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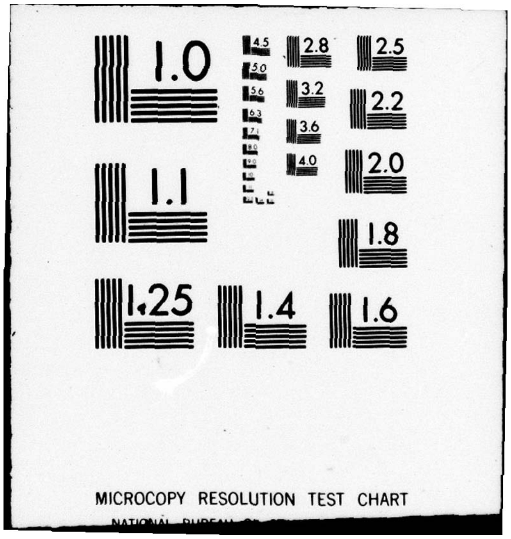

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Report No. FAA-RD 79-17

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GROUND RUN-UP NOISE CONTROL FACILITIES FOR CIVIL AIRCRAFT - A SURVEY,

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Dr. David/Braslau

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16. Abstract

This survey of existing ground run-up suppressors and barriers for civil aircraft includes a review of acoustical, aerodynamical, and mechanical effects associated with facilities in the United States, Europe, and Japan. Evaluations were made of each suppressor based upon published and unpublished reports, and supplemented where necessary by direct questionnaires to the operators, designers, and users of the facilities.

Acoustical data where available have been compiled for near and far field points at all directions from aircraft heading. Aerodynamic and mechanical effects on airframe and engine performance during run-up have been identified in terms of exhaust gas reingestion, engine or airframe damage, or restrictions on facility operation. The potential for standards development is discussed with respect to available information with recommendations for additional studies needed before such standards could be promulgated.

Summary tables are included in the text for ease in comparison of data type and availability. Data sheets for each facility are included in an appendix.

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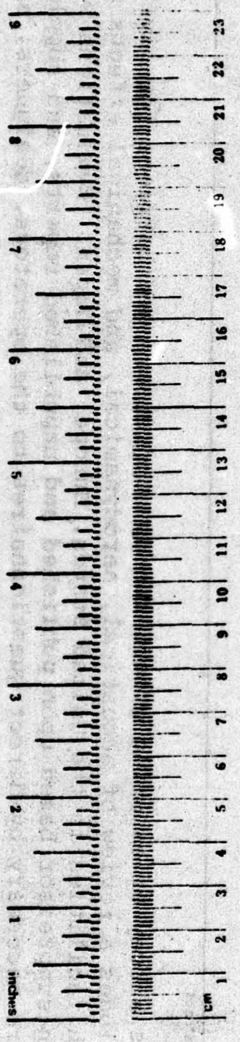
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

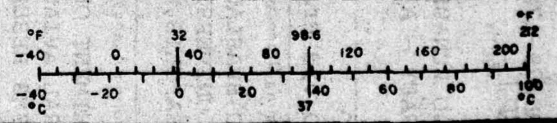
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13[illegible]



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



GROUND RUN-UP NOISE CONTROL FACILITIES
FOR CIVIL AIRCRAFT

A SURVEY

January 30, 1979

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1.0 INTRODUCTION AND SUMMARY

1.1 PURPOSE

In 1976 the Airport and Airway Development Act was amended to include under the term "airport development" the "purchase of noise suppressing equipment, the construction of physical barriers, and landscaping for the purpose of diminishing the effect of aircraft noise on any area adjacent to a public airport".

Preliminary to the possible establishment of specifications or standards for noise control facilities to contain ground level noise from aircraft, primarily that due to ground run-ups for maintenance purposes, this review of available noise suppressor and control facilities has been completed. The purpose of the review is to identify those facilities which are presently in use and which could be used at airports in the United States for those aircraft and engine types presently used and anticipated at those airports.

The identification of effectiveness of these facilities along with potential adverse effects on engines and airframes is necessary before any facility of this type can be incorporated into airport planning or operation. The level of detail required for such a projection is naturally related to the magnitude of the problem, although the objective of this summary is to compile all available acoustical data and reports of potential mechanical impacts, to determine whether the present data are sufficient upon which to base design standards and specifications.

1.2 SCOPE AND METHODOLOGY

This survey has been limited to available published and unpublished documentation. In addition to the excellent previous survey of the Dunn reports (Reference 1) and supporting materials collected by the Federal Aviation Administration (SRDS), other materials contained in the files of the Minneapolis-St. Paul Metropolitan Airports Commission and David Braslau Associates, Incorporated (Reference 2) have been incorporated into the study.

In addition to this already available information, questionnaires were developed and submitted to selected airports where known effective noise suppression facilities are in operation. These questionnaires were directed primarily to an expansion of the data base on acoustical performance and potential adverse effects on engine and airframe from facility use.

1.3 BASIC TERMINOLOGY USED IN THIS REPORT

Several terms or expressions are used throughout this report and are assumed to have the following interpretation:

Ground Run-Up (run-up, ground maintenance run-up). This term refers to that engine maintenance procedure during which an engine or engines are run on the ground at a maintenance facility, with the aircraft in a static position. These procedures are generally used for fuel flow adjustment and throttle setting or throttle stop checks. The term does not refer to the run-up of piston engines prior to takeoff, nor to the revving of turbine engines prior to brake release on takeoff.

Part Power (trim power). This power setting is generally prescribed by the engine manufacturer as that setting for which fuel flow adjustments are to be made. The setting is normally well below maximum power but sufficiently above idle power as to create potential noise impacts around the facility.

Noise Suppressor. This term refers in this report to a facility which has been specifically designed and constructed to reduce noise levels associated with ground run-ups, through treatment of the jet exhaust. The term is not intended to include hush-houses, barriers, or run-up pens (see below).

Hush-House. This is an enclosed or partially enclosed structure which surrounds the entire aircraft. It is clear that such facilities may be suited for smaller aircraft, although it is feasible that larger structures could be built for the larger wide-body aircraft presently in use.

Noise Barrier. This is a wall or screen standing alone (or with others, see run-up pen) which serves to interrupt noise propagation between the engine and potential receivers of noise from the engine. These barriers may take on various shapes and may or may not be treated with acoustical materials.

Run-Up Pen. This is a combination of noise barriers that is designed to obstruct noise propagation in more than one direction. It is usually open on one side to accommodate the placement of aircraft.

Aircraft Heading. This is the direction of the nose of the aircraft and is considered to have a 0° heading or direction (as north on a compass). Noise levels are then specified at various distances from the center of the aircraft (or engine) with a direction measured in degrees clockwise from aircraft heading. Thus, the highest noise levels associated with jet engines generally fall along the 135° and 225° directions (i.e., 45° to either side of the exhaust direction from an engine).

Sound Level. Sound level is given in decibels. The A-weighted level has become more acceptable for use in evaluation of community noise impacts, and is a measure which weights individual frequencies to approximate response of the human ear. This level is abbreviated as dBA. The level for a single frequency is abbreviated as dB. Octave band sound pressure levels are specified from 31.5 to 8000 Hz, with each frequency band center double that of the lower one.

1.4 SUMMARY OF FINDINGS

The type of acoustical data for suppressors and barriers varies widely, and makes a simple comparison of facilities difficult. A summary of data available is presented in Section 5, Table 5-2.

Noise suppressors can reduce levels by 27 dBA at 100 meters but only by about 10 dBA at a distance of 1 mile. For available data on noise reduction effectiveness, see the data summary sheets contained in Section 7.5.

Noise barriers and run-up pens can reduce levels by 10 dBA at 1 km from the engine. Detailed data are also presented in the data summary sheets in Section 7.5.

Hush-houses, while effective for noise reduction, are expensive. It is estimated that a hush-house similar to that at the Hamburg Airport, which cannot accommodate wide-body aircraft, would cost approximately $8 million in 1978. See Section 5, Table 5-11 for cost comparisons.

Barriers and run-up pens rely more heavily on ideal meteorological conditions than do suppressors, which operate directly on jet exhaust. See, for example, the discussion of the run-up pen at Osaka in Section 6.3.

Some problems with airframe vibration and/or exhaust gas reingestion have been encountered with noise suppression facilities which enclose a major part of the aircraft. See, for example, discussions of the Tegel pyramid and the Hamburg hush-house, in Section 5.3.

Reports of potential problems with airframe or engine performance appear to be fewer with facilities which are owned, operated, and used by an airline, than for those owned and operated by an airport and used by other airlines.

Cost data vary widely, as can be seen from Table 5-11 in Section 5, and only approximate estimates for present day construction costs in the United States may be made.

In conclusion, it is clear that further study would be required before detailed uniform standards and specifications for noise suppression equipment could be developed.

2.0 RECOMMENDATIONS

2.1 GROUND RUN-UP REQUIREMENTS

While a survey of available noise control equipment for ground run-up operations can provide a basis for evaluation of potential noise control, a more comprehensive and precise definition of the potential problem posed by ground run-ups would be the next step towards problem solution.

A number of studies have been performed by the U.S. Environmental Protection Agency under provisions of the Noise Control Act of 1972 to define primary noise problems in the nation. The U.S. DOT, in its 23 Airport Study (Reference 3), has also tried to define major airport noise problems by examining present and future operations and aircraft types, and estimating what future noise impacts might be.

An analogous procedure could be easily designed for ground run-up noise exposure:

Step 1: Identify U.S. aircraft fleet and engine mix through the study period.

Step 2: Identify specific, typical, and average maintenance requirements for the engines used in the fleet through the study period.

Step 3: Identify primary maintenance areas for scheduled, and nonscheduled carriers and general aviation turbine operations.

Step 4: Correlate maintenance requirements and schedules from Step 2 with the maintenance locations in Step 3.

Step 5: Develop generalized noise contours in dBA with associated times and durations for the major maintenance locations identified in Step 3.

Step 6: Compare projected noise contours with appropriate noise standards and criteria (see discussion below).

Step 7: Develop description of probable noise impact and area or population impacted.

Step 8: Determine level of noise reduction required to reduce impact to an acceptable level (as defined in Step 6).

Step 9: Review potential noise control devices and barriers to determine which may be applicable to particular problem areas, or appropriate run-up management techniques.

Step 10: Develop revised noise contours, based upon reductions anticipated by use of ground control equipment, for the problem locations.

Step 11: Compare new noise contours with standards and criteria to determine residual impact.

Step 12: Evaluate potential social and economic impacts of residual noise impacts.

Step 13: Determine costs associated with noise control facilities used in Step 10.

Step 14: Develop benefit-cost ratios as a whole and for individual airports where potential ground run-up problems occur or may occur.

Step 15: Make recommendations to the Federal Aviation Administration as to the cost-effectiveness and the feasibility of a standardized or nationwide program for ground run-up noise abatement.

Such a study would identify whether or not there is a large-scale problem, and what the most cost-effective means would be to solve that problem.

It should be noted that, with changing fleet composition, re-engined fleets, and the development of new engines, maintenance requirements are continually changing. Moreover, because of costs and fuel consumption, many operators are seeking ways to reduce or eliminate ground run-ups, either through revised maintenance procedures or in-flight monitoring.

The feasibility of ground run-up facilities must be based on ownership and user requirements, which may vary from airport to airport. This also depends on available locations and clearances for such a facility. The study at Minneapolis-St. Paul International (Reference 2) indicated that the run-up problem could be solved without capital investment in suppressors or barriers simply by limiting, with regulations, the time, place, and weather conditions at, during, and under which ground running would be permissible.

A more difficult problem that must be solved before noise control requirements can be imposed more widely is that of appropriate standards or criteria. The run-up study in Minnesota was simplified because of explicit noise standards (L_{10} and L_{50}) which could be clearly compared with predicted levels and durations. In states where different standards are used, the development of impact from ground run-up may not be as simple. The FAA Integrated Noise Model uses a descriptor of "time above", which could be directly applied to run-up levels. However, it has been left for each community to determine what time above level should be acceptable. The U.S. Environmental Protection Agency and the Housing and Urban Development Department presently use a descriptor L (day/night) which is a 24-hour energy-summed noise level. With this descriptor, the contribution from ground run-ups may be inconsequential when compared with in-flight noise. It would appear therefore, as part of the overall study on potential impact of ground operations, that a special effort be devoted to the identification of appropriate noise standards and criteria, and that this effort be carried out in conjunction with other federal and state agencies.

2.2 NOISE SUPPRESSORS

Specific needs and potential use of noise suppressors can be established by the type of study recommended above. The ability to predict noise contours from suppressor data will require, however, that sufficient information is available or that noise reduction capabilities of suppressors are standardized. As discussed in Section 6, no standard method of data presentation for noise suppressors exists at the present time. Therefore, it would be necessary to develop a more precise methodology for use in noise control prediction. The following studies are recommended:

Study 1: Evaluate potential for standard noise reduction data or "certification" of ground run-up suppressors.

As noted above, this would require the identification of specific locations with respect to the aircraft, under certain combinations of engine power settings and given meteorological conditions. For "certification" it would be sufficient to provide data in dBA only, while for use in prediction of community noise levels, octave band data would be necessary. This study would determine if such an approach is realistic and if participation from the major noise suppressor manufacturers could be achieved.

Study 2: Evaluate potential for airport ownership of noise suppressor facilities.

The feasibility of noise suppressors would be considered under Step 15 of the overall study program. A major problem which must be confronted is that most suppressors are owned and operated by the users themselves. For suppressors not owned by users, there are conflicting reports of effectiveness and damage to engines and airframes. The financial, regulatory, and scheduling problems associated with a multi-user facility, owned and operated by an airport, must be examined in more detail before being recommended as an effective solution to the ground run-up noise problem.

2.3 NOISE BARRIERS

Although barriers are somewhat easier to design than suppressors, proper design requires technical competence in the subjects of acoustics, aerodynamics, and mechanics, as well as a knowledge of jet engine and airframe design and performance. As pointed out in this survey, a number of problems can occur even with single walls, if the aircraft is too close or winds unfavorable. Where run-up pens are used, the potential for exhaust gas reingestion is high, unless proper design precautions are taken. It would appear that to preclude potential problems, either previous designs should be used, or appropriate wind tunnel or other tests carried out to ensure against such problems. The following studies are recommended:

Study 1: Evaluate potential for standard noise reduction data or "certification" of noise barriers.

This is not as critical for noise barriers as for suppressors, since barriers may take on different geometries and layouts to solve particular problems. Where run-up pens or parallel walls are considered, however, a standard could be established. As part of such a study, the modifications in performance due to adverse meteorological conditions should be evaluated, so that the limitations on performance with given meteorology can be included in the information provided to a potential user of the facility. As with suppressors, specified noise data should be available for barriers. Source characteristics must be precisely defined, so that theoretical computations and even model tests can be made. In most models, a point source generator is commonly used, but this may not be satisfactory if the actual noise source is a complex volume source close to the barrier.

Study 2: Develop Handbook for Airport Noise Barrier Design

A barrier design handbook for aircraft similar to one prepared for the Federal Highway Administration for highways (Reference 4) could be developed. The handbook was founded on a wide body of information on highway noise and experience with barriers. Since that type of information is not as available for aircraft ground run-up, additional studies or data collection may have to be completed before such a handbook could be developed. In addition, the problem of back pressures and exhaust gas reingestion, not present with highway barriers, must be considered. Should a program for the support and construction of airport noise barriers be initiated, such a handbook should be developed, at least to protect aircraft against potential hazards.

3.0 PREVIOUS STUDIES AND DATA COLLECTION

3.1 DUNN REPORTS AND SUPPORTING DOCUMENTATION

An extensive worldwide survey of existing ground run-up noise suppression equipment and facilities was carried out in 1974 and 1975 by M.D. Dunn, Principal Engineer, Environment and Security Branch of the Australian Department of Transport (Reference 1). A comprehensive list of 16 questions addressing all aspects of the noise control facilities was used during visits to airports where such facilities were in use. This list is contained for purposes of reference in Section 7.2.

For the data collection process, ground run-up devices were divided into 5 basic categories:

1) Walls/Banks/Pens
2) Tubular Suppressors
3) Fixed Tubes with Deflectors and Side Walls
4) Hush Hangars
5) Inlet Devices (i.e., screens)

Information on costs and who is responsible for installation of the facility was reviewed, indicating that in some cases the facility is built by the airport and used by all carriers, built by the major carrier and used by all, or built by a carrier and used only by their own aircraft.

Because of the large amount of information contained in the Dunn reports, that material will not be reiterated here. That study served to identify facilities which appear applicable to aircraft used in the United States, and provided a basis for developing a modified questionnaire dealing more directly with acoustical performance and adverse effects on airframe or engines.

Data contained in the Dunn reports are not sufficiently detailed, quantitative, or standardized to serve as a basis for establishment of standards or specifications for such facilities. Types of information sought in the present study which were not contained in the Dunn reports include sound pressure level data at specified locations (distance and direction from the aircraft or engine) in A-weighted decibels as well as octave band values, documented reports of adverse effects on engines or airframes due to use of suppressors, and current cost estimates for construction of such facilities in the United States.

A summary of the noise control facilities described in the Dunn reports is presented in Table 3-1.

3.2 MINNEAPOLIS-ST. PAUL INTERNATIONAL GROUND RUN-UP STUDY

Because of legislative requirements, a detailed study on noise control requirements for ground run-up was carried out by David Braslau Associates, Incorporated for the Metropolitan Airports Commission (Reference 2). That study contained an overview of noise suppressors and noise wall proposals which could be used for the aircraft at that airport.

TABLE 3-1

SUMMARY OF NOISE SUPPRESSORS AND WALLS DESCRIBED BY M. DUNN
DATA FROM EUROPEAN AND JAPAN TRIP
MAY 1974

Type	Location	Aircraft Type	Acoustical Data	Other Remarks
Cullum Muffler	Amsterdam	DC8	Measured	Rarely Used
Concrete Walls	Amsterdam	All	Measured	
Wall	Frankfurt	All	n.a.	Run-Up Bay
Wall	Frankfurt	All	Theoretical	2 km from Airport
Hush Hangar	Hamburg	707,727,737	Measured	
Pyramid	Berlin	All	Theoretical	
Wall	Dusseldorf	All	Measured	
Cullum Muffler (mobile)	Zurich	Caravelle	n.a.	
Schneider Muffler (fixed)	Zurich	DC9,SE210, BAC111,F28	Measured	
Gerber Tubes (adjust.)	Zurich	707,DC8,CV990	Measured	
Gerber Tubes	Zurich	747	Measured	
Gerber Tubes	Zurich	DC10	Measured	
Boet Mufflers	Orly	727	Measured	
Boet Mufflers	Orly	707	Measured	
Bertin Tubes	Orly	Caravelle	n.a.	
Boet Tubes & Walls	de Gaulle	DC10/A300	Theoretical	Firm Order Only (1974)
Wall	de Gaulle	All	n.a.	
Cullum Mufflers	Heathrow	Trident,BAC111	n.a.	
Walls (parallel)	Heathrow	L1011	n.a.	
Cullum Mufflers	Heathrow	B747	n.a.	
Cullum Mufflers	Heathrow	B707	n.a.	
IAC Suppressor (port.)		B707	n.a.	
IAC Suppressor (adjust.)		B707	Theoretical	
IAC Hush-House		HS125	Measured	
IAC Suppressor	Bristol	Concorde	n.a.	
IHI Suppressor	Narita	B747/B707	n.a.	
Wall	Osaka	B727	n.a.	

DATA FROM U.S.A. TRIP
FEBRUARY 1975

Koppers Suppressor		B707/CV880	Estimated	No Longer Used
Koppers Suppressor		RF/F4	Measured	Military Only
Koppers Suppressor	Heathrow/ Sao Paulo	L1011/B707	Theoretical	Proposed Only
IAC Suppressors			n.a.	Military Only (Pan Am Used Screens)
Getter Hush-House	Miramar	F4,F8,F14,F15	n.a.	Military Only
Boeing Coanda Suppressor	Wichita	Military,JT8D Engines	n.a.	Under Development
Walls (parallel)	Minneapolis	All	Theoretical	Proposed Only
Noise Barrier	Los Angeles	All	Measured	Unsuccessful

Detailed modeling was based upon acoustical data obtained from major operators at the airport to determine if a field operating rule could be used in lieu of a noise control facility. Options developed for controlling run-up noise at the airport included strict controls on aircraft heading, bans on run-ups during certain wind conditions except for emergencies, and the erection of one, two, or three walls in different configurations. Because of the proximity of most available apron areas to the runway/taxiway system on the airport, the erection of fixed structures in these areas is restricted. A run-up location was selected on the field at a location that was acceptable to all major operators, even though the site had been constructed by a specific air carrier for its own maintenance operations. The use, scheduling, and cost allocation of noise suppression facilities were major concerns of the airport operator as well as potential users of such a facility. Use of a suppressor owned and operated by an airport rather than an operator raised a number of difficult questions.

Noise monitoring concepts, data collection, and modeling from this study have served as a basis for the development of acoustical data requirements recommended in the present study.

3.3 OTHER DATA

In addition to literature describing specific noise suppressors and barriers, collected in the Dunn (Reference 1) and Braslau (Reference 2) reports, major manufacturers have prepared documentation on the construction and performance of various devices.

Cullum Detuners Ltd. has prepared a "History of Mufflers" developed by the company (Reference 5). This report discusses the various design concepts for controlling ground run-up noise of aircraft and describes successful suppressors designed by the company. Details on construction of hush-houses, acoustic splitters, and exhaust detuners are provided. Specific data are given for facility design and operation for the General Dynamics F-16 aircraft, and photographs of Cullum run-up installations from 1954 through 1978 are presented. A brief history of the company is also included.

Industrial Acoustics Company has issued a series of documents dealing with ground run-up equipment (References 6, 7, and 8). In addition to the basic technology of ground run-up suppressors, an introduction to jet noise and the reasons for ground run-ups is presented. Descriptions are provided for fixed or demountable test cells, portable ground run-up suppressors, air-cooled suppressors, intake noise silencers, and exhaust suppressor gap noise silencing. The recent suppressor system for the Concorde is also described (see Reference 9). For the Multi-jet Suppressor, effectiveness for a typical jet engine is presented for a distance of 1000 m and 360°, with some octave band data on suppressor performance.

The firm of Oskar Gerber has prepared a brochure showing several types of suppressors designed by that company, with accompanying reduction data (in dBA in all directions) for the Starfighter and the JT9D engine using different suppressors. A description of fixed tubular suppressors and associated noise screens is contained in the brochure, which emphasizes the importance of using such screens in conjunction with normal exhaust mufflers.

Ishikawajima Harima Heavy Industries has constructed, under license from Oskar Gerber, a major suppressor at Narita. In addition, the company has prepared a colorful brochure showing the effectiveness of suppressors for military and civil aircraft (Reference 10). While contours for the B747 are only computed, actual data have been collected since the facility has been in operation, and are discussed further in Section 5. The company has also prepared sketches and specifications for a number of other suppressors.

S.A. André Boët has prepared technical specifications for a number of suppressors. These are discussed separately in Section 5 (see References 11-14).

While a large number of suppliers and manufacturers of sound control and suppression equipment are contained in the Dunn reports (see Reference 1, Phase 1, Appendix 4, pp 7-8), the informational brochures discussed above serve as an example of the type of information which is available from manufacturers of equipment. The discussion of available information presented here is not intended to be complete, but only indicates the type of information available for those desiring more specific information in certain areas.

4.0 DATA COLLECTION FOR THIS STUDY

4.1 DEVELOPMENT OF DATA REQUIREMENTS

Based upon the primary purpose and scope of this study, data needs for both acoustical performance and potential adverse mechanical effects have been identified.

4.1.1 Acoustical Data Requirements

Potential effectiveness of noise suppression facilities may be estimated using theoretical methods, based upon a reliable and sufficient data base. The prediction of noise levels in the far field (where land uses may be adversely impacted by ground run-up noise) requires at least information on sound pressure levels and an associated frequency analysis (octave band data are sufficient for most purposes) at a specific distance from the engine and suppression facility at points in at least eight directions from the aircraft. While data in most other suppressor studies have described noise behind the aircraft (because noise levels there are the highest), the study for Minneapolis-St. Paul (Reference 2) showed that noise levels in front of the aircraft can be of a more objectionable intensity than noise levels behind the aircraft under some conditions. Suppression facilities equipped with intake noise control features can provide substantial attenuation of frontal noise and should be considered for use where such attenuation is needed.

To develop more useful descriptions of the effectiveness of noise suppressors, performance data of the following kinds were solicited from their owners, designers, and users:

- The make and model number of the aircraft and engine generating the noise.
- The power settings of the engine when noise measurements were being made.
- Meteorological conditions prevailing during the noise measurements.
- Location of the measurement device (microphone) with respect to both ground and noise generator.
- Other pertinent information.

4.1.2 Information on Potential Adverse Mechanical Effects

Because of the sensitivity of some engines to compressor stall and others to back pressure, it is essential that suppressors and barrier devices be designed so as to minimize or eliminate such potential impacts. Because reflected sound can cause fatiguing or destructive vibrations in airframes, hush hangars, and other facilities (e.g., noise pens or barriers) because they redirect sound waves, they must be carefully designed, carefully sited, and carefully used. There have been reports (see Section 5.3) of such damage to engines, i.e., engines destroyed or damaged, and some damage to airframes because of inadequate consideration to such effects in noise control design. In most cases, wind tunnel studies have been performed prior to construction and operation of the facilities. In other cases, the problems have been identified only after the suppressor is in operation. In some cases, the problem has been solved, while in others, no satisfactory solution was found.

For these reasons, the following data have been requested:

- What damage to engines or airframes has occurred with facility operation?
- What problems with restricted air flow, exhaust gas reingestion, or back pressure have occurred?
- What problems with acoustical loading of airframes or components have been reported?
- What agreements or warranty changes have been obtained from manufacturers whose engines are tested in such facilities?

4.1.3 Other Data

Construction and operating cost data were requested so as to develop estimates of approximate cost, should these facilities be constructed at airports in the United States.

Information as to the owner and user of the facilities is important, as it provides a basis for the evaluation of user response. Space requirements depend upon the type of facility being considered. Setup requirements, except for mobile suppressors and large walled-in areas, are generally similar, although any special considerations or equipment would be of interest to potential users of such facilities.

For these reasons, data were also requested concerning:

- Owner/operator of the facility.
- Space requirements.
- Construction and maintenance costs.
- Setup requirements.
- Safety requirements.

4.2 DEVELOPMENT OF QUESTIONNAIRES

Because noise control facility performance data and information on side effects provided by Dunn and others were insufficient for FAA purposes, this study was commissioned and additional data sought. Having a very small budget for this study, data collection methods were limited essentially to obtaining the information through the mails. Questionnaires were developed for obtaining the kinds of information described in Section 4.1 above. Questionnaires were made as simple and as brief as possible to obtain only that information needed for evaluating the suitability of existing facilities for possible employment in the United States. An example of the questionnaire used in this study is contained in Section 7.3.

4.3 DATA COLLECTION PROCESS

Step 1:	Specific suppressors or facilities in selected cities and airports were identified, using previous studies and discussions with appropriate airport and airline representatives.
Step 2:	Questionnaires were prepared for each of the suppressors or suppressor groups, addressed to the owner/operator, the designer, and the user of each facility.
Step 3:	The questionnaires were sent to those FAA offices which maintained liaison with the cities in question, with a request for questionnaire distribution in such a manner as to ensure a timely response.
Step 4:	For those airports with significant noise suppression facilities, a follow-up memo was requested through the appropriate FAA office.
Step 5:	Questionnaires were received and translated as necessary.
Step 6:	Additional data were collected during a brief visit to Zurich.
Step 7:	Questionnaires were evaluated and compared with previously existing information.

4.4 EVALUATION OF RESPONSES

Table 4-1 presents a tabulation of responses received.

4.4.1 Berlin

In Berlin, use of the noise control facility is required for all run-ups. Responses from 5 companies indicated use of the facility and provided some insight into potential problems which might arise from a facility owned and operated by someone other than the user.

A noise measurement report by the Technical University of Berlin and supporting documentation from Dipl. Ing. Thomas Meyer contained sufficient data to develop a noise reduction contour for the facility at a distance of 100 meters.

4.4.2 Osaka

A very detailed and complete reply to our questionnaire was submitted by All Nippon Airways concerning construction and use of a 3-walled run-up pen in Osaka. In addition, a noise measurement report as to the effectiveness of the facility was included, indicating that the structure performed as well or better than predicted by computation.

4.4.3 Tokyo

Questionnaire responses were provided by the designer (IHI) and operator and user (Japan Airlines) for the facility at Narita. Since the facility has not been in use that long, only preliminary noise measurement information was submitted.

TABLE 4-1

RESPONSE TO QUESTIONNAIRES AND UPDATED INFORMATION RECEIVED

Berlin	
Berlin Airport	Questionnaire Response
Technical University of Berlin	Noise Measurement Report No. 6574
Pan American	Questionnaire Response
Air France	Questionnaire Response
British Airways	Questionnaire Response
Dan-Air Engineering Ltd.	Questionnaire Response
Aeroamerica	Questionnaire Response
Thomas J. Meyer	Questionnaire Response
Osaka	
All Nippon Airways	Questionnaire Response
All Nippon Airways	Noise Measurement Report
Tokyo	
Japan Airlines	Questionnaire Response
Ishikawajima Harima Heavy Industries	Questionnaire Response
London	
Cullum Detuners Ltd.	"History of Mufflers" - Cullum Detuners Ltd.
Paris	
Aeroport de Paris	Letter of Data Transmittal "Noise Mufflers for Jet Engine Run-Ups" Note on Ground Run-Up Silencers Field Rule for Ground Run-Ups Off Airport Noise Measurements for Ground Run-Ups
Düsseldorf	
Düsseldorf Airport	Letter Indicating Use of Wall not Mandatory
LTU Lufttransport-Unternehmen	Questionnaire Response
Frankfurt	
Frankfurt Airport	Letter of Transmittal Press Release on Freight Area Noise Barrier
Hamburg	
Hamburg Airport	Questionnaire Response with the following attachments: Noise Measurement Report on Hush-House (T.J. Meyer - 1969) Letter from T.J. Meyer on Improvement of Hush-House Noise Measurement Report on Hush-House (G.C. Dettmann - 1969)
Lufthansa	Questionnaire Response Article entitled, "The Noise Proof Hall"

4.4.4 London

A general informational document on Cullum mufflers was received.

4.4.5 Paris

A summary of noise control devices at Charles de Gaulle and Orly was submitted by Aeroport de Paris, along with an extensive record of off airport noise measurements associated with ground run-ups at Charles de Gaulle. A detailed field rule governing ground run-ups was also submitted.

4.4.6 Düsseldorf

A brief letter from Düsseldorf Airport indicated that use of the barrier was not mandatory and that no specific noise measures were available. A questionnaire response from one user (LTU) indicated some early problems with run-ups near the facility.

4.4.7 Frankfurt

A letter of transmittal and press release describing the noise wall separating the freight facility from Kelsterbach was received.

4.4.8 Hamburg

A questionnaire response by Hamburg Airport with detailed transmittals of information on the acoustic effectiveness of the hush-house provided an excellent summary of its effectiveness. It was indicated that less expensive means are now available for the control of noise from ground run-ups.

5.0 INFORMATION SUMMARIES FOR NOISE SUPPRESSORS AND BARRIERS

5.1 NOISE CONTROL DEVICES CONSIDERED

The noise control facilities evaluated in this report are listed in Table 5-1. It was felt that these noise control facilities would be representative of the state-of-the-art.

The list here represents a range of control facilities from a single noise barrier (for example, Frankfurt) to a completely enclosed structure (Hamburg). The type of device most cost-effective in any particular situation depends upon weather factors, the noise attenuation required, and the distances and topography between the source and receiver. It will be seen that, for properly oriented run-up pens, the attenuation at distances over 500 meters can be almost as great as that from a suppression device. It should be emphasized, however, that meteorological conditions have a significant and greater impact on the effectiveness of barriers than on suppression devices.

It should also be emphasized that with the introduction of new engines to power either the existing or new generations of aircraft, some of the results of this study may not be applicable. This will be discussed further in Section 6.0.

5.2 ACOUSTIC DATA AVAILABLE

The wide variety of parameters which affect acoustical performance as well as available measurements precludes a simplified summary of acoustical data. However, a presentation of data which are available for evaluation is contained in Table 5-2.

The following information is contained in this table:

ID No.:	Each facility is given an identification number for reference purposes.
Noise Control Facility:	The general type of facility is identified here.
Distance (near field or far field):	The distance at which the noise measurement has been made, if less than 500 feet.
Direction(s):	The direction or directions from the nose of the aircraft at which measurements have been made.
Level:	The type of sound level measurement made, i.e., dBA or other weightings ("model" under L1-4 indicates that the measurements were made from a model only).
Frequency Data:	The type of frequency data available (necessary for modeling purposes).

TABLE 5-1
NOISE SUPPRESSION DEVICES/BARRIERS REVIEWED

ID No.	City	Airport	Type of Device	Aircraft/ Engines	Remarks
A1-1	Amsterdam	Schipol	Cullum Suppressor	DC8	Rarely Used
A1-2	Amsterdam	Schipol	Concrete Wall	All	
B1-1	Berlin	Tegel	Noise "Pyramid"	All	
B2-1	Bristol	Filton	IAC Suppressor	Concorde	
D1-1	Düsseldorf		Noise Wall	All	Not Mandatory
F1-1	Frankfurt		Noise Wall	All	Freight Area
H1-1	Hamburg		Hush-House	JT3,JT8,CF6	
L1-1	London	Heathrow	Cullum Suppressor	Trident/ BAC111	
L1-2	London	Heathrow	Cullum Suppressor	B747	
L1-3	London	Heathrow	Cullum Suppressor	B707	
L1-4	London	Heathrow	Run-Up Pen	L1011	
L1-5	London	Gatwick	IAC Suppressor	B707	
L2-1	Los Angeles	International	Run-Up Pen	All	No Longer Used
O1-1	Osaka		Run-Up Pen	YS11,B737, B727,L1011	
P1-1	Paris	de Gaulle	Boet Suppressor	B747	
P1-2	Paris	de Gaulle	Boet Suppressor	A300/DC10/ Concorde	
P1-3	Paris	de Gaulle/Orly	Boet Suppressor	B707/DC8	
P1-4	Paris	de Gaulle/Orly	Boet Suppressor	B727	
P1-5	Paris	de Gaulle/Orly	Bertin Suppressor	Caravelle	
T1-1	Tokyo	Narita	IHI Suppressor	B747/DC8/ DC10	
Z1-1	Zurich	Kloten	Schneider Suppressor	DC9	
Z1-2	Zurich	Kloten	Gerber Suppressor	DC8/B707/ CV990	
Z1-3	Zurich	Kloten	Gerber Suppressor	B747	
Z1-4	Zurich	Kloten	Gerber Suppressor	DC10/GE CF6-50A	
Z1-5	Zurich	Kloten	Cullum Suppressor	DC9	Rarely Used

TABLE 5-2

SUMMARY OF ACOUSTIC DATA

Id No.	Noise Control Facility	Near Field (500' or less) Dis-tance	Direction(s)	Level	Freq. Data	Far Field (greater than 500') Dis-tance	Direction(s)	Level	Freq. Data
A1-1	Mufflers	--	--	--	--	2000 m	n.a.	dBA	--
A1-2	Wall	--	--	--	--	n.a.	n.a.	dBA	--
B1-1	Partial Hush-House	100 m	73°-164°	dBA	--	300 m	150°	dBA	--
B2-1	Mufflers	n.a.	n.a.	dBA	--	--	--	--	--
D1-1	Wall	--	--	--	--	--	--	--	--
F1-1	Wall	50 m	n.a.	dBA	--	500 m	n.a.	dBA	--
H1-1	Hush-House	125 m	30° Intervals	dBA,dBB, dBL	--	750 m - 1000 m	30° Intervals	dBA,dBB dBL	--
L1-1	Mufflers	300'	15°/30° Intervals	dBL,PNdB	Octave	--	--	--	--
L1-2	Mufflers	--	--	--	--	--	--	--	--
L1-3	Mufflers	300'	15°/30° Intervals	dBL, Phons	Octave	--	--	--	--
L1-4	Wall	280'	45°-100°	dBA (model)	--	1200 m	n.a.	dBA (model)	--
L1-5	Mufflers	300'	30° Intervals	dBL, PNdB	Octave	1100'/ 3200'	185°/260°	dBL, PNdB	Octave
L2-1	Wall	200'	30° Intervals	PNdB	--	2960'- 5300'	Four	PNdB	Octave
M1-1	Wall	--	--	--	--	--	--	--	--
O1-1	Wall	100 m	45° Intervals	dBA	Octave	470 m- 890 m	Four	dBA	Octave
P1-1	Mufflers	100 m	135°	dBA	--	--	--	--	--
P1-2	Mufflers	100 m	135°	dBA	--	--	--	--	--
P1-3	Mufflers	100 m	135°	dBA	--	--	--	--	--
P1-4	Mufflers	100 m	135°	dBA	--	--	--	--	--
P1-5	Mufflers	100 m	135°	dBA	--	--	--	--	--
T1-1	Mufflers	--	--	--	--	700 m	104° (nose)	dBA	Octave
Z1-1	Mufflers	200'	150°	dBA	Octave	2400 m	150°	dBA	Octave
Z1-2	Mufflers	--	--	--	--	--	--	--	--
Z1-3	Mufflers	100 m	360°	dBA	--	--	--	--	--
Z1-4	Mufflers	150 m	135°	dBA	--	600 m- 2400 m	135°	dBA	--
Z1-5	Mufflers	--	--	--	--	--	--	--	--

From the table, it can be seen that:

- The distance for near field measurements is variable, because of limitations of existing structures or terrain and the dimensions of the noise suppression facility in question.
- The distances at which far field measurements were made were not the same since they were chosen to describe the effectiveness of different noise control facilities for alleviating different problems at different airports.
- Sufficient data for noise contour development are only available for a small number of the suppressors.
- Most data are available in dBA.
- Octave band data, that would be necessary for modeling purposes, are available for only five of the facilities.

A summary of acoustical data for facilities where at least one distance, direction, and level are available, is presented here.

- B1-1 Partial Hush-House (Berlin/Tegel) (Reference 15)

Measurements of sound pressure levels were made on March 3, 1975 by the Technical University of Berlin. While run-ups were tested for the B720 and BAC111, data for the BAC111 provided the best basis for facility effectiveness. A total of nine tests were carried out, with spectral data collected at seven points and A-weighted levels measured at an 8th. The seven points were located 100 meters from the engine being run, and ranged from in front of the aircraft to 164°. The tests lasted 90 seconds with levels used registering at least 10 seconds.

The effect of placing the aircraft in the center and left and right of center in the facility was determined. A contour of noise levels for the BAC111 is presented in Section 7.5.1. A dicussion of the acoustical test and performance of the facility is contained in a response from Dipl. Ing. Thomas Meyer (see Section 7.4.1).

- H1-1 Hush-House (Hamburg) (References 16, 17, and 18)

A detailed report on run-ups of a B727 with a tail-in position inside the hush-house indicates that a 20 dBA reduction at 1000 m can be anticipated. The tail-in use of the hush-house for aircraft with tail engines (such as the B727) and other larger aircraft which were not able to fit into the structure as it was initially designed and expanded for jet operations was also considered. Figure 5-1 indicates the different levels, measured at 1000 meters from the hush-house for the tail-out (normal) measurement of September 23, 1964, and for tail-in (abnormal) measurements of September 30, 1969. It can be seen that the use of the hush-house as a muffler rather than as it was initially designed can be much more effective for noise reduction in the directions of interest.

- L1-1 Cullum Trident Suppressor (London/Heathrow) (Reference 19)

Measurements were made by the Ministry of Aviation on January 25, 1964, of run-ups with a Trident 1 with Spey engines fitted with noise suppressors. Measurements were made on a circle of 300' with its center at the exit of the port

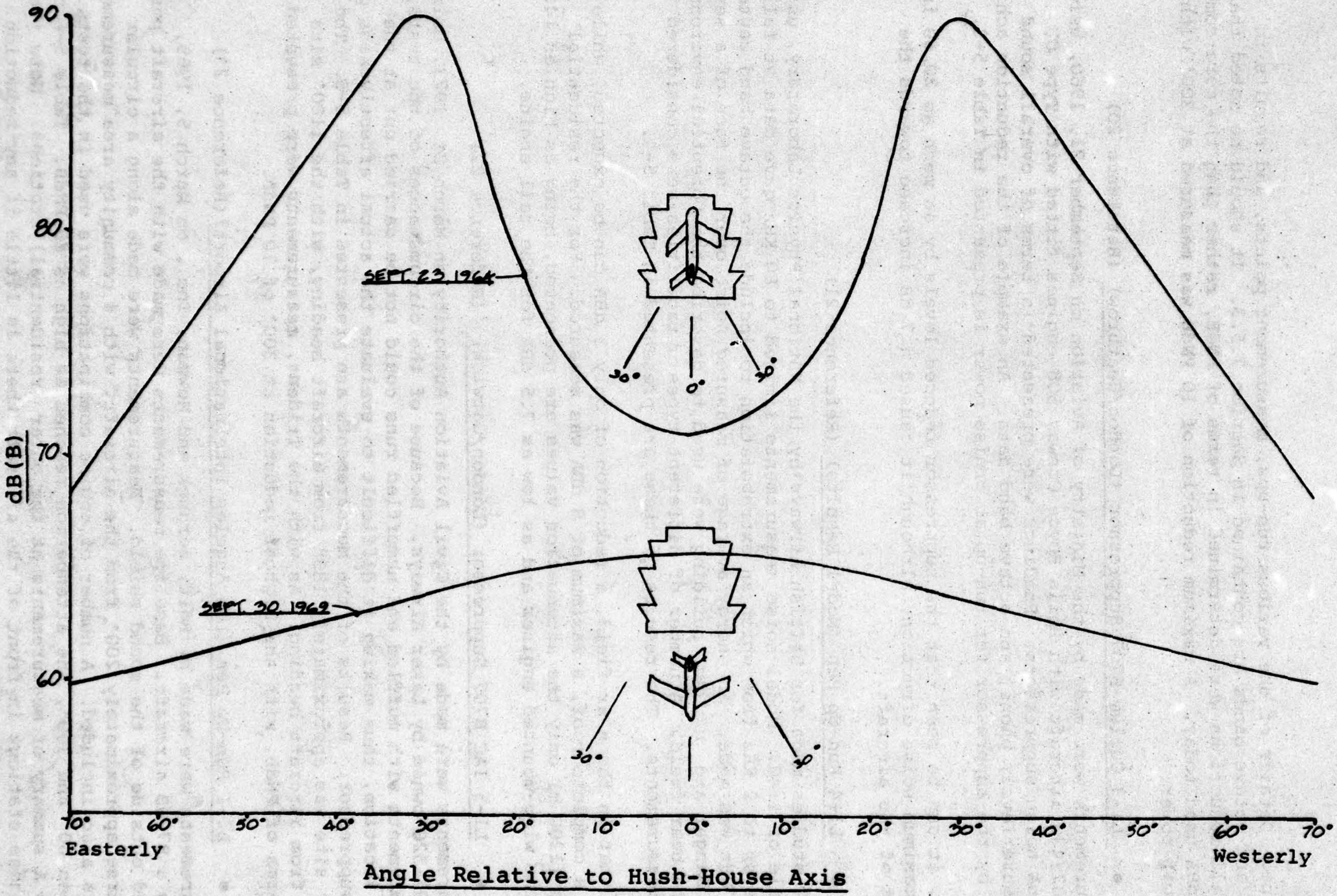

FIGURE 5-1
Sound Pressure Levels at 1,000 Meters From the Hush-House
-Hamburg-

engine. Details of the various run-ups, measurement points, and results in PNdB and octave bands are contained in Section 7.5.3. It should be noted that overall reductions were determined in terms of PNdB, rather than the more common dBA used today. A maximum reduction of 10 PNdB was measured at 300' with takeoff power.

- <u>L1-3 Cullum B707 Suppressor (London/Heathrow)</u> (Reference 20)

Measurements were made by the Ministry of Aviation on September 21, 1960, using a B707/436 aircraft with Rolls Royce Conway 508 engines fitted with Type OU 29975A noise suppressors. Readings were presented in terms of overall sound pressure level, phons, and octave band data. An example of the reduction achievable by the suppressor for run-up at cruise power is presented in Table 5-3.

Thus, it can be seen that the suppressor reduced levels by as much as 20 dB in the maximum noise direction, although it caused a 7 dB increase towards the front of the aircraft.

- <u>L1-4 Run-Up Pen (Model Results)</u> (Reference 21)

Model studies made for British Airways by the National Physics Laboratory, using a scale of 1:40. Model noise measurements limited to 80 KHz gave data at full scale up to 2 KHz from which an extrapolation to include the octave band centered on 2 KHz was made. An energy average of measured noise over the face of a service hangar and another building were used to describe the potential environment in the near field. A number of different types of facilities were considered in the measurements. The results of these are presented in Table 5-4.

Note that in the near field, a reduction of only 3 dBA can be expected, while with a complete roof, a maximum of 8 dBA was measured. For the residential areas (1200 m) only the attenuation values are presented, being as high as 14.8 for the wing-mounted engines and as low as 7.5 dBA for the tail engine.

- <u>L1-5 IAC B707 Suppressor (London/Gatwick)</u> (Reference 22)

Measurements were made by the Civil Aviation Authority on March 22, 1973, using a B707-320 owned by Laker Airways. Because of the circumstances of the tests, measurements with muffled and unmuffled runs could not be carried out at the same location, thus making it difficult to evaluate the actual effectiveness of the suppressor. Results of the measurements are presented in Table 5-5. The 3200' site was approximately 185° from aircraft heading, with the 1100' site 260° from aircraft heading. As with the Trident, measurements were presented in terms of PNdB, with the highest reduction at 300' of 10 PNdB.

- <u>L2-1 Run-Up Pen (Los Angeles International Airport)</u>(Reference 23)

Measurements were made by Bolt, Beranek and Newman, Inc., on March 5, 1969, using a B720B aircraft. Baseline measurements were made with the aircraft positioned outside of the sound shield. Measurements were made along a circular traverse approximately 200' from the aircraft, with 4 community area measurement points also included. A number of engine combinations were used in the tests. Between 60° and 300°, the attenuation reached as high as 20 PNdB. Table 5-6 presents a summary of measurements at the outer (residential) stations. Note that for those stations in front of the aircraft there is little if any reduction. (Note: Because of reingestion problems (see Section 5.3) use of this facility was discontinued.)

TABLE 5-3

CULLUM B707 SUPPRESSOR

Noise Level Measurements at 300' from Engine
(Cruise Power - Outer Port Engine)

Overall Sound Pressure Level (dB)

	Direction (angle from jet axis)					
	30°	45°	60°	90°	135°	180°
Port Side						
Unmuffled	121	120	113	103	100	105
Muffled (Muffler No. 1)	102	98	101	98	107	105
Starboard Side						
Unmuffled	115	118	--	--	--	--
Muffled (Muffler No. 1)	102	102	--	--	--	--
Reduction Due To Mufflers						
Port Side (Muffler No. 1)	19	21	12	5	-7	0
Starboard Side (Muffler No. 1)	13	16	--	--	--	--

TABLE 5-4

MODEL RESULTS FOR L1011 RUN-UP PEN

Average Value of Measurements over Facade of Servicing Hangar and North Block

Engine No.	Aircraft Unobstructed	Parallel Wall Enclosure	With Partial Roof	With Complete Roof
	dBA			
1	106.9	98.4	98.1	98.0
2	103.4	100.2	95.7	96.3
3	103.5	100.1	101.3	100.5

Average Value of Measurements Excluding Results Down Westerly Edge of Servicing Hangar

Engine No.	Aircraft Unobstructed	Parallel Wall Enclosure	With Partial Roof	With Complete Roof
	dBA			
1	106.7	96.6	94.2	93.1
2	103.1	99.2	93.8	87.4
3	102.2	92.9	89.8	87.6

Enclosure Attenuation in Relation to Residential Areas in Bedfont

Engine No.	Parallel Wall	With Partial Roof	With Complete Roof
	dBA		
1	14.8	11.9	12.8
2	7.5	10.7	15.3
3	14.6	12.7	14.1

TABLE 5-5

NOISE REDUCTION FOR INDUSTRIAL ACOUSTICS CORPORATION B707 SUPPRESSOR

Measuring Site	Distance From Aircraft (feet)	Engine Power Setting	Average Noise Levels PNdB		Noise Level Reduction (PNdB)
			Unmuffled	Muffled	
90°	300	Cruise	114	110	4
90°	300	Maximum	118	114	4
60°	300	Cruise	116	113	3
60°	300	Maximum	122	116	6
45°	300	Cruise	119	113	6
45°	300	Maximum	125	117	8
30°	300	Cruise	112	105	7
30°	300	Maximum	119	109	10
Lowfield	3200	Cruise	66	--	--
Heath	3200	Maximum	71	--	--
Heath	1100	Cruise	--	74	--
Heath	1100	Maximum	--	78	--

TABLE 5-6

NOISE REDUCTION OBSERVED AT OUTER MEASUREMENT STATIONS DUE TO SOUND SHIELD

Los Angeles International

Measurement Station	Distance To Point X	Angle of Radiation From Aircraft Heading	Power Setting*	Noise Reduction, PNdB	Noise Reduction Along 200 Foot Circular Traverse for Similar Angle of Radiation, PNdB
A	2960'	300°	#4PP,#1I	4	2
B	3530'	245°	#2PP,#3PP	8	21+
			#3PP,#2I	15	-
			#3TO,#2I	15++	-
C	5390'	70°	#4PP,#1I	-	10
D	5300'	110°	#3PP,#2I	4	22
			#4PP,#1I	5+++	27

* PP = Part Power, TO = Takeoff Power, I = Idle

[+] The power setting when the aircraft was in the baseline position for this measurement was #1PP, #4PP (outside of sound shield)

[++] The power setting when the aircraft was in position "2" for this measurement was #4TO, #1T (inside sound shield)

[+++] For this run the noise level was reduced to that of the ambient by the sound shield.

- O1-1 Run-Up Pen (Osaka) (Reference 24)

Measurements were made for All Nippon Airways on November 17 and December 7, 1971, using a B737 with JT8D-9 engines. Measurements were made at six points 45° apart along a circle with a 100 m radius from the engine. Five additional points (see Table 5-7) surrounding the airport were also used in the tests. Detailed results of the measurements are contained in Section 7.5.2. The results indicate that the run-up pen is very effective behind and to the sides of the aircraft, showing a reduction of 14 dBA at 90° and as much as 15 dBA at 135°, both angles measured from aircraft heading. There is a slight increase in noise level (maximum of 2 dBA) in front of the pen due to reflections from run-up pen walls. For the more remote stations, the noise level was equal to or less than that predicted with the run-up pen. This is shown clearly in Table 5-7.

TABLE 5-7

NOISE REDUCTION FROM RUN-UP PEN AT REMOTE POINTS

No.	Distance	Estimated Level without Wall	Design Level with Wall	Observed Level with Wall
P-1	850 m	70 dBA	65 dBA	57 dBA
P-2	630 m	75 dBA	65 dBA	68 dBA
P-3	470 m	85 dBA	70 dBA	66 dBA
P-3-1	720 m	90 dBA	75 dBA	73 dBA
P-4	890 m	80 dBA	80 dBA	80 dBA

Thus, it can be seen that the run-up pen is estimated to have reduced levels by as much as 19 dBA at Point P-3, and in general is at least as effective as theory would indicate.

- P1-1 Through P1-4 Boet Suppressors (Paris/de Gaulle and Orly) (References 11-14 and 25)

While a large number of nighttime noise level measurements are available at selected points around Charles de Gaulle Airport for aircraft at various locations on the airport, both using and not using suppression equipment, no specific study indicating suppressor effectiveness is available. The Boet Company has prepared specifications for each of their noise suppressors being used at Paris, and indicates a guaranteed reduction for the suppressors as follows:

Aircraft	Reduction at Noisiest Point Behind Silencers at 100 Meters
B747	20 dBA (residual at 1500 m about 50 dBA)
A300 B2/DC10	20 dBA (residual at 1500 m about 50 dBA)
B707/DC8	30 dBA (reduction of about 12 dBA at 2 km)
B727	29 dBA (reduction of about 10 dBA at 2 km)

- P1-5 Bertin Caravelle Suppressor (Paris/de Gaulle and Orly) (Reference 25)

A noise reduction contour (dBA) indicates a maximum reduction of 27 dBA behind the aircraft at a distance of 100 m. 1/3 octave band data are also available for the point 100 m and 45° from the engine axis. A reduction of over 30 dB is shown for the 250 Hz band.

- T1-1 High-Bypass Suppressor (Tokyo/Narita) (Reference 26)

Because the opening of Narita is recent, the Japanese have not had time to complete planned noise studies descriptive of suppressor effectiveness. However, measurements were made on August 8, 1978 with the results shown in Table 5-8.

TABLE 5-8

SOUND LEVEL MEASUREMENTS (140° and 700 m from nose)

	B747 (JT9D-7A, #2TO, #3 Part, #1,4 Idle)		DC10 (JT9D-59A, #2TO, #1,3 Idle)	
	w/suppressor	w/o suppressor	w/suppressor	w/o suppressor
63Hz	76	95	79	104
125	67	89	73	99
250	52	71	61	82
500	38	63	46	66
1000	38	63	46	66
2000	38	64	40	62
4000	35	60	35	59
8000	32	47	27	53
dBA	53	74	58	83

From these preliminary measurements, it can be seen that a reduction of 21 dBA was measured for a B747 and 25 dBA for a DC10. The Japanese expect to collect additional detailed data in the future.

- Z1-1 Schneider DC9 Suppressor (Zurich/Kloten)

Noise level data were provided to this author during a visit to Zurich. Measurements were made at 200' and 30° from the engine axis, for comparison with data provided by the Douglas Aircraft Corporation. The observed reductions are presented in Table 5-9.

TABLE 5-9

Frequency (Hz)	63	125	250	500	1000	2000	4000	8000	dBA
Attenuation (dB)	24	28	34	31	31	27	15	9	27

The primary objective of the suppressor installations at Zurich airport was to reduce aircraft run-up noise in Rümlang, a residential community 2400 meters from the run-up area. It has been reported that the installation has been performing successfully; and, as anticipated by the designers, community noise levels, attributable to the aircraft run-ups, do not exceed 50 dBA.

A new suppressor with an oval rather than a circular entrance cross section is presently in operation in Vienna, with a reduction of 29 rather than the 27 dBA achieved with a circular opening. This may be due to better airflow with suppressor use or less sensitivity to accurate placement of the aircraft.

- Z1-3 Gerber B747 Suppressor (Zurich/Kloten) (Reference 27)

Noise reduction data for this suppressor has been taken from a brochure prepared by Oskar Gerber. A 360° noise contour for the JT9D at takeoff power and a distance of 100 m is provided, indicating that a maximum attenuation expected at this distance is 19 dBA at approximately 135° from aircraft heading.

- Z1-4 Gerber DC10 Suppressor (Zurich/Kloten) (Reference 28)

Measurements were made on March 6/7, 1973, to determine if the suppressor met the guarantee of 50 dBA in Rümlang, 2400 meters from the run-up site. The observed noise levels (but not excess attenuation) achieved by use of the suppressor are shown in Table 5-10. The higher level for Engine #2 is due to the elevated nature of the tail engine and less benefit from ground attenuation.

TABLE 5-10

Engine Settings	Observed Level (2400 m)
#3-108%, #1-98%, #2-Idle	47 dBA
#2-108%, #1,3-Idle	49 dBA

- Experimental Coanda/Refraction Noise Suppressor (Reference 29)

This prototype suppressor was evaluated by The Boeing Company for the Naval Air Engineering Center to determine if it could be more effective acoustically and mechanically than existing suppressors for military engines. While the prototype was effective for a single engine, there is no program at the present time to continue development for in-airframe engine run-ups. The suppressor was most effective in reducing noise levels for high velocity streams associated with the afterburning mode, and does not appear to offer any particular benefit over existing technology for civil aircraft engine noise suppression. Such a system is also more important for high temperature exhausts associated with military engines, where direct contact with suppressor walls can be minimized.

Results of tests with this suppressor are presented here for completeness. Excerpts of the type of data available from test runs are included in Section 7.5.4. The suppressor reduced levels of an afterburning military J57 engine by as much as 35 dBA 250' from the device, and as much as 30 dBA at one mile.

5.3 LIMITATIONS ON USE AND POTENTIAL PROBLEMS

Limitations on use of facilities because of weather and the closely related problem of potential adverse impacts on engines or airframes are examined here for the suppressors under consideration. Only those facilities for which some type of information is available are addressed.

- B1-1 Partial Hush-House (Berlin/Tegel) (Reference 15)

While Berlin Airport indicated that the usability of the noise shelter is not limited by meteorological conditions, one airline indicated that with winds approaching 90° to aircraft heading, some problems are encountered and that wind conditions may at times prevent use of the facility. Another airline indicated that when the prevailing wind is directly into the hush-house, turbulence is created which causes airframe vibration and makes exhaust gas reingestion more probable. It was pointed out by another that severe icing conditions can make aircraft approach and positioning within the pyramid difficult.

Acoustic loading of the aircraft has been eliminated by use of unidentified highly absorptive materials, and that any significant vibrations below 50 Hz (which may excite structural elements) are not present. A plexiglass model was used for airflow tests prior to construction and changes made in the design to ensure that this would not occur. Based on model tests, Dipl. Ing. Meyer anticipated the installation of additional deflecting surfaces to prevent exhaust gas reingestion. Subsequent to the design work and prior to the installation of special deflecting panels, measurements of actual reingestion were made. The measurements indicated that special deflecting surfaces would not be necessary and so they were not installed.

One airline indicated that reverse airflow occurs during high power runs with the BAC111-500 and B727-200 aircraft which causes tail vibration and subsequent effects on engine performance. Another experienced one occasion of aircraft damage due to mispositioning within the pyramid, where excessive back-flow across the wings resulted in an access panel being blown off the aircraft. Another indicated that certain wind directions cause some reingestion particularly by outboard engines.

These contradictory responses may be attributed to a noise abatement facility built and operated by an organization other than users of the facility. Fewer reports of problems have been reported for those facilities owned and operated by the same entity.

- D1-1 Noise Barrier (Düsseldorf)

One operator indicated limitations on run-ups with RB-211 engines with winds not in line with aircraft heading. Only under ideal conditions of wind speed and direction can the RB-211-22B be run at maximum power, and is limited to 90% of maximum thrust for maintenance run-ups to prevent buffeting and stalling due to back pressure which may occur.

- H1-1 Hush-House (Hamburg) (References 16, 17, and 18)

Measurements were made within the structure using small flags to identify the nature of airflows. There was no indication of recirculation of exhaust gases out of the structure that could be reingested. Only a small closed flow was found within the intake tower.

- L2-1 Run-Up Pen (Los Angeles International) (Reference 23)

The circular and inward sloping nature of the barrier at Los Angeles caused initial problems with the ingestion of gases. While some modification in the structure was carried out, this did not solve the problem sufficiently, and with user reluctance to perform run-ups within the pen, its use was finally terminated.

- O1-1 Run-Up Pen (Osaka) (Reference 24)

A run-up restriction chart has been developed for the facility, and is contained in the All Nippon Air response in Section 7.4.3. As indicated in their response the facility is not used with winds above 15 meters/second (35 mph). Because of specified distances from the walls, no acoustic loadings have been experienced. No exhaust gas reingestion has occurred, as long as the run-up restrictions are followed.

- T1-1 IHI Suppressor (Tokyo/Narita) (Reference 26)

While no specific values have been given, it was indicated that under "adverse cross and tail wind conditions", Japan Airlines prohibits the use of the system so as to prevent engine stall. Japan Airlines indicated that the values of wind limits for the noise suppressor are the same as those for the case of run-ups in immediate downwind areas of buildings, where generated turbulence could cause problems with intake airflows.

- Z1-3/Z1-4 Gerber High-Bypass Suppressor (Zurich/Kloten) (References 27 and 28)

Only one run-up has been cancelled because of wind conditions since construction of the facilities in 1971 and 1972. Prevailing winds (based upon an airport wind rose) are generally from behind and to the sides of the aircraft heading. Some problems were initially encountered with the JT9D engine, which is one of the most sensitive to stall during ground run-up in cross winds, but a wind direction/speed monitoring device was constructed to allow the mechanic at the throttles to reduce power when such adverse conditions arose. In this manner, by taking advantage of the detected favorable wind shifts, the JT9D engine can be run-up under many marginally unfavorable and some nearly prohibitive conditions.

An unusual feature here is the heating system built into the apron pavement, which assures necessary stability of aircraft position during run-ups under weather conditions marked by snow and ice.

5.4 CONSTRUCTION COST ESTIMATES

Construction cost data are available in the currency of the country in which the suppressor was built and for the year of construction. Although it is possible to account for increased costs in the country of construction and changes in exchange rates with the U.S. dollar, it is difficult to account for other costs associated with differences in labor and management practices, regulations, cost of materials, and license fees. With these qualifications however, the following method has been used to develop cost estimates for the end of 1978:

1. Cost is identified in local currency for year of construction. Where cost is known in U.S. dollars, it is reconverted to local currency using exchange

rates for that year. Where exact date of construction is unknown, assumed dates have been used for this comparison.

2. The change in the wholesale price index was computed for each country from the time of construction to the end of 1978, using data provided by International Monetary Fund International Financial Statistics.

3. The exchange rate at the end of 1978 taken from the above reference was used to convert the local 1978 cost to U.S. dollars.

A summary of estimated 1978 construction costs is presented in Table 5-11.

TABLE 5-11

ESTIMATED 1978 CONSTRUCTION COSTS IN U.S. DOLLARS

Suppressor	Year	Local Currency Cost	Conversion to 1978[a]	Exchange Rate 1978[b]	U.S.$ Cost 1978
B1-1	1974	DM 5.4 mill	1.14	1.8823 DM/$	$3,270,000
B2-1	1970	£ 81,800	2.94	.5043 £/$	476,880
D1-1	1972	DM 1.27 mill	1.37	1.8823 DM/$	924,350
F1-1	1978	DM 8.1 mill	1.00	1.8823 DM/$	4,303,250
H1-1	1962	DM 9.0 mill	1.64	1.8823 DM/$	7,841,470
L1-2	1970	£ 60,000	2.94	.5043 £/$	349,790
L1-3	1960	£ 30,000	3.99	.5043 £/$	237,360
L2-1	1968	US $147,900	2.12	1.00 $/$	313,550
M1-1	1973	DM 1.24 mill	1.29	1.8823 DM/$	849,810
O1-1	1971	¥ 60 mill	1.64	196.29 ¥/$	501,300
P1-1	1970[c]	F 2.37 mill	1.81	4.3202 F/$	992,940
P1-2	1970	F 2.00 mill	1.81	4.3202 F/$	837,920
P1-3	1970	F 1.60 mill	1.81	4.3202 F/$	670,340
P1-4	1970	F 886,000	1.81	4.3202 F/$	371,200
T1-1 (1)	1972	¥ 219 mill	1.63	196.29 ¥/$	1,818,580
T1-1 (2)	1977	¥ 63.4 mill	0.97	196.29 ¥/$	313,300
Z1-1	1968	SF 200,000	1.37	1.6773 SF/$	163,360
Z1-2	1968	SF 870,000	1.37	1.6773 SF/$	710,600
Z1-3	1971	SF 1.33 mill	1.25	1.6773 SF/$	991,180
Z1-4	1972	SF 1.70 mill	1.21	1.6773 SF/$	1,226,380

[a] Conversion is based on the wholesale price index (reflecting construction costs) taken from International Monetary Fund International Financial Statistics, Annual Data 1952-1976, May 1977 and February 1979.

[b] Exchange rates as of December 31, 1978, were taken from the February 1979 issue of the above reference.

[c] Assumed since exact dates not available.

6.0 POTENTIAL FOR STANDARDS DEVELOPMENT

6.1 DEFINITIONS

The term "noise suppressor" will be used here to include all devices that interact with jet exhaust to reduce noise levels at least in some directions at a specified distance from the aircraft, or any type of barrier structure which is closed for some portion of its length above the exhaust flow from an engine.

The term "noise barrier" will be used here for any structure primarily intended to absorb, reflect, and refract noise, providing it is not closed above the exhaust flows from an engine.

Examination of the noise control devices considered here would place them under the following categories:

Noise Suppressors	Noise Barriers
All Tubular Suppressors	All Linear Noise Walls
Hamburg Hush-House	Run-Up Pens
Berlin Noise Shelter	

6.2 NOISE SUPPRESSORS

It is clear that design considerations for the above noise suppressor categories are quite different, but it should be emphasized that each tubular suppressor is also somewhat unique. Each type of suppressor design requires separate detailed aerodynamic, acoustic, mechanical, cost, and other analyses.

Some suppressors require careful placement in back of the engine, not only for acoustical but also for aerodynamic performance, while others do not.

The acoustic performance of recently constructed suppressors is somewhat similar, although no standard measurement point and engine setting(s) have been established for comparison of suppressors. Generally, one might expect to achieve from 20 to 25 dBA in the near field (i.e., less than 500 feet from the noise source) and from 10 to 20 dBA in the far field (approximately 1 mile from the noise source). This reduction generally occurs along the direction of maximum unsuppressed noise level, or 135° from the aircraft heading.

The combination of engine power settings for two-, three-, and four-engine aircraft is not infinite, but quite large. In order to develop a standard, it would be necessary to determine for each type of aircraft which combination of engine settings should be used (in conjunction with a suppressor device) to achieve a given noise reduction. For example, if it is assumed that the possible power settings for each engine are (1) engine off, (2) idle power, (3) cruise power, and (4) takeoff power, then the number of combinations are 16 for a twin-engine aircraft, 64 for a three-engine aircraft, and 256 for a four-engine aircraft. It may be, that with further study, the combinations used in maintenance procedures are sufficiently few to be easily identified and tested, but a more detailed analysis than the one presented here would be required.

Clearly, one of the findings of this study is that there is no suppressor that can accommodate all aircraft. The amount of airflow required for the different size engines is greater than can be incorporated into any design, although it should be noted that some tubular mufflers which have been designed for the larger engines are also used for the narrow-body and associated smaller engines. In Zurich, for example, business jets are required to conduct their maintenance run-ups using the B747 noise suppressor in order to obtain the noise reduction provided primarily by the appurtenant walls that, in essence, form a noise pen. The tubular mufflers are able, however, to accommodate these engines.

Aerodynamic performance is another area which must be designed into the suppressor for it to work efficiently and effectively. As has been noted above, there appears to be some disagreement among the users and owners of such facilities concerning the potential for engine damage. This is especially apparent when use of a common facility is mandatory. Specifications for aerodynamic performance may be simpler in that zero back pressure and reingestion could be required. This could possibly eliminate some of the presently manufactured suppressors under certain wind conditions, which implies that wind conditions would have to be carefully considered in setting specifications.

Problems with airframe vibration are much more likely to occur with the use of hush-houses or suppressors which completely or partially enclose the aircraft or parts of the aircraft. For such facilities, it may be necessary to specify the level of airframe oscillation or vibration which could be tolerated when using them. Extensive stress monitoring was carried out during tests with the Los Angeles run-up pen but found to be not critical.

In conclusion, it would appear that standards would have to be developed for the following three major areas:

1. <u>Aerodynamic Performance</u>

Under specific test conditions, not more than a specified maximum back pressure and maximum amount of exhaust gas reingestion would be allowed. There does not appear to be sufficient quantitative data upon which to base such standards.

2. <u>Acoustical Performance</u>

Under specified test conditions, i.e., meteorology, engine combination, and power setting, minimum allowable noise reductions would have to be specified at a near field and far field location along a line 135° from aircraft heading. The problem here is that the desired level of reduction may not always be the same and that while in some cases a 20 dBA reduction is needed, only 10 dBA may be required elsewhere. However, sufficient data on sound pressure levels at selected distances (octave band data) would enable noise levels to be computed at distances other than the specified points. Such data should also be available, for at least eight points on a circle, so that orientation of the run-up facility could also be taken into account. Measurements of noise reduction and suppressor effectiveness have not been specified at the same location and angle. Moreover, octave band data are available only for a small number of suppressors, and then not always for the same distances and locations with respect to the engine being run. In addition, the combination of engines during the tests are not consistent.

In summary,

a) A satisfactory acoustical specification would prescribe noise attenuation at several points, at different distances, and directions around the noise generator.

b) Existing data concerning the effectiveness of existing suppressors are not adequate for determining whether or not existing suppressors would be capable of meeting such a specification.

c) Additional data collection describing the effectiveness of existing suppressors will be necessary if a satisfactory acoustic performance specification is to be developed.

3. Airframe Performance

Under specified engine and power settings and environmental conditions, maximum vibration and associated stress levels in an airframe would be allowed. Damage or removal of surface panels by back airflows will be prohibited. Detailed stress measurements during tests at the Los Angeles run-up pen did not reveal any substantial problems with that facility, although reports of panel removal have been made for several other suppressors in operation. The development of vibration and stress data will require input from airframe manufacturers to determine where and to what extent vibrations of the airframe under ground run-up could be harmful.

6.3 NOISE BARRIERS

Specifications on aerodynamic, acoustic, and airframe performance discussed above for noise suppressors can also be applied to noise barriers, with minor modifications. Barriers may also restrict or disturb airflows, reflect sound energy, and provide acoustic shielding. They may be constructed to reflect or absorb sound so as to minimize potentially harmful impacts on the airframe or engine, while at the same time providing needed noise reduction. The capabilities of walls or screens to absorb noise may vary widely, reflecting as much as 99% of incident energy or as little as 10%.

Intake screens can be used to reduce noise forward of the aircraft while undergoing maintenance involving ground running of engines. Because it is often not necessary to reduce forward noise, and because the use of screens involves the inconveniences of setting them up before the maintenance work and dismantling them after the maintenance work, such screens are not commonly used.

Acoustic performance of barriers may be estimated using laboratory tests or computer modeling techniques. Such methods may yield results within one or two decibels of actual field tests, providing the laboratory model or theoretical assumptions are correct, and assumed meteorological conditions are realized. As can be seen from data on the run-up pen at Osaka (Section 7.5.2), the performance of walls was better than had been anticipated on the basis of careful estimates. The effectiveness of barriers and run-up pens is much more sensitive to weather conditions than is the effectiveness of suppressors. While noise barrier performance may be measured or estimated, it is therefore much more variable than that of suppressors. As in the case for suppressors, any performance standard for barriers would have to be related to engine combinations, and power settings.

Aerodynamic performance is no problem when the barrier is sufficiently far from the aircraft. However, the further the aircraft (or the receiver) is from the barrier, the less effective it becomes. As the engine is placed closer to the barrier, the potential for adverse flows associated with the barrier grows. It is just as essential with barriers as for suppressors that back pressures and reingestion do not occur. An example of a run-up pen where a number of such problems occurred is that of Los Angeles International Airport, where a circular inward sloping wall was constructed for run-ups. Not only were gases trapped under the walls, but the circular nature of the pen directed the exhausts to the front of the aircraft, causing severe problems.

Problems with airframe vibration can be minimized by use of appropriate geometries and absorptive designs. As noted above, concern over structural vibrations arose with the Los Angeles run-up pen, although no serious problems were identified.

In conclusion, as with barriers, standards for suppressors should cover three major areas covering aerodynamic, acoustical, and airframe performance:

1. Aerodynamic Performance

For any and all weather conditions, engine combinations, and power settings, either the maximum permissible exhaust pressure or reingestion coefficients would have to be established. (This study did not indicate that there are sufficient quantitative data available for the setting of such a standard.)

2. Acoustical Performance

For each set of weather conditions, engine combinations, and power settings, noise reductions would have to be specified for a number of positions at various directions and distances from the aircraft. There are three possible bases for establishing attenuation standards within the state-of-the-art:

a) Field measurements of attenuation using existing barriers.

b) Theoretical calculations of near field and far field attenuation, using octave band data for a number of positions around the aircraft.

c) Scale model tests, using octave band data for near field or far field estimates of noise attenuation.

3. Airframe Performance

For any or all weather conditions, engine combinations, and power settings, maximum permissible stress levels would have to be established. (It is not known whether aircraft manufacturers have and would make available sufficient data for the setting of such a standard.)

7.0 REFERENCES AND SUPPLEMENTARY MATERIAL

7.1 LIST OF REFERENCES

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7.2 SUMMARY OF DATA COLLECTED IN REFERENCE 1

ENGINE GROUND RUN-UP NOISE SUPPRESSION EQUIPMENT

Summary of Information Required from Manufacturers and/or Operators and/or Authorities

Questionnaire Cue Sheet

1. NOISE SUPPRESSION SYSTEM - DESIGN REQUIREMENTS FOR NOISE REDUCTION PERFORMANCE.

   (a) What noise level criteria?

   - disturbance noise level at airport boundary - if so, what?
   - disturbance noise level at nearby community - if so, what?
   - noise level at given distance from equipment - if so, what?
   - others?

   (b) Who establishes criteria?
   - aviation authority
   - airport authority
   - local government
   - local council
   - airline operator
   - others

2. NOISE SUPPRESSION SYSTEM - CONCEPT/TYPE

   (a) Resonators
   (b) Sound absorbing mufflers, splitters
   (c) Perforated diffusers
   (d) Cascade vanes, turning vanes
   (e) Walls, revetments, pens
   (f) Full "hush house"
   (g) Screens
   (h) Others.

3. NOISE SUPPRESSION SYSTEM - ADAPTABILITY

   (a) Fixed Direction Installation
   (b) Moveable installation to allow for wind changes.
   (c) Installation primarily for which aircraft/engine type? (Important to specify engine type).
   (d) Adaptable for various aircraft.

4. NOISE SUPPRESSION SYSTEM - WIND EFFECTS

   (See also 6(d) (vi) for meteorological effects and 15(f) and (g) for wind effects at particular airport).

   (a) What is maximum crosswind component at which engine can be operated, when connected to the system, without instability?

   (b) What is maximum tailwind component at which engine can be operated, when connected to the system, without instability or reingestion?

5. NOISE SUPPRESSION SYSTEM - AERODYNAMICS

(a) Inlet Airflow Control.

(b) Inlet Depression.

(c) Secondary Airflow Control.

(d) Method of Capture of Primary Exhaust, Fan Exhaust, Secondary Air.

(e) Airflow through exhaust system - Back pressure.

(f) Possibility of recirculation.

6. NOISE SUPPRESSION SYSTEM - ACOUSTICS (See also 9(e) and 15(d))

(a) Effectiveness in suppression of primary exhaust noise.

(b) " " " " fan " ".

(c) " " " " intake noise.

(d) What acoustic data can be provided for each muffler?

Particular points to determine :

(i) Calculation or test data?

(ii) What aircraft engine/s tested?

(iii) What thrust levels? (T.O. only or various).

(iv) Max. O.A.S.P.L. on aircraft structure due to muffler?

(v) ⅓ octave reductions at say 250 ft. radius, polar?

(vi) What data available on reductions at say 2 km radius under varying atmospheric conditions? (Particularly low altitude temperature inversions.)

(vii) Noise amplifications produced by muffler? Against aircraft structure ((iv) above), in near-field (operators working on aircraft), in far-field in forward arc.

(viii) Is the noise reduction achieved sensitive to the accuracy with which the aircraft is positioned?

(ix) "Reserve acoustic power" available for future engines?

7. NOISE SUPPRESSION SYSTEM - MECHANICAL/ELECTRICAL CONTROL ASPECTS

(a) Any requirement for movement of equipment during aircraft positioning?
- Manual or Power Operation?

(b) Power equipment requirements Electrical, Water etc.?

8. EFFECTS ON ENGINE PERFORMANCE

(a) Engine Inlet depression at all Powers. Is it measurable?

(b) Acceptable depression if no engine stalling occurs.

(c) Engine stability during running?

(d) Recirculation?

(e) Engine subjected to vibration, heat, etc.

(f) Are there any other engine performance limitations experienced?

9. WORKABILITY OF INSTALLATION

(a) Ease of Aircraft positioning and accuracy of positioning required?

(b) Time taken to position aircraft and acoustic equipment, (set up time)?

(c) Ease of access around engine when in position.

(d) Danger of contact between aircraft and suppression system, due to aircraft movement?

(e) Wing Flap Positioning - Acoustic Effect?

10. NOISE SUPPRESSION SYSTEM - SITE REQUIREMENTS

(a) Area required for installation including aircraft positioning requirements.

(b) Additional clearance area required (blast, etc.)

(c) Foundation requirements (loading).

11. NOISE SUPPRESSION SYSTEM - SAFETY REQUIREMENTS

(a) Effects of engine stall - system damage, engine damage, aircraft damage.

(b) Effects of engine fire - system damage, engine damage, aircraft damage. (See also 12(c)).

(c) Engine accessibility for fire extinguishers.

(d) Ability to move aircraft quickly if required.

(e) Personnel safety hazards.

12. NOISE SUPPRESSION SYSTEM - MAINTENANCE REQUIREMENTS

(a) Corrosion protection.

(b) Vibration, heat damage to acoustic treatment.

(c) Ease of acoustic treatment replacement in event of damage, fire etc.? (See 11(b).

(d) Power system maintenance.

13. NOISE SUPPRESSION SYSTEM - COSTS

(a) Price.

(b) Manufactured overseas or subcontracted in Australia.

(c) Transport costs.

(d) Installation costs.

(e) Setting up and calibration, acoustic testing, costs.

(f) Delivery time (manufacture time, installation time, calibration and acceptance time).

(g) Maintenance costs - details (i) actual?
(ii) estimate?

14. NOISE SUPPRESSION SYSTEM - VENDOR

(a) Experience in noise suppression.

(b) Previous system installed - of similar size.

(c) Capacity to engineer an acceptable system.

(d) On site supervision of installation, calibration and acoustic tests by vendor's engineer.

(e) Guarantees (acoustic, aerodynamic) and warranty.

15. NOISE SUPPRESSION SYSTEM AND ITS RELATIONSHIP TO PARTICULAR AIRPORT AND SURROUNDING COMMUNITY

(a) Location of equipment relative to :
  (i) Maintenance area.
  (ii) Community.

(b) Location of equipment relative to surrounding natural absorption media such as walls, trees, earth banks, etc.

(c) Frequency of complaints and type :
  (i) before installation of any noise suppression equipment.
  (ii) after installation of any noise suppression equipment.

(d) Noise levels experienced within surrounding community :
  (i) before installation of any noise suppression equipment.
  (ii) after installation of any noise suppression equipment. (See also 6)

(e) Is 24 hour ground running allowed by relevant authorities? If not, what restrictions are involved?

(f) What are prevailing wind conditions at particular airport under consideration? What variations are experienced? (See also 4)

(g) What percentage of occasions is the equipment unable to be used because of prevailing wind conditions? (See also 4)

16. GENERAL

(a) What airlines use the particular type of equipment under consideration?

(b) How often is the particular system used ________ runs/day?

(c) What type of "front-end" acoustic treatment is available? If any such equipment available ________ is it being used by any airline?

(d) Does there appear to be any technology break-through in noise suppression equipment imminent?

Source: Dunn Reports (Reference 1)

7.3 SAMPLE QUESTIONNAIRES

The following questionnaires were submitted to Aeroport de Paris for distribution to the Boët Company and Air France. Similar questionnaires were sent to the other locations.

From Boet and Co. we would like to have documents or information necessary to answer the following questions for each of the noise suppressors designed by them for Air France in Paris:

1. What considerations of acoustic loadings on aircraft structures (exclusive of engines) were made and what percent of the total design effort did such considerations require?

2. What considerations of flow constriction, exhaust gas reingestion, or acoustic loadings on the engine were made and what percent of the total design effort did such considerations require?

3. How accurately must the aircraft be positioned to achieve target levels of noise attenuation and ensure aerodynamic function of the facility? How accurately must the aircraft be positioned to avoid excessive acoustic loading of the airframe and/or problems with engine intake/exhaust flows?

4. What are the envelopes of meteorological conditions under which use of each suppressor was not recommended because of:

   a) Less than design noise attenuation
   b) Potential for excessive acoustic loadings
   c) Potential for aerodynamic problems

   and how often do these occur?

5. Which aircraft can and cannot use the suppressors according to technical specifications of the designers?

6. What were the theoretical noise attenuation predictions for each aircraft/engine type for whom the facility was designed?

7. What actual field measurements are available for each aircraft/engine type using each suppressor? We would like to know the sound pressure levels for near and/or far field (in octave bands centered at 63 Hz through 8000 Hz and in dBA) associated with the use of the facility by each aircraft and engine type. We would also like to know the location and height of microphones relative to the facility. Power settings and engine types associated with the above data are essential. Local meteorological conditions during the measurements would also be desirable.

8. Who can we telephone at Boet and Co. to discuss these questions in greater detail? We would like to have names, titles, and telephone numbers.

From Air France we would like to have documentation or information necessary to answer questions about the following suppression devices:

(1) Boet 727 Noise Suppressor at Orly
(2) Boet B707/DC8 Noise Suppressor at Orly
(3) Boet DC10/A300B Noise Suppressor at Charles de Gaulle
(4) Boet B747/A300B Noise Suppressor at Charles de Gaulle (if constructed)

Questions concerning ownership and operation of the suppression devices:

1. Have sound level measurements been made in the field to judge the effectiveness of the suppressors? We would like to have data on the near and/or far field sound pressure levels (in octave bands centered at 63 Hz through 8000 Hz and in dBA) associated with the use of <u>each</u> facility by each aircraft type using the facility. We would also like to know the location and height of microphones relative to the facility. Power settings and engine types associated with the above data are essential. Local meteorological conditions during the measurements would also be desirable.

2. Is the use of the suppressors required for all ground run up maintenance, or only certain users, or only under certain conditions? If so, what are the exceptions and conditions?

3. Are there any meteorological conditions under which use of any of the suppressors is not possible or prohibited, and if so, what are these?

4. What did it cost to design <u>each</u> suppressor? What did it cost to construct <u>each</u> suppressor? What does it cost to maintain <u>each</u> suppressor?

5. Is there one person who can provide answers to questions in greater detail who we could call? We would like the name, title, and telephone number.

Questions concerning the use of each suppression device:

1. Which aircraft and what engines have been run up at <u>each</u> suppressor? How many times per month or per year are each aircraft type run up in each facility?

2. Have any meteorological conditions been found to cause difficulties or delays in engine maintenance work in any of the suppressors, and if so, what were these conditions? Are those difficulties associated with particular aircraft/engine types, and if so, which?

3. What ground equipment is required to place the aircraft at each suppressor and how much does this equipment cost to buy and maintain? How difficult is it to position aircraft and how long does it take? How critical is the position in terms of acoustic and aerodynamic performance of each suppressor? What kind and numbers of personnel are required to position the aircraft?

4. Has there been any damage to engines or airframes caused by restricted air flow, exhaust gas reingestion, or acoustical loading while at any of the suppressors? If so, what types of engines/aircraft were involved and what were the meteorological or other causes for these problems? How many cases of this type have been reported, and what were they? Have any airframe and/or engine manufacturers voided or modified any guarantees or warranties because of use in any of the suppressors? If so, under what conditions?

5. Is there one person who can provide answers to questions in greater detail who we could call? We would like the name, title, and telephone number.

7.4 SELECTED RESPONSES

The following responses have been selected as representative of the type of data obtained in the present effort.

7.4.1 Berlin

Responses are included from the following:

- Thomas J. Meyer, in response to questions directed at the designer of the facility.
- In response to questions directed at users of the facility:
  - Pan American
  - British Airways
  - Dan-Air Engineering Ltd.
  - Aeroamerica

7.4.2 Düsseldorf

A response from a user of the run-up area (LTU) is included.

7.4.3 Osaka

A response from the owner, operator, and user (All Nippon Airways Company) is included.

7.4.4 Zurich

Responses, based on a visit to Swissair offices in Zurich, by Dr. David Braslau are included.

7.4.1 Berlin

Responses are included from the following:

- Thomas J. Meyer, in response to questions directed at the designer of the facility.
- In response to questions directed at users of the facility:
  - Pan American
  - British Airways
  - Dan-Air Engineering Ltd.
  - Aeroamerica

THOMAS J. MEYER
DIPL. PHYS.

2 HAMBURG 52
HOLZTWIETE 8
TEL. 82 69 20

Department of Transportation
Federal Aviation Administration
Att.: Mr. R.B. Ahlers
Washington, D.C. 20591

August 26, 1978

Dear Sir,

The Berliner Flughafen-Gesellschaft sent me a copy of your request concerning Anti-Noise Shelters of the type built at Berlin Tagel Airport and asked me to answer the questions of the attached questionary as far as I am concerned.

1. What considerations of acoustic loadings on aircraft structures (exclusive of engines) were made and what percent of the total design effort did such considerations require?
   Considerations concerning acoustic loadings on aircraft structures aimed not to enlarge these loadings compared with a position of the aircraft in the open air. This is one of the reasons why the whole inner surface has been covered with highly sound absorbing material. The absorbtion coefficient a_{sab} is more than 0,9 above 50 Hz and was tested in laboratory. The vibration sector (below 50 Hz) was controlled by measurements of the Bundesanstalt für Materialprüfung in Berlin at the completed building. There was no vibration of the building registered worth mentioning. In conclusion it can be stated that additional loadings of aircraft structures in reaction to similar loadings of the building structure are far below the loadings in open air positions, also in the vibration sector.
2. What considerations of exhaust gas reingestion or acoustic loadings on the engine were made and what percent of the total design effort did such considerations require?
   Specially careful considerations were made on the exhaust gas reingestion sector. A plexiglass model was built and the exhaust

2/...

flows were made visible in this model. As a result of these tests planes to conduct the jet streams were provided in order to improve the exhaust flows streaming through the building and to avoid recirculation completely. After the building had been finished to its present stage, reingestion measurements were made before the conducting planes had been installed. The reingestion coefficients were so low that the installation was abandoned. As to the acoustic loadings of the engines see question 1.

3. How accurately must the aircraft be positioned to achieve target levels of noise attenuation and ensure aerodynamic function of the facility? How accurately must the aircraft be positioned to avoid excessive acoustic loading of the airframe and/or problems with engine intake/exhaust flows?
   The position of the aircraft is normally on the center line of the cabin. The aircraft will be pulled on this line into the shelter as far as possible. It will be clear that the shielding effect becomes worse if the aircraft is not positioned as far as allowed by the geometrical form of shelter and aircraft including the movements of the aircraft during the engine tests. Dislocations of 2 to 3 meters are of course without any importance concerning the noise attenuation or the aerodynamic function of the facility as well as the acoustic loading of the airframe or problems with exhaust flows. In nose in positions the distance of the engines to the nearest point of the building should be at least the double diameter of the outer engine dimension in order not to obstruct the intake flow.
4. What are the limiting meteorological conditions under which use of the noise shelter was nor recommended because of:
   a) Less than design noise attentuation
   b) Potential for excessive acoustic loadings
   c) Potential for aerodynamic problems
   and how often do these occur?
   On this subject the Berliner Flughafen-Gesellschaft will be able to give the best information.

3/...

5. Which aircraft can and cannot use the pyramid according to technical specifications of the designers?
   The Pyramid built in Berlin is the first stage. It cannot be used without enlargement for large aircraft like Boeing 747, DC 10, Tristar, Airbus. The largest aircraft the cabin provides for fully sufficient noise attentuation in its present stage are types like Boeing 707 or DC 8. A shelter shielding also all large aircraft now in use or in the planning stage even in a much larger sector than it was necessary in Berlin is just planned by my office and my partners. The shelter will be completed during 1979.

6. What were the theoretical noise attenuation predictions for each aircraft/engine type for whom the facility was designed?
   For each aircraft/engine type maximum sound levels were determined in advance for the whole surrounding of the building. Doing this, favourable sound propagation conditions (f.i. inversions) were assumed, specially in direction to the open side of the cabin. The noise attenuation depends on the position of the engines within the shelter. The noise levels measured after the building was put in use were considerably lower than the calculated data. The measurements, however, were not made at inversion weather conditions.

7. What actual field measurements are available for each aircraft/engine type using the pyramid? We would like to know the sound pressure levels for near and/or far field (in octave bands centered at 63 Hz through 8000 Hz and in dBA) associated with the use of the facility by each aircraft and engine type. We would also like to know the location and height of microphones relative to the facility. Power settings and engine types associated with the above data are essential. Local meteorological conditions during the measurements would also be desirable.

   First of all measurements were made in the near field in order to find out the noise attenuation efficiency without influence of weather conditions. These measurements were made with the aircraft types Boeing 720 and BAC 1-11 by the Technische Universität Berlin. In addition measurements were made in the far field. The microphones were positioned between 1,5 and 3 meters above ground. The engines were brought to full power one after the other. The weather conditions during the measuring time were noted. The Berliner Flughafen-Gesellschaft possibly will be able to give additional information.

8. Whom can we telephone at Thomas J. Meyer and Partners to discuss these questions in greater detail? We would like to have names, titles and telephone numbers.
Questions concerning acoustical and aerodynamical problems will be put best to the underwriter directly, Holztwiete 8, Hamburg 52, telephone 040/826920, questions concerning the building structure to my partner Herbert Schutsch, Tutzinger Straße 5, Berlin 49, telephone 030/7445331. My partners LSB Gesellschaft für Lärmschutz m.b.H, Berlin, telephone 030/7444110 are responsible for the combined project planning. General manager for projects abroad is Manfred Freiherr von Malapert-Neufville.

Yours faithfully,

Thomas J. Meyer

PAN AM

August 18, 1978

Mr. Jerome F. Biron
U.S. Administrator for Aeronautics
Tempelhof Airport
1000 Berlin 42

Dear Mr. Biron,

The answers to the questions in your letter of August 15, 1978 are as follows:

The primary users of the noise suppression structure at Tegel are British Airways and Pan Am.

1. BAC 111-500 and B727-100 have been run-up in the pyramid. Pan Am makes about ten runs a month. BFG can give you the total figures for all airlines.

2. Problems are encountered whenever we have wind components approaching 90° to aircraft heading. This difficulty is experienced by all aircraft types. Wind conditions at times may prevent use of the facility.

3. To position the aircraft an aircraft towing vehicle and tow bar are required. This equipment is usually available at all airports.

The positioning of the aircraft is not difficult and requires only a few minutes.

The position of the aircraft is extremely critical and if the aircraft is not properly positioned the noise suppression effectivity is reduced.

Three men are required to position an aircraft. One each on the towing vehicle, in the aircraft and at the tail.

4. With the aircraft correctly positioned, it is not possible to do a high power check. The airflow back from the structure causes the tail of the aircraft to vibrate effecting engine performance.

This problem is a result of the basic design and has been experienced on both the BAC 111-500 and the B727-100. British Airways can probably give you further information on their experience. We are not aware of any involvement by an aircraft manufacturer relative to warranty.

5. The person who can probably give you more detailed information is Mr. Grosch, Technical Director, BFG, Phone 41 01 2200.

Sincerely,

M. P. Bavuso
Director, Maintenance IGS

1 BERLIN 52 · FLUGHAFEN TEGEL
TELEFON 41041

British airways

1 Berlin 52, Flughafen Tegel
Telefon (030) 41 01
Telegramme Britishair

Dilwyn Monk,
Station Engineer,
Flughafen Tegel.

U.S. Administrator
for Aeronautics.
Jerome F. Biron.

18th August 1978

Dear Mr. Biron,

ANTI - NOISE SHELTER - TEGEL AIRPORT BERLIN

I am in receipt of your letter and questionaire about the anti - noise shelter in use at Tegel Airport. The basic facts you require are as follows and apply only the experience of British Airways in the use of this facility.

1. British Aerospace S1-11 aircraft with Rolls Royce Spey engines. On approximately eight occassions per month and whenever power engine runs are required.

2. When the prevailing wind direction is directly into the cell a large amount of turbulence is created which causes certain vibrationary effects in the cell itself together with reingestion of exhaust gases. This occurs, to my knowledge with all aircraft/engine types.

3. No particular equipment other than special protective helmets for the use of the ground staff engaged in outside engine adjustments. No difficulty in the positioning of the aircraft but the actual position is very critical, ie., too far into the cell creates unacceptable vibration and ingestion, and too far out of the cell causes reingestion problems

4. None to my knowledge.

5. Priciple Development Engineer, Mr. Brian Downer, British Airways S1-11, Manchester Airport, England. Mr. Downer was involved in a survey of the facility on behalf of British Airways.

I trust the above information will be of assistance to you.

Sincerely,

DAN-AIR ENGINEERING LTD.

Directors: F. E. F. NEWMAN, M.C. B. V. S. WILLIAMS A. J. SNUDDEN F. HORRIDGE
B. M. O'REGAN R. J. SMITH E. T. EVANS

Gatwick Airport
Near Horley
Surrey

A.R.B. APPROVAL A1/4518/55

Telephone: 01-668 4211 or Crawley 28822
Telex: 87259

All correspondence to be addressed to the Company

In reply please quote

Jerome F. Biron Esq.,
U.S. Administrator for Aeronautics,
Tempelhof Airport,
West Berlin.

22nd August 1978.

Dear Mr. Biron,

I refer to your letter and questionaire dated 15th August, 1978 for which I thank you.

I return under cover of this letter a few relevant points which arise in response to the questionaire although I must confess that my replies do seem rather sparse. However, should you require clarification or amplification on any answer, please do not hesitate to contact me.

May I point out that Mr. Beech is no longer the resident Base Engineer of Dan-Air, Tegel Airport and all further correspondence should be addressed to me accordingly.

Trusting that I have been of some assistance on this matter and I await further communication from you,

Yours faithfully,

R.A.Garrood,
Base Engineer,

REGISTERED OFFICE: 36/38, NEW BROAD STREET, LONDON EC2M 1NH
REGISTRATION No. 545942 ENGLAND

1. Boeing 727-100 and BAC 1-11 300/400 aircraft. Approximately 6 per month of each aircraft type.
2. High wind speeds, dependent upon wind direction, can affect engine parameters.
   Severe icing conditions can make aircraft approach and positioning within pyramid difficult. (See item 3. in respect of positioning).
3. Conventional ground prime mover and tow-bar in respect of equipment. Manpower requirement entails 4 men. One to drive prime mover, one to sit at aircraft brakes and two men to advise on positioning from either wing-tip. Positioning within pyramid is critical in respect of engine performance parameters.
4. Dan-Air have experienced one occasion of aircraft damage due to mis-positioning of aircraft within pyramid. This instance occurred due to aircraft not being positioned centrally within pyramid causing an excessive back airflow across aircraft stub wings resulting in an access panel being lifted and finally coming adrift from aircraft.

RECEIVED
24 AUG 78 '0 4 [illegible]
USAA

aeroamerica
Flughafen Berlin-Tegel
1000 Berlin 52
[illegible]

Chief Maintenance,
Tegel Airport,
August 23, 1978,
Berlin.

Mr. Biron,
U.S. Administrator for
Aeronautics,
Tempelhof Airport.

Dear Mr. Biron,

Attached is the requested information relative to the ainti-noise shelter at Tegel.

I sincerely hope that this information will prove useful in the research by Airports Programs.

Sincerely,

Eric Schröeder
Chief of Mainenance
Aeroamerica

aeroamerica
Flughafen Berlin-Tegel
1000 Berlin 52
[illegible]

1. The aircraft that we run up in the anti-noise shelter is Boeing 720 JT3C-7. This particular aircraft is run up around five times per month, sixty times per year. We have three 720 aircrafts in operation at Berlin.

2. There have been meteorological conditions found to cause difficulties and delays in engine maintenance work in the pyramid. These conditions are westerly and southerlz winds. These winds will cause - particularly in outboard engines to ingest part of the exhaust gases. This is due to the reverser effect of the pyramid. This in turn will lead to misrig of the engine.

3. A regular aircraft tow tractor will place the aircraft in the shelter. It is not difficult to place it. It takes five to seven minutes to put the aircraft into the shelter. The position of the aircraft is not critical for acoustic reasons but it is for aerodynamic performance. Four men will be able to do the job.

4. There has not been any damage so far to the engines or airframes caused by restricted air flow, exhaust gas reingestion, or acoustical loading while in the pyramid. The reverser effect of the pyramid will cause the engine to stall and that may cause damage to the engine.

5. For more detailed answers please contacted one of the following maintenance personal:

   Burckhard Knaul- Maintenance Supervisor
   Wolfgang Krüger- Maintenance Supervisor
   Horst Wuttig- Maintenance Supervisor
   Udo Bieber- Maintenance Supervisor
   Erich Schröder- Chief Maintenance

   phone- 41012729

7.4.2 Düsseldorf

A response from a user of the run-up area (LTU) is included.

LTU

LTU-FLUGGESELLSCHAFT · FLUGHAFEN HALLE 8 · D 4000 DÜSSELDORF 30

Lufttransport-Unternehmen
GmbH & Co. KG
Telex: 8 584 997 (Verkauf)
8 584 895 (Buchung)
8 584 520 (Flugbetrieb) H 24
8 584 712 (Technik)
Telefon Sa.-Nr.:
(02 11) 4 15 21
bei Durchwahl
41 52 - 227
Buchung: 50 66 6

FAA Representative
American Embassy Bonn
Deichmanns Aue

5300 BONN 2

Ihre Zeichen	Ihr Schreiben vom	Unsere Zeichen	Datum
--	3.11.1978	Sto/su	December 22nd 1978

Subject: Noise Barrier - Düsseldorf Airport

Dear Sirs,

In reply to your letter we give you the following information.

LTU only

1)

Aircraft Type	Engines	Run-up per Month
Caravelle SE-210	Pratt&Whitney JT8D-7A	approx. 6 times
TriStar L-1011	Rolls-Royce RB-211-22B	approx. 5 times

2) Yes - on RB-211 engines due to wind directions which are no on line with aircraft. Difficulties are a combination of noise barrier and engine system (fuel control).

3) Towing vehicle - cost approx. $ 180.000,-- (for L-1011)
Towing vehicle - cost approx. $ 50.000,-- (for SE-210)

To position aircraft in barrier takes approx. 10 minutes (both types). No difficulties to position aircraft. Acoustic and aerodynamic performance unknown. Four people required to position aircraft (1 in towing vehicle, 1 in cockpit and 2 outside for guidance).

4) The RB-211-22B can only be operated to max. power under most ideal meteorological conditions. For 90% only part power is possible. Otherwise engine starts buffeting and stalling due to back pressure from the exhaust gases. One engine was destroyed due to surges, no warranty from manufacturer.

5) If necessary, please contact Airport Authorities of Düsseldorf Airport.

We hope our informations are helpfull and remain - whishing you a merry Christmas and a happy New Year -

yours faithfully
L T U
LUFTTRANSPORT-UNTERNEHMEN

H. Stomphorst
(Manager Maintenance/Engineering)

7.4.3 Osaka

A response from the owner, operator, and user (All Nippon Airways Company) is included.

Technical Information on B727 Noise Fence at Osaka Airport

Prepared by

All Nippon Airways Company

1. On the suppression walls at All Nippon Osaka Airport:

The suppression walls at All Nippon Osaka Airport are of the fence type. They were installed in November 1971 by All Nippon as a countermeasure for ground noise at the time of engine test run.

Originally, the size of the suppressor system was 40m in depth, 56m in width, and 8m in height. The system was used for the test runs for YS-11, B-737, and B-727.

In September 1977, the height of the back wall was increased to 10m so that the system could also be used for L-1011. Its effect on the surrounding area was to decrease the noise levels by 5-15 dB(A). And thus we consider the suppressor system is playing a big role for the preservation of the environment.

2. Answers to questions:

A. Questions concerning ownership and operation of the noise fence.

(1) Measurements of noise:

Measurements of noise were carried out in November and December 1971. See a separate report for details. The essential part of the report is as follows: (see the table)

1. Airframe

2. Engine JT8D-9

3. Meteological Conditions

Weather : Cloudy
Temperature: 13° C
Wind Speed: 4 kt
Height of Cloud: 6,000 ft.
Direction of Wind: 30°

4. Height of Microphone: 1.2m

5. Thrust of Engine: 1 eng t/o power

6. Results of Measurements: Noise levels at points 100m from the engine

Angle from the Nose	Noise Level (with Suppression Walls)	Noise Level (Without Suppression Walls	Decrease in Noise Levels
0	103	101	-2
45	104	103	-1
90	91	105	14
135	95	110	15
180	97	106	9
225	98	110	12

(Refer to Fig. 4 of the separate report for frequency analysis data)

7. Results of Measurements (2): Noise levels at the surrounding of the airport

Measurement Points			Noise Level (average)
No.	Angle from the aircraft nose	Distance	
P1	75°	850m	57
P2	135°	630m	68
P3	205°	470m	66
P4	340°	890m	80

(Refer to Fig. 5 of the separate report for frequency analysis data)

(2) Restrictions for engine test runs at Osaka Airport:

At Osaka Airport, as a rule, jet engines (regardless of their output powers) must be run in the suppression walls. Although No. 2 Engine of DC-10 is allowed to run outside the suppression walls, because the height of the exhaust vent is too high for the suppression walls, the time for test run and the maximum output power are restricted, mainly from noise considerations.

(3) Restrictions for the use of suppressor due to meteorological conditions:

So far, there has been no instances that made it impossible to use the suppressor because of meteorological conditions. It is quite conceivable, however, that if the wind speed exceeds 15 m/s due to typhoons the use of the suppressor system would be impossible.

The use of the suppressor system is restricted only when the wind from back (tail wind) is strong. From experiences, the following restrictions are imposed for each aircraft.

Wind / Aircraft	Nose Wind ~ No Wind	No Wind ~ Tail Wind 5 knots	Tail Wind 5 knots ~ Tail Wind 10 knots	Tail Wind 10 15 knots or more
YS-11	No Restrictions			Idle only 1)
B737 & B727	No Restrictions			No trim run 2)
L1011 3)	No restriction	No restriction for wing engines Ground idle only for center engine	Up to flight idle for wing engines Up to ground idle for center engines	

1) The restrictions were put in force after we observed three occasions of resonance phenomenon of propeller system due to tail wind.

2) The restrictions were put in force after we observed four or five instances of the cases that the effect of back pressure due to tail wind caused errors in power setting.

3) We made these restrictions in order to avoid compressor stall due to back pressure. (Note that we did not decide these restrictions because of the actual experience of compressor stall.)

(4) Cost of construction:

The cost for the design and construction of the system was 60 million year at 1971. (The cost does not include the cost of foundation work.) The maintenance cost is very small and is at the level of the electric bulbs used for illumination and can be considered negligible.

B. Questions concerning use of the fence:

(1) Aircrafts used and run-up data:

Initially, the facility was built for YS-11, B-737, B-727. In September 1977, it was modified in consideration for the use of L-1011. As a result, this facility could be used for all aircrafts, including those used in international lines, except No. 2 Engine of DC-10.

Most recent run-up data for our aircrafts are as follows:

Aircraft	Engine	Number of Run-ups (Monthly Average)
YS-11	Dart MK543-10	87
B737-281	JT8D-9, -17	13
B727-281	JT8D-9, -15, -17	27
L-1011-1	RB211-22B	7

In addition to the above, this facility is used by aircrafts of other companies 0~2 times a month.

(2) Restrictions due to meteorological:

See A (3)

(3) Auxiliary facilities and positioning of test run aircraft:

No special auxiliary facilities are needed. Positioning of aircraft can be done by a regular towing and no extra personnel or time are needed.

From the viewpoint of noise suppression, the positioning of the aircraft near the fence is more effective, but because of the effects on the strength of fence and the performance of engine, we have decided as follows. (Note that the strength of fence is made such that the blast fence will withstand the air velocity of 150 m/s and the noise fence 100 m/s.) (Before September 1977.)

The distance between the engine exhaust vent and noise fence (up to September 1977):

Aircraft	Normal Case	In the Case of Trim Run
B727	21 m	31 m 1)
B737	23.5 m	

1) From the viewpoint of the strength of fence, the distance of 21 m may be permissible in the case of trim run. However, in this case the effect of back pressure is such that it causes errors in power setting. So we made the distance to be 31m. This is not the case for B-737, however.

In September 1977, the height of the back wall was increased so that test run of L-1011 may be made. In this modification the strength of the fence was increased so that the blast fence can withstand the air speed of 170 m/s and noise fence 120 m/s.

As a result of this modification, the test run position has been changed as follows:

Test run position (after September 1977):

Aircraft	Distance Between Engine Exhaust Vent and Noise Fence
B727	33 m
B737	30 m
L-1011	19 m If we must run the center engine up to take-off power with tail wind, then 26m or 31m.

1) The distance from the end point of center engine to the noise fence.

(4) Effects of restricted air flow, exhaust gas reingestion, and acoustical loading:

So far we experienced no effects of such factors. So far no changes in guarantee and warranty from airframe/engine manufacturers.

C. Questions to the designers:

(1) Acoustic loadings:

Because there are sufficient distances between the airframe and the walls and, in fact, it is an open space, we pay no particular attention to the acoustic loadings to the airframe structure.

(2) Flow constriction. Exhaust gas reingestion:

We pay no particular attention. However, from experience we set restrictions for the use of the facility for tail wind condition.

(3) Test run position:

Main objective is "noise fence" and so we do not consider an accurate positioning for test run to be critically important.

(4) Envelopes of meteorological conditions:

We do not think they have much to do with the noise prevention and accoustic loading.

In the case of tail wind, in order to prevent the effect of engine performance and compressor stall, we sometimes move the airframe forward. Other than this, we do not pay any particular attention as far as design is concerned.

(5) Aircrafts used:

The following aircrafts were actually used in this facility. YS-11, B737, B727, L-1011, B747SR, A300, and B707.

(6) (7) Test run noise levels measured at four points in the surroundings.

Estimation and measurement of noise were done for B737.

dB(A)

Measurement Points			Noise Level		
No.	Angle from the Aircraft Noise	Distance	Measured Values (Avg. Values)	Estimated Values at the Time of Design	Estimated Values w/o Suppression Walls
P1	75°	850m	57	65	70
P2	135°	630m	68	65	75
P3	205°	470m	66	70	85
P4	340°	890m	80	80	80

For details of actual measurements, refer to A(1) and a separate report.

To whom to inquire about A(5), B(5), and C(8).

The suppression walls were built by

Installer: All Nippon Airways

Design: Kobayashi Rigaku Kenkyusho

Construction: Shin-Nihon Seitetsu

Technically, the following person is familiar with almost all aspects of this facility, and so any inquiries should be addressed to him:

Mr. Hisashi Ikeda, Senior Engineer
Engineering and Maintenance Division
All Nippon Airways
Telephone: (747) 5461
Telex: 2466384 TYO EZ

7.4.4 Zurich

Responses, based on a vist to Swissair offices in Zurich, by Dr. David Braslau are included.

Question 1: Sound level measurements

Other than measurements made by the Swiss Airports Authority (available at the Minneapolis-St. Paul Metropolitan Airports Commission), Swissair was primarily interested in a maximum noise level at the settlement of RÜmlang, located just west of the airport. The goal for all suppressors was a maximum of 50 dBA, at an angle of 45° from the tail direction of an aircraft which was being run-up. This corresponds with the maximum lobe of a typical jet noise contour. Measurements were to be made under standard atmospheric conditions, and with no wind. For all of the suppressors, the maximum level was never exceeded, and in general fell several dBA below this, ranging from 46 - 49 dBA. It is clear, that under this design criterion, there was no necessity for complex noise measurements at various distances and in different directions. The noise levels were also be be met for maximum power settings of the engines during ground run-up.

Question 2: Requirements for Run-up

The use of suppressors is required for all aircraft running up at Kloten. Where a suppressor is not available, for example for an Ilyshin or Tupolev aircraft, permission may be granted to run at a selected location on the field without the suppressor. General aviation jets are also required to use the run-up area, primarily the B747 facility, which is equipped with forward screen walls. This provides shielding for the smaller aircraft, and at the same time provides an exhaust muffler which can easily accommodate exhaust flows from these types of aircraft. Only under very severe wind conditions may run-ups be cancelled, but as discussed below under suppressor use, there have been no problems with compressor stall or reingestion during suppressor use.

Question 3: Critical Meteorological Conditions

Wind rose data for the airport were obtained and are plotted on the attached page. It can be seen that there are two general directions for wind at the airport, although all directions are well represented. Only a very small percentage of velocities above 21 knots has been recorded, with these being mainly in the 060 and 250 directions. The general orientation of the suppressors is 150°, which is neither parallel nor perpendicular to the primary maximum wind directions. Thus, a previous argument that wind conditions at Kloten are more favorable for the use of noise suppressors cannot be substantiated. It should be noted that only once since the suppressors have been in operation, has a ground run-up been cancelled.

Question 4: Suppressor Cost

The following table gives the cost of each suppressor and date of construction:

Suppressor	Date of Construction	Manufacturer	Cost	Remarks
DC-9	1968	Schneider	200,000 SF	Tube cost only
B747	1971	Gerber	1,330,000 SF	Steel only
DC-10	1972	Gerber	1,260,000 SF	Tubes only
DC-8	1968	Gerber	870,000 SF	Tubes only
Apron Heating			20,000 SF	200 w/m^2

The above costs include design and construction. It should be noted, that since the devices are supplied by manufacturers, the design costs are included in the total construction price.

Swiss air initially thought that construction of a hushhouse would be the best way to solve the ground-run-up problem. This was discarded as too complex and costly. The original suppressors were completely mobile (Cullum for the DC-9 and Caravelle) since it was thought that the aircraft would have to be pointed into the wind. In 1967, the fixed Gerber suppressors for the DC-8 were constructed, followed by the other suppressors noted above.

Maintenance of suppressors is minimal.

Question 1 - Aircraft and Engines Run-up at Facilities

Almost all types of aircraft have been run-up at the Swissair facilities. These include:

- All DC-9 models
- All DC-8 models
- B727
- B737
- B747
- Caravelle
- DC-10
- Most General Aviation Jets
- TU 104
- TU 134
- TU 154
- Trident

No specific records of the number of run-ups by each type of aircraft were obtained, but there are generally four run-ups per day at the facilities. (This should be confirmed.)

Question 2 - Critical Meteorological Conditions

As noted above, there have been almost no conditions under which run-ups could not be made. Only once was a run-up cancelled because of winds. The heated apron enables run-ups to be made under adverse ground cover conditions.

The most critical engine is the JT9D, and some initial probelms were found with run-ups with this aircraft. However, a simple solution was developed. For runs, a wind meter showing speed and direction was mounted in front of the aircraft, with a clear view of the parameters by the pilot or mechanic at the controls. When the wind speed or direction exceeded certain prescribed values, the throttles could simply be retarded, thus avoiding damage to the engines. This appears to have solved the problem for a very small additional cost.

Question 3 - Ground Equipment Requirements

Except for a tractor, no other special equipment is required for placement except for positioning flags (to assist the driver) and wheel chocks. The suppressor location is used to train tractor dirvers, since there is much less chance of damaging an aircraft there than in a hangar, and the positioning is not as critical. The noise level guarantees will be met by the 747 and the DC-10, when placed according to pavement markings. With the DC-9 suppressor, a distance of 60-80 cm between the engine exhaust and suppressor inlet is required. Because of differences in design of some DC-9 aircraft, the suppressor must be adjusted for vertical flow direction also.

Question 4 - Damage to Airframe/Other Problems

No damage has been noted to date (10 years) at the Swissair suppressors. Other than the above noted snowplow damage to the DC-8 suppressor, not damage or incidents of aircraft colliding with suppressors has been noted. Detailed discussions are held with engine manufacturers prior to suppressor use to ensure that this is satisfactory with the engine manufacturer. To date, no manufacturer has objected or modified any agreements. Swissair is presently reviewing the new suppressors for the DC-9-80 with Douglas Aircraft and Pratt and Whitney, which will be using the new JT8D-209 engine.

It should be noted that damage did occur with the first portable suppressors, since placement was difficult and very time consuming. No problems have been noted with the fixed suppressors, however.

Schneider DC-9 Suppressor

Most of the questions related to performance and problems have been covered above. Specific data on noise measurements for the DC-9 suppressor is as follows:

DC-9 Takeoff power
Engine located 50cm from inlet of silencer
Measurements are made at 30^o from tail direction of aircraft.

Frequency (HZ)	Attenuation (dB) 200 Feet	Attenuation (dB) 2400 M (Rümlang)
63	24	11
125	28	17
250	34	12
500	31	11
1000	31	10
2000	27	7
4000	15	2
8000	9	0
dBA	27	~10

It can be seen that the suppressor is very effective for all frequencies at 200 feet, and less effective for higher frequencies at the longer distance, mainly because these frequencies do not play a significant role at this distance. However, it appears that the attenuation of 10 dBA is sufficient to meet the 50 dBA maximum limit set at the 2400m measurement point. It should also be noted that the 200 feet point was used by Douglas Aircraft in their noise measurement work.

A new Schneider DC-9 suppressor has been built in Vienna for the DC-9-31 and DC-9-52 models. The difference between the present and the new suppressor is that the newer model has an eval opening (long axis vertical), rather than a circular opening. This simplified the vertical adjustment for the suppressor and allows it to be slightly more effective. The Vienna suppressor at the 200 foot measurement point had a reduction of 29 dBA, compared to the 27 dBA measured at the Zurich suppressor.

The plans for the new Zurich DC-9-80 suppressor were reviewed. An intake screen will be provided in the new design, and the tubes will exhaust through a single chimney. The design has not yet been finalized, and several variations for the intake noise reduction are being considered.

7.5 SELECTED ACOUSTICAL DATA

Selected examples of acoustical data available for run-up facilities are included here.

7.5.1 Berlin

Plotted data (based upon data from Reference 15) are shown for the BAC111, run-up at three different positions within the noise "pyramid". The plot indicates the loss of some effectiveness for different locations within the noise facility.

7.5.2 Osaka

Selected results from a noise measurement report (Reference 24) are reproduced here. The results indicate surprisingly high reductions in the near field, and attenuation at least as great as theoretical computations might indicate in the far field.

7.5.3 London

The detailed tests and readings for a Trident aircraft indicate the level of detail which might be needed for evaluation of such suppressors in other locations.

7.5.4 Coanda/Refraction Noise Suppression Concept

Some selected curves for tests on the prototype device are included here. The curves indicate a relatively constant effectiveness with distance. The radial measurements provide a complete picture of effectiveness with direction, and octave band data are provided for each radial direction at the far field points (defined as 250').

7.5.1 Berlin

Plotted data (based upon data from Reference 15) are shown for the BAC111, run-up at three different positions within the noise "pyramid". The plot indicates the loss of some effectiveness for different locations within the noise facility.

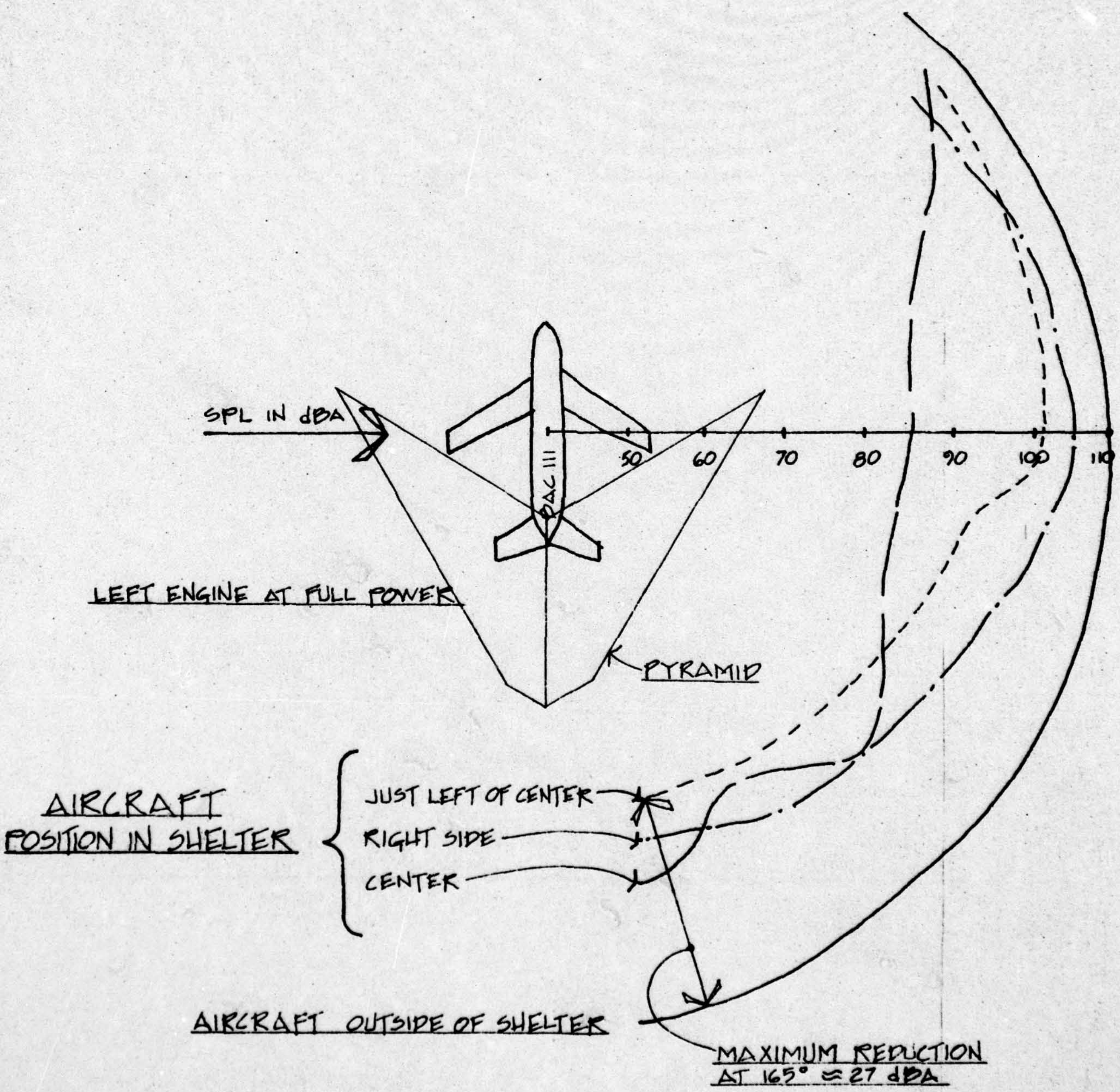

FIGURE 7-1

Tegel Pyramid

Observed Noise Levels at 100 Meters from Aircraft

7.5.2 Osaka

Selected results from a noise measurement report (Reference 24) are reproduced here. The results indicate surprisingly high reductions in the near field, and attenuation at least as great as theoretical computations might indicate in the far field.

3. Results of investigation by All Nippon Airways (Taken from Reference 24)

3-1 Meteorological conditions at the time of investigation:

Meteorological conditions are important in the propagation of noise to distant places. The meteorological conditions at the present investigation were as follows:

	First Test	Second Test
Weather:	Cloudy	Clear
Height of clouds:	6000 ft	--
Temperature:	13° C	6 or 7° C
Direction of wind:	30°	240°
Speed of wind:	4 knots	9 -14 knots

3-2 Noise levels near suppression walls:

Table 1 shows the results of actual measurements of noise levels at measuring points 100m from the center of engine. In this table, as a comparison, we included the noise levels measured when no suppression walls were present (the values were based on the data obtained for B-737 at the previous test) and the difference between the noise levels with and without the suppression walls. (The difference indicates the decrease in the noise level due to the presence of the suppression walls.)

Table 1: Noise levels at points 100m from the engine and the effects of suppression walls.

Position		Noise Level at Test Run with Suppression Walls	Noise Level without Suppression Walls	Decrease in Noise Level Due to the Presence of Suppression Walls
No.	Angle From the Nose			
F-1	0°	103 dB(A)	101 dB(A)	-2*
F-2	45	104	103	-1*
F-3	90	91	105	14
F-4	135	95	110	15
F-5	180	97	106	9
F-6	225	98	110	12

* - indicates the increase of level.

3-3 Noises at airport surroundings:

Table 2 shows the results of measurement of noise levels (at take-off power) at five representative points surrounding the airport. Since the measurement points are 500m away from the test run position, the noise level changes with time. Therefore, in the table we have shown both the range of fluctuations and the average values.

In the figure, we have shown the estimated noise levels at each point assuming there are no suppression walls and the airport surroundings are open and flat so that there are no obstacles between the test run point and the measurement points.

We have also shown the designed values of noise levels (including the effects of the buildings in between the test run point and the measurement points) with the suppression walls installed.

Table 2: Engine test run noise levels at five points surrounding the airport. (One B737 engine at take-off power.)

Measurement point		Measured Value (Average and Range of Fluctuations) dB(A)	Designed Value with Suppression Walls dB(A)	Estimated Value w/o Suppression Walls & w/o Obstacles dB(A)
Number	Distance			
P-1	850m	57 (55~58)	65	70
P-2	630	68 (66~71)	65	75
P-3	470	66 (65~67)	70	85
P-3-1	720	73 (72~74)	75	90
P-4	890	80 (78~82)	80	80

At Points P-1~P-3-1, the noise levels with the suppression walls were 57~73 dB(A) and they are close to or less than the designed values. So we consider that the present suppression walls are useful in decreasing the test run noise levels at these measurement points. We believe that we obtained the results that we anticipated.

It is noted that the actual measurement points are different from the "calculation points" used for design purposes. Therefore, we intend to make calculations for the actual measurement points and report the results in a separate paper.

Point P-4 faces the open side of the suppression walls. So from the beginning we expected that the suppression walls would give no useful effects to such point.

7.5.3 London

The detailed tests and readings for a Trident aircraft indicate the level of detail which might be needed for evaluation of such suppressors in other locations.

Introduction

On the 25th January, 1964 tests were made at the B.E.A. Engineering Base, London (Heathrow) Airport of the noise of a Trident 1 Aircraft (Spey engines fitted with noise suppressors) runningup on the ground with and without Cullum Ground Mufflers.

Measurements

2. Measurements were made on the port side at points on a circle of 300 ft. radius with its centre on the centre of the exit of the port engine. Corresponding symmetrical positions were used on the starboard side. The measuring positions are illustrated in Fig.1.

TABLE I

Details of the Measuring Positions around the Trident and Association of Positions with Runs

Operating Condition	Engine R.P.M.	ANGLE FROM JET AXIS (degrees)								
		30	45	60	90	30	45	60	90	180
		PORT SIDE RUN NO.				STARBOARD SIDE RUN NO.				
MUFFLED										
3 Engines Idling	6,500	1	1	1	1					1
Port Engine Cruise	11,500	2	2	2	2					2
Port Engine Maximum	12,400	3	3	3	3					3
3 Engines Idling	6,500					4	4	4	4	4
Starboard Engine Cruise	11,500					5	5	5	5	5
Starboard Engine Maximum	12,400					6	6	6	6	6
UNMUFFLED										
3 Engines Idling	6,500					7	7	7	7	7
Starboard Engine Cruise	11,500					8	8	8	8	8
Starboard Engine Maximum	12,400					9	9	9	9	9
3 Engines Idling	6,500	10	10	10	10					10
Port Engine Cruise	11,500	11	11	11	11					11
Port Engine Maximum	12,400	12	12	12	12					12

3. Throughout the tests the weather was good, the temperature being about 3°C, the relative humidity 80% and the wind 230°/04 knots.

Results

4. The results are summarised in Table II and details of the Octave Band Analysis are given in Appendix A. PNdB's have been calculated on the 1959 (original) basis.

TABLE II

Measurements made at 300 feet from the Tridents Engines

Aircraft Operating Conditions	ANGLE FROM JET AXIS (degrees)																	
	30		45		60		90		30		45		60		90		180	
	OA SPL dB	PN dB	OA SPL dB	PN dB	OA SPL dB	PN dB	OA SPL dB	PN dB	OA SPL dB	PN dB	OA SPL dB	PN dB	OA SPL dB	PN dB	OA SPL dB	PN dB	OA SPL dB	PN dB
MUFFLED	PORT SIDE								STARBOARD SIDE									
3 Engines Idling Power	84	94	88	99	81	99	-	-	-	-	-	-	-	-	-	-	84	101
Port Engine Cruise Power	98	107	98	109	100	111	92	105	-	-	-	-	-	-	-	-	92	103
Port Engine Max Power	99	109	100	110	101	113	95	108	-	-	-	-	-	-	-	-	92	102
3 Engines Idling Power	-	-	-	-	-	-	-	-	83	94	86	95	84	97	80	92	83	100
Starboard Engine Cruise Power	-	-	-	-	-	-	-	-	100	108	101	110	98	110	92	105	92	105
Starboard Engine Max. Power	-	-	-	-	-	-	-	-	101	109	101	110	101	112	94	108	92	104
UNMUFFLED	PORT SIDE								STARBOARD SIDE									
3 Engines Idling Power	-	-	-	-	-	-	-	-	84	92	88	95	83	94	-	-	82	95
Starboard Engine Cruise Power	-	-	-	-	-	-	-	-	118	125	120	127	115	121	106	117	99	106
Starboard Engine Max Power	-	-	-	-	-	-	-	-	122	129	122	129	116	123	107	119	100	108
3 Engines Idling Power	83	94	87	98	86	100	80	94	-	-	-	-	-	-	-	-	82	97
Port Engine Cruise Power	121	127	120	127	116	126	106	118	-	-	-	-	-	-	-	-	100	107
Port Engine Max. Power	122	129	122	129	118	127	107	118	-	-	-	-	-	-	-	-	101	108

TABLE IV

Noise Reduction due to Mufflers

Engine Operating Condition	ANGLE FROM JET AXIS (degrees)																	
	30		45		60		90		30		45		60		90		180	
	Noise Reduction - Port Side								Noise Reduction - Stbd. Side								Ahead	
	dB	PNdB	dB	PNdB	dB	PNdB	dB	PNdB	dB	PNdB	dB	PNdB	dB	PNdB	dB	PNdB	dB	PNdB
3 Engines Idling Power	-1	0	-1	-1	-1	1	-	-	1	-2	2	0	-1	-3	-	-	-2+	-4+
Port Engine Cruise Power	23	20	22	19	16	15	14	13	-	-	-	-	-	-	-	-	8	4
Port Engine Max Power	23	20	22	19	17	14	12	10	-	-	-	-	-	-	-	-	9	6
Starboard Engine Cruise Power	-	-	-	-	-	-	-	-	18	17	19	17	17	11	14	12	7	1
Starboard Engine Max Power	-	-	-	-	-	-	-	-	21	20	21	19	15	11	13	11	8	4

+MAXIMUM Value

Noise Measurements Made at 300 feet from the Trident

Angle from Jet Direction (degrees)	Operating Condition	Engine Power	Sound Pressure Level dB re 0.0002 dynes/cm^2 in Octave Bands 37.5-9,600 CPS								Overall Sound Pressure Level (dB)	Perceived Noise (PNdB)
			1	2	3	4	5	6	7	8		
30 Port	Unmuffled	3 Engines Idling	77	78	76	75	70	73	69	64	83	94
30 "	Muffled	" "	79	79	74	73	72	75	68	63	84	94
30 Port	Unmuffled	Port Engine Cruise	112	116	116	114	108	106	98	89	121	127
30 "	Muffled	" "	92	91	90	89	87	88	84	75	98	107
30 Port	Unmuffled	Port Engine Max	112	116	118	116	108	107	101	92	122	129
30 "	Muffled	" " "	94	92	91	90	92	90	86	76	99	109
45 Port	Unmuffled	3 Engines Idling	79	82	78	80	75	76	73	69	87	98
45 "	Muffled	" "	82	83	76	76	74	76	80	66	88	99
45 Port	Unmuffled	Port Engine Cruise	106	114	114	114	108	106	100	90	120	127
45 "	Muffled	" "	93	92	90	90	88	88	86	78	98	109
45 Port	Unmuffled	Port Engine Max	113	115	118	116	110	106	100	90	122	129
45 "	Muffled	" " "	94	94	90	91	90	92	87	78	100	110
60 Port	Unmuffled	3 Engines Idling	79	80	79	77	70	74	76	73	86	100
60 "	Muffled	" "	79	84	77	75	74	74	74	70	87	99
60 Port	Unmuffled	Port Engine Cruise	105	111	113	108	105	101	103	93	116	126
60 "	Muffled	" "	91	95	92	90	89	89	88	82	100	111
60 "	Unmuffled	Port Engine Max	106	112	114	110	107	103	104	95	118	127
60 "	Muffled	" " "	93	96	93	91	91	91	91	83	101	113
90 Port	Unmuffled	Port Engine Cruise	96	101	100	97	93	96	97	90	106	118
90 "	Muffled	" "	84	83	83	86	87	84	82	76	92	105
90 Port	Unmuffled	Port Engine Max	97	102	98	98	96	97	98	91	107	118
90 "	Muffled	" " "	83	88	87	87	88	85	87	80	95	108

180	Unmuffled	3 Engines Idling	75	73	73	70	72	72	71	71	82	97
180	Muffled	" "	74	75	72	72	73	74	71	75	83	100
180	Unmuffled	Port Engine Cruise	89	95	97	91	86	81	76	75	100	107
180	Muffled	" "	83	85	84	82	83	78	81	75	92	103
180	Unmuffled	Port Engine Max	89	95	98	92	88	82	79	75	101	108
180	Muffled	" " "	83	86	83	84	82	79	77	73	92	102
180	Unmuffled	STBD Engine Cruise	87	94	95	89	86	81	83	74	99	106
180	Muffled	" "	82	82	84	82	84	81	84	74	92	105
180	Unmuffled	STBD Engine Max	88	95	96	91	91	84	84	73	100	108
180	Muffled	" " "	82	84	84	84	84	81	83	74	92	104

APPENDIX A

Angle from Jet Direction (degrees)	Operating Condition	Engine Power	Sound Pressure Level dB re0.0002 dynes/cm^2 in Octave Bands 37.5-9,600 CPS								Overall Sound Pressure Level (dB)	Perceived Noise (PNdB)
			1	2	3	4	5	6	7	8		
90 STBD	Unmuffled	STBD Engine Cruise	95	100	100	100	97	97	95	86	106	117
90 "	Muffled	" "	83	83	82	85	87	85	83	76	92	105
90 STBD	Unmuffled	STBD Engine Max	96	101	101	101	98	97	97	91	107	119
90 "	Muffled	" " "	83	86	86	86	87	83	87	80	94	108
60 STBD	Unmuffled	3 Engines Idling	79	77	76	74	71	69	69	65	83	94
60 "	Muffled	" "	77	77	76	72	70	74	72	69	84	97
60 STBD	Unmuffled	STBD Engine Cruise	105	111	110	106	102	99	94	84	115	121
60 "	Muffled	" "	81	82	82	91	91	91	89	82	98	110
60 STBD	Unmuffled	STBD Engine Max	107	113	111	108	104	99	96	86	116	123
60 "	Muffled	" " "	91	94	93	93	94	91	90	82	101	112
45 STBD	Unmuffled	3 Engines Idling	82	80	79	79	74	76	70	64	88	95
45 "	Muffled	" "	80	80	76	74	72	78	70	64	86	95
45 STBD	Unmuffled	STBD Engine Cruise	112	114	116	113	107	106	99	89	120	127
45 STBD	Muffled	" "	96	92	92	94	94	92	87	76	101	110
45 STBD	Unmuffled	STBD Engine Max	113	115	118	116	110	106	100	90	122	129
45 "	Muffled	" " "	86	94	92	95	96	94	88	76	101	110
30 STBD	Unmuffled	3 Engines Idling	79	79	76	74	71	72	67	62	84	92
30 "	Muffled	" "	79	76	72	73	71	76	69	64	83	94
30 STBD	Unmuffled	STBD Engine Cruise	110	114	112	109	106	103	98	88	118	125
30 "	Muffled	" "	94	91	91	92	90	90	84	73	100	108
30 STBD	Unmuffled	STBD Engine Max	112	116	118	116	108	107	101	92	122	129
30 "	Muffled	" " "	95	92	92	93	93	90	86	74	101	109

7.5.4 Coanda/Refraction Noise Suppression Concept

Some selected curves for tests on the prototype device are included here. The curves indicate a relatively constant effectiveness with distance. The radial measurements provide a complete picture of effectiveness with direction, and octave band data are provided for each radial direction at the far field points (defined as 250').

AD-A075 348 BRASLAU (DAVID) ASSOCIATES INC MINNEAPOLIS MN F/G 1/4
GROUND RUN-UP NOISE CONTROL FACILITIES FOR CIVIL AIRCRAFT - A S--ETC(U)
JAN 79 D BRASLAU W1-78-5339-1
UNCLASSIFIED FAA-RD-79-17 NL

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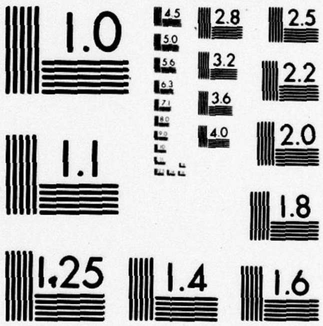


MICROCOPY RESOLUTION TEST CHART

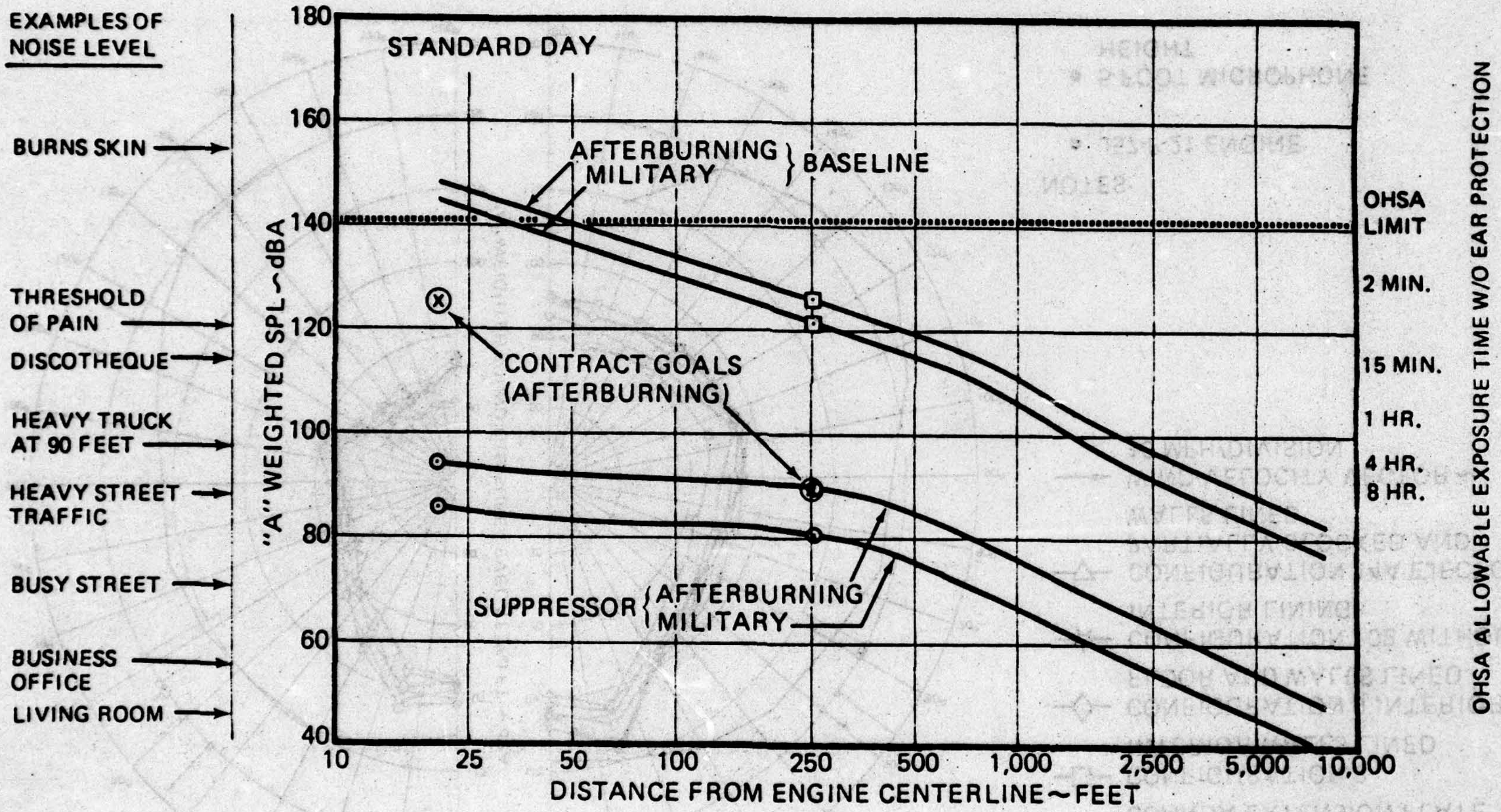
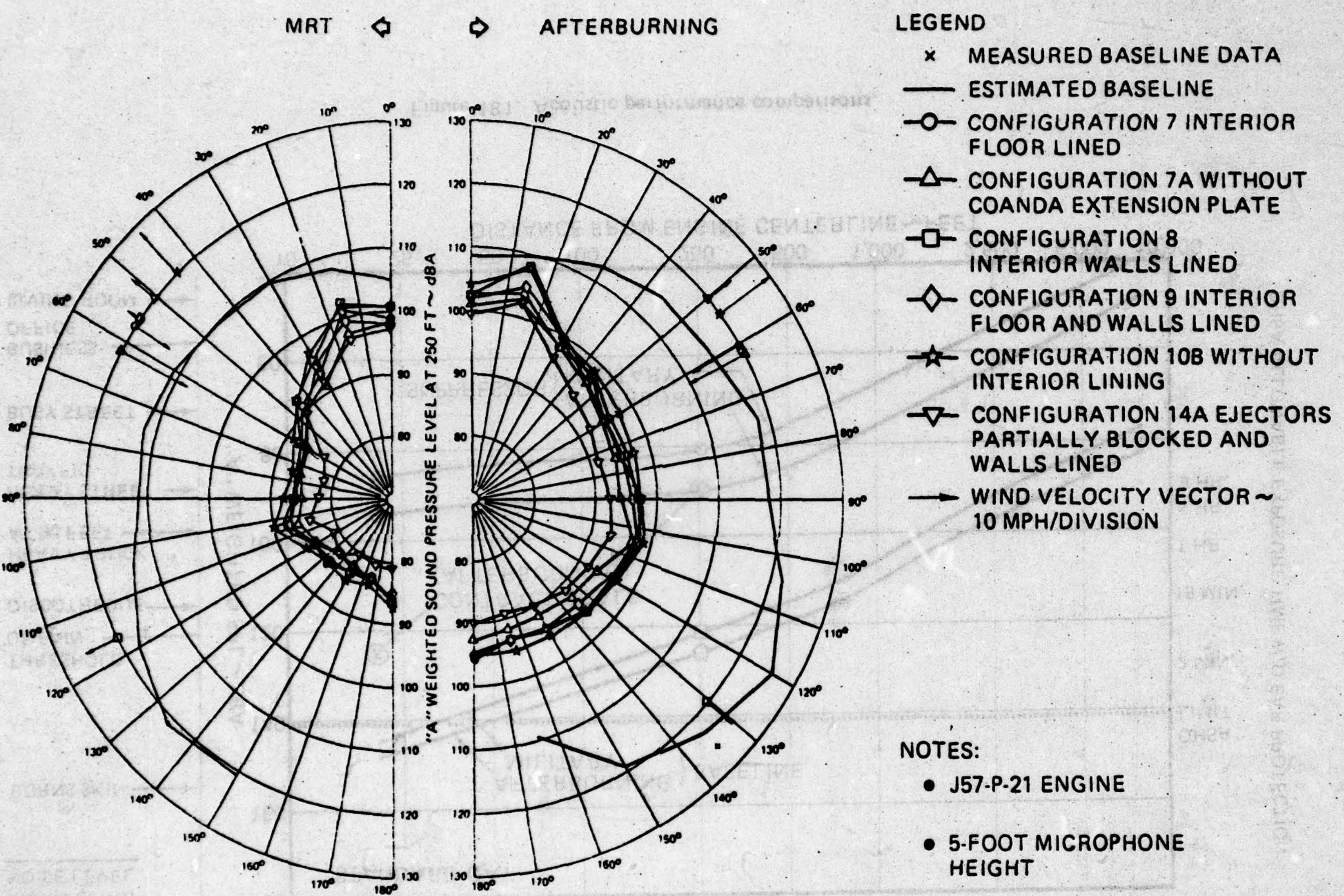


Figure 181. Acoustic performance comparisons.



NOTES:

- J57-P-21 ENGINE
- 5-FOOT MICROPHONE HEIGHT

Figure 157. Comparison of suppressor far field acoustic performance.

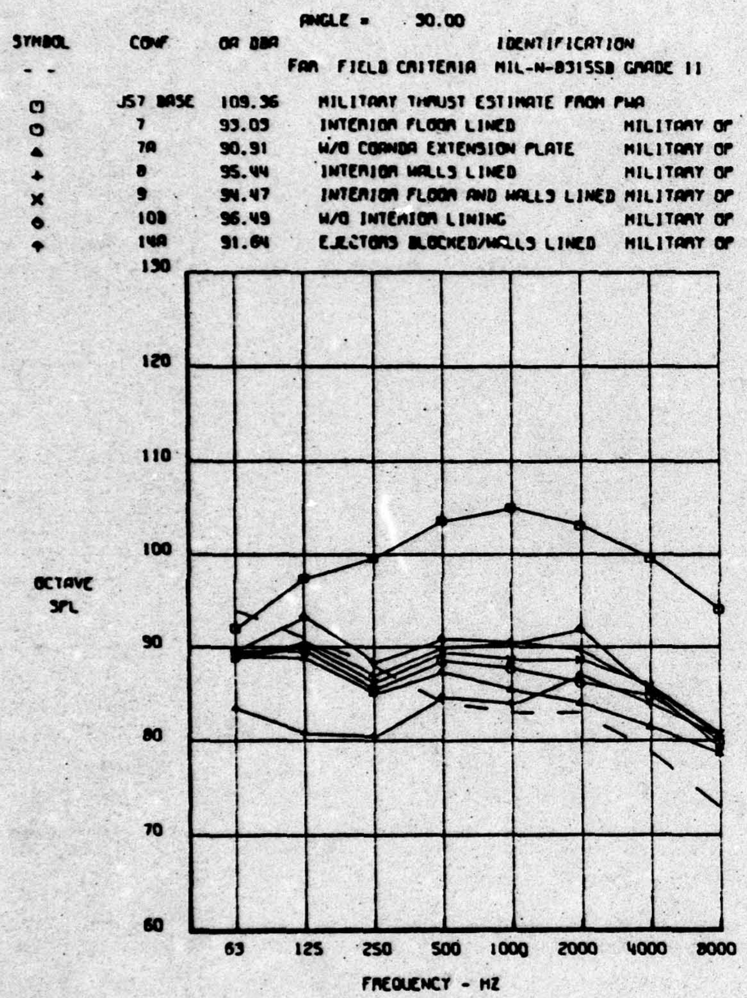


Figure 158. Comparison at MRT of suppressor acoustic performance at 30° to engine inlet.

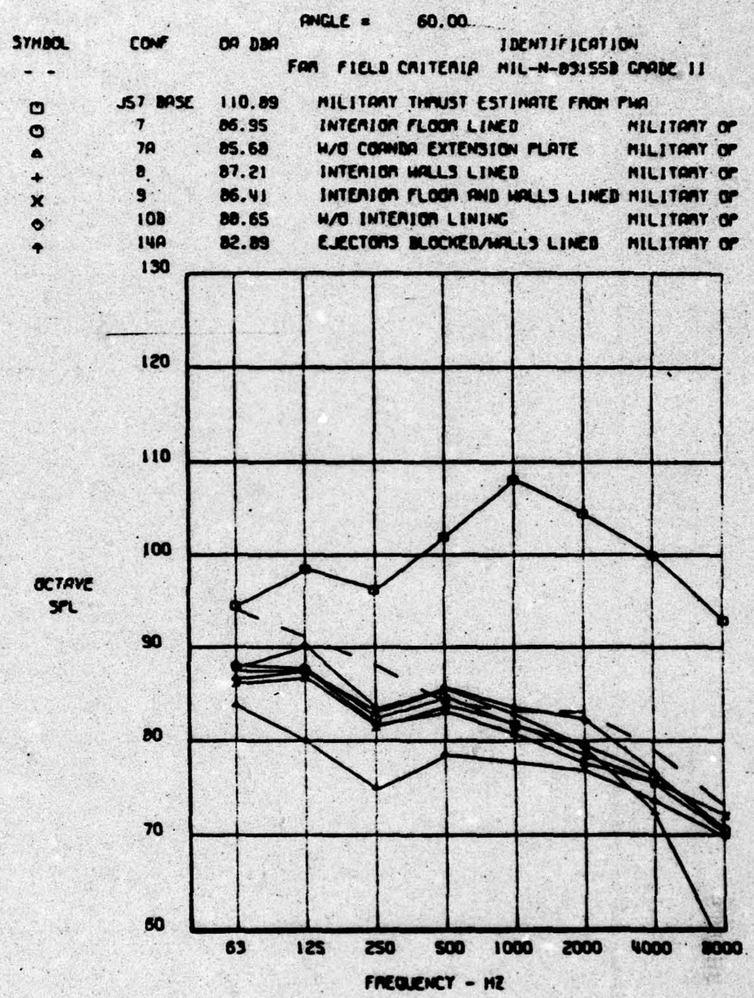


Figure 159. Comparison at MRT of suppressor acoustic performance at 60° to engine inlet.

7.6 DATA SHEETS

Cullum DC 8 Suppressor - Amsterdam		ID No. A1-1
Source of Data: Dunn Report	Date Prepared: May 1974	Location/Airport: Amsterdam/Schipol
	Owner/Operator: KLM	Date of Installation: 1951

Vendor/Designer: Cullum Detuners Ltd., London	Site Requirements: Approximately 1,000 m^2
Type of Suppressor/Barrier: Mufflers (four) (previously used for NATO aircraft)	Aircraft and Engine Types/Users: DC 8-63
Construction Cost: Not available	Maintenance Requirements/Cost: Not available
Safety Requirements: Not available	Set-Up Requirements: Aircraft must be carefully placed (some difficulties encountered)
Wind/Meteorology Restrictions: Not available	Effects on Engine Performance or Airframe: Not available
Current Use: Rarely used	
Acoustical Performance: No muffler 48-56 dBA (2 km) With muffler 42-61 dBA (2 km)	

Noise Wall - Amsterdam

ID No.
A1-2

Source of Data: Dunn Report	Date Prepared: May 1974	Location/Airport: Amsterdam/Schipol
	Owner/Operator: KLM	Date of Installation: 1971

Vendor/Designer: Not available	Site Requirements: Surrounds maintenance area
Type of Suppressor/Barrier: Concrete wall, 11 m height, 50° to horizontal	Aircraft and Engine Types/Users: All KLM aircraft
Construction Cost: Not available	Maintenance Requirements/Cost: Not available
Safety Requirements: Normal procedures	Set-Up Requirements: Not required
Wind/Meteorology Restrictions: No information available	Effects on Engine Performance or Airframe: No information available

Current Use:
All maintenance evidently carried out within walls

Acoustical Performance:
Walls give reductions of 5 to 9 dBA under normal atmospheric conditions (probably at 2 km but not specified)

Noise Shelter - Berlin/Tegel	ID No. B1-1

Source of Data: Dunn Report Berlin Airport Technical University Berlin Airline Users	Date Prepared: May 1974 August 1978 April 1975 1978	Location/Airport: Berlin - Tegel
	Owner/Operator: Berlin Airport	Date of Installation: 1974

Vendor/Designer: Thomas J. Meyer and Partners, Hamburg	Site Requirements: Approximately 4,500 m^2
Type of Suppressor/Barrier: Open-ended "hush-house" or "noise pyramid"	Aircraft and Engine Types/Users: All
Construction Cost: Planning costs: DM 400,000 Construction: DM 5 million (1974)	Maintenance Requirements/Cost: DM 30,000
Safety Requirements: Normal equipment	Set-Up Requirements: Placement critical for performance: 1 in tow vehicle 1 in aircraft 1 at tail
Wind/Meteorology Restrictions: 90° crosswind and greater	Effects on Engine Performance or Airframe: Full power run causes tail to vibrate on BAC 111-500 and B727-100 Mispositioning caused back airflow over wings causing detached access panel

Current Use: Required of all aircraft ground runups
Acoustical Performance: Maximum reduction of 27 dBA (100m from the engine at 165°)

IAC Concorde Suppressor

		ID No. B2-1
Source of Data: Industrial Acoustics Company Dunn Report	Date Prepared: No date May 1974	Location/Airport: Bristol/Filton R.A.F. Fairford
	Owner/Operator: British Aircraft Corporation	Date of Installation: 1970

Vendor/Designer: Industrial Acoustics Company	Site Requirements: Approximately 600 m^2
Type of Suppressor/Barrier: Fixed Silencer	Aircraft and Engine Types/Users: Concorde - Olympus 593
Construction Cost: US $ 196,000	Maintenance Requirements/Cost: No information
Safety Requirements:	Set-Up Requirements: Not available
Wind/Meteorology Restrictions: Not available	Effects on Engine Performance or Airframe: None indicated

Current Use:

Not available

Acoustical Performance:

20 dBA reduction (at unspecified distance)

Noise Barrier - Düsseldorf

ID No.

D1-1

Source of Data:

Dunn Report

Date Prepared:

May 1974

Location/Airport:

Düsseldorf

Owner/Operator:

Düsseldorf Airport

Date of Installation:

1972

Vendor/Designer:

Aero Group

Site Requirements:

Approximately 6,000 m^2

Type of Suppressor/Barrier:

Noise Fence (molded plastic adsorptive panels)

Aircraft and Engine Types/Users:

All aircraft (except DC10)

Construction Cost:

US $ 397,000 for wall and apron

Maintenance Requirements/Cost:

Minimal

Safety Requirements:

Normal

Set-Up Requirements:

10 minutes (1 in two vehicle, 1 in cockpit, and 2 outside for guidance)

Tow vehicle ($180,000) for L1011 (LTU)

Tow vehicle ($ 50,000) for Caravelle (LTU)

Wind/Meteorology Restrictions:

B747 limited to crosswind of 10 kts

RB-211-22B (L1011) limited by crosswind

(1-2% of time not useable due to wind)

Effects on Engine Performance or Airframe:

Recirculation took place with initial runs with B707/DC8 but problem solved by deflector panels

One RB-211-22B destroyed due to surges caused by back pressure problems

Current Use:

Mandatory for all aircraft/exceptions made based on engine limitations discussed above.

Acoustical Performance:

Reduction up to 10 dBA under favorable wind conditions (at 1 km), although there is some indication that noise levels may appear to increase under unfavorable wind conditions in some directions

Frankfurt Noise Wall	ID No. F1-1

Source of Data: Dunn Report Frankfurt Airport	Date Prepared: May 1974 November 1978	Location/Airport: Frankfurt
	Owner/Operator: Frankfurt Airport	Date of Installation: Not available

Vendor/Designer: Dipl. Ing. R. Kraege - Designer Prof. Dr. Reichow - Designer Strabag Bau AG - Construction	Site Requirements: On border of freight area Length = 2,000 m
Type of Suppressor/Barrier: Prestressed concrete wall with inverse parabolic section for maximum reflection dampening	Aircraft and Engine Types/Users: All
Construction Cost: DM 8.1 million	Maintenance Requirements/Cost: Minimal
Safety Requirements: None reported	Set-Up Requirements: None reported
Wind/Meteorology Restrictions: None reported	Effects on Engine Performance or Airframe: None reported

Current Use:
Separates freight center from Kelsterbach (community)

Acoustical Performance:

Distance of source to wall	Noise reduction behind barrier		
	1,000 m	2,000 m	3,000 m
50 m	20.5 dBA	20.0 dBA	19.5 dBA
500 m	13.5 dBA	13.0 dBA	13.0 dBA

Hush-House - Hamburg

ID No.
H1-1

Source of Data: Dunn Report Lufthansa Hamburg Airport	Date Prepared: May 1974 December 1978 November 1978	Location/Airport: Hamburg
	Owner/Operator: Lufthansa	Date of Installation: 1960

Vendor/Designer: Design: Gorsch-Gehrmann, Wiesbaden Shell Construction: Siemens Bauunion GmbH and Paul Hammers AG Acoustics/dynamic const: Grünzweig and Hartmann AG and Oscar Gossler GmbH	Site Requirements: Approximately 5,500 m^2
Type of Suppressor/Barrier: Hush-House	Aircraft and Engine Types/Users: Narrow body aircraft A300 partially accommodated B747/DC10 use hall only as muffler (Lufthansa only)
Construction Cost: (incl. planning & design) DM 9,000,000 (1962) (hush-house only) DM 415,000 (1976) Noise Wall	Maintenance Requirements/Cost: Sound proofing devices DM 410,000 Fire protection equip. DM 335,000 Normal Building Maint. DM 220,000
Safety Requirements: Not specified	Set-Up Requirements: 4 people required regardless of aircraft; B727 - lift nose gear to put in hall, taking about 30 minutes; therefore 727's normally runup using hall as muffler only
Wind/Meteorology Restrictions: Potential problems on No. 2 Engine on B727, otherwise, no problems	Effects on Engine Performance or Airframe: GE CF6 restricted to 80% N_2 because of insufficient flow at higher power No damage or reingestion reported

Current Use:
359 aircraft in 1977
297 aircraft in 1978 (through October)

Acoustical Performance:

Maximum performance (1964 measurements): (125 m from the Hush House)

Perpendicular to entrance:	25 dB (evidently linear)
30 to 60^0 from entrance:	20-25 dB
In front of Hall:	6 dB

Cullum Trident/BAC 111 Suppressors - Heathrow	ID No. L1-1

Source of Data: Dunn Report Cullum Betuners, Ltd. Ministry of Aviation	Date Prepared: May 1974 March 1964	Location/Airport: London/Heathrow
	Owner/Operator: British Airways	Date of Installation: 1964

Vendor/Designer: Cullum Detuners, Ltd., London	Site Requirements: Approximately 400 m^2
Type of Suppressor/Barrier: Tubular mufflers	Aircraft and Engine Types/Users: Trident BAC 111
Construction Cost: Not available	Maintenance Requirements/Cost: Note available
Safety Requirements: Not available (assumed standard)	Set-Up Requirements: Placement of aircraft by bug
Wind/Meteorology Restrictions: None identified	Effects on Engine Performance or Airframe: None identified

Current Use:
Probably in use but no frequency data

Acoustical Performance:

Engine Operating Condition	(All levels at 300') Angle From Jet Axis (degrees)																	
	30		45		60		90		30		45		60		90		180	
	Noise Reduction-Port Side								Noise Reduction-Stbd. Side								Ahead	
	dB	PNdB	dB	PNdB	dB	PNdB	dB	PNdB	dB	PNdB	dB	PNdB	dB	PNdB	dB	PNdB	dB	PNdB
Port/Starboard Engine Cruise Power:	23	20	22	19	16	15	14	13	18	17	19	17	17	11	14	12	7	1
Port/Starboard Engine Max. Power:	23	20	22	19	17	14	12	10	21	20	21	19	15	11	13	11	8	4

Cullum B747 Suppressor - Heathrow	ID No. L1-2

Source of Data: Dunn Report	Date Prepared: May 1974	Location/Airport: London/Heathrow
	Owner/Operator: British Airways	Date of Installation: 1970

Vendor/Designer: Cullum Detuners, Ltd., London	Site Requirements: 2,000 m^2 (estimate)
Type of Suppressor/Barrier: Tubular mufflers (on rails for fore and aft movement)	Aircraft and Engine Types/Users: B747
Construction Cost: Ł 60,000 (1970)	Maintenance Requirements/Cost: Not available
Safety Requirements: Assumed standard	Set-Up Requirements: Aircraft parked in predetermined position and mufflers moved forward to engines
Wind/Meteorology Restrictions: Tail winds not permissable	Effects on Engine Performance or Airframe: Some evidence of reingestion under unfavorable conditions
Current Use: Currently used but no frequency data	
Acoustical Performance: No data available	

Cullum B707 Suppressor - Heathrow

ID No.
L1-3

Source of Data:
Dunn Report
Ministry of Aviation (ORN 121)

Date Prepared:
May 1974
September 1969

Location/Airport:
London/Heathrow

Owner/Operator:
British Airways

Date of Installation:
1960

Vendor/Designer:
Cullum Detuners, Ltd., London

Site Requirements:
1,500 m^2 (estimated)

Type of Suppressor/Barrier:
Tubular mufflers (fixed but adjustable)

Aircraft and Engine Types/Users:
B707

Construction Cost:
£ 30,000 (1960)

Maintenance Requirements/Cost:
Not available

Safety Requirements:
Assumed standard

Set-Up Requirements:
Aircraft positioned by bug

Wind/Meteorology Restrictions:
None identified

Effects on Engine Performance or Airframe:
None identified

Current Use:
Probably in use but no frequency data

Acoustical Performance: Measurements for B707/436 (RR Conway 508 w/suppressors)

Reduction in dB (linear) at 300 feet for Max. Power

	Direction Angle from Jet Axis				
	30°	37½°	45°	60°	180°
Port Side (No. 1)	19	21	23	14	-2
Stbd. Side (No. 1)	14	19	20	--	--

L1011 Run-Up Pen - Heathrow

ID No.
L1-4

Source of Data: Cullum Detuners, Ltd. British Airways TN p/678	Date Prepared: September 1978 February 15, 1974	Location/Airport: London/Heathrow
	Owner/Operator: British Airways	Date of Installation: 1977

Vendor/Designer: Cullum Detuners, Ltd.	Site Requirements: Approximately 4,000 m^2 (estimate)
Type of Suppressor/Barrier: U-shaped wall (run-up pen)	Aircraft and Engine Types/Users: L1011
Construction Cost: No information available	Maintenance Requirements/Cost: No information available
Safety Requirements: Assumed standard	Set-Up Requirements: Placed in position by bug
Wind/Meteorology Restrictions: None for wing engines Potential problems for tail engine with adverse wind conditions	Effects on Engine Performance or Airframe: None identified

Current Use:

In current use by no frequency information available

Acoustical Performance:

Model results from National Physics Laboratory (at 1200m):

No. 1 Engine	14.8 dBA reduction
No. 2 Engine	7.5 dBA
No. 3 Engine	14.6 dBA

IAC B707 Suppressors - Gatwick		ID No. L1-5
Source of Data: Civil Aviation Authority	Date Prepared: May 1973	Location/Airport: London/Gatwick
	Owner/Operator: Laker Airways	Date of Installation: 1973 (estimated)

Vendor/Designer: Industrial Acoustics Company, Staines	Site Requirements: 300 m^2 (estimated)
Type of Suppressor/Barrier: Portable mufflers	Aircraft and Engine Types/Users: B707-320C
Construction Cost: No information available	Maintenance Requirements/Cost: No information available
Safety Requirements: Assumed standard	Set-Up Requirements: No information available
Wind/Meteorology Restrictions: None identified	Effects on Engine Performance or Airframe: None identified

Current Use:

No information available

Acoustical Performance:

Maximum power at 300 feet and 30° from jet axis on port side of aircraft:
Reduction: 10 PNdB

(Muffled and unmuffled levels at a greater distance could not be made at the same location and thus do not strictly represent the effectiveness of the suppressor)

Run-Up Pen - Los Angeles		**ID No.** L2-1
Source of Data: Los Angeles Airport Authority Dunn Report	**Date Prepared:** 1976 May 1974	**Location/Airport:** Los Angeles/ International
	Owner/Operator: Los Angeles Int'l.	**Date of Installation:** 1968

Vendor/Designer: Hight Construction Company	**Site Requirements:** Approximately 3,000 m^2
Type of Suppressor/Barrier: Circular inward sloping noise barrier	**Aircraft and Engine Types/Users:** Narrow body
Construction Cost: $147,845 (1968)	**Maintenance Requirements/Cost:** Minimal
Safety Requirements: Normal equipment	**Set-Up Requirements:** Placement by bug
Wind/Meteorology Restrictions: None initially identified	**Effects on Engine Performance or Airframe:** Reingestion/compressor stall

Current Use:

No longer used

Acoustical Performance:

Maximum reduction of 15 PNdB (245° from aircraft heading 3,500 feet from pen)

Noise Wall - München

ID No.
M1-1

Source of Data:
Munich Airport

Date Prepared:
February 1974

Location/Airport:
Munich - Riem

Owner/Operator:
Munich Airport

Date of Installation:
January 15, 1974

Vendor/Designer:
Construction: G. D. Maiback,
Plastikfabrik, Eislingen/Fils

Site Requirements:
Approximately 12,000 m^2 with apron

Type of Suppressor/Barrier:
U-shaped Noise Abatement Wall

Aircraft and Engine Types/Users:
All (except tail engine DC10)

Construction Cost:
DM 1,240,000 (1973)

Maintenance Requirements/Cost:
Minimal

Safety Requirements:
Normal

Set-Up Requirements:
Placed by bug

Wind/Meteorology Restrictions:
None identified

Effects on Engine Performance or Airframe:
None identified

Current Use:
No information available

Acoustical Performance:
20 dBA reduction through wall (no distance measurements available)

Noise Barriers - Osaka

ID No.
01-1

Source of Data:
All Nippon Airways - Questionnaire and noise measurement report

Date Prepared:
Questionnaire 1978
Noise Report - Dec. 71

Location/Airport:
Osaka

Owner/Operator:
All Nippon Airways

Date of Installation:
November 1971 (modified Sept. 1977 for L-1011)

Vendor/Designer:
Designer: Kobayashi Rigaku Kenkyusho
Construction: Shin-Nihon Seitetsu

Site Requirements:
Approximately 2,000 m^2

Type of Suppressor/Barrier:
Noise Fence

Aircraft and Engine Types/Users:
YS-11, B737-281, B727-281, L1011-1

Construction Cost:
JY 60 million (1971)
(not including foundation work)

Maintenance Requirements/Cost:
Minimal

Safety Requirements:
Normal equipment

Set-Up Requirements:
Placement by bug using normal personnel

Wind/Meteorology Restrictions:
YS-11 limited to idle/tail winds 10 kts
B737/B727 - no trim run/tail winds 10 kts
L-1011 - center engine idle only/tail winds 5-10 kts/flight idle for wing/ground idle for center/tail winds 10 kts

Effects on Engine Performance or Airframe:
YS-11 restrictions to prevent resonance of propeller system
B737/B727 restrictions to prevent back pressure
L101 restrictions to prevent compressor stall

Current Use:

YS-11	87/month	B727	27/month
B737	13/month	L1011	7/month

Acoustical Performance:

75° at 850 m	5 dBA reduction
135° at 630 m	10 dBA reduction
205° at 470 m	15 dBA reduction
340° at 890 m	0 dBA reduction

Boet B747 Suppressor - Charles de Gaulle	ID No. P1-1

Source of Data: Aeroport de Paris S.A. André Boët	Date Prepared: September 1978	Location/Airport: Paris/de Gaulle
	Owner/Operator: Air France	Date of Installation: Not available

Vendor/Designer: S.A. André Boët, Villeneuve-D'Ascq	Site Requirements: Approximately 700 m^2
Type of Suppressor/Barrier: Tubular mufflers with intake screens	Aircraft and Engine Types/Users: B747
Construction Cost: F 2,365,000 (no date) (suppressor only)	Maintenance Requirements/Cost: No information available
Safety Requirements: Standard	Set-Up Requirements: No information available
Wind/Meteorology Restrictions: None identified	Effects on Engine Performance or Airframe: None identified
Current Use: Currently in use but frequency not available	
Acoustical Performance: 20 dBA (at 100 m and 45° from rear axis of aircraft) 50-55 dBA maximum (at 2,500 m)	

Boet A300/DC 10 Suppressor - Charles de Gaulle	ID No. P1-2

Source of Data: Aerosport de Paris S.A. André Boët	Date Prepared: September 1978	Location/Airport: Paris/de Gaulle
	Owner/Operator: Air France	Date of Installation: Not available

Vendor/Designer: S.A. André Boët, Villeneuve-D'Ascq	Site Requirements: Approximately 700 m^2
Type of Suppressor/Barrier: Tubular mufflers with intake screens	Aircraft and Engine Types/Users: A300 DC 10 Concorde
Construction Cost: F 2,000,000 (no date) (suppressor only)	Maintenance Requirements/Cost: No information available
Safety Requirements: Standard	Set-Up Requirements: No information available
Wind/Meteorology Restrictions: None identified	Effects on Engine Performance or Airframe: None identified

Current Use:

Currently in use but frequency not available

Acoustical Performance:

20 dBA (at 100 m and 45^0 from rear axis of aircraft)

50 dBA maximum (at 2,500 m)

Boët B707/DC8 Suppressors - Orly and de Gaulle	**ID No.** P1-3

Source of Data: Aeroport de Paris S.A. André Boët	**Date Prepared:** September 1978	**Location/Airport:** Paris/Orly and de Gaulle
	Owner/Operator: Air France	**Date of Installation:** Not available

Vendor/Designer: S.A. André Boët, Villeneuve-D'Ascq	**Site Requirements:** Approximately 600 m^2
Type of Suppressor/Barrier: Tubular mufflers/no screens	**Aircraft and Engine Types/Users:** B707, DC8 series 50/60 - JT3 engines
Construction Cost: F 1,600,000 (no date) (suppressor only)	**Maintenance Requirements/Cost:** No information available
Safety Requirements: Standard	**Set-Up Requirements:** No information available
Wind/Meteorology Restrictions: Tail winds limited to 60 km/hr	**Effects on Engine Performance or Airframe:** None identified

Current Use:

Currently in use but frequency not available

Acoustical Performance:

27 dBA (at 100 m and 45° from rear axis of aircraft)

60 dBA maximum (at 2,500 m)

Boet B727 Suppressor - Orly		**ID No.** P1-4
Source of Data: Dunn Report Aeroport de Paris S.A. André Boët	**Date Prepared:** May 1974 September 1978	**Location/Airport:** Paris/Orly and de Gaulle
	Owner/Operator: Air France	**Date of Installation:** Not available

Vendor/Designer: S.A. André Boët, Villeneuve-D'Ascq	**Site Requirements:** Approximately 500 m^2
Type of Suppressor/Barrier: Tubular mufflers/with intake screen	**Aircraft and Engine Types/Users:** B727-200
Construction Cost: F 886,000 (no date) (suppressor only)	**Maintenance Requirements/Cost:** No information available
Safety Requirements: Normal equipment	**Set-Up Requirements:** No information available
Wind/Meteorology Restrictions: Maximum tail wind of 60 km/hr	**Effects on Engine Performance or Airframe:** None identified by manufacturer (user reported some back pressure problems with trim runs)
Current Use: Currently in use but frequency not available	
Acoustical Performance: 29 dBA (at 100 m and 45^0 from rear axis of aircraft) 60 dBA maximum (at 2,500 m)	

Bertin Caravelle Suppressor - Orly and de Gaulle	ID No. P1-5

Source of Data: Dunn Report Aeroport de Paris	Date Prepared: May 1974 September 1978	Location/Airport: Paris - Orly and de Gaulle
	Owner/Operator: Air France	Date of Installation: Not available

Vendor/Designer: Bertin & Cie, Plaisir	Site Requirements: Approximately 200 m^2
Type of Suppressor/Barrier: Tubular mufflers (Mobile)	Aircraft and Engine Types/Users: Caravelle
Construction Cost: Not available	Maintenance Requirements/Cost: Not available
Safety Requirements: Standard	Set-Up Requirements: Placed behind engines (close fit)
Wind/Meteorology Restrictions: None identified	Effects on Engine Performance or Airframe: None identified

Current Use:

Currently in use by frequency not available

Acoustical Performance:

25 dBA (at 100 m and 45° from rear axis of aircraft)

Japan Airlines Suppressor - Tokyo

ID No.
T1-1

Source of Data:
Japan Airlines
Dunn Report

Date Prepared:
September 1978
May 1974

Location/Airport:
Tokyo - Narita

Owner/Operator:
Japan Airlines

Date of Installation:
Not available

Vendor/Designer:
Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo (under license from Oskar Gerber)

Site Requirements:
Approximately 3,000 m^2

Type of Suppressor/Barrier:
Fixed mufflers (four engines) with noise screens

Aircraft and Engine Types/Users:
B747 - JT9D
DC 8 - JT3D
DC10 - JT9D

Construction Cost:
Design and construction 219 million ¥ (1972)

DC10 extension 63.4 million ¥ (1977)

Maintenance Requirements/Cost:
Minimal

Safety Requirements:
Normal safety equipment

Set-Up Requirements:
Minimum personnel:
- 1 tow car driver
- 2 wing tip observers
- 1 cockpit brake man
- 1 tail watcher

Wind/Meteorology Restrictions:
Cross and tail winds not permitted (modification being sought to eliminate restrictions)

Effects on Engine Performance or Airframe:
Manufacturer guarantees prevention of exhaust reingestion up to 5 kts in any direction

Current Use:

A/C Type	In the Suppressor			Out of the Suppressor		
	Jun	Jul	Aug	Jun	Jul	Aug
B747	22	29	17	13	20	23
DC10	7	1	3	5	0	0
DC8	51	62	53	5	7	6
Other Airlines	0	0	6	3	2	3

Acoustical Performance: Sound Level Measurements (140° from nose and 700m)

B747 (JT9D-7A,#2TO,#3part,#1,4 idle)										DC10 (JT9D-59A,#2TO,#1,3 idle)								
63Hz	125	250	500	1k	2k	4k	8k	dBA		63Hz	125	250	500	1k	2k	4k	8k	dBA
76	67	52	38	38	38	35	32	53	w/suppressor	79	73	61	46	46	40	35	27	58
95	89	71	63	63	64	60	47	74	w/o suppressor	104	99	82	66	66	62	59	53	83

Swissair DC 9 Suppressor/Zürich

ID No.
Z1-1

Source of Data:
Dunn Report
Swissair
Schneider+Co.AG

Date Prepared:
Dunn Rpt.-May 1974
Discussion - 28-29 Dec, 1978

Location/Airport:
Zürich - Kloten

Owner/Operator:
Swissair

Date of Installation:
1968

Vendor/Designer:
Schneider+Co.AG, Winterthur

Site Requirements:
Apron with appropriate markings for accurate placement
Approximately 150 m^2 required for suppressor

Type of Suppressor/Barrier:
Separate muffler for each engine, adjustable for vertical and horizonal thrust direction

Aircraft and Engine Types/Users:
DC-9 (JT8D)

Construction Cost:
SF 200,000 (1968)
(costs of mufflers only)

Maintenance Requirements/Cost:
Minimal

Safety Requirements:
Standard ear protection
Standard fire equipment
Standard wheel chocks

Set-Up Requirements:
Placement by bug using marks on pavement and flags for visibility

Wind/Meteorology Restrictions:
None identified

Effects on Engine Performance or Airframe:
None identified

Current Use:
At least once per week

Acoustical Performance:

25 dBA reduction at 200 feet at an angle of 30° from rear to aircraft

Approximately 10 dBA reduction at 2,400 meters along same radial

(360° readings were not made since guarantee treated the most adverse direction only)

Swissair DC8 Suppressor/Zürich	ID No. Z1-2

Source of Data: Dunn Report Oskar Gerber Swissair	Date Prepared: Dunn Report - May 1974 Discussion - 28-29 Dec 1978	Location/Airport: Zürich - Kloten
	Owner/Operator: Swissair	Date of Installation: 1968

Vendor/Designer: Oskar Gerber	Site Requirements: Approximately 1,400 m^2 Heated pavement is used
Type of Suppressor/Barrier: Horizontally adjustable mufflers	Aircraft and Engine Types/Users: DC8 B707 CV990
Construction Cost: SF 870,000 (1968) (costs of muffler tubes only)	Maintenance Requirements/Cost: Minimal
Safety Requirements: Standard ear protection Standard fire equipment Standard wheel chocks Heated pavement	Set-Up Requirements: Placement by bug using marks on pavement and flags for visibility
Wind/Meteorology Restrictions: None identified	Effects on Engine Performance or Airframe: None identified

Current Use: Primarily for DC8 aircraft, approximately once per week
Acoustical Performance: Not available

Swissair B747 Suppressor/Zürich

ID No.
Z1-3

Source of Data:
Dunn Report
Oskar Gerber
Swissair

Date Prepared:
Dunn Rpt - May 1974
Discussion - 28-29 Dec 1978

Location/Airport:
Zürich - Kloten

Owner/Operator:
Swissair

Date of Installation:
1971

Vendor/Designer:
Oskar Gerber Schall - und Schwingungstechnik GmbH, München

Site Requirements:
Approximately 2,000 m^2
Heated pavement is used

Type of Suppressor/Barrier:
Fixed mufflers (four engines) with side noise screens

Aircraft and Engine Types/Users:
B 747

Construction Cost:
SF 1,330,000

(steel work only)

Maintenance Requirements/Cost:
Minimal

Safety Requirements:
Standard ear protection
Standard fire equipment
Standard wheel chocks
Heated pavement

Set-Up Requirements:
Placement by bug using marks on pavement and flags for visibility

Wind/Meteorology Restrictions:
1. Only one runup cancelled since construction due to weather
2. Wind speed/direction monitor allows throttles to be retarded during wind conditions which could cause compressor stall

Effects on Engine Performance or Airframe:
None identified (extensive wind tunnel testing for proper design)

Current Use:
Approximately one runup per week

Acoustical Performance:
Maximum reduction of 19 dBA (at 100m and 135^0)

Swissair DC 10 Suppressor/Zürich		ID No. Z1-4
Source of Data: Dunn Report Swissair Oskar Gerber	Date Prepared: Dunn Rpt - May 1974 Discussion - Dec. 1978	Location/Airport: Zürich - Kloten
	Owner/Operator: Swissair	Date of Installation: 1972

Vendor/Designer: Oskar Gerber Schall - und Schwingungstechnik GmbH, München	Site Requirements: Approximately 1,600 m^2 Heated pavement is used
Type of Suppressor/Barrier: Fixed mufflers (three engines) with side noise screens	Aircraft and Engine Types/Users: DC 10/GE CF6-50A
Construction Cost: SF 1,700,000 (1972) (silencer tubes and walls only)	Maintenance Requirements/Cost: Minimal
Safety Requirements: Standard ear protection Standard fire equipment Standard wheel chocks Heated pavement	Set-Up Requirements: Placement by bug using marks on pavement and flags for visibility
Wind/Meteorology Restrictions: None reported	Effects on Engine Performance or Airframe: No harmful effects reported
Current Use: Approximately one runup per week	
Acoustical Performance: Maximum level of 47 dBA for wing engine (at 2400m and 135^{0}) Maximum level of 49 dBA for tail engine (at 2400m and 135^{0})	

Swissair DC 9 Suppressor/Zürich

		ID No. Z1-5
Source of Data: Dunn Report Swissair	Date Prepared: Dunn Rpt - May 1974 Discussion - Dec 1978	Location/Airport: Zürich - Kloten
	Owner/Operator: Swissair	Date of Installation: 1967

Vendor/Designer: Cullum Detuners Ltd., Derbyshire	Site Requirements: Approximately 150 m^2
Type of Suppressor/Barrier: Designed as mobile suppressor (muffler) (presently fixed)	Aircraft and Engine Types/Users: DC 9
Construction Cost: (Not available)	Maintenance Requirements/Cost: Minimal
Safety Requirements: Normal equipment	Set-Up Requirements: Originally suppressors moved to aircraft; Presently aircraft placed by bug
Wind/Meteorology Restrictions: None	Effects on Engine Performance or Airframe: None, except problems with proximity to nacelle

Current Use:

Rarely used

Acoustical Performance:

Not available