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CHARACTERISTICS OF THE TRANSMISSION LOSS APPARATUS AT NASA LANGLEY RESEARCH CENTER

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SUMMARY

A description of the Transmission Loss Apparatus at NASA Langley Research Center, which is specifically designed to accommodate general aviation type aircraft structures, is presented. The measurement methodology, refered to as the "Plate Reference Method", is discussed and compared with the classical method as described in the Standard of the American Society for Testing and Materials. This measurement procedure enables reliable and accurate noise transmission loss measurements down to the 50 Hz one-third octave band. The transmission loss characteristics of add-on acoustical treatments, applied to the basic structure, can be established by inclusion of appropriate absorption corrections for the treatment.

INTRODUCTION

Interior noise levels in light, propeller driven general aviation aircraft are generally high and annoying, despite the use of acoustical treatments (Refs. 1-5). The degree of interior noise depends largely upon aerodynamic generated sound transmitted through the sidewall fuselage and the radiation of structural born induced sound into the aircraft cabin. Highest excitation levels are found at the propeller blade passage frequency and its harmonics which occur typically at frequencies of 70 Hz or higher for cruise conditions of this type of aircraft. Reference 6 shows that the effectiveness of acoustic treatment is minimal for these low frequencies. This resulted in a need to expand knowledge of methods to control aircraft interior noise by establishing the noise transmission loss characteristics of light aircraft structures and acoustical treatments. To include the fundamental blade passage frequencies and their harmonics of turboprop and propfan driven aircraft a frequency region of interest is defined from 50 Hz to 8000 Hz. The purpose of this report is to present the characteristics of the NASA Langley Research Center Transmission Loss Apparatus which is located in the Aircraft Noise Reduction Laboratory, along with the measurement methodology which will be compared with the appropriate standards.

SYMBOLS

A	absorption area of the receiving room
ASTM	American Society for Testing and Materials
A_{eq}	equivalent absorption area
a, b	test panel dimensions
B&K	Bruel and Kjaer
C_w	Waterhouse correction term
c	speed of sound
D	flexural rigidity
d	distance

E	Young's modulus
f	frequency
f_c	critical frequency
f_{ss}	fundamental resonance frequency for simply supported boundaries
HP	Hewlett Packard
ISO	International Standards Organization
k	number of sound source positions
L	total length of all room edges
L_b	background noise level
L_i	space averaged sound pressure level
L_m	arithmetic mean of sound pressure levels
L_s	adjusted signal level
L_{sb}	signal and background level combined
M	dimensionless mass coefficient
m, n	panel mode numbers
N	number of acoustic room modes
NASA	National Aeronautics & Space Administration
NR	noise reduction
NR_{ref}	noise reduction for reference panel
n_d	modal density of test panel
R	transmission loss according to mass law
R_{ref}	mass law transmission loss of reference panel
S	sound exposed area of test panel
SPL	sound pressure level

S_t	total area of all room walls
s	standard deviation
T	reverberation time
TL	transmission loss of test panel
t	thickness
V	room volume
$\bar{\alpha}$	average absorption coefficient
λ	wavelength
ν	Poisson's ratio
ρ	air density in test rooms
ρ_s	mass per unit area of the test panel

DESCRIPTION OF TRANSMISSION LOSS APPARATUS

To experimentally establish the noise transmission loss characteristics of the test structure, the aircraft panel is mounted as a partition between two adjacent reverberant rooms which are designated source room and receiving room. The transmission loss apparatus has been modified since its design was first reported in Reference 7. A plan view of the modified apparatus is depicted in figure 1. In the source room, which measures 3.35 m by 3.66 m by 3.94 m, a random sound field is produced by two floor standing reference sound power sources. These calibrated units consist essentially of a centrifugal driven fan featuring very well defined operating characteristics and long term stability over a frequency range from 100 Hz to 10 k Hz. In this range the sound is broadband in character and the acoustic output power is greater than

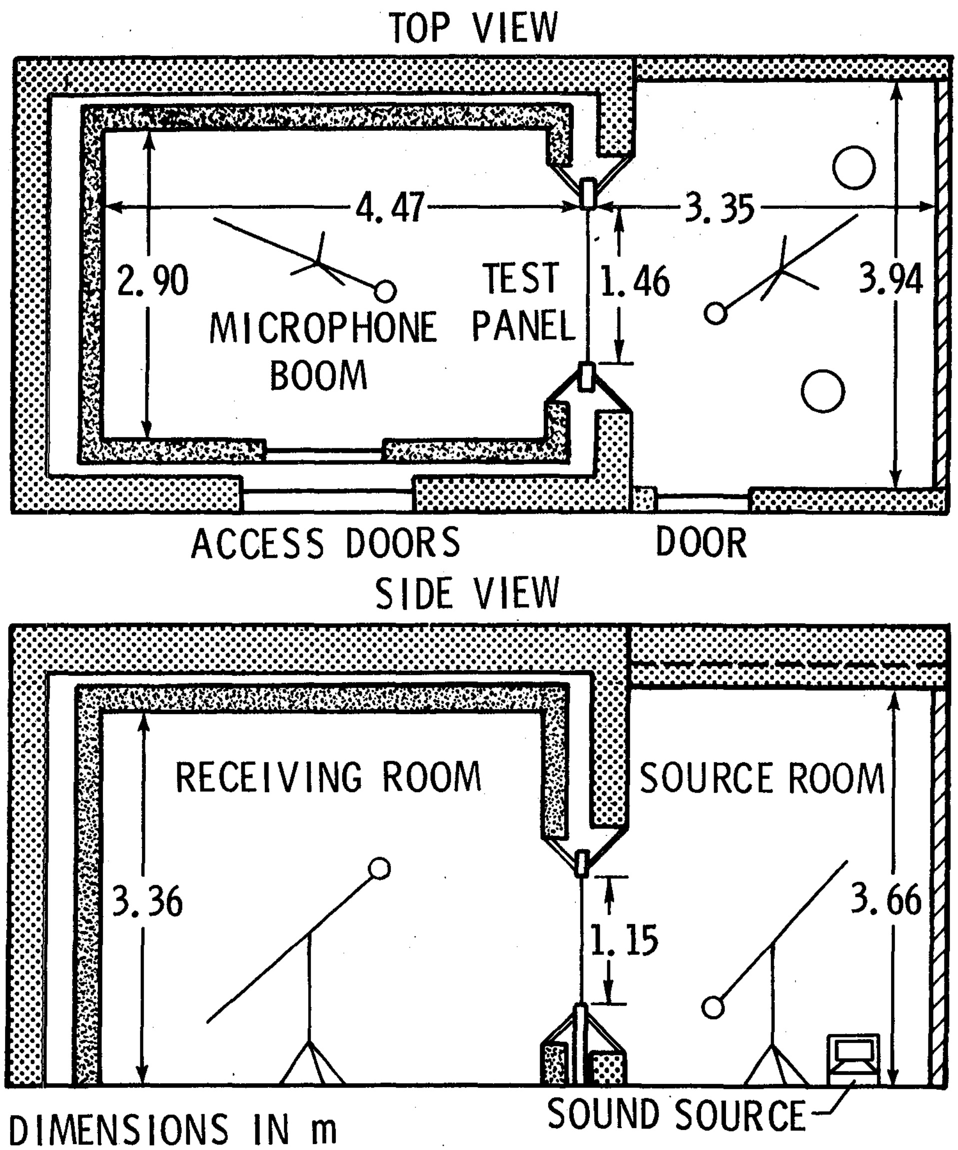

Figure 1. - Schematic of noise transmission loss apparatus

70 dB in any one-third octave frequency band. Sound from the source room is transmitted into the 4.47 m by 3.36 m by 2.90 m receiving room only by way of the test panel which has a sound exposed area of 1.15 m by 1.46 m. The test specimen is accommodated by a steel and rubber mounting frame, which is designed for minimum acoustical and structural flanking (Ref. 7). Boundary conditions are defined by the 54 bolt-nut combinations evenly spaced along the edges of the test structure. Four steel bars provide an even distribution of the applied clamping forces.

A space and time average of the sound pressure levels in each of the rooms is accomplished by means of a windscreen covered 1/2 inch microphone mounted at the end of a .91 m long rotating boom which has a rotational speed of 16^{-1} revolutions per second. The microphones complete two full rotations during the 32 seconds linear time averaging analysis which is performed by a digital one-third octave band frequency analyzer. The microphone signal coming from the receiving room is amplified by a gain of 40 dB to ensure adequate analyzer input levels. Figure 2 shows an aircraft test panel mounted in the apparatus as viewed from the source room. Part of the microphone boom and the windscreen covered microphone are visible in the foreground. The same test panel, covered with various layers of treatment, viewed from the receiving room is depicted in figure 3.

The data acquisition system is automated by the inclusion of

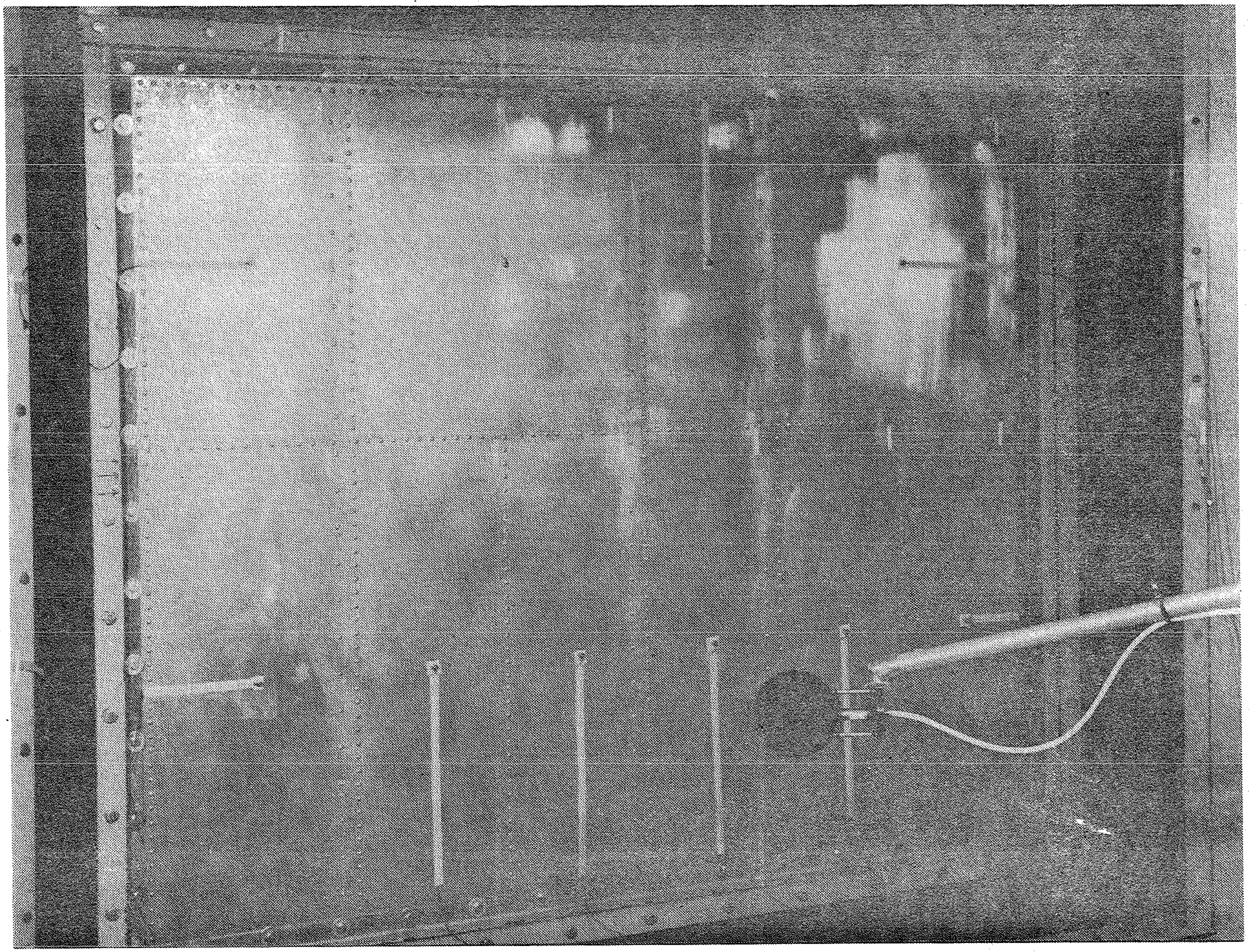

Figure 2. - Aircraft test panel structure viewed from the source room.

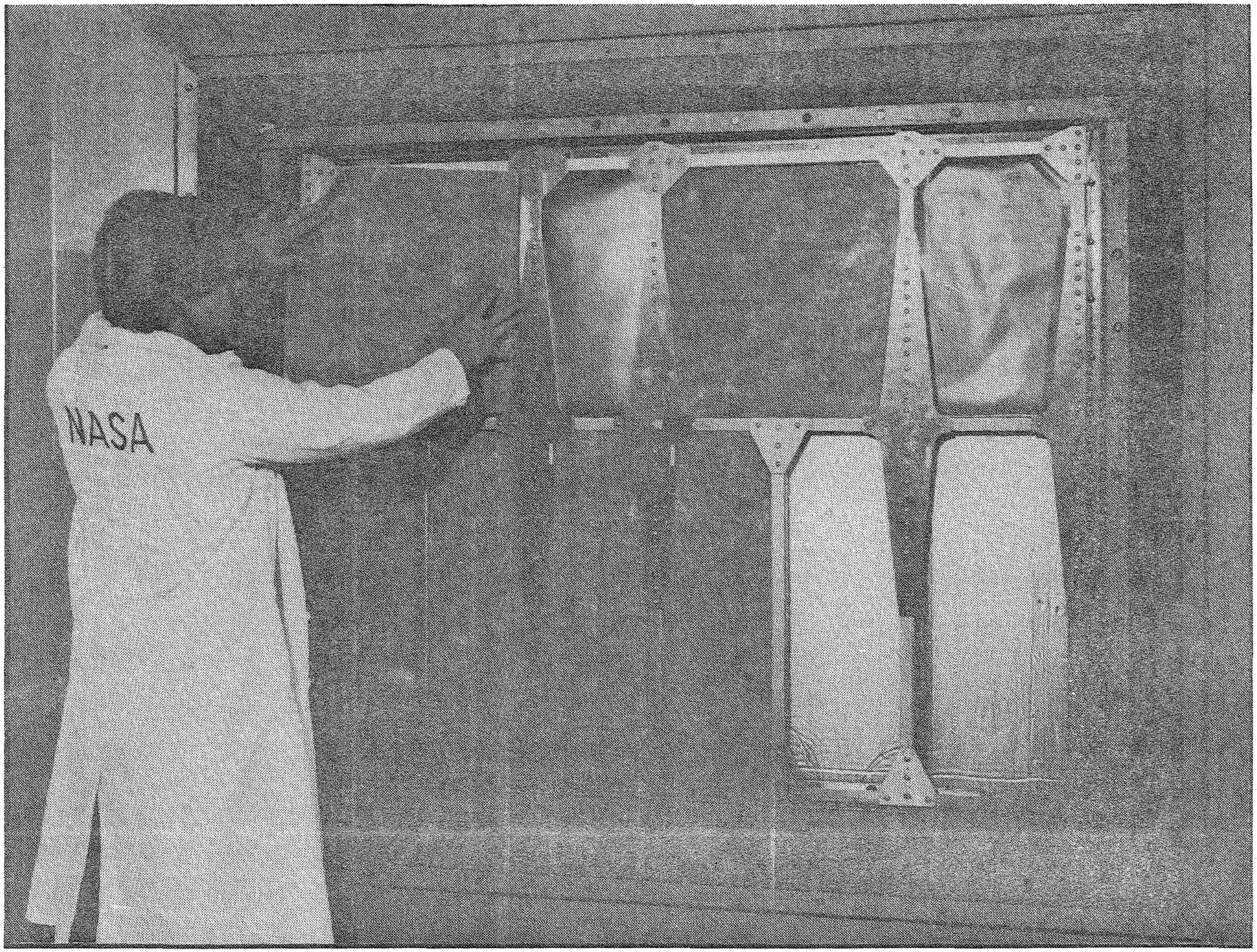

Figure 3. - Aircraft test panel structure showing different layers of acoustical treatment (View from the receiving room).

a microcomputer, a relay actuator and several remote relays to control the sound sources, amplifiers, power supplies and rotating booms (figure 4). The microprocessor manipulates the experimental data from source and receiving rooms, applies corrections, stores applicable data in flexible disc memory and finally presents noise transmission loss data in tabular and graphical form. The interactive computer program used for this purpose is written in BASIC and a flowchart is presented in Appendix A. A sample output for the transmission loss of an aircraft test panel with different treatment layers is given in Appendix B. Table 1 identifies the electronic equipment used in the transmission loss apparatus.

TABLE 1. - IDENTIFICATION OF ELECTRONIC EQUIPMENT USED IN TRANSMISSION LOSS MEASUREMENTS

	Source Room	Receiving Room
Reference sound power source	B&K 4204 (2)	
Microphone cartridge	B&K 4165	B&K 4165
Microphone preamplifier	B&K 2619	B&K 2619
Microphone power supply/ conditioner	B&K 2801	B&K 226/228
Remote relay	(2)	(2)
One-third octave band frequency analyzer		B&K 2131
Relay actuator		HP 59306 A
Desk top computer		HP 9845 B
Flexible disc memory		HP 9895 A
X-Y Plotter		HP 9872 T

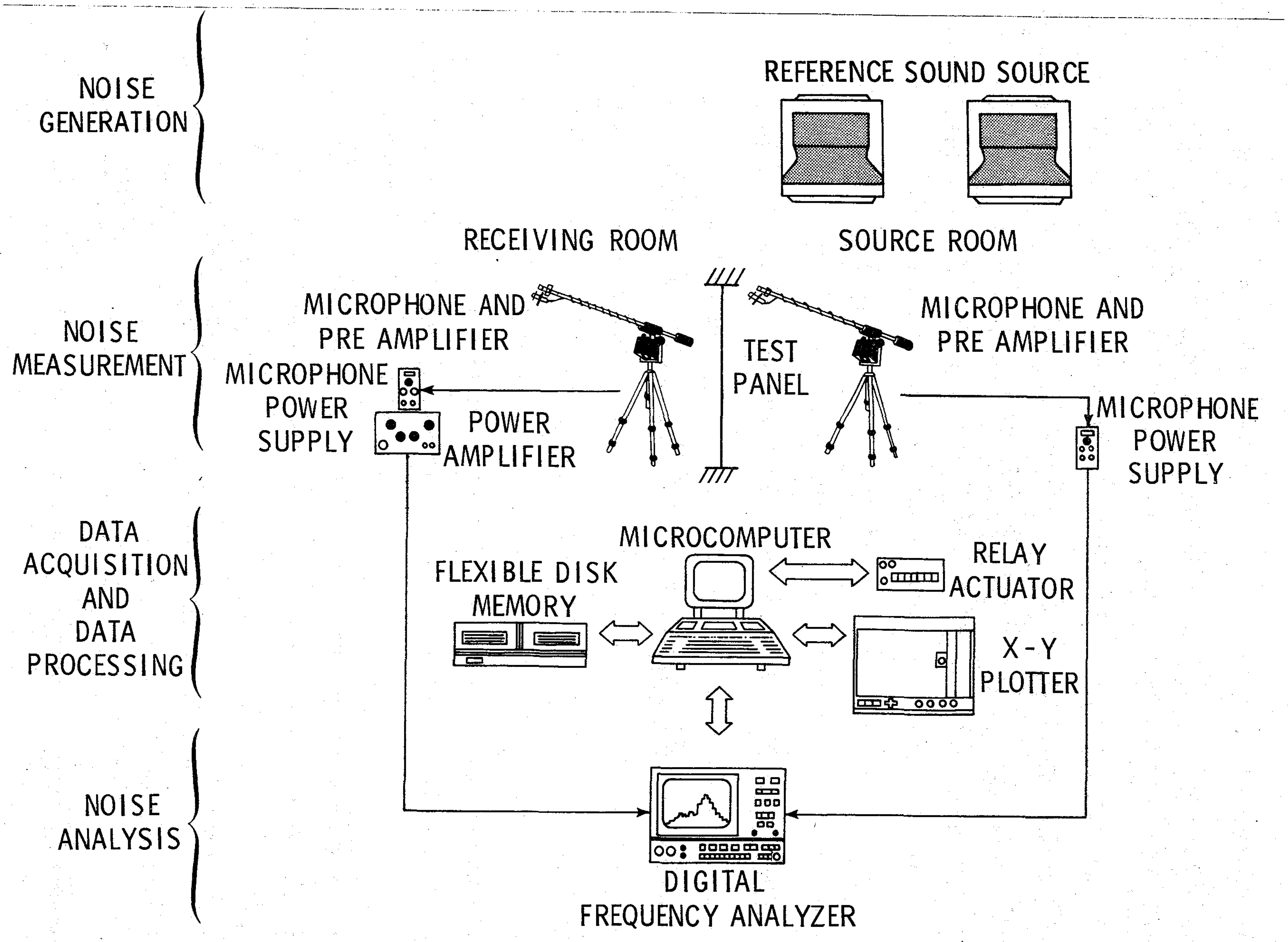

Figure 4. - General arrangement of electronic equipment

METHODOLOGY FOR NOISE TRANSMISSION LOSS MEASUREMENTS

Noise reduction is defined as the difference between the measured averaged sound pressure levels in the source and receiving rooms. These measured sound pressure levels are influenced by the transmission loss characteristics of the test specimen as well as the acoustic environment of the rooms. The Standard Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions (Ref. 8), often referred to as the Classical Method, assumes that the sound pressure levels are measured in a diffuse field in both source and receiving rooms. This method corrects for the room characteristics in the form of the absorption area A of the receiving room yielding the noise transmission loss TL of the test specimen:

$$TL = NR + 10 \log \left(\frac{S}{A}\right) \tag{1}$$

where S is the area of the test specimen common to both rooms. The absorption area may be obtained from Sabine's formula (Ref. 9):

$$A = .163 * \frac{V}{T} \tag{2}$$

where V is the volume of the receiving room and T is the reverberation time in the receiving room, which is defined as the elapsed time for a 60 dB decay in sound pressure level after a sound source has been shut off. Substitution of Equation (2) into Equation (1) results in an equation which contains an expression that includes the sound pressure level and the absorption in the receiving room. The same expression is used in Reference 10 for establishing the sound power level in this room except for the Waterhouse correction term:

$$C_W = 10 \log \left(1 + \frac{S\lambda}{8V}\right) \tag{3}$$

where λ is the wavelength. This correction term compensates for the increased sound pressure and energy density along the walls relative to the central portion of the room where the sound pressure is measured (Ref. 11). The Waterhouse correction term should be applied to both the receiving and source room. However, since the dimensions of the two rooms are of the same order, and as the distance from microphone to the wall in each of the rooms is approximately the same, the correction applied to the transmission loss will be negligible.

Equation (1) is only applicable above the frequency at which the sound field in the reverberation rooms becomes diffuse. Below this frequency the modal density in the test rooms decreases rapidly with decreasing frequency resulting in large spatial fluctuations in the time averaged sound spectrum. A method that corrects for these spatial sound pressure fluctuations is referred to as the "Plate Reference Method" and is based on the assumption that a large (1.15 m by 1.46 m), thin (.406 mm) aluminum reference panel behaves according to mass law. The validity of this assumption is determined by the modal density of the test panel and the frequency bandwidth at low frequencies and is limited at higher frequencies by the effect of the critical frequency. The resonance frequency of a thin flat panel, assuming simply supported edge conditions, can be calculated by using (Ref. 12):

$$f_{ss} = \frac{1}{2\pi}\sqrt{\frac{D}{\rho_s}}\left[\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2\right] \tag{4}$$

where ρ_s is the surface mass of the panel, m and n are the mode numbers, a and b are the plate dimensions and D is the flexural rigidity which is defined by:

$$D = \frac{Et^3}{12(1-\nu^2)} \tag{5}$$

where E is Young's modulus, t is the plate thickness and ν is Poisson's ratio. The critical frequency (Ref. 13) is given by:

$$f_c = \frac{c^2}{2\pi}\sqrt{\frac{\rho_s}{D}} \tag{6}$$

where c is the speed of sound (m/s). The modal density is defined as the number of modes with resonance frequencies in a frequency band of unit width. For frequencies much greater than the fundamental resonance frequency of the panel the modal density of the test panel is given by (Ref. 13):

$$n_d \approx \frac{ab}{2}\sqrt{\frac{\rho_s}{D}} \tag{7}$$

The reference panel exhibits a calculated resonance frequency of 1.2 Hz, a critical frequency of 33,500 Hz and a modal density of 1.334. The one-third octave band with a center frequency of 50 Hz has a bandwidth of 11.5 Hz and thus contains 15 panel resonances, a large enough number to expect mass law behavior. As the 8000 Hz one-third octave band is far below the critical frequency of the test panel (33,500 Hz) the Plate Reference Method is valid for the frequency range of interest (50 Hz - 8000 Hz one-third octave bands) which was established in the introduction. Although a limp, mass loaded, reference panel can be used (like rubber) calibration results in the low frequencies were affected by the shape of this reference panel. The rubber panel bends under its own weight, due to its large dimensions and lack of bending stiffness. This resulted in inconsistent results of the transmission loss measurement of this rubber panel.

The theoretical transmission loss R according to field incidence mass law is given in Reference 14:

$$R = 10 \log \left[\frac{.978 \, M^2}{\ln \left\{ \dfrac{1 + M^2}{1 + .043 \, M^2} \right\}} \right] \tag{8}$$

where the dimensionless mass coefficient is given by $M = \dfrac{\rho_s \pi f}{\rho c}$ and where ρ is the air density (kg/m^3).

Assuming the aluminum panel has transmission loss characteristics as described by Equation (8) an equivalent absorption area A_{eq} may be defined as:

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test procedure, the fixed test configuration and testing within a continuous time frame aid in achieving the highest possible accuracy.

The addition of treatments to the panel structure on the receiving room side not only affects the transmission loss of the structure but also alters the absorption characteristics of the room. A correction to A_{eq} is needed to account for the use of fiberglass blankets and other highly absorptive porous materials. This can be achieved by applying the treatment to the wall of the receiving room opposite the test panel, thus not changing the transmission loss of the test structure but only the absorption characteristics of the room. As the walls of the receiving room are parallel, a symmetric distribution of the acoustic modes may be assumed and the effect of the sound absorption of the treatment will be the same if applied to the test panel or to the opposite wall. A correction for the absorption of the porous material can then be introduced. As the panel area is only 2.5% of the total wall area of the receiving room, absorption corrections for most other, non-porous, treatments do not affect the transmission loss by more than .5 dB and might be omitted.

COMPARISON OF THE CHARACTERISTICS OF THE TRANSMISSION LOSS APPARATUS WITH ASTM AND ISO STANDARDS

The ASTM Standard (Ref. 8) and the ISO Standards 3741 and

3742 (Refs. 10 and 15) will be used in evaluating the characteristics of the transmission loss apparatus and in establishing a frequency range for which reliable transmission loss data can be obtained if the "Classical Method" approach is used. A comparison with other related literature is included.

Sound Diffusivity

The ASTM Standard Method for determining the noise transmission loss of a test specimen assumes a diffuse sound field in each of the test rooms. To achieve an adequate approximation of a diffuse sound field in each of the rooms it is required that there be a sufficient number of room resonances (normal modes) within a test band, that these normal modes be distributed as uniformly as possible over the band, that the modes have sufficient bandwidth and the directions of propagation corresponding to these modes be distributed as uniformly as possible (Refs. 16, 17 and 18). The recommended minimum frequency to ensure an adequate number of modes in the test room is given by (Ref. 8):

$$f = \left(\frac{4\ c^3}{V} \right)^{1/3} \qquad (10)$$

where V again is the volume of the room. Applying Equation (10) to both test rooms results in a one-third octave band with a center frequency of at least 160 Hz. According to the ASTM standard the 125 Hz one-third octave band will then provide acceptable results. ISO Standard 3741-1975(E) (Ref. 10) recommends a room volume of 70 m^3 for the measurement of sound power levels of broadband noise sources for the 200 Hz one-third octave band. The volume of each of the test rooms is about two-thirds of this recommended volume suggesting a minimum one-third octave test band with a center frequency of 250 Hz. The number of room modes in a frequency band can be calculated from (Ref. 19):

$$\frac{dN}{df} = \frac{4\pi V f^2}{c^3} + \frac{\pi S_t f}{2c^2} + \frac{L}{8c} \qquad (11)$$

where $\frac{dN}{df}$ is the modal density, N is the number of normal room modes, S_t is the surface area of all room walls combined, and L is the total length of the edges. Applying Equation (11) to the dimensions of source and receiving rooms (from Table 2) the approximate number of modes is 21 in the 160 Hz one-third octave band and 36 in the 200 Hz one-third octave band, both of which are sufficient to justify a diffuse field. ISO Standard 3741-1975 (E) (Ref. 10) presents a room qualification procedure for measurement of broad band sound based on the standard deviation of measured sound pressure levels in the test room and is given by:

$$s = (k - 1)^{-1/2}\left[\sum_{i=1}^{k} (L_i - L_m)^2\right]^{1/2} \qquad (12)$$

TABLE 2. - ACOUSTIC RESONANCE MODES IN SOURCE AND RECEIVING ROOMS

	Source Room			Receiving Room		
Volume V [m^3]	47.1			43.6		
Total Wall Area S_t [m^2]	78.5			75.5		
Total Edge Length L [m]	43.4			42.9		
One-third octave band center frquency [Hz]	160	200	250	160	200	250
Bandwidth [Hz]	37	46	58	37	46	58
Number of Acoustic Resonances N [-]	21	37	69	20	35	65
Modal Density $\frac{dN}{df}$ [s]	.57	.80	1.19	.54	.76	1.12

where L_i is the space averaged sound pressure level in dB, L_m is the arithmetic mean of sound pressure levels (dB) and k is the number of source positions. Table 3 presents the computed standard deviation for several one-third octave bands based on measurements in the receiving room.

TABLE 3. - STANDARD DEVIATION OF BROAD BAND SOUND IN THE RECEIVING ROOM (k = 25)

One-third octave band center frequency [Hz]	Standard deviation [dB]	Maximum allowable standard deviation [dB]
100	2.7	1.5
125	2.1	1.5
160	1.5	1.5
200	.7	1.0
250	.6	1.0
315	.8	1.0
400	.5	1.0
500	.3	1.0
630	.4	1.0

It is concluded from Table 3 that a diffuse sound field exists for one-third octave bands with a frequency of 200 Hz or higher when the rooms are excited with a random noise source. The 160 Hz one-third octave band gives acceptable results.

Room Dimensions

To ensure a uniform distribution of modes, with respect to frequency and to angle, no two dimensions of either one of the test rooms should be equal or in the ratio of small integers. Table 4 shows the ratios recommended by the ASTM Standard (Ref. 8) and the actual room dimensions of source and receiving rooms.

Also included in this table are the optimum ratios of the room dimensions for which the standard deviation of the real modal frequency distribution with respect to the distribution from Equation (11) is minimum, as calculated by Louden in Reference 20. It is concluded that neither one of the test rooms features optimum dimension ratios, although receiving room dimensions approximate the recommended ratios in the ASTM Standard for the lowest frequency bands.

TABLE 4. - RECOMMENDED AND ACTUAL RATIOS OF ROOM DIMENSIONS

ASTM Standard (Ref. 8)	1	:	1.26	:	1.59
Louden (Ref. 20)	1	:	1.4	:	1.9
Source Room	1	:	1.11	:	1.18
Receiving Room	1	:	1.16	:	1.54

Flanking Transmission

Measurements indicate that transmission loss for sound entering the receiving room via paths other than the test panel is 80 dB or higher for frequencies above 200 Hz (Ref. 21). This implies that for this frequency region noise transmission loss as high as 70 dB can be measured (Ref. 8). In the frequency range from 50 to 200 Hz transmission loss values of 23 to 30 dB have been measured without apparent flanking transmission.

Ambient Noise Levels

Ambient noise levels do not exceed 24 dB in the receiving room and 33 dB in the source room for any one-third octave band with a center frequency greater than 63 Hz. The ASTM Standard (Ref. 8) recommends that measured sound pressure levels, due to signal plus background noise should then exceed 34 dB in the receiving room. Corrections for the background noise should be applied if the levels in the receiving room are between 29 and 34 dB. The adjusted value of the signal level is then given by (Ref. 8):

$$L_s = 10 \log (10^{L_{sb}/10} - 10^{L_b/10}) \qquad (13)$$

where L_b is the background noise level, L_{sb} is the combined level of signal and background and L_s is the adjusted signal level.

Room Absorption

In general, room absorption should be as low as possible in order to achieve the best possible simulation of the ideal diffuse field condition and keep the region affected by the direct field of the source as small as possible. Table 5 presents reverberation times measured in the source and receiving rooms along with the average absorption coefficients $\bar{\alpha}$ as calculated from (Ref. 22):

$$\bar{\alpha} = .163 \frac{V}{S_t T} \qquad (14)$$

where V is the volume of the room, S_t is the total wall area of the room and T is the reverberation time.

TABLE 5.- REVERBERATION TIMES AND AVERAGE ABSORPTION COEFFICIENTS IN THE TRANSMISSION LOSS APPARATUS

One-third octave band center frequency [Hz]	Source Room		Receiving Room	
	T [s]	$\overline{\alpha}$ [-]	T [s]	$\overline{\alpha}$ [-]
125	1.45	.067	2.61	.036
160	1.62	.061	2.86	.033
200	1.65	.060	2.73	.034
250	1.70	.058	2.93	.032
315	1.74	.056	3.00	.031
400	1.62	.061	2.79	.034
500	1.58	.062	3.16	.030
630	1.59	.062	3.43	.027

At frequencies below about 200 Hz the average room absorption coefficient, $\overline{\alpha}$, for each room should be less than (Ref. 8):

$$\overline{\alpha} = \frac{V^{2/3}}{3S_t} \tag{15}$$

which value is .055 for both test rooms. This criterion for room absorption is easily met in the receiving room but not in the source room, as is shown in Table 5. Decreasing the absorption in the source room by 12% will satisfy the ASTM requirements in all one-third octave bands with center frequencies of 160 Hz and higher.

For the lowest test bands, with only few acoustic room modes, a suggested criterion is (Ref. 16):

$$T < 2.2 \frac{dN}{df} \qquad (16)$$

where $\frac{dN}{df}$ is the modal density which is defined by Equation (11) and given in Table 2 for the 160 Hz, 200 Hz and 250 Hz one-third octave bands. The criterion of Equation (16) is not met for both test rooms for the one-third octave bands with center frequencies of 250 Hz and lower. For those frequencies increased absorption in the test rooms will broaden modal responses and thus improve modal overlap.

Microphone Location and Distance to Boundaries

The minimum distance from the microphone to the test panel and any of the room boundaries is given by (Ref. 8):

$$d = \frac{c}{2f} \qquad (17)$$

which results in a minimum distance of .85 m for the 200 Hz one-third octave band. The actual minimum distance from the microphone, which is mounted at the end of a rotating boom, to any of the room boundaries is .54 m which would satisfy Equation (17) for the 315 Hz and higher one-third octave bands.

The minimum distance from the sound source to the test partition or the nearest measurement point shall be such that the direct field is at least 10 dB below the reverberant field. This is to ensure that the transmission loss results are not biased significantly by the direct field of the sound source, as the underlying theory involves the interaction of diffuse sound fields and the test partition. Measurements show that this condition is only met for the 200 Hz one-third octave band and lower for the present test configuration. This might be improved by changing the location of the sources and/or microphone boom. For an omnidirectional source mounted on a hard surface, the direct field is 10 dB below the reverberant field at a distance d from the source which is given by (Ref. 8):

$$d = .63 \sqrt{\bar{\alpha}\, S_t} \tag{18}$$

Assuming an average absorption coefficient $\bar{\alpha}$ = .06 in the source room, this minimum distance equals 1.43 m. This is almost a factor 1.5 more than the minimum distance in the present test configuration.

Validated Frequency Region

Comparing the characteristics of the test rooms of the Transmission Loss Apparatus with the recommendations in ASTM and ISO standards it is concluded that a random sound field in both test rooms is diffuse in the 250 Hz and higher one-third octave bands provided that the absorption in the source room is decreased by 12%. The 200 Hz one-third octave band might yield acceptable diffusitivity, but is not recommended. Table 6 presents a summary of recommended and acceptable minimum one-third octave band center frequencies for which sound diffusitivity in both test rooms of the facility is achieved.

TABLE 6. - RECOMMENDED AND ACCEPTABLE MINIMUM FREQUENCIES AT WHICH SOUND DIFFUSIVITY IS ACHIEVED

Criterion	Reference	Minimum one-third octave band frequency [Hz]	
		Recommended	Acceptable
Room volume	ASTM (Ref. 8)	160	125
Room volume	ISO (Ref. 10)	250	
Number of room modes		160	
Sound pressure level standard deviation	ISO (Ref. 10)	200	160
Average absorption coefficient (When absorption in the source room is decreased by 12%)	ASTM (Ref. 8)	160	

In the present configuration the criterion of minimum distance between microphone and room boundaries provides only accurate transmission loss data in the 315 Hz and higher one-third octave bands. Proper location of the microphone booms would enable noise transmission loss measurements in the frequency region where a diffuse field in both test rooms is anticipated (> 250 Hz one-third octave band).

CONCLUDING REMARKS

The layout and present configuration of the NASA Langley Noise Transmission Loss Apparatus has been presented. The test procedure according to the "Plate Reference Method", currently in use, has been discussed along with a comparison of the characteristics of the test rooms with the criteria and recommendations in ASTM and ISO standards. The Plate Reference Method, based on the assumption that a thin, large aluminum panel exhibits a mass law behavior, is a practical method that not only corrects for spatial sound pressure fluctuations, but also for non-diffusivity close to the room boundaries and in the direct field of the source. The automated procedure and proper temperature control gives reasonable accuracy in the frequency range of interest for identical test configurations. The room dimensions are not critical for executing this method, although higher diffusivity of the test rooms will contribute to a higher accuracy of the test results.

The "Classical Method" is dependent on the diffusivity on the test rooms and therefore is not valid, for the present apparatus configuration. However, if the absorption in the source room is decreased by 12%, which is easily accomplished, this method may be used in one-third octave bands with center frequencies of 200 Hz and higher. To extend the validity of this method to lower frequencies improvements may be obtained by a larger volume of the test rooms, non-parallel walls, rotating diffusers, optimized microphone sweeping area, improved sound absorption at the lowest frequencies and sound source location. Neither of these will result in a great improvement without appreciable design modifications that go beyond the scope of the present apparatus.

From the foregoing discussion the following conclusions can be made.

- Above the 200 Hz one-third octave band two noise transmission loss measurement methods giving the same results are available:
    1. The "Classical Method" according to the ASTM Standard (Ref. 8) which is based on a diffuse sound field in the test rooms.
    2. The "Plate Reference Method" based on the assumption that a large, thin, reference panel follows mass law.
- The Plate Reference Method can also be used in the 50-200 one-third octave bands without any modification to the present apparatus. Along with its ease of application, good accuracy and repeatibility, this method is prefered for testing light, propeller driven aircraft type structures for which the frequency of interest is defined from the 50 to the 8000 Hz one-third octave band.
- The Plate Reference Method is valid for only one test set-up and room configuration. A new calibration of the equivalent absorption area is required for any change other than installation of a different test structure.
- A correction to the equivalent absorption area is needed if the surface layer of the test structure facing the receiver room alters the absorption of this room. This correction is estimated currently by applying this layer

to the wall opposite the test structure, thus not changing the transmission loss but only the absorption in the receiving room.

- To minimize the effects of changes in temperature, atmospheric pressure or humidity it is recommended that all noise transmission loss tests be conducted within the same, continuous, time period that is kept as short as possible.

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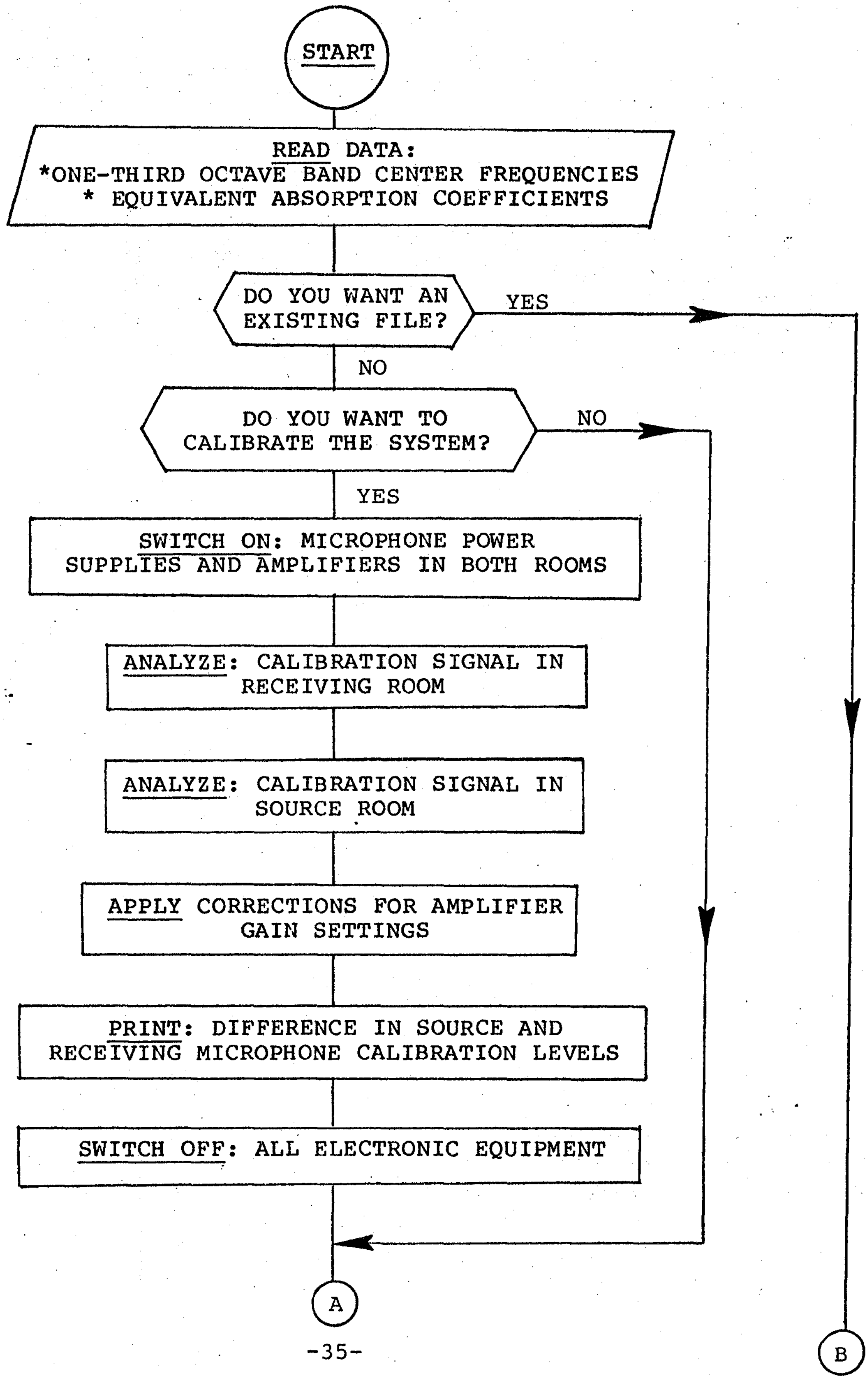
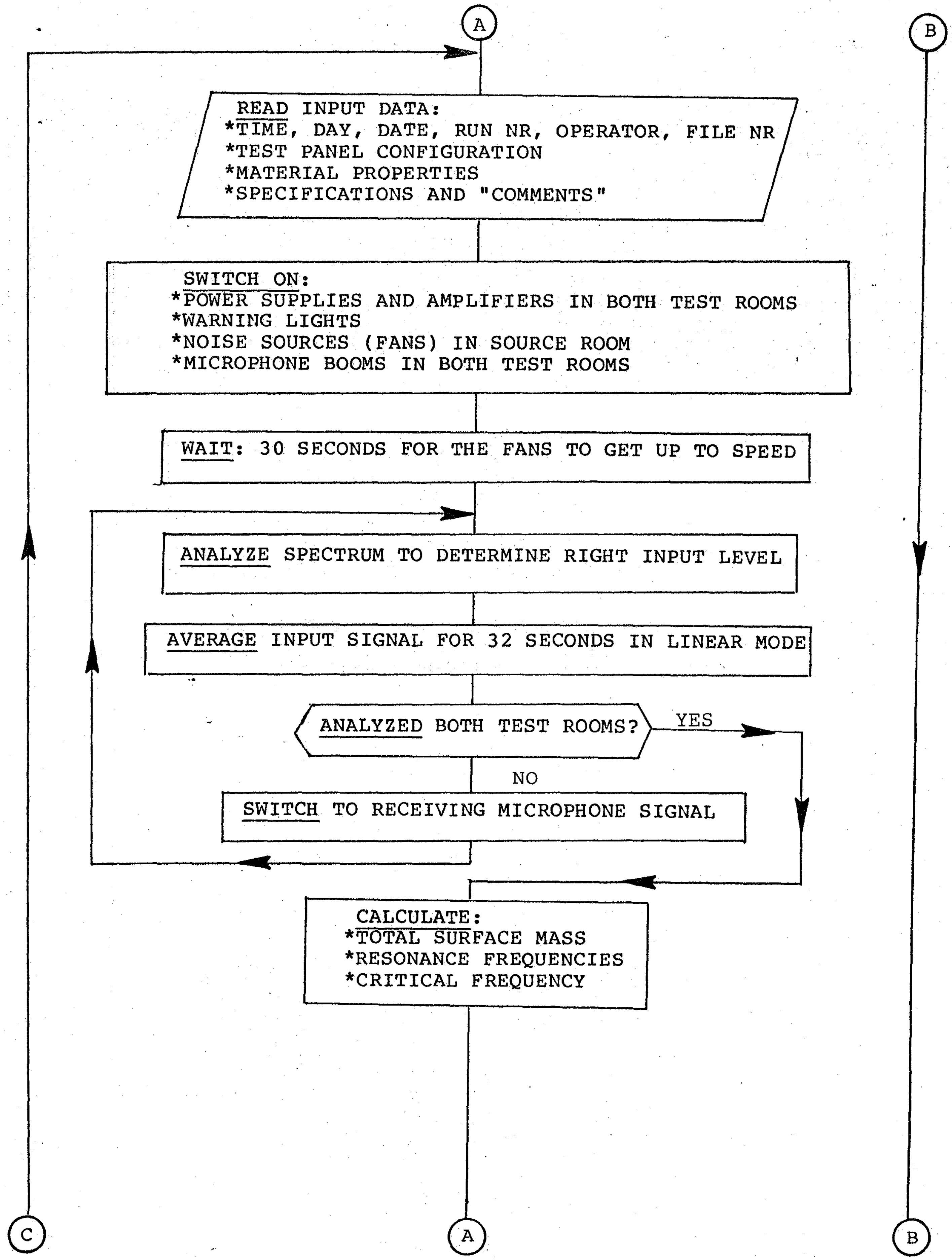
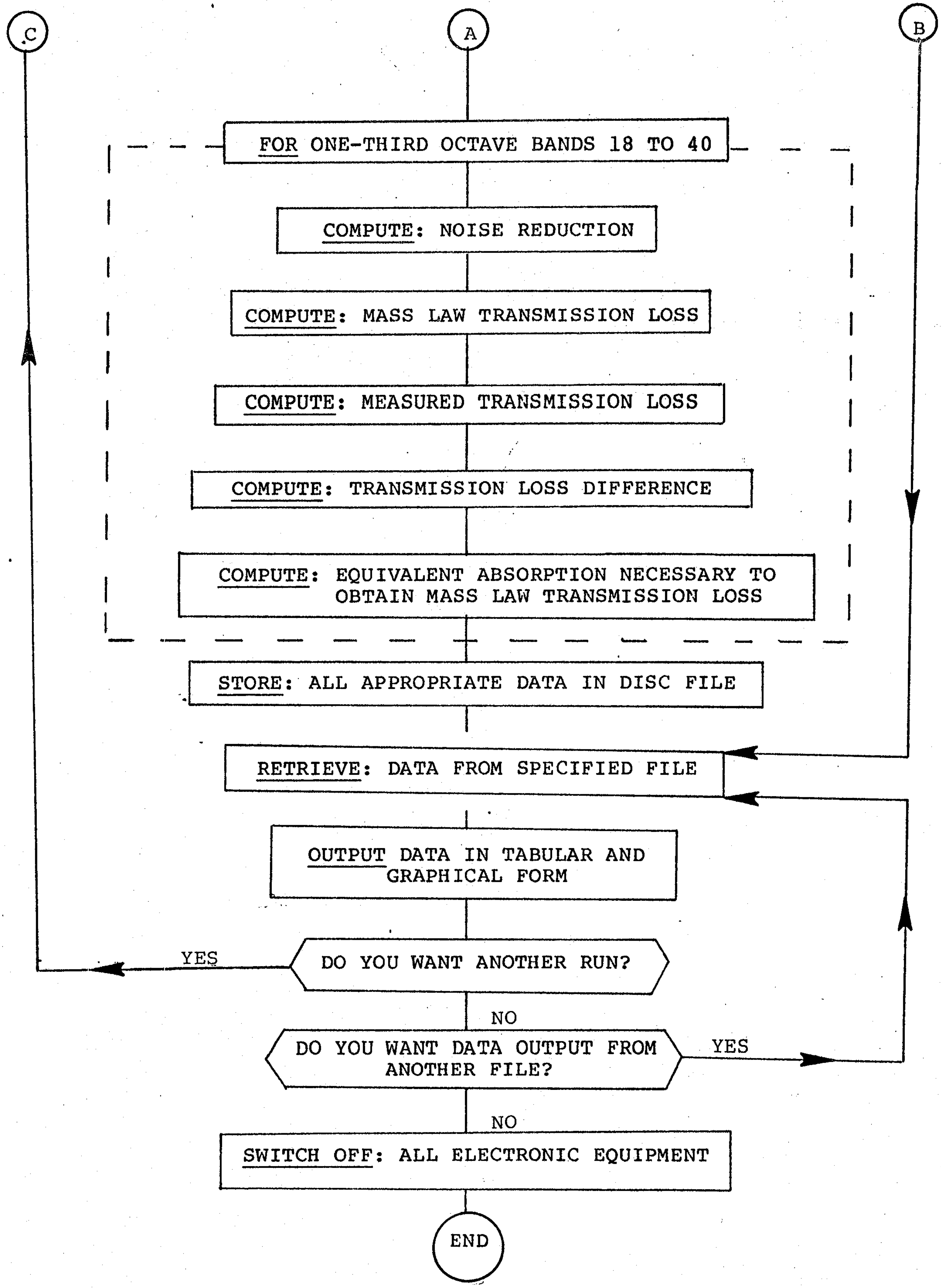
APPENDIX A

FLOW CHART OF HP 9845 B COMPUTER PROGRAM


START
READ DATA:
*ONE-THIRD OCTAVE BAND CENTER FREQUENCIES
* EQUIVALENT ABSORPTION COEFFICIENTS
DO YOU WANT AN EXISTING FILE?
YES
NO
DO YOU WANT TO CALIBRATE THE SYSTEM?
NO
YES
SWITCH ON: MICROPHONE POWER SUPPLIES AND AMPLIFIERS IN BOTH ROOMS
ANALYZE: CALIBRATION SIGNAL IN RECEIVING ROOM
ANALYZE: CALIBRATION SIGNAL IN SOURCE ROOM
APPLY CORRECTIONS FOR AMPLIFIER GAIN SETTINGS
PRINT: DIFFERENCE IN SOURCE AND RECEIVING MICROPHONE CALIBRATION LEVELS
SWITCH OFF: ALL ELECTRONIC EQUIPMENT
A
B


A
B
READ INPUT DATA:
*TIME, DAY, DATE, RUN NR, OPERATOR, FILE NR
*TEST PANEL CONFIGURATION
*MATERIAL PROPERTIES
*SPECIFICATIONS AND "COMMENTS"
SWITCH ON:
*POWER SUPPLIES AND AMPLIFIERS IN BOTH TEST ROOMS
*WARNING LIGHTS
*NOISE SOURCES (FANS) IN SOURCE ROOM
*MICROPHONE BOOMS IN BOTH TEST ROOMS
WAIT: 30 SECONDS FOR THE FANS TO GET UP TO SPEED
ANALYZE SPECTRUM TO DETERMINE RIGHT INPUT LEVEL
AVERAGE INPUT SIGNAL FOR 32 SECONDS IN LINEAR MODE
ANALYZED BOTH TEST ROOMS?
YES
NO
SWITCH TO RECEIVING MICROPHONE SIGNAL
CALCULATE:
*TOTAL SURFACE MASS
*RESONANCE FREQUENCIES
*CRITICAL FREQUENCY
C
A
B


C
A
B
FOR ONE-THIRD OCTAVE BANDS 18 TO 40
COMPUTE: NOISE REDUCTION
COMPUTE: MASS LAW TRANSMISSION LOSS
COMPUTE: MEASURED TRANSMISSION LOSS
COMPUTE: TRANSMISSION LOSS DIFFERENCE
COMPUTE: EQUIVALENT ABSORPTION NECESSARY TO OBTAIN MASS LAW TRANSMISSION LOSS
STORE: ALL APPROPRIATE DATA IN DISC FILE
RETRIEVE: DATA FROM SPECIFIED FILE
OUTPUT DATA IN TABULAR AND GRAPHICAL FORM
DO YOU WANT ANOTHER RUN?
YES
NO
DO YOU WANT DATA OUTPUT FROM ANOTHER FILE?
YES
NO
SWITCH OFF: ALL ELECTRONIC EQUIPMENT
END

APPENDIX B

SAMPLE OUTPUT OF COMPUTER PROGRAM FOR TRANSMISSION LOSS MEASUREMENTS

Date: Apr 28 1983 Time: 15.30 EST Run nr: 6 Operator: F.W.GROSVELD

****

Test panel: COMMANDER

****

File name: BRMLE

Center Frequency (Hz)	One-third octave band sound pressure levels (dB) Source room	Receiver room	NR	TL (mass law)	TL (meas)	TL (diff)	
50	74.3	39.7	34.6	8.7	19.84	-11.1	5148.7
63	74.2	47.6	26.6	10.4	9.94	.4	560.0
80	71.6	56.7	14.9	12.1	8.27	3.8	25.4
100	77.0	58.3	18.7	13.9	11.10	2.8	40.1
125	75.4	55.3	20.1	15.8	14.55	1.2	36.0
160	76.5	57.5	19.0	17.7	12.59	5.1	18.0
200	79.3	58.6	20.7	19.7	13.94	5.7	17.0
250	81.3	60.2	21.1	21.6	16.45	5.2	11.9
315	81.8	54.0	27.8	23.6	23.69	-.1	35.2
400	82.0	49.2	32.8	25.6	28.85	-3.3	70.5
500	82.0	44.0	38.0	27.6	35.34	-7.8	147.6
630	83.9	42.5	41.4	29.6	39.22	-9.7	204.0
800	87.5	44.1	43.4	31.6	41.34	-9.8	204.2
1000	88.0	41.9	46.1	33.6	44.84	-11.3	240.0
1250	89.3	42.0	47.3	35.6	46.63	-11.1	199.7
1600	88.7	39.2	49.5	37.6	48.83	-11.3	209.2
2000	87.7	36.0	51.7	39.6	51.12	-11.6	219.0
2500	86.3	31.3	55.0	41.6	54.50	-12.9	295.5
3150	84.7	26.3	58.4	43.6	57.62	-14.1	407.9
4000	83.4	23.5	59.9	45.6	58.81	-13.3	363.6
5000	81.8	23.0	58.8	47.6	57.21	-9.7	178.1
6300	79.0	21.0	58.0	49.6	55.82	-6.3	93.5
8000	75.1	20.0	55.1	51.6	53.62	-2.1	30.2
10000	71.1	21.0	50.1	53.6	54.29	-.7	6.0
A-Weighted	97.5	56.3	41.2				

Test panel properties :

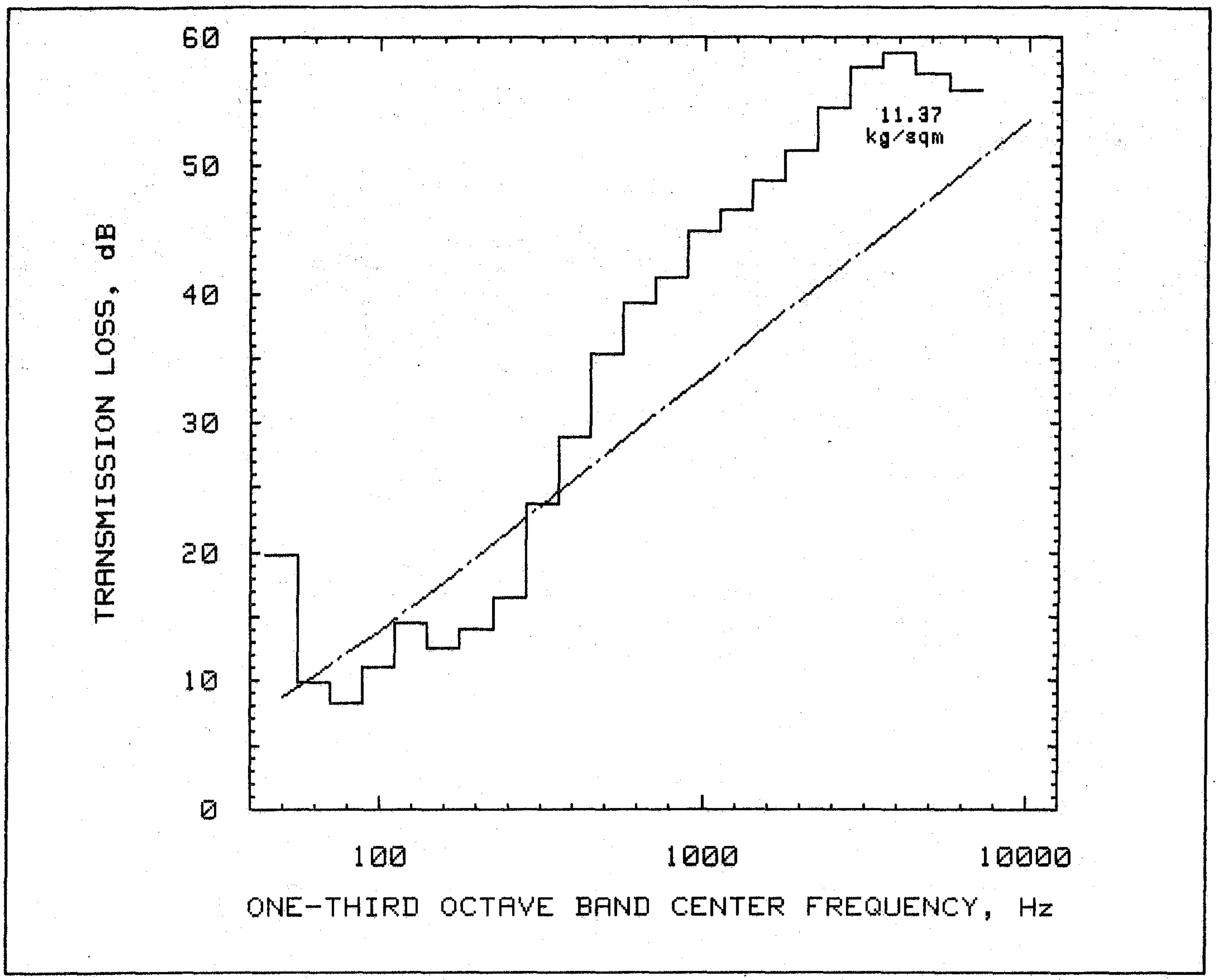
Density	=	7059	kg/cum
Mass per unit area	=	11.368	kg/sqm
Thickness	=	.00161	m
Young's modulus	=	71.0E+09	N/sqm
Poisson ratio	=	.33	
Width	=	1.153	m
Length	=	1.457	m
Resonance frequency	=	3.0	Hz
Critical frequency	=	13470	Hz

Absorption correction:

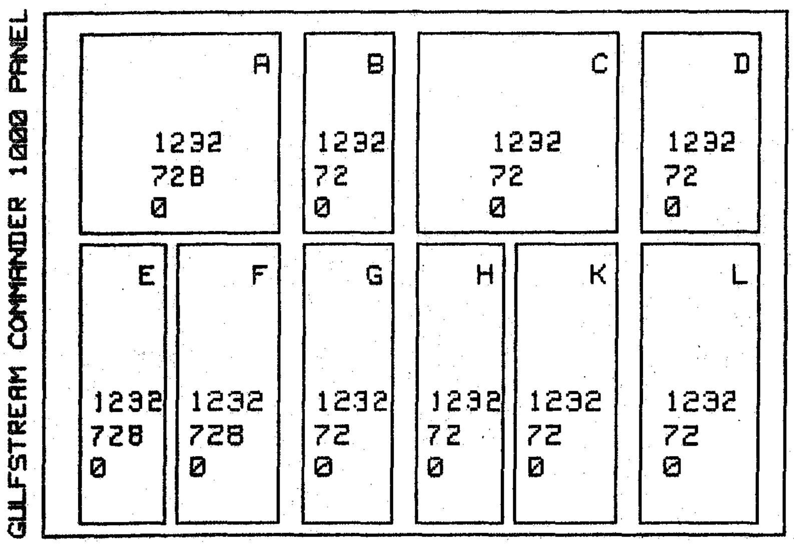
NC	F1	F2	F3
100	0	0	0

FC1

Comment :
TNB on the left side of the panel structure



Total treatment: 11.30 kg (24.91 lbs)   Mass/unit area: 10.38 kg/sm (2.13 psf)



0.	Bare skin	.063 inch AL
1.	Y-370	1.54 kg/sqm
2.	Fiberglass	0.24 kg/sqm
3.	Vinyl septum	1.79 kg/sqm
4.	TNB #101	4.96 kg/sqm
5.	Honeycomb	
6.	Trimpanel	1.27 kg/sqm
7.	Vinyl septum 2	1.37 kg/sqm
8.	Sticky TNB+101	4.96 kg/sqm

Test panel: COMMANDER   File name: BRMLE   Run nr: 6   Date: April 28 1983   FC1

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Langley Technical Monitor: D. G. Stephens

16. Abstract
A description of the Transmission Loss Apparatus at NASA Langley Research Center, which is specifically designed to accommodate general aviation type aircraft structures, is presented. The measurement methodology, referred to as the "Plate Reference Method", is discussed and compared with the classical method as described in the Standard of the American Society for Testing and Materials. This measurement procedure enables reliable and accurate noise transmission loss measurements down to the 50 Hz one-third octave band. The transmission loss characteristics of add-on acoustical treatments, applied to the basic structure, can be established by inclusion of appropriate absorption corrections for the treatment.

17. Key Words (Suggested by Author(s))
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Sound Transmission
Noise Measurement
Interior Aircraft Noise
Acoustic Attenuation

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