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PGA NEWS

CONTRIBUTIONS

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IRE PROFESSIONAL GROUP ON AUDIO

The Professional Group on Audio is an organization, within the framework of the IRE, of members with principal professional interest in Audio Technology. All members of the IRE are eligible for membership in the Group and will receive all Group publications upon payment of an annual assessment of $2.00.

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World Radio History

Musical Audio Engineering and Research Today

This issue of IRE TRANSACTIONS ON AUDIO is special in that all articles, other than news, are in the field of musical audio engineering and research. We have had single papers in this field before, but the present group of papers is unique.

There was a time in the history of audio when the ultimate engineering aim was to *reproduce* musical sound with perfect fidelity to the original. This worthy aim has not yet been fully achieved, but the attempts keep getting closer to facsimile reproduction.[1]

More recently there has been considerable engineering interest and commercial development in another direction, that of *producing* the original musical sound by electronic[2–4] means and electroacoustic radiation.[5] These two aims should not be confused,[6] just because their fulfillment requires that some of the same equipment components and some of the same techniques be used.

Audio engineering and research attention has been directed quite recently toward a third end, a means for enabling a composer to compose music directly for his listening audience, without the benefit of a musical performer.[7] The purist might wish that the image of the composer's auralization[8] could be transmitted directly to the listener's ear without the distortions of transducers or intervening media, and without the influence of monitoring by human ear, or level and tone control by audio engineer. However, it is necessary for such compositions to be stored by recording, for subsequent playback by or for the auditor, on equipment designed primarily for the reproduction of conventional music. Consequently the package cannot be delivered "without being touched by human hands."

Actually this is no disadvantage. The recorded composition is a product intended for a market, and it is therefore subject to revision before marketing, and criticism both before and after. In this sense it is similar to any other record or to a recorded tape.

In spite of the engineering ideal of perfect fidelity to the original, and the standardization of recording and playback characteristics, there isn't anything to prevent purposeful modification to the original sound from entering into the record-making process, nor should there be. There is an art to recording, as well as a science, and even if there were not, the musicians would find ways to get around the limitations imposed upon them, in order to achieve novel effects. (Remember the velocity microphone and the crooner!)

It has been pointed out[9] by the late H. I. Reiskind of RCA that the important thing in a disc recording is not how the music sounded in the studio, or on the monitoring headset, but how it is going to sound when played back on typical home-listening equipment. Thus the playback characteristics of phonographs are certain to exert a feedback influence upon the recording techniques used in making the records. For this reason, records should be a separate subject of scientific study, whether they are made from traditional musical instruments, from their modern counterparts, or from special sources such as a synthesizer.

Scientific research and engineering on musical instruments and the sounds they make is increasingly important to the audio field. The number of people in the United States who play a musical instrument has risen to nearly thirty million. As Mr. Chandler points out in this issue, audio engineers need to learn more about the nature of the music they are reproducing or producing.

At the same time the largest active listening audience today listens to records and, because recorded sound does differ from original sound, more needs to be known about recorded sound. Mr. Overley's article in this issue is a step in this direction. From the standpoint of record-playing systems it is not necessary to assume that the recorded sound is like the original, because the value of the information lies chiefly in its application to record playback systems.

One of the characteristics of recording and (especially) playback equipment which has been most difficult to control and to evaluate has been "flutter." The third paper in this issue, by Messrs. Comerci and Oliveros, describes an experiment in which controlled amounts of flutter were introduced into music recordings. Correlation was obtained between listener rankings of flutter and the output of a flutter-weighing network. It is of musical interest to note that flutter was rated more undesirable at frequencies lying above and below vibrato rate (6 to 7 cps) than at vibrato rate.

The final article of this issue is concerned with a psychological experiment in the playback of recorded sound. There will be readers who will be unhappy with the conclusions concerning frequency range preferences because of their devotion to the ideal of full frequency range. Note that the author finds that listeners can learn to prefer wider frequency range of reproduction. Be sure to read the article (especially the hypothesis), before drawing your own conclusions. And remember, although engineers are people, people are not necessarily engineers! Dr. Kirk also made use of records in his research. This leads to the main point of this editorial.

A great deal remains to be learned about musical sound, both original and in the recorded form. The membership of IRE-PGA must surely contain many people who have the urge to do research in this field. You don't have to have a laboratory with an anechoic chamber, use expensive microphones and recording equipment, buy musical instruments, and hire performers, in order to do useful research in musical audio. Being engineers, you can calibrate your high quality playback system (in the lab or at home), and can design or borrow the special filters or other test equipment your particular experiment requires.

Perhaps because you used recorded source material you will get a different answer from someone who has measured the actual musical instrument or singing voice. The answer is nevertheless true for the recording, which is what a large percentage of the population will hear. Discovering the difference might lead to even better records in the future.

DANIEL W. MARTIN, *Chairman*

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[1] "Technology in tails," IRE TRANS., vol. AU-4, pp. 49–50; May–June, 1956. Also W. T. Selsted and R. H. Snyder, "Acoustical and Electrical Considerations in Approaching Facsimile Reproduction of the Symphony Orchestra," Program of 2nd ICA Congress; June, 1956.

[2] B. F. Miessner, "Electronic music and instruments," PROC. IRE, vol. 24, pp. 1427–1463; November, 1936.

[3] H. LeCaine, "Electronic music," PROC. IRE, vol. 44, pp. 457–478; April, 1956.

[4] F. H. Slaymaker, "Bells, electronic carillons, and chimes," IRE TRANS., vol. AU-4, pp. 24–26; January–February, 1956.

[5] D. W. Martin, "Electronic organ tone radiation," IRE TRANS., vol. AU-3, pp. 77–84; May–June, 1955.

[6] D. W. Martin, "High fidelity in musical tone production?" IRE TRANS., vol. AU-2, pp. 102–104; July–August, 1954.

[7] H. F. Olson and H. Belar, "Electronic music synthesizer," 1955 IRE CONVENTION RECORD, part 7, p. 62 (Abstract only). Complete in *J. Acous. Soc. Amer.*, vol. 27, pp. 595–612; May, 1955.

[8] D. W. Martin, "Do you auralize?," IRE TRANS., vol. AU-8, pp. 2–3; July, 1952.

[9] H. I. Reiskind, "Design interrelations of records and reproducers," IRE TRANS. vol. PGA-5. pp 1–7; February, 1952.

PGA News

AUDIO PAPERS FOR IRE NATIONAL CONVENTION 1957

Technical papers on audio subjects make up a very important part of the IRE National Convention Technical Sessions. Engineers working on audio topics are invited to submit technical papers for presentation at sessions sponsored by the IRE Professional Group on Audio. Please send *three copies* of 100-word abstracts and 500-word summaries of Audio Papers before November 1, 1956 to:

Frank H. Slaymaker, PGA *Chairman*
National Convention Technical Program Committee
c/o The Institute of Radio Engineers, Inc.
1 East 79th Street.
New York 21, N.Y.

There is a large proportion of IRE members who are intensely interested in audio, even though they are not actively working in the field. The National Convention of IRE gives workers in audio fields a chance to present their work to a large and receptive audience.

OBITUARY

Hillel I. Reiskind (SM'52), manager of engineering for RCA Victor Records, died of a heart attack on May 7, in New York, N.Y. He was 49.

Mr. Reiskind graduated from Rensselaer Polytechnic Institute in 1928, and spent the early part of his career with Paramount Pictures, Inc. as a recording engineer. He joined RCA in 1936, and in 1954 was appointed manager of engineering for the RCA Victor Record Division. He was a member of the Acoustical Society of America, the Audio Engineering Society, the SMPTE, and Sigma Xi. He will be remembered by his friends for the many important contributions which he made to the art of phonograph recording and reproduction.

PGA STUDENT PAPERS COMPETITION

The following announcement of the above was prepared by Ben B. Bauer for the September, 1956 issue of the IRE Student Quarterly, and is reproduced here for the information of the PGA Members.

"You will want to know about the newly-created Student Papers Competition of the IRE Professional Group on Audio. However, let me first report to you about the progress of the Group. The Professional Group on Audio was the first and is the largest of the IRE Professional Groups, having been founded in 1950, and now counting well over 3,000 members. Before the advent of television, audio was almost always the end product and the purpose of radio. With the advent of television, audio might have been expected to be forgotten, but the opposite occurred. Interest in sound reproduction of ever higher fidelity has paralleled the phenomenal development of television. Radio receivers (without an image) or wide range phonographs are still considered more satisfying than a TV set without sound. The vitality of audio has been further demonstrated by recent strivings toward improved quality in the art of disc recording. Tape recording, stereophonic sound, and electronic music are multiplying interest in the audio branch of electronic engineering.

"The Professional Group on Audio was always keenly interested in student members, with the realization that students of today are the engineers of tomorrow. Among our first acts in this connection was to propose a lowered assessment scale for students, which since has been adopted by other professional groups, and by making copies of TRANSACTIONS available to faculty advisors in all IRE sections. At the present time, a committee under the chairmanship of Prof. Alexander Bereskin of the University of Cincinnati, is studying additional services which may be provided to student members. The growth of student members among the membership of the PGA is shown by Table I below, and it is a healthy growth which is very gratifying to our Administrative Committee.

TABLE I

Date	Members	Students	Total Membership
February 28, 1955	2481	144	2625
June 30, 1955	2593	209	2802
December 31, 1955	2688	351	3039
February 1, 1956	2788	374	3116

"To further the interest of students in the work of the PGA, the Administrative Committee, at its last meeting, approved a resolution presented by our Awards Committee under the chairmanship of Dr. Daniel W. Martin, and which reads as follows:

> 'The IRE Professional Group on Audio announces the establishment of an annual Student Papers Competition in Audio. All undergraduates are eligible. Papers must be related to audio, and must be submitted to the PGA Awards Committee by June 1. One award may be made of $100 for first price, and will be announced at the Fall Meeting of the IRE-PGA. All papers submitted will also be considered for possible publication in IRE Transactions on Audio.'

"It is hoped that many will enter into this competition and that the first Award can take place for papers entered during the academic year 1956–1957. Here is a chance for an important stepping stone in your professional advancement, and one that you will not want to miss."

NEC PAPER ABSTRACTS

The following abstracts are for the papers sponsored by the IRE Professional Group on Audio at the 1956 National Electronics Conference in Chicago.

Evaluation of High-Powered Outdoor Sound Systems, by R. W. Benson, Armour Research Foundation

Outdoor installations of high-powered sound systems have been made for the purpose of communicating over large areas from systems located on tall buildings and on airplanes. In order to evaluate the performance of these systems it is necessary to use actual speech materials rather than perform simple physical measures. Airborne systems are affected greatly by the Doppler shift in frequency which cannot be accounted for in a physical evaluation of a system and reflections from buildings introduces echoes for which it is impossible to calculate the effect upon intelligibility. Speech materials have been used to determine both the intensity levels as a function of distance and angle, as well as the intelligibility of the system for various power levels. The results of these studies lead directly to the design of more efficient communication systems. The application of the results of two studies will be shown for the design of optimum systems.

Compensation Networks for Ceramic Pickups, by Ben B. Bauer, Vice-President, Engineering, Shure Brothers, Inc., Evanston, Ill.

Increasing use of ceramic pickups in high fidelity applications has dictated a reexamination of networks used for response of these pickups to the RIAA Recording Characteristic. In a customary arrangement a pickup with an internal capacity C_1 is connected to a grid resistor R_3, and compensation is obtained by connecting a series resistor R_2 and capacitor C_2 across the pickup terminals. For an ideal ceramic pickup these circuit elements may be calculated in terms of time constants of the Standard Recording Characteristic, with the following results: $R_3 = 750 \times 10^{-6}/C_1$; $R_2 = R_3/6.88$; $C_2 = 2.92C_1$. With this type of network, and an ideal displacement-responsive pickup the RIAA Standard Recording Characteristic will be ideally reproduced.

An Experimental 9000-Watt Airborne Sound System, by D. W. Martin, A. Meyer, R. K. Duncan, and E. C. Broxon, The Baldwin Piano Co., Cincinnati 2, Ohio.*

An experimental 9000-watt speech announcing system AN/AIC-11(XA-1) was developed for installation in a B-26 aircraft. The system was used for studies of direct communication through the atmosphere to ground personnel from aircraft operating at relatively high altitude. The equipment consisted of a turbine generator type of auxiliary power unit; three 3000-watt amplifiers, each driving a separate twin-horn loudspeaker; signal preparation, control, and monitoring units; a loudspeaker mounting frame which rotates the loudspeakers and supports two of the twin-horns outboard from the fuselage, and magnetic tape recorders.

Some Miniature Audio Transducer Application Problems, by Hugh S. Knowles, President, Knowles Electronics, Inc., Franklin Pk., Ill.

Miniature microphones and "receivers" are customarily used in hearing aids, miniaturized radio receivers and applications in which size and output power limitations are dominant design factors. The effect of transducer size on the interrelated factors of efficiency, bandwidth, and signal-to-noise ratio need critical evaluation. Transistors are customarily used and their special noise characteristics and influence on transducer types to optimize *sn* require attention. Extreme compactness also introduces severe mechanical acoustical and electromagnetic feedback problems.

High-Power Droppable Air-to-Ground Loudspeaker System, by A. A. Gerlach, D. S. Schover, and F. C. Fischer, Cook Res., Lab. Div., Skokie, Ill.

This paper will present a general discussion of an air-to-ground droppable loudspeaker system presenting rather unusual operational requirements and results achieved with this system. A description of the design and construction features of the electroacoustical conversion and coupling unit, the electronic speech generation and amplification system, the power source requirements, the container design, and the deployment and timing system will be followed by a recording made of of the acoustical test program that was conducted at the completion of the development program.

NOISE ABATEMENT SYMPOSIUM

Problems concerned with hearing impairment will be among the subjects considered at the seventh annual Noise Abatement Symposium to be held in Chicago, Ill., October 11 and 12.

Four papers dealing with several aspects of industrial hearing loss—a matter of special interest to industry in states in which hearing loss compensation laws are in force or being considered—will be considered at the October 12 morning session.

The talks will cover legal phases of the problem, hearing loss compensation laws, the use of audiometers, and clinical experience with automatic audiometers.

Three other half-day sessions devoted to machinery and transportation noises and the control of noise through architectural design will complete the two-day meeting.

Six papers on reducing machinery noise will be presented October 11. Their subjects will be: jet engine noise reduction; estimating aircraft noise disturbance in building design; materials and techniques for damping vibrating panels; preventing noise in pump systems; controlling multiple noise sources by proper phasing; and reduction of transformer noise by enclosures.

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* Work done under government contracts AF33(038)-23313 and AF33(616)-2320.

The October 12 afternoon session, titled "Quieting a Noisy Environment," will cover the following: acoustical engineering principles of noise reduction; retaining high-sound transmission loss in modern factories; use of partial enclosures to reduce noise in factories; and reduction of noise in factory offices.

To accommodate an expected increased attendance, the 1956 symposium will be held at the Hotel Sherman instead of the campus of Illinois Institute of Technology, the site of previous meetings.

Symposium co-sponsors with Armour Research Foundation are Acoustical Society of America, American Society of Safety Engineers, National Noise Abatement Council, American Society of Planning Officials, American Industrial Hygiene Association, and Acoustical Materials Association.

H. E. ROYS, MANAGER RCA RECORD ENGINEERING DEPARTMENT

H. E. Roys, past chairman of the Philadelphia Chapter PGA, has been appointed new manager of record engineering for RCA, with offices at 501 North LaSalle Street, Indianapolis, Ind.

ADDITIONAL PATENTS OF IMPORTANCE

Semi J. Begun, of the Clevite Corporation, has pointed out that patent No. 1,640,881, issued August, 1927, to W. L. Carlson, and patent No. 1,653, 467, issued December, 1927, to J. A. O'Neill, were important ones omitted from the patent review in the May-June issue of the IRE Transactions on Audio. Carlson's patent was the first to disclose ac-biasing, while O'Neill's disclosed powdered recording media.

PGA CHAPTER ACTIVITIES

Albuquerque, N. M.

The following report of the 1955–1956 Albuquerque Chapter activities has been presented by B. J. Lawrence, *Secretary-Treasurer*.

During the past year there were held a total of seven meetings. Nonmembers were invited to all of the meetings. A brief resume of the meetings follows:

1) *October 26, 1955:* Discussion and demonstration of new techniques in tape recording, by C. Bailey of Magnecord, Inc. *Attendance 26.*

2) *November 16, 1955:* Demonstration and discussion of Bruel & Kjaer Audio Test Equipment, by Tony Schneider of Brush Electric Co. *Attendance 26.*

3) *December 15, 1955:* Talk and demonstration by Henry Schultz, of Indian Service, Education Dept., on collecting and enjoying hi-fidelity records. *Attendance 25.*

4) *January 17, 1956:* James Taylor, of Multi-Craft Finishers, presented talks and samples of materials relative to wood cabinet finishing. Also had demonstration of the "R-J" speaker enclosure. *Attendance 34.*

5) *February 23, 1956:* A discussion and demonstration of stereophonic techniques using Klipsch Horns, by Paul Klipsch, brought out a record attendance. Several live recording demonstrations were well received by the audience. *Attendance approx. 300.*

6) *April 24, 1956:* George Reidel, of Sandia Corp., discussed improving FM receivers and antennas for long distance reception. A reception demonstration was also given. A binaural system using a "Viking" tape unit was demonstrated also. *Attendance 15.*

7) *May 29, 1956:* A talk by Edward Ancona, of RCA, on stereophonic theater recording technique and installations was followed by a binaural demonstration. Officers were elected for next term. *Attendance 30.*

The average attendance for the seven meetings was 68 or a total of 476 for the year.

The new officers elected for the 1956–1957 term at the May 29 meeting were:

J. E. Palmer, *Chairman*
W. A. Bains, *Vice-Chairman*
A. D. Pepmueller, *Secretary-Treasurer*
H. R. Briggs, *Program Committee Chairman*

One more meeting, expected to be the last of the current season, was tentatively planned for the latter part of June, 1956.

Chicago, Illinois

The following report has been submitted by Earl L. Olson, *Secretary Treasurer* of the Chicago Chapter of the IRE-PGA.

Officers:

Chairman—Harold J. McCreary, Automatic Electric Co.
Vice-Chairman—Raymond T. Christensen, Zenith Radio Corp.
Secretary-Treasurer—Earl L. Olson, Jensen Industries Inc.
Program Chairman—Wallace H. Coulter, Coulter Electronics
Publicity Chairman—T. S. Pryst, Shure Brothers
Membership Chairman—Karl Kramer, Jensen Manufacturing Co.

The following six papers were presented:

- September 16: "Electroencephalographic Abnormalities and Their Clinical Correlates," Dr. Fred Stamps, University of Illinois Medical School. (Joint session with Electronic Computers.)
- October 21: "The Professional Employee in Industry," David G. Moore, University of Chicago. (Joint session with Engineering Management.)
- December 16: "A New 200-Selection Coin-Operated Phonograph," M. W. Kenney and A. G. Bodoh, J. P. Seeburg Corp. (Joint session with Industrial Electronics.)
- January 20: "Development of a Group of High-Fidelity Instruments," F. P. Bennett and W. A. Plice, Bell & Howell Co. (Joint session with Broadcast and Television Receivers.)
- April 20: "Electric Organs," G. E. Gilchrist, Lyon & Healy.
- May 18: "Loudspeaker Design Requirements for Specialized Applications," K. Kramer, J. F. Novak, and P. B. Williams, Jensen Manufacturing Co. (Joint session with Reliability and Quality Control.)

Attendance per meeting ranged from 40 to 75.

The following nominations for new officers were announced at the April 20 chapter session:

Chairman—T. S. Pryst, Shure Brothers
Vice-Chairman—W. H. Coulter, Coulter Electronics
Secretary-Treasurer—Robert J. Larson, Jensen Manufacturing Co.

There were no further nominations from the floor.

The election of new officers will take place at the May 18 chapter session.

Philadelphia, Pa.

The following report was made by C. D. O'Neal.

The Professional Group on Audio has one of the largest chapters in the Philadelphia Section of the IRE. We have about 225 members; the number is continually increasing. During the past year we have had five meetings. Attendance has been satisfactory at all meetings, and unusually good for those topics of most interest.

In an effort to give the membership the kind of programs it wants, we recently sent out a questionnaire. The members were asked to express a preference as to program material and type of meeting. The replies to this questionnaire were most encouraging. Replies expressed the following preferential interests: *Loudspeakers and enclosures, recording and reproduction techniques, home music systems, amplifiers, physics of music and hearing, stereophonic sound, and phono pick-ups.*

Our Administrative Committee has started your program planning for next year with the above subjects as their goal. This planning includes procuring the top members of the profession as speakers for each meeting. Watch the Bulletin for details of coming programs.

The membership has indicated a desire for refreshments after the meetings, and a willingness to pay for this feature. Where possible, these desires will be gratified.

Our April meeting at WCAU was well attended. Albert Preisman of the Capitol Radio Engineering Institute talked to us about Soundarama and high fidelity. Mr. Preisman has been in an eminent position in our profession for many years. His talk was technically sound; his enthusiasm for good quality sound reproduction is shared by all.

This meeting is typical of our efforts to provide a well-rounded program of interest to all audio engineers.

San Antonio, Texas

Bill Case reports that on June 13, in Austin, and on June 14, in San Antonio, the PGA, in conjunction with the San Antonio Section of the IRE, sponsored meetings at which the speaker was Walter O. Stanton, president of Pickering & Co. Mr. Stanton spoke on "Important Design Considerations for a Wide Range, High Compliance Phonograph Cartridge" and "A Push-Pull Electrostatic Loudspeaker Unit." A demonstration was included, followed by a highly successful question and answer period. This was part of a series of talks, during which Mr. Stanton spoke before PGA and IRE groups in Oklahoma City, Fort Worth, and Houston.

WITH OTHER ACOUSTICAL AND AUDIO SOCIETIES

The May, 1956 issue of the *Journal of the Acoustical Society of America* contains a number of articles which will be of interest to members of the IRE-PGA.

In a paper entitled, "Air Stiffness Controlled Condenser Microphone," T. J. Schultz, of Douglas Aircraft Company, Inc., describes a very small condenser microphone, $\frac{1}{2}$-inch in diameter and 0.1-inch thick. The microphone has a frequency response extending to almost 20 kc, with good time and temperature stability.

In "Some Notes on the Measurement of Acoustic Impedance," Osman K. Mawardi, of the Massachusetts Institute of Technology, treats the question of impedance measurements by the tube method. He shows that the measured impedance differs from that of the average impedance evaluated at the surface of the specimen. A number of recommendations for the method of preparation of a sample are also given.

Bruce P. Bogert, of Bell Telephone Laboratories, describes the "Vobanc—A Two-to-One Speech Band-Width Reduction System." The Vobanc (VOice BANd Compressor) is a speech bandwidth reduction system which provides a reduction of two in transmission channel bandwidth, without a comparable loss in articulation. A description is given of an experimental system and results obtained with it are described.

In two separate articles, A. C. Pietrasanta, of Bolt, Beranek, and Newman, Inc., treats "Jet Noise in Aircraft Carrier Islands" and "Noise Measurements around Some Jet Aircraft." This is an important problem which affects operations by interfering with communications aboard aircraft carriers, and it will also be of interest to those who are concerned with the problem of increasing noise over our urban areas.

Seven out of twenty-five papers in this issue are devoted to ultrasonics, attesting to the continued growth of this important field.

The issue contains several interesting "Letters to the Editor," its usual thorough "References to Contemporary Papers on Acoustics," by Robert N. Thurston, and "Review of Acoustical Patents," by Robert W. Young.

The October, 1955 issue of the *Journal of the Audio Engineering Society* contains a number of articles of interest to members of the IRE-PGA.

In an article on "Fundamentals of Speech Synthesis," Homer Dudley, of Bell Telephone Laboratories, reviews the work of the past two decades dealing with analysis of speech and efforts to synthesize speech. Many of these efforts have been contributed personally by Mr. Dudley. This is an excellent elementary review which will be of value to those who have not followed this interesting subject in the past.

J. Gittleman, of the Franklin Institute Laboratories for Research and Development, reviews "Magnetic Properties of Recording-Tape Pigments."

Richard E. Werner, of the Radio Corporation of America, writes about "On Electrical Loading of Microphones." He concludes that a microphone preamplifier for general use must have an input impedance no less than the highest impedance appearing at the output terminals or any microphone with which it may be used if a frequency response deviation of less than 6 db is to be maintained.

Robert A. von Behren, of Minnesota Mining and Manufacturing Company, treats "Some Design Criteria for Magnetic Tape." This is an interesting review of the factors which have led to the quality of the present day magnetic recording.

BEN B. BAUER

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Engineers and Music*

CHARLES H. CHANDLER†

Summary—**Engineers working in the field of audio, especially if they deal directly with musicians, may find themselves at a serious disadvantage because of a lack of musical knowledge. The acquisition of such knowledge, on the other hand, can increase their professional prestige, improve the quality of their work, and open new horizons for personal enjoyment. The author of this paper, a musician of varied experience as well as an engineer, shows that a very useful background in music is not hard to obtain. This article specifies in concrete terms the information which should be acquired for basic musical understanding, and gives suggestions as to how this information may be obtained.**

INTRODUCTION

THE VARIETY and range of electronic engineers' off-the-job interests and hobbies is well recognized. Especially in fields having a technical content (such as amateur radio, photography, etc.), engineers have an enviable record of activity. However, most engineers, especially if they are good ones, will rarely have had time to concern themselves with such a nontechnical and relatively esoteric subject as classical music. At college, for example, the usual EE curriculum is not likely to include any but the most basic "humanities." Even if some kind of music course were available as an elective, a conscientious student would seldom feel that he could justify taking the time to attend it. Yet, when his professional work begins, an engineer (and we are here concerned with engineers working in the audio field) may find himself in a very anomalous position. He may be involved with equipment which is intended to handle a certain type of program material, perhaps under very stringent specifications; and although his understanding of the equipment may be excellent, his understanding of the material it is expected to handle may be virtually nil.

This anomaly exists regardless of whether the engineer develops, designs, specifies, and installs, or simply sells audio equipment. Even if he deals with the recording or transmission of music, his acquaintance with it is rarely gained in any systematic manner.

Granted the foregoing, however, can the audio engineer not depend on his instruments and leave esthetic matters to the musicians? The answer is, yes and no. Probably most audio engineers do just this. Certainly the instruments are necessary, but it may be questioned whether they are sufficient. For one thing, the problem of the audio system that "measures good and sounds bad" remains. For another, unpleasant sounds sometimes issue from a loudspeaker: is this the fault of the system, or could it be the performer? And third, there are numerous occasions on which an engineer who deals directly with musicians comes away from a contact with the uncomfortable feeling that the two parties have been talking different languages. This is only a partial list; other instances will occur to the reader.

On the more positive side, musical knowledge can greatly sharpen the ear. An engineer with a musical background can help even musicians compare two systems by pointing out what to listen for, and will be able to select demonstration material intelligently. He will command far more respect from his clients, and will be better able to serve their needs. Finally, and by no means least, an understanding of classical music can be the entrée to a wide new field of personal pleasure and recreation.

Before passing to the next topic, let it be noted that the recording, transmission, and reproduction of serious music (as distinguished from speech and popular music) comprises an ever-increasing portion of the field of audio engineering. Another aspect not to be overlooked is the fact that almost every "electronic" engineer, whether an audio specialist or not, has at one time or another built himself some type of audio system, or has been consulted on the subject by a layman. To some extent, in consequence, any radio engineer may find himself judged on his audio-engineering ability. Thus the professional benefits of musical knowledge are by no means confined to audio engineers, but may be enjoyed to some degree by the entire radio-engineering fraternity. The personal benefits, of course, are fully available to all.

Much, perhaps all, of the foregoing has been said before. The need of audio engineers for a basic understanding of music has been felt, if not always expressed, on many occasions. To the best of the writer's knowledge, however, the indicated next step—that is, the outlining of the required information, done for engineers by an engineer—has never been taken. The present article endeavors to take that step.

PERSONAL PREREQUISITES

So far the discussion has necessarily been rather general and abstract. Now it is time to be specific and address the rest of the article directly to you, the reader. And the first question to deal with is that of your own capability for the comprehension and enjoyment of "serious" music.

To begin with, a degree of interest and perseverance is necessary. Since you have read this far through a tangle of subordinate clauses, you may consider yourself qualified on that score. Second, you should be able to perceive pitch, recognize a sequence of different pitches, and discriminate among several pitches played simultaneously. (Some people are physiologically unable to do these things; but such cases are exceedingly few.)

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* Manuscript received by the PGA, February 11, 1956.

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This ability is mostly a matter of using both brain and ears, and can be learned. To guide your listening, keep in mind that music has a very definite structure, both time-wise and pitch-wise; "inner" parts are often as important as the uppermost one. A conscious awareness of such parts, coupled with practice in listening for them, reveals much that would otherwise go unnoticed. The recognition of tone colors or timbres also improves with such practice. Finally, the ability to recognize rhythmic patterns, and to detect the subtle variations in timing which are such a large part of "expression," is desirable. In general, it is safe to say that if you enjoy popular music, these qualifications are all met. It is necessary merely to develop the abilities you have.

ESSENTIAL INFORMATION

We come now to the principal subject: the information you should have in order to understand what a composer is trying to say and how the performer or performers convey this message. In courses given by the author, it has been found that this information falls naturally into several categories which are treated below. These, with such elaboration as the scope of this article permits, form an outline which you can use as a guide to the acquisition of a useful body of musical knowledge.

Vocabulary

The terminology of music draws upon a number of languages, almost entirely excluding English. This situation results in an initial stumbling-block which, fortunately, is readily overcome. Get a pocket dictionary of musical terms and consult it freely. Take it to concerts and use it there. You will find almost immediately, for example, that in "pure" or abstract music, the title of the piece usually names the form (such as sonata, suite, prelude—you will hear more about form presently) and key of the work; while the titles of subdivisions or movements merely give cues to the manner or speed of performance. Descriptive or "program" music titles, of course, provide somewhat more information. Any good music store should be able to supply a pocket music dictionary for a dollar or less; such a book or its equivalent is a "must."[1–3]

The Production of Musical Sounds

This is the point at which the subject of music most closely touches the audio field. For general audio work it is obviously desirable to know the ranges of fundamental and harmonic frequencies, transient behavior, and related properties of musical instruments. (For designers of electronic musical instruments, of course, extensive knowledge in this field[2,4,5] is essential.) At least one book is available[6] which undertakes to describe the operation and tonal output of musical instruments.

However, no matter how complete your acquaintance with the technical aspects of frequency, overtone structure, attack, and decay envelopes, etc., it will profit you little in music until you correlate all this with what comes into your ears. The objective here is to be able to recognize the various instrumental colors, alone and in combination. When you can do this for each instrument alone, you will soon be able to identify individual voices even through the "sound curtain" of an orchestra. Besides adding to your enjoyment of orchestrational effects, this faculty will allow you to follow subordinate parts in a large work—and in such parts, much of the music's message is likely to be found.

If you have friends who play musical instruments, ask them for demonstrations. You will undoubtedly get all the recognition practice you need, plus many fine points on the technique of playing, the selection of reeds or strings, and the deficiencies of the solo literature (an especially sore point with viola players). Another line worth following would be to acquaint yourself with a well-annotated recording of Benjamin Britten's "Young Person's Guide to the Orchestra," which is musically rewarding as well as informative.

The Basic "Building Blocks" of Music

It is easy, but not very helpful, to say that a piece of music is a structure founded on the elements of rhythm and pitch, with tone color thrown in for variety. To say that in occidental music the pitch aspect is based on the twelve notes of the chromatic scale, repeated over many octaves, helps only a little more. As an engineer you will no doubt be interested in the fact that the semitones in an equally-tempered scale result from the repeated application, to a starting frequency, of a factor equal to the twelfth root of two; a musician may or may not know this. But to hear music as music, you should acquaint your ears with the common patterns of notes which are the fundamental building blocks of music. In a manner of speaking, these are the vocabulary of music itself—as distinguished from the verbal terminology which resides in your pocket dictionary.

Here again, musician friends can help you. Alternatively, courses are given in many communities in which, among other matters, the necessary ground will be covered. In any case, by fair means or foul, get a working understanding of the following terms: major and minor scales, and the subjective contrast in mood be-

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[1] "Elson's Pocket Music Dictionary," Oliver Ditson Co., Bryn Mawr, Pa.

[2] R. Illing, "A Dictionary of Music," Penguin Books, Inc., Baltimore, Md., 1950 *et seq.* This contains biographical as well as glossary information.

[3] R. Hughes, "Music Lovers' Encyclopedia," reviewed and edited by D. Taylor and R. Kerr, Doubleday, Doran and Co., New York, N. Y., 1939. A most useful one-volume work, it includes a dictionary of terms, biographies of musicians, opera synopses, and a number of highly-readable articles on a variety of musical subjects. The article which opens the book is an admirable explanation of the musical building-blocks mentioned in "The Basic 'Building Blocks' of Music," part of this work.

[4] R. H. Dorf, "Electronic Musical Instruments," Radio Magazines Inc., Mineola, N. Y., 1954.

[5] E. G. Richardson, "Orchestral acoustics," *Sci. Mon.*, vol. 80, p. 211; April, 1955.

[6] H. F. Olson, "Musical Engineering," McGraw-Hill Book Co., Inc., New York, N. Y.; 1952.

tween the two; chromatic and full-tone scales; intervals; key, the relationships of keys, and modulation; frequently encountered chords and arpeggios (knowing their names is less important than recognizing their sounds); tempo and time signature; melody and theme; harmony; counterpoint; homophony and polyphony; imitation; and ornament.

This sounds like rather a large order. If exhaustively pursued, it could require courses in theory, keyboard harmony, canon and fugue, and one or two other subjects for complete coverage. However, you want this information for listening, not for becoming another Beethoven. A very light touch on the subjects named will suffice, *if* you consistently endeavor to identify these "building blocks" when you listen to any music. (The same "if" applies, by the way, to just about everything else that is suggested in this outline; you will progress only by actively applying what you have learned to what you are hearing.)

While some idea of the meanings of these terms may be gained from the dictionary,[3] the audible demonstration of actual examples is far more effective.

Form

As literature has its quatrains, sonnets, short stories, and novels, so music also has its catalogue of forms. A musical composition employing all the building blocks named above would, in the absence of an over-all pattern, be diffuse, dull, and largely meaningless. Form is the framework into which the elemental parts are set, the structure or architecture which leads to a coherent whole. If you understand form, you will understand what a composer is trying to say, even though you may not understand the message completely at first hearing, or care much for his way of saying it.

It must be understood that musical forms are not a set of dry rules, nor a collection of straitjackets into which musical expression must be fitted. (Indeed, the great composers have habitually taken liberties with existing forms, and invented new ones whenever they saw fit.) Properly followed, these forms practically guarantee that a work will have variety, contrast, and coherence. For you, the listener, they also provide a set of guideposts which can do much to promote your understanding of a work, especially at first hearing. This is why musical titles so often simply name the form to be heard. It remains for the composer's genius to endow a form with beauty and musical meaning.

A very brief description of the principal forms will be undertaken here. To begin with, the basic element in form is simply an air or melody[1] (technically, a theme. It may be anything from a few seconds to a minute or so in duration. This theme may be very pleasant; but by itself it hardly constitutes a major work. An improvement is to follow it with another theme, preferably of a contrasting character and key. The result is an elementary but perfectly good form; an example is the simple verse-and-chorus structure of many songs.

A slightly more sophisticated form may then repeat the first theme again after the second one, bringing the work full circle to a satisfying close. The resulting "three-part form" may be described by assigning letters to stand for the themes, thus: $A\ B\ A$. Simple though it is, this form (with perhaps some elaboration on both themes) is extremely useful and has stood the test of time very well.

A number of other forms have obviously evolved from the three-part one. An example is the rondo: $A\,B\,A\,C\,A\,D\,A\,E \cdots A$. Somewhat further removed is the theme and variations: $A\ A'\ A''\ A_1\,A^*\ a\ \bar{a} \cdots A$. The fugue is another interesting relative. In this form the first theme (or subject), "A," is played by one instrument, which is then joined later by another and still another, as long as the composer's ingenuity permits. Each succeeding instrument or voice, upon its entrance, plays the subject, accompanied by those already playing. After all voices have been brought in, the body of the work then takes the form, roughly, $A\ B\ A'\ C\ A''\ D\ A_1\ E\ A^*F \cdots A$. It is, of course, the characteristic "fugal opening," suggestive of multiple flight and pursuit, that gives the form its name.

More extended musical works usually consist of a group of such forms as the above. Each one constitutes a section or "movement." The movements will, of course, be designed to provide variety in character and contrast in mood. A suite, for example, is merely a group of "concertized" dances, often of the type which were popular during the composer's lifetime. (In this connection it is desirable to acquaint yourself with the speed and rhythmic patterns characterizing such ancient dances as the pavane, gavotte, minuet, passacaglia, saraband, and others; you will encounter them many times.) At least one light and pleasant modern suite—Eric Coates' "Four Centuries"—includes a waltz and something suspiciously like a fox trot. Many such dances are, themselves, of three-part form.

There are, of course, many other forms, strict and otherwise, which cannot be described in the space allotted here. But one which must be covered is the so-called "sonata form," or more properly, formula. It was developed roughly two hundred years ago, but has been been found so satisfying and versatile that it has provided the basis of most serious music ever since. At least the first movement of any major work such as a sonata, symphony, quartet or concerto will, nearly always, use this structure. In many ways it may be considered as a logical extrapolation of the three-part form.

In the sonata formula, you will hear a theme, more or less elaborated upon, and then a second theme in contrasting mood and key. This is the exposition, and serves in effect to place the characters—that is, the themes—upon the stage. The body of the movement which follows is the development. Here the themes may be said to go through a process of growth, variation, even conflict—again comparable to the adventures of characters in a novel or play. They may be stretched, compressed, broken into fragments and rearranged, mixed with new themes and with each other, inverted, reorchestrated—whatever the composer's ingenuity can devise. These various manipulations may leave the original themes barely recognizable; but as a work in this form becomes familiar, the connection of each part with the basic themes is increasingly clear. Following the development, the original themes are again brought to the fore (recapitulation), and a terminating section (coda) may be added.

It is evident even from this brief description that following a work through its developmental portions may not be easy. It is, however, highly rewarding, and accounts for the lasting qualities of music in this form. When each repeated hearing of a work brings new aspects to light, it is not surprising that the composition can become a lifetime favorite. (It is probably a significant factor in the life of "popular" music that development is almost entirely lacking in this genre. Such music must depend almost entirely on orchestral color applied to an ear-catching theme and lyrics for its appeal.)

To sum up, remember that an understanding of form is a principal key to the comprehension of serious music. To get this understanding, secure all the guidance you can, listen all you can, and, most important, listen carefully and intelligently, fitting together what you hear and what you know.

History

As you listen to various works it is helpful and stimulating to sort them into their proper places in the sequence of musical history. Knowing the approximate period in which a work was written gives you a good idea what to expect and what to listen for. It also enables you to follow the progress of innovations in form, harmonic structure, and instrumentation. As a preliminary framework the major periods of interest, together with a few of the major composers representing each, are listed below. An extremely brief characterization of the style of each period is also given.[7]

Baroque (*Vivaldi, Corelli, Rameau, Telemann, J. S. Bach*): Characterized by relatively simple harmony but complex structure, with abundant use of counterpoint. Represented the apex of the polyphonic style; almost every voice in a work was given musically meaningful patterns rather than being completely subordinated to one principal voice.

Classical (*Haydn, Mozart, Beethoven*): Marked transition from the polyphonic to the homophonic style. Polish, clarity of structure, purity of melodic line, gave an effect of apparent (but deceptive) simplicity. Emergence of sonata formula and an increasing ratio of secular to liturgical works.

Classico-Romantic (*Schubert, Mendelssohn, Brahms*): Increased freedom of expression, but strong adherence to classical forms.

Romantic (*Berlioz, Weber, Schumann, Chopin*): Increasingly free expression of moods and emotions—in the case of many lesser composers, of mere sentiment. Larger orchestras, increased exploitation of orchestral tone color, growing emphasis on technical virtuosity of solo artists.

Late Romantic (*Liszt, Wagner, Tschaikowsky, R. Strauss, Respighi, Rachmaninoff*): Rich, sometimes heavy musical effects often built upon elaborate "programs"; harmonically wide ranging but rarely dissonant.

Transitional Modern (*Dohnanyi, Delius, Ravel, Sibelius, Bloch*): Increased harmonic freedom, yielding transient dissonances and colorful, often piquant effects. Interesting combinations of old forms with new tonal latitude; "impressionism" and other experiments.

Modern/Contemporary (*Stravinsky, Schönberg, Prokofieff, Sessions, Berg, Bartok, many others*): Perhaps most strongly marked by its high degree of harmonic freedom (to the point of seeming violently discordant to the unaccustomed ear). Tendency toward shorter phrases, less flowing voice lines, than previous periods. Virtual abandonment, in many works, of key relations—atonality; simultaneous use of two or more keys; experiments with such devices as "twelve-tone row." Complex rhythmic structure with frequent shifts of time base. Some experimentation with new scales, new instruments, and the synthesis of music ("*La musique concrète*") from sound sources not usually considered as musical instruments.

Naturally, these divisions are rough and arbitrary. The composers given are placed more on the basis of the character of their music than on mere dates. This list may serve to establish a broad perspective; more detailed information can be obtained from works on music history[8–10] and encyclopedia articles.[3,11,12]

In fairness to modern music it should be pointed out that, for good or ill, the book has been thrown away and the field of experiment is wide open. As with scientific endeavor, time will show some results to have been important, some otherwise. It is true that much contemporary music seems to have been written to impress critics, musicologists, other composers, anyone but a lay member of an audience.[13] Nevertheless it is instruc-

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[7] For the sake of brevity in these descriptions, technical terms have not been spared. These terms, if some be obscure at present, will readily yield to a combined application of the music dictionary and a knowledge of the musical building blocks already mentioned.

[8] W. Lovelock, "A Concise History of Music," Thos. Crowell Co., New York, N. Y.; 1954.

[9] T. M. Finney, "A History of Music," Harcourt, Brace and Co., New York, N. Y.; 1935.

[10] D. N. Ferguson, "A History of Musical Thought," F. S. Crofts and Co., New York, N. Y.; 1935.

[11] W. Apel, "Harvard Dictionary of Music," Harvard Univ. Press, Cambridge, Mass.; 1951. This is another one-volume work, complete and scholarly.

[12] "Grove's Dictionary of Music and Musicians," 3rd ed., Macmillan Co., New York, N. Y.; 1927, *et seq.* This is probably the largest and most comprehensive musical encyclopedia, in spite of the modesty of its title.

[13] H. Pleasants, "The Agony of Modern Music," Simon and Schuster, New York, N. Y.; 1955.

tive to read contemporaneous criticisms of music that was new a century ago.

Literature

In this day of plentiful and low-priced records, a good listening acquaintance with the musical literature should be very easy to obtain. As a beginning, get to know one major work by at least one of the composers named in each period above. You will probably find a favorite period rather quickly and can use this as a base for broadening your acquaintance in both directions. Do not hesitate to sample new and unfamiliar works; mere exposure yields great benefits in the long run. A knowledge of form will stand you in good stead here.

Eventually you will find that you have accumulated a "repertoire" which is itself a most useful frame of reference. It will enable you to correlate periods with styles and associate composers' names with their works, and it will be extremely helpful in the selection of demonstration material—not to mention the choice of music for your own enjoyment.

Performers

As a finishing touch for your musical education, it is desirable to be conversant, at least to some degree, with the major performers (both solo and group) in the musical field. You can make recordings serve you in this as well as in other areas of musical knowledge. Your interest here should cover at least the contemporary scene. In due time it may well extend over the entire period during which music has been recorded.

You will quickly find favorite instrumental performers, singers and orchestras; this is as it should be. But do not neglect the broader view. Get a listening acquaintance with all the "majors," and—if only by hearsay—some idea of their specialities and idiosyncrasies. You will develop taste by comparing performances with reputations and reviews; if you sometimes disagree with these, so much the better—your own opinion is the only one that ultimately matters anyway.

And finally—get to "live" performances whenever you can. You will be surprised how often some essential component of musical quality simply does not come out of a loudspeaker, but depends on the presence of the artist. This can be both a humbling and a stimulating experience for an audio engineer. (There are also cases in which the actual performer does not measure up to his recorded image.)

If nothing else, hearing the best of live music will sharpen your ear, supplement your musical experience—and make you intolerant, as nothing else will, of distortion and second-rate sounds.

How to Get the Information

Sources of musical information have been mentioned from time to time in the foregoing. Books and articles,[3,8–16] records, musical friends, and (above all!) intent listening, can all make important contributions to your progress. Also, there are courses. These come in all shapes and sizes, power and frequency-response ratings, and with a variety of labels: Music Appreciation, Listening to Music, Music Without Tears, Understanding Music, and many more. They are offered by schools, colleges, community centers, Y's, and music teachers. It is very nearly impossible to tell *a priori* which are good; but it is probably safe to say that if you are starting from scratch it would be a remarkably poor course which would give you no benefit. The opportunity to ask questions, if freely used, would justify any reasonable cost. The main thing is to avoid outright misinformation. If you already have some background, you will be better able to assess the quality of a course in advance. In either case, if the course in question has been given in the past, there should be no lack of opinion among those who attended previously.

All in all, a "music listening" course can be very helpful, if only as a contact with a live source of information and listening guidance. Its total value will depend as much on your participation as on its intrinsic merits, and the information sources already mentioned should not be neglected. The objective is to make music intelligible. Its beauty will then speak for itself.

Finally, a word of assurance. The ground so sketchily covered above may seem extensive, perhaps formidably so. Yet the only real difficulty is one of terminology; this is readily overcome. To talk and think about music, you must have terms, which may be acquired one at a time. To understand the talk and enjoy the music, you further need auditory referents for the terms. These may also come to you one by one, although it will more likely be as a gradual and uneven increase in the illumination of a large area. In any case, merely reading this article has provided a beginning.

Conclusion

The understanding and enjoyment of serious music is not such a subtle and elusive art as is all too often believed. This understanding may be gained from the joint application of a relatively small body of essential knowledge, and careful, intelligent listening. The present article has endeavored to supply as concrete as possible an outline of the required information, and some suggestions as to how it may be obtained. The rest must come from the listener.

It is hoped that this article may result, for some of us at least, in better audio, enhanced prestige for our profession—and greatly increased enjoyment of a great art.

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[14] D. Taylor, "Of Men and Music," Simon and Schuster, New York, N. Y.; 1938. This is a miscellany of articles, entertaining and informative.

[15] V. Thomson, "The State of Music," Wm. Morrow and Co., New York, N. Y.; 1939. Here is another very readable collection of essays, with the composer's viewpoint particularly well represented.

[16] E. T. Canby, "Keeping the score," *Audio Engrg.*, June, July, and August, 1953. This is a series of three articles.

Energy Distribution in Music*

JOHN P. OVERLEY†

Summary—**A knowledge of the manner in which the acoustic power encountered in music varies with respect to frequency can be a useful tool in the design of components to be used in audio reinforcement or reproduction systems. This paper deals with the amplitude of fractional-second energy peaks, without reference to the rate of their occurrence. It is these peaks which must be considered when distortion is of primary consideration; average power is useful only in predicting temperature rise (where applicable) of signal-handling components. Throughout the discussion emphasis is placed upon the difference between average and peak energy consideration.**

The source material from which the distribution analysis is drawn consisted of recent commercial vinyl recordings played on a carefully equalized reproducing system. Ten various types of music are classified and a distribution curve for each is drawn. The methods used in arriving at a typical curve are shown by breaking the spectrum into octaves with a band-pass filter.

The distribution information mentioned above is applied to the design of a three-channel loudspeaker system as an example of use. Other possible applications are mentioned.

PRESENT-DAY audio systems designed for voice and music reproduction vary greatly in specifications and application, but all have in common the requirement to respond to more than one frequency. The frequency pass band may range from the narrow limits of 200–3,000 cps, typical of a voice communication system, to the extended range of 20–20,000 cps or better, achieved only in certain high-fidelity systems. Each component in a system should be capable of delivering the required power without exceeding the maximum permissible distortion or risking damage due to overload.

In the design and testing of various audio components it is helpful to know the expected signal energy distribution with respect to frequency. In other words, because the energy in typical speech and music is not uniformly distributed throughout the audio frequency spectrum, design compromises may be effected to reduce the possibility of overload at any frequency. The distribution curves developed in this article were intended primarily for use in the design of loud speaker systems, but are applicable to other components.

Before proceeding with an explanation of the recorded data, let us examine a few of the energy characteristics of typical human speech and, in particular, music. Consider, for a moment, the sound of an orchestra. The dynamic level may vary over an extreme range of values, depending upon how many instruments are playing, the loudness of each, and acoustics of the room or auditorium. Usually, the maximum sound energy at *any* frequency will occur during the loud musical passages when most players are active. An instrument played loudly not only produces the greatest level of fundamental, but its tone may be considerably richer in harmonic content than when it is played softly. Thus, if we are interested in finding the maximum energy present at any frequency, the investigation, for the most part, may be narrowed to a study of the apparent loudest passages. Certain exceptions to this generalization are recognized: a solo instrument or voice may be recorded at a higher than normal level with a separate microphone for emphasis; certain combinations, such as a choir of women's voices, require unusual sound handling ability, as we shall see later. Now consider a sustained chord played by the orchestra at a constant, high volume level. Although no audible variations exist, a volume indication will exhibit continual fluctuation over a susbtantial range. Because the phase of each instrument bears a random relationship to every other one, their vector sum (the resultant sound intensity) is not a constant. At a certain time when several instruments are "in phase," very high instantaneous values of sound amplitude may result. In this manner a series of peaks is generated whose amplitudes are many times that of the average. If an audio system is to give distortionless reproduction, it must be capable of passing, without clipping, the highest peaks which have a time duration sufficiently long, and occur frequently enough, to be perceived by the human ear. Such peaks may be due not only to several instruments playing in unison or at harmonically related frequencies as described above, but are also influenced by the reverberation of the chamber and by the harmonic structure of each single instrument.

It is, therefore, necessary to distinguish between average energy and peak energy. To illustrate this concept, compare two electrical signals of the same peak amplitude, but one which is sinusoidal in nature, and the other which is a pulse of short duration (see Fig. 1).

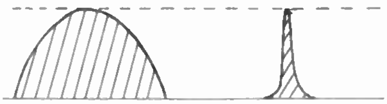

Fig. 1

Average or total energy is proportional to the shaded area under the curves. It is approximately the quantity which would be measured by a volume indicating meter of the conventional type. Obviously, the sine wave represents a much greater average energy than the pulse. Peak energy is a function of maximum amplitude, however, and is seen to be identical for the two signals. Hence, for distortion-free reproduction, the power handling requirements of any component (covering the full frequency range) would be the same in each case even though a conventional VU meter would register

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† Radio Mfg. Engrs., Inc., Washington, Ill.

widely different readings. It has been the practice of the broadcast and recording industries to allow an arbitrary margin of 10 db between VU indications and the equipment overload point, to handle the majority of these peaks without clipping. It is to be understood, however, that this 10 db is a compromise with the signal-to-noise ratio, and is inadequate in many instances from a perfectionist's point of view. In general, the more complex the harmonic structure or the greater the number of simultaneous sound sources, the greater is the margin required to minimize clipping. It is for this reason that audiophile advocates over twenty watts of available electrical power for a home music reproducing system, whereas a few hundred milliwatts of sinusoidal power will produce an uncomfortably loud sound level on the same equipment. A chorus of women's voices has been noted to have a particularly high ratio of peak-to-average energy. Consequently, some engineers reduce the recording level below normal for this type of material.

The degree to which peaks may be clipped or compressed is open to considerable discussion. It depends in part upon the *amount* of peak amplitude reduction, frequency of occurrence of such peaks, the type of program material, frequency response of the system, and (to a great degree) tolerance of the listener. Moderate clipping may result in "listening fatigue" before its severity permits recognition by an *A-B* listening test. It should be mentioned that momentary overloads due to occasional peaks must not induce temporary instability in the equipment. This effect would lengthen the duration of clipping and grossly increase the severity of resulting distortion. Many otherwise acceptable public address amplifiers suffer from this fault.

The following information on energy distribution music and speech is based upon peaks as short as a fraction of a second in duration, occurring in the loudest passages of voice and music. It represents the approximate distribution of energy vs frequency under highest signal conditions—exactly those conditions which should determine the power handling requirements of audio components. *Average* or *total* energy distribution would be of little value here unless the power limitation in a reproducer were one of temperature rise rather than distortion. This condition is rarely encountered in program material reproduction since heating effects are proportional to rms power (much closer in value to average than peak power for typical signals).

The following data were compiled to fulfill the need for energy distribution information based upon peak rather than average values. To obtain these data, special phonograph recordings representing the most advanced techniques were played back on carefully equalized high quality transcription equipment. These provided the source material. It was felt that this was representative of typical good quality in frequently encountered sources. Frequency response of the playback components was of primary importance, since it directly affected the results of this study.

Each musical selection to be analyzed was first played without any frequency restrictions and the gain of the playback amplifier adjusted to give an arbitrary output meter deflection for the maximum recorded level. The sound level meter was then adjusted for a band-pass response one octave wide and the recording replayed, noting the meter reading at the same instant of maximum level on the record. This process was repeated, yielding an energy level reading in decibels for each frequency band. The highest octave (above 9600 cps) was always measured first to minimize possible "erasure" of high frequencies from the vinyl pressing due to repeated playing. A *Scott* type 420-A sound analyzer was utilized to measure the relative energy present in each of the ten bands into which the audible frequency spectrum was divided. Very sharp cutoff filters within the analyzer serve to minimize possible error due to the presence of high level signals just beyond the desired cutoff frequency.

Table I is a tabulation of results obtained in the manner just described. Each reading is given in db after the total sound has been corrected to an arbitrary standard level of 47 db. Many musical passages were measured and averaged to obtain each figure. To convert the data to a more useful form, the table was first changed from decibel values to relative powers and then the curves of Figs. 2 through 5 were drawn, based on this information. It must be remembered that these curves represent the average of a great number of measurements made on music and speech of the appropriate type. Although an individual passage may be widely divergent from the distribution shown here, each curve does predict the maximum power to be *expected* in any given frequency band. Surprising consistency was observed among various musical samples during the preparation of each curve.

Energy distribution information finds a wide application in the design of audio frequency reproducing components. It is useful in obtaining maximum possible performance over the entire spectrum for a given manufacturing cost. As an example, let us consider its use in the design of a 3-way loud speaker system by predicting the maximum power which will be encountered in each of the three channels. Assume that the crossover frequencies have been determined by other considerations to be 800 cps and 3,500 cps. Since we anticipate all types of voice and music signals, the average curve should be consulted.

On the graph, 800 cycles is seen to correspond to 64 per cent of the total signal power as read on the left hand ordinate, indicating that this percentage of total peak power occurs below 800 cps. The loudspeaker channel passing frequencies above 3,500 cps must handle only about 3 per cent of the total peak power, as read on the right hand ordinate scale. The remaining 33 per cent (the difference between the 800 cps and 3,500 cps "y" intercepts) finds its way into the midfrequency channel.

TABLE I

Average Peak Energy Levels (db) of Sound vs Frequency
Frequency Band CPS

Source	20–37	37–75	75–150	150–300	300–600	600–1200	1200–2400	2400–4800	4800–9600	9600–20 kc	Over-all
Pipe Organ	31	42	42	39	38	38	35	29	16	−2	47
Symphony Orchestra Heavy Strings with Woodwinds and Brasses	*	33	36	37	42	39	43	27	28	12	47
Speech: Male Voice	*	30	38	41	43	41	38	34	29	16	47
Small Concert Orchestra Heavy Brasses	*	35	37	33	39	40	42	37	28	18	47
Soprano Solo (Classical) Orchestra Accompaniment	*	14	22	29	40	43	34	32	20	3	47
Symphony Orchestra, Full Orchestra	*	24	36	38	42	41	39	35	29	17	47
Dance Band, Instrumental	*	28	35	36	36	41	42	39	32	15	47
Background Music Semiclassical Small String Group	*	38	35	39	43	42	41	39	31	13	47
Baritone Solo (Popular) Band Accompaniment	*	41	42	41	45	43	37	32	27	5	47
Large Mixed Chorus—Classical	*	21	29	33	43	41	41	37	19	1	47
Piano Solo	*	22	30	38	43	42	35	28	13	−4	47

* Negligible signal level; noise and rumble exceed 20 db in some recordings.
Each reading represents an average of the peak level expected in a loud passage. All values have been corrected for equal over-all level.

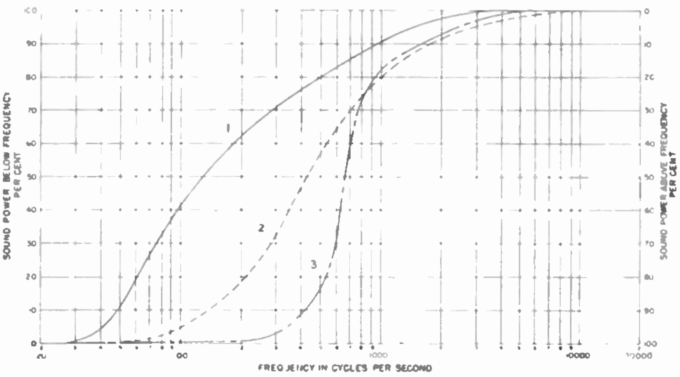

Fig. 2—Peak energy levels of sound vs frequency. 1) Pipe organ; large, reverberant building. 2) Speech; male voice—radio announcer. 3) Soprano solo; classical music—orchestral accompaniment.

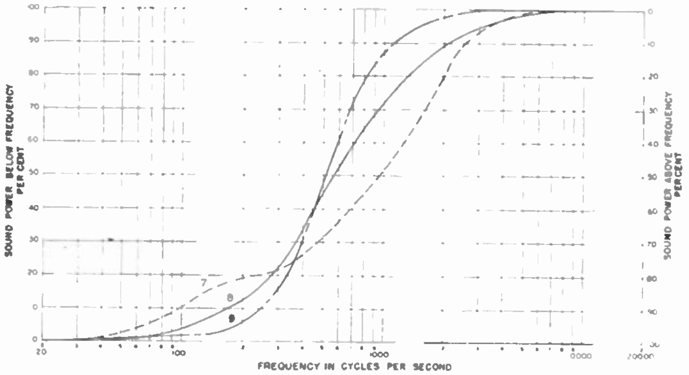

Fig. 4—Peak energy levels of sound vs frequency. 7) Small concert orchestra—heavy brasses. 8) Symphony orchestra—full orchestra, 9) Piano solo; close microphone technique.

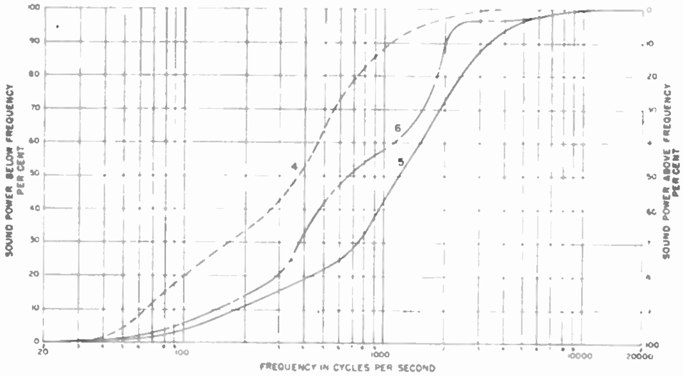

Fig. 3—Peak energy levels of sound vs frequency. 4) Baritone solo; popular music—band accompaniment. 5) Typical dance band; instrumental. 6) Symphony orchestra; heavy strings, with woodwinds and brasses.

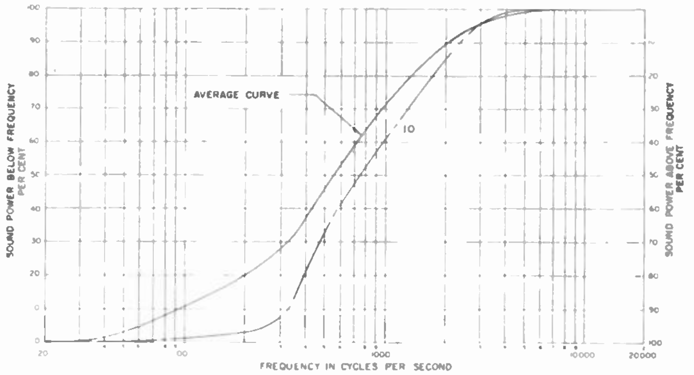

Fig. 5—Peak energy levels of sound vs frequency. 10) Large mixed chorus; classical music.

From these data it is clearly unnecessary to construct a high-frequency "tweeter" capable of handling more than a very small fraction of the power found in the low frequency channel for equal overload points on the average signal. For a given cost, this means that a greater percentage of permanent magnet material in the loud speaker system may be allocated to the low-frequency driver, enhancing its power handling ability. Moreover, since the tweeter may be designed for lower power, its physical size may be reduced, and diaphragm design altered. This leads to improved frequency and transient response, as well as better dispersion of sound.

Energy distribution curves also may be used as a basis for the determination of tape and disc recording pre-emphasis curves, showing best compromise between signal-to-noise ratio and high-frequency distortion. Reasonable agreement exists with some of the commonly used present-day characteristics, based largely on subjective experience in the recording industry. As a final example of application, this distribution information may be applied in designing a multiple amplifier system. Here the incoming high and low-frequency signal components are separated and supplied to two independent amplifiers. Since the usual practice is to cross over above 800 cps, it may be seen that the low-frequency channel is called upon to provide the major share of power. Good design therefore dictates that most of the output transformer iron be utilized in the low-frequency unit. Again, advantages are obtained in reducing power capability of the high-frequency unit, in this case, low leakage reactance and capacitances of the output transformer.

In certain installations it is possible that conditions of noise or specialized signal will modify the normal power handling requirements. Even with relatively good quality phonograph equipment, for example, rumble in the 30 cps region may exceed low-frequency signal components. In public address applications, high-frequency loud speaker components must be capable of withstanding the abnormal condition of momentary acoustic feedback.

To summarize the preceding material, a knowledge of energy distribution vs frequency is a valuable tool in designing audio equipment for uniform overload characteristics across the frequency spectrum on a typical signal. Careful use of such information will permit many times the power to be realized without distortion than in a system of the same cost, designed with a uniform power handling capability at all frequencies.

A large number of examples of signals of several types were measured, and are presented in the accompanying charts and graphs to fulfill this need. A few present day applications have been mentioned; however, it is believed that this information may find increased future use in the highly competitive audio field.

EXPLANATION OF CURVES

Each curve represents the approximate distribution of peak sound energy over the audible frequency range from a source of music or speech. Values are for maximum fractional-second peaks which occur with reasonable regularity, but are not weighted on the basis of how often they appear. These are not total energy curves. Sources are given in the figure captions.

The per cent of total peak sound energy for any frequency band may be found by reading the difference in the y-direction between two points on the curve corresponding in frequency to the ends of the band. Relative peak power at any frequency is indicated by the slope of the curve at that point.

ACKNOWLEDGMENT

The writer wishes to thank H. H. Scott for making available the sound analyzing equipment, and to associates at Electro-Voice, Inc. for their inspiration and assistance.

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An Audio Flutter-Weighting Network*

F. A. COMERCI† AND E. OLIVEROS†

***Summary*—Listener preference rankings of selected samples of programs containing many types of flutter will be compared to measurements of the same flutter using a meter weighted with respect to flutter rate in accordance with the threshold of perceptibility. It will be shown that the correct weighting curve varies with the level of flutter, and modification should be made to the flutter meter in order to obtain objective rankings of program containing the same type of flutter.**

IN THE PROCESSES of recording and reproducing sound, a serious distortion results from instantaneous relative speed variations between the respective transducer and the recording medium. This distortion, termed flutter, manifests itself as a frequency modulation of all the tones comprising the recorded program. It has long been recognized that the perceptibility of frequency modulation in tones is influenced to a significant extent by the flutter rate or the cyclic rate of variation of the transport medium speed.[1,2] An attempt to incorporate a flutter index in the form of flutter rate weighting formulas, in a standard method for measuring flutter,[3] was made a few years ago, but was dropped because of a void of information relative to whether perceptibility thresholds for flutter in pure tones could be applied to the complex waveforms of speech and music programs. A group of several subjective experiments conducted at the New York Material Laboratory for the Navy Bureau of Ships[4] indicated that the relative effect of flutter on music was similar to its effect on a 1000 cps tone and that, for complex flutter waveshapes, a measure of the root-mean-square deviation from the mean frequency would give an adequate indication of the combined effect of all the flutter components on a tone or program. It was concluded from these experiments that not only could the threshold of perceptibility for pure tones be used as a basis for applying flutter index formulas for program but they could also be used as the basis for incorporating a flutter rate weighting-filter in flutter-measuring instruments. The following considerations were advanced to support the use of a flutter index weighting-filter:

1) That the predominant frequency components of speech and music program are between 500 and 5000 cps where the effect of flutter is constant with tone frequency and most perceptible.
2) That over the range of probable program listening levels the effect of flutter is constant and most perceptible.
3) That although the absolute perceptibility thresholds vary with the acoustic characteristics of listening areas and with the content of program (type of musical instruments etc.) the relative effect of flutter rate is essentially the same. A flutter index measuring instrument should indicate the effect of a particular flutter on a program which is most susceptible to the effects of flutter and for conditions under which the flutter is most perceptible.

In these experiments, it was shown that the flutter thresholds for earphone listening to a 1000 cps tone recorded on magnetic tape were approximately three times greater than those for earphone listening to a 1000 cps tone from a frequency modulated oscillator. This difference was believed to be due to masking by an inherent flutter in the 1000 cps recording or to noise and distortion products associated with it. Insofar as the weighting network is concerned, this difference is not troublesome, for the relative effect of flutter at various flutter rates from 0.5 to 100 cps was essentially the same for the recorded and generator tones except for flutter rates below 1.5 cps, where it was felt that the lower relative thresholds for the recorded tone was due either to a better subjective technique, or to the fact that the relative data for the recorded tone below 5 cps flutter rates were actually obtained for loudspeaker listening. It is noted that the results at these lower flutter rates are in better agreement with thresholds obtained for loudspeaker listening in large auditoriums. In view of this, the inverse curve of that representing the average flutter perceptibility thresholds of recorded 1000 cps tone, chord, piano music, and orchestra music for flutter rates from 0.5 to 100 cps was proposed for the flutter rate weighting-network. A well-damped root-mean-square indicating meter was proposed as an indicating meter.

The experiments reported herein were conducted by the Material Laboratory for the Navy Bureau of Ships and represent an extension of the previous work. A flutter index meter was devised and flutter index measurements of many complex variations of flutter were compared with subjective quality rankings of three

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† Material Laboratory, New York Naval Shipyard, Brooklyn, N. Y.

[1] E. G. Shower and R. Biddulph, "Differential pitch sensitivity of the ear," *J. Acous. Soc. Amer.*, vol. 3, pp. 275–287; October, 1931.

[2] W. J. Albersheim and D. Mackenzie, "Analysis of sound film drives," *J. SMPE*, vol. 37, pp. 452–479; November, 1941.

[3] SMPE Committee on Sound, "Proposed standard specifications for flutter or wow as related in sound records," *J. SMPE*, vol. 49, pp. 147–159; November, 1947.

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types of program containing the same flutter variations. Experiments were also conducted to determine whether any change in ranking was associated with various listening conditions.

Flutter Index Meter

An available flutter meter which contained a low impedance output originally designed for operating an oscillographic recorder was selected for modification to a flutter index meter. Measurements showed that the sensitivity of the low impedance output circuit was constant over a flutter rate range from 0.5 to 200 cps and was linear over this range for flutter amplitudes up to 2.8 per cent peak. It could be converted into a flutter index meter simply by connecting a suitable weighting filter and indicating meter to this low impedance output circuit. A standard "VU" meter was used as the indicating instrument instead of a thermocouple meter in order to have a standard damping characteristic. There is reason to believe that the actual pitch heard by a listener is a function of the tone frequency over a time period of approximately 140 milliseconds, for the ear ceases to hear a change in pitch when sinusoidal flutter rate is increased above about 5 to 7 cycles per second. The "VU" meter is similar in its damping for it ceases to register any amplitude modulation when the modulation rate exceeds about 7 cps. Thus, the "VU" meter, in addition to providing a standard damping, also has a damping which is similar to that believed to be associated with the pitch sensitivity of the ear. Comparison of flutter readings obtained from the "VU" meter (rectified average over a standard time period) and a thermocouple meter (rms over a nonstandard time period) for the complex flutter waveshapes used in the experiments indicated that any differences were insignificant. The filter inserted between the flutter meter and the "VU" meter provided an over-all sensitivity to constant flutter amplitude, as shown in Fig. 1. The design objective was determined from the average perceptibility thresholds for the four program samples of of the previous experiments.[4] For the low flutter rates, where the pointer of the "VU" meter tended to follow the flutter amplitude excursion rather than indicate an average, the average peak swing was taken as the reading. The amount of variation between the actual sensitivity curve and the design objective was not considered important in view of the variance anticipated for the subjective quality rankings but was taken into account in analyzing results. The sensitivity of the flutter index meter was adjusted so that readings on the per cent scale of the "VU" meter would agree with listener preference ranking scores that would be expected from fluttered program. In particular, the sensitivity was adjusted so that the meter gave a reading of 100 per cent for a flutter amplitude of 2 per cent peak at a flutter rate of 3 cps. This value of flutter was found in the previous experiments to just begin to cause saturation (approach a maximum ranking score) in a listener preference ranking vs flutter amplitude curve.

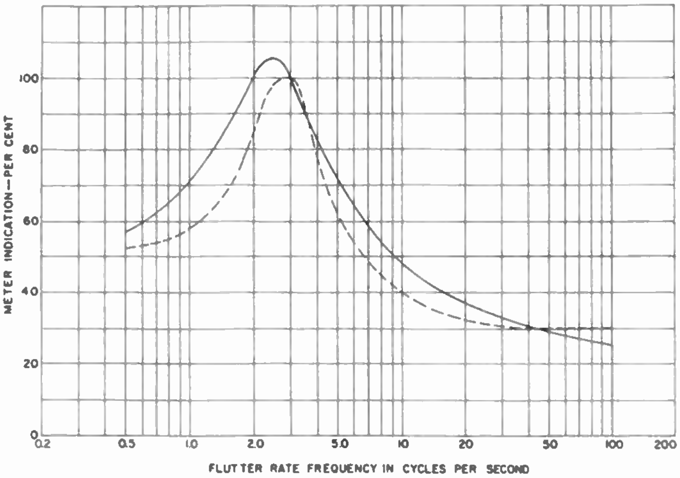

Fig. 1—Sensitivity vs flutter rate for Material Laboratory flutter index meter
Input flutter—2 per cent peak
——— measured sensitivity
--------- design objective.

Subjective Rankings

The ranking technique employed was the Listener Preference Ranking Test used in the previous experiment.[4] This test consisted of paired comparisons by a group of judges on program samples containing the variations of flutters to be compared. One of the flutter variations was used as a control standard of comparison to which all the others were compared and judged as being "much worse," "worse," "same," "better," or "much better." A category of "don't know" was included to account for the possibility that because of inattentiveness or other similar reason the judge was unable to make a comparison. The judgments for each group to be ranked, in this case each program, were then quantified for each judge, assigning a number of rank to each judgment category for each judge. The quantification scheme was designed to provide an equal basis of comparison for each judge in a numerical form. The average number of rank assigned by the group of judges for a given flutter variation was then taken as its ranking score. The higher numbers were associated with the least preference of "much worse" quality.

Flutter Generation

Flutter variations were introduced into the program in two ways. One method employed the Material Laboratory Flutter Generator,[4] which used a magnetic head mounted to a loudspeaker cone to provide relative longitudinal motion between the head and a magnetic tape. The flutter generated in this manner was controlled by the signal fed to the loudspeaker voice coil. The second method utilized a high quality tape recorder which had a low flutter content when operating with the

the flywheel removed from the tape drive capstan. The desired flutter was introduced by varying the frequency of the power source used to power the synchronous driving motor. The power source was derived from a 50-watt audio amplifier fed from a frequency modulated 60-cycle oscillator. This system made it possible to reasonably duplicate flutter found in actual equipment by substituting for the 60-cps oscillator, a fluttered signal from a 60-cps recording as reproduced from the particular equipment. The first generator was not able to generate flutter rates below about 3 cps while the latter was limited to flutter rates below 35 cps. Hence, the Material Laboratory Flutter Generator was used to generate flutter for one listener preference test in which the flutter variations consisted primarily of high-frequency flutter rates above 5 cps, while the modified recorder was used to generate flutter for another listener preference test in which the flutter variations were confined to flutter rates below 25 cps. Two tests were employed, for any differences other than flutter which might exist between the two generators might have influenced the comparisons.

In Listener Preference Test I, samples of the following program material were selected from magnetic tape recordings of local FM broadcasts.

1) A ten-second sample of a piano rendition of a popular melody "You'll Never Know." The particular sample was taken from a part containing both short and sustained notes including both high and low pitches.
2) A ten-second sample of a military band playing "Tales of the Vienna Woods." The sample consisted of clarinets and brass instruments and had several sustained chords.
3) A ten-second sample of a male news commentator.

To generate flutter, these samples together with a twenty-second sample of a 3000-cps tone, which was recorded on a tape using the same recorder used to record the program, were spliced together at the center of a 1200-foot reel of tape. They were played back on the Material Laboratory Flutter Generator which was used to introduce thirty flutter variations. These were recorded on another recorder to obtain samples of fluttered program for use in the subjective tests and samples of fluttered tone for use in obtaining flutter index measurements. Since the sample of 3000-cps tone had been subjected sequentially to the same recording and reproducing processes as did the program, the flutter in these samples were the equivalent of that introduced in the program. Flutter oscillograms obtained from the tone samples (see Fig. 2), indicate the complexity and range of the thirty flutter variations compared in the test. These variations were randomly selected to give a representative sampling of flutter rates from 4 to 100 cps and amplitudes which promised to provide a range from nonperceptible to maximum perceptibility. The program samples were spliced together to permit "A-B" comparisons between each flutter variation and the control standard of ocmparison for each program. Program randomization was not employed and for each comparison the standard was presented first.

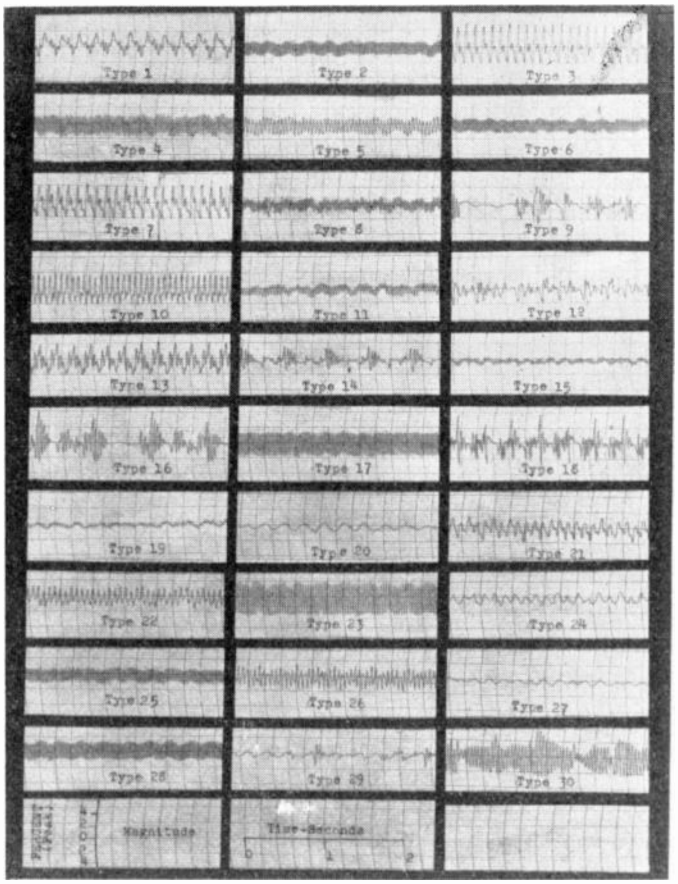

Fig. 2—Oscillograms for flutter variations used in Listener Preference Test I.

In Listener Preference Test II flutter comparison tapes were obtained in a manner similar to that of Test I except for the difference in flutter generation. The program selections were:

1) "Viola and Piano Sonata in F Minor," by Rubinstein. A ten-second passage was selected in which the piano instrument was predominant and included rich chords, a fast group of short single piano notes as well as sustained notes at a reasonably high pitch.
2) A military band playing "Under the Double Eagle," a march. A ten-second passage was selected which contained woodwind and brass instruments.
3) A ten-second sample of a male news commentator.

This test consisted of comparisons of forty flutter variations. Twenty of these had single flutter rates selected over a flutter rate range from 0.5 to 25 cps with amplitudes randomly chosen to provide equal predicted increments of quality. Ten were randomly selected to contain a combination of high and low frequency flutter rates with amplitudes which were predicted to provide equal increments of quality. The remaining ten were representative of actual motion picture projector, disc

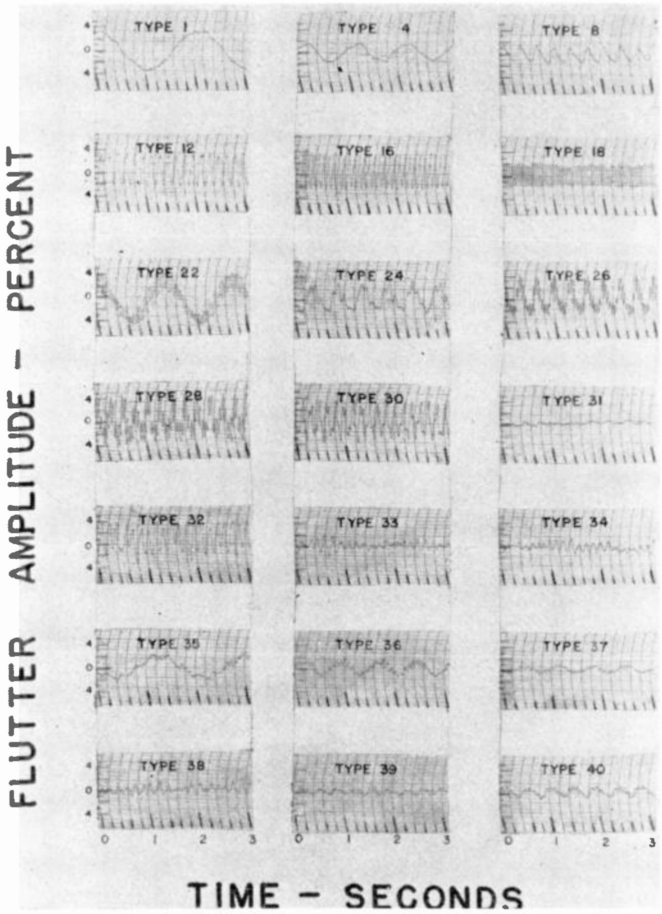

Fig. 3—Oscillograms for representative flutter variations used in Listener Preference Test II.

playback and tape recording equipment. The particular flutter variations are indicated in Table II and oscillograms for several are shown in Fig. 3. The samples of fluttered program, when spliced to permit comparisons, were arranged in a statistically random fashion with respect to type program, flutter variation, and presentation of standard first.

LISTENER PREFERENCE TESTS

For the Listener Tests, eighteen judges, all male and ranging in age from 23 to 40 years, were seated fairly comfortably in an acoustically-soft listening room about 100 feet long, 20 feet wide, and 10 feet high. Each judge had had previous experience in comparing fluttered program. The walls and ceiling of the room were polycylindrical and covered with acoustic tile. The floor was rug covered concrete. The reverberation time was approximately 0.25 seconds at 1000 cps, and the ambient noise level was about 60 db. consisting of predominantly low frequency machinery rumble. This listening condition will be referred to later as "Condition A."

The program comparison tapes were reproduced and projected through a triaxial loudspeaker system which was centrally located in front of a perforated motion picture screen hanging about 15 feet from one end of the room. The judges were grouped close together about 20 feet from the loudspeaker on its axis along the length of the room. The peak program level at the judges positions was about 90 db (ref. 0.0002 microbar). The response of the over-all system from initial program recording through the various recording and reproducing processes and flutter generation to final presentation to the judges was essentially that of the loudspeaker. Its response was uniform with ±5 db from 200 to 10,000 cps and decreased gradually below 200 cps by approximately 6 db per octave and above 10,000 cps by about 12 db per octave giving what should be considered adequate response from 40 to 15,000 cps. The harmonic distortion of the system for sinusoidal signals from 100 cps to 10,000 cps and amplitude representing the amplitude of program peaks was less than 1.5 per cent peak. The signal-to-noise-ratio excluding the ambient noise in the room was about 45 db. Inherent flutter was about 0.3 per cent peak at a flutter rate of 6 cps. Inherent amplitude variations in the order of approximately 4 per cent peak were introduced by the magnetic tape recording processes and were random in nature. Any amplitude variation, which might have been caused by the flutter generators could not be detected in the electrical signal.

In order to guard against listener fatigue, the judges were asked to provide no more than fifty comparisons at a single seating and no more than three seatings were usually undertaken during the morning from about 9:00 A.M. to 11:30 A.M. Prior to presentation of comparisons the judges were told that they were to compare the two selections on the basis of preferred quality and not to attempt to assess the technical differences in the programs. They were given samples of the range of quality on which their judgements would be made.

PROCEDURES

Listener preference ranking scores were obtained for each of the three programs for each experiment. Results were expressed in per cent of the maximum score obtained.

The ranking scores thus obtained were compared to flutter index measurements obtained from the samples of 3000-cps tone.

The results of the above comparison indicated that the flutter index meter required certain modifications as will be explained later. These modifications were made and the ranking scores were then compared to flutter index measurements obtained with the modified flutter index meter.

To ascertain whether various conditions of listening might affect the listener preference ranking scores and hence the usefulness of the flutter index meter, Listener Preference Test II was repeated with twelve judges for the following different room conditions, frequency response ranges and sound levels.

Condition B

The judges were seated in a diffuse reverberation chamber. This chamber had polycylindrical walls and ceiling of poured concrete. The floor was also poured concrete but flat. The chamber was approximately 20 feet long, 20 feet wide, and 10 feet high. In the absence of the judges, the reverberation time was approximately 8 seconds at 100 cps and 5 seconds at 1000 cps. The triaxial loudspeaker was located in one corner of the chamber while the judges were seated close together in the center of the room. Peak program level at the listening position was about 90 db (ref. 0.0002 microbar). The ambient noise was approximately 60 db.

Condition C

The judges were seated in a small acoustic listening room. This room had flat brick surfaces on which were hung removable panels of acoustic tile randomly spaced over the surface. The floor was covered with a rug. The room was approximately 20 feet long, 15 feet wide, and 12 feet high. The reverberation time of this room was about 0.5 seconds at 1000 cps. The triaxial loudspeaker was located in one corner of the room while the judges were seated in an opposite corner. The peak program level was again approximately 90 db while the ambient noise was about 60 db.

Condition D

Same acoustic conditions as "C" but the frequency response of the system was restricted by sharp cutoff filters to the range 300 to 3000 cps.

Condition E

Same acoustic conditions as "C" but the peak program level was reduced to about 80 db.

Condition F

The judges were presented the program at a level of 60 db through high quality earphones having a range from about 40 to 8000 cps.

RESULTS

The flutter index measurements and listener preference ranking scores for the thirty flutter variations used in Listener Preference Test I are shown in Table I along with peak-to-peak flutter readings which were determined from flutter oscillograms for each flutter variation. The ranking scores for the band and piano program were observed to be sufficiently similar to warrant the use of an average preference score for the two programs for the purpose of comparing the rankings to a flutter measurement. Ordinarily, since the listener preference test gives a ranking for only those items compared in a single test, it is improper to use the scores obtained from one test for comparison with another test. For the present case, it should be stressed that paired comparisons were made only between two flutter variations of the same program material and quantification of judgments was performed separately for each program. A comparison of one variation of flutter in one program with the same or different variation of flutter in another program was not made. Hence, it is improper to assume that the flutter variations had the same effect on piano as it had on band program. It can only be said that the rankings were similar or that if piano music containing one type of flutter sounded worse than piano music containing another flutter, then band programs containing the former flutter would sound equally worse than band music containing the latter flutter. Comparison of the ranking scores with the peak-to-peak flutter measurements, as expected, shows that little relationship exists between them. An appreciable relationship between the listener preference ranking scores and the flutter index measurements did exist.

TABLE I

FLUTTER INDEX MEASUREMENTS AND LISTENER PREFERENCE RANKING SCORES FOR LISTENER PREFERENCE TEST I

Flutter Variation Number	Flutter Measurement		Listener Preference Ranking Scores (Per Cent of Maximum Score)			
	Peak-to-Peak Flutter Per Cent	Flutter Index	Piano	Band	Speech	Average Piano & Band
1	4.0	55	59	41	20	50
2	2.5	55	61	59	38	60
3	6.2	67	100	97	89	98
4	3.5	49	75	83	70	79
5	3.0	49	62	77	66	70
6	2.7	57	51	56	60	54
7	5.6	84	82	97	89	90
8	2.4	52	51	55	59	53
9	5.7	43	63	57	45	60
10	5.0	55	86	88	84	87
11	2.5	31	49	44	50	47
12	4.0	52	44	59	34	52
13	5.0	61	66	86	60	76
14	4.0	39	32	48	36	40
15	1.5	25	28	22	25	25
16	8.5	55	85	76	60	81
17	4.4	58	62	74	87	68
18	8.0	58	65	71	82	68
19	1.2	23	25	19	25	22
20	1.8	41	12	9	22	11
21	3.5	54	33	42	39	38
22	3.6	47	48	59	59	54
23	5.5	61	93	97	100	95
24	2.7	38	29	27	30	28
25	2.7	25	53	40	57	47
26	3.7	43	41	50	69	46
27	1.0	26	20	14	15	17
28	3.3	54	69	85	84	77
29	3.5	26	34	23	26	29
30	7.5	58	91	100	87	96

The flutter index measurements and listener preference ranking scores for the forty flutter variations used in Listener Preference Test II are shown in Table II along with peak-to-peak flutter readings which were determined from the flutter oscillograms. Here again, because of similar ranking scores for piano and band programs, their average ranking score is listed. Again, little relationship exists between the ranking scores and peak-to-peak flutter but an appreciable relationship exists between these scores and the flutter index measurements. When the average preference scores for piano and band were plotted against flutter index readings for each test it was noted that the points seemed to indicate two straight line relationships, one for low flutter rates and another for high flutter rates, shown as A and B,

TABLE II

FLUTTER INDEX MEASUREMENTS AND LISTENER PREFERENCE RANKING SCORES FOR LISTENER PREFERENCE TEST II

Flutter Variation Number	Flutter Measurement			Listener Preference Ranking Scores (Per Cent Maximum Score)			
	Peak-to-Peak Flutter Per Cent	Flutter Rate (cps)	Flutter Index	Piano	Band	Speech	Average Band & Piano
1	6.6	0.5	90	93	93	39	93
2	7.6	0.5	97.5	89	94	47	92
3	2.0	0.75	31	65	19	39	42
4	3.0	1	55	43	47	47	45
5	7.6	1	100	97	100	48	99
6	4.6	1.5	97	93	88	33	91
7	2.6	2	55	36	54	47	45
8	3.0	3	60	43	44	49	44
9	4.4	3	85	87	86	53	87
10	6.0	4	87	91	100	52	96
11	1.6	6	20	39	34	41	37
12	5.4	6	55	98	98	44	98
13	0.8	8	10	26	23	44	25
14	1.5	10	18	35	28	38	32
15	2.4	5	32	39	41	34	40
16	5.6	10	45	88	92	84	90
17	7.0	15	48	100	100	100	100
18	3.6	20	32	64	83	69	74
19	5.6	20	40	77	99	86	88
20	5.3	25	36.5	93	90	87	92
21	8.6 4	0.5 12	95	100	100	92	100
22	6.0 2.0	0.75 27	96	87	98	73	93
23	1.0 0.3	1 12	20	32	27	35	30
24	3.6 2.0	2 9	90	57	78	49	68
25	2.6 0.8	2 24	75	74	44	44	59
26	4.0 2.0	3 24	88	86	89	54	88
27	1.0 0.5	4 21	20	34	33	32	34
28	4.4 3.0	4 18	68	94	95	62	95
29	3.4 1.4	5 18	43	75	73	58	74
30	4.8 2.0	6 15	56	98	83	65	91
31	—	—	10	35	32	43	34
32	—	—	55	90	94	84	92
33	—	—	35	39	54	46	47
34	—	—	25	25	39	46	32
35	—	—	60	53	59	46	56
36	—	—	45	46	43	41	45
37	—	—	25	21	27	47	24
38	—	—	28	37	44	31	41
39	—	—	25	30	25	49	28
40	—	—	40	31	25	31	28

respectively, in Fig. 4. When the listener preference ranking scores for speech were plotted against flutter index the same two straight line relationships were indicated. However, in the case of speech there was a scattering of points on that side of the lines which signified good quality but an excessive flutter index. This was expected, for it was known that large amounts of flutter at flutter rates below 5 cps could not be detected in speech. The weighting curve used in the flutter meter was considered applicable to music only but it was felt that it could also be applied to speech since any resulting flutter index measurement would always be on the safe side.

On examining the two straight-line relationships it was noted that practically all of the points indicating the line B on Fig. 4 were associated with a flutter rate between approximately 10 and 25 cps and amplitudes greater than 1 per cent peak. This was thought to be due to either the particular room acoustics under which the listener preference tests were performed or a nonlinearity in the relationship between the effect of flutter and its amplitude for this flutter rate range. Further experiments showed that the room acoustics, at least for the recorded program used, had only a minor effect on the results of the listener preference tests. Therefore, the discrepancy was attributed to nonlinearity. In the previous work[4] since there was a linear relationship between the listener preference scores and flutter at rates from 0.5 to 5 cps, it was assumed that this linearity would extend to all flutter rates. It is conceivable, that in detecting flutter at flutter rates above 10 cps, human factors differing from those used at flutter rates below 7 cps come into play.

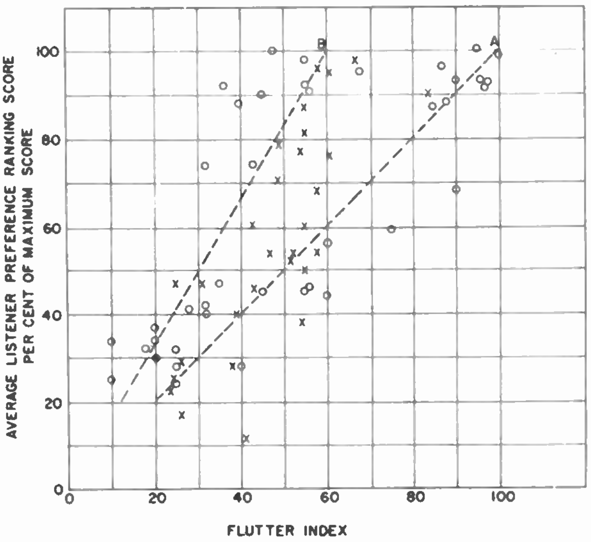

Fig. 4—Average listener preference ranking scores for piano and band programs vs flutter index
x Listener Preference Test I
0 Listener Preference Test II.

To correct for the above would require a new extended experiment to determine the exact relationships existing between the flutter perception and amplitude for various listening conditions. However, as an immediate means for obtaining a realistic measurement of flutter, a simple expedient was considered. As mentioned, the excessive ranking scores, or more accurately stated, the low flutter index readings, occurred only when the flutter exceeded 1 per cent. It would then only be necessary to measure the average unweighted flutter for flutter rates above about 10 cps. If the 1 per cent peak level (0.7 per cent rms level) were not exceeded, then the flutter index meter having the weighting curve of Fig. 1 would be satisfactory. If the 1 per cent level were exceeded, then the weighting curve

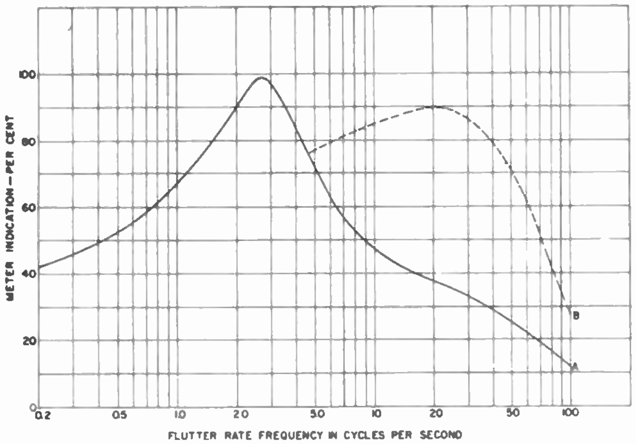

Fig. 5—Sensitivity vs flutter rate for Material Laboratory modified flutter index meter
Input flutter—2 per cent peak
Curve A—sensitivity for switch in open position
Curve B—sensitivity for switch in closed position.

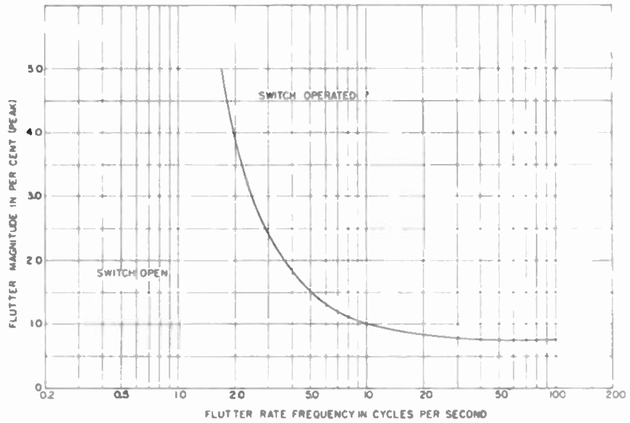

Fig. 6—Operating characteristics for automatic electronic switch of Material Laboratory modified flutter index meter
Switch actuating rise time constant—0.1 second
Switch actuating decay time constant—0.25 second.

would have to be modified. Fortunately, in Listener Preference Test II enough sinusoidal flutters of known amplitude were included to permit an adequate estimate of the proper modification to the weighting curve.

A flutter index meter was subsequently designed which incorporated the two weighting networks with an automatic electronically-operated switch. The two weighting curves employed are shown in Fig. 5. Curve A represents the active weighting characteristic for the switch open position. Curve B represents the active weighting characteristic for the switch closed position. The operation of the automatic switch is controlled by the unweighted flutter signal, as shown by its operating characteristics in Fig. 6. The switch actuating circuit operated on a rise time-constant of 0.1 sec and a decay time-constant of 0.25 sec.

Flutter index readings obtained with this modified flutter index meter for the flutter variations of both listener preference tests are compared with the average listener preference ranking scores for piano and band in Fig. 7. The flutter index measurements are tabulated in

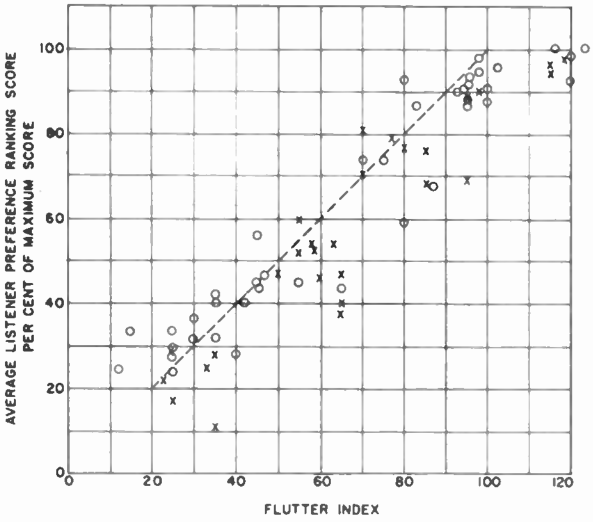

Fig. 7—Average listener preference ranking scores for piano and band program vs modified flutter index
x Listener Preference Test I
0 Listener Preference Test II.

TABLE III

FLUTTER INDEX READINGS OBTAINED WITH MODIFIED WEIGHTING NETWORK FOR EXPERIMENTS I AND II

Experiment	Flutter Type	Flutter Index	Flutter Type	Flutter Index
I	1	—	16	70
	2	—	17	95
	3	120	18	85
	4	77	19	23
	5	70	20	35
	6	58	21	65
	7	98	22	63
	8	59	23	115
	9	55	24	35
	10	95	25	65
	11	50	26	60
	12	55	27	25
	13	85	28	80
	14	65	29	25
	15	33	30	115
II	1	80	21	130+
	2	95	22	120
	3	35	23	25
	4	45	24	87
	5	120	25	80
	6	100	26	100
	7	55	27	25
	8	65	28	98
	9	95	29	70
	10	102	30	94
	11	30	31	15
	12	98	32	95
	13	12	33	48
	14	30	34	35
	15	42	35	45
	16	93	36	45
	17	116	37	25
	18	75	38	35
	19	95	39	25
	20	83	40	40

Table III. The relationship is considerably improved. The relationship for speech was similarly improved.

The piano and band ranking scores of the flutter variations used in Listener Preference Test II for the 6 types of listening conditions are listed in Table IV to

TABLE IV

Comparison of Listener Preference Ranking Scores for Various Listening Conditions

No.	Listening Conditions												All Listening Conditions
	A		B		C		D		E		F		Average
	Piano	Band	Piano	Band	Piano	Band	Piano	Band	Piano	Band	Piano	Band	
1	93	93	95	97	92	100	100	100	92	89	94	100	95.4
2	89	94	94	94	96	97	100	97	100	98	96	99	96.2
3	65	19	55	28	40	19	43	19	52	21	46	24	36.0
4	43	47	55	54	57	50	73	48	56	56	64	59	55.2
5	97	100	83	94	100	100	100	100	100	100	100	100	97.8
6	93	88	100	97	100	100	96	100	100	97	93	95	96.6
7	36	54	54	49	28	46	31	57	40	50	36	49	44.2
8	43	44	48	41	49	38	47	42	61	43	30	44	44.2
9	87	86	96	81	89	86	100	94	96	85	90	82	88.5
10	91	100	91	93	100	100	100	100	98	100	88	100	96.8
11	39	34	39	25	29	25	39	32	40	25	31	30	32.3
12	98	98	100	100	100	100	100	100	100	100	92	100	99.0
13	26	23	28	23	29	27	30	26	21	24	34	26	26.4
14	35	28	29	26	18	26	29	33	33	31	33	30	29.3
15	39	41	62	55	44	51	44	36	43	57	42	39	46.1
16	88	92	98	84	100	100	100	97	100	100	85	97	95.1
17	100	100	96	93	100	100	100	100	96	100	100	100	98.8
18	64	83	71	79	82	81	98	95	92	89	42	68	78.7
19	77	99	87	96	100	97	100	100	94	100	68	91	92.4
20	93	90	96	77	98	91	96	93	95	93	79	83	90.3
21	100	100	100	100	100	100	100	100	100	100	100	100	100.0
22	87	98	92	87	94	100	100	100	100	97	80	97	94.3
23	32	27	27	30	22	24	29	27	19	30	31	37	27.9
24	57	78	78	76	66	83	69	90	91	83	69	83	76.9
25	74	44	92	63	84	52	100	60	91	41	80	39	68.3
26	86	89	88	92	97	96	100	100	100	100	74	95	93.1
27	34	33	35	33	32	31	30	31	34	25	38	31	32.3
28	94	95	100	90	100	100	100	100	100	100	90	96	97.1
29	75	73	96	77	83	82	100	83	87	83	54	73	80.5
30	98	83	100	81	92	91	100	89	100	92	79	86	90.9
31	35	32	28	31	43	24	37	24	38	20	48	24	32.0
32	90	94	100	86	96	100	95	100	92	100	95	90	94.8
33	39	54	36	48	33	56	35	52	39	49	29	44	42.8
34	25	39	26	36	25	36	17	30	21	26	27	30	28.2
35	53	59	36	46	63	59	56	59	55	64	54	65	55.8
36	46	43	84	43	50	39	56	42	52	40	63	40	49.8
37	21	27	25	31	25	32	17	31	22	24	30	30	26.3
38	37	44	44	39	28	26	32	32	33	28	28	31	34.3
39	30	25	29	27	44	29	26	28	27	26	34	26	29.3
40	31	25	41	32	30	18	34	30	25	24	33	26	29.1

show that the differences in listening conditions had small effect on the subjective ranking.

Discussion

The various types of flutter employed in this experiment were representative of all the amplitudes and waveforms encountered in actual recording equipment over flutter rates from 0.5 to 100 cps. It might be expected that flutter rates above 100 cps might be encountered. Recently, flutter rates as high as 3000 cps are being observed in magnetic tape recorders. In view of this, it would have been interesting to extend the experiments to these flutter rates. Unfortunately, the flutter generators available could not produce adequate flutter amplitudes above flutter rates of 100 cps. Besides, previous observations indicated that judgements of flutter perceptibility in programs for this range were erratic. It has been shown[5] that in the range above flutter rates of 100 cps flutter perceptibility thresholds for tone can be used to predict the masking curves for the ear. It, therefore, would appear that perceptibility of flutter for such rates would be alien to the perceptibility of noise and could be included in a noise measurement (noise behind the signal).

It should be noted that in a few of the flutter variations the peak flutter amplitude varied periodically with time, for example, observe types 9 and 16 in Fig. 2. For this type of variation, the effect on the listener seemed to be connected with the average amplitude of the flutter over about a two-second time period. It also seemed to be a function of how the large amplitude periods coincided with the program peaks. Since, in obtaining flutter index readings, the average peak swing of the indicating instrument was used to indicate the flutter index, the flutter index readings tended to be too high relative to the corresponding listener preference score. Such a reading applies a margin of safety for that type of flutter.

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[5] H. Schecter, "Perceptibility of Frequency Modulation in Pure Tones," Ph.D. Dissertation, Mass. Inst. Tech., Cambridge, Mass.; 1949.

In a recent British publication,[6] a flutter meter with a peak indicator and a flutter weighting network which peaks at flutter rates between 5 and 10 cps was proposed for obtaining realistic flutter measurements. This contradicts the results of the experiments reported herein. Another flutter meter was built using the above proposed weighting network. An oscillographic recorder was used as an indicator from which the peak weighted amplitudes for all of the flutter variations of Listener Preference Test II were obtained. The corresponding ranking scores were compared with these readings but little correlation was obtained. Most of the variation appeared to be due to the different weighting network but it was felt that some also resulted from the use of a peak indicator. A concrete explanation for the contradiction cannot be advanced at this time but it is expected that this will be the subject of another paper.

In order to compare the results of the present experiments with those previous,[4] the listener preference ranking scores of the latter for flutter rates from 0.5 to 5 cps and amplitudes up to 5 per cent peak were replotted in the form of equal ranking score contours as shown by the solid lines of Fig. 8. On this curve were plotted forty-three of the seventy flutter variations employed in the present experiments, indicating in circles the appropriate ranking scores obtained. The remainder of the seventy flutter variations were not included since they either duplicate observations that are shown or their amplitudes and rates could not be determined adequately. The ranking scores, indicated at the plotted observations, are related to the contour lines. It should be noted that most of the ranking scores between 25 and 30 per cent fall on or below the threshold curve, all the ranking scores of about 33 per cent fall near the LP-30 line etc. until all ranking scores between 80 and 100 per cent fall above the LP-80 contour line. This shows agreement between the previous and present experiments. The dotted lines on this figure represent an extension of the equal ranking score contours to flutter rates above 5 cps as estimated from the results of the present experiment. These extended contours, by their squeezing together above 10 cps, suggest the nonlinearity experienced for the flutter rates between 10 and 25 cps. It is obvious that further experiments are required to obtain an adequate measure of this nonlearity.

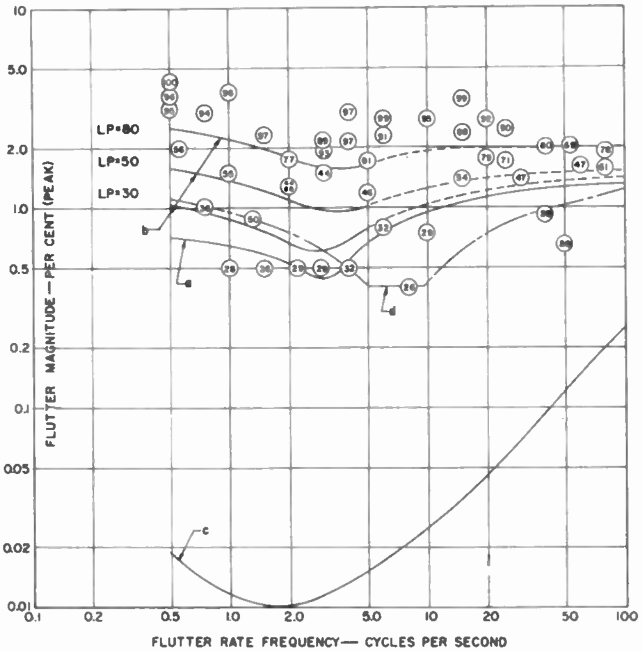

Fig. 8—Comparison of listener preference ranking scores with results of previous experiments. Encircled numbers represent listener preference ranking scores obtained for Listener Preference Tests I and II. a) Material Laboratory—flutter perceptibility threshold for recorded piano program (earphone listening at 90 db level). b) Material Laboratory—equal listener preference ranking score contours for piano program (90 db level). c) Bell Telephone Laboratory—flutter perceptibility threshold for 1000-cps tone in reverberant auditorium (level unknown). d) Stott and Axon—flutter perceptibility threshold for recorded piano program (loudspeaker listening at 75-phon level).

CONCLUSION

A flutter index meter having the characteristics of the modified flutter meter used in these experiments will provide a reading that will adequately predict the subjective ranking score which would be obtained were that flutter introduced in program sample and included in a Listener Preference Test similar to that employed herein. Thus, such a meter will provide a simple objective measure of the effect of flutter on program material.

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[6] A. Stott and P. E. Axon, "The subjective discrimination of pitch and amplitude fluctuations in recording systems," *Proc. IEE*, paper No. 1874R; September, 1955.

Learning, A Major Factor Influencing Preferences for High-Fidelity Reproducing Systems[*]

ROGER E. KIRK[†]

Summary—**Frequency range preference of 210 college students for monaurally reproduced music and speech was determined by an A-B-A preference test. Two groups of subjects then listened to music reproduced over a restricted frequency range and a relatively unrestricted frequency range respectively for six and one-half weeks. The results of a post-frequency range preference test indicate that: 1) learning plays an important role in determining preferences for sound reproducing systems; 2) continued contact with a particular system produces shifts in preference for this system; and 3) the average college student prefers music and speech reproduced over a restricted frequency range rather than an unrestricted frequency range.**

INTRODUCTION

DURING RECENT years numerous experiments have been conducted to determine the effect of varying certain characteristics of sound reproducing systems on listener preferences for these systems. It is tacitly assumed in these experiments, in lieu of evidence pro or con, that the listener's previous auditory experience does not significantly affect his preferences. This experiment was designed to test the validity of this assumption for the stimulus dimension of frequency range. The following hypothesis regarding frequency range preferences for music and speech was formulated.

> The average listener after listening to the radio, phonograph, and live sound sources for many years has developed specific "sets" for music and speech emanating from a particular source, to sound a particular way. For example, when we hear music coming from a phonograph we expect to hear a monaural presentation and a restricted frequency range. When we go to the concert hall our "set" changes and we expect to hear a "stereophonic" presentation and an unrestricted frequency range. When music or speech reproduction differs perceptibly from our established "set" we will not like this reproduction. Continued contact with a particular reproducing system in a particular environmental setting will result in the establishment of a set to prefer this system.

METHOD

In order to test this hypothesis, a high quality electroacoustic reproducing system with adjustable high- and low-pass filters was used. The components of the reproducing system included a General Electric magnetic cartridge, Clarkstan 16-inch transcription arm, Rek-O-Kut turntable, Bell 20 watt amplifier and Altec "Voice of the Theater" speaker system. The adjustable high- and low-pass filters were inserted between the transducer and preamplifier to provide the four electrical system response curves shown in Fig. 1. The stimulus material consisted of five high-fidelity phonograph records selected for their wide program appeal and high quality.

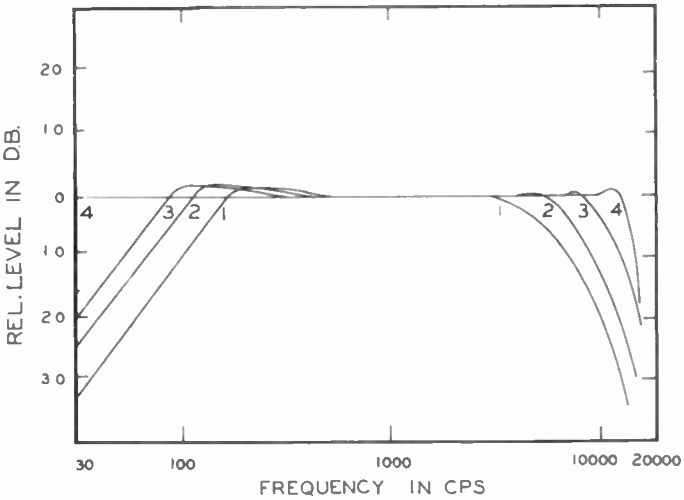

Fig. 1—Four response curves used in frequency-range preference test.

One hundred and nineteen male and 91 female subjects, all of whom were Ohio State University students, served in the experiment. The subjects ranged in age from 16 to 26 with approximately 85 per cent of the subjects falling between the ages of 17 to 19 years of age. The subjects were told that they were participating in in an experiment on different sound systems. They were told that they would hear music and speech played under two different conditions. Their task was to select the presentation which they found most pleasing. Each of the four frequency range conditions shown in Fig. 1 was paired with every other frequency range, making a total of six paired comparison judgments for each of the five phonograph records. The subjects received a frequency range preference score from 0 to 30 depending upon the number of times they preferred the wider frequency range presentation.

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[*] Manuscript received by the PGA, July 19, 1956. Presented at the Second International Congress on Acoustics in conjunction with the 51st meeting of the Acoustical Society of America, Cambridge, Mass., June 22, 1956. This work was performed at Ohio State Univ., Columbus, Ohio.

[†] Baldwin Piano Co., Cincinnati, Ohio. Formerly with Ohio State University.

RESULTS

Results of the Initial Frequency Range Preference Test

The results of the initial frequency range preference test are shown in Table I. It is evident from Table I that the subjects prefer a restricted frequency range rather than a relatively unrestricted frequency range for monaurally reproduced music and speech. The amount of frequency range restriction preferred by the subjects depends in part upon the type of stimulus material used in the preference test. The data in Table I are in substantial agreement with that of Chinn and Eisenberg[1] and with that of Bauer.[2] There is a tendency on the part of the subjects in this experiment, however, to prefer a wider frequency range than the subjects in either of the two previous experiments.

TABLE I†

Record	180–3000	120–5000	90–9000	30–15,000	χ^2
String Quartet	1	2	3	4	28.4**
Symphony Orchestra	4	1	2	3	10.9*
Organ	3	2	1	4	33.2**
Popular	3	2	1	4	45.2**
Male Speech	4	3	1	2	8.5

† Rank orders assigned to the four frequency range conditions in the initial frequency range preference test. The last column indicates the statistical significance of the rank orders.

*P=0.05.

** P=0.001.

Results of Listening to Music Reproduced Over an Unrestricted Frequency Range

According to the "set" hypothesis advanced earlier, continued listening to a particular frequency range in a particular listening environment should result in the establishment of a "set" to prefer this frequency range. On the basis of the initial preference scores of the subjects, two experimental groups were matched with two control groups. One of the experimental groups listened to music reproduced over the same reproducing system that was used in the initial preference test, except that the filters were set to pass the wide frequency range from 30–15,000 cps. This experimental group listened to thirteen sessions of recorded music for an average of forty minutes per session over a period of six and one-half weeks. The phonograph recordings used for these listening sessions were organ, string quartet, and symphony orchestra records chosen for their similarity to the records used in the initial preference test. The control group received no organized music listening program. At the end of the six and one-half weeks, the experimental and control groups again took the frequency range preference test. Since the two groups were originally matched on the basis of their frequency range preference scores, any difference in scores on the second test must be attributed to the thirteen listening sessions which the experimental group received. The results of this frequency range preference test are shown in Fig. 2. It is evident from this figure that listening to music over a wide frequency range produces significant shifts in preference for this range.

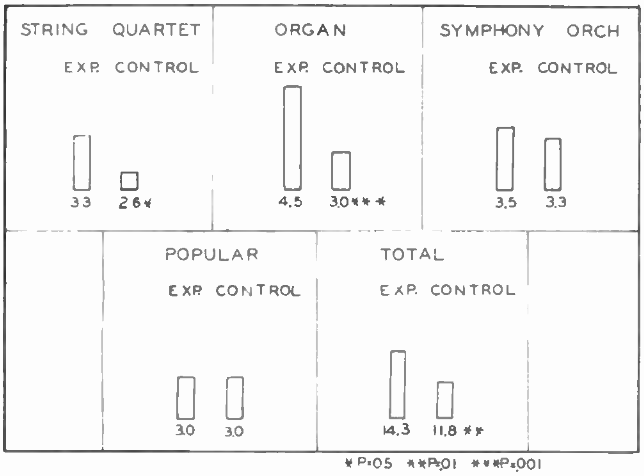

Fig. 2—Effect of listening to music reproduced over a wide-frequency range on preferences for frequency range. The vertical bars and corresponding numbers refer to the mean number of times the subjects preferred the wider frequency range condition.

Results of Listening to Music Reproduced Over a Restricted Frequency Range

The question next arises as to whether the phenomenon observed with wide frequency range reproduction is duplicated with exposure to a very restricted frequency range. In order to determine what effect listening to a restricted frequency range would have on preferences for this range, the subjects in the second experimental and control groups were used. This phase of the experiment was identical to that just described, except that the experimental group listened to music reproduced over a frequency range of 180 to 3000 cps. The results of the frequency range preference test given after the thirteen sessions of listening to music over this restricted frequency range shown in Fig. 3. It is evident that listening to music reproduced over a restricted frequency range produces significant shifts in preference for this range.

Relationship Between Frequency Range Preferences and Number of Years of Musical Study

In order to investigate the relationship between frequency range preferences and number of years of musical study, the subjects were divided into three groups on the basis of the number of years that they had studied music. One group consisted of 95 subjects with less than one year of musical study. The second group consisted of 102 subjects with from one through seven years of study and the third group consisted of 22 subjects with from eight through twelve years of study. The frequency range preferences of these three groups

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[1] H. A. Chinn and P. Eisenberg, "Tonal-range and sound-intensity preferences of broadcast listeners," PROC. IRE, vol. 33, pp. 571–581; August, 1945.

[2] B. B. Bauer, "Crystal pickup compensation circuits," *Electronics*, vol. 18, p. 132; November, 1945.

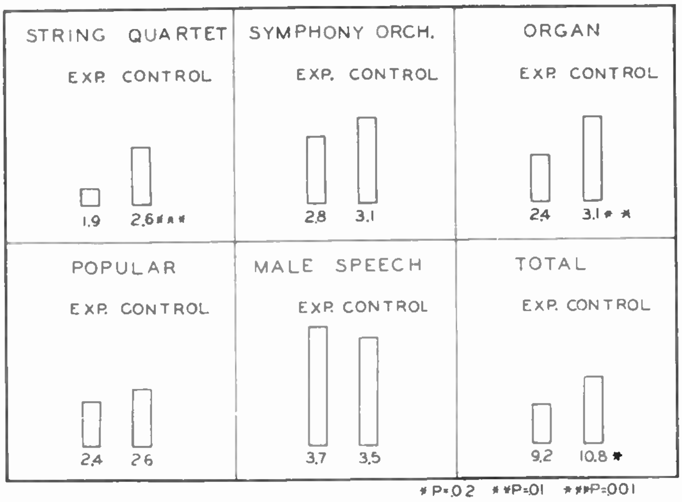

Fig. 3—Effect of listening to music reproduced over a restricted frequency range on preferences for frequency range. The vertical bars and corresponding numbers refer to the mean number of times the subjects preferred the wider frequency range condition.

are shown in Fig. 4. It is evident from Fig. 4 that the subjects who had studied from eight through twelve years preferred the restricted frequency range more often than did the subjects who had studied music less than one year.

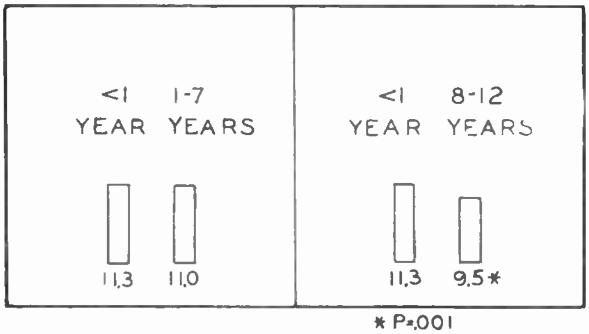

Fig. 4—Frequency range preferences of subjects with different amounts of musical training.

Discussion

The data which have been presented indicate that the listener's previous auditory experience significantly affects his frequency range preferences for reproduced music and speech. The average listener develops specific "sets" for music and speech in a particular environment to sound a particular way. The evocation of the "appropriate" listening set is probably determined primarily by the auditory and visual cues present in the total stimulus configuration which impinges upon the listener.

The findings of this experiment, that college students prefer to hear music and speech reproduced over a restricted frequency range rather than a relatively unrestricted frequency range, are in substantial agreement with the findings of Chinn and Eisenberg[3] and Bauer.[4] In each of these experiments, an electroacoustic reproducing system of adjustable properties was used to determine frequency range preferences for music and speech. An investigation by Olson[5] indicates that listeners prefer an unrestricted frequency range for "live" music. The apparent discrepancy between the results of Olson's experiment and experiments employing nonaural electroacoustically reproduced music can readily be resolved by postulating the existence of "sets" relative to live music performance and other "sets" relative to monaural reproduced music. Listeners because of their past auditory experience expect an unrestricted frequency range in the former situation and a restricted frequency range in the latter situation.

The paradoxical finding of this experiment and previous experiments, that musicians prefer a more restricted frequency range reproduction of music than does the average listener, can be interpreted within the framework provided by the "set" hypothesis. If one is willing to grant the assumption that musicians as a group listen to more reproduced music than does the average person, it becomes obvious then that musicians have more numerous opportunities to develop "sets" for a restricted frequency range. One may argue that musicians have more contact not only with reproduced music but with live music as well. This is obviously true, but the "set" which is operative when a musician is playing a concert would appear to be quite different from the "set" which is operative when the musician is at home listening to his phonograph or radio.

It is interesting to note that the experimental groups showed a greater frequency range preference shift for some of the phonograph records than for other records. The most frequently played phonograph records in the thirteen listening sessions were organ records, string quartet records, and symphony orchestra records in that order. These records were chosen for their similarity to the records used in the frequency range preference test. One would predict from the "set" hypothesis that the experimental groups would show the greatest preference shift for the test records which were most like the records used in the thirteen listening sessions. It is evident from Figs. 2 and 3 that this prediction is confirmed by the data. These results are compatible with data on stimulus generalization in audition and other sensory areas.

Information regarding the subject's musical background, musical tastes and record playing facilities was secured by means of a questionnaire which was filled out by the subjects prior to the administration of the frequency range preference test. With the exception noted earlier of the relationship between years of musical study and frequency range preferences, no significant relationship was found between the above variables and the subject's frequency range preference scores.

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[3] Chinn, and Eisenberg, *loc. cit.*

[4] Bauer, *loc. cit.*

[5] H. Olson, "Frequency range preferences for speech and music," *J. Acous. Soc. Amer.*, vol. 19, p. 549; July, 1947.

In order to determine the ability of the subjects to detect the higher fidelity presentation in the preference test, the test was readministered to one group of subjects. Prior to this readministration of the frequency range preference test, these subjects were given a short lecture on high-fidelity sound reproduction. A demonstration of each of the four frequency range conditions was included in this lecture. After the lecture, the subjects were asked to pick out the higher fidelity presentation instead of indicating preferences for the frequency ranges as they had done before. The subjects were able to correctly identify the higher fidelity presentation an average of 89 per cent of the time for the organ, string quartet, popular, and speech records. The mean per cent correct identification for the symphony orchestra record was only 71 per cent. The greater difficulty of the subjects in selecting the higher fidelity presentation for the symphony orchestra record is attributed to the numerous changes in tone color, rhythmic figures, and dynamics which are present in the music. These factors were minimized in the preference test insofar as possible by attempting to avoid changing the frequency range condition at the same time that a marked change occurred in the instrumentation, time or character of the music.

The author would like to emphasize the need for caution in generalizing from the data presented. The frequency range preference data are applicable for the reproducing system used in the investigation and for a highly select group of subjects, namely, college students. The five phonograph records which served as the stimulus material are not typical of phonograph records in general. The categories: string quartet, symphony orchestra, organ, popular dance, and male speech were used for convenience in presenting the data, and it is not meant to imply that the phonograph records in the categories are completely representative of a type of music. The interpretation of listener preferences for a restricted frequency range in terms of listener sets does not preclude the possibility that other factors may be operating in addition to the listener's set.[6]

CONCLUSION

The average college student prefers monaurally reproduced music and speech reproduced over a restricted frequency range rather than a relatively unrestricted frequency range. The amount of frequency range restriction preferred by college students is in part a function of the type of stimulus material to which they are listening.

Learning plays an important role in determining listener preferences for sound reproducing equipment. Continued contact with a particular system produces shifts in preference for this system. The assumption that the listener's previous auditory experience does not significantly affect his preferences for sound reproducing equipment is untenable in the light of the data presented in this experiment.

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[6] For a discussion of other factors, see C. J. Le Bel, "Psycho-acoustical aspects of listener preference tests," *Audio Engrg.*, vol. 31, pp. 9–12, 44–48; August, 1947.

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Charles H. Chandler (M'47–SM'51) received the B.A. degree in physics and mathematics from the College of Wooster, Ohio, in 1940, and the M.S. degree in electrical physics from Ohio State University in 1946. During World War II he served as a Signal Corps officer, and saw duty in England, India, and the China Theatre of operations, terminating his service with the rank of major.

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John P. Overley (A'54) was born in Kalamazoo, Mich. in 1928. He majored in physics and did special work in electronics, receiving the B.A. degree from Kalamazoo College in 1950. During 1950–1952 he did graduate work at Wayne University while serving as a graduate assistant instructor in physics.

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