APPENDIXES

APPENDIX I—ACKNOWLEDGMENTS

The information contained in this handbook has been gathered from so many diverse sources that it is virtually impossible to give due credit in each particular instance. Especially is this true of the first half of Section I, where much of the information consists of collections of relatively independent facts. In the last half of Section I, it is hoped that specific experimental data, as well as equations and methods of analysis that can be explicitly ascribed to individual authors, have been more adequately acknowledged in the text. The writer wishes to thank the many crystal manufacturers who have cooperated so generously in supplying information and suggestions for inclusion in the Handbook. He is particularly indebted to **Bliley Electric Company, HEEMCO, Hunt Corporation, Hupp Electronics Company, McCoy Electronics Company**, and **Reeves-Hoffman Company** for their contributions and interest and also for the personal courtesies extended the writer during a data-collecting field trip.

At this point, the writer would like to ackowledge those individuals and organizations to whom he is most indebted for the present contents of the Handbook.

Bell Telephone Laboratories.—The greater part of the information on the subject of crystal-unit fabrication contained in the Handbook has, at least partly, had its origin in research projects at Bell Telephone Laboratories. All frequency-constant, temperature-coefficient, and frequency-deviation curves of the various crystal elements developed at Bell Telephone Laboratories have been obtained from graphs made available to the public by the Bell Telephone Company. These illustrations are included below in the individual acknowledgements of published works of Bell scientists.

Bokovoy, S. A.—Most of the descriptive data concerning the V-cut crystal, the single-frequency X-cut crystal, and the dielectric-sandwich type of crystal mounting have been obtained from U. S. and British patents issued to the inventor, Mr. Bokovoy, of the Radio Corporation of America.

(**Mr. P. D. Gerber** was coinventer of the dielectric-sandwich mounting—U. S. Patents 2,078,229 and 2,101,893.) Handbook illustrations redrawn from Bokovoy patents are: figure 1-22 (U. S. Patent 2,064,288, May 31, 1934); figures 1-39, 1-40, and 1-41 (British Patent 457,342, November 26, 1936); figures 1-73 to 1-77 (U. S. Patent 2,101,393, December 14, 1937); and figure 1-78 (U. S. Patent 2,078,229, April 27, 1937).

Bond, W. L.—Two treatises by Mr. Bond, "Methods for Specifying Quartz Crystal Orientation and Their Determination by Optical Means" and "Sawing, Grinding, and Lapping" (Chapters II and IX, respectively, *Quartz Crystals for Electrical Circuits*, Heising) have been useful sources of information to the writer. Handbook figure 1-59 has been reprinted from the former article with the permission of the publisher, D. Van Nostrand Co.

Borgelt, E. H.—*See* Foreword.

Bottom, V. E.—Much of the information contained in "The Mathematics of the Equivalent Electrical Circuit of the Quartz Crystal Unit" by Mr. Bottom (Chapter II, *Fundamental Principles of Crystal Oscillator Design*, Circuit Section, Long Branch Signal Laboratory, Signal Corps, 1945-46) has been incorporated in Section I of the Handbook.

Bower, G. G.—Information obtained from Mr. Bower's treatise, "Crystal-Controlled Electron-Coupled Oscillators" (Chapter V, *Fundamental Principles of Crystal Oscillator Design*, Circuit Section, Long Branch Signal Laboratory, Signal Corps) has been included in the Handbook.

Brown, W. F.—Information contained in "Quartz Crystal Overtone Oscillators," Technical Note No. RAD. 460, by Mr. Brown, Royal Aircraft Establishment, Farnborough, has been of great value to the writer in preparing the discussion of series-mode oscillators.

Cady, W. G.—So much of information contained in the Handbook is indirectly, if not directly, dependent upon the work of Dr. Cady that no attempt

ACKNOWLEDGEMENTS

can be made to itemize particular instances, other than to acknowledge that figure 1-21 is reprinted from Dr. Cady's textbook, *Piezoelectricity*, McGraw-Hill Book Co., 1946, with the permission of the author and publisher.

Camfield, C. J.—Information obtained from "The Design of Fundamental Mode Quartz Crystal Oscillators," Technical Note No. RAD. 525, by Mr. Camfield, Royal Aircraft Establishment, Farnborough, has been included in the Handbook. Handbook figure 1-131 is based upon the design of an agc circuit described in the above treatise.

Capitol Radio Engineering Institute.—The writer is indebted to Capitol Radio Engineering Institute for many valuable items of information scattered throughout the Handbook. Of particular note are the empirical data contained in the discussion of the use of the Miller circuit as a small power oscillator (paragraph 1-339).

Carpantier, V. J.—*See* Foreword.

Caruthers, R. S.—The writer is indebted to Mr. Caruthers for information contained in paragraphs 1-449 to 1-451, which has been obtained from a treatise on transistor oscillators as published in *The Transistor* by Bell Telephone Laboratories. Handbook figures 1-189 and 1-190 have been copied from this source with the permission of Bell Telephone Laboratories.

Devlin, J. J.—Appreciation is extended Mr. Devlin for valuable assistance in editing parts of Sections II, III, IV, V, and the Appendix.

D'Heedene, A. R.—The treatise, "Effects of Manufacturing Deviations on Crystal Units for Filters" (Chapter XIV, *Quartz Crystals for Electrical Circuits*, Heising), by Mr. D'Heedene, has proven a valuable source of information to the writer. Handbook figure 1-117 has been copied from an illustration contained in the above work with the permission of the publisher, D. Van Nostrand Co.

Drews, W. F. et al.—The treatise by Mr. Drews and coauthor **A. E. Swickard**, "The Wire Mounted Crystal Unit" (Chapter XVI, *Quartz Crystals for Electric Circuits*, Heising), has been an important source of information for the writer. Handbook figure 1-68 has been drawn from an illustration contained in the above article, with the permission of the publisher, D. Van Nostrand Co.

Edson, W. A. et al.—For that part of Section I covering the theory and application of series-mode quartz crystal oscillators, the writer is heavily indebted to the work of Mr. Edson and those assisting him at the Georgia Institute of Technology in a Signal Corps research project directed toward the investigation of v-h-f crystal oscillators. Many of the results of this investigation, as described in the 1950 Final Report on Signal Corps Contract W36-039-sc-32100, "High Frequency Crystal-Controlled Oscillator Circuits," prepared by Mr. Edson, **W. T. Clary**, and **J. C. Hogg, Jr.**, have been included in the discussions of the Butler, transitron, basic transformer-coupled, grounded-grid, grounded-plate, and impedance-inverting oscillators. Also, the circuit equations derived in the h-f oscillator report have provided valuable check points and guides for the circuit analyses and equation derivations of this Handbook. In addition, all equations presented without derivations in the discussion of the above-mentioned oscillators can be assumed to have been taken directly from the above-mentioned h-f oscillator report.

The writer has also been greatly aided by the information contained in the timely book by Mr. Edson, *Vacuum-Tube Oscillators*, copyright 1953, John Wiley and Sons. The analysis of the Meacham bridge oscillator contained therein has served as the principal guide for the slightly modified approach to the same circuit followed in the Handbook. Appreciation is extended to the author and publishers for permission to use the graphical chart shown in the Handbook figure 1-162.

Fair, I. E.—The writer is indebted to the work of Mr. Fair for information concerning the relative performance characteristics of crystal units in parallel-mode oscillator circuits, as described in "Piezoelectric Crystals in Oscillator Circuits" (Chapter XII, *Quartz Crystals for Electrical Circuits*, Heising), and in "Design Data on Crystal Controlled Oscillators" (Appendix II, *Information Bulletin on Quartz Crystal Units*, Armed Services Electro Standards Agency, Fort Monmouth, N. J., August, 1952). Figure 1-164 of the Handbook has been copied from the latter treatise. The crystal performance parameters, M (figure of merit) and PI (performance index), were originally conceived and defined by Mr. Fair.

Goldsmith, P.—Appreciation is extended for the time and assistance generously given the writer in obtaining information relating to the results of experiments conducted at the Armour Research Foundation of Illinois Institute of Technology (USAF Contract No. AF 18(600)-157) on parallel-mode crystal oscillators, in which Mr. Goldsmith had participated as project engineer.

Gordon, S. G. et al.—Information used in the Handbook concerning the preparation of crystal blanks has been obtained from the treatise by Mr. Gordon and **Mr. W. Parrish**, entitled "Cutting Schemes for Quartz Crystals" (*American Mineralogist Symposium on Quartz Oscillator Plates*, 1945). Handbook figures 1-60 and 1-62 have been copied from this source.

Greenidge, R. M. C.—"The Mounting and Fabrication of Plated Quartz Crystal Units" (Chapter XIII, *Quartz Crystals of Electrical Circuits*, Heising), by Mr. Greenidge, has proven an important source of information for the writer. Handbook figures 1-80, 1-83, and 1-86 have been drawn from illustrations contained in the above article with the permission of the publisher, D. Van Nostrand Co.

Gruen, H. E.—Of great value to the Handbook has been the circuit data obtained from Mr. Gruen for over thirty oscillators of comparatively recent design which employ currently recommended crystal units. This information was originally catalogued and the circuits tested during a preliminary investigation of the feasibility of standard packaged oscillator designs—a project engineered for the U. S. Air Force by Mr. Gruen at the Armour Research Foundation of Illinois Institute of Technology, with **Mr. E. A. Roberts** serving as Instrument Supervisor. The writer also wishes to thank Mr. Gruen for giving so generously of his time in helping the writer check test data for inclusion in the Handbook.

Hedeman, W. R.—The method of synthesizing frequencies, as described in paragraphs 1-455 to 1-462, is based upon the **Bendix** synthesizing method described by Mr. Hedeman in "Few Crystals Control Many Channels," *Electronics* magazine, March, 1948.

Heising, R. A.—The subject matter on the fabrication of quartz crystal units in the Handbook is more dependent upon the information in Mr. Heising's *Quartz Crystals for Electrical Circuits*, D. Van Nostrand Co., copyright 1946, than upon that in any other single publication. Because this collection of articles by members of the technical staffs of **Bell Telephone Laboratories** and **Western Electric Company** represents so much of the original discovery, work, and thought that has formed the foundation of the modern quartz-crystal industry in the United States, the book has been invaluable as a reference in the preparation of the Handbook. The many performance curves of the different types of quartz cuts pioneered by Bell Laboratories have proven of particular value. Mr. Heising has also been the source of much of the information concerning the historical development of piezoelectric crystals. The following figures of the Handbook have been reprinted, copied, drawn, or redrawn—entirely, in part, or in modified form—with the permission of Mr. Heising and D. Van Nostrand Co. from illustrations appearing in the aforesaid publication: 1-5, 1-8, 1-11, 1-12, 1-13, 1-19(G), 1-23, 1-24, 1-25, 1-28, 1-29, 1-33, 1-34, 1-35, 1-38, 1-43, 1-44, 1-53, 1-54, 1-56, 1-58, 1-59, 1-63, 1-65, 1-68, 1-71, 1-80, 1-81, 1-82, 1-83, 1-84, 1-86, 1-87, and 1-117.

Henry, C. W.—*See* Foreword.

Institute of Radio Engineers.—I.R.E. Standards on Piezoelectric Crystals, as described in the *Proceedings of the I.R.E.*, vol. 37, No. 12, December, 1949, have been followed in the Handbook.

Jakob, M.—*Heat Transfer*, Vol. I, by M. Jakob, copyright 1949, John Wiley and Sons, proved of great value to the writer as a basic reference source during the preparation of the discussion on crystal-oven design in Part I, Section IV of the Handbook.

Jones, M. B.—The writer is indebted to Mr. Jones for many suggestions for improving the usefulness and appearance of the Handbook, and for contributing freely of his time in designing and preparing the layout of the printed manuscript.

Kitter, W. M.—Appreciation is extended Mr. Kitter for valuable assistance in editing and correcting a number of illustrations, data sheets, and tables in Sections II and III.

Koga, I.—The writer has been greatly benefited by a number of equations (acknowledged in the text) derived by Mr. Koga in the treatise "Characteristics of Piezo Electric Quartz Oscillators," *Proceedings of the I.R.E.*, vol. 18, 1930.

Llewellyn, F. B.—Of great aid to the writer has been "Constant-Frequency Oscillators," F. B. Llewellyn, *Proceedings of the I.R.E.*, vol. 19, 1931.

Lobel, A.—The writer is considerably indebted to Mr. Lobel for valuable assistance in preparing, organizing, and editing data sheets and tables appearing in Sections II, III, IV, V, and the Appendixes.

Magie, W. F.—The writer is indebted to Mr. Magie for the translation of the original paper by **P. Curie** on "Piezoelectricity." The translation contained in the Handbook has been reprinted from *A Source Book in Physics*, W. F. Magie, copyright 1935, McGraw-Hill Book Co., with the permission of the author and publisher.

Mason, W. P.—Much of the descriptive information contained in Section I covering the theory of piezoelectricity and the characteristics of piezoelectric elements is based upon information obtained in the published treatises of Mr. Mason. From *Piezoelectric Crystals and Their Application to Ultrasonics,* copyright 1950, D. Van Nostrand Co., has been obtained most of the information regarding the different types of synthetic piezoelectric crystals as well as a part of the data concerning the X-group of quartz crystals. Figures 1-20, 1-32, and 1-55 of the Handbook have been reprinted entirely or in part from Mr. Mason's book with the permission of the author and the publisher. Equations 1-248 (1) and (2) have also been obtained from this source.

From "Low Temperature Coefficient Quartz Crystals," *Bell System Technical Journal,* January, 1940, permission has been obtained from the author and publisher to use the curves illustrated in Handbook figures 1-45 and 1-46.

The theory of quartz piezoelectric properties, presented in paragraphs 1-69 to 1-74, is based primarily upon **Lord Kelvin's** model of the quartz molecule, as extended by Mason to illustrate a simplified concept of quartz piezoelectricity in "Quartz Crystal Applications" (Chapter I of *Quartz Crystals for Electrical Circuits,* Heising). From this same article has been obtained much of the general information relating to the various types of quartz cuts, as well as the following Handbook illustrations: figures 1-8, 1-9 (originally from *Collected Works of Lord Kelvin,* Cambridge Press), 1-11, 1-19(G), 1-43, 1-44, 1-53, 1-54, and 1-56.

A large part of the information concerning the characteristics of the X-group of quartz crystals has been obtained from "Low-Frequency Quartz-Crystal Cuts Having Low Temperature Coefficients" (Chapter XVII of *Quartz Crystals for Electrical Circuits,* Heising), of which Mr. Mason is coauthor with **Mr. R. A. Sykes.** From this source have been obtained figures 1-23, 1-24, 1-25, 1-28, 1-29, 1-33, 1-34, 1-35, 1-38.

Equation 1-82 (1) is a modification of an equation developed by Mr. Mason in "Electrical Wave Filters Employing Quartz Crystals as Elements," *Bell System Technical Journal,* July, 1934.

Miller, C. J., Jr.—The writer has greatly benefited by two treatises by Mr. Miller: "Equivalent Network of a Quartz Crystal Unit and Its Application" and "The Pierce Oscillator," which appear as chapters I and III, respectively, in *Fundamental Principles of Crystal Oscillator Design,* Circuit Section, Long Branch Signal Laboratory, Signal Corps, 1945-46. The approach to the generalized crystal oscillator and the methods discussed for measuring vacuum-tube-circuit capacitances have proved particularly useful. Figure 1-100 of the Handbook has been traced from one Miller illustration, and figure 1-103 is a modification suggested by another.

Nachman, M. W.—*See* Foreword.

Philco Corporation.—Regrettably, space simply does not permit acknowledgments of the many personal contributions to the composition of this Handbook that have been made by Philco personnel, but for which the writer nevertheless wishes to express his sincere appreciation. Without the good faith and cooperation of the management and staff of the **Philco Technical Publications Department,** in particular, this Handbook would not have been possible.

Prichard, A. C.—Information obtained from Mr. Prichard's treatise "The Miller Oscillator" (Chapter IV, *Fundamental Principles of Crystal Oscillator Design,* Circuit Section, Long Branch Signal Laboratory, Signal Corps) has been included in the Handbook.

Roberts, E. A. et al.—Appreciation is felt for the assistance and many courtesies extended the writer when collecting data originally obtained in experiments performed under the supervision of Mr. Roberts at the Armour Research Foundation of the Illinois Institute of Technology. Of particular value has been the information concerning the performance of parallel-mode oscillators that is contained in the interim report on USAF research Contract No. AF 18(600)-157, "Investigation of Oscillator Circuits for Proposed Standards," June 22, 1953. Copies of illustrations from this report are shown in figures 1-129, 1-130, 1-143, 1-144, 1-145, 1-146, 1-147, and 1-148. Research engineers contributing materially to the project were **E. K. Novak, P. Goldsmith,** and **J. Kurinsky.**

Robinson, S. A. et al.—The discussion of capacitance-bridge oscillators is based primarily upon the final report, "H. F. Harmonic Crystal Investigation," of an Air Force research project undertaken by the Research Division of Philco Corporation in 1947 (AF Contract No. W33-038-ac-14172), with Messrs. Robinson, **C. D. O'Neal,** and **F. N. Barry** serving as project engineers. Handbook figures 1-112, 1-113, 1-114, 1-165(A), 1-166, 1-167, 1-168, 1-169, 1-170, 1-171, and 1-172 have been copied from this report.

Ronan, J. A.—Part of the information concerning the plating of crystals has been obtained from Mr. Ronan's technical report, "Fabricating Techniques for Crystal Unit CR-23/U," Signal Corps Engineering Laboratories.

Schnepps, B.—The writer is greatly indebted to the conscientious work of Mr. Schnepps in preparing, organizing, and editing data sheets and tables appearing in Sections II, III, IV, V, and the Appendixes.

Signal Corps.—The writer wishes to thank **Mr. W. L. Doxey**, Chief, and others of the staff at the **Frequency Control Branch, Signal Corps Engineering Laboratories**, Fort Monmouth, N. J., for their cooperation in making available a large amount of useful bibliographical material. With their assistance, it has been possible to consult a much broader range of publications, illustrations, and reports than would otherwise have been possible.

It should be mentioned that from the Signal Corps Technical Manual, TM-2540, *Quartz Crystals, Theory, Fabrication and Performance Measurements*, much of the information concerning the fabrication of quartz crystal units has been obtained. The following Handbook illustrations have been obtained from this manual: figures 1-5,* 1-6, 1-10,* 1-42, 1-57,* 1-58,* 1-59,* 1-63,* 1-64, 1-66,* 1-67, and 1-89. Those figures marked with an asterisk have been obtained from negatives made available by the Signal Corps.

Also of great use to the writer has been the *Information Bulletin on Quartz Crystal Units*, Armed Services Electro Standards Agency, Fort Monmouth, N. J. *See* **Fair, I. E.** and **Sykes, R. A.** for illustrations obtained from this source.

In Section III, the illustrations of all Group-II crystal holders have been redrawn from drawings furnished by the Signal Corps.

Finally, the circuit data for a large number of the individual oscillators described have been obtained from Signal Corps technical manuals.

Stock, D. J. R., et al.—Much of the discussion of crystal-unit drive-level characteristics is based upon information contained in the final report, "Investigation, Studies and Evaluation of Performance of Crystal Unit Characteristics," 1952, of a research project (Signal Corps Contract No. DA36-039-sc-5493) undertaken by the Research Division of New York University College of Engineering, Mr. Stock serving as project engineer, with the assistance of **L. Silver, E. Strongin,** and **A. Yevlove.** Handbook figures 1-115, 1-116, and 1-118 have been obtained from this report.

Sykes, R. A. (*See also* Foreword)—The discussions contained in Section I, entitled "Modes of Vibration" and "Rule-of-Thumb Equations for Estimating Parameters," are based upon and follow closely the information contained in the exposition of these subjects by Mr. Sykes in "Design Data on Crystal Units" (Appendix I, *Information Bulletin on Quartz Crystal Units*, Armed Services Electro Standards Agency, Fort Monmouth, N. J., August, 1952). Handbook illustrations obtained from the foregoing treatise are figures 1-26, 1-27, 1-30, 1-31, 1-36, 1-37, 1-49, 1-50, 1-51, 1-52, 1-85, and 1-88(B).

The information contained in the discussion of the modes of vibration of quartz crystals is also dependent upon the more extended treatment of the same subject by Mr. Sykes in "Modes of Motion in Quartz Crystals, the Effects of Coupling and Methods of Design" (Chapter VI, *Quartz Crystals for Electrical Circuits*, Heising). Handbook equations 1-81 (4) and 1-82 (1) have been obtained from this source. Also from this treatise are figures 1-12 and 1-13, which have been copied with the permission of the publisher, D. Van Nostrand Co.

"Principles of Mounting Quartz Plates" (Chapter VIII, *Quartz Crystals for Electrical Circuits*, Heising), by Mr. Sykes, is the source of the information included in the Handbook concerning the cantilever method of crystal mounting, and also of much of the information concerning pressure mounts in general, wire mounts, and air-gap mounts. The equation in paragraph 1-158, and figures 1-71, 1-81, 1-82, 1-84, and 1-87 of the Handbook are taken from this work, with the permission of the publisher, D. Van Nostrand and Co.

For acknowledgments of information obtained from "Low-Frequency Quartz-Crystal Cuts Having Low Temperature Coefficients," coauthored by Mr. Sykes, see **Mason, W. P.**

Vigoureux, P. et al.—*Quartz Vibration*, by P. Vigoureux and **C. F. Booth**, H. M. Stationery Office, London, has been a valuable source of reference for the writer. Of special usefulness has been the information on the design of crystal ovens, much of which has not been obtainable elsewhere.

Western Electric Co.—The writer is indebted to the Western Electric Co. for making available the design recommendations of Bell Telephone Laboratories engineers, pertaining to the oscillator circuit illustrated in figure 1-157.

Willard, G. W.—Mr. Willard's treatises, "Raw Quartz, Its Imperfections and Inspection" and "Use of the Etch Technique for Determining Orientation and Twinning in Quartz Crystals" (Chapters IV and V, respectively, *Quartz Crystals for Electrical Circuits*, Heising) have been principal sources of information covering their respective subjects. Handbook figures 1-5, 1-58, 1-63, and

1-65 have been obtained from the above sources with the permission of the publisher, D. Van Nostrand Co.

Wojcicki, F. J.—*See* Foreword.

Wright Air Development Center.—*See* Foreword.

Addendum

Dasher, B. J. et al.—A large proportion of the data contained in the discussion of junction transistor oscillators has been obtained from the quarterly reports on "Transistor Oscillators of Extended Frequency Range" by Messrs. Dasher, **D. L. Finn, S. N. Witt, W. B. Warren, Jr., T. N. Lowry, et al.,** of the Georgia Institute of Technology, Atlanta, Georgia. (Dept. of the Army Contract No. DA-36-039-sc-42716).

Finden, H. J.—The information on the Plessy synthesizer has been obtained primarily from "The Frequency Synthesizer" by Mr. Finden, *Journal of the Institution of Electrical Engineers,* vol. 90, Part III, 1943.

The information on the attenuation of unwanted frequencies in frequency synthesis is based on "Developments in Frequency Synthesis" by Mr. Finden, *Electronic Engineering,* May 1953.

Gerber, E. A.—The treatise "A Review of Methods for Measuring the Constants of Piezoelectric Vibrators" by Dr. Gerber, *Proceedings of the I.R.E.,* September 1953, has been a valuable source of reference in preparing the discussions on the measurements of crystal oscillators.

The writer also wishes to thank the engineering staff in the charge of Dr. Gerber at the **Frequency Control Branch of the Signal Corps Engineering Laboratories** for the time and effort spent in reviewing the Handbook revision material and for the many suggestions and corrections which have helped to improve the usefulness and accuracy of the text.

Gruen, H. E. — The information on the Gruen packet oscillator series was obtained from "Development of Packet Oscillator Series" by Mr. Gruen, a project of the Armour Research Foundation, I.I.T., completed in 1955. (USAF Contract No. AF 33(616)-2125).

Hahnel, A. — The information on crystal-phase-controlled harmonic multipliers is based upon "Multichannel Crystal Control of VHF and UHF Oscillators" by Mr. Hahnel, *Proceedings of the I.R.E.,* January 1953, and upon "A Single Crystal Multi-Channel Oscillator" by Messrs. **L. R. Battersby** and **E. A. Conover** (Signal Corps Project No. 132A, March 1954).

Savolainen, U. — The information on bimetallic thermostats in paragraph 4-18 was obtained from "Designing Bimetal Control Devices" by Mr. Savolainen, *Product Engineering,* August 1950.

Sherman, J. W. Jr.—The writer is indebted to Mr. Sherman of the General Electric Company for the method described in paragraph 1-584 for simulating marginal crystal units in parallel-mode circuits.

ACKNOWLEDGMENTS FOR USE OF COPYRIGHTED ILLUSTRATIONS

Figure Number	*Courtesy of*
1-2, 1-4, 1-15, 1-16	Institute of Radio Engineers
1-5, 1-8, 1-9, 1-11, 1-12, 1-13, 1-19(G), 1-20, 1-23, 1-24, 1-25, 1-28, 1-29, 1-32, 1-33, 1-34, 1-35, 1-38, 1-43, 1-44, 1-53, 1-54, 1-55,	D. Van Nostrand Company
1-56, 1-58, 1-59, 1-63, 1-65, 1-68, 1-71, 1-80, 1-81, 1-82, 1-83, 1-84, 1-86, 1-87, 1-117	D. Van Nostrand Company
1-21	McGraw-Hill Book Company
1-45, 1-46	*Bell Systems Technical Journal*
1-162	John Wiley and Sons
1-189, 1-190	Bell Telephone Laboratories

ACKNOWLEDGMENTS FOR USE OF COPYRIGHTED QUOTATIONS

Paragraph Number	*Courtesy of*
1-57 to 1-68	McGraw-Hill Book Company

APPENDIX II—BIBLIOGRAPHY

1. Adler, R.: "A New System of Frequency Modulation," *Proc. I.R.E.*, vol. 35, pp. 25—31, 1947.
2. Adler, R.: "Locking Phenomena in Oscillators," *Proc. I.R.E.*, vol. 34, pp. 351—357, 1946.
3. Aigrain, P. R., and E. M. Williams: "Theory of Amplitude Stabilized Oscillators," *Proc. I.R.E.*, vol. 36, pp. 16—19, 1948.
4. Aigrain, P. R., and E. M. Williams: "Pseudosynchronization in Amplitude Stabilized Oscillators," *Proc. I.R.E.*, vol. 36, pp. 800—801, 1948.
5. Aldous, D. W.: "A New Temperature-controlled Crystal Cutting-head," *Electronic Eng.*, vol. 14, p. 605, 1942.
6. *American Minerologist:* Comprehensive series of articles on quartz and quartz-oscillator plates, as well as glossary of terms used in the industry, *A. Min.*, vol. 30, pp. 205—468, May-June 1945.
7. American Radio Relay League: *ARRL Handbook*, West Hartford, Conn., yearly.
8. Ames, M. E.: "Wide Range Deviable Oscillator," *Electronics*, vol. 22, pp. 96—100, May 1949.
9. Anderson, F. B.: "Seven-League Oscillator," *Proc. I.R.E.*, vol. 39, pp. 881—890, 1951.
10. Anderson, J. E.: "Frequency Characteristics of Piezoelectric Oscillators," *Electronics*, vol. 11, pp. 22—24, August 1938.
11. Andrew, V. J.: "The Adjustment of the Multivibrator for Frequency Division," *Proc. I.R.E.*, vol. 19, pp. 1911—1917, 1931.
12. Anon.: "Improved Material for Magnetic Amplifiers," *Electronics*, vol. 21, p. 128, August 1948.
13. Anon.: "Stable Time and Frequency Standard," *Electronics*, vol. 22, pp. 82—84, April 1949.
14. Appleton, E. V.: "The Automatic Synchronization of Triode Oscillators," *Proc. Camb. Phil. Soc.*, vol. 21, pp. 231—248, 1922-1923.
15. Appleton, E. V., and B. van der Pol: "On the Form of Free Triode Vibrations," *Phil. Mag.*, vol. 42, pp. 201—220, 1921.
16. Arguimbau, L. B.: *Vacuum-tube Circuits*, John Wiley, New York, 1948.
17. Arguimbau, L. B.: "An Oscillator Having a Linear Operating Characteristic," *Proc. I.R.E.*, vol. 21, pp. 14—28, 1933.
18. Armed Services Electro Standards Agency: *Information Bulletin on Quartz Crystal Units*, ASESA 52-9, Fort Monmouth, N. J., August 1952.
19. Armstrong, E. H.: "Some Recent Developments of Regenerative Circuits," *Proc. I.R.E.*, vol. 10, pp. 244-260, 1922.
20. Arndt, J. P.: *Guard Rings to Prevent Surface Leakage*, Patent 2,289,954.
21. Artz, M.: "Frequency Modulation of Resistance-Capacitance Oscillators," *Proc. I.R.E.*, vol. 32, pp. 409-414, 1944.
22. Atanasoff, J. V., and P. J. Hart: "Dynamical Determination of the Elastic Constants and Their Temperature Coefficients for Quartz," *Phys. Rev.*, vol. 59, pp. 85—96, 1941.
23. Atanasoff, J. V., and E. Kammer: "A Determination of the c_{44} Elastic Constant for Beta-quartz," *Phys. Rev.*, vol. 59, pp. 97—99, 1941.
24. Babat, G., and M. Losinsky: "Power Oscillators," *W. E.*, vol. 17, pp. 16—18, 1940.
25. Balamuth, L.: "A New Method for Measuring Elastic Moduli and the Variation with Temperature of the Principal Young's Modulus of Rocksalt between 78°K and 273°K," *Phys. Rev.*, vol. 45, pp. 715—720, 1934.
26. Baldwin, C. F.: "Quartz Crystals in Radio," *Communications*, vol. 22, pp. 20f., October 1942.
27. Baldwin, C. F.: "Quartz Crystals," *G. E. Rev.*, vol. 43, pp. 188—194, 237—243, 1940.
28. Baldwin, C. F., and S. A. Bokovoy: "Practical Operating Advantages of Low Temperature-Frequency Coefficient Crystals," *QST*, vol. 19, pp. 26, 27, 92, January 1935.
29. Ballantine, S.: "High Quality Radio Broadcast Transmission and Reception (Rochelle salt "sound-cell")," *Proc. I.R.E.*, vol. 22, pp. 564—629, 1934.
30. Ballantine, S.: "A Piezo-electric Loud Speaker for the Higher Audio Frequencies," *Proc. I.R.E.*, vol. 21, pp. 1399—1408, 1933.
31. Ballou, J. W., and S. Silverman: "Young's Modulus of Elasticity of Fibers and Films by Sound Velocity Measurements," *Jour. Acous. Soc. Am.*, vol. 16, pp. 113—119, 1944.
32. Bancroft, D.: "The Velocity of Longitudinal Waves in Cylindrical Bars," *Phys. Rev.*, vol. 59, pp. 588—593, 1941.
33. Bancroft, D.: "The Effect of Hydrostatic Pressure on the Susceptibility of Rochelle Salt," *Phys. Rev.*, vol. 53, pp. 587—590, 1938.
34. Bantle, W., and P. Scherrer: "Anomaly of the Specific Heat of Potassium Dihydrogen Phosphate at the Upper Curie Point," *Nature*, vol. 143, p. 980, 1939.
35. Bardeen, J., and W. H. Brattain: "The Transistor, a Semi-Conductor Triode," *Phys. Rev.*, vol. 74, p. 230, 1948.
36. Barrett, C. S., and C. E. Howe: "X-ray Reflection from Inhomogeneously Strained Quartz," *Phys. Rev.*, vol. 39, pp. 889—897, 1932.
37. Bartelink, E. H. B.: "A Wide-Band Square-Wave Generator," *Trans. A.I.E.E.*, vol. 60, pp. 371—376, 1941.
38. Bartlett, R. M.: "*N*-Phase Resistance-Capacitance Oscillators," *Proc. I.R.E.*, vol. 33, pp. 541—545, 1945.
39. Barton, Edwin H.: *A Text-Book on Sound*, Macmillan & Co., Ltd., London, 1919, 687 pp.
40. Bass, S. L., and T. A. Kauppi: "Silicones—A New Class of High Polymers of Interest to the Radio Industry," *Proc. I.R.E.*, vol. 33, pp. 441—447, 1945.
41. Batcher, R. R.: "Thermistors in Electronic Circuits," *Electronic Inds.*, vol. 4, pp. 76—80, January 1945.
42. Batcher, R. R.: "Application of Piezoelectric Crystals to Receivers," *Electronics*, vol. 3, pp. 57—58, August 1931.
43. Bauer, B.: "Design Notes on the Resistance-Capacity Oscillator Circuit," *Hewlett-Packard J.*, November and December 1949.
44. Baumgardt, E.: "Velocity of Propagation of Elastic Waves in Piezoelectric Crystals," *C. R.*, vol. 206, pp. 1887—1890, 1938.

45. Baumzweiger, B.: "Application of Piezoelectric Vibration Pick-ups to Measurement of Acceleration, Velocity and Displacement," *Jour. Acous. Soc. Am.*, vol. 11, pp. 303—307, 1940.
46. Baxter, H. W.: "A Recording Instrument for Transient Pressures," *Electrician*, vol. 113, pp. 121—122, 1934.
47. Bazzoni, C. B.: "The Piezo-electric Oscillograph," *Radio News*, vol. 7, pp. 142—143, 233—237, August 1925.
48. Bacon, D.: "Improving Crystal Filter Performance," *QST*, vol. 24, pp. 58f., December 1940.
49. Beck, F. J., and J. M. Kelly: "Magnetization in Perpendicularly Superposed Direct and Alternating Fields," *J. Appl. Ph.*, vol. 19, pp. 551—562, 1948.
50. Becker, J. A., Green, C. B., and G. L. Pearson: "Properties and Uses of Thermistors—Thermally Sensitive Resistors," *Trans. A.I.E.E.*, vol. 65, pp. 711—725, 1946.
51. Bechmann, R.: "The Crystal Control of Transmitters," *W. E.*, vol. 11, pp. 249—253, 1934.
52. Beers, G. L.: "A Frequency-Dividing Locked-in-Oscillator Frequency-Modulation Receiver," *Proc. I.R.E.*, vol. 22, pp. 730—737, 1944.
53. Begun, S. J.: "Some Problems of Disk Recording," *Proc. I.R.E.*, vol. 28, pp. 389—398, 1940; *Jour. Soc. Motion-Picture Eng.*, vol. 36, pp. 666—674, 1941.
54. Benjamin, R.: "Blocking Oscillators," Part IIIA, *J. I.E.E.*, vol. 93, pp. 1159—1175, 1946.
55. Bennett, W. R.: "A General Review of Linear Varying Parameter and Non-linear Circuit Analysis," *Proc. I.R.E.*, vol. 38, pp. 259—263, 1950.
56. Benson, J. E.: "Modes of Vibration and Design of V-cut Quartz Plates for Medium Broadcast Frequencies," *A.W.A. Tech. Rev.*, vol. 6, pp. 73—89, 1943.
57. Benson, J. E.: "A Note on the History of Piezoelectric Crystal Filters," *A.W.A. Tech. Rev.*, vol. 5, pp. 191—192, 1941.
58. Benson, J. E.: "Crystal Control of the Mixer Oscillator in a Superheterodyne Receiver," *A.W.A. Tech. Rev.*, vol. 4, pp. 127—137, 1939; vol. 5, pp. 29—40, 1940.
59. Benson, J. E.: "A Piezoelectric Calibrator," *A.W.A. Tech. Rev.*, vol. 5, pp. 47—50, 1940.
60. Berberich, L. J., Fields, C. V., and R. E. Marbury: "Characteristics of Chlorinated Impregnants in Direct-Current Paper Capacitors," *Proc. I.R.E.*, vol. 33, pp. 389—397, 1945.
61. Bertram, S.: "The Degenerative Positive-Bias Multivibrator," *Proc. I.R.E.*, vol. 36, pp. 277—280, 1948.
62. Bertsch, C. V.: "X-ray Studies of Crystals Vibrating Piezoelectrically," *Phys. Rev.*, vol. 49, pp. 128—132, 1936.
63. Biggs, A. J., and G. M. Wells: "The Measurement of the Activity of Quartz Oscillator Crystals," *J.I.E.E.*, vol. 93, part III, No. 21, January 1946.
64. Bird, J. R.: "Recent Improvements in Crystal Pickup Devices," *Proc. I.R.E.*, vol. 25, p. 660, 1937.
65. Black, H. S.: "Stabilized Feedback Amplifiers," *Bell System T. J.*, vol. 13, pp. 1—18, 1934; also *Elec. Eng.*, vol. 53, p. 114, 1934.
66. Bliley Electric Co.: *Development of Harmonic Mode Crystals*, Signal Corps Contract No. W36–039–sc-32136, February 1949.
67. Bloch, A.: "New Methods for Measuring Mechanical Stresses at Higher Frequencies," *Nature*, vol. 136, pp. 223—224, 1935; see also *Electronics*, vol. 8, pp. 212-213, 1935.
68. Bloomenthal, S.: "The Converse Piezoelectric Effect in Mixed Crystals Isomorphous with Rochelle Salt," *Physics*, vol. 4, pp. 172—177, 1933.
69. Bode, H. W.: *Network Analysis and Feedback Amplifier Design*, D. Van Nostrand, New York, 1945.
70. Boella, M.: "Performance of Piezo-Oscillators and the Influence of the Decrement of the Quartz on the Frequency of Oscillations," *Proc. I.R.E.*, vol. 19, p. 1252, 1931.
71. Bokovoy, S. A.: "Quartz Crystals—Development and Application," *Elec. Comm.*, vol. 21, pp. 233—246, 1944.
72. Bokovoy, S. A.: "Piezoelectric Quartz Element," Patent 2,111,384, filed September 30, 1936, issued March 15, 1938.
73. Bokovoy, S. A.: "Mounting for Piezoelectric Elements," Patent 2,078,229, filed December 31, 1935, issued April 27, 1937.
74. Bokovoy, S. A.: "Quartz Piezo-Electric Element," Patent 2,064,288, filed May 31, 1934, issued December 15, 1936.
75. Bokovoy, S. A., and Baldwin, C. F.: "Improvements in or Relating to Piezo-Electric Crystals," methods of cutting quartz for use as length-and-breadth mode oscillators, British Patent Specification 457,342, filed May 31, 1935, issued November 26, 1936.
76. Booth, C. F.: "The Application and Use of Quartz Crystals in Telecommunications," *J.I.E.E.*, vol. 88, part 3, pp. 97—128, 1941; discussion, pp. 128—144.
77. Booth, C. F., and C. F. Sayers: "The Production of Quartz Resonators for the London-Birmingham Coaxial Cable System," *P.O.E.E.J.*, vol. 32, pp. 7—15, 88—93, 1939.
78. Booth, C. F., and E. J. C. Dixon: "Crystal Oscillators for Radio Transmitters: An Account of Experimental Work Carried Out by the Post Office," *W. E.*, vol. 12, pp. 198—200, 1935; *J.I.E.E.*, vol. 77, pp. 197—236, discussion pp. 237—244, 1935; *Proc. Wireless Sec., I.E.E.*, vol. 10, pp. 129—168, discussion, pp. 169—176, 1935.
79. Bond, W. L.: "Sawing, Grinding and 'Lapping'"; refer to book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 290—316, 1946.
80. Bond, W. L.: "The Ring Eccentricity 'Correction'"; refer to book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 91—94, 1946.
81. Bond, W. L.: "Methods for Specifying Quartz Crystal Orientation and Its Determination by Optical Means," *Bell Syst. T. J.*, vol. 22, pp. 224—262, 1943; also printed in book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 57—91, 1946.
82. Bond, W. L., and E. J. Armstrong: "The Use of X-rays for Determining the Orientation of Quartz Crystals," *Bell Syst. T. J.*, vol. 22, pp. 293—337, 1943; also printed in book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 95—139, 1946.
83. Bond, W. L.: "Processing Quartz," *Bell Labs. Rec.*, vol. 22, pp. 359—361, 1944.
84. Bond, W. L.: "The Mathematics of the Physical Properties of Crystals," *Bell Syst. T. J.*, vol. 22, pp. 1—72, 1943.
85. Bond, W. L.: "A Mineral Survey for Piezoelectric Materials," *Bell Syst. T. J.*, vol. 22, pp. 145—152, 1943.
86. Bond, W. L.: "Division of Metal Plating by Stylus," Patent 2,248,057.
87. Bosch, W. C., and W. G. Allée, Jr.: "Circuit Details for a Small Supersonic Oscillator of the Piezoelectric Type," *Am. Phys. Teacher*, vol. 6, pp. 272—273, 1938.
88. Bothwell, F. E.: "Nyquist Diagrams and the Routh-Hurwitz Stability Criterion," *Proc. I.R.E.*, vol. 38, pp. 1345—1348, 1950.
89. Bottom, V. E., Colorado A. & M. College: *Parameters Which Determine the Performance of Piezoelectric Plate*, Sig. Corps Contract DA36–039–sc—32083, July 1950.

90. Bottom, V. E.: "The Mathematics of the Equivalent Electrical Circuit of the Quartz Crystal Unit," printed in *Fundamental Principles of Crystal Oscillator Design*, U. S. Army Signal Corps, Long Branch Signal Laboratory, pp. 20—35, 1945.
91. Bower G. G.: "Crystal-Controlled Electron-Coupled Oscillator," printed in *Fundamental Principles of Crystal Oscillator Design*, U. S. Army Signal Corps, Long Branch Signal Laboratory, pp. 79—84, 1945.
92. Boyle, R. W., and D. O. Sproule: "Oscillation in Ultrasonic Generators and Velocity of Longitudinal Vibrations in Solids at High Frequencies," *Nature*, vol. 123, p. 13, January 5, 1929.
93. Boyle, R. W.: "Ultrasonics," *Science Progress*, vol. 23, pp. 75—105, 1928.
94. Boyle, R. W., Lehmann, J. F., and S. C. Morgan: "Some Measurements of Ultrasonic Velocities in Liquids," *Trans. Roy. Soc. Can.*, vol. 22, sec. 3, pp. 371—378, 1928.
95. Bradley, A. J., and A. H. Jay: "Quartz as a Standard for Accurate Lattice-spacing Measurements," *Proc. Phys. Soc. (London)*, vol. 45, pp. 507—522, 1933.
96. Bradley, W. E.: "Superregenerative Detection Theory," *Electronics*, vol. 21, pp. 96—98, September 1948.
97. Bradley, W. E.: "Single Stage F-M Detector," *Electronics*, vol. 19, pp. 88—91, October 1946.
98. Bragg, W., and R. E. Gibbs: "The Structure of Alpha- and Beta-quartz," *Proc. Roy. Soc.*, vol. 109, pp. 405—427, 1925.
99. Bragg, W. L.: *Atomic Structure of Minerals*, Cornell University Press, Ithaca, New York, 1937, 292 pp.
100. Briggs, H. B.: "A Supersonic Cell Fluorometer," *Jour. Optical Soc. Am.*, vol. 31, pp. 543—549, 1941.
101. Brotherton, M.: *Capacitors*, D. Van Nostrand, New York, 1946.
102. Brown, G. H., Hoyler, C. N., and R. A. Bierwith: *Theory and Application of Radio Frequency Heating*, D. Van Nostrand, New York, 1947.
103. Brown, G. H.: "Efficiency of Induction Heating Coils," *Electronics*, vol. 17, pp. 124—129, August 1944.
104. Brown, H. A.: "Oscilloscope Patterns of Damped Vibrations of Quartz Plates and Q Measurements with Damped Vibrations," *Proc. I.R.E.*, vol. 29, pp. 195—199, 1941.
105. Brown, R. H.: "Harmonic Amplifier Design," *Proc. I.R.E.*, vol. 35, pp. 771—777, 1947.
106. Brown, S. L., and S. Harris: "Measurements of Temperature Coefficient and Pressure Coefficient of Quartz Crystal Oscillators," *R.S.I.*, vol. 2, pp. 180—183, 1931.
107. Brown, W. F., Jr.: "Interpretation of Torsional Frequencies of Crystal Specimens," *Phys. Rev.*, vol. 58, pp. 998—1001, 1940.
108. Brown, W. F.: "Quartz Crystals Overtone Oscillators," Royal Aircraft Establishment, Farnborough, England, Tech. Note: Rad. 460, September 1949.
109. Browne, C. ●.: "Demonstration of High-Frequency Fluctuations in the Intensity of a Beam of Light," *Proc. Phys. Soc. (London)*, vol. 40, p. 36, 1927.
110. Bruce, W. A., and G. E. M. Jauncey: "Dependence of Diffuse Scattering of X-rays from Quartz upon the Angle between the Crystal Axis and the Plane of Scattering, (abstract) *Phys. Rev.*, vol. 49, pp. 418—419, 1926.
111. Bruck, G. S.: "Simplified Frequency Modulation," *Proc. I.R.E.*, vol. 34, p. 458, 1946.
112. Brunetti, C., and L. Greenough: "Some Characteristics of a Stable Negative Resistance," *Proc. I.R.E.*, vol. 30, pp. 542—546, 1942.
113. Brunetti, C.: "The Transitron Oscillator," *Proc. I.R.E.*, vol. 27, pp. 88—94, 1939.
114. Brunetti, C.: "The Clarification of Average Negative Resistance with Extension of Its Use," *Proc. I.R.E.*, vol. 25, pp. 1593—1616, 1937.
115. Buckley, O. E.: "The Evolution of the Crystal Wave Filter," *Jour. Applied Phys.*, vol. 8, pp. 40—47, 1937.
116. Buehler, E., and A. C. Walker: "Growing Quartz Crystals," *Sci. Monthly*, vol. 69, pp. 148—155, 1949.
117. Builder, G., and J. E. Benson: "Simple Quartz-crystal Filters of Variable Bandwidth," *A.W.A. Tech. Rev.*, vol. 5, pp. 93—103, 1941; also in *Wireless Eng. Exptl. Wireless (London)*, vol. 20, pp. 183—189, 1943.
118. Builder, G.: "A Stabilized Frequency Divider," *Proc. I.R.E.*, vol. 29, pp. 177—181, 1941.
119. Builder, G., and J. E. Benson: "Contour-mode Vibrations in Y-cut Quartz-crystal Plates," *Proc. I.R.E.*, vol. 29, pp. 182—185, 1941; *A.W.A. Tech. Rev.*, vol. 5, pp. 181—189, 1941.
120. Builder, G.: "A Note on the Determination of the Equivalent Electrical Constants of a Quartz-crystal Resonator," *A.W.A. Tech. Rev.*, vol. 5, pp. 41—45, 1940.
121. Builder, G., and J. E. Benson: "Precision Frequency-control Equipment Using Quartz Crystals," *A.W.A. Tech. Rev.*, vol. 3, pp. 157—214, 1938; *Proc. World Radio Convention*, Sydney, Australia, 1938.
122. Builder, G.: "Resistance-balancing in Wave Filters," *A.W.A. Tech. Rev.*, vol. 3, pp. 83—100, 1938.
123. Builder, G.: "Quartz Crystals for the Control and Measurement of Frequency," *A.W.A. Tech. Rev.*, vol. 2, pp. 104—105, 1936.
124. Burgess, R. E.: "Oscillator Power Relations," *Wireless Eng.*, vol. 23, pp. 237—240, 1946.
125. Burns, G. K.: "Manufacture of Quartz Crystal Filters," *Bell System Tech. Jour.*, vol. 19, pp. 516—532, 1940.
126. Bushby, R. W.: "Thermal Frequency Drift Compensation," *Proc. I.R.E.*, vol. 30, pp. 546—553, 1942.
127. Butler, F.: "Series Resonant Crystal Oscillators," *W. E.*, vol. 23, p. 1, 1946.
128. Butler, F.: "Cathode-Coupled Oscillators," *W. E.*, vol. 21, p. 521, November 1944.
129. Cady, W. G.: *Piezoelectricity*, McGraw-Hill, New York, 1946.
130. Cady, W. G., and K. S. Van Dyke: "Proposed Standard Conventions for Expressing the Elastic and Piezoelectric Properties of Right- and Left-quartz," *Proc. I.R.E.*, vol. 30, pp. 495—499, 1942.
131. Cady, W. G.: "A Survey of Piezoelectricity," *A.P.T.*, vol. 6, pp. 227—242, 1938.
132. Cady, W. G.: "The Longitudinal Piezoelectric Effect in Rochelle Salt Crystals," *Proc. Ph. Soc.*, vol. 49, pp. 646—653, 1937.
133. Cady, W. G.: "The Piezoelectric Resonator and the Effect of Electrode Spacing upon Frequency," *Physics*, vol. 7, pp. 237—259, 1936.
134. Cady, W. G.: "A Quartz Crystal Used as a Selective Filter," Patent 1,994,658, filed June 7, 1927, issued March 19, 1935.
135. Cady, W. G.: "The Potential Distribution Between Parallel Plates and Concentric Cylinders Due to Any Arbitrary Distribution of Space Charge," *Physics*, vol. 6, pp. 10—13, 1935.
136. Cady, W. G.: "The Application of Methods of Geometrical Inversion to the Solution of Certain Problems in Electrical Resonance," *Proc. A.A.A.S.*, vol. 68, pp. 383—409, 1933.
137. Cady, W. G.: "Low Frequency Vibrations in Rochelle Salt and Quartz Plates," (abst.), *Phys. Rev.*, vol. 39, p. 862, 1932.
138. Cady, W. G.: "Piezoelectric Terminology," *Proc. I.R.E.*, vol. 18, pp. 2136—2142, 1930.
139. Cady, W. G.: "Electroelastic and Pyro-electric Phenomena," *Proc. I.R.E.*, vol. 18, pp. 1247—1262, 1930.
140. Cady, W. G.: "Some Electromechanical Properties of Rochelle Salt Crystals," (abst.), *Phys. Rev.*, vol. 33, pp. 278—279, 1929.

141. Cady, W. G.: "Bibliography on Piezoelectricity," *Proc. I.R.E.*, vol. 16, pp. 521—535, 1928.
142. Cady, W. G.: "A Shear Mode of Crystal Vibration," (abst.), *Phys. Rev.*, vol. 29, p. 617, 1927.
143. Cady, W. G.: "Piezoelectric Standards of High Frequency," *J.O.S.A.*, vol. 10, pp. 475—489, 1925.
144. Cady, W. G.: "An International Comparison of Radio Wavelength Standards by Means of Piezoelectric Resonators," *Proc. I.R.E.*, vol. 12, pp. 805—816, 1924.
145. Cady, W. G.: "Piezoelectrically Driven Tuning-forks and Rods," *Phys. Rev.*, vol. 21, pp. 371—372, 1923.
146. Cady, W. G.: "A Method of Testing Plates from Piezoelectric Crystals," *J.O.S.A.*, vol. 6, pp. 183—185, 1922.
147. Cady, W. G.: "The Piezoelectric Resonator," *Proc. I.R.E.*, vol. 10, pp. 83—114, 1922.
148. Cady, W. G.: "Theory of Longitudinal Vibrations of Viscous Rods," *Phys. Rev.*, vol. 19, pp. 1—6, 1922.
149. Camfield, G. J.: "The Design of Fundamental Mode Quartz Crystal Oscillators," Royal Aircraft Establishment, Farnborough, England, Tech. Note: Rad. 525, July 1952.
150. Carnahan, C. W., and H. P. Kalmus: "Synchronized Oscillators as F-M Receiver Limiters," *Electronics*, vol. 17, pp. 108—111, August 1944.
151. Carruthers, R. S.: "Some Experimental and Practical Applications of Transistor Oscillators," pp. 397—414 of *The Transistor*, prepared by Bell Telephone Laboratories, Inc., Murray Hill, N. J., November 1951.
152. Chaffee, J. G.: "The Application of Negative Feedback to Frequency-Modulation Systems," *Bell System T. J.*, vol. 18, pp. 404—437, 1939; also *Proc. I.R.E.*, vol. 27, pp. 317—331, 1939.
153. Chaffee, E. L., and C. N. Kimball: "A Method of Determining the Operating Characteristics of a Power Oscillator," *J. Frank Inst.*, vol. 221, p. 237, 1936.
154. Chaffee, E. L.: "Equivalent Circuits of an Electron Triode and the Equivalent Input and Output Admittances," *Proc. I.R.E.*, vol. 17, p. 1633, September 1929.
155. Chance, B., *et al.: Waveforms*, McGraw-Hill, New York, 1949.
156. Chance, B.: "Some Precision Circuit Techniques Used in Wave Form Generation and Time Measurement," *R.S.I.*, vol. 17, pp. 396—415, 1946.
157. Chang, C. K.: "A Frequency-Modulated Resistance-Capacitance Oscillator," *Proc. I.R.E.*, vol. 31, pp. 22—25, 1943.
158. Chang, H., and V. C. Rideout: "The Reactance Tube Oscillator," *Proc. I.R.E.*, vol. 37, pp. 1330—1331, 1949; also p. 1096, 1950.
159. Christopher, A. J., and J. A. Kater: "Mica Capacitors for Carrier Telephone Systems," *Elec. Eng. (Transactions Sect.)*, vol. 65, pp. 670—673, 1946.
160. Chu, E. L.: "Notes on the Stability of Linear Networks," *Proc. I.R.E.*, vol. 32, pp. 630—637, 1944.
161. Clapp, J. K.: "An Inductance-Capacitance Oscillator of Unusual Frequency Stability," *Proc. I.R.E.*, vol. 36, pp. 356—358; also p. 1261, 1948.
162. Clapp, J. K.: "A Bridge Controlled Oscillator," *General Radio Experimenter*, vol. XVIII, No. 11, p. 1, April 1944.
163. Clapp, J. K., and J. D. Crawford: "Frequency Standardization," *QST*, vol. 14, pp. 9—15, March 1930.
164. Clapp, J. K.: "Universal Frequency Standardization from a Single Frequency Standard," *J.O.S.A.*, vol. 15, pp. 25—47, 1927.
165. Close, R. N., and M. T. Lebenbaum: "Design of Phantastron Time-Delay Circuits," *Electronics*, vol. 21, pp. 100—107, April 1948.
166. Cochran, D., and R. W. Samsel: "Ultrasonics—A Method of Determining the Acoustic Properties, Absorption and Velocity, for Materials to be Used as Ultrasonic Windows, Lenses, and Reflectors," *Gen. Elec. Rev.*, vol. 47, pp. 39—41, 1944.
167. Cocking, W. T.: "Linear Saw-Tooth Oscillator," *W. World*, vol. 52, pp. 176—178, June 1946.
168. Colby, M. Y., and S. Harris: "An X-ray Study of a Long X-cut Quartz Crystal Vibrating Under the Transverse Piezoelectric Effect," *Phys. Rev.*, vol. 46, pp. 445—450, 1934.
169. Colby, M. Y., and S. Harris: "Effect of Etching on the Relative Intensities of the Companents of Double Laue Spots Obtained from a Quartz Crystal," *Phys. Rev.*, vol. 43, pp. 562—563, 1933.
170. Colebrook, F. M.: "A Theoretical and Experimental Investigation of High Selectivity Tone-corrected Receiving Circuits," *Radio Res. Board, Nat. Phys. Lab., Spec. Rept. 12*, London, 1932.
171. Compton, A. H., and S. K. Allison: *X-rays in Theory and Experiment*, D. Van Nostrand, pp. 340—346, New York, 1935.
172. Cook, R. K.: "Absolute Pressure Calibrations of Microphones" (use of tourmaline disk), *Bur. Standards Jour. Research*, vol. 25, pp. 489—505, 1940.
173. Cooke, W. T.: "The Variation of the Internal Friction and Elastic Constants with Magnetization in Iron, Part I," *Phys. Rev.*, vol. 50, pp. 1158—1164, 1936.
174. Cork, J. M.: Laue Patterns from Thick Crystals at Rest and Oscillating Piezoelectrically," *Phys. Rev.*, vol. 42, pp. 749—752, 1932.
175. Cortez, S. H.: "Interferometer Method for Measuring the Amplitude of Vibration of Quartz Bar Crystals," *J.O.S.A.*, vol. 24, pp. 127—129, 1934; erratum, vol. 24, p. 194, 1934.
176. Coursey, R.: *Electrical Condensers*, Pitman, London, 1927.
177. Crain, H. M.: "Low-Frequency Discriminator," *Electronics*, vol. 22, pp. 96—97, June 1949.
178. Crandall, Irving B.: *Theory of Vibrating Systems and Sound*, D. Van Nostrand, New York, 1926, 272 pp.
179. Creighton, J. L., Lau, H. B., and R. J. Turner: "Crystal Oscillators and Their Application to Radio Transmitters Control," *J.I.E.E.*, vol. 94, part IIIA, No. 12, 1947.
180. Crosby, M. G.: "Communication by Phase Modulation," *Proc. I.R.E.*, vol. 27, pp. 126—136, 1939.
181. Crossley, A.: "Modes of Vibration in Piezoelectric Crystals," *Proc. I.R.E.*, vol. 16, pp. 416—423, 1928.
182. Crossley, A.: "Piezoelectric Crystal-controlled Transmitter," *Proc. I.R.E.*, vol. 15, pp. 9—36, 1927.
183. Dake, H. C., Fleener, F. L., and B. H. Wilson: *Quartz Family Minerals*, Whittlesey House, New York, 1938, 304 pp.
184. Dale, A. B.: *The Form and Properties of Crystals*, University Press, Cambridge, London, 1932, 186 pp.
185. Davey, Wheeler P.: *A Study of Crystal Structure and Its Applications*, McGraw-Hill, New York, 1934, 695 pp.
186. David, E. E., Jr.: "Some Aspects of RF Phase Control in Microwave Oscillators," Technical Report 100, June 11, 1949, Research Laboratory of Electronics, Masssachusetts Institute of Technology.
187. David, E. E., Jr.: "Locking Phenomena in Microwave Oscillators," Technical Report 63, April 8, 1948, Research Laboratory of Electronics, Massachusetts Institute of Technology.
188. Davies, R. M.: "On the Determination of Some of the Elastic Constants of Rochelle Salt by a Dynamical Method," *Phil. Mag.*, vol. 16, pp. 97—124, 1933.
189. Davis, K. H.: "Multivibrator Step-Down by Fractional Ratios," *Bell Lab. Record*, vol. 26, p. 114, March 1948.
190. Davy, N., Littlewood, J. H., and M. McCraig: "The Force-Time Law Governing the Impact of a Hammer on a Stretched String," *Phil. Mag.*, vol. 27, pp. 133—143, 1939.

191. Dawson, L. H.: "Piezoelectricity of Crystal Quartz," *Phys. Rev.*, vol. 29, pp. 532—541, 1927.
192. Day, J. R.: "Serrasoid F-M Modulator," *Electronics*, vol. 21, pp. 72—76, October 1948.
193. Debye, P., and F. W. Sears: "Scattering of Light by Supersonic Waves," *Proc. Nat. Acad. Sci.*, vol. 18, pp. 409—414, 1932.
194. Debye, P.: *Polar Molecules*, Chemical Catalog Company, Inc., New York, 1929, 172 pp.
195. De Lange, O. E.: "A Variable Phase-Shift Frequency-Modulated Oscillator," *Proc. I.R.E.*, vol. 37, pp. 1328—1330, 1949.
196. De Laup, S.: "Sine Waves in R-C Oscillators," *Electronics*, vol. 14, pp. 34—36, January 1941.
197. d'Heedene, A. R.: "Effects of Manufacturing Deviations on Crystal Units for Filters," refer to book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 458—492, 1946.
198. Doherty, R. E., and E. G. Keller: *Mathematics of Modern Engineering*, John Wiley, New York, 1936.
199. Doherty, W. H.: "Synchronized FM Transmitter," *F. M. Mag.*, vol. 1, pp. 21—25, December 1940.
200. Donal, J. S., and R. R. Bush: "A Spiral-Beam Method for the Amplitude Modulation of Magnetrons," *Proc. I.R.E.*, vol. 37, pp. 375—382, 1949.
201. Dow, J. B.: "A Recent Development in Vacuum-Tube Oscillator Circuits," *Proc. I.R.E.*, vol. 19, pp. 2095-2108, 1931.
202. Drews, W. F., and A. E. Swickard: "The Wire Mounted Crystal Unit," refer to book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 493—536, 1946.
203. Druesne, M. A. A.: "Quartz Crystals," *Communications*, vol. 23, pp. 46f., September 1943.
204. Dudley, B.: "Introduction to Transients," *Electronics*, vol. 17, p. 132, August 1944.
205. Dye, D. W.: "The Modes of Vibration of Quartz Piezoelectric Plates as Revealed by an Interferometer," *Proc. Roy. Soc.*, vol. 138, pp. 1—16, 1932.
206. Dye, D. W.: "Piezoelectric Quartz Resonator and Equivalent Electrical Circuit," *Proc. Ph. Soc.*, vol. 38, pp. 399—457; discussion, pp. 457—458, 1926.
207. Easton, A.: "Pulse-Modulated Oscillator," *Electronics*, vol. 20, pp. 124—129, March 1947.
208. Eastman, A. V.: *Fundamentals of Vacuum Tubes.*
209. Eccles, W. H., and W. A. Leyshon: "Some New Methods of Linking Mechanical and Electrical Vibrations," *Proc. Ph. Soc.*, vol. 40, pp. 229—232, 1928.
210. Eccles, W. H., and F. W. Jordan: "Trigger Relay," *Radio Rev.*, vol. 1, p. 143, October 1919.
211. Edson, W. A.: *Vacuum-Tube Oscillators*, John Wiley and Sons, New York, 1953, 476 pp.
212. Edson, W. A., *et al.:* "High Frequency Crystal-Controlled Oscillator Circuits," Final Report on Signal Corps Contract W36–039–sc—36841, Georgia Institute of Technology, State Engineering Experiment Station, Atlanta, Ga., December 1950.
213. Edson, W. A., *et al.:* "The Keying Properties of Quartz Crystal Oscillators," Final Report on Signal Corps Contract W36–039–sc—32100, Georgia Institute of Technology, State Engineering Experiment Station, Atlanta, Ga., December 1947.
214. Edson, W. A.: "Intermittent Behavior in Oscillators," *Bell Syst. T. J.*, vol. 24, pp. 1—22, 1945.
215. Edwards, C. M.: "A Precision Decade Oscillator for 20 Cycles to 200 Kilocycles," *Proc. I.R.E.*, vol. 39, pp. 277—378, 1951.
216. Ekstein, H.: "Free Vibrations of Anisotropic Bodies," *Phys. Rev.*, vol. 66, pp. 108—118, 1944.
217. Ellis, W. G.: "New Electrophones for High-fidelity Sound Reproduction," *Radio Eng.*, vol. 13, pp. 18f., October 1933.
218. Eltgroth, G. V.: "Frequency Stability of Tuned Circuits," *Electronics*, vol. 17, p. 118, February 1944.
219. Ervin, C. T.: "A Piezoelectric Gauge for Recording the Instantaneous Pressure in Shotguns," *Jour. Franklin Inst.*, vol. 213, pp. 503—514, 1932.
220. Espenschied, L.: "Quartz Crystals Used in Ladder Form Circuits to Obtain Band-pass Filters," Patent 1,795,204, filed January 3, 1927, issued August 8, 1933.
221. Espley, D. C.: "Harmonic Production and Cross Modulation in Thermionic Valves with Resistive Loads," *Proc. I.R.E.*, vol. 22, pp. 781—790, 1934.
222. Essen, L.: "A New Form of Frequency and Time Standard," *Proc. Ph. Soc.*, vol. 50, pp. 413—423; discussion, pp. 423—426, 1938.
223. Essen, L.: "The Dye Quartz Ring Oscillator as a Standard of Frequency and Time," *Proc. Roy. Soc.*, vol. 155, pp. 498—519, 1936.
224. Essen, L.: "International Frequency Comparisons by Means of Standard Radio-frequency Emissions," *Proc. Roy. Soc. (London)*, vol. 149, pp. 506—510, 1935.
225. Essen, L.: "Oscillations of Hollow Quartz Cylinders," *Nature*, vol. 135, p. 1076, 1935.
226. Essen, L.: "Examples of the Electrical Twinning of Quartz," *J. Sci. Instr.*, vol. 12, pp. 256—257, 1935.
227. Essen, L.: "Description of the Quartz Control of a Transmitter at 1785 Kilocycles per Second," *Proc. Wireless Sec. I.E.E.*, vol. 9, pp. 167—169, 1934.
228. Evans, R. C.: "The Dielectric Constant of Mixed Crystals of Sodium Ammonium and Sodium Potassium Tartrates," *Phil. Mag.*, vol. 24, pp. 70—79, 1937.
229. Everitt, W. L.: *Communication Engineering*, McGraw-Hill, New York, 2nd ed., 1937.
230. Everitt, W. L.: "Optimum Operating Conditions for Class C Amplifiers," *Proc. I.R.E.*, vol. 22, pp. 152-176, 1934.
231. Fair, I. E., Bell Telephone Laboratories: "Design Data on Crystal Controlled Oscillators" printed in *Information Bulletin on Quartz Crystal Units*, ASESA 52-9, Armed Services Electro Standards Agency, Fort Monmouth, N. J., pp. 1—21, August 1952.
232. Fair, I. E.: "Piezo Electric Crystals in Oscillator Circuits," *Bell System Tech. J.*, vol. 24, pp. 161—216, 1945; also printed in book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 356—411, 1946.
233. Fair, I. E.: "Using High Crystal Harmonics for Oscillator Control," *Bell Labs. Rec.*, vol. 21, pp. 237-242, 1943.
234. Federal Telephone and Radio Corp.: "Reference Data for Radio Engineers," New York, 2nd ed., 1946.
235. Fehr, R. O.: "Quartz-crystal Accelerometer," *Gen. Elec. Rev.*, vol. 45, pp. 269—272, 1942.
236. Feinberg, R.: "Symmetrical and Asymmetrical Multivibrators," *W. E.*, vol. 26, pp. 153—158 and 326—330, 1949.
237. Fischer, H. B.: "A Crystal Control Superheterodyne Receiver," *Bell Labs. Record*, vol. 11, pp. 273—278, 1933.
238. Fleming, L.: "Thermistor-Regulated Low-Frequency Oscillator," *Electronics*, vol. 19, pp. 97—99, October 1946.
239. Fleming-Williams, B. C.:"A Single-Valve Time-Base Circuit," *W. E.*, vol. 17, pp. 161—163, 1940.
240. Flint, W. A.: "New Double-crystal Band-pass Filters," *Electronics and Television and Short-wave World*, vol. 13, pp. 552—554, 1940.
241. Floyd, G. H.: "Vacuum Capacitors," *Proc. I.R.E.*, vol. 32, pp. 463—470, 1944.
242. Ford, J. R., and N. I. Korman: "Stability and Frequency Pulling of Loaded Unstabilized Oscillators," *Proc. I.R.E.*, vol. 34, pp. 794—799, 1946.
243. Fortescue, R. L.: "Quasi-Stable Frequency Dividing Circuits," *J.I.E.E.*, vol. 84, pp. 693—698, 1939.

244. Foster, D. E., and A. E. Newton: "Measurements of Iron Cores at Radio Frequencies," *Proc. I.R.E.*, vol. 29, pp. 266—276, 1941.
245. Foster, D. E., and S. W. Seeley: "Automatic Tuning, Simplified Circuits and Design Practice," *Proc. I.R.E.*, vol. 25, pp. 289—313, 1937.
246. Foster, R. M.: "A Reactance Theorem," *Bell Syst. T. J.*, vol. 3, pp. 259—269, 1924.
247. Fowler, R. H.:*Statistical Mechanics*, 2nd ed., Cambridge University Press, London, 1936, 864 pp.
248. Fowler, R. H.: "A Theory of the Rotations of Molecules in Solids and of the Dielectric Constants of Solid and Liquids," *Proc. Roy. Soc.*, vol. 149, pp. 1—28, 1935.
249. Fox, F. E., and G. D. Rock: "A Quartz Plate with Coupled Liquid Column as a Variable Resonator," *Proc. I.R.E.*, vol. 30, pp. 29—33, 1942.
250. Fox, F. E., and G. D. Rock: "Ultrasonic Absorption in Water," *Jour. Acous. Soc. Am.*, vol. 12, pp. 505-510, 1941.
251. Fox, F. E., and G. D. Rock: "An Ultrasonic Stroboscope for Measuring Sound Wave-Length in Liquids," *Rev. Sci. Instruments*, vol. 10, pp. 345—348, 1939.
252. Fox, F. E., and G. D. Rock: "An Ultrasonic Source of Improved Design: Optical Studies of Ultrasonic Waves in Liquids," *R.S.I.*, vol. 9, pp. 341-345, 1938.
253. Fox, F. E., and G. D. Rock: "The Ultrasonic Radiation Field of a Quartz Disk Radiating Into Liquid Media," *Phys. Rev.*, vol. 54, pp. 223—228, 1938.
254. Fox, F. E.: "Ultrasonic Interferometry for Liquid Media," *Phys. Rev.*, vol. 52, pp. 973—981, 1937.
255. Fox, G. W., and D. W. Stebbins: "Effect of Quartz Filters on the Distribution of Energy in Laue Patterns," *Phys. Rev.*, vol. 55, pp. 405—408, 1939.
256. Fox, G. W., and J. R. Frederick: "Further Study of X-ray Diffraction in Quartz," *Phys. Rev.*, vol. 53, pp. 135—136, 1938.
257. Fox, G. W., and W. A. Fraser: "X-ray Extinction in Piezoelectrically Oscillating Crystals," *Phys. Rev.*, vol. 47, pp. 899—902, 1935.
258. Fox, G. W., and G. A. Fink: "The Piezoelectric Properties of Quartz and Tourmaline," *Physics*, vol. 5, pp. 302—306, 1934.
259. Fox, G. W., and M. Underwood: "On the Piezoelectric Properties of Tourmaline," *Physics*, vol. 4, pp. 10-13, 1933.
260. Fox, G. W., and W. G. Hutton: "Experimental Study of Parallel-cut Piezoelectric Quartz Plates," *Physics*, vol. 2, pp. 443—447, 1932.
261. Fox, G. W., and P. H. Carr: "The Effect of Piezoelectric Oscillation on the Intensity of X-ray Reflections from Quartz," *Phys. Rev.*, vol. 37, pp. 1622-1625, 1931.
262. Fox, G. W., and J. M. Cork: "Regular Reflection of X-rays from Quartz Crystals Oscillating Piezoelectrically," *Phys. Rev.*, vol. 38, pp. 1420—1423, 1931.
263. Frayne, J. G.: "Reversible Inductivity of Rochelle Salt Crystals," *Phys. Rev.*, vol. 21, pp. 348—359, 1923.
264. Freehafer, J. E.: "Supersonic Vibrations," *Newark Eng. Notes*, vol. 5, no. 1, pp. 18—19, December 1941.
265. Freeman, R. L.: "Improvements in AFC Circuits," *Electronics*, vol. 9, pp. 20—23, November 1936.
266. Frink, F. W.: "The Basic Principles of Superrengerative Reception," *Proc. I.R.E.*, vol. 26, pp. 76—107, 1938.
267. Frommer, J. C.: "A Graphical Method to Find the Optimal Operating Conditions of Triodes as Class C Telegraph Transmitters," *Proc. I.R.E.*, vol. 30, pp. 519—525, 1942.
268. Frondel, C.: "History of the Quartz Oscillator-plate Industry," pp. 205—213, "Final Frequency Adjustment of Quartz Oscillator-plates," pp. 416—431, "Effect of Radiation on the Elasticity of Quartz," pp. 432—446, "Secondary Dauphiné Twinning in Quartz," pp. 447—460, *A. Min.*, vol. 30, May-June 1945.
269. Furst, U. R.: "Harmonic Analysis of Overbiased Amplifiers," *Electronics*, vol. 17, pp. 143—144, March 1944.
270. Fyler, G. W.: "Parasites and Instability in Radio Transmitters," *Proc. I.R.E.*, vol. 23, pp. 985—1012, 1935.
271. Gager, F. M., and J. B. Russell, Jr.: "A Quantitative Study of the Dynatron," *Proc. I.R.E.*, vol. 23, pp. 1536—1566, 1935.
272. Galitzin, B.: "Apparatus for Direct Determination of Accelerations," *Proc. Roy. Soc. (London)*, vol. 95, p. 492, 1919.
273. Gardiner, E. L.: "Crystal Band-pass Filters," *Wireless World and Radio Rev. (London)*, vol. 43, pp. 382-384, 407—408, 447—448, 463—464, 1938; *T. and R. Bull. (London)*, vol. 15, pp. 75—79, 141—144, 178-179, 213—216, 251—253, 1939.
274. Gardner, M. F., and J. L. Barnes: *Transients in Linear Systems*, vol. I, John Wiley, New York, 1942.
275. George, W. D., Selby, M. C., and R. Scolnik: "Precision Measurement of Electrical Characteristics of Quartz-Crystal Units," *Proc. I.R.E.*, vol. 36, pp. 1122-1131, 1948.
276. George, W. D.: "Production of Accurate One-second Time Intervals," *Jour Research Nat. Bur. Standards*, vol. 21, pp. 367—373, 1938.
277. Gerber, E. A., and H. P. Wasshausen: "High Frequency Crystals for Frequency Control—Lapping and Polishing Methods," Report No. E-1080, Sig. Corps Engineering Laboratories, Fort Monmouth, N. J., September 25, 1951.
278. Gentile AF Depot: "Crystal Handbook for Equipment Using FT-164 Crystal Holder (Unit)," HB-16F-1, April 30, 1953; "Crystal Handbook for Equipments Using AR-3 Crystal Holder (Unit)," HB-16F-2, April 13, 1953; "Crystal Handbook for Equipments Using FT-243 Crystal Holder (Unit)," HB-16F-3, May 22, 1953.
279. Gibbs, R. E., and L. C. Tsien: "The Production of Piezoelectricity by Torsion," *Phil. Mag.*, vol. 22, pp. 311—322, 1936.
280. Gibbs, R. E., and V. N. Thatte: "Temperature Variation of the Frequency of Piezoelectric Oscillations of Quartz," *Phil. Mag.*, vol. 14, pp. 682—694, 1932.
281. Gibbs, R. E.: "Structure of Alpha Quartz, "*Proc. Roy. Soc.*, vol. 110, pp. 443—455, 1926.
282. Ginzton, E. L., and L. M. Hollingsworth: "Phase-Shift Oscillators," *Proc. I.R.E.*, vol. 29, pp. 43—49, 1941; also corrections, vol. 32, p. 641, 1944.
283. Gladwin, A. S.: "Oscillation Amplitude in Simple Valve Oscillators," *W. E.*, vol. 26, pp. 159—170 and 201—209, 1949.
284. Glasoe, G. N., and J. V. Lebacqz: *Pulse Generators*, McGraw-Hill, New York, 1948.
285. Glegg, K.: "Cathode-Coupled Multivibrator Operation," *Proc. I.R.E.*, vol. 38, pp. 655—675, 1950.
286. Glucksman, H. A.: "Superregeneration—An Analysis of the Linear Mode," *Proc. I.R.E.*, vol. 37, pp. 500-504, 1949.
287. Golay, M. J. E.: "A Rochelle Salt Electrometer," *R.S.I.*, vol. 8, pp. 228—230, July 1937.
288. Goldsmith, F. H.: "A Noise and Wear Reducing Phonograph Reproducer with Controlled Response," *Jour. Acous. Soc. Am.*, vol. 13, pp. 281—283, 1942.
289. Goldsmith, P., *et al.*, Armour Research Foundation of Illinois Institute of Technology: "Investigation of Oscillator Circuits for AN/ARC-22," Air Force Contract AF 18(600)-157, Final Report, June 22, 1953.
290. Good, W. A.: "Rigidity Modulus of Beta-brass Single Crystals," *Phys. Rev.*, vol. 60, pp. 605—609, 1941.

291. Gordon, J. F.: "A New Angular-Velocity-Modulation System Employing Pulse Techniques," *Proc. I.R.E.*, vol. 34, pp. 328—334, 1946.
292. Gordon, S. G.: "The Inspection and Grading of Quartz," *A. Min.*, vol. 30, pp. 269—290, May-June 1945.
293. Gordon, S. G., and W. Parrish: "Cutting Schemes for Quartz Crystal," *A. Min.*, vol. 30, pp. 347—370, May-June 1945.
294. Goss F. A.: "Division of Metal Plating by Stylus," Patent 2,302,024.
295. Gouriet, G. G.: "High Stability Oscillator," *W. E.*, vol. 27, pp. 105—112, 1950.
296. Grant, K.: "High-frequency Interruption of Light," *Nature*, vol. 120, p. 586, 1927.
298. Gravley, C. K.: "An Instrument for Measuring Surface Roughness," *Electronics*, vol. 15, pp. 70—73, 1942.
299. Greenidge, R. M. C.: "The Mounting and Fabrication of Plated Quartz Crystal Units," *Bell Syst. T. J.*, vol. 23, pp. 234—259, 1944; also printed in book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 412—435, 1946.
300. Griffiths, W. H. F.: "Recent Improvements in Air Cored Inductances," *W. E.*, vol. 19, pp. 8—19 and 56—63, 1942.
301. Griffiths, W. H. F.: "The Temperature Compensation of Condensers," *W. E.*, vol. 19, pp. 101—111 and 148—157, 1942.
302. Grime, G., and J. E. Eaton: "Determination of Young's Modulus by Flexural Vibrations," *Phil. Mag.*, vol. 23, pp. 96—99, 1937.
303. Groszkowski, J.: "The Temperature Coefficient of Inductance," *Proc. I.R.E.*, vol. 25, pp. 448—464, 1937.
304. Groszkowski, J.: "Oscillators with Automatic Control of the Threshold of Regeneration," *Proc. I.R.E.*, vol. 22, pp. 145—151, 1934.
305. Groszkowski, J.: "The Interdependence of Frequency Variation and Harmonic Content, and the Problem of Constant-Frequency Oscillators," *Proc. I.R.E.*, vol. 21, pp. 958—981, 1933.
306. Groszkowski, J.: "Frequency Division," *Proc. I.R.E.*, vol. 18, pp. 1960—1970, 1930.
307. Groth, E. J., and L. N. Liebermann: "Precision Measurement of the Velocity of Sound at Supersonic Frequencies Using a Microphone" (abstr.), *Phys. Rev.*, vol. 65, p. 350, 1944.
308. Gruen, H. E., and E. A. Roberts, Armour Research Foundation of Illinois Institute of Technology: "Feasibility Study for Package Oscillator Design."
309. Guillemin, E. A.: *Communication Networks*, vol. I, John Wiley, New York, 1931.
310. Guillemin, E. A., and P. T. Rumsey: "Frequency Multiplication by Shock Excitation," *Proc. I.R.E.*, vol. 17, pp. 629—651, 1929.
311. Gunn, R.: "A New Frequency-Stabilized Oscillator System," *Proc. I.R.E.*, vol. 18, pp. 1560—1574, 1930.
312. Hall, E. L., Heaton, V. E., and E. G. Lapham: "The National Primary Standard of Radio Frequency," *Jour. Research Nat. Bur. Standards*, vol. 14, pp. 85—98, 1935.
313. Harding, J. W., and F. W. G. White: "On the Modes of Vibration of a Quartz Crystal," *Phil. Mag.*, vol. 8, pp. 169—179, 1929.
314. Harnwell, G. P., and J. B. H. Kuper: "A Laboratory Frequency Standard," *Rev. Sci. Instruments*, vol. 8, pp. 83—86, 1937.
315. Harries, J. H. O.: "Apertures in Cavities," *Electronics*, vol. 19, pp. 132—135, December 1946.
316. Harris, W. A.: "Space-Charge Limited Current Fluctuations in Vacuum-Tube Amplifiers and Input Systems," *R.C.A. Rev.*, vol. 5, pp. 505—524, 1941.
317. Harrison, A. E., and N. W. Mather: "Graphical Analysis of Tuned Coupled Circuits," *Proc. I.R.E.*, vol. 37, pp. 1015—1020, 1949.
318. Harrison, C. W.: "The Measurement of the Performance Index of Quartz Plates," refer to book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 458—492, 1946.
319. Harrison, J. R., and I. P. Hooper: "The Striated Luminous Glow of the Piezoelectric Quartz Resonator at Flexural Vibration Frequencies," *Phys. Rev.*, vol. 55, p. 674, 1939.
320. Harrison, J. R.: "Push-pull Piezoelectric Oscillator Circuits," *Proc. I.R.E.*, vol. 18, pp. 95—100, 1930.
321. Harrison, J. R.: "Piezoelectric Oscillator Circuits with Four-electrode Tubes," *Proc. I.R.E.*, vol. 16, pp. 1455—1467, 1928; discussion, pp. 1467—1470.
322. Harrison, J. R.: "Piezoelectric Resonance and Oscillatory Phenomena with Flexural Vibrations in Quartz Plates," *Proc. I.R.E.*, vol. 15, pp. 1040—1054, 1927.
323. Hartley, J. J., and R. H. Rinaldi: "Demonstration of the Application of Piezoelectric Properties of a Rochelle Salt Crystal and the Three-electrode Valve to the Determination of Impact Stresses in Granular Material," *Proc. Phys. Soc. (London)*, vol. 38, p. 273, 1926.
324. Hartley, R. V. L.: "Oscillations in Systems with Nonlinear Reactance," *Bell Syst. T. J.*, vol. 15, pp. 424—440, 1936.
325. Haynes, J. R.: "Apparatus for the Direct Measurement of Force/Displacement Characteristics of Mechanical Systems at Audio-frequencies," *Jour. Acous. Soc. Am.*, vol. 13, p. 332, 1942.
326. Hazeltine, A., Richman, D., and B. D. Laughlin: "Superregenerator Design," *Electronics*, vol. 21, pp. 95—102, September 1948.
327. Healy, C. P., and J. C. Niven: "Mould and Humidity in Radio and Signals Equipment," *Proc. I.R.E.*, vol. 33, pp. 300—306, 1945.
328. Heaton, V. E., and E. G. Lapham: "Quartz Plate Mountings and Temperature Control for Piezo Oscillators," *Proc. I.R.E.*, vol. 20, pp. 261—271, 1932; discussion, p. 1064; *J. Res. N.B.S.*, vol. 7, pp. 683—690, 1931.
329. Hedeman, W. R.: "Few Crystals Control Many Channels," *Electronics*, vol. 21, pp. 118—121, March 1948.
330. Heising, R. A.: *Quartz Crystals for Elect[illegible]ts*, D. Van Nostrand, New York, 1946.
331. Heising, R. A.: "Stability in High Freq[illegible]il-lators," *Proc. I.R.E.*, vol. 31, pp. 595—60[illegible]
332. Heising, R. A.: "The Audion Oscillator," *Phys. Rev.*, vol. 16, pp. 216—237, 1920.
333. Heldt, P. M.: "Piezoelectric Indicators," *Automotive Ind.*, vol. 70, pp. 657—658 and 660, 1934.
334. Henderson, J. T.: "Properties of Tourmaline Crystals Used as Piezoelectric Resonators," *Trans. Roy. Soc. Can.*, vol. 22, pp. 127—131, 1928.
335. Herget, C. M.: "A Constant Path Acoustic Interferometer for Gases at Variable Pressure," *Rev. Sci. Instruments*, vol. 11, pp. 37—39, 1940.
336. Herold, E. W.: "Negative Resistance and Devices for Obtaining It," *Proc. I.R.E.*, vol. 23, pp. 1201—1223, 1935.
337. Hershberger, W. D., and L. E. Norton: "Frequency Stabilization with Microwave Spectral Lines," *R.C.A. Rev.*, vol. 9, pp. 38—49, 1948.
338. Hight, S. C., and G. W. Willard: "A Simplified Circuit for Frequency Sub-standards Employing a New Type of Low-frequency Zero-temperature-coefficient Quartz Crystal," *Proc. I.R.E.*, vol. 25, pp. 549—563, 1937.
339. Hight, S. C.: "Quartz Plates for Frequency Sub-standards," *Bell La[illegible] Rec.*, vol. 16, pp. 21—25, 1937.
340. Hight, S. C.: "Wind from Quartz Crystals," *Bell Labs. Rec.*, vol. 14, pp. 121—123, 1935.

341. Hinton, W. R.: "The Design of R-C Oscillator Phase-Shifting Networks," *Electronic Eng.*, vol. 22, pp. 13-17, 1950.
342. Hitchcock, R. C.: "The Dimensions of Low-frequency Quartz Oscillators," *R.S.I.*, vol. 1, pp. 13—21, 1930.
343. Holden, A. N., and W. P. Mason: "Constants of Heavy-water Rochelle Salt," *Phys. Rev.*, vol. 57, pp. 54—56, 1940.
344. Holton, G. J.: "Rodometric Examination of Quartz Crystals," *Electronics*, vol. 17, pp. 114f., 1944.
345. Holubow, H.: "DC Saturable Reactors for Control Purposes," *Electronic Ind.*, vol. 4, pp. 76—79, March 1943.
346. Honess, A. P.: *The Nature, Origin and Interpretation of the Etch Figures on Crystals*, John Wiley & Sons, Inc., New York 1927, 171 pp.
347. Hopper, A. L., and S. E. Miller: "Considerations in the Design of a Radar Intermediate-Frequency Amplifier," *Proc. I.R.E.*, vol. 35, pp. 1208—1220, 1947.
348. Horton, J. W., and W. A. Marrison: "Precision Determination of Frequency," *Proc. I.R.E.*, vol. 16, pp. 137—154, 1928.
349. Horton, J. W.: "Vacuum-Tube Oscillators," *Bell Syst. T. J.*, vol. 3, pp. 508—524, 1924.
350. Houstoun, R. A.: "The Ultrasonic Diffraction Grating," *Phil. Mag.*, vol. 35, pp. 192—202, March 1944.
351. Houstoun, R. A.: "A New Method of Measuring the Velocity of Light" (Fizeau's method, using quartz crystal), *Nature*, vol. 142, p. 833, 1938; see also *Proc. Roy. Soc. Edinburgh*, A, vol. 61, pp. 102—114, 1941, vol. 62, pp. 58—63, 1943—1944, and *Phil. Mag.*, vol. 35, pp. 192—202, 1944.
352. Hovgaard, O. M.: "Application of Quartz Plates to Radio Transmitters," *Proc. I.R.E.*, vol. 20, pp. 767-782, 1932.
353. Howe, G. W. O.: "Natural and Resonant Frequencies of Coupled Circuits," *W. E.*, vol. 18, pp. 221—223, 1941.
354. Hubbard, J. C.: "Sound Velocity and Absorption by Ultrasonic Interferometry," *Phys. Rev.*, vol. 59, p. 935, 1941.
355. Hubbard, J. C.: "Ultrasonics—A Survey," *Am. Jour. Phys.*, vol. 8, pp. 207—221, 1940.
356. Hubbard, J. C., and I. F. Zartman: "A Fixed Path Acoustic Interferometer for the Study of Matter," *Rev. Sci. Instruments*, vol. 10, pp. 382—386, 1939.
357. Hubbard, J. C.: "The Crevasse Phenomenon in Piezoelectric Quartz and Its Application in Physical Measurements" (ultramicrometer), *Jour. Acous. Soc. Am.*, vol. 10, pp. 87—88, 1938.
358. Hubbard, J. C.: "The Acoustic Resonator Interferometer, I," *Phys. Rev.*, vol. 38, pp. 1011—1019, 1931; II, *Phys. Rev.*, vol. 41, pp. 523—535, 1932; *errata*, vol. 46, p. 525, 1934.
359. Huggins, W. H.: *The Potential Analogue in Network Synthesis and Analysis*, Publication E 5066, Air Force Cambridge Research Laboratories, Cambridge, Mass., March 1951.
360. Huggins, W. H.: "Multifrequency Bunching in Reflex Klystrons," *Proc. I.R.E.*, vol. 35, p. 1518, 1947.
361. Hull, G. F.: "Some Applications of Physics to Ordnance Problems," *Jour. Franklin Inst.*, vol. 192, pp. 327—347, 1921.
362. Hull, A. W.: "The Dynatron, a Vacuum Tube Possessing Negative Resistance," *Proc. I.R.E.*, vol. 6, pp. 5—36, 1918.
363. Hund, A.: "Reactance Tubes in Frequency Modulation Applications," *Electronics*, vol. 15, p. 68, October 1942.
364. Hund, A.: *Frequency Modulation*, McGraw-Hill, New York, 1942.
365. Hund, A.: *High-frequency Measurements*," McGraw-Hill, New York, 1933, 491 pp.
366. Hund, A., and R. B. Wright: "New Piezo-oscillations with Quartz Cylinders Cut Along the Optical Axis," *Proc. I.R.E.*, vol. 18, pp. 741—761, 1930; *J. Res. N.B.S.*, vol. 4, pp. 383—394, 1930.
367. Hund, A.: "Note on a Piezoelectric Generator for Audiofrequencies," *J. Res. N.B.S.*, vol. 2, pp. 355-358, 1929.
368. Hund, A.: "Generator for Audio Currents of Adjustable Frequency with Piezoelectric Stabilization," *Sci. Pap. Bur. St.*, vol. 22, pp. 631—637, 1928 (No. 569).
369. Hund, A.: "Notes on Quartz Plates, Air Gap Effect and Audio-frequency Generation," *Proc. I.R.E.*, vol. 16, pp. 1072—1078, 1928.
370. Hund, A.: "Uses and Possibilities of Piezoelectric Oscillators," *Proc. I.R.E.*, vol. 14, pp. 447—469, 1926.
371. Hunter, L., and S. Siegel: "The Variation with Temperature of the Principal Elastic Moduli of NaCl Near the Melting Point," *Phys. Rev.*, vol. 61, pp. 84-90, 1942.
372. Huntoon, R. D., and A. Weiss: "Synchronization of Oscillators," *Proc. I.R.E.*, vol. 35, pp. 1415—1423, 1947.
373. Hussey, L. W., and L. R. Wrathall: "Oscillations in an Electromechanical System," *Bell Syst. T. J.*, vol. 15, pp. 441—445, 1936.
374. Ide, J. M.: "Some Dynamic Methods for Determination of Young's Modulus," *Rev. Sci. Instruments*, vol. 6, pp. 296—298, 1935.
375. Ide, J. M.: "Magnetostrictive Alloys with Low Temperature Coefficients of Frequency," *Proc. I.R.E.*, vol. 22, pp. 177—190, 1934.
376. "International Critical Tables," vol. 6, pp. 207—212, *Electroelastic and Pyroelectric Phenomena*, McGraw-Hill, New York, 1929.
377. I.R.E.: *Standards on Piezoelectric Crystals, Recommended Terminology*, 1945.
378. I.R.E.: "Proposed Standard Conventions for Expressing the Elastic and Piezoelectric Properties of Right and Left Quartz," *Proc. I.R.E.*, p. 495, November 1942.
379. Iseley, F. C.: "The Relation Between the Mechanical and Piezoelectrical Properties of a Rochelle Salt Crystal," *Phys. Rev.*, vol. 24, pp. 569—574, 1924.
380. Ives, R. L.: "The Relay Oscillator and Related Devices," *J. Frank. Inst.*, vol. 242, pp. 243—277, 1946.
381. Jackson, C. H.: "Development of an Improved Crystal Exciter Unit," *Civil Aeronautics Authority (U.S.A.), Tech., Development Rept.*, 26, pp. 1—14, July 1940.
382. Jacobsen: "Effect of Shear on the Flexure Frequencies of Beams," *Jour. Applied Mechanics*, March 1938.
383. Jaderholm, H. W.: "Iron Powder Cores and Coils," *Proc. I.R.E.*, vol. 33, p. 904, 1945.
384. Jaffee, H.: "Crystalline Transitions and Dielectric Constant" (abst.), *Phys. Rev.*, vol. 53, p. 917, 1938.
385. Jaffee, H.: "Polymorphism of Rochelle Salt," *Phys. Rev.*, vol. 51, pp. 43—47, 1937.
386. Jauncey, G. E. M., and W. A. Bruce: "Diffuse Scattering of X-rays from Piezoelectrically Oscillating Quartz," *Phys. Rev.*, vol. 54, pp. 163—165, 1938.
387. Jefferson, H.: "The Pierce Piezoelectric Oscillator," *W. E.*, vol. 18, pp. 232—237, 1941.
388. Jefferson, H.: "Stabilization of Feedback Oscillators," *W. E.*, vol. 22, pp. 384—389, 1945.
389. Jeffree, J. H.: "The Scophony Light Control," *Television and Short-wave World*, vol. 9, pp. 260f., 1936; see also Brit. patent 439,236 (1934).
390. Joffé, A. F.: *The Physics of Crystals*, 1st ed., McGraw-Hill, New York, 1928, 198 pp.
391. Johnson, J. B.: "Thermal Agitation of Electricity in Conductors," *Phys. Rev.*, vol. 32, pp. 97—109, 1928.
392. Johnson, K. C.: "Single-Valve Frequency-Modulated Oscillator," *W. E.*, vol. 55, pp. 122—123 and 168—170, 1949.

393. Johnson, R. W.: "Extending the Frequency Range of the Phase-Shift Oscillator," *Proc. I.R.E.*, vol. 33, pp. 597—602, 1945.
394. Johnson, W. C.: *Mathematical and Physical Principles of Engineering Analysis*, McGraw-Hill, New York, 1944.
395. Kakiuchi, Y.: "The Increase of X-ray Reflection from Quartz Due to a Strong Electric Field," *Phys. Rev.*, vol. 54, p. 772, 1938.
396. Kalmus, H. P.: "Some Notes on Superregeneration with Particular Emphasis on Its Possibilities for Frequency Modulation," *Proc. I.R.E.*, vol. 32, pp. 591—600, 1944.
397. Kammer, E. W., and J. V. Atanasoff: "A Determination of the Elastic Constants of Beta-quartz," *Phys. Rev.*, vol. 62, pp. 395—400, 1942.
398. Kantor, M.: "Theory and Design of Progressive and Ordinary Universal Windings," *Proc. I.R.E.*, vol. 35, pp. 1563—1570, 1947.
399. Kao, P. T.: "Relaxation Oscillations Produced by a Quartz Piezoelectric Oscillator," *C. R.*, vol. 191, pp. 932—934, 1930.
400. Karcher, J. C.: "A Piezoelectric Method for the Instantaneous Measurement of High Pressures," *Sci. Pap. Bur. St.*, vol. 18, pp. 257—264, 1922 (No. 445); *J. Frank. Inst.*, vol. 194, pp. 815—816 (abst.), 1922.
401. Keall, O. E.: "Analysis of Bridge Circuit for Piezoelectric Quartz Resonators," *Marconi Rev.*, No. 59, pp. 19—29, March-April 1936.
402. Keithley, J. F.: "Low-Frequency Oscillator," *Electronics*, vol. 21, pp. 108—109, September 1948.
403. Keller, E. G.: "Analytical Methods of Solving Discrete Nonlinear Problems in Electrical Engineering," *Trans. A.I.E.E.*, vol. 60, pp. 1194—1200, 1941.
404. Kellogg, J. B. M., and S. Millman: "Molecular Beam Magnetic Resonance Method," *Rev. Mod. Phys.*, vol. 18, pp. 323—352, 1946.
405. Kelvin, Lord: *Baltimore Lectures*, C. J. Clay & Sons, London, 1904.
406. Kelvin, Lord: "On the Piezoelectric Property of Quartz," *Phil. Mag.*, vol. 36, pp. 331, 342, 384, 453, 1893.
407. Kelvin, Lord: *Mathematical and Physical Papers*, vol. 5, Cambridge University Press, London, 1911; *Phil. Mag.*, vol. 36, pp. 331, 342, 384, 414, 453, 1893.
408. Keys, D. A.: "Adiabatic and Isothermal Piezoelectric Constants of Tourmaline," *Phil. Mag.*, vol. 46, pp. 999—1001, 1923.
409. Keys, D. A.: "Piezoelectric Method of Measuring Explosion Pressures," *Phil. Mag.*, vol. 42, pp. 473—488, 1921.
410. Kiebert, M. V., and A. F. Inglis: "Multivibrator Circuits," *Proc. I.R.E.*, vol. 33, pp. 534—539, 1945.
411. Kilgore, G. R., Shulman, C. I., and J. Kurshan: "A Frequency Modulated Magnetron for Super-High Frequencies," *Proc. I.R.E.*, vol. 35, pp. 657—664, 1947.
412. Kimbark, E. W.: "Electrical Transmission of Power and Signals," John Wiley, New York, 1949.
413. Kingston, R. H.: "Resonant Circuits with Time-Varying Parameters," *Proc. I.R.E.*, vol. 37, pp. 1478—1481, 1949.
414. Kinn, T. P.: "Vacuum-Tube Radio-Frequency-Generator Characteristics and Application to Induction Heating Problems," *Proc. I.R.E.*, vol. 33, pp. 640—657, 1945.
415. Kinzer, J. P., and I. G. Wilson: "Some Results on Cylindrical Cavity Resonators," *Bell Syst. T. J.*, vol. 26, pp. 410—445, 1947.
416. Kirby, T.: "Twin Oscillator," *Electronics*, vol. 22, p. 170, October 1949.
417. Kishpaugh, A. W., and R. E. Coram: "Low Power Radio Transmitters for Broadcast Requirements for 100 to 1000 Watts," *Proc. I.R.E.*, vol. 21, pp. 212—227, 1933.
418. Klingaman, G. W., and G. H. Williams: "Shielding of Dielectric Heating Installations," *Electronics*, vol. 18, pp. 106—109, May 1945.
419. Knox, R. E.: "The Use of Quartz Crystals in Wave Filters," *Electronics*, vol. 13, pp. 78f., November 1940.
420. Koga, I.: "Equivalence of Two Piezoelectric Oscillating Quartz Crystals of Symmetrical Outlines with Respect to a Plane Perpendicular to an Electrical Axis," *Phil. Mag.*, vol. 27, pp. 640—643, 1939.
421. Koga, I.: "Young's Modulus of a Crystal in Any Direction," *Proc. I.R.E.*, vol. 24, pp. 532—533, 1936.
422. Koga, I.: "Notes on Piezoelectric Quartz Crystals," *Proc. I.R.E.*, vol. 24, pp. 510—531, 1936.
423. Koga, I.: "Thermal Characteristics of Piezoelectric Oscillating Quartz Plates," *U.R.S.I. Gen. Assembly, Document 33, Comm. I*, London, 1934.
424. Koga, I.: "Vibration of Piezoelectric Oscillating Crystal," *Phil. Mag.*, vol. 16, pp. 275—283, 1933.
425. Koga, I.: "Note on the Piezoelectric Quartz Oscillating Crystal Regarded from the Principle of Similitude," *Proc. I.R.E.*, vol. 19, pp. 1022—1023, 1931.
426. Koga, I.: "Characteristics of Piezo-Electric Quartz Oscillators," *Proc. I.R.E.*, vol. 18, pp. 1935—1959, 1930.
428. Kryloff, N., and N. Bogoliuboff: *Introduction to Non-Linear Mechanics*," Princeton University Press, 1943.
429. Kunz, K. S.: "Bilinear Transformations Applied to the Tuning of the Output Network of a Transmitter," *Proc. I.R.E.*, vol. 37, pp. 1211—1217, 1949.
430. Kurtz, E. B., and G. F. Corcoran: *Introduction to Electric Transients*," John Wiley, New York, 1935.
431. Kusunose, Y., and S. Ishikawa: "Frequency Stabilization of Radio Transmitters," *Proc. I.R.E.*, vol. 20, pp. 310—339, 1932.
432. Labaw, L. W.: "Wave Front Determination in a Supersonic Beam" (abst.), *Phys. Rev.*, vol. 66, p. 354, 1944.
433. Lack, F. R., Willard, G. W., and I. E. Fair: "Some Improvements in Quartz Crystal Circuit Elements," *Bell Syst. T. J.*, vol. 13, pp. 453—463, 1934.
434. Lack, F. R.: "Observations on Modes of Vibration and Temperature-coefficients of Quartz Crystal Plates," *Proc. I.R.E.*, vol. 17, pp. 1123—1141, 1929; *Bell Syst. T. J.*, vol. 8, pp. 515—535, 1929.
435. Ladner, A. W., and C. R. Stoner: *Short-Wave Wireless Communication*, John Wiley, New York, 5th ed., 1950.
436. Lamb, Horace: *The Dynamical Theory of Sound*, Edward Arnold & Co., London, 1910, 303 pp.
437. Lampkin, G. F.: "An Improvement in Constant Frequency Oscillators," *Proc. I.R.E.*, vol. 27, pp. 199—201, 1939.
439. Lamb, J. J.: "A New I.F. Coupling System for Superhet Receivers," *QST*, vol. 21, pp. 28—30, April 1937.
440. Lamb, J. J.: "A Practical Survey of Pentode and Beam Tube Crystal Oscillators for Fundamental and Second Harmonic Output," *QST*, vol. 21, pp. 31—38, pp. 106, 107, April 1937.
441. Lamb, J. J.: "Receiver Selectivity Characteristics," *QST*, vol. 19, pp. 37—41, May 1935.
442. Lamb, J. J.: "Tritet Multi-band Crystal Control, *QST*, vol. 17, pp. 9—15, October 1933.
443. Lamb, J. J.: "A More Stable Crystal Oscillator of High Harmonic Output," *QST*, vol. 17, pp. 30—32, June 1933.
444. Lamb, J. J.: "Developments in Crystal Filters for S-S Superhets," *QST*, vol. 17, pp. 21—24, November 1933.
445. Lamb, J. J.: "Short-wave Receiver Selectivity to Match Present Conditions," *QST*, vol. 16, pp. 9—20, 90, August 1932.

446. Lane, C. E.: "Duplex Crystals," *Bell Lab. Record*, vol. 24, pp. 59—62, 1946.

447. Lane, C. E.: "Crystal Channel Filters for Carrier Cable Systems," *Bell Syst. T. J.*, vol. XVII, p. 125.

448. Lane, C. E.: "Limitations in Band Filter Design," *Bell Labs. Record*, vol. 16, pp. 56—61, October 1937.

449. Lane, C. T.: "Magnetic Properties of Rochelle Salt," *Phys. Rev.*, vol. 45, p. 66, 1934.

450. Langer, R. M.: "Passage of X-rays through Oscillating Crystals," *Phys. Rev.* (abstract), vol. 49, p. 206, 1936.

451. Langer, R. M.: "X-ray Reflections from Oscillating Crystals," *Phys. Rev.*, vol. 38, pp. 573—574, 1931.

452. Larmor, J.: "Electro-crystalline Properties as Conditioned by Atomic Lattices," *Proc. Roy. Soc.*, vol. 99, pp. 1—10, 1921.

453. Last, E.: "Blocking Oscillator," *Electronics*, vol. 18, p. 184, October 1945.

454. Law, H. B., and F. J. M. Laver: "Measurements of the Dependence of the Frequencies of Some 100 Kc/s Quartz Crystal Units on Their Amplitude of Vibration," *P.O.E.D.*, Radio Report No. 1830, December 1948.

455. Lawson, H. W.: "Precision Tuning Fork with Vacuum-Tube Drive," *Gen. Radio Expt.*, vol. 20, pp. 1—5, September 1945.

456. Lawson, A. W., and P. H. Miller, Jr.: "Piezometer for Transient Pressures (crystals of tartaric acid, tourmaline, and sucrose)," *Rev. Sci. Instruments*, vol. 13, pp. 297—298, 1942.

457. Lawson, A. W.: "The Vibration of Piezoelectric Plates," *Phys. Rev.*, vol. 62, pp. 71—76, 1942.

458. Lawson, A. W.: "A Determination of the Elastic Modulus s_{11} of Beta-quartz," *Phys. Rev.*, vol. 59, pp. 608—612, 1941.

459. Lawson, A. W.: "Comment on the Elastic Constants of Alpha-quartz," *Phys. Rev.*, vol. 59, p. 838, 1941.

460. Lawson, A. W.: "The Piezoelectricity of Beta-quartz," *Science*, vol. 92, p. 419, 1940.

461. Lea, N.: "Notes on Stability of L-C Oscillators," *J.I.E.E.*, vol. 92, pp. 261—274, 1945.

462. le Corbeiller, Ph.: "The Nonlinear Theory of the Maintenance of Oscillations," *J.I.E.E.*, vol. 79, pp. 361—368, 1936.

463. Lee, R.: "Radio Telegraph Keying Transients," *Proc. I.R.E.*, vol. 22, pp. 213—215, 1934.

464. Leonard, S. C.: "Measurement of Minute Changes of Capacitance and Inductance," *Electronics*, vol. 11, p. 18, March 1938.

465. Linder, E. G.: "Attenuation of Electromagnetic Fields in Pipes Smaller Than the Critical Size," *Proc. I.R.E.*, vol. 30, pp. 554—556, 1942.

466. Llewellyn, F. B.: "Constant Frequency Oscillators," *Bell Syst. T. J.*, vol. 11, pp. 67—100, 1932; *Proc. I.R.E.*, vol. 19, pp. 2063—2094, 1931.

467. Llewellyn, F. B.: "A Study of Noise in Vacuum Tubes and Attached Circuits," *Proc. I.R.E.*, vol. 18, pp. 243—265, 1930.

468. Loomis, A. L., and W. A. Marrison: "Modern Developments in Precision Timekeepers," *Electrical Engineering*, vol. 51, pp. 542—549, 1932.

469. Loomis, A. L.: "Precise Measurement of Time," *Monthly Notices Roy. Astron. Soc.*, vol. 91, pp. 569—575, 1931.

470. Love, A. E. H.: *A Treatise on the Mathematical Theory of Elasticity*, 4th ed., Cambridge University Press, London, 1934, 643 pp.

471. Lucas, H. J.: "Some Developments of the Piezoelectric Crystal as a Frequency Standard," *J.I.E.E. (London)*, vol. 68, pp. 855—872, 1930; reprinted in *Wireless Section*, vol. 5, pp. 151—163, 1930; discussion, pp. 163—168.

472. Ludloff, H. F.: "Ultrasonics and Elasticity," *Jour. Acous. Soc. Am.*, vol. 12, pp. 193—197, 1940.

473. Lukesh, J. S.: "The Effect of Imperfections on the Usability of Quartz for Oscillator-plates," *A. Min.*, vol. 30, pp. 291—295, May-June 1945.

474. Lynch, T. E., and S. J. Begun: "General Considerations of the Crystal Cutter," *Communications*, vol. 20, pp. 9f., December 1940.

475. Lynn, J. G., Zwemer, R. L., and A. J. Chick: "The Biological Application of Focused Ultrasonic Waves," *Science*, vol. 96, pp. 119—120, July 1942; see also *Sci. American*, vol. 168, p. 115, March 1943, and *Jour. Gen. Physiol.*, vol. 24, pp. 179—193, 1942.

476. Lythall, W. B.: "Frequency Instability of Pulsed Transmitters with Long Wave Guides," *J.I.E.E.*, vol. 93 (part IIIA), pp. 1081—1089, 1946.

477. Lyons, H.: "Microwave Frequency Dividers," *J. Appl. Phys.*, vol. 21, pp. 59—60, 1950.

478. Maa, D. Y.: "A General Reactance Theorem for Electrical, Mechanical, and Acoustical Systems," *Proc. I.R.E.*, vol. 31, pp. 365—371, 1943.

479. MacKinnon, K. A.: "Crystal Control Applied to the Dynatron Oscillator," *Proc. I.R.E.*, vol. 20, pp. 1689—1714, 1932.

480. Mallett, E.: "Frequency Stabilization of Valve Oscillators," *J.I.E.E.*, vol. 68, pp. 2063—2094, 1930; also *Wireless Sect.*, vol. 5, p. 124, 1930.

481. Mallett, E., and V. J. Terry: "The Quartz Oscillator," *W. World*, vol. 16, pp. 630—636, 1925.

482. Malling, L. M.: "Triode Linear Saw-tooth-Current Oscillator," *Proc. I.R.E.*, vol. 32, pp. 753—757, 1944.

483. Maloff, I. G., and D. W. Epstein: *Electron Optics in Television*, McGraw-Hill, New York, 1938.

484. Mandell, W.: "Resonance in Crystal Beams of Sodium-ammonium Seignette Salt," *Proc. Roy. Soc.*, vol. 165, pp. 414—431, 1938.

485. Mandell, W.: "The Determination of the Piezoelectric Moduli of Ammonium Seignette Salt," *Proc. Roy. Soc.*, vol. 121, pp. 130—140, 1928.

486. Mandell, W.: "The Change in Elastic Properties on Replacing the Potassium Atom of Rochelle Salt by the Ammonium Group," *Proc. Roy. Soc.*, vol. 121, pp. 122—130, 1928.

487. Mandell, W.: "The Determination of the Elastic Moduli of the Piezoelectric Crystal Rochelle Salt by a Statical Method," *Proc. Roy. Soc.*, vol. 116, pp. 623—636, 1927.

488. Marks, B. H.: "Ceramic Dielectric Materials," *Electronics*, vol. 21, pp. 116—120, August 1948.

489. Marcum, J., and T. P. Kinn: "Heating with Microwaves," *Electronics*, vol. 20, pp. 82—85, March 1947.

490. Marrison, W. A.: "The Crystal Clock," *Proc. Nat. Acad. Sci.*, vol. 16, pp. 496—507, 1930.

491. Marrison, W. A.: "A High Precision Standard of Frequency," *Proc. I.R.E.*, vol. 17, pp. 1103—1122, 1929; *Bell Syst. T. J.*, vol. 8, pp. 493—514, 1929.

492. Mason, C. A., and B. B. Ray: "Piezoelectric Vibration Meter: Its Use for the Detection of Bearing Vibrations," *Electrician*, vol. 117, pp. 565—567, 1936.

493. Mason, W. P.: *Piezoelectric Crystals and Their Application to Ultrasonics*, D. Van Nostrand, New York, 1950, 508 pp.

494. Mason, W. P.: "Quartz Crystal Applications," *Bell Syst. T. J.*, vol. 22, pp. 178—223, 1943; also printed in book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 11—33, 1946.

495. Mason, W. P.: "Voigt's Elastic and Piezoelectric Relations and Their Application to the Determination of Low Temperature Coefficient Crystals," refer to book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 31—56, 1946.

496. Mason, W. P., and R. A. Sykes: "Low Frequency Quartz-crystal Cuts Having Low Temperature Coefficients," *Proc. I.R.E.*, vol. 32, pp. 208—215, 1944; also printed in book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 537—554, 1946.

497. Mason, W. P., and I. E. Fair: "A New Direct Crystal-Controlled Oscillator for Ultra-Short Wave Frequencies," *Proc. I.R.E.*, vol. 30, pp. 464—472, 1942.

498. Mason, W. P.: *Electromechanical Transducers and Wave Filters*, D. Van Nostrand, New York, 1942, 333 pp.

500. Mason, W. P.: "Electrical and Mechanical Analogies," *Bell Syst. T. J.*, vol. 20, pp. 405—414, 1941.

501. Mason, W. P., and R. A. Sykes: "Electrical Wave Filters Employing Crystals with Normal and Divided Electrodes," *Bell Syst. T. J.*, vol. 19, pp. 221—248, 1940.

502. Mason, W. P.: "The Location of Hysteresis Phenomena in Rochelle Salt Crystals," *Phys. Rev.*, vol. 58, pp. 744—756, 1940.

503. Mason, W. P.: "Low Temperature Coefficient Quartz Crystals," *Bell Syst. T. J.*, vol. 19, pp. 74—93, 1940.

504. Mason, W. P.: "A New Quartz-crystal Plate, Designated the GT, Which Produces a Very Constant Frequency Over a Wide Temperature Range," *Proc. I.R.E.*, vol. 28, pp. 220—223, May 1940.

505. Mason, W. P.: "A Dynamic Measurement of the Elastic, Electric and Piezoelectric Constants of Rochelle Salt," *Phys. Rev.*, vol. 55, pp. 775—789, 1939.

506. Mason, W. P.: "Resistance Compensated Band-pass Crystal Filters for Use in Unbalanced Circuits," *Bell System Tech. Jour.*, vol. 16, pp. 423—436, 1937.

507. Mason, W. P.: "Quartz Crystal Filters," *Bell Labs. Record*, vol. 13, pp. 305—311, 1935.

508. Mason, W. P.: "The Motion of a Bar Vibrating in Flexure, Including the Effects of Rotary and Lateral Inertia," *J.A.S.A.*, vol. 6, pp. 246—249, 1935.

509. Mason, W. P.: "An Electromechanical Representation of a Piezoelectric Crystal Used as a Transducer," *Proc. I.R.E.*, vol. 23, pp. 1252—1263, 1935; *Bell Syst. T. J.*, vol. 14, pp. 718—723, 1935.

510. Mason, W. P.: "Electrical Wave Filters Employing Quartz Crystals as Elements," *Bell Syst. T. J.*, vol. 13, pp. 405—452, 1934, or patent 2,173,589.

511. Mather, N. W.: "Multivibrator Circuits," *Electronics*, vol. 19, pp. 136—138, October 1946.

512. Matsumura, S., and S. Kanzaki: "Quartz Plates with a Very Small Temperature-coefficient of Oscillation Frequency," *U.R.S.I. Gen. Assembly, Document* 34, *Comm.* I, London, 1934.

513. Maxwell, J. C.: "On Governors," *Proc. Roy. Soc.*, vol. 16, pp. 270—283, 1868.

514. Mayberry, W.: "Supersonics," *Electronics*, vol. 10, pp. 7—9, July 1937.

515. McCrath, J. W., and A. R. Kurtz: "Isolation of an Ultrasonic Crystal Radiator from Conducting Liquids," *Rev. Sci. Instruments*, vol. 13, p. 128, 1942.

516. McCreary, H. J.: "The Magnetic Cross Valve and Its Application to Sub-frequency Power Generation," *Proc. Natl. Elec. Conf.*, vol. 5, pp. 450—466, 1949.

517. McDade, J. R.: "The Phantastron Control Circuit," *Elec. Eng.*, vol. 67, pp. 974—977, 1948.

518. McGaughan, H. S., and C. B. Leslie: "A Resistance-Tuned Frequency-Modulated Oscillator for Audio Frequency Applications," *Proc. I.R.E.*, vol. 35, pp. 974—978, 1947.

519. McKinley, D. W. R.: "Measurement of Small Optical Activities with the Quartz Crystal Light Modulator," *Can. Jour. Research*, vol. 17, pp. 202—207, October 1939.

520. McKinley, D. W. R.: "Application of Quartz Crystals to the Modulation of Light," *Can. Jour. Research*, sec. A, vol. 16, pp. 77—81, 1938.

521. McSkimin, H. J.: "Theoretical Analysis of Modes of Vibration for Isotropic Rectangular Plates Having All Surfaces Free," *Bell Syst. T. J.*, vol. 23, pp. 151—177, 1944; also printed in book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 249—275, 1946.

522. McSkimin, H. J.: *The Distribution of Stress and Strain for Rectangular Isotropic Plates Vibrating in Normal Modes of Flexures*, Thesis, New York University, June 1940.

523. Meacham, L. A.: "The Bridge-stabilized Oscillator," *Proc. I.R.E.*, vol. 26, pp. 1278—1294, 1938; *Bell Syst. T. J.*, vol. 17, pp. 574—591, 1938; short account in *Bell Labs. Rec.*, suppl. to vol. 18, January 1940.

524. Meacham, L. A.: "High-precision Frequency Comparisons," *Bridge of Eta Kappa Nu*, vol. 36, pp. 5—8, February-March 1940.

525. Meahl, H. R.: "Quartz Crystal Controlled Oscillator Circuits," *Proc. I.R.E.*, vol. 22, pp. 732—737, 1934.

526. Meissner, A.: "Piezoelectric Crystals at Radio Frequencies," *Proc. I.R.E.*, vol. 15, pp. 281—296, 1927.

527. Mendelssohn, J., and K. Mendelssohn: "Specific Heat of a Substance Showing Spontaneous Electric Polarization," *Nature*, vol. 144, p. 595, 1939.

528. Meyer, O., and S. L. Penfield: "Results Obtained by Etching a Sphere and Crystals of Quartz with Hydrofluoric Acid," *Trans. Conn. Acad. Sci.*, vol. 8, pp. 158—165, 1889.

529. Mickey, L., and A. D. Martin: "Development of Standard Frequency Transmitting Sets," *Jour. Research Nat. Bur. Standards*, vol. 12, pp. 1—12, 1934.

530. Millen, J., and D. Bacon: "Modern Design of High-frequency Stages for the Amateur Superhet," *QST*, vol. 19, pp. 13f., January 1935.

531. Miller, J. M.: "Quartz Crystal Oscillators," *U. S. Navy Radio Sound Rept.*, issue of April 1, May 1, June 1, 1925, pp. 53—64.

532. Miller, C. J., Jr., Capt.: "The Equivalent Network of a Quartz Crystal Unit and Its Application," printed in *Fundamental Principles of Crystal Oscillator Design*, U. S. Army Signal Corps, Long Branch Signal Laboratory, pp. 1—18, 1945.

533. Miller, C. J., Jr., Capt.: "The Pierce Oscillator," printed in *Fundamental Principles of Crystal Oscillator Design*, U. S. Army Signal Corps, Long Branch Signal Laboratory, pp. 37—64, 1945.

534. Miller, R. L.: "Fractional-Frequency Generators Utilizing Regenerative Modulation," *Proc. I.R.E.*, vol. 27, pp. 446—456, 1939.

535. Minorsky, N.: *Introduction to Nonlinear Mechanics*, J. W. Edwards, Ann Arbor, Mich., 1947.

536. Mittelman, E.: "Load Matching in Electronic Heating," *Electronics*, vol. 18, pp. 110—115, February 1945.

537. Modrak, P.: "Quartz and Tourmaline," *W. E.*, vol. 14, pp. 127—134 and 175—183, 1937.

538. Modrak, P.: "Small Temperature Coefficient of Frequency Quartz Plates," *W. E.*, vol. 16, pp. 6—15, 1939.

539. Mögel, H.: "Monitoring the Operation of Short-wave Transmitters," *Proc. I.R.E.*, vol. 19, pp. 214—232, 1931.

540. Montgomery, B. E.: "An Inductively Coupled Frequency Modulator," *Proc. I.R.E.*, vol. 29, pp. 559—563, 1941.

541. Moore, J. B.: "Design of Stable Heterodyne Oscillators," *Electronics*, vol. 18, pp. 116—118, October 1945.

542. Morrison, H.: "Ten-frequency Receiver," *Bell Labs. Record*, vol. 19, pp. 307—309, 1941.

544. Morrison, J. T.: "A New Broadcast Transmitter Circuit Design for Frequency Modulation," *Proc. I.R.E.*, vol. 28, pp. 444—449, 1940.

545. Moullin, E. B.: *The Theory and Practice of Radio Frequency Measurements*, 2nd ed., Charles Griffin & Company, Ltd., London, 1931, 487 pp.
546. Moullin, E. B.: "Spontaneous Fluctuations of Voltage," Oxford, London, 1938.
547. Moullin, E. B.: "Effect of Curvature of the Characteristic on Frequency of Dynatron Generators," *J.I.E.E.*, vol. 73, p. 186, 1933.
548. Mueller, H.: "The Dielectric Anomalies of Rochelle Salt," *Ann. N. Y. Acad. Sci.*, vol. 40, pp. 321—356, 1940.
549. Mueller, H.: "Properties of Rochelle Salt, IV," *Phys. Rev.*, vol. 58, pp. 805—811, 1940.
550. Mueller, H.: "Properties of Rochelle Salt, III," *Phys. Rev.*, vol. 58, pp. 565—573, 1940.
551. Mueller, H.: "Properties of Rochelle Salt, II," *Phys. Rev.*, vol. 57, pp. 829—839, 1940.
552. Mueller, H.: "Properties of Rochelle Salt, I," *Phys. Rev.*, vol. 47, pp. 175—191, 1935.
553. Mueller, H.: "Influence of Electrostatic Fields on the Elastic Properties of Rochelle Salt," *Phys. Rev.*, vol. 57, pp. 842—843, 1940.
554. Muller, W.: "Transitron Oscillator for High Stability," *Electronic Inds.*, vol. 4, p. 110, December 1945.
555. Murphy, E. J., and S. O. Morgan: "The Dielectric Properties of Insulating Materials," *Bell Syst. T. J.*, vol. 16, pp. 493—512, 1937, vol. 17, pp. 640—669, 1938.
556. Myers, L. M.: *Television Optics: An Introduction*, Pitman Publishing Corporation, New York, 1936, 338 pp.
557. Myers, L. M.: "Application of the Electrometer Triode to the Determination of Piezoelectric Constants," *Brit. Rad. Ann.*, pp. 15—20, 1934-5.
558. Myers, L. M.: "A Piezoelectric Peak Voltmeter," *Marconi Rev.*, 1934, pp. 4—8, November-December.
559. Nelson, E. L.: "Radio Broadcasting Transmitters and Related Transmission Phenomena," *Bell Syst. T. J.*, vol. 9, pp. 121—140, 1930.
560. Newitt, J. H.: "R-C Oscillator Performance," *Electronics*, vol. 17, p. 126, March 1944.
561. Nicolson, A. M.: "The Piezoelectric Effect in the Composite Rochelle Salt Crystal," *Trans. A.I.E.E.*, vol. 38, pp. 1467—1485, 1919; *Proc. A.I.E.E.*, vol. 38, pp. 1315—1333, 1919; *Electrician (London)*, vol. 83, pp. 32f., 1919; Patent 2,212,845, filed April 10, 1918, issued August 27, 1940.
562. Nishikawa, S., Sakisaka, Y., and I. Sumoto: "X-ray Investigation of the Mode of Vibration of Piezoelectric Quartz Plates," *Phys. Rev.*, vol. 38, pp. 1078—1079, 1931, and vol. 43, pp. 363—364, 1933.
563. Nolle, A. W.: "Adjustment Speed of Automatic Control Systems," *Proc. I.R.E.*, vol. 36, pp. 911—916, 1948.
564. Norgorden, O.: "The Inverse Piezoelectric Properties of Rochelle Salt at Audio Frequencies," *Phys. Rev.*, vol. 49, pp. 820—828, 1936.
565. Norgorden, O.: "The Piezoelectric Properties of Rochelle Salt," *Phys. Rev.*, vol. 50, p. 782, 1936 (letter to the editor).
566. Norrman, E.: "The Inductance-Capacitance Oscillator as a Frequency Divider," *Proc. I.R.E.*, vol. 34, pp. 799—803, 1946.
567. Norrman, E.: "Tuning Fork Stabilization," *Electronics*, vol. 13, pp. 15—17, January 1940.
568. Norrman, E.: "A Precision Tuning Fork Frequency Standard," *Proc. I.R.E.*, vol. 20, pp. 1715—1731, 1932.
569. North, H. Q.: "Properties of Welded Contact Germanium Rectifiers," *J. Appl. Ph.*, vol. 17, pp. 912-923, 1946.
570. Norton, R. L.: "Crystal Controlled Diathermy," *Electronics*, vol. 19, pp. 113—115, October 1946.
571. Nyquist, H.: "Regeneration Theory," *Bell Syst. T. J.*, vol. 11, pp. 126—147, 1932.
572. Nyquist, H.: "Thermal Agitation of Electric Charge in Conductors," *Phys. Rev.*, vol. 32, pp. 110—113, 1928.
573. O'Brien, E. J.: "A Coupled-Circuit Frequency Modulator," *Proc. I.R.E.*, vol. 32, pp. 348—350, 1944.
574. Offner, F. F.: "The Effect of Q on Power-Amplifier Efficiency," *Proc. I.R.E.*, vol. 34, pp. 896—897, 1946.
575. Offner, F.: "Recorder for Electrical Potentials. Damping of Piezo-electric Systems," *Jour. Applied Phys.*, vol. 11, pp. 347—352, 1940.
576. Okolicsanyi, F.: "The Wave-slot, an Optical Television System," *Wireless Eng. Exptl. Wireless (London)*, vol. 14, pp. 527—536, October 1937.
577. Oliver, M. H., and S. J. Fry: "A Method of Measuring the Impedance of Quartz Crystals at Series Resonance," *T.R.E.* Tech. Note No. 26.
578. Oram, D. K.: "Full-range Selectivity with 455-kc. Quartz Crystal Filters," *QST*, vol. 22, pp. 33f., December 1938.
579. Osborn, P. H.: "A Study of Class B and Class C Amplifier Tank Circuits," *Proc. I.R.E.*, vol. 20, pp. 813—834, 1932.
580. Osterberg, H., and J. W. Cookson: "An Interference Method for Measuring the Piezoelectric Moduli of Alpha-quartz: The Moduli," *R.S.I.*, vol. 6, pp. 347-356, 1935.
581. Osterberg, H., and J. W. Cookson: "Longitudinal, Shear, and Transverse Modes of Vibration in Quartz and Tourmaline," *Physics*, vol. 6, pp. 246—256, 1935.
582. Osterberg, H., and J. W. Cookson: "A Theory of Two-dimensional Longitudinal and Flexural Vibrations in Rectangular Isotropic Plates," *Physics*, vol. 6, pp. 234—246, 1935.
583. Osterberg, H., and J. W. Cookson: "Some Piezoelectric and Elastic Properties of β-quartz," *J. Frank. Inst.*, vol. 220, pp. 361—371, 1935.
584. Osterberg, H., and J. W. Cookson: "Piezoelectric Stabilization of High Frequencies," *R.S.I.*, vol. 5, pp. 281—286, 1934.
585. Osterberg, H.: "A Refracting Interferometer for Examining Modes of Vibration in Quartz Plates," *R.S.I.*, vol. 5, pp. 183—186, 1934.
586. Osterberg, H.: "A Multiple Interferometer for Analyzing the Vivbrations of a Quartz Plate," *Phys. Rev.*, vol. 43, pp. 819—829, 1933.
587. Osterberg, H.: "A Triple Interferometer for Distinguishing Flexural and Longitudinal Vibrations in Quartz," *J.O.S.A.*, vol. 23, pp. 30—34, 1933.
588. Osterberg, H.: "An Interferometer Method of Studying the Vibrations of an Oscillating Quartz Plate," *J.O.S.A.*, vol. 22, pp. 19—35, 1932.
589. Osterberg, H.: "An Interferometer Method of Observing the Vibrations of an Oscillating Quartz Plate," *Proc. Nat. Acad. Sci.*, vol. 15, pp. 892—896, 1929.
590. Ostlund, E. M., Vallerino, A. R., and M. Silver: "Center-Frequency-Stabilized Frequency Modulation Systems," *Proc. I.R.E.*, vol. 35, pp. 1144—1147, 1947.
591. Page, R. M., and W. E. Curtis: "The van der Pol Four-Electrode Relaxation Oscillator," *Proc. I.R.E.*, vol. 18, pp. 1921—1929, 1930.
592. Page, R. M.: "An Investigation of the Phenomena of Frequency Multiplication, as Used in Tube Transmitters," *Proc. I.R.E.*, vol. 17, pp. 1619—1655, 1929.
593. Parrish, W.: "Methods and Equipment for Sawing Quartz Crystals," pp. 371—388, "Machine Lapping of Quartz Oscillator-plates," pp. 416—431, *A. Min.*, vol. 30, May-June 1945.
594. Parrish, W., and S. G. Gordon: "Orientation Techniques for the Manufacture of Quartz Oscillator-plates," pp. 296—325, "Precise Angular Control of Quartz-cutting by X-rays," pp. 326—346, *A. Min.*, vol. 30, May-June 1945.
595. Pauling, L.: *The Nature of the Chemical Bond*, Cornell University Press, Ithaca, N. Y., 1939.
596. Peirce, B. O.: *A Short Table of Integrals*, Ginn & Co., Boston, 2nd rev. ed., 1910.

597. Peterson, E., Manley, J. M., and L. R. Wrathall: "Magnetic Generation of a Group of Harmonics," *Bell Syst. T. J.*, vol. 16, pp. 436—455, 1937.
598. Peterson, E., Kreer, J. G., and L. A. Ware: "Regeneration Theory and Experiment," *Proc. I.R.E.*, vol. 22, pp. 1191—1210, 1934.
599. Peterson, E.: "Impedance of a Non-Linear Circuit Element," *Trans. A.I.E.E.*, vol. 46, p. 528, 1923.
600. Pielemeier, W. H., Saxton, H. L., and D. Telfair: "Supersonic Effects of Water Vapor in CO_2 and Their Relation to Molecular Vibrations," *Jour. Chem. Phys.*, vol. 8, pp. 106—115, 1940.
601. Pielemeier, W. H.: "Acoustical Detection of Electrically Weak Vibrations in Quartz Plates," *J.A.S.A.*, vol. 9, pp. 212—216, 1938.
602. Pierce, J. R.: "Noise in Resistances and Electron Streams," *Bell Syst. T. J.*, vol. 27, pp. 158—174, 1948.
603. Pierce, J. R., and W. G. Shepherd: "Reflex Oscillators," *Bell Syst. T. J.*, vol. 26, pp. 460—681, 1947.
604. Pierce, G. W.: "The Songs of Insects," *Jour. Franklin Inst.*, vol. 236, pp. 141—146, 1943 (see also *Radio Rev. Australia*, vol. 5, p. 303, 1937).
605. Pierce, G. W.. "Magnetrostriction Oscillators," *Proc. I.R.E.*, vol. 17, pp. 42—88, 1929.
606. Pierce, G. W.: "Piezoelectric Crystal Oscillators Applied to the Precision Measurement of the Velocity of Sound in Air and Carbon Dioxide at High Frequencies," *Proc. A.A.A.S.*, vol. 60, pp. 277—302, 1925.
607. Pierce, G. W.: "Piezoelectric Crystal Resonators and Crystal Oscillators Applied to the Precision Calibration of Wavemeters," *Proc. A.A.A.S.*, vol. 59, pp. 81–106, 1923.
608. Pitt, A., and D. W. R. McKinley: "Variation with Temperature of the Piezoelectric Effect in Quartz," *Can. J. Res., A*, vol. 14, pp. 57—65, 1936.
609. Pitt, A., and W. J. Jackson: "Measurement of the Velocity of Sound in Low Temperature Liquids at Ultrasonic Frequencies," *Can. Jour. Research*, vol. 12, pp. 686—689, 1935.
610. Plasencia, H. T.: "Spanish Standard for the Roentgen (piezoelectric device for standard charge)," *Radiology*, vol. 34, pp. 82—94, January 1940.
611. Poppele, J. R., Cunningham, F. W., and A. W. Kishpaugh: "Design and Equipment of a Fifty-kilowatt Broadcast Station for WOR," *Proc. I.R.E.*, vol. 24, pp. 1063—1081, 1936.
612. Porter, B. H.: "The Supersonic Oscillator," *Ind. Eng. Chem.*. vol. 12, pp. 748—749, 1940.
613. Post, E. J., and H. F. Pit: "Alternate Ways in the Analysis of a Feedback Oscillator and Its Applications," *Proc. I.R.E.*, vol. 39, pp. 169—174, 1951.
614. Pound, R. V.: "Frequency Stabilization of Microwave Oscillators," *Proc. I.R.E.*, vol. 35, pp. 1405—1415, 1947.
615. Powers, W. F.: "Temperature Coefficient of Frequency of Quartz Resonators" (abst.), *Phys. Rev.*, vol. 23, p. 783, 1924.
616. Poynting, J. H., and J. J. Thomson: *A Text-book of Physics*, vol. 4, "Electricity and Magnetism," part 1; "Pyroelectricity and Piezoelectricity," pp. 148—163, London, 1920.
617. Prichard, A. C., Druesne, M. A. A., and D. G. McCaa: "Increase in Q Value and Reduction in Aging of Quartz Crystal Blanks," *Proc. I.R.E.*, vol. 38, p. 314, 1950.
618. Prichard, A. C.: "The Miller Oscillator," printed in *Fundamental Principles of Crystal Oscillator Design*, U. S. Army Signal Corps, Long Branch Signal Laboratory, pp. 65—77, 1945.
619. Prince, D. C.: "Vacuum Tubes as Power Oscillators," *Proc. I.R.E.*, vol. 11, pp. 275—315, 405—435, and 527–550, 1923.
620. Proshauer, R., and H. E. Smith: "Fungus and Moisture Protection," *Electronics*, vol. 18, pp. 119—123, May 1945.
621. Puckle, O. S.: "A Time Base Employing Hard Valves," *J. Television Soc. (London)*, vol. 2, p. 147, 1936.
622. Puckle, O. S.: *Time Bases*, John Wiley, New York, 2nd ed., 1951.
623. Pullen, K. A.: "The Cathode-Coupled Amplifier," *Proc. I.R.E.*, vol. 24, pp. 402—405, 1946.
624. Quimby, S. L., and S. Siegel: "The Variation of the Elastic Constants of Crystalline Sodium with Temperature between 80°K and 210°K," *Phys. Rev.*, vol. 54, pp. 293—299, 1938.
625. Quimby, S. L.: "New Experimental Methods in Ferromagnetism" (abstr.), *Phys. Rev.*, vol. 39, pp. 345–353, 1932.
626. Quimby, S. L.: "On the Experimental Determination of the Viscosity of Vibrating Solids," *Phys. Rev.*, vol. 25, p. 558, 1925.
627. Radio News Staff: "Ultra-selectivity with Crystal Filters," *Radio News*, vol. 15, pp. 477f., 1934; vol. 16, pp. 603f., 1935.
628. Rambo, S. I.: "AFC for RF Heating," *Electronics*, vol. 19, pp. 120—122, April 1946.
629. Rayleigh, Lord: *The Theory of Sound*, Macmillan & Company, Ltd., London, 1926, vol. 1, 480 pp.; vol. 2, 504 pp.
630. Rayner, E. H.: "The Researches of the Late Dr. D. W. Dye on the Vibrations of Quartz," *J.I.E.E. (London)*, vol. 72, pp. 519—527, 1933; *Proc. Wireless Sec., I.E.E.*, vol. 8, pp. 99—107, 1933.
631. R.C.A.: "Low-frequency Crystal Units (80 kc to 250 kc)," Bureau of Ships Contract Nobsr–42409, December 1950.
632. R.C.A.: "Mechanical Overtone Crystal Units, 50 mc to 150 mc or Higher," Signal Corps Contract W3-039–sc—38265, October 1950.
633. R.C.A.: "Low-frequency AT Cut Crystal Plates(500 kc to 1,000 kc)," Signal Corps Contract W36–039–sc–5460, January 14, 1952.
634. Read, T. A.: "The Internal Friction of Single Metal Crystals," *Phys. Rev.*, vol. 58, pp. 371—380, 1940.
635. Record, F. A., and J. L. Stiles: "An Analytical Demonstration of Hartley Oscillator Action," *Proc. I.R.E.*, vol. 31, pp. 281—287, 1943.
636. Reddick, H. W., and F. H. Miller: *Advanced Mathematics for Engineers*, John Wiley, New York, 2nd ed., 1947.
637. Regener, V. H.: "Decade Counting Circuits," *R.S.I.*, vol. 17, pp. 185—189, 1946.
638. Regener, V. H.: "Reversible Decade Counting Circuits," *R.S.I.*, vol. 17, 375—376, 1946.
639. Reich, H. J.: "The Use of Vacuum Tubes as Variable Impedance Elements," *Proc. I.R.E.*, vol. 30, pp. 288–293, 1942.
640. Reich, H. J.: *Theory and Applications of Electron Tubes*, McGraw-Hill, New York, 1939.
641. Reich, H. J.: "Trigger Circuits," *Electronics*, vol. 12, pp. 14—17, August 1939.
642. Rice, S. O.: "Mathematical Analysis of Random Noise," *Bell Syst. T. J.*, vol. 23, pp. 282—332, 1944, and vol. 24, pp. 46—156, 1945.
643. Richards, W. T.: "Supersonic Phenomena," *Rev. Modern Phys.*, vol. 11, pp. 36—64, 1939.
644. Richards, W. T.: "Recent Progress in Supersonics," *Jour. Applied Phys.*, vol. 9, pp. 298—306, 1938.
645. Ridenour, L. N.: *Radar System Engineering*, McGraw-Hill, New York, 1947.
646. Riebman, Leon: "Theory of the Superregenerative Amplifier," *Proc. I.R.E.*, vol. 37, pp. 29—33, 1949.
647. Rideout, V. C.: "Automatic Frequency Control of Microwave Oscillators," *Proc. I.R.E.*, vol. 35, pp. 767–771, 1947.

648. Rinehart, J. S.: "Temperature Dependence of Young's Modulus and Internal Friction of Lucite and Karolith," *Jour. Applied Phys.*, vol. 12, pp. 811—816, 1941.
649. Roberts, E. A., Goldsmith, P., Kurinsky, J., and E. K. Novak, Armour Research Foundation of Illinois Institute of Technology: "Investigation of Oscillator Circuits for Proposed Standards," Air Force Contract AF 18(600)-157, June 22, 1953.
650. Roberts, S.: "Dielectric and Piezoelectric Properties of Barium Titanate," *Phys. Rev.*, vol. 71, 2nd ser., p. 890, 1947.
651. Robinson, D. M.: "The Supersonic Light Control and Its Application to Television with Special Reference to the Scophony Television Receiver, *Proc. I.R.E.*, vol. 27, pp. 483—486, 1939; also papers by J. Sieger (pp. 487—492), G. Wikkenhauser (pp. 492—496), and H. W. Lee (pp. 496—500).
652. Robinson, J.: "The Stenode Radiostat," *Radio News*, vol. 12, pp. 590f., 1931. More on this device will be found in *Electronics*, *Radio News*, *Wireless Eng. Exptl. Wireless*, and *Wireless World* from 1931 on.
653. Robinson, S. A., and F. N. Barry, Philco Corporation: "H.F. Harmonic Crystal Investigation," Air Force Contract W33-038-ac—14172, April 1947.
654. Rogers, Austin F., and Paul F. Kerr: *Optical Mineralogy*, McGraw-Hill, New York, 1942, 390 pp.
655. Ronan, J. M.: "Fabricating Techniques for Crystal Unit CR-23/U (49.9 to 51.1 Mc)," Engineering Report No. E-1108, Sig. C. Proj. No. 4302E, Signal Corps Engineering Laboratories, Fort Monmouth, N. J., February 2, 1953.
656. Rose, F. C.: "The Variation of the Adiabatic Elastic Moduli of Rocksalt with Temperature between 80°K and 270°K," *Phys. Rev.*, vol. 49, pp. 50—54, 1936.
657. Rosenthal, A. H.: "Storage in Television Reception," *Electronics*, vol. 14, pp. 46f., October 1941; also *Electronic Eng.* (British), pp. 578f, January 1942.
658. Rosenthal, L., *et al.*, Rutgers University: "Research Measurements of Power Dissipation Temperature Rise Characteristics of Crystal Units," Signal Corps Contract W36-039-sc—32081, August 1947.
659. Sabaroff, S.: "A Voltage Stabilized High-frequency Crystal Oscillator Circuit," *Proc. I.R.E.*, vol. 25, pp. 623—629, 1937.
660. Salisbury, W. W., and C. W. Porter: "An Efficient Piezoelectric Oscillator," *R.S.I.*, vol. 10, pp. 269—270, 1939.
661. Sanders, E. W.: "Wave Propagation in Shearing Quartz Oscillators of High Frequency," *J. Appl. Ph.*, vol. 11, pp. 299—300, 1940.
662. Sanders, E. W.: "Modes of Fracture in Piezoelectric Crystals," *QST*, vol. 21, pp. 17—18, 84, 1937.
663. Sarbacher, R. I., and W. A. Edson: *Hyper and Ultra-High Frequency Engineering*, John Wiley, New York, 1943.
664. Sarbacher, R. I.: "Power-Tube Performance in Class C Amplifiers and Frequency Multipliers as Influenced by Harmonic Voltage," *Proc. I.R.E.*, vol. 31, pp. 607-625, 1943.
665. Sarbacher, R. I.: "Graphical Determination of Power Amplifier Performance," *Electronics*, vol. 15, p. 52, December 1942.
666. Sawdey, R. S., Jr.: "Piezoelectric Surface Analyzer," *Radio*, pp. 20—23, March 1943.
667. Sawdey, R. S., Jr.: "Bimorph Rochelle Salt Crystals and Their Applications," *Radio*, pp. 23f., September 1943.
668. Sawyer, C. B.: "The Use of Rochelle Salt Crystals for Electrical Reproducers and Microphones," *Proc. I.R.E.*, vol. 19, pp. 2020—2029, 1931.
670. Sawyer, C. B., and C. H. Tower: "Rochelle Salt as a Dielectric," *Phys. Rev.*, vol. 35, pp. 269—273, 1930.
671. Schaffner, H.: *Range of Synchronization of Subharmonic External Resonance*, Report from E. E. Research Laboratory, University of Illinois, 1949.
672. Schelkunoff, S. A.: "Representation of Impedance Functions in Terms of Resonant Frequencies," *Proc. I.R.E.*, vol. 32, pp. 83—90, 1944.
673. Schlesinger, Kurt: "Cathode-Follower Circuits," *Proc. I.R.E.*, vol. 26, p. 1278, October 1938.
674. Schmidt, C. R.: "Frequency Division with Phase-Shift Oscillators," *Electronics*, vol. 23, pp. 111—113, June 1950.
675. Scott, H. H.: "A General Purpose Vibration Meter," *Jour. Acous. Soc. Am.*, vol. 13, pp. 46—50, 1941.
676. Scott, H. J.: "A Precise Radio-frequency Generator," *Bell Labs. Record*, vol. 11, pp. 102—108, 1932.
677. Scroggie, M. G.: "Applications of the Dynatron," *W. E.*, vol. 10, pp. 527—540, 1933.
678. Searles, C. E.: "Discussion of Crystal Units and Oscillators," ASESA 340, June 1, 1952, and printed in "Information Bulletin on Quartz Crystal Units," ASESA 52-9, Armed Services Electro Standards Agency, Fort Monmouth, N. J., pp. 1—13, August 1952.
679. Searles, C. E., and D. A. Venn: "Theory and Description of Radio Frequency Ohmmeter ZM-2/U," *Tele-Tech*, March 1950.
680. Seddon, J. C.: "Square Wave Keying of Oscillators," *Electronics*, vol. 23, p. 162, February 1950.
681. Seeley, S. W., and J. Avins: "The Ratio Detector," *R.C.A. Rev.*, vol. 8, pp. 201—236, 1947.
682. Seeley, S. W., and E. I. Anderson: "U-H-F Oscillator Frequency-Stability Considerations," *R.C.A. Rev.*, vol. 5, pp. 77—88, 1940.
683. Selgin, P. J.: *Electrical Transmission in the Steady State*, McGraw-Hill, New York, 1946.
684. Shannon, C. E.: "Communication in the Presence of Noise," *Proc. I.R.E.*, vol. 37, pp. 10—21, 1949.
685. Sharpless, T. K.: "High Speed N-Scale Counters," *Electronics*, vol. 21, pp. 122—125, March 1948.
686. Shaw, H. S.: "Oscillating Crystals," *QST*, vol. 7, pp. 30f., July 1924.
687. Shea, T. E.: "Transmission Networks and Wave Filters," D. Van Nostrand, New York, 1929.
688. Shear, S. K., and A. B. Focke: "The Dispersion of Supersonic Waves in Cylindrical Rods of Polycrystalline Silver, Nickel and Magnesium," *Phys. Rev.*, vol. 57, pp. 532—537, 1940.
689. Shenk, E. R.: "The Multivibrator, Applied Theory and Design," *Electronics*, vol. 17, pp. 136—141, 140-145, 138—142, January, February, March 1944.
690. Shepherd, W. G., and R. O. Wise: "Variable-Frequency Bridge-Type Frequency-Stabilized Oscillators," *Proc. I.R.E.*, vol. 31, pp. 256—269, 1943.
691. Shore, S. X.: A series of articles on the grading and orientation of quartz crystals and the sawing, lapping, finishing, and testing of quartz plates, *Communications*, vol. 23, October-December 1943, vol. 24, January, February 1944.
692. Shulvas-Sorokina, R. D.: "Is It Possible to Determine the Piezoelectric Constant at High Temperature by the Statistical Method?" *Phys. Rev.*, vol. 34, pp. 1448—1450, 1929.
693. Shulvas-Sorokina, R. D., and M. V. Posnov: "The Time of Relaxation in Crystals of Rochelle Salt," *Phys. Rev.*, vol. 47, pp. 166—174, 1935.
694. Siegel, S.: "Review of Supersonic Methods for Measuring Elastic and Dissipative Properties of Solids," *Jour. Acous. Soc. Am.*, vol. 6, pp. 26—30, 1944.
695. Siegel, S., and S. L. Quimby: "The Variation of Young's Modulus with Magnetization and Temperature in Nickel," *Phys. Rev.*, vol. 49, pp. 663—670, 1936.
696. Signal Corps Engineering Laboratories: "Crystal Data Sheets," vol. 1, Project 4422D, Fort Monmouth, N. J., March 1, 1951.

697. Silver, L., Strongin, E., and A. Yevlove: "Investigation, Studies and Evaluation of Performance of Crystal Unit Characteristics," N. Y. University, Research Division, Fourth Quarterly Progress Report, 1952, prepared for U. S. Signal Corps, Contract No. DA36-039-sc—5493.

698. Simon, A. W.: "On the Theory of the Progressive Universal Winding," *Proc. I.R.E.*, vol. 33, pp. 868—871, 1945.

699. Sing, C.: "Series Sawtooth Oscillator," *Electronics*, vol. 23, p. 178, August 1950.

700. Sivian, L. J.: "Absolute Sound Pressure Measurements with Tourmaline" (abst.), *Jour. Acous. Soc. Am.*, vol. 92, p. 462, 1941.

701. Skellett, A. M.: "Modes of Vibration of a Round Plate Cut from a Quartz Crystal," *J.O.S.A.*, vol. 20, pp. 293—302, 1930.

702. Skellett, A. M.: "A Visual Method for Studying Modes of Vibration of Quartz Plates," *J.O.S.A.*, vol. 17, pp. 308—317, 1928.

703. Skinner, L. V.: *Criteria for Stability in Circuits Containing Non-Linear Resistance*, Doctor's Thesis, University of Illinois, 1948.

704. Slater, J. C.: "Microwave Electronics," *Rev. Mod. Phys.*, vol. 18, pp. 441—512, 1946.

705. Slater, J. C.: "Theory of Transition in KH_2PO_4," *Jour. Chem. Phys.*, vol. 9, pp. 16—33, 1941.

706. Sloane, R. W., and E. G. James: "Transit Time Effects in Diodes in Pictorial Form," *J.I.E.E.*, vol. 79, pp. 291—296, 1936.

707. Slonziewski, T.: "High-Accuracy Heterodyne Oscillators," *Bell Syst. T. J.*, vol. 19, p. 407, 1940.

708. Smith, A. W., and L. M. Ewing: "The Diffraction of Light by Supersonic Waves in Liquids; Apparatus for Demonstration and for an Intermediate Laboratory Experiment," *Am. Jour. Phys.*, vol. 8, pp. 57—59, 1940.

709. Smith, P. H.: "Optimum Coax Diameters," *Electronics*, vol. 23, p. 111, February 1950.

710. Smith, W. V., de Guevedo, J. L. G., Carter, R. L., and W. S. Bennett: "Frequency Stabilization of Microwave Oscillators by Spectrum Lines," *J. Appl. Ph.*, vol. 18, p. 1112, 1947, and vol. 19, p. 831, 1948.

711. Sokolnikoff, I. S., and E. S.: *Higher Mathematics for Engineers and Physicists*, McGraw-Hill, New York, 1948.

712. Sosman, R. B.: *The Properties of Silica*, Chemical Catalog Company, Inc., New York, 1927, 856 pp.

713. Soucy, C. I.: "Temperature Coefficients in Electronic Circuits," *Electronics*, vol. 21, pp. 117—121, January 1948.

714. Speight, J. W.: "The Electrodynamic Characteristics of the Quartz Piezoelectric Oscillator," *Can. J. Res.*, vol. 12, pp. 812—819, 1935.

715. Spitzer, C. F.: "Sustained Subharmonic Response of Non-Linear Series Circuits," *J. Appl. Ph.*, vol. 16, pp. 105—110, 1945.

716. Spring, W. S.: "Characteristics of Deltamax," *Electronics*, vol. 22, p. 152, June 1949.

717. Stamford, N. C.: "The Production of Rochelle Salt Piezoelectric Resonators Having a Pure Longitudinal Mode of Vibration," *Proc. I.R.E.*, vol. 25, pp. 465—471, 1937.

718. Stanesby, H.: "A Simple Narrow-band Crystal Filter," *Post Office Elec. Eng. Jour.*, vol. 35, pp. 4—7, April 1942.

719. Stanesby, H., and E. R. Broad: "A Narrow Band Filter Using Crystal Resonators," *Post Office Elec. Eng. Jour.*, vol. 33, pp. 176—182, 1941.

720. Stansel, F. R.: "A Secondary Frequency Standard Using Regenerative Frequency-Dividing Circuits," *Proc. I.R.E.*, vol. 30, pp. 157—162, 1942.

721. Starr, A. T.: "Electro-acoustic Reactions," *W. E.*, vol. 17, pp. 247—256, 303—309, 1940.

722. Stephenson, C. C., and A. C. Zettlemoyer: "The Heat Capacity of Ammonium Dihydrogen Phosphate from 15° to 300°K. The Anomaly at the Curie Temperature," *J. Am. Chem. Soc.*, vol. 66, pp. 1405—1408, 1944.

723. Stephenson, C. C., and A. C. Zettlemoyer: "The Heat Capacity of Potassium Dihydrogen Arsenate from 15° to 300°K. The Anomaly at the Curie Temperature," *J. Am. Chem. Soc.*, vol. 66, pp. 1402—1405, 1944.

724. Stephenson, C. C., and J. G. Hooley: "The Heat Capacity of Potassium Dihydrogen Phosphate from 15° to 300°K. The Anomaly at the Curie Temperature," *J. Am. Chem. Soc.*, vol. 66, pp. 1397—1401, 1944.

725. Stephenson, C. C., and H. E. Adams: "The Heat Capacity of Ammonium Dihydrogen Arsenate from 15° to 300°K. The Anomaly at the Curie Temperature," *J. Am. Chem. Soc.*, vol. 66, pp. 1409—1412, 1944.

726. Sterky, H.: "Frequency Multiplication and Division," *Proc. I.R.E.*, vol. 25, pp. 1153—1174, 1937.

727. Stevens, H. C., and J. M. Snodgrass: "A Piezoelectric Myograph" (for measurement of contracting muscle), *Proc. Soc. Exptl. Biol. Med.*, vol. 30, pp. 939—943, 1933.

728. Stockman, H.: "Superregenerative Circuit Applications," *Electronics*, vol. 21, pp. 1153—1174, 1937.

729. Stoiber, R. E., Tolman, C., and R. D. Butler: "Geology of Quartz Crystal Deposits," *A. Min.*, vol. 30, pp. 245—268, May-June 1945.

730. Stone, J. E.: "An Ultra-Low Frequency Oscillator," *Electronics*, vol. 23, pp. 94—95, January 1950.

731. Strong, J. A.: "New Method of Investigating the Modes of Vibration of Quartz Crystals," *Nature*, vol. 129, p. 59, 1932.

732. Sturley, K. R.: "The Phase Discriminator," *W. E.*, vol. 21, pp. 72—78, 1944.

733. Sturtevant, M.: "A Voltage Controlled Multivibrator," *Electronics*, vol. 22, p. 144, October 1949.

734. Sulzer, P. G.: "The Tapered Phase-Shift Oscillator," *Proc. I.R.E.*, vol. 36, pp. 1302—1305, 1948.

735. Summerhayes, H. R.: "A 260 to 350 Megacycle Converter Unit," *Proc. I.R.E.*, vol. 31, p. 252, 1943.

736. Swan, A. G.: "Radiation from R-F Heating Generators," *Electronics*, vol. 19, p. 162, May 1946.

737. Sykes, R. A., Bell Telephone Laboratories: "Design Data on Crystal Units," printed in *Information Bulletin on Quartz Crystal Units*, ASESA 52-9, Armed Services Electro Standards Agency, Fort Monmouth, N. J., pp. 1—16, August 1952.

738. Sykes, R. A.: *Equations of Elastic and Piezoelectric Constants for Rotation of Axes About the X Axis*, refer to book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 247—248, 1946.

739. Sykes, R. A.: *Location of Mass on Supporting Wire*, refer to book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 287—289, 1946.

740. Sykes, R. A.: "Modes of Motion in Quartz Crystals, the Effects of Coupling and Methods of Design," *Bell Syst. T. J.*, vol. 23, pp. 52—96, 1944; also printed in book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 205—246, 1946.

741. Sykes, R. A.: "Principles of Mounting Quartz Plates," *Bell Syst. T. J.*, vol. 23, pp. 178—189, 1944; also printed in book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 276—286, 1946.

742. Synge, E. H.: "Application of Piezoelectricity to Microscopy," *Phil. Mag.*, vol. 13, pp. 297—300, 1932.

743. Taschek, R., and H. Osterberg: "Crystalline Symmetry and Shear Constants of Rochelle Salt," *Phys. Rev.*, vol. 50, p. 572, 1936.
744. Teare, B. R., Jr., and E. R. Schatz: "Copper-Covered Steel Wire at Radio Frequencies," *Proc. I.R.E.*, vol. 32, pp. 397—403, 1944.
745. Telfair, D., and W. H. Pielemeier: "An Improved Apparatus for Supersonic Velocity and Absorption Measurements," *Rev. Sci. Instruments*, vol. 13, pp. 122—126, 1942.
746. Terman, F. E.: *Radio Engineers Handbook*, McGraw-Hill, New York, 1943.
747. Terman, F. E., and W. C. Roake: "Calculation and Design of Class C Amplifiers," *Proc. I.R.E.*, vol. 24, p. 620, April 1936.
748. Terman, F. E.: "Resonant Lines in Radio Circuits," *Elec. Eng.*, vol. 53, p. 1046, 1934.
749. Terman, F. E.: "Resistance Stabilized Oscillators," *Electronics*, vol. 6, p. 190, July 1933.
750. Terry, E. M.: "The Dependence of the Frequency of Quartz Piezo-Electric Oscillators Upon Circuit Constants," *Proc. I.R.E.*, vol. 16, p. 1486, 1928.
751. Thomas, H. A.: *Theory and Design of Valve Oscillators*, Chapman & Hall, London, 2nd ed., 1951.
752. Thomas, H. A.: "The Dependence on Frequency of the Temperature Coefficient of Inductance of Coils," *J.I.E.E.*, vol. 84, pp. 101—112, 1939.
753. Thompson, B. J., North, D. O., and W. A. Harris: "Fluctuations in Space-Charge-Limited Currents at Moderately High Frequencies," *R.C.A. Rev.*, vol. 6, pp. 114—124, 1941.
754. Thomas, H. P., and R. H. Williamson: "A Commercial 50-kilowatt Frequency-Modulation Broadcast Transmitting Station," *Proc. I.R.E.*, vol. 29, pp. 537—545, 1941.
755. Thomson, J. J.: "Piezoelectricity and Its Applications" (quartz and tourmaline for explosion pressures), *Engineering*, vol. 107, pp. 543—544, 1919.
756. Thompson, L.: "Shock Waves in Air and Characteristics of Instruments for Their Measurement" (discharge of heavy artillery, use of quartz, Rochelle salt, and tourmaline), *Jour. Acous. Soc. Am.*, vol. 12, pp. 198—204, 1940.
757. Thomson, W. T.: "Effect of Rotary and Lateral Inertia on Flexural Vibration of Prismatic Bars," *J.A.S.A.*, vol. 11, pp. 198—204, 1939.
758. Thurston, G. M.: "Adjusting to Frequency," refer to book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 317—332, 1946.
759. Thurston, G. M.: "A Crystal Test Set," *Bell Labs. Rec.*, vol. 22, pp. 477—480, 1944.
760. Thurston, G. M.: "Flatness and Parallelism in Quartz Plates," *Bell Labs. Rec.*, vol. 22, pp. 435—439, 1944.
761. Tibbetts, R. W.: "Rochelle Salt Crystal Devices of Low Impedance" (loud-speaker and oscilloscope), *Electronics*, vol. 16, pp. 88f., April 1943.
762. Tillyer, E. D., American Optical Co.: "Y Cut Crystal Vibrating in a Shear Mode," Patent 1,907,613, issued May 9, 1933.
763. Titchmarch, E. C.: *Theory of Functions*, Oxford, pp. 191—192, 1932.
764. Tolansky, S.: "Topography of a Quartz Crystal Face," *Nature*, vol. 153, pp. 195—196, 1944.
765. Tomlinson, G. A.: "Recent Developments in Precision Time-keeping," *Observatory*, vol. 57, pp. 189—195, 1934.
766. Tournier, M.: "History and Applications of Piezoelectricity," *Elec. Comm.*, vol. 15, pp. 312—327, 1937; *ENT*, vol. 15, pp. 320—334, 1937.
767. Travis, C.: "Automatic Frequency Control," *Proc. I.R.E.*, vol. 23, pp. 1125—1141, 1935.
768. Tschappat, W. H.: "New Instruments for Physical Measurements" (pressure gauge for interior ballistics), *Mech. Eng.*, vol. 45, pp. 673—678, 1923; see also vol. 48, pp. 821—825, 1926.
769. Tsi-Ze, Ny, Ling-Chao Tsien, and Fang Sun-Hung: "Oscillations of Hollow Quartz Cylinders Cut Along the Optic Axis," *Proc. I.R.E.*, vol. 24, pp. 1484—1494, 1936.
770. Tucker, D. G.: "Forced Oscillations in Oscillator Circuits and the Synchronization of Oscillators," *J.I.E.E.*, vol. 92, pp. 226—233, Part III, 1945.
771. Tucker, D. G.: "The Synchronization of Oscillators," *Electronic Eng.*, vol. 15, pp. 412—418 and 457—461, 1943; also vol. 16, pp. 26—30 and 114—117, 1944.
772. Tucker, D. G.: "The Generation of Groups of Harmonics," *Electronic Eng.*, vol. 15, pp. 232—237, 1942.
773. Tuller, W. G., Galloway, W. C., and F. P. Zaffarano: "Recent Developments in Frequency Stabilization of Microwave Oscillators," *Proc. I.R.E.*, vol. 36, pp. 794—800, 1948.
774. Tutton, A. E. H.: *Crystallography and Practical Crystal Measurement*, 2nd ed., Macmillan & Company, Ltd., London, 1922, 2 vols., 746 and 699 pp.
775. Tyrrell, W. A.: "Hybrid Circuits for Microwaves," *Proc. I.R.E.*, vol. 35, pp. 1294—1306, 1947.
776. U. S. Air Force, Air Material Command, Wright-Patterson Air Force Base, Civilian Personnel Division in Conjunction with Gentile Air Force Specialized Depot: "Quartz Crystal Fabrication Assignments," April 1952.
777. U. S. Air Force Technical Order, T.O. No. 16-35TS330-5, and U. S. Army Technical Manual, TM 11-5051: "Crystal Impedance Meter TS-330/TSM," April 1951, U. S. Government Printing Office, Washington, D. C., 64 pp.
778. U. S. Air Force Technical Order, T.O. No. 16-35TS537-5, and U. S. Army Technical Manual, TM 11-5052: "Crystal Impedance Meter TS-537/TSM," U. S. Government Printing Office, Washington, D. C.
779. U. S. Air Force Technical Order, T.O. No. 16-35TS683-5, and U. S. Army Technical Manual (TM 11-2652 cancelled), or Radio Frequency Laboratories, Inc., Instruction Book: "Crystal Impedance Meter TS-683/TSM," 54 pp., December 10, 1951.
780. U. S. Air Force Technical Order, T.O. No. 16-35TS710-( ), and U. S. Army Technical Manual: "Crystal Impedance Meter TS-710/TSM," U. S. Government Printing Office, Washington, D. C., when printed.
781. U. S. Army Signal Corps, Long Branch Signal Laboratory, Circuit Section: "Fundamental Principles of Crystal Oscillator Design," 84 pp., 1945.
782. U. S. Army Technical Manual: "Quartz Crystals Theory, Fabrication and Performance Measurements," TM 11-2540, December 1950, U. S. Government Printing Office, Washington, D. C., 130 pp.
783. Valasek, J.: "Infrared Absorption by Rochelle Salt Crystals," *Phys. Rev.*, vol. 45, pp. 654—655, 1934.
784. Valasek, J.: "Note on the Piezoelectric Effect in Rochelle Salt Crystals," *Science*, vol. 65, pp. 235—236, 1927.
785. Valasek, J.: "Dielectric Anomalies in Rochelle Salt Crystals," *Phys. Rev.*, vol. 24, pp. 560—568, 1924.
786. Valasek, J.: "Properties of Rochelle Salt Related to the Piezoelectric Effect," *Phys. Rev.*, vol. 20, pp. 639-664, 1922.
787. Valasek, J.: "Piezoelectric Activity of Rochelle Salt Under Various Conditions," *Phys. Rev.*, vol. 19, pp. 478—491, 1922.
788. Valasek, J.: "Piezoelectricity and Allied Phenomena in Rochelle Salt," *Phys. Rev.*, vol. 17, pp. 475—481, 1921.

789. van der Pol, B.: "The Nonlinear Theory of Electric Oscillations," *Proc. I.R.E.*, vol. 22, pp. 1051—1086, 1934.
790. van der Pol, B., and M. J. O. Strutt: "On the Stability of the Solutions of Mathieu's Equation," *Phil. Mag.*, vol. 5, pp. 18—38, 1928.
791. van der Pol, B.: "On Relaxation Oscillations," *Phil. Mag.*, vol. 2, pp. 978—992, 1926.
792. van der Pol, B.: "On Oscillation Hysteresis in a Triode Generator with Two Degrees of Freedom," *Phil. Mag.*, vol. 43, pp. 700—719, 1922.
793. van der Ziel, A.: "On the Mixing Properties of Nonlinear Condensers," *J. Appl. Ph.*, vol. 19, pp. 999-1006, 1948.
794. Van Dyke, K. S.: "The Standardization of Quartz Crystal Units," *Proc. I.R.E.*, vol. 33, pp. 15—20, 1945.
795. Van Dyke, K. S.: "The Piezoelectric Quartz Resonator," *A. Min.*, vol. 30, pp. 214—244, May-June 1945.
796. Van Dyke, K. S., and A. M. Thorndike: "The Three-crystal Method of Quartz Resonator Measurement" (abst.), *Phys. Rev.*, vol. 57, p. 560, 1940.
797. Van Dyke, K. S.: "On the Right- and Left-handedness of Quartz and Its Relation to Elastic and Other Properties," *Proc. I.R.E.*, vol. 28, pp. 399—406, 1940.
798. Van Dyke, K. S.: "Vibration Modes of Low Decrement for a Quartz Ring" (abst.), *Phys. Rev.*, vol. 53, p. 945, 1938.
799. Van Dyke, K. S.: "Some Unusual Demonstrations with Piezoelectric Resonators" (abst.), *Phys. Rev.*, vol. 53, p. 686, 1938.
800. Van Dyke, K. S.: "Note on a Peculiar Case of Fracture of a Quartz Resonator," *A. Appl. Ph.*, vol. 8, pp. 567—568, 1937.
802. Van Dyke, K. S.: "A Determination of Some of the Properties of the Piezoelectric Quartz Resonator," *Proc. I.R.E.*, vol. 23, pp. 386—392, 1935; *Document* AG, No. 24, *Comm.* I., *U.R.S.I. Gen. Assem.*, 1934.
803. Van Dyke, K. S.: "Temperature Variation of Viscosity and of the Piezoelectric Constant of Quartz" (abst.), *Phys. Rev.*, vol. 42, p. 587, 1932.
804. Van Dyke, K. S.: "The Electric Network Equivalent of a Piezoelectric Resonator" (abst.), *Phys. Rev.*, vol. 40, p. 1026, 1932.
805. Van Dyke, K. S.: "The Measurement of the Decrement of Piezoelectric Resonators" (abst.), *Proc. I.R.E.*, vol. 18, p. 1989, 1930.
806. Van Dyke, K. S.: "The Piezoelectric Resonator and Its Equivalent Network," *Proc. I.R.E.*, vol. 16, pp. 742—764, 1928.
807. Van Dyke, K. S.: "Some Experiments with Vibrating Quartz Spheres" (abst.), *Proc. I.R.E.*, vol. 16, pp. 706—707, 1928; *Phys. Rev.*, vol. 31, pp. 1113, 1133, 1928 (absts.).
808. Van Dyke, K. S.: "The Use of the Cathode Ray Oscillograph in the Study of Resonance Phenomena in Piezoelectric Crystals" (abst.), *Phys. Rev.*, vol. 31, p. 303, 1928.
809. Van Dyke, K. S.: "The Electric Network Equivalent of a Piezoelectric Resonator" (abst.), *Phys. Rev.*, vol. 25, p. 895, 1925.
811. van Slooten, J.: "Stability and Instability in Triode Oscillators," *Philips Tech. Rev.*, vol. 7, pp. 40—45 and 171—177, 1942.
812. van Slooten, J.: "The Stability of a Triode Oscillator with Grid-Condenser and Leak," *W. E.*, vol. 16, pp. 16—19, 1939.
813. Van Vleck, J. H.: *The Theory of Electric and Magnetic Susceptibilities*, Oxford, Clarendon Press, New York, 1932, 384 pp.
814. Vaughan, W. C.: "Phase Shift Oscillator," *W. E.*, vol. 26, pp. 391—399, 1949.
815. Vazsonyi, A.: "A Generalization of Nyquist's Stability Criteria," *J. Appl. Ph.*, vol. 20, pp. 863—867, 1949.
816. Vecchiacchi, F.: "Oscillations in the Circuit of a Strongly Damped Triode," *Proc. I.R.E.*, vol. 19, pp. 856—872, 1931.
817. Verman, L. C.: "Negative Circuit Constants," *Proc. I.R.E.*, vol. 19, pp. 676—681, 1931.
818. Vigness, I.: "Dilatations in Rochelle Salt," *Phys. Rev.*, vol. 48, pp. 198—202, 1935.
819. Vigness, I.: "Inverse Piezoelectric Properties of Rochelle Salt," *Phys. Rev.*, vol. 46, pp. 255—257, 1934.
820. Vigoureux, J. E. P., and H. E. Stoakes: "All-electric Clock," *Proc. Phys. Soc. (London)*, vol. 52, pp. 353-357, 1940 (discussion pp. 357—358).
821. Vigoureux, J. E. P.: "Development of Formulas for the Constants of the Equivalent Electrical Circuit of a Quartz Resonator in Terms of Elastic and Piezoelectric Constants," *Phil. Mag.*, vol. 6, pp. 1140-1153, 1928.
822. Vigoureux, J. E. P.: "The Valve-maintained Quartz Oscillator," *J.I.E.E. (London)*, vol. 68, pp. 265—295, 1930; discussion, pp. 867—872; *Proc. Wireless Section, I.E.E.*, vol. 5, pp. 41—71, 1930; discussion, pp. 163—168.
823. Vigoureux, J. E. P.: *Quartz Resonators and Oscillators*, H. M. Stationary Office, Adastral House, Kingsway, London, W. C. 2, 1931, 217 pp.
824. Vigoreux, J. E. P., and C. F. Booth: *Quartz Vibrators and Their Application.* His Majesty's Stationary Office, Adastral House, Kingsway, London, W. C. 2.
826. Vigoureux, J. E. P.: *Quartz Oscillators and Their Applications*, His Majesty's Stationery Office, London, 1939, 131 pp.
827. Voigt, W.: *Lehrbuch der Kristallphysik*, B. G. Tubner, Leipzig, 1st ed., 1910, 964 pp.; 2nd ed., 1928, 978 pp., identical with the first except for the addition of an appendix on secondary effects in the flexure and torsion of circular cylinders, based on refs. 583 and 576.
828. von Ardenne, M.: "Distortion of Saw-Tooth Wave Forms," *Electronics*, vol. 10, pp. 36—38, November 1937.
829. von Hippel, A., Breckenridge, R. G., Chesley, R. G., and L. Tiza, *Ind. and Eng. Chem.*, vol. 38, p. 1097, 1946.
830. Wallace, R. L., and W. J. Pietenpol: "Some Properties and Applications of *n-p-n* Transistors," *Proc. I.R.E.*, vol. 39, pp. 753—767, 1951.
831. Waltz, W. W.: "Crystal Filter Design," *Radio Engineering*, vol. 16, pp. 7—10 (January), 14—17 (February), 16—17 (March), 12—14 (April), 1936.
832. Warren, B. E., and H. M. Krutter: "X-ray Study of Crystal Structure of Rochelle Salt and Effect of Temperature" (abst.), *Phys. Rev.*, vol. 43, p. 500, 1933.
833. Watanabe, Y.: "The Piezoelectric Resonator in High-Frequency Oscillation Circuits," *Proc. I.R.E.*, vol. 18, pp. 695—717 and 862—893, 1930.
834. Watson, H. G. I., and D. A. Keys: "A Piezoelectric Method of Measuring the Pressure Variations in Internal Combustion Engines," *Can. Jour. Research*, vol. 6, pp. 322—331, 1932.
835. Webb, H. W., and G. E. Becker: "Theory of the Multivibrator," *J. Appl. Ph.*, vol. 15, pp. 825—834, 1944.
836. Webster, R. A.: "Piezoelectric Gauge and Amplifier" (pile of 21 quartz plates, for pressures up to 30,000 lb./in.^{2}), *Jour. Franklin Inst.*, vol. 211, pp. 607—615, 1931.
837. Webster, R. A.: "Piezoelectric versus Mechanical Spring Pressure Gauge," *Jour. Applied Phys.*, vol. 10, pp. 890—891, 1939.
838. Weinhart, H. W., and H. G. Weke: "Metal Electrodes Deposited on Quartz Crystals by the Evaporation Process," refer to book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 333—355, 1946.

839. Wesleyan University: "Piezoelectric Crystal Studies and Measurements," Signal Corps Contract DA36-039-sc—73, July 31, 1948.
840. Western Electric Co.: *Quartz Crystal Units*, General Bulletin.
841. Whale, H. A.: "Optimum Conditions for an R-C Oscillator," *Electronics*, vol. 21, p. 178, February 1948.
842. Wheeler, H. A.: "Formulas for the Skin Effect," *Proc. I.R.E.*, vol. 30, pp. 412—424, 1942.
843. Wheeler, L. P.: "An Analysis of a Piezoelectric Oscillator Circuit," *Proc. I.R.E.*, vol. 19, pp. 627—646, 1931.
844. Wheeler, L. P., and W. E. Bower: "A New Type of Standard Frequency Piezoelectric Oscillator," *Proc. I.R.E.*, vol. 16, pp. 1035—1044, 1928.
845. Wheeler, M. S.: "Frequency Contours for Microwave Oscillator with Resonant Load," *Proc. I.R.E.*, vol. 37, pp. 1332—1336, 1949.
846. White, G. J.: "Crystal I.F. Coupling and Filters," *Proc. I.R.E. Australia*, vol. 1, pp. 50—56, 1938.
847. Whinnery, J. R.: "Skin Effect Charts and Formulas," *Electronics*, vol. 15, pp. 44—48, February 1942.
848. Wing, A. H.: "On the Theory of Tubes with Two Control Grids," *Proc. I.R.E.*, vol. 29, pp. 121—136, 1941.
849. Winlund, E. S.: "Electronic Heating in the Furniture Industry," *Electronics*, vol. 19, pp. 108—113, May 1946.
850. Wilson, A. J. C.: "The Heat Capacity of Rochelle Salt Between −30° and +30°C," *Phys. Rev.*, vol. 54, pp. 1103—1109, 1938.
851. Wilson, J. E.: "The Crystal Filter Treated as an Impedance Bridge Circuit," *Communications*, vol. 21, pp. 18, 20, April 1941.
852. Wilson, I. G., Schramm, C. W., and J. P. Kinzer: "High-Q Resonant Cavities for Microwave Testing," *Bell Syst. T. J.*, vol. 25, pp. 408—434, 1946.
853. Willoner, G., and F. Tihelka: "A Phase-Shift Oscillator with Wide-Range Tuning," *Proc. I.R.E.*, vol. 36, pp. 1096—1100, 1948.
854. Willis, E. S.: "Channel Crystal Filters for Broad-band Carrier Systems," *Bell Labs. Record*, vol. 17, pp. 62—65, 1938.
855. Williams, A. L., and J. P. Arndt: "Crystal Microphone Design for Single-direction Pickup," *Electronics*, vol. 8, pp. 242—243, August 1935.
856. Williams, A. L.: "Piezo-electric Loudspeakers and Microphones," *Electronics*, vol. 4, pp. 166—167, May 1932; see also *Jour. Soc. Motion-picture Eng.*, vol. 25, pp. 196f., 1934, and *Proc. I.R.E.*, vol. 23, pp. 1420-1421, 1935.
857. Williams, E.: "A Valve Oscillator Theorem," *W. E.*, vol. 20, pp. 489—491, 1943.
858. Williams, E. K., and A. W. Marsh: "Harmonic Mode Crystals and Oscillator Circuits for the 40-50 Mc/s Range," *T.R.E.* Tech. Note No. 99, January 1951.
859. Williams, N. H.: "Modes of Vibration of Piezoelectric Crystals," *Proc. I.R.E.*, vol. 21, pp. 990—995, 1933.
860. Williams, S. R.: *Magnetic Phenomena*, McGraw-Hill, New York, 1931.
861. Willard, G. W.: "Inspecting and Determining the Axis Orientation of Quartz Crystals," *Bell Labs. Rec.*, vol. 22, pp. 320—326, 1944.
862. Willard, G. W.: "Raw Quartz, Its Imperfections and Inspection," *Bell Syst. T. J.*, vol. 22, pp. 338—361, 1943; also printed in book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 164—204, 1946.
863. Willard, G. W.: "Ultrasonic Absorption and Velocity Measurements in Numerous Liquids," *Jour. Acous. Soc. Am.*, vol. 12, pp. 438—449, 1941.
864. Willard, G. W.: "Use of the Etch Technique for Determining Orientation and Twinning in Quartz Crystals," *Bell Syst. T. J.*, vol. 23, pp. 11—51, 1944; also printed in book by Heising, R. A.: *Quartz Crystals for Electrical Circuits*, D. Van Nostrand, New York, pp. 164—204, 1946.
865. Wood, A. B.: "The Piezoelectric Oscillograph," *Phil. Mag.*, vol. 50, pp. 631—637, 1925.
866. Wood, A. B., Tomlinson, G. A., and L. Essen: "The Effect of the Fitzgerald-Lorentz Contraction on the Frequency of Longitudinal Vibration of a Rod" (two quartz oscillators, one stationary and one rotating), *Proc. Roy. Soc. (London) A*, vol. 158, pp. 606—633, 1937.
867. Wood, H. O.: "On a Piezoelectric Accelerograph," *Bull. Seismol. Soc. Am.*, vol. 11, pp. 15—57, 1921.
868. Wood, R. G., and C. H. McCale: "Simple Apparatus for Detecting the Pyroelectric Effect in Crystals," *J. Sci. Instr.*, vol. 17, pp. 225—226, 1940.
869. Wood, R. W.: *Supersonics, the Science of Inaudible Sounds*, Charles K. Colver Lectures, 1937, Brown University, Providence, R. I., 1939, 158 pp.
870. Woodyard, J. R.: "Application of the Auto-Synchronized Oscillator to Frequency Demodulation," *Proc. I.R.E.*, vol. 25, pp. 610—619, 1937.
871. Wooster, W. A.: *A Text-book on Crystal Physics*, Cambridge University Press, London, 1938, 295 pp.
872. Wright, J. W.: "The Piezoelectric Crystal Oscillator," *Proc. I.R.E.*, vol. 17, pp. 127—142, 1929.
873. Wright, R. B., and D. M. Stuart: "Some Experimental Studies of the Vibrations of Quartz Plates," *J. Res. N.B.S.*, vol. 7, pp. 519—553, 1931.
874. Wyckoff, R. W. G.: *The Structure of Crystals*, The Chemical Catalogue Co., 1931.
875. Wyckoff, R. W. G.: *The Analytical Expression of the Results of the Theory of Space-groups*, Carnegie Institute of Washington, 1922, 180 pp.; 2nd edition, 1930, 180 pp.
876. Wynn-Williams, C. E.: "A Piezoelectric Oscillograph," *Phil. Mag.*, vol. 49, pp. 289—313, 1925.
877. Young, C. H.: "A Precise Decade Oscillator," *Bell Labs. Record*, vol. 28, pp. 487—489, 1950.
878. Young, J. D., and H. M. Beck: "Design Equations for Reactance Tube Circuits," *Proc. I.R.E.*, vol. 37, pp. 1078—1082, 1949.
879. Zacek, A., and V. Petrzilka: "Radial and Torsional Vibrations of Annular Quartz Plates," *Phil. Mag.*, vol. 25, pp. 164—175, 1938.
880. Zacharias, J.: "The Temperature Dependence of Young's Modulus for Nickel," *Phys. Rev.*, vol. 44, pp. 116—122, 1933.
881. Ziegler, A. W.: "Channel Crystal Filters for Broad-band Carrier Systems: Physical Features," *Bell Labs. Record*, vol. 17, pp. 66—70, 1938.
882. Zeigler, A. W.: "Wire Mounts," Patent 2,275,122, issued March 3, 1942.
883. Zeleny, A., and J. Valasek: "Variation of the Dielectric Constant of Rochelle Salt Crystals with Frequency and Applied Field Strength," *Phys. Rev.*, vol. 46, pp. 450—453, 1934.

884. Bagley, A., and D. Hartke: "Measurement of the Carrier Frequency of RF Pulses," paper presented at 4th *Conference on High Frequency Measurement*, Washington, D. C., January 1955; also circular of Hewlett-Packard Co.
885. Bagley, A., D. Hartke, and W. D. Myers: "Frequency and Time Measurements with the New H-P High Speed Counter," *Hewlett-Packard Jour.*, vol. 5, March-April 1954.
886. Battersby, L. R., and E. A. Conover: "A Single Crystal Multi-Channel Oscillator," *Technical Memorandum No. M-1567*, Signal Corps Project No. 132A, March 1954.
887. Bechmann, R., and D. R. Hale: "Electronic Grade Synthetic Quartz," *Brush Strokes* (Brush Electronics Co.), vol. 4, pp. 1—7, September 1955.
888. Bechmann, R.: "The Frequency-Temperature Behavior of Piezoelectric Resonators Made of Natural and Synthetic Quartz," *I. R. E. Convention Record*, vol. 3, part 9 (Ultrasonics, Medical and Industrial Electronics), pp. 56—61, 1955.
889. Bechmann, R.: "On Circuits for Piezoelectric Quartz Oscillators and Resonators for Frequency Stabilization and Filters," *Telefunken-Hansmitteilungen*, No. 78, March 1938.
890. Dasher, B. J., *et al:* "Transistor Oscillators of Extended Frequency Range," Reports on Department of the Army Contract No. DA-36-039-sc-42712, Georgia Institute of Technology, State Engineering Experiment Station, Atlanta, Ga., 1954.
891. Eberhard, E., and R. Endres: Descriptions of several transistor oscillators using high-impedance crystal units, U. S. Patent 2,570,436.
892. Finden, H. J.: "Developments in Frequency Synthesis," paper presented at *Conference on High Frequency Measurements*, Washington, D. C., 1953; also, in revised form, *Electronic Eng.*, May 1953.
893. Finden, H. J.: "The Frequency Synthesizer," *J.I.E.E.*, vol. 90, part III, 1943.
894. Gerber, E. A.: "A Review of Methods for Measuring the Constants of Piezoelectric Vibrators," *Proc. I.R.E.*, vol. 41, pp. 1103—1112, September 1953.
895. Gerber, E. A.: "Quartz-Crystal Measurement at 10 to 180 Megacycles," *Proc. I.R.E.*, vol. 40, pp. 36—40, January 1952.
896. Gerber, E. A.: "Amplitude of Vibration in Piezoelectric Crystals," *Electronics*, vol. 24, pp. 142, 204—218, April 1951, and p. 236, September 1951.
897. Gruen, H. E.: "Development of Packet Oscillator Series," Reports on U. S. Air Force Contract No. AF 33(616)-2125, Armour Research Foundation of Illinois Institute of Technology, 1954-55.
898. Hahnel, A.: "A Multichannel Crystal Oscillator," *I.R.E. Transactions on Vehicular Communications*, June 1955.
899. Hahnel, A.: "Phase Controlled Multichannel Oscillator," *Electronics*, pp. 164—165, April 1955.
900. Hahnel, A., and L. Battersby: "A Single Tube Spectrum Generator for High Order Harmonics," *Technical Memorandum No. M-1558*, Signal Corps Project No. 132A, January 1954.
901. Hahnel, A.: "A Multichannel UHF Crystal Oscillator," *Technical Memorandum No. M-1548*, Signal Corps Project No. 132A, December 1953.
902. Hahnel, A.: "Multichannel Crystal Control of VHF and UHF Oscillators," *Proc. I. R. E.*, vol. 41, pp. 79-81, January 1953.
903. Hale, D. R.: "The Properties of Synthetic Quartz Crystals and their Growing Techniques," *Brush Strokes* (Brush Electronics Co.), vol. 1, pp. 1—6, December 1952.
904. Hale, D. R.: "The Laboratory Growing of Quartz," *Science*, vol. 107, pp. 393—394, 1948.
905. Hammond, D. L.: "Effects of Impurities on the Resonator and Lattice Properties of Quartz," paper presented at 9th annual *Frequency Control Symposium*, Frequency Control Branch, Signal Corps Engineering Laboratories, Ft. Monmouth, N. J., May 1955.
906. Hok, G.: "Response of Linear Resonant Systems to Excitation of a Frequency Varying Linearly with Time," *Jour. Appl. Phys.*, vol. 19, no. 3, pp. 242—250, 1948.
907. James Knights Co.: *Crystal Handbook*, 1953.
908. Kerr, P. F., and E. Armstrong, "Recorded Experiments in the Production of Quartz," *Bull. Geol. Soc. Am.*, vol. 54, suppl. 1, pp. 1—43, 1943.
909. Koerner, L. F.: "Progress in Development of Test Oscillators for Crystal Units," *Proc. I. R. E.*, vol. 39, pp. 16—26, January 1951.
910. Lauer, F. J. M.: "Crystal Resonators as Frequency Substandards," *Proc. IEE* (London), vol. 97, part III, pp. 93—99, March 1950.
911. Lynch, A. C.: "Measurement of the Equivalent Electrical Circuit of a Piezoelectric Crystal," *Proc. Phys. Soc.* (London), vol. 63, sec. B, pp. 323—331, May 1950.
912. Mendoussee, J. S., P. D. Goodman, and W. G. Cady: "A Capacitance Bridge for High Frequencies," *Rev. Sci. Instr.*, vol. 21, pp. 1002—1009, December 1950.
913. National Bureau of Standards: "High-Stability One-Megacycle Frequency Standard," *NBS Tech. News Bull.*, November 1954.
914. Prichard, A. C., and M. Bernstein: "Crystal Impedance Meters Replace Test Sets," *Electronics*, vol. 26, pp. 176—180, May 1953.
915. Rosenthal, L. A., and T. A. Peterson, Jr.: "Measurement of the Series Resonant Resistance of a Quartz Crystal," *Rev. Sci. Instr.*, vol. 20, pp. 426—429, June 1949.
916. Rothange, C. H., and F. Hamburger: "Measurement of the Electrical Characteristics of Quartz Crystal Units by Use of a Bridged T-Network," Proc. *I. R. E.*, vol. 38, pp. 1213-1216, October 1950.
917. Schure, A.: *Crystal Oscillators*, John F. Rider, New York, 1955.
918. Srivastava, K. G.: "A New and Quick Method for Detection of Piezoelectricity and Measurement of the Piezoelectric Constants," *Indian Jour. Phys.*, vol. 25, pp. 33—34, January 1951.
919. U. S. Air Force Technical Order, T. O. No. 12R2-2ARC27-2, *Radio Set AN/ARC-27.*
920. U. S. Air Force Technical Order, T. O. No. 12R2-2ARC33-2, *Radio Set AN/ARC-33.*
921. U. S. Air Force Technical Order, T. O. No. 12R5-2ARN14-12, *Radio Receiving Set AN/ARN-14.*
922. U. S. Air Force Technical Order, T. O. No. 31R2-2GRC27-12, *Radio Receiver R-278/GR.*
923. Van Dyke, K. S., and E. C. Crume, Jr.: "Bibliography of Piezoelectricity," Reports on Department of the Army Contract No. DA 36-039-sc-42587, Wesleyan University, 1953.
924. Venn, D. A.: "Measuring VHF Impedance of Piezoelectric Crystals at Resonance," *Tel-Tech.*, pp. 44—46, March 1950.
925. Walker, A. C.: "Hydrothermal Growth of Quartz Crystals as Related to Phase Considerations," *Ind. and Eng. Chem.*, vol. 46, pp. 1670—1676, 1954.
926. Wolfskill, J. M.: Production techniques for etching crystal blanks, U. S. Patent 2,481,806, 1949, and U. S. Patent 2,364,501, 1944.
927. Wolfskill, J. M.: "Resonant Pin" crystal mount, U. S. Patent 2,240,453, 1941.
928. Woodward, G.: "A Precision Transistor Oscillator," *Philco TechRep Div. Bull.*, vol. 3, pp. 12—13, March 1953.

APPENDIX III—LIST OF MANUFACTURERS

Manufacturers of crystals, crystal products, and crystal accessories are listed alphabetically by company name followed by letter symbols representing the product or products available from stock, presently in manufacture, or capable of being produced within a reasonable time. The products enumerated beside a firm name are those represented as being available at the time of preparation of this handbook. In the first column are listed the Standard Codes of Manufacturers' Names.

The list represents a cross-section of the crystal industry; it is presented for reference purposes only and is not intended as an exclusive directory of recommended commercial sources. Manufacturers desiring to be included in this list should contact Communications and Navigation Laboratory, Attention WCLNE-1, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. A tabulation of the crystal products manufactured and comments on their availability should be submitted, along with the full company name and address.

Mfrs Code	*Manufacturer*	*Product**
	Aeronautical Electronics, Inc. Raleigh-Durham Airport P.O. Box 6043 Raleigh, N. C.	B, C
CYA	Alden Products Co. 112 N. Main St. Brockton 64, Mass.	G, H
CAS	American Lava Corp. Chattanooga 5, Tenn.	E, G
CAHZ	Bassett, Rex, Inc. 1314 N.E. 17th Court Fort Lauderdale, Fla.	C
CRR	Bendix Radio Div. Bendix Aviation Corp. Baltimore 4, Md.	I
CQB	Bliley Electric Co. Union Station Bldg. Erie, Pa.	C, G, I, J
	Bodnar Industries, Inc. 19 Railroad Ave. New Rochelle, N. Y.	B
	Bram Chemical Co. 820 65th Ave. Philadelphia 26, Pa.	A, B, C, D
	Breon Laboratories 1520 Evergreen Rd. Williamsport, Pa.	A, B, C
CBD	Brush Electronics Co. 3405 Perkins Ave. Cleveland 14, Ohio	A, B, E, F
CBVZ	Bulova Watch Co. Quartz Crystal Div. 62-10 Woodside Ave. Woodside, Long Island	B, C, H, I, J
	Caribe Aircraft Radio Corp. Coamo, Puerto Rico	I
CBN	Centralab Div. of Globe-Union, Inc. 914Y E. Keefe Ave. Milwaukee 1, Wis.	E, G
CMG	Cinch Mfg. Co. 1026 S. Homan Ave. Chicago 24, Ill.	H
CBQR	Clark Crystal Co. 2 Farm Road Marlboro, Mass.	B, C, D
CBPR	Constantin, L. L., & Co. Lodi, N. J.	G

*PRODUCT SYMBOLS

A—CRYSTALS—RAW
B—CRYSTALS—UNFINISHED
C—CRYSTAL UNITS—QUARTZ
D—CRYSTAL UNITS—TOURMALINE
E—CRYSTAL TRANSDUCERS—BARIUM TITANATE
F—CRYSTAL TRANSDUCERS—ROCHELLE SALTS
G—CRYSTAL HOLDERS
H—CRYSTAL SOCKETS
I—CRYSTAL OVENS
J—PACKAGED OSCILLATORS

Mfrs Code	Manufacturer	Product*
CBYB	Cryco, Inc. 1138 Mission St. South Pasadena, Calif.	C
	Crystals, Inc. Odell, Ill.	C
CJL	Daltron Corp. 5066 Santa Monica Blvd. Los Angeles 29, Calif.	C
	Diamond Drill Carbon Co. 244 Madison Ave. New York 16, N. Y.	A
DABS	Downing Crystal Co. 191 Shaffer Ave. Westminster, Md.	A, B, C, I
CAZQ	DX Radio Products Co., Inc. 2300 W. Armitage Ave. Chicago 47, Ill.	C
CEB	Eby, Hugh H., Inc. 4700 Stenton Ave. Philadelphia 40, Pa.	H
CBEK	Edo Corp. College Point, N. Y.	E, F
	Eidson Electronic Co. 1902 N. Third St. Temple, Texas	B, C
	Elco Corp. "M" St. below Erie Ave. Philadelphia 24, Pa.	H
	Elgin National Watch Co. Electronics Division 2435 N. Naomi Street Burbank, Calif.	H
CBEF	Electrical Industries, Inc. 44 Summer Ave. Newark 4, N. J.	G
	Electro-Voice, Inc. Buchanan, Mich.	E, F
CER	Erie Resistor Corp. 644 W. 12th St. Erie, Pa.	E
GWM	Frequency Control Branch Components Department Signal Corps Engineering Laboratories Fort Monmouth, N. J.	C
CDP	General Ceramics & Steatite Corp. Keasbey, N. J.	G
	General Crystal Co. P.O. Box 9 Burlington, Wis.	C
CG	General Electric Co. Semi-Conductor Section Electronics Park Syracuse, N. Y.	C
CBGY	Gombos Co., John, Inc. 107 Montgomery Ave. Irvington 11, N. J.	G
	Gulton Mfg. Co. Metuchen, N. J.	E
	Hermetic Seal Products Co. 29-37 S. 6th St. Newark 7, N. J.	G
	HEEMCO (Hill Electronic Engineering & Manufacturing Co.) New Kingstown, Pa.	C, I, J
CACG	Hoffman Co., P. R. 321 Cherry St. Carlisle, Pa.	B, C
CAAN	Hunt Corp., The 453 Lincoln St. Carlisle, Pa.	B, C, I
CKZ	Hupp Electronics Co. (Formerly Standard Piezo Co.) Carlisle, Pa.	C, I
	Ingram Labs, Inc. Griffin, Ga.	C
	International Crystal Mfg. Co. 18½ N. Lee Ave. Oklahoma City 1, Okla.	C, H, J
CEJ	Johnson Co., E. F. Waseca, Minn.	H

*PRODUCT SYMBOLS

A—CRYSTALS—RAW
B—CRYSTALS—UNFINISHED
C—CRYSTAL UNITS—QUARTZ
D—CRYSTAL UNITS—TOURMALINE
E—CRYSTAL TRANSDUCERS—BARIUM TITANATE
G—CRYSTAL HOLDERS
H—CRYSTAL SOCKETS
F—CRYSTAL TRANSDUCERS—ROCHELLE SALTS
I—CRYSTAL OVENS
J—PACKAGED OSCILLATORS

Mfrs Code	*Manufacturer*	*Product**
CACK	Kaar Engineering Co. 2995 Middlefield Rd. P.O. Box 1320 Palo Alto, Calif.	C
CBSS	Keystone Electronics Co. 114 Manhattan St. Stamford, Conn.	C
	King Laboratory, Inc. 2645 South Second West Salt Lake City, Utah	A
CADI	Knights Co., James, The 131 S. Wells St. Sandwich, Ill.	B, C, G, I, J
CAJR	Lavoie Laboratories Morganville, N. J.	I
CBVS	Lewis Co., Inc. E. B. 11 Bragg St. East Hartford 8, Conn.	B, C
CLF	Littelfuse, Inc. 4757 N. Ravenswood Ave. Chicago 40, Ill.	H
	L. & O. Research & Development Corp. 134 North Wayne Ave. Wayne, Pa.	I
	Maryland Lava Co. Bel Air, Md.	A, E, G
CBXK	McCoy Electronics Co. Chestnut & Watt Sts. Mt. Holly Springs, Pa.	B, C, I
	Meridian Laboratory Lake Geneva, Wis.	C, I
	Methode Mfg. Corp. 2021 W. Churchill St. Chicago 47, Ill.	H
CZX	Midland Mfg. Co., Inc. 3155 Fiberglas Rd. Kansas City 15, Kansas	B, C, I
CJA	Millen Mfg. Co., James, Inc. 150 Exchange St. Malden, Mass.	H

Mfrs Code	*Manufacturer*	*Product**
CKM	Miller Laboratories, August E. 9226 Hudson Blvd. North Bergen, N. J.	B, C, D, H, I, J
CZN	Monitor Products Co. 815 Fremont Ave. South Pasadena, Calif.	B, C, G, I, J
CGG	Motorola, Inc. 4545 West August Blvd. Chicago 51, Ill.	C
	Murray American Corp. 15 Commerce St. Chatham, N. J.	A
CNA	National Co., Inc. 61 Sherman St. Malden 48, Mass.	H, J
	National Electronic Mfg. Corp. 186 Granite St. Manchester, N. H.	G
REN	Nebel Lab., R. E. 1624 E. 12th St. Brooklyn 29, N. Y.	B, C, G
	Northern Engineering Laboratories 434 Wilmont Ave. Burlington, Wisconsin	C
	Pan American Trade Development Corp. 2 Park Ave. New York 16, N. Y.	A
CAIJ	Pan-Electronics Corp. P.O. Box 584 Griffin, Ga.	B, C
CAMG	Petersen Radio Co., Inc. 2800 W. Broadway Council Bluffs, Iowa	C
	Piezo Products Co. Whitney St. Sherborn, Mass.	C
CBWN	Precision Crystal Laboratory 2223 Warwick Ave. Santa Monica, Calif.	B, C, I, J

*PRODUCT SYMBOLS

A—CRYSTALS—RAW
B—CRYSTALS—UNFINISHED
C—CRYSTAL UNITS—QUARTZ
D—CRYSTAL UNITS—TOURMALINE
E—CRYSTAL TRANSDUCERS—BARIUM TITANATE
F—CRYSTAL TRANSDUCERS—ROCHELLE SALTS
G—CRYSTAL HOLDERS
H—CRYSTAL SOCKETS
I—CRYSTAL OVENS
J—PACKAGED OSCILLATORS

Mfrs Code	Manufacturer	Product*
	Precision Piezo Service 427 Mayflower St. Baton Rouge, La.	B, C
CL	Premier Research Laboratories, Inc. 79-89 Seventh Ave. New York 11, N. Y.	B, C, D, G. J
CBPN	Radiation Counter Laboratories, Inc. 5121 W. Grove St. Skokie, Ill.	I
CRV	Radio Corporation of America Commercial Electronics Products Camden 2, N. J.	C
CUR	Reeves-Hoffman Corp. Cherry and North Sts. Carlisle, Pa.	B, C
	Scientific Electronic Labs., Inc. 866 Bergen St. Newark 8, N. J.	G
CADG	Scientific Radio Products, Inc. 215 S. Eleventh St. Omaha 8, Neb.	B, C, I, J
	Sealtron Co. Reading Rd. at Amity Cincinnati 15, Ohio	G
CBXR	Sherold Crystals, Inc. 1510 McGee St. Kansas City 15, Kansas	C, D
CBZA	Standard Crystal Co. 1714 Locust St. Kansas City 8, Mo.	B, C, I

Mfrs Code	Manufacturer	Product*
CSJ	Stupakoff Ceramic & Mfg. Co. Latrobe, Pa.	E, G
CHS	Sylvania Electric Products, Inc. 12 Second Ave. Warren, Pa.	H
CAYM	Tedford Crystal Labs. 4126 Colerain Ave. Cincinnati 23, Ohio	C
	United States Gasket Co. Fluorocarbon Products Div. P.O. Box 648 Camden, N. J.	H
CAMU	Valpey Crystal Corp. 1244 Highland St. Holliston, Mass.	B, C, D, I
CAND	V Precision Instrument Co. 57-02 Hoffman Drive Elmhurst, N. Y.	C
CW	Western Electric Co. Radio Div., Electronic Products Sales Dept. 120 Broadway New York 5, N. Y.	C
CBVJ	Wright Electronics Inc. 1519 McGee St. Kansas City 8, Mo.	B, C, D, I
	X-tron Electronics 890 71st Ave. Oakland 21, Calif.	A, B, C
	Young Brothers Co. 1829 Columbus Rd. Cleveland, Ohio	I

*PRODUCT SYMBOLS

A—CRYSTALS—RAW
B—CRYSTALS—UNFINISHED
C—CRYSTAL UNITS—QUARTZ
D—CRYSTAL UNITS—TOURMALINE
E—CRYSTAL TRANSDUCERS—BARIUM TITANATE
F—CRYSTAL TRANSDUCERS—ROCHELLE SALTS
G—CRYSTAL HOLDERS
H—CRYSTAL SOCKETS
I—CRYSTAL OVENS
J—PACKAGED OSCILLATORS

APPENDIX IV—RELATED SPECIFICATIONS, STANDARDS, PUBLICATIONS, AND DRAWINGS

ORDERING INFORMATION

D-1. Copies of specifications, standards, publications, and drawings required by contractors in connection with specific procurement functions should be obtained from the procurement agency or as directed by the contracting officer.

D-2. The following may be obtained from the Commanding General, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio:

a. U. S. Air Force Specifications and Drawings.

b. Federal Specifications.

c. Military Specifications and Standards.

D-3. The following may be obtained from the Commanding Officer, Signal Corps Procurement Agency, 2800 South 20th Street, Philadelphia 45, Pennsylvania:

a. U. S. Army Specifications.

b. National Military Establishment and Joint Army-Navy Specifications.

c. Signal Corps Drawings and Marking Instructions.

D-4. The following may be obtained from the Bureau of Supplies and Accounts, Navy Department, Washington 25, D. C. (activities of the Armed Forces should make application to the Commanding Officer, Naval Supply Center, Norfolk 11, Va.):

a. Navy Department Specifications.

b. Federal Specifications.

c. Military Specifications.

D-5. The following may be obtained from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.:

a. Department of Commerce Publications.

b. Federal Specifications.

D-6. Both the title and identifying number or symbol should be stipulated when requesting copies of specifications, standards, publications, and drawings.

SPECIFICATIONS

U. S. AIR FORCE

AN-P-13	Preservation and Packaging Parts and Equipment (General Specification for) (*Note:* This is an Air Force-Navy Aeronautical specification applicable only to Air Force purchases).
40985	Marking of Interior Packages (for Communications Equipment).

AIR FORCE-NAVY AERONAUTICAL

AN-P-34	Plating Nickel.

FEDERAL

NN-B-601	Boxes, Wood-Cleated Plywood, for Domestic Shipment.
NN-B-621	Boxes, Wood, Nailed and Lock-Corner.
QQ-A-318	Aluminum-Alloy (AL-52) (Aluminum-Magnesium-Chromium); Plate and Sheet.
QQ-B-611	Brass, Commercial; Bars, Plates, Rods, Shapes, Sheets, and Strips.
QQ-B-746	Bronze, Phosphor; Bars, Plates, Rods, Shapes, Sheets, and Strips.
QQ-M-151	Metals; General Specification for Inspection of.
QQ-N-321	Nickel-Silver (German Silver); Bars, Plates, Rods, Shapes, Sheets, and Strips.

QQ-S-571 Solder; Soft (Tin, Tin-Lead, and Lead-Silver).

QQ-S-636 Steel; Carbon (Low Carbon), Sheets and Strips.

QQ-S-763 Steel, Corrosion-Resisting; Bars and Forging (Except for Re-forging).

LLL-B-631 Boxes; Fiber Corrugated (for Domestic Shipment).

LLL-B-636 Boxes; Fiber, Solid (for Domestic Shipment).

MILITARY

MIL-C-16B Crystal Unit, Quartz (CR-1A/AR, Pressure, Mounted).

MIL-C-239B Crystal Unit, Quartz (CR-5/U).

MIL-C-3098B Crystal Units, Quartz.

MIL-C-10405 (Sig C) Crystal Units, Quartz, Pressure and Spacer Mounted.

MIL-H-10056B Holders, Crystal.

MIL-L-10547 Liners, Case, Waterproof.

MIL-P-14 Plastic-Materials, Molding, and Plastic Parts, Molded; Thermosetting.

MIL-P-116 Packaging and Packing for Overseas Shipment—Preservation, Methods of.

MIL-R-3065 Rubber and Synthetic Rubber Compounds, General Purpose (Except Tires, Inner-Tubes, Sponge Rubber, and Hard Rubber).

MIL-T-945A Test-Equipment, for Use with Electronic Equipment: General Specification.

JAN-C-173 Coating Materials, Moisture- and Fungus-Resistant, for the Treatment of Communications, Electronic, and Associated Electrical Equipment.

JAN-P-13 Plastic-Materials, Laminated, Thermosetting; Sheets and Plates.

JAN-P-14 Plastic-Materials, Molded, Thermosetting.

JAN-P-105 Packaging and Packing for Overseas Shipment—Boxes; Wood, Cleated, Plywood.

JAN-P-106 Packaging and Packing for Overseas Shipment—Boxes; Wood, Nailed.

JAN-P-108 Packaging and Packing for Overseas Shipment—Boxes, Fiberboard (V-Board and W-Board), Exterior and Interior.

JAN-P-120 Packaging and Packing for Overseas Shipment—Cartons, Folding, Paperboard.

JAN-P-125 Packaging and Packing for Overseas Shipment—Barrier Materials, Waterproof, Flexible.

JAN-P-133 Packaging and Packing for Overseas Shipment—Boxes, Set-up, Paperboard.

JAN-P-139 Packaging and Packing for Overseas Shipment—Plywood, Container Grade.

JAN-P-140 Packaging and Packing for Overseas Shipment—Adhesives, Water-Resistant, Case-Liner.

JAN-S-28A Sockets, Electron Tube, and Accessories.

U. S. ARMY

72-53 Finishes (For Ground Signal Equipments).

72-119-A Holders for Quartz Crystals.

94-40645 Marking; Exterior, Domestic and Export Shipments by Contractors.

100-2 Standard Specification for Marking Shipments by Contractors.

SIGNAL CORPS INSTRUCTIONS

726-15 Marking of Interior Containers (For Signal Corps Equipment).

NAVY

General Specification for Inspection of Material (applicable only to Navy purchases).

22W13 Wire, Steel, Corrosion-Resisting.

46N7 Nickel-Copper-Silicon-Alloy: Castings.

RELATED SPECS AND STANDARDS

STANDARDS

MILITARY

(Military Standards for individual Crystal Units and for drive adjustment procedures for the standard crystal impedance meters are contained in Military Specification MIL-C-3098B.)

MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes.
MIL-STD-129	Marking of Shipments.
JAN-STD-15	Electrical and Electronic Symbols.

PUBLICATIONS

U. S. AIR FORCE

HB-16F-1	Gentile AF Depot—Crystal Handbook for Equipments FT-164 Crystal Holder (Unit).
HB-16F-2	Gentile AF Depot—Crystal Handbook for Equipments Using AR-3 Crystal Holder (Unit).
HB-16F-3	Gentile AF Depot—Crystal Handbook for Equipments Using FT-243 Crystal Holder (Unit).
S-16-F	USAF Supply Catalog, Class 16-F, Code 2100, Radio Crystals.

SIGNAL CORPS

Project 4422D†	Crystal Data Sheets (technical requirements for fabrication of crystal units contained in various equipments).

NAVY

NAVSHIPS 900,152	Manufacturer's Designating Symbols.

Navy Shipment Marking Handbook.

DEPARTMENT OF COMMERCE

National Bureau of Standards Handbook H28	Screw-Thread Standards for Federal Services.

AMERICAN IRON AND STEEL INSTITUTE

Steel Products Manual (Stainless and Heat-Resisting Steels).††

† Direct requests for this publication to: Commanding General, Signal Corps Engineering Laboratories, SCCSCL-PMM-3, Fort Monmouth, N. J.

†† Direct requests for this publication to: American Iron and Steel Institute, 350 Fifth Avenue, New York 1, New York.

DRAWINGS

U. S. AIR FORCE

52B13216	Crystal Holder HC-( )/U, Assembly (Crystal Holders HC-11/U and HC-12/U).

SIGNAL CORPS

SC-A-200	Crystal Holder FT-164.
SC-D-247	Crystal Holder FT-249, Outline Dimensions and Marking Information.
SC-D-5213	Crystal Holder FT-171-B, Drawing List.
SC-D-6306	Crystal Holder FT-243.
SC-D-7627	Crystal Units DC-34 and DC-35, Outline Dimensions.
SC-D-9553	Crystal Holder FT-241-A, Critical Dimensions.
SC-D-14444	Standard Oscillator TS-39/TSM-1, Circuit Diagram.
SC-D-14445	Standard Oscillator TS-39/TSM-1, Calibration and Operation.
SC-D-17316	Crystal Impedance Meter TS-330/TSM, Circuit Diagram.
SC-D-17499	Crystal Holder FT-243, Marking for Standard Units.
SC-D-20032	Crystal Holder HC-4/U, Assembly.
SC-D-20035	Crystal Holder HC-3/U, Assembly.
SC-D-20036	Crystal Holder HC-2/U, Assembly.
SC-D-20724	Crystal Holder HC-5/U, Assembly.
SC-D-20877	Crystal Holder HC-1/U, Assembly.
SC-D-22892	Crystal Holder FT-171-B, Assembly.
SC-D-25222	Crystal Impedance Meter TS-537/TSM, Circuit Diagram.
SC-D-26189	Crystal Holder FT-249, Case Assembly.

APPENDIX V—DEFINITIONS OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

ac (a-c)	alternating current
ADP	ammonium dihydrogen phosphate
afc (a-f-c)	automatic frequency control
AGC	automatic gain control
amp	ampere(s)
approx	approximately
AWG	American Wire Gauge
bfo	beat-frequency oscillator
C	centigrade
cal	calorie(s)
cap.	capacitance
cc	cubic centimeter(s)
CFI	crystal frequency indicator
CI	crystal impedance (meter)
cm	centimeter(s)
Co	Company
cont	continued
cos	cosine
cot	cotangent
cps	cycles per second
c to c	center to center
cw (c-w)	continuous wave
db	decibels
dc (d-c)	direct current
deg	degrees
dia	diameter
DKT	dipotassium tartrate
EDT	ethylene diamine tartrate
eff	effective
emf	electromotive force
etc.	et cetera
F	Fahrenheit
f	farad(s)
fig.	figure
freq	frequency
ft	foot (feet)
gm	gram(s)
gnd	ground
h	henry(s)
hf (h-f)	high frequency
if (i-f)	intermediate frequency
in.	inch(es)
ins	insulat(ion)(ed)
I.R.E.	Institute of Radio Engineers
K	Kelvin
kc	kilocycle(s)
lb	pound(s)
lf (l-f)	low frequency
lg	long, length
μa	microampere(s)
ma	milliampere(s)
max	maximum
mc	megacycle(s)
mf (m-f)	medium frequency
mfr	manufacturer
Mil	Military
min	minimum, minute(s)
mm	millimeter(s)
mmf, $\mu\mu$f	micromicrofarad(s)
mtg	mounting
mw	milliwatt(s)
NA	not applicable
nat.	natural
NL	not listed
no.	number(s)
osc	oscillator
oz	ounce(s)
PE	paper, enamel (wire insulation per JAN-W-583)
PI	performance index
pl	plate(d)
ppm	parts per million
pr	pair(s)
qty	quantity
rec	receiver
ref	reference
rf (r-f)	radio frequency
rms	root mean square
RTMA	Radio and Television Manufacturer's Association
sec	second(s)
/sec	per second
sin	sine
soc. min. de France	societe mineralogique de France
spec	specification(s)
sq	square
std	standard
tan	tangent
temp	temperature
term.	terminal
thd	thread(ed)
T.O.	(Air Force) Technical Order
USAF	United States Air Force
V	volt(s)
vhf (v-h-f)	very high frequency
vlf (v-l-f)	very low frequency
w/	with
xmtr	transmitter
xtal	crystal

SYMBOLS

Definitions are given for all usages of symbols appearing in this manual. For each usage, the first paragraph wherein the symbol appears is listed. For a complete definition, in most instances, it is necessary to examine the symbol in context by referring to the cited paragraph.

Symbol			*Paragraph*
A	(1)	quartz element	1-90
	(2)	effective electrode area	1-191
	(3)	constant-transconductance mode of vacuum-tube operation	1-273
	(4)	cross-sectional area	4-32
	(5)	area of radiating surface	4-35
AB		mode of vacuum-tube operation where control grid is biased on bend of E_cI_b curve between cutoff point and constant-g_m region	1-273
AC		quartz cut	1-23
AT		quartz cut	1-23
a		proportionality constant relating load resistance to the effective input resistance of transformer-coupled oscillator	1-395
a_1	(1)	empirical proportionality constant for length harmonic in quartz thickness-shear frequency equation	1-81
	(2)	empirical proportionality constant for width harmonic in quartz face-shear frequency mode	1-82
a_2		empirical proportionality constant for width harmonic in quartz thickness-shear frequency equation	1-81
B	(1)	quartz element	1-90
	(2)	cutoff-bias mode of vacuum-tube operation	1-273
BC		quartz cut	1-23
BT		quartz cut	1-23
C	(1)	Carbon	1-29
	(2)	quartz element	1-90
	(3)	motional-arm (or series-arm) capacitance of crystal equivalent circuit	1-183
	(4)	greater-than-cutoff-bias mode of vacuum-tube operation	1-273
	(5)	heat capacity of thermofilter	4-58
C_A		air-gap capacitance between crystal and electrode	1-183
C_B		blocking capacitor	1-220
C_b		adjustable capacitance, connected as one arm of capacitance-bridge circuit in series with crystal unit; used to balance bridge at off-resonance frequency when crystal unit appears as a capacitance, so that bridge is only unbalanced near resonance of crystal	1-365
C_C		heat capacity of crystal in crystal-oven circuit	4-58
C_{CH}		heat capacity of crystal holder in crystal-oven circuit	4-58

Symbol			*Paragraph*
C_d	(1)	total distributed capacitance across leads and terminals of crystal unit	1-201
	(2)	dynamic positive capacitance effectively in series with vacuum-tube plate-to-cathode capacitance	1-289
	(3)	Cadmium	Sect. III
C_e		electrostatic capacitance across quartz-plate dielectric	1-183
C_g	(1)	total effective grid-to-cathode capacitance of vacuum-tube circuit	1-278
	(2)	suppressor grid-to-ground capacitance of transitron crystal-oscillator circuit	1-425
C_g'		equivalent grid-circuit capacitance when grid impedance is represented as equivalent resistance in series with equivalent capacitive reactance	1-298
C_{gc1}		grid-to-cathode capacitance of first vacuum tube in two-tube crystal-oscillator circuit	1-383
C_{gc2}		grid-to-cathode capacitance of second vacuum tube in two-tube crystal-oscillator circuit	1-383
C_{g1}		input capacitance of first tube in two-tube parallel-resonant crystal oscillator	1-345
C_{g1g2}		excitation-grid-to-screen-grid capacitance of vacuum tube	1-322
C_{g2}		input capacitance of second tube in two-tube parallel-resonant crystal oscillator	1-345
C_H		heat capacity of crystal-oven heater and adjacent thermal distributing layers	4-58
C_{HT}		sum of heat capacities of heater and thermostat in crystal oven ($C_H + C_T$)	4-59
C_{H1}		distributed capacitance of crystal unit between crystal holder and one electrode-terminal side of crystal (capacitance on side of crystal opposite to C_{H2})	1-183
C_{H2}		distributed capacitance of crystal unit between crystal holder and one electrode-terminal side of crystal (capacitance on side of crystal opposite to C_{H1})	1-183
C_k		distributed cathode-to-ground capacitance in modified grounded-grid oscillator	1-419
C_L		distributed capacitance of leads and terminals of crystal unit	1-182
C_n	(1)	dynamic negative plate-to-cathode capacitance effectively introduced by vacuum tube in Pierce crystal oscillator	1-278
	(2)	capacitance in impedance-inverting network of impedance-inverting crystal oscillator equal to electrostatic shunt capacitance of crystal unit	1-426
C_O		heat capacity of crystal-oven walls	4-58
C_o		total electrostatic shunt capacitance of crystal-unit equivalent circuit	1-184

Symbol			*Paragraph*
(eff) C_o		effective electrostatic shunt capacitance of crystal unit (equal to C_o plus any circuit capacitance directly shunted across unit terminals)	1-230
C_p		total effective electrostatic plate-to-cathode capacitance of vacuum-tube plate circuit	1-278
C_p'		total effective plate-to-cathode capacitance of generalized oscillator taking into account dynamic effects of vacuum tube	1-278
C_{pk}		plate-to-cathode capacitance of vacuum-tube circuit	1-278
C_{pg}		plate-to-grid capacitance of vacuum-tube circuit; normally represents only stray capacitance	1-278
C_T	(1)	total capacitance ($C_o + C_x$) shunting series arm of generalized crystal-oscillator circuit	1-211
	(2)	total capacitance of capacitance-bridge oscillator circuit	1-365
	(3)	effective heat capacity of thermostat in crystal oven	4-58
C_v		external capacitance directly shunting crystal unit; considered as circuit variable	1-230
C_x		equivalent load capacitance shunting parallel-mode crystal unit	1-211
C_{x_p}		component of load capacitance of crystal unit in Miller oscillator due to inductive plate circuit (applicable when effect of grid-circuit losses on frequency can be considered negligible)	1-332
C_{x_p}'		component of load capacitance of crystal unit in Miller oscillator due to inductive plate circuit	1-332
CT		quartz cut	1-23
C_1		equivalent series-arm capacitance of desired-frequency mode of crystal unit	1-183
C_1, C_2, etc.		capacitances in schematic diagram	1-220
$C_2, C_3, \ldots C_k$		equivalent series-arm capacitance of unwanted-frequency modes of crystal unit	1-183
$C_6H_{14}N_2O_6$		ethylene diamine tartrate	1-36
c		stiffness factor	1-78
D	(1)	quartz element	1-90
	(2)	Q degradation of crystal unit; equal to ratio of total effective resistance into which crystal must operate to crystal resonance resistance $\left(\frac{R_c}{R}\right)$	1-396
	(3)	number of discriminators in synthesizer circuit	1-456
	(4)	diameter	4-18
D, D_1, D_2, $D_{1,2}$		plate-stabilized modes of vacuum-tube operation	1-298
DT		quartz cut	1-23

Symbol			*Paragraph*
d	(1)	distance between parallel atomic planes	1-127
	(2)	diameter of pin or wire	1-158
	(3)	differential sign	1-203
	(4)	piezoelectric constant giving ratio of strain to field	1-248
	(5)	linear displacement of bimetallic sensing element	4-18
E		quartz element	1-90
E_b		d-c plate voltage of vacuum tube	1-288
E_c	(1)	d-c bias voltage of excitation grid of vacuum tube	1-293
	(2)	rms r-f voltage across crystal unit	1-312
E_{co}		cut-off voltage of vacuum tube	1-312
E_{CR}		rms r-f voltage across crystal unit in capacitance-bridge oscillator circuit	1-365
E_{c1}		d-c bias voltage of excitation grid of first vacuum tube in two-tube crystal-oscillator circuit	1-378
E_{c2}	(1)	d-c voltage of screen grid	1-298
	(2)	d-c bias voltage of excitation grid of second vacuum tube in two-tube crystal oscillator	1-378
E_g		grid-to-cathode excitation voltage (rms) of vacuum tube	1-233
E_{gm}		peak amplitude of vacuum-tube excitation voltage	1-296
E_{g1}		grid-to-cathode excitation voltage (rms) of first vacuum tube in two-tube crystal-oscillator circuit	1-345
E_{g2}	(1)	grid-to-cathode excitation voltage (rms) of second vacuum tube in two-tube crystal-oscillator circuit	1-345
	(2)	screen-grid rms voltage of vacuum tube	1-425
E_{g3}		suppressor-grid rms voltage of vacuum tube	1-425
E_h		harmonic plate voltage of vacuum tube	1-322
E_L		rms voltage across load resistor in transformer-coupled oscillator	1-393
E_o	(1)	rms voltage across equivalent parallel-resonant crystal-oscillator circuit (same as r-f voltage, E_c, across crystal unit)	1-232
	(2)	rms voltage output from oscillator circuit	1-342
	(3)	rms voltage across center leg of bridge in Meacham-bridge oscillator	1-358
E_p		r-f plate voltage (rms) of vacuum tube	1-233
E_{pm}		maximum value of a-c component of vacuum-tube plate voltage	1-312
E_{p1}		r-f plate voltage (rms) of first vacuum tube in two-tube crystal-oscillator circuit	1-345
E_{p2}		r-f plate voltage (rms) of second vacuum tube in two-tube crystal-oscillator circuit	1-345
E_{R_e}		rms voltage across crystal unit (or equivalent resonance resistance in CI meter)	1-436
E_s		rms voltage across secondary of plate transformer	1-358

Symbol		*Paragraph*
E_v	mechanical vibrational energy of crystal	1-249
E_4	rms voltage across thermistor in bridge circuit of Meacham-bridge oscillator	1-358
ET	quartz cut	1-23
e	emissivity	4-35
e_b	instantaneous value of vacuum-tube plate voltage	1-312
e_c	instantaneous value of vacuum-tube grid voltage	1-312
e_h	instantaneous harmonic voltage across vacuum-tube plate tank circuit	1-322
e_p	instantaneous value of a-c component of vacuum-tube plate voltage	1-312
F	quartz element	1-90
F_p	frequency-stability factor for parallel-mode crystal-oscillator circuit; equal to rate of change in crystal-unit reactance per fractional change in frequency	1-243
F_s	frequency-stability factor for series-mode crystal-oscillator circuit; equal to rate of change in crystal-unit reactance per fractional change in frequency	1-240
F_X	coefficient of frequency stability; equal to percentage change in reactance of stabilizing element per percentage change in frequency	1-227
F_{X_e}	frequency-stability coefficient; equal to percentage rate of change in overall effective reactance (X_e) of crystal unit for a percentage change in frequency; a measure of the stabilizing effect of crystal unit against percentage change in reactance of load capacitance, C_x	1-243
F_{X_s}	frequency-stability coefficient: equal to percentage rate of change in series-arm reactance (X_s) of crystal unit for a percentage change in frequency; a measure of the stabilizing effect of crystal unit against percentage change in reactance of total effective shunt capacitance, C_T	1-243
FT	quartz cut	1-23
f	(1) frequency	1-78
	(2) farad	1-188
	(3) nominal frequency at which crystal unit is assumed to operate	1-208
	(4) fundamental frequency of crystal-oven temperature cycles	4-60
f_a	antiresonant frequency of crystal unit	1-204
f_c	fundamental frequency of first crystal oscillator in synthesizer circuit	1-455
f_d	frequency of discriminator in synthesizer circuit	1-455
f_F	frequency of force acting on oscillator	1-265
f_H	highest frequency	1-248

Symbol		*Paragraph*
f_h	any particular harmonic of fundamental crystal-oscillator frequency passed by harmonic selector in synthesizer circuit	1-455
f_L	lowest frequency	1-248
f_o	(1) frequency of oscillator	1-265
	(2) frequency of variable oscillator in synthesizer circuit	1-455
f_p	parallel-resonant frequency of equivalent crystal-oscillator circuit	1-210
f_{p1}	operating parallel-resonant frequency of first crystal unit	1-317
f_{p2}	operating parallel-resonant frequency of second crystal unit	1-317
f_r	resonant frequency of crystal unit	1-204
f_{rx}	frequency at which an external reactance, X_x, is series-resonant with the equivalent reactance, X_e, of a crystal unit	1-217
f_s	series-resonant frequency of series arm	1-203
f_x	output frequency of second crystal oscillator in synthesizer circuit	1-455
F_1, F_2, etc	dominant frequencies in various parts of frequency-control circuits as indicated in schematic diagrams	1-319
G	quartz element	1-90
G_1, G_2, etc	voltage gains of coupling stages around oscillator loop	1-267
G_1'	voltage gain of the first part of G_1, which in turn is the overall gain of a coupling stage that can be subdivided into two or more steps of gains G_1', G_1'', etc.	1-378
G_1''	voltage gain of the second part of G_1, which in turn is the overall gain of a coupling stage that can be subdivided into two or more steps of gains G_1', G_1'', etc.	1-378
GT	quartz cut	1-23
g_m	transconductance of vacuum tube	1-273
g_{m1}	transconductance of first vacuum tube in two-tube crystal-oscillator circuit	1-348
g_{m2}	transconductance of second tube in two-tube crystal-oscillator circuit	1-348
H	(1) Hydrogen	1-29
	(2) quartz element	1-90
	(3) crystal holder	1-183
	(4) number of first-crystal-oscillator harmonics utilized in synthesizer circuit	1-456
I_A	rate of absorption of radiant heat	4-40
I_{AC}	peak a-c thermal current through thermofilter	4-58
I_b	average value of d-c plate current of vacuum tube	1-277
I_{bm}	maximum d-c value of vacuum-tube plate current (plate current at peak of positive excitation alternation)	1-312
I_{b1}	average value of d-c plate current of first vacuum tube in two-tube crystal-oscillator circuit	1-378

Symbol		*Paragraph*
I_{b2}	average value of d-c plate current of second vacuum tube in two-tube crystal-oscillator circuit	1-378
I_c	(1) total r-f current through crystal unit (rms)	1-232
	(2) average d-c vacuum-tube grid current	1-296
	(3) r-f collector current in transistor oscillator	1-540
I_{C_o}	a-c current through electrostatic shunt capacitance of crystal unit	1-300
I_e	r-f emitter current in transistor oscillator	1-540
I_G	instantaneous calorie output per second of crystal-oven heater when operating (equivalent to wattage of heater)	4-58
I_g	r-f grid current (rms) of vacuum tube	1-233
I_{gm}	peak amplitude of r-f current	1-293
I_{gx}	reactive component of rms grid current due to grid-to-cathode capacitance of vacuum tube	1-383
I_{g1}	that part of r-f plate current of second tube that is fed back to grid of first tube in two-tube parallel-resonant crystal oscillator	1-345
I_{g2}	that part of r-f plate current of first tube that is fed to grid of second tube in two-tube parallel-resonant crystal oscillator	1-345
I_H	(1) thermal current	4-32
	(2) average rate of heat leakage to the outside in crystal-oven heater (equal to average power consumption of oven)	4-58
I_m	apparent maximum a-c component of vacuum-tube plate current	1-312
I_N	average net rate of heat supplied to crystal oven during initial heating period	4-71
I_o	portion of total r-f current through crystal unit that flows through electrostatic shunt capacitance	1-394
I_p	a-c component of vacuum-tube plate current (rms)	1-270
I_{pm}	maximum (peak) amplitude of a-c component of vacuum-tube plate current	1-312
I_{p1}	a-c component of plate current of first vacuum tube in two-tube crystal-oscillator circuit	1-377
I_{p2}	a-c component of plate current of second vacuum tube in two-tube crystal-oscillator circuit	1-377
I_R	total heat radiated per second	4-35
I_s	(1) equivalent r-f current through series arm	1-249
	(2) portion of total rms plate current flowing through inductance of secondary in plate transformer of capacitance-bridge oscillator	1-366
I_2	portion of total rms plate current flowing through the effective electrostatic plate-to-cathode capacitance of capacitance-bridge oscillator circuit	1-367
I_3	portion of total rms plate current flowing through center leg of bridge circuit in capacitance-bridge oscillator	1-366

Symbol			*Paragraph*
I_4	(1)	rms current through thermistor in bridge circuit in Meacham-bridge oscillator	1-360
	(2)	portion of total rms plate current flowing through plate-to-grid leg of bridge circuit in capacitance-bridge oscillator	1-366
i		measure of imbalance in Meacham-bridge oscillator	1-359
i_b		instantaneous value of total vacuum-tube d-c plate current	1-312
i_p		instantaneous value of a-c component of vacuum-tube plate current	1-312
J		quartz element	1-90
j		complex-number operator; equal to $\sqrt{-1}$	1-281
J_1, J_2, etc		jacks in schematic diagrams	1-436
K	(1)	Potassium	1-29
	(2)	thermal conductivity	4-32
$K_2C_4H_4O_6 \cdot \frac{1}{2}H_2O$		dipotassium tartrate	1-38
k	(1)	frequency constant	1-79
	(2)	electromechanical coupling factor	1-227
	(3)	gain of vacuum tube; equal to ratio of r-f plate voltage to r-f grid voltage	1-233
	(4)	ratio of grid-leak resistance to minimum permissible performance index of Military Standard crystal unit	1-300
	(5)	proportionality constant relating value of fixed resistance in Meacham bridge to crystal resistance	1-358
	(6)	coefficient of transformer coupling	1-393
	(7)	temperature coefficient of thermostat deflection in parts per degree centigrade, equal to k_a, k_b, or k_c	4-18
k_m		maximum practical ratio of grid-leak resistance to minimum performance index of Military Standard crystal unit	1-300
k_1		frequency constant for length- or width-extensional mode	1-79
k_2		frequency constant for thickness-extensional mode	1-80
k_3		frequency constant for thickness-shear mode	1-81
k_4		frequency constant for face-shear mode of square plates	1-82
k_4'		frequency constant for face-shear mode	1-82
k_5		frequency constant for length-width-flexural mode	1-83
k_6		frequency constant for length-thickness-flexural mode	1-84
L	(1)	motional-arm (or series-arm) inductance of crystal-unit equivalent circuit	1-183
	(2)	length of thermal conductor	4-32
L_a		inductance of plate transformer in modified grounded-grid oscillator	1-419
L_b		cathode-to-ground inductance in modified grounded-grid oscillator	1-419

Symbol		*Paragraph*
L_e	equivalent, or effective, inductance of crystal unit when unit is viewed as an equivalent resistance and reactance in series	1-236
$L_g a$	suppressor-grid circuit tank inductance in transitron crystal-oscillator circuit	1-425
L_k	cathode-to-ground inductance in modified grounded-grid oscillator	1-417
L_L	distributed inductance of leads and terminals of crystal unit	1-183
L_o	external inductance connected across crystal unit to antiresonate with electrostatic shunt capacitance of the unit	1-385
L_p	(1) inductance of plate circuit	1-328
	(2) inductance of primary in plate transformer of capacitance-bridge oscillator	1-365
	(3) inductance of plate-to-ground transformer in modified grounded-grid oscillator	1-417
L_s	inductance of secondary in plate transformer of capacitance-bridge oscillator	1-365
L_T	dynamic inductance between plate and cathode effectively introduced by vacuum tube	1-278
L_1	equivalent series-arm inductance of desired-frequency mode of crystal unit	1-183
L_1, L_2, etc	inductances in schematic diagrams	1-220
$L_2, L_3, \ldots L_k$	equivalent series-arm inductance of unwanted-frequency modes of crystal unit	1-183
l	length	1-79
l_1	mechanical one-quarter wavelength of wire	1-165
l_2	mechanical three-quarter wavelength of wire	1-165
l/t	ratio of length to thickness	1-141
M	(1) quartz element	1-90
	(2) figure of merit	1-227
	(3) coefficient of inductive coupling	1-419
$M, M_1, M_2, \ldots M_k$	meter	1-188
MT	quartz cut	1-23
m	(1) quartz face	1-42
	(2) harmonic integer	1-81
	(3) constant for mode of vibration in frequency equation of clamp-free rod in flexural vibration	1-158
	(4) proportionality constant relating total resistance on crystal side of Meacham bridge to the value of the resistance of the variable arm alone	1-358
N	(1) nitrogen	1-29
	(2) quartz element	1-90
	(3) ratio of a conveniently assumed reference value of R_e to any particular value of R_e $(= R_{e_N})$; thus $N = (\text{ref})\, R_e/R_{e_N}$	1-312
	(4) same as in definition (3), but in the particular case where (ref) R_e is the maximum permissible resonance resistance of a Military Standard crystal unit and R_{e_N} is the minimum expected resonance resistance	1-362

Symbol			*Paragraph*
	(5)	turns ratio of autotransformer in grounded-grid oscillator (equal to ratio of total turns to turns of secondary)	1-407
	(6)	total number of frequency channels in synthesizer circuit	1-442
Na		Sodium	1-29
$NaKC_4H_4O_6$-$4H_2O$		Rochelle salt	1-29
N_g		turns ratio of grid transformer in vacuum-tube circuit	1-358
N_p		turns ratio of plate transformer in vacuum-tube circuit	1-359
$NH_4H_2PO_4$		ammonium dihydrogen phosphate	1-29
NT		quartz cut	1-23
n	(1)	integer; equal to harmonic of oscillation	1-79
	(2)	a positive integer; equal to the sequence number of any given frequency in a set of frequencies (e.g. in an ascending sequence of evenly-spaced crystal frequencies numbered 1, 2, . . . etc., n = 1 for the No. 1 crystal, n = 2 for the No. 2 crystal, etc.)	1-445
O		Oxygen	1-29
P		Phosphorus	1-29
P_c		power dissipated in crystal unit	1-233
P_{cm}		maximum power dissipation recommended for Military Standard crystal unit	1-293
P_g		power dissipated in vacuum-tube grid circuit	1-296
P_L		power dissipated in crystal-oscillator load	1-397
P_o		power dissipated in output circuit	1-333
P_p		power dissipated in plate circuit of transformer-coupled oscillator	1-395
P_{ZL}		power dissipated in oscillator tank circuit	1-312
P_1	(1)	power dissipated by R_1 (crystal-unit) arm in Meacham-bridge oscillator	1-361
	(2)	position of any given adjustment of adjustable thermostat	4-16
p		harmonic integer	1-81
Q		quality factor	1-36
Q_e		effective quality factor of crystal unit equal to X_e/R_e	1-227
Q_{em}		maximum possible effective quality factor of a given crystal unit	1-217
Q_f		imaginary effective overall phase-rotating quality factor of an oscillator feedback circuit	1-272
Q_g		quality factor of vacuum-tube input impedance	1-272
Q_{pgc}		overall quality factor of a-c impedance of oscillator feedback circuit from plate to grid to cathode	1-272
Q_s		effective quality factor of series arm of crystal unit (equal to X_s/R)	1-213
R	(1)	motional-arm (or series-arm) resistance of crystal-unit equivalent circuit	1-183

Symbol			*Paragraph*
	(2)	effective lumped thermal resistance of thermo-filter in crystal oven	4-58
R_A		thermal resistance of air outside crystal oven	4-58
R_a		plate load resistance of first vacuum tube in two-tube parallel-resonant crystal oscillator	1-345
R_b	(1)	plate load resistance of second vacuum tube in two-tube parallel-resonant crystal oscillator	1-345
	(2)	external resistance in base circuit of transistor	1-548
R_{CC}		effective thermal resistance of crystal chamber in crystal oven	4-58
R_{CH}		effective thermal resistance of crystal holder	4-58
R_c	(1)	total effective resistance faced by crystal unit (normally useful only when unit is assumed to operate at resonant frequency)	1-241
	(2)	collector resistance of transistor	1-540
	(3)	external resistance in collector circuit of transistor	1-548
R_{cg}		effective grid resistance in oscillator circuit	1-331
R_e	(1)	equivalent, or effective, resistance of crystal unit when unit is viewed as an equivalent resistance and reactance in series	1-204
	(2)	external resistance in emitter circuit of transistor	1-546
R_e'		effective resistance, R_e, of crystal unit when assuming stray shunt capacitance introduced by circuit is part of total electrostatic shunt capacitance of crystal unit	1-278
R_{em}		specified maximum effective resistance of parallel-mode, Military Standard crystal unit	1-293
R_{e_N}		any particular value of R_e whose ratio to a conveniently assumed reference value, (ref) R_e, is equal to N	1-312
R_{ep}		equivalent, or effective, resistance (R_e) of crystal unit when operating at parallel-resonance frequency, f_p, of equivalent crystal-oscillator circuit	1-210
R_f		total resistance of feedback circuit	1-297
R_{fe}		effective resistance of feedback circuit insofar as it affects oscillator frequency	1-297
R_g		grid-leak resistance	1-277
R_g'		resistive component of grid impedance when latter is represented as equivalent resistance in series with equivalent reactance	1-297
R_{ge}		effective grid resistance in equivalent oscillator circuit	1-333
R_{g1}		grid-leak resistance of first vacuum tube in two-tube crystal-oscillator circuit	1-345
R_{g2}		grid-leak resistance of second vacuum tube in two-tube crystal-oscillator circuit	1-345
R_H		thermal resistance	4-33
R_I		terminal-to-terminal r-f insulation resistance of crystal unit	1-183
R_k		cathode biasing resistance	1-307

Symbol			*Paragraph*
R_L	(1)	distributed resistance of leads and terminals of crystal unit	1-183
	(2)	equivalent, or effective, load resistance of oscillator tube	1-278
	(3)	load resistance of transistor oscillator circuit	1-450
R_L'		equivalent load resistance of vacuum-tube plate-circuit impedance when represented as in series with reactive component	1-300
R_m		maximum permissible resonance resistance of series-mode Military Standard crystal unit	1-362
R_O		effective thermal resistance of crystal oven between heater and the outside	4-58
R_o		equivalent output resistance connected across vacuum-tube plate circuit having such a value that its losses equal the power output for a given r-f plate voltage	1-333
R_p		plate resistance of vacuum tube	1-268
R_{p1}		plate resistance of first vacuum tube in two-tube crystal-oscillator circuit	1-378
R_{p2}		plate resistance of second vacuum tube in two-tube crystal-oscillator circuit	1-378
R_T	(1)	total load resistance in series with total reactance, X_T, shunting series arm of equivalent crystal-oscillator circuit	1-211
	(2)	sum of fixed resistance and resistance of indicator lamp in bridge circuit of Meacham-bridge oscillator	1-358
R_x		equivalent load resistance in series with reactance, X_x, shunting crystal unit in equivalent parallel-resonant crystal circuit	1-210
R_{ZL}		resistive component of load impedance	1-281
R_1		equivalent series-arm resistance of desired-frequency mode of crystal unit	1-183
R_1, R_2, etc		resistances in schematic diagram	1-277
R_2, R_3, ... R_k		equivalent series-arm resistance of unwanted-frequency modes of crystal unit	1-183
r	(1)	quartz face	1-42
	(2)	ratio of total electrostatic shunt capacitance, C_o, to motional-arm capacitance, C, of crystal equivalent circuit	1-208
	(3)	power ratio in grounded-grid oscillator, equal to P_L/P_c	1-411
r_b		effective internal, small-signal, linear, base resistance of transistor when transistor represented by equivalent T network	1-548
r_c		effective internal, small-signal, linear, collector resistance of transistor when transistor is represented by equivalent T network	1-540
r_e	(1)	ratio of electrostatic capacitance, C_e, across quartz-plate dielectric, to motional-arm capacitance, C, of crystal-unit equivalent circuit	1-197
	(2)	effective internal, small-signal, linear, collector resistance of transistor when transistor is represented by equivalent T network	1-548

Symbol		*Paragraph*
S	thermistor sensitivity in Meacham-bridge oscillator	1-360
S, S_1, S_2, etc	switches in schematic diagram	1-188
Si	Silicon	1-40
SiO_2	silicon dioxide	1-40
s	(1) quartz face	1-43
	(2) elastic compliance factor	1-78
	(3) activity sensitivity of bridge circuit in Meacham-bridge oscillator	1-360
T	temperature	4-35
T_{AC}	peak amplitude of temperature cycles	4-61
T_C	average crystal temperature	4-56
T_H	average heater temperature	4-56
T_o	operating temperature of oven and/or thermostat	4-16
T_s	absolute temperature of surroundings of radiating surface	4-40
t	(1) thickness	1-80
	(2) time (in seconds)	1-296
t/l	ratio of thickness to length	1-101
$\tan^{-1}$	arctangent (an angle whose tangent is)	1-280
V	(1) quartz cut	1-23
	(2) applied d-c voltage	1-248
	(3) volume	4-25
V_1, V_2, etc	vacuum tubes in schematic diagram	1-309
v	velocity	1-78
w	width	1-79
w/l	ratio of width to length	1-79
X	(1) quartz cut	1-23
	(2) crystal axis	1-23
	(3) number of crystals for second crystal oscillator in synthesizer circuit	1-442
X′	directional axis of the crystal dimension that initially coincided with a true X axis before rotation	Fig. 1-17
X_C	(1) capacitive reactance	1-187
	(2) motional-arm capacitive reactance of crystal-unit equivalent circuit	1-190
	(3) thermal reactance of thermofilter capacity	4-61
X_{C_b}	capacitive reactance of balancing capacitance of capacitance-bridge circuit	1-365
X_{C_g}	reactance of effective grid-to-cathode capacitance of vacuum-tube circuit	1-280
$X_{C_{g1}}$	reactance of effective grid-to-cathode capacitance of first vacuum tube in two-tube crystal oscillator circuit	1-383
X_{C_g}'	capacitive reactive component of grid impedance when latter is represented as equivalent capacitance in series with equivalent resistance	1-297

Symbol		*Paragraph*
X_{C_n}	(1) equivalent positive reactance of dynamic negative plate-to-cathode capacitance effectively introduced by vacuum tube in Pierce crystal oscillator	1-281
	(2) reactance of C_n in impedance-inverting crystal oscillator	1-426
X_{C_o}	shunt capacitive reactance of crystal-unit equivalent circuit	1-187
X_{C_p}	reactance of total effective electrostatic plate-to-cathode capacitance of vacuum-tube plate circuit	1-281
X_e	equivalent, or effective, reactance of crystal unit when unit is viewed as an equivalent resistance and reactance in series	1-204
X_e'	effective reactance, X_e, of crystal unit when assuming stray shunt capacitance introduced by circuit is part of total electrostatic shunt capacitance of crystal unit	1-278
X_{ep}	effective reactance, X_e, of crystal unit when operating at parallel-resonance frequency, f_p, of generalized crystal-oscillator circuit	1-210
X_g	generalized reactive component of grid impedance in oscillator circuit	1-331
X_L	(1) inductive reactance	1-187
	(2) motional-arm inductive reactance of crystal-unit equivalent circuit	1-190
X_{LL}	reactance of distributed inductance of leads and terminals of crystal unit	1-187
X_{Ls}	inductive reactance of secondary of plate transformer in capacitance-bridge oscillator	1-365
X_p	reactive component of plate impedance in oscillator circuit	1-331
X_p'	reactive component of plate impedance in Miller oscillator when expressed as a combined function of plate and grid circuit	1-332
X_{pg}	plate-to-grid reactance in vacuum-tube circuit	1-331
X_s	total series-arm reactance of crystal-unit equivalent circuit	1-203
X_{sa}	total series-arm reactance, X_s, of crystal-unit equivalent circuit at antiresonance	1-208
X_{sp}	total series-arm reactance, X_s, of crystal-unit equivalent circuit when operating at parallel resonance with total effective load capacitance, C_T, of generalized oscillator circuit (employed only when convenient to distinguish between X_s used in the general sense and X_s when used in the particular case of the equivalent parallel-resonant crystal-oscillator circuit)	1-214
X_T	total reactance in series with total load resistance, R_T, shunting series arm of equivalent crystal-oscillator circuit	1-211

Symbol			*Paragraph*
X_{TP}		total reactance in series with total load resistance, R_T, shunting series arm of equivalent parallel-resonant crystal-oscillator circuit (employed only when convenient to distinguish between X_T used in the general sense and when used in the particular case of the equivalent parallel-resonant crystal-oscillator circuit)	1-211
X_x		reactance in series with load resistance, R_x, shunting crystal unit in equivalent parallel-resonant crystal circuit	1-210
X_{ZL}		reactive component of load impedance	1-281
x	(1)	quartz face	1-43
	(2)	dimension of crystal blank in X-axis direction	1-51
Y	(1)	quartz cut	1-23
	(2)	crystal axis	1-23
Y′		directional axis of the crystal dimension that initially coincided with a true Y axis before rotation	Fig. 1-17
YT		quartz cut	1-90
y		dimension of crystal blank in Y-axis direction	1-51
Z	(1)	quartz axis	1-51
	(2)	impedance	1-188
Z′		directional axis of the crystal dimension that initially coincided with a true Z axis before rotation	Fig. 1-17
Z″		directional axis of the crystal dimension that initially coincided with the Z′ axis before rotation	Fig. 1-17
Z_e		equivalent, or effective, impedance of crystal unit	1-209
Z_f		impedance of feedback circuit	1-378
Z_g	(1)	grid-to-cathode impedance as viewed by the excitation source	1-233
	(2)	impedance of excitation source as viewed by grid of vacuum tube	1-398
Z_{g1}		input impedance of first tube in two-tube parallel-resonant crystal oscillator	1-345
Z_{g2}		input impedance of second tube in two-tube parallel-resonant crystal oscillator	1-345
Z_k		vacuum-tube a-c plate-circuit impedance between cathode and ground (in the Butler oscillator, Z_k is the output impedance of the cathode follower)	1-378
Z_k'		output impedance of cathode follower as viewed by the crystal in grounded-plate oscillator	1-422
Z_L		a-c load impedance	1-268
Z_n		input impedance of impedance-inverting network	1-426
Z_o		characteristic impedance of impedance-inverting network	1-426
Z_p	(1)	impedance of an equivalent parallel-resonant crystal circuit; antiresonant impedance of	

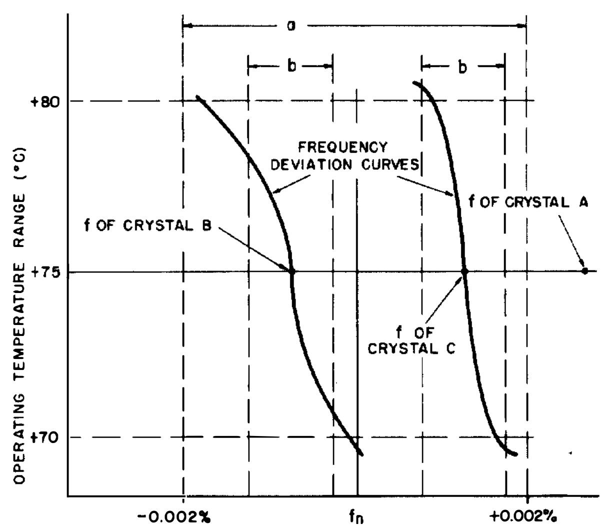
Symbol		*Paragraph*
Z_p (Cont)	crystal unit in parallel with equivalent load capacitance, C_x (equal to the performance index of a crystal unit having a rated load capacitance, C_x)	1-214
(2)	a-c impedance of vacuum-tube plate circuit	1-269
Z_{pg}	a-c impedance between plate and excitation grid of vacuum tube	1-269
Z_{pgc}	total a-c impedance of oscillator feedback circuit from plate to grid to cathode	1-270
Z_{p1}	external plate impedance of first tube in two-tube crystal oscillator	1-348
Z_{p2}	external plate impedance of second tube in two-tube crystal oscillator	1-348
Z_s	series-arm impedance of crystal-unit equivalent circuit	1-426
Z_1	effective plate impedance of cathode follower in two-tube Butler circuit as faced by cathode-to-ground output circuit	1-378
Z_2	effective plate impedance of grounded-grid vacuum tube in two-tube Butler circuit as faced by cathode-to-ground input circuit	1-378
z (1)	quartz face	1-42
(2)	dimension of crystal blank in Z-axis direction	1-51
0	zero quantity; used only in data charts of composite schematic diagrams that represent more than one circuit. Equivalent to short circuit when used to designate value of resistance or inductance; equivalent to open circuit when used to designate value of capacitance	Fig. 1-135
5°X	quartz cut	1-90
—18°X	quartz cut	1-90
α	current amplification factor of transistor	1-450
Δ	any small difference or incremental change	1-203
Δf	any small change in frequency, but usually the difference between crystal-unit operating frequency, f, and series-resonance frequency, f_s	1-203
Δf_a	difference between antiresonant frequency, f_a, and series-resonance frequency, f_s, of crystal unit	1-208
Δf_o	any small change in frequency of variable oscillator in synthesizer circuit	1-461
Δf_p	difference between parallel-resonance frequency, f_p, of crystal circuit and series-resonance frequency, f_s, of crystal unit	1-211
Δf_r	difference between resonance frequency, f_r, and series-resonance frequency, f_s, of crystal unit	1-206
Δf_{rx}	difference between the frequency, f_{rx}, at which the crystal unit is series-resonant with an external load capacitance, C_x, and the series-resonance frequency, f_s, of the crystal unit itself	1-217
ΔH	a change in thermal energy	4-65

Symbol			*Paragraph*
ΔT		a change or difference in temperature; a "temperature drop" along a heat-conducting path	4-18
ΔV		a difference of potential; a voltage drop	4-34
ΔX_e		any small change in the effective reactance, X_e, of a crystal unit, where the unit impedance is viewed as an effective resistance and reactance in series	1-223
∂		$\equiv$ partial differential of	1-298
ε		dielectric constant	1-248
θ	(1)	second angle of rotation, used in defining orientation of crystal cut	1-88
	(2)	angle of incidence of X-rays with atomic plane	1-127
	(3)	impedance phase angle of crystal-oscillator circuit	1-240
	(4)	that angle of vacuum-tube excitation-voltage excursion during which no plate current flows	1-312
	(5)	angle indicating small phase shift in variable-leg voltage of Meacham-bridge oscillator	1-358
θ_{E_g}		phase angle of vacuum-tube grid-to-cathode excitation voltage with respect to a designated reference	1-270
θ_{E_p}		phase angle of vacuum-tube r-f plate voltage with respect to a designated reference	1-270
θ_{I_g}		phase angle of vacuum-tube r-f grid current with respect to a designated reference	1-270
θ_N		that angle of vacuum-tube excitation-voltage excursion during which no plate current flows for the case when R_e equals a particular value, R_{e_N}	1-312
θ_{Zg}		$\equiv$ phase angle of the a-c voltage across the grid-to-cathode impedance with respect to the a-c current through the impedance	1-270
$\theta_{Z_{pgc}}$		phase angle of the voltage across the impedance of the oscillator feedback circuit with respect to the current through the impedance	1-270
λ		wavelength	1-78
μ	(1)	micro	1-191
	(2)	amplification factor of vacuum tube	1-268
μ_1		amplification factor of first vacuum tube in two-tube crystal-oscillator circuit	1-378
μ_2		amplification factor of second vacuum tube in two-tube crystal-oscillator circuit	1-378
π		pi (approximately equal to 3.14)	1-158
ρ	(1)	density	1-78
	(2)	negative resistance	1-232
ρ_s		negative resistance of generalized crystal oscillator when circuit is represented as series-connected	1-232
ρ_T		equivalent negative resistance of vacuum tube when tube is represented by an equivalent reactance and negative resistance in parallel	1-278

Symbol		*Paragraph*
$\sum_{n=1}^{\infty}$	algebraic sum of the indicated quantities corresponding to all *integral* values of n from 1 to ∞	1-598
σ	the Stefan-Boltzmann constant, equal to the radiancy of an ideal black body per (degree)^4	4-35
ϕ	(1) first angle of rotation, used in defining orientation of crystal cut	1-88
	(2) angle indicating small phase shift of center-leg voltage in Meacham-bridge oscillator	1-358
	(3) angular displacement in radians of bimetallic element	4-18
ψ	third angle of rotation, used in defining orientation of crystal cut	1-88
Ω	ohm (s)	1-207
ω	nominal angular frequency at which crystal unit is assumed to operate	1-208
$=$	is equal to	1-78
$\approx$	is approximately equal to	1-82
$>$	is greater than	1-206
$>>$	is much greater than	1-206
$<$	is less than	1-232
$<<$	is much less than	1-106
$\rightarrow$	as one quantity approaches another in value	1-281
$\pm$	plus or minus	1-88
$\lvert \; \rvert$	the absolute or unsigned value of any quantity contained within the verticals	1-208
∞	infinite quantity; equivalent to an open circuit when used to designate the value of a resistance or an inductance, and equivalent to a short circuit (d-c as well as a-c) when used to designate a capacitance in the data charts of those figures showing composite schematic diagrams that represent more than one circuit. Equivalent to an r-f bypass value when used to designate the value of a capacitance in a single-circuit drawing	1-280
%	per cent	1-104
°	(1) degree(s), temperature	1-29
	(2) degree(s), orientation angle	1-88
	angular minute(s)	1-90

Fraction of Unit	*Lowest Integral Part Per Power of 10*	*Decimal Part Per Unit*	*Decimal Part Per 100 (Per Cent)*	*Miscellaneous Fractional Expressions*
1/1000	1 PP 10^3	0.001	0.1 %	1000 p/p/million
2/10,000	2 PP 10^4	0.0002	0.02	200 p/p/million
12/100,000	12 PP 10^5	0.00012	0.012	120 p/p/million
1/10,000	1 PP 10^4	0.0001	0.01	100 p/p/million
75/1,000,000	75 PP 10^6	0.000075	0.0075	75 p/p/million
5/100,000	5 PP 10^5	0.00005	0.005	50 p/p/million
3/100,000	3 PP 10^5	0.00003	0.003	30 p/p/million
2/100,000	2 PP 10^5	0.00002	0.002	20 p/p/million
1/100,000	1 PP 10^5	0.00001	0.001	10 p/p/million
5/1,000,000	5 PP 10^6	0.000005	0.0005	5 p/p/million
1/1,000,000	1 PP 10^6	0.000001	0.0001	1 p/p/million
1/10,000,000	1 PP 10^7	0.0000001	0.00001	1 p/p/10 million
1/100,000,000	1 PP 10^8	0.00000001	0.000001	1 p/p/100 million
1/1,000,000,000	1 PP 10^9	0.000000001	0.0000001	1 p/p/billion
1/10,000,000,000	1 PP 10^{10}	0.0000000001	0.00000001	1 p/p/10 billion

Conversion Table for Commonly Encountered Fractional Parts



FREQUENCY

fn = NOMINAL FREQUENCY OF CRYSTAL (AS MARKED ON CRYSTAL UNIT)

f = ACTUAL FREQUENCY MEASURED AT MIDPOINT (75 °C) OF OPERATING TEMPERATURE RANGE

a = NOMINAL FREQUENCY TOLERANCE (±0.002% OF fn) SPECIFIED AT MIDPOINT (75°C) OF OPERATING TEMPERATURE RANGE OF CRYSTALS UNDER TEST.

b = MAXIMUM FREQUENCY DEVIATION ALLOWED (±0.0005% OF f) WITHIN OPERATING TEMPERATURE RANGE (+70°TO+80°C)

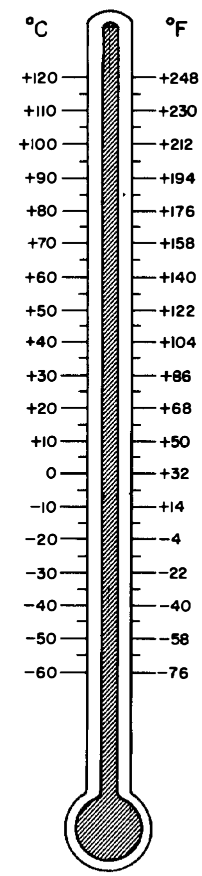
RESULTS OF TESTS

CRYSTAL-A REJECTED: NOMINAL FREQUENCY TOLERANCE NOT WITHIN ±0.002% OF fn

CRYSTAL-B REJECTED: FREQUENCY DEVIATION NOT WITHIN ±0.0005% OF f

CRYSTAL-C ACCEPTED: NOMINAL FREQUENCY TOLERANCE AND FREQUENCY DEVIATION WITHIN SPECIFIED LIMITS

Diagram illustrating distinction between nominal frequency tolerance and frequency deviation with temperature of crystal units



Temperature conversion chart: degrees centigrade to degrees fahrenheit