INDEX AND SUMMARY:
A RESEARCH PROGRAM TO REDUCE THE INTERIOR NOISE IN GENERAL AVIATION AIRCRAFT,
NASA GRANT NSG 1301

KU-FRL-417-24

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SUMMARY

This report is an index of the published works from NASA Grant NSG 1301, entitled "A Research Program to Reduce the Interior Noise in General Aviation Aircraft." Included are a list of all published reports and papers, a compilation of test specimen characteristics, and summaries of each published work.

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CHAPTER 1

PROJECT-RELATED PUBLICATIONS

This chapter lists the reports and papers written under NASA Grant NSG 1301/NASA Contract NCCI-6.

1.1 REPORTS

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KU-FRL-317-1	March 1977	"SEMI-ANNUAL PROGRESS REPORT" (documentation of research accomplished April 15,1976, through February 1, 1977); by T. Peschier	52
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KU-FRL-317-3	August 1977	"DESIGN OF AN ACOUSTIC PANEL TEST FACILITY'; by T. Henderson	100
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KU-FRL-317-6	January 1978	"EXPERIMENTAL AND THEORETICAL SOUND TRANSMISSION THROUGH AIRCRAFT PANELS"; by D. Durenberger	158

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KU-FRL-317-7	March 1978	"INTERIM REPORT" (description, evaluation, & discussion of certain elements of the test set-up/procedure, with suggestions for alterations in the experimentation); by F. Grosveld	24
KU-FRL-317-8	August 1978	"NOISE REDUCTION THROUGH A CAVITY-BACKED FLEXIBLE PLATE"; by C. van Dam	100
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KU-FRL-417-10	July 1979	"THE EFFECT OF OBLIQUE ANGLE OF SOUND INCIDENCE, REALISTIC EDGE CONDITIONS, CURVATURE AND IN-PLANE PANEL STRESSES ON THE NOISE REDUCTION CHARACTERISTICS OF GENERAL AVIATION TYPE PANELS"; by F. Grosveld, J. Laméris, and D. Dunn	118
KU-FRL-417-11	August 1979	"ACOUSTIC PLANE WAVES NORMALLY INCIDENT ON A CLAMPED PANEL IN A RECTANGULAR DUCT"; by H. Unz	129
KU-FRL-417-12	February 1980	"NOISE REDUCTION CHARACTERISTICS OF FLAT, GENERAL AVIATION TYPE, DUAL PANE WINDOWS"; by F. Grosveld and R. Navaneethan	64
KU-FRL-417-13	August 1980	"STUDY OF TYPICAL PARAMETERS THAT AFFECT SOUND TRANSMISSION THROUGH GENERAL AVIATION AIRCRAFT STRUCTURES"; by F. Grosveld	534
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KU-FRL-417-15	February 1981	"NOISE REDUCTION CHARACTERISTICS OF MULTILAYERED PANELS"; by R. Navaneethan and M. Williams	111

Report No.	Date	Title and Author	No. of Pages
KU-FRL-417-16	May 1981	"STUDY OF NOISE REDUCTION CHARACTERISTICS OF MULTILAYERED PANELS AND DUAL PANE WINDOWS WITH HELMHOLTZ RESONATORS"; by R. Navaneethan	175
KU-FRL-417-17	October 1981	"INFLUENCE OF DEPRESSURIZATION AND DAMPING MATERIAL ON THE NOISE REDUCTION CHARACTERISTICS OF FLAT AND CURVED STIFFENED PANELS"; by R. Navaneethan, B. Streeter, and S. Koontz	308
KU-FRL-417-18	March 1982	"STUDY OF NOISE REDUCTION CHARACTERISTICS OF COMPOSITE FIBER-REINFORCED PANELS, INTERIOR PANEL CONFIGURATIONS, AND THE APPLICATION OF THE TUNED DAMPER CONCEPT"; by J. Laméris, S. Stevenson, and B. Streeter	163
KU-FRL-417-19	December 1982	"STUDY OF THE DAMPING CHARACTERISTICS OF GENERAL AVIATION AIRCRAFT PANELS AND DEVELOPMENT OF COMPUTER PROGRAMS TO CALCULATE THE EFFECTIVENESS OF INTERIOR NOISE CONTROL TREATMENT"; by R. Navaneethan, J. Hunt, and B. Quayle	112
KU-FRL-417-20	January 1983	"USER'S GUIDE TO MULTILAYER SOUND TRANSMISSION LOSS PROGRAM"; by R. Navaneethan (FRL Internal Report)	53
KU-FRL-417-21	May 1983	"STUDY OF NOISE REDUCTION CHARACTERISTICS OF DOUBLE-WALL PANELS"; by R. Navaneethan, B. Quayle, S. Stevenson, and M. Graham	179
KU-FRL-417-22	December 1983	"MEASUREMENT OF TRANSMISSION LOSS CHARACTERISTICS USING ACOUSTIC INTENSITY TECHNIQUES AT THE KU-FRL ACOUSTIC TEST FACILITY"; by R. Navaneethan and B. Quayle	124

Report No.	Date	Title and Author	No. of Pages
KU-FRL-417-23	July 1984	"GENERAL AVIATION AIRCRAFT INTERIOR NOISE PROBLEM: SOME SUGGESTED SOLUTIONS"; by R. Navaneethan	491

1.2 TECHNICAL PAPERS

Paper No.	Date	Title and Author	No. of Pages
KU-FRL-317-P1	November 1977	"THE TRANSMISSION OF SOUND THROUGH AIRCRAFT PANELS"; by D. Durenberger and T. Peschier. AIAA informal paper presented at the Fourth Annual General Aviation Technology Fest, Wichita, Kansas, November 18-19, 1977.	12
KU-FRL-317-P2	April 1978	"A RESEARCH PROGRAM TO REDUCE THE INTERIOR NOISE LEVEL IN GENERAL AVIATION AIRPLANES"; by D. Durenberger, F. Grosveld, and K. van Dam. Paper presented at NASA Langley Research Center, Acoustics and Noise Reduction Div., Hampton, Virginia, April 24, 1978. Presented at Cessna Aircraft Co., Pawnee Div., Wichita, Kansas, April 18, 1978.	21
KU-FRL-317-P3	August 1978	"SOME NOISE TRANSMISSION LOSS CHARACTERISTICS OF TYPICAL GENERAL AVIATION STRUCTURAL MATERIALS"; by J. Roskam, C. van Dam, D. Durenberger, and F. Grosveld. AIAA paper 78-1480, presented at the Aircraft Systems and Technology Conferences, Los Angeles, California August 21-23, 1978. (Obtain from AIAA.)	9
KU-FRL-317-P4	November 1978	"GENERAL AVIATION INTERIOR NOISE RESEARCH"; by F. Grosveld. AIAA informal paper presented at the Fifth Annual General Aviation Technology Fest, Wichita, Kansas, November 10-11, 1978.	23

Paper No.	Date	Title and Author	No. of Pages
KU-FRL-317-P5	January 1979	"A RESEARCH PROGRAM TO REDUCE INTERIOR NOISE IN GENERAL AVIATION AIRPLANES: APRIL 24, 1978 - APRIL 30, 1979"; by F. Grosveld. Paper presented at NASA Langley Research Center, January 15-16, 1979, Hampton, Virginia.	33
KU-FRL-317-P6	April 1979	"SUMMARY OF NOISE REDUCTION CHARACTERISTICS OF TYPICAL GENERAL AVIATION MATERIALS"; by J. Roskam, F. Grosveld, and J. van Aken. Society of Automotive Engineers paper 790627, presented at the Business Aircraft Meeting, Wichita, Kansas, April 3-6, 1979 (Obtain from SAE.)	40
KU-FRL-417-P7	January 1980	"STRUCTURAL PARAMETERS THAT INFLUENCE THE NOISE REDUCTION CHARACTERISTICS OF TYPICAL GENERAL AVIATION MATERIALS"; by J. Roskam and F. Grosveld. AIAA paper 80-0038, presented at the 18th Aerospace Sciences Meeting, Pasadena, California, January 14-16, 1980. (Obtain from AIAA.)	10
KU-FRL-417-P8	August 1980	"NOISE REDUCTION CHARACTERISTICS OF GENERAL AVIATION TYPE DUAL PANE WINDOWS"; by F. Grosveld, R. Navaneethan, and J. Roskam. AIAA paper 80-1874, presented at the AIAA Aircraft Systems Meeting, Anaheim, California, August 5-6, 1980. (Obtain from AIAA.)	7

Paper No.	Date	Title and Author	No. of Pages
KU-FRL-417-P9	May 1981	"A MICROCOMPUTER-BASED SYSTEM FOR NOISE CHARACTERISTICS ANALYSIS"; by M. Mosser, D. Rummer, and R. Navaneethan. ISMM paper, presented at Symposium on Mini and Microcomputers in Control and Measurement, San Francisco, California, May 20-22, 1981. (Obtain from ACTA Press, P.O. Box 2481, Anaheim, CA, 92804.)	3
KU-FRL-417-P10	April 1981	"SUMMARY OF TYPICAL PARAMETERS THAT AFFECT SOUND TRANSMISSION THROUGH GENERAL AVIATION AIRCRAFT STRUCTURES"; by F. Grosveld, R. Navaneethan, and J. Roskam. SAE technical paper 810562, presented at the Business Aircraft Meeting & Exposition, Wichita, Kansas, April 7-10, 1981. (Obtain from SAE.)	22
KU-FRL-417-P11	March 1983	"NOISE REDUCTION CHARACTERISTICS OF GENERAL AVIATION TYPE DOUBLE WALL STRUCTURES"; by B. Quayle. AIAA student paper, presented at 1983 AIAA Region V Student Conference.	36

CHAPTER 2

SUMMARIES OF PUBLISHED WORKS

This chapter contains a summary of each project-related publication. This compilation of summaries is meant to serve as a reference point to the other publications and will not attempt to present all the results of the research project. Those results may be found in each of the other publications.

2.1 SUMMARIES OF REPORTS

KU-FRL-317-1

"SEMI-ANNUAL PROGRESS REPORT" (documentation of research accomplished April 15, 1976, through February 2, 1977); by T. Peschier. March 1977, 52 pgs.

The purpose of this report is to document research accomplished from April 15, 1976, through February 1, 1977, under the funding of NASA Grant NSG 1301. This document therefore has the character of a progress report, while a final report will be submitted in April 1977.

The proposal for this research program states that the objective of this program was to develop an effective and competent research team at the University of Kansas in the area of general aviation interior (cabin) noise. This would be a preparation for a long-range follow-up research program in both interior and exterior noise.

The definition of this follow-up program was to be one of the major tasks to be performed under NSG 1301, along with the following activities, which were also intended as desirable preparations:

1. Familiarization with interior noise state of the art;
2. Detail design of an on-board interior noise measuring and recording system;
3. Development of in-flight procedures for utilizing and of ground procedures for analyzing and interpreting the data.

Although both interior and exterior noise were mentioned in the proposal as research areas to be explored under NSG 1301, the emphasis was shifted to interior noise.

In an early stage of the research program, however, some very valuable practical experience was obtained as a result of exterior noise activities, while related analytical studies resulted in a better understanding of characteristics of general aviation noise sources.

KU-FRL-317-2

"PROGRESS REPORT, COVERING PERIOD MARCH 1, 1977, to JUNE 17, 1977"; by T. Peschier, D. Andrews, and T. Henderson. June 1977, 36 pages.

This report continues the documentation of the follow-up interior noise research program which was accepted by NASA in April 1977. The construction of the acoustic test facility (a plane-wave tube) was initiated, and a description of this facility is given.

Manufacturers of sound reduction treatments (i.e., panel vibration damping and absorptive materials) were contacted about the existence and availability of materials suitable for lightweight aircraft structures. Information with respect to these activities is documented within the report.

A large portion of the activities was dedicated to studying the relevance of KU-FRL test results in predicting (theoretically or semi-empirically) interior noise levels in general aviation aircraft. It was decided to make a few additions to the program as described in the NASA proposal of March 1977. These additions are

1. To use three (instead of two) noise sources in the plane-wave tube to evaluate the influence of excitation spectrum on panel response. The three sources will be a) white noise, b) pure harmonic sound (of variable frequency) and c) actual general aviation fuselage panel excitations (as measured in flight).
2. To use theoretical and experimental data obtained in the course of the project to develop more efficient noise reduction materials (or procedures to apply these), or to develop guidelines for the design of such materials for procedures.

The reliability of this facility and examples of data gathered using this system are also included. The test results are compared to pertinent acoustical theories for panel bahavior, and the minor anomalies in the data are also discussed. A new method for predicting panel behavior in the stiffness region is also presented.

KU-FRL-317-4

"GENERAL AVIATION INTERIOR NOISE STUDY"; by T. Peschier. August 1977, 158 pages.

This report presents the organization and work completed under a National Aeronautics and Space Administration-funded research project to study the transmission of sound through general aviation airplane structures. Also reported are descriptions and discussions of the testing equipment and procedures of the project and of relevant analysis and prediction methods. In addition, a description is included of the exposure of general aviation passengers to noise and of important noise sources and receiving space (i.e., cabin) effects.

The project is the second of two consecutive phases of a research program, the broad goal of which is to reduce interior noise in general aviation airplanes. The objective of the first program phase was to develop an effective and competent noise research team at the University of Kansas. This phase was intended as one of the preparations for the second phase, a long-range follow-up research project. During the last part of phase one and the first part of phase two, many other preparations were made including the design, construction , and calibration of a test facility, purchasing of equipment, development of testing and data reduction procedures, and the study of pertinent literature. It is this period of preparation that is covered in this report (February 1977 through the middle of August 1977).

KU-FRL-317-5

PROGRESS REPORT, dealing with influences of stiffness, mass, pressurization, and vibration damping materials on panels, as tested in the KU-FRL test facility;
by T. Peschier, D. Durenberger, K. van Dam, and Tzy-Chuan Shu.
October 1977, 75 pages.

The objective of this NASA-sponsored KU-FRL noise project (NSG 1301) is to investigate experimentally and analytically the transmission of sound through isolated panels. The purpose of this report is to give the first test results of the panels tested up to mid-September.

In the month of August the KU-FRL noise research team completed the construction and the calibration of the test facility and started testing flat panels. During this time the team also continued predictions of behavior of the panels according to pertinent analytical methods. The first results have permitted improvement of semi-empirical methods of predicting panel transmission loss.

In this report the influence of stiffness and mass of the plate will be discussed. Also the effect of pressurization and the usefulness of damping materials will be described.

Beech, Cessna, and Grumman American Aircraft Corporations provided most of the panels, and some of the panel treatments, tested for this report. Insul-Coustics Corporation and Specialty Composites Corporation provided some of the vibration damping materials tested.

KU-FRL-317-6

"EXPERIMENTAL AND THEORETICAL SOUND TRANSMISSION THROUGH AIRCRAFT PANELS"; by D. Durenberger. January 1978, 158 pages.

This report describes the work performed under a National Aeronautics and Space Administration-funded research project on aircraft-oriented acoustics.

The more important recent events are presented. These include a description of project operation, expansions in testing capabilities, and the principal findings since the previous reports were published.

Equipment for testing panels at non-normal incidence to sound is a noteworthy addition to the facility. This capability is expected to yield useful data which is otherwise very difficult to obtain, either theoretically or experimentally.

Recent advances made by the project team are expected to very significantly improve the understanding and applicability of the test data which have been and will be obtained. The influence of individual test facilities nearly always "colors" the data acquired. When the phenomena responsible are understood, test data can be applied much more intelligently than otherwise possible.

A compendium of recent test data on panels with holes, on honeycomb panels, and on various panel treatments is also provided.

KU-FRL-317-7

"INTERIM REPORT" (description, evaluation, and discussion of certain elements of the test set-up/procedure, with suggestions for alterations in the experimentation); by F. Grosveld.
March 1978, 24 pages.

This report evaluates the research regarding general aviation aircraft noise which was completed during the period of January 16 through March 12, 1978. Some actual problem areas have been denoted, and possible alterations and alternate methods are indicated. Since it is impossible to oversee all the difficulties and complications of a long-term effort within a period of seven weeks, this report should be seen as an evaluation of the noise project and a subject for discussion.

KU-FRL-317-8

"NOISE REDUCTION THROUGH A CAVITY-BACKED FLEXIBLE PLATE"; by C. van Dam. August 1978, 100 pages.

A prediction method is found for the noise reduction through a cavity-backed panel. The analysis takes into account only cavity modes in one direction. The results of this analysis are used to find the effect of acoustic stiffness of a backing cavity on the panel behavior. The resulting changes in the noise reduction through the panel are significant. The results of this analysis show good agreement with the results of the method of Guy and Bhattacharya. The agreement with experimental results obtained with the test facility, however, is poor.

KU-FRL-317-9

"INVESTIGATION OF THE CHARACTERISTICS OF AN ACOUSTIC PANEL TEST FACILITY"; by F. Grosveld and J. van Aken. September 1978, 150 pages.

Characteristics of the test facility, as used by the noise research team of the University of Kansas, have been investigated. The purpose of these investigations was to determine the effects on the sound pressure level in the test facility, caused by varying a) microphone positions, b) equalizer setting, and c) panel clamping forces. Measurements have been done using a "Beranek tube" or this Beranek tube in combinations with an "extension tube" and a "special test section." (This special test section was designed to be used for sound transmission tests with an angle of incidence between sound and panel other than 90°.) In all configurations, tests have been executed with and without a test panel installed.

Finally, the influence of the speaker back panel and the back panel of the Beranek tube on the sound pressure levels inside the test tube have been investigated.

KU-FRL-417-10

"THE EFFECT OF OBLIQUE ANGLE OF SOUND INCIDENCE, REALISTIC EDGE CONDITIONS, CURVATURE AND IN-PLANE PANEL STRESSES ON THE NOISE REDUCTION CHARACTERISTICS OF GENERAL AVIATION TYPE PANELS";
by F. Grosveld, J. Laméris, and D. Dunn. July 1979, 118 pages.

Experiments have been conducted in the KU-FRL acoustic test facility to investigate the effect of an oblique angle of sound incidence, realistic edge conditions, curvature, and in-plane stresses on the noise reduction characteristics of general aviation type panels. A theoretical analysis of the effect of an oblique angle of sound incidence is given in the first section, while in the second section this analysis is compared with the experimental results. The design and construction of special test devices are also described. These special test devices are used to determine the effect of curvature and riveted or bonded edge conditions. The curvature effect on the noise reduction is analyzed theoretically and the experimental results are compared. The design and construction of a tension device is also covered. Using this tension device, uniaxial and biaxial stresses can be applied to a test panel. Initial noise reduction results for a panel under uniaxial stress are discussed, and finally the main conclusions and recommendations conclude this report.

It appears that a cavity acts as a stiffener to the panel. The fundamental panel/cavity resonance frequency is higher than that of a free vibrating panel that is not backed by a cavity. An increase in stiffness raises the fundamental resonance frequency, while adding mass causes the reverse effect. These considerations are the basis for the analysis given in this report.

KU-FRL-417-11

"ACOUSTIC PLANE WAVES NORMALLY INCIDENT ON A CLAMPED PANEL IN A RECTANGULAR DUCT"; by H. Unz. August 1979, 129 pages.

This report explains the use of basic theoretical concepts to develop the theory of acoustic plane waves normally incident on a clamped panel in a rectangular duct. The coupling theory between the elastic vibrations of the panel (plate) and the acoustic wave propagation in infinite space and in the rectangular duct is considered in detail. The partial differential equation which governs the vibration of the panel (plate) is modified by adding to it stiffness (spring) forces and damping forces, and the fundamental resonance frquency f_o and the attenuation factor α are discussed in detail.

The noise reduction expression based on the present theory is found to agree well with the corresponding experimental data of a sample aluminum panel in the mass-controlled region ($f > f_o$), the damping-controlled region ($f \sim f_o$), and the stiffness-controlled region ($f < f_o$). All the frequency positions of the upward and downward resonance spikes in the sample experimental data are identified theoretically as resulting from four cross interacting major resonance phenomena: the cavity resonance, the acoustic resonance, the plate resonance, and the wooden back panel resonance. Detailed tables are given for the values of these resonance frequencies in each case.

KU-FRL-417-12

"NOISE REDUCTION CHARACTERISTICS OF FLAT, GENERAL AVIATION TYPE, DUAL PANE WINDOWS"; by F. Grosveld and R. Navaneethan.
February 1980, 64 pages.

This report describes the work carried out to investigate noise reduction characteristics of general-aviation-type, dual pane windows in various configurations. The effects of inner and outer pane thickness, distance between the two panels, edge conditions, inclination of the inner pane, and depressurization of the air in between the panes are investigated.

The experimental study was conducted on Plexiglas windows backed by a closed, rigid, fiberglass-filled cavity. The frequency region of interest extends from 20 Hz to 5000 Hz. The sound-exposed area of the dual pane windows has dimensions of 15 x 15 inches. Results show the beneficial effects of thickening the panes, "floating" edge conditions, and depressurization, with constraints subject to a certain frequency region. It is concluded that the concept of depressurization of the air between thin (1/8 inch) Plexiglas panel and application of multiple-freedom edge conditions for the inner pane can lead to promising results. A trade-off study to combine the beneficial parameters is recommended.

KU-FRL-417-13

"STUDY OF TYPICAL PARAMETERS THAT AFFECT SOUND TRANSMISSION THROUGH GENERAL AVIATION AIRCRAFT STRUCTURES"; by F. Grosveld.
August 1980, 534 pages.

Studies have indicated that interior noise levels in general aviation aircraft are generally high and annoying, despite the use of acoustical treatments. The degree of interior noise depends largely upon sound transmission through the individual panel-type structures of the fuselage sidewall. In this report the oganization of and work completed for an ongoing general aviation interior noise research project is presented. Experimental results of typical parameters that affect the noise reduction characteristics of panel-type structures are discussed. These parameters include panel type, thickness, curvature, and edge conditions; in-plane stresses; depressurization; damping; sound-absorbing and stiffening treatments; dual-pane window structures; and oblique angles of sound incidence. The noise reduction measurements are conducted in a low-cost acoustic panel test facility, the configuration and characteristics of which are described. The effects of the cavities on both sides of the test specimen are discussed. Experimental results are found to be comparable with pertinent analytical predictions. A microcomputer data acquisition system, incorporated in the electronic equipment, is discussed; and program information is included. A significant data base describing the effect of the parameters investigated is presented. Results indicate that depressurization and high stiffness-to-mass materials considerably raise the noise reduction below the fundamental panel/cavity resonance frequency. It is concluded that trade-off studies incorporating the applicable conflicting parameters are needed to optimize the acoustic design of a general aviation aircraft structure.

KU-FRL-417-14

"ACOUSTIC PLANE WAVES INCIDENT ON AN OBLIQUE CLAMPED PANEL IN A RECTANGULAR DUCT"; by H. Unz. August 1980, 136 pages.

This report explains the use of basic theoretical concepts to develop the theory of acoustic plane waves incident on an oblique clamped panel in a rectangular duct. The coupling theory between the elastic vibrations of the panel (plate) and the oblique incident acoustic plane wave in infinite space is considered in detail and is used for the oblique clamped panel in the rectangular duct. The partial differential equation which governs the vibrations of the clamped panel (plate) is modified by adding to it stiffness (spring) forces and damping forces. The transmission loss coefficient and the noise reduction coefficient for oblique incidence are defined and derived in detail. The resonance frequencies excited by the free vibrations of the oblique finite clamped panel (plate) are derived and calculated in detail for the present case.

The detailed features and the oscillatory trends of the experimental noise reduction coefficient curves for oblique aluminum panels of angles θ = 15°, 30°, 40°, 60° in the square duct are explained in detail, based on the theory presented in this report. All the frequency positions of the downward and upward resonance spikes in the experimental data are identified theoretically as resulting from four major resonance phenomena: the cavity resonance, the acoustic resonance, the wooden back panel resonance, and the plate resonance. Detailed tables are given for the values of these resonance frequencies in each case.

KU-FRL-417-15

"NOISE REDUCTION CHARACTERISTICS OF MULTILAYERED PANELS";
by R. Navaneethan and M. Williams. February 1981, 111 pages.

This report describes the work carried out to investigate the noise reduction characteristics of multilayered panels suitable for use in general aviation aircraft. Effects of the densities of various noise control materials on the noise reduction characteristics of multilayered panels are discussed. The effect of the presence of an air gap in multilayered panels was investigated. Sandwiching of sound-absorption materials or foam between two aluminim panels promises to be a good noise reduction configuration in the stiffness-controlled region. A combination of the foam and fibrous sound-absorption material as the core offers a high noise reduction in this frequency region.

This report also describes the continuing work carried out to calculate the panel deflections using laser scanning techniques.

KU-FRL-417-16

"STUDY OF NOISE REDUCTION CHARACTERISTICS OF MULTILAYERED PANELS AND DUAL PANE WINDOWS WITH HELMHOLTZ RESONATORS"; by R. Navaneethan. May 1981, 175 pages.

In this report, the experimental noise attenuation characteristics of flat, general-aviation-type, multilayered panels are presented. Experimental results of stiffened panels, damping tape, honeycomb materials, and sound-absorption materials are presented. Single-degree-of-freedom theoretical models have been developed for sandwich-type panels with both shear-resistant and non-shear-resistant core material. The experimental investigation, performed to test the concept of Helmholtz resonators used in conjunction with dual-pane windows in increasing the noise reduction around a small range of frequency, is also described. It is concluded that the stiffening of the panels either by stiffeners or by sandwich construction increases the low-frequency noise reduction. Application of damping materials, while damping out the resonance peaks, lowers the fundamental resonance frequency. The theoretical models, within the constraints of the assumptions made in deriving them, predict the fundamental resonance frequency and the low-frequency noise reduction fairly accurately. It is also concluded that the concept of Helmholtz resonators in conjunction with dual-pane windows offers an attractive low-cost solution to increase the noise attenuation of dual-pane windows around a small range of frequency.

KU-FRL-417-17

"INFLUENCE OF DEPRESSURIZATION AND DAMPING MATERIAL ON THE NOISE REDUCTION CHARACTERISTICS OF FLAT AND CURVED STIFFENED PANELS"; by R. Navaneethan, B. Streeter, and S. Koontz. October 1981, 308 pages.

In this report, the work carried out to investigate the noise reduction characteristics of general-aviation-type flat and curved, stiffened panels at the University of Kansas Flight Research Laboratory noise research facility are presented. The effects of depressurization, damping material, and noise source are described.

The experimental study was carried out on 20 x 20 inch panels in a frequency range of interest from 20 Hz to 5000 Hz. The noise sources used were a swept sine wave generator and a random noise generator.

The results indicate that under the conditions tested, the effect of noise source was negligible. Increasing the pressure differential across the panel gives better noise reduction below the fundamental resonance frequency due to an increase in stiffness. The largest increase occurs in the first one psi pressure differential. The curved, stiffened panel exhibited similar bahavior, but with a lower increase of low-frequency noise reduction. Depressurization on curved, stiffened panels results in a decrease of the noise reduction at higher frequencies, confirming theoretical work done by Koval. The effect of damping tapes on the overall noise reduction values of the test specimens was small away from the resonance frequency. In the mass-law region a slight and proportional improvement in noise reduction is observed by the addition of damping material. Adding sound-absorption material to a panel with damping material increases beneficially noise reduction at high frequencies.

KU-FRL-417-18

"STUDY OF NOISE REDUCTION CHARACTERISTICS OF COMPOSITE FIBER-REINFORCED PANELS, INTERIOR PANEL CONFIGURATIONS, AND THE APPLICATION OF THE TUNED DAMPER CONCEPT";
by J. Laméris, S. Stevenson, and B. Streeter.
March 1982, 163 pages.

In this report, the work carried out to investigate the noise reduction characteristics of square, fiber-reinforced, laminated panels and interior panel configurations at the University of Kansas Flight Research Laboratory is presented. In addition, the concept of a tuned damper has been investigated as an application to increase the noise reduction of a panel at its fundamental resonance frequency.

The experimental study was carried out on 20 x 20 inch panels in a frequency range of 20 Hz to 5000 Hz. Tests were conducted under normal sound incidence in the KU-FRL Beranek tube acoustic facility.

The results of the tests with the fiber-reinforced, laminated panels indicate better low-frequency noise reduction characteristics for the graphite-epoxy panels than for the Kevlar panels, due to their higher stiffness. Variations in thickness caused by the manufacturing process have prevented the making of decisive conclusions about the influence of the ply orientation.

Various kinds of interior panel configurations have been studied. Sandwich panels consisting of a foam core and fiberglass facings exhibit higher sound attenuation characteristics than most of the single-layer panels tested. Doubling the core thickness of these panels had a larger beneficial effect than doubling the thickness of the skin layer. Treatments such as carpet, Royalite, and woolen/leather covering are generally more effective at higher frequencies due to the addition of mass.

Tests with a tuned ring damper have indicated that it is possible to increase the damping and noise reduction in a wide range of frequencies around the fundamental resonance frequency of a panel. Using two viscoelastic damping materials, LD-400 and Aquaplas, a gain of 8 to 9 dB was measured at a weight penalty of about 9% of the panel mass. However, theoretical analysis of this tuned damper concept did not predict well the experimental results and needs more study. Also some disadvantages of the type of damper used have been discussed.

KU-FRL-417-19

"STUDY OF THE DAMPING CHARACTERISTICS OF GENERAL AVIATION AIRCRAFT PANELS AND DEVELOPMENT OF COMPUTER PROGRAMS TO CALCULATE THE EFFECTIVENESS OF INTERIOR NOISE CONTROL TREATMENT";
by R. Navaneethan, J.Hunt, and B. Quayle. December 1982, 112 pages.

In this report, the work carried out at the University of Kansas Flight Research Laboratory (KU-FRL) to determine the damping characteristics of square, general aviation panels is presented. In addition, the progress on the work to date on the development of a simple interior noise level control program is also reported.

Structural damping plays an important role in the determination of noise reduction characteristics of panels. Since the damping varies considerably with different installations, it is not readily predicted. For this reason the investigation of the damping characteristics of panels installed in the KU-FRL test facility was undertaken. The tests were carried out on 20 x 20 inch panels at different test conditions. Tests were conducted on free-free panels, clamped panels, and panels as installed in the KU-FRL acoustic test facility. Tests with free-free panels verified the basic equipment set-up and test procedure. They also provided a basis for comparison.

The results indicate that the effect of installed panels is to increase the damping ratio at the same frequency. However, a direct comparison is not possible, as the fundamental frequency of a free-free panel differs from the resonance frequency of the panel when installed. The damping values of panels installed in the test facility are closer to the damping values obtained with fixed-fixed panels. Effects of damping tape, stiffeners, and bonded and riveted edge conditions were also investigated.

The noise reduction characteristics of a large number of general aviation aircraft panels have been investigated at this facility. An attempt is now being made to calculate these characteristics analytically. For this purpose a well-known model to predict the transmission loss of the multilayered panels has been chosen. This model is being modified to include the effects of the experimental results obtained at the KU-FRL test facility. Skin, air gap, porous insulation blanket, septum, and trim panels are typical of the layers that are being considered. The agreement between the experimental results and the theoretical results obtained without any modifications to the program is generally poor. Several modifications and refinements are being made to the program to agree with the test results. The progress to date is also presented.

KU-FRL-417-20

"USER'S GUIDE TO MULTILAYER SOUND TRANSMISSION LOSS PROGRAM"; by R. Navaneethan. January 1983, 53 pages.

This report is a guide to the use of a computer program that calculates the sound transmission loss through a multilayered panel. Instructions for setting up the input data file and running the program are given. Also included are the equations used in the programs, flow diagrams, and a listing of the computer program.

KU-FRL-417-21

"STUDY OF NOISE REDUCTION CHARACTERISTICS OF DOUBLE-WALL PANELS";
by R. Navaneethan, B. Quayle, S. Stevenson, and M. Graham.
May 1983, 179 pages.

In this report, the work carried out to investigate the noise reduction characteristics of general-aviation-type, flat, double-wall structures at the University of Kansas Flight Research Laboratory is presented. The test specimens are typical of the double-wall structures that are currently being used in general aviation aircraft. The object of this investigation is to generate a data base of such panels. A secondary objective is to develop a simple theory that will reasonably predict the noise reduction characteristics of such panels without excessive computer memory and time.

The experimental study was carried out on 20 by 20 inch panels with an exposed area of 18 by 18 inches. The tests were performed at normal incidence and at room temperature and pressure. A frequency range from 20 to 5000 Hz was covered. The noise source was a slowly swept sine wave generator.

The experimental results, in general, follow the expected trends. At low frequencies the double-wall structures are no better than the single-wall structures. However, for depths normally used in the general aviation industry, the double-wall structure becomes effective from 300 Hz. At high frequencies, double-wall panels are very attractive. The graphite-epoxy skin panels have higher noise reduction at very low frequencies

(>100 Hz) than the Kevlar skin panels. But the aluminum panels have higher noise reduction in the high-frequency region, due to their greater mass. Use of fiberglass insulation is not effective in the low-frequency region, and at times it is even negative. But the insulation is effective in the high-frequency region. It damps out the panel-air-panel resonances as well as increases noise reduction due to viscous effects.

The interior trim panel used in the industry can be advantageously used as a noise control treatment element in double-wall structures. However, the tests indicate that most trim panels do not behave like limp panels. Certain base material and treatment combinations for the trim panels perform much better than others, even in spite of their weight penalties; and further study may be required to determine exactly their noise attenuation characteristics. In the meantime, use of measured single-panel slope for the trim panels as an additional parameter provides a reasonable approximation for theoretical predictions.

Within its limitations, the theoretical model predicts the transmission loss of these multilayered panels reasonably well.

KU-FRL-417-22

"MEASUREMENT OF TRANSMISSION LOSS CHARACTERISTICS USING ACOUSTIC INTENSITY TECHNIQUES AT THE KU-FRL ACOUSTIC TEST FACILITY";
by R. Navaneethan and B. Quayle. December 1983, 124 pages.

In this report, the work carried out at the University of Kansas Flight Research Laboratory (KU-FRL) to measure the transmission loss characteristics of panels using the acoustic intensity technique is presented. The report describes the theoretical formulation, installation of hardware, modifications to the test facility, and development of computer programs and test procedures. A listing of all the programs is also provided.

The initial test results indicate that the acoustic intensity technique can be easily adapted at the KU-FRL test facility to measure transmission loss characteristics of panels. Use of this method will give average transmission loss values. The fixtures developed to position the microphones along the grid points are very useful in plotting the intensity maps of vibrating panels.

Based on the experience gained so far, several improvements to the test facility and test procedures are also identified.

KU-FRL-417-23

"GENERAL AVIATION AIRCRAFT INTERIOR NOISE PROBLEM: SOME SUGGESTED SOLUTIONS"; by R. Navaneethan. July 1984, 491 pages.

This report describes the work completed for an ongoing general aviation interior noise research project. A broad-based approach--i.e., laboratory investigation of sound transmission through panels, use of modern data analysis techniques, and application to actual aircraft--was used to determine methods to reduce general aviation interior noise.

The laboratory investigations were carried out in a low-cost acoustic test facility. The experimental noise reduction characteristics of stiffened flat and curved panels with damping treatment are discussed. The experimental results of double-wall panels used in the general aviation industry are given. The effects of skin panel material, fiberglass insulation, and trim panel material on the noise reduction characteristics of double-wall panels are investigated. These results are compared with the theoretical predictions from classical sound transmission theory for multilayered panels. The changes needed in the classical sound transmission theory for a better agreement are discussed. It is also shown that the same theory can successfully be used to design the interior noise control treatment of a new aircraft.

The development of the acoustic intensity system for this test facility is described. The use of cepstral analysis techniques to determine the absorption coefficients of interior trim panels in situ is discussed. Also a computer program, which can be used to analyze the problem of high interior noise of the production aircraft and to study the effectiveness of the noise control treatment, is given. The use of this program on aircraft noise control has shown the validity of the models used. The results indicate that with minor modifications the classical sound transmission theory can be used not only to predict the panel sound transmission loss characteristics but also to analyze actual noise control treatment of an aircraft.

2.1 SUMMARIES OF PAPERS

KU-FRL-317-P1

"THE TRANSMISSION OF SOUND THROUGH AIRCRAFT PANELS";
by D. Durenberger and T. Peschier. November 1977; 12 pages.

This paper includes the following items:

1. Background of the KU-NASA-Industry noise project,
2. How sound transmission through panels determines cabin noise levels,
3. Methods of increasing sound blockage of panels.

In spring 1977, the University of Kansas submitted a proposal to NASA Langley Research Center for a sound transmission research project. The project was funded through the Noise Effects Branch of the Acoustics and Noise reduction Division. The work of assembling a laboratory test facility began in May 1977.

KU-FRL-317-P2

"A RESEARCH PROGRAM TO REDUCE THE INTERIOR NOISE LEVEL IN GENERAL AVIATION AIRPLANES"; by D. Durenberger, F. Grosveld, and K. van Dam.
Paper presented at NASA Langley Research Center, Acoustics and Noise Reduction Div., Hampton, Virginia, April 24, 1978. Presented at Cessna Aircraft Co., Pawnee Div., Wichita, Kansas, April 18, 1978;
21 pages.

This presentation gives the main results of a project funded by the National Aeronautics and Space Administration to study the transmission of sound through general aviation airplane structures. The research objectives of this project were the results of a study of the factors which affect

3. To provide a systematic collection of panel and panel treatment sound attenuation characteristics, based on both experimental and analytical considerations;
4. To use these results to extend or develop prediction methods.

This paper explains the experimentation which was accomplished through this program.

KU-FRL-317-P3

"SOME NOISE TRANSMISSION LOSS CHARACTERISTICS OF TYPICAL GENERAL AVIATION STRUCTURAL MATERIALS"; by J. Roskam, C. van Dam, D. Durenberger, and F. Grosveld.
AIAA paper 78-1480 presented at the Aircraft Systems and Technology Conferences, Los Angeles, California, August 21-23, 1978; 9 pages.

Experimentally measured sound transmission loss characteristics of flat aluminum panels with and without damping and stiffness treatment are presented and discussed. The effect of pressurization on sound transmission loss of flat aluninum panels is shown to be significant.

The purpose of this paper is to present some initial results of measurements of sound transmission loss characteristics through flat aluminum panels. First a description of the test facility is provided. Second, a discussion is presented of major factors which affect sound transmission loss. The relative benefits of adding mass, increasing stiffness, cabin-pressurization, and vibration damping are shown through comparison of test results. It is shown that significant benefits can be obtained from a small amount of pressurization.

KU-FRL-317-P4

"GENERAL AVIATION INTERIOR NOISE RESEARCH"; by F. Grosveld. AIAA informal paper presented at the Fifth Annual General Aviation Technology Fest, Wichita, Kansas, November 10-11, 1978; 23 pages.

This presentation will give the state of the art of the KU-FRL Noise Project, which has the broad goal of reducing the interior noise in general aviation airplanes. Past, current, and future work will be discussed in each of the following items:

1. Test facility,
2. Test results,
3. Theoretical work.

First a short history of the noise project will be given, including the main objectives of each phase.

The preparation phase started April 15, 1976, when the Flight Research Laboratory of the University of Kansas began to develop a noise research team and started to define a long-range follow-up research program in interior noise. The project was funded through NASA Langley Research Center, Acoustics and Noise Reduction Division.

The work of assembling an acoustic test facilty began in May 1977. In this acoustic test facility, noise reduction characteristics of various panels can be determined.

Testing of various, flat, structural panels began in August 1977. Since then, a systematic collection of panel and panel treatment sound attenuation characteristics has been obtained in the form of transmission loss curves. In June 1978 an extensive test program was carried out to determine the characteristics of the acoustic test facility. In the meantime, progress reports have been made concerning the experimental results and the theoretical approach of these tests.

KU-FRL-317-P5

"A RESEARCH PROGRAM TO REDUCE INTERIOR NOISE IN GENERAL AVIATION AIRPLANES"; by F. Grosveld. Paper presented at NASA Langley Research Center, Hampton, Virginia, January 15-16, 1979; 33 pages.

This paper presents an outline of activities done and to be done of a project funded by the National Aeronautics and Space Administration to study the transmission of sound through general aviation airplane structures (NASA NSG 1301).

First the activities between April 24, 1978, and December 15, 1978, will be discussed; and this chapter is subdivided into the following sections:

1. Expansion in Testing Capabilities
2. Theoretical and Experimental Research
3. Evaluation of the Test Results.

The second chapter covers future work through April 30, 1979, that will be performed under the existing grant.

The proposal to NASA for extension of the program for the period of May 1, 1979 - April 30, 1980, has been included in this report as an appendix.

KU-FRL-316-P6

"SUMMARY OF NOISE REDUCTION CHARACTERISTICS OF TYPICAL GENERAL AVIATION MATERIALS"; by J. Roskam, F. Grosveld, and J. van Aken. Society of Automotive Engineers paper No. 790627, presented at the Business Aircraft Meeting, Wichita, Kansas, April 3-6, 1979; 40 pages.

The paper presents the results of a large number of systematic tests to determine noise reduction characteristics of general aviation materials. Effects of material type (metallic and composite), thickness, panel stiffening, vibration damping materials, sound absorption materials and pressurization on noise reduction are included. Several promising methods for reducing cabin interior noise in light airplanes are discussed based on the results.

KU-FRL-417-P7

"STRUCTURAL PARAMETERS THAT INFLUENCE THE NOISE REDUCTION CHARACTERISTICS OF TYPICAL GENERAL AVIATION MATERIALS"; by J. Roskam and F. Grosveld. AIAA paper 80-0038, presented at 18th Aerospace Sciences Meeting, Pasadena, California, January 14-16, 1980; 10 pages.

This paper explains the experimental investigation of the effect of panel curvature and oblique angle of sound incidence on noise reduction charactristics of an aluminum panel. Panel curvature results show significant increase in stiffness with comparable decrease of sound transmission through the panel in the frequency region below the panel/cavity resonance frequency. Noise reduction data have been achieved for aluminum panels with clamped, bonded, and riveted edge conditions. These edge conditions are shown to influence noise reduction characteristics of aluminum panels. Experimentally measured noise reduction characteristics of flat aluminum panels with uniaxial and biaxial in-plane stresses are presented and discussed. Results indicate important improvement in noise reduction of these panels in the frequency range below the fundamental panel/cavity resonance frequency.

KU-FRL-417-P8

"NOISE REDUCTION CHARACTERISTICS OF GENERAL AVIATION TYPE DUAL PANEL WINDOWS"; by F. Grosveld, R. Navaneethan, and J. Roskam.
AIAA paper 80-1874, presented at the AIAA Aircraft Systems Meeting, Anaheim, California, August 5-6, 1980; 7 pages.

The paper explains the experimental investigations into the noise reduction characteristics of general-aviation-type, dual-pane windows in various configurations. The effects of inner and outer pane thickness, spacing betwween the panes, edge conditions, inclination of the inner pane and depressurization of the air in between the panes are presented. The space in between the two window panes is sealed airtight in all cases. Results show that increasing the mass of a "floating" window pane does not increase the noise reduction below the fundamental resonance frequency. It is concluded that the concept of depressurization of the air between thin (1/8") Plexiglas panes and application of multiple-freedom edge conditions for the inner pane are promising to reduce noise levels in general aviation airplanes.

KU-FRL-417-P9

"A MICROCOMPUTER-BASED SYSTEM FOR NOISE CHARACTERISTICS ANALYSIS"; by M. Mosser, D. Rummer, and R. Navaneethan. ISMM paper, presented at Symposium on Mini and Microcomputers in Control and Measurement, San Francisco, California, May 20-22, 1981; 3 pages.

The designers of general aviation aircraft today are interested in reducing the interior noise levels for greater comfort of the pilots and passengers. A project is under way at the University of Kansas Flight Research Laboratory to measure and catalog the noise reduction properties of a variety of materials and combinations of materials which are candidates for use in the construction of general aviation aircraft. This paper describes the design and use of a microcomputer-based system for noise analysis in this work.

A test chamber is divided into two parts by a separating panel fabricated from the material to be tested. A noise generator applies noise to one side of the specimen. The microcomputer system measures and records the noise spectra on both sides of the specimen. The attenuation properties of the specimen are calculated and displayed. A color video display can be used for a "quick look" and hard copy produced by an X-Y chart recorder for use in the catalog and reports.

The system described was completed in June 1980 and has been used to study many materials currently used, as well as many proposed new materials and combinations of materials. This research has identified some promising configurations for reduction of noise inside general aviation aircraft.

KU-FRL-417-P10

"SUMMARY OF TYPICAL PARAMETERS THAT AFFECT SOUND TRANSMISSION THROUGH GENERAL AVIATION AIRCRAFT STRUCTURES";
by F. Grosveld, R. Navaneethan, and J. Roskam. SAE Technical Paper 810562, presented at the Business Aircraft Meeting and Exposition, Wichita, Kansas, April 7-10, 1981; 22 pages.

This paper presents results of a systematic experimental investigation of parameters which affect sound transmission through general aviation structures. Parameters studied include angle of sound incidence, panel curvature, panel stresses, and edge conditions for bare panels; pane thickness, spacing, inclination of window panes, and depressurization for dual-pane windows; densities of hard foam and sound absorption materials, air gaps, and trim panel thickness for multilayered panels. Based on the study, some promising methods for reducing interior noise in general aviation airplanes are discussed.

KU-FRL-417-P11

"NOISE REDUCTION CHARACTERISTICS OF GENERAL AVIATION TYPE DOUBLE WALL STRUCTURES"; by B. Quayle. AIAA Student Paper, presented at 1983 AIAA Region V Student Conference, March 1983; 36 pages.

This paper describes the results of recent tests to determine the noise reduction characteristics of simulated general aviation type double-wall structures. The experimental study was conducted in the University of Kansas Flight Research Laboratory (KU-FRL) acoustic test facility. Parameters that were varied in the study include different skin materials and interior trim panels, varying wall depth and stiffener configurations, and the effect of fiberglass insulation. The paper compares the experimental results with those from a theoretical study conducted at the KU-FRL. These were found to compare favorably within the limitations of the theoretical model. The experimental results follow expected trends, and a comparative analysis of the varied parameters is presented in the paper. The study will add to a data base that will allow manufacturers to maintain low noise levels in their aircraft with a minimum weight penalty.

CHAPTER 3

PANEL INVENTORY

This inventory contains the basic information about test panels used in the noise research project. They are grouped both by type of panel and by materials in order to provide an easy reference. For further information, please consult the previous reports dealing with each category.

List of 18 x 18 Inch Panels for Which Noise Reduction Data Are Presented

Group	General Type	Subgroup	Material	Nominal Thickness	Panel Treatment	KU/FRL Identity Number	Particulars
1	Bare panels						
		1.1 Aluminum	2024-T3 Alclad Alum.	.016"	None	30	
			2024-T3 Alclad Alum.	.020"	None	31	
			2024-T3 Alclad Alum.	.025"	None	32	
			2024-T3 Alclad Alum.	.032"	None	33/72	
			2024-T3 Alclad Alum.	.040"	None	34/108	
		1.2 Plexiglas	Plexiglas	.125"	None	37	
			Plexiglas	.1875"	None	38	
			Plexiglas	.250"	None	29	
		1.3 Fiberglass	Fiberglass	~.313"	Composite	80	
		1.4 Steel	Steel	.016"	None	36	
			Steel	.020"	None	35	
			Noiseless steel	.050"	Composite	44	
		1.5 Honeycomb	Honeycomb	.50"	Composite	49	Aluminum core, sandwiched between two .016" thick 2024-T3 Aluminum sheets
			Honeycomb	.50"	Fiberglass faces Aluminum core	3	1/4" cells, 5052 Al core, C-weight fiberglass
			Honeycomb	.50"	Fiberglass faces Aluminum core	4	Glasswool in 1/4" cells, 5052 Al core, C-weight fiberglass
			Honeycomb	.125"	Fiberglass faces Aluminum core	5	1/8" cells, 5052 Al core, C-weight fiberglass

Group	General Type	Subgroup	Material	Nominal Thickness	Panel Treatment	KU/FRL Identity Number	Particulars
			Honeycomb	.25"	Fiberglass faces Aluminum core	11	1/8" cells, 5052 Al core, C-weight fiberglass
			Honeycomb	.50"	Fiberglass faces Aluminum core	12	1/8" cells, 5052 Al core C-weight fiberglass
			Honeycomb	1.00"	Fiberglass faces Aluminum core	13	1/8" cells, C-weight fiberglass, 5052 Al core
			Honeycomb	1.00"	Fiberglass faces Nomex core	14	1/8" cells, C-weight fiberglass
		1.6 Acrylic	Acrylic	.25"	None	158	
			Acrylic	.25"	None	157	Pre-stretched
		1.7 Lead Vinyl	Lead Vinyl	.025"	None	128/159	
		1.8 Wood	Wood	.75"	None	160	Pressboard
2	Holes & Slits in the center of a .040" thick Alclad 2024-T3 Aluminum Panel						
		2.1 Holes	2024-T3 Alclad Alum.	.040"	None	91/108	
			2024-T3 Alclad Alum.	.040"	Hole: 4/64" diameter	92	
			2024-T3 Alclad Alum.	.040"	Hole: 6/64" diameter	93	
			2024-T3 Alclad Alum.	.040"	Hole: 8/64" diameter	94	
			2024-T3 Alclad Alum.	.040"	Hole: 11/64" diameter	95	
			2024-T3 Alclad Alum.	.040"	Hole: 15/64" diameter	96	
			2024-T3 Alclad Alum.	.040"	Hole: 24/64" diameter	97	
			2024-T3 Alclad Alum.	.040"	Hole: 32/64" diameter	98	

Group	General Type	Subgroup	Material	Nominal Thickness	Panel Treatment	KU/FRL Identity Number	Particulars
			2024-T3 Alclad Alum.	.404"	Hole: 48/64" diameter	101	
			2024-T3 Alclad Alum.	.404"	Hole: 1" diameter	103	
			2024-T3 Alclad Alum.	.404"	Hole: 1 32/64" diameter	106	
			2024-T3 Alclad Alum.	.404"	Hole: 2 50/64" diameter	109	
		2.2 Slits	2024-T3 Alclad Alum.	.404"	Slit: 3/32" by 17/32"	110	
			2024-T3 Alclad Alum.	.404"	Slit: 1" by 3/32"	118	
			2024-T3 Alclad Alum.	.404"	Slit: 1" by 5/32"	119	
			2024-T3 Alclad Alum.	.404"	Slit: 2" by 5/32"	126	
3	Pressurized Panels						
		3.1 Pressurized Bare Panels					
		3.1.1 Aluminum .016" thick	2024-T3 Alclad Alum.	.016"	None	30/141	Pressure Differential: 0 psi
			2024-T3 Alclad Alum.	.016"	None	142	Pressure Differential: .5 psi
			2024-T3 Alclad Alum.	.016"	None	52	Pressure Differential: 1.0 psi
			2024-T3 Alclad Alum.	.016"	None	53	Pressure Differential: 1.5 psi
		3.1.2 Aluminum .020" thick	2024-T3 Alclad Alum.	.020"	None	31	Pressure Differential: 0 psi
			2024-T3 Alclad Alum.	.020"	None	54	Pressure Differential: .5 psi

Group	General Type	Subgroup	Material	Nominal Thickness	Panel Treatment	KU/FRL Identity Number	Particulars
			2024-T3 Alclad Alum.	.020"	None	55	Pressure Differential: 1.0 psi
			2024-T3 Alclad Alum.	.020"	None	56	Pressure Differential: 1.5 psi
		3.1.3 Aluminum .025" thick	2024-T3 Alclad Alum.	.025"	None	147	Pressure Differential: 0 psi
			2024-T3 Alclad Alum.	.025"	None	148	Pressure Differential: .5 psi
			2024-T3 Alclad Alum.	.025"	None	149	Pressure Differential: 1.0 psi
		3.1.4 Aluminum .032" thick	2024-T3 Alclad Alum.	.032"	None	33	Pressure Differential: 0 psi
			2024-T3 Alclad Alum.	.032"	None	57	Pressure Differential: 1 psi
			2024-T3 Alclad Alum.	.032"	None	58	Pressure Differential: 2 psi
			2024-T3 Alclad Alum.	.032"	None	59	Pressure Differential: 3 psi
		3.1.5 Aluminum .040" thick	2024-T3 Alclad Alum.	.040"	None	153	Pressure Differential: 0 psi
			2024-T3 Alclad Alum.	.040"	None	154	Pressure Differential: .5 psi
			2024-T3 Alclad Alum.	.040"	None	155	Pressure Differential: 1.0 psi
		3.1.6 Steel	Steel	.020"	None	35	Pressure Differential: 0 psi

Group	General Type	Subgroup	Material	Nominal Thickness	Panel Treatment	KU/FRL Identity Number	Particulars
			Steel	.020"	None	60	Pressure Differential: .5 psi
			Steel	.020"	None	61	Pressure Differential: 1.0 psi
			Steel	.020"	None	62	Pressure Differential: 2.0 psi
		3.2 Pressurized Stiffened Panels					
		3.2.1 Stiffened Aluminum	2024-T3 Alclad Alum.	.025"	4 Z-stiffeners (squared)	40	Pressure Differential: 0 psi
			2024-T3 Alclad Alum.	.025"	4 Z-stiffeners (squared)	63	Pressure Differential: 1.0 psi
			2024-T3 Alclad Alum.	.025"	4 Z-stiffeners (squared)	64	Pressure Differential: 2.0 psi
			2024-T3 Alclad Alum.	.025"	4 Z-stiffeners (squared)	65	Pressure Differential: 3.0 psi
		3.2.2 Stiffened Aluminum with Treatment	2024-T3 Alclad Alum.	.025"	4 Z-stiffeners (squared) with Y-370 in the middle	66	Pressure Differential: 0 psi
			2024-T3 Alclad Alum.	.025"	4 Z-stiffeners (squared) with Y-370 in the middle	67	Pressure Differential: 1.0 psi
4	Treated Panels						
		4.1 Stiffened Aluminum	2024-T3 Alclad Alum.	.025"	2 stiffeners Z & U (crossed)	120	
			2024-T3 Alclad Alum.	.025"	2 stiffeners Z & Ω (crossed)	121	

Group	General Type	Subgroup	Material	Nominal Thickness	Panel Treatment	KU/FRL Identity Number	Particulars
			2024-T3 Alclad Alum.	.025"	2 Z-stiffeners (parallel)	39	
		4.2 Beaded Aluminum	2024-T3 Alclad Alum.	.032"	None	33	
			2024-T3 Alclad Alum.	.032"	Beaded	156	
		4.3 Y-370 Treatment					
		4.3.1 Aluminum treated with Y-370	2024-T3 Alclad Alum.	.032"	None	33	
			2024-T3 Alclad Alum.	.032"	40% .25" thick Y-370	41	
			2024-T3 Alclad Alum.	.032"	70% .25" thick Y-370	42	
			2024-T3 Alclad Alum.	.032"	100% .25" thick Y-370	43	
		4.3.2 Stiffened Aluminum treated with Y-370	2024-T3 Alclad Alum.	.025"	4 Z-stiffeners	40	
			2024-T3 Alclad Alum.	.025"	4 Z-stiffeners with Y-370 in the middle	66	
		4.3.3 Honeycomb treated with Y-370	Honeycomb	.50"	None	49	
			Honeycomb	.50"	100% .25" thick Y-370	50	
		4.4 LD-400 treatment	2024-T3 Alclad Alum.	.032"	None	33	
			2024-T3 Alclad Alum.	.032"	39.5% LD-400	45	

Group	General Type	Subgroup	Material	Nominal Thickness	Panel Treatment	KU/FRL Identity Number	Particulars
			2024-T3 Alclad Alum.	.032"	63.2% LD-400	46	
			2024-T3 Alclad Alum.	.032"	92.2% LD-400	47	
			2024-T3 Alclad Alum.	.032"	100% LD-400	48	
		4.5 Rubber/foam IC913 & IC914 treatment					
		4.5.1 Rubber/foam material treatment	2024-T3 Alclad Alum.	.025"	None	161	
			2024-T3 Alclad Alum.	.025"	With rubber/foam material	162	
		4.5.2 IC-913 treatment	2024-T3 Alclad Alum.	.025"	70% IC 913	163	
			2024-T3 Alclad Alum.	.025"	98% IC 913	166	
		4.5.3 IC-914 treatment	2024-T3 Alclad Alum.	.025"	72% IC 914	164	
			2024-T3 Alclad Alum.	.025"	100% IC 914	167	
		4.6 IC-998 treatment	2024-T3 Alclad Alum.	.032"	None	33	
			2024-T3 Alclad Alum.	2 x .016"	IC 998 in between two Aluminum sheets	68	1/8" diameter beads at 45° ~ 2" apart
			2024-T3 Alclad Alum.	2 x .016"	100% IC 998 in between two Aluminum sheets	75	applied radially on the panel
		4.7 A-13 treatment	2024-T3 Alclad Alum.	.025"	None	32	
			2024-T3 Alclad Alum.	.025"	100% A-13	70	

Group	General Type	Subgroup	Material	Nominal Thickness	Panel Treatment	KU/FRL Identity Number	Particulars
			2024-T3 Alclad Alum.	.025"	100% A-13 laminated to 100% A-13	69	
		4.8 TNB treatment					
		4.8.1 TNB-102 treatment	2024-T3 Alclad Alum.	.025"	None	32	
			2024-T3 Alclad Alum.	.025"	100% TNB-102 with PSA	71	
		4.8.2 TNB-101 & A-13 treatment	2024-T3 Alclad Alum.	.032"	None	33	
			2024-T3 Alclad Alum.	.032"	100% TNB-101 & .75" thick foam & PSA	2	
		4.8.3 TNB-101 & A-13 treatment	2024-T3 Alclad Alum.	.040"	None	34	
			2024-T3 Alclad Alum.	.040"	100% TNB-101 & foam & A-13 & PSA	10	
		4.9 Sound Stopper treatment	2024-T3 Alclad Alum.	.025"	None	32	
			2024-T3 Alclad Alum.	.025"	100% Singer Sound Stopper (paste) .016" thick	73	
		4.10 Pyrell treatment	2024-T3 Alclad Alum.	.032"	None	33	
			2024-T3 Alclad Alum.	.032"	Pyrell 4 lb. foam	1	

Group	General Type	Subgroup	Material	Nominal Thickness	Panel Treatment	KU/FRL Identity Number	Particulars
		4.11 Aluminum panels with paper Honeycomb	2024-T3 Alclad Alum.	.032"	None	33	
			2024-T3 Alclad Alum.	.032"	.50" thick paper Honeycomb	78	
			2024-T3 Alclad Alum.	.032"	.50" thick paper Honeycomb & constraining layer self-adhesive Aluminum .008" thick	7	
		4.12 Aluminum panels with fiberglass	2024-T3 Alclad Alum.	.020"	None	31	
			2024-T3 Alclad Alum.	.020"	Carney 1" thick absorptive fiberglass	6	
			2024-T3 Alclad Alum.	.020"	100% fiberglass (3.5 lb/ft^3)	9	
			2024-T3 Alclad Alum.	.020"	100% fiberglass (6 lb/ft^3)	8	
5	Curved Panels						
		5.1 Aluminum	2024-T3 Alclad Alum.	.016"	None	206	Bonded; R = 10"
			2024-T3 Alclad Alum.	.016"	None	207	Riveted; R = 10"
			2024-T3 Alclad Alum.	.016"	None	208	Bonded; R = 20"
			2024-T3 Alclad Alum.	.016"	None	209	Riveted; R = 20"
			2024-T3 Alclad Alum.	.020"	None	214	Bonded; R = 10"
			2024-T3 Alclad Alum.	.020"	None	215	Riveted; R = 10"
			2024-T3 Alclad Alum.	.020"	None	216	Bonded; R = 20"

Group	General Type	Subgroup	Material	Nominal Thickness	Panel Treatment	KU/FRL Identity Number	Particulars
			2024-T3 Alclad Alum.	.020"	None	217	Riveted; R = 20"
			2024-T3 Alclad Alum.	.032"	None	222	Bonded; R = 10"
			2024-T3 Alclad Alum.	.032"	None	223	Riveted; R = 10"
			2024-T3 Alclad Alum.	.032"	None	224	Bonded; R = 20"
			2024-T3 Alclad Alum.	.032"	None	225	Riveted; R = 20"
6	Inclined Panels						
		6.1 Aluminum	2024-T3 Alclad Alum.	.016"	None	210	Bonded; $\alpha = 0^\circ$
			2024-T3 Alclad Alum.	.016"	None	211	Riveted; $\alpha = 0^\circ$
			2024-T3 Alclad Alum.	.016"	None	212	Bonded; $\alpha = 60^\circ$
			2024-T3 Alclad Alum.	.016"	None	213	Riveted; $\alpha = 60^\circ$
			2024-T3 Alclad Alum.	.020"	None	218	Bonded; $\alpha = 0^\circ$
			2024-T3 Alclad Alum.	.020"	None	219	Riveted; $\alpha = 0^\circ$
			2024-T3 Alclad Alum.	.020"	None	220	Bonded; $\alpha = 60^\circ$
			2024-T3 Alclad Alum.	.020"	None	221	Riveted; $\alpha = 60^\circ$
			2024-T3 Alclad Alum.	.032"	None	226	Bonded; $\alpha = 0^\circ$
			2024-T3 Alclad Alum.	.032"	None	227	Riveted; $\alpha = 0^\circ$
			2024-T3 Alclad Alum.	.032"	None	228	Bonded; $\alpha = 60^\circ$
			2024-T3 Alclad Alum.	.032"	None	229	Riveted; $\alpha = 60^\circ$
7	Interior Panels						
		7.1 Aluminum	2024-T3 Alclad Alum.	.025"	None	311	45% open
			2024-T3 Alclad Alum.	.025"	.5" foam & leather covering	312	45% open

Group	General Type	Subgroup	Material	Nominal Thickness	Panel Treatment	KU/FRL Identity Number	Particulars
			2024-T3 Alclad Alum.	.025"	Carpet	313	45% open
			2024-T3 Alclad Alum.	.032"	Klege-Flex type 45	321	
			2024-T3 Alclad Alum.	.032"	ST 2052 x1005 damping treatment	322	
			2024-T3 Alclad Alum.	.064"	2 rectangular cutouts in one sheet	345	two .032" Al panels bonded together
			2024-T3 Alclad Alum.	.064"	4 rectangular cutouts in one sheet	346	two .032" Al panels bonded together
		7.2 Klege-Cell	Klege-Cell type 75	0.25"	None	315	1 layer of type A fiberglass both sides
			Klege-Cell type 75	0.25"	.125" neoprene + wool covering	316	1 layer of type A figerglass both sides
			Klege-Cell type 75	.125"	None	317	1 layer of type A fiberglass both sides
			Klege-Cell type 75	.125"	.020" Royalite covering	318	1 layer of type A fiberglass both sides
			Klege-Cell type 75	.125"	Carpet	319	1 layer of type A fiberglass both sides
			Klege-Cell type 75	.125"	.5" foam + leather covering	320	1 layer of type A fiberglass both sides
		7.3 Rohacell	Rohacell, grade 51	0.25"	None	323	1 layer of 120 phenolic pre-preg skin both sides
			Rohacell, grade 51	0.25"	.125" neoprene + woolen covering	325	1 layer of 120 phenolic pre-preg skin both sides
			Rohacell, grade 51	0.25"	None	347	2 layers of 120 phenolic pre-preg skin both sides

Group	General Type	Subgroup	Material	Nominal Thickness	Panel Treatment	KU/FRL Identity Number	Particulars
			Rohacell, grade 51	.125"	None	341	1 layer of 120 phenolic pre-preg skin both sides
			Rohacell, grade 51	.125"	None	342	1 layer of 120 phenolic pre-preg skin both sides
			Rohacell, grade 51	.125"	Carpet	343	1 layer of 120 phenolic pre-preg skin both sides
			Rohacell, grade 51	.125"	.25" neoprene + leather covering	344	1 layer of 120 phenolic pre-preg skin both sides
		7.4 Others	Lexan	.090"	None	314	
			Orcofilm blanket	.25"	None	326	
			Compressed fiberglass	.187"	0.2" carpet	352	
			Sound Damp Headliner	0.125"	None	1005	5 layers: 1. 285 Kevlar back (mounting) 2. PCI SR-370 Sound Damp 3. 120 Kevlar/Nomex/ 120 Kevlar 4. ATR 250 urethene adhesive 5. Schneller 7 oz. vinyl/ Tedlar Headliner Cover
8	Composite Panels						<u>Layer Orientation:</u>
		8.1 Graphite-Epoxy	Graphite-epoxy	.038"	None	330	45-0-45 middle layer of unidirectional type
			Graphite-epoxy	.049"	None	331	0-0-0
			Graphite-epoxy	.030"	None	332	45-0-45
			Graphite-epoxy	.040"	None	333	0-45-0
			Graphite-epoxy	.029"	1 Stiffener	334	45-0-45

Group	General Type	Subgroup	Material	Nominal Thickness	Panel Treatment	KU/FRL Identity Number	Particulars
			Graphite-epoxy	.029"	2 Stiffeners	335	45-0-45
			Graphite-epoxy with Nomex core	0.75"	None	1001	6 plies: 0-90-0 Cloth orientation: 45 degrees
			Graphite-epoxy with Nomex core	0.75"	None	1002	8 plies: Cloth orientation: 45 degrees
			Graphite-epoxy with Nomex core	1.00"	Soldamp (0.25")	1011	6 plies: 0-90-0 Cloth orientation: 45 degrees
		8.2 Kevlar	Kevlar	.028"	None	336	0-0-0
			Kevlar	.028"	None	337	45-0-45
			Kevlar	.020"	None	338	0-45-0
			Kevlar	.029"	1 Stiffener	339	45-0-45
			Kevlar	.029"	2 Stiffeners	340	45-0-45
		8.3 Fiberglass	Fiberglass with Nomex core	0.28"	None	1003	0.03" E.A.R. damping
			Fiberglass with Nomex core	0.31"	None	1004	0.06" E.A.R. damping
			Fiberglass	0.25"	None	1006	FIS MATTE
9	Skin Panels						
		9.1 Aluminum	2024-T3 Alclad Alum.	.032"	One 3" stiffener	353	1.53 lb.
			2024-T3 Alclad Alum.	.032"	One 2" stiffener	357	1.53 lb.
			2024-T3 Alclad Alum.	.032"	One 1" stiffener	358	1.53 lb.

Group	General Type	Subgroup	Material	Nominal Thickness	Panel Treatment	KU/FRL Identity Number	Particulars
		9.2 Composites	Kevlar	.029"	One 3" stiffener	339	0.70 lb.
			Kevlar	.029"	Two 3" stiffeners	340	0.85 lb.
			Graphite-epoxy	.029"	Three 3" stiffeners	335	0.90 lb.