO THE MEASURED NOISE LEVEL TO ACCOUNT FOR THE NUMBER "N" OF OPERATION.

ANOTHER ISSUE HAS BEEN INTRODUCED TO TAKE INTO ACCOUNT THE NIGHTIME EFFECT :

A NOISE OCCURING DURING THE NIGHT IS CONSIDERED 10 FOLD NOISIER THAN A SIMILAR NOISE PRODUCED DURING THE DAY IN ORDER TO LIMIT THE DEGREE OF ANNOYANCE TO THE SAME VALUE.

SLIDE 11

- IN ADDITION TO NOISE REDUCTION AT SOURCE, SUBSTANTIAL REDUCTION OF EXPOSURE TO NOISE ON THE GROUND IS OBTAINED BY APPLICATION OF NOISE ABATEMENT OPERATING PROCEDURES WHICH INCLUDE :

  - TAKE OFF PROCEDURES USING STEEP INITIAL CLIMB GRADIENT IN ORDER TO REACH THE NOISE SENSITIVE AREAS AT MAXIMUM POSSIBLE HEIGHT.

  - APPROACH PROCEDURE OVER NOISE CRITICAL AREAS.

  - USE OF NOISE PREFERENTIAL RUNWAYS TO DIRECT INITIAL AND FINAL FLIGHT PATHS OF AIRCRAFT AWAY FROM NOISE SENSITIVE AREAS.

  - USE OF NOISE PREFERENTIAL ROUTES AVOIDING THESE AREAS UPON DEPARTURE AND ARRIVAL

  - THE USE OF TURNS TO DIRECT AIRCRAFT AWAY FROM NOISE SENSITIVE AREAS LOCATED UNDER OR ADJACENT TO USUAL TAKE-OFF AND APPROACH FLIGHT PATH.

- THE PURPOSE OF THESE PROCEDURES IS TO KEEP AIRCRAFT AS FAR AWAY AS POSSIBLE FROM COMMUNITIES AND KEEP NOISE DISTURBANCE TO A MINIMUM.

SLIDE 12 ILLUSTRATES THE PRIME NOISE SOURCES IN JET ENGINES

- INTERNALLY GENERATED NOISE HAS BEEN WELL CONTAINED IN THE DESIGN OF ROTATING MACHINERY AND THE USE OF ACOUSTICAL TREATMENT.
  THE NOISE PRODUCED BY TURBINES IS RELATIVELY WELL KNOWN.

- ON THE OTHER HAND, COMBUSTORS REMAIN A SERIOUS SOURCE OF CONCERN.
  WE PARTICULARLY NEED TO IMPROVE OUR KNOWLEDGE CONCERNING THE RELATIONSHIP BETWEEN COMBUSTION AND JET MIXING PROCESS.

7.1 THE RESEARCH PRIORITIES, ARE :

- EXHAUST NOISE INCLUDING COMBUSTOR/CORE INFLUENCE
- FAN NOISE
- POWERPLANT INSTALLATION EFFECTS
- AIRFRAME, FLAPS AND LANDING GEAR

SLIDE 13 7.2 FURTHER IMPROVEMENTS IN REDUCING NOISE LEVELS AT SOURCE ARE EXPECTED BY MANUFACTURERS.

- AS AN EXAMPLE A 4 EPNdB REDUCTION COULD BE OBTAINED BY EXHAUSTING HOT GAS OF A HIGH BY-PASS RATIO TURBOFAN IN THE OUTER STREAM AND COOL GAS IN THE INNER STREAM

- THE SAME REDUCTION IS EXPECTED WITH ADDITION OF A THERMAL ACOUSTIC SHIELD IN THE LOWER PART OF THE NOZZLE, REDUCING THE HIGH FREQUENCY JET NOISE DURING TAKE-OFF AND APPROACH.

SLIDE 14 7.3 NOISE CERTIFICATION LEVELS AT THE APPROACH REFERENCE POINT ARE NOW SIGNIFICANTLY CLOSE TO THE AIRFRAME AERODYNAMIC NOISE FLOOR WHICH WOULD BE PRODUCED BY THE AIRCRAFT IF IT HAD NO ENGINES. SOME IMPROVEMENTS COULD BE ACHIEVED IN THE LONGER TERM.

THIS NOISE IS PRODUCED BY THE TURBULENCE GENERATED BY THE AIRFRAME AND ITS VARIOUS COMPONENTS SUCH AS LANDING GEAR, FLAPS, CAVITIES AND OTHER FEATURES WHICH DISRUPT SMOOTH AIRFLOW.

- THIS AERODYNAMIC NOISE FLOOR PREVENTS FROM DESCENDING MUCH BELOW THE LEVELS WHICH HAVE BEEN REACHED AND WE MUST BEAR IN MIND THAT ADDITIONAL STEPS WILL BE VERY COSTLY.

THE NOISE STANDARDS DEVELOPED BY ICAO ANNEX 16 CHAPTER 2 AND FAR 36 STAGE 2 WERE AROUND 8 TO 10 EPNdB ABOVE THIS LIMIT ; THOSE INTRODUCED BY CHAPTER 3/ STAGE 3 WERE ONLY AROUND 5 TO 7 EPNdB ABOVE THE SAME LIMIT.

7.4 THE POSITION OF POWERPLANTS COULD ALSO BE OPTIMIZED.

7.5 NEVERTHELESS IT SHOULD BE POINTED OUT THAT THERE IS A LIMIT TO POSSIBLE NOISE REDUCTION.

ICAO MEETINGS CANS 6 AND 7, HAVE CONCLUDED THAT NO MAJOR ADVANCE IN ENGINE REDUCTION IS TO BE FORESEEN AT PRESENT.

SMALL IMPROVEMENTS ARE POSSIBLE BUT WOULD BE INCREASINGLY DIFFICULT TO OBTAIN, AND WOULD BE ACCOMPANIED BY INCREASINGLY GREATER FINANCIAL AND OTHER PENALTIES.

7.6 IN ADDITION TO TECHNOLOGICAL IMPROVEMENTS THE NOISE CERTIFICATION PROCESS, WHICH NOW COMPRISES MAJOR CONSTRAINTS AND SOME IRRELEVANCIES COULD BE BETTER STRUCTURED AND SIMPLIFIED.

- THE REQUIREMENTS FOR REPEATED FLIGHT TESTS ARE BEING REPLACED BY THE USE OF GROUND BASED DATA.
- IN ADDITION, THE CONCEPT OF FAMILY PLANE WHICH REQUIRES A FLIGHT TEST ONLY FOR THE PARENT AIRCRAFT COULD BE EXPLORED TO REMOVE UNNECESSARY SPECIFICATIONS.

SLIDE 15

- A VERY LARGE AMOUNT OF MONEY HAS BEEN SPENT IN MAKING JET TRANSPORT AIRCRAFT QUIETER.
- AN IMPORTANT PART OF THIS EXPENDITURE HAS BEEN PAID BY THE AIRLINES DIRECTLY OR INDIRECTLY.
- IN ADDITION TO CONSIDERABLE CAPITAL COSTS, AIRLINES HAVE TO PAY HEAVY EXTRA OPERATING COSTS.

8.1 CAPITAL COSTS (IATA ESTIMATION = ABOUT USD 1 BILLION)

- MANUFACTURERS' NOISE REDUCTION RESEARCH AND DEVELOPMENT
  FUNDAMENTAL RESEARCH - DEVELOPMENT OF EARLY JET AIRCRAFT NOISE SUPPRESSORS AND DIFFERENT HUSH KITS FOR ENGINES AND NACELLES HUH HOUSES AND TEST CELLS AT AIRPORTS.
- NOISE CERTIFICATION OF AIRCRAFT.
- COST OF RETROFIT AND REPLACEMENT AIRCRAFT.

  ALL COSTS OF THE PREVIOUS ITEMS ARE SMALL IN COMPARISON TO THIS EXPENDITURE. IN 1974 IT WAS ESTIMATED THAT THE RETROFIT OF AIRCRAFT WOULD COST IATA AIRLINES ABOUT USD 3 BILLION. NOT ALL A/C WHICH IT WAS PLANNED AT THAT TIME WOULD BE UPGRADED, HAVE IN FACT BEEN RETROFITTED, MANY OLDER AIRCRAFT HAVE BEEN RETIRED AND REPLACED BY NEW TYPES THIS HAS NOT OF COURSE REDUCED THE EXPENDITURE.

  - OVER 1500 OF MUCH LESS NOISY AIRCRAFT HAVE BEEN BOUGHT OVER THE LAST 15 YEARS. AT USD 50 MILLION EACH THAT REPRESENTS A TOTAL COST OF OVER USD 75 BILLION
  - WHAT PROPORTION OF THIS VAST COST CAN BE ASSIGNED TO NOISE REDUCTION IS DEBATABLE BUT NO ONE CAN DOUBT THAT MANY OF THESE A/C WERE ORDERED MUCH EARLIER THAN THEY WOULD HAVE BEEN IF NO NOISE REDUCTION DEADLINES AND RESTRICTIONS EXISTED.

8.2 OPERATING COSTS

ALTHOUGH THE ADDITIONAL CAPITAL COSTS LOOK ENORMOUS, THE EXTRA OPERATING COSTS DUE TO REDUCE NOISE WILL EVENTUALLY EXCEED THEM.

- COSTS OF EXTRA FUEL BURNT TO CARRY THE DEAD WEIGHT OF NOISE SUPPRESSION HARDWARE. AS AN EXAMPLE. IT TAKES ABOUT 100 LB OF FUEL PER FLIGHT HOUR TO CARRY AN EXTRA EMPTY WEIGHT OF 2500 LB - TOTAL ESTIMATE : APPROX. USD 20 MILLION/YEAR
- INCREASE IN FUEL CONSUMPTION DUE TO THE LOSS OF EFFICIENCY OF THE ENGINES - AROUND 1 % OF FUEL COSTS - APPROX. UDS 150 MILLION/YEAR.
- NOISE CHARGES, EXTRA LANDING FEES - MAINLY FOR INSULATION OF NEARBY DWELLINGS AND PURCHASE OF PROPERTY NEAR THE AIRPORT - NO ESTIMATION AVAILABLE -
- LOST OF EXTRA FLIGHT TIME DUE TO THE USE OF NOISE ~~PER~~ PREFERENTIAL RUNWAYS AND MINIMUM NOISE ROUTES - AT LEAST USD 200 MILLION/YEAR.
- OTHER OPERATIONAL COSTS INCURRED - THE COST OF CURFEWS IS CONSIDERABLE - REDUCING A/C UTILIZATION, CAUSING DELAYS AND SCHEDULING PROBLEMS AND REDUCING REVENUE - EARNING OPPORTUNITIES.
- LAWSUITS

8.3 CONCLUSIONS A VERY LARGE AMOUNT OF MONEY HAS BEEN ~~MADE~~ SPENT TO REDUCE A/C NOISE. ESTIMATIONS OF THE TOTAL AIRLINE EXPENDITURE ON NOISE REDUCTION HAVE BEEN MADE. THE RESULT IS BETWEEN 1 AND 3 % OF AIRLINE REVENUE.

SLIDE 16

1 - MANUFACTURERS AND AIRLINES HAVE ALREADY ACHIEVED CONSIDERABLE EFFORTS IN AIRCRAFT NOISE REDUCTION AND MUST CONTINUE THEIR ACTION.

- MANUFACTURERS HAVE ACHIEVED IMPORTANT RESEARCH AND DEVELOPMENT PROGRAMS AND HAVE PRODUCED NEW AIRCRAFT AND ENGINES INCORPORATING IMPROVED TECHNOLOGY.

- FUNDAMENTAL RESEARCH SHOULD BE REACTIVATED TO ENSURE CONTINUATION OF THE DOWNWARD TREND OF AIRCRAFT NOISE.

- AIRLINES HAVE GIVEN AN IMPORTANT CONTRIBUTION BY :
  - . MAKING IMPORTANT INVESTMENTS IN NEW, QUIETER AIRCRAFT, OFTEN WITH INCREASED SEATING CAPACITY.
  - . EARLY RETIREMENT/REPLACEMENT OF OLDER AIRCRAFT.
  - . APPLYING NOISE ABATEMENT OPERATIONAL PROCEDURES.
  - . UNDERGOING NUMEROUS COSTLY CONSTRAINTS AND PENALTIES (NOISE CHARGES - CURFEW MEASURES LAWSUITS).

2 - SUBSTANTIAL YEAR TO YEAR IMPROVEMENTS HAVE ALREADY BEEN RECORDED IN AIRPORT ENVIRONMENT AND MUST BE PURSUED. THE PEAK OF NOISE EXPOSURE CURVE AT MAJOR AIRPORTS IS BEHIND. PROVIDED THAT CONTINUOUS IMPROVEMENTS ARE MADE ON ALL FRONTS, BY EARLY 1990'S EXPOSURE SHOULD BE HALF OF THE PEAK VALUE OCCURING AROUND 1970.

3 - NO MAJOR TECHNOLOGICAL IMPROVEMENT CAN BE FORESEEN, ADDITIONAL LIMITED NOISE REDUCTION WILL BE VERY COSTLY.

4 - THE TOTAL AIRLINE EXPENDITURE REPRESENTS 1 TO 3 % OF AIRLINE REVENUE. IT IS TIME TO CONSIDER THE CONSEQUENCES OF ALL CONSTRAINTS. AIRLINES NEED ALL THE MONEY THAT CAN BE SAVED TO BUY NEW, STILL QUIETER AIRCRAFT.

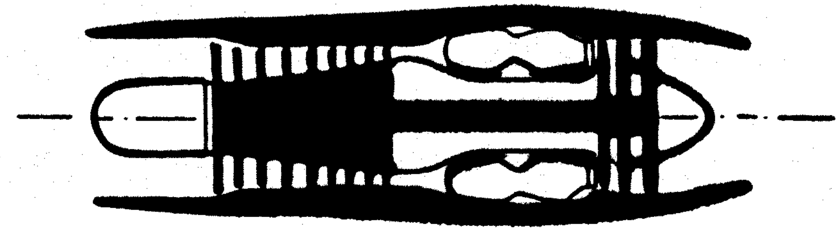
SLIDE 1

MAIN TECHNOLOGY IMPROVEMENTS

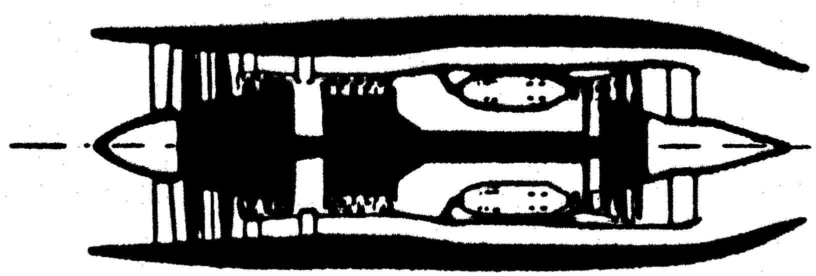
- 1950's = INTRODUCTION OF THE FIRST COMMERCIAL JET AIRCRAFT POWERED BY TURBOJETS OR LOW BY-PASS RATIO ENGINES
- 1960's = INTRODUCTION OF THE TURBOFAN TAKE-OFF NOISE REDUCTIONS OF APPROXIMATELY 8dB
- 1970's = INTRODUCTION OF HIGH BY-PASS RATIO ENGINES FOR LARGE LONG RANGE AIRCRAFT SIGNIFICANT REDUCTIONS IN NOISE LEVELS — 10 TO 15 dB
- 1980's = INTRODUCTION OF HIGH BY-PASS RATIO ENGINES FOR SHORT AND MEDIUM RANGE AIRCRAFT
  OVERALL IMPROVEMENT OF ABOUT 3 TO 4 dB

THREE GENERATIONS OF AIRCRAFT ENGINES

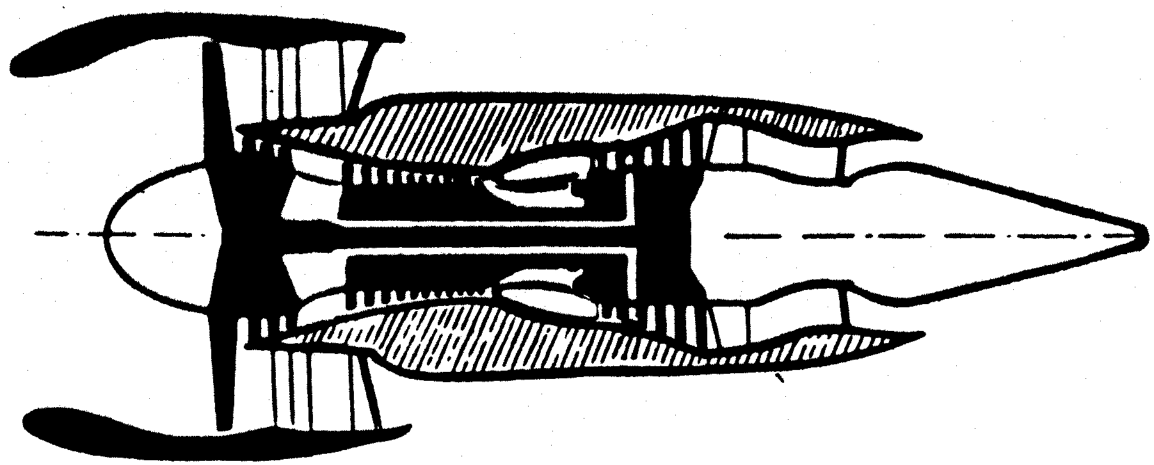
SLIDE 2



SINGLE-FLOW TURBOJET
LATE 50s

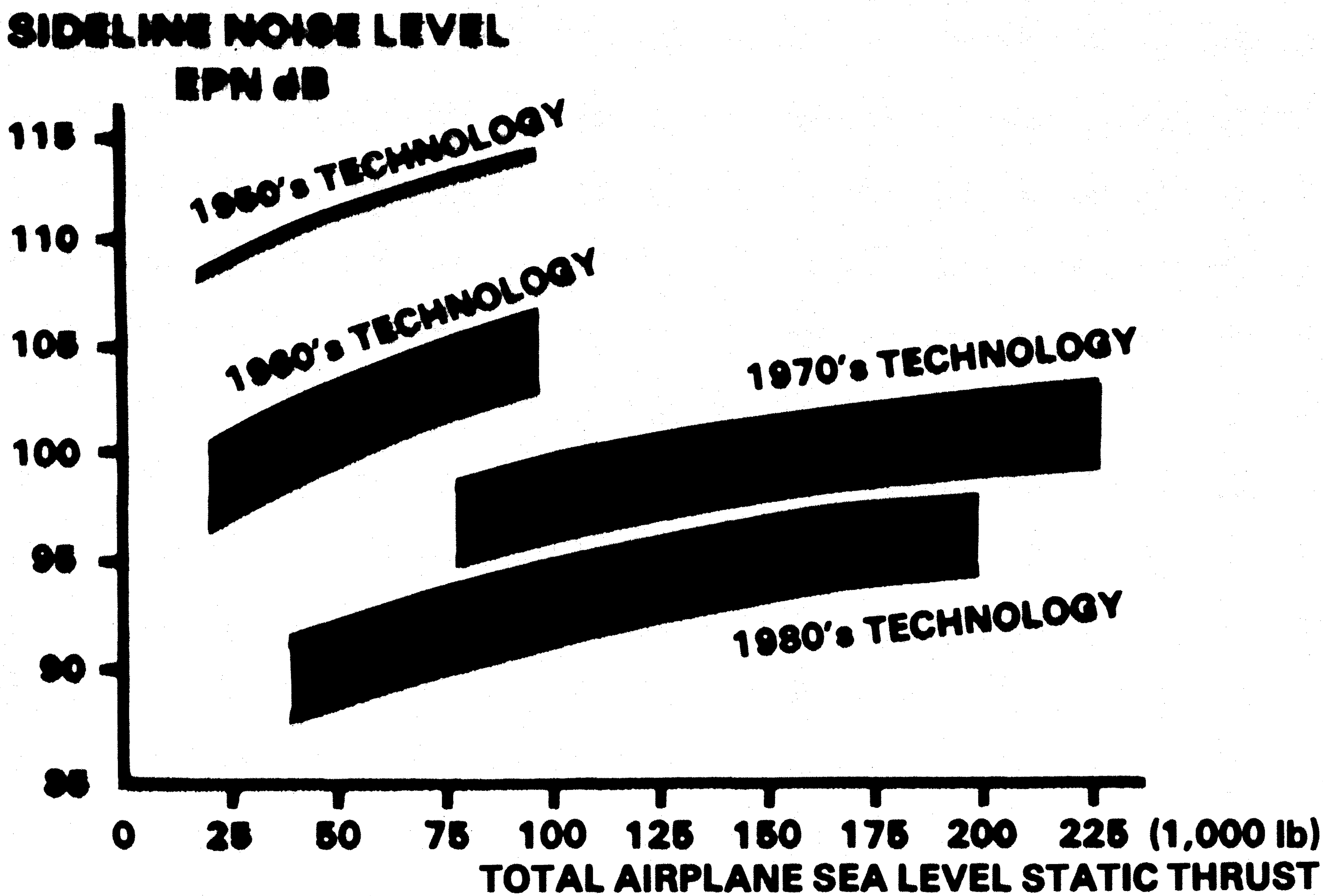


LOW BY-PASS RATIO TURBOFAN
EARLY 60s



HIGH BY-PASS RATIO TURBOFAN
EARLY 70s

AIRCRAFT ENGINE NOISE HISTORY

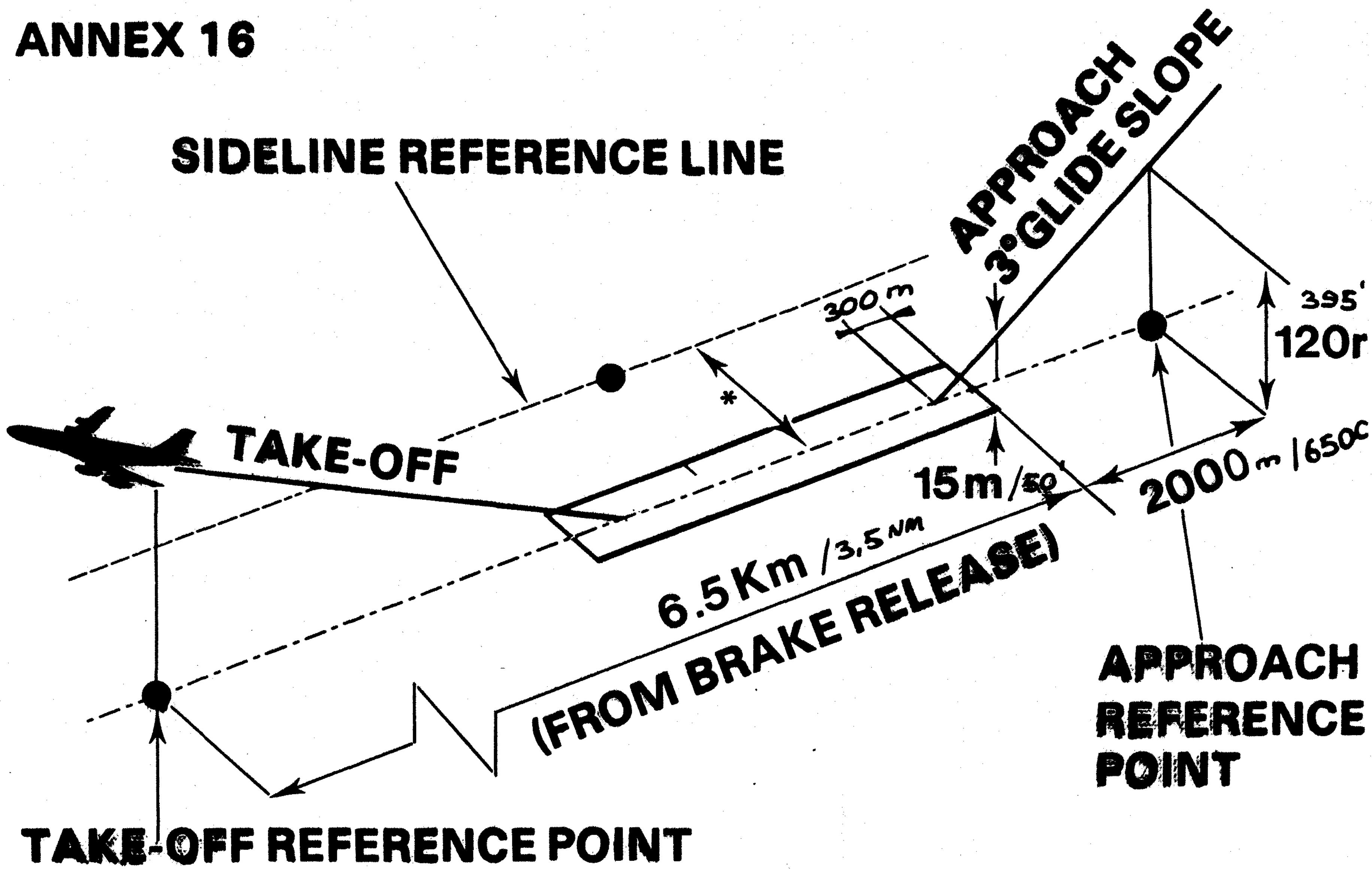


NOISE REGULATIONS

- 1969 — FAR 36 REGULATION ADOPTED BY THE UNITED STATES
- 1971 — ANNEX 16 TO CHICAGO CONVENTION ADOPTED BY ICAO
- 1976 — ICAO AND FAA AGREEMENT FOR MORE STRINGENT STANDARDS
- 1979 — CUT-OFF DATE FOR OLDER A/C OPS
  - — USA 1ST JAN 1985
  - — ICAO-EEC 1ST JAN 1988

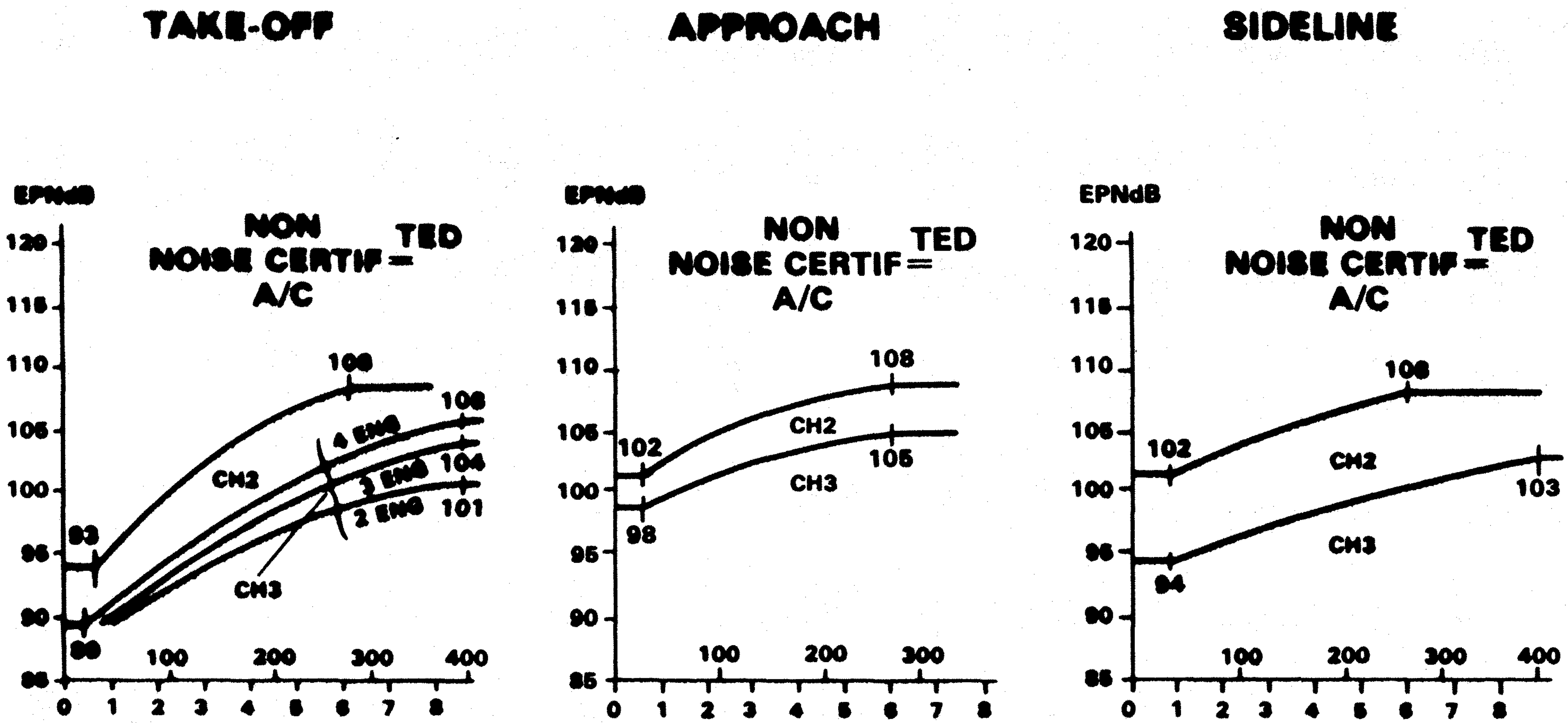
ICAO NOISE REFERENCE POINTS

ANNEX 16



* 0,35 NM / 650 m FOR CHAPTER 2
0,25 NM / 450 m FOR CHAPTER 3

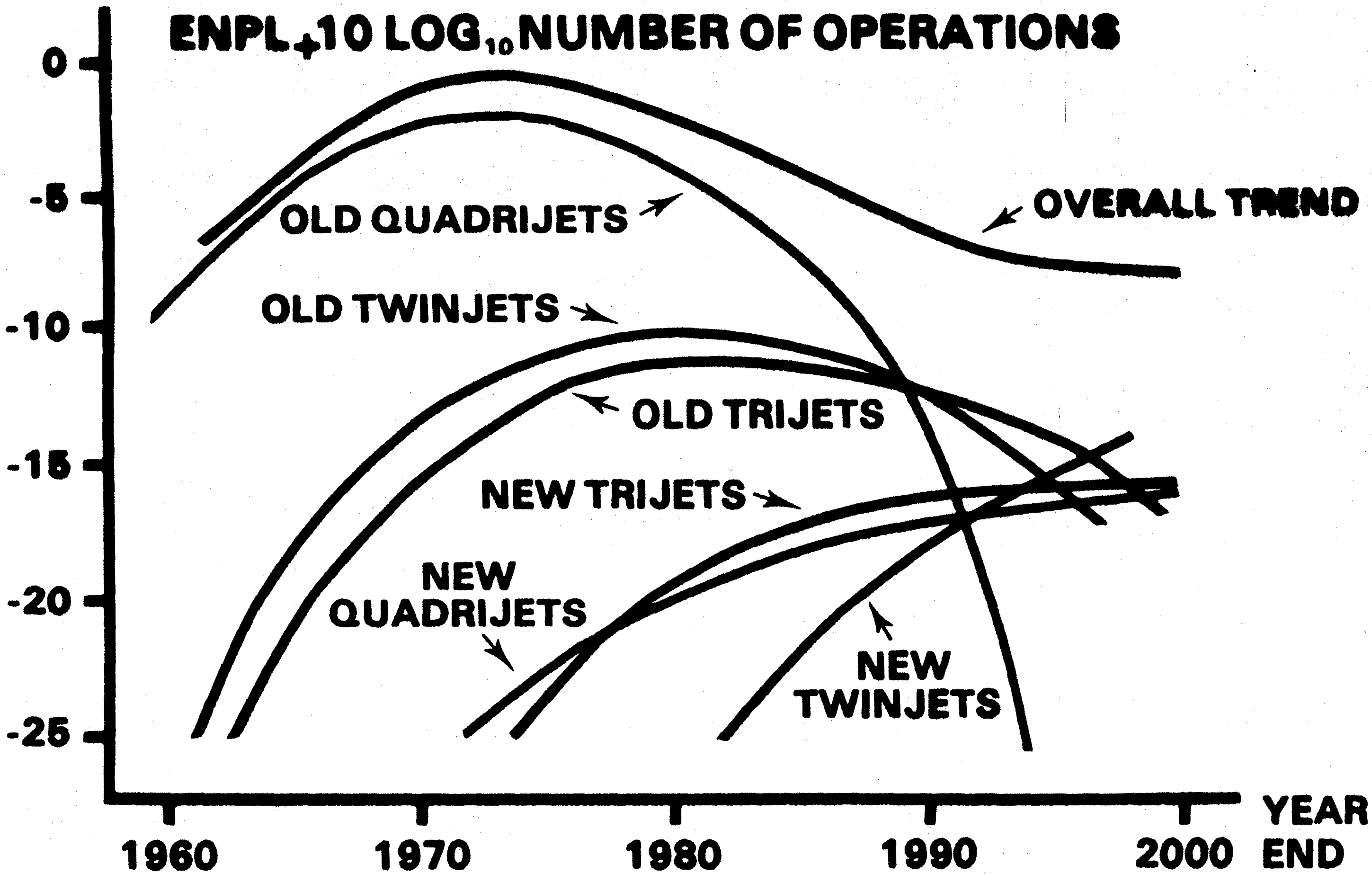
ICAO ANNEX 16 NOISE LEVELS



MAXIMUM TAKE-OFF WEIGHT | UPPER SCALE METRIC TONS
| LOWER SCALE 100.000 Lb.

GLOBAL AIRCRAFT NOISE TRENDS

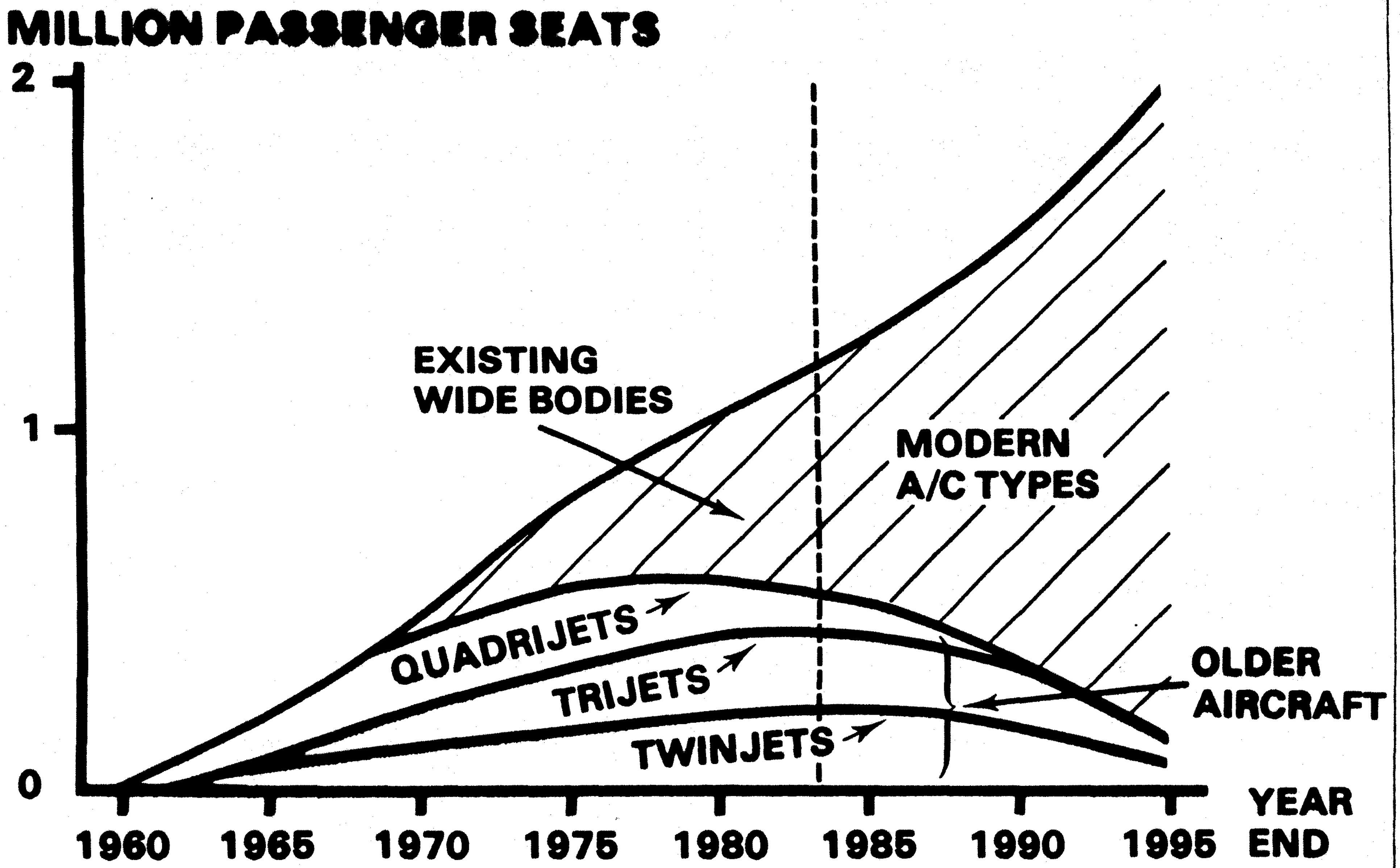
RELATIVE FLEET NOISE LEVEL



THE WORLD'S AIRLINE FLEET

SLIDE 8

IN TERMS OF AVAILABLE PASSENGER SEATS

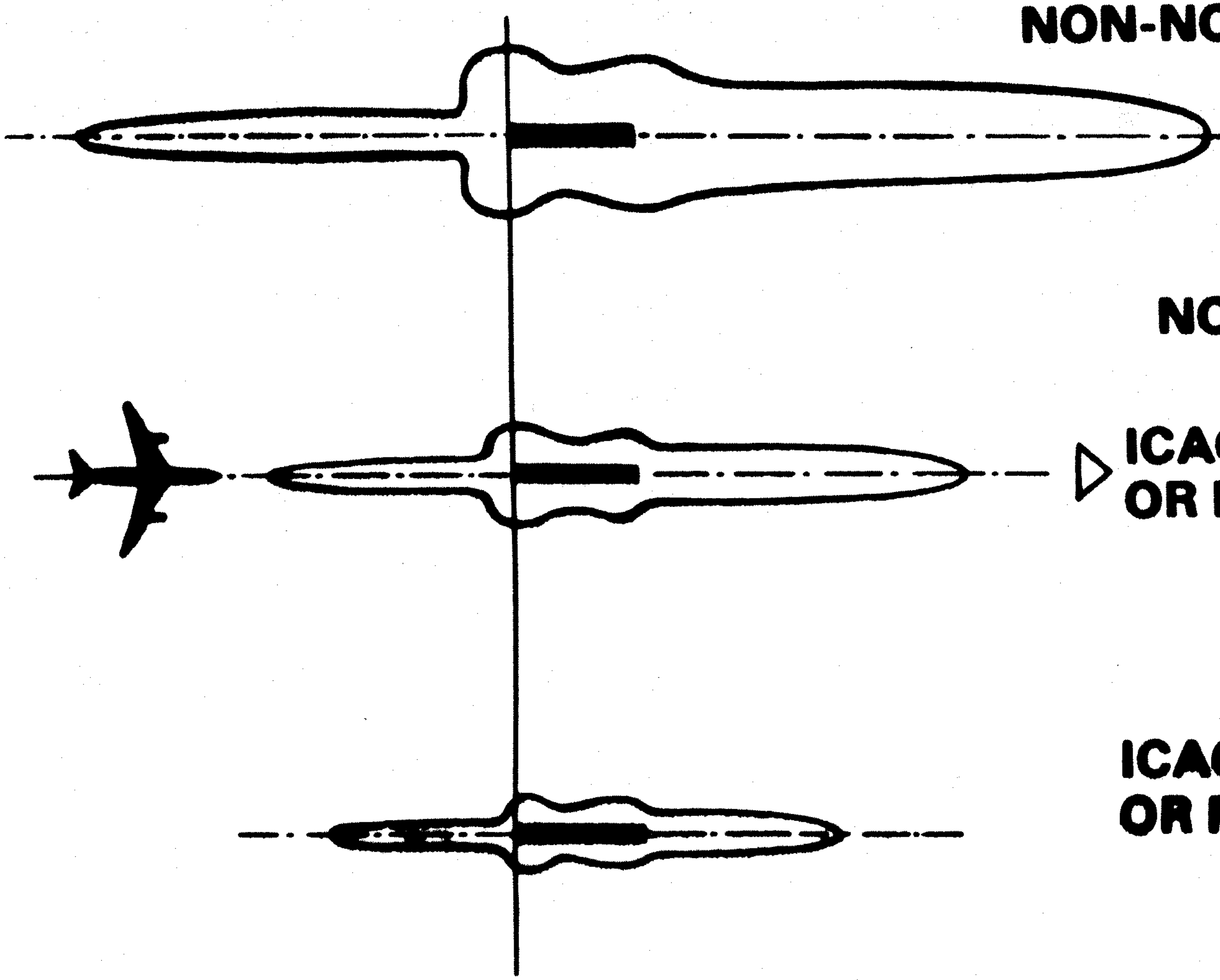


REDUCTION OF FOOTPRINT PATTERNS

Ex. 90 EPN dB NOISE CONTOURS

APPROACH THRESHOLD TAKE-OFF

AREA ORDER OF MAGNITUDE



NON-NOISE CERTIFICATED A/C

AREA 21 SQ MI
55 SQ KM

NOISE CERTIFICATED A/C

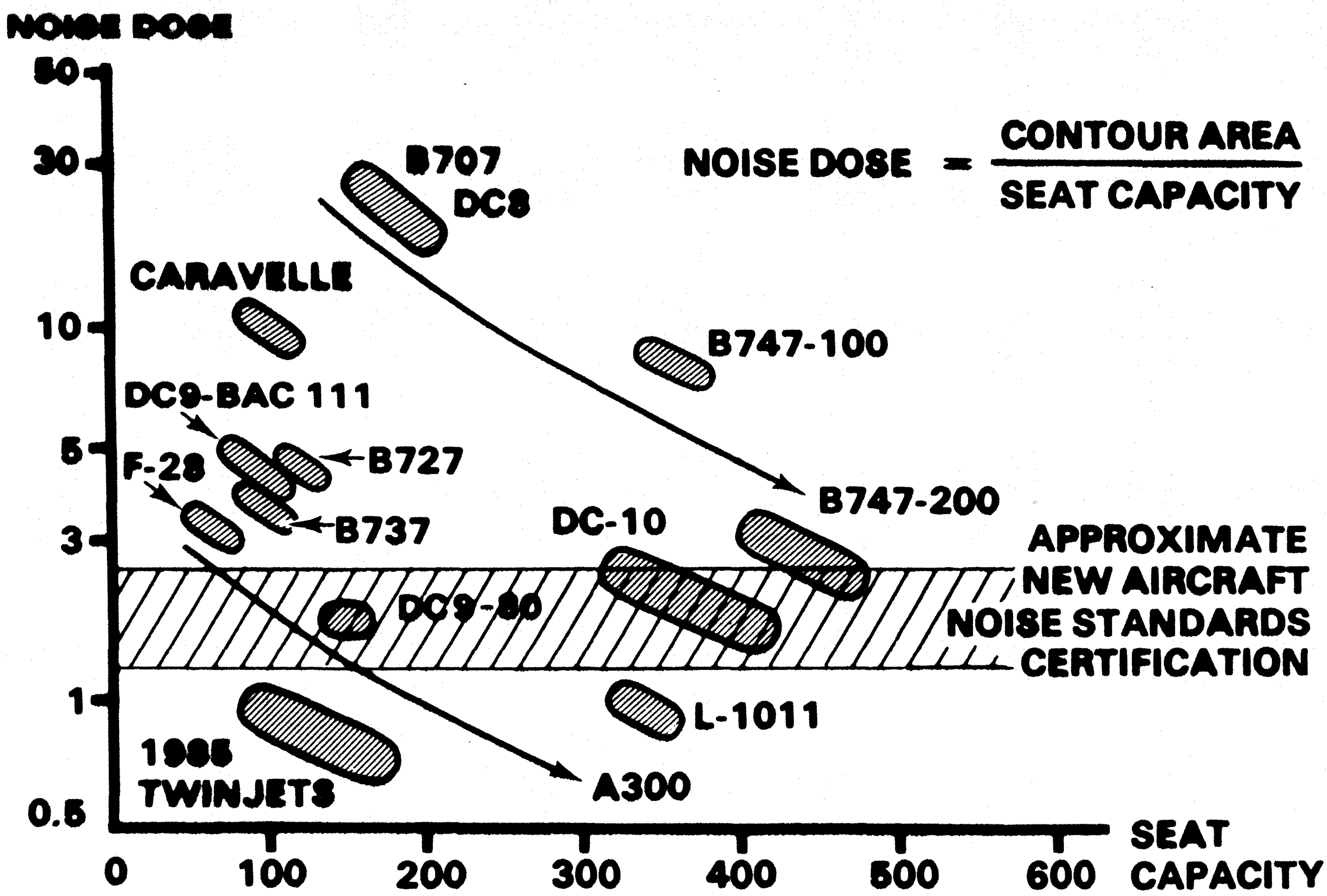
ICAO ANNEX 16 CHAPTER 2 OR FAR 36 STAGE 2

AREA 9 SQ MI
23 SQ KM

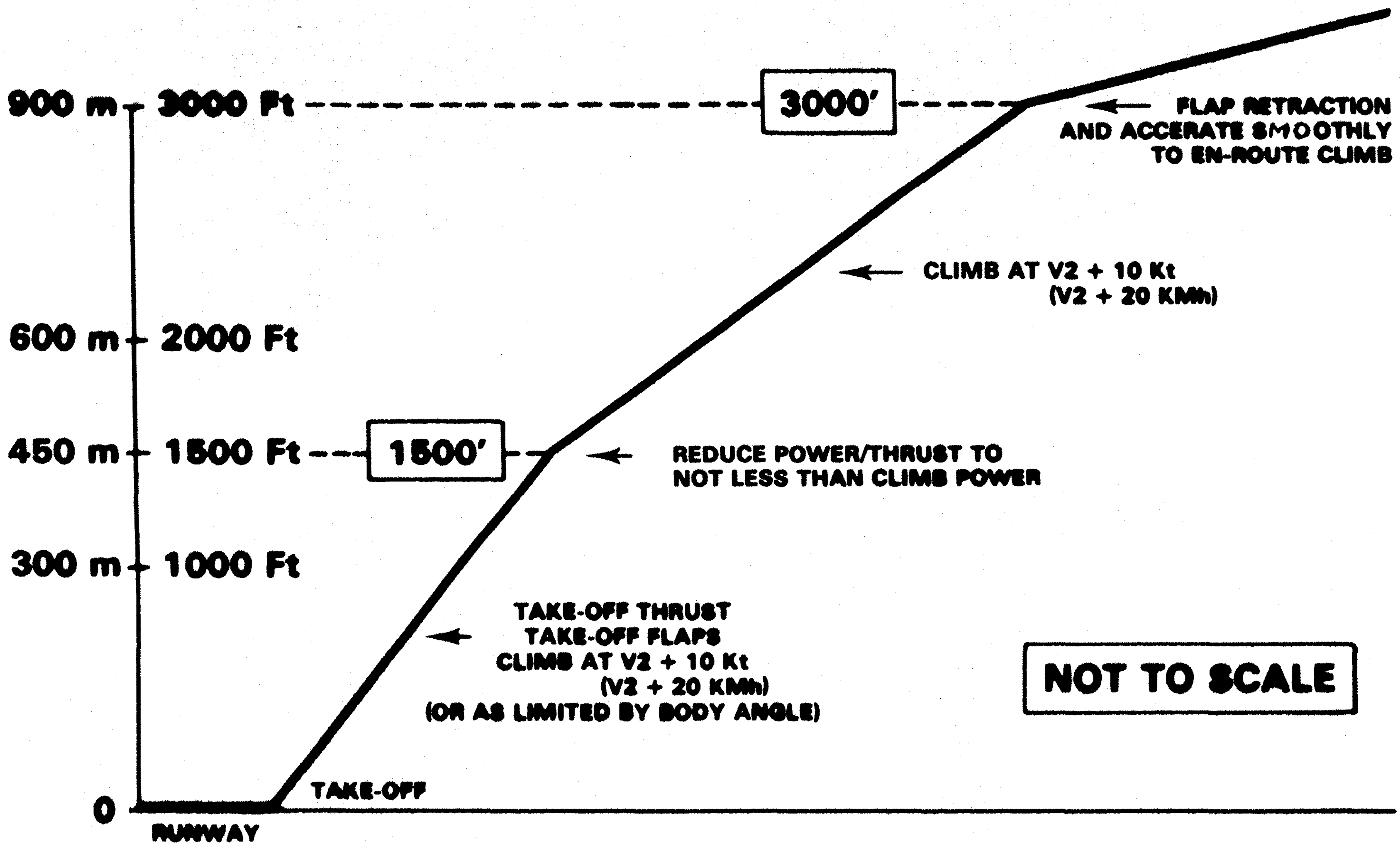
ICAO ANNEX 16 CHAPTER 3 OR FAR 36 STAGE 3

AREA 4 SQ MI
10 SQ KM

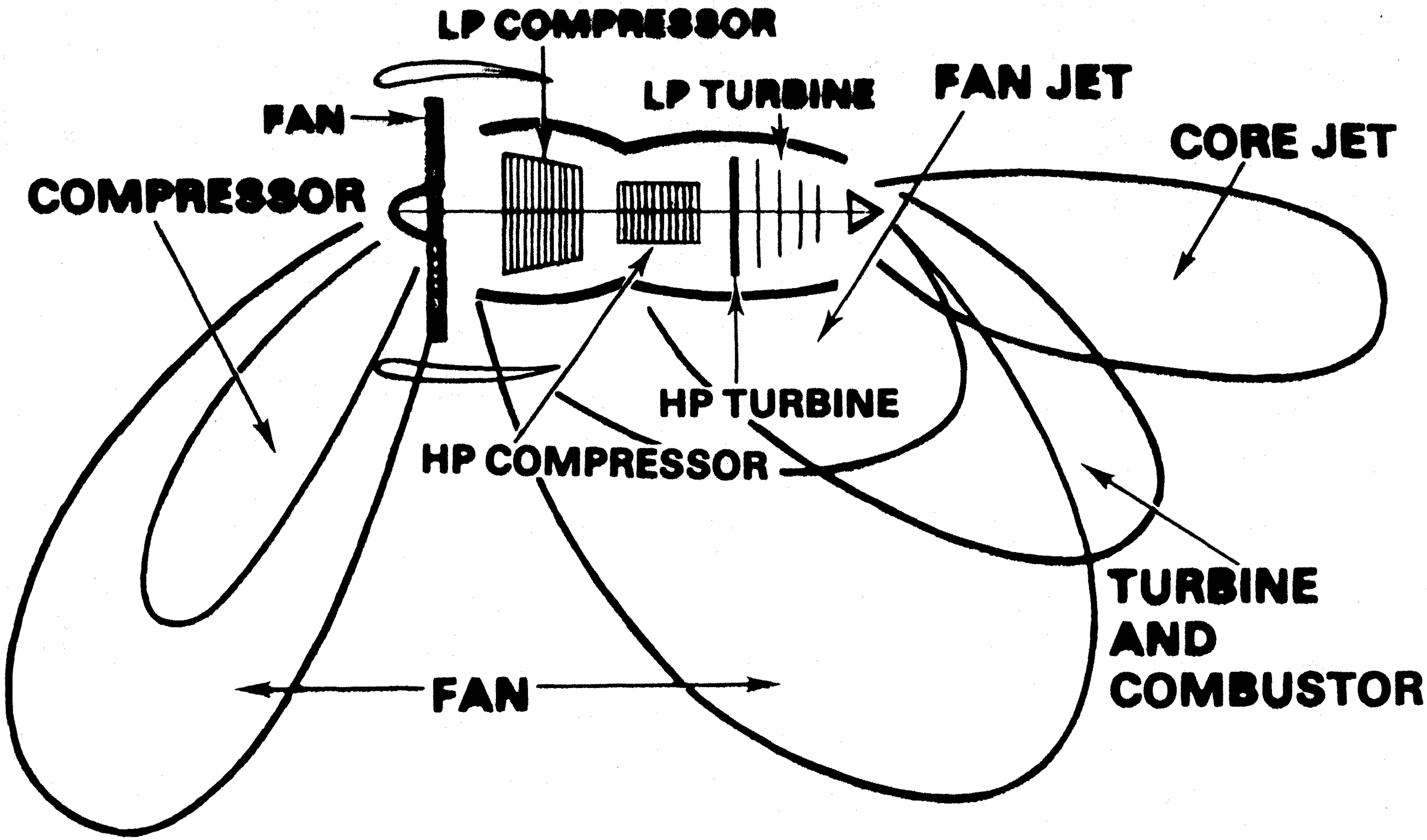
NOISE DOSE PER AIRCRAFT SEAT



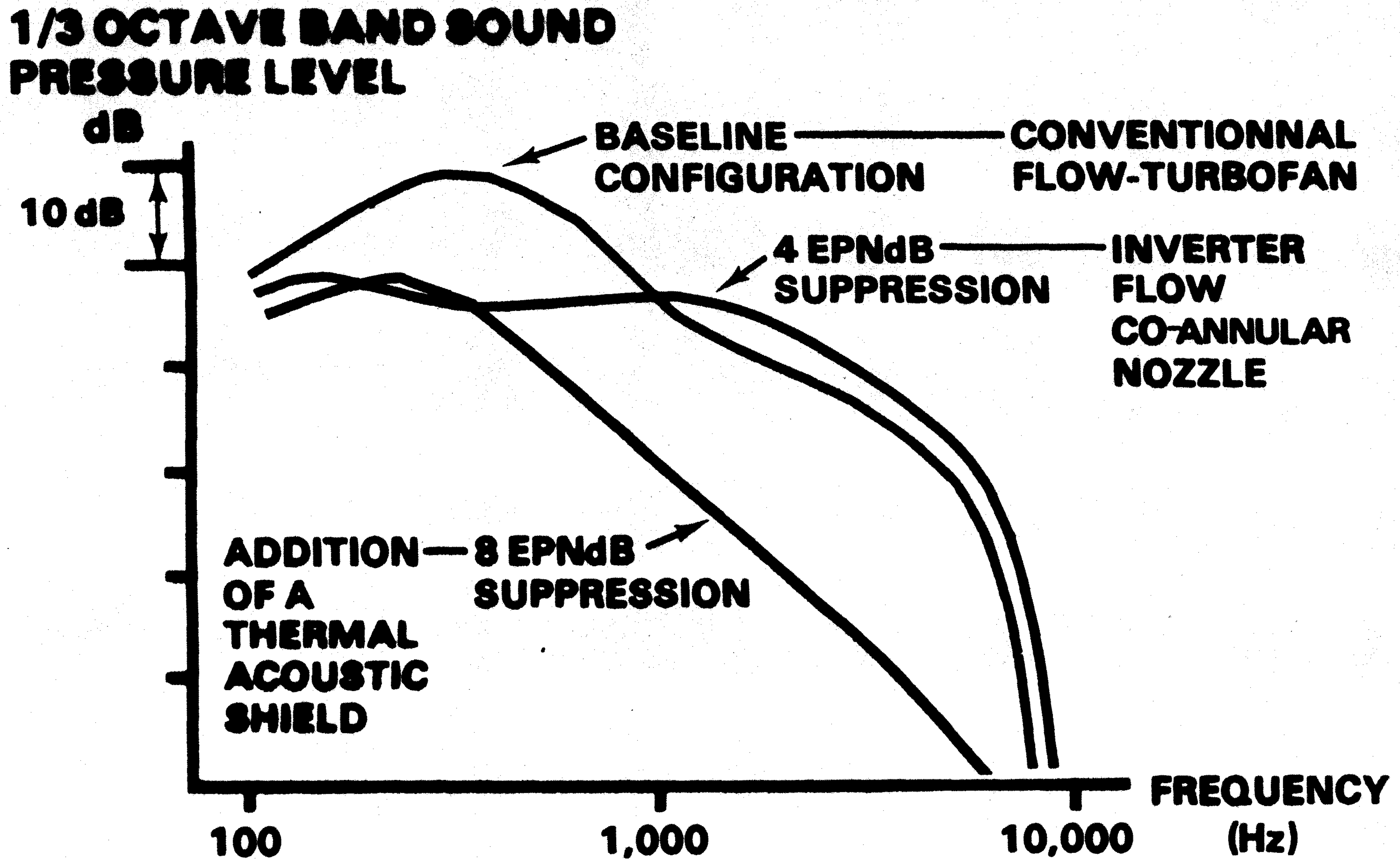
IATA NOISE ABATEMENT TAKE-OFF/CLIMB PROCEDURE



PRIME NOISE SOURCES IN JET ENGINES



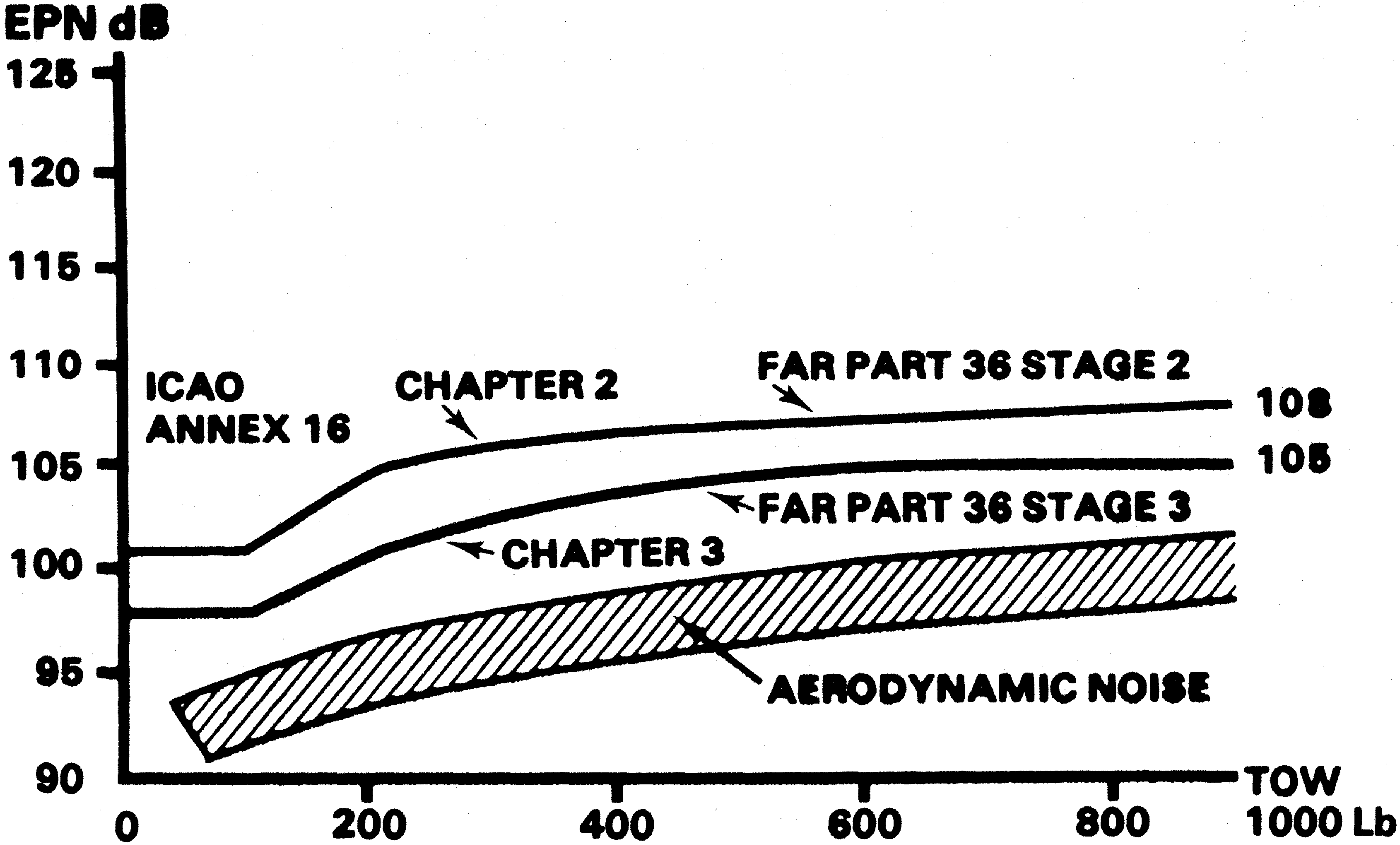
PROGRESS IN JET NOISE REDUCTION TECHNOLOGY



AERODYNAMIC NOISE

FLIGHT TEST RESULTS (APPROACH)

COMPARED WITH REG. NOISE LIMITS NOISE LEVEL



SLIDE 15

THE COST OF QUIETNESS

AIRLINE EXPENDITURE ON NOISE REDUCTION

I — CAPITAL COSTS

- MANUFACTURER'S NOISE REDUCTION R & D
- EARLY JET A/C NOISE SUPPRESSORS
- COST PENALTY DUE TO NOISE REDUCTION HARDWARE INSTALLED ON A/C
- HUSH HOUSES AND TEST CELLS AT AIRPORTS
- COST OF RETROFIT AND REPLACEMENT AIRCRAFT

(Items above:) SPECIFIC AIRLINE CAPITAL COSTS $ 1 BIL.

— RETROFIT (PREVIOUS ESTIMATE BY 1972)	$ 3 BIL.
— PURCHASE OF NEW A/C (PERCENTAGE OF)	$ 75 BIL.

II — OPERATING COSTS

EXTRA FUEL BURNT TO CARRY EXTRA WEIGHT	$ 20 MIL/YR.
INCREASE OF FUEL CONSUMPTION (+ 1%)	$ 150 MIL/YR.
EXTRA FLIGHT TIME IN OPERATION	$ 200 MIL/YR.

- NOISE CHARGES — CURFEWS — LAWSUITS = NO ESTIMATION AVAILABLE

III — TOTAL AIRLINE EXPENDITURE 1 TO 3% OF REVENUE

CONCLUSIONS — PROGRESS IN A/C NOISE REDUCTION

- MANUFACTURES AND AIRLINES HAVE ALREADY MADE AND CONTINUE TO ACHIEVE CONSIDERABLE EFFORTS
  - — MANUFACTURERS: — IMPORTANT R & D PROGRAMMES
    - — PRODUCTION OF IMPROVED TECHNOLOGY AIRCRAFT AND ENGINES
- — AIRLINES: — IMPORTANT INVESTMENTS — PURCHASING OF NEW QUIETER AIRCRAFT
  - — EARLY RETIREMENT OF OLDER AIRCRAFT
  - — APPLICATION OF NOISE ABATEMENT PROCEDURES
  - — NUMEROUS COSTLY CONSTRAINTS & PENALTIES (NOISE CHARGES — CURFEWS — LAWSUITS)
- SUBSTANTIAL IMPROVEMENTS IN AIRPORT ENVIRONMENT
- IT IS TIME TO CONSIDER THE CONSEQUENCES OF ALL CONSTRAINTS
  TOTAL AIRLINE EXPENDITURE = 1 TO 3% OF REVENUE

AIRLINES NEED ALL THE MONEY THAT CAN BE SAVED TO BUY NEW STILL QUIETER AIRCRAFT